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PLANNING REPORT NO. 28

WISCONSIN - REGIONAL, S.E.

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Dept. of Urban & Regional Planning
The University of Wisconsin
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Madison, Wisconsin 53706

A REGIONAL AIR QUALITY ATTAINMENT AND MAINTENANCE PLAN FOR SOUTHEASTERN WISCONSIN 2000



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PLANNING REPORT NUMBER 28

A REGIONAL AIR QUALITY ATTAINMENT AND MAINTENANCE PLAN FOR SOUTHEASTERN WISCONSIN: 2000

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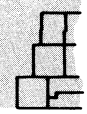

June 21, 1980

STATEMENT OF THE CHAIRMAN

This report sets forth the results, findings, and recommendations of the regional air quality attainment and maintenance planning program, and is representative of the continuing high priority that the Commission places on the protection of the natural resources and the preservation of the overall quality of the environment in the Southeastern Wisconsin Region. The air quality planning effort was conducted by the Regional Planning Commission in response to requests made in November 1973 by the Wisconsin Departments of Natural Resources and Transportation to prepare a plan to ensure the long-term maintenance of the established federal and state ambient air quality standards. At that time, it was envisioned that the existing State Implementation Plan would provide for the attainment of the air quality standards in the Region by the year 1975. In accordance with established Commission procedure, a Technical Coordinating and Advisory Committee on Regional Air Quality Maintenance Planning was created early in 1974 to guide the conduct of this planning program.

During 1975, when it became obvious that the existing State Implementation Plan would not provide for the near-term attainment of the ambient air quality standards, the scope of the air quality maintenance planning effort was expanded to include analyses of alternative air pollution abatement measures designed to achieve the standards throughout the Region as expeditiously as practicable. The air quality planning effort thus assumed a dual emphasis; the prompt attainment of the ambient air quality standards and the long-term maintenance of those standards in southeastern Wisconsin.

In many ways, the regional air quality attainment and maintenance planning program was among the most difficult planning efforts ever undertaken by the Commission. The air resource, for example, transcends political and geographic boundaries without constriction or confinement. Thus, whether the air breathed by the residents of southeastern Wisconsin is salubrious or deleterious is in part determined by the level of control placed on sources of air pollution well removed from the Region. Moveover, since the study of air pollution as a science is in its relative infancy, many of the analytical techniques and devices used to identify and describe air pollutants and their effects, to define the magnitude and extent of existing and probable future air pollution problems, and to evaluate the effectiveness of alternative air pollution abatement measures are continuously evolving and being refined. The process of evolution and refinement in the tools available for the study of air pollution is reflected in numerous and frequent revisions made to the federal and state regulatory scheme for the control of air pollution. The regional air quality attainment and maintenance plan is deeply based within this federal and state air pollution control regulatory scheme. This is due, in part, to the interstate nature of the air pollution problem and, in part, to the increasing assumption of responsibility for air pollution control by the federal government through the instrument of the U. S. Environmental Protection Agency.

The recommended regional air quality attainment and maintenance plan set forth within this document provides a framework of action to achieve and ensure the preservation of the established ambient air quality standards throughout the Southeastern Wisconsin Region. While the recommended plan is extensive and far-reaching—affecting public and private agencies, industries, business concerns, and citizens—the plan is also intended to be flexible and responsive to changing energy, environmental, and economic conditions in the Region in future years. The ultimate goal of the recommended plan, however, is to enhance and preserve the air resource for the residents of the Southeastern Wisconsin Region.

Respectfully submitted,

George C. Berteau
Chairman

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Chapter I

INTRODUCTION

In 1974 a regional ambient air quality maintenance planning program was undertaken by the Southeastern Wisconsin Regional Planning Commission. The initiation of this planning program served to explicitly recognize the importance of the atmosphere as a natural resource essential to the health and well-being of all kinds of life within the Region, and a vital element requiring careful consideration in planning for the physical and economic development of the Region. The planning program was designed to identify the nature and extent of air pollution problems within the Region, assess the overall effectiveness of past attempts to abate these problems, and develop a practical, long-range plan to maintain a level of ambient air quality within the Region that will promote the public health and welfare. As such, the ambient air quality attainment and maintenance planning program constituted an important, integral element of the overall comprehensive areawide planning program for the seven-county Southeastern Wisconsin Region, a program with particularly close and direct relationship to the land use and transportation planning efforts of the Commission. An understanding of the need for and objectives of regional planning and the manner in which these needs and objectives are being met in southeastern Wisconsin is accordingly necessary for a proper understanding of the findings and recommendations of the regional ambient air quality attainment and maintenance planning program.

NEED FOR REGIONAL PLANNING

Regional planning may be defined as comprehensive planning for a geographic area larger than a county but smaller than a state, an area united by social and economic interests, geography, and common developmental and environmental problems. The need for such planning has been brought about by certain important social and economic changes which, although national phenomena, have had far-reaching impacts on the problems facing local government. These changes include: rapid population growth and urbanization; increasing agricultural and industrial productivity, income levels, and leisure time; generation of mass recreational needs and pursuits; increasingly intensive use and consumption of natural resources; development of private water supply and sewage disposal systems; development of extensive electric power and communications networks; and development of limited access, all weather highway systems and mass automotive transportation. Under the effects of these factors, entire regions—like southeastern Wisconsin are evolving into one large mixed rural-urban complex. This urban diffusion over ever larger areas of the earth surface is, in turn, creating environmental and developmental problems of an unprecedented scale and complexity. Rural as well as urban people must concern themselves increasingly with these problems or face irreparable damage to the underlying and sustaining land, water, and air resources.

The areawide problems which necessitate a regional planning effort in southeastern Wisconsin all have their sources in the population growth and redistribution and in the attendant urban diffusion occurring within the Region. These areawide problems include, among others: inadequate storm water drainage and increasing flood damages; underdeveloped sewerage and inadequate sewage disposal facilities; inadequate water supply; deterioration and destruction of the natural resource base, including air and water pollution; increasing demand for outdoor recreation and for park and open space reservation; inadequate transportation facilities; and, underlying all of the aforementioned problems, rapidly changing and unplanned land use development. These problems are all truly regional in scope since they transcend the fiscal abilities as well as the geographic boundaries of any one municipality and can only be resolved within the context of a comprehensive, areawide planning effort and through the cooperation of all levels and units of government concerned.

THE REGIONAL PLANNING COMMISSION

The work of the Southeastern Wisconsin Regional Planning Commission (SEWRPC) represents an attempt to provide the necessary areawide planning services for one of the nation's large urbanizing Regions. The Commission was created in August 1960 under the provisions of Section 66.945 of the Wisconsin Statutes to serve and assist the local, state, and federal levels, units, and agencies of government in planning for the orderly and economical development of the seven-county Region. The Commission's role is entirely advisory; and participation by local units of government in its work is on a voluntary, cooperative basis. The Commission is composed of 21 members, three from each county in the Region. The Commissioners—who serve without pay—are, pursuant to State Statute, appointed to the Commission by the Governor and the constituent County Boards.

The powers, duties, and functions of the Commissioners and the qualifications required for appointment to the Commission are carefully set forth in the state enabling legislation. The Commission is authorized to employ experts and a staff as necessary to execute its responsibilities. Basic funds necessary to support Commission operations are provided by the member counties, with the budget apportioned among the seven counties on the basis of relative equalized assessed property valuation. The Commission is authorized to request and accept aid

in any form from all levels and agencies of government to accomplish its objectives and is authorized to deal directly with the state and federal government for this purpose. The Commission, its committee structure, and its staff organization, together with its relationship to the constituent levels and units of general purpose government are graphically shown in Figure 1.

THE REGIONAL PLANNING CONCEPT IN SOUTHEASTERN WISCONSIN

Regional planning as conceived by the Commission is not a substitute for, but a supplement to, local, state, and federal planning. Its objective is to assist the various levels, units, and agencies of government in finding solutions to areawide developmental and environmental problems which cannot be properly resolved within the framework of a single municipality or county. As such, regional planning has three principal functions:

1. Inventory—the collection, analysis, and dissemination of basic planning and engineering data on a uniform, areawide basis so that, in light of such data, the various levels and agencies of government and private investors operating within the Region can better make decisions concerning community development.

2. Plan Design—the preparation of a framework of advisory, long-range plans for the physical, social, and economic development of the Region, these plans being limited to functional elements having areawide significance. To this end, the Commission is charged by law with the function and duty of "making and adopting a master plan for the physical development of the Region." The permissible scope and content of this plan, as outlined in the enabling legislation, extend to all phases of regional development, implicitly emphasizing, however, the preparation of alternative spatial designs for land use and for supporting transportation and utility facilities.

3. Plan Implementation—the promotion of regional plan implementation through provision of a center to coordinate the planning and plan implementation activities of the various levels and agencies of government operating within the Region, and through the introduction of information on areawide problems, the recommendation of solutions to these problems and the introduction of alternatives into the existing decision-making process.

The work of the Commission, therefore, is visualized as a continuing planning process providing outputs of value to the making of development decisions by public and private agencies and to the preparation of plans and plan implementation programs at local, state, and federal governmental levels. It emphasizes close cooperation between the governmental agencies and private enterprises responsible for the development and maintenance of land uses in the Region and for the design, construction, operation, and maintenance of the supporting public works facilities. All Commission work programs are intended to be carried out within the context of a continuing planning program which provides for periodic reevaluation of the plans and for the extension of planning information and advice necessary to convert the plans into action programs at the local, regional, state, and federal levels.

THE REGION

The Southeastern Wisconsin Planning Region, as shown on Map 1, is composed of Kenosha, Milwaukee, Ozaukee, Racine, Walworth, Washington, and Waukesha Counties. Exclusive of Lake Michigan, these seven counties have a total area of 2,689 square miles, or about 5 percent of the total area of Wisconsin. About 40 percent of the state population (1975) lives within these seven counties, which contain three of the eight and one-half standard metropolitan statistical areas in Wisconsin. The Region contains about 40 percent of the tangible wealth in Wisconsin as measured by equalized assessed property valuation, and represents the greatest wealth-producing area of the state, with about 42 percent of the state's labor force being employed within the Region. The Region contains 154 local units of government, exclusive of school and other special-purpose districts, and encompasses all or parts of 11 major watersheds. It has been subject to rapid population growth and urbanization, and from 1960 to 1975 accounted for approximately 40 percent of the total population increase in the state.

Geographically, the Region is located in a relatively favorable position with regard to continued growth and development. It is bounded on the east by Lake Michigan, which provides an ample supply of fresh water for both domestic and industrial use, as well as being an integral part of a major international transportation network. It is bounded on the south by the rapidly expanding northeastern Illinois metropolitan region and on the west and north by the fertile agricultural lands and desirable recreational areas of the rest of the State of Wisconsin. As shown on Map 2, many of the most important industrial areas and heaviest population concentrations in the Midwest lie within a 250-mile radius of the Region, and over 33 million people reside within this radius.

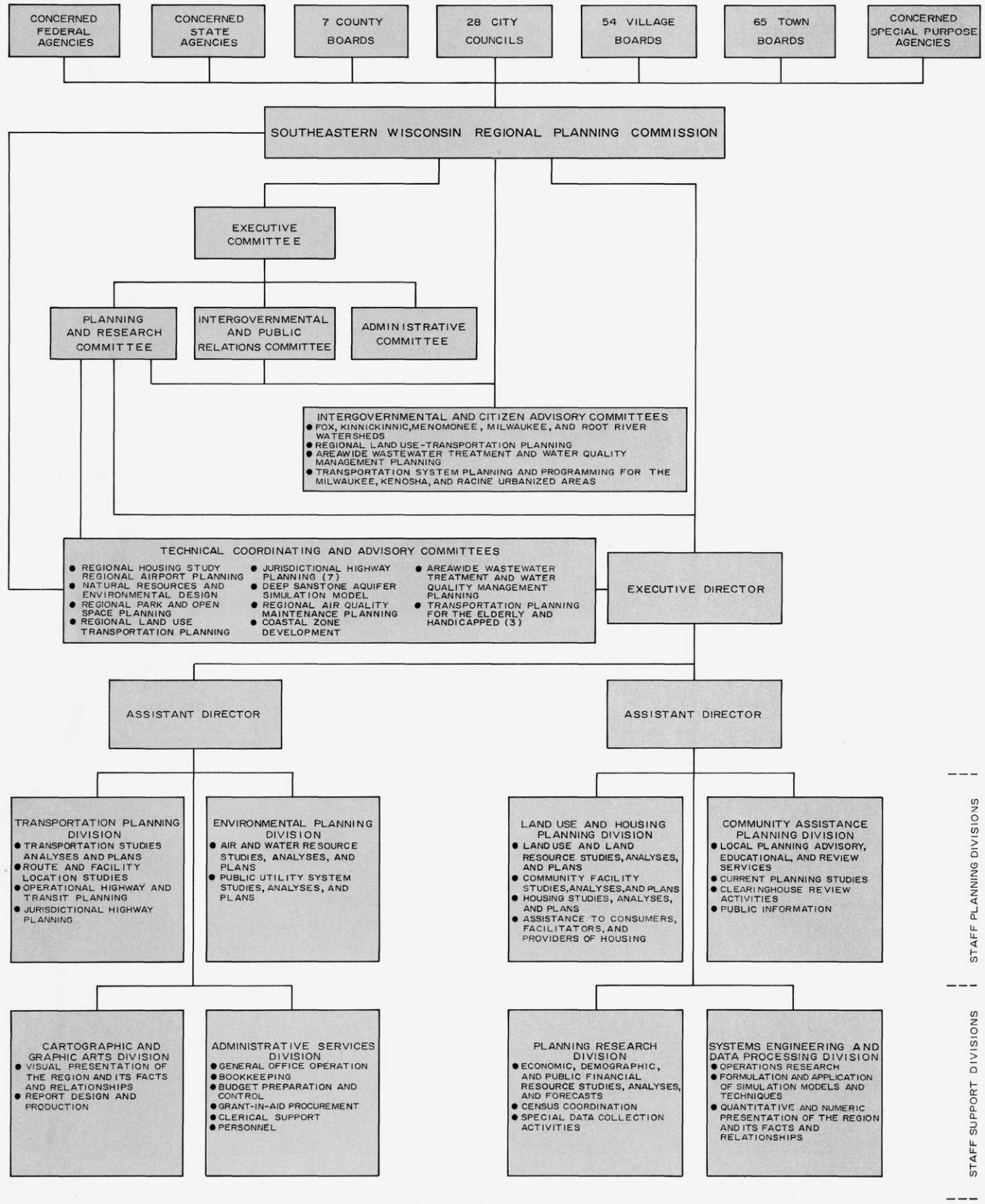
COMMISSION WORK PROGRAMS

Initial Work Program

The initial work program of the Commission was directed entirely toward basic data collection. It included six basic regional planning studies which were begun in July 1961 and completed by July 1963: a statistical program and data processing study, a base mapping program, an economic base and structure study, a population study, a natural resources inventory, and a public utilities study. All of these early studies were directed toward providing the basic foundation of planning and engineering data necessary for comprehensive regional planning and were documented in six published planning reports. Although none of these studies involved the preparation of plans,

Figure 1

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION ORGANIZATIONAL STRUCTURE: 1977



Source: SEWRPC.

Map 1

THE SOUTHEASTERN WISCONSIN REGION



The seven-county southeastern Wisconsin planning Region comprises a total area of about 2,689 square miles, or about 5 percent of the total land and inland water area of Wisconsin. The Region contains, however, about 40 percent of the state's population and about 40 percent of the tangible wealth in Wisconsin, as measured by equalized property valuation. The Region contains 154 general purpose local units of government and encompasses all or part of 11 major watersheds. The Region has been subject to rapid population growth and urbanization, and from 1960 to 1975 accounted for about 40 percent of the population increase in the state.

Source: SEWRPC.

Map 2

THE REGIONAL SETTING IN THE MIDWEST



Many of the most important industrial areas and largest population and employment concentrations in the midwest are located within 250 miles of the Southeastern Wisconsin Region. About 33 million people, or nearly one-sixth of the entire population of the United States, live within the 250-mile radius.

Source: SEWRPC.

their findings did, however, provide a valuable point of departure for all subsequent Commission work, including the regional air quality maintenance planning program.

As a part of its initial work program, the Commission also adopted a policy of community planning assistance in which functional guidance and advice on planning problems are extended to local units of government, and regional planning studies are interpreted locally so that the findings and recommendations of these studies may be incorporated into local development plans. Six local planning guides have been prepared under this program to provide information helpful in the preparation of local plans and plan implementation ordinances. These guides are intended to help implement regional and local plans and to assist local public officials in carrying out day-to-day planning functions. The guides consist of the following subjects: subdivision control, official mapping, zoning, organization of local planning agencies, floodland and shoreland development, and use of soil survey data in planning and development. All include model ordinances and provide a framework for plan implementation through local land use control measures.

Regional Land Use-Transportation Study

The first major work program of the Commission directed toward the preparation of long-range development plans was a regional land use-transportation study, initiated in January 1963 and completed in December 1966. This study produced two key elements of a comprehensive plan for the physical development of the Region: a land use plan and a surface transportation plan, including highway and transit elements. The findings and recommendations of the study have been published in the three-volume SEWRPC Planning Report No. 7, Regional Land Use and Transportation Plans; in SEWRPC Planning Report No. 8, Soils of Southeastern Wisconsin, and in five supporting technical reports.

Continuing Regional Land Use-Transportation Study

Before the initial land use-transportation planning effort had been completed, the Commission, along with its constituent local units of government and the affected state and federal agencies of government, acted to establish a continuing regional land use-transportation planning effort in southeastern Wisconsin. This effort provides for maintaining current the basic data forecasts on which the adopted land use and transportation plans are based, and for conducting periodic reappraisals and revisions of the adopted regional land use and transportation plans grounded in analyses of the results of the data base maintenance activities. Included in the surveillance activities are the collection of current, definitive data on changing public attitudes and values relating to both housing and transportation, on the amount and spatial location of changes in population and economic activity, on land use development, on automobile and truck availability, on trip generation and distribution, on mode of transportation utilized, on local land use and transportation plan development, and on plan implementation actions.

The study design for the continuing regional land use-transportation study called for a complete reappraisal of the adopted 1990 regional land use and transportation plans based upon the findings of major reinventories conducted in 1972 of the changes in land use and transportation system development and of the factors affecting such development that took place within the Region since the conduct of the initial benchmark inventories in 1963. The inventories provided new information on population and economic activity, the public financial resource base, land use development, the natural resource and public utility base, community plans and zoning activities, transportation facilities, and travel habits and patterns. The major reinventory findings are documented in SEWRPC Planning Report No. 25, A Land Use Plan and a Transportation Plan for Southeastern Wisconsin—2000, Volume One, Inventory Findings.

Reappraisal of the adopted 1990 regional land use and transportation plans and the comprehensive regional air quality maintenance planning effort were conducted concurrently and in a fully coordinated, indeed totally integrated, manner. In reviewing and evaluating the land use and transportation system development objectives and standards as part of the major plan reappraisal process, it was determined that the probable effects on ambient air quality of alternative land use and transportation system plans would be an overriding consideration. Accordingly, each alternative land use and transportation plan developed in the plan reevaluation process was evaluated with respect to its effect on ambient air quality in southeastern Wisconsin. The results of that evaluation are reported later, herein, and presented in more detail in SEWRPC Planning Report No. 25, A Land Use Plan and a Transportation Plan for Southeastern Wisconsin—2000, Volume Two, Alternative and Recommended Plans.

Comprehensive Watershed Studies

The regional planning program very early recognized the significance of existing water-related resource problems, including flooding and water pollution. The natural watershed was selected by the Commission as the basic water and water-related resource planning unit, and comprehensive watershed plans have been completed for the Root, Fox, Menomonee, and Milwaukee River watersheds within the Region. In addition, the Commission has undertaken a comprehensive planning program for the Kinnickinnic River watershed.

The basic purpose of watershed planning programs, as developed within the context of the overall regional planning program, is to permit public evaluation and choice of alternative water-resource development policies and plans and, through the preparation of a long-range plan for the development of water-related community facilities, to provide for the coordination of local, state, and federal water resource management programs within the Region and its watersheds. Specifically, the objectives of the watershed planning programs include: the abatement of flood damage; the protection of floodways and floodplains from incompatible development; the abatement of water pollution and the protection of water

supply; the preservation of land for park and related open space; the preservation of woodlands, wetlands, wildlife habitat, and prime agricultural lands; and the promotion of wise and judicious use of the Region's limited land and water resources. In addition, the watershed plans serve to refine and adjust the regional land use plan, particularly in the riverine areas, and help achieve a more complete integration of land and water resource planning.

Areawide Water Quality Management Planning Program

In 1975 the Commission initiated an areawide water quality management planning program. This program is intended to build upon previous Commission water resource-related planning efforts, updating and refining the comprehensive watershed development plans and the regional sanitary sewerage system plan and extending those plan elements to all portions of the Region and to the year 2000. The concurrent conduct of the air quality maintenance planning program and the areawide water quality management planning program enabled the resultant plans to be fully coordinated both with each other and with the preparation of a new regional land use plan.

Other Regional and Subregional Planning Programs

The Commission has undertaken five additional regional planning programs: a regional sanitary sewerage system planning program, a regional library facilities and services planning program, a regional airport system planning program, a regional housing study, and a regional park and outdoor recreation planning program. In addition, the Commission has completed and adopted detailed urban development plans for the Kenosha and Racine Urban Planning Districts. All of these have important implications for regional air quality maintenance planning.

THE REGIONAL AIR QUALITY MAINTENANCE PLANNING PROGRAM

In considering a program to reevaluate the regional land use and transportation plans adopted by the Commission in 1966, the Commission recognized that any such reevaluation must include specific consideration of the potential impacts of alternative land use and transportation plan proposals on ambient air quality in the Region. In its initial transportation planning efforts, the Commission had considered the relative amounts of air pollutants produced by transportation systems and utilized these estimates in a relative manner in evaluating alternative plan proposals. The impact of such emissions on ambient air quality, however, was not determined nor considered in the plan selection process. With the increasing importance of air quality management and new federal requirements pertaining to this manner, the Commission resolved to investigate the means for more fully determining the effects of alternative land use and transportation system plans on ambient air quality under the regional transportation plan reevaluation effort.

Meetings to discuss such an approach were held in the fall of 1973 among representatives of the Wisconsin Department of Natural Resources; the Wisconsin Department of Transportation; the U. S. Environmental Protection Agency; the U. S. Department of Transportation, Federal Highway Administration; and the Southeastern Wisconsin Regional Planning Commission. It became evident at those meetings that a broader approach would be far more desirable than simply directing air pollution studies toward the single functional purpose of evaluating the air quality implications of alternative regional transportation plans. The newer, more comprehensive approach would involve the preparation of a regional air quality maintenance plan addressing all point, line, and area air pollution sources, and relating such sources to land use as well as transportation system development. The broader approach would not only meet federal transportation planning requirements for ensuring that areawide transportation plans do not conflict with plans for attaining air quality standards but would also meet federal requirements for the preparation of a regional air quality maintenance plan for southeastern Wisconsin. Subsequent to such meetings, the Wisconsin Departments of Natural Resources and Transportation, on November 12, 1973, requested the Commission to undertake the preparation of a comprehensive air quality maintenance plan for the Region.

Accordingly, the Commission on April 25, 1974, pursuant to Section 66.945(7) of the Wisconsin Statutes, created a Technical Coordinating and Advisory Committee on Regional Air Quality Maintenance Planning to assist the Commission in an investigation of the desirable scope and content of the needed air quality maintenance planning program for the Region. The Committee consisted of knowledgeable public officials, university staff, and citizens concerned about air pollution and air pollution control within the Region.

The Commission initially charged the Committee with preparation of a Prospectus for a regional air quality maintenance planning program. The purpose of the Prospectus was to document the need for such a study, define the necessary scope and content of the needed study, recommend a time schedule, budget, and cost allocation for the study. The Prospectus was intended to be used as a basis for obtaining the funding necessary to mount the study. The Prospectus was completed by the Committee in May 1974; approved by the Commission on July 9, 1974; published and, in accordance with the advisory role of the Commission, transmitted to the appropriate governmental agencies for consideration and action. The U. S. Environmental Protection Agency and the Wisconsin Departments of Natural Resources and Transportation subsequently endorsed the Prospectus and agreed to provide all the funds necessary for execution of the program. The U. S. Environmental Protection Agency agreed to provide 60 percent of the needed funds, and the Wisconsin Departments of Natural Resources and Transportation agreed to provide 20 percent each.

The Prospectus, as prepared by the Advisory Committee, was not a finished study design. It was a preliminary design intended to obtain support and financing for the necessary study, an objective which it fully achieved. Major work elements, a staff and consultant organization,

and a time schedule and cost estimates were outlined in a preliminary manner in the Prospectus. Work on the air quality maintenance program, as outlined in the Prospectus, began in August 1974.

Need for the Study

As more fully documented in the Prospectus, four major considerations dictated the need for undertaking an areawide air quality maintenance planning program within the Southeastern Wisconsin Region:

1. Measured and estimated ambient air pollutant concentration levels were found to exist within the Region that exceed air quality standards established by the federal and state governments, particularly in the more intensely urbanized areas of the Region. More specifically, evidence exists that the national ambient air quality standards for particulate matter, carbon monoxide, sulfur dioxide, and photochemical oxidants are presently exceeded in certain areas of the Region. Estimated nitrogen dioxide concentrations in the Region exceed the established air quality standard by a very small measure. The major sources of the pollutants contributing to air pollution in the Region are transportation movements, industrial processes, and power generation.

2. Anticipated regional population growth and urbanization with concomitant increases in both stationary and mobile sources of air pollution have the potential of further degrading the ambient air quality level within the Region in the absence of a sound, long-term air quality maintenance plan. Not only does an air pollution problem presently exist within the Region, as evidenced by the fact that ambient air quality within the Region does not meet certain federally established standards for such quality, but this problem has the potential of increasing over the next two or three decades as a result of continued population growth and urbanization within the Region. Air pollution, because of its direct relationship to human activities—activities well-characterized by land use patterns and related transportation movements—is primarily an urban problem. Available data concerning ambient air quality levels clearly indicate that the levels of air pollutants in the atmosphere are directly related to the intensity of urban development. As urbanization increases, the attendant air pollution problems may also be expected to intensify. Moreover, as urban development diffuses over increasingly large areas of the Region, air pollution may be expected to become increasingly an areawide problem. Therefore, the changes in the levels and spatial distribution of population, employment, and urban land uses; in income and automobile availability; and in the amount, spatial distribution, and mode of travel which can be expected to occur within the Region over the next two to three decades have extremely important implications for air quality planning within the Region.

3. The need exists to evaluate the probable effects of alternative land use and transportation system development plans and programs on ambient air quality. Although air pollution is clearly an areawide problem intensified by urban development, the data and techniques necessary to relate urban land use patterns and attendant transportation movements to ambient air quality were not available within the Southeastern Wisconsin Region. If the effects of alternative land use and transportation system development decisions on air quality were to be explicitly considered, then the means of relating air pollution to various alternative land use patterns and supporting transportation system plans in a quantitative manner must be provided. The Regional Planning Commission historically has had the capability of estimating the total amounts of various major pollutants which would be generated by the transportation movements attendant to alternative land use patterns and supporting transportation systems. It has not possessed the ability to quantitatively evaluate the effect of these emissions on ambient air quality levels. To develop this capability required the formulation and application of a regional ambient air quality simulation model which would permit the simulation of ambient air quality levels, expressed in terms of the major pollutants, under alternative land use patterns and transportation system configurations. Such a simulation model must be able to provide an accurate assessment of the pollution distribution in response not only to the emission sources but also to the dynamic nature of the atmospheric processes.

4. The need also exists to formulate for the Region an effective air quality maintenance strategy or plan which can be used to coordinate federal, state, and local air pollution control efforts and properly relate such efforts to areawide land use and transportation system development. The State Legislature in 1967 delegated to the Wisconsin Department of Natural Resources the authority to establish a comprehensive air pollution control program within the state. In June 1973 the U. S. Environmental Protection Agency required all states to delineate air quality maintenance areas (AQMA's) which may have the potential for exceeding any national standard within the next decade due to current air quality and/or projected growth rates. Furthermore, it was required of the states that the impact of anticipated growth and development on air quality be carefully analyzed and the analysis be coordinated with land use and transportation planning and development. On June 21, 1974, the Wisconsin Department of Natural Resources identified the Southeastern Wisconsin Region as an area having the potential for violation of the specified air quality standards within the next ten years. On June 2, 1975, the Administrator of the U. S. Environmental Protection Agency formally designated the seven-county Southeastern Wis-

consin Region as the Wisconsin portion of the Illinois-Indiana-Wisconsin Interstate Air Quality Maintenance Area.

In a related action, the U. S. Department of Transportation, Federal Highway Administration, directed that a continuing working relationship be established among all official areawide transportation planning agencies—such as the Southeastern Wisconsin Regional Planning Commission—and the state air quality management agencies. This relationship should assure that air pollution problems are adequately considered in the planning and development of highway transportation facilities within urbanizing regions.

Study Objectives

The primary objective of the regional air quality maintenance planning program is to develop a sound and workable long-range plan for meeting established ambient air quality objectives and supporting standards. The effective abatement of air pollution and attainment of the desired levels of ambient air quality can only be accomplished through proper consideration of the interrelationships existing among land use development, transportation movements and facilities, and ambient air quality. Therefore, the regional air quality maintenance plan must be fully coordinated with areawide plans for land use and transportation system development and contain recommendations relating to land use and transportation system development, as well as to air pollution control strategies. The latter may include adjustments in the existing and probable future land use patterns and in the operation of the existing transportation system, as well as proposals for emission controls. Furthermore, the regional air quality maintenance plan must be fully coordinated with the areawide water quality management plan in order to ensure that the two plans and their attendant strategies do not conflict or hinder either plan from achieving their respective goals and objectives. The planning program is intended to provide planning and engineering data required for the effective maintenance of the overall quality of the air resource on an areawide basis and the analytical means required to assess, on a continuing basis, the potential impact on ambient air quality of proposed major land use and transportation facility developments. To this end, the program is to provide recommendations for the establishment, operation, and maintenance of a continuing atmospheric and ambient air quality monitoring system adequate to accurately assess ambient air quality levels and related meteorological conditions within the Region and progress over time toward attainment of established air quality objectives and supporting standards.

The air quality planning program is intended to culminate in the preparation of a regional air quality maintenance plan that will identify the best means of maintaining regional air quality at a level consistent with the established air quality objectives and standards, considering alternative land use and transportation development patterns as well as air pollutant abatement strategies. In the preparation of the regional air quality maintenance plan, a detailed analysis of all significant aspects of growth and development within the Region will be made, and the implications of such growth and development for pollutant emissions and ambient air quality determined. An estimate of probable future air pollutant emissions and ambient air quality will be made from an analysis of potential socioeconomic, land use, and transportation changes within the Region and of relationships between such changes and air quality levels. If such an estimate clearly indicates that current pollution control strategies will permit attainment and maintenance of ambient air quality objectives, given forecast socioeconomic, land use, and transportation changes, the existing strategies will be deemed to constitute the regional air quality plan. If not, then alternative land use and transportation development policies as well as pollution control strategies will be examined, and regional air quality maintenance strategies formulated.

Staff, Consultant, and Committee Structure

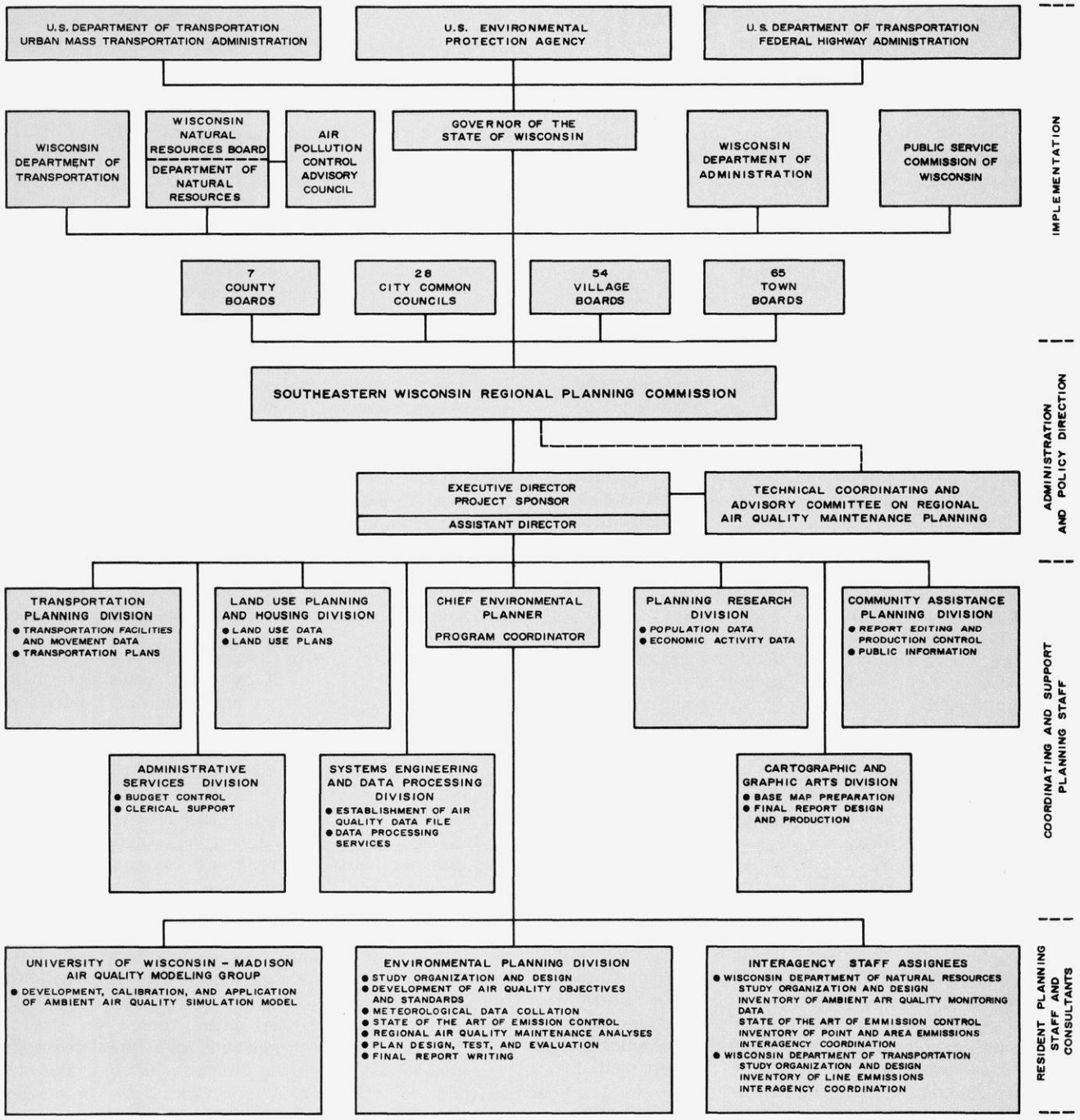
The basic organizational structure for the regional air quality maintenance planning program is outlined in Figure 2. As the agency responsible for comprehensive regional planning in southeastern Wisconsin, the Southeastern Wisconsin Regional Planning Commission undertook responsibility for the conduct of the entire planning program. Commission staff work under the work program was centered in the Environmental Planning Division, supplemented primarily by staff skills in Transportation and Land Use Planning Divisions. The Commission Chief Environmental Planner served as the program coordinator.

As indicated in Figure 2, only one consultant was employed during the study, that consultant being retained for the purpose of supplementing Commission staff skills in the area of air quality simulation modeling. The University of Wisconsin-Madison, Air Quality Modeling Group was selected as consultant in the belief that the model developed by that group, the Wisconsin Atmospheric Diffusion Model (WIS*ATMDIF), was one of the most advanced ambient air quality simulation models in the United States. Under the contract entered into between the University and the Commission, the University agreed to apply the model to the Southeastern Wisconsin Region, calibrating and validating the model to regional meteorological and topographical conditions. The results of this modeling effort were to provide the foundation for reliably estimating future air pollutant concentrations within the Region based on forecast emission inventories. In addition, when simulated pollutant concentrations for the forecast years indicated that emission controls would be necessary to achieve and maintain the national ambient air quality standards (NAAQS), strategies designed to reduce the pollutant concentrations were evaluated for their effectiveness through use of the model. The modeling results also were used by the Commission in the design, test, and evaluation of alternative regional air quality maintenance plans and in the selection of a recommended plan.

A comprehensive regional air quality maintenance planning program covers a broad spectrum of related governmental and private development programs, and no

Figure 2

ORGANIZATIONAL STRUCTURE FOR THE REGIONAL AIR QUALITY MAINTENANCE PLANNING PROGRAM



Source: SEWRPC.

agency, whatever its function and authority, can "go it alone" in the conduct of such a study. The basic Commission organization provides for the attainment of the necessary interagency coordination and lay citizen advisory function through the establishment of advisory committees, as well as through interagency staff assignments. For the air quality maintenance planning program, one committee was created after careful deliberation to provide for the active participation of concerned governmental agencies, universities, and knowledgeable citizen leaders.

The function of the Technical Coordinating and Advisory Committee is to provide technical guidance in the many

areas of science and engineering needed in the conduct of a comprehensive air quality study; to place at the disposal of the program the experience, knowledge, and resources of the represented federal, state, and local agencies having responsibilities for initiating and administering air quality programs; and to provide the overall technical policy direction for the program. In addition, the Committee members have the function of familiarizing local elected officials with the study and its findings and recommendations, and generating an understanding of the study objectives, the plan recommendations, and plan implementation procedures among such officials. The Committee has a particularly important role in selecting the final plan and assuring its financial and administrative feasibility. The full membership of this Committee is set forth in Appendix A.

The regional air quality maintenance planning program and this report are the result of a joint work effort by the Commission, the University of Wisconsin-Madison, the Wisconsin Departments of Natural Resources and Transportation, and the Technical Coordinating and Advisory Committee. The Commission staff assumed responsibility for those work elements of a general regional planning nature, as well as for certain work elements of a functional planning nature. These included land use, demographic, and economic data collation, analyses, and forecasts; climatological and meteorological data collation; mapping collation; preparation of forecasts of regional growth and change; preparation of development objectives and standards; plan preparation, test, and evaluation; and final report writing. The University of Wisconsin-Madison was responsible for those functional planning elements relating to the design, calibration, and application of the ambient air quality simulation model. The Wisconsin Department of Natural Resources was responsible for the collection and collation of ambient air quality monitoring data. Work elements shared by the Commission staff and the interagency staff assignees from the Wisconsin Departments of Natural Resources and Transportation included the preparation of a study design; the conduct of air pollutant emission inventories; and a state of the art study with respect to emission control technology.

SCHEME OF PRESENTATION

The major findings and recommendations of the regional air quality maintenance planning program are documented in this report. The report sets forth the basic principles and concepts underlying the program, and presents the salient findings of the program inventories and analyses. Inventory chapters present data on the socioeconomic and natural resource bases of the Region; the existing quality of the ambient air within the Region; the quantity of pollutant emissions generated within the Region; the meteorological regime influencing the dispersion of air pollutants over the Region; the technology available for the control of air pollution; and air quality law. Subsequent chapters contain forecast data of pollutant emissions and the resultant pollutant concentrations as determined by application of the ambient air quality simulation model. The final chapters present alternative air quality maintenance strategies, a recommended plan for maintaining the highest possible standard of air quality within the Region based on the regional air quality objectives and supporting standards, and specific recommendations for plan implementation.

This report is intended to allow for careful, critical review of potential air quality maintenance strategies by public officials, agency staff personnel, and citizen leaders within the Region, and to provide the basis for plan implementation by the federal, state, and local agencies of government concerned. The report can only summarize in brief fashion the large volume of information assembled in the extensive data collection, analysis, and forecasting phases of the regional ambient air quality maintenance planning program. The reproduction of all of this information in report form is prohibitive due to the complexity and magnitude of the material involved. All of the basic data is on file in the Commission offices, and is available at cost to member units and agencies of government and the public in general upon specific request. This report, therefore, serves the additional purpose of indicating the type of data available from the Commission which may be of value in assisting federal, state, and local units of government and private investors in making more advised decisions concerning physical development within the Region.

Chapter II

BASIC PRINCIPLES AND CONCEPTS

INTRODUCTION

Air pollution problems are among the most complex and difficult problems affecting urban regions. Air pollution may reach levels that are harmful to human health and even fatal to human life; that injure or destroy plant and animal life; and that severely damage personal and real property. Air pollution also may affect the acidity, alkalinity, and fertility of surface waters, and may even contribute to the contamination of the soil.

The far-reaching effects of air pollution have prompted action by the U. S. Congress and the Wisconsin Legislature through legislation, and by private citizens through litigation, to bring about a reduction in the concentration of pollutants in the ambient air through the control of pollutant emissions and to ensure that, once clean air is obtained, it will be maintained even with increasing development in urbanizing regions. The regional air quality attainment and maintenance planning program for southeastern Wisconsin is a direct result of this public and private concern for the achievement and maintenance of clean air.

This chapter discusses the basic concepts underlying the regional air quality attainment and maintenance planning program for southeastern Wisconsin, sets forth the basic planning problem involved, describes the basic principles upon which the planning effort for southeastern Wisconsin was conducted, and describes the basic process followed in conducting the program for southeastern Wisconsin.

BASIC CONCEPTS

The following section is intended to describe certain basic concepts upon which the regional air quality attainment and maintenance planning program has been founded. These basic concepts relate to the federal and state air quality standards and their relationship to public health and welfare, the planning period, the geographic planning unit, and the relationship of air quality planning to land use and transportation planning, to water quality management planning, and to the nonsignificant deterioration of clean air.

Federal Air Quality Standards

In understanding the regional air quality maintenance planning program, it is important to distinguish between an ambient air quality standard and an emission standard. An ambient air quality standard is a limit on the amount of a given pollutant permitted in the atmosphere. An emission standard is the maximum amount of a given pollutant that may be discharged to the atmosphere from a specific source. The latter is often referred to as an emission limitation. The enforcement of emission standards is one means of achieving the ambient air quality standards.

As discussed in more detail in Chapters III and VI of this report, the federal Clean Air Act places responsibility for the establishment of national ambient air quality standards in the U. S. Environmental Protection Agency (EPA). To date, the EPA has established ambient air quality standards for six pollutants: suspended particulate matter, sulfur dioxide, carbon monoxide, nitrogen dioxide, photochemical oxidants reported as ozone, and hydrocarbons. These ambient standards have varying and, in some cases, multiple averaging times, specifying concentrations measured on an average annual 24-hour, eight-hour, three-hour, and one-hour basis. To assist in achieving these ambient standards, the federal Clean Air Act also provides for establishment by the EPA of emission standards or limitations. Uniform federally prescribed emission standards have been promulgated for certain new major stationary sources of air pollutants, such as new electric power generation plants, and for some nonstationary sources such as automobiles. The states have been delegated the responsibility to promulgate emission standards for existing stationary sources and new minor stationary sources.[1] In addition, there are uniform federally prescribed emission limitations for all sources of those pollutants which the Administrator of the U. S. Environmental Protection Agency has determined to be hazardous. Such emission standards apply to both new and existing sources.

It is important to note that neither the reduction in pollutant emissions which the emission standards are intended to bring about, nor even the attainment of the ambient air quality standards are strictly ends in themselves. Rather, they represent a means to the ultimate goal set by the U. S. Congress of protecting public health and welfare. One of the basic assumptions underlying the regional air quality attainment and maintenance planning program for southeastern Wisconsin is that attainment of the ambient air quality standards is necessary to adequately protect the public health and welfare from the deleterious effects of air pollution. Because of the acceptance of this basic assumption, the regional air quality attainment and maintenance planning program does not include those benefit-cost analyses usually conducted

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[1] *The term major source includes any structure, building, facility, installation, or operation which produces emissions greater than 50 tons per year of either particulate matter, sulfur oxides, nitrogen oxides, or nonmethane hydrocarbons (organics), or emissions of 500 tons per year of carbon monoxide.*

under Commission planning programs as an aid in decisionmaking. Rather, it is assumed that, since the U. S. Congress has mandated the attainment of the national ambient air quality standards, those standards will be met. The air quality attainment maintenance planning program for southeastern Wisconsin thus will attempt only to identify the various ways in which the ambient air quality standards can be met, and select from among those ways the least costly.

The Planning Period

Air quality planning may involve three time scales: short-term, defined as a period no longer than a few days; middle-term, defined as a period of from one to five years; and long-term, defined as a period of more than five years. Short-term air quality planning involves the preparation of contingency plans for efforts to reduce the harmful effects of air pollution episodes. Such planning may involve the selection of applicable measures and the establishment of procedures for reducing severe ambient air pollutant concentrations when either significantly increased emissions production or the forecast of adverse meteorological conditions or a combination of both indicates that the ambient air quality standards will be significantly exceeded for a short period of time over a given geographic area. Present ambient air quality monitoring and weather forecasting abilities limit this time scale to a period ranging from a few hours to a few days. It is not the purpose of the regional air quality attainment and maintenance planning effort for southeastern Wisconsin to deal with short-term air pollution episodes. Such efforts are the responsibility of the state enforcement agency, the Wisconsin Department of Natural Resources, through what are, in effect, operational planning measures. These operational planning measures are specified in the state implementation plan for air quality prepared by the DNR and submitted to the EPA.

Middle-term air quality planning is primarily concerned with reducing existing ambient air pollution levels to, or below, the national ambient air quality standards within a specified time period, generally not exceeding five years. The attainment of the air quality standards through emission limitations often requires the application of control measures which, because of the lead times and costs involved, must be carried out over several years. Consequently, in those geographic areas where the ambient air quality standards are now violated, it may be expected that ambient air quality will gradually, rather than abruptly, improve.

The basic analytical method for middle-term air quality planning is an attainment analysis. The attainment analysis seeks to determine whether or not, given the current sources of air pollution and given the currently prescribed air pollution control measures, such as the new stationary and mobile source emission limitations prescribed by the U. S. Environmental Protection Agency and the existing stationary source emission limitations prescribed by the Wisconsin Department of Natural Resources, the ambient air quality standards will be met over an approximate five-year period. The responsibility for conducting such middle-term air quality planning rests with the Wisconsin Department of Natural Resources, and the attainment analyses conducted by that Department are considered to be an integral part of the state implementation plan for air quality.

One of the purposes of the regional air quality planning program for southeastern Wisconsin is to assist the Wisconsin Department of Natural Resources in the conduct of the necessary air quality attainment analyses. To the extent that such assistance was given through the regional air quality planning program, the results are reported herein. Furthermore, to the extent that these attainment analyses indicate that the air quality standards will not likely be met given the current set of emission limitations, long-term growth considerations aside, it is the purpose of the regional air quality planning program to develop, evaluate, and select air quality control strategies that will result in the attainment of the standards.[2] As discussed in more detail in Chapter XII of this report, the attainment analyses and supplemental analyses conducted under the areawide air quality management planning program indicate that, given the current schedule of emission limitations set forth in the state implementation plan, there should be no problem in attaining the federal ambient air quality standards for carbon monoxide and nitrogen dioxide by the year 2000. The attainment analyses further indicate it is likely that the current set of emission limitations will not be sufficient to attain the air quality standards for particulate matter on both an average annual and 24-hour basis, sulfur dioxide on both the annual and 24-hour basis, and hydrocarbons and photochemical oxidants. The regional air quality planning program must address the residual particulate, sulfur dioxide, and hydrocarbon problems. In the case of particulate matter and sulfur dioxide the areas of nonattainment are geographically limited to small subareas of the Region.

Planning for the middle-term, while recommending the means for meeting the ambient air quality standards under existing conditions, does not provide for consideration of the effects of anticipated long-term regional development and redevelopment on ambient air quality. Hence, long-term air quality planning is intended to insure that, once the ambient air quality standards have been attained, changes in land use and concomitant changes in transportation movements will not result in air quality levels that again exceed the standards. The primary function of the regional air quality planning effort for southeastern Wisconsin is to address the long-term air

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[2] *See Attainment Analysis Southeastern Wisconsin Intrastate Air Quality Control Region Total Suspended Particulate Matter and Sulfur Dioxide, Wisconsin Department of Natural Resources, October 1976. This analysis was reviewed and its conclusions were approved by the SEWRPC Technical Coordinating and Advisory Committee on Regional Air Quality Maintenance Planning on September 30, 1976, and by SEWRPC on October 11, 1976.*

quality maintenance planning problem. In essence, the long-term air quality maintenance planning effort assumes that the current set of emission limitations, together with any air quality control strategies found essential to attain the air quality standards under the middle-term planning effort, will continue to be applied to the plan design year. Additional analyses are then conducted to determine whether anticipated changes in land use development, transportation movements, and full utilization will be likely to result in air pollution exceeding the federal ambient air quality standards. If the analyses indicate that this may be expected to be the case, then the air quality maintenance planning effort must include the development, evaluation, and selection of those additional air quality control strategies needed to insure that the ambient standards will not be violated as the Region grows and changes.

The federal regulations for air quality maintenance planning generally provide that all such planning efforts should be based upon an approximate 10-year planning period. Thus, for southeastern Wisconsin, the air quality maintenance planning period would extend by federal regulation to about 1985. However, in October 1975 the U. S. Environmental Protection Agency indicated that air quality maintenance planning efforts should extend into the future as far as the duration of the longest federally sponsored planning program having air quality impacts in an air quality maintenance area. At the present time the Southeastern Wisconsin Regional Planning Commission has several federally sponsored planning programs that relate to air quality, particularly programs relating to land use and transportation planning and to areawide water quality management planning. Each of these federally assisted programs has as its design year the year 2000. In addition, it has been determined that, in order to better relate the land use and transportation planning effort to the air quality maintenance planning effort, the regional land use and transportation plans would be staged for the year 1985. Consequently, the regional land use, transportation, water quality management, and air quality maintenance planning efforts are to be fully coordinated, each resulting in the preparation of a long-term plan for the year 2000, and each resulting in the preparation of a 1985 stage that corresponds to the initial planning period proposed for air quality maintenance planning purposes in southeastern Wisconsin.

The Geographic Planning Unit

Air quality maintenance planning must be accomplished on a regional basis. Land use and attendant travel patterns, which together determine to a large degree the amount and spatial distribution of pollutant emissions, develop over an entire urban region without regard to artificial corporate limit lines. In addition, the ambient air which receives the emissions is an enormous, dynamic, fluid body affected by meteorological conditions over widespread areas of the earth's surface. Consequently, air quality planning cannot be effectively conducted by a single municipality, a single county, or even, for some purposes, a single substate region. In fact, the air resource is a common resource shared statewide, nationally, and internationally. Although the problem may be continental, if not global, some compromise must be made to ensure that the necessary planning is done on a manageable scale. Thus, while some portions of the overall air quality planning effort can best be conducted at the national level as, for example, the setting of national ambient air quality standards and emission limitations for motor vehicles, other portions of the overall air quality planning effort that involve pollutants, such as particulate matter and photochemical oxidants which may have long atmospheric residence times and which may be transported considerable distances, can best be handled at the multistate level, and still others at the state and substate regional level.

As discussed in more detail in Chapter III of this report, the U. S. Congress, in a 1967 amendment to the Federal Clean Air Act of 1963, provided the legal basis for the required cooperative, intergovernmental approach to air quality planning. Under the approach envisioned in this legislation, the U. S. Environmental Protection Agency (EPA) and its predecessor agencies, after consultation with the states, designate multicounty air quality control regions. The Southeastern Wisconsin Intrastate Air Quality Control Region, which is coterminous with the seven-county Southeastern Wisconsin Planning Region, was designated by the EPA on April 1, 1971. Subsequently, the remainder of the State was divided into seven additional air quality control regions, the boundaries of which are shown on Map 3. Four of the eight regions are interstate in geographic scope. Under the envisioned intergovernmental approach to air quality planning, the states are required to adopt the national ambient air quality standards as promulgated by the EPA, and must submit a plan, termed the state implementation plan, to the EPA. This plan must be designed to ensure that the standards will be met and maintained in each air quality control region. The Wisconsin state implementation plan was prepared by the Wisconsin Department of Natural Resources and submitted to the EPA in January 1972.[3]

On May 31, 1972, the EPA approved the Wisconsin state implementation plan. Subsequently, this and related approvals of other state plans were challenged in federal court by environmental protectionist groups who contended that the state implementation plans did not contain adequate provisions for ensuring that the air quality standards would be maintained once they were initially met. As a result of that litigation, the EPA on March 3, 1973, disapproved all state implementation plans insofar as they relate to the maintenance of air quality standards.

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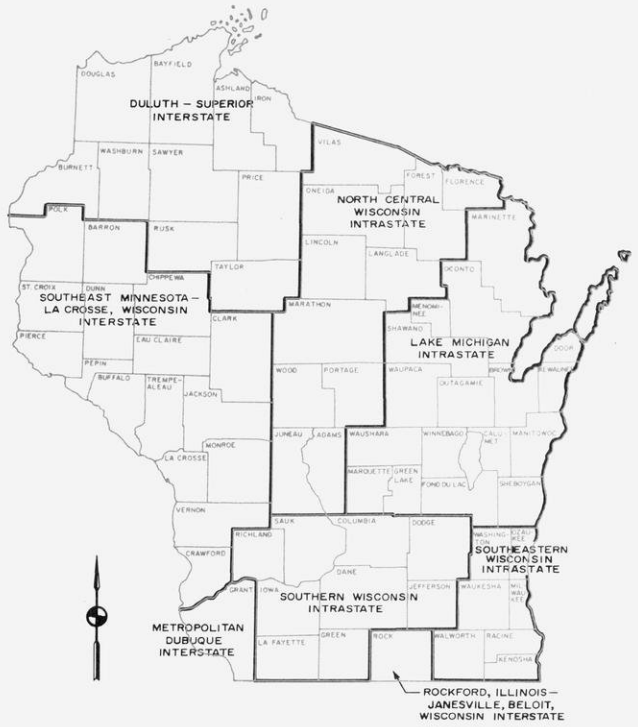
[3]*See A Proposed Statewide Implementation Plan to Achieve Air Quality Standards for Particulates, Sulfur Oxides, Nitrogen Oxides, Hydrocarbons, Oxidants, and Carbon Monoxide in the State of Wisconsin, Wisconsin Department of Natural Resources, January 1972. This plan has not been amended to date (April 1977).*

Map 3

AIR QUALITY CONTROL REGIONS
IN THE STATE OF WISCONSIN



The State of Wisconsin has been divided into four interstate and four intrastate air quality control regions. These regions were established pursuant to the federal Clean Air Act Amendments of 1970 to delineate multicounty areas having a common air pollution problem.

Source: SEWRPC.

In June 1973 the EPA published regulations requiring all states to identify those areas which may have potential for exceeding any national air quality standard by 1985 due to anticipated growth and development. These areas were termed air quality maintenance areas. The EPA required that the impact of such growth and development on air quality be carefully analyzed in each such air quality maintenance area, and that this analysis be coordinated with land use and transportation planning and development. This latter action was reinforced by a directive from the U. S. Department of Transportation, Federal Highway Administration, that a continuing working relationship be established between all metropolitan transportation planning agencies and the state air quality management agencies to ensure that air quality problems are adequately considered in the planning and development of transportation facilities within urban regions.

In response to the June 1973 EPA requirement for the establishment of air quality maintenance areas, the Wisconsin Department of Natural Resources proposed in June 1974 that two subareas of the State—the seven-county Southeastern Wisconsin Region and a three-county area consisting of Brown, Outagamie, and Winnebago Counties—be designated as air quality maintenance areas. On June 2, 1975, the EPA accepted the designation of Brown, Outagamie, and Winnebago Counties of the Lake Michigan intrastate region as an air quality maintenance area, but rejected the designation of the seven-county Southeastern Wisconsin Region as such an area, substituting instead a tristate air quality maintenance area, consisting of the seven southeastern Wisconsin counties; McHenry, Lake, Kane, DuPage, Cook, and Will Counties in Illinois; and Lake and Porter Counties in Indiana (see Map 4). This total area was designated as the Illinois-Indiana-Wisconsin Interstate Air Quality Maintenance Area. The area was divided into three portions corresponding to that part of the area included within each of the three respective states. Thus, although the seven-county Southeastern Wisconsin Region constitutes an intrastate, rather than an interstate, air quality control region, for air quality maintenance planning purposes the seven-county Southeastern Wisconsin Region constitutes only a portion of a much larger tristate air quality maintenance area.

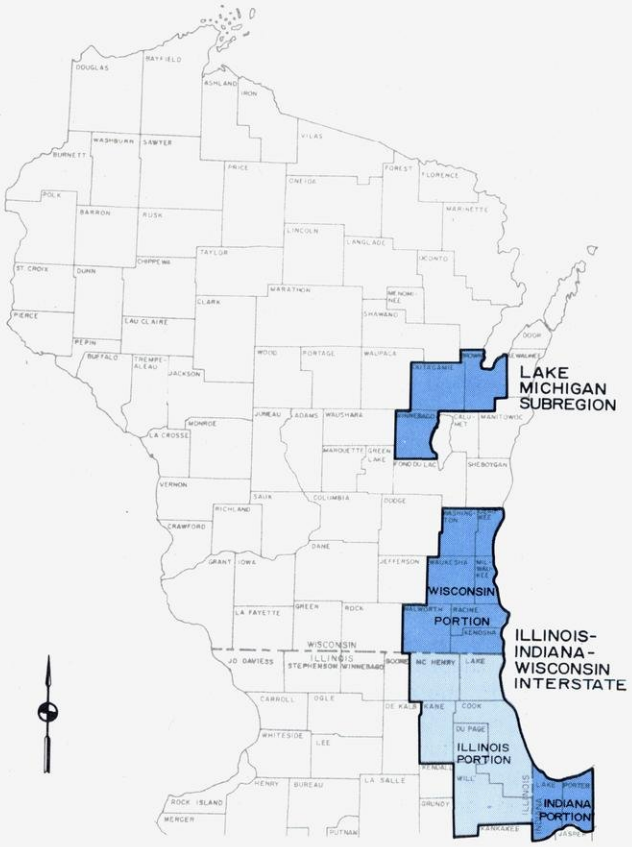
The intergovernmental approach envisioned in the preparation of state implementation plans, and of air quality maintenance plans as a subelement of state implementation plans, requires that each state in the Illinois-Indiana-Wisconsin Interstate Air Quality Maintenance Area assume the primary responsibility for the analysis of existing and probable future air quality control problems and the development of appropriate air quality maintenance plans for those counties within the maintenance area and within each respective state. The designation of an interstate air quality maintenance area provides the formal mechanism through which the three individual states may coordinate their work and, if necessary, resolve those air quality problems which cannot be entirely resolved within the framework of an individual state planning effort. Basic responsibility remains with the EPA for coordination of efforts among the three states and for integration of air quality maintenance plans developed for each of the three portions of the tristate area into a single plan for the entire interstate air quality maintenance area.

In designating the Illinois-Indiana-Wisconsin Interstate Air Quality Maintenance Area, the EPA indicated that air quality maintenance planning efforts for that area should consider at least three pollutants: particulate matter, sulfur dioxide, and photochemical oxidants. In addition, the EPA indicated that two additional pollutants be considered in the Illinois portion of the tristate air quality maintenance area: carbon monoxide and nitrogen dioxide.

As noted above under the discussion of the planning period, it is intended that the regional air quality maintenance planning program for southeastern Wisconsin include those attainment and maintenance analyses necessary to determine whether or not the national ambient air quality standards will be met in the middle-term planning period given the current national and state emission limitations and whether or not these standards,

Map 4

AIR QUALITY MAINTENANCE AREAS
IN THE STATE OF WISCONSIN



The seven-county Southeastern Wisconsin Air Quality Control Region is a portion of a larger tristate air quality maintenance area which also includes six counties in northeastern Illinois and two counties in northwestern Indiana. The interstate designation recognizes that certain forms of pollution may be carried long distances in the atmosphere, and abatement of the attendant problems cannot always be addressed within the boundaries of a single intrastate planning region.

Source: SEWRPC.

once met, can be maintained over the long-term planning period given anticipated changes in land use development and attendant transportation movements in the Region.

For three of the six pollutants for which national ambient air quality standards have been specified—carbon monoxide, nitrogen dioxide, and sulfur dioxide—the seven-county Southeastern Wisconsin Region constitutes a logical geographic planning unit because of the predominance of local emissions of these three pollutant species as compared to the quantities of these species which are transported into the Region. For the remaining three pollutants, however, namely, particulate matter, hydrocarbons, and photochemical oxidants, the appropriateness of the seven-county Southeastern Wisconsin Region as a planning area is less clear. This is due to the fact that these pollutant species are capable of long-range transport and, given the proximity of southeastern Wisconsin to northeastern Illinois and the Chicago area, sources from outside the regional boundaries may contribute significantly to concentrations of these species in the air within the Region. Thus, the air pollution attainment and maintenance problems associated with these pollutants cannot necessarily be resolved within the seven-county Region.

Given this problem, two alternative planning approaches for these three pollutants appear to be available. Under the first approach, the amount of pollutants that are transported into the Region would be estimated and an air quality maintenance plan prepared that would seek to reduce pollution to that level which, in the absence of the transported pollutants, would meet the national ambient air quality standards. The basis for such an approach would be that it is not possible to determine through an intraregional analysis alone the most cost-effective solution to reducing pollution levels to the national standard. If transported pollutants are ignored, the resultant plan might unnecessarily and unfairly place a burden on the population and economy of the Region. Under the second alternative approach, the estimated pollutants that are transported into the Region would be accepted and a plan prepared to meet the national air quality standards irrespective of the problem of determining a cost-effective solution.

Neither of these two approaches appears to be totally acceptable. Given the recognized interstate character of the air quality attainment and maintenance planning required for particulate matter and hydrocarbons and photochemical oxidants, it is proposed that the air quality maintenance planning effort within the Wisconsin portion of the tristate air quality maintenance area seek to minimize particulate matter and hydrocarbons and photochemical oxidants. It is further anticipated that the air quality maintenance planning efforts for the Illinois and Indiana portions of the area will similarly act to reduce such harmful emissions. The effect of such emission reductions, and particularly the effect of such reductions of the formulation of photochemical oxidants over the entire tristate area, however, are phenomena which cannot be addressed within the seven-county Southeastern Wisconsin Region air quality maintenance planning effort alone. Rather, these phenomena will likely have to be further addressed by the EPA through a tristate air quality maintenance planning mechanism or perhaps application of such a mechanism to an even larger area.

Relationship Between Air Quality Planning and Land Use and Transportation Planning

Air pollution is clearly an areawide problem intensified by urban development. Consequently, comprehensive land use and transportation planning can be an effective means for managing the air resources of an area. Alternative regional land use development patterns can result in different air quality levels. Thus, those land use patterns that tend to minimize air pollution should be encouraged.

The density and spatial distribution of residential, commercial, and industrial land uses; major transportation terminals; agricultural areas; and woodland and wetland areas can all affect the overall air quality of an area. Consequently, these factors should be explicitly considered in the development of an integrated set of regional land use and air quality management plans. Similarly, alternative configurations of transportation systems and the relative use of alternative modes of transportation can have important effects on air quality, as can the strategies for operation of such facilities. Consequently, it is important that alternative transportation systems also be explicitly considered in the development of an integrated set of transportation and air quality maintenance plans.

In considering the relationship between air quality maintenance planning and land use and transportation system development planning, it is important to bear in mind that the problem of relating air quality to alternative urban designs manifests itself at two scales: (1) microscale and (2) macroscale. The microscale is concerned with the detailed relationships existing between mesometeorological conditions, ambient air quality, and the location and design of transportation facilities and various urban structures. This scale is concerned with relatively small areas and corridors within a larger substate region, and with site planning, specific route location, and detailed project design. It is intended to address such questions as the best siting, size, and configuration of individual buildings and structures and the detailed location and geometric design of transportation facilities. It is not intended that the regional air quality maintenance planning program for southeastern Wisconsin concern itself with the aforementioned microscale relationships. Rather, such relationships are more properly considered on a case-by-case basis during plan implementation.

The second of the scales, the macroscale, is concerned with the general relationships that exist between atmospheric motions, pollutant emissions, and entire systems of urban land use patterns and supporting transportation networks. As such, the macroscale concerns entire urban regions and is intended to address such questions as the best location for residential, commercial, and industrial concentrations; agricultural and open space green belts; and major transportation terminals, including airports and parking facilities. This scale is also concerned with alternative configurations of transportation systems and alternative strategies for effecting the use of the various modes comprising these systems, including terminal areas. The regional air quality maintenance planning program for southeastern Wisconsin is intended to be concerned with these macroscale relationships, formulating a regional air quality maintenance plan within which subsequent microscale planning efforts can be properly conducted.

Relationship Between Air Quality Planning and Water Quality Planning

Air quality maintenance planning and water quality maintenance planning are interrelated, for it is possible that a plan designed to abate pollution in one of these areas can result in more pollution in the other area. For example, the use of control technology and equipment to reduce pollutant emissions to the air, such as limestone scrubbers, produces a liquid sludge which must be disposed of together with other sludges resulting from water and wastewater treatment. One possible way to dispose of sludge generated in the sewage treatment process is through incineration, which may, in turn, increase air quality problems. Planning for sewerage system development may also affect air quality by influencing the regional distribution of population and resulting land use patterns. Consequently, it is essential that care be taken to coordinate the development of areawide air and water quality management plans so that such plans can be mutually supportive.

Nonsignificant Deterioration of Clean Air

One of the important concepts of air quality planning involves the nonsignificant deterioration of clean air, that is, of ambient air which currently meets or exceeds the federal air quality standards. Acting pursuant to a court order, the U. S. Environmental Protection Agency (EPA) has promulgated regulations pertaining to the prevention of significant air quality deterioration. As discussed in more detail in Chapter III of this report, these regulations provide for the grouping of all "clean air" areas—that is, all areas of the country in which the ambient air quality standards are presently met—into one of three classes. Those areas in which almost any deterioration in air quality would be considered significant and, therefore, to be avoided would fall into Class I. Implicit in the designation of this Class is the concept that it is in the national and public interest that an existing air quality more pristine than that required by the national ambient air quality standards should be preserved and maintained. Those areas in which the deterioration normally accompanying moderate, well controlled growth would be considered insignificant would fall into Class II. Implicit in the designation of this Class is the concept that it is in the national and public interest to limit deterioration of air quality to a level somewhat better than that permitted under the national ambient air quality standards. Finally, those areas in which deterioration up to the national ambient air quality standards would be considered insignificant would fall into Class III. Implicit in the designation of this Class is the concept that the public health and welfare will be adequately protected by a level of air quality that meets, but is not necessarily superior to, the national ambient standards.

In establishing the mechanism by which the significant deterioration of clean air might be prevented, the EPA placed incremental limits for Class I, Class II, and Class III areas on the increase of ambient air concentrations of particulate matter and sulfur dioxide permitted over a base line concentration, determined by the Administrator to be as of August 7, 1977.[4] These increments,

[4] *No incremental increases were defined for carbon monoxide, nitrogen oxides, hydrocarbons, or photochemical oxidants since, in the opinion of the Administrator of the EPA, existing analytical procedures were not adequate to determine the impact of individual sources on air quality concentrations of these reactive pollutants.*

which have been set by the Administrator, are shown in Table 1.

The nonsignificant deterioration regulations, as presently enforced, pertain only to the construction of new stationary sources and the modification of existing stationary sources, which have been identified as a facility of one of the following 28 types: fossil fuel steam electric plants of more than 250 million BTU per hour heat input; coal cleaning plants; Kraft pulp mills; Portland cement plants; primary zinc smelters; iron and steel mills; primary aluminum ore reduction plants; primary copper smelters; municipal incinerators capable of charging more than 250 tons of refuse per 24-hour day; hydrofluoric, sulfuric, and nitric acid plants; petroleum refineries; lime plants; phosphate rock processing plants; byproduct coke oven batteries; sulfur recovery plants; carbon black plants (furnace process); primary lead smelters; fuel conversion plants, sintering plants; secondary metal production plants; chemical process plants; fossil fuel boilers of more than the 250 million British thermal units per hour heat input; petroleum storage and transfer facilities with a capacity exceeding 300,000 barrels; taconite ore processing facilities; glass fiber processing plants; and charcoal production facilities. The designation of these 28 sources does not preclude additional sources from being identified in the future. In addition to fossil fuel steam electric plants, municipal incinerators and coke ovens are presently in operation within the Region. With the exception, however, of new fossil fuel steam electric plants which may be proposed for construction in southeastern Wisconsin, there are no forecast facilities of the nature defined in the nonsignificant deterioration regulations operating within the Region.

It is important to note that the ambient air concentrations of particulate matter and sulfur dioxide from sources other than the 28 prescribed categories are not covered by the nonsignificant deterioration regulations.

Table 1

ALLOWABLE POLLUTANT CONCENTRATION INCREASES UNDER NONSIGNIFICANT DETERIORATION REGULATIONS

Pollutant	Class I ($\mu g/m^3$)	Class II ($\mu g/m^3$)	Class III ($\mu g/m^3$)
Particulate Matter			
Annual Geometric Mean . .	5	19	37
24-Hour Maximum.	10	37	75
Sulfur Dioxide			
Annual Arithmetic Mean . .	2	20	40
24-Hour Maximum.	5	91	182
3-Hour Maximum.	25	512	700

Source: Adapted from the Federal Register, Vol. 43, No. 118, June 19, 1978, p. 26384.

Given the current regulatory process, it is possible, therefore, that ambient air concentrations of these two pollutant species could increase up to the levels permitted by the national ambient air quality standards due to increased emissions from such nonstationary categories as mobile sources or domestic spaceheating. At the present time, the EPA has not resolved this apparent deficiency in the regulatory process.

The EPA initially designated all clean air areas of the country in Class II and provided a procedure under which states could reclassify any such area to accommodate particular local social, economic, and environmental needs. To date, the State of Wisconsin has not acted to request a change in the Class II designation of any clean air areas in the State, including such areas as lie within the seven-county Southeastern Wisconsin Region. It should be noted that the preconstruction review to date of those sources affected by the nonsignificant deterioration regulations have shown that increases of ambient air concentrations of particulate matter and sulfur dioxide would not exceed the established increments.[5] The need has not yet arisen, therefore, to reevaluate the designation of the Class II assignment for the Region.

The Southeastern Wisconsin Region, however, constitutes the urban-industrial heart of the State of Wisconsin and, as such, is vitally important to the continued economic health and well-being of the State. In this context, and based on ambient air quality monitoring data, emissions inventory data, and regional land use and transportation systems development data, it would appear conceptually logical to develop the regional air quality maintenance plan in such a manner as to conform to the criteria established for a Class III nonsignificant deterioration area. Areas with special ecosystems, such as the Kettle Moraine State Forest and state designated scientific areas, however, should be considered as inviolate areas where the quality of the ambient air will be maintained at the cleanest level attainable. If, indeed, attainment of the national ambient air quality standards will adequately protect the public health and welfare of those residents in areas of the Region which are not now meeting such standards, then it follows that the public health and welfare of the residents of those areas of the Region where the air is presently cleaner than levels prescribed by the standards would not be compromised if the air quality level were deteriorated up to, but not exceeding, the standards. Development of the regional air quality maintenance plan in this manner neither precludes the retention of the concepts implied in the Class I and Class II designations where possible and prudent, nor does it place undue constraints on continued economic growth in areas of the Region where such growth is deemed in the public interest, environmentally compatible, and socially acceptable.

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[5] *The only facility in the Region thus far reviewed for its impact on the nonsignificant deterioration regulations is the proposed new fossil fuel steam electric plant in the Town of Pleasant Prairie, Kenosha County.*

Emission Offset Policy

Since many areas of the country are not presently meeting the national ambient air quality standards, the U. S. Environmental Protection Agency set forth a position on permitting new construction in these nonattainment areas in an interpretive ruling generally termed the emission offset policy.[6] While the construction or modification of an air pollution source formerly was presumably not permitted in areas where ambient air pollutant concentrations exceeded the standards, the emission offset policy provided for such activity within certain constraints. The primary constraint under this interpretive ruling was that, prior to receiving permission to construct or modify a major source, the applicant, before commencing operation, must attain a reduction in emissions in the area greater than the emissions that the proposed source would produce. The new emission source must also be constructed to attain the lowest achievable emission rate,[7] and all other sources of the company in the same air quality control region must be in compliance with existing federal and state regulations or on a compliance schedule. Overall, this interpretive ruling is intended to allow continued growth in nonattainment areas while assuring that progress is made toward meeting the ambient air quality standards. Conceptually, therefore, the emissions offset policy seeks to provide a positive net air quality benefit.

It should be emphasized that the policy statement calls for a greater than "one-for-one" emission offset and provides that no leftover emission offset credit may be "banked" for future pollution growth once an emission offset has been achieved by a particular new source. The geographic extent of the air quality analysis for the emission offset is left to a case-by-case determination by the states.

The emission offset policy is primarily a short-term planning solution for establishing a compatible relationship between achieving the national ambient air quality standards and permitting the continuation of economic growth in nonattainment areas. As mentioned previously, the regional air quality maintenance plan is concerned primarily with the middle-term and long-term planning efforts, that is, the attainment and maintenance of the national ambient air quality standards, respectively. Also, the emission offset policy relates solely to facility development on a site-by-site basis, whereas the regional air quality maintenance plan addresses the air pollution problem on a systematic, areawide scale. Conceptually, therefore, specific application of the emission offset policy to short-term and microscale air pollution problems within the Region is beyond the scope of this planning report.

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[6] *Federal Register, December 21, 1976.*

[7] *The lowest achievable emission rate is that rate which minimizes the discharge of air pollution into the atmosphere through the installation and operation of the best available emission control technology.*

THE AIR QUALITY MAINTENANCE PLANNING PROGRAM

Ambient air quality conditions are becoming of increasing concern to public officials and private citizens in the Region. This increased concern for air quality largely reflects the fact that ambient air quality has a direct effect on human health and well-being. Air is one of the most important natural resources. Not only is air a particularly important determinant of the quality of the environment for life, but it is essential to life itself. The earth's atmosphere provides the vital blend of oxygen and other gases needed to support animal and plant life. Pure air, consisting only of this vital blend of gases necessary for life, is not known to exist in nature. Air always contains foreign matter in the form of smoke, soot, dust, fly ash, fumes, mists, odors, pollens, and spores, in addition to uncombined water vapor. Some of this foreign particulate and gaseous matter is contributed by such natural sources as volcanic activity, wind storms, lightning-caused fires, and certain types of biological activity. Added to this naturally occurring foreign matter in the atmosphere are contaminants contributed by man from land cultivation, waste burning, heat and power generation, industrial processes, and transportation movements.

Those foreign particulate and gaseous materials which are contributed to the atmosphere through the activities of man and which have a deleterious effect on either the use of air or on the contribution which air makes to the overall quality of the environment are herein defined as air pollutants. Urbanization tends to intensify the contribution of air pollutants from human activities because urbanization tends to concentrate commercial and industrial activities, transportation movements, waste burning, power generation, and space heating. When the rate at which pollutants contributed by human activities and by natural occurrences exceeds the natural absorptive, diffusive, and dispersive capacity of the atmosphere, and when the concentration of pollutants becomes so severe as to seriously and adversely affect health and property, an air pollution problem exists. The social and economic consequences of air pollution are thus far reaching, with many complex secondary, as well as primary, effects on human well-being.

Because of the many complex social, economic, and physical factors involved in the control of air pollution, the manner in which air quality problems are considered and ultimately resolved involves many important public and private policy determinations. Such determinations must be made in view of an urbanizing Region which is constantly changing and, therefore, determinations should be made through a comprehensive planning process that takes into account other important factors, such as the need to maintain a healthy regional economic base, weighing such factors against the need to attain and maintain clean ambient air and meet the established air quality standards. Only through such a planning process can the effect of different courses of action toward maintaining ambient air quality be properly evaluated, and the best course of action intelligently selected.

Accordingly, the basic purpose of the regional air quality maintenance planning process should be twofold:

1. To permit broad public evaluation and choice of alternative air quality maintenance plans, policies, and programs that will ensure the maintenance of clean, safe ambient air for all inhabitants of the Region once the federal ambient air quality standards are attained.

2. To provide, through the medium of a long-range plan for air quality maintenance, full coordination with land use development and with other functional forms of regional development such as transportation, public utility, and community facility development; and to provide full coordination of local, state, and federal air quality maintenance policies and programs within the Region.

Goals to be attained by this planning process include protection of the public health and well-being, protection of real and personal property, and development of a sound, areawide pattern of land use and transportation system development which promotes the wise use of limited land, water, and air resources.

BASIC PRINCIPLES

Based upon the foregoing considerations, four basic principles were formulated under the regional air quality maintenance planning program for southeastern Wisconsin. Together these principles form the basis for the specific air quality maintenance planning process applied in that program. These principles are:

1. Air quality maintenance planning must be areawide in scope. Air quality problems develop over entire urban regions without regard to political boundaries. The overall air quality planning effort, recognizing the areawide nature of the problem, must be conducted concurrently at the national, multistate, state, and substate regional levels. It is believed that it will be possible to formulate effective air quality control strategies for some pollutants considering only growth and development within the seven-county Southeastern Wisconsin Region. With respect to some pollutants, however, intraregional controls and strategies may not be sufficient to ensure attainment and maintenance of the air quality standards. In such cases, state and multistate coordination of air quality maintenance planning will be necessary.

2. Air quality maintenance planning must be conducted concurrently with land use, transportation, and water quality management planning. Anticipated changes in the levels and spatial distribution of population, employment, and urban land uses; in income and automobile availability; and in the amount, spatial distribution, and mode of travel which can be expected to occur within the Region over the next two to three decades have extremely important implications for air quality maintenance planning. Clearly, if the air pollution problems presently existing within the Region are not to be further intensified, careful attention must be given to the potential effects on air quality of land use and transportation system development decisions in the Region. Similarly, strategies for the abatement of air pollution should not encourage or contribute to the degradation of water quality, nor should strategies for the abatement of water pollution encourage or contribute to the degradation of air quality. Such considerations require the conduct of a comprehensive regional air quality maintenance planning program that is fully integrated with the regional land use, transportation, and water quality management planning programs.

3. Air quality maintenance planning must recognize the need to maintain a healthy regional economy. Strategies selected for the abatement of air pollution within the Region must seek to minimize and distribute the costs of implementation so that they do not represent a prohibiting factor to future economic growth and development or unduly burden any one sector of the economy with the entire responsibility for the control of air pollutant emissions.

4. Air quality maintenance planning must recognize the existence of the limited natural resource base to which urban and rural development must be adjusted to ensure a pleasant and habitable environment. The growth and distribution of air pollutant emission sources must be such that, given the capacity of the atmosphere to diffuse the pollutants, the pollutant concentration levels in the ambient air are maintained below the established standards.

THE AIR QUALITY MAINTENANCE PLANNING PROCESS

Based upon the foregoing principles, the Commission employed a seven-step planning process through which the principal factors affecting air quality maintenance within the Region could be identified and described both graphically and numerically; the primary areas requiring air quality maintenance strategies identified; and various strategies formulated and evaluated for their effectiveness in abating air pollution. These steps are: study design, formulation of objectives and standards, inventory, analysis and forecast, plan design, plan test and evaluation, and plan selection and adoption. Plan implementation, although beyond the foregoing planning process, must be considered throughout the process if the plans are to be realized.

Air quality maintenance planning requires that relationships be established between human activities and pollutant emissions and between the amount of emissions and

the resultant ambient air concentrations of pollutants. Furthermore, it is necessary to be able to estimate what effect anticipated changes in human activities will have on ambient air quality and, of particular importance to air quality maintenance planning, to what extent the emission sources of the various pollutant species can be controlled through either direct or indirect measures.

The process involved in determining the complex interrelationships among the sources of pollutant emissions, the amount of pollutant emissions, and ambient air quality involves collecting and collating a comprehensive emissions inventory for a base year and analyzing these data through the use of an air quality simulation model. Comparison of estimated air quality levels determined by application of the simulation model with the monitored air quality levels for the same time period allows the relationships to be quantified. Changes in human activities, including transportation movements, as reflected by changes in the amounts or distribution of pollutant emissions, can then be tested by application of the simulation model and the effect of such changes on ambient air quality determined. In this manner, the probable effects on ambient air quality of alternative regional growth patterns may be assessed and control measures selected based upon their relative effectiveness in attaining and maintaining clean air.

The use of an air quality simulation model thus provides the basic analytical tool in the air quality maintenance planning effort. The model is used to analyze relative changes in air quality levels for alternative regional development plans. In addition, with respect to air quality control strategies the model provides a basis for the comparison of pollutant concentration levels to established standards. Moreover, and significantly, the state of the art of air quality simulation model development has not yet progressed to the point of quantitatively simulating the complex process by which certain pollutants photochemically react in the presence of sunlight to form oxidants. Consequently, determining the effectiveness of strategies for controlling photochemical oxidant production must be based on less sophisticated techniques such as rollback or proportional modeling, which rely on either linear or nonlinear assumptions about the relationship between pollutant emissions and ambient air quality. This method assumes that a given reduction of pollutant emissions will produce a corresponding reduction in ambient air quality levels. Given all the limitations of modeling, the utilization of the simulation modeling technique nevertheless remains the singularly most important analytical device available for air quality maintenance planning.

After establishment of the fundamental relationships necessary for understanding the factors influencing ambient air quality and after estimating of future air quality levels based upon assumed future land use and transportation system development patterns, assuming that a residual problem remains in meeting the national ambient air quality standards, air quality maintenance planning must address itself to the applicability of alternative air quality control strategies to the design year conditions. When tested and evaluated, those alternative air quality control strategies form the basis for plan synthesis.

The principal result of the foregoing process is a regional ambient air quality maintenance plan designed to ensure the attainment and maintenance of clean, safe, ambient air for all residents of the Region. In addition, the process must be viewed as the beginning of a continuing planning effort that permits plan reevaluation, modification, and adaptation to the changing physical and socioeconomic conditions in the Region, as well as changes in available technology for air pollution control and modeling methods.

Each step in the planning process includes individual operations which must be carefully designed, scheduled, and controlled to fit the overall process. An understanding of this is essential to appreciate and understand the results of the work effort. Each step in the work process is diagrammed in Figure 3 and is briefly described below.

Study Design

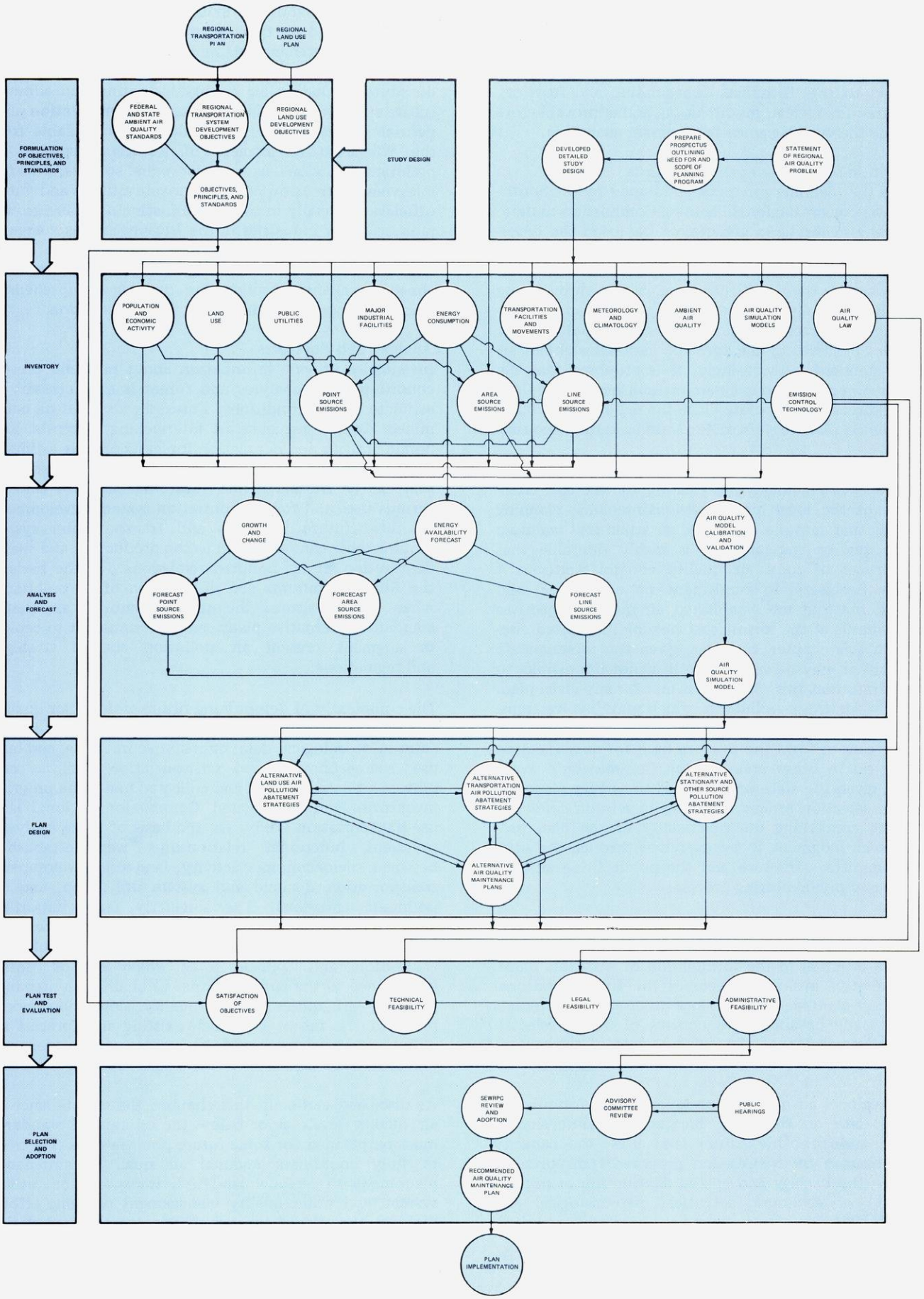
Every planning program must include a formal structure or study design so that the program can be carried out in a logical and consistent manner. This study design must specify the content of the fact-gathering operations, define the geographic area for which data are to be gathered and plans prepared, outline the manner in which the data collected are to be processed and analyzed, specify requirements for forecasts, and define the nature of the plans to be prepared.

The study design for the regional air quality maintenance planning program for southeastern Wisconsin took the form of 13 detailed staff memoranda which set forth methods and procedures to be followed in accomplishing each work element.[8] All of the memoranda were prepared

[8] *The study design was composed of the following Commission staff memoranda of the regional air quality maintenance planning program: No. 1, "Study Design—Program Organization," December 6, 1974; No. 2, "Inventory—Ambient Air Quality," January 24, 1975; No. 3, "Inventory—Point Source Emissions," January 28, 1975; No. 4, "Inventory—Area Source Emissions," June 24, 1975; No. 5, "Inventory—Line Source Emissions," June 13, 1975; No. 6, "Inventory—Meteorological Data," January 21, 1975; No. 7, "Inventory—State of the Art of Emissions Control," November 10, 1975; No. 8, "Analysis and Forecasts—Point Sources," August 14, 1975; No. 9, "Analysis and Forecasts—Area Sources," November 12, 1975; No. 10, "Analysis and Forecasts—Line Sources," November 12, 1975; No. 11, "Atmospheric Simulation Model," January 21, 1975; No. 12, "Alternative Plan Design, Test, and Evaluation," December 3, 1975; and No. 13, "Time Schedule—Manpower and Resources Allocations," June 13, 1975. These memoranda are on file at the Commission offices.*

Figure 3

GENERAL STEPS IN A COMPREHENSIVE AIR QUALITY MAINTENANCE PLANNING STUDY



Source: SEWRPC.

by the staff of the Southeastern Wisconsin Regional Planning Commission with the assistance of personnel from the Wisconsin Department of Natural Resources and the University of Wisconsin-Madison Air Quality Modeling Group. As each staff memorandum was completed, it was presented to the Technical Coordinating and Advisory Committee for review, modification, and approval before becoming the working guide for program execution.

Formulation of Objectives and Standards

In all of the planning programs conducted by the Southeastern Wisconsin Regional Planning Commission to date, one of the major tasks undertaken has been the development of objectives and supporting principles and standards. In the case of air quality maintenance planning, however, the U. S. Congress, acting through the U. S. Environmental Protection Agency, had already established the essential objectives to be attained, expressing such objectives in the form of national ambient air quality standards. Accordingly, it is proposed that the clean air objectives and standards established by the Congress be directly incorporated into the regional air quality maintenance planning effort for southeastern Wisconsin.

It is further proposed that only one additional objective be established; namely, one relating to the cost-effectiveness of the local air quality maintenance planning strategies that may be employed to attain and maintain the air quality standards. It is highly desirable that whatever set of local air quality control strategies it may be necessary to implement be economical and efficient, meeting the established air quality objectives and standards at the lowest cost possible. As noted elsewhere in this chapter, however, given the present state of the art, it may be very difficult, if not impossible, to demonstrate that this objective is met for any given plan, especially for those pollutants which may involve transport into the Region. Consequently, cost-effectiveness analyses cannot form the primary basis for plan selection as they do in other areas of the Commission's work. Instead, given the state of the art of air quality planning, the plan selection process will have to rely on collective judgment concerning the practicality of the plan proposals, such judgment to be exercised through the advisory committee structure and the public informational meeting and public hearing process.

Inventory

Reliable planning data collected on a uniform, areawide basis are essential to the formulation of workable plans. Consequently, inventory becomes the first operational step in any planning process, since no intelligent forecasts can be made or alternative courses of action selected without knowledge of the current state of the system being planned.

Sound regional air quality maintenance plan formulation requires data on the kind, location, and intensity of existing and probable future land uses; the capacity and utilization of existing and proposed transportation facilities; the density and spatial distribution of population and of economic activities; meteorological and climatological data; existing ambient air quality monitoring data; pollutant emissions data for existing point, area, and line sources; existing air pollution control technology; and air quality control law. In the regional air quality maintenance planning program, data collection efforts included a review of the air quality planning literature, including air quality legislation and administrative rules and the Wisconsin state implementation plan; perusal of agency files, particularly files available from the Wisconsin Department of Natural Resources on pollutant emissions from major point sources; personal interviews with knowledgeable private citizens and public officials, especially in the determination of future growth rates in major industries in the Region; and exchange of information through interagency staff meetings. Extensive use was made of the regional planning data base already available through the ongoing comprehensive planning program conducted by the Commission.

Analysis and Forecasts

Inventories provide information about past and present conditions, but analyses and forecasts are necessary to estimate future conditions. Future needs must be determined from a sequence of interlocking forecasts. Economic activity and population forecasts provide estimates of the probable future growth in the Region, estimates that can be translated into future demands for land for various uses and for transportation system development. In turn, future land use and transportation system requirements can be related to the production and spatial distribution of air pollutant emissions. On the basis of the forecast amounts and distribution of air pollutants, when viewed against the national ambient air quality standards, alternative plans can be formulated to replace or augment present air pollution control strategies and regulations.

The complexity of determining future ambient air quality required careful analyses of existing ambient air quality data; meteorological data; emission source data; and land use, socioeconomic, and transportation facilities and movement data acquired and collected under the program inventories and the related Commission regional land use-transportation study. On the basis of these analyses, pertinent functional relationships were established between socioeconomic activity, land use development, transportation demand and system utilization, and air pollutant emissions. The singularly most important analytical device provided under this study was an ambient air quality simulation model, the formulation, calibration, and application of which was of central importance to the entire regional air quality maintenance planning program. The air quality simulation model provided the means by which existing and forecast air pollutant emissions could be related to ambient air pollutant concentrations over the entire Region.

As discussed earlier in this chapter, the maintenance of air quality levels at or below the established standards must be planned for some future point in time. The need to fully coordinate regional air quality maintenance planning with regional land use, transportation, utility system, and water quality management planning efforts dictated the use of the same basic forecast and design

year used in the preparation of the other regional plan elements—the year 2000. In order to provide for a reasonable staging of the plan, an intermediate forecast for the year 1985 was established. These forecasts and design year periods provide a convenient means for totally integrating air quality planning into the ongoing comprehensive regional planning program of the Commission.

Plan Design, Test, and Evaluation

Commission planning programs traditionally have been concerned with the design of such large physical systems as land use, transportation, and public utility systems. The regional air quality maintenance planning program is not directly concerned with the design of a physical system. Rather, the program is concerned with the postulation, test, and evaluation of alternative measures—both land use control and transportation system management measures and direct emission control measures—to achieve the established air quality standards in those subareas of the Region where the attainment and maintenance analyses indicate that such standards will not likely be met in the middle or long-term planning time scale.

The air quality maintenance plan design problem, therefore, consists essentially of determining the amounts and spatial distribution of air pollutant emissions which may be allowed to occur without violation of the established ambient air quality standards within the Region. Existing and forecast land use needs and transportation demands must be reconciled, as necessary, with the attainment and maintenance of ambient air quality pollutant levels below the established standards through a balanced plan of emission controls. Basically, the process consists of selecting an emission control strategy for a given pollutant and then testing the strategy, through the use of simulation modeling, to determine its effectiveness in achieving and maintaining the natural ambient air quality standards and abating air pollution as necessary.

The above procedure involves careful analysis of existing pollutant emissions and ambient air quality and the preparation of forecasts for those factors which determine the production of air pollutant emissions. The air pollutant emission forecasts may then be related to projected ambient air quality levels in the design year through the application of the ambient air quality simulation model. The result of these analytical operations is a quantitative evaluation and description of those areas of the Region which have the potential for exceeding the air quality standards. After having identified these problem areas for each pollutant, alternative control strategies are then applied to the forecast emissions data and their effect on lowering ambient air pollutant concentrations evaluated through the application of the simulation model.

The magnitude of the design problem largely depends on three factors related to the pollutants: the chemical and physical characteristics of the pollutant violating the standard, including considerations of whether or not the violation is a result of direct emission from a particular source or comes about in the atmosphere through photochemical reactions; the areal extent for which the standard is violated; and the nature of the sources producing the pollutant violating the standard. These three factors, which determine to a large degree the type of strategy which may be available for abating the air pollution problem, are the basis upon which preliminary design solutions are developed for test and evaluation.

The alternative plans must also be subject to several levels of review and evaluation including economic, technical, and financial feasibility; legality; and citizen and public official reaction. Interagency meetings and public hearings were used as devices to test and evaluate the alternative plans. These steps help to demonstrate which alternative plan is technically sound, financially feasible, legally possible, and politically practical.

Plan Selection and Adoption

The general approach used for the selection of the final air quality maintenance plan from among the alternative plan strategies advanced was to proceed through presentation of the alternatives and the analyses of the technical, economic, financial, and legal feasibility of the alternatives to the Technical Coordinating and Advisory Committee for review, interagency meetings, public informational meetings, and public hearings to a final decision and adoption by the Commission in accordance with the provisions of the state regional planning enabling legislation. The function of the Commission is to recommend to federal, state, and local units of government the best final air quality maintenance plan for consideration and action. This plan, together with specific recommendations for implementation addressed to both the public and private sector, represents the recommended regional air quality maintenance plan. The final decisive step to be taken in the process is the acceptance or rejection of the plan by the units and agencies of government concerned and, upon acceptance, its subsequent implementation by public and private action. Consequently, plan selection and adoption must be founded in the active involvement of the various governmental bodies, technical agencies, and private interest groups concerned with development throughout the Region. The use of advisory committees in both formal and informal public hearings appears to be the most practical and effective procedure for achieving such involvement in the planning process and for openly arriving at agreement on objectives and on a final plan which can be cooperatively adopted and jointly implemented.

Plan Implementation

Although plan implementation is not an element in the seven-step planning process, in a practical sense the recommended plan is not complete until the steps required for its implementation are specified. Toward this end, the plan must identify the appropriate institutional and administrative structure necessary to implement the plan, as well as identify any changes necessary in legislation and regulations relating to air quality control.

The capabilities of the various levels, units, and agencies of government concerned with and responsible for air quality maintenance in the Region were analyzed in terms of meeting the air quality objectives and supporting standards as set forth in the plan. Available federal and state financial and technical assistance programs also were identified, and a recommended organizational structure for plan implementation set forth. Because of the completely advisory role of the Commission, implementation of the recommended plan will be entirely dependent upon action by local, state, and federal agencies of government and by entities in the private sector. The Commission intends, however, to develop a continuing regional air quality maintenance planning process to monitor progress toward plan implementation and, in cooperation with the Technical Coordinating and Advisory Committee on Regional Air Quality Maintenance Planning, maintain coordination among the various planning and plan implementation agencies.

Chapter III

AIR QUALITY LAW

INTRODUCTION

In any sound planning effort, it is necessary to investigate the legal factors affecting the problem under consideration. This is particularly true in the area of air resources planning for which federal and state laws and regulations largely provide the basis for air quality maintenance planning and plan implementation.

Clean air constitutes one of the most important natural resources. Without it, man's daily social and economic activities will decrease in scope and quality. Because this resource is of such vital concern to man, air quality law has taken on added dimensions in the last two decades. Changes in this complex and dynamic body of law likely will take place as public pressure for clean air and the reaction to it become more intense. To provide the basis for a careful analysis of existing law as it relates to air quality planning in southeastern Wisconsin, a survey of the legal framework was undertaken for air quality management at the federal, state, and local levels. This chapter consists of a summary presentation of the results of that survey. The material contained herein does not presume to present a detailed analysis of the law, but rather is intended to summarize the salient legal factors bearing on air quality planning for southeastern Wisconsin.

Attention in this chapter is focused on those aspects of the law generally applicable to the planning and management of air resources in southeastern Wisconsin. Included is a general summary of the legal framework for air quality management at the federal, state, and local levels. Most of the discussion deals with federal air quality control machinery, since most air quality management authority flows from federal legislation to the state and local levels. The law is dynamic and particularly so on air quality maintenance, and this chapter does not dispense with the need for continuing study of the legal aspects of air quality maintenance planning.

FEDERAL AIR QUALITY MANAGEMENT

Background

It was probably because of the massive, areawide urbanization that took place after World War II that air quality deterioration became a concern of the federal government. It was during this time period that Congress first became concerned with air pollution and its attendant problems. In 1955, Congress enacted the first federal legislation relating to air pollution control. Entitled "Air Pollution Control—Research and Technical Assistance,"[1] the Act provided for grants-in-aid to state and local pollution control agencies for air pollution research and training and demonstration projects and for the extension of technical assistance from the federal government on air pollution problems to state and local agencies. The Act further provided for an authorization for the Surgeon General of the United States to collect and publish air pollution information. This initial legislation envisioned a rather narrow role for the federal government. It was assumed and stated by Congress in the Act that the prevention of air pollution was to be primarily a function of state and local governments. Because the initial federal legislation contained provisions for assistance to state and local agencies, there soon was established a pattern of federal and state cooperation in the air quality management field.

With passage of the Clean Air Act of 1963,[2] a shift to greater federal responsibility in the area of air pollution control took place. The character of federal grants changed under the 1963 Act to one of providing grants-in-aid for state air pollution control programs, as opposed to providing "seed" money for research and training and demonstration projects. The Clean Air Act of 1963 also authorized the Secretary of the U. S. Department of Health, Education and Welfare (HEW) to intervene directly when air pollution was found to endanger the public health and welfare and the individual state concerned was unable or unwilling to cope with the problem on its own.[3] This power of intervention implied an acceptance by the federal government of responsibility for dealing with major air pollution problems. A further expansion of the federal role was the encouragement through funding provisions of a greater degree of intergovernmental cooperation between municipalities and states.

Following the steps taken in the 1963 Act, the amendments of 1965[4] espoused a greater degree of federal involvement in air pollution control. The shift in the 1965 Amendments from reliance on the use of Congressional taxation and spending powers to use of regulatory powers emanating from the "commerce clause" in the Federal Constitution set the stage for greatly increased federal involvement.

With passage of the Air Quality Act of 1967,[5] the federal role in air pollution control was further expanded. This

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[1] *P. L. No. 84-159, 69 Stat. 322 (1955).*

[2] *P. L. No. 88-206, 77 Stat. 392 (1963).*

[3] *Id., sec. 5, 77 Stat. at 396-398.*

[4] *P. L. No. 89-272, 79 Stat. 992 (1965).*

[5] *P. L. No. 90-148, 81 Stat. 485 (1967).*

Act empowered the Secretary of Health, Education and Welfare to issue federal air quality criteria[6] and mandated action to meet these standards in designated air quality control regions. A state was free to adopt standards of its own in lieu of the federal standards but failure to do so authorized the Secretary to promulage such standards for the recalcitrant state. Even with this increased intervention into the air quality field by the federal government, the responsibility for setting air quality standards and adopting policies to meet the standards in the 57 federally designated air quality regions remained with the states.[7]

Federal enforcement actions were viewed in the 1967 Act as extraordinary measures. All of the abatement procedures were reserved for a situation best described as "extra-hazardous." There were four separate situations in which federal abatement actions were provided. In the case of intrastate air pollution, the Secretary of HEW could take action only if requested by the governor of the affected state, and then only when such intrastate pollution was found to be of such a significance as to warrant exercise of federal jurisdiction.[8] Federal abatement action could also be invoked where a substantial danger to the public health existed and where state and local officials had failed to act.[9] Once again, action by the federal government was left to those situations of an emergency nature. A third situation existed in which interstate pollution had occurred in an air quality control region with established air quality standards and such pollution caused air quality to fall below these standards.[10] The fourth and final situation which called for federal enforcement action was a situation in which the pollution was interstate in nature and adverse effects were felt in more than one state.[11] The first and fourth procedures were retained in the 1970 Clean Air Act Amendments, while the second and third procedures were absorbed in newer and more effective enforcement sanctions contained in the 1970 Clean Air Act Amendments.

Under the Presidential Reorganization Plan No. 3 of 1970, the U. S. Environmental Protection Agency (EPA) was created. In addition, the functions formally vested by prior federal clean air enactments in the Department of HEW were transferred to the EPA.[12] The EPA was established to coordinate in one agency a variety of research, monitoring, standard formulation, and enforcement activities which had previously been dispersed through several federal departments and agencies.

In 1970 Congress further amended the Clean Air Act to strengthen the effectiveness of the various programmatic, regulatory, and enforcement activities as contained in former air quality legislation.[13]

The 1970 Amendments contained several significant provisions not contained in earlier Clean Air Legislation. Ambient air quality standards were mandated by these Amendments and resulted in administrative regulations to that effect. In addition, emission standards were promulgated for certain new stationary sources and nonstationary sources including new model automobiles and certain hazardous air pollutants. A greater degree of federal enforcement activity also was mandated by the 1970 Amendments. Finally, citizen enforcement suits seeking enforcement of various regulatory provisions of the Clean Air Act were allowed. The following discussion of the Clean Air Act Amendments of 1977 will address those recent amendments and vestiges of former clean air legislation currently in force.

Clean Air Act Amendments of 1977

Structurally, the 1977 Amendments are divided into three titles, as were the 1970 Amendments. Title I, "Air Pollution Prevention and Control," contains basic policy statements; financial, research, and technical assistance authorizations; national emission standards for new stationary sources and hazardous air pollutants; prevention of significant deterioration of air quality; and plan requirements for nonattainment areas. Title II, "Emission Standards for Moving Sources," relates to emissions from mobile sources generally referred to as line sources in this report including automobiles, trucks, and aircraft. Title III, "General," contains the administrative language of the Act including definitions of terms, emergency powers, citizen enforcement suits, administrative procedures, air quality monitoring and modeling, authorizations, and judicial review. Not unlike the federal Water Pollution Control Act,[14] the Clean Air Act may be functionally divided into programmatic, regulatory, and enforcement elements.

Programmatic Elements: Section 101(a)(3) of the Act states that "the prevention and control of air pollution at its source is the primary responsibility of the state and local governments."[15] This language is a vestige of concepts contained in earlier legislative enactments dealing with the control of air pollution but is now an anomaly in view of the almost total federal supervisory

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[6] *Id., sec. 107(b), 81 Stat. at 491: The terms standard and criteria are defined in Chapter V of this report.*

[7] *Id., sec. 108(c)(2), 81 Stat. at 491.*

[8] *Id., sec. 108(d)(1), 81 Stat. at 494.*

[9] *Id., sec. 108(k), 81 Stat. at 497.*

[10] *Id., sec. 108(c)(4), 81 Stat. at 497.*

[11] *Id., sec. 5(c)(1)(A), 77 Stat. 392 (1963).*

[12] *Reorganization Plan No. 3 of 1970; 42 U. S. C. 4321.*

[13] *P. L. No. 91-604, 84 Stat. 1676, 42 U. S. C. secs. 1857 et seq. (1970).*

[14] *P. L. 92-500, 33 U. S. C. secs. 1251 et seq. (1972).*

[15] *Clean Air Act sec. 101(a)(3), 42 U. S. C. 1857 a-3.*

and approval authorities contained in the Act. Section 101 goes on to state that protection of the nation's air resources and promotion of the public health are major goals of the Act.

Cooperation among federal, state, and local authorities is promoted within Title I of the Act. Title I provides for interstate agreements, uniformity of state laws, promotion of the establishment of state agencies dealing with the abatement of air pollution, and other similar coordination measures.

The Act recognized the connection between regulatory program success and required research. Provision is made in Section 103 for the Administrator of the Environmental Protection Agency (hereinafter referred to as the Administrator) to "establish a national research and development program for the prevention and control of air pollution . . . ."[16] As part of such a program, the coordination of technical and scientific research and investigation is to be developed. Financial assistance also is provided. An element of such a cooperative effort is authority for the Administrator to publish results of such investigation, cooperate with both private and public agencies, make grants to such agencies, provide training for personnel of air pollution control agencies, develop methods and processes for the prevention or control of air pollution, and call special conferences where substantial air pollution problems exist. It is further authorized that the Administrator shall provide for construction of appropriate facilities for the above-mentioned programs. Section 104 authorized research relating to fuels and motor vehicles.

Continuing the scheme of federal assistance, Section 105 authorizes grants for the support of air pollution planning and control programs. Grants of up to two-thirds of the costs of planning, developing, establishing, or improving such programs and up to one-half of their maintenance are provided by the Act. The regional air quality maintenance planning program for southeastern Wisconsin is funded in part under this section. All of these grants are subject to conditions set forth in Section 105.[17]

General Regulatory Plan of the Clean Air Act: Steps to be taken to establish the regulatory mechanisms set forth in the Act begin with designation by the Administrator of air quality control regions throughout the country. These intrastate or interstate air quality control regions are areas deemed by the Administrator to have existing air quality problems. The individual states also were required to divide the remainder of their state, not designated by the Administrator, into air quality control regions.[18] Following the designations, the states were required to adopt air quality standards at least as stringent as the national ambient air quality standards. Further, the states were required to prepare implementation plans detailing the means by which they were to attain the adopted standards and, in addition, provisions relating to prevention of significant deterioration of air quality and nonattainment areas. A detailed discussion of each of these major elements in the formulation of the regulatory facets of the Act is presented herein.

National Primary and Secondary Ambient Air Quality Standards: Concurrently with the establishment of air quality control regions, the Administrator was required to establish national primary and secondary ambient air quality standards.[19] The primary ambient air quality standard is that level of ambient air quality which, in the judgement of the Administrator, is required to protect the public health. The primary ambient air quality standard is to be achieved as expeditiously as practicable but in no case later than three years from the date of approval of the state implementation plan.[20] The Act allows for extensions of up to two years for the attainment of the primary standards. Secondary ambient air quality standards are designed to protect the public welfare. This level of air quality is to be achieved within a "reasonable" time.[21]

The pollutants to which the Administrator was to direct the primary and secondary standards were those which, in the judgment of the Administrator, have an adverse effect on public health and welfare and which are products of numerous and diverse mobile or stationary sources. The pollutants for which national ambient air quality standards have been promulgated are suspended particulate matter, sulfur dioxide, hydrocarbons, carbon monoxide, nitrogen dioxide, and photochemical oxidants.[22] These standards are set forth in detail in Chapter VI of this report. In addition, Section 109(c) requires the Administrator within one year of the enactment of the Clean Air Act Amendments of 1977 to promulgate a national primary ambient air quality standard for NO_2 concentrations over a period of not more than three hours unless it is shown that such a standard is not necessary to protect public health. National primary ambient air quality standards are to be reviewed by the Administrator no later than December 31, 1980, and at five-year intervals thereafter.

Implementation Plans: Following the establishment of national primary and secondary ambient air quality standards, each state was required to develop and submit to the Administrator an implementation plan for all regions of the state. Such plans must provide for the

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[16] *Clean Air Act sec. 103, 42 U. S. C. 1857 b.*

[17] *Clean Air Act sec. 105, 42 U. S. C. 1857 c.*

[18] *Clean Air Act sec. 107(c), 42 U. S. C. 1857 c-2(c).*

[19] *Clean Air Act sec. 109, 42 U. S. C. sec. 1857 c-4.*

[20] *Clean Air Act sec. 110(a)(2)(A)(i), 42 U. S. C. sec. 1857 c-5(a)(2)(A)(i).*

[21] *Id.*

[22] *40 C.F.R. Part 50, 36 Federal Register 22384 (1971).*

attainment and maintenance of the primary and secondary air quality standards within each region. In the case of a primary standard, attainment of such standard must be achieved within three years of the date of approval of the plan.[23] With a secondary standard, a "reasonable" time was granted.[24] The Administrator must determine whether the state's implementation plan is sufficient to meet the reasonable time requirement. Such a plan is required to be comprehensive and must include, ". . . emission limitations, schedules and timetables for compliance with such limitations, and such other measures as may be necessary to insure attainment and maintenance of such primary or secondary standard, including, but not limited to, transportation controls, air quality maintenance plans, and preconstruction review of direct sources of air pollution . . . ."[25] Other implementation plan requirements include provisions for intergovernmental cooperation, assurances of adequate personnel and funding provided by states, compliance with nonattainment and prevention of significant deterioration statutory and regulatory provisions, requirements that owners and operators of stationary sources install monitoring equipment and that periodic reports be made on the nature and amounts of these emissions.

The Administrator has the authority to approve or disapprove of any state implementation plan or portion thereof. In the event a state fails to submit an implementation plan for any primary or secondary ambient air quality standard or the plan does not meet the statutory criteria, the Administrator is required to submit a federally prepared implementation plan for an individual state. Before action by the Administrator is begun, however, states are given the opportunity to resubmit an implementation plan with the necessary revisions.

A recent Supreme Court decision on review of state implementation plans under Section 110 of the Clean Air Act Amendments of 1970 stated that factors of economic and technological feasibility cannot be considered in the review of the adequacy of a state implementation plan (SIP) by the Administrator. In Union Electric v. Environmental Protection Agency, the Supreme Court concluded that in the Administrator's review of Missouri's Clean Air Act implementation plan, the Administrator was precluded from considering the economic and technological feasibility of the plan's sulfur dioxide emission limitations since Section 110 of the Act required the Administrator to approve the state implementation plan if that plan satisfies the criteria as specified in Section 110 of the Act. Of these factors, none includes technological or economic feasibility criteria.[26]

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[23] *Clean Air Act sec. 110(a)(2)(A), 42 U. S. C. sec. 1857 c-s(a)(2)(A)(i) and (ii).*

[24] *Id.*

[25] *Clean Air Act sec. 110(a)(2)(B), 42 U. S. C. sec. 1857 c-s(a)(2)(B), also see Clean Air Act sec. 110(a)(2)(A-K), 42 U. S. C. sec. 1857 c-s(a)(2)(A-K).*

[26] *Union Electric v. Environmental Protection Agency, 96 U. S. 2518 (1976). This decision reversed a lower court holding that economic and technological feasibility must be considered in reviewing the adequacy of a state implementation plan. See Duquesne Light Company v. Environmental Protection Agency, 522 F. 2d 1186, (CA3, 1975). In order for the Administrator's decision on a state's implementation plan to be judicially overruled, it must be determined to have been made in an arbitrary and capricious manner. Section 110(a)(2)(A-K) of the Clean Air Act Amendments of 1977 provides the criteria which must be satisfied before the state implementation plan will be approved. The state implementation plan must include the following elements:*

1) *The plan provides for the attainment of a primary ambient air quality standard within three years and a secondary ambient air quality standard in a reasonable time.*

2) *The plan includes emission limitations, schedules, and timetables for attainment and maintenance of primary and secondary standards including transportation plans, air quality management plans, and preconstruction review of direct sources.*

3) *The plan includes provision for adequate devices, methods, and systems to monitor, compile, and analyze ambient air quality and make such data available to the Administrator.*

4) *The plan provides for preconstruction review of the location of new sources.*

5) *The plan contains provisions prohibiting any stationary source within the state plan from emitting any air pollutant which will prevent attainment of maintenance of primary or secondary national ambient air quality standards or interfere with plan provisions dealing with the prevention of significant deterioration of air quality.*

6) *The plan provides adequate personnel funding and authority to implement the plan. In addition, the plan requires stationary source owners to monitor emissions and provide periodic reports on the nature and amount of these emissions to state authorities.*

7) *The plan provides, to the extent practicable and necessary, for periodic testing and inspection of motor vehicles to enforce compliance with applicable emission standards.*

8) *The plan provides for revision after public hearings of the plan whenever necessary.*

(Footnote 26 continued on next page)

An early controversy was whether a proposed implementation plan containing dispersion techniques, such as tall stacks, was consistent with the specific requirements for implementation plans under the Act. Recent Court decisions have stated that Congress did not intend increased stack height and supplementary control systems to be used as a means of attaining ambient air quality standards where reasonably available emission control technology was available.[27] Section 123 states that the degree of emission limitation required for control of any pollutant under an applicable implementation plan shall not be affected by so much of the stack height of any source which exceeds good engineering practices or any other dispersion technique. This section does not affect stack heights in existence before the date of enactment of the Clean Air Act Amendments of 1970.

In the area of transportation controls, considerable leverage can be exerted by the federal government in view of the federal funds provided to construct transportation facilities. There is authority under the National Environmental Policy Act, the Environmental Quality Improvement Act, and the Department of Transportation Act to require that federal action under the direction of the Department of Transportation be utilized to implement the Act. However, various courts have reflected the opposite view.[28]

Emission Offset Policy: A problem which has recently surfaced concerns the tradeoff or offset policy for new source review recently announced by the Environmental Protection Agency. Since the national ambient air quality standards' attainment dates will pass shortly and these standards have not been attained in many areas of the country, the question arose as to whether and to what extent the new stationary sources may legally be permitted to be constructed in these nonattainment areas. In response, the U. S. Environmental Protection Agency published an interpretive ruling on the preconstruction review requirements of 40 C.F.R. 51.18, cited below:

> Each plan shall set forth legally enforceable procedures which shall be adequate to determine whether the construction or modification of a facility, building, structure, or installation, or combination thereof, will result in violations of applicable portions of the control strategy or will interfere with attainment maintenance of a national standard either directly because of emissions from it or indirectly, because of emissions resulting from mobile source activities associated with it.[29]

The U. S. Environmental Protection Agency set forth in the interpretive ruling the policy that the Clean Air Act allows a major new or modified source to locate in an area that exceeds a national ambient air quality standard only if certain stringent conditions can be met. An initial problem was in defining "major source."

> The term major source shall, as a minimum, cover any structure, building, facility, installation or operation for which the allowable emission rate is equal to or greater than the following:
>
> Particulate matter . . . . . 100 tons per year
> Sulfur oxides . . . . . 100 tons per year
> Nitrogen oxides . . . . . 100 tons per year
> Nonmethane
> hydrocarbons . . . . . 100 tons per year
> Carbon monoxide . . . . . 1,000 tons per year[30]

In addition to the interpretive ruling, the U. S. Environmental Protection Agency also released proposals to amend 40 C.F.R. Part 51 relating to review of new sources and modifications. In the proposed amendment, the following definition of major source was offered:

(Footnote 26 continued)

9) *The plan provides that after June 30, 1979, no major stationary source may be constructed or modified in any nonattainment area unless such permit application meets all nonattainment plan provisions.*

10) *The plan requires fees from owners or operators of major stationary sources to cover the costs of application review and enforcement of permit terms and conditions.*

[27] *For cases stating that continuous emission controls be used to the extent available see: Kennecot Copper Corporation v. Environmental Protection Agency, 526 F. 2d 1149 (CA9, 1975) cert. denied 96 U. S. 1665 (1976) and Big Rivers v. Environmental Protection Agency, 523 F. 2d 16 (CA6, 1975) cert. denied 96 U. S. 1663 (1976).*

[28] *For three recent cases which have sharply limited the power of the Administrator to require states to enact specific legislation promulgating transportation controls as contained in state implementation plans, see Brown v. Environmental Protection Agency, 521 F. 2d 827 (CA9, 1975), Maryland v. Train, 521 F. 2d 971 (D. C. Cir. 1975), and District of Columbia v. Train, 521 F. 2d 971 (D. C. Cir. 1975). These cases were consolidated and brought before the United States Supreme Court in Environmental Protection Agency v. Brown, 9 E.R.C. 2075 (1976). The Environmental Protection Agency in its brief and oral argument before the Court indicated that EPA regulations relating to transportation controls need to be modified. In response to this admission, the United States Supreme Court vacated the Circuit Court judgements and remanded the cases for consideration of mootness.*

[29] *40 C.F.R. sec. 51.18 (1976).*

[30] *41 Federal Register 246, 55528, December 21, 1976.*

Major source shall as a minimum, cover any structure, building, facility, installation or operation (or combination thereof) for which the allowable emission rate is equal to or greater than the following:

	Tons Per Year
Particulate Matter	50
Nitrogen Oxides	50
Nonmethane hydrocarbons (organics)	50
Sulfur Oxides	50
Carbon Monoxide	500

[31]

Similarly, the term major modification was defined to include "a modification to any structure, building, facility, installation or operation (or combination thereof) which increases the allowable emission rate by the amounts set forth above."[32]

If a source is constructed or modified in increments, none of which individually meets the above criteria and none of which is part of a planned incremental process previously approved by the reviewing authority, all increments occurring after the date of the interpretive ruling shall be added together to determine the applicability under the interpretive ruling. In addition, the following shall not be determined to be a modification under both the interpretive ruling and the proposed amendments:

(1) Maintenance, repair, and replacement which the reviewing authority determines to be routine for a source category.

(2) An increase in the hours of operation, unless limited by previous permit conditions.

(3) Use of alternate fuel or raw material if the source is designed to accommodate such alternative use (unless limited by previous permit conditions).

(4) Change in ownership of a stationary source.[33]

Among the preconditions which must be met before receiving a construction permit under the offset policy are the following:

1) The source must be constructed to attain the lowest achievable emission rate.

2) All sources operated by any given owner applying for the permit in the Air Quality Control Region must be in compliance with all applicable state implementation plan requirements or in compliance with an approved schedule and timetable for compliance under a state implementation plan.

3) More than a one-for-one emission offset must be attained before the new source commences operation. The baseline for calculating the offsets to be credited are reasonably available control technology for sources in an air quality control region where state implementation plan revisions or study has been required.

4) The emission offsets must provide a positive net air quality benefit.

5) Banking of emission offset credits will not be allowed.

6) In those areas where the U. S. Environmental Protection Agency has found that a state implementation plan is inadequate to attain the national ambient air quality standard and has requested a state implementation plan revision, permits to be granted on or after January 1, 1979, must specify that construction may not commence until the U. S. Environmental Protection Agency has approved or promulgated the plan revision.[34]

It is the local or state air pollution control authority that will determine where the "tradeoffs" will come, either by allowing industry to arrange for the tradeoff or by allowing state and local governments to do so.

Several problems arise in the implementation and enforcement of the nonattainment policy. If state and local governments mandate specific tradeoffs to be made before a new source permit is allowed, a taking of property without compensation might be alleged. In addition, the nonattainment policy might engender business practices which violate antitrust laws by encouraging large major sources to acquire smaller sources for the purpose of tradeoffs.

The Clean Air Act Amendments of 1977 added statutory language concerning nonattainment areas. Section 129 states that the interpretive ruling of December 21, 1976, shall apply until July 1, 1979, except that "the baseline to be used for determination of appropriate emission offsets under such regulation shall be the applicable implementation plan of the state in effect at the time of application for a permit by a proposed major statutory

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[31] *41 Federal Register 246, 55559, December 21, 1976.*

[32] *Id.*

[33] *Id.*

[34] *At the present time, the Administrator has requested a Wisconsin state implementation plan revision for photochemical oxidants. In addition, it appears likely that revisions will be needed for particulates and sulfur dioxides in view of a recently completed attainment analysis conducted by the Wisconsin Department of Natural Resources.*

source." [35] Major source means any stationary facility which directly emits or has potential to emit 100 tons or more of any air pollutant.

Nonattainment plans in effect after July 1, 1979, must provide for the attainment of each national ambient air quality standard as expeditiously as practicable but in the case of national primary ambient air quality standards not later than December 31, 1982, as a precondition for modification of construction of any major stationary source. If the state demonstrates that attainment of the national primary ambient air quality standard for photochemical oxidants or carbon monoxides prior to December 31, 1982 is not possible, the applicable implementation plan may provide for attainment no later than December 31, 1987.

A permit program is required to be part of a state implementation plan for the construction and operation of new or modified major stationary sources in nonattainment areas. Such permits will be issued if the permitting agency determines that:

> (A) by the time the facility is to commence operation, total allowable emissions from existing sources in the region, from new sources which are not major emitting facilities, and from the proposed facility will be sufficiently less than total emissions from existing sources allowed under the implementation plan prior to the application for such permit to construct or modify so as to represent . . . reasonable further progress . . .
>
> (B) that emissions of such pollutant resulting from the proposed new or modified major stationary source will not cause or contribute to emissions levels which exceed the allowance permitted for such pollutant for such area from new or modified major stationary sources . . .[36]

In addition, the proposed source must operate at the lowest achievable emission rate, and any other major sources owned and operated by the applicant in the state must be in compliance or on a schedule for compliance with all applicable emission limitations and standards under the Clean Air Act Amendments of 1977. Finally, reasonable further progress as utilized in Section 171 is defined as "annual incremental reductions in emissions of the applicable air pollutant . . . which are sufficient in the judgement of the Administrator to provide for attainment of the applicable national ambient air quality standard by the date required in Section 172(a)."[37]

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[35] *Clean Air Act sec. 129(a)(1).*

[36] *Clean Air Act sec. 173(1)(A) and (B).*

[37] *Clean Air Act sec. 171(1).*

Nonsignificant Deterioration: The United States Supreme Court in the case of Sierra Club v. Fri affirmed a lower court ruling that Section 101 of the Clean Air Act required a policy of nondegradation of clean air. In response to this decision, the U. S. Environmental Protection Agency promulgated rules for the prevention of significant deterioration. Initially, all state implementation plans were disapproved insofar as they failed to provide for the prevention of significant deterioration. As part of these regulations, three classes of different allowable incremental increases in total suspended particulates and sulfur dioxide were created. Class I applied to areas in which practically any change in air quality would be considered significant. Class II applied in areas where the deterioration normally accompanying moderate, well planned growth would be considered insignificant. Class III applied to those areas in which deterioration up to the national standards would be considered insignificant. In addition, standards were initially promulgated for Class I and Class II specifying allowable increases in particulates and sulfur dioxide concentrations. The Clean Air Act Amendments of 1977 added standards for Class III areas. These increments are set forth in Table 1.

Part C of the Clean Air Act Amendments of 1977, entitled "Prevention of Significant Deterioration of Air Quality," granted statutory authority to the Environmental Protection Agency to promulgate and enforce regulations dealing with nonsignificant deterioration.[38] These nonsignificant deterioration provisions were made applicable to new or modified major emitting facilities. This term was defined in Section 169 to include the following stationary sources.

> The term major emitting facility means any of the following stationary sources of air pollutants which emit, or have the potential to emit, one hundred tons per year or more of any air pollutant from the following types of stationary sources: fossil-fuel fired steam electric plants of more than two hundred and fifty million British thermal units per hour heat input, coal cleaning plants (thermal dryers), kraft pulp mills, Portland Cement plants, primary zinc smelters, iron and steel mill plants, primary aluminum ore reduction plants, primary copper smelters, municipal

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[38] *On October 3, 1977, in the case of Montana Power Company v. E.P.A., (Nos. 76-529 et al) the United States Supreme Court ruled that a U. S. Court of Appeals decision upholding significant deterioration provisions should be remanded back to that Court of Appeals in view of the recently enacted Clean Air Act Amendments of 1977. The significant deterioration regulations had been challenged as being unconstitutional because the Environmental Protection Agency lacked statutory authority under the Clean Air Act Amendments of 1970. The Clean Air Act Amendments of 1977 contained such specific statutory authority.*

incinerators capable of charging more than two hundred and fifty tons of refuse per day, hydrofluoric, sulfuric and nitric acid plants, petroleum refineries, lime plants, phosphate rock processing plants, coke oven batteries, sulfur recovery plants, carbon black plants (furnace process), primary land smelters, fuel conversion plants, sintering plants, secondary metal production facilities, chemical process plants, fossil fuel boilers of more than the two hundred and fifty million British thermal units per hour heat input, petroleum storage and transfer facilities with a capacity exceeding three hundred thousand barrels, taconite ore processing facilities, glass fiber processing plants, charcoal production facilities. Such term also includes any other source with the potential to emit two hundred and fifty tons per year or more of any air pollutant.[39]

The designation of these new stationary sources does not preclude additional sources being identified in the future.

Initially all areas of the country were designated Class II areas. States may submit to the Administrator proposals to redesignate areas to a different class. Class II areas may be redesignated Class III if the following conditions exist: the governor has approved the redesignation and this approval is supported by concurring legislation enacted by local governments representing a majority of the residents of the area to be redesignated; and if such redesignation will not cause or contribute to concentrations of any air pollutant which exceeds any maximum allowable increase or maximum allowable concentration permitted under the classification of any other area. The Administrator must approve such a redesignation unless public notice and hearing requirements of the above procedural requirements are not met.

All major emitting facilities on which construction is commenced after August 7, 1977, are subject to the Clean Air Act's Prevention of Significant Deterioration provisions and a permit must be secured in accordance with these provisions. Other requirements include the following statutory provisions:

> (3) the owner or operator of such facility demonstrates that emissions from construction or operation of such facility will not cause, or contribute to, air pollution in excess of any (A) maximum allowable increase or maximum allowable concentration for any pollutant in any area to which this part applies more than one time per year, (B) national ambient air quality standard in any air quality control region, or (C) any other applicable emission standard or standard of performance under this Act:
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> (4) the proposed facility is subject to the best available control technology for each pollutant subject to regulation under this Act emitted from, or which results from, such facility;[40]

In addition, an owner or operator of a major emitting facility is required to conduct such monitoring as may be necessary.

There are several potential problems in the application of the current significant deterioration provisions. One problem occurs in the situation when there are different class areas within a single Air Quality Control Region and many of the anticipated future new sources within that region are new sources covered by the significant deterioration provisions. What is created is a system of enforcement and planning for two different sets of standards, i.e., the pollutant concentration increments for significant deterioration for Class I, II, and III areas and the national ambient air quality standards. In addition, some practical problems are posed by the presence of two areas within the single Air Quality Control Region. Air quality planning, enforcement, and implementation may become so complex as to severely burden the present air quality planning programs. An additional problem is present when these area designations encompass parts of several general purpose local units of government.

A second problem arises in the application of significant deterioration regulations when new sources not covered by significant deterioration regulations are allowed to be located within a Class I, II, or III area and they emit particulates and sulfur dioxide up to the primary standard and thus cause the significant deterioration provisions to be exceeded. Subsequent new source review of any new source covered by significant deterioration provisions must result in denial of that new source permit.

Ozone Protection: Several new sections relating to ozone protection were added by the Clean Air Act Amendments of 1977. The U. S. Congress found on the basis of available information that halocarbon compounds introduced into the environment threaten to reduce atmospheric ozone concentrations and that the resultant decrease in atmospheric ozone may lead to increased incidence of ultraviolet radiation at the earth's surface, causing increased rates of skin cancer, threatening food crops and otherwise damaging the natural environment. Section 153 authorizes the Administrator to conduct studies "of the cumulative effect of all substances, practices, processes and activities which may affect the stratosphere, especially ozone in the stratosphere."[41]

An interim report on such study is to be provided to Congress by January 1, 1978, with a final report due two years later. If at any time prior to the submission of this final report the Administrator finds that:

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[39] *Clean Air Act sec. 169(1).*

[40] *Clean Air Act sec. 165(a)(3) and (4).*

[41] *Clean Air Act sec. 153(a).*

> any substance, practice, process or activity may reasonably be anticipated to affect the stratosphere, especially ozone in the stratosphere, and such effect may reasonably be anticipated to endanger public health or welfare, the Administrator shall promptly promulgate regulations respecting the control of such substance, practice, process or activity, and shall simultaneously submit notice of the promulgation of such regulations to the Congress.[42]

In addition, the Administrator may promulgate similar regulations after final release of the report.

Federal Emission Standards: Several special control measures involving direct federally dictated emission standards are provided. These involve new stationary sources, hazardous air pollutants, and nonstationary sources.

New Stationary Source Standards: A new stationary source is defined as " ... any stationary source, the construction or modification of which is commenced after the publication of regulations prescribing a standard of performance under this section which will be applicable to such source."[43] The Administrator is directed to identify categories of stationary sources which he has determined to "cause(s) or contribute(s) significantly to air pollution which may reasonably be anticipated to endanger public health or welfare."[44] The federal performance standards to be promulgated by the Administrator are emission standards which reflect the degree of emission limitations achievable by the best control system that has been adequately demonstrated taking into consideration the costs involved, environmental impacts, and energy requirements.[45]

The Administrator is empowered to establish standards for new sources and may distinguish among classes, types, and sizes within categories of new sources. States are given the opportunity of developing a procedure for implementation and enforcing standards of performance for new sources located within the respective states. If the Administrator finds that such procedures are adequate, he may delegate the authority to implement and enforce such standards. These standards can be no less strict than those set by the Administrator. The Administrator, however, never relinguishes the right to enforce such standards in the event a state is not performing the implementation or enforcement functions. As a condition for issuance of permits for new stationary sources, the owner must show

> that the technological system of continuous emission reduction which is to be used at such source will enable it to comply with the standards of performance which are to apply to such source and that the construction or modification and operation of such source will be in compliance with all other requirements of this Act.[46]

States are to include within their implementation plans controls for existing sources. The state implementation plan must include emission limitations, schedules, and timetables for compliance with such limitations.

Hazardous Air Pollutants: Congress has vested in the Administrator primary authority for the regulation and control of hazardous air pollutants. A hazardous air pollutant is defined as

> an air pollutant to which no ambient air quality standard is applicable and which in the judgement of the Administrator causes or contributes to air pollution which may be reasonably anticipated to result in an increase in mortality or an increase in serious irreversible, or incapacitating reversible illness.[47]

The Administrator was directed to publish a list of such hazardous air pollutants within 90 days after enactment and, within 180 days of inclusion of any air pollutant in such list, publish proposed regulations establishing emission standards for such pollutant. To date, the Administrator has followed this procedure for five substances.[48] It is clear that, once the Administrator has placed an air pollutant within the scope of Section 112, no new source may be constructed absent a determination that the emission standard for the hazardous pollutant involved will not be violated. Existing sources are given 90 days after promulgation of the final standards to conform their emissions to the new standards. Each state may develop and submit

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[42] *Clean Air Act sec. 157(a).*

[43] *Clean Air Act sec. 111(a)(2), 42 U.S.C. sec. 1857 c-6 (a)(2).*

[44] *Clean Air Act sec. 111(b)(1)(A), 42 U.S.C. sec. 1857 c-6(b)(1)(A).*

[45] *See 40 C.F.R. 60. The categories of new sources for which standards have been promulgated are the following: Portland Cement plants, sulfuric acid plants, nitric acid plants, municipal incinerators, fossil fuel-fired steam generators, asphalt concrete plants, petroleum refineries, storage vessels for petroleum liquids, secondary lead smelters, secondary brass and bronze ingot plants, iron and steel plants, sewage treatment plants, primary copper, zinc and lead smelters, primary aluminum production plants, phosphate fertilizer production, and ferroalloy steel production.*

[46] *Clean Air Act sec. 111(j), 42 U.S.C. sec. 1957 c-6(j).*

[47] *Clean Air Act sec. 112(a)(1), 42 U.S.C. sec. 1857 c-7 (a)(1).*

[48] *See 40 C.F.R. 61. The substances termed hazardous are asbestos, beryllium, mercury, benzene, and vinyl chloride.*

to the Administrator a procedure for implementing and enforcing emission standards for hazardous air pollutants for stationary sources located within the state and, if acceptable, the Administrator may delegate authority to implement and enforce such standards.

Nonstationary Sources: Title II of the Clean Air Act deals exclusively with emission standards for moving sources. Nonstationary sources are one of three areas where the Administrator has the authority to promulgate national emission standards, as opposed to ambient air quality standards. Section 202 grants authority to prescribe standards applicable to the emission of any air pollutant from new motor vehicles. Section 209 of the Act states that no state shall enforce any standards for new motor vehicles or new motor vehicle engines or require inspection of any other approval which relates to control of emissions as a condition precedent to the initial sale or registration of such motor vehicle, motor vehicle engine, or equipment. Provision for waiver of application of the above Section is provided when a state has adopted standards for the control of emissions from new motor vehicles or new motor vehicle engines prior to March 30, 1966, and if such state determines that the state standards will be at least as protective of the public health and welfare as are applicable federal standards. In addition, whenever federal regulations covering any motor vehicle part or motor vehicle engine part is in effect, no state other than those which have been granted the above-mentioned waiver may adopt or enforce any standard or requirement of certification, inspection, or approval which relates to motor vehicle emissions. The above restrictions do not preclude or deny to any state the right to control or regulate the use, operation, or movement of registered or licensed motor vehicles. California has established its own set of emission standards and has been granted a waiver. To date, automobile emission standards have been set for three pollutants: hydrocarbons, carbon monoxides, and nitrogen oxides. The Act requires the following emission standards to be achieved for new light duty motor vehicles: During model years 1977 through 1979, emissions shall not exceed 1.5 grams per vehicle mile of hydrocarbons and 15.0 grams of carbon monoxide per vehicle mile, reduced in 1980 to 7.0 grams of carbon monoxide per vehicle mile. In addition, during or after model year 1980, a 90 percent reduction of hydrocarbons and a 90 percent reduction of carbon monoxide in 1981 is required from emissions of such pollutants allowable under standards applicable to light duty vehicles and engines manufactured in model year 1970. Nitrogen oxide emissions shall not exceed 2.0 grams per mile during 1977 through 1980 model years and thereafter 1.0 gram per mile. Manufacturers of 300,000 vehicles or less are required to meet a nitrogen oxide emission standard of 2.0 grams per vehicle mile for 1981 and 1982 for light duty motor vehicles. For heavy duty vehicles manufactured during model years 1979 through 1982, regulations shall be promulgated by the Administrator containing standards which reflect the greatest degree of emission reduction achievable through the application of available technology for emissions of carbon monoxide, hydrocarbons, and nitrogen oxides. In 1983 a 90 percent reduction of carbon monoxide and hydrocarbons, and in 1985 a 75 percent reduction in nitrogen oxide emissions are required from the average of the measured emissions from heavy duty gasoline fueled vehicles and engines manufactured during the base line model year. In addition, the Administrator shall promulgate regulations applicable to emissions of particulate matter for model year 1981.

Manufacturers may request waivers for model years 1981 and 1982 from carbon monoxide standards and for four model years after 1980 for nitrogen oxide standards. If such a waiver is granted, the Administrator is to prescribe emission standards to be applied in lieu of the former standards.

Section 202 further provides for grants and contracts with the National Academy of Sciences for scientific study of the feasibility of meeting emission standards. Regulations promulgated under Title II of the Clean Air Act are in force for the useful life of vehicles and engines, a life subsequently determined by the Administrator to be 50,000 miles or five years.

Section 206 requires the Administrator to test any new motor vehicle or engine submitted by the manufacturer to determine whether such motor vehicle conforms with emission regulations. If such engine or vehicle conforms to such regulations, the Administrator shall issue a certificate of conformity for a period not in excess of one year. Upon the sale of a new light duty motor vehicle by a dealer, the dealer must furnish a certificate indicating that the vehicle conforms to Section 202 emission requirements.

A final section of Title II relating to automobiles is that dealing with the regulation of fuels and fuel economy. Section 211 provides authority for the Administrator to prohibit certain fuels or fuel additives from being sold in open commerce. This section has provided authority for non-lead requirements in newer model cars. The criteria used by the Administrator in removing a fuel or fuel additive from the open market are the following:

> (A) if in the judgement of the Administrator any emission product of such fuel or fuel additives causes, or contributes to, air pollution which may reasonably be anticipated to endanger the public health or welfare, or
>
> (B) if emission products of such fuel or fuel additive will impair to a significant degree the performance of any emission control device or system which is in general use, or which the Administrator finds has been developed to a point where in a reasonable time it would be in general use were such regulation to be promulgated.[49]

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[49] *Clean Air Act sec. 211(b)(3)(c), 42 U.S.C. sec. 1857 f-6(e), see also 40 C.F.R. 79.*

The Administrator was authorized by Section 213 to conduct a study to determine the feasibility of establishing a fuel economy improvement standard of 20 percent for new motor vehicles manufactured during and after model year 1980.

Part B of Title II, entitled "Aircraft Emission Standards-Establishment of Standards," follows much the same format at that part of Title II relating to automobiles and other ground vehicles. After appropriate study, the Administrator is to issue regulations which shall take effect after "such period as the Administrator finds necessary to permit the development and application of the requisite technology . . . ."[50] Responsibility for the enforcement of such standards lies within the U. S. Secretary of Transportation. The regulations of the U. S. Secretary of Transportation include provisions making such standards applicable in the issuance, amendment, modification, suspension, or revocation of any certificate authorized by the Federal Aviation Act or the Department of Transportation Act. Section 226 authorizes the Administrator and the Secretary of Transportation to conduct a joint study of the problem of carbon monoxide intrusion into the passenger section of sustained use motor vehicles. States are prohibited from adopting or enforcing any standard respecting emissions of any air pollutant from any aircraft or engine thereof unless such standard is identical to a standard applicable to such aircraft under Part B of Title II.

Enforcement Provisions of the Clean Air Act: Through the Clean Air Act, both federal and state governments and agencies carry out enforcement roles. It is only in the area of mobile sources of pollution, particularly automobiles, that—with the exception of the State of California—an exclusive role of enforcement is vested in the federal government. Enforcement of ambient air standards relies on a federal-state cooperative effort.

Federal Enforcement Machinery for Ambient Standards: Essential in any method of enforcement are the functions of inspection, monitoring, and entry. Section 114 of the Act provides the Administrator with the authority to require the owner or operator of any emission source to

> (A) establish and maintain such records, (B) make such reports, (C) install, use, and maintain such monitoring equipment or methods, (D) sample such emissions and (E) provide other information as he may reasonably require.[51]

This section also provides for right of entry, access to records, and inspection and sampling rights. All such information obtained is required to be made public except where trade secrets are involved.[52]

Although the Administrator may delegate his authority to a state which develops a procedure for inspection and monitoring, federal enforcement authority under Section 114 is nevertheless preserved. Although the U. S. Environmental Protection Agency has the authority to inspect and monitor emissions in a state, the state still has the primary duties of data collection and monitoring in accordance with its implementation plans. However, whether a state can be forced to carry out such duties is an issue that remains unsettled. If a state does not bear its share of the enforcement burden, the threat of stricter federal enforcement might be realized. Stricter federal enforcement creates the same apprehension among states as does the threat of federally promulgated implementation plans for recalcitrant states.

Whenever the Administrator finds that any person is in violation of any requirement of an applicable implementation plan, the Administrator shall notify the person in violation of the plan and the state in which the plan applies of such finding. If the violation does not cease after 30 days, the Administrator may issue an order of compliance or bring civil suit.[53] When the violation is a result of a state's refusal to enforce the implementation plan effectively, the Administrator must notify the state. If the violation continues for more than 30 days, it is mandated that there be a period of federally assumed enforcement which ends upon a state's effective assumption of enforcement duties.[54] Any compliance order issued by the Administrator shall not take effect until the person to whom it is issued is given an opportunity to confer with the Administrator. A civil action may be commenced by the Administrator upon refusal to adhere to a compliance order. Whenever the Administrator determines that a state is not acting in compliance with state implementation plan requirements related to nonattainment areas, the Administrator may issue an order prohibiting the construction or modification of any major stationary source within a nonattainment area. The Administrator or a state may issue an order for any stationary source which specifies a date for final compliance with any requirement of an implementation

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[50] *Clean Air Act sec. 231(b), 42 U.S.C. sec. 1857 f-9(b), see also 40 C.F.R. 87.*

[51] *Clean Air Act sec. 114(a)(1), 42 U.S.C. sec. 1857 c-9(a).*

[52] *In Natural Resources Defense Council v. Environmental Protection Agency, 6 E.R.C. 1248 (C.A.S., 1975) the Fifth Circuit stated that the Clean Air Act requires the Administrator to disapprove an implementation plan provision which directs a state to keep confidential any information obtained concerning secret processes, or manufacturing methods since sec. 110(a)(2)(F)(iii) and (iv) requires full disclosure of all emission data obtained by a state even if such data could otherwise qualify for trade secret protection. Also see Natural Resources Defense Council v. Environmental Protection Agency, 6 E.R.C. (CA 2, 1975).*

[53] *Clean Air Act sec. 113(a)(1), 42 U.S.C. sec. 1857 c-8 (a)(1).*

[54] *Clean Air Act sec. 113(a)(2), 42 U.S.C. sec. 1857 c-8 (a)(2).*

plan set for later than the date for attainment of any national ambient air quality standard if appropriate public hearings are held; the order contains a schedule of compliance with interim and final requirements. Major sources are required to pay noncompliance penalties.

An issue of utmost importance is whether economic and social factors or technical feasibility may be taken into account in enforcement discretion. Natural Resources Defense Council v. Environmental Protection Agency[55] held that a state agency responsible for the enforcement of an implementation plan may not take economic and social factors into account in the issuance of abatement orders. Section 113 contains no indication that technical nonfeasibility should be available as a defense to an enforcement action. However, in Buckeye Power Company v. Environmental Protection Agency,[56] the Sixth Circuit Court of Appeals indicated that industry should be able to raise claims of technological nonfeasibility as a defense in a civil suit to enforce an abatement order.

First time convictions of persons violating plan provisions during the period of federal assumption of enforcement may result in fines of up to $25,000 a day and $50,000 a day for subsequent convictions.[57] Any person who knowingly makes false statements or falsifies required air pollution documents or records or tampers with any monitoring devices may upon conviction be punished by a fine of not more than $10,000. Federal installations are required to comply with applicable state, local, and federal plans except that the President may exempt certain federal installation upon finding that it is in the paramount interest of the United States.[58] Federal facilities, however, may not be exempted from Clean Air Act requirements relating to new stationary sources and hazardous air pollutants. No officer, agent, or employee of the United States may be held personally liable for any violation.

The Administrator has authority to employ three alternative enforcement procedures: issuance of a compliance order, commencement of a civil action including a suit for injunctive relief, and prosecution for criminal penalties in the case of intentional violations during periods of federally assumed enforcement. The issue has arisen of whether both federal and state enforcement powers may be exercised independently, resulting in inconsistent enforcement. The problem arises when an industry seeks to challenge the Administrator's approval of a state's implementation plan while simultaneously pursuing within the state system a variance from the state plan. Two courts have addressed themselves to such a problem but have done little to clarify the situation.[59]

Section 303 allows the Administrator limited use of emergency enforcement powers. It must be shown that a pollution source or combination of sources is presenting an imminent and substantial danger to the health of persons and that state or local officials have not acted to abate such sources. This authority is directed to the episode of intense pollution occurrence and has been exercised only once in Birmingham, Alabama, on November 18, 1971. Administrator Ruckelshaus ordered 23 producing operations to shut down until Birmingham's air quality returned to acceptable levels. Such an order may not be for more than 24 hours unless a suit is filed in an appropriate United States District Court to immediately restrain any person causing or contributing to the pollution problem.

Enforcement of Federal Emission Standards: As was noted earlier, emission standards are directly set by the federal government for three categories of sources of pollutants. Enforcement of emissions standards for new stationary and hazardous sources in a joint effort between the Environmental Protection Agency and state agencies. Nonstationary source standards are enforced totally by the Environmental Protection Agency.

New Stationary Source Standard Enforcement: Both the Administrator and the states are involved in the implementation and enforcement of new stationary source standards. Section 110(a)(2)(D) and (E) requires that state implementation plans contain

> (D) a program to provide for the enforcement of emission limitations and regulation of the modification, construction, and operation of any stationary source, including a permit program . . . for any major emitting facility within such region as necessary to assure (i) that national ambient air quality standards are achieved and maintained, and (ii) a procedure, meeting the requirements of paragraph (4), for review of the location of new sources to which the standard of performance will apply; (E) it contains adequate provisions (i) prohibiting any stationary source within the state from emitting any air pollutant in amounts which will (I) prevent attainment or maintenance by any other state of any such national primary or secondary ambient air quality standard, or (II) interfere with measures required to be

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[55] *Natural Resources Defense Council v. Environmental Protection Agency, 478 F 2d 875, (CA 1, 1973).*

[56] *Buckeye Power Company v. Environmental Protection Agency, 481F. 2d 162, 168, (CA 6, 1973).*

[57] *Clean Air Act sec. 113(c)(1)(B), 42 U.S.C. sec. 1857 c-8(c)(1).*

[58] *See County of Milwaukee v. Veterans Administration Center, 357 F. Supp. 192 (E.D. Wisc., 1973).*

[59] *See Getty Oil Company v. Ruckelshaus, 342 F. Supp. 1006 (D. Del., 1972) aff'd 467F. 2d 349 (CA 3, 1972) cert. denied 402 U.S. 1125 (1973), and Duquesne Light Company v. Environmental Protection Agency, 481 F 2d 1 (CA 3, 1973).*

included in the applicable implementation plan for any other State under Part C to prevent significant deterioration of air quality.[60]

States must provide for authority to prevent construction of or modification of any new source which the state determines would prevent the attainment or maintenance of either the primary or secondary standards.

> Each state may develop and submit to the Administrator a procedure for implementing and enforcing standards of performance for new sources located in such State. If the Administrator finds the state procedure is adequate, he shall delegate to such state any authority he has under this Act to implement and enforce such standards.[61]

The Administrator shall have complete authority for enforcing any applicable standard relating to new sources if this power is not delegated to states. In addition, if states fail to enforce new source standards which are part of their implementation plans, the Administrator may enforce the provisions of such plan. Federal enforcement of state implementation plans was discussed earlier in this chapter.[62]

In Portland Cement Company v. Ruckelshaus, it was argued that cement plants were being discriminated against because power plants were allowed to emit more particulate matter under new source performance standards. The U. S. Environmental Protection Agency argued that superior technology was available for control of particulate pollution related to cement plants. The court agreed with the U. S. Environmental Protection Agency and stated the following: "The essential question is whether the mandated standards can be met by a particular industry for which they are set, and this can typically be decided on the basis of information concerning that industry alone."[63] Section 111(b)(2) states that the Administrator may distinguish among classes, types, and sizes within categories of new sources for the purpose of establishing new source standards.

Hazardous Air Pollutant Enforcement: Primary responsibility is given to states to enforce national emission standards for hazardous air pollutants. Each state may develop a procedure for implementing and enforcing emission standards for hazardous air pollutants for stationary sources located in the state. If the Administrator finds that the state procedure is adequate, he shall delegate Environmental Protection Agency authority to the state to implement and enforce such standards. Section 112, however, goes on to state, "Nothing in this subsection shall prohibit the Administrator from enforcing any applicable emission standard under this section.[64]

Mobile Source Standard Enforcement: It is a prohibited act to distribute in commerce, offer for sale, or import into the United States

> any motor vehicle or new motor vehicle engine manufactured after the effective date of the regulations under this part which are applicable to such vehicle or engine unless such vehicle or engine is covered by a certificate of conformity issued under this part.[65]

Additional prohibited acts include refusal to permit access to records, removing or rendering inoperative auto-pollutant control devices, and the sale of vehicles not meeting standards promulgated. Penalties for violations of Sections 203(a)(1-4) shall not be more than $10,000.[66]

The Administrator is authorized to test any motor vehicle or motor vehicle engine which is submitted by a manufacturer to determine if such vehicle or engine conforms with the regulations prescribed by Section 202 of the Act. If such a test is satisfactory, the Administrator is to issue a certificate of compliance for a one-year period. If nonconformity with Section 202 is found, the Administrator shall deny, suspend, or revoke the certificate of conformity until such date as when the vehicle or engine complies with the regulation.

Manufacturers of motor vehicles are required to warrant to the ultimate purchaser and each subsequent purchaser that a vehicle or engine is

> (A) designed, built, and equipped so as to conform at the time of sale with applicable regulations under Section 202 and (B) free from defects in materials and workmanship

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[60] *Clean Air Act sec. 110(a)(2)(D)&(E), 42 U.S.C. sec. 1857 c-5(a)(2)(D)&(E).*

[61] *Clean Air Act sec. 111(c)(1), 42 U.S.C. sec. 1957 c-6(c).*

[62] *This discussion centered on secs. 113 and 114 of the Clean Air Act.*

[63] *Portland Cement v. Ruckelshaus, 486 F. 2d 375, 389 (D.C. Cir., 1973).*

[64] *Clean Air Act sec. 112(d)(1), 42 U.S.C. sec. 1857 c-7 (d)(2).*

[65] *Clean Air Act sec. 203(a)(1), 42 U.S.C. sec. 1857 f-2 (a)(1).*

[66] *See U. S. v. Haney Chevrolet, 6 E.R.C. 1440 (M.D. Fla., 1973) which stated that sec. 203(a)(3) of the Clean Air Act which prohibits automobile manufacturers or dealers from knowingly removing automobile pollution controls after a car's sale and delivery to the ultimate purchaser does not violate the Fifth Amendment Due Process clause even though that section does not bar others from removing those devices.*

which cause such vehicle or engine to fail to conform with applicable regulations for its useful life.[67]

Along with the above mentioned warranty, the manufacturer is required to furnish with each new vehicle instructions as to the proper maintenance to insure the continued functioning of emission control devices and systems. Additionally, all manufacturers are required to maintain records and provide information to enable the Administrator to determine whether said manufacturer is acting in compliance with Title II of the Act.

States are precluded from active regulation of emissions from new motor vehicles or new motor vehicle engines. A state may not require certification, inspection, or any other approval relating to the control of emissions as a condition precedent to the initial sale or registration of such motor vehicle. In addition, states are prohibited from enforcing any regulations on the use of a fuel or fuel additives in motor vehicles or motor vehicle engines. States are not, however, denied the right to control or regulate the use or operation or movement of licensed motor vehicles.

Miscellaneous Provisions of the Clean Air Act: With the passage of the 1970 Clean Air Act Amendments, an authorization unprecedented in federal legislation was enacted. Section 304(a) granted for the first time to citizens concurrent authority with state and federal agencies to seek enforcement of the regulatory provisions of the Act. Suits may be brought against any person, the United States, and any other government instrumentality for violation of any emission standard promulgated by the Act or of any order issued by the Administrator or state official. Suits against states by citizens of different states are prohibited by the Eleventh Amendment to the United States Constitution. Suits are also allowed against the Administrator where it is alleged that the Administrator failed to perform a nondiscretionary act requested by the Act.[68] In addition a citizen suit may be commenced against any person who proposes to construct or constructs any new major emitting facility without securing a permit and complying with significant deterioration and nonattainment provisions of the Act. A limitation is placed on citizen suits in the form of a 60-day notice period of the violation to the Administrator, the state of the violation, and to the alleged violation.[69]

Section 307(b)(1) provides the mechanism providing for judicial review of the Administrator's actions in the promulgation of natural primary and secondary ambient air quality standards, any emission standards, and any other standards. Such an action may only be filed in the United States Court of Appeals for the District of Columbia. A petition for review of implementation plan approvals may be filed in the appropriate circuit of the United States Court of Appeals.

Section 316 provides that the Administrator may not withhold, condition, or restrict any sewage treatment grant on the basis of any requirement of the Clean Air Act with the following exceptions: such treatment works will not comply with standards of performance relating to new stationary sources or hazardous air pollutants; the state does not have in effect a state implementation plan which provides for increases of air pollutants which may reasonably be anticipated to result directly or indirectly from new sewage treatment capacity; such increases in emissions resulting from the construction of new sewerage facilities would interfere or be inconsistent with the applicable implementation plan for any other state.

Section 319 provides that, within one year of the enactments of the Clean Air Act Amendments of 1977, the Administrator is to promulgate regulations establishing an air quality monitoring system throughout the United States. Such system is to utilize uniform air quality monitoring criteria and methodology; provide air quality monitoring stations in major urban areas; provide for daily analysis, reporting, and record keeping of air quality based on a uniform air quality index with periodic reports to the public. In addition, Section 320 requires the Administrator to conduct periodic conferences dealing with air quality monitoring. Section 309 of the Clean Air Act requires the Administrator to review and comment in writing on the environmental impact of any matter related to the Act or other provisions of authority granged to the Administrator in any proposed federal legislation for any newly authorized federal projects or any major federal action falling within the scope of the National Environmental Policy Act. In the event the Administrator determines that such legislation, action, or regulation is unsatisfactory from the standpoint of public health, welfare, or environmental quality, the matter will be referred to the Council on Environmental Quality.

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[67] *Clean Air Act sec. 207(a)(1), 42 U.S.C. sec. 1857 f-5(a).*

[68] *See Wisconsin Environmental Decade v. Wisconsin Power and Light Company, 7 E.R.C. 2000 (W.D. Wisc., 1975) Federal District Court lacks jurisdiction under sec. 304 of the Clean Air Act to review the findings of the Environmental Protection Agency made under sec. 113 that the power company was not in violation of Wisconsin's Implementation Plan since sec. 304 confers jurisdiction only in cases in which the agency has failed to perform a nondiscretionary act or duty and does not confer jurisdiction to review Environmental Protection Agency performance of those duties.*

[69] *See Highland Park v. Train, 6 E.R.C. 1464, (N.D. Ill., 1974) aff'd in 7 E.R.C. 2073 (CA 7, 1975) in which the court held that failure to give the 60-day notice bars a sec. 304 suit. Also see West Penn. Power v. Train, 522 F. 2d 302 (CA 3, 1975), cert. denied 8 E.R.C. 2200 (1976) and Natural Resources Defense Council v. Environmental Protection Agency, 7 E.R.C. 2041 (D.C. Cu, 1975).*

Energy Supply and Environmental Coordination Act of 1974

The Energy Supply and Environmental Coordination Act of 1974[70] (hereinafter referred to as the Energy Act) was enacted in June 1974 as a direct response to the Organization of Petroleum Exporting Countries' oil embargo and the resulting energy crisis. Provisions of the Energy Act must be coordinated with Section 113(d) of the Clean Air Act relating to a conversion of use of petroleum products and natural gas to coal in major stationary sources.

Briefly stated, the purposes of the Energy Act are the following: "(1) to provide for a means to assist in meeting the essential needs of the United States for fuels, in a manner which is consistent, to the fullest extent practicable, with existing national commitments to protect and improve the environment, and (2) to provide requirements for reports respecting energy resources.[71]

A major provision of the Energy Act provides for the conversion of any major fuel burning installation or power plant burning natural gas or petroleum as a primary fuel to burn coal. Strict guidelines are provided in determining the feasibility of conversion. The Federal Energy Administrator is empowered to make such a determination and, in addition, that Administrator may require those installations in the planning stage to be built to be capable of using coal.

Section 113(d)(5) of the Clean Air Act provides the Administrator of the U. S. Environmental Protection Agency authority to temporarily suspend any stationary source fuel or emission requirement if the Administrator finds that a person will be unable to comply with standards because of the unavailability of certain types of fuel, or if the source which has been converted to coal is unable to meet applicable standards. When such suspensions are granted, interim temporary regulations shall be enacted. Suspensions are conditional upon compliance with interim requirements for control of emissions and measures necessary to protect health. Sources which are granted compliance extensions are required to use the best practicable system or systems of emission reduction. Such compliance must be had no later than December 31, 1980. An additional period of not more than five years may be granted by the Administrator.[72]

Whenever the Federal Energy Administrator orders conversion, the Environmental Protection Agency Administrator is to notify the Federal Energy Administrator whether compliance with applicable standards may be had. If compliance is not possible, the Environmental Protection Agency Administrator shall notify the Federal Energy Administrator of the earliest possible compliance date. The Administrator is required to study and report to Congress as to the implementation plan to be followed.

Most of the substantive provisions of the Energy Act are closely related to provisions of the Clean Air Act. The Energy Act may, however, create problems in implementing the Clean Air Act. With the stress on conversion to coal-operated plants, increases in sulfur oxides, sulfates, and particulates may be expected. In addition, transportation systems needed to convey the additional coal will increase the emissions from nonstationary sources.

Resource Conservation and Recovery Act of 1976

With increasing amounts of solid waste generation, increased disposal costs, decreased availability of landfill sites, and new air and water pollution control restrictions, solid waste disposal has become a great concern to both government and industry. The federal role in solid waste management is set forth in the Resource Conservation and Recovery Act of 1976.[73] Briefly stated, the role of the federal government is one of providing technical and financial assistance to the states, but beyond that no active federal role is set forth except in the area of hazardous waste management. The Administrator of the U. S. Environmental Protection Agency is required to promulgate regulation and standards applicable to generators of hazardous wastes and transporters of hazardous wastes, and to establish a system of permits for the treatment, storage, or disposal of hazardous wastes. With nonhazardous wastes, the Resource Conservation and Recovery Act of 1976 recognizes the federal role in the following manner:

> . . . that while the collection and disposal of solid wastes should continue to be primarily the function of state, regional and local agencies, the problems of waste disposal as set forth above have become a matter national in scope and in concern and necessitate federal action through financial and technical assistance . . . .[74]

The Resource Conservation and Recovery Act does recognize that

> (3) As a result of the Clean Air Act, the Water Pollution Control Act and other Federal and State Laws respecting public health and the environment, greater amounts of solid waste (in the form of sludge and other pollution treatment residues) have been created. Similarly, inadequate and environmentally unsound practices for the disposal or use of solid wastes have created greater amounts of air and water pollution and other problems for the environment and for health;

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[70] *P.L. No. 93-319, 88 Stat. 246 (1974).*

[71] *Energy Supply Act sec. 1(b) 15 U.S.C. sec. 791.*

[72] *Clean Air Act sec. 113(d)(5), 42 U.S.C. sec. 1857 c-8.*

[73] *P.L. No. 94-580, 42 U.S.C. secs. 8251 et. seq. (1976).*

[74] *Resource Conservation and Recovery Act sec. 1002(a)(4)(1976).*

(4) Open dumping is particularly harmful to health, contaminates drinking water from underground and surface supplies and pollutes the air and land.[75]

States are required to develop plans for solid waste management. Such plans must contain the following minimum provisions: a prohibition on the establishment of new open dumps within the state; closure or upgrading of any existing open dumps to comply with standards designed to eliminate health hazards and minimize potential health hazards; and all disposal of solid waste eventually to be in sanitary landfill sites.

This Act attempts to provide federal input to the resolution of these problems in the form of technical and financial assistance to the states. However, the overriding concerns of the Clean Air Act may dictate that federal enforcement be used especially vis a vis incinerations of solid waste. For the most part, however, solid waste disposal is a captive of state regulatory and enforcement provisions. The various provisions of the Resource Conservation and Recovery Act of 1976 include grants for resource recovery systems, recommended guidelines for solid waste disposal, grants for training projects, and planning grants.

National Environmental Policy Act

One of the significant pieces of national legislation in recent years is the National Environmental Policy Act of 1969.[76] This Act broadly declares it is national policy to encourage a productive and enjoyable relationship between man and his environment; to promote efforts which will prevent or eliminate damage to the environment; and to enrich the understanding of the ecological systems and natural resources important to the nation. This Act has broad application to projects in any way related to federal action. The only restriction is that the activity must be a major federal action significantly affecting the quality of the human environment.

The mechanism by which the intent of the National Environmental Policy Act is carried out is the preparation of an environmental impact assessment for each affected project. Such statement must include documentation of the environmental impact of the proposed project; any adverse environmental effects which cannot be avoided should the project be constructed; any alternatives to the proposed project, the relationship between the local short-term uses of man's environment and the maintenance and enhancement of long-term projectivity; and any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented. Section 309 of the Clean Air Act requires the Administrator to comment on the environmental impact of any matter relating to the Administrator's duties and responsibilities granted pursuant to the Clean Air Act. In the event the Administrator determines that the impact of proposed legislation, action, or regulation is unsatisfactory from the standpoint of public health or welfare or environmental quality, the matter is to be referred to the Council on Environmental Quality.

AIR QUALITY MANAGEMENT IN WISCONSIN

Air quality management in Wisconsin is primarily the responsibility of the Wisconsin Department of Natural Resources. The Wisconsin Department of Natural Resources is responsible for the implementation and enforcement of applicable state and federal air quality control legislation. The term legislation as used here includes administrative regulation. In addition to the statutory law of air quality management, Wisconsin common law has had an important impact on state air quality management. This section of the chapter will address both of these important areas.

Wisconsin's Common Law and Air Quality

During the development of air pollution law, a significant contribution has been made by judicial decisions.[77] Wisconsin's public policy in the air pollution field began with court-made law long before statutory enactments took place. In a large majority of cases, suits were initiated by citizen plaintiffs. Several factors limited the effectiveness of this method of creating public policy. Judge-created rules were made applicable to parties outside the original lawsuit only by additional litigation, since only parties privy to the initial action were directly affected by a decision. A major burden thus was placed on the citizen litigant, and financial restraints and burdens of proof often worked to deter private initiation of law suits.

A major decision in bringing a lawsuit was that of deciding which common law concept would be used as a basis for the litigation. Three concepts seemed to be the most feasible; however, only the nuisance action was used with any amount of success. A contract might be created under which the receptor would pay the polluter to discontinue such activities. A court action would be needed to enforce such a contract. Problems inherent in this system are obvious. In the case of multiple polluters, a single contract would have no bearing on parties outside of the contract. "Information and transaction costs prevented contract law from providing a workable mechanism within which to achieve court enforced pollution abatement.[78]

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[75] *Resource Conservation and Recovery Act sec. 1002(b)(4)(5)(1976).*

[76] *42 U.S.C. secs. 4321 et seq., 83 Stat. 852 (1970).*

[77] *For an extensive discussion of the origins and progression of Wisconsin common law and air quality, see Jan G. Laitos, The Social and Economic Roots of Judge Made Air Pollution Policy in Wisconsin, 58 Marq. L.R. 465 (1975). The following discussion parallels in part the format utilized in the above article.*

[78] *Id. pp. 471-472.*

Property law was another device which had possible application to air pollution controversies. However, more often than not, it was used effectively against the citizen plaintiff. The maxim, "whose is the soil, his it is up to the sky," was invoked to establish a vested right in land owners to use the atmosphere over their land as they wished. Polluters claimed that the fact of property ownership allowed them to use that property with the expectation of its productive employment free of legal restraints.

A third device used by a citizen plaintiff was the tort law concept of nuisance. "The law of torts was grounded in the concept of liability for the results of one's actions. Liability in turn required a showing of fault or wrongdoing." [79] However, reliance on fault created several problems for the citizen plaintiff. It needed to be demonstrated that a special injury distinctive to the plaintiff existed. This requirement placed great burdens on the plaintiff because of the need to demonstrate special damage to health, business, or other monetary assets. Purely aesthetic or recreational interests were never sufficient. Because of the particularized harm concept, the possibility that parties might raise the harm done to others was foreclosed. Accordingly, within the large body of tort law, the concept of nuisance was one doctrine that seemed to most fully address the needs of the citizen plaintiff. A nuisance action at common law lay in the interference with private rights to use land in which one had a property interest. In order to prove a nuisance, plaintiffs ordinarily had to show that the invasion was one continuing in nature. An additional problem was the possibility of prescriptive rights being created by the continued acquiesence of the plaintiff. A further disruption of the effectiveness of the nuisance doctrine was the distinction between private and public nuisance. A public nuisance was one which affected interests common to the general public. In order to prevail, the plaintiff needed to prove that he suffered special damage, different in kind from that suffered by the general public.[80] An additional problem was that of sufficiently proving that damages were an inadequate remedy and that an injunction was necessary. When granting an injunctive remedy, the court must resort to balancing the equities, a decision usually not favorable to the plaintiff.

Citizen Suits and the Wisconsin Supreme Court: The Wisconsin Supreme Court has decided a number of cases that had originally been brought by private citizens against both private and public air polluters. Prior to 1900, the Wisconsin Supreme Court generally protected the interests of active producers from the claims of pollution receptors who did not use their land to produce goods. This followed the general national trend of judicially protecting business and manufacturing enterprises.[81] After 1900, a gradual shift developed in which the Court's preference for market-oriented activities gave way to protection of plaintiff's interests.

In Wisconsin's first pollution case Slight v. Gutzlaff,[82] the plaintiff, asserting his interest as an owner of a residence, brought an action against a defendant whose lime kiln emitted smoke and cinders. The Wisconsin Supreme Court rejected the plaintiff's argument that it was the use of the kilns and not the kilns itself that constituted the nuisance. This argument would have placed little significance on ownership of the pollution source. Another homeowner argued in McCann v. Strang[83] that a coal burning power plant had decreased the rental value of the land. Because of the public necessity for an enterprise such as a power plant, the Supreme Court required a stronger showing of pollution damage caused by the industry before the defendant's conduct could be enjoined.

Another early Wisconsin case which attempted to raise the interests of the consumer as opposed to the market interest was Clark v. Wambold.[84] In that case the court applied the strict proof of damages standard as recited in McCann, and held that "The fact that odors are carried abroad on a summer breeze will not make an actionable nuisance. It becomes one of those minor discomforts of life which must be borne in deference to the principle that one man's enjoyment of property cannot always be the controlling factor."[85]

Other instances in which courts favored polluters were cases in which the defendant was either a transport enterprise or local government and in which the plaintiff attempted to raise interests of others via the class action or actions brought on behelf of an affected class. Early courts in general were not effective instruments either for protecting the interests of land owners asserting consumer values or for regulating the use of air resources. It was a choice between a pattern of slow economic growth or following prevailing social concerns at the time. Additionally, the lack of information concerning the causes, effects, and solutions to problems of air pollution hampered the courts.

The groundwork for successful citizen suits was laid in 1883 with the decision of Pennoyer v. Allen.[86] This was

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[79] *Id. p. 476.*

[80] *Prosser, LAW OF TORTS, sec. 88, p. 586 (4th edition, 1971).*

[81] *See Jan G. Laitos, The Social and Economic Roots of Judge Made Air Pollution Policy in Wisconsin, 58 Marq. L.R. 465 (1975).*

[82] *Slight v. Gutzlaff, 35 Wis. 675 (1874).*

[83] *Mc Cann v. Strang, 97 Wis. 551, 72 N.W. 1117 (1897).*

[84] *Clark v. Wambold, 165 Wis. 70, 160 N.W. 1039 (1917).*

[85] *Id. at 72, 160 N.W. at 1040.*

[86] *Pennoyer v. Allen, 56 Wis. 502, 6 N.W. 887 (1883).*

the first Wisconsin Supreme Court case which favored the interests of pollution receptors over polluters. From Pennoyer, a set of criteria evolved for resolution of air pollution controversies. Courts would favor consumer values when the following conditions were present: the commercial activity polluted the air over the homeowners' land; this air pollution interfered with or impaired plaintiff's use of his property; and this interference was substantial.

It was relatively soon that the Pennoyer standard was the controlling case.[87] In addition, the cases of Anstee v. Monroe Light and Fuel Company[88] and Cunningham v. Miller[89] indicated that the Court would entertain suits which would broaden the potential class of plaintiffs who might seek relief.

In the period following World War II, the Wisconsin Supreme Court consistently ruled in favor of citizen plaintiffs in air pollution controversies. The judicial system through the middle 1960's was the only branch of State Government in Wisconsin willing to recognize consumer values injured by air pollution.

A major trend in case law was the elimination of various defenses invoked by polluters. Two of these defenses were that users of polluting operations could not be held liable for any damage caused and that cities performing functions of a general and diffuse benefit to the community should be given a high priority over specialized interests. The first defense was derived from Slight v. Gutzlaff. The case of Kamke v. Clark and others: Pabst Brewing Company[90] overruled the Slight defense and put operators of polluting industries on notice that they could be held liable. No longer could operators claim the Slight defense where the nuisance was a continuing one and the operator knew he was maintaining a nuisance.

The decision in Costas v. City of Fond du Lac[91] eliminated the second of the above-mentioned defenses. A restaurant, motel, and theater owner sought to enjoin the defendant city from permitting gases to emanate from its sewage treatment plant. The Supreme Court upheld a lower court injunction. Previously the municipal defense of providing functions of general benefit would have prevailed. Costas stressed the financial capabilities possessed by municipalities to abate these publicly owned nuisances.

Other decisions of the Wisconsin Supreme Court struck down defenses used by polluters. In Dolata v. Berthelet Fuel and Supply Company[92] the defendant argued that the pollution source and nuisance were present before the plaintiff arrived. The Court repudiated the concept that plaintiffs were barred from recovery merely because they happened to locate near a preexisting nuisance. This holding was later strengthened in the case of Rode v. Sealtite Insulation Manufacturing Corporation.[93]

An additional defense often used by polluters involved a polluting industry locating within a district as permitted by industrial zoning ordinances. It was argued by defendants that a nonnegligent industry operating within such zoned districts could not be held accountable for its pollution of the air in a nuisance action. Wisconsin rejected this rule in the case of Bie v. Ingersoll.[94] In Bie, the court stated that property must be used in such a way that it will not deprive others of the use and enjoyment of their property.

A further impediment to successful nuisance litigation involving air pollution was the problem of proving damages. Dolata had previously established a stiff standard for proving damages. In 1960, however, the case of Sohns v. Jensen[95] considerably relaxed the Pennoyer standard. Six years later in Boershinger v. Elkay Enterprises, Inc.[96] the Wisconsin Supreme Court ruled a valid cause of action was stated when the plaintiffs' complaint merely alleged that defendant's rendering plant could potentially interfere with the general use of plaintiff's residence.

In Jost v. Dairyland Power Coop[97] farmers who lived near the defendant's electric generating plant claimed damage was caused to crops, pine trees, and farm structures as a result of defendant's sulfur dioxide emissions. The damages claimed in this nuisance action varied from

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[87] *See Rogers v. John Week Lumber Company, 117 Wis. 5, 93 N.W. 821 (1903) and Holman v. Mineral Point Zinc Company, 135 Wis. 132, 115 N.W. 327 (1908).*

[88] *Anstee v. Monroe Light and Fuel Company, 171 Wis. 291, 177 N.W. 26 (1920).*

[89] *Cunningham v. Miller, 178 Wis. 22, 189 N.W. 531 (1922).*

[90] *Kamke v. Clark and Others: Pabst Brewing Co., 268 Wis. 465, 67 N.W. 2d 841 (1955).*

[91] *Costas v. City of Fond du Lac, 24 Wis. 2d 409, 129 N.W. 2d 217 (1964).*

[92] *Dolata v. Berthelet Fuel and Supply Company, 254 Wis. 194, 36 N.W. 2d 97 (1948).*

[93] *Rode v. Sealtite Insulation Manufacturing Corporation, 3 Wis. 2d 286, 88 N.W. 2d 345 (1958).*

[94] *Bie v. Ingersoll, 27 Wis. 2d 490, 135 N.W. 2d 250 (1965).*

[95] *Sohns v. Jensen, 11 Wis. 2d 449, 105 N.W. 2d 818 (1960).*

[96] *Boershinger v. Elkay Enterprises, Inc., 26 Wis. 2d 102, 145 N.W. 2d 108 (1966).*

[97] *Jost v. Dairyland Power Cooperative, 45 Wis. 2d 164, 172 N.W. 2d 647 (1969).*

$15,000 to $25,000 for each farmer. After an adverse decision in the trial court, the cooperative appealed on two grounds. As a first defense, it was alleged that the defendant was a public utility and its operations conformed to the best known engineering standards available. The Wisconsin Supreme Court disposed of the public utility argument. Citing Pennoyer v. Allen, the Court stated that, "Due care does not defeat a claim for nuisance. Nor is freedom from negligence a defense if the consequences of continued conduct cause substantial injury."[98] As a second defense, the cooperative argued that the economic usefulness of the plant outweighed the damage claims submitted by the farmers. This argument was dismissed by a unanimous Wisconsin Supreme Court.

The Jost decision extended Supreme Court protection of private citizens and the resulting nuisance actions further than any other decision. It is a result of the continuing line of Supreme Court decisions initiated by private citizens that most of the barriers erected by polluter defendants have been torn down.

Government Prosecution of Air Polluters: The trend in court decisions on government-initiated suits against air polluters has closely paralleled the trend found in private citizen suits. Judicial reluctance to interfere with the market system once again was the major reason for judicial unwillingness to uphold government prosecutions. It was not until the 1960's that the Supreme Court consistently affirmed public prosecutions of air pollution sources. Generally, the prosecutions were based on statutes and ordinances, especially general nuisance legislation. These prosecutions may be divided into three classes involving municipal, county, and state proceedings against offending air polluters.

Municipal Prosecutions: The Wisconsin Supreme Court has generally shown disfavor toward governmental interference with industry in an air pollution controversy. This is particularly true when municipal proceedings were involved. In the 1890 case of City of Janesville v. Carpenter[99] the Wisconsin Supreme Court refused to enjoin the construction of a building as requested by the City. It had been alleged that such construction would obstruct the circulation of air. The Supreme Court found this complaint to be insufficient. Some 48 years later in Juneau v. Badger Cooperative Oil Company[100] the Court held that a city was not a private individual within the meaning of the state's general nuisance statute. Therefore, the City of Juneau was not entitled to enjoin as a potential air pollution nuisance the construction of defendant's oil refinery.

With amendment of the general state Nuisance Statute in 1939 giving cities, towns, and villages the power to sue to abate nuisances, it was thought that municipal prosecution in air pollution cases would no longer be frustrated. This was not the result, as the case of Milwaukee v. Milbrew[101] showed. The Supreme Court overturned the lower court conviction of Milbrew. In so doing, the Wisconsin Supreme Court stated that "a municipality's interest (in air pollution sources) should be aroused only when there is physical injury to property or occupant, where injury is substantial and the facts are weighty."[102] This degree of proof standard stood as a substantial bar to local pollution control prosecutions. The Supreme Court was unwilling to allow any type of municipal interference with the private market sector in regards to air pollution control. This was brought out in the 1966 case of Boerschinger v. Elkay Enterprises, Inc.[103] In Boerschinger, a town had attempted to except air polluters from the dictates of its zoning plan. The Supreme Court ruled that once a town had adopted a comprehensive zoning ordinance which created districts in which certain polluting plants were prohibited, the town could not thereafter amend the ordinance granting an exception to one owner. It appears that the course chosen by the Wisconsin Supreme Court is a disallowance of municipal interference with the private market in the area of air pollution control.

County Prosecutions: The Supreme Court initially applied the same principles it had used in determining the outcome of municipal prosecutions to decide county air pollution prosecution issues. In Hartung v. City and County of Milwaukee,[104] the Supreme Court rejected Milwaukee County's contention that defendant's operation of dump trucks constituted a public nuisance. It was determined that the operation of the trucks in a rock quarry was a valid, preexisting, nonconforming use. From this determination, it was a small step to declare that the trucks were not a public nuisance that could be regulated by law.

In the case of City of West Allis v. Milwaukee County,[105] the Court recognized the need for a more centralized countywide air pollution regulatory policy. In that case, the Court held that the State Legislature could authorize counties to purchase land for refuse disposal and to

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[98] *Id. at 173, 172 N.W. 2d at 651-652.*

[99] *City of Janesville v. Carpenter, 77 Wis. 288, 46 N.W. 128 (1890).*

[100] *Juneau v. Badger Cooperative Oil Co., 227 Wis. 620, 279 N.W. 666 (1938).*

[101] *Milwaukee v. Milbrew, 240 Wis. 527, 3 N.W. 2d 386 (1942).*

[102] *Id. at 531, 3 N.W. 2d at 389.*

[103] *Boershinger v. Elkay Enterprises, Inc., 32 Wis. 2d 168, 145 N.W. 2d 475 (1966).*

[104] *Hartung v. City and County of Milwaukee, 2 Wis. 2d 269, 86 N.W. 2d 475 (1957).*

[105] *City of West Allis v. Milwaukee County, 39 Wis. 2d 356, 159 N.W. 2d 36 (1968).*

construct pollution reducing waste systems. This determination was made in spite of judicial cognizance of the state's home rule amendment. County policies appeared to take precedence over attempts by municipalities to control pollution.

State Prosecutions: Prior to 1970, the office of the Wisconsin Attorney General had never used Wisconsin's nuisance statute to prosecute those whose only offense had been to pollute the air in violation of that statute. The Dairyland Cooperative Power plant in Alma, Wisconsin, became the first industry prosecuted in such an action. This was the same cooperative involved in the earlier mentioned litigation of Jost v. Dairyland Power Cooperative,[106] a private citizen suit. The state complaint charged Dairyland with operating a plant which "emits fumes, smoke, gases, soot and other particles and chemicals so as to contaminate and pollute the atmosphere."[107] Section 823.01 of the Wisconsin Statutes provides authority for the commencement of nuisance actions. "Any person, county, city, village or town may maintain an action to recover damages or to abate a public nuisance from which injuries peculiar to the complainant are suffered, so far as necessary to protect the complainant's rights and to obtain an injunction to prevent the same."[108] Further authority is provided in Section 280.02 for the Attorney General to commence an action to enjoin a public nuisance and prosecute in the name of the State.

Dairyland submitted a motion to dismiss for failure to state a cause of action because the public nuisance statute was directed to abate only such illegal activities as gambling and prostitution. Secondly, Dairyland asserted that Wisconsin's Clean Air Act had preempted the field of air pollution control. It was further stated that the Act set up a comprehensive scheme to deal with air pollution through the Department of Natural Resources, and that the Attorney General only had authority to enforce abatement orders issued by the Department of Natural Resources and could not proceed in an independent nuisance action. The Supreme Court ruled against the demurrer as submitted by Dairyland. It was stated by the Court that the existence of a public nuisance was a matter of fact and not dependent upon Department of Natural Resources determination. Additionally, the Court ruled that the Attorney General's statutory nuisance powers were independent of any powers given the Department of Natural Resources under Wisconsin's air pollution legislation.

Wisconsin Air Pollution Control Legislation

Comprehensive air pollution control legislation was not created by the Wisconsin State Legislature until Chapter 83, Laws of 1967, was enacted. Chapter 83 was subsequently amended by Chapter 83, Laws of 1975, effective October 4, 1975. Prior to the enactment of Chapter 83 of the Laws of 1967, air pollution control legislation was in the form of grants of power to counties for the control of air pollution. Because of the extensive requirements of the federal Air Quality Act of 1965 and the federal Clean Air Act Amendments of 1970 and 1977, comprehensive statewide air pollution control legislation became a necessity.

Sections 144.30-144.46 of the Wisconsin Statures contain the bulk of state air pollution control legislation. Chapters NR 154, "Air Pollution Control" and NR 155, "Ambient Air Quality" of the Wisconsin Administrative Code contain the necessary administrative rules and regulations needed to carry out the legislative policy contained in the air pollution statutes. A review of statutory and Administrative Code Provisions is needed to obtain a clear perspective of Wisconsin air pollution control legislation.

Section One of Chapter 83, Laws of 1975, contains a statement of policy and purposes. It is a general statement of the need for intergovernmental cooperation in the abatement of pollution problems and the close relationship between all types of pollution. In addition, it is stated that "it is the express policy of the state to mobilize governmental effort and resources at all levels, allocating such effort and resources to attain the maximum benefit for the people of the state as a whole."[109] Further, it is stated that "it is the intention of the Act to vest authority for the statewide control of air pollution and solid waste disposal in the same state agency which has general supervision and control over the waters of the state."[110] Accordingly, the Wisconsin Department of Natural Resources (DNR) is designated the state agency which has general statewide control of air pollution.

The DNR has been delegated much authority in the supervision of the state's natural resources, with the statutory definition of air pollution sufficiently broad to enable the DNR to protect the public welfare in terms of injury to property and public health. The current statutory definition is broad enough to allow the DNR considerable discretion in enforcement and implementation of the Statutes and administrative regulations: "(2) air pollution means the presence in the atmosphere of one or more air contaminants in such quantities and of such duration as is or tends to be injurious to human

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[106] *Jost v. Dairyland Power Cooperative, 45 Wis. 2d 164, 172 N.W. 2d 647 (1969).*

[107] *State v. Dairyland Power Cooperative, 52 Wis. 2d 45, 187 N.W. 2d 878 (1971).*

[108] *Wis. Stats. 823.01 (1975).*

[109] *Wisconsin Laws 1975, Chapter 83.*

[110] *Id.*

health or welfare, animal or plant life, or property, or would unreasonably interfere with the enjoyment of life or property.[111]

Among the powers of the DNR as provided in Section 144.31 of the Wisconsin Statutes (Chapter 83, Laws of 1975) are the following: 1) adopt, amend, and repeal rules and regulations; 2) enforce the law by appropriate administrative and judicial proceedings, including injunctive relief; 3) compel the attendance of witnesses at hearings and other administrative proceedings; 4) compel the production of books and records for use in administrative hearings; 5) secure necessary technical information by contract or otherwise; and 6) prepare comprehensive plans for the control of air pollution. In addition, the DNR is authorized in Section 144.32 to apply for and accept federal aid for the control of air pollution.

The DNR has access to records and inspection powers similar to that available to the Administrator of the U. S. Environmental Protection Agency. Section 144.34 states that "Any duly authorized officer, employee, or representative of the department may enter and inspect any property, premise or place on or at which an air contaminant source or solid waste disposal site or facility is located or being constructed or installed at any reasonable time for the purpose of ascertaining the state of compliance with Sections 144.30 to 144.46 and 144.54 and rules in force pursuant thereto." [112] Any records obtained by the Department in the administration of Sections 144.30 to 144.46 are entitled to confidentiality if they relate to information unique to such owner and would harm him competitively.

The air pollution control powers of the DNR are listed in Section 144.36 of the Wisconsin Statutes and are the following: 1) prepare and develop one or more comprehensive plans for the prevention, abatement, and control of air pollution in the State with the continuing power of revision and implementation; 2) conduct studies, investigations, and research relating to air pollution and the causes, effects, prevention, abatement, and control of said pollution; and 3) consult with interested parties on the efficiency of a proposed device or system relating to an air pollution problem.[113] In addition, Section 144.37 grants authority for the creation of an air pollution control advisory council whose purpose is to advise the Natural Resources Board on all matters pertaining to air pollution.

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[111] *Wis. Stats. 144.30(2) (1975). In addition, Chapter NR 154.01(6) defines air pollution as follows: "Air pollution is the presence in the atmosphere of one or more air contaminants in such quantities and of such duration as is, or tends to be, injurious to human health or welfare, animal or plant life, or property or would unreasonably interfere with the enjoyment of life or property."*

[112] *Wis. Stats. 144.34 (1975).*

[113] *Wis. Stats. 144.36 (1975).*

Similar to the federal Clean Air Act, the Wisconsin Statutes provide for the promulgation of emission standards, division of the State into Air Quality Control Regions, enforcement provisions, new source regulation, hazardous substance regulation, and nonstationary source regulation. This closely integrated structure provides for a comprehensive program within which to abate and control air pollution.

Section 144.38(1)(a) of the Wisconsin Statutes provides authority for the Department to classify by rule "air contaminant sources which may cause or contribute to air pollution, according to levels and types of emissions and other characteristics which relate to air pollution."[114] Such classifications may be made for the State as a whole or for a designated region. Subsection (b) provides the person responsible for an air containment source of a class for which reports are required to furnish such information as the Department may require.

Both primary and secondary ambient air standards have been promulgated in Chapter NR 155 of the Wisconsin Administrative Code. Constant revision of these standards is provided for as necessary to be consistent with national ambient air standards. NR 155 sets primary and secondary ambient air standards for the following pollutants: sulfur dioxide, suspended particulate matter, carbon monoxide, photochemical oxidants, hydrocarbons, and nitrogen dioxide.[115] Section NR 155.04 describes applicable testing procedures to be used in measuring air quality for the above pollutants.

As required by the federal Clean Air Act, Wisconsin has been divided into air quality control regions. At present, there are four interstate air quality control regions: Duluth-Superior Interstate Air Quality Control Region; Metropolitan Dubuque Interstate Air Quality Control Region; Rockford-Janesville-Beloit Air Quality Control Region; and Southeast Minnesota-LaCrosse Interstate Air Quality Control Region. The four intrastate air quality control regions are the following: Lake Michigan Intrastate Air Quality Control Region; the Southern Wisconsin Intrastate Air Quality Control Region; the North Central Wisconsin Intrastate Air Quality Control Region; and the Southeastern Wisconsin Intrastate Air Quality Control Region (see Map 3). The latter Region is identical in geographical area to the area served by the Southeastern Wisconsin Regional Planning Commission. Both include the counties of Kenosha, Milwaukee, Ozaukee, Racine, Walworth, Washington, and Waukesha.

Wisconsin has specifically provided the following nondegradation clause in NR 155.06(4): "Existing Air Quality: Where air quality is better than secondary standards, the department shall review plans for all new sources which have the potential to degrade significantly existing local or regional air quality. If the department

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[114] *Wis. Stats. 144.38 (1975).*

[115] *NR 155.03.*

determines that significant degradation of air quality will result the department shall hold a hearing in the affected area to assess the public attitude on permitting such a source.[116] This nondegradation feature is different from the federal provision in that the federal provision arose as a result of judicial interpretation of the Clean Air Act. As was mentioned earlier, the Administrator disapproved state implementation plans because they failed to provide for the prevention of significant deterioration of existing air quality.[117] Wisconsin has not been delegated the authority to implement the federal nonsignificant deterioration standards in their new source review procedures.

The federal Clean Air Act requires states to submit an implementation plan to the Administrator of the Environmental Protection Agency for approval. Wisconsin submitted such a plan on January 14, 1972.[118] The plan has been approved with certain exceptions, and several revisions have been submitted by the State in a continuing amendment process. A major deficiency in the Wisconsin plan was the absence of a provision providing for public availability of emission data reported by operators and owners of pollution sources. A corresponding deficiency was the legal inadequacy of Section 144.33 of the Wisconsin Statutes which precludes the release of emission data in certain situations. The Administrator promulgated replacement provisions in the Federal Register.[119] In addition, Wisconsin's implementation plan was found to be deficient because of the lack of a plan for review of new or modified indirect sources. The Administrator incorporated federal provisions for review of new or indirect sources as found in 40 C.F.R. 52.22(b). Section 144.39 of the Wisconsin Statutes has been recently amended and is now consistent with 40 C.F.R. 52.22.

In 1975, the Administrator of the Environmental Protection Agency identified those areas which have a potential for failing to maintain one or more of the national ambient air quality standards. In Wisconsin, the Southeastern Wisconsin Air Quality Control Region was designated as being a part of the Illinois-Indiana-Wisconsin Interstate Air Quality Maintenance Area for total suspended particulates, sulfur dioxide, and photochemical oxidants.[120] On July 16, 1976, the Regional Administrator determined that Wisconsin's implementation plan was insufficient to attain and maintain the oxidant national ambient air quality standards. Wisconsin was to provide an assessment of where oxidant state implementation plans should be revised. In addition, the State was to incorporate into this assessment an analysis of the adequacy of the state implementation plan to attain national ambient air quality standards for suspended particulate matter and sulfur dioxide. If the State fails to submit the assessments, the U. S. Environmental Protection Agency will begin to develop a revision of the Wisconsin state implementation plan in these matters.[121]

The Wisconsin implementation plan also contains the following sections: existing air quality and emissions by region, control plans for each of the regions, emergency episode plans, air quality surveillance, intergovernmental cooperation, and legal authority. The introduction to the plan states that its purpose is to provide for the implementation, maintenance, and enforcement of national ambient air quality standards within each air quality region of the State. Section NR 155.06 provides guidelines for the application of air standards: "(1) In all air regions: No local programs may grant variances of construction of operating permits in conflict with the implementation plan for that region; (2) In all air regions: Any person may be required to reduce his emissions below limits established in an implementation plan or by air pollution control rules where his emissions cause or substantially contribute to exceeding an air standard in a localized area. In this case, appropriate special orders, which are not general in application, may be used."[122]

Chapter NR 154, Air Pollution Control, provides emission standards for emissions into the ambient air. Section NR 154.09 prohibits any emission into the ambient air in excess of the limits set in the rules with the following exceptions: "(a) When an approved program or plan with a time schedule for correction has been undertaken and correction is being pursued with diligence. (b) When emissions in excess of the limits are temporary and due to scheduled maintenance, start up, or shut down of operations carried out in accord with a plan and schedule approved by the department. (c) The use of emergency or reserve equipment needed for meeting of high peakloads, testing of the equipment, or other uses approved by the department."[123] In addition, Section NR 154.10 states applicable limitations on open burning with enumerated exceptions.

Section NR 154.11 relates to the control of particulate emissions. This Section sets particulate emission standards and control requirements for the following categories: fugitive dust; certain processes among which are smelters, lime kilns, and petroleum refineries; fuel burning installations and incinerators; and visible emissions. Sections NR 154.12-154.15 and 154.18 include provi-

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[116] *NR 155.06.*

[117] *40 Federal Register 25004, June 12, 1975. The provisions of sec. 52.21(b)(c)(d)(e) and (f) were incorporated by reference and made a part of the implementation plan for the State of Wisconsin.*

[118] *40 C.F.R. 52.*

[119] *40 Federal Register 55334 (November 28, 1975).*

[120] *40 Federal Register 23746 (June 2, 1975).*

[121] *41 Federal Register 32311-32131 (August 2, 1976).*

[122] *NR 155.06.*

[123] *NR 154.09.*

sions for control of sulfur emissions, carbon monoxide emissions, nitrogen compound emissions, malodorous emissions, and organic compound emissions.

Section NR 154.19 provides for the control of hazardous pollutants. No person shall be permitted to release hazardous pollutants into the ambient air so as to cause injury to human health, plant, or animal life. Hazardous pollutants include but are not limited to the following materials, their mixtures or compounds; asbestos, beryllium, cadmium, chromium, chlorine, florine, lead, mercury, pesticides, and radioactive material. Specific emission limitations are provided for asbestos, mercury, and beryllium. It is stated within this section that limitations of emissions of hazardous pollutants shall follow general or special orders issued by the DNR.

In the area of new stationary sources, the DNR has established a preconstruction review system. Section 144.39 of the Wisconsin Statutes states that "The department shall require that notice be given prior to the construction, installation, or establishment of particular types or classes of air contaminant sources specified in its rules."[124] Section NR 154.04(1)(a-n) lists a large number of new sources of pollutants, including indirect sources, for which DNR approval is necessary. An application for construction of a new direct stationary source or the addition to, enlargement of, or modification of an existing source must contain the following information: ownership, associated stationary sources, diagram of the facilities, anticipated emission rates, project costs, process designs, equipment types, fuel usages, and other similar criteria. Section NR 154.05 lists the criteria used by the DNR in determining whether construction of the new stationary source shall be allowed. Primary concerns are air quality impact, feasibility of design for emission controls, and commitments by ownership for future modifications if needed.[125]

Chapter 144.35 of the Wisconsin Statutes includes provisions for violations and enforcement. Upon notice of violation, the DNR is to serve written notice upon the alleged violator. Within 10 days after date of notice, a hearing may be requested. If no hearing is requested, such notice and order become effective. If, after a hearing, the DNR finds a violation, it must affirm or modify its former order. When no violation is found, the DNR is to rescind its order. Section NR 154.08 provides for forfeitures of not less than $10 nor more than $5,000 for each violation, failure, or refusal. Each day of violation is considered to be a separate offense. The DNR may, in its order, prescribe dates by which any necessary action shall be taken.

Authorization for the DNR to provide by rule for the control of emissions from motor vehicles is also provided by Chapter 144 of the Wisconsin Statutes. Any rule relating to automobile emissions must, however, be consistent with federal law. Section 144.42 provides, "The Department shall not require, as a condition precedent to the initial sale of a vehicle or vehicular equipment, the inspection, certification, or other approval of any feature or equipment designed for the control of emissions from motor vehicles, if such feature has been certified, approved or otherwise authorized pursuant to federal law."[126] Under threat of loss of vehicle registration, it is a prohibited act to remove, dismantle, or otherwise cause to be inoperative any equipment constituting an operative element of the air pollution control system of a motor vehicle.

State statutes contain authority for the proper officials to take action in the event of an emergency air pollution situation. Section NR 154.20 specified three separate stages in an emergency episode, those being the air pollution alert, air pollution warning, and air pollution emergency. Progressively restrictive measures and powers are allocated to the DNR in such emergency situations.

Solid Waste Disposal: Solid waste disposal standards have been left to the states to promulgate with the exception of hazardous wastes and open dumping mentioned earlier in this chapter. Section 144.43 of the Wisconsin Statutes provides authority for the DNR to adopt minimum standards for the location, design, construction, sanitation, operation, and maintenance of solid waste disposal facilities and sites. After such standards have been promulgated, no person may operate a solid waste disposal site or facility which does not adhere to these standards. In addition, a license is required without which no person is permitted to maintain a solid waste site or facility. Local governing bodies may establish standards which are more restrictive than those adopted by the State.

Any solid waste incinerator having a capacity of 1,000 pounds per hour must be licensed by the DNR. Prevention of air pollution is provided by the following language: "(m) During normal operation, the temperature and residence time in the combustion chambers shall be adequate to fulfill air pollution emission standards, to produce a non-combustionable material and to result in odor free operation. (n) the incinerator shall be so designed and operated that it will not cause a nuisance because of the emission of obnoxious odors, gases, contaminants or particulate matter greater than limits established by state and local air pollution control regulations."[127] As a general rule, open burning in landfill sites is severely curtailed with very limited exceptions.

The solid waste disposal laws and regulations have been written with air and water pollution concerns given high priority. Open pit landfill sites with continuous burning is for the most part a practice of the past. The emphasis

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[124] *Wis. Stats. 144.39 (1975).*

[125] *46 OP Attorney General (1975).*

[126] *Wis. Stats. 144.42 (1975).*

[127] *NR 151.11(5)(m and n).*

is placed upon quick, clean, and odorless disposal of solid wastes either through incineration or sanitary land fill.

Wisconsin Environmental Policy Act: The Wisconsin Legislature in April 1972 created Section 1.11 of the Wisconsin Statutes on governmental consideration of environmental impact. Under this legislation, all agencies of the State must include an environmental impact statement in every recommendation or report on proposals for legislation or other major actions which would significantly affect the quality of the human environment. Such statements must include "(1) The environmental impact of the proposed action; 2) Any adverse environmental effects which cannot be avoided should the proposed be implemented; 3) Alternatives to the proposed actions; 4) The relationship between local short term uses of man's environment and the maintenance and enhancement of long term productivity; and 5) Any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented." [128] The effect of the state legislation is, therefore, to extend the environmental assessment concept to all state action not already covered under the requirements of the National Environmental Policy Act.

A state agency must list the proposed activity under one of several categories. These categories include facilities development, financial assistance, standards development, regulation, policy recommendations, facility maintenance, and various types of plans. Once an action is categorized, it is further divided into one of three types which are described as follows:

(1) Type I actions clearly are major and significantly affect the quality of human environment and thus will always require an environmental impact statement.

(2) Type II actions may or may not be major or significantly affect the environment depending on the facts of the particular case, and thus may not require environmental impact statement preparation; . . . and

(3) Type III actions are ones where the action could not be major or significantly affect the quality of the human environment and thus will not require environmental impact statements.[129]

Preparation of the environmental impact statement is the responsibility of the lead agency involved in the action. If expertise is possessed by another agency involved in the same action, environmental impacts may be assessed by more than one agency. The following agencies are cited in Appendix B of the Revised Guidelines for the Wisconsin Environmental Policy Act of 1972 as those agencies possessing the expertise necessary to evaluate environmental considerations relating to air quality and climate: Department of Administration, Department of Health and Social Services, Department of Natural Resources, Department of Transportation, and the Board of Regents-University of Wisconsin.

LOCAL AIR POLLUTION CONTROL MACHINERY

All towns, villages, and cities in Wisconsin have, as part of a broad grant of authority by which they exist, sufficient police power to regulate by ordinance any condition or set of circumstances bearing upon the health, safety, and welfare of the community. Factors affecting air quality would fall within this regulatory sphere by virtue of the potential danger to health and welfare. It is noteworthy, however, that such ordinances cannot conflict with federal and state legislation in this area.

Local and county boards of health have powers to adopt and enforce rules and regulations designed to improve the public health. This broad grant of authority includes regulatory controls over environmental sanitation, including air pollution as it relates to the public health. County boards of health, established by the action of county boards of supervisors pursuant to Section 140.09 of the Wisconsin Statutes, can provide an effective mechanism for the enactment of county-wide regulations designed in part to prevent and control further pollution of the ambient air.

Statutory Authority for Local Control of Air Pollution Section 144.41 of the Wisconsin Statutes sets forth a statutory authorization for the establishment and administration of a county air pollution control program. There are, however, several conditions which must be met before a county is authorized to initiate such a program.

1. The county must consult with incorporated municipalities within its jurisdiction before the county may administer an air pollution control program within its jurisdiction, including incorporated areas.

2. Any ordinance which is part of such a program must contain requirements at least as strict as those requirements contained in Sections 144.30-144.46 of the Wisconsin Statutes pertaining to air quality control. In addition, countywide enforcement must be provided.

3. Appropriate levels of staff, funding, and other resources must be provided.

4. The plan may authorize municipalities to participate in the administration and enforcement of air pollution programs.

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[128] *Wis. Stats. 1.11 (1975).*

[129] *Wisconsin Environmental Policy Act of 1972—Revised Guidelines, p. 5 (1976).*

5. Such a program must be approved by the DNR.[130]

A county also is authorized to consult with regional planning commissions and may administer all or part of its air pollution program in cooperation with other counties and municipalities. In the event that county administration is determined to be inadequate to prevent and control air pollution in the particular jurisdiction, or such program is being administered inconsistently with a view towards the requirements of Sections 144.30-144.46 of the Wisconsin Statutes, the DNR shall conduct a hearing. If after such a hearing the Department determines that there are inadequacies in the county program, corrective measures are required within 60 days. If such corrective measures are not undertaken within the 60-day time period, the DNR is authorized to administer the county program.

State aids are provided for the training of technical personnel to facilitate the administration of county air pollution control programs. Additional aids may be granted by the DNR for in-service training of county personnel on an annual basis.

Section NR 154.07 states the requirements of a county air pollution control program. Specifically, such a plan must include enforcement provisions for the following: open, backyard and leaf burning; opacity standards for stationary, semistationary, and mobile sources; incinerators; fugitive dust and odors; pollutants from sources not specified in NR 154.04; pollutants from sources specified in NR 154.04 where authorized by the Wisconsin Department of Natural Resources; and applicable zoning restrictions where air pollution considerations are involved. The county air pollution control program must provide for consultation on traffic planning, approval and implementation of freeways, highway relocation, and highway widenings where air pollution considerations are involved.

County Air Pollution Control Agencies Currently in Operation

At the present time, one of the seven counties in the Southeastern Wisconsin Region has created an air pollution control agency under the authority provided by Section 144.41 of the Wisconsin Statutes. Racine County has established a program insuring cooperation among Racine County, the City of Racine, and the Wisconsin Department of Natural Resources in the development and implementation of an air pollution control program. In addition, Milwaukee County has long been a leader among local governmental bodies in the implementation of pollution control measures. In 1948, Milwaukee County adopted Chapter 88 of its General Ordinances creating and staffing the Department of Air Pollution Control. Throughout the years, many amendments were made to Chapter 88, making this ordinance progressively stronger. The most comprehensive version of Chapter 88, entitled "Air Pollution Control Ordinance," was adopted in 1972. Responsibility for air pollution abatement in the Milwaukee area, however, was transferred in 1974 to the Wisconsin Department of Natural Resources, and the activities of the Milwaukee County Department of Air Pollution Control have been assumed by the State. As mentioned earlier, county administration of air pollution control is made possible with the enactment of Section 144.41 of the Wisconsin Statutes. It is important to note that counties that desire to implement their own air pollution control ordinance must follow the guidelines set forth in Section 144.41 of the Wisconsin Statutes. Emission standards must be consistent with those promulgated by the State. The State of Wisconsin may, if necessary, take control of the county's air pollution control program and correct any inadequacies found in the county program.

The only county in the Southeastern Wisconsin Air Quality Control Region which has provided a county air pollution control structure is Racine County. It is similar to the former ordinance in Milwaukee County in that it is subject to the same statutorily dictated restraints discussed earlier in this chapter. The County itself is not in a position to perform all of the responsibilities needed to be consistent with the state implementation plan and air pollution control directives present in both the U. S. Environmental Protection Agency and statewide programs. Agreements are in force among Racine County, the City of Racine, and the Wisconsin Department of Natural Resources. Racine County enforces source limitations as found in NR 154, coordinates County enforcement activities with the DNR, provides monitoring services and works with the Racine County Health Department. The DNR enforces Sections NR 154 and 155; assists in engineering evaluation, emission inventories, and investigation of complaints at the request of Racine County; and issues departmental orders to those sources not in compliance with NR 154. The City of Racine performs the necessary technical services not provided by Racine County.

PRIVATE STEPS FOR AIR POLLUTION CONTROL

The following discussion deals with direct action which may be taken by private individuals or organizations to effectively abate air pollution. Effective steps are available for pursuit of such action at all levels of government. The U. S. Congress has provided for citizen suits through Section 304 of the Clean Air Act. Any person is allowed to commence an action on his own behalf against various government officials and private individuals. Section 304 suits may be commenced against persons alleged to be in violation of emission standards or orders issued by the Administrator of the Environmental Protection Agency or individual states. It should be noted that there are strict procedural guidelines for commencement of such an action. A suit may be filed against the Administrator of the U. S. Environmental Protection Agency to compel performance of a nondiscretionary act or duty. Provision is included in Section 304 for the award of costs of litigation, which may include attorney and expert witness fees, whenever the court determines that such an award is appropriate.

[130] *Wis. Stats. 144.41 (1975).*

Section 144.537 of the Wisconsin Statutes presently enables six or more citizens to file a complaint leading to a public hearing by the Department of Natural Resources on alleged or potential acts of pollution. Within 90 days after the close of the hearing, the Department of Natural Resources is required to make findings of fact, conclusions of law, and others. In addition, a review of Department of Natural Resources orders may be had pursuant to Section 144.56 of the Wisconsin Statutes by "any owner or other person in interest." [131] The Department must grant a hearing to any owner or interested person who desires to review a Department order. Within 60 days after the close of the hearing reviewing a Department order, the Department must affirm, repeal, or modify the order. This review contemplates eventual judicial determination under Chapter 227 of the Wisconsin Statutes when necessary. Local air pollution control ordinances may also have mechanisms by which citizen action against air polluters may be initiated.

In addition to the above statutory provisions, the common law nuisance action is available to private citizens. The effectiveness of such a cause of action has increased dramatically over the past two decades. Many defenses which once were available to defendant polluters are no longer being recognized by the judicial system.

SUMMARY

This chapter has described in summary form the legal and institutional framework for air quality management at the federal, state, and local levels of government. Federal control over air quality is near total, and most powers possessed and exercised by state and local units of government have been delegated to them by federal legislation and accompanying administrative promulgations. With the passage of the current version of the Clean Air Act, the U. S. Congress set in motion a series of actions with far-reaching ramifications for air quality management within the Region. National primary and secondary ambient air standards have been promulgated which will direct the emphasis of control strategies at state and local levels. Direct federal approval of state air quality implementation plans also is required. States may set emission standards, but must do so with the goal of meeting the national primary and secondary ambient air standards. For new stationary sources and hazardous substances, direct federally promulgated emission standards are mandated. The mobile source problem—primarily motor vehicles—is closest to being under total federal supervision. For standards which have been set by the federal government, state and local governments may set similar standards but they must be as strict or stricter than the federal standards.

Responsibility for air quality management in Wisconsin is centered in the Wisconsin Department of Natural Resources. The Department, having been given the authority, prepared a statewide implementation plan which includes standards for emissions and overall administration of the requirements of the federal Clean Air Act. Strict control over new stationary sources is provided by the Department of Natural Resources through an application and permit system. Responsibility for enforcement is placed upon the Department of Natural Resources, with the possibility of federal enforcement in the event of inadequate enforcement by the State of Wisconsin.

Air quality management on a regional basis is provided in the form of the Southeastern Wisconsin Intrastate Air Quality Control Region. Wisconsin must specify in its implementation plan the manner in which national primary and secondary ambient air quality control standards will be achieved in each air quality control region. In addition, the U. S. Environmental Protection Agency Administrator designated the Southeastern Wisconsin Intrastate Air Quality Control Region to be part of the Illinois-Indiana-Wisconsin Air Quality Maintenance Area. This designation was in recognition of the special problems present in the large metropolitan area and the need for an interstate approach to these problems.

State Statutes provide authority for programs dealing with air quality management. Milwaukee County was a leader in the implementation of a countywide program. Until the program was assumed by the State of Wisconsin, Milwaukee County had an active Department of Air Pollution Control. Racine County also has established a local program of air quality management. The program in Racine County is based on a high degree of intergovernmental cooperation among Racine County, the City of Racine, and the State of Wisconsin.

Air quality law is not a simple or fixed body of law. It has historical roots which reach back beyond the creation of related statutory law. Long before the initial federal and state clean air laws were enacted, the common law of air quality was gradually evolving. As public rights and priorities were clarified, greater opportunities were presented for citizen and governmental participation in the resolution of air quality controversies through civil litigation. The statutory law of air quality has undergone tremendous change since its inception. With each enactment of amending legislation, federal and state statutory authority over air quality management is strengthened. In the wake of such legislation, judicial refinement on clarification often is necessary. Because of this ongoing evaluation, constant attention is necessary to keep pace with this rapidly changing body of law.

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[131] *Wis. Stats. 144.56 (1975).*

Chapter IV

DESCRIPTION OF THE REGION—MAN-MADE FEATURES

INTRODUCTION

The Southeastern Wisconsin Region is a complex of natural and man-made features which interact to form a continually changing environment for human life. The important man-made features, such as the regional land use pattern, the public utility networks, and the transportation system, together with the resident population and the supporting economic activities, comprise the socioeconomic base of the Region. The characteristics of this socioeconomic base are significant factors in determining the amount and spatial distribution of air pollutant emissions within the Region. These characteristics include the size and distribution of the population and the degree to which it is mobile, the available work and labor force, and the historical and existing development patterns. The socioeconomic base is not only a major determinant of air pollutant emissions, but is an important determinant of the degree and nature of the exposure of the resident population to pollutant concentrations in the ambient air. Thus, an understanding of the regional socioeconomic base is essential to sound areawide air quality maintenance planning.

Demographic data pertaining to the size and distribution of the population, and to such population characteristics as age, sex, marital status, size of household, educational attainment, and income serve as measures of the extent of urban development in the Region and as indicators of development patterns and trends, and such data, consequently, provide a basis for defining regional air pollution problems in terms of human activities and movements. Demographic data further allow an estimate to be made of the size and composition of the population adversely affected by poor air quality levels within the Region, which is of particular importance in air quality maintenance planning since increasing pollutant concentration levels adversely affect different segments of the population to varying degrees depending on factors such as age and general physical health. Economic activity, expressed in terms of the regional work and labor force size, composition, and distribution, exerts a considerable influence on the population levels and distribution within the Region and is, therefore, an important determinant of urban development patterns.

This chapter also presents a review of the historic and existing land use and transportation system patterns which have developed in response to the changing socioeconomic needs and demands of the Region's inhabitants. A detailed inventory of the characteristic land uses and of the supporting transportation network within the Region is essential not only to the identification of the extent of urban development and trends of such development, but to the collation and spatial allocation of a comprehensive air pollutant emmission inventory. Insofar as the public utility base has the potential for placing constraints on urban development, the availability of electrical power, natural gas and, particularly, sanitary sewer and public water supply facilities within the Region are also reviewed in this chapter.

Those elements which comprise the man-made features of the Region-population, economic activity, land use, transportation facilities, and public utility networks together determine the location and extent of urban development and thereby broadly define the nature and extent of the air pollution problem. This chapter, therefore, presents data on these elements, and on trends in these elements, as such data may affect ambient air quality planning. Additional detailed data concerning the demographic, economic, land use, transportation, and public utility base of the Region may be obtained from SEWRPC Technical Reports Nos. 10 and 11, entitled, respectively, The Economy of Southeastern Wisconsin and the Population of Southeastern Wisconsin, and from SEWRPC Planning Report No. 25, A Regional Land Use Plan and a Regional Transportation Plan for Southeastern Wisconsin: 2000, Volume One, Inventory Findings.

DEMOGRAPHIC BASE

Air pollution, because of its direct relationship to human activities—activities well-characterized by land use patterns and related transportation movements—is primarily an urban problem. Available data concerning ambient air quality levels clearly indicate that levels of air pollutants in the atmosphere are directly related to the intensity of urban development. Since an overwhelming majority of the inhabitants of the Region live and work in urbanized areas, most of the regional population are subjected to and affected by ambient air pollutant concentrations that are periodically in excess of the established standards. As urbanization increases, the number of persons subjected to air pollution will increase, and as urban development diffuses over increasingly large areas of the Region, rural as well as urban people will be affected. Therefore, an understanding of the size and distribution of the population within the Region, and of the population characteristics which influence the location and extent of urban development, is essential to sound, comprehensive regional air quality planning.

Population Size

The resident population of the Region in 1975 stood at about 1,790,000 persons. This represents an increase of about 34,000 persons, or about 2 percent, over the 1970 population of about 1,756,000 persons. Waukesha County, with an increase of 31,400 persons, exhibited

the largest absolute population increase. Ozaukee and Washington Counties experienced the greatest percentage gain in population over the five-year period with 19 and 20 percent increases, respectively. Milwaukee County was the only county in the Region showing a net loss of population, with a decrease of 41,700 persons, or about 4 percent, under the 1970 population.

From 1960 to 1970 the population of the Region grew at the rate of about 18,000 persons per year, a considerably slower rate of growth than the approximately 33,000-persons-per-year growth rate experienced from 1950 to 1960. Although the population of the Region increased by 182,000 persons from 1960 to 1970, the population of the central city of Milwaukee--the twelfth largest city in the nation--decreased by almost 24,000 persons. However, this decrease was representative of national trends. The adjacent first-ring suburbs of Shorewood, West Milwaukee, and Whitefish Bay also showed population decreases, while other first-ring suburbs such as Wauwatosa, West Allis, and St. Francis showed almost stable population levels. Large increases in population occurred in outlying suburban areas of Ozaukee, Washington, Waukesha, and Racine Counties.

Population growth within the Region over the past century has generally occurred at a higher rate than within the State or the nation (see Figure 4 and Table 2. Consequently, the regional share of the total national population increased from 0.49 percent in 1850 to 0.86 percent in 1970, while the regional share of the state population increased from 37 percent in 1850 to nearly 40 percent in 1970. However, between 1970 and 1975 the regional share of the state population fell to about 39 percent, and the regional share of the total national population declined to about 0.84 percent. These declines reflect certain basic changes in population growth and migration within the nation.

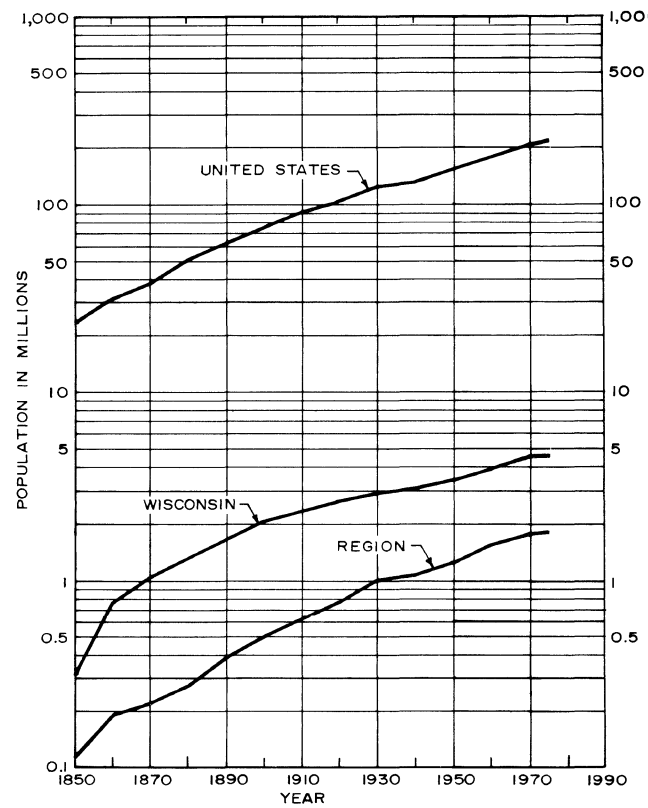
Population Distribution

The long-term population growth trend in the Region has been marked by two phenomena which are of considerable importance to understanding existing, as well as probable future, air quality conditions and the effects of such conditions on people and property. First, the Southeastern Wisconsin Region, like most major metropolitan regions of the United States, is becoming increasingly urban. As already indicated, increased urbanization generally results in increased levels of air pollution. In 1850 the population of the Region was approximately 75 percent rural and 25 percent urban; by 1900 this relationship had almost reversed to 30 percent rural and 70 percent urban; and by 1970 less than 2 percent of the regional population was considered rural, while 98 percent was considered urban. The 120-year rural-urban change is shown graphically in Figure 5. The Southeastern Wisconsin Regional Planning Commission has estimated that in 1975 only about 25,600 persons, or 1.4 percent, of the total regional population could be considered rural. This trend toward urbanization is one of the most significant distributional changes which has taken place within the Region, the State, and the nation.

Second, the population of the Region is being increasingly decentralized--diffused across established municipal and county boundaries--and as a result, former predominantly rural areas are experiencing air pollution problems with increasing frequency. During the 30-year period from 1900 to 1930, the highest rates of population increase occurred in the three urban Counties of Kenosha, Milwaukee, and Racine. By 1930, 72 percent of the total population of the Region was concentrated in Milwaukee County. Urban decentralization over the last four decades (1930-1970), however, has reversed this trend. Between 1960 and 1970 rates of population increase of more than 35 percent were observed in certain outlying counties of the Region, notably Ozaukee, Washington, and Waukesha Counties, while the population increased by only 2 percent in Milwaukee County. Between 1970 and 1975, Milwaukee County experienced a population loss of more than 41,000 persons, or approximately 4 percent of the 1970 residents. Milwaukee, as can be seen on Table 3 and Figure 6, was the only county in the Region which lost population in that time interval. In 1975, only 56.6 percent of the total

Figure 4

POPULATION LEVELS IN THE REGION, WISCONSIN, AND THE UNITED STATES: 1850-1975



Source: U. S. Bureau of the Census and SEWRPC.

Table 2

POPULATION TRENDS IN THE UNITED STATES, WISCONSIN, AND THE REGION: SELECTED YEARS 1850-1975

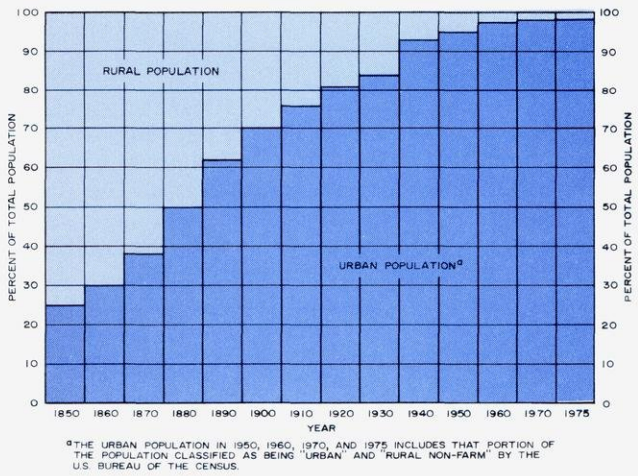
Year	Region			Wisconsin			United States			Regional Population as a Percent of:	
	Population	Change From Preceeding Time Period		Population	Change From Preceeding Time Period		Population	Change From Preceeding Time Period		Wisconsin	United States
		Absolute	Percent		Absolute	Percent		Absolute	Percent		
1850	113,389	--	--	305,391	--	--	23,191,876	--	--	37.1	0.49
1860	190,409	77,020	67.9	775,881	470,498	154.1	31,443,321	8,251,445	35.6	24.5	0.60
1870	223,546	33,137	17.4	1,054,670	278,789	35.9	38,448,371	7,005,050	22.6	21.2	0.58
1880	277,119	53,573	24.0	1,315,497	260,827	24.4	50,155,783	11,707,412	30.1	21.2	0.55
1890	386,774	109,655	39.6	1,693,330	377,833	28.7	62,947,714	12,791,931	25.5	22.8	0.61
1900	501,808	115,034	29.7	2,069,042	375,712	22.2	75,994,575	13,046,861	20.7	24.2	0.66
1910	631,161	129,353	25.8	2,333,860	264,818	12.8	91,972,266	15,977,691	21.0	27.0	0.69
1920	783,681	152,520	24.2	2,632,067	298,207	12.8	105,710,620	13,738,354	14.9	29.8	0.74
1930	1,006,118	222,437	28.4	2,929,006	306,939	11.7	122,775,046	17,064,426	16.1	34.2	0.82
1940	1,067,699	61,581	6.1	3,137,587	198,581	6.8	131,669,587	8,894,541	7.2	34.0	0.81
1950	1,240,618	172,919	16.2	3,434,575	296,988	9.5	151,325,798	19,656,211	14.9	36.1	0.82
1960	1,573,620	333,002	26.8	3,952,771	518,196	15.1	179,323,175	27,997,377	18.5	39.8	0.88
1970	1,756,086	182,466	11.6	4,417,933	465,162	11.8	203,184,772	23,861,597	13.3	39.7	0.86
1975	1,789,871[a]	33,788	1.9	4,581,700[a]	163,767	3.7	212,796,000	9,611,228	4.7	39.1	0.84

[a] *Wisconsin Department of Administration estimates.*

Source: U. S. Bureau of the Census, Wisconsin Department of Administration, and SEWRPC.

Figure 5

DISTRIBUTION OF URBAN AND RURAL POPULATION IN THE REGION: 1850-1975



Source: U. S. Bureau of the Census and SEWRPC.

population of the Region was concentrated in Milwaukee County. The result of the most recent changes in population distribution within the Region has been an areawide diffusion of population around the central Cities of Milwaukee, Racine, and Kenosha. As a result of this diffusion, population densities within the developed urban areas of the Region have declined sharply from a maximum of about 11,400 persons per square mile in 1920 to about 8,500 persons per square mile in 1950; 4,800 persons per square mile in 1963; and 4,400 persons per square mile in 1970.

Population Characteristics

Data concerning such characteristics of the population as age and sex, composition, and residential mobility are relevant to any study of air quality, since they not only influence development patterns and therefore pollutant emissions, but also determine the potential effects of air quality on health.

Age: As indicated in Figure 7, the age composition of the regional population changed significantly between 1960 and 1970. The most striking changes are the increase in the proportion of young persons between the ages of 10 and 24 years, the decreases in the proportion of children under 5 years, the decreases in the proportion of adults between 30 and 39 years, and the increase in the proportion of the population age 70 and older. As indicated in Table 4, there is considerable variation in the proportion of the population comprised by each age group among the seven counties. For example, the proportion of young persons under 20 years of age ranged from 37 percent in Milwaukee County to 44 percent in Ozaukee, Washington, and Waukesha Counties. On the other hand, the proportion of elderly persons, age 65 years and over was very low in Waukesha County (6 percent) and relatively high in Walworth County (12 percent). The variations among the counties in the age composition are further indicated by the median age of the population in each county, which ranges from 24.9 years in Washington County to 28.6 years in Milwaukee County.

Table 3

POPULATION DISTRIBUTION IN THE REGION BY COUNTY: SELECTED YEARS 1900-1975

County	1900		1930		1960		1970		1975[a]		Difference 1960-1970		Difference 1970-1975	
	Population	Percent of Region	Population	Percent of Region	Population	Percent of Region	Population	Percent of Region	Population	Percent of Region	Absolute	Percent	Absolute	Percent
Kenosha	21,707	4.3	63,277	6.3	100,615	6.4	117,917	6.7	126,651	7.1	17,302	17.2	8,734	7.4
Milwaukee	330,017	65.8	725,263	72.1	1,036,047	65.8	1,054,249	60.1	1,012,536	56.6	18,202	1.7	-41,713	-4.0
Ozaukee	16,363	3.3	17,394	1.7	38,441	2.5	54,461	3.1	64,932	3.6	16,020	41.7	10,471	19.2
Racine	45,644	9.1	90,217	9.0	141,781	9.0	170,838	9.7	178,916	10.0	29,057	20.5	8,078	4.7
Walworth	29,259	5.8	31,058	3.1	52,368	3.3	63,444	3.6	67,511	3.8	11,076	21.1	4,067	6.4
Washington	23,589	4.7	26,430	2.6	46,119	2.9	63,839	3.6	76,579	4.2	17,720	38.4	12,740	20.0
Waukesha	35,229	7.0	52,350	5.2	158,249	10.1	231,338	13.2	262,746	14.7	73,089	46.2	31,408	13.6
Region	501,808	100.0	1,005,989	100.0	1,573,620	100.0	1,756,086	100.0	1,789,871	100.0	182,466	11.6	33,785	1.9

[a] *Wisconsin Department of Administration estimates.*

Source: U. S. Bureau of the Census, Wisconsin Department of Administration and SEWRPC.

Sex: The sex composition of the regional population has also been changing. As indicated in Table 5, there was a significant decrease in the proportion of males in the regional population between 1960 and 1970, with at least slight decreases being observed within each 10-year age group except the 10 to 19-year group. A major cause of the increase in the proportion of females in the regional population is the fact that women have a longer life expectancy than men. The substantial reduction in the number of males per 100 females in the 60-69 and 70 and older age groups during the past decade reflects this longer female life expectancy.

As indicated in Table 6, there was a decrease in the sex ratios within each county between 1960 and 1970, with large decreases being observed in Kenosha and Milwaukee Counties. In fact, there was an absolute decrease in the number of males in Milwaukee County between 1960 and 1970. It is interesting to note that the lowest sex ratios in 1970 were found in the urban Counties of Kenosha, Milwaukee, and Racine, in keeping with the historical tendency for the female proportion of the population to be relatively high in urban areas and relatively low in rural areas.

Race: In addition to changes in the age and sex composition, the racial composition of the regional population, as indicated in Table 7, changed somewhat during the 1960-1970 decade. In the 1970 census, nearly 93 percent of the regional population was reported as white; while in the 1960 census, slightly more than 95 percent was reported as white. The balance of the population was nonwhite, a category which includes persons reporting their race as black, American Indian, Japanese, Chinese, Filipino, or other race. In both 1960 and 1970, the overwhelming majority--more than 90 percent--of the nonwhite population in the Region was comprised of persons of the black race.

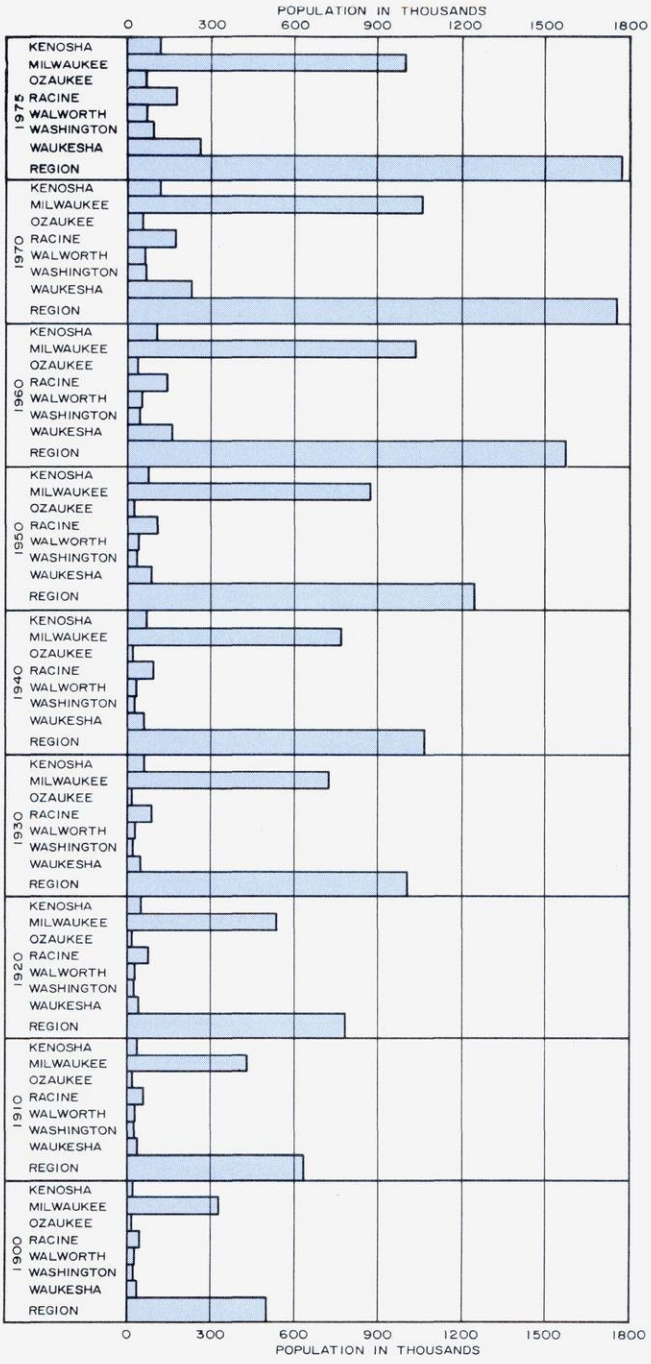
As indicated in Table 8, the nonwhite population comprised about 2 percent of the total population in Kenosha County, nearly 11 percent in Milwaukee County, about 7 percent in Racine County, and less than 1 percent in the other counties in the Region. Furthermore, the nonwhite populations of the Region are concentrated in the central cities of Kenosha, Milwaukee, and Racine. In fact, nearly 96 percent of the nonwhite population in the Region and 98 percent of all blacks in the Region resided in these three cities in 1970.

It should be noted that the Spanish American population is included in the white population in Tables 7 and 8 because Spanish Americans are not defined as a separate race by the U.S. Bureau of the Census. The Census Bureau, however, does enumerate Spanish Americans as a separate ethnic group. One of the three Spanish indicators used is the number of "persons of Spanish language." The results are summarized for the Region and the seven counties individually in Table 9. In 1970, there were more than 30,000 persons of Spanish language in the Region representing nearly 2 percent of the regional population. For the seven counties, the proportion of Spanish Americans ranged from less than 1 percent in Washington and Ozaukee Counties to 3 percent in Racine County. As was the case for the nonwhite population, the Spanish American population was heavily concentrated in the large urban areas of the Region. Thus, in 1970, 77 percent of the Spanish American population in the Region resided in the Cities of Kenosha, Milwaukee, Racine, and Waukesha.

Marital Status: The changing marital status of the regional population is an important consideration in the analysis of housing demand and determination of housing needs and, therefore, of land use development, public utility, and transportation demands. These demands, in turn, influence the amount and distribution of air pollu-

Figure 6

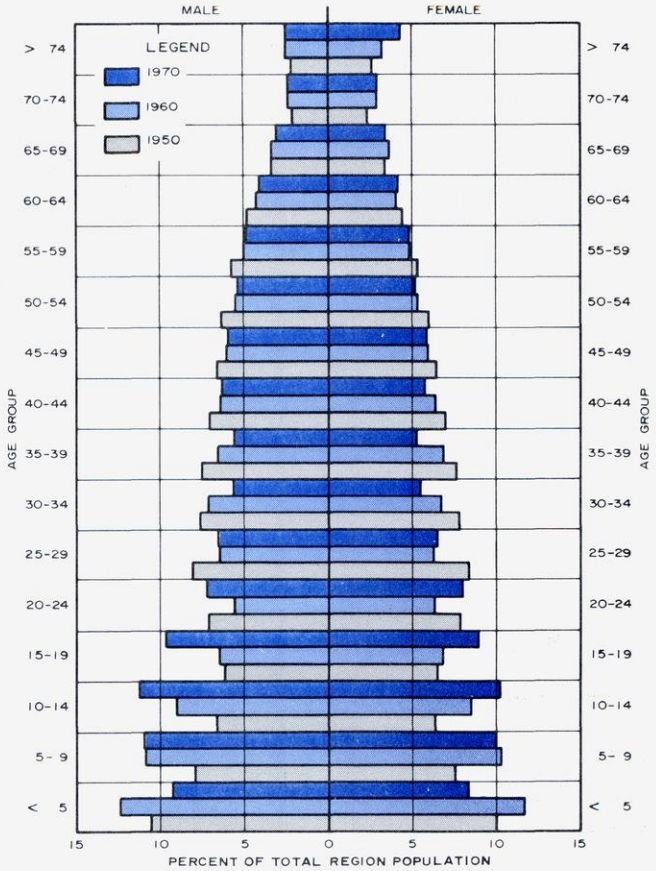
POPULATION DISTRIBUTION IN THE REGION BY COUNTY: 1900-1975



Source: U. S. Bureau of the Census, Wisconsin Department of Administration, and SEWRPC.

Figure 7

TOTAL POPULATION BY AGE AND SEX IN THE REGION: 1950, 1960, AND 1970



Source: U. S. Bureau of the Census and SEWRPC.

tants emitted within the Region. Of particular significance is the probable change in an individual's housing requirements when the person marries or when death or divorce cause subsequent change in the person's marital status. The change between 1960 and 1970 in the marital status of persons 14 years old and older is summarized for the Region in Table 10 and Figure 8. The most significant change in marital status is the decrease in the proportion of married persons. In 1970 62 percent of the population was married, considerably lower than the figure of nearly 68 percent in 1960. There was a corresponding increase in the never married population from 22 percent in 1960 to 27 percent in 1970. The proportion of widowed persons remained constant, while the proportion of divorced persons increased slightly between 1960 and 1970.

There was considerable variation in the marital status of the population 14 years old and older among the counties in 1970 (see Table 11). Of the seven counties, Walworth County had the highest proportion of never married males (34 percent) and the lowest proportion of married

Table 4

AGE COMPOSITION OF THE POPULATION IN THE REGION BY COUNTY: 1970

County	Population														Median Age[b]
	Under 10		10-19		20-29		30-44		45-64		65 and Older		Total		
	Number	Percent of County Population	Number	Percent of County Population	Number	Percent of County Population	Number	Percent of County Population	Number	Percent of County Population	Number	Percent of County Population	Number	Percent of County Population	
Kenosha	23,759	20.1	23,767	20.2	16,218	13.8	19,471	16.5	23,484	19.9	11,218	9.5	117,917	100.0	26.9
Milwaukee	190,252	18.1	198,589	18.8	157,237	14.9	172,169	16.3	224,478	21.3	111,338	10.6	1,054,063	100.0	28.6
Ozaukee	11,748	21.6	12,068	22.2	6,313	11.6	10,398	19.1	9,925	18.2	3,969	7.3	54,421	100.0	25.6
Racine	35,549	20.8	35,934	21.0	22,835	13.4	28,977	17.0	32,102	18.8	15,441	9.0	170,838	100.0	26.0
Walworth	10,997	17.3	13,493	21.3	9,910	15.6	9,459	14.9	12,177	19.2	7,408	11.7	63,444	100.0	26.4
Washington	14,672	23.0	13,410	21.0	8,256	12.9	11,309	17.7	10,945	17.2	5,247	8.2	63,839	100.0	24.9
Waukesha	49,549	21.4	52,637	22.8	25,945	11.2	46,706	20.2	41,734	18.0	14,794	6.4	231,365	100.0	25.4
Region	336,526	19.2	349,898	19.9	246,714	14.1	298,489	17.0	354,845	20.2	169,415	9.6	1,755,887[a]	100.0	27.6

[a] *The 1970 regional population of 1,755,887 excludes 199 persons who were added subsequent to the conduct of the 1970 census and not allocated to the various age group categories.*

[b] *The median age is that age which divides the population distribution into two equal parts, half being younger than the median age and half being older.*

Source: U. S. Bureau of the Census and SEWRPC.

Table 5

SEX COMPOSITION OF THE POPULATION IN THE REGION BY AGE GROUP: 1960 AND 1970

Age Group	Sex Ratio[a]	
	1960	1970
Under 10	103.9	103.4
10-19	99.9	101.8
20-29	93.0	88.7
30-39	98.3	96.4
40-49	96.9	96.6
50-59	97.7	93.2
60-69	93.7	85.2
70 and Older	78.0	67.3
All Ages	97.3	94.3

[a] *The sex ratio indicates the number of males per 100 females within each age group.*

Source: U. S. Bureau of the Census and SEWRPC.

Table 6

SEX COMPOSITION OF THE POPULATION IN THE REGION BY COUNTY: 1960 AND 1970

County	Sex Ratio[a]	
	1960	1970
Kenosha	102.0	95.9
Milwaukee	95.7	92.0
Ozaukee	100.0	99.6
Racine	97.6	95.6
Walworth	99.3	98.1
Washington	102.3	99.9
Waukesha	101.7	99.2
Region	97.3	94.3

[a] *The sex ratio indicates the number of males per 100 females within each county.*

Source: U. S. Bureau of the Census and SEWRPC.

males (60 percent); conversely, Ozaukee County had the lowest proportion of never married males (nearly 28 percent) and the highest proportion of married males (nearly 69 percent). For the female population, the never married proportion ranged from 22 percent in Kenosha County to 27 percent in Walworth County. The married proportion ranged from 57 percent in Milwaukee County to 67 percent in Ozaukee County.

Education: The level of formal education is one indicator of the social and economic status of the population. Since most formal education is completed by the time a person reaches age 25, the statistical measure of educational attainment pertains to the population over 25 years of age. The educational attainment of the population over 25 years of age, as shown in Table 12 and Figure 9, increased substantially between 1960 and 1970.

The median number of years of schooling completed increased from 11.0 years in 1960 to 12.2 years in 1970.[1] A further indication of the general rise in educational attainment is the increase in the proportion of the population over 25 who had completed high school or attended college, from nearly 44 percent in 1960 to 56 percent in 1970.

As indicated in Table 13, there was much variation in the educational attainment of the population over 25 among the counties in the Region. The proportion of the population with some college or four or more years of college was lowest in Kenosha County (15 percent) and highest in Waukesha County (nearly 29 percent). On the other hand, the proportion of persons over 25 who had an

1 *The median number of years of school completed is the number which divides the distribution of persons over age 25 in half, with half having completed more years of school than the median and half fewer years.*

Table 7

RACIAL COMPOSITION OF THE POPULATION IN THE REGION: 1960 AND 1970

Race	Population			
	1960		1970	
	Number	Percent of Total	Number	Percent of Total
White	1,499,662	95.3	1,626,056	92.6
Nonwhite	73,952	4.7	129,831	7.4
Black	69,591	4.4	119,321	6.8
American Indian	2,225	0.1	4,617	0.3
Japanese	748	0.1	1,237	0.1
Chinese	603	0.1	1,234	--[a]
Filipino	247	--[a]	693	--[a]
Other	538	--[a]	2,729	0.2
Total	1,573,614	100.0	1,755,887	100.0

[a] *The percent of the total population is less than one-tenth of 1 percent.*

Source: U. S. Bureau of the Census and SEWRPC.

Table 9

SPANISH AMERICAN POPULATION[a] IN THE REGION BY COUNTY: 1970

County	Persons of Spanish Language	
	Number	Percent of Total Population
Kenosha	2,690	2.3
Milwaukee	17,960	1.7
Ozaukee	370	0.7
Racine	5,440	3.2
Walworth	790	1.2
Washington	305	0.5
Waukesha	3,272	1.4
Region	30,827	1.8

[a] *Persons of Spanish language.*

Source: U. S. Bureau of the Census and SEWRPC.

Table 8

RACIAL COMPOSITION OF THE POPULATION IN THE REGION BY COUNTY: 1970

County	Population											
	White		Nonwhite								Total	
			Black		American Indian		Other		Subtotal			
	Number	Percent of County Population	Number	Percent of County Population	Number	Percent of County Population	Number	Percent of County Population	Number	Percent of County Population	Number	Percent of County Population
Kenosha	115,623	98.1	1,930	1.6	143	0.1	221	0.2	2,294	1.9	117,917	100.0
Milwaukee	939,989	89.2	106,033	10.1	3,717	0.3	4,324	0.4	114,074	10.8	1,054,063	100.0
Ozaukee	54,197	99.6	92	0.2	61	0.1	71	0.1	224	0.4	54,421	100.0
Racine	159,511	93.4	10,572	6.2	343	0.2	412	0.2	11,327	6.6	170,838	100.0
Walworth	62,879	99.1	287	0.5	56	0.1	222	0.3	565	0.9	63,444	100.0
Washington	63,652	99.7	45	0.1	62	0.1	80	0.1	187	0.3	63,839	100.0
Waukesha	230,205	99.5	362	0.2	235	0.1	563	0.1	1,160	0.5	231,365	100.0
Region	1,626,056	92.6	119,321	6.8	4,617	0.3	5,893	0.3	129,831	7.4	1,755,887	100.0

Source: U. S. Bureau of the Census and SEWRPC.

Table 10

MARITAL STATUS OF PERSONS 14 YEARS OF AGE AND OLDER IN THE REGION: 1960 AND 1970

Marital Status	Population 14 Years of Age and Older											
	1960						1970					
	Male		Female		Total		Male		Female		Total	
	Number	Percent of Total Males 14 and Older	Number	Percent of Total Females 14 and Older	Number	Percent of Total Population 14 and Older	Number	Percent of Total Males 14 and Older	Number	Percent of Total Females 14 and Older	Number	Percent of Total Population 14 and Older
Married[a] . . .	372,485	69.7	373,134	66.0	745,619	67.8	392,760	65.0	397,847	59.9	790,607	62.3
Widowed . . .	19,343	3.6	61,841	10.9	81,184	7.4	18,387	3.0	75,687	11.4	94,074	7.4
Divorced . . .	11,914	2.2	15,826	2.8	27,740	2.5	16,645	2.8	25,097	3.8	41,742	3.3
Never Married .	131,082	24.5	114,885	20.3	245,967	22.3	176,549	29.2	165,573	24.9	342,122	27.0
Total	534,824	100.0	565,686	100.0	1,100,510	100.0	604,341	100.0	664,204	100.0	1,268,545	100.0

[a] *The number of married persons includes persons reported in the census as being separated. The number of separated persons in the Region totaled 9,788 in 1960 and 15,636 in 1970.*

Source: U. S. Bureau of the Census and SEWRPC.

elementary education or less was lowest in Waukesha County (nearly 18 percent) and highest in Washington County (32 percent). This variation in the educational attainment of the population among the seven counties is summarized by the median number of years of schooling completed for persons over 25 in each county (see Table 13). The median number of years of schooling in 1970 was highest in Waukesha County (12.5 years) and lowest in Kenosha County (11.8 years).

Residential Mobility: Still another population characteristic which must be considered in the analysis of air quality is the residential mobility of the regional population. From data collected on a sample basis in the 1970 census, information was obtained with regard to the place of residence in 1965 for persons five years old and older. Similar information was obtained in the 1960 census. Persons who lived in the same residence five years prior to census enumeration were classified as nonmovers. Persons who lived in a different residence five years earlier were classified as local movers if that residence was in the same county, and as migratory movers if that residence was in a different county in Wisconsin, in a different state, or outside the United States.

As indicated in Table 14, 44 percent of the regional population five years old and older lived in a different residence in 1970 than in 1965 and were, therefore, classified as movers. A comparison of 1960 and 1970 census data reveals that while there were slight decreases in the proportion of the population that lived in a different county in the State, in a different state or abroad five years previous, the most striking change was the decrease in the proportion of local movers from nearly 34 percent to 25 percent.

Household Size: One of the more important characteristics of the regional population with respect to urban development is the number and size of households.[2] From 1950 to 1970 the total number of households in the Region increased at a more rapid rate than the household population (see Table 15). While there was a substantial increase in both the number of households and the household population, the average number of persons per household in the Region declined from 3.36 in 1950 to 3.30 in 1960 and 3.20 in 1970. The overall decline in the number of persons per household since 1950 has occurred primarily as a result of the rapid increase in the number of one-person households, and is indicative of a tendency for unmarried persons to maintain occupancy away from relatives. The spatial distribution of average household sizes in the Region in 1963 and 1972 is shown on Map 5. The smaller average household sizes generally occur in central cities and outlying rural areas of the Region. The larger average household sizes generally occur in suburban areas of the Region.

Housing Value: Single-family housing values in the Region since 1950 have followed trends similar to those of per capita incomes. Changes in both the actual or market value and the constant[3] 1967 dollar value of single-family housing units in the Region, however, have not been as great as changes in per capita income levels which are shown in Table 16. From 1950 to 1960, the market value of single-family housing units in the Region increased by about $4,600, or 41 percent, and the constant 1967 dollar value increased by about $2,300, or 16 percent. During this same period per capita income levels increased by about $900, or about 66 percent, in actual dollars, and by $650, or 35 percent, in constant 1967 dollars (see Tables 16 and 17).

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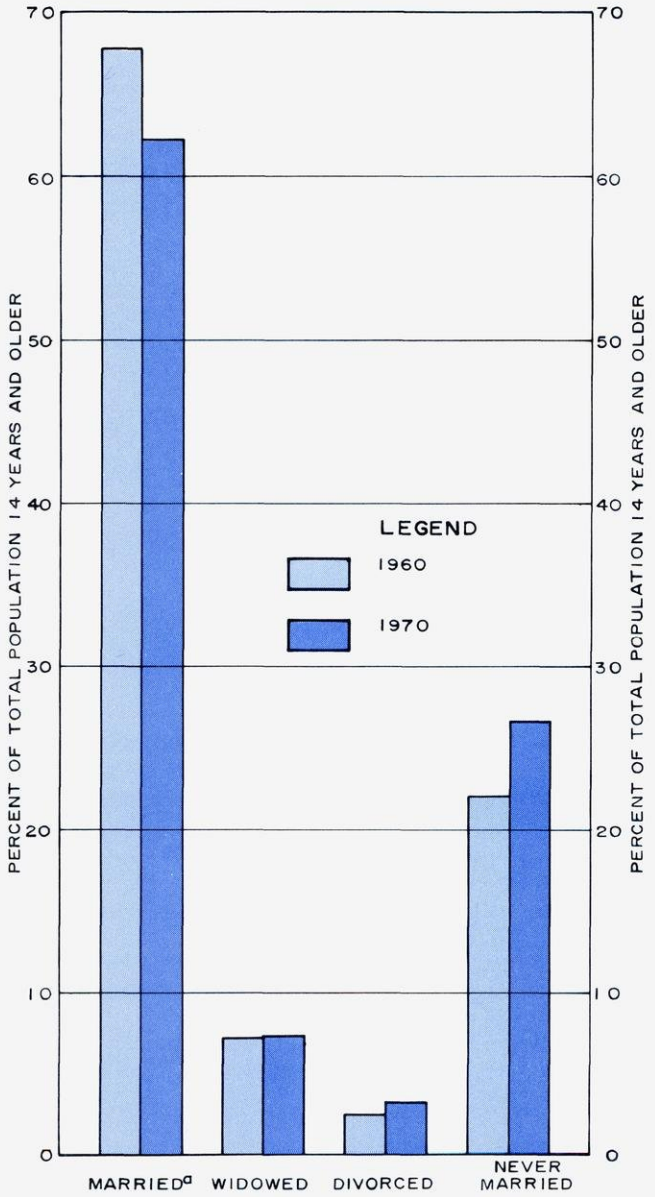
[2] *A household is defined as an individual or family occupying a separate dwelling unit, as opposed to persons who reside in group quarters, such as dormitories or boarding houses, or who are inmates of institutions.*

[3] *In order to permit comparison free of price distortions, all housing market values were adjusted to, and expressed in terms of, 1967 dollars, using the consumer price index published by the U.S. Department of Labor.*

Figure 8

DISTRIBUTION OF THE POPULATION 14 YEARS OF AGE AND OLDER IN THE REGION BY MARITAL STATUS 1960 AND 1970



[a] THE NUMBER OF MARRIED PERSONS INCLUDES PERSONS REPORTED IN THE CENSUS AS BEING SEPARATED. THE PROPORTION OF THE REGIONAL POPULATION AGE 14 YEARS AND OVER REPORTED AS SEPARATED WAS 0.89 PERCENT IN 1960 AND 1.23 PERCENT IN 1970.

Source: U. S. Bureau of the Census and SEWRPC.

From 1960 to 1970 per capita income levels in the Region increased by more than $1,200, or 55 percent, in actual dollars, and by about $450, or 18 percent, in constant 1967 dollars. At the same time, the market value of single-family housing units increased by about $4,700, or 30 percent, measured in actual dollars. Over this same 10-year period, however, the constant 1967 dollar value of single-family housing units did not change appreciably, indicating that the entire increase in single-family housing unit market value was offset by the rate of price inflation for consumer goods and services and, as such, there was no real increase in the value of homes in the Region from 1960 to 1970.

The spatial distribution of housing values throughout the Region for 1960 and 1970 is shown on Map 6. As shown on this map, geographic concentrations of housing values in the Region are somewhat similar to those of the median household income in the Region (see Map 7). Concentrations of higher median single-family housing unit values are located primarily in the suburban areas of the Region, while significant concentrations of lower median single-family housing unit values are found primarily in the older areas of the central city portions of Kenosha, Milwaukee, and Racine, and to a lesser extent, in outlying rural areas.

ECONOMIC BASE

Changes in the levels and distribution of the population of an area are closely related to changes in the amount and distribution of economic activity in that area. This is true not only because much of the population migration into an area is dependent upon the availability of jobs, but because jobs must ultimately be available to hold the natural increase and prevent the outmigration of native young people entering the labor force. The changes in the population levels and in the distribution of the population within the Region may, therefore, be basically attributed to changes in the amount and distribution of the economic activity in the Region. These changes, in turn, influence the ambient air quality within the Region.

This section presents an analysis of the general trends in economic activity in the Southeastern Wisconsin Region over the period 1950-1970. Where available, data for the year 1975 was also reported. For the purpose of this report, changes in the levels and distribution of economic activity are measured in terms of changes in the regional labor force and work force size, composition, and distribution.

Labor Force Size and Composition

The segment of the population most closely related to the economy is the labor force. The labor force of an area consists of all of its residents who are 14 years of age and older enumerated at their place of residence and who are either employed at one or more jobs or temporarily unemployed. Changes in the size of the labor force of the Region reflect, in part, changes which have taken place within the regional economy. Table 18 shows the changes that have occurred in the labor force size in the United States, Wisconsin, and the Region from 1950 to 1975.

Table 11

DISTRIBUTION OF MALES AND FEMALES 14 YEARS OF AGE AND OLDER IN THE REGION BY MARITAL STATUS BY COUNTY: 1970

County	Males 14 Years of Age and Older				Females 14 Years of Age and Older			
	Never Married	Married[a]	Widowed or Divorced	Total	Never Married	Married[a]	Widowed or Divorced	Total
Kenosha	27.8	66.7	5.5	100.0	22.3	63.2	14.5	100.0
Milwaukee	29.6	63.8	6.6	100.0	25.6	57.4	17.0	100.0
Ozaukee	27.7	68.7	3.6	100.0	23.6	66.8	9.6	100.0
Racine	28.1	66.6	5.3	100.0	24.1	62.1	13.8	100.0
Walworth	34.2	60.5	5.3	100.0	27.3	58.1	14.6	100.0
Washington	28.4	67.5	4.1	100.0	23.0	65.9	11.1	100.0
Waukesha	27.9	68.5	3.6	100.0	23.6	66.5	9.9	100.0
Region	29.2	65.0	5.8	100.0	24.9	59.9	15.2	100.0

[a] *The percentage of married persons includes persons reported in the census as being separated.*

Source: U. S. Bureau of the Census and SEWRPC.

Table 12

EDUCATIONAL ATTAINMENT LEVELS OF THE POPULATION 25 YEARS OF AGE AND OLDER IN THE REGION: 1960 AND 1970

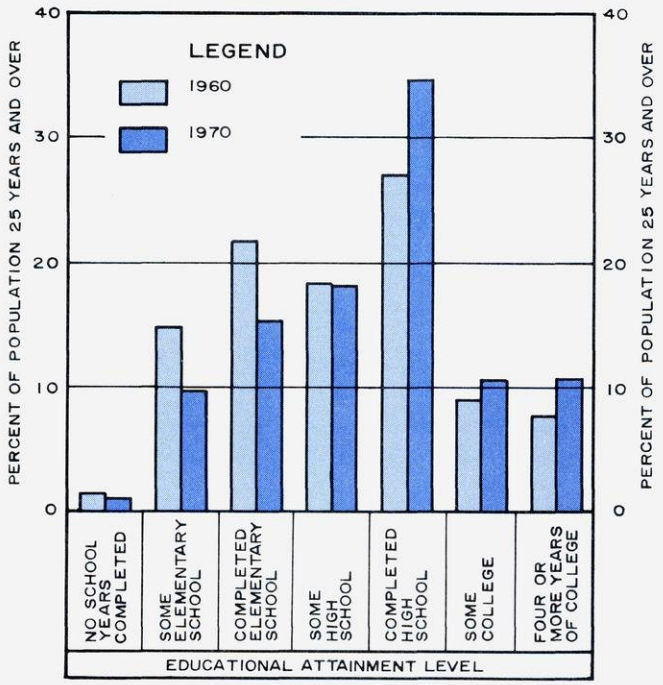
Level of Educational Attainment	Population 25 Years of Age and Older			
	1960		1970	
	Number	Percent of Total	Number	Percent of Total
No School Years Completed	11,305	1.3	9,830	1.0
Some Elementary School	131,150	14.9	89,452	9.6
Completed Elementary School	191,349	21.7	143,104	15.3
Some High School	162,249	18.4	170,115	18.1
Completed High School	237,848	27.0	325,357	34.7
Some College	79,033	9.0	99,195	10.6
Four or More Years of College	68,016	7.7	99,936	10.7
Total	880,950	100.0	936,989	100.0
Median Number of School Years Completed[a]	11.0		12.2	

[a] *The median number of school years completed is the number which divides the distribution of persons over age 25 in half; that is, half completed more years of school than the median and half completed fewer years.*

Source: U. S. Bureau of the Census and SEWRPC.

Figure 9

DISTRIBUTION OF THE POPULATION 25 YEARS OF AGE AND OLDER IN THE REGION BY EDUCATIONAL ATTAINMENT LEVEL: 1960 AND 1970



Source: U. S. Bureau of the Census and SEWRPC.

Table 13

EDUCATIONAL ATTAINMENT LEVELS OF THE POPULATION 25 YEARS OF AGE AND OLDER IN THE REGION BY COUNTY: 1970

County	Population 25 Years of Age and Older																Median Years Of School Completed[b]
	No School Years Completed		Some Elementary School		Completed Elementary School		Some High School		Completed High School		Some College		Four or More Years of College		Total		
	Number	Percent[a]	Number	Percent[a]	Number	Percent[a]	Number	Percent[a]	Number	Percent[a]	Number	Percent[a]	Number	Percent[a]	Number	Percent[a]	
Kenosha	1,004	1.6	6,557	10.6	9,446	15.3	14,685	23.7	20,830	33.7	5,109	8.3	4,216	6.8	61,847	100.0	11.8
Milwaukee	6,405	1.1	60,406	10.5	88,647	15.3	107,751	18.6	195,714	33.8	60,090	10.4	59,487	10.3	578,500	100.0	12.1
Ozaukee	178	0.7	1,705	6.2	4,588	16.6	3,729	13.5	9,647	34.9	3,487	12.6	4,282	15.5	27,616	100.0	12.4
Racine	1,311	1.5	9,019	10.3	14,101	16.1	17,587	20.0	29,940	34.1	8,079	9.2	7,723	8.8	87,760	100.0	12.1
Walworth	199	0.6	2,493	7.6	5,442	16.6	4,996	15.2	11,942	36.5	3,918	12.0	3,754	11.5	32,744	100.0	12.3
Washington	132	0.4	2,966	9.3	7,129	22.4	4,283	13.5	11,858	37.4	2,898	9.1	2,524	7.9	31,790	100.0	12.1
Waukesha	601	0.5	6,306	5.4	13,751	11.8	17,084	14.6	45,426	38.9	15,614	13.4	17,950	15.4	116,732	100.0	12.5
Region	9,830	1.0	89,452	9.6	143,104	15.3	170,115	18.1	325,357	34.7	99,195	10.6	99,936	10.7	936,989	100.0	12.2

[a] *Percent of population 25 years of age and older in each county.*

[b] *The median number of years of school completed is the number which divides the distribution of persons over age 25 in half, with half having completed more years of school than the median and half fewer years.*

Source: U. S. Bureau of the Census and SEWRPC.

Table 14

RESIDENTIAL MOBILITY OF THE POPULATION FIVE YEARS OF AGE AND OLDER IN THE REGION 1960 AND 1970

Residential Mobility Status[a]	Population 5 Years of Age and Older			
	1960		1970	
	Number	Percent Of Total	Number	Percent Of Total
Nonmovers	680,196	49.2	896,919	56.0
Movers	703,234	50.8	705,862	44.0
Local	466,849	33.7	398,447	24.8
Migratory	216,126	15.6	217,343	13.6
From Different County in State	111,046	8.0	113,750	7.1
From Different State	91,441	6.6	93,141	5.8
From Abroad	13,639	1.0	10,452	0.7
Moved, Residence in 1965 (1955) Not Reported	20,259	1.5	90,072	5.6
Total Population	1,383,430	100.0	1,602,781	100.0

[a] *Residential mobility status is based on the place of residence five years prior to census enumeration.*

Source: U. S. Bureau of the Census and SEWRPC.

Table 15

HOUSEHOLD POPULATION TRENDS IN THE REGIOn 1950-1970

Household Characteristic	1950	1960	1970	Difference 1950 - 1960		Difference 1960 - 1970	
				Absolute	Percent	Absolute	Percent
Total Number of Households	354,544	465,913	536,486	111,369	31.4	70,573	15.1
Household Population	1,190,193	1,537,235	1,714,200	347,042	29.1	176,965	11.5
Persons Per Household	3.36	3.30	3.20	-0.6	-1.8	-.10	-3.0

Source: U. S. Bureau of the Census and SEWRPC.

The labor force in the Region increased from 540,100 persons in 1950 to 831,500 persons in 1975—an overall increase of 291,400 persons, or 54 percent over the 25-year period. The labor force increased at a slightly slower rate between 1960 and 1970 than between 1950 and 1960, with growth rates of nearly 17 percent and 18 percent, respectively, thus indicating a slowing down of economic growth in the Region during this period. Table 18 further indicates that the rate of growth in the regional labor force was slower between 1960 and 1970 than that of either the State or the nation, whereas from 1950 to 1960 the regional labor force grew at a more rapid rate than at the national or state levels. In 1975 the size of the regional labor force stood at an estimated 831,500 persons, an increase of about 87,000 persons over 1970. This represents a growth rate of only 12 percent for the first half of the decade. These labor force trends indicate that the Region has experienced difficulty in competing for economic growth with other parts of the United States and, to a lesser extent, with other areas of the State of Wisconsin.

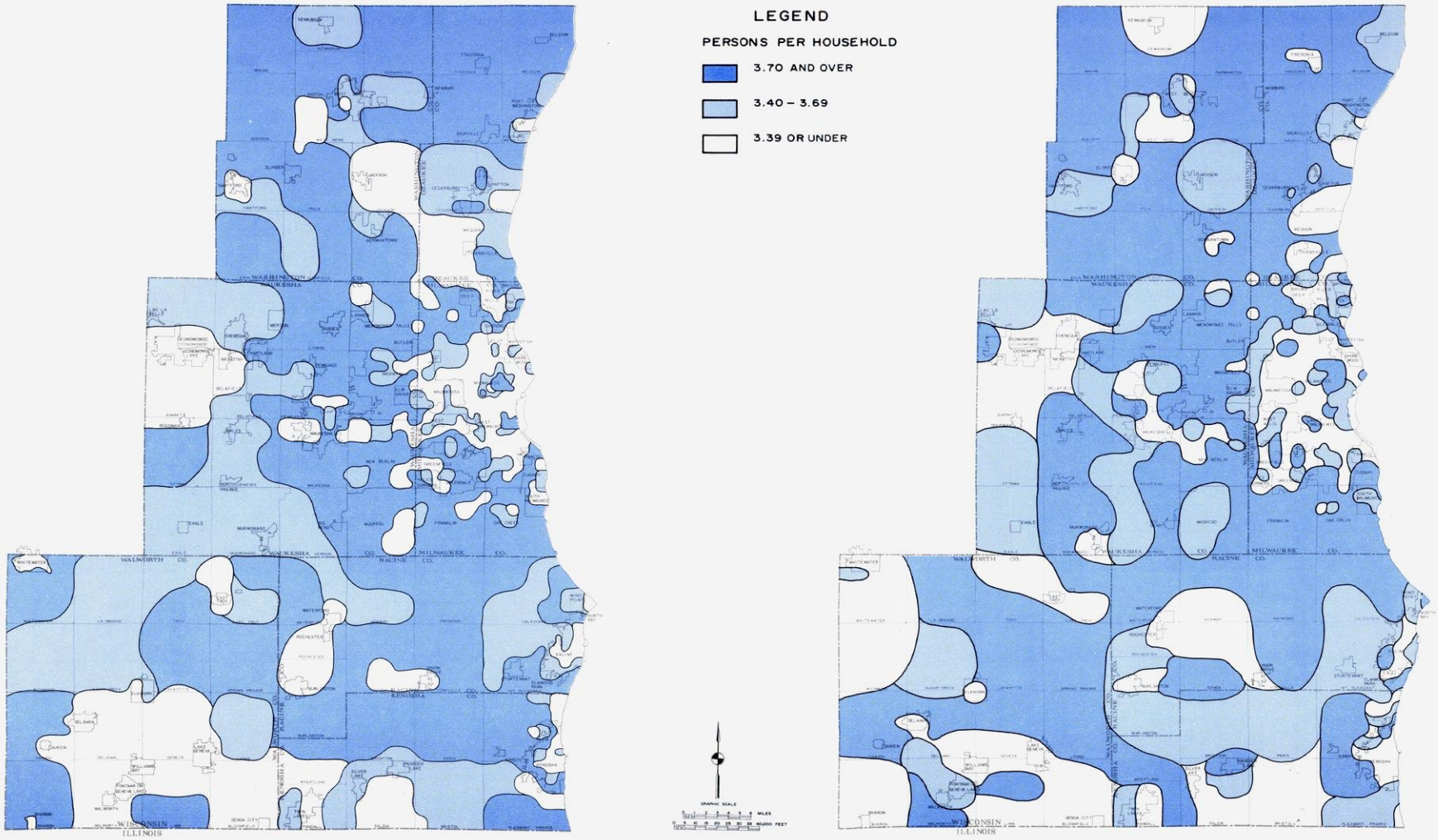
Changes in the composition of the Region's labor force reflect the increasing role of female members. Table 19 and Figure 10 show the regional labor force composition trends from 1950 to 1970, the latest year for which such data are available. It is apparent that female participation in the labor force is increasing rapidly relative to male participation. The female labor force members increased

Map 5

AVERAGE HOUSEHOLD SIZE IN THE REGION: 1963 AND 1972

1963

1972



There were over one-half million households in the Region in 1972, with an average size of about 3.2 persons per household. In 1963 the average household size was nearly 3.4 persons. The decline in average household size may be attributed to the decline in the birthrate and consequent smaller family sizes, as well as to an increasing tendency for single persons to maintain occupancy away from relatives, resulting in an increase in the number of one-person households. As in 1963, larger average household sizes in 1972 are generally associated with increased distance from the central cities. A comparison of the above maps reveals, however, that a number of rural areas previously exhibiting household sizes of at least 3.7 persons now reflect smaller household sizes.

Source: SEWRPC.

Table 16

INCOME TRENDS IN THE UNITED STATES, WISCONSIN, AND THE REGION: SELECTED YEARS 1950-1970

Geographic Area And Income Measure	Year			Difference 1950 to 1960		Difference 1960 to 1970		Year		Difference 1963 to 1972	
	1950	1960	1970	Number	Percent	Number	Percent	1963[b]	1972[b]	Number	Percent
United States											
Total Income (in millions)											
Actual	$165,063	$331,700	$635,563	$166,637	101.0	$303,863	91.6	$378,400	$742,900	$364,500	96.3
Constant[a]	228,612	374,390	546,966	145,778	63.8	172,576	46.1	412,600	588,800	176,200	42.7
Per Capita Income											
Actual	1,070	1,849	3,128	779	72.8	1,279	69.2	2,006	3,564	1,558	77.7
Constant[a]	1,481	2,087	2,692	606	40.9	605	29.0	2,188	2,825	637	29.1
Wisconsin											
Total Income (in millions)											
Actual	$ 3,581	$ 7,287	$ 13,457	$ 3,706	103.5	$ 6,170	84.7	$ 8,100	$ 14,700	$ 6,600	81.4
Constant[a]	4,960	8,225	11,581	3,265	65.8	3,356	40.8	8,800	11,600	2,800	31.8
Per Capita Income											
Actual	1,043	1,844	3,046	801	76.8	1,202	65.2	1,992	3,327	1,335	67.0
Constant[a]	1,445	2,081	2,621	636	44.0	540	25.9	2,164	2,625	461	21.3
Region											
Total Income (in millions)											
Actual	$ 1,660	$ 3,492	$ 6,029	$ 1,832	110.4	$ 2,537	72.7	$ 4,000	$ 6,900	$ 2,900	72.5
Constant[a]	2,299	3,941	5,189	1,642	71.4	1,248	31.7	4,400	5,500	1,100	25.0
Per Capita Income											
Actual	1,338	2,219	3,433	881	65.8	1,214	54.7	2,398	3,836	1,438	60.0
Constant[a]	1,853	2,505	2,954	652	35.2	449	17.9	2,615	3,060	445	17.0

[a] *Adjusted for price change; base year 1967 equals 100.0.*

[b] *Based on estimates derived from 1963 and 1972 inventories of travel.*

Source: U. S. Department of Commerce, Bureau of the Census; U. S. Department of Labor; Wisconsin Department of Administration; and SEWRPC.

39 percent from 1960 to 1970, compared to the male increase of only 6 percent. Furthermore, the female segment of the regional labor force has increased at progressively faster rates over the 20-year period than the male segment. Consequently, the female portion of the labor force increased nearly 10 percent over the past two decades, from 29 to 39 percent. The male portion, therefore, has declined from 71 to 61 percent over this period. This increase in female participation may be attributed to the employment of wives contributing to the family income, accelerated growth in retailing and service jobs, and emphasis on equal employment opportunities for females. It should also be noted that the group made up of females 14 years of age and older have increased relative to the group made up of males 14 years and older (see Table 20). Females, then, now represent a much larger proportion of the potentially employable population than they previously did.

The proportion of the total regional population that was a part of the labor force—termed the labor force participation rate—from 1950 to 1970 is shown in Table 20. From 1960 to 1970, the proportion of the population that was a part of the labor force increased by over 1 percent, which is almost identical to the percent increase from 1950 to 1960. These participation rate increases are primarily the result of the accelerated growth of the female labor force and the rapidly declining birth rate in the Region during the 1960's. The decrease in male participation may be partially attributed to increased education requirements and earlier retirements.

Work Force Size and Composition

Another important measure of economic activity in the Region is the size and composition of the work force.

Table 17

TRENDS IN SINGLE-FAMILY HOUSING VALUES IN THE REGION: SELECTED YEARS 1960-1970

Market Value	1950		1960		1970		Difference 1950-1960	Difference 1960-1970	Difference 1950-1970
	Number[a]	Percent of Total	Number[a]	Percent of Total	Number[a]	Percent of Total			
Less than $10,000 . . .	50,423	42.1	28,760	12.7	14,536	5.4	- 43.0	- 49.4	- 71.2
$10,000-14,999	45,369	37.8	72,371	31.9	42,822	15.8	59.5	- 40.8	- 5.6
15,000-19,999	14,876	12.4	73,697	32.5	72,767	26.9	395.4	- 1.3	389.2
20,000 or More	9,295	7.7	51,825	22.9	140,201	51.9	457.6	170.5	408.3
Total	119,963	100.0	226,653	100.0	270,326	100.0	88.9	19.3	125.3
Median Market Value	$11,100	--	$15,700	--	$20,400	--	41.4	29.9	83.8
Median Value in Constant 1967 Dollars	15,300	--	17,800	--	17,800	--	16.3	0.0	16.3

[a] *Includes only those single-family housing units for which value is tabulated.*

Source: U. S. Bureau of the Census and SEWRPC.

Table 18

LABOR TRENDS IN THE UNITED STATES, WISCONSIN, AND THE REGION BY COUNTY: SELECTED YEARS 1950-1975

County	Labor Force				Change 1950-1960		Change 1960-1970		Change 1970-1975		Change 1950-1975	
	1950	1960	1970	1975	Absolute	Percent	Absolute	Percent	Absolute	Percent	Absolute	Percent
Kenosha	32,600	39,800	47,700	58,800	7,200	22.1	7,900	19.8	11,100	23.3	26,200	80.4
Milwaukee	386,500	433,100	458,600	491,500	46,600	12.1	25,500	5.9	32,900	7.2	105,000	27.2
Ozaukee	9,600	14,400	22,400	27,100	4,800	50.0	8,000	55.5	4,700	21.4	17,500	182.3
Racine.	46,800	55,000	69,300	78,800	8,200	17.5	14,300	26.0	9,500	13.7	32,000	68.4
Walworth.	16,500	20,500	26,800	29,100	4,000	24.2	6,300	30.7	2,300	8.6	12,600	76.4
Washington . . .	14,300	17,400	26,100	31,600	3,100	21.7	8,700	50.0	5,500	21.1	17,300	121.0
Waukesha.	33,800	58,500	93,600	114,600	24,700	73.1	35,100	60.0	21,000	22.4	80,800	239.0
Region	540,100	638,700	744,500	831,500	98,600	18.3	105,800	16.6	87,000	11.7	291,400	54.0
Wisconsin	1,396,400	1,533,000	1,799,300	2,128,000	136,600	9.8	266,300	17.4	328,700	18.3	731,600	52.4
United States	59,304,000	68,144,000	82,897,000	94,773,000	8,840,000	14.9	14,753,000	21.6	11,876,000	14.3	35,469,000	59.9

Source: U. S. Department of Labor, Bureau of Labor Statistics; Wisconsin Department of Industry, Labor, and Human Relations; and SEWRPC.

The work force consists of employed workers 14 years of age and older enumerated at their place of work and persons counted as unemployed residents of the Region. Work force data are tabulated monthly by the Wisconsin Department of Industry, Labor, and Human Relations. Work force trends closely parallel labor force trends, but absolute values differ because of the different means of enumeration. Because of the frequency of data tabulation, work force data provide for the analysis of annual changes in employment in contrast to the labor force data enumerated as part of the U. S. Census of Population, which generates point estimates of the labor force every 10 years.

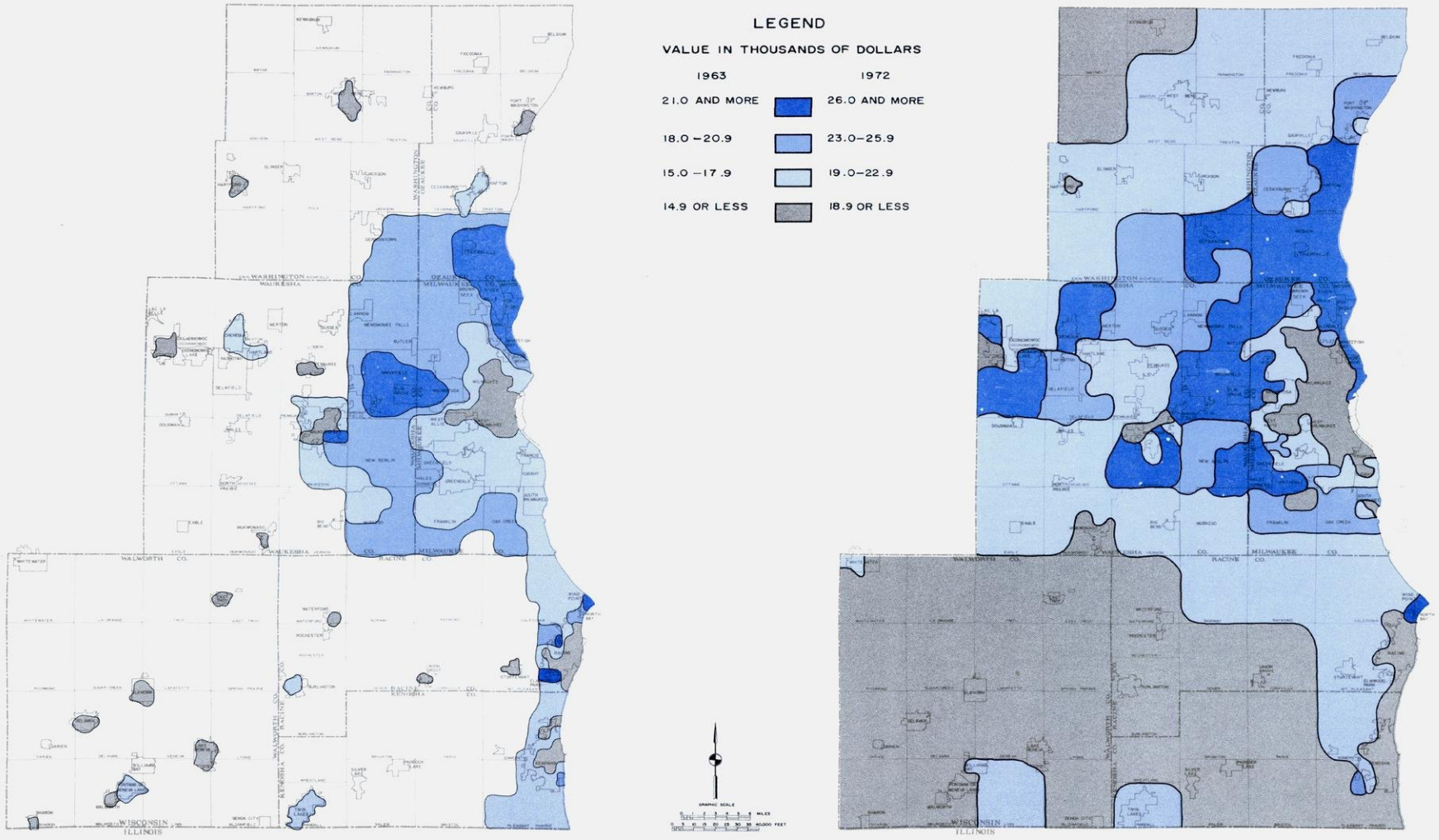
Table 21 shows the changes in the size of the work force for the United States, Wisconsin, and the Region from 1950 to 1970. The regional work force increase from 1950 to 1960 of nearly 18 percent occurred at about

Map 6

MEDIAN SINGLE-FAMILY HOUSING VALUE IN THE REGION: 1960 AND 1970

1960

1970



The above maps reflect the distribution of single-family housing values in the Region for 1960 and 1970. The housing value ranges shown for each year, while different in actual dollar value, are equivalent in constant dollar value. A single-family home worth $18,000 in 1960, for example, is equivalent to a single-family home worth $23,000 in 1970. Single-family housing value data were available in 1960 only for the more urban portions of the Region, but were available for the entire Region in 1970. It is evident from a comparison of the above maps that single-family housing values are generally rising throughout the Region. The lowest value single-family housing is located in the central cities of the Region and in the rural portions of Kenosha, Racine, Walworth, and Washington Counties.

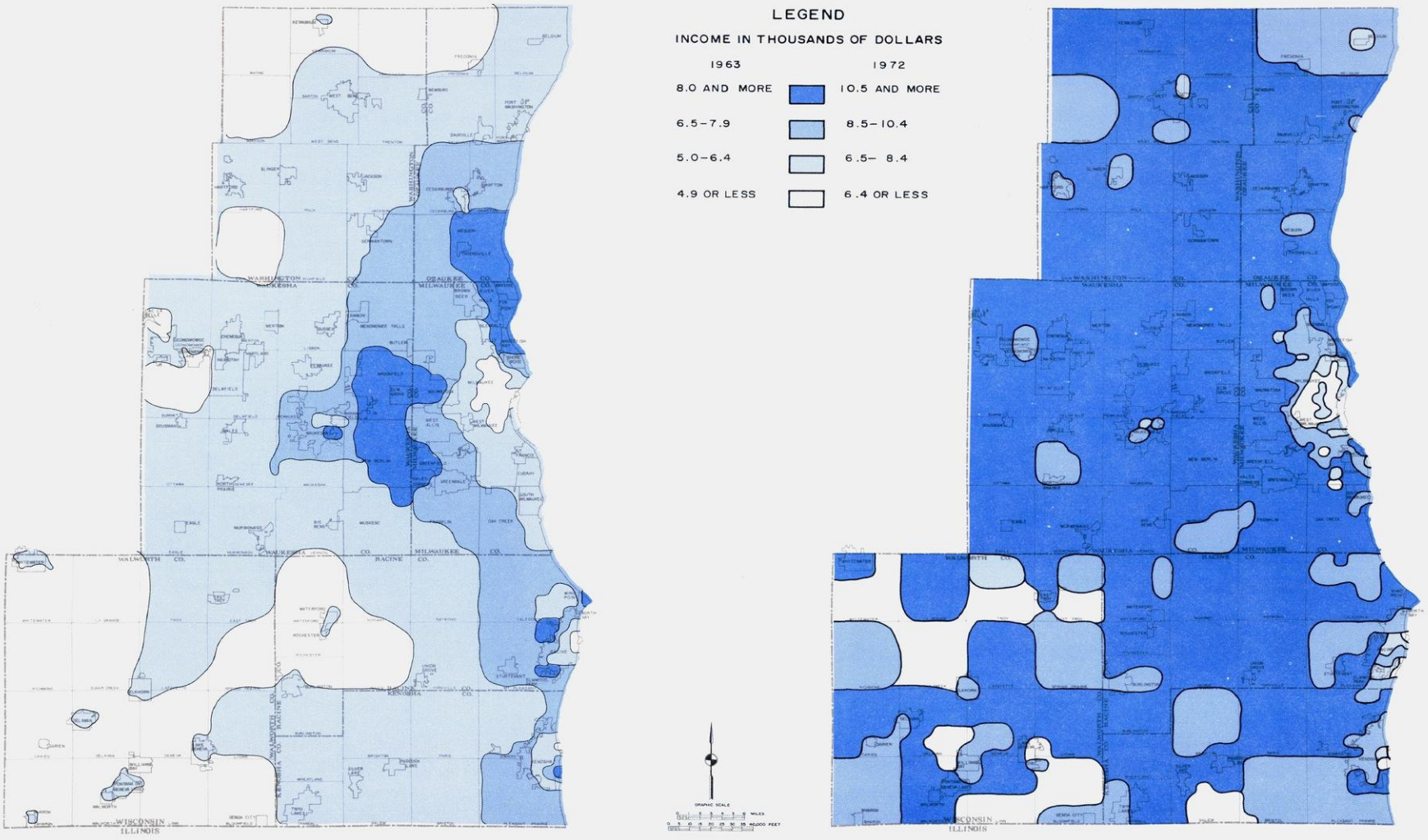
Source: U. S. Bureau of the Census.

Map 7

MEDIAN HOUSEHOLD INCOME IN THE REGION: 1963 AND 1972

1963

1972



The above maps indicate the distribution of median household income in the Region for 1963 and 1972. The income ranges shown for each year, while different in actual dollar value, are equivalent in constant dollar value. A household income of $8,000 in 1963, for example, is equivalent to a household income of $10,500 in 1972. It is evident that household income levels have risen substantially over the 1963-1972 period, with large areas of the Region exhibiting median household incomes in excess of $10,500. As in 1963, the lowest household incomes are found in portions of the older central cities and in scattered rural areas.

Source: SEWRPC.

Table 19

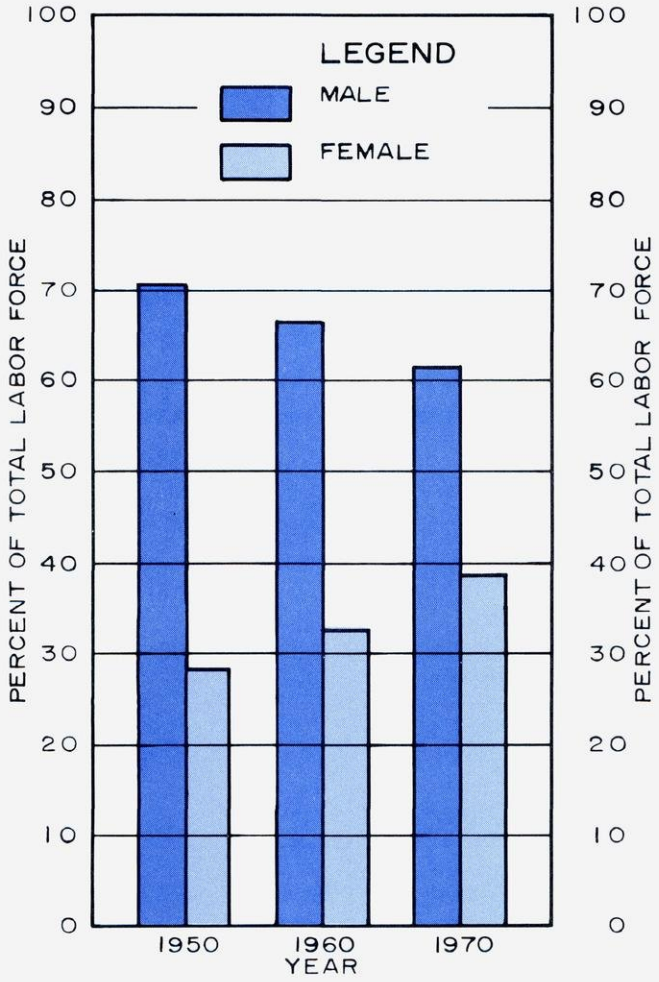
LABOR FORCE COMPOSITION IN THE REGION: 1950, 1960, AND 1970

Labor Force Composition	1950		1960		1970		Percent Difference	
	Number	Percent of Total Labor Force	Number	Percent of Total Labor Force	Number	Percent of Total Labor Force	1950-1960	1960-1970
Male	384,946	71.3	432,433	67.7	456,918	61.4	12.3	5.7
Female . . .	155,111	28.7	206,300	32.3	287,596	38.6	33.0	39.4
Total	540,057	100.0	638,733	100.0	744,514	100.0	18.3	16.6

Source: U. S. Bureau of the Census and SEWRPC.

Figure 10

SEX COMPOSITION OF THE LABOR FORCE IN THE REGION: 1950, 1960, AND 1970



Source: U. S. Bureau of the Census and SEWRPC.

the same rate as Wisconsin and at a more rapid rate than that of the United States during this same period. During the 1960 to 1970 period, however, work force increases nationally and in the State of Wisconsin exceeded regional growth, which is consistent with labor force trends previously discussed. This again indicates that the Region has been experiencing increasing difficulty in competing for industrial development with other sections of the country and that other areas within the State have had more rapid economic growth than the Region in the recent past. Although comparable figures are not available for the nation or the remainder of the State, the size of the regional work force stood at 841,200 persons in 1975.

Number of Jobs

A measure of economic activity which is closely related to the work force is the number of jobs available to residents of the Region. The number of jobs within the Region consists of the employed component of the work force, which includes all employed persons 14 years of age and older enumerated at their place of work. Table 22 and Figure 11 show the absolute and relative changes in the number of jobs within the United States, the State of Wisconsin, and the Region from 1950 to 1972.

The amount of economic activity in the Region, as measured by the number of available jobs, has increased at varying rates in the recent past (see Figure 11). From 1950 to 1957, there was a rapid increase in the number of jobs in the Region, followed by a sharp decline in 1958 corresponding to a national economic recession. From 1958 to 1960, there was again a rapid increase in the number of jobs, followed by another sharp decline in 1961, again corresponding to a national economic recession. During the balance of the 1960's job growth within the Region proceeded at a steady rate except for a slight economic slowdown from 1966 to 1967 and during the recession of 1970.

The recent trend in regional economic activity has paralleled the trend in national economic activity. However, fluctuations in periods of expansion and recession are

Table 20

PARTICIPATION OF THE POPULATION IN THE LABOR FORCE IN THE REGION: SELECTED YEARS 1950-1970

Population 14 Years and Older	1950	1960	1970	Difference 1950 - 1960 Absolute	Difference 1950 - 1960 Percent	Difference 1960 - 1970 Absolute	Difference 1960 - 1970 Percent	Difference 1950 - 1970 Absolute	Difference 1950 - 1970 Percent
Male	466,938	534,824	604,341	67,886	14.5	69,517	13.0	137,403	29.4
Female	485,157	565,703	664,204	80,546	16.6	98,501	17.4	179,047	36.9
Total	952,095	1,100,527	1,268,545	148,432	15.6	168,018	15.3	316,450	33.2
Labor Force									
Male	384,946	432,433	456,918	47,487	12.3	24,485	5.7	71,972	18.7
Female	155,111	206,300	287,596	51,189	33.0	81,296	39.4	132,485	85.4
Total	540,057	638,733	744,514	98,676	18.3	105,781	16.6	204,457	37.9
Participation Rate				Difference 1950 - 1960		Difference 1960 - 1970		Difference 1950 - 1970	
Male	82.4	80.0	75.6	- 1.6		- 5.2		- 6.8	
Female	32.0	36.5	43.3	4.5		6.8		11.3	
Total	56.7	58.0	59.2	1.3		1.2		2.5	

Source: U. S. Bureau of the Census and SEWRPC.

Table 21

COMPARATIVE WORK FORCE SIZE IN THE UNITED STATES, WISCONSIN, AND THE REGION: 1950, 1960, AND 1970

Geographic Area and Work Force	1950	1960	1970	Percent Difference 1950-1960	Percent Difference 1960-1970
United States					
Work Force	62,208,000	69,628,000	82,715,000	11.9	18.8
Percent Unemployed	5.3	5.5	4.9	--	--
Employed	58,911,000	65,798,500	78,662,000	11.7	19.5
Wisconsin					
Work Force	1,401,400	1,647,000	1,932,100	17.5	17.3
Percent Unemployed	3.8	3.9	4.6	--	--
Employed	1,348,100	1,582,800	1,842,400	17.6	16.4
Southeastern Wisconsin Region					
Work Force	572,200	673,200	776,200	17.6	15.3
Percent Unemployed	3.4	3.8	4.5	--	--
Employed	552,700	647,900	741,600	17.2	14.5

Source: U. S. Bureau of Labor Statistics; Wisconsin Department of Industry, Labor, and Human Relations; and SEWRPC.

Table 22

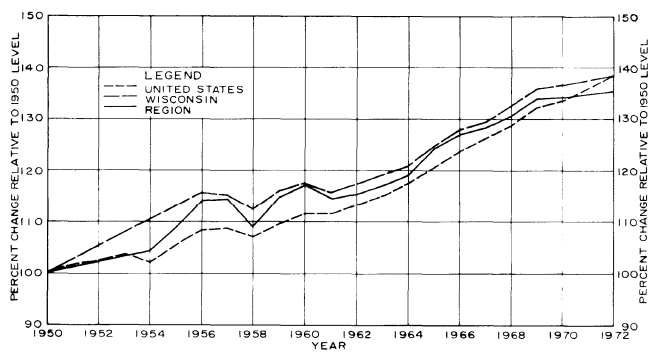
EMPLOYMENT STATUS OF THE WORK FORCE IN THE UNITED STATES, WISCONSIN, AND THE REGION: SELECTED YEARS 1950-1972

Area	Year				Percent Difference			
	1950	1960	1970	1972	1950-1960	1960-1970	1970-1972	1950-1972
United States								
Work Force	62,208,000	69,628,000	82,715,000	86,524,000	11.9	18.8	4.6	39.1
Percent								
Unemployed	5.3	5.5	4.9	5.6	--	--	--	--
Employed	58,911,000	65,798,500	78,662,000	81,702,000	11.7	19.5	3.9	38.7
Wisconsin								
Work Force	1,401,400	1,647,000	1,932,100	1,973,400	17.5	17.3	2.1	40.8
Percent								
Unemployed	3.8	3.9	4.6	5.0	--	--	--	--
Employed	1,348,100	1,582,800	1,842,400	1,872,900	17.6	16.4	1.6	38.9
Region								
Work Force	572,200	673,200	776,200	785,400	17.6	15.3	1.2	37.2
Percent								
Unemployed	3.4	3.8	4.5	4.7	--	--	--	--
Employed	552,700	647,900	741,600	748,800	17.2	14.5	1.0	35.5

Source: U. S. Bureau of Labor Statistics; Wisconsin Department of Industry, Labor, and Human Relations; and SEWRPC.

Figure 11

RELATIVE JOB GROWTH IN THE UNITED STATES, WISCONSIN, AND THE REGION: 1950-1972



Source: U. S. Bureau of Labor Statistics; Wisconsin Department of Industry, Labor, and Human Relations; and SEWRPC.

much greater for the Region than for the nation due to the high concentration of regional economic activity in the production of capital goods, which, as a derived demand, is highly responsive to lesser fluctuations in general consumer demand for goods and services. In addition, the growing divergence in the rates of growth in economic activity in the Region and the nation as measured by jobs reflects the increasing difficulty which the Region is experiencing in competing for industrial development with other parts of the nation.

As further indicated in Table 22, unemployment in the Region increased from 3 percent of the work force in 1950 to almost 4 percent of the Region's work force in 1960. The regional unemployment rate in 1970 averaged 4 percent of the work force, almost as high as the U. S. average, and reflects the 1970-1971 recession in the United States economy. In comparison, the 1950 and 1960 rates of regional unemployment were considerably below the U. S. average. In 1975, 62,200 persons in the Region, or 7.4 percent of the total regional work force, were unemployed. The current regional unemployment rate reflects not only the effects of a national recession and the capital goods orientation of the regional economy, but recent decisions of some larger southeastern Wisconsin firms to locate or relocate some operations in other areas of the State or nation.

CHANGES IN DISTRIBUTION OF ECONOMIC ACTIVITY

Significant changes have occurred in the distribution of economic activity within the Region in the past two and one-half decades, and are shown in Table 23, in terms of job totals. The number of jobs in the Region increased from 552,700 in 1950 to 779,000 in 1975, an increase of 226,300 jobs, or 41 percent. The counties which experienced the largest relative job growth rates from 1950 to 1960 were Kenosha, Ozaukee, Walworth, Washington, and Waukesha Counties. All experienced faster growth rates than the regional average, indicating a shift in economic activity generally toward the suburban and rural areas of the Region. Kenosha County, however, is an exception to this shift in economic activity. Job growth

Table 23

DISTRIBUTION OF JOBS IN THE REGION BY COUNTY: SELECTED YEARS 1950-1975

County	1950		1960		1970		1975		Change 1950-1960		1960-1970		1970-1975		1950-1975	
	Jobs	Percent	Jobs	Percent	Jobs	Percent	Jobs	Percent	Jobs	Percent	Jobs	Percent	Jobs	Percent	Jobs	Percent
Kenosha . . .	27,700	5.0	40,100	6.2	39,200	5.3	46,700	6.0	12,400	44.8	- 900	- 2.2	7,500	19.1	19,000	68.6
Milwaukee . .	438,100	79.3	486,200	75.0	510,900	68.9	515,700	66.2	48,100	11.0	24,700	5.1	4,800	0.9	77,600	17.7
Ozaukee . . .	6,200	1.1	9,500	1.5	17,900	2.5	20,200	2.6	3,300	53.2	8,400	33.4	2,300	12.8	14,000	225.8
Racine.	43,200	7.8	48,500	7.5	61,900	8.2	68,600	8.8	5,300	12.3	13,400	27.6	6,700	10.8	25,400	58.8
Walworth. . .	12,300	2.2	18,300	2.8	24,200	3.3	25,700	3.3	6,000	48.8	5,900	32.2	1,500	6.2	13,400	108.9
Washington .	9,700	1.8	14,500	2.2	20,300	2.7	22,600	2.9	4,800	49.5	5,800	40.0	2,300	11.3	12,900	133.0
Waukesha. . .	15,500	2.8	30,800	4.8	67,200	9.1	79,500	10.2	15,300	98.7	36,400	118.2	12,300	18.3	64,000	412.9
Region	552,700	100.0	647,900	100.0	741,600	100.0	779,000	100.0	95,200	17.2	93,700	14.5	37,400	5.0	226,300	40.9

Source: SEWRPC.

in this county was directly related to the prosperity in the transportation equipment industry during this period. Conversely, Milwaukee and Racine Counties both experienced job growth during the 1950 to 1960 period at a rate lower than the regional average, indicating a shift of economic activity out of these areas.

Jobs in the Region increased by 93,700, or 14 percent, over the 1960 to 1970 decade. During this period, the largest relative job growth occurred in Ozaukee, Racine, Walworth, Washington, and Waukesha Counties, indicating a further shift in economic activity away from the urban areas toward the suburban and rural areas of the Region. These shifts are a continuation of the economic activity location trends identified in the initial economic studies of the Commission.[3] The trend toward decentralization of jobs from Kenosha County is, however, more recent and results primarily from job reductions in the transportation equipment industry. The largest concentrations of jobs are in Milwaukee, Racine, and Waukesha Counties. About 85 percent of the regional jobs in 1975 were located in these three counties combined.

Between 1970 and 1975 there was an increase of 37,400 jobs, or 5 percent, in the Region. Though all counties experienced some increase in the number of jobs, Waukesha County had the largest increase with 12,300 new jobs, or a third of all new jobs in the Region for that five-year period and an 18 percent growth over the number of jobs in that county during 1970. In the same interval, Milwaukee County experienced an increase of 4,800 jobs, or less than 1 percent, while Milwaukee County's share of the total number of regional jobs decreased from 68.9 percent in 1970 to 66.2 percent in 1975, continuing an almost uninterrupted decline since 1950. The number of jobs in Milwaukee County during 1975, 515,700, is actually about a 3 percent decrease over the number of jobs in 1974, the peak year with 531,400 jobs.

Table 18 shows the labor force trends in each county of the Region over the past two and one-half decades. Since the labor force is enumerated at place of residence, the labor force changes generally parallel population changes. The greatest labor force increases during the periods 1950 to 1960 and 1960 to 1970 were in suburban Waukesha, Ozaukee, and Washington Counties, with the lesser increases occuring in the urban Counties of Milwaukee, Kenosha, and Racine. This trend in economic activity parallels regional population trends for the same period. Tables 18 and 23 indicate that 1970 marked the first time since 1950 that the Region had a larger labor force residing within its boundaries than it had available jobs. Also in 1970, all of the regional counties except Milwaukee had a larger labor force residing within their boundaries than they had jobs available. This indicates that even though economic activity is decentralizing in the Region, Milwaukee County is still a major supplier of jobs to residents of the Region. To illustrate this further, the 1970 Census of Population indicates that nearly 51 percent of the workers residing in Waukesha County, nearly 56 percent of those residing in Ozaukee County, and 65 percent of those residing in Washington County work in the county in which they reside. Origin and destination studies conducted by the Regional Planning Commission identify the pattern of job location versus the residence of the worker. Comparisons of this data more specifically identify changes in these patterns.

The changes in land use that have resulted from the previously discussed changes in location of economic activity in the Region are shown in Table 24 and Map 8. As indicated in this table, about 2,600 acres of land within the Region were converted to commercial and industrial use between 1963 and 1970. More than half of this development occurred in Waukesha and Milwaukee

[3] *The results of this work were published in SEWRPC Planning Report No. 3, The Economy of Southeastern Wisconsin, June 1963; and Planning Report No. 7, The Land Use-Transportation Study, Volume 2, Forecasts and Alternative Plans--1990, June 1966.*

Table 24

COMMERCIAL AND INDUSTRIAL LAND USE CHANGES IN THE REGION BY SUBAREA: 1963-1970

County Subarea[a]	Commercial Land Use[b]						Industrial Land Use[c]						Total Commercial and Industrial Land Use					
	1963		1970		Difference 1963-1970		1963		1970		Difference 1963-1970		1963		1970		Difference 1963-1970	
	Acres	Percent of Total	Acres	Percent of Total	Number	Percent	Acres	Percent of Total	Acres	Percent of Total	Number	Percent	Acres	Percent of Total	Acres	Percent of Total	Number	Percent
Kenosha	452.93	7.86	504.08	7.74	51.15	11.29	684.97	8.39	811.02	8.08	126.05	18.40	1,137.90	8.17	1,315.10	7.94	177.20	15.57
17	354.05	6.15	404.33	6.21	50.28	14.20	650.50	7.96	737.53	7.35	87.03	13.38	1,004.55	7.21	1,141.86	6.90	137.31	13.67
18	98.88	1.71	99.75	1.53	0.87	0.88	34.47	0.43	73.49	0.73	39.02	113.20	133.35	0.96	173.24	1.04	39.89	29.91
Milwaukee	2,591.76	45.00	2,874.71	44.11	282.95	10.92	4,415.72	54.06	4,898.68	48.80	482.96	10.94	7,007.48	50.31	7,773.39	46.95	765.91	10.93
5	163.92	2.85	196.09	3.01	32.17	19.63	309.12	3.78	319.03	3.18	9.91	3.21	473.04	3.40	515.12	3.11	42.08	8.90
6	423.60	7.35	573.25	8.80	149.65	35.33	536.98	6.57	877.67	8.74	340.69	63.45	960.58	6.90	1,450.92	8.77	490.34	51.05
7	746.47	12.96	687.39	10.55	- 59.08	- 7.91	1,423.03	17.43	1,350.90	13.46	- 72.13	- 5.07	2,169.50	15.57	2,038.29	12.31	- 131.21	- 6.44
8	230.69	4.00	276.84	4.25	46.15	20.01	280.07	3.43	367.71	3.66	87.64	31.29	510.76	3.67	644.55	3.89	133.79	26.19
9	1,027.08	17.84	1,141.14	17.50	114.06	11.11	1,866.52	22.85	1,983.37	19.76	116.85	6.26	2,893.60	20.77	3,124.51	18.87	230.91	7.98
Ozaukee	306.71	5.32	330.50	5.07	23.79	7.76	312.94	3.83	444.42	4.43	131.48	42.01	619.65	4.45	774.92	4.68	155.27	25.06
1	77.77	1.35	93.62	1.44	15.85	20.38	154.34	1.89	189.88	1.89	35.54	23.03	232.11	1.67	283.50	1.71	51.39	22.14
2	228.94	3.97	236.88	3.63	7.94	3.47	158.60	1.94	254.54	2.54	95.94	60.49	387.54	2.78	491.42	2.97	103.88	26.80
Racine	641.38	11.14	574.80	8.82	- 66.58	- 10.38	749.41	9.18	1,098.50	10.94	349.09	46.58	1,390.79	9.99	1,673.30	10.11	282.51	20.31
15	295.85	5.14	209.06	3.21	- 86.79	- 29.34	157.14	1.92	296.48	2.95	139.34	88.67	452.99	3.25	505.54	3.05	52.55	11.60
16	345.53	6.00	365.74	5.61	20.21	5.85	592.27	7.26	802.02	7.99	209.75	35.41	937.80	6.74	1,167.76	7.06	229.96	24.52
Walworth	545.87	9.48	593.02	9.10	47.15	8.64	729.73	8.93	827.20	8.24	97.47	13.36	1,275.60	9.16	1,420.22	8.58	144.62	11.34
19	398.26	6.92	438.04	6.72	39.78	9.99	537.58	6.58	590.44	5.88	52.86	9.83	935.84	6.72	1,028.48	6.21	92.64	9.90
20	147.61	2.56	154.98	2.38	7.37	4.99	192.15	2.35	236.76	2.36	44.61	23.22	339.76	2.44	391.74	2.37	51.98	15.30
Washington	243.92	4.24	299.00	4.59	55.08	22.58	317.81	3.89	433.70	4.32	115.89	36.47	561.73	4.03	732.70	4.43	170.97	30.44
3	121.38	2.11	145.91	2.24	24.53	20.21	192.20	2.35	266.24	2.65	74.04	38.52	313.58	2.25	412.15	2.49	98.57	31.43
4	122.54	2.13	153.09	2.35	30.55	24.93	125.61	1.54	167.46	1.67	41.85	33.32	248.15	1.78	320.55	1.94	72.40	29.18
Waukesha	976.79	16.96	1,340.74	20.57	363.95	37.26	957.48	11.72	1,525.09	15.19	567.61	59.28	1,934.27	13.89	2,865.83	17.31	931.56	48.16
10	411.90	7.15	524.53	8.05	112.63	27.34	268.28	3.29	422.35	4.21	154.07	57.43	680.18	4.88	946.88	5.72	266.70	39.21
11	121.70	2.11	184.07	2.82	62.37	51.25	48.30	0.59	239.48	2.39	191.18	395.82	170.00	1.22	423.55	2.56	253.55	149.15
12	137.00	2.38	224.36	3.44	87.36	63.77	295.13	3.61	383.84	3.82	88.71	30.06	432.13	3.10	608.20	3.67	176.07	40.74
13	220.07	3.82	285.73	4.39	65.66	29.84	133.22	1.63	221.95	2.21	88.73	66.60	353.29	2.54	507.68	3.07	154.39	43.70
14	86.12	1.50	122.05	1.87	35.93	41.72	212.55	2.60	257.47	2.56	44.92	21.13	298.67	2.15	379.52	2.29	80.85	27.07
Region	5,759.36	100.00	6,516.85	100.00	757.49	13.15	8,168.06	100.00	10,038.61	100.00	1,870.55	22.90	13,927.42	100.00	16,555.46	100.00	2,628.04	18.87

[a] *See Map 8 for subarea location within the Region.*

[b] *Commercial land use as referred to herein includes land devoted to local and regional retail and service operations, exclusive of offstreet parking areas.*

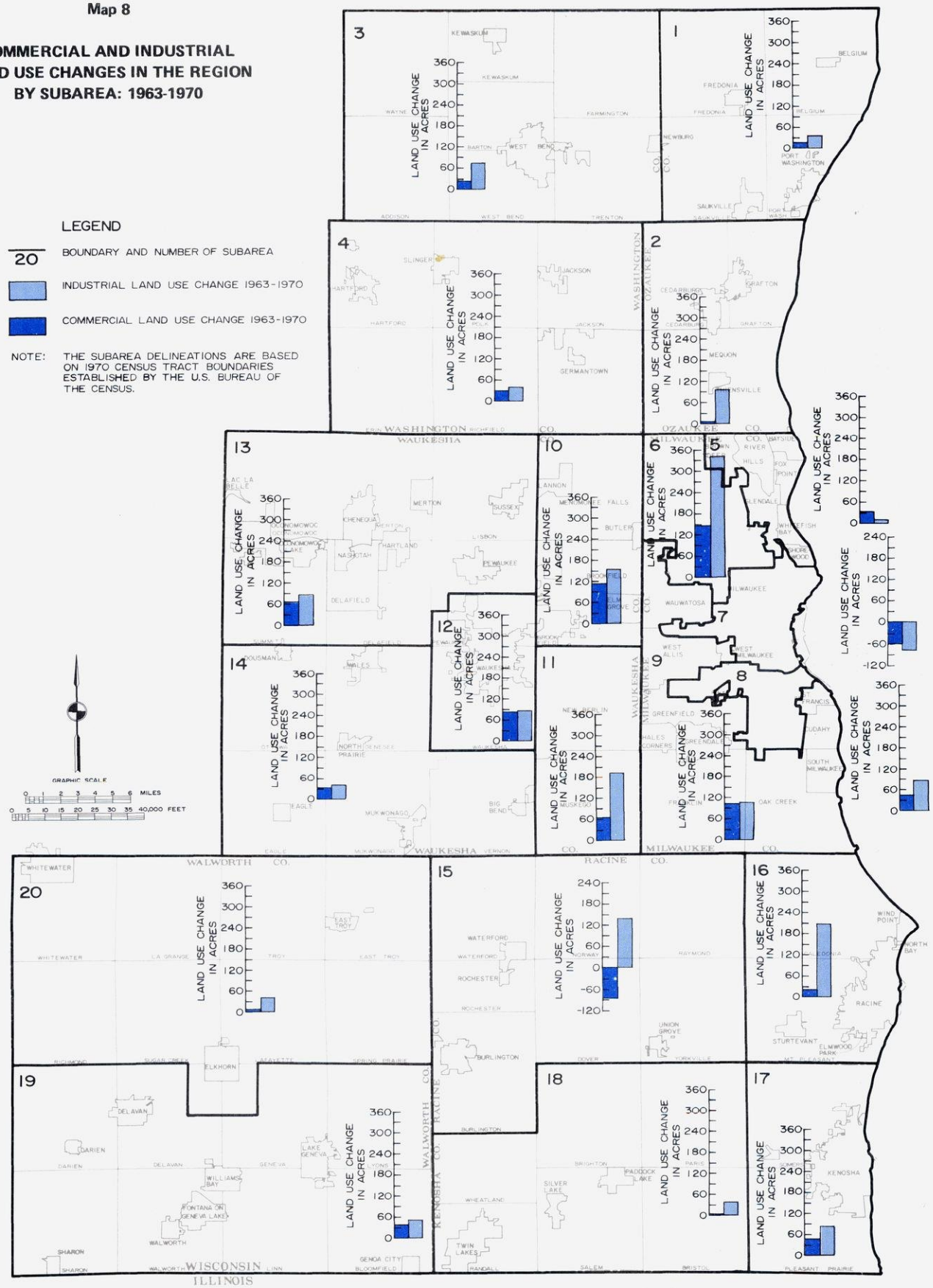
[c] *Industrial land use as referred to herein includes land devoted to manufacturing and open or enclosed wholesale storage operations, exclusive of offstreet parking areas.*

Source: SEWRPC.

Countries, although Milwaukee County's proportion of the Region's commercial and industrial land has diminished since 1963. The greatest net increase in commercial and industrial land use over the 1963 to 1970 period occurred in Waukesha County, followed by Milwaukee County. Map 8 graphically indicates the location of the commercial and industrial land use changes within the Region over the 1963 to 1970 period. The growth in commercial and industrial development in the suburban and rural areas of the Region, especially in suburban Milwaukee County and all of Waukesha County, is evident. The increased commercial and industrial activity in these areas has been generally manifested in large suburban shopping centers and industrial parks.

Map 8

COMMERCIAL AND INDUSTRIAL LAND USE CHANGES IN THE REGION BY SUBAREA: 1963-1970



Between 1963 and 1970, about 2,600 acres of land within the Region were converted to commercial and industrial use. The general location of these land use changes during this period is shown on this map. Rapid commercial and industrial development is evident in the suburban and rural areas of the Region, particularly in suburban Milwaukee County and in Waukesha County. The increased commercial and industrial activity in these areas has been generally manifested in the development of large new suburban shopping centers and industrial parks.

Source: SEWRPC.

Structure of the Economy

The character of the regional economy can best be described in terms of its economic base and structure,[4] since the number and types of industry directly affect land use and transportation needs which, in turn, affect the level and locational aspects of air quality problems. In this regard, economic activity within the Region can be classified into eight major industry groups: 1) agriculture; 2) construction and mining; 3) manufacturing; 4) trade; 5) transportation, communication, and utilities; 6) finance, insurance, and real estate; 7) private services; and 8) government services.

Economic activity within the Region is heavily concentrated in manufacturing (see Figure 12). Of the total number of jobs in the Region in 1975, the last year for which both regional and national data are available, 32 percent was in manufacturing compared to approximately 23 percent nationally. Also, of the total jobs in the Region approximately 21 percent was in private services compared to about 17 percent nationally. Private services include medical and other professional services provided by hospitals, clinics, dental offices, legal firms, and charitable institutions, as well as by architects, engineers, and social workers. The proportions of economic activity in all other industry groups within the Region, as measured by jobs, were less than the national averages.

The structure of economic activity within the regional manufacturing industry, which is important to the regional economy, is also quite different from the structure within the manufacturing industry nationally (see Figure 13). In contrast to the manufacturing industry of the United States, the manufacturing industry in the Region is more heavily concentrated in the production of durable goods, particularly nonelectrical machinery and electrical equipment. In 1975 about 42 percent of the total manufacturing jobs within the Region were in industries producing these types of goods, compared to about 21 percent nationally. Compared to the national distribution, there is also a concentration in the Region of fabricated metal product manufacturing. On the other hand, there is a relatively low concentration of activity associated with the production of nondurable goods, such as textile, apparel, leather, chemical, petroleum, rubber, and plastic products. The only nondurable goods manufacturing activity, in addition to printing and publishing, which has a proportion of manufacturing employment approximately that of the national economy is the production of paper and wood products.

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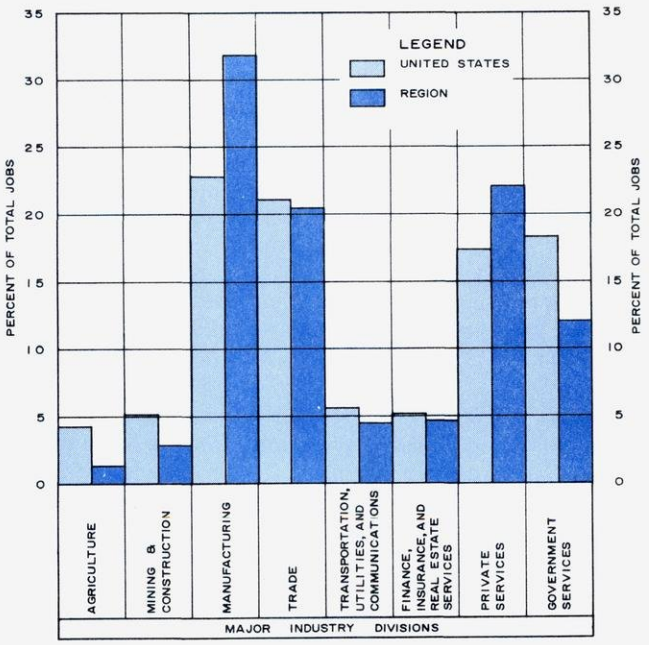
4 *The economic base of an area may be defined as those activities which provide the basic employment and income on which the rest of the area's economy depends. The economic structure of an area may be defined as the manner in which this employment is distributed among the major industrial sectors of the area's economy.*

Figure 12

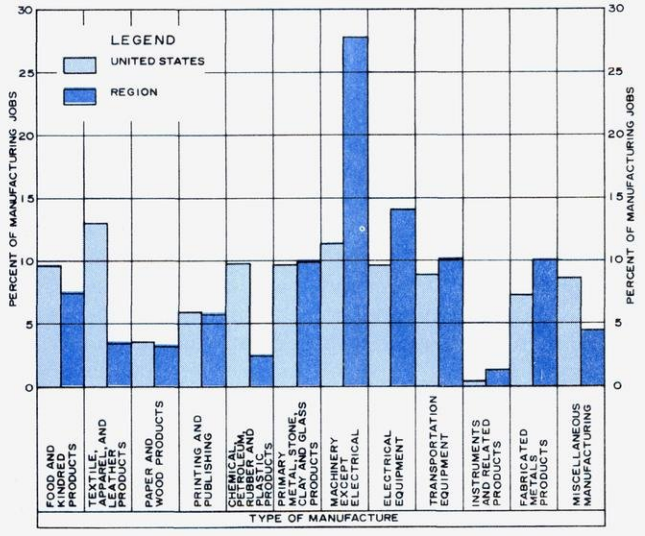
PERCENTAGE DISTRIBUTION OF JOBS BY MAJOR INDUSTRY GROUP IN THE UNITED STATES AND THE REGION: 1975



Source: U. S. Bureau of Labor Statistics; Wisconsin Department of Industry, Labor, and Human Relations; and SEWRPC.

Figure 13

PERCENTAGE DISTRIBUTION OF MANUFACTURING JOBS BY TYPE OF MANUFACTURING IN THE UNITED STATES AND THE REGION: 1975



Source: U. S. Bureau of Labor Statistics; Wisconsin Department of Industry, Labor, and Human Relations; and SEWRPC.

Personal Income

Personal income in the Region has been increasing at a rapid rate. As shown in Table 16, total regional income increased nearly 73 percent from 1960 to 1970. This rate of increase, however, was less than the national and state rates of increase during this period, and less than the regional rate of increase of 110 percent from 1950 to 1960, when the rate of personal income growth in the Region exceeded both the state and national increases. Similarly, income increases as measured in constant 1967 dollars indicate a lesser increase of total income in the Region from 1960 to 1970 than national and state increases. From 1963 to 1972 the estimated rate of personal income growth in the Region was more than 72 percent when measured in actual dollars, and 25 percent when measured in constant 1967 dollars. A comparison of estimated personal income increases from 1963 to 1972 again shows lesser increases in the Region than in the nation and State.

The rates of increase in per capita income since 1960 have also been slightly less in the Region than in the State or nation. Per capita income levels in the Region increased by about 55 percent from 1960 to 1970 compared to increases in Wisconsin and the United States of 65 and 69 percent, respectively. Similarly, estimated per capita income level changes from 1963 to 1972, indicate a 60 percent increase in the Region, compared to increases of 67 and 78 percent for Wisconsin and the United States, respectively. The levels of per capita income measured in constant 1967 dollars show the same trends as those indicated by the actual dollar figures. The regional level of per capita income, however, has been consistently higher than the state and national levels. In 1972 the estimated average income per person in the Region was approximately $3,836 in actual dollars and $3,060 in constant 1967 dollars. The spatial distribution of regional income on a household basis for 1963 and 1972 is shown on Map 7.

LAND USE BASE

The type and intensity of land use in a particular area exert a considerable influence on the quality of the ambient air since the degree of pollutant emissions depends on the areal extent and intensity of both rural and urban land use developments. Land use is also the principal factor determining transportation demand and, consequently, influences the spatial and temporal distribution of pollutant emissions from motor vehicles. A detailed, comprehensive inventory of existing land use is, therefore, essential to the identification, location, and quantification of existing sources of air pollutant emissions within the Region. Moreover, such an inventory, when coupled with a knowledge of historic development patterns, provides one of the best available bases for understanding urban activity and probable future land use patterns. Thus, attention is focused herein upon historical, as well as existing, land use development and upon regionwide factors influencing land use.

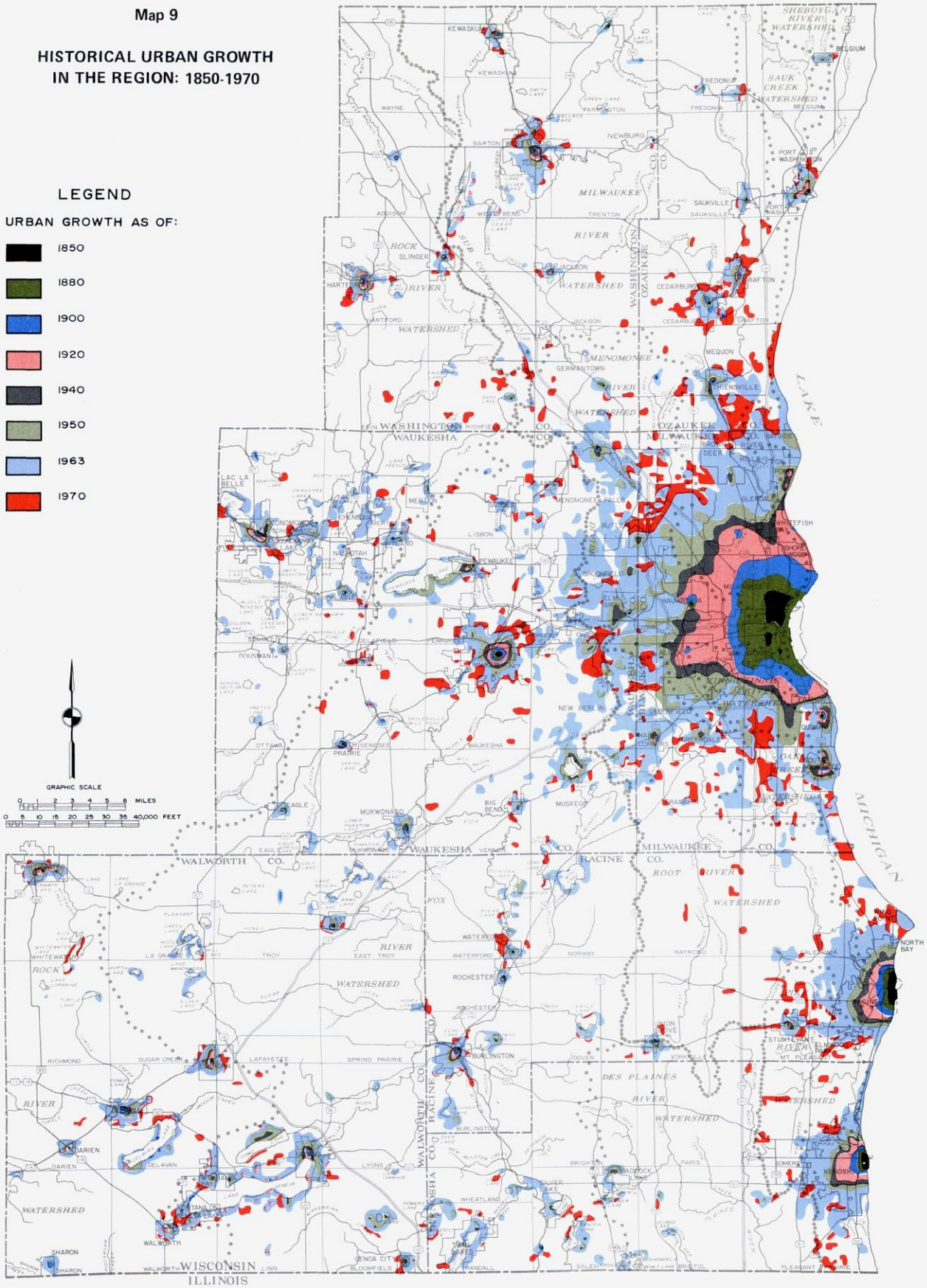
Historic Growth Patterns

The first permanent European settlement in the Region was established in 1795 as a trading post on the east side of the Milwaukee River, just north of what is now Wisconsin Avenue in the City of Milwaukee. The origins of most of the other existing urban centers within the Region can be traced to the establishment of such trading posts or to the establishment of certain types of agricultural services such as saw and grist mills. The location of these earliest urban activities was heavily influenced by water power and water transportation needs. Rapid settlement by Europeans of what is now the Southeastern Wisconsin Region followed the Indian cessions of 1829 and 1833, which transferred to the federal government ownership of all of the lands that now comprise the State of Wisconsin south of the Fox River and east of the Wisconsin River. Federal surveyors, after the close of the Blackhawk War of 1832, began to survey, subdivide, and monument the federal lands; and by 1836 the U.S. Public Land Surveys had been essentially completed in southeastern Wisconsin. Completion of the U.S. Public Land Surveys in the Region and subsequent sale of the public lands brought many settlers from New England, Germany, Austria, and Scandinavia. Initial urban development occurred along the Lake Michigan shoreline at the ports of Milwaukee, Port Washington, Racine, and Southport (now Kenosha), as these settlements were more directly accessible to immigration from the East Coast through the Erie Canal-Great Lakes transportation route. By 1850 there were more than 113,000 people in the Region, and the accompanying historic development existing in the Region at the time (see Map 9).

Changes over time in the amount of land devoted to urban use within the Region are indicated in Table 25, while the historic urban growth pattern is indicated on Map 9. The amount of land devoted to urban development within the Region has increased steadily since 1850. Over the 100-year period from 1850 to 1950, urban development within the Region occurred in relatively tight, concentric rings outward from the established urban centers of the Region, a pattern resembling the annual growth rings of a tree. A very dramatic change in the pattern of urban development within the Region, however, occurred in about 1950. From 1950 to 1963, while the regional population increased by about 30 percent, or by about one-third of a million persons, the amount of land devoted to urban use increased by almost 150 percent, or by about 102 square miles. Urban development became discontinuous and highly diffused, the term "urban sprawl" being quite descriptive of this more recent pattern of urban development within the Region. This pattern continued from 1963 to 1970, over which period an additional 57 square miles of land was actually converted from rural to urban use within the Region. If regional development trends continue as in the recent past, between 10 and 15 square miles of rural land may be converted to urban use each year within the Region. Under this type of urbanization, the entire seven-county Region is becoming a single mixed rural-urban complex. Many once isolated and independent communities are

Map 9

HISTORICAL URBAN GROWTH IN THE REGION: 1850-1970



Urban development within the Region occurred in a fairly regular pattern until about 1950, forming concentric rings of relatively high-density urban development contiguous to, and outward from, the existing urban areas and long-established mass transit, utility, and community facility systems. Soon after World War II, however, the character of urban growth began to change to a much more diffused pattern of urban development, with relatively low densities and a high proliferation of clusters of noncontiguous development. Between 1963 and 1970, the sprawl pattern continued, with an additional 96 square miles of land committed to urban use within the Region, representing a rate of about 14 square miles per year.

Source: SEWRPC.

Table 25

CHANGES IN POPULATION DENSITY IN THE REGION' 1850-1970

Year	Urban Population		Rural Population		Total Population	Area (Square Miles)		Persons Per Square Mile	
	Number	Percent of Total	Number	Percent of Total		Urban	Total	Urban	Total
1850	28,623	25.2	84,766	74.8	113,389	4	2,689	7,155.8	42.2
1880	139,509	50.3	137,610	49.7	277,119	18	2,689	7,750.5	103.1
1900	354,082	70.6	147,726	29.4	501,808	37	2,689	9,569.8	186.6
1920	635,376	81.1	148,305	18.9	783,681	56	2,689	11,346.0	291.4
1940[a]	991,535	92.9	76,164	7.1	1,067,699	90	2,689	11,017.1	397.1
1950[a]	1,179,084	95.0	61,534	5.0	1,240,618	138	2,689	8,544.1	461.4
1963[a]	1,634,200	97.6	40,100	2.4	1,674,300	340	2,689	4,806.5	622.6
1970[a]	1,728,949	98.5	27,137	1.5	1,756,086	397	2,689	4,355.0	653.1

[a] *The "rural-nonfarm" population is included in the urban total.*

Source: U. S. Bureau of the Census and SEWRPC.

growing together, and urban development is spilling over the subcontinental divide, which traverses the Region, into the Fox-Illinois River Valley.

The influence of the amenities afforded by certain elements of the natural resource base upon the pattern of urban development within the Region is clearly indicated on Map 9 by the pattern of development ringing the shorelines of the many inland lakes within the Region, as well as by the urban development bordering the shoreline of Lake Michigan. Although much of this lake-related development originally consisted of summer residences, most of these have been converted to year-round residences, and new lake-oriented development has been almost entirely of a year-round residential nature. This lake-oriented urban development within the Region has created certain serious lake water quality problems and holds important implications for the provision of sanitary sewerage service.

Historic Density Trends

The changes in population density within the Region from 1850 to 1970 are also shown in Table 25. During this 120-year period, the population of the Region increased nearly 15-fold, from about 113,000 persons to about 1.76 million persons, while the amount of land devoted to urban use increased almost 100-fold, from 4 square miles to 397 square miles. Overall population densities within the Region increased steadily from 42 persons per square mile in 1850 to 653 persons per square mile in 1970. As already noted, population densities within the developed urban area of the Region, however, have exhibited a quite different trend. Such population densities increased steadily from 7,156 persons per square mile in 1850 to a peak of 11,346 persons per square mile in 1920. Urban population densities then began a steady decline to a level of 8,544 persons per square mile in 1950. After 1950, urban population densities declined even more sharply to about 4,807 persons per square mile in 1963, and continued to decline to 4,355 persons per square mile in 1970. It should be noted, however, that although overall population densities within the developed urban areas of the Region have been steadily declining since 1920, this decline has been accompanied by localized increases in population densities. Such localized population increases may be the result of urban renewal activities or, in isolated instances, of what in effect constitutes new community development. For example, the Northridge Lakes community development within the northwestern portion of the City of Milwaukee will have a population density of about 15,000 persons per square mile when fully developed. Similarly, the redevelopment of certain older residential areas of the central cities and older suburbs within the Region, which replace single-family, duplex, or flat-type residential development with apartment development--often high-rise apartment development--may result in population density increases in localized areas. With respect to overall population densities within the Region, however, such high-density development and redevelopment are offset by large areas of new suburban and exurban development which, even when it involves apartment projects, results overall in relatively low urban population density. This continued overall decline in urban population density accompanied by localized increases has important implications for the provision of many public facilities and services and for air pollution problems and practical solutions to such problems.

These increases in population and urban land use and decreases in population density were accompanied by significant changes in the way of life within the Region. Widespread urban development in the rural-urban fringe areas of the Region well beyond the historic central cities

and their suburbs is a fairly recent phenomenon. In this area residents can enjoy many of the amenities of rural life and, yet avail themselves of a wide variety of urban services, including employment in urban industries. Such widespread urban development, however, serves to intensify certain long-standing environmental and developmental problems as well as to create new problems, of an unprecedented complexity and scale.

Existing Land Use

The amount and spatial distribution of land uses existing within the Region as of April 1970 are summarized graphically on Map 10. This map provides a picture of existing regional development at a given point in time, and its study can provide many valuable insights into regional activity and development and the areawide problems related thereto. The absolute and proportional areas presently devoted to each major land use category within the Region are summarized by county in Table 26.

Although southeastern Wisconsin is a highly urbanized region, less than 20 percent of its total area is presently devoted to urban land uses. The largest land use category within the Region is still agriculture, which presently occupies about 60 percent of the total area of the Region. The next largest land use categories are the water and wetland group and the woodlands and open lands category, both of which presently occupy 10 percent of the total area of the Region. Therefore, more than 80 percent of the Region is presently devoted to agriculture, woodlands, and other open lands, or lies under water.

Table 26

DISTRIBUTION OF LAND USE IN THE REGION BY COUNTY: 1970

County	Land Use									
	Residential[a]	Commercial	Industrial[b]	Transportation[c]	Government[d]	Recreation	Water and Wetlands	Open Lands[e]	Agricultural	Total
Kenosha										
Acres . . .	13,477	504	811	8,927	1,324	2,672	19,445	17,010	113,930	178,100
Percent . .	7.6	0.3	0.5	5.0	0.7	1.5	10.9	9.5	64.0	100.0
Milwaukee										
Acres . . .	45,632	2,875	4,899	35,431	7,490	9,924	4,207	15,999	28,607	155,064
Percent . .	29.4	1.9	3.2	22.9	4.8	6.4	2.7	10.3	18.4	100.0
Ozaukee										
Acres . . .	12,321	330	444	8,054	940	1,657	14,879	10,897	100,491	150,013
Percent . .	8.2	0.2	0.3	5.4	0.6	1.1	9.9	7.3	67.0	100.0
Racine										
Acres . . .	16,625	575	1,099	12,442	1,744	2,585	17,712	17,572	147,207	217,561
Percent . .	7.6	0.3	0.5	5.7	0.8	1.2	8.1	8.1	67.7	100.0
Walworth										
Acres . . .	13,408	593	827	12,020	1,192	4,275	39,160	36,763	261,744	369,982
Percent . .	3.6	0.2	0.2	3.3	0.3	1.2	10.6	9.9	70.7	100.0
Washington										
Acres . . .	11,525	299	434	11,286	919	1,664	35,638	30,503	186,466	278,734
Percent . .	4.1	0.1	0.2	4.1	0.3	0.6	12.8	10.9	66.9	100.0
Waukesha										
Acres . . .	43,278	1,341	1,525	21,247	3,009	6,219	49,789	43,562	201,676	371,646
Percent . .	11.6	0.4	0.4	5.7	0.8	1.7	13.4	11.7	54.3	100.0
Region										
Acres . . .	156,266	6,517	10,039	109,407	16,618	28,996	180,830	172,306	1,040,121	1,721,100
Percent . .	9.1	0.4	0.6	6.3	1.0	1.7	10.5	10.0	60.4	100.0

[a] *Includes all residential areas, developed and under development.*

[b] *Includes all manufacturing, wholesale, and storage.*

[c] *Includes off-street parking of more than 10 spaces.*

[d] *Includes institutional uses.*

[e] *Includes woodlands, unused lands, and quarries.*

Source: SEWRPC.

The urban-type land use occupying the greatest area is residential use, which presently accounts for about 9 percent of the total area of the Region. Residential use, however, accounts for about 47 percent of the urban-type land uses. A close second is the transportation, utilities, and communication category, which accounts for about 6 percent of the total area of the Region and about 33 percent of the urban-type land uses.

The very small area and proportion of land presently devoted to the urban economic activities, which are so important to the support of regional growth and development, are both surprising and significant. The amount of land area presently devoted to commercial, manufacturing, and wholesaling functions within the Region, exclusive of onsite parking, is only 16,554 acres, or 1 percent of the total land area, yet this small area provides the basis for more than 212,900 commercial, 252,100 manufacturing, and 32,000 wholesale jobs, or, in all, about two-thirds of the total jobs in the Region.

Residential: The residential category of the land use inventory included and identified both land actually occupied by a residence of some kind and vacant land which was either under development for residential use or immediately available for such use. The latter category included vacant building sites between existing residences and improved but still vacant residential subdivisions.

At the time of the 1970 land use inventory, there were 156,266 acres of land in the Region, or about 9 percent of the regional total, devoted to this land use. Table 27 details the amounts and relative proportions of land devoted to the different types of residential use. The largest land consumer in this group is the single-family detached residence, which occupies about 78 percent of the total residential land area in the Region. Lands under residential development accounted for about 16 percent of the total, while two-family residences accounted for about 4 percent of the total. Mobile homes and multiple-family residences combined consumed less than 2 percent of the total residential land in the Region.

Commercial: The commercial land use category includes all retail and service-type commercial uses, including both local and regional shopping centers, highway-oriented commercial areas, and professional and executive offices, excluding onsite parking of more than 10 spaces. There are presently 6,517 acres of land in the Region, or less than 1 percent of the regional total, devoted to this land use category.

Industrial: This land use category includes all manufacturing activities, wholesaling offices, warehouses, and storage yards but excludes onsite parking of 10 or more spaces. There are presently 10,039 acres of land in the Region, or less than 1 percent of the regional total, devoted to this land use category.

A trend in the location of industrial activity within the Region has developed between 1963 and 1970, with industrial development occuring throughout the western areas of the Region. This pattern is consistent with the total job growth for the Region shown in Table 22, and again indicates the general decentralization pattern of economic activity within the Region (see Map 8).

Table 27

RESIDENTIAL LAND USE IN THE REGION BY TYPE: 1970

Type of Residential Use	Acres	Percent
Single-family	122,507	78.4
Two-family	5,573	3.6
Multifamily (less than 4 stories)	2,970	1.9
Multifamily (4 or more stories)	118	0.1
Mobile Homes	515	0.3
Residential Land Under Development	24,583	15.7
Total	156,266	100.0

Source: SEWRPC.

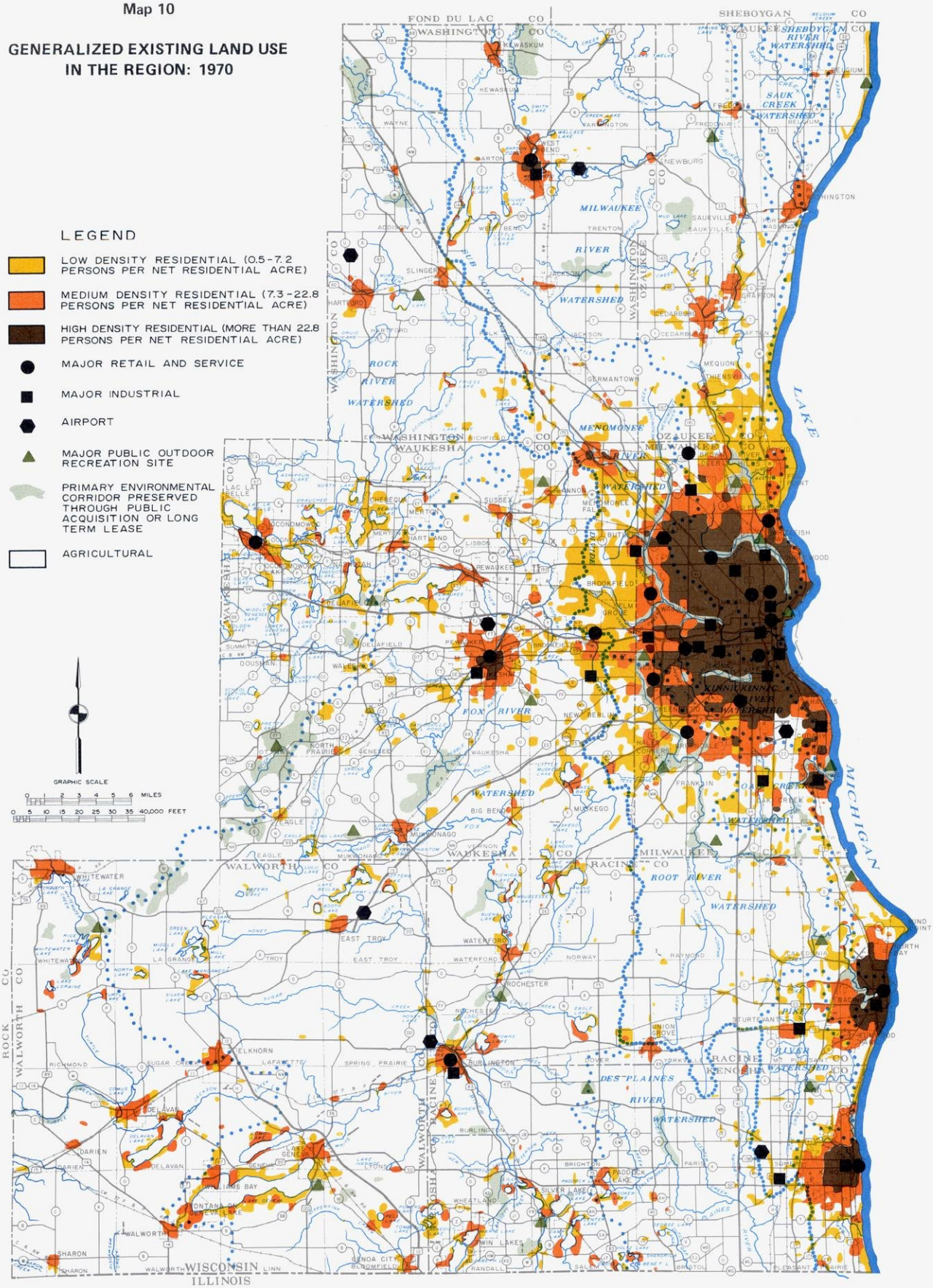
Communication, Utility, and Transportation: The communication, utility, and transportation land use category includes all street and highway rights-of-way; railroad rights-of-way and yards; airport, rail, ship, bus, and truck terminals; communication facilities, such as radio or television stations and transmission towers; utility rights-of-way and plants, such as sewage disposal and water treatment and storage facilities; and all offstreet parking areas containing more than 10 parking spaces. There are presently 109,407 acres of land in the Region, or about 6 percent of the regional total land area, devoted to this land use category. Of this total, 10,470 acres, or nearly 10 percent, are devoted to communication and utility facilities and rights-of-way. In addition, 19,203 acres, or about 18 percent of the total, are devoted to all other transportation uses except street and highway rights-of-way. A total of 79,734 acres, or approximately 73 percent of all land comprising this category, are devoted to street and highway rights-of-way, including local land access, collector, and arterial streets and highway rights-of-way.

Of the total land area devoted to these transportation rights-of-way, 44,334 acres, or nearly 56 percent, are devoted to local and collector streets, the primary function of which is access and service to residential development.

Governmental, Institutional, and Recreational: The land areas devoted to governmental, institutional, and active recreational uses were classified in the land use inventory according to local or regional service orientation. If the service emphasis of a governmental or institutional use was oriented toward more than one community (minor civil division), it was classified as regional. If such service emphasis was oriented toward a single community or neighborhood, except for high schools in the City of

Map 10

GENERALIZED EXISTING LAND USE IN THE REGION: 1970



This map summarizes the spatial distribution of land uses existing within the Region as of April 1970. Although southeastern Wisconsin is a highly urbanized Region, less than 20 percent of its total area is presently devoted to urban-type land uses. Agriculture, while declining in economic importance within the Region, still occupies 60 percent of the total land use in the Region, with the remaining 20 percent being occupied by water, woodlands, and wetlands.

Source: SEWRPC.

Milwaukee, it was classified as local. Regional uses include universities and colleges, certain high schools, large central libraries, museums, zoological and botanical gardens, golf courses, bathing beaches, marinas, major athletic fields, hospitals, county courthouses, welfare agencies, and military installations. Local uses include elementary schools; certain high schools; churches; branch libraries; fire stations; all active park areas other than those classified as regional; and city, village, and town halls. All recreational facilities were further classified as public or nonpublic. There are presently 45,614 acres of land in the Region, or about 3 percent of the regional total, devoted to the governmental, institutional, and recreational land use category. Of this total, 22,231 acres, or about 45 percent, are oriented toward Region-serving activities. This is not surprising when the land-consuming nature of such uses as golf courses, cemeteries, and military installations is considered.

Woodlands and Open Lands: This land use category includes all land areas presently containing trees or heavy brush; lands not presently devoted to urban use, crops, or grazing; land areas presently devoted to such temporary uses as sites for solid waste disposal; and quarries, either operating or non-operating. There are presently 172,306 acres of land in the Region, or nearly 10 percent of the regional total, devoted to this land use category. Approximately 73 percent of this area is devoted to woodlands, and about 22 percent is devoted to open lands, including unused lands. Only 5 percent, or 8,348 acres, is classified as quarries or pits.

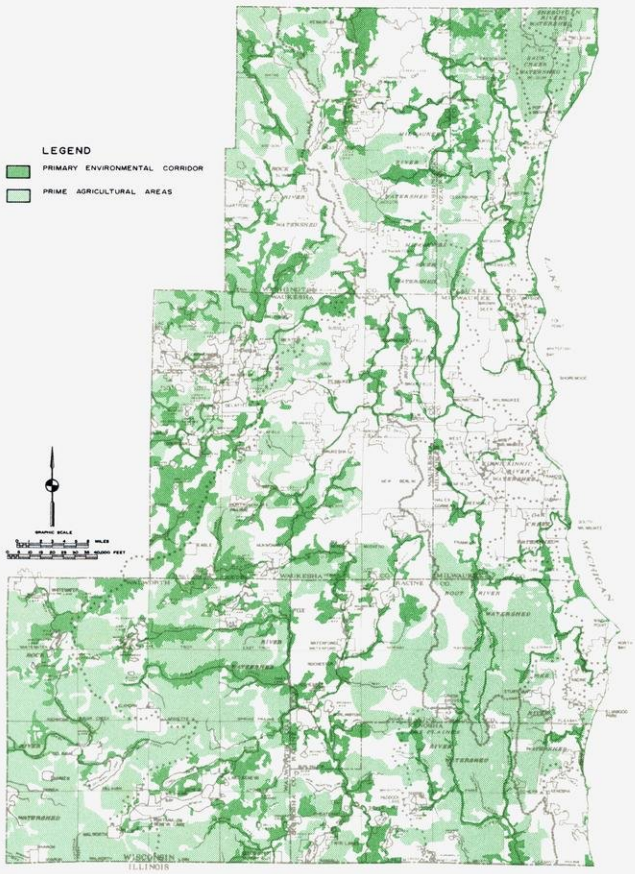
Water and Wetlands: The water and wetlands use category includes all inland lakes; all streams, rivers, and canals more than 50 feet in width; and open lands which are intermittently covered with water or which are wet due to a high water table. Presently there are 180,830 acres of water and wetland areas in the Region, or about 10 percent of the regional total.

Agricultural: The agricultural land use category includes all croplands, pasturelands, orchards, nurseries, and fowl and fur farms. Farm dwelling sites were classified as residential land and assigned a site area of 20,000 square feet. All other farm buildings were included in the agricultural land use category. Agriculture is the largest land use in the Region, and about 60 percent of the total area of the Region, or 104,012 acres, is devoted to this use.

Approximately 491,000 acres, or about 29 percent of the regional total, are classified as prime agricultural land. The extent and spatial distribution of these areas are shown on Map 11. Prime agricultural lands have soils particularly well suited for agricultural use. The delineation of these lands is based upon the size and extent of the area farmed; the historic capability of the area to consistently produce better than average crop yields; and the relationship of such lands to important high-value recreational, cultural, or scientific resource areas.

Map 11

PRIME AGRICULTURAL AREAS IN THE REGION: 1970



Approximately 491,000 acres, or nearly 29 percent of the total area of the Region, have been identified in regional planning analyses as prime agricultural lands. The preservation of these lands in agricultural use will contribute significantly to the maintenance of a healthy economical balance within the Region; provide for the production of certain food commodities within close proximity to the urban centers of the Region; provide open space to give form and structure to urban development; and contribute to the charm and beauty of the Region.

Source: SEWRPC.

TRANSPORTATION BASE

Transportation facilities, including surface, air, and water facilities, are important elements influencing travel characteristics and the spatial distribution of rural and urban development, and, consequently, local ambient air quality, within an area.

Surface Transportation Facilities

Surface transportation facilities within the Region are of three basic types: arterial streets and highways, including freeways and expressways; collector and minor streets, including subdivision roads and cul-de-sacs; and mass transportation facilities. These three major types of sur-

face transportation facilities form an integrated network which determines the pattern of movement of people and goods throughout the Region and, consequently, the amount and spatial distribution of air pollutant emmissions from vehicular sources. Because of the importance of transportation movements to air quality maintenance planning, a brief discussion of each of the three major types of surface transportation facilities in southeastern Wisconsin follows.

Arterial Street and Highway Facilities: The accessibility provided by the regional transportation system influences the spatial location, intensity, and type of land use development. The extensively developed, all-weather highway system within the Southeastern Wisconsin Region has had a marked influence on the spatial location of urban development. This influence has, however, been significantly modified by the location within the Region of such natural resources as lakes, streams, woodlands, and fertile farmlands. The major highway network within the Region as it existed in 1963 and 1972 is shown on Maps 12 and 13, respectively. The network consists of an essentially radial pattern of state and county trunk highways interconnecting the urban and rural areas of the Region. Most of the arterial highways presently (1972) carrying traffic volumes in excess of 4,000 vehicles per average weekday are major intercity routes carrying traffic to and from the Region's three central cities of Milwaukee, Kenosha, and Racine.

An inventory of highway facilities and service levels was conducted as part of the Commission's initial regional land use-transportation planning effort and is periodically updated under the Commission's continuing land use-transportation planning effort. Definitive data are collected to permit calculation of the capacity of each of the approximately 5,200 links or segments comprising the 3,100-mile arterial street and highway system as that system presently exists within the Region. Summaries of the arterial street and highway system mileage, vehicle miles of travel, and volume-to-capacity ratios are developed on a system-wide basis from the inventory data. Table 28 presents the total street and highway system mileage and arterial system mileage by facility type within each county of the Region for 1972. The table indicates that the total street and highway mileage within the Region was 9,819 miles in 1972, with arterial street and highway mileage comprising 3,119 miles, or about 32 percent of the total street and highway system.

Collector and Minor Streets: Collector and minor streets provide access to the individual neighborhoods of the urban areas and to the individual building sites of these neighborhoods, and comprise the majority of the land area devoted to surface transportation use. These land access and collector streets also serve as rights-of-way for community utilities, such as sanitary sewers, water mains, storm drains, and gas and electric power lines. In addition, land access streets and collector streets assure the provision of light and air to the individual building sites comprising the urban area and provide the overland drainage system for that area. As indicated in Table 28, there was a total of 6,700 miles of collector and minor streets in the Region in 1972, representing approximately 68 percent of the total street and highway mileage in the Region at that time.

Mass Transportation Facilities: A network of mass transit facilities complements and supplements the surface transportation service provided by the regional arterial street and highway network. Indeed, in many instances the only means of affordable transportation, especially for low and moderate-income households, is made available through mass transit facilities.

Mass transportation may be defined as the transportation of relatively large groups of people by relatively large, generally publicly or quasi-publicly owned vehicles routed between or along significant concentrations of related trip origins and destinations. Some form of mass transportation is essential in sizable urban area, not only to meet the needs of that segment of the population unable to command direct use of personalized transportation, but to provide an alternative, more efficient mode of travel for certain types of trips within and between urban areas. The supply and use of mass transit are discussed more completely in other Commission publications, and only a brief description of transit services within the Region is provided in this section.

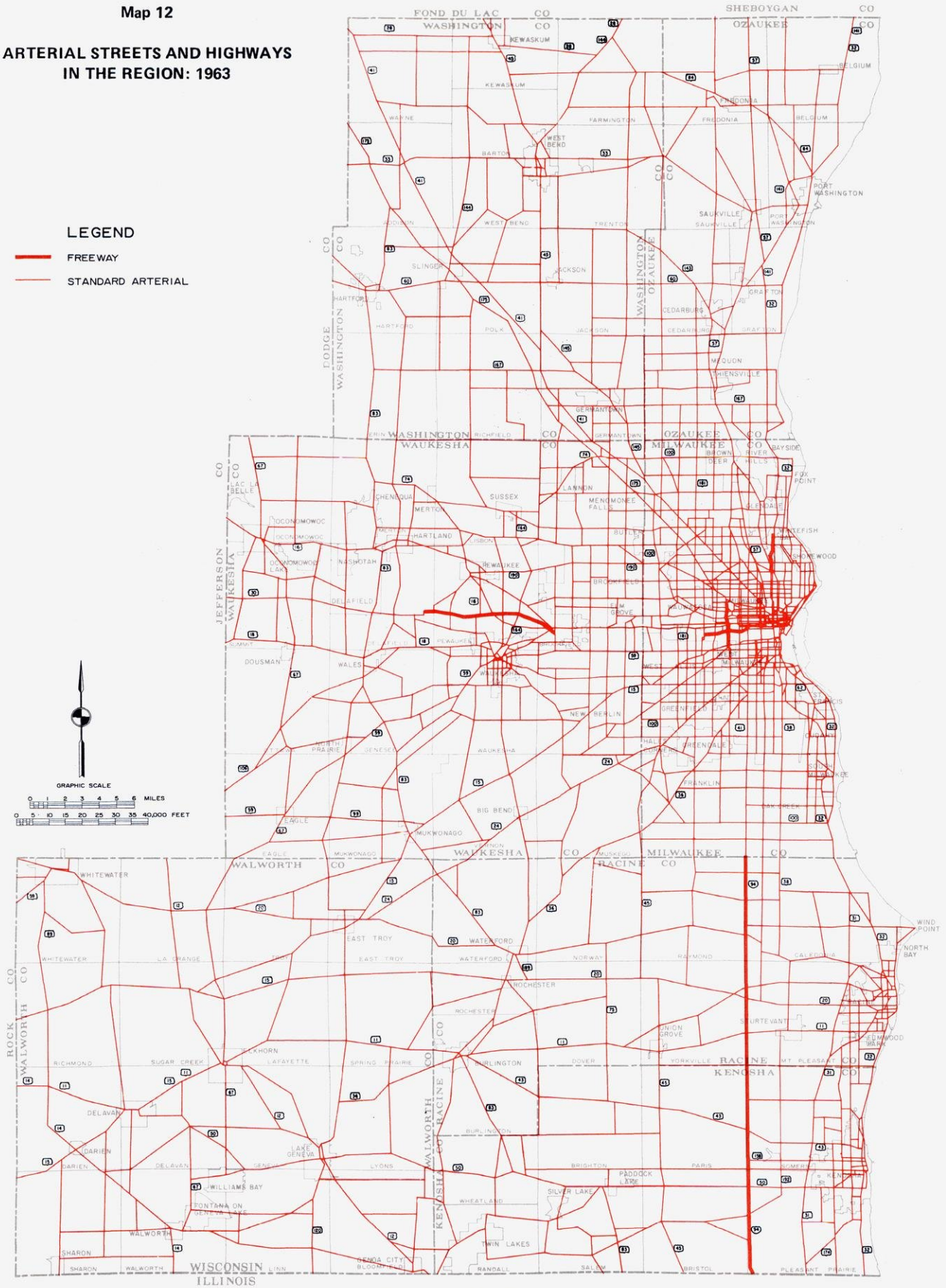
Intraregional: The intraregional common carrier fixed route service may be subdivided into primary, secondary, and tertiary levels of service. The primary level of service is intended to facilitate transregional, or intercommunity, travel by connecting the various major activity centers and communities of the Region. Thus, the primary level service consists of service provided by those mass transportation facilities which join the major regional activity centers, such as regional commercial, industrial, institutional, and recreational centers, to each other and to the residential communities comprising the Region. The major purpose of the primary level of mass transportation service is to provide a network of relatively high-speed lines which serve and connect these kinds of centers and residential communities. Primary level mass transportation service is characterized by relatively high operating speeds and relatively low accessibility.

Primary transit service may be further subdivided into rapid and modified rapid transit subcategories. Rapid transit service can be defined as service provided at relatively high operating speeds over exclusive, fully grade-separated rights-of-way with station stops, if any, between terminals generally located no less than one mile or more apart. Rapid transit service may, thus, be provided by commuter rail facilities, by "heavy" rail transit facilities, or by motor buses operating on exclusive busways. Modified rapid transit may be provided by motor buses operating in mixed traffic on freeways or by "light" rail facilities if such facilities are provided with an exclusive but not necessarily fully grade-separated right-of-way.

The secondary level of intraregional common carrier fixed route service consists of express service. This is defined as service provided over arterial streets with stops

Map 12

ARTERIAL STREETS AND HIGHWAYS IN THE REGION: 1963

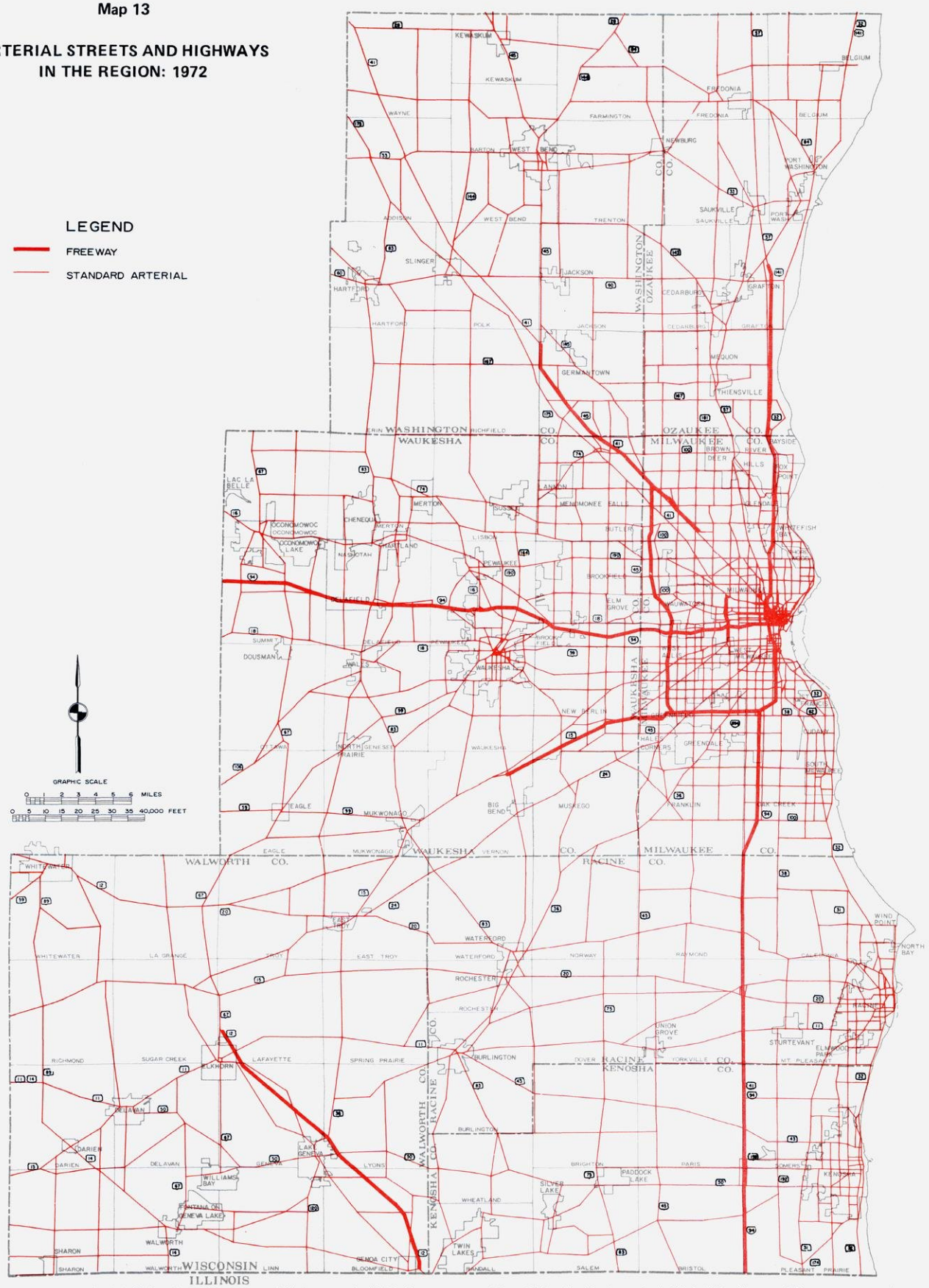


In 1963 there were a total of 8,943 miles of streets and highways of all kinds—arterial, collector, and land access—open to traffic within the Region, of which 3,188 miles, or 36 percent, were functioning as arterial streets and highways. Although the responsibility for the financing, construction, operation, and maintenance of these arterial facilities rests with one federal agency, one state agency, seven county units of government, and 147 local units of government within the Region, these facilities must form a single integrated system able to safely and efficiently serve the existing and probable future travel demands within the Region without regard to county and municipal boundary lines.

Source: SEWRPC.

Map 13

ARTERIAL STREETS AND HIGHWAYS IN THE REGION: 1972



By 1972 there were a total of 9,819 miles of streets and highways of all kinds open to traffic within the Region, of which 3,119 miles, or 32 percent, were functioning as arterial streets and highways. This represents a reduction of 69 miles, or about 2 percent, from the total arterial street and highway mileage existing in the Region in 1963. This reduction in the arterial street system was the result of refinements in the delineation of the arterial network under the county jurisdictional highway system planning programs. These refinements reflect, in part, the effects of new facility—particularly freeway—construction and, in part, a greater acceptance of the neighborhood unit concept in local planning with its important implications for the location and spacing of arterial street and highway facilities. The arterial facilities removed from the system in this process were reverted to collector or land access classification and use.

Source: SEWRPC.

Table 28

DISTRIBUTION OF STREET AND HIGHWAY MILEAGE IN THE REGION BY COUNTY AND TYPE OF FACILITY: 1972

County	Mileage by Type of Facility - 1972						
	Arterial				Collector and Minor Streets	Total[a]	Arterial Miles As Percent of Total
	Freeway and Expressway	Freeway and Expressway Ramps	Other	Total			
Kenosha	12.1	7.4	267.7	287.2	593.3	880.5	32.6
Milwaukee	64.5	61.5	669.7	795.7	1,851.7	2,647.4	30.1
Ozaukee	13.0	3.2	237.3	253.5	466.7	720.2	35.2
Racine	12.0	6.0	337.4	355.4	728.0	1,083.4	32.8
Walworth	19.1	3.8	389.1	412.0	846.9	1,308.9	31.5
Washington	28.5	5.6	310.7	344.8	821.1	1,165.9	29.6
Waukesha	46.4	21.7	602.1	670.2	1,342.5	2,012.7	33.3
Region	195.6	109.2	2,814.0	3,118.8	6,700.2	9,819.0	31.8
Percent of Total	6.3	3.5	90.2	100.0	68.2	100.0	--

[a] *Total street and highway mileage does not include private streets and roads or roads in public park and institution lands.*

Source: Wisconsin Department of Transportation and SEWRPC.

generally located at intersecting transit routes and major traffic generators, generally no less than 1,200 feet apart. The secondary mass transportation system may provide "feeder" service to the primary system as well as greater depth and breadth of access from subregional areas. Secondary express service could be provided by motor bus or by light rail cars when such vehicles are operated in mixed traffic on shared rights-of-way. The operation of motor buses or light rail vehicles over exclusive lanes within an otherwise shared right-of-way would constitute a high level of secondary service. In general, secondary mass transit service may be distinguished from primary mass transit service in that it provides a greater degree of accessibility at somewhat slower operating speeds.

The tertiary level of fixed route common carrier mass transportation service is characterized by a high degree of accessibility and a relatively low operating speed. This tertiary level may be subdivided into two categories: local and collection-circulation-distribution. Local service may be defined as service provided primarily over arterial and collector streets with stops for passenger pickup and discharge located no more than 1,200 feet apart. Such service could be provided by motor bus, trolley bus, or light rail vehicles. Collection-circulation-distribution service may be defined as service provided for the movement of passengers within major activity centers by motor bus or ban, trolley bus, light rail vehicles, automated guideway vehicles, and other types of people movers such as moving ramps.

Each of the three categories of intraregional fixed route mass transit service was provided within the Region in 1972. Primary service consisted entirely of the modified rapid transit "freeway flyer" motor bus service provided in the Milwaukee urban area by the Milwaukee and Suburban Transport Corporation.

Secondary intraregional mass transit service in the Region for the year 1972 was largely composed of express bus lines operated by Wisconsin Coach Lines, Inc., and by the Milwaukee and Suburban Transport Corporation. The secondary service provided by the Transport Corporation consists of two express bus lines, one from the Milwaukee Central Business District (CBD) south toward the southerly lakeshore suburbs of Milwaukee and the other from the Milwaukee CBD west and north to the Washington Park area of Milwaukee. Secondary mass transit service provided by Wisconsin Coach Lines, Inc., was found in the Milwaukee-Waukesha corridor with 17 eastbound trips and 20 westbound trips per weekday. Secondary service between Milwaukee and Port Washington, Watertown, Racine, and Kenosha also was provided.

Tertiary mass transportation service was provided in the Kenosha, Milwaukee, and Racine urbanized areas in 1972. The Kenosha Transit-Parking Commission provided tertiary service in the Kenosha urbanized area; the Milwaukee and Suburban Transport Corporation provided such service within Milwaukee County; Wisconsin Coach Lines, Inc. provided such service in the City of

Waukesha; and Flash City Transit Company provided such service in the Racine urbanized areas. In addition, a tertiary level collection-circulation-distribution system was operated by the University of Wisconsin-Parkside in Kenosha County.

Interregional: In addition to the intraregional mass transit service described above, interregional bus service is provided by eight private operators which together operated over about 500 miles of streets and highways within the Region in 1972. These carriers are Badger Coaches, Inc.; Central-West Motor Stages, Inc.; Greyhound; North American Coach Company; Peoria-Rockford Bus Company; Tri-State Coach Lines, Inc.; Wisconsin Coach Lines, Inc.; and Wisconsin-Michigan Coaches, Inc. Interregional railroad passenger service is provided within the Region by the National Railroad Passenger Corporation (AMTRAK) from the City of Milwaukee and the Village of Sturtevant. Interregional commuter railroad service to Chicago is operated by the Chicago, Milwaukee, St. Paul & Pacific Railroad (Milwaukee Road) from the Village of Walworth and by the Chicago & Northwestern Transportation Company from the City of Kenosha. C&NW service from the City of Lake Geneva was discontinued in August 1975.

System Utilization

In order to provide a measure of the utilization of the existing arterial street and highway system, the Commission periodically obtains average weekday traffic volume counts for each segment, or link, in the system. Traffic volume-counting programs conducted by the Wisconsin Department of Transportation and by the County and City of Milwaukee on a regular continuing basis provided much of the necessary current traffic volume data. In order to obtain complete data for the entire arterial network, however, these counts are supplemented by counts taken by other local municipalities, as well as by the Commission itself. These programs, which included control and sampling counts for the arterial system as a whole, also included the cordon and screen line counts necessary to evaluate the accuracy of the Commission origin and destination surveys.

The complete nature of the traffic counting program in the Region makes it possible to estimate with a high degree of confidence the average weekday and peak-hour traffic flows on all segments of the arterial network and to calculate total vehicle miles of travel on the arterial street and highway system. As shown on Map 14, arterial streets and highways are most heavily utilized in the urban areas of the Region. In fact, more than 43 percent of all urban arterial facilities have average weekday volumes of more than 8,500 vehicles, while more than 66 percent of all rural arterial facilities have average weekday volumes of less than 2,400 vehicles.

Significant changes have occurred over the last decade regarding the utilization of the arterial street and highway system as indicated by a comparison of the 1963 traffic flows on Map 14 with the 1972 traffic flows as depicted on Map 15. The changes in the system utilization result in part from new urban development and in part from the redistribution of traffic flows, which resulted from significant additions to the freeway system completed within the Region since 1963. The completed freeway segments carry heavy volumes of traffic and have generally resulted in reductions in traffic flows on facilities paralleling the freeways and in increases in traffic flows on the arterial facilities serving the freeway interchanges.

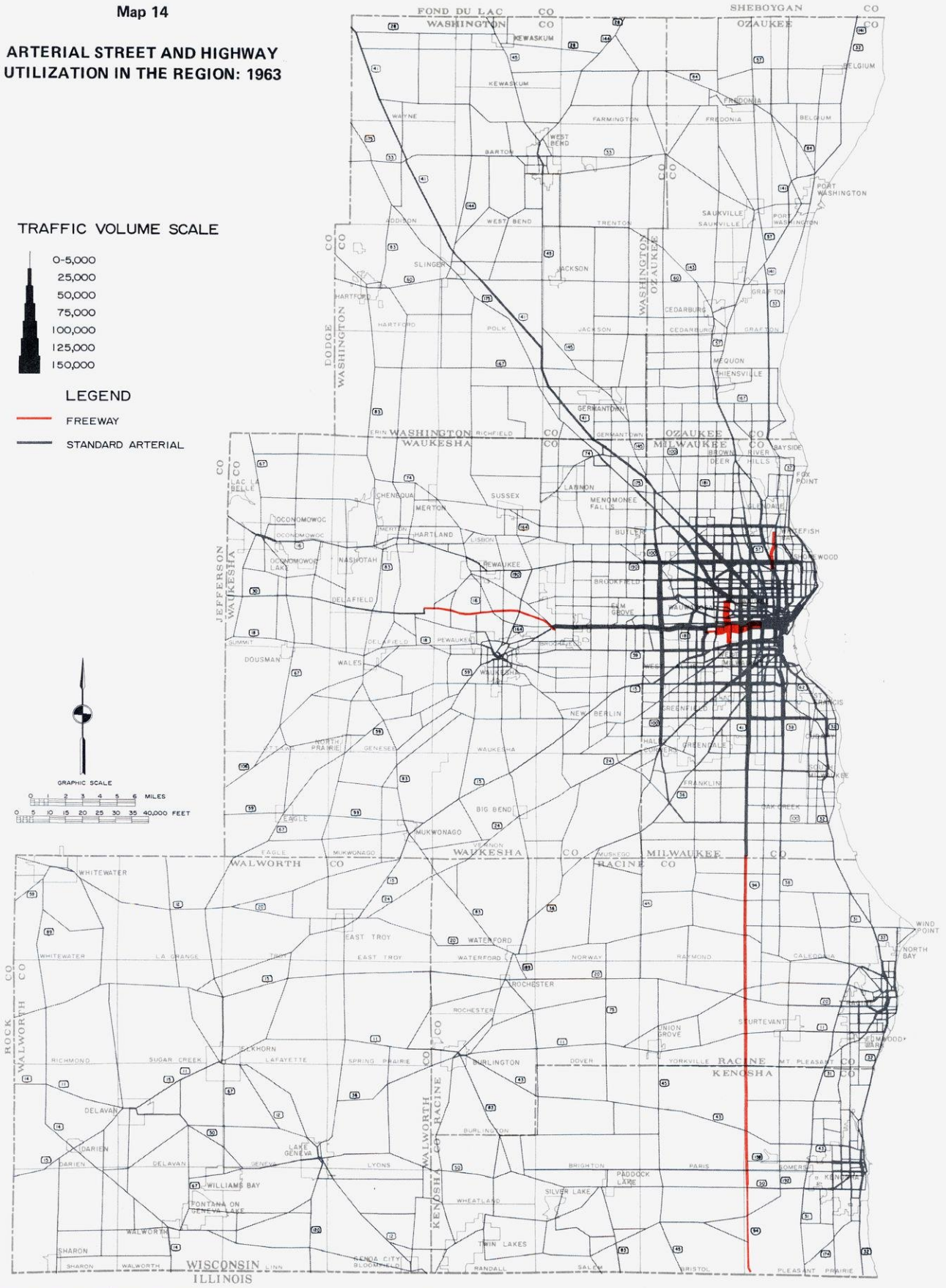
The utilization of arterial streets and highways within the Region can also be expressed in terms of the total vehicle miles of travel occurring on the arterial street and highway system. More than 20.1 million vehicle miles of travel occurred on this system within the Region on an average weekday in 1972 (see Table 29). Most of this travel occurred within urban areas. Milwaukee County alone accounted for 54 percent of the total arterial vehicle miles of travel, and exhibited by far the most intensive use of the existing arterial street and highway system, with more than 13,400 vehicle miles of travel per mile of arterial street and highway.

Table 29 indicates the changes in the distribution of the vehicle miles of travel which have occurred within the Region since 1963. the demand on the arterial system, measured in terms of vehicle miles of travel and on an average weekday, increased from 13.1 million to 20.1 million vehicle miles, or approximately 54 percent, between 1963 and 1972. The largest increases in utilization occurred in Milwaukee and Waukesha Counties, with increases of about 3.3 million vehicle miles of travel, or 47 percent of the regional increase, and 1.5 million vehicle miles of travel, or 22 percent of the regional increase, respectively over the nine-year period. Together these two counties accounted for about 69 percent of the total increase within the Region. The highest rates of increase in arterial system use occurred in Waukesha and Ozaukee Counties, which experienced approximately 85 and 76 percent rates of increase, respectively.

Analysis of the current use and of changes in the use of the arterial street and highway system of the Region clearly indicates that the freeway and expressway system has become the basic foundation of the regional surface transportation system. In 1963, freeways and expressways, which then comprised 4 percent of the existing arterial street and highway system, carried slightly more than 11 percent of the total vehicle miles of arterial travel. By 1972, freeways and expressways comprised 10 percent of the existing arterial street and highway mileage, but carried approximately 31 percent of the total arterial vehicle miles of travel. Moreover, of the increase of 7.1 million daily vehicle miles of travel occurring between 1963 and 1972, about 68 percent, or 4.8 million vehicle miles, occurred on the freeway system, while only 32 percent, or 2.3 million vehicle miles, occurred on the standard surface arterials. This shift to utilization of freeway facilities has been greatest in Milwaukee County, where total daily vehicle miles of travel on the freeway system increased more than seven-fold, from about 0.53 million in 1963 to approximately 3.98 million in 1972,

Map 14

ARTERIAL STREET AND HIGHWAY UTILIZATION IN THE REGION: 1963

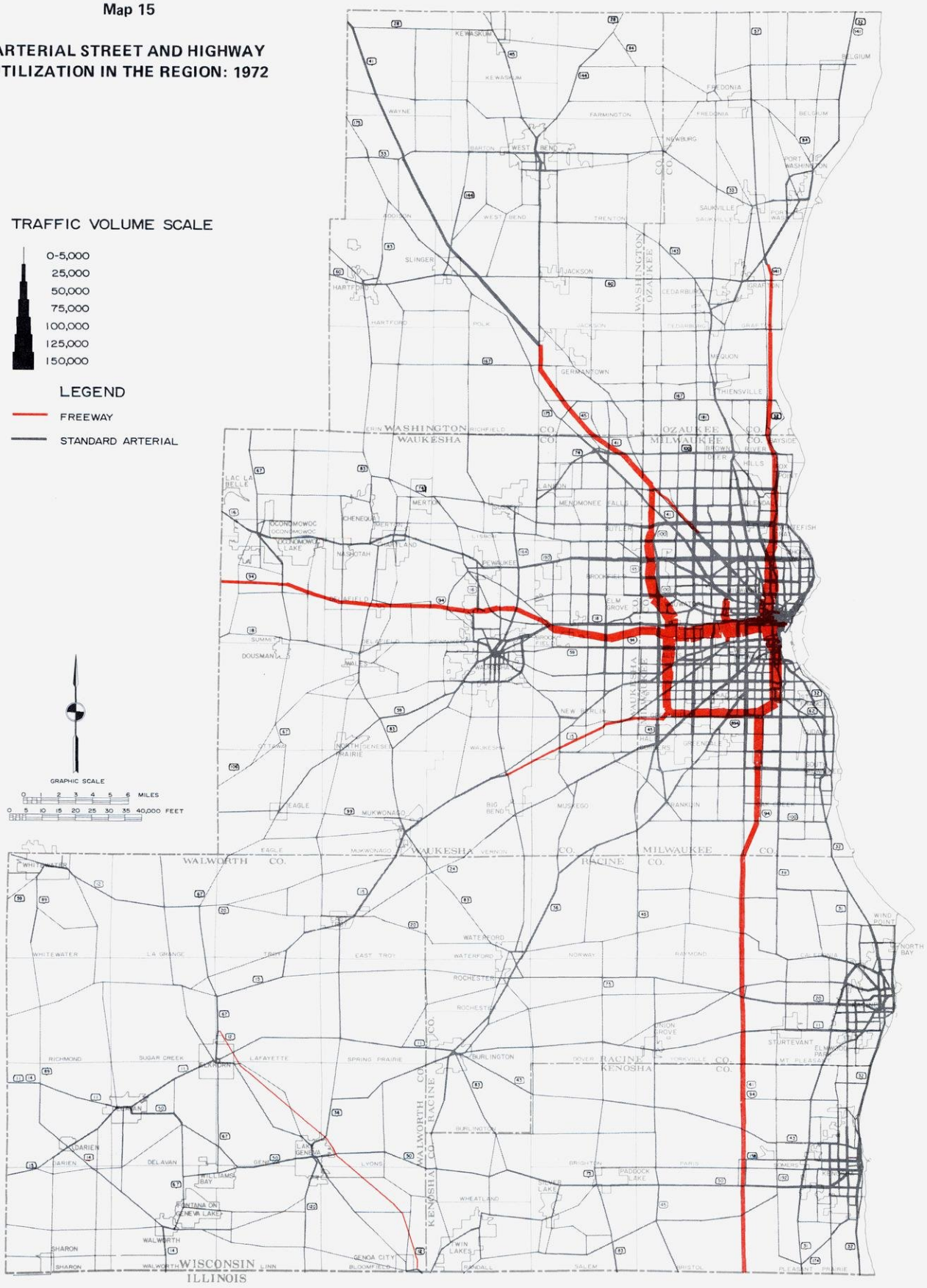


Average weekday traffic flows on the arterial street and highway system in the Region in 1963 are shown on the above map. This traffic flow pattern is largely representative of prefreeway conditions in the Region, since very few miles of urban freeway were open to traffic in 1963. In the Milwaukee metropolitan area, very heavy traffic volumes occurred on such standard surface arterials as Bluemound Road, S. 27th Street, Capitol Drive, Fond du Lac Avenue, Appleton Avenue, Oklahoma Avenue, and STH 100, the former metropolitan bypass route.

Source: SEWRPC.

Map 15

ARTERIAL STREET AND HIGHWAY UTILIZATION IN THE REGION: 1972



By 1972, the regional freeway system had been developed to the point where significant changes in the utilization of the arterial street and highway system had occurred. The freeways had become highly efficient and immensely popular carriers of travel, as indicated by the heavy volumes of freeway travel shown on the above map. Significant reductions in traffic flows on facilities in the travel corridors served by newly constructed freeways have been effected, as shown by a comparison of the above map with Map 14. Traffic flows have been held at or actually reduced below 1963 levels, for example, on Bluemound Road, S. 27th Street, Oklahoma Avenue, and STH 100. Where freeways have not been built in accordance with adopted regional transportation plan recommendations, such as, for example, the Bay Freeway and Fond du Lac Freeway travel corridors, traffic volumes on the standard surface arterials have significantly increased.

Source: SEWRPC.

Table 29

ARTERIAL VEHICLE MILES OF TRAVEL IN THE REGION ON AN AVERAGE WEEKDAY BY COUNTY: 1963 AND 1972

County	1963 Average Weekday Vehicle Miles of Travel (in thousands)			
	Freeway and Expressway	Freeway and Expressway Ramps	Other Arterials	Total
Kenosha	202	2	734	938
Milwaukee	454	77	6,817	7,348
Ozaukee	18	2	464	484
Racine	202	1	922	1,125
Walworth	--	--	685	685
Washington	343	2	351	696
Waukesha	147	12	1,637	1,796
Region	1,366	96	11,610	13,072

County	1972 Average Weekday Vehicle Miles of Travel (in thousands)				Increment (in thousands) 1963 to 1972	
	Freeway and Expressway	Freeway and Expressway Ramps	Other Arterials	Total	Number	Percent
Kenosha	375	7	1,046	1,428	490	52.2
Milwaukee	3,635	342	6,718	10,695	3,347	45.5
Ozaukee	215	8	627	850	366	75.6
Racine	409	6	1,398	1,813	688	61.2
Walworth	54	2	817	873	188	27.4
Washington	187	3	961	1,151	455	65.4
Waukesha	930	40	2,344	3,314	1,518	84.5
Region	5,805	408	13,911	20,124	7,052	53.9

Source: Wisconsin Department of Transportation and SEWRPC.

while total daily vehicle miles of travel on standard surface arterials in the County actually decreased slightly from 6.8 million in 1963 to 6.7 million in 1972.

A significant characteristic of the utilization of the arterial street and highway system is the average trip length of the travel occurring on each segment. A relationship exists between the average trip length on a street or highway and the level of service it provides, since tripmakers making longer trips commonly utilize those arterial facilities which maximize travel speed, safety, convenience, and comfort. Thus, arterial streets and highways providing the highest levels of service are normally utilized by travel exhibiting the longest trip lengths. The pattern of average trip length in 1963, as shown on Map 16, underwent substantial modifications between 1963 and 1972, primarily because of the completed additions to the regional freeway system. Map 17 shows the average trip lengths on each segment of the existing arterial street and highway system in 1972. The longest trip lengths, as expected, occur on the freeway and expressway system, which provides the highest level of traffic service and which has regional and interregional continuity.

Relationship of Arterial System Use to Capacity

The relationship between the average daily weekday traffic utilizing a particular section of the arterial system and its design capacity referred to as the volume/capacity (V/C) ratio, is a useful means of identifying and quantifying existing and probable future imbalances between arterial street and highway use and supply. This relationship, when determined and evaluated for the entire arterial system, is also useful in identifying major travel corridors where additional capacity is needed even under existing travel demands.

This volume/capacity ratio was computed for each link of the arterial network. The results are indicated on Map 18 for 1963 and Map 19 for 1972. In order to facilitate their presentation and subsequent analysis, the V/C ratios have been grouped into three categories: under capacity, V/C

= 0.90 or less; at capacity, V/C = 0.91 to 1.10; and over capacity, V/C = 1.11 or more. The significance of these ranges of volume-to-capacity ratios is that those facilities operating under design capacity provide fully adequate service having stable flow and few restrictions on operating speed; those facilities operating at design capacity provide adequate service having stable flow, higher volume, and more restrictions speed and lane changing, while experiencing restricted traffic flow at times; and those facilities operating over design capacity experience traffic congestion at times approaching unstable flow, and little freedom to maneuver.

As shown on Map 19 and in Table 30, which identify the distribution of the arterial segments operating at these levels of congestion, most of the arterial system mileage within the Region operating at or over design capacity is located in the intensely developed urban areas. Of the arterial street and highway mileage within the Region which is presently (1972) operating at or over design capacity, 87 percent is located within the Milwaukee, Racine, and Kenosha urbanized areas. Moreover, as summarized in Table 30, more than 16 percent of Milwaukee County's arterial mileage is presently operating at or over design capacity. At the same time, not more than 7 percent of the arterial mileage in the three still primarily rural counties--Ozaukee, Walworth, and Washington– is operating at or over design capacity.

Between 1963 and 1972, the number of miles of arterial streets and highways operating over design capacity was reduced from 191.8 to 165.6, or by 14 percent (see Table 30). The number of miles of arterials operating at design capacity, however, increased from 139.9 in 1963 to 151.9 in 1972, or by 9 percent. Thus, the effect of changes in arterial supply and use from 1963 to 1972 was a net reduction of 14.2 miles, or 4 percent–from 331.7 to 317.5 miles--in facilities operating at or over design capacity. These changes have been brought about largely through the construction of the freeway system, which has served to accommodate more than 67 percent of the increase in travel within the Region over the nine-year period as measured by vehicle miles of arterial travel.

Utilization of Mass Transit Facilities

A comparison of route miles, population, and area served by local transit in 1963 and 1972 in shown in Table 31. The local transit service area increased between 1963 and 1972 in each of the urban areas. The largest change--37 percent--in service area took place in the Kenosha urban area. The service areas in the Racine and Milwaukee areas also increased, but by smaller increments. The Kenosha urban area also experienced the largest change--13 percent--in resident population served. Round-trip route miles of service provided increases in all three urbanized areas, with the Milwaukee urban area increasing by about 27 percent. In spite of this large increase in the Milwaukee urban area, the resident population served declined by about 1 percent since 1963, indicating that, due primarily to declining population densities, a large expansion in route miles was required simply to serve about the same number of residents.

A comparison of land area and resident population served by local mass transportation in 1963 and 1972 indicates that the transit systems in the Milwaukee and Kenosha urbanized areas have expanded their respective service areas to extend service to new urbanized areas. The percentage of the total resident population served, however, dropped about 4 percent in the Milwaukee urbanized area, and there, was no significant change in the Kenosha urbanized area. Within the Racine urbanized area, however, there were significant decreases in the percent of total land area and resident population served, indicating that expansion of the local transit system has not kept pace with the growth of the urbanized area.

Although round-trip route miles and area served have generally increased in all three urbanized areas, bus miles and seat miles of local service operated have shown marked decreases, indicating a lengthening of headways, a reduction in hours of service, and, in the case of Racine, the use of smaller buses (see Table 32). The service reductions within each urban area have followed the decline in transit patronage, as indicated in Table 33.

Table 30

VOLUME-TO-CAPACITY RATIOS FOR THE ARTERIAL STREET AND HIGHWAY SYSTEM IN THE REGION BY COUNTY: 1963 AND 1972[a]

County	1963 V/C Range 0.00-0.90 Mileage	1963 V/C Range 0.00-0.90 Percent of Total	1963 V/C Range 0.91-1.10 Mileage	1963 V/C Range 0.91-1.10 Percent of Total	1963 V/C Range Above 1.10 Mileage	1963 V/C Range Above 1.10 Percent of Total	1963 Total Mileage
Kenosha	260.8	92.6	7.2	2.6	13.5	4.8	281.5
Milwaukee	589.8	74.5	85.4	10.8	116.3	14.7	791.5
Ozaukee	250.3	94.5	6.3	2.4	8.3	3.1	264.9
Racine	327.7	93.3	10.0	2.8	13.6	3.9	351.3
Walworth	390.5	97.7	3.9	1.0	5.3	1.3	399.7
Washington	401.8	99.9	0.5	0.1	0.0	0.0	402.3
Waukesha	635.6	91.2	26.6	3.8	34.8	5.0	697.0
Region	2,856.5	89.6	139.9	4.4	191.8	6.0	3,188.2

County	1972 V/C Range 0.00-0.90 Mileage	1972 V/C Range 0.00-0.90 Percent of Total	1972 V/C Range 0.91-1.10 Mileage	1972 V/C Range 0.91-1.10 Percent of Total	1972 V/C Range Above 1.10 Mileage	1972 V/C Range Above 1.10 Percent of Total	1972 Total Mileage
Kenosha	250.4	87.2	14.7	5.1	22.0	7.7	287.1
Milwaukee	662.9	83.3	71.8	9.0	61.0	7.7	795.7
Ozaukee	237.9	93.8	10.1	4.0	5.5	2.2	253.5
Racine	316.0	88.9	19.1	5.4	20.3	5.7	355.4
Walworth	404.5	98.2	2.7	0.7	4.8	1.1	412.0
Washington	326.0	94.6	9.7	2.8	9.1	2.6	344.8
Waukesha	603.5	90.0	23.8	3.6	42.9	6.4	670.2
Region	2,801.2	89.8	151.9	4.9	165.6	5.3	3,118.7

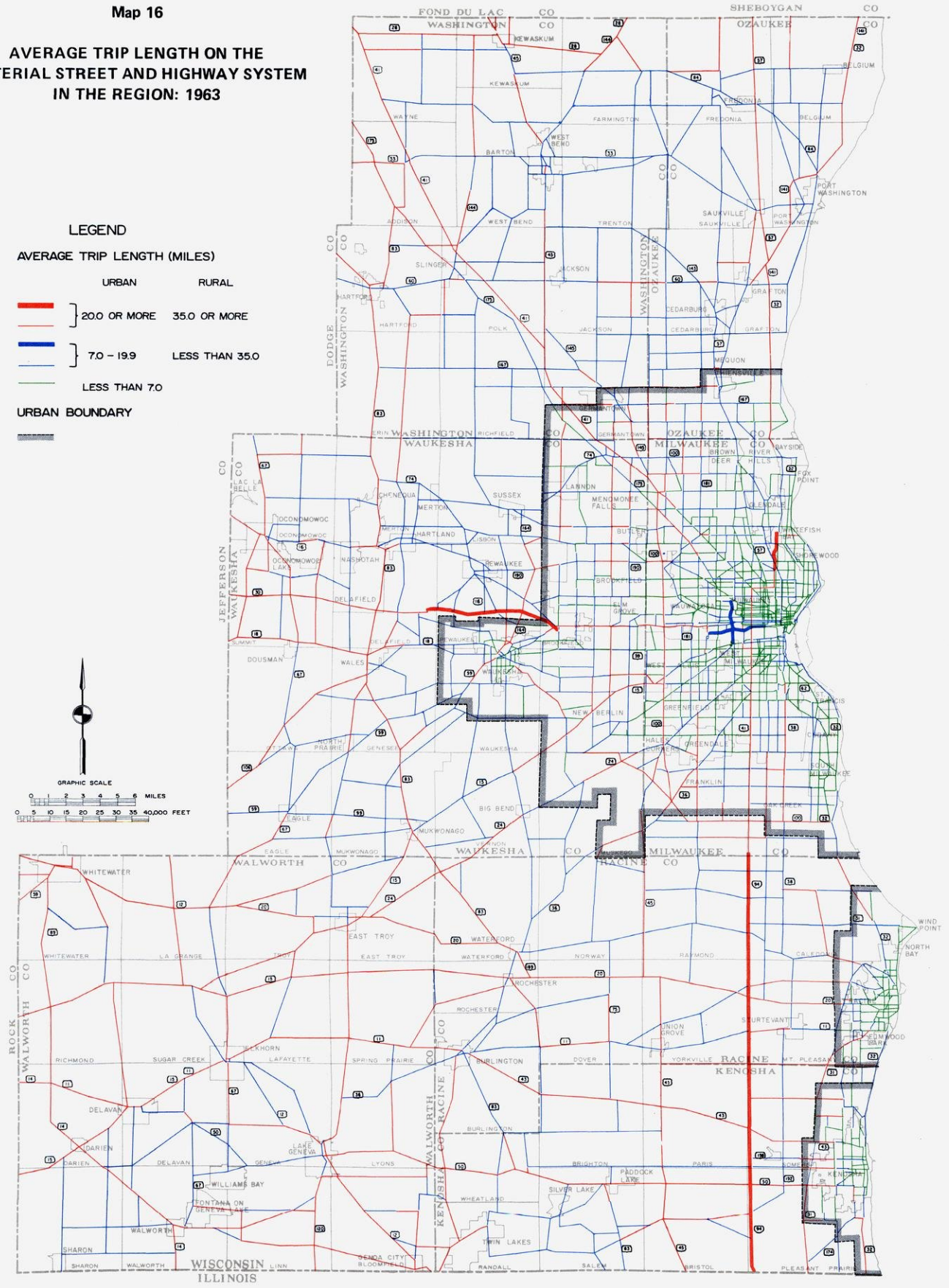
[a] *The significance of the volume-to-capacity ratio of the ranges used is:*

0.00-0.90 - Under design capacity, fully adequate and safest operational level.
0.91-1.10 - At design capacity but still adequate.
Over 1.10 - Over design capacity, congested at times.

Source: SEWRPC.

Map 16

AVERAGE TRIP LENGTH ON THE ARTERIAL STREET AND HIGHWAY SYSTEM IN THE REGION: 1963

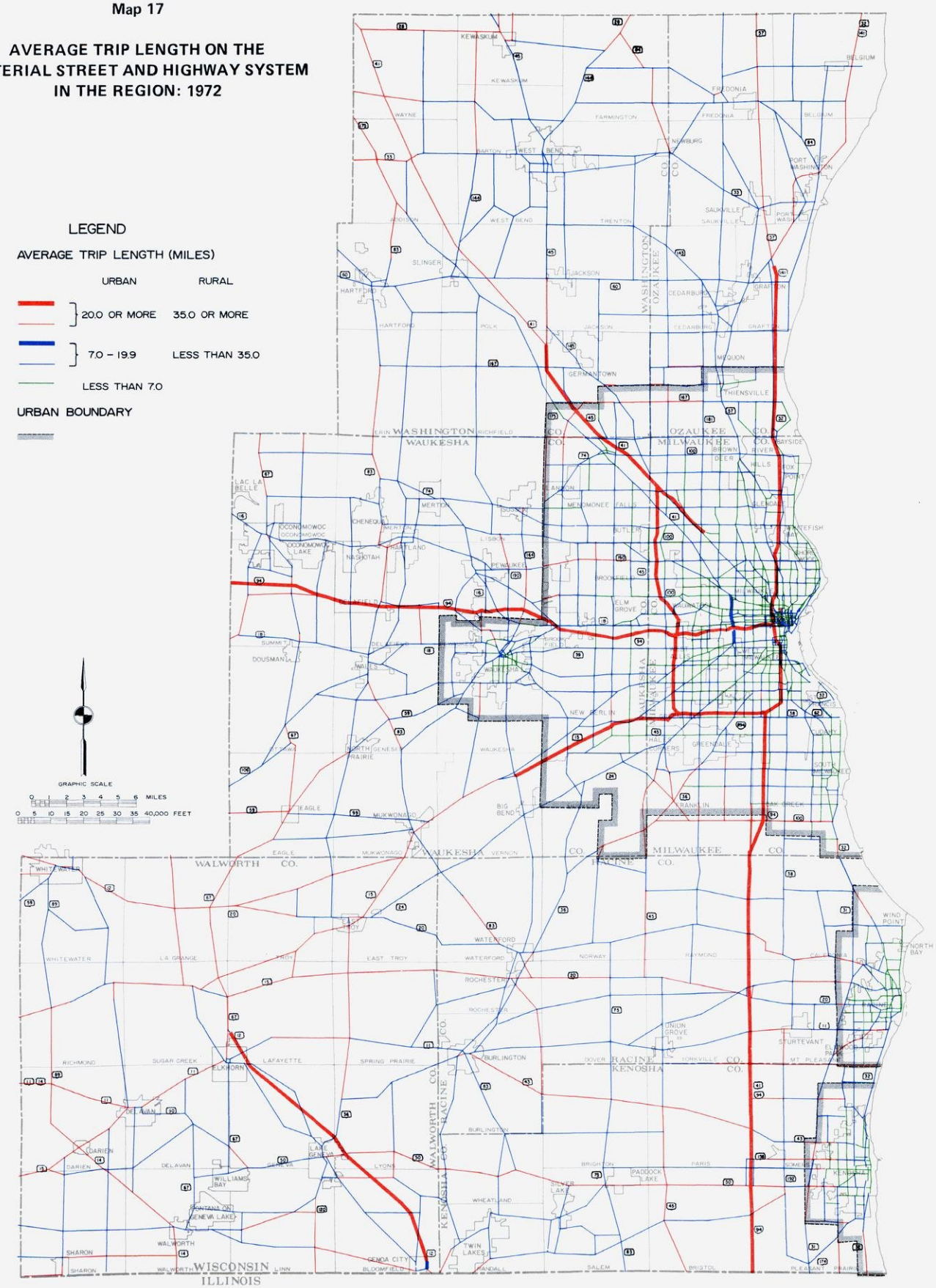


A relationship should exist between the average trip length on a street or highway and the level of service it provides, since tripmakers making longer trips commonly desire to utilize those arterial facilities which maximize travel speed and safety. The pattern of average trip length in 1963 is shown on the above map, and is representative of conditions in the Region prior to the development of a freeway system. As may be expected, in the Milwaukee metropolitan area the longest trips were found to occur on the major state trunk highways, such as S. 27th Street (USH 41), N. Port Washington Road (STH 141), Bluemound Road (USH 18), W. National Avenue (STH 15), STH 100, and USH 41.

Source: SEWRPC.

Map 17

AVERAGE TRIP LENGTH ON THE ARTERIAL STREET AND HIGHWAY SYSTEM IN THE REGION: 1972

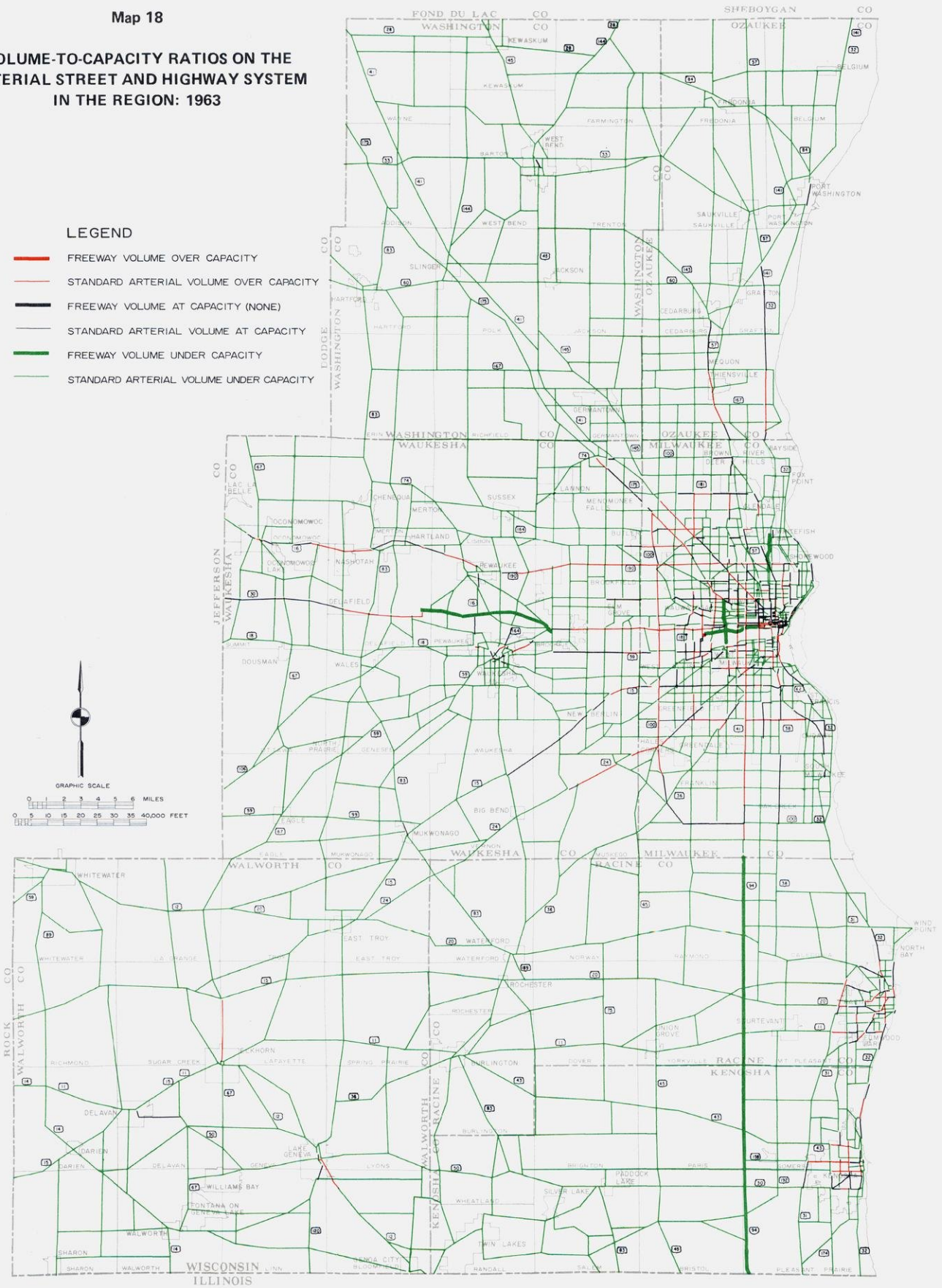


The impact of the developing regional freeway system on the pattern of average trip length on the arterial street and highway system in the Region can be seen by comparing the above map for 1972 with the 1963 average trip length pattern shown on Map 16. In the Milwaukee metropolitan area, the longest trip lengths now occur on the freeway system. Average trip lengths have been reduced on those standard surface arterials in travel corridors now served by freeways, including S. 27th Street, N. Port Washington Road, Bluemound Road, W. National Avenue, and STH 100.

Source: SEWRPC.

Map 18

VOLUME-TO-CAPACITY RATIOS ON THE ARTERIAL STREET AND HIGHWAY SYSTEM IN THE REGION: 1963

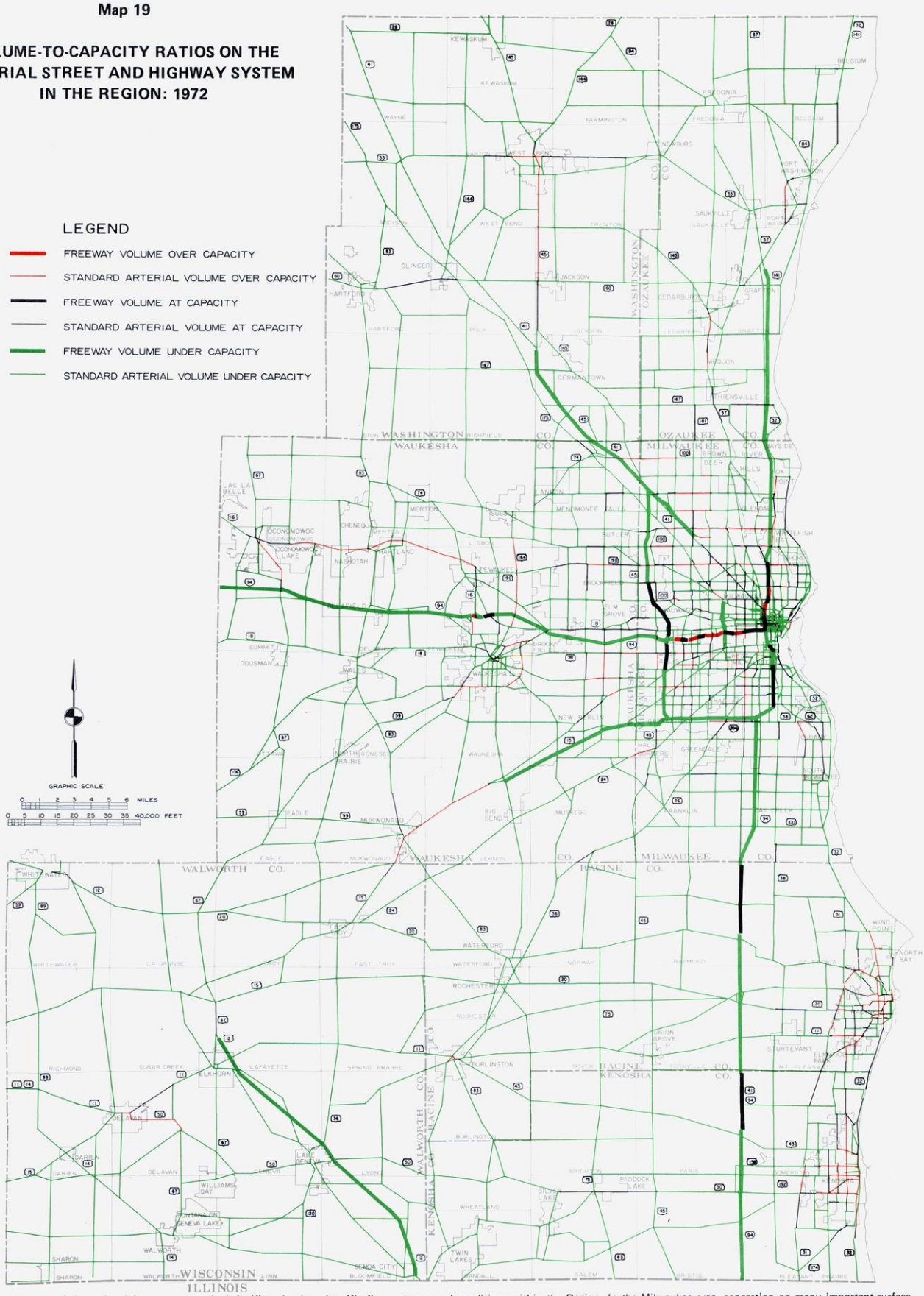


The above map reflects traffic flow patterns and conditions within the Region prior to urban freeway construction. About 6 percent of the arterial street and highway system in the Region, or about 192 miles, was operating over design capacity or under congested conditions in 1963. Another 4 percent, or about 140 miles, was operating at design capacity. The remaining 90 percent, or 2,857 miles, was operating freely below design capacity. Congestion was particularly severe in the three major urban centers of the Region. In Milwaukee County, about 25 percent of all arterial streets and highways, or about 202 miles, was operating at or over design capacity. This included such important surface arterials as W. National Avenue, S. 27th Street, Bluemound Road, STH 100, W. Fond du Lac Avenue, W. Appleton Avenue, and N. Port Washington Road.

Source: SEWRPC.

Map 19

VOLUME-TO-CAPACITY RATIOS ON THE ARTERIAL STREET AND HIGHWAY SYSTEM IN THE REGION: 1972



By 1972 the development of the regional freeway system had significantly altered traffic flow patterns and conditions within the Region. In the Milwaukee area, congestion on many important surface arterials, such as W. National Avenue, S. 27th Street, Bluemound Road, STH 100, W. Fond du Lac Avenue, W. Appleton Avenue, and N. Port Washington Road, had been relieved by the construction of freeway facilities. The overwhelming majority of this congested arterial mileage—87 percent—is located in the Milwaukee, Racine, and Kenosha urbanized areas. In Milwaukee County about 17 percent of the arterial system was operating at or over design capacity, as compared to 25 percent of the arterial system in 1963. This significant reduction in traffic congestion in Milwaukee County is largely due to the opening of freeway facilities. The freeway facilities in Milwaukee County absorbed more than the 3.3 million vehicle miles by which travel demand in that county increased over the decade, thereby permitting a corresponding decrease in traffic congestion on the surface arterials. For the Region as a whole, arterial traffic congestion was held at about 1963 levels despite an 8 percent increase in population, a 40 percent increase in motor vehicle registrations, a 25 percent increase in trip generation, and a 54 percent increase in arterial vehicle miles of travel. Without the regional freeway system, such increases in travel demand could not have been absorbed without increasing traffic congestion to intolerable levels.

Source: SEWRPC.

Table 31

LAND AREA SERVED, POPULATION SERVED, AND ROUTE MILES OPERATED BY LOCAL MASS TRANSIT IN THE REGION BY URBAN AREA: 1963 AND 1972

Urban Area	Urban Area Size (Acres)		Area Served by Local Transit[a] (Acres)		Percent of Total Urban Area Served		Urban Area Population		Population Served by Local Transit[a]		Percent of Total Population Served		Round-Trip Route Miles		
	1963	1972	1963	1972	1963	1972	1963[b]	1972[b]	1963[b]	1972[b]	1963	1972	1963	1972	Percent Change
Milwaukee[c]	250,900	292,100	90,500	105,500	36	36	1,216,500	1,267,400	1,053,100	1,043,600	87	82	716	986	38
Racine	9,300	18,000	8,300	11,200	88	62	95,900	115,200	96,600	100,600	101	88	76	81	7
Kenosha[d]	8,500	11,200	8,100	12,900	96	115	73,400	86,500	74,000	83,900	101	97	55	59	7
Subtotal	268,700	321,300	106,900	129,600	40	40	1,385,800	1,469,100	1,223,700	1,228,100	88	84	847	1126	33
Port Washington[e]	3,200	--	2,600	--	80	--	7,500	--	7,400	--	98	--	9	0	-100
Total	271,900	--	109,500	--	40	--	1,393,300	--	1,231,100	--	88	--	856	1126	32

[a] *Area of U. S. Public Land Survey quarter sections within one-quarter mile of transit route.*

[b] *SEWRPC estimate.*

[c] *Includes Milwaukee and Waukesha transit systems (excludes school "trippers" in the City of Waukesha and includes primary and secondary transit service provided by the Milwaukee and Suburban Transport Corporation).*

[d] *Excludes school trippers.*

[e] *Service discontinued in 1966.*

Source: SEWRPC.

Table 32

UTILIZATION OF LOCAL MASS TRANSIT ON AN AVERAGE WEEKDAY IN THE REGION BY URBAN AREA: 1963 AND 1972

Urbanized Area	Transit Vehicle Miles			Local Mass Transit Service Provided—Seat Miles			Local Mass Transit Service Used—Passenger Miles			Percent of Utilization	
	1963	1972	Percent Change	1963[a]	1972	Percent Change	1963[a]	1972	Percent Change	1963[a]	1972
Milwaukee[b]	78,886	61,314	-22	3,201,300	3,186,000	--	966,700	551,500	-43	30	17
Racine	3,548	1,555	-56	129,900	29,500	-77	31,800	5,300	-83	24	18
Kenosha	2,465	1,138	-54	80,800	43,200	-47	15,100	3,900	-74	19	9
Total	84,899	64,007	-25	3,412,000	3,258,700	-4	1,013,600	560,700	-45	30	17

[a] *Service provided by Port Transit Lines, Inc. in the City of Port Washington is not included.*

[b] *Includes primary and secondary transit service provided by the Milwaukee and Suburban Transport Corporation.*

Source: SEWRPC.

Table 33 indicates a 41 percent decrease in annual revenue passengers carried within the Milwaukee urban area--from 89 million in 1963 to 52 million in 1972. This compares with a similar 41 percent decrease in the number of local mass transportation rides per capita, from 85 in 1963 to 50 in 1972. Similarly, within the Racine urban area annual revenue passengers declined 82 percent--from three million in 1963 to one-half million in 1972, while local mass transportation rides per capita declined from 30 in 1963 to five in 1972. Within the Kenosha urban area, ridership declines paralleled those in the Racine urban area, decreasing 73 percent–from two million annual revenue passengers in 1963 to one-half million in 1972. At the same time, local mass transportation rides per capita declined from 26 in 1963 to six in 1972. There were the following exceptions to these general downward trends between 1963 and 1972: in 1965 the Milwaukee urban area experienced a general stabiliza-

Table 33

ANNUAL REVENUE PASSENGERS AND RIDES PER CAPITA ON LOCAL MASS TRANSIT IN THE REGION BY URBAN AREA: 1963 AND 1972

Urban Area	Annual Revenue Passengers			Population Served by Local Mass Transportation		Local Mass Transit Rides Per Capita		
	1963	1972	Percent Change	1963	1972	1963	1972	Percent Change
Milwaukee[a]	88,997,579	52,417,783	-41	1,053,100	1,043,600	85	50	-41
Racine	2,901,986	525,681	-82	96,600	100,600	30	5	-83
Kenosha	1,884,416	503,191	-73	74,000	83,900	26	6	-76
Port Washington[b]	129,874	0	-100	7,400	--	18	--	-100
Total	93,913,855	53,446,655	-43	1,231,100	1,228,100	76	43	-43

[a] *Includes primary and secondary transit service provided by the Milwaukee and Suburban Transport Corporation.*

[b] *Service discontinued in 1966.*

Source: SEWRPC.

tion of ridership; patronage in Kenosha increased following a fare reduction in 1969 and public acquisition in 1971; and ridership in Racine stabilized in 1973.

Regional Travel Patterns

Quantity of Total Travel: There were about 4.68 million persons trips[5] made within the Region on an average weekday in 1972. This figure represents an increase of about 887,000 person trips per day, or about 23 percent, since 1963. Of these 4.68 million person trips about 4.50 million, or about 96 percent of the total, were internal person trips; that is, trips having both the origin and destination within the Region. These 4.50 million internal person trips represent an increase of 902,000 trips, or 25 percent, since 1963. The average number of internal person trips per capita increased from 2.2 in 1963 to 2.5 in 1972, while the average number of internal person trips per household increased from 7.3 to 7.9.

In 1972 there were approximately 3.41 million vehicle trips, consisting mainly of auto, truck, and taxi trips, made within the Region on an average weekday, representing an increase of 848,000 vehicle trips, or 33 percent, since 1963. Of the 3.41 million vehicle trips, about 3.29 million, or 96 percent, were internal vehicle trips, representing an increase of 824,000 such trips, or 33 percent, since 1963.

In addition to these internal person and vehicle trips, there were about 177,000 external person trips and about 126,000 external vehicle trips made into, out of, or through the Region in 1972. These figures represent a decrease of 15,000 person trips, or about 8 percent, and an increase of 24,000 vehicle trips, or about 24 percent, since 1963 (see Table 34).

Auto-oriented travel on an average weekday accounted for the large majority of total internal person travel within the Region in 1963 and 1972. Auto driver trips alone accounted for 60 percent of total person trips in 1963 and 64 percent in 1972, while auto passenger trips accounted for an additional 27 percent of the total in both 1963 and 1972. Of the remaining modes, mass transit passenger trips accounted for 9 percent of the total in 1963 and 4 percent in 1972, and school bus trips accounted for 3 percent of the total in 1963 and 4 percent in 1972. All other modes together, such as taxi passengers, truck passengers, and, in 1972, motorcycle drivers and passengers, accounted for 0.5 percent or less in both 1963 and 1972 (see Table 35).

Table 35 also indicates that from 1963 to 1972, auto driver trips increased by 731,000, or 34 percent, while auto passenger trips increased by only 242,000, or 25 percent. This reflects the effects of the substantial growth not only in the number of automobiles available to drivers, but also in the number and proportions of multi-auto households within the Region. The lesser growth in auto passenger travel resulted in a decrease in the average auto occupancy rate for the Region from 1.46 persons per auto in 1963 to 1.43 persons in 1972.

Vehicle Availability: In addition to the approximately 704,600 automobiles and 21,000 motorcycles available to residents of the Region in 1972, there were approximately 77,250 trucks and 450 taxis licensed for use on an

[5] *A person trip is defined herein as a one-way journey between a point of origin and a point of destination by a person five years of age or over traveling as an auto driver or as a passenger in an auto, taxi, truck, motorcycle, school bus, or other mass transit carrier. To be considered, the trip must have been at least the equivalent of one full city block in length.*

Table 34

AVERAGE WEEKDAY PERSON AND VEHICLE TRIPS BY SURVEY TYPE: 1963 AND 1972

Survey Type	1963				1972				Difference: 1963-1972			
	Person Trips		Vehicle Trips		Person Trips		Vehicle Trips		Person Trips		Vehicle Trips	
	Number	Percent of Total	Number	Percent of Total	Number	Percent of Total	Number	Percent of Total	Number	Percent	Number	Percent
Personal Interview												
Home Interview	3,603,000	94.9	2,166,000	84.3	4,504,900	96.2	2,905,000	85.0	901,900	25.0	739,000	34.1
Truck and Taxi	--	--	300,400	11.7	--	--	385,300	11.3	--	--	84,900	28.3
Subtotal	3,603,000	94.9	2,466,400	96.0	4,504,900	96.2	3,290,300	96.3	901,900	25.0	823,900	33.4
External Cordon	191,700	5.1	101,600	4.0	176,900	3.8	125,700	3.7	- 14,800	- 7.7	24,100	23.7
Total	3,794,700	100.0	2,568,000	100.0	4,681,800	100.0	3,416,000	100.0	887,100	23.4	848,000	33.0

Source: SEWRPC.

Table 35

DISTRIBUTION OF AVERAGE WEEKDAY INTERNAL PERSON TRIPS IN THE REGION BY MODE OF TRAVEL: 1963 AND 1972

Mode of Travel	Person Trips				Difference 1963-1970	
	1963		1972			
	Number	Percent of Total	Number	Percent of Total	Number	Percent
Auto Driver	2,165,700	60.1	2,897,000	64.3	731,300	33.8
Auto Passenger	985,100	27.4	1,227,400	27.2	242,300	24.6
Mass Transit	324,300	9.0	186,200	4.1	-138,100	- 42.6
School Bus	119,900	3.3	173,800	3.9	53,900	45.0
Other	8,000	0.2	20,500	0.5	12,500	156.3
Total	3,603,000	100.0	4,504,900	100.0	901,900	25.0

Source: SEWRPC.

average weekday. These figures represented increases from 1963 to 1972 of 177,300 automobiles, or 34 percent, and of 18,750 trucks, or 32 percent, and a decrease of 50 taxis, or about 10 percent.

In 1972 these 803,300 autos, trucks, taxis, and motorcycles made a total of 3,290,300 vehicle trips on an average weekday, an increase of 823,900 vehicle trips, or 33 percent, from 1963 to 1972. This increase is substantially higher than the 25 percent increase in total internal person trips during the same period, and reflects the more rapid growth in automobile availability (34 percent) and truck availability (32 percent) than in the regional population, which increased only nine percent.

Automobiles, averaging 4.1 vehicle trips per day in both 1963 and 1972, accounted for 88 percent of total vehicle trips in both 1963 and 1972. Trucks, averaging five trips per day in 1963 and 4.8 trips per day in 1972, accounted for 12 percent of total vehicle trips in 1963 and 11 percent in 1972. Taxis, averaging 14 trips per day in 1963 and 31.8 trips per day in 1972, accounted for less than one-half of 1 percent of total trips in both 1963 and 1972. Motorcycles, averaging 0.4 trip per day in 1972, accounted for 0.3 percent of total trips. The average number of vehicle trips per day for total vehicles was 4.2 in 1963 and 4.1 in 1972 (see Table 36).

The large difference in the average number of vehicle trips made by taxis in 1963 and 1972 is believed to be explained by the far greater proportion of taxis actually in use in 1972–82 percent--than in 1963--55 since the trip average was based on the total number of taxis licensed for, rather than actually in use.

Table 36

VEHICLE AVAILABILITY AND AVERAGE WEEKDAY INTERNAL VEHICLE TRIPS IN THE REGION BY TYPE: 1963 AND 1972

Type of Vehicle	1963					1972				
	Vehicles		Vehicle Trips		Average Number of Trips	Vehicles		Vehicle Trips		Average Number of Trips
	Number	Percent of Total	Number	Percent of Total		Number	Percent of Total	Number	Percent of Total	
Automobile	527,300	89.9	2,166,000	87.8	4.1	704,600	87.7	2,897,000	88.0	4.1
Truck	58,500	10.0	293,400	11.9	5.0	77,250	9.6	371,000	11.3	4.8
Taxi	500	0.1	7,000	0.3	14.0	450	0.1	14,300	0.4	31.8
Motorcycle	--	--	--	--	--	21,000	2.6	8,000	0.3	0.4
Total	586,300	100.0	2,466,400	100.0	4.2	803,300	100.0	3,290,300	100.0	4.1

Source: SEWRPC.

Purpose of Internal Person Trips: The activities of a household are usually centered on the home. Therefore, home-oriented travel accounted for a large proportion of total internal person travel on an average weekday. The importance of home as a generator of person trips was emphasized by the finding that trips to home equaled 41 percent of total trip destinations in both 1963 and 1972, and was further emphasized by the finding that an equal proportion began at home (see Table 37). Trips which have either an origin or destination at home were found to comprise more than four-fifths of total internal person travel. It is apparent, then, that future travel facility requirements within the Region will be determined in large measure by the amount and location of future residential development.

Second in importance of all trip purpose categories were trips to work, which accounted for 18 percent of the total in 1963 and 16 percent in 1972 (see Table 37). The total number of internal person trips made for work purposes within the Region on an average weekday, as reported in the 1963 and 1972 surveys, was found to closely match, in each instance, independent estimates of average daily employment within the Region for those years, taking into consideration the variations in daily work attendance and the influence of nonresident employment within the Region. Of the remaining trip purpose categories, personal business trips accounted for 13 percent of the total in 1963 and 15 percent in 1972; shopping trips accounted for 12 percent in both 1963 and 1972; social-recreation trips accounted for 12 percent in 1963 and 11 percent in 1972; and trips to attend school accounted for 5 percent in both 1963 and 1972.

Substantial increases in tripmaking during this period were found in all trip purpose categories (see Table 37). The largest increases were noted in trips to home (377,300, or 26 percent), trips to conduct personal business (189,600 or 41 percent), and shopping trips (119,400, or 28 percent). Somewhat smaller but still important increases were noted in trips for social-recreation purposes (84,700, or 20 percent), for work purposes (76,400, or 12 percent), and to attend school (54,500, or 33 percent).

Daily Patterns in Person Travel: The patterns shaped by the variations of daily volumes of total person travel in 1963 and 1972 are quite similar, as shown in Figure 14. The patterns, strongly influenced by Friday travel volumes in both years, indicate that total person travel varied no more than 6 percent from the daily average for any weekday other than Friday, which had total person trip volumes 14 percent above average in 1963 and 9 percent above average in 1972. Because auto driver trip volumes heavily dominated total person trip volumes in both 1963 and 1972, the patterns of auto driver trips closely matched those of total person trips in both years. The patterns of mass transit passenger trips were almost exactly alike in 1963 and 1972, varying by no more than 8 percent from the weekday average in both years, and reflecting the high degree of regularity of such travel by day.

The patterns of auto, truck, and taxi passenger trips had the largest variance from the weekday average in both years, with the travel on Friday rising to 25 percent above the average in 1963 and to 19 percent above the average in 1972. The patterns of school bus trips, although exhibiting differences by day of week in 1963 and 1972, varied by no more than 11 percent from the weekday average. The patterns of school bus trips were less similar in 1963 and 1972 than the patterns of other modes. These differences are likely random in nature, and may occur because of the use of other modes in inclement weather; because of the randomness of scheduling field trips, teacher conferences, and other special school activities; and because of absenteeism.

It is important to point out, however, that although person trip volumes varied day by day, the percentage of the day's trips carried by each mode remained approximately the same as the percentage of the total for each mode. The maximum deviation from the average week-

Table 37

DISTRIBUTION OF AVERAGE WEEKDAY INTERNAL PERSON TRIPS IN THE REGION BY TRIP PURPOSE AT DESTINATION: 1963 AND 1972

Trip Purpose at Destination	Person Trips				Difference 1963-1972	
	1963		1972			
	Number	Percent of Total	Number	Percent of Total	Number	Percent
Home	1,458,900	40.5	1,836,200	40.8	377,300	25.9
Work	664,400	18.4	740,800	16.4	76,400	11.5
Personal Business	465,300	12.9	654,900	14.5	189,600	40.7
School	165,500	4.6	220,000	4.9	54,500	32.9
Social-Recreation	423,400	11.8	508,100	11.3	84,700	20.0
Shopping	425,500	11.8	544,900	12.1	119,400	28.1
Total	3,603,000	100.0	4,504,900	100.0	901,900	25.0

Source: SEWRPC.

day by day of week for each mode was: for auto drives, 1.5 percent in 1963 and 1.8 percent in 1972; for auto, truck, and taxi passengers, 3 percent in 1963 and nearly 3 percent in 1972; for transit passengers, 0.6 percent in 1963 and 0.3 percent in 1972; and for school bus passengers, 0.7 percent in both years.

The reason for the daily variations in person travel are indicated in Figure 15, which shows the daily variations by trip purpose. The very large increases in tripmaking on Fridays in 1963 and 1972 were caused by the significant increases in trips for personal business, social-recreation, and shopping purposes. Friday shopping trips were 44 and 22 percent above the weekday average in 1963 and 1972, respectively. Friday trips for personal business and social-recreation were about 12 and 26 percent, respectively, above the weekday average in both 1963 and 1972. Work trips on Friday were about 2 percent below the weekday average in both 1963 and 1972, and trips to attend school were 10 percent and 14 percent below the weekday average in 1963 and 1972, respectively.

Hourly Patterns of Internal Person Travel: The hourly distributional patterns of internal person trips by trip purpose indicate that, although total person trip volumes increased substantially within the Region on an average weekday from 1963 to 1972, the regular ebb and flow of travel remained remarkedly similar, both in the proportion of trips by trip purpose within the hourly distributions and in the proportion and times of peak periods. The single exception was a more pronounced decline in 1963 than in 1972 in person activity in the hour beginning at 6 p.m.

The patterns formed by the hourly distribution of person trips by trip purpose at destination, as reflected in Figures 16 and 17, present a graphic representation of person travel within the Region on an average 1963 and 1972 weekday. The patterns show the relative inactivity of the early morning hours followed by a sharp peak centered around 7 a.m. as trips to work and school began. Trips for shopping, personal business, and social-recreation began during the later morning hours and continued fairly evenly until midafternoon. The afternoon peak period beginning at 3 p.m. was larger and more sustained than the morning peak, and was characterized predominantly by trips to return home. The sharp decline in person trip activity from the afternoon peak was slowed in the early evening hours, as trips for shopping and social-recreational purposes reached their maximum hourly volumes for the day.

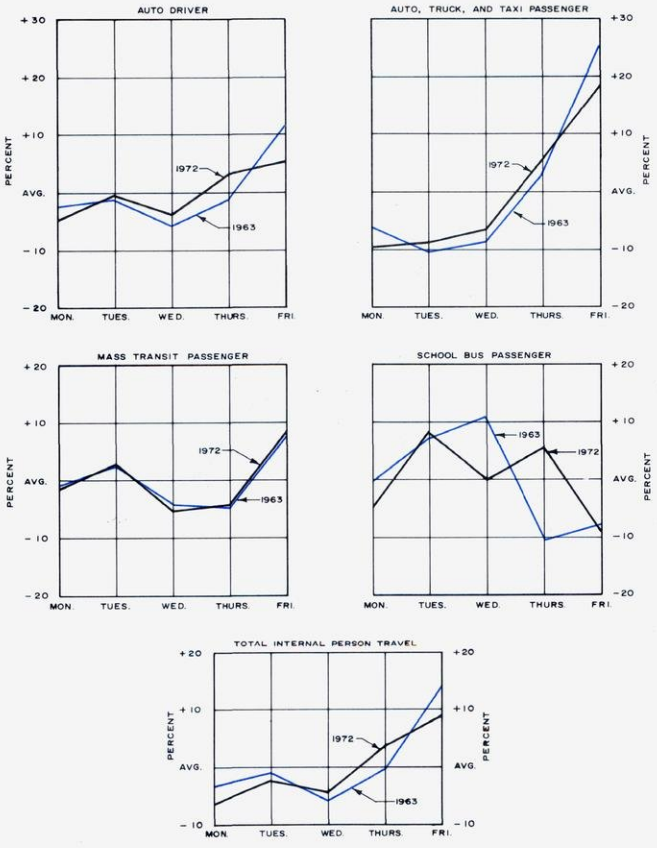
The 1963 and 1972 hourly distributional patterns of internal person trips by mode of travel were also found to be quite similar both in the proportion of trips by mode of travel and in the proportions and times of peak periods, as shown in Figures 18 and 19. One major exception can be noted in the decline from 1963 to 1972 in the number and proportion of mass transit trips in virtually every hour of the day. Another exception is the more pronounced decline in 1963 and 1972 of auto driver trips, as in the case of 1963 person trips, in the hour beginning at 6 p.m. The largest hourly volumes of 1963 and 1972 auto driver, school bus, and mass transit passenger trips occurred during the morning and afternoon peak periods, while the largest hourly volumes for auto, truck, and taxi passengers combined occurred in the hour beginning at 7:00 p.m. Within each hour of the day, auto driver trips outnumbered trips by all other modes combined.

Air Transportation

As of 1971, the air transportation system developed in the Southeastern Wisconsin Region comprised a complex network of airways and 46 publicly and privately owned airports or air bases as shown on Map 20. These airports

Figure 14

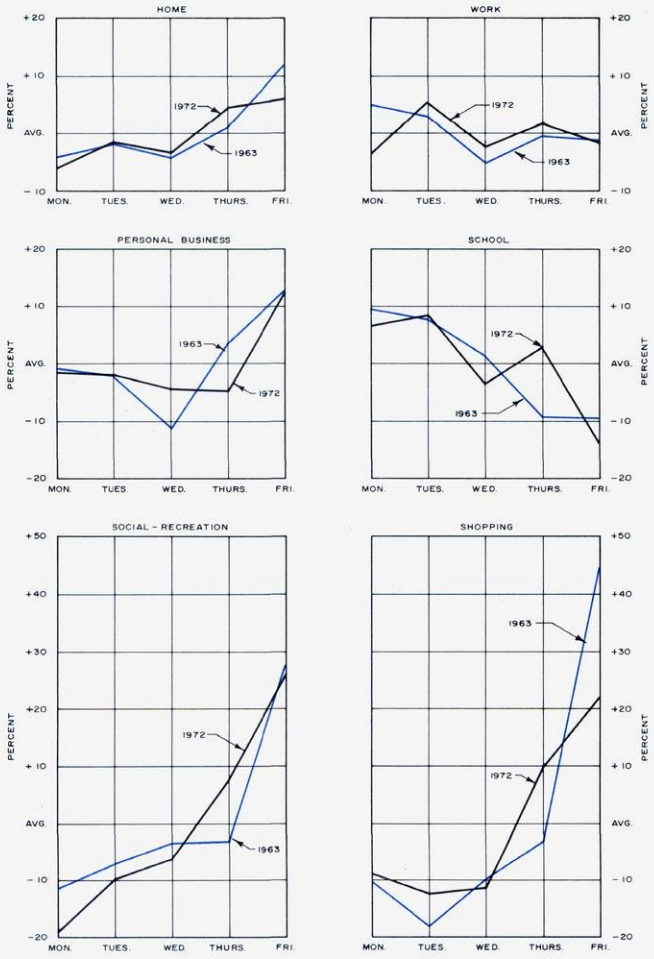
DAILY VARIATION OF AVERAGE WEEKDAY INTERNAL PERSON TRIPS IN THE REGION BY MODE OF TRAVEL 1963 AND 1972



Source: SEWRPC.

Figure 15

DAILY VARIATION OF AVERAGE WEEKDAY INTERNAL PERSON TRIPS IN THE REGION BY TRIP PURPOSE 1963 AND 1972



Source: SEWRPC.

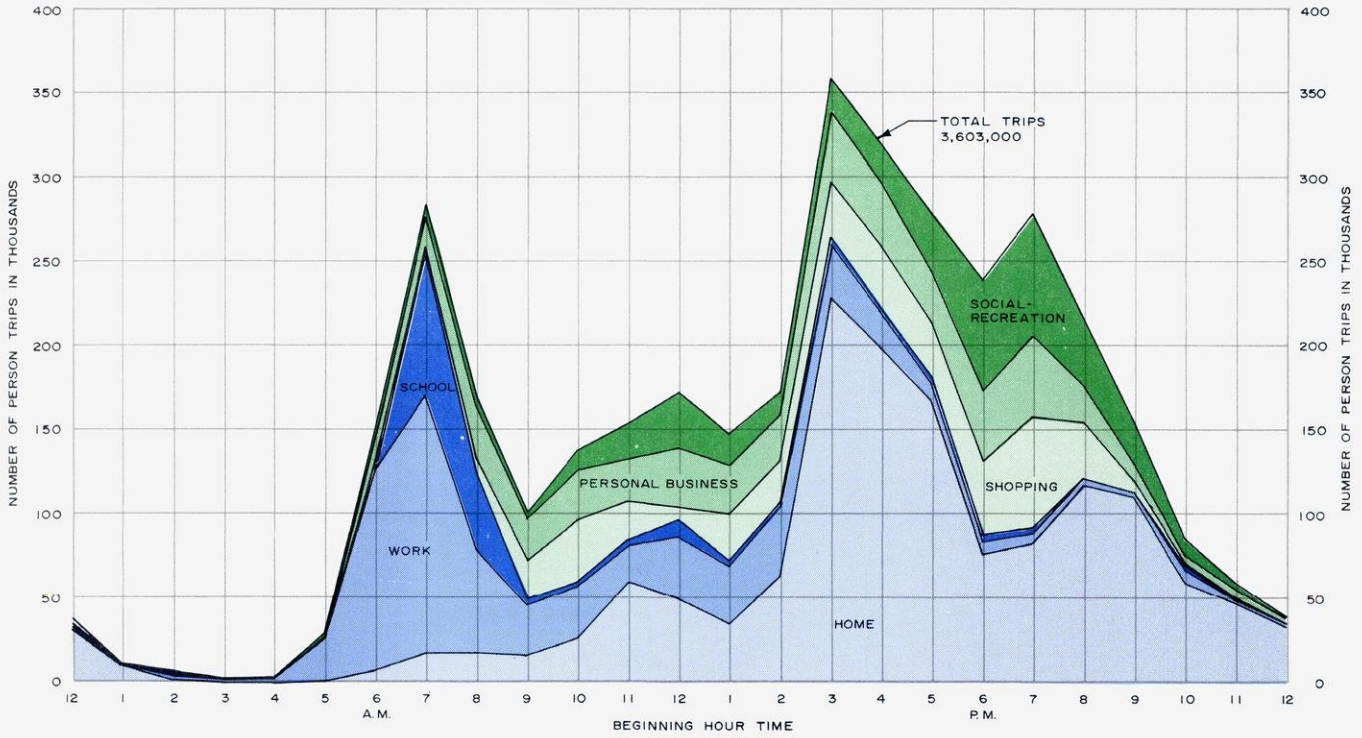
fall into one of four major service categories--air carrier, general aviation, military, and special use. There is only one air carrier airport in the Region which accommodates commercial airline service to the general public on a regularly scheduled basis: the publicly owned General Mitchell Field. The air carrier airport in effect constitutes a major interregional transportation terminal handling relatively large volumes of passengers, mail, and cargo in large, high-performance aircraft.

The general aviation airports, consisting of both public and privately owned facilities, are intended to serve smaller training, business, charter, agricultural, recreational, pleasure, and air taxi aircraft. In addition to General Mitchell Field, which provides general aviation as well as commercial air carrier service, there are 43 other active airport facilities for primary use by general aviation located within the Region. Not all of these, however, are open to unlimited public use, as some of the airports serve the personal requirements of the owners or cater strictly to specific aircraft types. The 25 general aviation public use airports, both publicly and privately owned, accommodate the majority of the business and pleasure aviation activity in the Region. The 18 general aviation private, personal, or restricted use airports within the Region are of less importance to the existing regional airport system.

The 46 airports in the Region accommodated an estimated total of 884,403 operations in 1971, with General Mitchell Field accounting for 230,903, or about 26 percent of this total. In 1971, the number of aircraft based in the Region was approximately 1,050 planes, with General Mitchell Field accounting for about 180, or 17

Figure 16

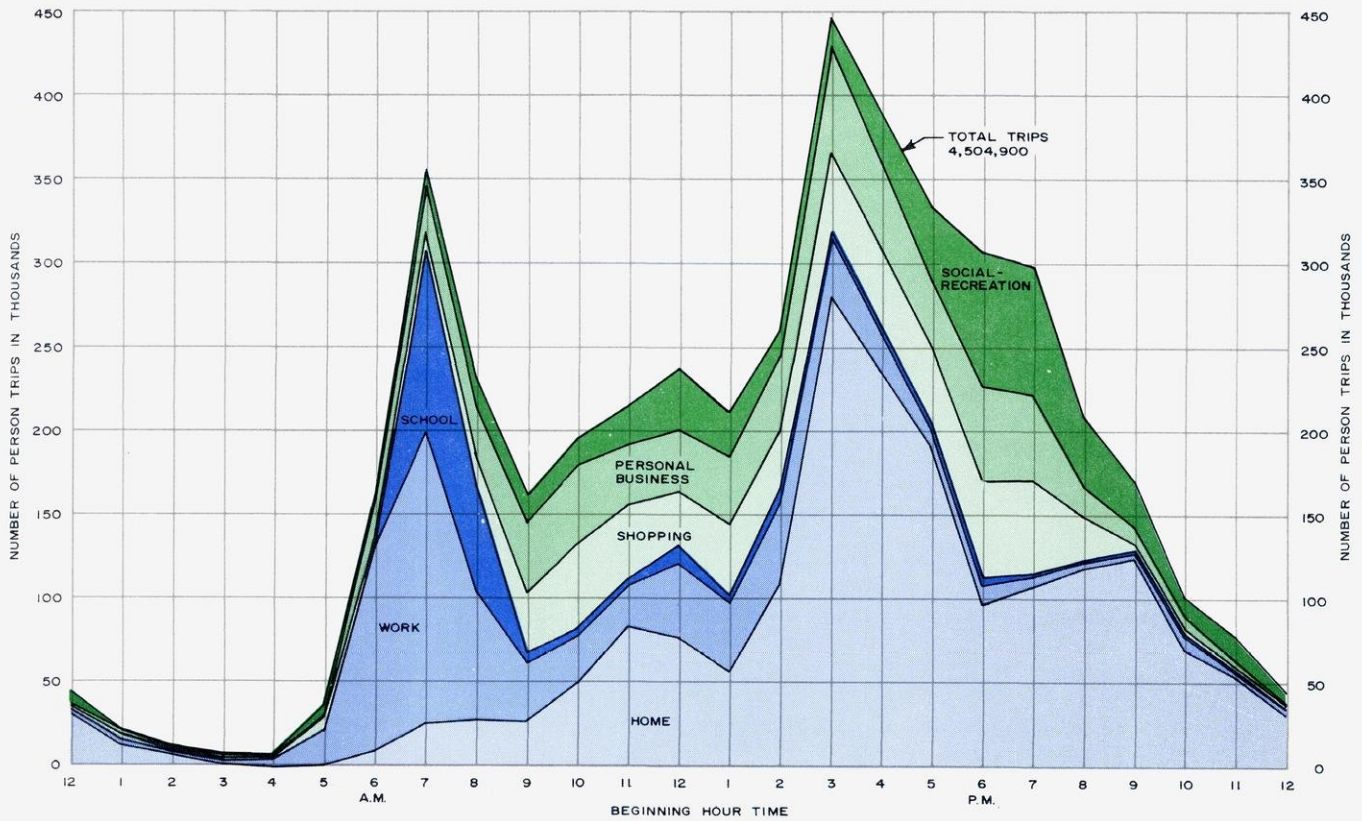
HOURLY VARIATION OF AVERAGE WEEKDAY INTERNAL PERSON TRIPS IN THE REGION BY TRIP PURPOSE AT DESTINATION: 1963



Source: SEWRPC.

Figure 17

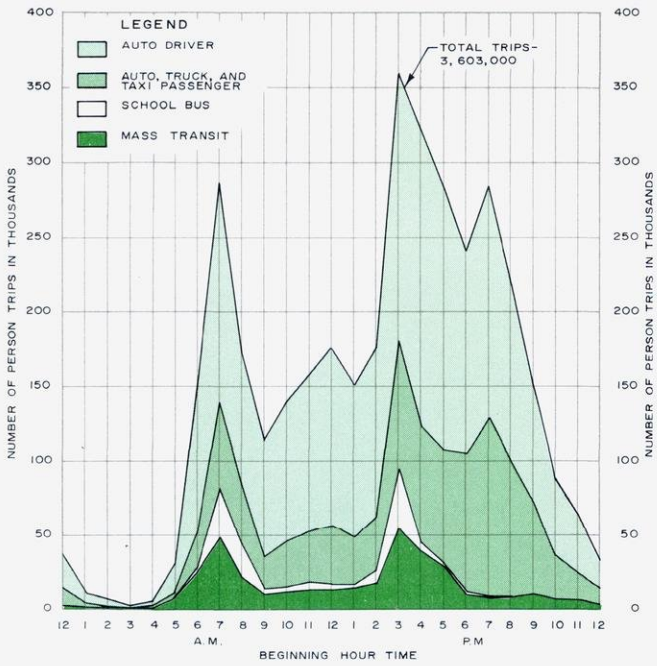
HOURLY VARIATION OF AVERAGE WEEKDAY INTERNAL PERSON TRIPS IN THE REGION BY TRIP PURPOSE AT DESTINATION: 1972



Source: SEWRPC.

Figure 18

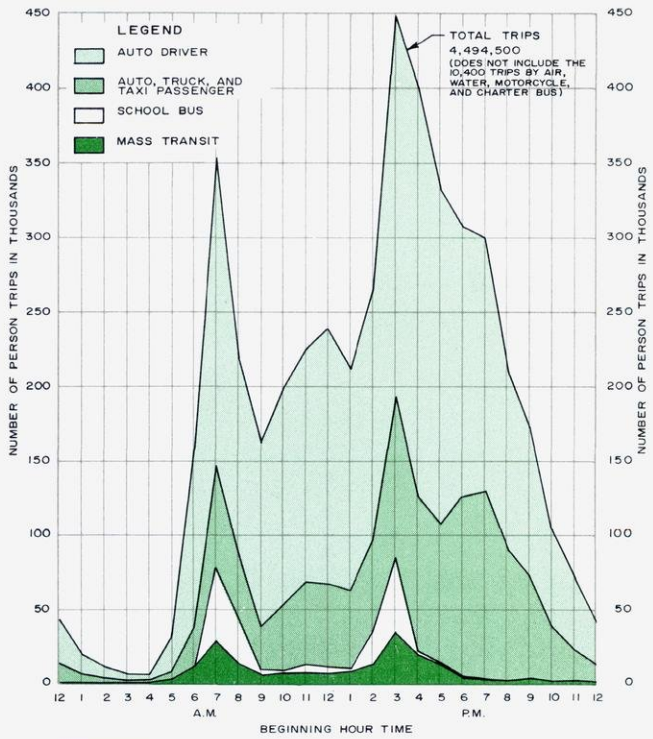
HOURLY VARIATION OF AVERAGE WEEKDAY INTERNAL PERSON TRIPS IN THE REGION BY MODE OF TRAVEL: 1963



Source: SEWRPC.

Figure 19

HOURLY VARIATION OF AVERAGE WEEKDAY INTERNAL PERSON TRIPS IN THE REGION BY MODE OF TRAVEL: 1972



Source: SEWRPC.

percent of the total. Commercial passenger travel demand at General Mitchell Field during 1971 was approximately 1,460,560 persons.[6]

Presently, there are no exclusive military use airports within the Region. Both General Mitchell Field in Milwaukee County and West Bend Municipal Airport in Washington County are joint use civil/military facilities providing military aviation service. There are two landing areas located within the Region that might well be considered within the special use category; that is, facilities restricted to certain aircraft types. These land areas include the Johnson Wax Heliport in Racine and the Edgewood Air Seaplane Base at Lake Geneva in Walworth County.

Water Transportation

Four cities in southeastern Wisconsin--Kenosha, Milwaukee, Port Washington, and Racine--have Lake Michigan harbors and harbor facilities. All four harbors are equipped to accommodate seagoing freight or scheduled passenger ships as well as private pleasure craft, although no scheduled passenger service ends or originates from these four ports. Some freight lines offer limited passenger accommodations. The Chesapeake & Ohio Company operates a seasonally scheduled rail and car-ferry between the Milwaukee harbor and the City of Ludington, Michigan. This ferry also has some accommodations for passengers.

PUBLIC UTILITY BASE

Public utility systems are one of the most important factors influencing urban growth and development. All urban development today is highly dependent upon the utility systems which serve the individual land uses with power, light, communication, heat, water, and sewerage. Water supply and sanitary sewerage utilities have a particularly important relationship to urban land use development in general and to housing development in particular. Water supply facilities bring portable water from its sources to the user, while sanitary sewerage facilities collect the used water, convey it to a treatment plant, and after treatment, return it to the natural environment from which it came.

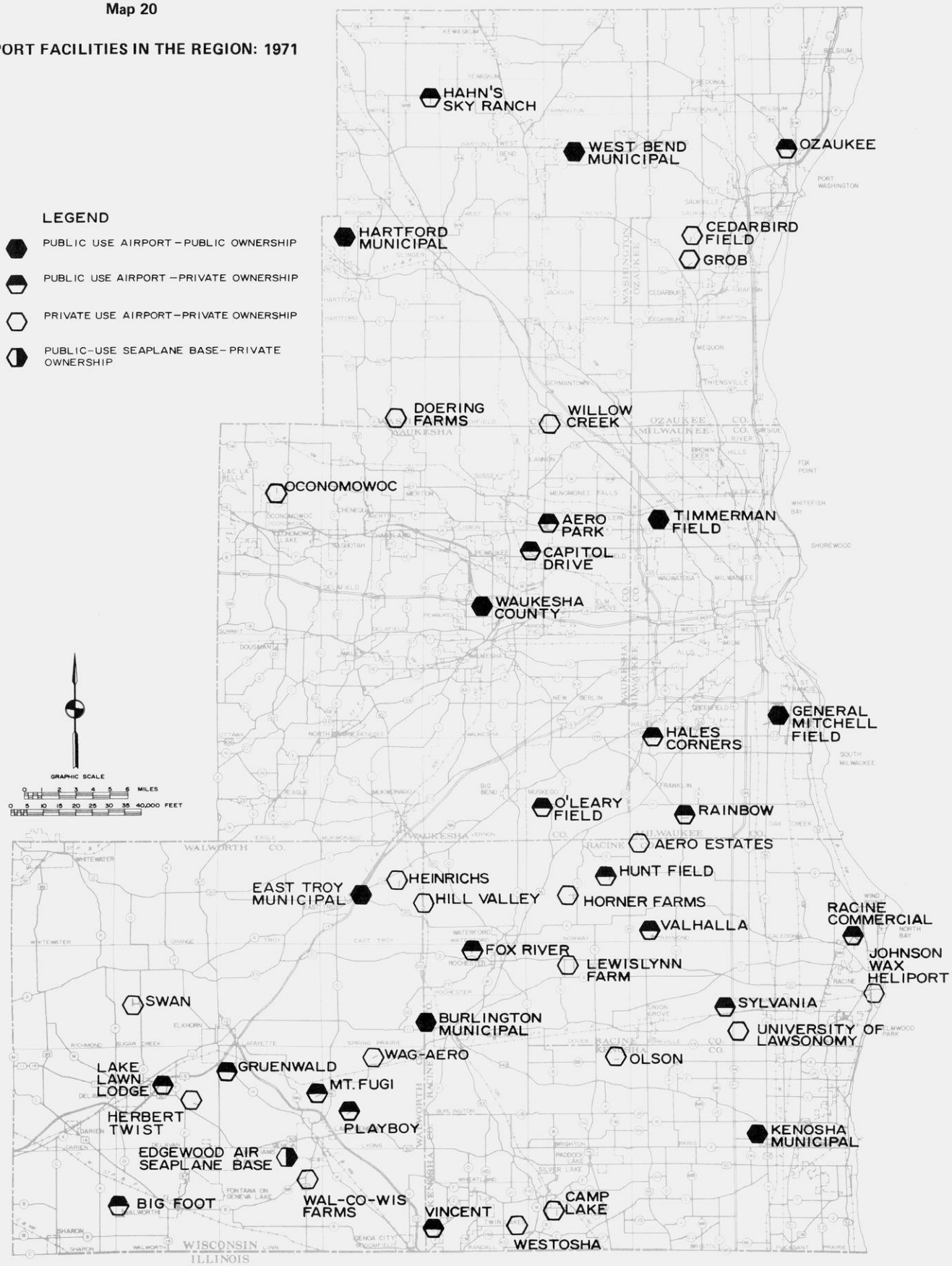
Sanitary Sewerage Utilities

Virtually all sanitary sewerage service within the Region is provided by publicly owned agencies. These agencies generally take the form of commissions in the case of

6 *For a more detailed discussion of regional aircraft operations and demand see SEWRPC Planning Report No. 21, A Regional Airport System Plan for Southeastern Wisconsin, December 1975.*

Map 20

AIRPORT FACILITIES IN THE REGION: 1971



The growing importance of air travel in the Region has led to the establishment of a regional airport system planning program designed to prepare a long-range plan for the future development of airport facilities in the Region for 1990. An inventory of all existing airport facilities in the Region revealed, as shown on this map, that there are a total of 46 airports or air bases in the Region (1971), including one scheduled air carrier airport, 25 general aviation public use airports, one public use seaplane base, one private use heliport, and 18 general aviation private use airports. Of the 27 public use airports, eight are owned and operated by the local units of government in the Region.

Source: SEWRPC.

utilities providing areawide sewer service, a department in the case of utilities providing sewer service in an incorporated municipality, or a town sanitary or utility district in the case of a utility providing sewer service to an unincorporated area. Inventories conducted in 1975 under the regional water quality management planning program revealed there are a total of 95 centralized public sanitary sewerage systems presently operated within the Region. These 95 systems serve a total area of about 353 square miles, or about 13 percent of the total area of the Region, and a total population of about 1.5 million persons, or about 86 percent of the total population of the Region. A total of 61 sewage treatment facilities are currently operated by the utilities owning, operating, and maintaining the 95 public sanitary sewerage systems, with many of the utilities contracting with adjacent utilities for sewage treatment purposes. In addition, there are 67 privately owned sewage treatment plants presently in operation within the Region. These generally serve isolated land use enclaves, mainly for industrial, commercial, and recreational enterprises. In all there are 128 sewage treatment facilities within the Region.

Septic Tank System Development: The construction of public sanitary sewerage facilities has not fully kept pace with the rapid urbanization of the Region, and this has been a contributing factor to the widespread use of onsite soil absorption sewage disposal systems. An estimated total of 246,000 persons in the Region, or about 14 percent of the total regional population, rely on such septic tank sewage disposal systems for domestic sewage disposal. About 27,000 of these persons live on farms. The remaining 219,000 persons constitute urban dwellers generally living in scattered fashion throughout the rural and rural-urban fringe areas of the Region. About 139,000 of the 219,000 urban dwellers live within urbanizing areas of the Region, however, and within potential service areas of centralized sanitary sewer systems.

Water Utilities

Most of the water supply service within the Region is provided by public water utilities. There are a total of 72 publicly owned water utilities within the Region. Of these 72 utilities, all but one--the North Shore Water Utility in Milwaukee County--provide retail water service to consumers. The North Shore Water Utility provides only wholesale water service to three water utilities--the Glendale Water Utility, the Village of Whitefish Bay Water Utility, and the Water Utility of the Village of Fox Point. Together, these 72 publicly owned water utilities serve an area of about 327 square miles, or about 12 percent of the total area of the Region, and about 1.6 million persons, or about 89 percent of the total 1975 resident population of the Region.

In addition to the publicly owned water utilities, there are 79 privately or cooperatively owned water systems throughout the Region. Many of these small water systems serve isolated residential enclaves, while some serve summer residents only and suspend operations during cold weather. Very few of these private systems have standby supply or storage facilities, and the majority do not keep detailed records or file annual reports with state or regulatory bodies. It is anticipated that many of these systems will eventually be absorbed into publicly owned municipal water utilities.

All water supplied by the publicly owned water utilities is drawn either from Lake Michigan or from wells. The Region is not only rich in surface water resources but in groundwater resources, being underlain by two separate aquifers. Treated Lake Michigan water in an amount averaging 322 mgd (millions of gallons per day) was supplied in 1975 to an aggregate service area of about 252 square miles, or about 9 percent of the total area of the Region, and a population of about 1.4 million persons, or about 78 percent of the total population of the Region. Twenty-one of the 72 public utilities in the Region utilize Lake Michigan as a source of supply. Of these 21, seven own and operate water intake and treatment facilities, while 14 utilities purchase water on a wholesale basis. Generally, Lake Michigan offers an unusually good source of supply to those areas lying east of the subcontinental divide and within economic reach of this source of supply.

Well water in an amount averaging about 35 mgd was supplied in 1975 to an aggregate area of about 75 square miles, or about 3 percent of the total area of the Region, and to a population of about 235,000 persons, or about 13 percent of the total resident population of the Region. Fifty-one of the public utilities in the Region utilize the groundwater as a source of supply. In general, water service from a municipal utility is a matter of local policy furnished only to property within the municipal limits of that municipality. Only the Cities of Kenosha, Milwaukee, and Racine in the Region provide water service beyond their corporate limits in any substantial amounts.

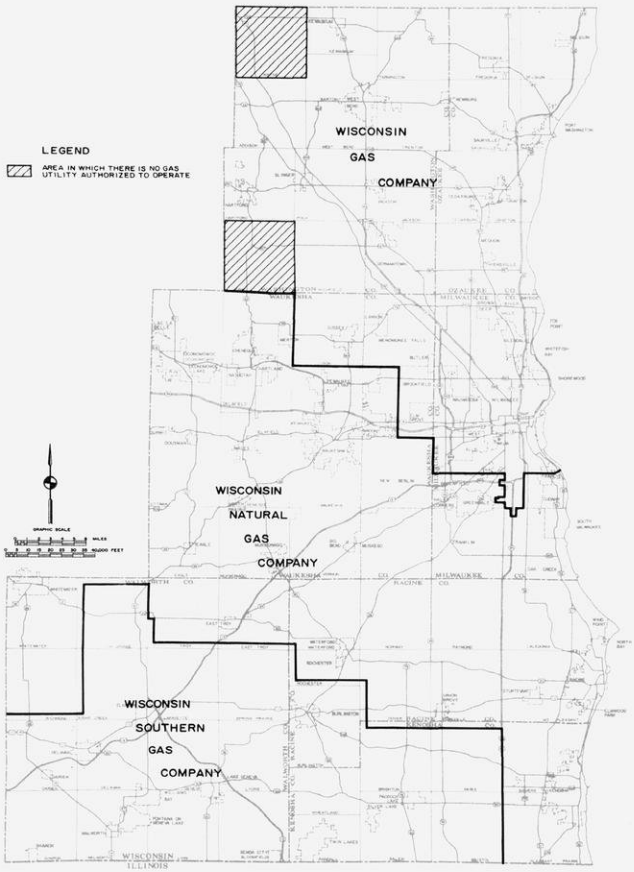
Gas and Electric Utilities

As shown on Map 21, three gas utilities are authorized to operate within the Region and provide all public gas service therein. The Wisconsin Gas Company is authorized to operate in parts of Milwaukee, Ozaukee, Washington, and Waukesha Counties. The Wisconsin Natural Gas Company is authorized to operate in parts of Kenosha, Milwaukee, Racine, Walworth, and Waukesha Counties. The Wisconsin Southern Gas Company is authorized to operate in parts of Kenosha, Racine, and Walworth Counties. Only in the Towns of Erin and Wayne, both in Washington County, is there no gas utility authorized to operate. Natural gas is supplied to the three gas utilities by the Michigan-Wisconsin Pipeline Company and the Natural Gas Pipeline Company of America.

Two major privately owned electric utilities are authorized to operate within the Region and, together with five small municipal utilities, provide service to the entire Region. The Wisconsin Electric Power Company (WEPCO) is authorized to operate throughout nearly the entire Region. The Wisconsin Power and Light Company is authorized to operate in parts of Kenosha and Walworth Counties. Municipal electric power utilities are

Map 21

GAS UTILITY SERVICE AREAS IN THE REGION



All gas service in the Southeastern Wisconsin Region is provided by the following utilities: the Wisconsin Gas Company, the Wisconsin Natural Gas Company, and the Wisconsin Southern Gas Company. Only in the Towns of Erin and Wayne, both in Washington County, is there no gas utility authorized to operate.

Source: SEWRPC.

operated by the Cities of Cedarburg, Elkhorn, Hartford, and Oconomowoc, and by the Village of Slinger. The major commercial electrical power generating facilities operating within the Region are shown on Map 22.

The extent and availability of natural gas and electrical power services has, in the past, been considered virtually ubiquitous and as such, did not constitute a major constraint on the location or intensity of urban development within the Region. Since 1973, however, when the nation and the Region were subjected to severe motor fuel limitations, energy requirements have become a more important development consideration. Moreover, the types of energy utilized to sustain the regional settlement pattern will have a major impact on pollutant emissions and ambient air quality. Because present energy consumption patterns determine, in part, the future demand for the various sources of energy, it is important to examine the historic usage of specific energy sources in order to provide a basis for forecasting probable future utilization patterns.

Overview of Energy Supply and Demand: It is evident that the Untied States is undergoing changes in energy consumption patterns as a result of the depletion of certain kinds of domestic fossil fuel reserves and an increasing dependency on foreign sources for those fuels. The ability of those foreign sources to unilaterally reduce the supply of fuels, as evidenced by the oil embargo enforced by the Organization of Petroleum Exporting Countries (OPEC) in the last quarter of calendar year 1973, has produced a fundamental change in public attitudes concerning the continued availability and utilization of present energy sources. Moreover, both domestic and foreign supplies of the primary fuels in most common useage today--petroleum and natural gas--are being depleted to the point where alternative energy sources must be developed to meet the increasing energy demand if continued economic stability is to be ensured.

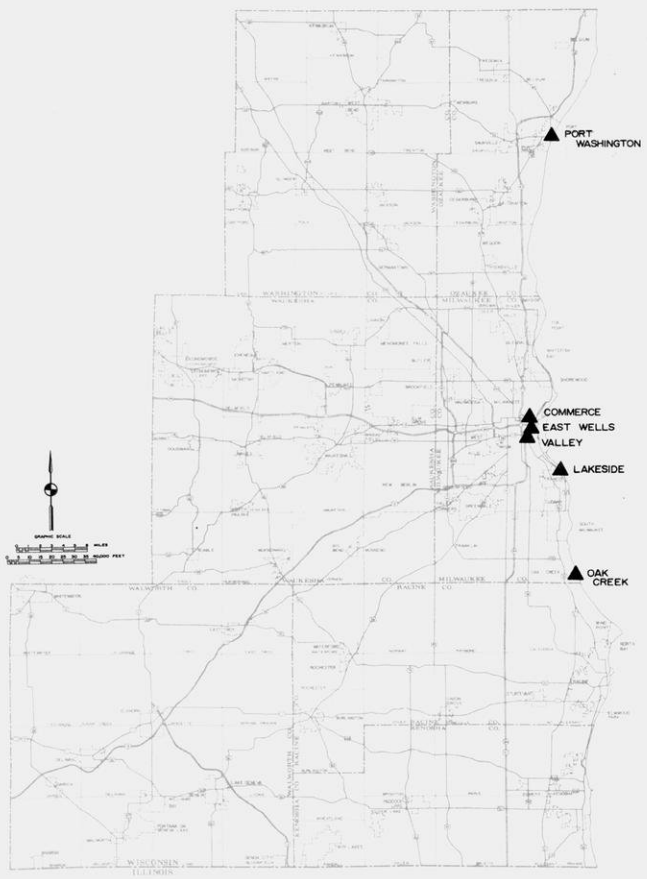
A shift in fuel type development and use by result in the intensification of certain environmental problems. The necessity of burning high-sulfur coal, for instance, may introduce violations in the sulfur dioxide ambient air quality standards which would not be envisioned if a cleaner fuel, such as natural gas, were available to meet the demand. Sound air quality maintenance planning is, therefore, dependent on an understanding of the factors which influence energy consumption.

Energy consumption patterns in the United States have shifted several times in the last century. Figure 20 shows how the reliance on various sources of energy have changed since 1850. Prior to the Civil War, wood was the predominant energy source, accounting for nearly 90 percent of the total energy consumed in the United States, with coal accounting for the other 10 percent. By 1910, coal had become the major energy source, providing approximately 79 percent of the total energy used. At the same time, wood accounted for less than 10 percent, and the relatively new sources of hydropower, petroleum and natural gas[7] made up the remainder. Until the introduction of large-scale nuclear power generation in the early 1970's, petroleum and natural gas provided an increasing proportion of the energy consumed, reaching a maximum of 78 percent in 1972. In 1973, petroleum furnished 46 percent of the total energy consumption, natural gas furnished 31 percent, coal furnished 18 percent, and hydropower and nuclear power furnished 5 percent. Continuing the shift in energy source utilization, the 1975 balance indicates that about 65 percent of the

[7] *Petroleum, as used in this text, is defined as all mobile hydrocarbons which can be recovered from the subsurface by the drilling of wells at the surface, and includes crude oil and its liquid products, as well as liquid condensates (liquid petroleum gas-LPG) which form from natural gas.*

Map 22

EXISTING MAJOR ELECTRICAL POWER GENERATING FACILITIES OPERATING WITHIN THE REGION: 1973



As may be seen from the above map, there were six electrical power generation facilities in the Region in 1973 operated by the Wisconsin Electric Power Company—an investor-owned utility. These six facilities have a combined maximum rated capacity of more than 2,400 megawatts of electrical power. In addition, there are five municipal electric utilities—operated by the Cities of Cedarburg, Elkhorn, Hartford, and Oconomowoc and the Village of Slinger—which provide relatively small amounts of electrical power. The electrical power generation facilities in the Region, however, do not meet the total demand for electricity in the seven-county area. Electrical power, therefore, is brought into the Region from power plants located outside of southeastern Wisconsin.

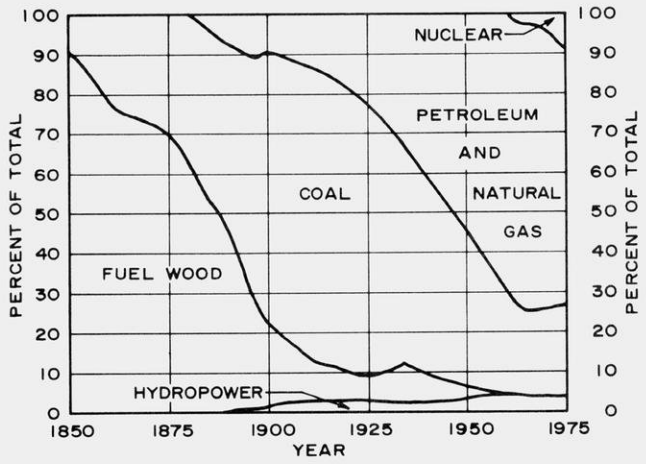
Source: SEWRPC.

total energy used was provided from petroleum and natural gas, 23 percent from coal, and 12 percent from hydropower and nuclear power.

The absolute quantity of energy consumed annually in the United States between 1900 and 1973 has increased from approximately 8 x 10^{15} Btu's[8] to about 75 x 10^{15} Btu's--a more than nine-fold increase in less than 75 years. The population of the United States over this same period increased from about 76 million persons in 1900 to about 210 million, less than a three-fold increase, indicating a marked increase in per capita energy use.

Figure 20

HISTORIC PATTERNS OF ENERGY CONSUMPTION IN THE UNITED STATES: 1850-1975



Source: Ford Foundation.

In terms of energy used for residential, commercial, industrial, and transportation purposes, comparable data are available for both the State and the United States for 1973. Table 38 presents the energy consumed by each of these sectors in Btu's. In 1973 approximately 2.2 percent of the total national population resided in Wisconsin. Wisconsin, however, used about 1.4 percent of the total energy consumed, a slightly smaller energy use on a per capita basis than for the United States as a whole. Energy use for residential and transportation purposes was slightly lower in Wisconsin than the United States as a whole, while use for industrial and commercial purposes was substantially lower.

Although comparable historic figures on the relative and absolute energy usage in the State are not available for all years, certain data have been collated by the Stanford Research Institute for the ten-year period of 1964 through 1973, and by the Energy Systems and Policy Research Group at the Institute for Environmental Studies, University of Wisconsin-Madison, for a five-year period, of 1970 through 1974.[9] Table 39 presents the total energy requirements for the eleven years for which

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[8] *A British Thermal Unit (Btu) is defined as the amount of equivalent heat energy necessary to raise one pound of water one degree Fahrenheit at or near 39.2° Fahrenheit.*

[9] *See Stanford Research Institute, Meeting Wisconsin's Energy Requirements--1975-2000 (Two Volumes), April 1975; and Energy Systems and Policy Research Group, Institute for Environmental Studies, 1975 Survey of Energy Use in Wisconsin, University of Wisconsin-Madison, May 1976.*

Table 38

ENERGY CONSUMPTION IN WISCONSIN AND THE UNITED STATES BY USE SECTOR: 1973

	State (10^{12} Btu)			United States (10^{12} Btu)			State Total as Percent United States
	Primary Fuels	Electrical Power	Total	Primary Fuels	Electrical Power	Total	
Residential	255.9	38.2	294.1	9,400	2,300	16,300	1.8
Commercial	72.4	23.6	96.0	6,200	1,400	10,400	0.1
Industrial	256.0	40.2	296.2	21,400	2,700	29,500	0.1
Transportation	319.9	--	319.9	18,800	--	18,800	1.7
Miscellaneous	18.5	0.2	18.7	--	--	--	--
Total	922.7	102.2	1,024.9	55,800	6,400	75,000	1.4

Source: Energy Systems and Policy Research Group, University of Wisconsin-Madison, Ford Foundation and SEWRPC.

information is available for the State. The disparity in the energy requirements for the overlapping period considered in both studies reflects differences in the calculation procedures used by each institute and is representative of the difficulties and uncertainties inherent in making estimates of energy use.

In 1973, total energy requirements in Wisconsin approximated 1.02 x 10^{15} Btu's or, as already noted, approximately 1.4 percent of the total national energy requirement of 75 x 10^{15} Btu's. On a per capita basis, using 1973 estimates of population and energy use, the annual national energy requirement per person was about 3.6 x 10^{8} Btu's, while for Wisconsin the value was considerably lower at approximately 2.8 x 10^{8} Btu's.

The type of primary fuel used for combustion has a direct influence on pollutant emissions and on ambient air quality. A general review, therefore, of the quantities of each fuel type and its major sector of utilization is presented below.

Petroleum: Table 40 presents a geographic breakdown of the production and reserves of petroleum remaining to be extracted from all known sources. It should be noted that the amount of petroleum reserves presented in Table 40 is the result of estimates of proven resources made by a number of geologists.[10] Most estimates place the known petroleum reserves between 600 and 700 billion barrels. At the present rate of global consumption the estimated reserve of 694 x 10^{9} barrels may be expected to last from 35 to 40 years. Although 90 percent of the world's producing wells are in North America, this area has only about 7 percent of the world's proven oil reserves. The United States, Wisconsin, and the Region, consequently, may be expected to become more and more dependent on foreign imports. In 1973 the United States imported approximately 35 percent of its oil needs. By 1975, this figure had grown to slightly more than 40 percent.

The end uses of petroleum in Wisconsin for the eleven-year period of 1964 through 1974 are shown in Table 39. According to the University's report, a small decrease in petroleum is evident between 1973 and 1974, primarily because of the OPEC embargo initiated in October 1973. This decrease appears to be a temporary anomaly in the otherwise increasing demand for petroleum which may be expected over the next 25 years.

Natural Gas: Natural gas production from domestic sources in the continental United States has been steadily decreasing since 1967, when production reached a maximum of 289 x 10^{12} cubic feet. Demand for natural gas has risen each year, however, primarily because it is a "clean" fuel and the costs have been well below other types of primary fuel. This deficit between domestic supply and demand has been made up through increasing imports.

As shown on Table 39, the primary user of natural gas in Wisconsin is the industrial sector, accounting for approximately 48 percent of the total consumption in 1973.

[10] *Proven reserves are defined as estimated quantities of crude oil which geological and engineering data demonstrate with reasonable certainty to be recoverable in future years from known reservoirs under existing economic and operating conditions. Reservoirs are considered proved if economic producibility is supported by either actual production or conclusive formation tests.*

TABLE 39

SUMMARY END USE DEMANDS FOR ENERGY IN WISCONSIN[a]
(trillions of Btu per year)

End Use	1964	1965	1966	1967	1968	1969	1970		1971		1972		1973		1974
Residential															
LPG	12.7	13.0	17.4	18.5	19.0	19.5	17.3	(---)	20.6	(---)	22.4	(---)	20.7	(---)	(---)
Oil	117.9	123.4	123.6	147.7	143.1	134.3	127.7	(97.02)	124.0	(93.16)	118.0	(91.23)	118.9	(88.65)	(84.22)
Gas	70.1	80.7	85.1	93.0	96.0	106.7	108.9	(108.9)	113.4	(113.4)	125.4	(125.4)	112.9	(112.9)	(119.5)
Coal and Wood	20.1	16.8	14.7	12.3	10.1	8.2	6.9	(4.7)	5.8	(4.0)	4.6	(2.4)	3.4	(1.4)	(1.1)
Electricity	21.1	22.4	23.6	25.8	27.6	30.2	32.4	(32.71)	34.6	(34.58)	36.4	(36.61)	38.2	(38.16)	(38.55)
Subtotal	241.9	256.3	264.4	297.3	294.8	298.9	293.2	(243.33)	298.4	(245.14)	306.8	(255.64)	294.1	(241.11)	(243.37)
Commercial															
LPG	4.7	4.3	5.7	6.2	9.2	6.6	5.8	(---)	6.7	(---)	7.5	(---)	7.5	(---)	(---)
Oil	7.4	5.6	4.3	4.8	5.1	7.2	6.7	(60.47)	5.3	(60.27)	6.7	(61.81)	5.4	(60.77)	(59.67)
Gas	19.7	24.8	29.6	32.3	34.3	40.5	43.4	(52.50)	45.6	(48.0)	53.0	(55.30)	53.4	(56.4)	(67.0)
Coal	12.7	15.8	15.6	14.4	15.8	14.0	12.2	(7.10)	10.5	(5.08)	6.0	(4.33)	5.0	(2.0)	(2.4)
Electricity	12.2	13.2	14.3	15.2	16.6	17.8	19.4	(17.60)	20.4	(18.5)	22.0	(20.10)	23.6	(22.0)	(22.2)
Subtotal	56.7	63.7	69.5	72.9	81.0	86.1	87.5	(130.57)	88.5	(131.85)	95.2	(141.54)	96.0	(141.17)	(151.27)
Industrial															
LPG	2.8	3.1	3.3	2.1	2.1	3.2	3.1	(---)	3.7	(---)	4.2	(---)	5.7	(---)	(---)
Oil	24.0	14.5	16.3	14.3	13.8	12.7	11.5	(21.61)	10.7	(21.10)	12.1	(21.90)	12.3	(21.05)	(20.38)
Gas	71.9	78.0	90.7	100.3	116.2	130.2	140.6	(135.7)	157.5	(157.0)	171.2	(175.0)	164.5	(172.00)	(163.3)
Coal	137.7	144.0	142.3	137.9	131.5	127.7	118.8	(134.81)	80.6	(96.43)	65.0	(82.18)	73.5	(48.20)	(45.4)
Electricity	20.8	22.6	25.1	26.4	29.0	31.2	31.9	(31.28)	33.4	(32.81)	36.5	(35.73)	40.2	(39.03)	(39.52)
Subtotal	257.2	262.2	277.7	281.0	292.6	305.0	305.9	(323.40)	285.9	(307.34)	289.0	(314.81)	296.2	(280.28)	(268.60)
Transportation															
LPG	0.5	0.5	0.5	0.6	0.9	1.2	0.8	(---)	0.8	(---)	1.0	(---)	1.0	(---)	(---)
Oil	205.4	209.2	220.5	231.3	246.4	262.2	275.1	(259.94)	288.1	(273.43)	307.1	(290.59)	316.8	(304.87)	(303.19)
Gas	1.3	1.6	1.5	1.7	1.7	1.9	1.9	(---)	1.9	(---)	2.1	(---)	2.1	(---)	(---)
Electricity	---	---	---	---	---	---	---	(---)	---	(---)	---	(---)	---	(---)	(---)
Subtotal	207.2	211.3	225.5	233.6	249.0	265.3	277.8	(259.94)	290.8	(273.43)	310.2	(290.59)	319.9	(304.87)	(303;19)
Miscellaneous															
LPG	---	---	---	0.1	0.1	0.2	0.4	(---)	0.5	(---)	0.6	(---)	0.6	(---)	(---)
Oil	8.4	10.4	10.4	11.5	13.3	11.9	10.4	(27.41)	10.6	(24.55)	9.1	(23.74)	9.5	(25.94)	(21.10)
Gas	4.1	4.3	6.2	5.4	6.6	0.2	2.3	(31.10)	0.1	(29.7)	3.8	(28.20)	8.4	(28.60)	(34.60)
Electricity	0.2	0.2	0.2	0.2	0.2	0.2	0.2	(2.62)	0.2	(2.82)	0.2	(2.95)	0.2	(3.08)	(3.06)
Subtotal	12.7	14.9	16.8	7.2	20.2	12.5	13.3	(61.13)	11.4	(57.07)	13.7	(54.89)	18.7	(57.62)	(58.76)
Total End Use															
LPG	20.7	20.9	26.9	27.5	31.3	30.7	27.4	(---)	32.3	(---)	35.7	(---)	35.5	(---)	(---)
Oil	363.1	363.1	375.1	409.6	420.7	428.3	431.4	(466.45)	438.7	(472.51)	453.0	(489.26)	464.0	(501.28)	(488.57)
Gas	167.1	189.4	213.1	232.7	254.8	279.5	297.1	(328.20)	318.5	(348.10)	355.5	(383.90)	341.3	(369.90)	(384.40)
Coal	170.5	176.6	172.6	164.6	157.4	149.9	137.9	(146.61)	96.9	(105.51)	75.6	(88.91)	81.9	(51.60)	(48.90)
Electricity	54.3	58.4	63.2	67.6	73.4	79.4	83.9	(84.21)	88.6	(88.71)	95.1	(95.39)	102.2	(102.27)	(103.33)
Total	775.7	808.4	850.9	902.0	937.6	967.8	977.7	(1,025.47)	975.0	(1,014.83)	1,014.9	(1,057.46)	1,024.9	(1,025.05)	(1,025.20)

[a] *The data have been extracted from the Stanford Research Institute report, Meeting Wisconsin's Energy Requirements -- 1975 to 2000, April 1975. The figures in parentheses between 1970 and 1974 have been taken from the Energy Systems and Policy Research Group, Institute for Environmental Studies, University of Wisconsin-Madison report, 1975 Survey of Energy Use in Wisconsin, May 1976.*

Source: Stanford Research Institute, University of Wisconsin-Madison, and the SEWRPC.

Table 40

WORLD PRODUCTION AND RESERVES OF PETROLEUM

Region	Producing Wells (thousands)	Average Production per Well (barrels per day)	Reserves (billions of barrels)
North America	550.2	21	50
South America	26.2	167	80
Europe	4.8	57	12
Middle East	3.1	5,910	356
Africa	2.7	2,137	106
Asia-Pacific	6.7	359	15
Eastern Europe	N/A	N/A	75
Total	593.7	--	694

NOTE: N/A indicates data not available.

Source: Stanford Research Institute.

Residential use accounted for 33 percent of the total consumption, and commercial use accounted for about 16 percent. Table 39 also indicates that industry relies heavily on natural gas, using more than twice as much of that fuel type as coal, the second most commonly used fuel for industrial purposes. The severity of the natural gas shortages experienced in the past few years has already led the three gas utilities in the Region to refuse service to new industrial customers. Although new residential connections are presently being made, there is uncertainty as to how long they will continue to be accepted.

Coal: It is anticipated that coal will be the major substitute fuel to alleviate shortages in natural gas supplies primarily in the industrial sector. As may be seen in Table 39, coal use in Wisconsin has declined over the past decade. This trend, however, may be expected to be reversed within the next few years as the industrial sector is forced to convert from natural gas.

According to estimates made by the U.S. Geological Survey, there are more than 3×10^{12} tons (approximately 7×10^{19} Btu's) of domestic coal reserves, which comprise approximately 88 percent of the nation's total domestic energy resources. The main use of coal is for electric power generation, with more than 50 percent of the electricity used in the United States being produced through coal combustion.

Electricity: There are three types of electric utilities operating within Wisconsin. Investor-owned utilities are the major source of electricity in Wisconsin, accounting for approximately 86 percent of the total generated power. Most of Wisconsin's electricity is generated by the combustion of fossil fuels in the steam turbine cycle, with coal the predominant fuel type. The steam turbine generation method is supplemented by diesel engines and gas turbines using oil and natural gas. Nuclear fuels and hydroelectric generation are also contributing to electric power generation in the State. The energy types used for electrical power generation in Wisconsin from 1970 through 1974 are summarized in Table 41.

Table 42 is a list of the major commercial electrical power plants operating within the Region, and their maximum rated capacity in megawatt hours. All of the electrical power generating facilities shown on this table are owned by the Wisconsin Electric Power Company. The electrical power generation requirements of this company are shown in Table 43 for the years 1969 through 1975, along with the percentage change in power requirements from the previous year. In the same 1969-1975 period, the number of electric space heating customers increased from 1,117 to 10,902--nearly nine-fold increase. The significance of the reduced rate of growth in electrical energy requirements in 1974 as compared with 1973 is not yet evident. It should be noted that the area served by the Wisconsin Electric Power Company extends into counties adjacent to the Region and, therefore, the figures provided above cannot be applied directly to the seven-county Southeastern Wisconsin Region.[11] The data, however, may be considered representative of regional trends in electrical energy consumption.

Other Energy Sources: Historically, the only other fuel type providing any measurable energy in the Southeastern Wisconsin Region is wood. In general, however, wood is not presently used as a primary fuel for space heating and may be considered negligible as an energy source. Also, the use of solar power for space heating and electrical energy production has not advanced into the Region as of yet due to its high cost and limited efficiency in higher latitudes. A further discussion of future alternative energy sources and applications is presented in Chapter XII of this report.

[11] *An attempt was made to obtain electrical energy utilization data for the seven-county Southeastern Wisconsin Region. The records of the power companies, however, are structured in a manner compatible with each company's service area, making data collection for other geographic areas impractical.*

TABLE 41

ENERGY TYPES USED FOR WISCONSIN ELECTRICITY GENERATION, 1970-1974

Energy Types	Measurements	1970	1971	1972	1973	1974
Coal	Tons (x 10^6)	10.162	10.023	10.578	10.007	9.403
	Btu (x 10^{12})	229.67	226.51	239.07	226.16	212.52
	Percent of Year's Total Btu	*83.7*	*74.0*	*75.7*	*67.4*	*61.0*
	kWh Generated (x 10^6)	22,376	20,699	22,193	21,023	19,306
	Percent of Year's Total kWh Generated	*81.7*	*71.0*	*72.8*	*65.3*	*59.2*
Natural Gas	MCF (x 10^9)	30.51	29.09	27.64	28.01	33.90
	Btu (x 10^{12})	31.1	29.7	28.2	28.6	34.6
	Percent of Year's Total Btu	*11.3*	*9.7*	*8.9*	*8.5*	*9.9*
	kWh Generated (x 10^6)	2,885	2,732	2,618	2,624	3,062
	Percent of Year's Total kWh Generated	*10.5*	*9.4*	*8.6*	*8.1*	*9.4*
Petroleum	Gal (x 10^6)	51.99	36.42	37.75	56.19	36.07
	Btu (x 10^{12})	7.72	5.39	5.49	8.09	5.08
	Percent of Year's Total Btu	*2.8*	*1.8*	*1.7*	*2.4*	*1.5*
	kWh Generated (x 10^6)	675.	468.	487.	714.	448.
	Percent of Year's Total kWh Generated	*2.5*	*1.6*	*1.6*	*2.2*	*1.4*
Nuclear Power	Btu (x 10^{12})	0.35	37.8	35.7	65.2	90.2
	Percent of Year's Total Btu	*0.1*	*12.4*	*11.3*	*19.4*	*25.9*
	kWh Generated (x 10^6)	33	3,614	3,311	5,967	8,276
	Percent of Year's Total kWh Generated	*0.1*	*12.4*	*10.9*	*18.5*	*25.4*
Hydroelectric Power	Btu (x 10^{12})	5.65	6.64	7.46	7.49	6.10
	Percent of Year's Total Btu	*2.1*	*2.2*	*2.4*	*2.2*	*1.8*
	kWh Generated (x 10^6)	1,413	1,659	1,866	1,872	1,524
	Percent of Year's Total kWh Generated	*5.2*	*5.7*	*6.1*	*5.8*	*4.7*

Source: Energy Systems and Policy Research Group, University of Wisconsin-Madison.

Table 42

EXISTING MAJOR ELECTRICAL POWER GENERATION PLANTS IN THE REGION: 1973

Power Plant	Maximum Rated Capacity (megawatts)
Commerce Street Station	31
Lakeside	259
Oak Creek	1,477
Port Washington	394
Valley	268
Wells Street Station	10
Region	2,439

Source: Wisconsin Electric Power Company.

Table 43

ELECTRICAL POWER GENERATION REQUIREMENTS OF THE WISCONSIN ELECTRIC POWER COMPANY, 1969-1975

Year	Energy Generated (billions of watt-hours)	Difference From Previous Year (percent)
1969	10,477	--
1970	10,998	+ 4.97
1971	11,451	+ 4.12
1972	12,262	+ 7.08
1973	12,994	+ 5.97
1974	13,056	+ 0.48
1975	13,494	+ 3.35

Source: Wisconsin Electric Power Company.

SUMMARY

The seven-county Southeastern Wisconsin Region is an interrelated complex of natural and man-made features, which together form a rapidly changing environment for human life. The important man-made features of the Region include its land use patterns, its public utility networks, and its transportation system. Together with the population residing in and the economic activities taking place within the Region, these features may be thought of as the socioeconomic base of the Region. An understanding of this base is essential to sound areawide air quality maintenance planning, and to this end this chapter constitutes a description of the socioeconomic base of the Region. The most important aspects of that description are summarized below.

The population of the Region in 1975 was estimated to be 1,789,871 persons, or about a 2 percent increase over the 1970 regional population of 1,756,083. This increase represents a growth rate of about 6,800 persons per year between 1970 and 1975, considerably lower than the 18,000 persons per year growth rate between 1960 and 1970, or the 33,000 persons per year growth rate between 1950 and 1960. Population growth within the Region has been occurring primarily in the newer outlying suburban and rural-urban fringe areas of the Region, while the populations of the older central cities and suburbs of the Region have remained relatively stable or have actually declined, as in the City of Milwaukee. Between 1970 and 1975, the population residing in Milwaukee County decreased by about 41,700 persons, or 4 percent. Milwaukee County's share of the total regional population has also continued to decline from a maximum concentration of about 72 percent of the total residents of the Region in 1930 to about 57 percent in 1975. Waukesha County experienced the largest growth in population between 1970 and 1975, gaining about 31,400 persons. The Region as a whole showed an increase in 1975 of about 34,000 persons, or about 2 percent, over the 1970 population.

The population growth has been accompanied by marked changes in certain characteristics of the population. The composition of the population is becoming increasingly urban, and at the present time less than 2 percent of the total regional population is classified as rural farm. The number of households within the Region has been increasing faster than the total population with an attendant decline in the household size. Personal income has been increasing at a higher rate than has the total population so that per capita and per household incomes have increased markedly over the last two decades, with the areas of highest average household income being located in the most rapidly growing newer suburban and rural-urban fringe areas of the Region.

The characteristics of the regional population, including the composition by age, sex, and race, and education attainment, also changed significantly between 1960 and 1970. With respect to the age composition, the most striking changes are the increase in the proportion of young persons between the ages of 10 and 24 years and the decreases in the proportion of children under 5 years, and in the proportion of adults between 30 and 39 years. The greatest number of elderly persons, age 65 and older, are located in Milwaukee County. In 1970, about 111,300 elderly persons, or about 6 percent of the total regional population, resided in Milwaukee County.

The racial composition of the regional population changed somewhat during the last decade. The 1970 census indicated that 92.6 percent of the regional population was white, while in 1960 the percentage of white population was 95.3. The balance of the population was nonwhite, and in both 1960 and 1970 the majority of this group was comprised of persons of the black race. The nonwhite populations of the Region are concentrated in the central cities of Kenosha, Milwaukee and Racine. Nearly 96 percent of the nonwhite population in the Region, and 98 percent of the black population in the Region, resided in these three cities in 1970.

Employment opportunities have increased at a rate of approximately 8,740 jobs per year over the last 15 years to a current level of approximately 779,000 jobs within the Region in 1975. The economic factors which promote population growth and urbanization in the Region are largely centered in and around the major urban centers of Milwaukee, Racine, and Kenosha, although a diffusion of economic activity into the outlying areas of the Region is occurring. Of the 37,400 new jobs created in the Region between 1970 and 1975, Waukesha County had the greatest number with about 12,300 new jobs, or about an 18 percent growth over the number of jobs in that county during 1970. In the same interval, Milwaukee County experienced an increase of 4,800 jobs, or only about 1 percent over the number of jobs in 1970. The number of jobs in Milwaukee County during 1975, 515,700, is actually about a 3 percent decrease over the number of jobs in 1974, the peak year with 531,400 jobs.

Land within the Region has been undergoing a particularly rapid conversion from rural to urban use. Recent urban development within the Region has been discontinuous and highly diffused, consisting primarily of many scattered, low-density, isolated enclaves of residential development located away from established urban centers. Urban population densities within the Region, which peaked in 1920 at a level of about 11,400 persons per square mile, have steadily declined to a level of about 4,300 persons per square mile in 1970. The highly diffused nature of recent urban development and the sharp decline in urban population density have intensified many long-standing environmental problems within the Region and have created new environmental and developmental problems of an unprecedented scale and complexity, including air quality problems. If regional development trends continue as in the recent past, between 10 and 15 square miles of rural land may be expected to be converted to urban use each year within the Region. Under this type of areawide urban development, many once-isolated and independent communities have grown together.

The southeastern Wisconsin Region is the most highly urbanized area within the State; yet less than 20 percent of its total area is presently devoted to urban type land uses. The largest single land use category within the Region is still agriculture, which presently occupies about 60 percent of the total area. The next largest land use categories are the water and wetland group and woodlands and open lands, both of which occupy about 10 percent of the total area of the Region. The "urban" type land use occupying the greatest area is residential, which presently accounts for about 9 percent of the total area of the Region.

Surface transportation facilities are of three basic types: arterial streets and highways, collector and minor streets, and mass transit facilities. There were 9,819 miles of surface transportation facilities in the Region in 1972. Collector and minor streets accounted for 6,700 miles, or more than 68 percent of the total miles, and surface arterial streets and highways accounted for 3,119 miles, or about 32 percent of the total miles. In 1963, freeways and expressways carried about 11 percent of the total vehicle miles of arterial travel within the Region; by 1972, this percentage had increased to slightly more than 33 percent. In other words, freeways and expressways, which comprised one-tenth of the total arterial street and highway system mileage in 1972, carried one-third of the total vehicle miles of travel.

In its most common form in the Region today, mass transit is provided by buses operating on urban streets. The importance of mass transit varies among subgroups of the regional population. In this regard, access to mass transit facilities is particularly important to the elderly and low-income population, who often have no alternative form of transportation.

Approximately 20 million vehicle miles of travel occurred on the arterial street and highway system of the Region on an average weekday in 1972. Most of this arterial utilization occurred within the intensely urbanized areas of the Region, with Milwaukee County accounting for more than 53 percent of the total vehicle miles of travel and exhibiting by far the most intensive use of the arterial system, with more than 13,400 vehicle miles of travel occurring per mile of arterial street and highway on an average weekday, a marked increase over the comparable figure of about 9,300 vehicle miles per mile in 1963. Although comprising less than 10 percent of the total arterial system mileage, the freeway and expressway system was found to carry more than 30 percent of the total vehicle miles of travel which occurred within the Region on an average weekday.

Substantial changes have also occurred since 1963 in the use of the arterial street and highway system of the Region. Vehicle miles of travel on the arterial street and highway system within the Region increased by 54 percent from 1963 to 1972, or by approximately seven million vehicle miles per average weekday. The majority of this increase, 69 percent, occurred in Milwaukee and Waukesha Counties. Increases in the utilization of the arterial street and highway system occurred in every county of the Region, with Waukesha and Ozaukee Counties experiencing the greatest rates of increase -- 85 and 76 percent, respectively. Much of the increase in arterial and highway utilization has been absorbed by the developing freeway and expressway system, with more than 67 percent of the total increase in arterial utilization from 1963 to 1972 occurring on these limited access facilities. Within this time period, Mil-

waukee County freeway and expressway facilities actually absorbed an amount greater than the 3.3 million vehicle miles of increase in travel demand within the County, with a corresponding decrease in traffic on the surface arterials.

Approximately 318 miles, or about 10 percent of the total arterial street and highway system within the Region, were found to be operating either at or over design capacity in 1972. Most of the congested arterial streets and highways were located within the intensely urbanized areas of the Region. Milwaukee County was found to have about 17 percent of its total arterial street and highway mileage operating at or over design capacity in 1972. Racine, Kenosha, and Waukesha Counties, the remaining three counties which contain high concentrations of urban development, all had approximately 10 percent or more of the arterial street and highway mileage operating at or over capacity.

The arterial street and highway mileage operating at or over capacity actually decreased within the Region by about 4 percent -- from about 332 miles in 1963 to about 275 miles in 1970 -- then increased to about 318 miles in 1972. Milwaukee and Walworth Counties exhibited reductions of about 69 miles and about one mile, respectively, while the other five counties exhibited a combined increase of about 56 miles in arterial streets and highways operating at or over capacity. The total net reduction in traffic congestion was effected in spite of an 8 percent increase in population, a 40 percent increase in motor vehicle registration, a 25 percent increase in trip generation, and a 54 percent increase in vehicle miles of travel.

Mass transportation service within the Region was provided only in the Kenosha, Milwaukee, and Racine urbanized areas in 1972. The Milwaukee mass transit operation was by far the dominant operation, accounting for more than 98 percent of the seat miles and passenger miles of service provided and for more than 98 percent of the revenue passengers carried within the Region.

Scheduled total bus and seat mileage of service, however, decreased from 85,000 miles and 3.4 million seat miles in 1963 to 64,000 miles and 3.3 million seat miles in 1972. The percent utilization of scheduled seat miles of service by passenger miles of use declined on an average weekday from 19 percent to 9 percent in Kenosha, from 30 percent to 17 percent in Milwaukee and Waukesha, and from 24 percent to 18 percent in Racine.

The proportion of the resident population of urbanized areas served by local mass transit also declined from 88 percent in 1963 to 84 percent in 1972. This decrease was particularly evident in the Racine urbanized area, where the transit system showed significant decreases in the percent of total land area and resident population served -- from about 100 percent to 88 percent.

Significant reductions in the use of local mass transportation also occurred within the Region between 1963 and 1972, with all local mass transportation systems experiencing substantial ridership declines which have tended to stabilize in recent years. Within the Milwaukee urbanized area, annual revenue passengers have decreased by 41 percent, from 89 million in 1963 to 52 million in 1972, while annual revenue passengers per capita have declined from 85 to 50. The Kenosha and Racine urbanized areas have shown similar declines in annual revenue passengers, from 1.9 million and 2.9 million to 0.5 million, respectively. Per capita revenue passengers also declined from 26 to 6 and from 30 to 5 in Kenosha and Racine, respectively.

On an average weekday in 1972, nearly 4.7 million person trips and 3.4 million vehicle trips were made within the Region. These figures represented increases from 1963 to 1972 of 887,000 person trips, or 23 percent; and of 848,000 vehicle trips, or 33 percent. Nearly all of these person and vehicle trips, or more than 95 percent in each year, were made by residents of the Region.

Of the total person trips, auto driver trips alone accounted for 60 percent in 1963 and 64 percent in 1972. Auto passenger trips accounted for an additional 27 percent of the total in both 1963 and 1972. Of the remaining modes, mass transit passenger trips accounted for 9 percent of the total in 1963 and 4 percent in 1972. All other modes together accounted for 0.5 percent or less in both 1963 and 1972.

The number of automobiles available to residents of the Region increased from 527,000 in 1963 to 705,000 in 1972, an increase of 178,000 autos, or 34 percent, compared to an 8 percent increase in the regional population during that period. In both 1963 and 1972, approximately 88 percent of total internal vehicle trips were made by automobile or taxi and only 12 percent were made by trucks.

Of all internal person trips occurring within the Region, 80 percent were either made to or from home, indicating the importance of residential location in tripmaking. Approximately 41 percent of total internal person trips within the Region on an average weekday in both 1963 and 1972 consisted of trips made to place of residence. Trips to work accounted for 18 percent of all internal person trips made within the Region on an average weekday in 1963 and for 16 percent in 1972, and were second in importance of all trip purposes.

The daily pattern in person travel indicates that total person travel varied no more than 6 percent from the daily average for any weekday other than Friday. The large increases in tripmaking on Fridays are caused by significant increases in trips for personal business, social-recreation, and shopping purposes.

The hourly distributional patterns of internal person trips indicated that although total person trip volumes increased substantially on an average weekday from 1963 to 1972, the regular ebb and flow of travel remained markedly similar both in the proportion of trips by trip purposes and in the proportion and times of peak periods. At all hours of the day, auto driver trips outnumbered trips by all other modes combined.

Public utility systems are among the most important and permanent elements of urban growth and development. The majority of sanitary sewerage service and water supply service within the Region is provided by publicly owned agencies. There are a total of 95 centralized public sanitary sewerage systems presently operated by utilities within the Region. These 95 systems serve a total area of about 353 square miles, or about 13 percent of the total area of the Region, and a total population of about 1.5 million persons. Seventy-two publicly owned water utilities are presently in operation within the Region and serve about 1.6 million persons.

The construction of public sanitary sewerage and water supply facilities has not fully kept pace with the rapid urbanization of the Region, necessitating the widespread use of onsite sewage disposal systems. An estimated 246,000 persons, or about 14 percent of the total regional population, rely on such septic tank sewage disposal systems. Only about 27,000 of these persons actually live on farms, with the remaining 219,000 persons constituting urban dwellers generally living in scattered fashion throughout the Region. About half of the total area of the Region is covered by soils which are unsuitable for use by onsite sewage disposal facilities.

The Region is unusually rich with respect to water resources. Urban development located east of the subcontinental divide, which traverses the Region, can utilize both Lake Michigan and the two underlying groundwater aquifers as a source of supply. Because of legal constraints on interbasin diversion, urban development west of that divide must depend primarily upon the groundwater. Public water supply system service areas have generally tended to follow public sewerage service areas within the Region, although the extension of public water supply services has generally lagged behind the extension of sanitary sewerage service.

Gas and electric power services, which have in the past been considered readily available throughout the Region, did not present a major constraint on the location and intensity of urban development. Since 1973, however, when the nation and the Region were subjected to severe motor fuel limitations, energy requirements have become a more important development consideration. Moreover, the types of energy utilized to sustain the regional settlement pattern will have a major impact on pollutant emissions and ambient air quality.

In part, the observed air pollution problems within the Region are directly related to the increasing urbanization occurring in the seven-county area. This urbanization is well characterized by the socioeconomic base within the Region and is comprised of such elements as population levels, the distribution of economic activity, the land use base, the transportation base, and the public utility base. In attempting to resolve conflicts between meeting the changing socioeconomic needs and demands of the resident population and attaining and maintaining clean ambient air, it is essential to understand the interrelationships and interactions between human activities and movements and the environment in order to comprehensively plan for the growth and development of the Region.

Chapter V

DESCRIPTION OF THE REGION: THE NATURAL RESOURCE BASE

INTRODUCTION

The natural resource base is a primary determinant of the development potential of a region and of its ability to provide a pleasant and habitable environment for all forms of life. The principal elements of the natural resource base, in addition to the air resource, are climate, physiography, soils, mineral and organic deposits, vegetation, water resources, and fish and wildlife.[1] Air as a natural resource, particularly as it is influenced by atmospheric pollutants, is considered separately in Chapters VI and VII of this report; however, climate, which may be defined as a generalized, statistical representation of the meteorological events occurring over an area sharing common air resources, is considered in this chapter in order to provide a description of the overall weather regime affecting the Region.

Without a proper understanding and recognition of the resource elements of the natural resource base and of their interrelationships, human use and alteration of the natural environment proceed at the risk of excessive costs in terms of both monetary expenditures and destruction of nonrenewable or slowly renewable resources. In this age of high resource demand, urban expansion and rapidly changing technology, it is essential that the natural resource base be a primary consideration in any areawide planning effort since these aspects of contemporary civilization make the underlying and sustaining resource base highly vulnerable to misuse and destruction. An understanding of other elements of the natural resource base is indispensable to sound areawide ambient air quality maintenance planning because of the relationships which exist between air quality, climate, physiography, vegetation, and water resources and because of the impact which air quality may have on plant and animal as well as on human life.

This chapter identifies and describes those significant elements of the natural resource base of the Southeastern Wisconsin Region other than the air resource itself; indicates and quantifies the spatial distribution and extent of these resources; characterizes, where possible, the quality of each component element of the natural resource base; and seeks to identify those elements and characteristics of the natural resource base which must be considered in ambient air quality maintenance planning and in land use and transportation system planning as such planning relates to air quality maintenance planning. The importance of such consideration cannot be overemphasized because rural and urban development, by its impacts on the natural resource base including the ambient air, has the potential either to degrade or to protect and enhance the natural heritage and environmental quality of the Region.

CLIMATE

Wisconsin's midcontinental location, far removed from the moderating effect of the oceans, gives the Region a typical continental type climate characterized by a continuous progression of markedly different seasons and a large range in annual temperature. The summers are relatively warm, influenced by the warm southwesterly winds common during that season, with occasional periods of hot, humid weather and sporadic periods of very cool weather. Winters tend to be cold, cloudy, and snowy, accentuated by prevailing frigid northwesterly winds. There is often a short midwinter thaw occasioned by brief periods of unseasonably warm weather. Streams and lakes begin to freeze over in November, with the larger and deeper bodies of water usually being covered with ice by mid-December. Lake and stream ice breakup occurs in late March or early April due to increasing solar radiation.

The Southeastern Wisconsin Region is positioned astride cyclonic storm tracks along which low pressure centers move from the west and southwest. The Region also lies in the path of high pressure centers moving in a generally southeasterly direction. This location at the confluence of major migratory air masses results in the Region as a whole being influenced by a continuously changing pattern of different air masses having alternately low and high pressure centers, and results in frequent weather changes being superimposed on the afore-

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[1] *The elements of the natural base listed are those most closely related to air quality, either by the direct or indirect effects of these elements on air quality or by the direct or indirect effects of air quality on these elements. For a more complete description of all elements of the natural resource base of the Region, including geology and groundwater, see SEWRPC Planning Report No. 5, Natural Resources of Southeastern Wisconsin; SEWRPC Planning Report No. 8, Soils of Southeastern Wisconsin; SEWRPC Planning Report No. 9, A Comprehensive Plan for the Root River Watershed; SEWRPC Planning Report No. 12, A Comprehensive Plan for the Fox River Watershed, Volume One, Inventory Findings and Forecasts; SEWRPC Planning Report No. 13, A Comprehensive Plan for the Milwaukee River Watershed; Volume One, Inventory Findings and Forecasts, SEWRPC Planning Report No. 16, A Regional Sanitary Sewerage System Plan for Southeastern Wisconsin; and SEWRPC Planning Report No. 25, A Regional Land Use Plan and A Regional Transportation Plan for Southeastern Wisconsin--2000, Volume One, Inventory Findings.*

mentioned large annual range in weather characteristics, particularly in winter and spring when distinct weather changes consist of marked variations in temperatures, type, and amount of precipitation, relative humidity, wind magnitude and direction, and cloud cover.

In addition to these distinct variations in weather, the Region exhibits spatial variations in weather resulting primarily from its proximity to Lake Michigan, particularly during the spring, summer, and fall seasons when the temperature differential between the lake water and the land air masses tends to be the greatest. During these periods, the presence of the lake tends to moderate the climate of the eastern border of the Region. It is common, for example, for mid-day summer temperatures in shoreline areas to drop abruptly to a level 10°F lower than inland areas because of cooling lake breezes generated by pressure differences resulting from differential heating of the land and water surfaces. This Lake Michigan temperature influence is generally limited, however, to a narrow band of the Region lying within several miles of the shoreline.

Temperature

Atmospheric stability is highly dependent upon the horizontal and vertical distribution of temperatures. Whether the atmosphere has a tendency to be stable or unstable is vital to atmospheric processes which produce weather and affect air quality.

Summer temperatures throughout the Region, as reflected by monthly means for July and August, are in the 68°F to 73°F range, with northerly lakeshore locations exhibiting lower monthly mean summer temperatures than southerly inland locations. (See Table 44; Figure 21) The influence of Lake Michigan on summer temperatures may be demonstrated by contrasting Waukesha and Milwaukee data. Waukesha's monthly mean temperatures for June, and July are 67°F and 72°F, respectively, whereas Milwaukee, which lies east of Waukesha and is subject to the influence of Lake Michigan, exhibits monthly means for June and July that are 2°F and 1°F, respectively lower than those at Waukesha. The influence of Lake Michigan on summer temperatures is also demonstrated by average daily maximum and average daily minimum temperatures for inland locations as opposed to lakeshore locations. For example, average daily maximum temperatures at Waukesha for July and August are 83°F and 81°F, respectively, whereas Milwaukee, because of its close proximity to Lake Michigan, has July and August average daily maximum temperatures that are 3°F and 2°F, respectively, lower than those measured at Waukesha. Thus, in addition to abrupt daytime drops in summer shoreland temperatures attributable to wind shifts that produce cooling lake breezes, Lake Michigan also is responsible for markedly lower monthly mean and average daily maximum temperatures for land areas in close proximity to the lake as compared to inland areas located at approximately the same latitude.

Winter temperatures in southeastern Wisconsin, as measured by monthly means for January and February, are shown in Table 44 and Figure 21. These are in the range of 19°F to 26.0°F for all stations, there being no significant differences in monthly means, average daily minimums, and average daily maximums between inland and lake shore locations as is true for summer temperatures.

Lake Michigan significantly affects temperatures of the Region during the transitional period of March, April, and May between winter and summer. At this time the lake, because it warms more slowly than the adjacent land areas, retards the temperature rise for land areas located along the shoreline relative to inland locations as evidenced by data presented in Table 44 and in Figure 21. Monthly mean temperatures for Waukesha

Table 44

TEMPERATURE CHARACTERISTICS AT SELECTED LOCATIONS IN THE REGION

Month	Observation Station[a]																												Month
	Lakeshore Locations												Inland Locations												Regional Summary				
	Port Washington			Milwaukee			Racine			Kenosha			West Bend			Waukesha			Whitewater			Lake Geneva						
	1959-1977			1940-1976			1940-1977			1948-1977			1940-1977			1940-1977			1949-1977			1945-1977						
	Average Daily Maximum[b]	Average Daily Minimum[b]	Mean[c]	Average Daily Maximum[b]	Average Daily Minimum[b]	Mean[c]	Average Daily Maximum[b]	Average Daily Minimum[b]	Mean[c]	Average Daily Maximum[b]	Average Daily Minimum[b]	Mean[c]	Average Daily Maximum[b]	Average Daily Minimum[b]	Mean[c]	Average Daily Maximum[b]	Average Daily Minimum[b]	Mean[c]	Average Daily Maximum[b]	Average Daily Minimum[b]	Mean[c]	Average Daily Maximum[b]	Average Daily Minimum[b]	Mean[c]	Average Daily Maximum[d]	Average Daily Minimum[d]	Mean[e]	
January	27	11	19	28	13	20	30	14	22	29	13	21	27	10	19	27	11	19	29	11	20	29	12	20	28.2	11.9	20.0	January
February	31	16	23	31	16	24	33	17	25	33	18	26	30	13	22	31	15	23	33	15	24	33	15	24	31.9	15.6	23.9	February
March	39	24	32	40	25	32	41	26	34	41	26	33	39	23	31	40	23	32	43	23	33	42	24	33	40.6	24.2	32.5	March
April	50	34	42	53	36	45	55	36	46	53	36	45	55	34	45	56	35	46	59	36	47	57	35	47	54.8	35.2	45.4	April
May	60	43	52	64	44	54	65	45	55	64	44	54	66	44	55	67	45	56	71	46	59	69	45	58	65.8	44.5	55.4	May
June	71	53	62	75	55	65	77	56	66	75	54	65	77	55	66	78	55	67	80	56	68	80	56	68	76.6	55.0	65.9	June
July	77	60	69	80	61	71	82	62	72	80	61	71	82	60	71	83	60	72	85	60	72	84	61	73	81.6	60.6	71.4	July
August	77	59	68	79	61	70	81	61	72	79	61	70	80	59	70	81	59	70	83	58	70	83	60	72	80.4	59.8	70.2	August
September	70	53	61	71	53	62	74	54	64	72	53	63	72	51	62	73	51	62	75	50	63	75	52	64	72.8	52.1	62.6	September
October	60	43	52	61	43	52	63	44	54	62	43	53	62	42	52	63	41	52	65	41	53	64	43	54	62.5	42.5	52.8	October
November	45	31	38	45	30	38	47	32	40	47	31	39	45	29	37	45	29	37	48	29	39	46	30	38	46.0	30.1	38.2	November
December	35	19	27	32	18	25	34	19	27	35	19	27	32	16	24	32	17	25	33	17	25	33	18	26	33.2	17.9	25.6	December
Yearly Average	53.5	37.2	45.4	54.9	37.9	46.5	56.8	38.8	48.1	55.8	38.3	47.3	55.6	36.3	46.2	56.3	36.8	46.8	58.7	36.8	47.8	57.9	37.6	48.1	56.2	37.4	47.0	Yearly Average

[a] *Observation stations were selected both on the basis of the length of record available and geographic location within the Southeastern Wisconsin Region. Port Washington, Milwaukee, Racine, and Kenosha are representative of areas with temperatures influenced by Lake Michigan, whereas West Bend, Waukesha, Whitewater, and Lake Geneva are typical of inland areas having temperatures that are not generally influenced by Lake Michigan. Kenosha and Lake Geneva are representative of southerly areas in the Region, whereas Port Washington and West Bend typify northern locations.*

[b] *The monthly average daily maximum temperature and the monthly average daily minimum temperature are obtained by using daily measurements to compute an average for each month in the period of record the results are then averaged for all the months in the period of record.*

[c] *The monthly mean temperature is the mean of the average daily maximum temperature and the average daily minimum temperature for each month.*

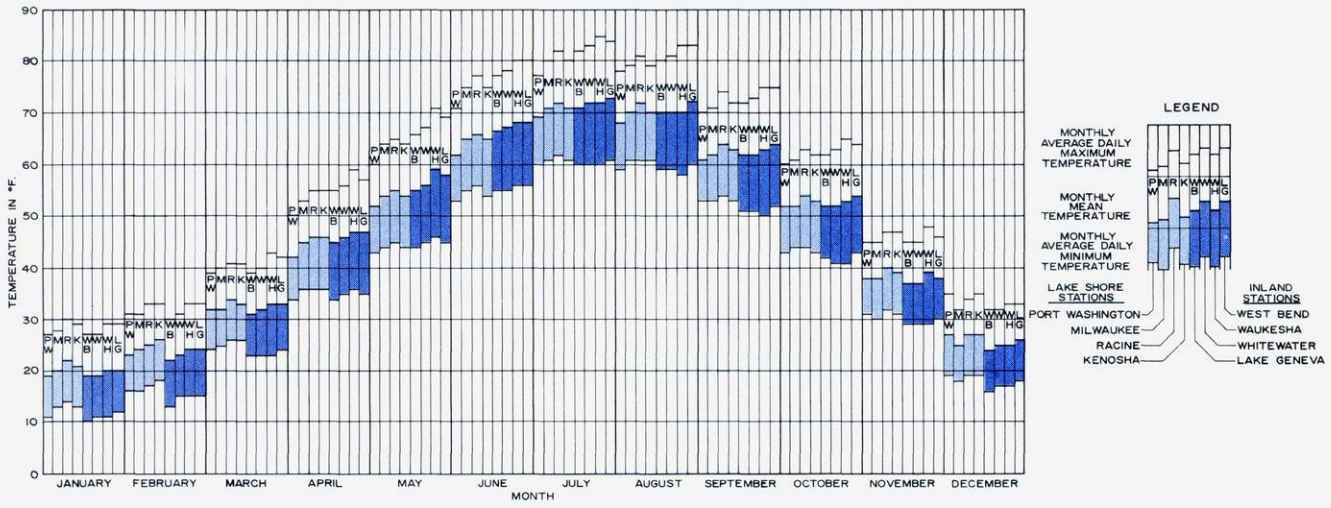
[d] *The monthly average daily maximum and minimum temperatures for the Region as a whole were computed as averages of the corresponding values for the eight observation stations.*

[e] *The monthly mean for the Region as a whole is the mean of the Regional monthly average daily maximum and average daily minimum, which is equivalent to the average of the monthly means for the eight observation stations.*

Source: SEWRPC.

Figure 21

TEMPERATURE CHARACTERISTICS AT SELECTED LOCATIONS IN THE REGION



Source: National Weather Service, Wisconsin Statistical Reporting Service, and SEWRPC.

during March, April, and May are 32°F, 46°F, and 56°F, respectively, whereas Milwaukee, since its temperature rise during the winter-summer transitional period is retarded by Lake Michigan, exhibits monthly mean temperatures which although about the same in March, are about 1°F and 2°F below those measured at Waukesha in April and May, respectively. The end result of this winter to summer transition process is, as discussed earlier, summer conditions characterized by lower temperatures in shoreland areas than at inland locations. The summer to winter transition period, as shown graphically in Figure 21, is characterized by a slightly greater drop in monthly mean temperature in inland areas than in shoreline areas, since the former begin the transition period at a higher level than the latter and both inland and shoreline areas converge to similar temperature levels in winter.

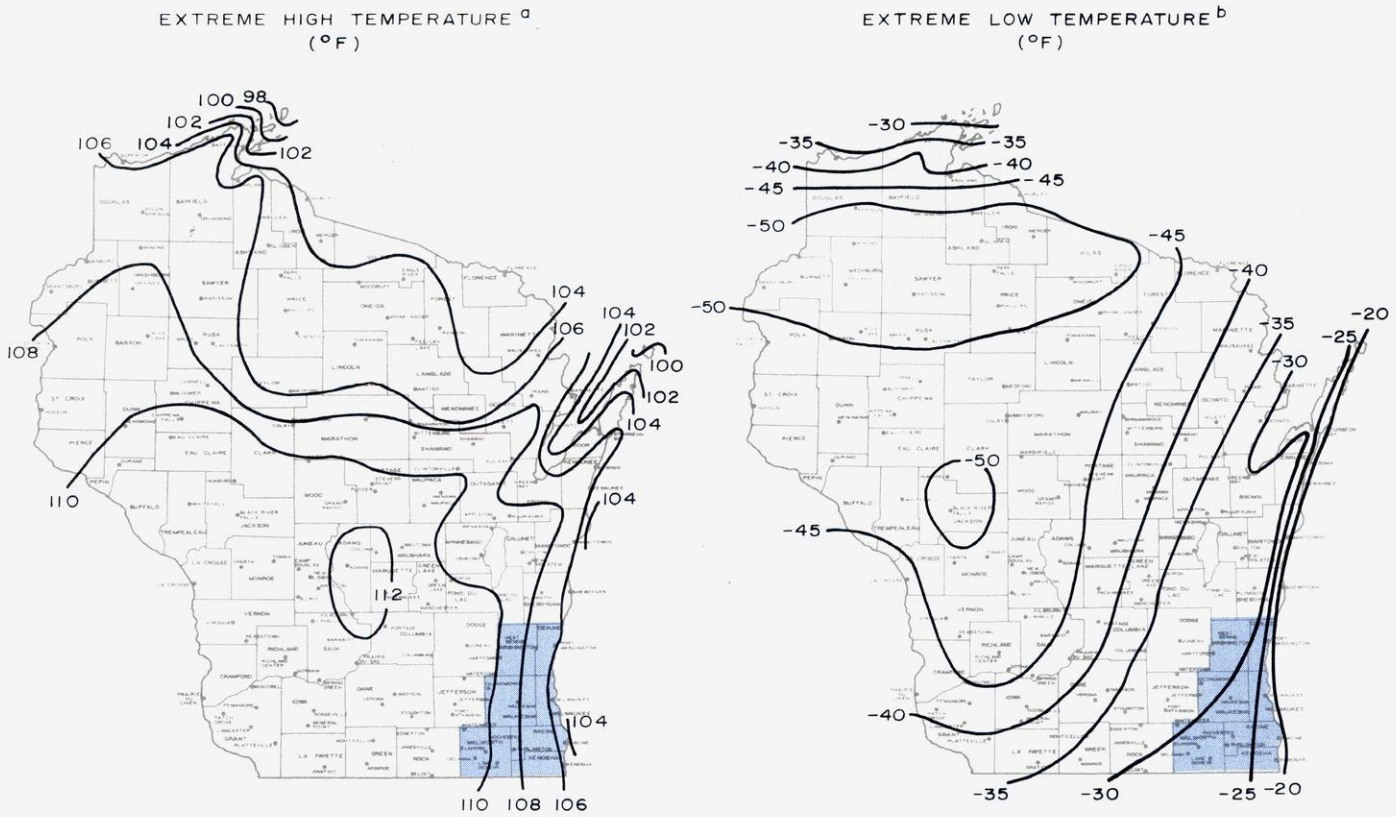
Marked latitudinal differences in temperature, clearly evident on Figure 21, occur along the approximately 80-mile-long portion of Lake Michigan shoreline which comprises the eastern boundary of the planning Region. Southerly locations, as typified by Kenosha, exhibit significantly higher monthly mean, average daily maximum, and average daily minimum temperatures than do northerly areas as typified by Port Washington. For example, January and February monthly mean temperatures at Kenosha are 21°F and 26°F, respectively, which is 2°F and 3°F , respectively, greater than those recorded at Port Washington. Observed monthly mean temperatures at Kenosha for July and August are 2°F above those recorded at Port Washington for the same months.

The growing season, which is defined as the number of days between the last 32°F freeze in spring and the first in the fall, averages about 165 days for the Region. The lakeshore area has a growing season of about 175 days while inland locations exhibit a shorter growing season of about 155 days. The last 32°F frost in the spring normally occurs within the last week of April for areas in close proximity to Lake Michigan and during the first half of May for inland locations, whereas the first freeze in the fall usually occurs in the two week span during mid-October for all locations in the Region. Lake Michigan's moderating effect inhibits spring frost formation in the eastern extremities of southeastern Wisconsin, thereby giving that portion of the Region a slightly longer growing season.

Extreme high and low temperatures for Southeastern Wisconsin, based on 30 or more years of historic records at observation stations distributed throughout the Region, are shown on Figure 22. The data indicate that extreme high temperatures within the Region have ranged from 104°F in the extreme eastern portion of Racine County to slightly more than 110°F in the western extremities of Washington, Waukesha, and Walworth Counties, whereas extreme low temperatures have ranged from about -20°F along the entire Lake Michigan shoreline to -33°F in the northwestern corner of Washington County. Lake Michigan has influenced temperature extremes in that the lakeshore areas exhibit extreme summer high temperatures that are lower than those experienced inland because of the summer cooling effect of the lake. Moreover, unlike winter monthly mean and winter average daily minimum and maximum temperatures, the lake apparently has influenced extreme winter low temperatures, in that those temperatures are higher for lakeshore areas than those experienced inland because of the winter warming effect of the lake. The range in historic extreme temperatures, therefore, is smaller along the Lake Michigan shoreline than at inland locations because of the moderating effect of the lake.

Figure 22

EXTREME HIGH AND LOW TEMPERATURES IN THE REGION
BASED ON DATA FOR STATIONS WITH AT LEAST 40 YEARS OF RECORD



[a] THE EXPECTED EXTREME HIGH TEMPERATURE FOR AN AVERAGE YEAR AT A GIVEN LOCATION MAY BE APPROXIMATED BY SUBTRACTING 10 TO 15°F FROM THE EXTREME HIGH TEMPERATURE SHOWN ON THE FIGURE.

[b] THE EXPECTED EXTREME LOW TEMPERATURE FOR AN AVERAGE YEAR AT A GIVEN LOCATION MAY BE APPROXIMATED BY ADDING 10 TO 15°F TO THE EXTREME LOW TEMPERATURE SHOWN ON THE FIGURE.

Source: National Weather Service, Wisconsin Statistical Reporting Service, and SEWRPC.

In addition to utilizing the regional data summarized in Figure 22, historic extreme temperatures and the moderating influence of Lake Michigan on those temperatures may also be demonstrated by examining data for specific observation stations having similar latitudes. Historic data for the 100-year period at Milwaukee extending through 1970 indicate that the highest temperature ever recorded in that City was 105°F in July 1934, while the lowest temperature ever recorded was -25°F in January of 1875. The highest temperature recorded during the 48 year period 1930 through 1977 at Waukesha, which is located approximately 15 miles inland from Milwaukee and therefore farther removed from the moderating influence of Lake Michigan, was 109° in July 1936. The lowest was -27°F in January 1944. Even through the 48-year Waukesha record is considerably shorter than the 100-year record at Milwaukee, observed temperatures have been more extreme at the former location.

Precipitation

Precipitation is one of several processes by which pollutants may be removed from the atmosphere. This happens in two ways: by falling raindrops intercepting particulates, a process known as washout; and by raindrops forming around and intercepting particulates during the raindrop formation within the clouds and falling then as precipitation, a process known as rainout. Precipitation in the form of snow and sleet removes pollutants from the atmosphere in the same manner as rain. While cleansing the atmosphere, such washout and rainout, together with dry fallout through gravitational settling, contribute to land and water pollution. The total amount of particulates which are removed from the atmosphere through the washout and rainout processes cannot be quantified at the present time due to the lack of the necessary observations and measurements relating precipitation rates to pollutant removal. Such observations and measurements are being

undertaken by the International Joint Commission Menomonee River Pilot Watershed Study, a study in which the Commission is a cooperating agency. The results of this investigation, expected to be available in 1978, will provide a quantitative basis for determining washout and rainout rates of pollutant removal within the Region.

Precipitation and snowfall data for eight representative precipitation observation stations in southeastern Wisconsin located on the Lake Michigan shoreline at Port Washington, Milwaukee, and Kenosha and inland at West Bend, Waukesha, and Lake Geneva are presented in Table 45 and Figure 23. These data, which encompass periods of record ranging from 15 to 57 years, illustrate the temporal and spatial variations in the type and amount of precipitation that normally occur within the Region.

The data indicate that the average annual total precipitation in the Region, based on data for the six representative stations, is 31.26 inches, expressed as water equivalent, and that the average annual snowfall measured as snow at the time of snowfall is 44.5 inches. Average total monthly precipitation for the Region ranges from 1.29 inches in December to 3.77 inches in June. The principal snowfall months are December, January, February, and March when average monthly snowfalls are 9.2, 11.9, 8.9, and 9.7 inches, respectively, and during which time 89 percent of the average annual snowfall may be expected to occur. Snowfall is the predominant form of precipitation during these months since over one-half of the total precipitation during these months, expressed as water equivalent, usually occurrs as snow, Approximately 20 inches, or two-thirds of the average annual precipitation, normally occurs during the late April through mid-October growing season, primarily as rainfall. Assuming that 10 inches of measured snowfall is equivalent to one inch of water, the average annual snowfall of 44.5 inches is equivalent to 4.45 inches of water and, therefore, only 19.2 percent of the average annual total precipitation occurs as snowfall. It is of interest to note that approximately three-quarters of the 31.26-inch average annual precipitation leaves the Region as evapo-transpiration; the remaining one-quarter is transported from the Region as streamflow.

Data indicate that Lake Michigan does not have as pronounced an effect on precipitation within the Region as it does on temperature. A minor Lake Michigan effect is evident in a rainfall reduction of up to about 0.5 inch per month in late spring and summer in the eastern areas of the Region as compared to the western areas. This reduction may result from the lake waters maintaining a cooler lower atmosphere that inhibits convective precipitation.

The influence of Lake Michigan as a source of moisture is reflected by slightly higher seasonal snowfalls for the entire Region as compared to snowfalls for inland areas lying west of the Region[2]. Minor intraregional spatial snowfall differences occur in that seasonal snowfall tends to be greatest in the topographically higher northwest portion of the Region because moisture masses moving through that area are forced upward by the higher terrain where lower temperatures normally associated with increased height induce more snowfall than would occur in the absence of the topographic barrier.

Extreme precipitation data for the entire Region, based on observations for stations located throughout southeastern Wisconsin having relatively long periods of record, are presented in Table 46. The minimum annual precipitation within the Region, as determined from the tabulated data for the indicated observation period, occurred at Waukesha in 1901, when only 17.30 inches of precipitation occurred, or 57 percent of the average annual precipitation of 30.3 inches for southeastern Wisconsin. The maximum annual precipitation within the Region occurred at Milwaukee in 1876 when 50.36 inches of precipitation occurred, or 166 percent of the average annual precipitation for southeastern Wisconsin. The minimum seasonal snowfall was 5.0 inches, or about 11.5 percent of the regional annual average snowfall, and was recorded at Racine during the winter of 1901-1902, whereas the maximum annual or seasonal snow fall was 109.8 inches, or about 251 percent of the regional annual average, and was recorded at Milwaukee during the winter of 1885-1886.

The maximum monthly precipitation measured in the Region was 13.17 inches, which occurred at West Bend in August 1924, while the maximum monthly snowfall was 56.0 inches as recorded at Waukesha in January 1918. The maximum 24-hour or daily precipitation ever recorded in southeastern Wisconsin, based on the data presented in Table 46, occurred in the West Bend area on August 4, 1924, when 7.58 inches of rain fell, and the greatest 24-hour or daily snow fall was 30.0 inches recorded at Racine in February 1898.

Snow Cover

Accumulated snow depth at a particular location and time depends primarily upon antecedent snowfall, rainfall, and temperature characteristics, and the amount of solar radiation. Rainfall is relatively unimportant as a melting agent but can, because of compaction effects, significantly affect the depth of snow cover on the ground.

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[2] *The effect of Lake Michigan on the annual snowfall in southeastern Wisconsin is minor relative to lake-effect snowfall experienced on the eastern shore of the lake. In the winter, prevailing northwesterly winds move cold, dry air over the relatively warm surface of Lake Michigan. The air gains moisture and heat energy and rises, producing annual snowfalls in excess of 80 inches, about twice that experienced in Wisconsin, over most of the western portion of the State of Michigan. For additional information see: Dewey, K. F., "Lake-Effect Snowfall and Some Implications for a Great Lakes Air Pollution Model," Northern Illinois University, Department of Geography, September 1970.*

Table 45

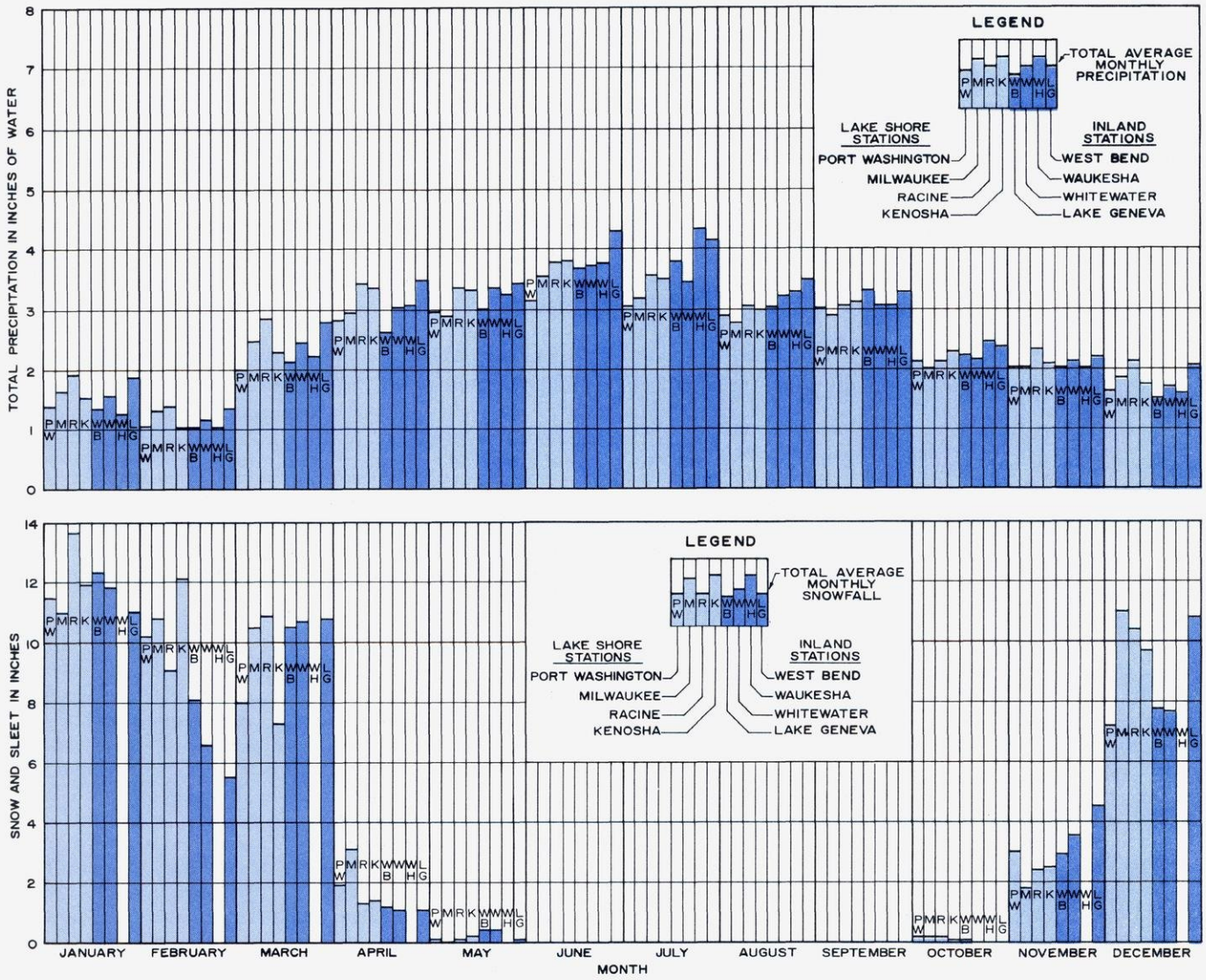
PRECIPITATION CHARACTERISTICS AT SELECTED LOCATIONS IN THE REGION: SELECTED YEARS 1896-1970

Month	Observation Station																		Month
	Lakeshore Locations								Inland Locations										
	Port Washington		Milwaukee		Racine		Kenosha		West Bend		Waukesha		Whitewater		Lake Geneva		Regional Summary		
	1940-1977	1894-1950	1940-1976		1940-1977	1950-1973	1945-1977	1945-1959	1940-1977	1930-1959	1940-1977	1930-1959	1948-1977		1945-1977	1945-1959	Regional Summary		
	Average Total Precipitation	Average Snow and Sleet	Average Total Precipitation	Average Snow and Sleet	Average Total Precipitation	Average Snow and Sleet	Average Total Precipitation	Average Snow and Sleet	Average Total Precipitation	Average Snow and Sleet	Average Total Precipitation	Average Snow and Sleet	Average Total Precipitation	Average Snow and Sleet	Average Total Precipitation	Average Snow and Sleet	Average Total Precipitation	Average Snow and Sleet	
January	1.38	11.5	1.62	11.0	1.92	13.6	1.54	11.9	1.37	12.3	1.55	11.8	1.29	N/A	1.88	11.0	1.57	11.9	January
February	1.08	10.2	1.31	10.8	1.49	9.1	1.03	12.1	1.04	8.1	1.18	6.6	1.03	N/A	1.37	5.5	1.19	8.9	February
March	2.00	8.0	2.48	10.5	2.85	10.9	2.30	7.3	2.12	10.5	2.43	10.7	2.24	N/A	2.80	10.1	2.40	9.7	March
April	2.86	1.9	2.97	3.1	3.46	1.3	3.40	1.4	2.66	1.2	3.05	1.1	3.10	N/A	3.51	1.1	3.13	1.6	April
May	2.98	0.1	2.89	Trace	3.37	0.1	3.26	0.2	3.01	0.4	3.38	0.4	3.27	N/A	3.43	0.1	3.20	0.2	May
June	3.25	0.0	3.58	0.0	3.84	0.0	3.86	0.0	3.70	0.0	3.77	0.0	3.80	N/A	4.33	0.0	3.77	0.0	June
July	3.07	0.0	3.21	0.0	3.58	0.0	3.51	0.0	3.79	0.0	3.47	0.0	4.36	N/A	4.15	0.0	3.64	0.0	July
August	2.92	0.0	2.79	0.0	3.08	0.0	3.00	0.0	3.04	0.0	3.22	0.0	3.31	N/A	3.51	0.0	3.11	0.0	August
September	3.11	0.0	2.91	0.0	3.08	0.0	3.14	0.0	3.34	0.0	3.09	0.0	3.08	N/A	3.29	0.0	3.13	0.0	September
October	2.13	0.2	2.01	0.2	2.15	0.2	2.31	0.1	2.21	0.1	2.15	0.0	2.44	N/A	2.37	0.0	2.22	0.1	October
November	2.03	3.0	2.03	1.8	2.35	2.4	2.10	2.5	2.02	2.9	2.16	3.5	2.01	N/A	2.21	4.5	2.11	2.9	November
December	1.65	7.2	1.88	11.0	2.15	10.4	1.74	9.7	1.50	7.8	1.75	7.7	1.61	N/A	2.07	10.8	1.79	9.2	December
Year	28.46	42.1	29.68	48.4	33.32	48.0	31.19	45.2	29.80	43.3	31.20	41.8	31.54	N/A	34.92	43.1	31.26	44.5	Year

Source: National Weather Service, Wisconsin Statistical Reporting Service, and SEWRPC.

Figure 23

PRECIPITATION CHARACTERISTICS AT SELECTED LOCATIONS IN THE REGION



Source: National Weather Service, Wisconsin Statistical Reporting Service, and SEWRPC.

Table 46

EXTREME PRECIPITATION EVENTS IN THE REGION: SELECTED YEARS 1870-1970

Observation Station[a]		Period of Precipitation Records Except Where Indicated Otherwise	Total Precipitation (Water Equivalent)											Snowfall									
			Maximum Annual		Minimum Annual		Maximum Monthly			Maximum Daily				Maximum Annual		Minimum Annual		Maximum Monthly			Maximum Daily			
Name	County		Amount	Year	Amount	Year	Amount	Month	Year	Amount	Day	Month	Year	Amount	Year	Amount	Year	Amount	Month	Year	Amount	Day	Month	Year
Milwaukee	Milwaukee	1870-1970	50.36[c]	1876	18.69[c]	1901	10.03	June	1917	5.76[d]	22-23	June	1917	109.0[e]	1885-1886	11.0[e]	1884-1885	52.6	Jan.	1918	20.3[f]	4-5	Feb.	1924
Racine	Racine	1895-1970	48.33	1954	17.75	1910	10.98	May	1933	4.00	11	Sept.	1933	85.0	1897-1898	5.0[g]	1901-1902	38.0	Feb.	1898	30.0[f]	19-20	Feb.	1898
Waukesha	Waukesha	1892-1970	43.57	1938	17.30	1901	11.41	July	1952	5.09	18	July	1952	83.0[g]	1917-1918	9.1	1967-1968	56.0	Jan.	1918	20.0[f]	5-6	Jan.	1918
West Bend	Washington	1922-1970	40.52	1938	19.72	1901	13.17[b]	Aug.	1924	7.58[b]	4	Aug.	1924	86.5	1935-1936	19.6	1967-1968	38.0	Jan.	1943	21.0	10-11	Dec.	1970

[a] *An observation station was included if a minimum of 30 years of record was available.*

[b] *Based on the period 1895-1959 as reported in A Survey Report for Flood Control on the Milwaukee River and Tributaries, U.S. Army Engineer District, Chicago, Corps of Engineers, November 1964.*

[c] *Based on the period 1841-1970.*

[d] *Maximum precipitation for a 24-hour period.*

[e] *Maximum and minimum snowfalls for a winter season.*

[f] *Maximum snowfall for a 24-hour period.*

[g] *Estimated from incomplete records.*

Source: U. S. Army Corps of Engineers, National Weather Service, Wisconsin Statistical Reporting Service, and SEWRPC.

Snow depth as measured at Milwaukee for the 70-year period of 1900 through 1969 and published in Snow and Frost in Wisconsin, a 1970 Wisconsin Statistical Reporting Service report, is summarized and presented in Table 47. It should be emphasized that the tabulated data pertains to snow depth on the ground as measured at the place and time of observation and is not a direct measure of average snowfall. Recognizing, as discussed above, that snowfall and temperatures and therefore snow accumulation on the ground vary spatially within the Region, the Milwaukee area data presented in Table 47 should be considered only as an approximation of conditions that would be encountered in other parts of the Region. As indicated by the data, snow cover is most likely during the months of December, January, and February when at least a 0.40 probability exists of having one inch or more of snow cover at Milwaukee. Furthermore, during January and the first half of February, at least a 0.25 probability exists of having five or more inches of snow on the ground. During March, the month in which severe spring snowmelt-rainfall flood events are most likely to occur, at least a 0.30 probability exists of having one inch or more of snow on the ground during the first half of the month while the probability of having that much snow cover diminishes to 0.07 by the end of the month.

Minor Climatic Elements

Evaporation rate, wind magnitude and direction, the amount of daylight, and the expected extent of sky cover are considered minor climatic factors and, as such, are available in detailed form primarily for the Milwaukee area of the Region. It is possible, however, to develop a generalized description of evaporation, wind, sunshine, and sky cover conditions for the Region by using Milwaukee data.

Evaporation: Evaporation is the natural process whereby water is transformed from liquid or solid state to the vapor state and returned to the atmosphere. Total evaporation includes evaporation from water and snow surfaces and directly from the soil. It also includes evaporation of precipitation intercepted by vegetation and evaporation of water transpired by vegetation.

Limited evaporation data available for the Region indicate an average annual evaporation from a water surface of about 28 inches, with about three-quarters of this, or 21 inches, occurring during the six-month May through October period. As indicated earlier in this chapter and summarized in Table 45, the average annual precipitation for the Region is about 30 inches, which exceeds the average annual evaporation by about two inches. During the aforementioned six-month May through October period, regional precipitation is about 18 inches and, therefore, evaporation from a water surface may be expected to exceed precipitation by about three inches.

Wind: Wind plays a very significant role in the transportation and diffusion of air pollutants. The wind direction controls the direction a pollutant will travel from the source, and the wind speed determines the travel time and dilution from the source to the receptor. The wind also aids in the removal of materials from the atmosphere by impaction, that is, the particles being driven onto buildings, vegetation, and the ground.

Prevailing winds in the Region follow a clockwise pattern in terms of the prevailing direction over the seasons of the year, being northwesterly in the late fall and winter, northeasterly in the spring, and southwesterly in the summer and early fall. Wind velocities in southeastern Wisconsin may be expected to be less than 5 miles per hour about 15 percent of the time, between 5 and 15 miles per hour about 60 percent of the time, and in excess of 15 miles per hour about 25 percent of the time.

Figure 24 presents wind direction data for seven locations within the Region and for seven additional sites located

Table 47

SNOW COVER PROBABILITIES AT MILWAUKEE BASED ON DATA FOR 1900-1970

Date		Snow Cover[a]									
		1.0 Inch or More		5.0 Inches or More		10.0 Inches or More		15.0 Inches or More		Average (Inches)	
Month	Day	Number of Occurrences[b]	Probability of Occurrence[c]	Number of Occurrences[b]	Probability of Occurrence[c]	Number of Occurrences[b]	Probability of Occurrence[c]	Number of Occurrences[b]	Probability of Occurrence[c]	Per Occurrence[d]	Overall[e]
November	15	5	0.07	0	0.00	0	0.00	0	0.00	1.2	0.09
	30	12	0.17	1	0.01	1	0.01	0	0.00	2.8	0.49
December	15	33	0.47	10	0.14	0	0.00	0	0.00	3.3	1.54
	31	32	0.46	9	0.13	1	0.01	0	0.00	3.6	1.66
January	15	43	0.61	17	0.24	4	0.06	2	0.03	4.9	2.94
	31	48	0.69	22	0.31	9	0.13	4	0.06	6.2	4.26
February	15	44	0.63	23	0.33	7	0.10	3	0.04	6.0	3.69
	28	27	0.39	8	0.11	3	0.04	1	0.01	4.5	1.69
March	15	23	0.33	6	0.09	4	0.06	0	0.00	3.9	1.21
	31	5	0.07	1	0.01	1	0.01	0	0.00	3.4	0.24

[a] *Data pertain to snow depth on the ground as it was measured at the time and place of observation, and are not a direct measure of average snowfall.*

[b] *Number of occurrences is the number of times during the 70-year period of record when measurements revealed that the indicated snow depth was equaled or exceeded on the indicated date.*

[c] *Probability of occurrence for a given snow depth and date is computed by dividing the number of occurrences by 70, and is defined as the probability that the indicated snow cover will be reached or exceeded on the indicated date.*

[d] *Average snow cover per occurrence is defined as the sum of all snow cover measurements in inches for the indicated date divided by the number of occurrences for that date, that is, the number of times in which 1.0 inch or more of snow cover was recorded.*

[e] *Overall average snow cover is defined as the sum of all snow cover measurements in inches for the indicated date divided by 70, that is, the number of observation times.*

Source: National Weather Service, Wisconsin Statistical Reporting Service, and SEWRPC.

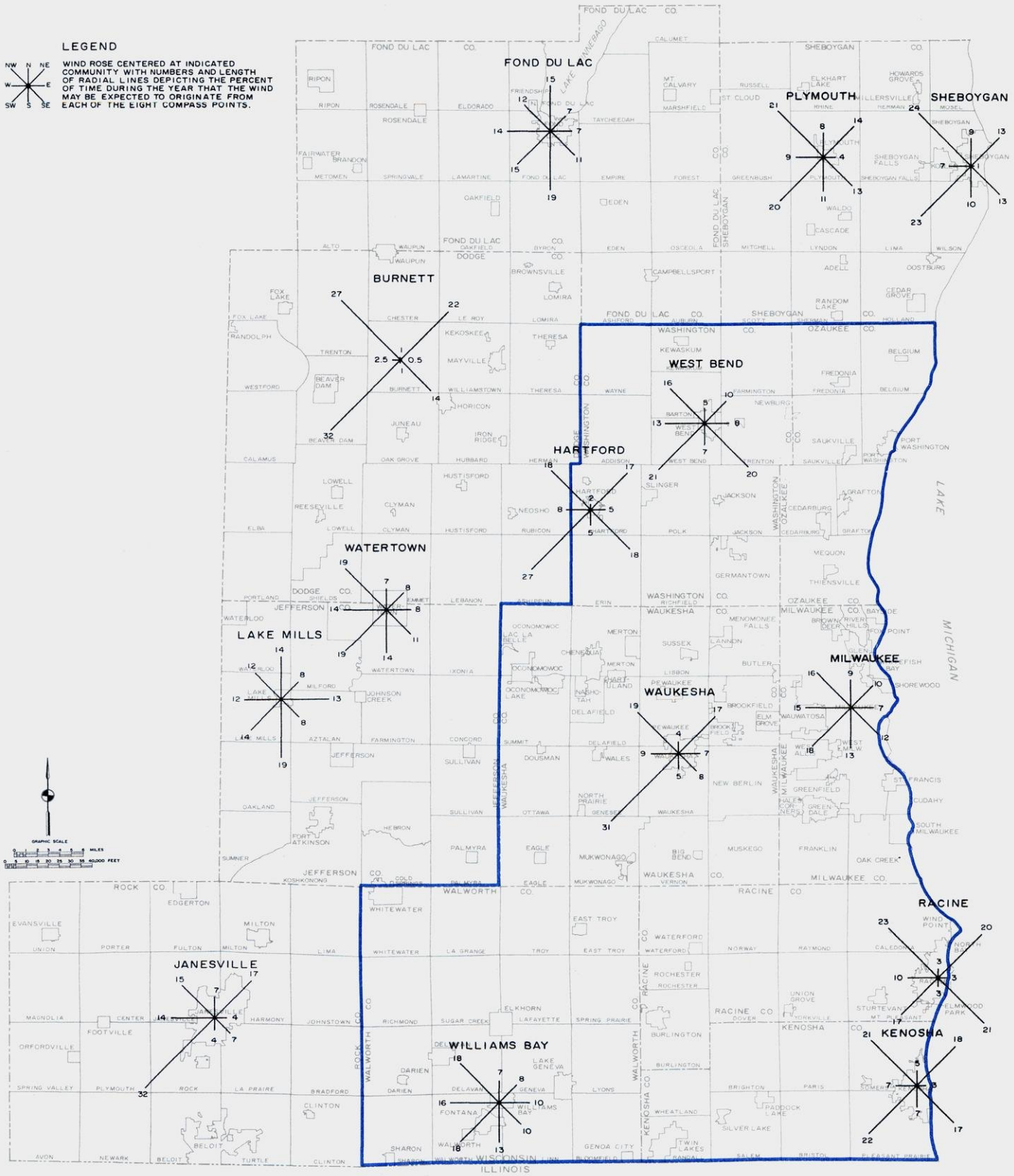
immediately north or west of the Region. As shown by the wind roses, the Region exhibits a rather uniform distribution of wind direction, that is, there are no extreme differences in the frequency of wind direction from one location to another in or near the Region on an annual basis. Of the eight compass points depicted for each of the seven in-Region locations in Figure 24, the dominant directions from which the wind blows tend to be the southwest, northwest, northeast, and southeast, while the wind may be expected to originate from due north, south, east, or west only a relatively small proportion of the time. Based on averages of the indicated percentages for each of the seven in-Region locations, the wind may be expected to blow from the southwest and northwest each about 20 percent of the time, and from the southeast and northeast each about 15 percent of the time. Thus, the winds in southeastern Wisconsin may be expected to blow from these four of the eight compass points about 70 percent of the time.

Daylight and Sky Cover: Sunlight has an important function in the chemical reactions that occur in the atmosphere among pollutants. For instance, sunlight is necessary for the formation of photochemical oxidants. The annual variation in the time of sunrise and sunset and the daily hours of sunlight are presented in Figure 25 as is the expected sky cover information, in the form of the expected percent of clear, partly cloudy, and cloudy days each month. As illustrated in Figure 25, the annual variation in daylight ranges from a minimum of 9.0 hours on about December 22, the winter solstice, to a maximum of 15.4 hours on about June 21, the summer solstice.

Mean monthly sky cover for the sunrise to sunset period varies somewhat during the year. The smallest amount of daytime sky cover may be expected to occur during the four-month July through October period when the mean monthly sky cover is at or slightly above 0.5. Clouds or other obscuring phenomena are most prevalent during the five-month November through March period when the mean monthly daytime sky cover is about 0.7. The tendency for maximum annual sky cover in the winter and for minimum annual sky cover in the summer is also illustrated by examining the expected relative number of days classified as clear, partly cloudy, and cloudy for months in each of these seasons. During the summer months, as shown in Figure 25, about one-third of the days may be expected to be categorized as clear, one-third as partly cloudy, and one-third as cloudy. Greater sky cover occurs in the winter, however, when

Figure 24

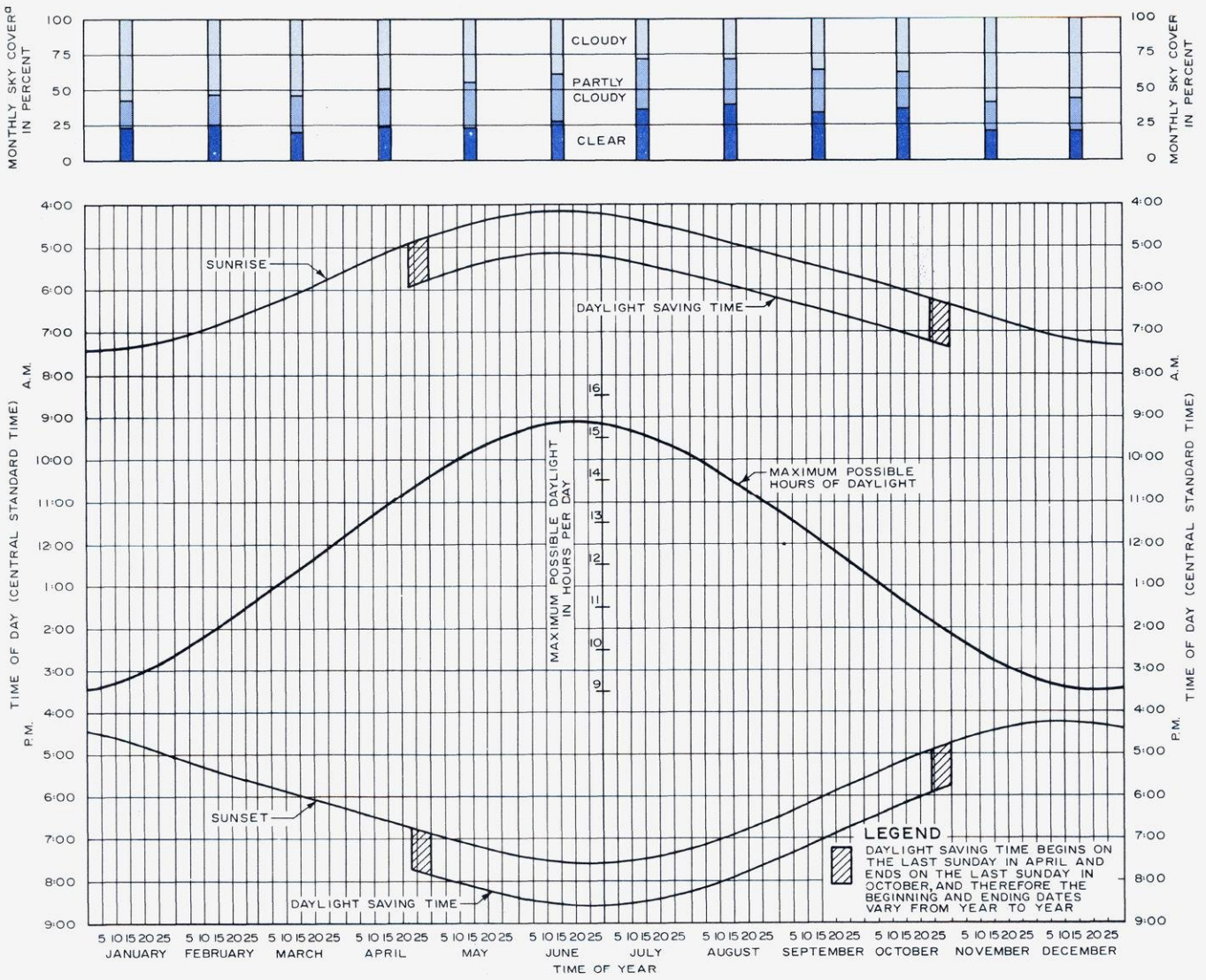
ANNUAL FREQUENCY DISTRIBUTION OF WIND DIRECTION IN SOUTHEASTERN WISCONSIN



Source: Wisconsin State Planning Board.

Figure 25

SUNRISE, SUNSET, AND SKY COVER AT MILWAUKEE



[a]BASED ON MILWAUKEE SKY COVER DATA. THESE MONTHLY DATA ARE SIMILAR TO THOSE OBSERVED AT MADISON AND AT GREEN BAY, WHICH SUGGESTS THAT THERE IS VERY LITTLE VARIATION IN THIS MONTHLY DATA FOR THE LARGE GEOGRAPHIC REGION RELATIVE TO THE KINNICKINNIC RIVER WATERSHED, REPRESENTED BY THESE THREE NATIONAL WEATHER SERVICE STATIONS. THEREFORE, THE MILWAUKEE DAYLIGHT AND SKY COVER MONTHLY DATA MAY BE CONSIDERED APPLICABLE TO THE WATERSHED. SKY COVER CONSISTS OF CLOUDS OR OBSCURRING PHENOMENA, AND IS EXPRESSED IN TENTHS. A DAY IS CLASSIFIED AS CLEAR IF THE SKY COVER DURING THE DAYLIGHT PERIOD IS 0-0.3, PARTLY CLOUDY IF THE SKY COVER IS 0.4-0.7, AND CLOUDY IF THE SKY COVER IS 0.8-1.0. MONTHLY SKY COVER INDICATES, BY MONTH, THE PERCENT OF DAYS THAT HISTORICALLY HAVE BEEN CLEAR, PARTLY CLOUDY, OR CLOUDY.

Source: U. S. Naval Observatory, National Weather Service, and SEWRPC.

more than one-half of the days are classified as cloudy, with the remainder being approximately equally divided between partly cloudy and clear.

PHYSIOGRAPHY

The Southeastern Wisconsin Planning Region is located in the upper Midwest between Lake Michigan on the east, the Green Bay-Lake Winnebago lowlands on the north, the Rock River basin on the west, and the low dunes and swampland at the headwaters of the Illinois River on the south. The seven-county Region within the jurisdiction of the Southeastern Wisconsin Regional Planning Commission extends for approximately 52 miles from east to west at its widest extent and approximately 72 miles from north to south. The Region encompasses approximately 2,621 square miles of land area and 68 square miles of inland water area exclusive of Lake Michigan, or a total gross land and water area of approximately 2,689 square miles or 1,720,000 acres. Topographic elevations range from approximately 580 feet above mean sea level at the Lake Michigan shore to about 1,320 feet above mean sea level at Holy Hill in southwestern Washington County. The Region lies astride a major subcontinental divide between the upper Mississippi River and the Great Lakes-St. Lawrence River drainage basins.

Physiography and topography directly influence air quality inasmuch as the terrain can affect the transport and diffusion of air pollutants. Irregular and rough terrain, for example, interrupt the laminar flow of air, producing turbulence eddies, which, in turn, greatly affect the dispersion of the air pollutants.

Physiographic and Topographic Features

Glaciation has largely determined the physiography and topography as well as the soils of this part of the state. The physiographic features or surficial land forms of southeastern Wisconsin are shown on Map 23, wheras regional topography or variation in elevation is generalized on Map 24. The dominant physiographic and topographic feature is the Kettle Moraine, an interlobate glacial deposit, or moraine, formed between the Green Bay and Lake Michigan tongues, or lobes, of the continental glacier which moved in a generally southerly direction from its point of origin in what is now Canada. Maximum elevations in the Region are located in the Kettle Moraine and include areas located around Lake Geneva in Walworth County, areas in southwestern Waukesha County north of Eagle, areas in central Waukesha County around Lapham Peak, and areas around Holy Hill and Hartford in southwestern and western Washington County. The Kettle Moraine, which is oriented in a general northeast-southwest direction across western Washington, Waukesha and Walworth Counties, is a complex system of kames, or crudely stratified conical hills; kettle holes marking the site of glacial ice blocks that became separated from the ice mass and melted to form depressions; and eskers, consisting of long, narrow ridges of drift deposited in abandoned drainageways. It forms some of the most attractive and interesting landscapes within the Region as well as being the area of the highest elevation and the area of greatest local elevation difference, or relief, within southeastern Wisconsin. The Kettle Moraine of Wisconsin, much of which lies within the Region, is considered as one of the finest examples of glacial interlobate moraine in the world. Because of its still predominantly rural character and its exceptional natural beauty, the Kettle Moraine and surrounding area is and may be expected to continue to be subjected to increasing pressure for urban development.

The remainder of the Region is covered by a variety of glacial land forms and features including kames, ground moraine or heterogeneous material deposited beneath the ice; recessional moraines, consisting of material deposited at the forward margins of the ice sheet; lacustrine basins, or former lake sites; outwash plains formed by the action of flowing glacial meltwater; eskers, or elongated meandering ridges of crudely stratified water-lain sand and gravel deposits; and drumlins, or elongated mounds of drift molded by and parallel to the advancing glacier.

Glacial land forms are of economic significance because some are prime sources for sand and gravel for highway and other construction purposes. Many of the larger topographic depressions of the Region, including the kettle holes, have developed into the numerous lakes which dot large areas of western Washington, Waukesha, and Walworth Counties and which are becoming increasingly popular both as recreational areas and as residential centers.

Surface Drainage

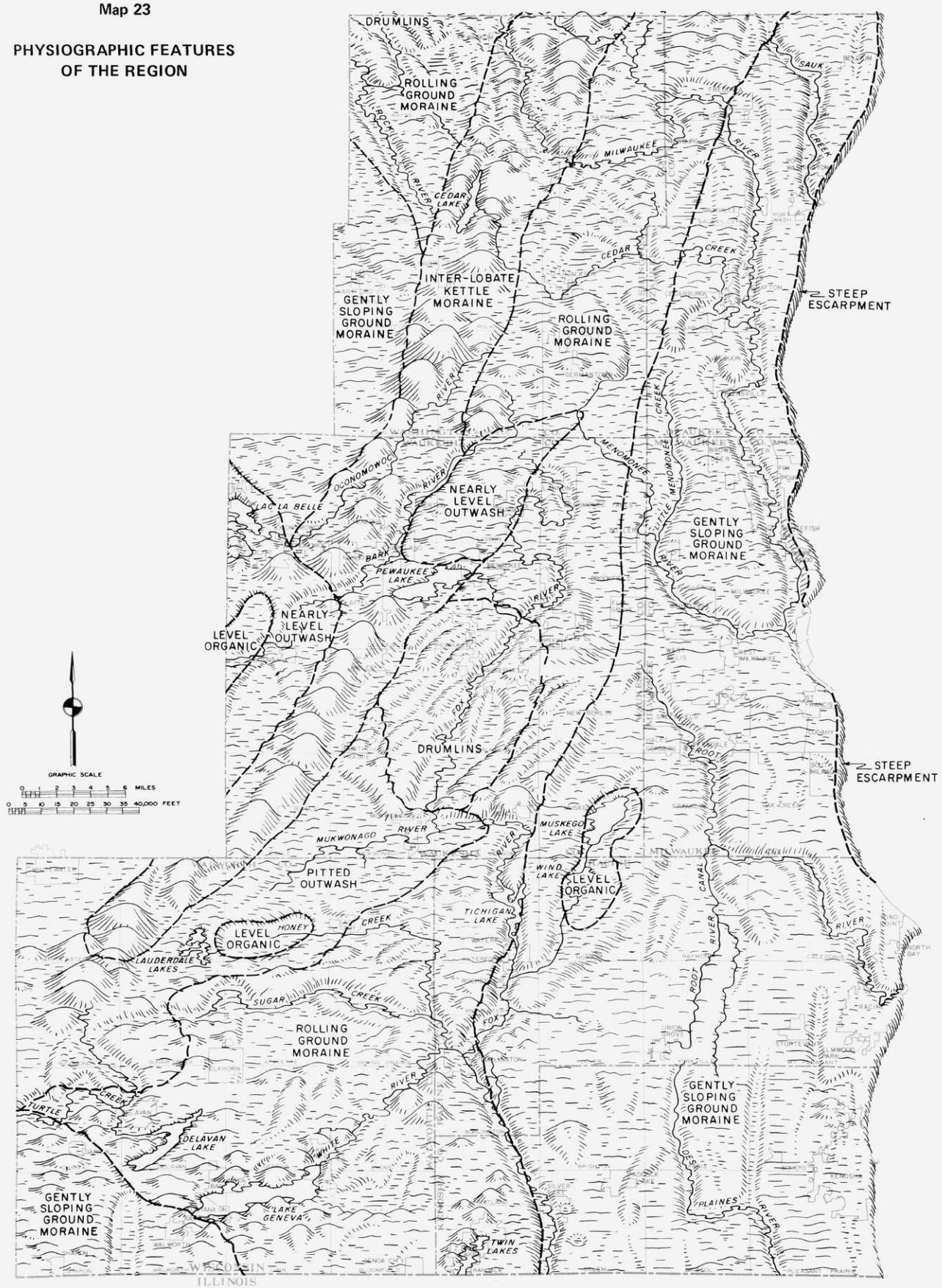
Surface drainage is poorly developed but highly diverse within the planning Region due to the effect of the relatively recent glaciation. The land surface, as a result of being covered by glacial drift, is complex, containing thousands of closed depressions that range in size from mere pits to large areas. Significant areas of the Region are covered by wetlands, and many streams are mere threads of water through these wetlands. The 11 major watersheds of southeastern Wisconsin are depicted on Map 25 along with the surface drainage pattern of the major perennial stream system.

A major subcontinental divide, oriented in a generally northwesterly-south-easterly direction, approximately bisects the Region so that about 1,685 square miles, or 63 percent of the Region, lying west of the divide, drains to the Mississippi River, while the remaining 1,004 square miles, or 37 percent, is tributary to the Great Lakes-St. Lawrence River drainage basin. The subcontinental divide not only exerts a major physical influence on the gross drainage pattern of the Region, but also carries with it certain legal constraints on the diversion of water across the divide and thereby constitutes an important consideration in urban land use development.

The surface water drainage pattern of southeastern Wisconsin may be further subdivided so as to identify 11 major watersheds. Five of them--the Root River, Menomonee River, Kinnickinnic River, Oak Creek,

Map 23

PHYSIOGRAPHIC FEATURES OF THE REGION

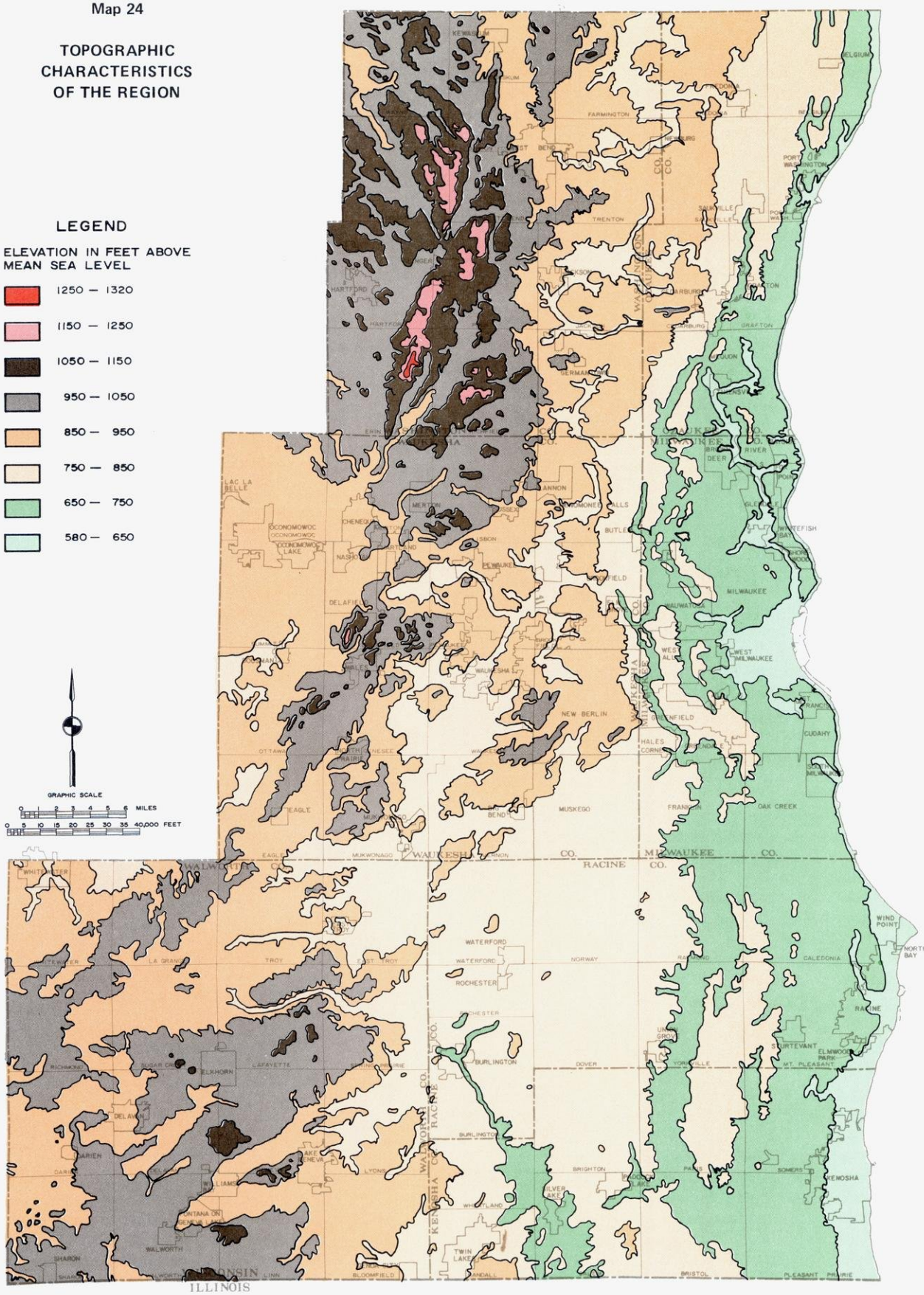


Physiographic features, or surficial land forms, throughout southeastern Wisconsin were determined largely by repeated stages of glaciation, the last of which, the Wisconsin stage, is believed to have ended about 10,000 years ago. Included in the great variety of interesting and attractive glacial land forms covering the Region are ground and recessional moraines, abandoned lake basins, outwash plains, kames, eskers, and drumlins. The dominant feature is the Kettle Moraine, an interlobate moraine lying in a northeasterly-southwesterly direction within the western part of the Region and formed by and between the Green Bay and Lake Michigan lobes of the continental glacier.

Source: SEWRPC.

Map 24

TOPOGRAPHIC CHARACTERISTICS OF THE REGION



The topography, or relative elevation of the land surface throughout the Region, is determined by the configuration of the bedrock geology in combination with overlying glacial deposits. Elevations within southeastern Wisconsin range from a low of about 580 feet above mean sea level (MSL) on the Lake Michigan shore to a high of 1,320 feet MSL at Holy Hill in southwestern Washington County. Topographic highs and some of the most attractive landscapes and scenic vistas in the Region are coincident with the interlobate Kettle Moraine area in the western portion of the Region.

Source: SEWRPC.

and Pike River watersheds are wholly contained within the Region. In addition to these 11 major watersheds, there are numerous small catchment areas contiguous to Lake Michigan that drain directly to the lake by local natural watercourses and artificial drainageways, and these areas together may be considered as comprising a twelfth watershed[3]. The drainage in the Region tends to exhibit a disordered dendritic pattern except for a small area of trellised or rectangular drainage evident in the Des Plaines River watershed and in the Racine County portion of the Root River watershed. The Fox River watershed and the headwaters of the Rock River and Des Plaines River watersheds drain to the south and southwest towards their confluences with the Illinois River, a tributary of the Mississippi River. The remainder of the Region drains in a generally easterly direction towards Lake Michigan by way of the Milwaukee, Menomonee, Root, and other drainages.

MINERAL AND ORGANIC RESOURCES

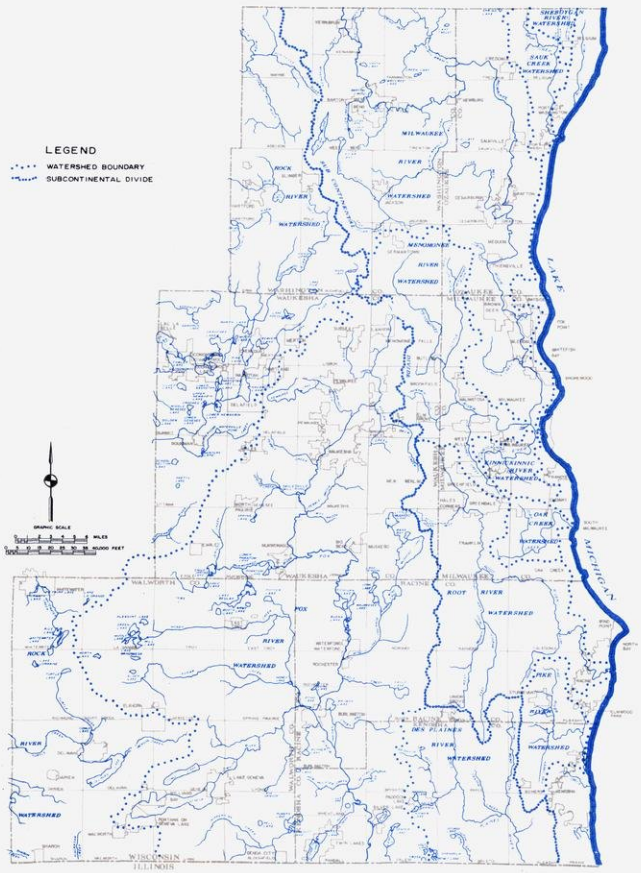
Sand and gravel, dolomite building stone, and organic material are the three principal mineral and organic resources in the Region that have significant commercial value as a result of their quantity, quality, and location. The commercial utilization of the Region's mineral resources, which is limited to the mining of nonmetal deposits, is primarily directed toward supplying the construction materials needed for the continuing development of southeastern Wisconsin. In all phases of extracting and transporting the mineral resources for developmental uses, there is a considerable amount of particles and dust emitted into the air. This source of particulate matter may be a major contributor to excessive pollution levels in areas surrounding extraction operations.

Sand and Gravel

The Region as a whole has an abundant supply of sand and gravel deposits as a result of its glacial history, with the highest quality deposits being found in glacial outwash areas, particularly near the interlobate Kettle Moraine, where the washing action of flowing meltwaters has sorted the unconsolidated material so as to form more or less homogeneous and therefore commercially attractive deposits.

Map 25

WATERSHEDS AND SURFACE WATER RESOURCES OF THE REGION



A subcontinental divide traverses the Southeastern Wisconsin Region. That part of the Region lying east of this divide is tributary to the Great Lakes-St. Lawrence River drainage system, while that part of the Region lying west of this divide is tributary to the Mississippi River drainage system. This subcontinental divide has important implications for water resources planning and management, since major diversions of water across this divide are restricted by law and interstate and international compacts. The generally dendritic surface water drainage pattern of the Region, which is the result of the glacial land forms and features, divides the Region into 11 individual watersheds, three of which—the Des Plaines, Fox, and Rock River watersheds—lie west of the subcontinental divide. In addition to the 11 watersheds, there are numerous small catchment areas along the Lake Michigan shoreline that drain directly to the lake, which together may be considered to comprise a twelfth watershed.

Source: SEWRPC.

Deposits of sand and gravel are, as shown on Map 26, scattered throughout the Region. The greatest concentration of commercial strip mining activity, however, occurs in Waukesha County because sand and gravel in that area have the most favorable quantity and quality characteristics. Sand and gravel deposits are important sources of concrete aggregate, gravel for road subgrade and surfacing, sand for mortar and molding sand.

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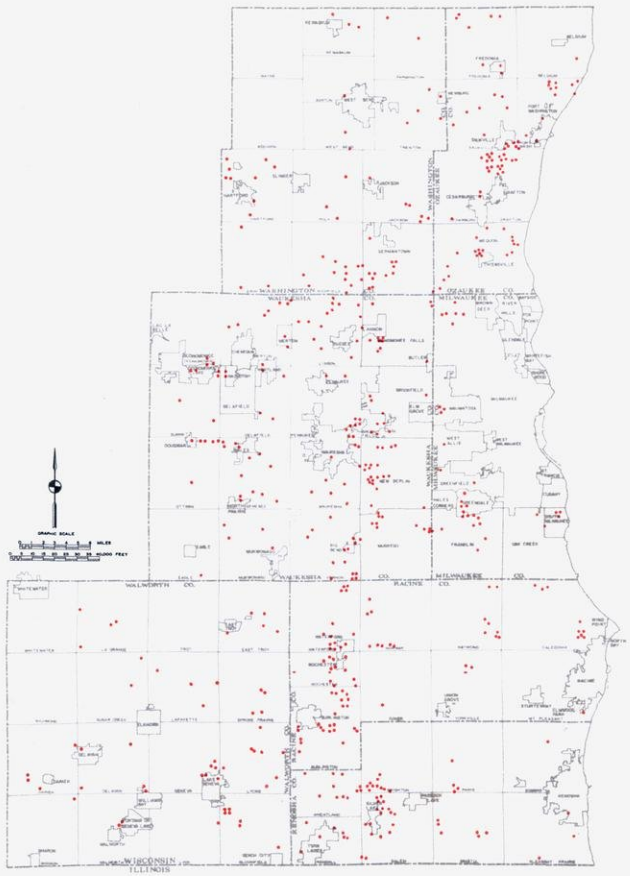
[3] *The Commission has completed comprehensive watershed studies for the 197-square-mile Root River watershed; the 939-square-mile Fox River watershed; the 694-square-mile Milwaukee River watershed, 430 square miles of which lie in the Region; and the 136-square-mile Menomonee River watershed. Comprehensive watershed studies have, therefore, been completed for 1,702 square miles, or 63 percent, of the 2,689 square mile seven-county Region. The Commission is currently conducting a comprehensive planning program for the 25-square-mile Kinnickinnic River watershed.*

Map 26

SAND AND GRAVEL PITS IN THE REGION



An abundant supply of sand and gravel deposits is scattered throughout southeastern Wisconsin, with the highest quality sources being found in glacial outwash areas where flowing melt waters tended to sort the sand and gravel so as to form more or less homogeneous, and therefore commercially attractive, deposits. Sand and gravel deposits, which are commercially mined by strip mining techniques, constitute a very important raw material for construction and certain industrial activities in the Region in that they provide concrete aggregate, gravel for road subgrades and surfacing, sand for mortar, and molding sand.

Source: Wisconsin Geological and Natural History Survey and SEWRPC.

Stone Quarries

Niagara dolomite, which lies immediately below the glacial deposits throughout most of the Region, has commercial value where it is found relatively close to the ground surface, both as a dimensional building stone and, when crushed, as an aggregate for construction or as a fertilizer for agricultural purposes. The dolomite is mined in open quarries, and all the regional commercial operations that produce stone for building purposes are located in Waukesha County, where they are concentrated in rock outcrop areas in the northeastern portion of the county. Waukesha County quarries yield thinly bedded, compact, and fine-grained dolomite well suited for the mining and production of dimensional building stone. Although it is in fact dolomite--that is, primarily calcium magnesium carbonate--the high quality dimensional building stone commercially mined and produced in Waukesha County is commonly known or referred to as limestone--that is, primarily calcium carbonate--or lannon stone. Crushed limestone is produced not only in Waukesha County but also at other quarries located throughout the Region. The presence of quarrying operations in an area indicates relatively thin glacial deposits and close proximity of bedrock to the ground surface.

Organic Deposits

Organic deposits are widely distributed throughout southeastern Wisconsin in small, scattered, lowlying, poorly drained areas. At these locations, excessive moisture inhibits oxidation and decay of the residues of water-tolerant plants producing organic peat deposits and muck soils with significant resulting fertilization potential. These organic deposits overlay the glacial drift of the Region and exhibit variable depths ranging from less than a foot to many feet.

Organic deposits have environmental value, often covering areas suitable for certain kinds of wildlife habitat and recreation areas, and have commercial value in their ability to support field crops such as corn or soybeans, specialized crops such as vegetables, and sod farming and peat mining, the last of which is excavated from open pits and marketed as an additive to improve soils for potted plants, gardens, and greenhouse nurseries. Agricultural use of organic deposits is contingent upon sufficient depth so that artificial drainage can be developed and maintained.

Organic deposits generally serve to identify those areas of southeastern Wisconsin that are least suited for extensive urbanization and attendant major construction activity.

SOILS

The nature of the soils of the Region has been determined primarily by the interaction over time of the parent glacial deposits covering the Region with the topography, climate, plants, and animals of the Region. Within each soil profile, the effects of these soil-forming factors are reflected in the transformation of soil material in place, chemical removal by wind or water erosion, additions by chemical precipitation or by physical deposition, and transfer of some soil components from one part of the soil profile to another.

Soil Diversity and the Regional Soil Survey

Soil forming factors, particularly topography and the nature of the parent glacial materials, exhibit wide spatial variations in southeastern Wisconsin and, therefore, hundreds of different soil types have developed within the Region. In order to assess the significance of these unusually diverse soil types to sound regional development, the Commission in 1963 negotiated a cooperative agreement with the U.S. Soil Conservation Service under which detailed operational soil surveys were completed for the entire planning region. The results

of the soil surveys have been published in SEWRPC Planning Report No. 8, Soils of Southeastern Wisconsin. The regional soil survey has not only resulted in the mapping of the soils within the Region in great detail and the provision of data on the physical, chemical, and biological properties of the soils but has also provided interpretations of the soil properties for engineering, agricultural, and resource conservation purposes, and for planning for various rural and urban uses, including proper location and design of housing developments.

Soil Characteristics and Properties

Soil characteristics, resulting from the interaction of soil-forming factors and processes, are important to the prediction of soil properties, the making of soil interpretations, and the classification of soils. The principal soil characteristics used in the regional soil survey to describe and interpret soils are soil texture, structure, color, consistence, reaction, slope, and position. Soil texture is an expression of the proportion of sand, silt, and clay-sized particles in the soil mass. It is one of the more important soil characteristics in considering the suitability of a soil for housing development because of the number of properties and interpretations that are affected by it, including soil permeability, the relative ease with which water passes through the soil. This quality, permeability, is a critical factor in the proper operation of onsite sewage disposal systems, available moisture capacity and fertility holding capacity, soil erodibility, and bearing capacity.

The shape and stability of soil particles in the soil mass are expressed as soil structure. This soil characteristic influences, to some degree, the aforementioned soil permeability and erodibility properties of the soil. Soil color is a characteristic used as an indicator of the relative organic matter content and the quality of soil drainage. Consistence is described in terms that indicate resistance to change of form or rupture, and is an expression of the adhesion between soil particles comprising the soil mass.

Soil slope is a primary determinant of the amount of runoff that occurs and of the rate at which it occurs; and, therefore, slope is a measure of erosion susceptibility. Slope is also a limiting factor in residential construction and in the development and operation of onsite sewage disposal systems. Soil position relative to the surrounding topography is the principal controlling factor in determining the quality of drainage and therefore also has important implications for the construction of housing and for the construction and operation of public sanitary sewerage systems and private sanitary sewerage systems to serve residential as well as other areas of development.

Findings of the Regional Soil Survey

Under the regional soil survey, all of the soils of the Region were mapped; their characteristics and properties, as noted above, were identified; and, most important, the data were interpreted so as to provide a detailed description on a consistent, areawide basis of the soil resources of southeastern Wisconsin. The usefulness of generalized soil maps for definitive planning purposes within the Region is severely limited because of the wide range of soil diversity resulting from the Region's glacial history; and, therefore, one of the primary values of the operational soil surveys lies in their detail. Any generalization of the findings of the soil surveys can only be meaningful in light of a full understanding of the complexity of the soil relationships in the Region and of the fact that such a generalization, while useful to a broad identification of general areawide development problems relating to soils, cannot be used in plan preparation and implementation.

Generalized Soil Suitability Interpretations: Map 27 shows, in very generalized form, the major soil relationships existing within the Region based upon seven broad suitability associations. The soils designated on this map as Group "A," which cover about 29 percent of the Region, are generally well suited for both agricultural use and urban development. These soils are not only very productive as cropland but have good drainage and foundation characteristics for all types of urban development. This soils group generally occurs in a belt line lying between the present westerly limits of intensive urban development and the easterly limits of the Kettle Moraine. It is interesting to note that this broad soils group does not occur at all in Milwaukee County and occurs to only a very limited extent in Ozaukee, Kenosha, and Racine Counties.

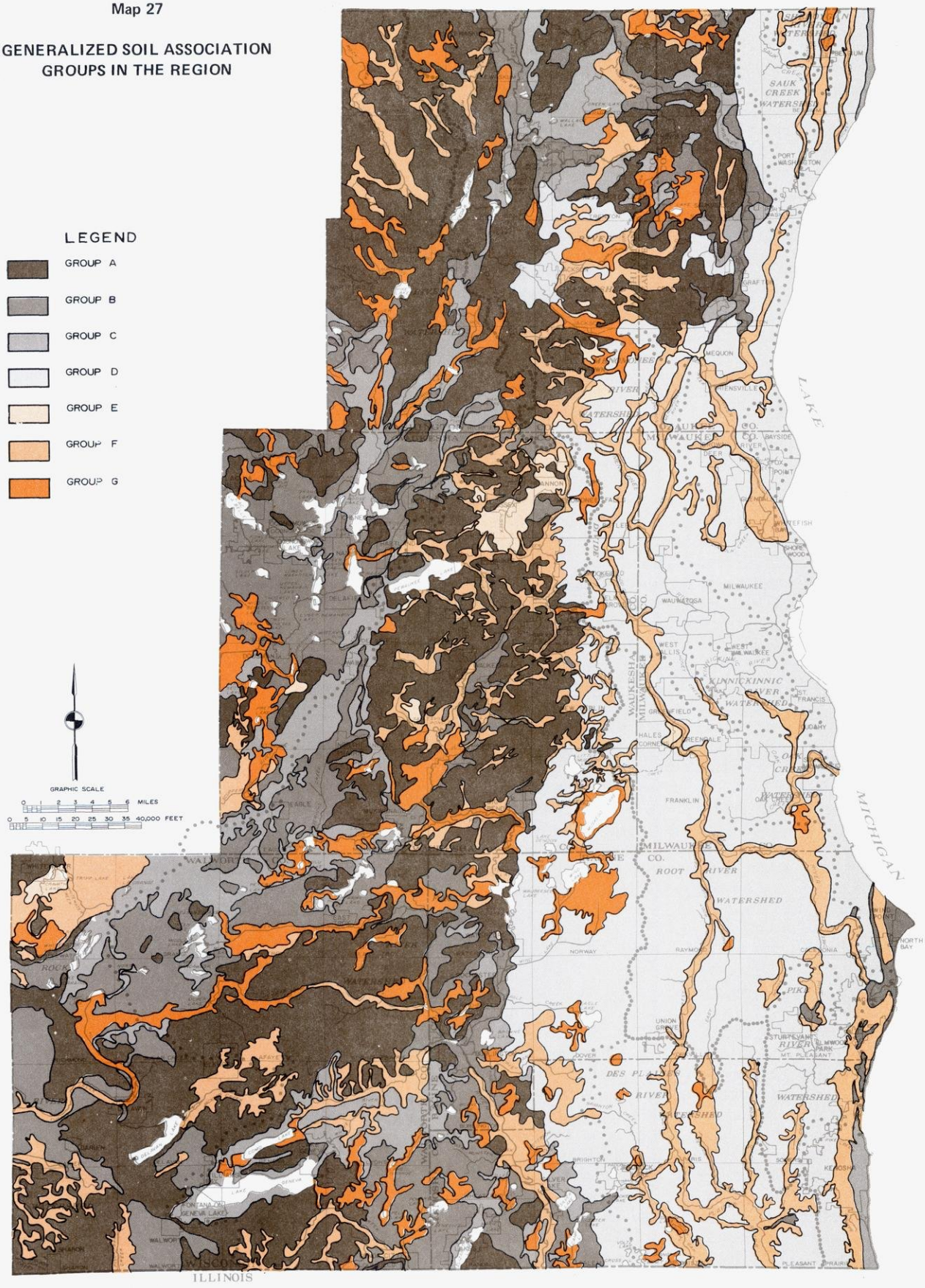
The soils designated as Group "B" generally have a sandy-gravelly subsurface and are well suited to both agricultural use and urban development with septic tank sewage disposal systems. Approximately 14 percent of the Region is covered by this general soils group, which occurs in the Kettle Moraine and the Recessional Moraine areas of the Region and to a very limited extent along the Lake Michigan shore.

The soils designated as Group "C" are fair to poorly suited for agricultural use. Their suitability for urban development is limited by characteristically steep slopes. These soils are suited for very large lot residential development which does not disturb the natural topography. Approximately 8 percent of the Region is covered by this soils group, which is prevalent in the Kettle Moraine and the Recessional Moraine areas of the Region.

The soils designated as Group "D" are generally well suited for agricultural use but generally poorly suited for urban development requiring the use of onsite septic tank sewage disposal systems. Urban development on these soils generally requires a high level of municipal improvements and careful attention to storm water drainage. Nearly 31 percent of the Region is covered by this general soils group, which occurs primarily between the Lake Michigan shore and the westerly limits of present urban development. Most of the existing urban development in the Region has occurred on the soils in this group.

Map 27

GENERALIZED SOIL ASSOCIATION GROUPS IN THE REGION



As shown on this generalized soil map of the seven-county Southeastern Wisconsin Region, nearly one-half of the 2,689-square-mile Region is covered by soils in groups D, E, F, or G which are generally poorly suited for development with onsite soil absorption sewage disposal systems. The detailed soil survey completed for the Region in 1966 provides more definitive soils data for use in local, as well as regional, planning and development.

Source: U. S. Soil Conservation Service and SEWRPC.

The soils designated as Group "E" are generally not well suited for either cropland or urban development. Bedrock normally occurs within four feet of the surface, and bedrock outcrops are common. Good gravel and rock deposits, which are suitable for commercial development, can be found in this group. Approximately 1 percent of the Region is covered by this group, which occurs primarily in isolated pockets throughout the Region.

The soils designated as Group "F" are generally poorly drained, have a high water table, and are interspersed with areas of peat, muck, and other organic soils. Approximately 11 percent of the Region is covered by this group, which generally occurs along streams and watercourses of the Region; and for this reason the soils in this group are commonly subject to flooding. These characteristics generally preclude their use for nearly all forms of development except limited agricultural, wetland, forest, wildlife conservation, and recreational uses.

The soils designated as Group "G" are peat and muck soils generally unsuited for urban development of any kind. These areas, when left in a natural state, are ideally adapted for wildlife habitat and if properly drained are suitable for certain types of agricultural use. Approximately 6 percent of the Region is covered by this soils group, which occurs in scattered corridors and pockets throughout the Region.

Detailed Soil Suitability Interpretations: Particularly important to air quality planning are the soil suitability interpretations for specified types of urban development. These are: residential development with public sanitary sewer service, residential development without public sanitary sewer service on lots smaller than one acre in size, and residential development without public sanitary sewer service on lots one acre or larger in size. Some of the more important considerations in determining soil suitability for urban development include depth to bedrock, depth of water table, likelihood of flooding, soil permeability, and slope.

On the basis of the detailed soil surveys, it is evident that much of the Southeastern Wisconsin Region exhibits severe or very severe limitations for specific types of urban development. As illustrated on Map 28, approximately 716 square miles, or about 27 percent of the Region, are covered by soils which are poorly suited for residential development with public sanitary sewer service or poorly suited for residential development of any kind. Approximately 1,637 square miles, or about 61 percent of the Region, are covered by soils which are poorly suited for residential development without public sanitary sewer service on lots smaller than one acre in size (see Map 29). As illustrated on Map 30, approximately 1,181 square miles, or about 44 percent of the Region, are covered by soils poorly suited for residential development without public sanitary sewer service on lots one acre or larger in size. It should be noted that the use of suitability ratings on which these maps are based are empirical, being based upon the performance of similar soils elsewhere for the specified uses, permeability, high shrink-swell potential, low bearing capacity, frost heave, and frequent flood overflow.

Certain agriculturally related soil interpretations are also important to air quality maintenance planning. Agricultural operations may affect air quality through the operation of internal combustion engines for farm operations, through land clearing and attendant open brush burning operations, and through wind erosion. Prime agricultural lands recommended to remain in agricultural use are identified and mapped in Chapter III of this report. The potential effects on air quality of the continued maintenance of these lands in agricultural use and continued use of machinery operation and open burning are reflected in the air quality analyses findings set forth later in this report. Although the regional soil survey provides interpretive data relating to the susceptibility of the various soil types to wind erosion, the actual effects of wind on soil erosion on open agricultural lands can only be assessed on a field-by-field basis. Therefore, no explicit consideration was given to the relationships existing between soil suitability, wind erosion, and air quality.

VEGETATION

Presettlement Vegetation

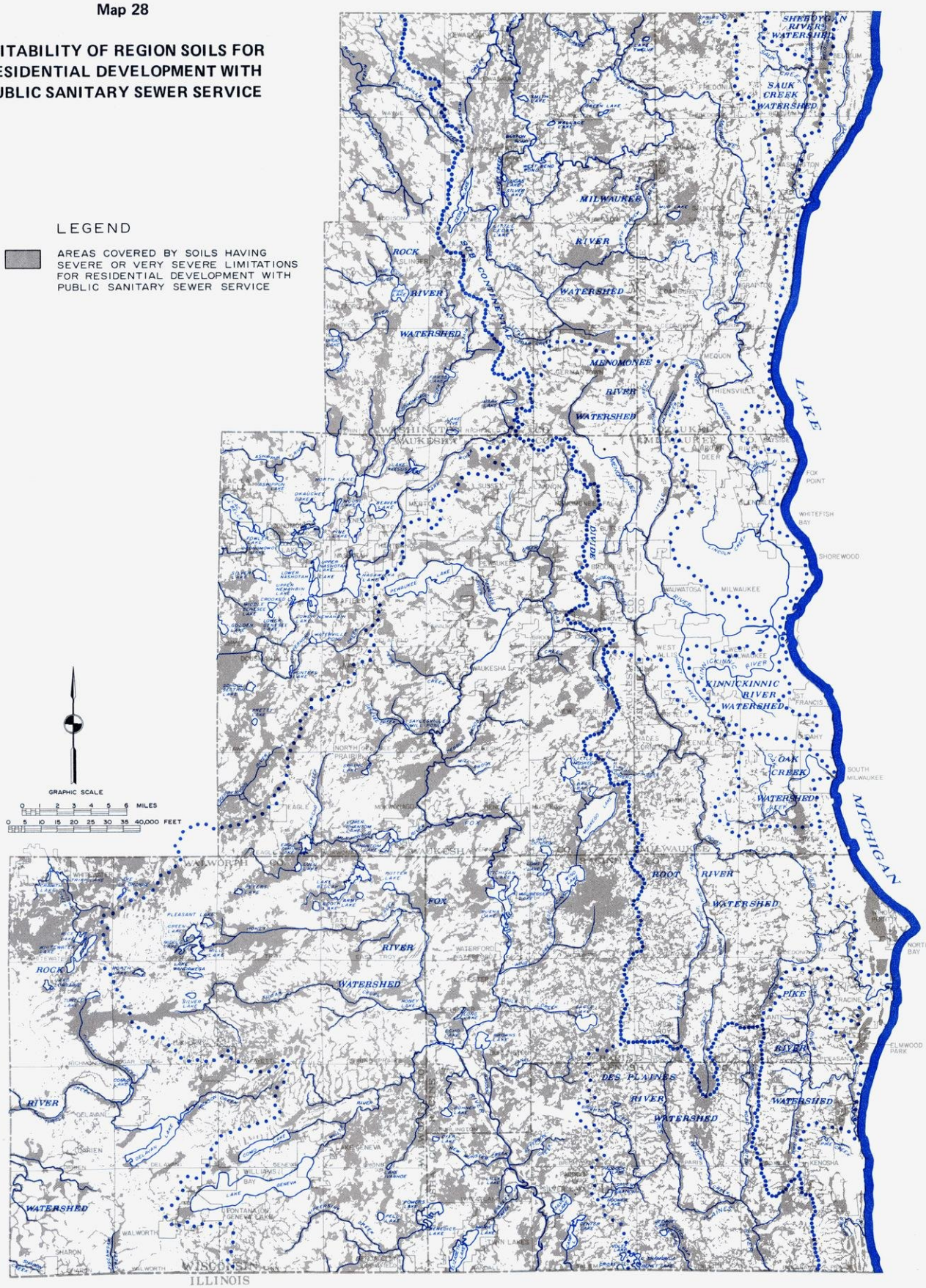
Historically, vegetational patterns in the Region were influenced by climate, glacial deposits, soil, fire, topography, and natural drainage characteristics. Historical records, including the original U.S. Public Land Survey carried out within the Region in 1836, indicate that frequent fires set by the Indians or initiated by natural causes maintained large portions of southeastern Wisconsin either as open level plains containing orchardlike stands of oak or as prairies dominated by big bluestem grass and colorful prairie forbs. Other portions of the Region that were protected from fire by the drainage pattern or local relief developed into mixed hardwood forests. The upland timber for the most part consisted of the hardwood species: sugar maple, oak, elm, ash, hickory, beech, linden, walnut, and ironwood; and one coniferous species, white pine. Common species found in the lowland forests included black ash, elm, willow, cedar, tamarack, aspen, and soft maple.

Woodlands

Woodlands in the Region have much value beyond monetary return for their forest products. Under good management they can serve a variety of uses compatible with other benefits. The quality of life within an area is greatly influenced by the overall quality of the environment, as measured in terms of clean air, clean water, scenic beauty, and diversity. In addition to contributing to clean air and water, the maintenance of woodlands within the Region can contribute to the continuance of a diversity of plant and animal life in association with human life. The existing woodlands of the Region, which required a century or more to develop, can, however, be

Map 28

SUITABILITY OF REGION SOILS FOR RESIDENTIAL DEVELOPMENT WITH PUBLIC SANITARY SEWER SERVICE

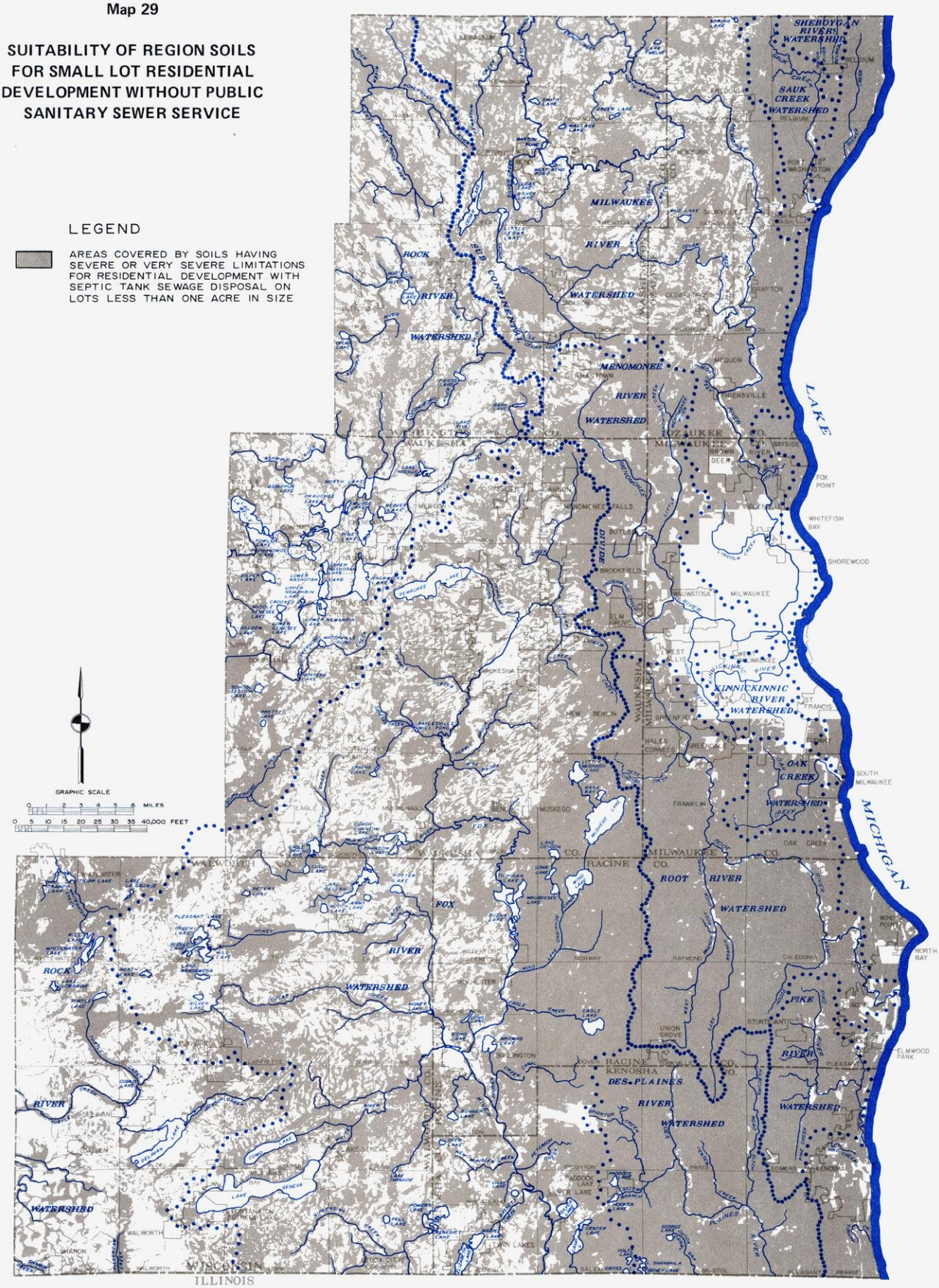


A recognition of the limitations inherent in the soil resource base is essential to the sound urban and rural development of the Region. About 716 square miles, or 27 percent of the area of the Region, are covered with soils which are poorly suited for residential development with public sanitary sewer service or, more precisely, residential development of any kind. These soils, which include wet soils having a high water table or poor drainage, organic soils which are poorly drained and provide poor foundation support, and soils which have a flood hazard, are especially prevalent in the riverine areas of the Region.

Source: U. S. Soil Conservation Service and SEWRPC.

Map 29

SUITABILITY OF REGION SOILS FOR SMALL LOT RESIDENTIAL DEVELOPMENT WITHOUT PUBLIC SANITARY SEWER SERVICE

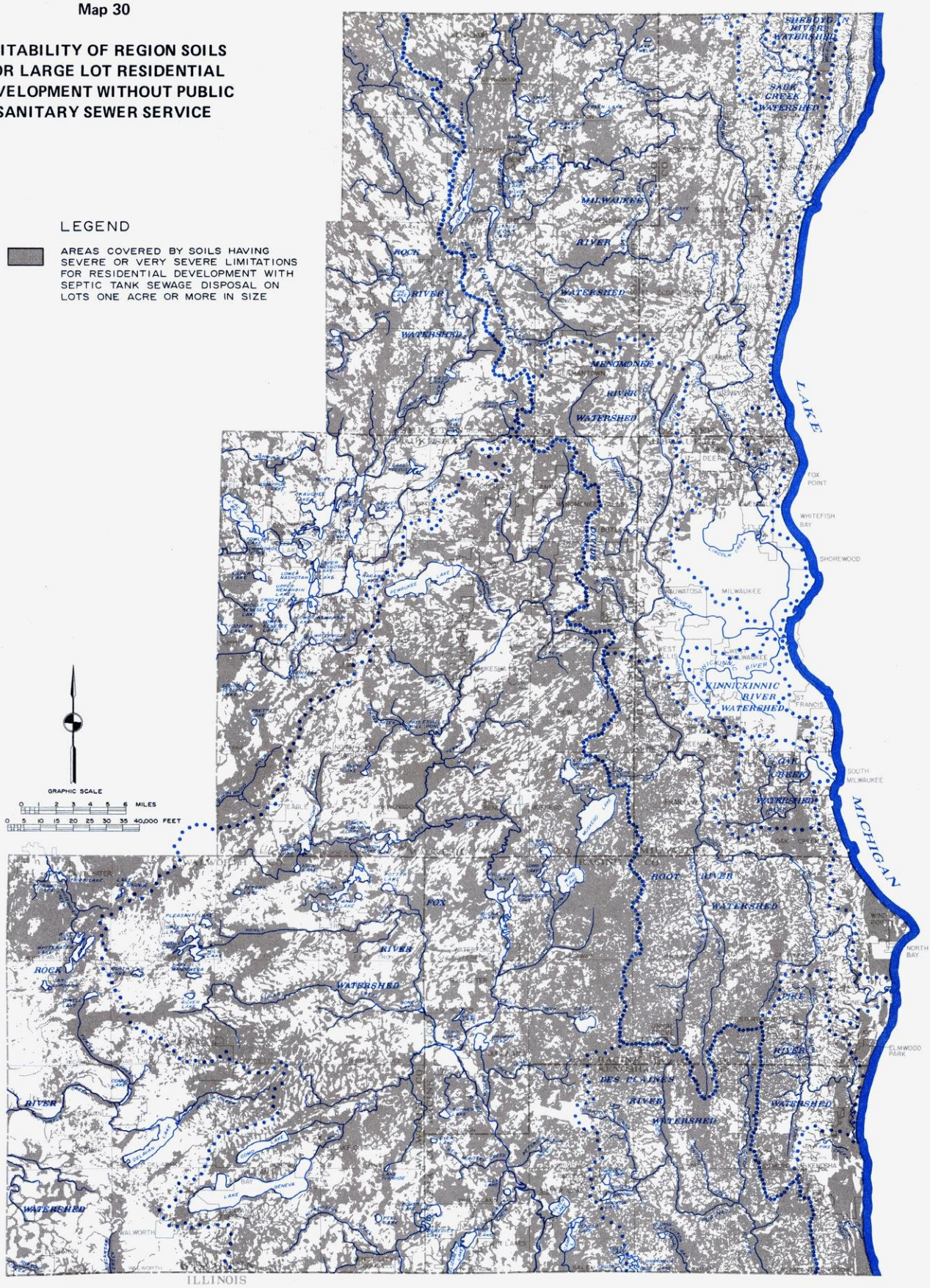


Approximately 1,637 square miles, or about 61 percent of the area of the Region, are covered by soils poorly suited for residential development on lots having an area smaller than one acre and not served by public sanitary sewerage facilities. Reliance on septic tank sewage disposal systems in these areas, which are covered by relatively impervious soils or are subject to seasonally high water tables, can only result in eventual malfunctioning of such systems and the consequent intensification of water pollution and public health problems in the Region.

Source: U. S. Soil Conservation Service and SEWRPC.

Map 30

SUITABILITY OF REGION SOILS FOR LARGE LOT RESIDENTIAL DEVELOPMENT WITHOUT PUBLIC SANITARY SEWER SERVICE



Approximately 1,181 square miles, or about 44 percent of the area of the Region, are covered by soils poorly suited for residential development on lots having an area of one acre or more and not served by public sanitary sewerage facilities. The inherent limitations of these soils for septic tank sewage disposal systems cannot be overcome simply by the provision of larger lots, and the use of such systems on these soils which cannot absorb the sewage effluent, ultimately results in surface ponding and runoff of partially treated wastes into nearby watercourses.

Source: U. S. Soil Conservation Service and SEWRPC.

destroyed through mismanagement within a comparatively short time. The deforestation of hillsides contributes to the siltation of lakes and streams and the destruction of wildlife habitat. Woodlands can and should be maintained for their total values: scenic, wildlife, open space, educational, recreational, and watershed protection, as well as for their forest products. Under balanced use and sustained yield management, woodlands can serve many of these benefits at the same time.

Primarily located on ridges and slopes, along lakes and streams, and in wetland, woodlands provide an attractive natural resource of immeasurable value. Not only is the beauty of lakes, streams, and glacial land forms of the Region accentuated by woodlands, but they are essential to the maintenance of the overall environmental quality of southeastern Wisconsin.

Six forest types are recognized within the Region: northern upland hardwoods, southern upland hardwoods, northern lowland hardwoods, southern lowland hardwoods, northern lowland conifers, and northern upland conifers. The northern and southern upland hardwood types are the most common in the Region. The two upland hardwood types are most utilized for production of commercial forest products.

Natural stands of trees within the Region consist largely of even-aged mature or nearly mature specimens with insufficient reproduction and saplings to maintain the stands when the old treed are harvested or die of disease or age. This lack of young growth is an unnatural condition brought about by mismanagement, and is associated with many years of excessive grazing by livestock.

Inventories of woodlands within the Southeastern Wisconsin Region were conducted by the Commission as part of the 1963 and 1970 land use inventories. As indicated in Table 48 and on Map 31, woodlands in the Region in 1970 covered a total combined areas of about 125,300 acres, or approximately 7 percent of the total area of the Region, with over 91,700 acres, or 73 percent, located in Walworth, Washington, and Waukesha Counties. Milwaukee County, with about 3,200 acres, had the smallest amount of woodlands of any county in the Region.

Woodlands in the Region in 1963 covered a combined area of about 130,400 acres. Between 1963 and 1970, there were both decreases in woodlands in certain areas of the Region, due largely to the conversion of woodlands to intensive urban and agricultural land uses, as well as increases in woodlands in certain areas of the Region as a result of reforestation activities. The overall effect of these changes in woodlands between 1963 and 1970 is a net loss of about 5,100 acres of woodlands, representing a 4 percent decrease in the total amount of woodlands since 1963.

Wetlands

Water and wetland areas probably provide the singularly most important landscape feature within the Region, and can serve to enhance all proximate uses. Their contribution to resource conservation and recreation within the Region is immeasurable, and they contribute both directly and indirectly to the regional economy. Recognizing the many environmental attributes of wetland areas, continued efforts should be made to protect this recource by discouraging costly--both in monetary and environmental terms--wetland draining, filling, and urbanization.

Wetlands represent a variety of stages in the natural filling of lake and pond basins as well as floodplain areas. Wetlands are considered herein as areas which have the water table at or near the land surface and are generally unsuited or poorly suited for most agricultural or urban development purposes. Wetlands, however, have important ecological value in a natural state. Wetlands contribute to flood control and stream purification, since such areas naturally serve to temporarily store excess runoff and thereby tend to reduce peak flood flows. It has been found that except during exceptional periods of high runoff following prolonged drought, concentrations of nutrients in waters leaving such areas are considerably lower than in waters entering the wetlands.

Wetlands within Wisconsin have been classified by the Wisconsin Department of Natural Resources according to the national wetland classification system.[4] Under this system seven major classes of wetlands are recognized, including potholes, fresh meadows, shallow marshes, deep marshes, shrub swamps, timber swamps, and bogs.

The wetlands with standing water are well suited for waterfowl and marsh furbearers, while drier types support upland game due to the protection afforded by vegetative cover. Shallow-water wetlands are subject to winter freeze and summer drought, and therefore are considered lower in value than the deep-water types of wetlands.

Inventories of water and wetlands within the Southeastern Wisconsin Region were conducted by the Commission as part of the 1963 and 1970 land use inventories. The water and wetland land use category includes all inland lakes, excluding Lake Michigan; all streams, rivers, and canals more than 50 feet in width; and open lands which are intermittently covered with water or which are wet due to a high water table. As indicated in Table 49 and on Map 32, water and wetland areas in the Region in 1970 covered about 180,800 acres, or about 10 percent of the area of the Region, with over 124,500 acres, or 69 percent, being located in Walworth, Washington, and Waukesha Counties.

Of the total water and wetland category, only 48,000 acres, or 27 percent, actually consisted of surface water. The remaining 132,800 acres consisted of swamps, marshes, and other wetland areas. Large amounts of

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[4] *Classification of Wetlands in the United States, Special Scientific Report: Wildlife No. 20, Fish and Wildlife Service, 1953.*

Table 48

WOODLANDS IN THE REGION BY COUNTY: 1963 AND 1970

County	Woodlands					
	1963[a]		1970		Difference: 1963-1970	
	Acres	Percent	Acres	Percent	Acres	Percent
Kenosha	9,616	7.4	9,112	7.3	- 504	- 5.2
Milwaukee	3,455	2.6	3,213	2.6	- 242	- 7.0
Ozaukee	8,550	6.6	8,272	6.6	- 278	- 3.3
Racine	13,709	10.5	12,927	10.3	- 782	- 5.7
Walworth	32,750	25.1	31,755	25.3	- 995	- 3.0
Washington	27,855	21.4	27,410	21.9	- 455	- 1.6
Waukesha	34,482	26.4	32,597	26.0	- 1,885	- 5.5
Region	130,417	100.0	125,286	100.0	- 5,131	- 3.9

[a] *Identification and quantification of woodlands in the Region were based upon aerial photo interpretation completed as part of the regional land use inventories conducted in 1963 and 1970. The 1963 woodland acreage data differ slightly from the 1963 forest and woodlands acreage data presented in SEWRPC Planning Report No. 7, The Land Use and Transportation Study, Volume One, Inventory Findings, since the latter acreage was determined by the Wisconsin Conservation Commission for SEWRPC and included swamp woodlands and wet mesic woodlands which were considered wetlands in the SEWRPC land use inventories, and also included only those woodlands 20 acres or more in area.*

Source: SEWRPC.

Table 49

SURFACE WATER AND WETLANDS IN THE REGION: 1963 AND 1970

County	Surface Water and Wetlands					
	1963[a]		1970		Difference: 1963-1970	
	Acres	Percent	Acres	Percent	Acres	Percent
Kenosha	19,584	10.7	19,445	10.8	- 139	- 0.7
Milwaukee	4,522	2.5	4,207	2.3	- 315	- 7.0
Ozaukee	15,083	8.3	14,879	8.2	- 204	- 1.4
Racine	17,218	9.4	17,712	9.8	494	2.9
Walworth	39,164	21.5	39,160	21.7	- 4	--[b]
Washington	36,032	19.7	35,638	19.7	- 394	- 1.1
Waukesha	50,871	27.9	49,789	27.5	- 1,082	- 2.1
Region	182,474	100.0	180,830	100.0	- 1,644	- 0.9

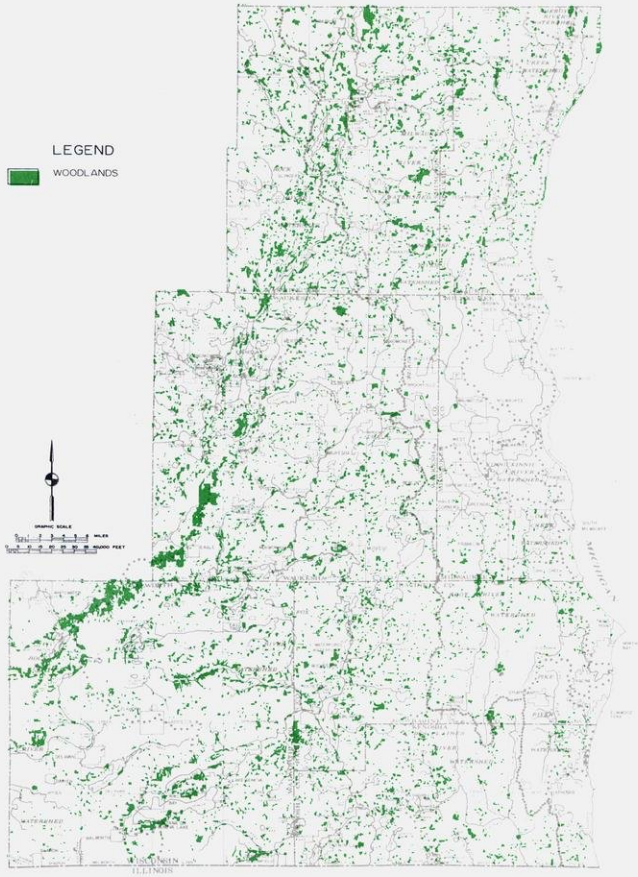
[a] *The 1963 water and wetland acreage data differ slightly from the data presented in SEWRPC Planning Report No. 7, The Land Use Transportation Study, Volume One, Inventory Findings, because the availability of more detailed information since 1963 permitted a refinement of water and wetland delineation for that year.*

[b] *Less than 0.1 percent.*

Source: SEWRPC.

Map 31

WOODLANDS IN THE REGION: 1970

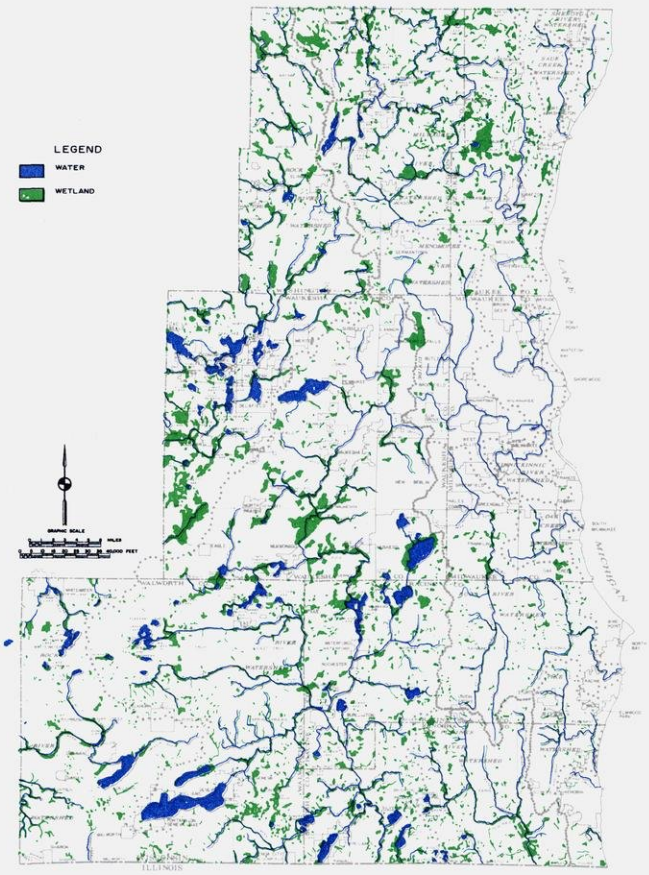


Woodlands currently occupy about 125,000 acres, or about 7 percent of the total land area of the Region. Woodlands have much value beyond monetary return for forest products. The maintenance of woodlands contributes to clean air and water and to the maintenance of a diversity of plant and animal life. Woodlands also provide an attractive natural resource of immeasurable value. Significant concentrations of woodlands are located in the Kettle Moraine State Forest and in several major stream valley areas in Walworth and Waukesha Counties. Together, these areas contain about 64,000 acres of woodland, representing slightly over one-half of the remaining woodlands in the Region.

Source: SEWRPC.

Map 32

EXISTING WATER AND WETLAND AREAS: 1970



About 180,800 acres, or approximately 10 percent of the area of the Region, were covered by water and wetlands in 1970. These wetlands constitute a valuable resource, supporting wide varieties of desirable forms of plant and animal life; assisting in reducing storm water runoff, stabilizing streamflows, and enhancing stream water quality by functioning as nutrient and sediment traps; and providing aesthetically pleasing vistas on the landscape. The extent of water and wetlands may change slightly over time as a result of drainage and landfill operations, as well as the construction of new impoundment areas. Furthermore, variations in precipitation may cause the boundaries of wetland areas to fluctuate. As a result of these changes, there was a net decrease of about 1,600 acres, or approximately 1 percent, in the water and wetland category in the Region between 1963 and 1970.

Source: SEWRPC.

surface water areas are located in northwestern Waukesha County, southern Walworth County, and southwestern Kenosha County, while concentrations of wetland areas occur in the Cedarburg Bog in Ozaukee County, the Jackson and Theresa Marshes in Washington County, and the Menomonee Falls and Vernon Marshes in Waukesha County.

The extent of water and wetlands may change slightly in a given area over time as a result of drainage and landfill operations, as well as the construction of new impoundment areas. Furthermore, variations in precipitation may cause the boundaries of wetland areas to fluctuate from time to time. As a result of these phenomena, there was a net decrease of about 1,600 acres, or approximately 1 percent, in the water and wetlands category in the Region between 1963 and 1970.

WATER RESOURCES

Surface water resources, consisting of lakes, streams, and associated floodlands, form the most important single element of the natural resource base of the Region. Their contribution to the economic development, recreational

activity, and aesthetic quality of the Region is immeasurable. The groundwater resources of southeastern Wisconsin are closely interrelated with the surface water resources because they sustain lake levels and provide the base flow of streams. The groundwater resources, along with Lake Michigan, constitute the major sources of supply for domestic, municipal, and industrial water users.

Surface Water Resources

Lakes and streams constitute an extremely valuable part of the natural resource base of southeastern Wisconsin. Because they are focal points for water-related recreational activities popular with the inhabitants of the Region, they provide extremely attractive sites for properly planned residential development and, when viewed in the context of open space areas, they greatly enhance the aesthetic aspects of the environment. It is important to note that lakes and streams, while valued highly by the urban and rural population of the Region, are extremely susceptible to deterioration from the activities of that population. Water quality can degenerate as a result of excessive nutrient loads from malfunctioning or improperly placed septic tank systems, inadequate operation of waste treatment facilities, careless agricultural practices, and inadequate soil conservation practices. Lakes and streams are also adversely affected by the excessive development of lakeshore and riverine areas in combination with the filling of peripheral wetlands, which remove valuable nutrient and sediment traps while adding nutrient and sediment sources. The regional surface water resources must be properly managed to adjust man's uses to the quantity and quality of surface waters that are available and to achieve a reasonable balance between public and private use and enjoyment of those surface water resources. A tabular summary[5], by county, of the surface water resources of southeastern Wisconsin is presented in Table 50.

Lakes: Major lakes are defined herein as those having 50 acres or more of surface water area, a size capable of supporting reasonable recreational use with relatively little degradation of the resource. There are 100 major lakes within the Region, the location and relative size of which are shown on Map 25 and Table 50. Major lakes in the Region have a combined surface water area of 57 square miles, or about 2 percent of the area of the Region, and provide a total of 448 miles of shoreline. The number of major lakes per county ranges from none in Milwaukee County to 33 in Waukesha County. The remaining five counties of Walworth, Kenosha, Washington, Racine, and Ozaukee contain, respectively, 25, 15, 15, 10, and two major lakes. Lake Geneva is by far the largest lake in southeastern Wisconsin, having a surface area of 5,262 acres, and is more than twice as large as Pewaukee Lake, which, with an area of 2,493 acres, is the second largest lake in the Region.

The lakes of southeastern Wisconsin are almost exclusively of glacial origin, being formed by depressions in outwash deposits, terminal and interlobate moraines, and ground moraines. Some lakes, such as Green Lake in northeastern Washington County or Brown's Lake in southwestern Racine County, owe their origins to kettles, that is, depressions formed in the glacial drift as a result of the melting of ice blocks, that became separated from the melting continental ice sheet, and the subsequent subsidence of sand and gravel contained on and within those blocks. By virtue of their origin, glacially formed lakes are fairly regular in shape, with their deepest points located predictably near the center of the basin, or near the center of each of several connected basins. The beaches are characteristically gravel or sand on the windswept north, east, and south shores, while fine sediments and encroaching vegetation are common on the protected west shores and in the bays.

There are 228 lakes and ponds in the Region of less than 50 acres of surface water area, which are considered in this report as minor lakes. These minor lakes, the regional distribution of which is summarized in Table 50, have a combined surface water area of four square miles, or about 0.15 percent of the area of the Region, and provide 141 miles of shoreline. These small lakes generally have a few riparian owners and only marginal fisheries. In most cases, the value of the minor lakes is primarily aesthetic, and these lakes are incapable of retaining even this value with any degree of improper shoreland development.

It is also important to consider the present overall quality of the lakes in southeastern Wisconsin. The 694-square-mile Milwaukee River watershed, 433 square miles of which lie in southeastern Wisconsin, has 12 major lakes which lie entirely within the Region. The 934-square-mile Fox River watershed has 46 major lakes. These two watersheds were the subject of SEWRPC comprehensive watershed studies which included the collection, collation, and analysis of extensive lake water quality data for the purpose of assessing pollution problems in the major lakes and of developing plan elements to solve those problems. Since these two watershed studies were completed relatively recently, and since the in-Region portions of these watersheds comprise just over 50 percent of the 2,689-square-mile area of the Region and contain 58 of the 100 major lakes in southeastern Wisconsin, the water quality characteristics of the major lakes in the Milwaukee and Fox River watershed studies may be taken as representative of regional lake water quality conditions and trends.

At least 13 of the 58 major regional lakes in these two watersheds were found to be in advanced stages of eutrophication as indicated by high phosphorus concentrations, low dissolved oxygen contents, and excessive growths of algae and aquatic weeds. Many other major lakes within the Fox and Milwaukee River watersheds were found to be receiving nutrients at rates such that

[5] *See Appendix C of SEWRPC Planning Guide No. 5, Floodland and Shoreland Development Guide, for a detailed tabulation, by county, of lakes, and ponds in southeastern Wisconsin. This report indicates the location of each lake and pond, and summarizes pertinent morphometric parameters for major lakes which have been revised under the Commission's Fox and Milwaukee River watershed studies published as SEWRPC Planning Reports No. 12, A Comprehensive Plan for the Fox River Watershed, Volumes One and Two, and No. 13, A Comprehensive Plan for the Milwaukee River Watershed, Volumes One and Two.*

Table 50

LAKES AND STREAMS IN THE REGION BY COUNTY

County		Lakes[a]									
		Major[b]						Minor[c]			
			Total Surface Area		Total Shoreline Length (miles)	Largest Lake			Total Surface Area		Total Shoreline Length (miles)
Name	Area (square miles)	Number	Square Miles	Percent of County		Name	Area (acres)	Number	Square Miles	Percent of County	
Kenosha	278.28	15	5.06	1.82	48.62	Elizabeth Lake	637.80	9	0.27	0.10	5.85
Milwaukee ...	242.19	--	--	--	--	--	--	40	0.26	0.11	14.99
Ozaukee	234.49	2	0.47	0.20	4.75	Mud Lake	245.40	36	0.63	0.27	25.40
Racine.....	339.87	10	5.48	1.61	59.52	Wind Lake	936.20	7	0.17	0.05	4.59
Walworth....	578.08	25	19.52	3.38	131.40	Lake Geneva	5,262.40	9	0.35	0.06	9.10
Washington ..	435.50	15	4.22	0.97	40.59	Big Cedar	932.00	43	0.70	0.16	24.32
Waukesha....	580.66	33	22.07	3.80	162.89	Pewaukee	2,493.00	84	1.62	0.28	57.08
Region	2,689.07	100	56.82	2.11	447.77	--	10,506.80	228	4.00	0.15	141.33

County		Lakes[a]				Major Streams[d]			
		Total							
			Total Surface Area		Total Shoreline Length (miles)			Total Surface Area	
Name	Area (square miles)	Number	Square Miles	Percent of County		Number	Total Length (miles)	Square Miles	Percent of County
Kenosha	278.28	24	5.33	1.92	54.47	19	106.40	0.73	0.03
Milwaukee ...	242.19	40	0.26	0.11	14.99	15	102.99	0.62	0.03
Ozaukee	234.49	38	1.10	0.47	30.15	29	112.20	1.25	0.05
Racine.....	339.87	17	5.65	1.66	64.11	14	100.55	0.96	0.01
Walworth....	578.08	34	19.87	3.44	140.50	29	173.00	0.58	0.01
Washington ..	435.50	58	4.92	1.13	64.91	38	219.80	1.03	0.02
Waukesha....	580.66	117	23.69	4.08	219.97	50	333.30	1.31	0.02
Region	2,689.07	328	60.82	2.26	589.10	194	1,148.24	6.48	0.02

[a] *Appendices B, C, and D to SEWRPC Planning Guide No. 5, Floodland and Shoreland Development Guide, contain detailed tabulations, by county, of all streams, lakes, and ponds in the Southeastern Wisconsin Region. These appendices indicate the location of each stream, lake, and pond and summarize pertinent morphometric parameters. Surface areas and shoreline lengths for some of the major lakes have been revised under the Commission Fox and Milwaukee River watershed studies, documented in SEWRPC Planning Report No. 12, A Comprehensive Plan for the Fox River Watershed, Volumes One and Two, and SEWRPC Planning Report No. 13, A Comprehensive Plan for the Milwaukee River Watershed, Volumes One and Two. Entries in this table reflect the revised figures for major lakes.*

[b] *A major lake is defined as one having 50 acres or more of surface water area.*

[c] *A minor lake is defined as one having less than 50 acres of surface water area.*

[d] *A major stream is defined as one which maintains, at a minimum, a small, continuous flow throughout the year except for unusual drought conditions.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

nuisance growths of algae and aquatic weeds may be expected in the near future. In general, some indication of overfertilization was found in all major lakes in the Fox and Milwaukee River watersheds.

Domestic sewage pollution, as indicated by measured coliform levels and chloride concentrations, was found to constitute a health hazard in several of the lakes, including Little Cedar Lake in the Milwaukee River watershed and Little Muskego Lake in the Fox River watershed. High pesticide levels were encountered in the two watersheds, indicating another form of surface water contamination.

It is apparent, therefore, that many of the major lakes of southeastern Wisconsin are being degraded as a result of man's activities to the point where they now have, or soon will have, little or no value for recreational purposes, as desirable locations for properly planned and controlled lake-oriented residential development, or even as aesthetic assets in the Region.

Streams: As discussed earlier and as shown on Map 25, the surface drainage system of southeastern Wisconsin may be viewed as existing within 11 individual watersheds, five of which--the Root River, Menomonee River, Kinnickinnic River, Oak Creek, and Pike River watersheds--are contained entirely within the Region. In addition to the 11 watersheds, numerous small catchment areas immediately adjacent to the Lake Michigan shoreline drain directly to the lake via local natural streams and artificial drainageways, and these tributary areas together may be considered to comprise a twelfth watershed. The Region contains only a very small part of the Wisconsin portion of the large Rock River watershed, the streams of that watershed within the Region being limited to the headwater portions of such tributaries to the Rock as the Bark and Oconomowoc Rivers and Turtle Creek.

Three of the 12 watersheds contained wholly or partly in southeastern Wisconsin--the Fox, Rock, and Des Plaines River watersheds, which have a combined area of 1,680 square miles, or 63 percent of the area of the Region--lie west of the subcontinental divide. As a result, the rivers and streams within these catchment areas flow in a generally south and southwesterly direction, and are a part of the Mississippi River drainage system. The rivers and streams in the nine watersheds comprising the remainder of southeastern Wisconsin, which have a combined area of 1,009 square miles, or 37 percent of the area of the Region, flow in an easterly direction and discharge into Lake Michigan, and are a part of the Great Lakes-St. Lawrence River drainage system. A tabular summary of watershed characteristics for southeastern Wisconsin is presented in Table 51, and a graphical representation of the range of watershed sizes is shown in Figure 26.

One of the most interesting, variable, and occasionally unpredictable features of each watershed is its stream flow regimen with its ever changing, sometimes widely fluctuating, discharges and stages. The stream systems of the Region receive a relatively uniform flow of groundwater from the shallow aquifer underlying the Region. This groundwater discharge constitutes the base

Table 51

WATERSHEDS IN THE REGION BY COUNTY

Watershed[a,b]	County														Total Watershed Area Within Region (square miles)	Percent of Region
	Kenosha		Milwaukee		Ozaukee		Racine		Walworth		Washington		Waukesha			
	Area (square miles)	Percent of Watershed	Area (square miles)	Percent of Watershed	Area (square miles)	Percent of Watershed	Area (square miles)	Percent of Watershed	Area (square miles)	Percent of Watershed	Area (square miles)	Percent of Watershed	Area (square miles)	Percent of Watershed		
Fox River[d,f]	96.33	10.31	0.46	0.05	--	--	164.34	17.59	337.39	36.11	0.30	0.03	335.49	35.90	934.31	34.74
Rock River[d]	--	--	--	--	--	--	--	--	239.06	39.04	178.68	29.18	199.67	31.79	612.41	22.77
Milwaukee River[e,f]	--	--	57.40	13.26	150.62	34.79	--	--	--	--	224.98	51.96	--	--	433.00	16.10
Root River[c,e,f]	2.18	1.11	58.65	29.79	--	--	122.94	62.45	--	--	--	--	13.10	6.65	196.87	7.32
Menomonee River[c,e,f]	--	--	55.08	40.52	11.76	8.65	--	--	--	--	31.75	23.36	37.75	27.77	135.94	5.06
Des Plaines River[d]	122.61	91.51	--	--	--	--	11.37	8.49	--	--	--	--	--	--	133.98	4.98
Minor Tributaries to Lake Michigan[c,e]	27.14	28.41	19.89	20.82	27.47	28.76	21.02	22.00	--	--	--	--	--	--	95.52	3.55
Pike River[c,e]	30.02	59.26	--	--	--	--	20.64	40.74	--	--	--	--	--	--	50.66	1.88
Sauk Creek[e]	--	--	--	--	33.71	100.00	--	--	--	--	--	--	--	--	33.71	1.25
Oak Creek[c,e]	--	--	26.33	100.00	--	--	--	--	--	--	--	--	--	--	26.33	0.97
Kinnickinnic River[c,e]	--	--	24.85	100.00	--	--	--	--	--	--	--	--	--	--	24.85	0.92
Sheboygan River[e]	--	--	--	--	11.43	100.00	--	--	--	--	--	--	--	--	11.43	0.43
Total	278.28	--	242.66	--	234.99	--	340.31	--	576.45	--	435.71	--	580.61	--	2,689.01	100.00

[a] *Includes only that area of each watershed that lies within the seven-county Southeastern Wisconsin Region.*

[b] *Watersheds are listed in order of decreasing size within the Region.*

[c] *Indicates watershed wholly contained within the Region.*

[d] *Indicates watershed west of the subcontinental divide that is tributary to the Mississippi River basin. Three watersheds having a combined area of 1,682.66 square miles, or about 62.6 percent of the Region, are in this category.*

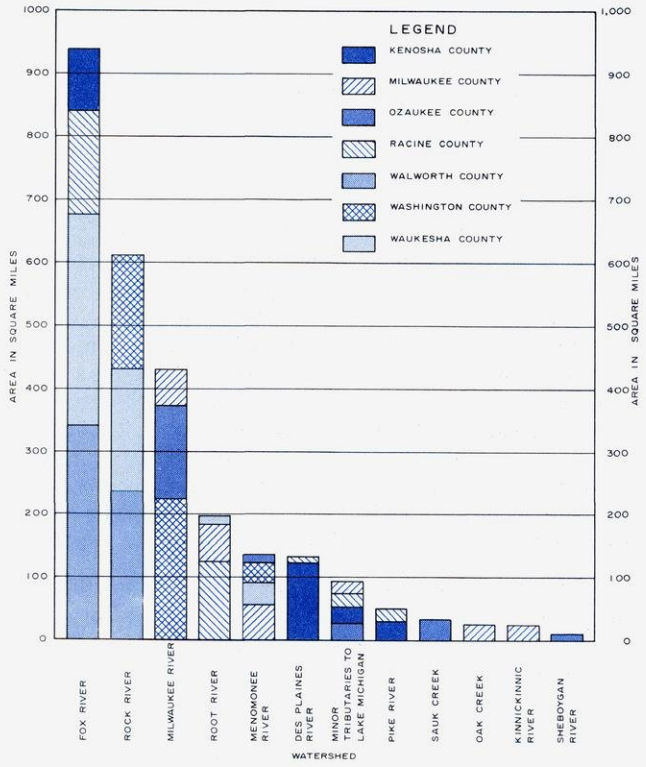
[e] *Indicates watershed east of the subcontinental divide that is tributary to the Great Lakes-St. Lawrence River basin. Nine watersheds having a combined area of 1,006.56 square miles, or 37.4 percent of the Region, are in this category.*

[f] *Indicates watersheds for which comprehensive watershed plans have been prepared and adopted by the Southeastern Wisconsin Regional Planning Commission.*

Source: SEWRPC.

Figure 26

SIZE AND DISTRIBUTION OF WATERSHEDS IN THE REGION BY COUNTY



Source: SEWRPC.

flow of the streams. The streams also periodically intercept surface water runoff from rainfall and snowmelt, which is superimposed on the base flow and sometimes causes the streams to leave their channels and occupy the adjacent floodlands. The volume of water drained annually from southeastern Wisconsin by the stream system is equivalent to seven to eight inches of water spread over the seven-county Region, which amounts to about one-fourth of the average annual precipitation.

Major streams are defined herein as perennial streams which maintain, at a minimum, a small, continuous flow throughout the year except under unusual drought conditions. Within the Region, there are approximately 1,148 miles of such major streams as summarized by county in Table 50. The length of major streams per county ranges from a low of 101 lineal miles in Racine County to a high of 333 lineal miles in Waukesha County. The latter county also has the largest number of major lakes, and is therefore particularly well endowed with surface water resources.

During a 14-month period extending from January 1964 through February 1965, the Commission conducted an extensive stream water quality sampling program during which 3,933 water samples were collected at 87 sampling stations established on 43 streams in the Region. The samples were analyzed for 32 chemical, physical, biochemical, and bacteriological water quality indicators for the purpose of assessing the then existing condition of stream water quality in relation to pollution sources, land use, and population distribution and concentration. Data developed during this regional stream water quality study were used to forecast probable future streams water quality conditions. Regional stream water quality data as of 1964 and 1965, interpretations of that data, and forecasts of future stream water quality conditions were published in 1966 in SEWRPC Technical Report No. 4, Water Quality and the Flow of Streams in Southeastern Wisconsin.

The study found that the original naturally high quality of the streams in the Region had been markedly deteriorated by the activities of man, as indicated by such key indicators of pollution as chlorides, dissolved solids, dissolved oxygen, and coliform bacteria. This deterioration may be attributed to the failure to properly adjust both rural and urban development within the Region to the capability of streams and watercourses to assimilate the pollution loadings attendant to such development. Evidence of occasional or persistently severe stream pollution was found in all of the 12 watersheds contained wholly or partly in the seven-county planning Region. The regional stream water quality study also revealed that not only has stream water quality markedly deteriorated as a result of man's activities, but that the deteriorated stream water quality has, in turn, impaired or prohibited the very aesthetic and recreational uses sought by the expanding urban population of the Region. Of the 43 streams sampled in the Region, 26 were found to be unsuitable for any recreational activities in all or portions of the stream.

In 1967 the Commission undertook a comprehensive study of the Fox River watershed. It concluded a determination of existing stream water quality conditions in the watershed, and the development of a stream water quality simulation model to be used as a tool in the construction of a comprehensive watershed development plan, having as a major element a stream water quality management plan (see SEWRPC Planning Report No. 12, A Comprehensive Plan for the Fox River Watershed). Because this study was completed soon after the regionwide water quality study, and because the Wisconsin Department of Natural Resources had conducted additional sampling efforts as part of a stream basin survey, no major additional data collection efforts with respect to stream water quality were mounted in the study. The existing data were, however, thoroughly analyzed and utilized in the development and calibration of a stream water quality simulation model for the Fox River watershed.

In general, the findings of this study indicated that stream water pollution was very evident in most areas of the upper Fox River watershed, and was forecast to increase as the urbanization of this upper watershed area proceeded. The study concluded that pollution in the Fox River watershed rendered 4 of the 13 major streams unsuitable for the preservation and enhancement of aquatic life, with the remaining nine unsuitable for any recreational activities either in some sections of the stream or throughout the entire stream.

In 1968 the Commission undertook a comprehensive study of the Milwaukee River watershed. In addition to

all of the stream water quality data previously collected as part of the regional stream water quality study in 1964 and 1965, a special stream water quality sampling program was mounted in the Milwaukee River watershed study. It provided definitive data to permit a more thorough analysis of the existing stream water quality conditions in the watershed and the development and calibration of a stream water quality simulation model (see SEWRPC Planning Report No. 13, A Comprehensive Plan for the Milwaukee River Watershed).

The data collected from the previous regional stream water quality study, together with the additional data collected under the Milwaukee River watershed study, indicated that although water quality conditions varied greatly from the upper to the lower reaches of the watershed, pathogenic concentrations and nutrient pollution, as indicated by coliform count and phosphorus concentration, are serious problems throughout almost all of the watershed. Organic pollution, as indicated by dissolved oxygen levels, was not found to be as serious a problem in the Milwaukee River watershed as in the Fox River watershed. Nevertheless, relatively long reaches of the Milwaukee River were found to exist in which dissolved oxygen levels fell below the minimum levels required to sustain fish life. Aesthetic pollution was clearly found, particularly in the lower reaches of the watershed.

Municipal sewage treatment plant discharges were found to constitute the major cause of water pollution in the middle and upper reaches of the Milwaukee River watershed, while sanitary and combined sewer overflows were found to be the major cause in the lower reaches of the watershed. More than 84 miles of the main stem of the Milwaukee River, or about 85 percent of its total length, did not meet the standards for the established stream water use objectives. About 20 percent of the total length of the 29 major tributaries of the Milwaukee River, or about 44 miles, similarly did not meet the standards for the established water use objectives. In general, the Milwaukee River and its tributaries in the lower reaches were considered to be grossly polluted.

In 1968 the Commission entered into a cooperative agreement with the Wisconsin Department of Natural Resources whereby that Department and the Commission undertook a continuing stream water quality monitoring program within the Region. The objective of the program was to build upon the bench mark water quality data initially collected under the regional stream water quality study and the Milwaukee River watershed study by providing, on a continuous basis, the water quality information necessary to permit assessment of the long-term trends in stream water quality within the Region.

Although the stream water quality data collected under this continuing program have not to date been analyzed in detail, review of the data on a selected basis indicates that no significant, long-term changes in stream water quality conditions within the Region are as yet apparent. Consequently, although localized changes in water quality conditions have undoubtedly occurred since the initial 1964-1965 sampling period, the general conclusions of the Commission's regional stream water quality survey remain essentially valid.

In general, it is apparent from all of the Commission's stream water quality data to date that many miles of major streams in southeastern Wisconsin are being degraded as a result of existing waste water treatment and disposal practices to a point where they are unsafe for most recreational activities and have a greatly reduced aesthetic value. All of the aforementioned Commission studies also clearly demonstrate the very basic interrelationship between land use and stream water quality, and thereby emphasize the need for concurrent areawide planning of land use and water quality control measures.

Floodlands

The floodlands of a river or stream are the wide, gently sloping areas contiguous with, and usually lying on both sides of, a river or stream channel. Rivers and streams occupy their channels most of the time. However, during even minor flood events, stream discharges increase markedly so that the channel is not able to convey all the flow. As a result, stages increase and the river or stream spreads laterally over the floodlands. The periodic flow of a river onto its floodlands is a normal phenomenon and, in the absence of major, costly structural flood control works, will occur regardless of whether or not urban development occurs on the floodlands.

For planning and regulatory purposes, floodlands are normally defined as the areas, excluding the channel, subject to inundation by the 100-year recurrence interval flood event. This is the event that would be reached or exceeded in severity once on the average of every 100 years. Stated another way, there is a 1 percent chance that this event will be reached or exceeded in severity in any given year. Commission studies indicated that about 6 to 10 percent of the total land area of any given watershed will be within the 100-year floodlands of the Region's rivers and streams. Obviously, the 100-year recurrence interval floodland contains within its boundaries the areas inundated by floods of less severe but more frequent occurrence such as the 50-, 25-, and 5-year recurrence interval events.

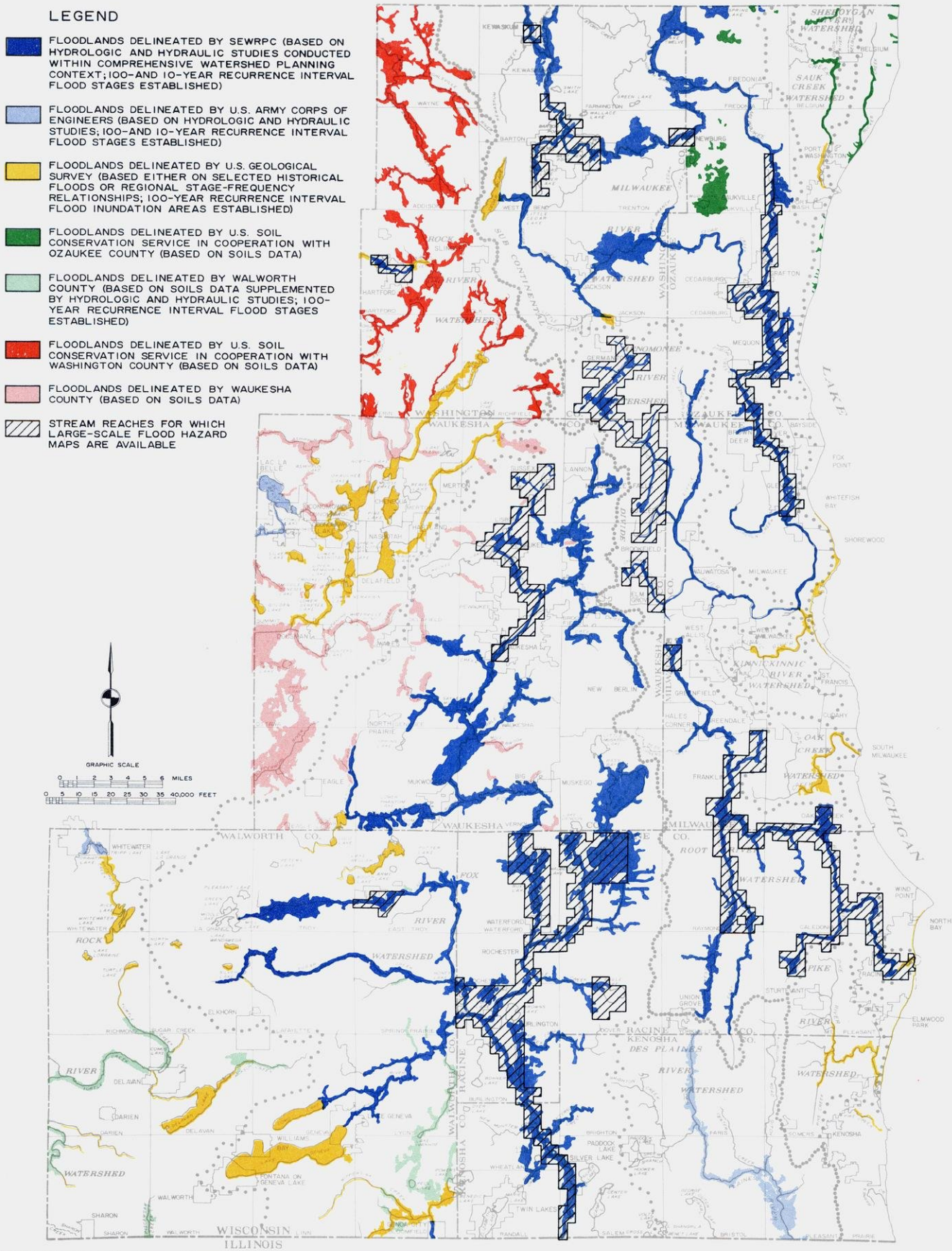
Floodland areas are generally not well suited to urban development because of flood hazards, high water tables, and inadequate soils. These floodland areas are, however, generally prime locations for much needed park and open space areas, and therefore, within the context of regional land use planning, every effort should be made to discourage indiscriminate urban development in floodplains while encouraging open space uses.

Flood hazard data for the numerous streams of the Southeastern Wisconsin Region, and particularly data on the limits of the natural floodlands of the streams for a flood of a specified recurrence interval, are important inputs to the regional planning process. Due to the importance of floodland data, the Commission, as an integral part of its comprehensive watershed studies, provides definitive data, including a delineation of the limits of the floodplains, on the 10- and 100-year recurrence interval floods for most of the perennial streams in each watershed.

The status of existing flood hazard data in the Region as of January 1, 1976, is summarized on Map 33. The Commission has completed comprehensive watershed

Map 33

FLOODLANDS IN THE REGION


LEGEND
FLOODLANDS DELINEATED BY SEWRPC (BASED ON HYDROLOGIC AND HYDRAULIC STUDIES CONDUCTED WITHIN COMPREHENSIVE WATERSHED PLANNING CONTEXT; 100- AND 10-YEAR RECURRENCE INTERVAL FLOOD STAGES ESTABLISHED)
FLOODLANDS DELINEATED BY U.S. ARMY CORPS OF ENGINEERS (BASED ON HYDROLOGIC AND HYDRAULIC STUDIES; 100- AND 10-YEAR RECURRENCE INTERVAL FLOOD STAGES ESTABLISHED)
FLOODLANDS DELINEATED BY U.S. GEOLOGICAL SURVEY (BASED EITHER ON SELECTED HISTORICAL FLOODS OR REGIONAL STAGE-FREQUENCY RELATIONSHIPS; 100-YEAR RECURRENCE INTERVAL FLOOD INUNDATION AREAS ESTABLISHED)
FLOODLANDS DELINEATED BY U.S. SOIL CONSERVATION SERVICE IN COOPERATION WITH OZAUKEE COUNTY (BASED ON SOILS DATA)
FLOODLANDS DELINEATED BY WALWORTH COUNTY (BASED ON SOILS DATA SUPPLEMENTED BY HYDROLOGIC AND HYDRAULIC STUDIES; 100-YEAR RECURRENCE INTERVAL FLOOD STAGES ESTABLISHED)
FLOODLANDS DELINEATED BY U.S. SOIL CONSERVATION SERVICE IN COOPERATION WITH WASHINGTON COUNTY (BASED ON SOILS DATA)
FLOODLANDS DELINEATED BY WAUKESHA COUNTY (BASED ON SOILS DATA)
STREAM REACHES FOR WHICH LARGE-SCALE FLOOD HAZARD MAPS ARE AVAILABLE
GRAPHIC SCALE
0 1 2 3 4 5 6 MILES
0 5 10 15 20 25 30 35 40,000 FEET
WISCONSIN
ILLINOIS
LAKE MICHIGAN
WASHINGTON CO.
OZAUKEE CO.
WAUKESHA CO.
WALWORTH CO.
RACINE CO.
KENOSHA CO.
MILWAUKEE CO.
MILWAUKEE
WAUKESHA
WHITEWATER
ROCK RIVER WATERSHED
FOX RIVER WATERSHED
MILWAUKEE RIVER WATERSHED
KINNICKINNIC RIVER WATERSHED
OAK CREEK WATERSHED
ROOT RIVER WATERSHED
DES PLAINES RIVER WATERSHED
SAUK CREEK WATERSHED
SHEBOYGAN RIVER WATERSHED
DELAVAN
DARIEN
ELKHORN
GENEVA
FONTANA ON GENEVA LAKE
WALWORTH
SHARON
WATERFORD
ROCHESTER
BURLINGTON
PADDOCK LAKE
SILVER LAKE
TWIN LAKES
KENOSHA
PORT WASHINGTON
CEDARBURG
MEQUON
FREDONIA
BELGIUM
WEST BEND
HARTFORD
JACKSON
GERMANTOWN
MENOMONEE RIVER
MERTON
DELAFIELD
NASHOTAH
LAC LA BELLE
OCONOMOWOC
NORTH PRAIRIE
EAGLE
MUKWONAGO
MUSKEGO
NEW BERLIN
BROOKFIELD
ELM GROVE
WAUWATOSA
WEST ALLIS
GREENFIELD
HALES CORNERS
GREENDALE
FRANKLIN
OAK CREEK
SOUTH MILWAUKEE
ST FRANCIS
BAYSIDE
FOX POINT
WHITEFISH BAY
SHOREWOOD
WIND POINT
NORTH BAY
ELMWOOD PARK
RACINE
UNION GROVE
STURTEVANT
PLEASANT PRAIRIE
SOMERS
BRISTOL
PARIS
WILLIAMS BAY
LYONS
BRIGHTON
RANDALL
SALEM
TROY
RICHMOND
SUGAR CREEK
LAFAYETTE
TURTLE
LA GRANGE
LIBERTY GROVE
PLEASANT LAKE
LAKE COMO
WHITEWATER LAKE
LAKE LAWRENCE
LAKE LA GRANGE
LAKE ENTERPRISE
LAKE SHANGRILA
LAKE BEULAH
LAKE WANDAWEGA
LAKE GEORGE
LAKE ELIZABETH
LAKE SHANGRILA
LAKE NORTH
LAKE SOUTH
LAKE MARIE
LAKE SUNSET
LAKE SUNSET
LAKE SUNSET

studies for the Root, Fox, Milwaukee, and Menomonee River watersheds resulting in the delineation of floodlands for about 620 miles of major stream channel, not including stream channels in the Milwaukee River watershed lying outside of the Region in Sheboygan and Fond du Lac Counties. Both 10- and 100-year recurrence interval floodplain limits have been established for the indicated stream reaches in these watersheds by the Commission. It is important that a flood used to delineate floodlands for land use planning as well as for land use regulation purposes have a specified recurrence interval so that a sound economic analysis of the benefits and costs and of the advantages and disadvantages of various combinations of land use regulation, public acquisition, and public construction for flood damage abatement and prevention can be fully analyzed.

While the Commission is the only agency which has developed flood hazard data for the Region on the basis of comprehensive watershed studies, other federal and local agencies have developed flood hazard data for additional stream reaches within the Region. These are also indicated on Map 33.

FISH AND WILDLIFE RESOURCES

Fish and wildlife are valuable assets to the natural resource base of the Region. The variety and relative abundance of wildlife in the Region have provided numerous recreational pursuits and pleasures for fishermen, hunters, and nature enthusiasts. Fees collected as part of fish and game licenses have also contributed to the regional economy. The remaining wildlife not only provide a valuable and much sought recreational resource, but also contribute both directly and indirectly to the regional economy of the Region.

Lake and Stream Fisheries

As noted earlier in this chapter, water quality data for 57 of the 100 major lakes in the Region were obtained under the Commission's Fox and Milwaukee River watershed studies. Only 4 of these 57 lakes were considered incapable of supporting significant populations of desirable fish under existing conditions. Assuming that the foregoing 57 lakes are representative of the 100 major lakes in the Region, most of the major lakes in southeastern Wisconsin are capable of supporting significant fish populations under existing conditions.

The earlier discussion of water quality in major lakes also noted, however, that 13 of 57 major regional lakes were found to be in advanced stages of eutrophication as revealed by excessive phosphorus concentrations, low dissolved oxygen content, and excessive algae and aquatic weed growths. Thus, while most of the 100 major lakes in the Region are currently capable of supporting significant fish populations, a decline in water quality in general, and fishery suitability in particular, is occurring. This decline may be expected to continue in the absence of a sound areawide water quality management plan and proper implementation of that plan.

Dominant fish species of lakes within the Region in order of importance to its fishery include bluegill, largemouth bass, northern pike, walleye, bullhead, black crappie, yellow perch, and carp. Other fish species existing in the lakes and streams, but of lesser importance to the fisherman, are pumpkinseed, warmouth, white sucker, and sunfish. Nearly every lake capable of supporting a fishery has a fish population comprised of northern pike, largemouth bass, bluegill, and bullhead. A few of the lakes, however, also support good walleye, muskellunge, cisco, and trout populations.

Lake fisheries are sustained primarily by natural spawning areas within the lakes. Presently, there are adequate shallow weedbed areas available for fish spawning within most major lakes. Other factors, however, such as deteriorating water quality, fluctuating water quality, and lack of adequate boating regulations to protect spawning areas tend to limit the effectiveness of these areas for natural spawning. In many instances, therefore, lake fisheries must be sustained by fish stocking procedures.

Only limited quality stream fisheries are available within the Region. The Commission's Fox and Milwaukee River watershed studies found, for example, that stream fisheries were generally limited in that only some of the relatively large streams in these two watersheds are capable of supporting self-sustaining populations of walleye, smallmouth bass, northern pike, or panfish. Very few streams presently support trout populations. It is recognized that not every stream in the Region can, or should, be of such quality that it can support walleye, smallmouth bass, or trout. These species are, however, important indicators of environmental quality, and should be maintained or restored in selected streams throughout the area.

Wildlife Habitat Areas

Wildlife in southeastern Wisconsin is composed primarily of small upland game such as rabbit and squirrel; some predators such as fox and raccoon; game birds, including water fowl; and pan and game fish. Deer are also found in some areas, but the herds are small when compared with other regions of the state.

Inventories of land and inland water in the Region known to be inhabited by various forms of wildlife were carried out cooperatively by the Wisconsin Department of Natural Resources and the Southeastern Wisconsin Regional Planning Commission in 1963 and 1970. As indicated in Table 52 and on Map 34, wildlife habitat areas in 1970 covered approximately 259,800 acres, or 15 percent of the total area of the Region. The overwhelming majority of this area, over 192,500 acres, or 74 percent, occurred in Walworth, Washington, and Waukesha Counties. It should be noted that more than 77,900 acres, or 76 percent of the total high-value wildlife habitat areas, and more than 70,000 acres, or 75 percent of the total medium-value wildlife habitat areas, occur in these counties as well. Significant concentrations of high-value wildlife habitat occur in the Kettle Moraine area in northwestern Walworth County,

Table 52

WILDLIFE HABITAT AREAS IN THE REGION BY VALUE

County	Value[a]	1963[b]		1970		Difference: 1963-1970	
		Acres	Percent	Acres	Percent	Acres	Percent
Kenosha	High	9,965	44.4	10,083	44.0	118	1.2
	Medium	6,285	28.0	6,136	26.8	- 149	- 2.4
	Low	6,189	27.6	6,683	29.2	494	8.0
	Total	22,439	100.0	22,902	100.0	463	2.1
Milwaukee	High	0	0.0	0	0.0	0	0.0
	Medium	1,251	66.6	1,225	68.9	- 26	- 2.1
	Low	626	33.4	553	31.1	- 73	- 11.7
	Total	1,877	100.0	1,778	100.0	- 99	- 5.3
Ozaukee	High	6,082	38.4	6,033	38.1	- 49	- 0.8
	Medium	8,422	58.1	8,310	52.4	- 112	- 1.3
	Low	1,341	8.5	1,512	9.5	171	12.8
	Total	15,845	100.0	15,855	100.0	10	0.1
Racine	High	9,044	23.8	8,945	33.4	- 99	- 1.1
	Medium	8,177	30.5	8,015	30.0	- 162	- 2.0
	Low	9,553	35.7	9,803	36.6	250	2.6
	Total	26,774	100.0	26,763	100.0	- 11	--[c]
Walworth	High	28,754	45.2	26,890	42.7	- 1,864	- 6.5
	Medium	20,272	31.9	20,775	32.9	503	2.5
	Low	14,593	22.9	15,368	24.4	775	5.3
	Total	63,619	100.0	63,033	100.0	- 586	- 0.9
Washington	High	19,844	38.3	19,340	37.2	- 504	- 2.5
	Medium	21,380	41.2	21,414	41.2	34	0.2
	Low	10,623	20.5	11,240	21.6	617	5.8
	Total	51,847	100.0	51,994	100.0	147	0.3
Waukesha	High	32,421	41.1	31,710	40.9	- 711	- 2.2
	Medium	28,809	36.6	28,255	36.5	- 554	- 1.9
	Low	17,559	22.3	17,542	22.6	- 17	- 0.1
	Total	78,789	100.0	77,507	100.0	- 1,282	- 1.6
Region	High	106,100	40.6	103,001	39.6	- 3,109	- 2.9
	Medium	94,596	36.2	94,130	36.3	- 466	- 0.5
	Low	60,484	23.2	62,701	24.1	2,217	3.7
	Total	261,190	100.0	259,832	100.0	- 1,358	- 0.5

[a] *High-value wildlife habitat areas have a high diversity of species. The territorial requirements of the major species are met, in that minimum population levels are possible. The structure and composition of the vegetation provide for nesting, travel routes, concealment, and modification of weather impact. Also, such areas have experienced little or no disturbance as a result of man's activities and are located in close proximity to other wildlife habitat areas.*

Medium-value wildlife habitat areas maintain all of the criteria described for a high-value habitat, but at a lower level. The species diversity may not be as high as in the high-value areas. The territorial requirements of the major species may not be adequately met, in that minimum population levels are not possible or are just barely met. The structure and composition of the vegetation may not adequately provide for nesting, travel routes, concealment, or modification of weather impact. The areas may have undergone disturbance as a result of man's activities, and also may not be located in close proximity to other wildlife habitat areas.

Low-value wildlife habitat areas are of a supplemental or remnant nature. They are usually considerably disturbed but are included in the inventory since they provide the only available range in the vicinity, supplement areas of a higher quality, or they provide corridors linking higher habitat areas.

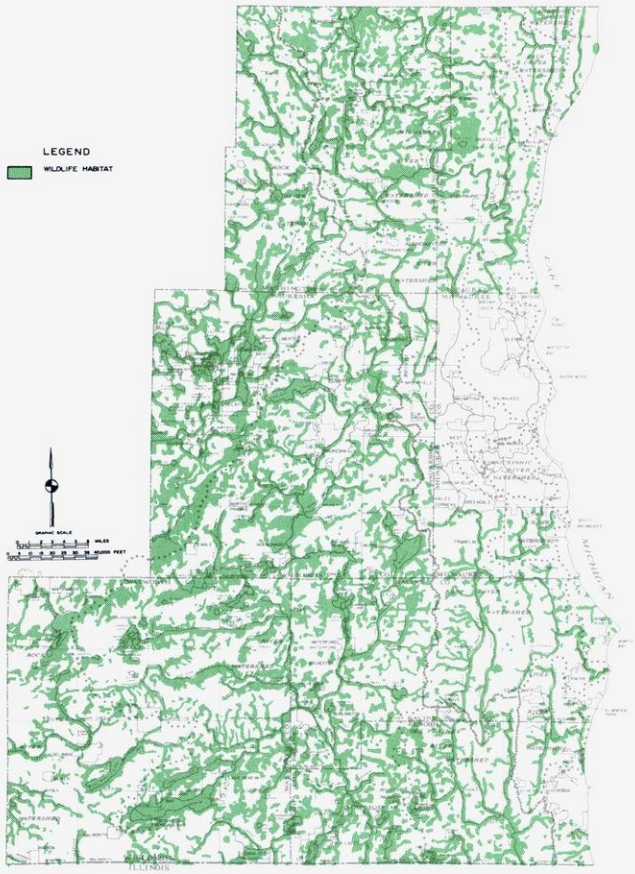
[b] *The 1963 wildlife habitat acreage data differ slightly from the data presented in SEWRPC Planning Report No. 7, The Land Use Transportation Study, Volume One, Inventory Findings, because the availability of more detailed information since 1963 permitted a refinement of the wildlife habitat delineation for that year.*

[c] *Less than 0.05 percent.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Map 34

WILDLIFE HABITAT AREAS IN THE REGION: 1970



The remaining wildlife habitat areas and the wildlife therein provide an important recreational resource and constitute a valuable aesthetic asset of southeastern Wisconsin. As of 1970, approximately 260,000 acres, or 15 percent of the area of the Region, were identified as wildlife habitat.

Source: Wisconsin Department of Natural Resources and SEWRPC.

western Waukesha and Washington Counties and in a band 12 to 16 miles wide along the Fox River in eastern Walworth County and western Racine and Kenosha Counties.

Wildlife habitat areas in 1963 covered 261,200 acres of the Region. This indicates a net loss of about 1,300 acres of wildlife habitat areas in the Region for the 1963 to 1970 period. While this loss of 1,300 acres of wildlife habitat may appear insignificant, further review of Table 52 indicates a decrease of more than 3,000 acres, or about 3 percent, of high-value wildlife habitat areas in the Region during this same period. Walworth County experienced a decrease of more than 1,800 acres, or almost 7 percent, of its total high-value wildlife habitat areas during this period. Kenosha County, with an increase of about 120 acres of high-value wildlife habitat areas, is the only county to experience such an increase during this period.

The destruction of wildlife habitat areas is overwhelmingly a result of urbanization. While some wildlife habitat areas are lost because of widening or new construction of transportation facilities, most have been destroyed as a result of residential development indicating that some high-value wildlife habitat sites are high-value sites for residential development as well.

Wildlife habitat must furnish food, cover, and protection. Consequently, areas of the Region having large proportions of forest, wetland, pasture land, and cropland and small proportions of land devoted to urban development have the largest areas and highest quality of the remaining wildlife habitat. If the remaining wildlife habitat in the Region is to be preserved, the forest lands, wetlands, and related surface water, together with the proximate croplands and pasture lands, must be protected from mismanagement and continued urban encroachment.

ENVIRONMENTAL CORRIDORS

The Corridor Concept

One of the most important tasks completed under the initial regional land use planning effort was the identification and delineation of those areas in the Region in which concentrations of natural resource related elements, especially where these elements are concentrated in identifiable geographic areas, was essential both to the maintenance of the overall environmental quality of the Region as well as to the continued provision of amenities required to maintain the quality of life for the resident population.

Seven resource elements of the natural resource base, all of which have been previously discussed in this chapter, are considered essential to the maintenance of both the ecological balance as well as the overall quality of life in the Region. These include: 1) lakes, rivers, and streams and their associated floodplains, 2) wetlands, 3) woodlands, 4) wildlife habitat areas, 5) rugged terrain and high relief topography, 6) significant geological formations and physiographic features, and 7) wet or poorly drained soils. In addition, there are certain other elements which, although not a part of the natural resource base per se, are closedly related to or centered on that base. These elements are: 1) existing outdoor recreation sites, 2) potential outdoor recreation and related open-space sites, 3) historic sites and structures, and 4) significant scenic areas and vistas.

The delineation of these natural resource and natural resource-related elements on a map of the Region results in an essentially lineal pattern encompassed in narrow elongated areas which have been termed environmental corridors by the Commission. Primary environmental corridors are those areas which encompass 3 or more of the aforementioned 11 environmental elements.

It is important to point out that, because of the many interlocking and interacting relationships existing between living organisms and their environment, the destruction or deterioration of one element of the total environment

may lead to a chain reaction of deterioration and destruction. The drainage of wetlands, for example, has a far-reaching effect, since drainage may destroy fish spawning grounds, wildlife habitat, groundwater recharge areas, and the natural filtration action and floodwater storage areas of interconnecting lake and stream systems. The resulting deterioration of surface water quality may, in turn, lead to a deterioration of the quality of the groundwater which serves as a source of domestic, municipal, and industrial water supply and on which low flows in rivers and streams may depend. Similarly, the destruction of forest cover, which may have taken a half century to develop, may result in soil erosion and stream siltation and in more rapid runoff and increased flooding, as well as in destruction of wildlife habitat. Although the effects of any one of these environmental changes may not in and of itself be overwhelming, the combined effects must lead eventually to serious deterioration of the supporting resource base. The need to maintain the integrity of the remaining environmental corridors thus becomes apparent.

Primary Environmental Corridors

The primary environmental corridors of southeastern Wisconsin generally lie along major stream valleys, surround major lakes, or are found in the Kettle Moraine area, and contain almost all of the remaining high-value wildlife habitat areas and woodlands within the Region, in addition to most of the wetlands, lakes and streams, and associated floodlands. These corridors also contain many of the best remaining potential park sites. The primary environmental corridors are, in effect, a composite of the best of the individual elements of the natural resource base of southeastern Wisconsin.

Primary environmental corridors were identified within the Region in 1963 as part of the Commission's original land use-transportation planning program. The corridor delineation has since been refined, primarily as a result of the Commission watershed studies but also because of the availability of more detailed information which permitted a more definitive delineation of these lands.

The delineation of primary environmental corridors is indicated on Map 35, while a presentation of the land use components which comprise the corridor are indicated in Table 53. The gross primary environmental corridor area, defined as including all land uses, both urban and rural, within the corridor configuration, totaled 347,108 acres, or about 20 percent of the total area of the Region. Net primary environmental corridor areas are defined as the gross corridor acreage minus the incompatible urban land use acreages in the corridor. Net corridor areas, therefore, include recreational land use, agricultural and related land use, water, wetland and woodland uses, and other open space land uses.

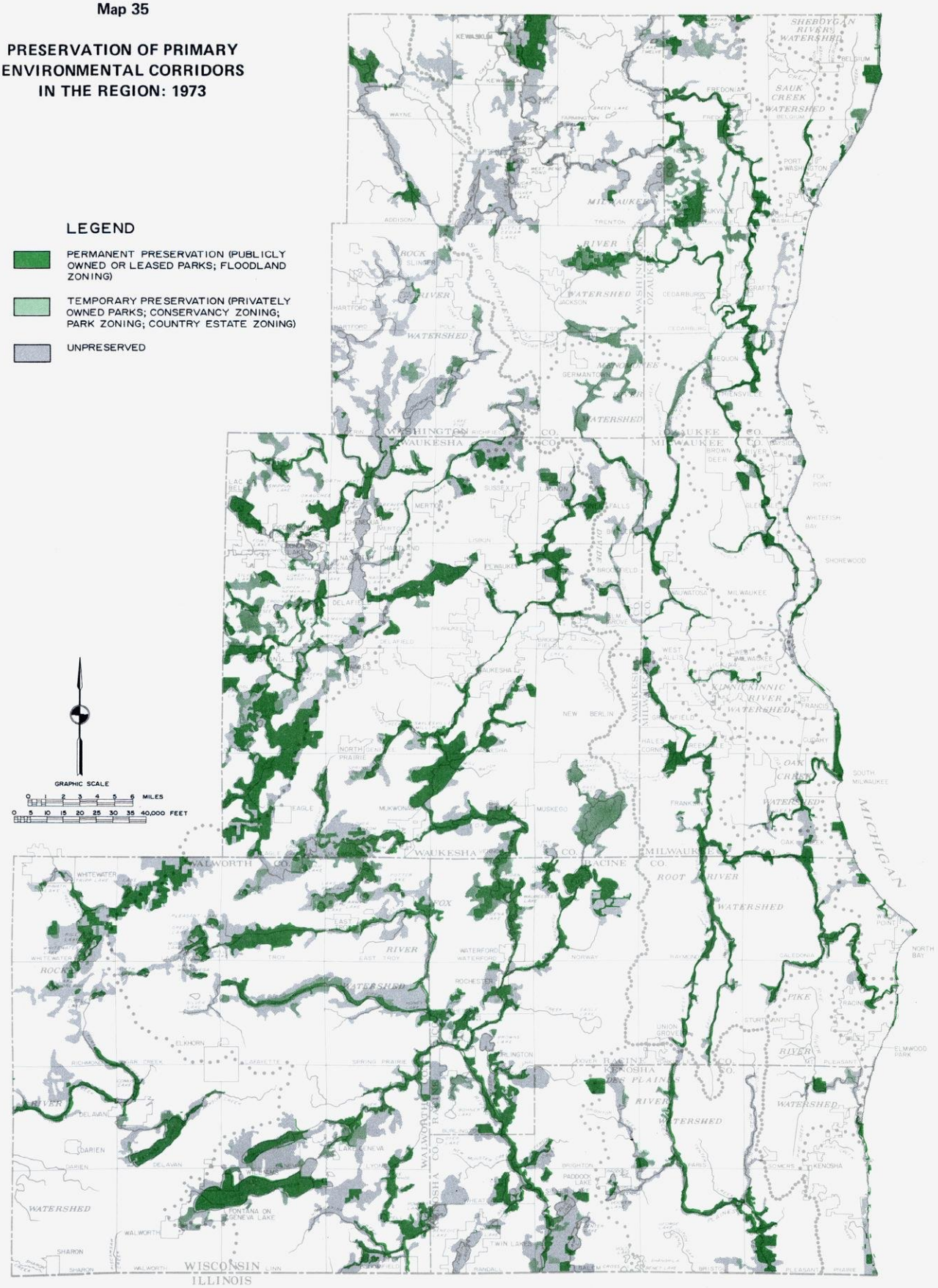
An analysis has been made of changing land uses within the net primary environmental corridors since 1963, as well as quantification of the extent to which the corridors have been preserved. Net primary environmental corridors in 1970 totaled more than 322,226 acres, or about 93 percent of the total gross corridor acreage. The majority of net corridor acreage in 1970 consisted of agricultural and related land (92,800 acres), wetlands (90,700 acres), and woodlands (64,900 acres). The 322,226 acres of net corridor in 1970 represent a decrease of 3,815 acres from the 326,041 acres of net corridor which existed within the Region in 1963. Decreases in net corridor acreage in the Region resulted primarily from losses in agricultural use (5,200 acres) and to a lesser extent from losses in woodland (1,600 acres) and wetlands (1,400 acres). While some of the losses in agricultural, woodland, and wetland uses may have resulted in gains in recreational land use, which is also considered part of the net environmental corridor, much of this land was lost as a result of urban encroachment, especially residential land use, which increased by 3,000 acres, and transportation uses, which increased by 700 acres. Increases in commercial and industrial land uses in the corridor during the 1963-1970 period totaled only about 250 acres.

It is interesting to note that the loss of net primary environmental corridor acreage was not uniform within all counties of the Region. Waukesha County experienced the largest loss of net corridor acreage, over 1,650 acres, with the loss occurring primarily as a result of a decrease in the agricultural and wetlands land use categories. Walworth County lost almost 900 acres of net environmental corridor, primarily in the agricultural and woodland categories. Losses in the net corridor acreage were less than 500 acres for the remaining five counties of the Region, with virtually no loss at all in Kenosha County.

Significant achievements have been made regarding the preservation of primary environmental corridors. Table 54 quantifies the amount and Map 35 indicates the spatial distribution of primary environmental corridor land preserved as of 1973. Primary environmental corridors were considered permanently preserved if they were publicly owned as park, outdoor recreation, or related open space lands; if they were publicly leased for park, outdoor recreation, or open space (long-term lease 25 years or more); or if they were protected through a locally enacted floodland zoning ordinance which substantially carries out the Commission plan recommendation regarding preservation of floodland areas. Primary environmental corridors were considered temporarily preserved if they were protected through a locally enacted conservancy district zone; if they were part of a private park, outdoor recreation, open space area; if they were protected through a locally enacted public or private park and outdoor recreation zone; or if they were part of an exclusive agricultural or country estate district. As indicated in Table 54, almost 130,600 acres, or 38 percent, of the 347,108 gross primary environmental corridor acreage had been permanently preserved as of 1973. The majority of this area (82,700 acres) is preserved through floodland zoning. More than 47,400 acres, or 14 percent, of the gross acreage has been temporarily preserved, with the majority of this area (24,000 acres) being protected through conservancy zoning districts. In total, over 178,000 acres, or 51 percent, of the gross primary environmental corridors in the Region were either permanently or temporarily preserved as of 1973.

Map 35

PRESERVATION OF PRIMARY ENVIRONMENTAL CORRIDORS IN THE REGION: 1973



Significantly achievements have been made since adoption of the regional land use plan in preserving primary environmental corridor lands. By 1973, about 129,500 acres, or 38 percent of the total primary environmental corridor acreage, had been permanently preserved; that is, such lands were either publicly owned or leased for park and outdoor recreation purposes or protected from development by a floodland zoning ordinance. An additional 47,000 acres, representing about 14 percent of the primary environmental corridor acreage, have been temporarily preserved through the enactment of conservancy or park zoning or through private park ownership. In total, about 176,500 acres, or 52 percent of the primary environmental corridor area of the Region, were either permanently or temporarily preserved by the end of 1973.

Source: SEWRPC.

The preservation of the primary environmental corridors from degradation is and should continue to be one of the principal objectives of the adopted regional land use plan. They should be considered virtually inviolate, and their preservation in a natural state or in park and related open space uses, including limited agricultural and country estate type uses, will serve to maintain a high level of environmental quality in the Region and protect its unique natural beauty.

SUMMARY

The natural resource base is a particularly important determinant of the development potential of the Region and of its ability to provide a pleasant and habitable environment for all forms of life. In addition to the air resource itself, the principal elements of the actual base that must be considered in an areawide, comprehensive maintenance planning effort are climate, physiography, soils, mineral and organic deposits, vegetation, water resources, and fish and wildlife. Each of these major elements of the natural resource base of the Region has been identified and described in this chapter, the spatial distribution and extent quantified, the quality characterized, and relations to air quality maintenance planning identified. The importance of properly considering in the air quality maintenance planning effort the elements of the natural resource base herein identified and described cannot be overemphasized. Without a proper understanding and recognition of the various elements of the natural resource base and of their interrelationship, human use and alteration of the natural environment proceeds at the risk of excessive costs in terms of monetary expenditures and destruction of nonrenewable or

Table 53

DISTRIBUTION OF PRIMARY ENVIRONMENTAL CORRIDOR LANDS IN THE REGION BY MAJOR LAND USE WITHIN COUNTY: 1963 AND 1970

County	Year	Gross Primary Environmental Corridor													
		Total		Urban Development										Subtotal	
				Residential		Commercial		Industrial		Transportation		Governmental and Institutional			
		Acres	Percent of Region	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent of Gross Corridor
Kenosha	1963	30,663	8.8	1,610	5.3	40	0.1	39	0.1	737	2.4	152	0.5	2,578	8.4
	1970	30,663	8.8	1,608	5.2	41	0.1	44	0.2	694	2.3	155	0.5	2,542	8.3
	Change 1963-1970	0	--	-2	--[c]	1	--[c]	5	--[c]	-43	-0.1	3	--[c]	-36	-0.1
Milwaukee	1963	18,038	5.2	1,577	8.7	51	0.3	375	2.1	1,507	8.3	250	1.4	3,760	20.8
	1970	18,111[b]	5.2	1,583	8.7	110	0.6	334	1.8	1,610	8.9	291	1.6	3,928	21.7
	Change 1963-1970	73	--[c]	6	--[c]	59	0.3	-41	-0.3	103	0.6	41	0.2	168	0.9
Ozaukee	1963	25,135	7.3	1,652	6.6	48	0.2	28	0.1	669	2.6	39	0.2	2,436	9.7
	1970	25,135	7.3	1,959	7.8	47	0.2	27	0.1	745	3.0	63	0.3	2,841	11.3
	Change 1963-1970	0	--	307	1.2	-1	c	-1	--[c]	76	0.3	24	0.1	405	1.6
Racine	1963	34,251	9.9	1,111	3.2	15	0.1	52	0.2	761	2.2	174	0.5	2,113	6.2
	1970	34,277[b]	9.9	1,344	3.9	22	0.1	65	0.2	836	2.4	194	0.6	2,461	7.2
	Change 1963-1970	26	--[c]	233	0.7	7	--[c]	13	--[c]	75	0.2	20	0.1	348	1.0
Walworth	1963	88,527	25.5	1,975	2.2	81	0.1	39	--[c]	1,429	1.6	148	0.2	3,672	4.1
	1970	88,527	25.5	2,630	2.9	105	0.1	47	0.1	1,616	1.8	145	0.2	4,543	5.1
	Change 1963-1970	0	--	655	0.7	24	--[c]	8	--[c]	187	0.2	-3	--[c]	871	1.0
Washington	1963	56,285	16.2	988	1.8	37	0.1	42	0.1	1,107	2.0	39	0.1	2,213	3.9
	1970	56,285	16.2	1,360	2.4	41	0.1	61	0.1	1,156	2.1	67	0.1	2,685	4.8
	Change 1963-1970	0	--	372	0.6	4	--[c]	19	--[c]	49	0.1	28	--[c]	472	0.9
Waukesha	1963	94,110	27.1	1,816	2.0	82	0.1	191	0.2	1,904	2.0	203	0.2	4,196	4.5
	1970	94,110	27.1	3,119	3.3	116	0.1	281	0.3	2,140	2.3	226	0.2	5,882	6.3
	Change 1963-1970	0	--	1,303	1.3	34	--[c]	90	0.1	236	0.3	23	--[c]	1,686	1.8
Region	1963	347,009	100.0	10,729	3.1	354	0.1	766	0.2	8,114	2.3	1,005	0.3	20,968	6.0
	1970	347,108[b]	100.0	13,603	3.9	482	0.1	859	0.2	8,797	2.5	1,141	0.3	24,882	7.2
	Change 1963-1970	99	--[c]	2,874	0.8	128	--[c]	93	--[c]	683	0.2	136	--[c]	3,914	1.2

Table 53 (continued)

County	Year	Gross Primary Environmental Corridor															
		Total		Net Primary Environmental Corridor												Subtotal	
				Recreation		Agriculture and Related		Water		Wetlands		Woodlands		Other Open Lands			
		Acres	Percent of Region	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent of Gross Corridor
Kenosha	1963	30,663	8.8	1,290	4.2	9,694	31.7	3,474	11.3	9,047	29.5	2,958	9.6	1,622	5.3	28,085	91.6
	1970	30,663	8.8	1,770	5.8	9,864	32.2	3,577	11.6	8,727	28.5	2,673	8.7	1,510	4.9	28,121	91.7
	Change 1963-1970	0	--	480	1.6	170	0.5	103	0.3	- 320	- 1.0	- 285	- 0.9	- 112	- 0.4	36	0.1
Milwaukee	1963	18,038	5.2	6,039	33.5	2,823	15.7	865	4.8	1,517	8.4	1,249	6.9	1,785	9.9	14,278	79.2
	1970	18,111	5.2	6,638	36.7	2,209	12.2	918	5.1	1,461	8.1	1,193	6.5	1,764	9.7	14,183	78.3
	Change 1963-1970	73	--[c]	599	3.2	- 614	- 3.5	53	0.3	- 56	- 0.3	- 56	- 0.4	- 21	- 0.2	- 95	- 0.9
Ozaukee	1963	25,135	7.3	910	3.6	6,597	26.2	1,514	6.0	8,871	35.3	3,838	15.3	969	3.9	22,699	90.3
	1970	25,135	7.3	952	3.7	6,307	25.1	1,541	6.1	8,783	34.9	3,721	14.8	990	3.9	22,294	88.7
	Change 1963-1970	0	--	42	0.1	- 290	- 1.1	27	0.1	- 88	- 0.4	- 117	- 0.5	21	--[c]	- 405	- 1.6
Racine	1963	34,251	9.9	1,024	3.0	13,824	40.4	3,791	11.0	7,166	20.9	5,132	15.0	1,201	3.5	32,138	93.8
	1970	34,277	9.9	1,167	3.4	13,255	38.7	3,976	11.6	7,187	21.0	4,943	14.5	1,288	3.8	31,816	92.8
	Change 1963-1970	26	--[c]	143	0.4	- 569	- 1.7	185	0.6	21	0.1	- 189	- 0.5	87	0.3	- 322	- 1.0
Walworth	1963	88,527	25.5	2,679	3.1	27,709	31.3	13,496	15.2	17,106	19.3	21,391	24.2	2,474	2.8	84,855	95.9
	1970	88,527	25.5	4,030	4.6	25,952	29.3	13,747	15.5	17,037	19.2	20,779	23.5	2,439	2.8	83,984	94.9
	Change 1963-1970	0	--	1,351	1.5	- 1,757	- 2.0	251	0.3	- 69	- 0.1	- 612	- 0.7	- 35	--[c]	- 871	- 1.0
Washington	1963	56,285	16.2	629	1.1	14,819	26.3	3,413	6.1	21,585	38.4	12,574	22.3	1,052	1.9	54,072	96.1
	1970	56,285	16.2	803	1.4	14,251	25.3	3,450	6.1	21,423	38.1	12,574	22.3	1,099	2.0	53,600	95.2
	Change 1963-1970	0	--	174	0.3	- 568	- 1.0	37	--[c]	- 162	- 0.3	0	--	47	0.1	- 472	- 0.9
Waukesha	1963	94,110	27.1	3,606	3.8	22,464	23.9	15,258	16.2	26,760	28.4	19,406	20.6	2,420	2.6	89,914	95.5
	1970	94,110	27.1	4,224	4.5	20,924	22.2	15,320	16.3	26,065	27.7	19,037	20.2	2,658	2.8	88,228	93.7
	Change 1963-1970	0	--	618	0.7	- 1,540	- 1.7	62	0.1	- 695	- 0.7	- 369	- 0.4	238	0.2	- 1,686	- 1.8
Region	1963	347,009	100.0	16,177	4.7	97,930	28.3	41,811	12.0	92,052	26.5	66,548	19.2	11,523	3.3	326,041	94.0
	1970	347,108	100.0	19,584	5.6	92,761	26.7	42,529	12.3	90,684	26.1	64,920	18.7	11,748	3.4	322,226	92.8
	Change 1963-1970	99	--[c]	3,407	0.9	- 5,169	- 1.6	718	0.3	- 1,368	- 0.4	- 1,628	- 0.5	225	0.1	- 3,815	- 1.2

[a] *The primary environmental corridor acreage differs from data presented in SEWRPC Planning Report No. 7, The Land Use-Transportation Study, Volume One, Inventory Findings—1963, and in SEWRPC Planning Report No. 25, A Regional Land Use Plan and a Regional Transportation Plan for Southeastern Wisconsin—2000, Volume One, Inventory Findings, due to the availability of more detailed natural resource base information permitting a refinement of primary environmental corridor delineation.*

[b] *Average totals for both Milwaukee and Racine County increased between 1963 and 1970 as a result of fill being added in Lake Michigan in each respective county.*

[c] *Less than 0.05 percent.*

Source: SEWRPC.

slowly renewable resources. Certain elements of the natural resource base (see Table 55), excluding the air resource itself which is described in Chapters VI and VII of this report, are particularly important considerations in regional air quality maintenance planning. The available pertinent information concerning these elements is summarized in the following paragraphs.

The Region has a continental type climate characterized primarily by a continuous progression of markedly different seasons and a large range in annual temperature, onto which are superimposed frequent distinct changes in weather conditions which, particularly in the winter and spring, normally occur once every two or three days. In addition to marked temporal weather changes, the Region exhibits spatial weather differences, the most significant of which is the summer cooling attributable to Lake Michigan experienced primarily by areas in close proximity to the lake.

The annual temperature range, which is based on monthly means for eight geographically representative observation stations, extends from a January low of 19°F to a July high of 73°F.

Precipitation within the planning region occurs as rain, sleet, hail, and snow, and precipitation events range in intensity, duration, and significance from gentle showers to destructive thunderstorms as well as major rainfall or rainfall-snowmelt events resulting in property and crop

Table 54

PRESERVATION OF PRIMARY ENVIRONMENTAL CORRIDORS IN THE REGION: 1973

County	1970 Gross Primary Environmental Corridor (acres)	Primary Environmental Corridor Preserved												
		Permanent Preservation				Temporary Preservation							Total	
		Public Parks Owned (acres)	Floodland Zoning (acres)	Subtotal		Conservancy Zoning (acres)	Private Recreation (acres)	Park Zoning (acres)	Exclusive Agriculture Zoning (acres)	Country Estate Zoning (acres)	Subtotal			
				Acres	Percent of Gross Corridor						Acres	Percent of Gross Corridor	Acres	Percent of Gross Corridor
Kenosha	30,663	3,232	6,193	9,425	30.7	239	1,194	0	580	0	2,013	6.6	11,438	37.3
Milwaukee	18,111	9,618	1,072	10,690	59.0	62	777	7	0	85	931	5.2	11,621	64.2
Ozaukee	25,135	2,642	7,547	10,189	40.5	3,168	603	54	3,387	0	7,212	28.7	17,401	69.2
Racine	34,277	4,191	13,564	17,755	51.8	739	632	75	2,474	0	3,920	11.4	21,675	63.2
Walworth	88,527	7,319	22,981	30,300	34.2	2,061	5,517	2	0	0	7,580	8.6	37,880	42.8
Washington	56,285	7,243	62	7,305	13.0	4,502	2,183	22	3,288	0	9,995	17.7	17,300	30.7
Waukesha	94,110	13,593	31,335	44,928	47.8	13,004	1,712	7	610	471	15,804	16.7	60,732	64.5
Region	347,108	47,838	82,754	130,592	37.6	23,775	12,618	167	10,339	556	47,455	13.7	178,047	51.3

Source: SEWRPC.

damage, inundation of poorly drained areas, and stream flooding. The annual total precipitation, based on six geographically representative observation stations, is 31.26 inches expressed as water equivalent, with monthly averages ranging from a December low of 1.29 inches to a high of 3.77 inches in June. Relative to total annual precipitation, annual snowfall quantities are extremely variable as demonstrated by historical records at Milwaukee which indicate that snowfall ranged from a low of 11.0 inches during the winter of 1884-85 to a high of 109 inches during the winter of 1885-86. The maximum 24-hour precipitation recorded in the Region was 7.58 inches in the West Bend area on August 4, 1924, and the greatest 24-hour snowfall recorded was 30.0 inches at Racine in February 1898.

Precipitation events are particularly significant to air quality since they tend to cleanse the atmosphere by removing pollutants through the processes of rainout and washout. Data concerning rainout and washout rates of pollutant removal, although not presently available, should become available by 1978 under the International Joint Commission Menomonee River Pilot Watershed Study. The annual evaporation in the Region is about 28 inches and is approximately equal, both annually and seasonally, to the precipitation.

Prevailing winds, which determine the direction pollutants will travel from their source and which aid in the removal and dispersion of pollutants from the atmosphere, follow a clockwise pattern in terms of the prevailing direction over the seasons of the year, being northwesterly in the late fall and in the winter, northeasterly in the spring, and southwesterly in the summer and early fall. Wind velocities may be expected to be less than 5 miles per hour about 15 percent of the time, between 5 and 15 miles per hour about 60 percent of the time, and in excess of 15 miles per hour about 25 percent of the time. Winds may be expected to blow from the southwest and northwest each about 20 percent of the time, and from the southeast and northeast each about 15 percent of the time.

Data on the variation in the time of sunrise and sunset and the daily hours of sunlight are of importance to air quality maintenance planning because of the role sunlight plays in the formation of photochemical oxidants. Daylight hours range from a minimum of 9.0 hours on about December 22 to a maximum 15.4 hours on about June 21. The smallest amount of sky cover occurs during the July through October period when the mean monthly daytime sky cover is approximately 0.5, whereas a sky cover of about 0.7 may be expected during the November through March period. Correspondingly, the frequency and intensity of photochemical formation reaches a maximum in months with the greatest number of daylight hours and lowest percentage of cloud cover.

Glaciation provided southeastern Wisconsin with an interesting, varied, and attractive landscape exemplified by the Kettle Moraine area that is still very much in evidence because of the predominantly rural as opposed to urban--and therefore altered--nature of the existing land use pattern. The regional topography resulting from this glaciation influences the dispersion of air pollutants by disturbing the laminar flow of winds found in areas with little or no relief. The effect of the perturbations in the wind field caused by regional topographic features is to induce a vertical transport of pollutants and generate turbulent eddies; both of these air movements aid in the diffusion of atmospheric contaminants.

Regional surface drainage is characterized by a disordered dendritic pattern, primarily because of the heterogeneous nature of the glacial drift. There is a preponderance of ponds and lakes, and much of the Region is covered by wetlands with many streams being mere threads of water

Table 55

DISTRIBUTION OF NATURAL RESOURCES WITHIN THE REGION BY COUNTY: 1970

County	Area (square miles)	Environmental Corridor Lands		Lakes and Major Streams		Surface Water and Wetlands		Wildlife Habitat Areas		Woodlands	
		Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent
Kenosha	278.28	29,490	8.6	3,878	9.0	19,445	10.8	22,902	8.8	9,112	7.3
Milwaukee . . .	242.19	14,779	4.3	563	1.3	4,207	2.3	1,778	0.7	3,213	2.6
Ozaukee	234.49	24,648	7.2	1,504	3.5	14,879	8.2	15,855	6.1	8,272	6.6
Racine	339.87	33,750	9.9	4,230	9.8	17,712	9.8	26,763	10.3	12,927	10.3
Walworth. . . .	578.08	88,527	25.9	13,088	30.4	39,160	21.7	63,033	24.3	31,755	25.3
Washington . .	435.50	56,286	16.5	3,808	8.8	35,638	19.7	51,994	20.0	27,410	21.9
Waukesha . . .	580.66	94,051	27.6	16,000	37.2	49,789	27.5	77,507	29.8	32,597	26.0
Region	2,689.07	341,531	100.0	43,071	100.0	180,830	100.0	259,832	100.0	125,286	100.0

Source: SEWRPC

through those wetlands. A major subcontinental divide bisects the planning region so that 1,680 square miles, or 63 percent of the Region, drain toward the Mississippi River, while 1,009 square miles, or 37 percent of the Region, are tributary to the Great Lakes-St. Lawrence River drainage basin. This configuration determines the gross surface water drainage pattern and also creates certain legal and water use problems.

The surface water drainage pattern of southeastern Wisconsin may be further subdivided so as to identify 11 individual watersheds, five of which--the Root River, Menomonee River, Kinnickinnic River, Oak Creek, and Pike River watersheds--are wholly contained within the Region. In addition to the 11 watersheds, there are numerous small catchment areas contiguous with Lake Michigan that are drained directly to the lake by local natural streams and artificial drainageways. These areas may be considered as comprising a twelfth watershed.

Sand and gravel, dolomite building stone known locally as lannon stone or limestone, and organic material are the three primary mineral and organic resources of southeastern Wisconsin that have commercial value as a result of their quantity, quality, and location. As a result of its glacial history, the Region has an abundant supply of sand and gravel deposits, the most productive of which are concentrated in the Kettle Moraine area and are important sources of concrete aggregate and of gravel for construction purposes. Niagara dolomite is mined in open quarries, most of which are located in Waukesha County, and supplies high-quality dimensional building stone and, when crushed, concrete aggregate and gravel for construction purposes. The mining, processing, and transporting of the sand, gravel, and dolomite are sources of particulate matter in the atmosphere.

Organic deposits are widely distributed throughout the Region in small, scattered, low-lying poorly drained areas. These deposits form the basis for some wildlife wetland, and recreation areas and, because of their fertilization potential, have commercial value in their ability to support certain field and specialized crops, as well as having value in sod farming and peat mining. Organic deposits identify areas having severe limitations for development of onsite sewage disposal systems because of poor drainage characteristics and because of potential infiltration problems through sewer pipe joints and cracks. Therefore, sites of organic deposits place a constraint on urban development and, consequently, should remain areas which generate limited amounts of air pollution emissions.

Soils are a source of particulate matter in the atmosphere through both natural causes, such as wind erosion, and man-made causes, such as tilling operations. Soils are also of importance to air quality maintenance planning in that certain types of soils place a constraint on urban development and thereby influence the spatial distribution of the anticipated regional growth.

A wide variety of soil types has developed in southeastern Wisconsin as a result of the interaction of parent glacial deposits covering the Region, of topography, climate, plants, animals, and time. As a result of a detailed soil survey, all the diverse soil types of southeastern Wisconsin have been mapped; their physical, chemical, and biological properties identified; and interpretations have been made for planning purposes. Soil survey data and interpretations reveal that approximately 716 square miles, or about 27 percent of the Region, are covered by soils that are poorly suited for residential development with public sanitary sewer service; approximately 1,637 square miles, or about 61 percent of the Region, are poorly suited for residential development without sanitary sewer service on lots smaller than one acre in size; and about 1,181 square miles, or approximately 44 percent of the Region, are poorly suited for residential development without public sanitary sewer service on lots one acre or larger in size.

Historically, vegetational patterns in southeastern Wisconsin are determined by natural factors such as climate, glacial deposits, soil type, fire, topography, and

drainage characteristics, but man, since his settlement of the Region, has increasingly influenced the quantity and quality of woodlands and wetlands. Woodlands comprised 125,286 acres, or approximately 7 percent, of the regional land area in 1970. In addition to commercial value, these woodlands have significant aesthetic value in conjunction with the beauty of the Region's lakes, streams, and glacial land forms. Woodland areas may also be significant sources of pollutant emissions during forest wildfires. Wetlands, which covered about 180,800 acres, or about 10 percent of the seven-county planning region in 1970, attenuate peak flood flows, protect stream water quality by serving as nutrient and sediment traps, and provide necessary wildlife habitat.

Lakes, streams and their floodlands, and groundwater, which comprise the water resources of southeastern Wisconsin, constitute the single most important natural resource category because of their multifaceted functions, including the support of numerous, popular water-oriented recreation activities; habitat for fish and wildlife; and desirable sites for vacation homes and permanent residential developments. In addition, these water resources provide water for domestic, municipal, and industrial water users. The Region contains 1,148 lineal miles of major streams and 100 major lakes, the latter having a total surface area of 57 square miles, or about 2 percent of the area of the Region, and a total shoreline length of 448 miles.

Water quality is affected to some extent by the level of pollutants in the atmosphere. The precipitation-related processes of washout and rainout, as well as the gravitational settling of contaminants onto the surface of water bodies, add to the pollutant loading of lakes and streams within the Region. Air quality maintenance planning must, therefore, be cognizant of the deleterious impacts air pollutants have on water quality management efforts. Commission studies indicate that many of the major lakes and many miles of major streams in the planning Region are being degraded as a result of man's activities to the point where they now have, or soon will have, little or no value for recreational purposes, as desirable locations for controlled water-oriented residential development, or as aesthetic assets of southeastern Wisconsin. Of the 43 major streams in the Region for which water quality analyses have been performed, 26 are unsuitable for the preservation and enhancement of fish and aquatic life, with 33 unsuitable for recreational activities. In general, the surface waters of the Region may be characterized as highly polluted. Surface water degradation is partially attributable to air pollutants entering the hydrologic system by precipitation, settling out, or impaction.

From 6-10 percent of the total area of the Region is estimated to lie within the inundation limits of a 100-year recurrence interval flood event. The 100-year floodplain has been delineated for 620 lineal miles of major stream channel in the Root, Fox, Milwaukee, and Menomonee River watersheds within the seven-county Region. This floodplain serves to identify those portions of the Region poorly suited for urban development because of flood hazards, high water tables, inadequate soils, and high cost for public utilities and services, such as sanitary sewerage systems, while at the same time identifying areas well suited for much needed open space uses. Public land use policies should direct urban development to more suitable areas outside of the floodplains, thereby reserving the floodplains for open space uses consistent with the underlying natural resource base.

Generally, the lakes and streams within the seven-county planning Region are capable of supporting a limited fishery with the exception of most streams in Milwaukee County. A 1970 wildlife habitat inventory revealed that 260,000 acres, or 15 percent of the Region, contained high-quality wildlife habitat furnished food and cover for small upland game, larger predators, game birds, and fish. Wildlife habitat areas constitute both a valuable recreation resource and an aesthetic asset, the protection of which is strongly contingent on rational land use.

The delineation of selected natural resource and natural resource-related elements on a regional map produces an essentially lineal pattern encompassed in narrow, elongated areas which have been termed "environmental corridors" by the Southeastern Wisconsin Regional Planning Commission. Primary environmental corridors occupy approximately 341,500 acres, or 20 percent of the planning Region, and contain almost all of the remaining high-value wildlife habitat areas and woodlands within southeastern Wisconsin; most of the wetlands, lakes and streams, and associated floodlands; as well as many significant physiographic features and historic sites. The primary environmental corridors are a composite of the best of the individual elements comprising the natural resource base of southeastern Wisconsin. The preservation of these primary environmental corridors in a natural state or in park and related open space uses, including limited agricultural and country estate type use, is essential to maintaining a high level of environmental quality in the Region and to protecting its natural beauty, and as such preservation of environmental corridors is one of the principal objectives of the adopted regional land use plan and the supporting ambient air quality maintenance planning program.

Chapter VI

AMBIENT AIR QUALITY

INTRODUCTION

For the purposes of this study, an air pollutant is defined as any gaseous, liquid, or solid substance which, when introduced into the atmosphere in sufficient concentrations by the activities of man, may interfere directly or indirectly with human health, safety, and comfort; damage or destroy plant and animal life; or contribute to the deterioration of any form of material property. The level of all pollutants in the ambient air is collectively referred to as air pollution.

This chapter reviews the history of the air pollution problem with particular attention to the major air pollution disasters which prompted the initial investigations into the nature and extent of the problem. These investigations have lead to the identification of individual pollutant species, the formulation of air quality criteria, and the promulgation of ambient air quality standards. A detailed description of the physical and chemical characteristics of the six pollutants for which ambient air quality standards have been established--particulate matter, sulfur dioxide, carbon monoxide, nitrogen dioxide, hydrocarbons, and photochemical oxidants (ozone)--is presented herein, along with a discussion of their primary sources of release into the atmosphere and their principal removal processes from the environment. Also presented is an overview of the scientific evidence associating various ambient air concentrations of these pollutants to observed adverse effects in humans, and plant and animal life and on artifacts and aesthetic conditions. This evidence, collectively termed air quality criteria, is the basis on which the ambient air quality standards are prescribed. Five additional air pollutants--vinyl chloride, asbestos, mercury, beryllium, and benzene --designated as being hazardous to human health but for which ambient air quality standards are not appropriate measures of control are examined as to their characteristics, sources, and health effects. Also, lead, a pollutant for which air quality criteria have been collated and recommended but for which ambient air quality standards have not yet been developed and promulgated, is discussed herein.

A definition of the nature and extent of the air quality problem in a given geographic area is dependent on the establishment of a network of monitoring sites which sample the ambient air for pollutant concentrations on a regular and continuing basis. The air quality monitoring network in the Southeastern Wisconsin Region, as it has been developed over the years by federal, state, and local air pollution control agencies, is described and evaluated in this chapter. Since the reliability and accuracy of the air quality monitoring data are primarily a function of the sampling instruments and procedures used, a discussion of the various monitoring techniques and equipment prefaces the summary presentation of the existing ambient air quality levels in the Region. Through the use of data tables and isopleth maps, when available, the levels of each pollutant species within the seven-county Southeastern Wisconsin Region are defined for the years 1973 to 1976. Also, local trends in particulate matter concentrations, the only pollutant for which there is a sufficiently long period of record, are examined from several monitoring sites in the Region.

This chapter also reviews the existing mechanism by which the responsible state air pollution control agency, the Wisconsin Department of Natural Resources, may impose certain emergency pollution abatement procedures when dangerously high levels of atmospheric contaminants threaten the public health and welfare. Further, since the protection of the public health is the primary objective of the ambient air quality standards, the means by which regional inhabitants may be rapidly and meaningfully informed of excessive pollutant levels, and thereby take precautionary measures to avoid undue exposure, is described herein.

The chapter concludes with an estimate of the cost, or economic loss, attributable to air pollution in southeastern Wisconsin, and more importantly, an estimate of the population residing in areas of the Region where the ambient air quality standards have been exceeded. Although placing a dollar amount on the economic and social effects of air pollution can provide only a crude measure of its true socioeconomic impact, it does provide a means by which the financial requirements of air pollution control may be placed in a realistic perspective.

WORLD HISTORY OF THE AIR POLLUTION PROBLEM

Air pollution is not solely a contemporary problem brought about by the technological and industrial progress of the last century. It has always been the unwanted byproduct of human endeavors to adjust the environment to meet human needs. In the early history of man, fire was used for cooking and heating in such a manner as to cause the air within residences to be filled with the products of incomplete combustion. The invention of the chimney removed the air contaminats from dwelling interiors but deposited them in the ambient air immediately above. As population centers evolved, the ambient air often became locally saturated with the contaminants. The Roman philosopher Seneca (4 B.C.-65 A.D.) depicts the air pollution problem in Rome around 61 A.D. in the following narrative:

> As soon as I had gotten out of the heavy air of Rome and from the stink of the smokey chimneys thereof, which, being stirred, poured forth whatever pestilential vapors and soot they had enclosed in them, I felt an alteration of my disposition.

Eleanor of Aquitaine, the wife of King Henry II of England, found the air pollution caused by the burning of wood in Tutbury Castle in Nottingham so unendurable that she moved out in 1157. In 1273 coal burning was causing such a great discomfort in London that its use was officially banned. Coal was so popular as a fuel, however, that its use continued, forcing Edward I to issue a royal proclamation in 1306 forbidding the use of "sea-coal" in furnaces. The "sea-coal" had a high content of noxious elemental sulfur and sulfur compounds. This proclamation gave rise to the phrase, "carrying coal to Newcastle." Newcastle, a city on the eastern coast of England, had a localized abundance of high-sulfur coal which could not be mined under the directive. London's air pollution became so bad in 1661 that John Evelyn submitted a document to King Charles II and the Parliament entitled, "Fumifugium, or the Inconvenience of the Aer, and Smoake of London Dissipated," which outlined a procedure to alleviate the problem.

Prior to the Industrial Revolution, air pollution was produced by industries involving metallurgy, ceramics, and the preservation of animal products. Copper and gold were forged, and clay was baked and glazed to form pottery and bricks before the fourth millennium B.C. Iron was forged and leather tanned before 1000 B.C. The principal fuel used in these processes prior to about 1000 A.D. was wood or its variant, charcoal. Coal was minded and used for fuel before 1000 A.D. but was not made into coke until about 1600. It took about another century for coke to figure significantly in metallurgical practice.

The Industrial Revolution of the 18th Century was the result of acquiring the technological ability to use steam as the power to pump water and move machinery. The reciprocating steam engine invented by James Watt in 1784 was the culmination of this technology. Until it was replaced by the steam turbine in the 20th Century, the reciprocating steam engine was the principal motive power for industrial processes.

Both the steam engine and the steam turbine require boilers fired by carbonaceous fuels, primarily coal, although some fuel oil was used for steam generation late in the 19th Century. The smoke and ash produced by the burning of coal or oil in the boiler furnaces of stationary power plants, locomotives, marine vessels, and homes were the greatest single source of air pollution during the 19th century. Great Britain attempted to deal with the intensifying air pollution problem by establishing a Parliamentary Select Committee in 1819 to review measures for controlling coal burning "in a manner less prejudicial to public health and comfort." This committee recognized the need to control smoke emissions but was unable to detail a procedure for doing so. A second Parliamentary Select Committee established in 1843, and a third in 1845, also proved ineffectual.

Great Britain's recognition of smoke and ash emissions as a health problem led to the Public Health Act of 1848, the first such act of its kind, and to the later acts of 1866 and 1875. The Alkali Act of 1863 governed air pollution from the emerging chemical industry in Britain, which was considered separately from the smoke-producing industries.

No national policy of smoke abatement, as air pollution control was termed at the time, was developed in the United States during the 19th century. Smoke abatement laws and regulations were considered to be a municipal responsibility. The first municipal smoke abatement ordinances appeared in the 1880's in Chicago and Cincinnati and were directed at industrial, locomotive, and marine sources.

The expansion of industry and the rapid increase in the number and size of urban centers continued to intensify the air pollution problem in the United States. In the early part of the 20th century, the electic motor came into wide-spread use as a replacement for the steam engine. The increasing demand for electricity, both for industrial and domestic uses, lead to the establishment of numerous electric power generating plants which primarily used coal to fire the boilers. The electric motor, however, did lead to technological changes in the control of air pollution. The perfection of the motor-driven fan allowed large-scale gas-treating systems to be built; the invention of the electrostatic precipitator made the control of particulate matter feasible in many industrial processes; and the progress in chemical engineering made the control of pollutants in the vapor phase possible.

The most significant development compounding the severity of the air pollution problem in this period was the automobile. The number of motor vehicles sold in the United States grew from 4,192 in 1900 to 4,265,830 in 1915, a three-fold increase in only 25 years. Motor vehicle sales in the mid-1970's are on the order of 10 to 11 million vehicles per year.

The internal combustion engine, which powered the early vehicles, emitted its unburnt products directly through uncontrolled exhaust. Since the automobile was predominantly used in the urban centers, air pollutant emissions in these already heavily polluted areas were substantially increased.

During the second quarter of the 20th century, the air pollution problems in major cities around the world intensified to the point where fatal episodes of high pollutant concentrations occurred. The notorious smog of Los Angeles first become a matter of concern in the 1940's. These episodes and the striking visual degradation of the ambient air prompted the first investigations into the problem. Large-scale surveys of air pollution were undertaken in Salt Lake City, Utah in

1926; New York City, New York in 1937; and Leicester, England in 1939. In addition, the first National Air Pollution Symposium in the United States was held in Pasadena, California in 1949, and the first United States Technical Conference on Air Pollution was held in Washington, D.C. in 1950.

Despite this increasing awareness and concern over the air pollution problem, no significant national air pollution policy or legislation was adopted anywhere in the world until 1947, when California became the first state to enact air pollution control legislation. It was not until 1955 that the first federal air pollution legislation was enacted in the United States with the passage of the Air Pollution Control--Research and Technical Assistance Act. This act provided grants-in-aid to state and local pollution control agencies for research, training, and demonstration projects. The Act also authorized the Surgeon General to collect and publish air pollution information. Responsibility for administering the program was given to the Public Health Service of the U.S. Department of Health, Education and Welfare until it was transferred in 1970 to the newly created U.S. Environmental Protection Agency. A more detailed review of the federal, state, and local legislation on air pollution is presented in Chapter III of this report.

In 1956, four years after a major air pollution disaster occurred in London, Great Britain passed a Clean Air Act. This Act successfully promoted a conversion in home heating methods from the burning of soft coal on grates in separate fireplaces in each room to the use of smokeless fuels or central or electric heating. In the 10 years between 1958 and 1968, this conversion effort proved capable of reducing smoke in British air by more than 50 percent.

By 1970, nearly every European country as well as Japan, Australia, and New Zealand had experienced serious levels of air pollution in their major cities. All of these countries have found it necessary to enact national air pollution control legislation and many have established national air pollution research centers.

From an historical standpoint, the onset of major air pollution disasters over the past 50 years was probably the primary motivating force in initiating research, legislation, and controls on air pollution. Detailed studies made of several severe air pollution episodes provided the first understanding of the nature of atmospheric pollutants and their effect on the environment. The following sections present a synopsis of the causes and results of several major air pollution disasters which have occurred since 1930.

Meuse Valley, Belgium--1930

Between December 1 and December 5, 1930 approximately 6,000 persons in Meuse Valley, Belgium were taken ill, of which 60 persons died, as a result of intense concentrations of air pollutants. The area of the Meuse Valley where the episode occurred is approximately 15 miles long, 1.5 miles wide, and 330 feet deep. It is an area of heavy industrialization. At the time of the air pollution episode there were, among other industries, four very large steel plants, three large metallurgical works, four electric power generating plants, one coking plant, and one sulfuric acid plant located in the valley. In addition to these industries, most of the homes and commercial buildings in the area used coal for heating.

The meteorological conditions prevailing during December 1-5 were characterized by high atmosphere pressures and mild winds of a general easterly direction. There was considerable diurnal cooling, with temperatures dropping as much as 15-20°F at night. A fog which developed on the first day became increasingly worse with time. In general, the meteorological conditions were extremely unfavorable for the normal vertical dispersion of the pollutants from the numerous emission sources in the Meuse Valley.

From the autopsies conducted under the medical review following the disaster, it was determined that the morbidity and mortality experienced during the episode were due primarily to respiratory disorders induced or aggravated by contaminants that built up in the fog. Although the medical investigators concluded that the contaminants that most likely caused the observed illnesses and deaths were sulfur compounds, they added that the synergistic effect of other contaminants may have been a contributing factor.

It is particularly interesting to note that although the disaster was investigated in detail, no recommendations were made to prevent a recurrence. In fact, a review of the meteorological records taken at the nearby Cointe Observatory revealed that similar conditions occurred around the Meuse Valley in at least nine years between 1892 and 1930. The investigators noted that medical records from January 14 to 20, 1911, a period of meteorological conditions similar to those in the December 1 to 5, 1930 period, indicated that the same type of air pollution disaster probably occurred then but went unrecorded for unknown reasons.

Donora, Pennsylvania--1948

The first well-documented air pollution disaster in the United States occurred in Donora, Pennsylvania during the period of Wednesday, October 27 to Sunday October 31, 1948. This disaster has been identified as the cause of 20 deaths and approximately 6,000 illnesses. The Borough of Donora is located on the Monongahela River about 30 miles south of Pittsburgh. It is situated on the inside of a horseshoe bend in the river which practically boxes in the community on all four sides. The river bank level is approximately 760 feet above sea level and the east bank of the river rises abruptly to a height of about 1,100 feet above sea level. The hills on the west bank, the side on which Donora is located, rise more gradually to a height of about 1,150 feet.

As a result of the disaster, the Pennsylvania Department of Health, the Borough of Donora, and the United Steel Workers of America requested the U.S. Public Health

Service to determine the cause of the episode and make recommendations to prevent its recurrence. With the assistance of the U.S. Weather Bureau, the U.S. Public Health Service investigated three major topics associated with the episode: the effect on people and animals; the type and amount of contaminants; and the prevailing meteorological conditions. During the five months of study there were an average of 25 scientists working in the field and another 25 scientists working in the laboratory.

In the area immediately around Donora there was located a very large steel plant, a zinc refinery, and a sulfuric acid manufacturing plant. Other heavy industries in the nearby area included four more steel or steel-related plants, a glass plant, and a power plant. The investigation also showed that domestic heating systems and railway steam locomotives were significant contributors to the air pollution load of the valley.

The meteorological conditions of the October 27-31 period were of very low wind speeds and a high degree of atmospheric stability, with the highest stability occurring on October 29 and 30. Seventeen of the 20 deaths took place on the 30th. Fog and smoke built up and were not dissipated by diurnal heating. The fog broke up and stability returned to normal only with the approach of a frontal zone on October 31st.

The results of the medical studies showed that 6,000 persons out of the total population of 13,000 residents were affected by the contaminants in the air--10 percent of whom were severely affected. The incidence rates showed marked variation with age. While only 16 percent of the children under age six were affected, about 60 percent of all persons older than 65 were affected. The ages of the 20 persons that died ranged from 52 to 84 years with a mean of 65 years. Many of the people that died had a past record of respiratory problems. Autopsies performed on three of the victims showed acute changes in the lungs such as capillary dilation, hemorrhage, edema, and purulent bronchitis.

Although there were insufficient data to specifically identify the causative agent, the investigators concluded that the deaths and illnesses associated with the episode could have been produced by the synergistic action of sulfur compounds with particulate matter. They did not, however, eliminate other contaminants as contributing factors.

The investigating team made 10 recommendations for the prevention of a similar disaster. Nine of the recommendations concerned controlling specific pollutant emissions at their source, and the tenth proposed the establishment of a program of weather forecasts to warn the residents of the valley of impending meteorological conditions which would favor a buildup of atmospheric contaminants.

It is interesting to note that the investigators discovered that there were almost twice as many deaths in Donora in April 1945 than in any ordinary April or any other month. The meteorological records for that month showed that it was characterized by periods of high atmospheric stability. As in the case of the Meuse Valley episode in 1911, it appears that another air pollution diaster went unreported.

Poza Rica, Mexico--1950

On November 24, 1950 an air pollution disaster occurred in Poza Rica, Mexico which is unique from the previous two incidents described for the following reasons: first, the disaster in Poza Rica was the result of a single industrial accident; second, the illnesses and deaths were caused by receiving a dosage of the responsible contaminant over a period of less than one half hour; and finally, for the first time in the history of air pollution the causative agent was definitely identified.

The City of Poza Rica is located approximately 130 miles northeast of Mexico City in the heart of one of Mexico's largest gas and oil producing areas. At the time of the disaster it has a population of about 22,000 persons. Heavy industry in the area included several gas-treatment and sulfur-recovery plants. Poza Rica was built on a valley floodplain of the Rio Cazones. It is surrounded by hills having a height of about 330 feet.

The meteorological conditions at Poza Rica in the early morning of November 24, 1950 were characterized by a low-level inversion, which made the air extremely stable, little wind movement, and a pronounced fog. Conditions were unfavorable for the vertical transport and dispersion of pollutants.

At approximately 4:50 a.m., as workers were arriving at the sulfur-recovery plant which had opened only three days before, a sudden gas surge through the main recovery unit caused hydrogen sulfide to be released directly into the atmosphere. Several employees were overcome and became unconscious when they reached the main entrance to the plant approximately 300 feet from the unit. At 5:10 a.m. the unit was shut down and local officials were notified. In all, the incident caused the death of 22 persons and the hospitalization of 320 others.

The onset and the symptoms and signs, as well as the pathological findings, are consistent with hydrogen sulfide poisoning, and there were no findings which conflicted with this diagnosis. Therefore, it was concluded that the hydrogen sulfide that caused the morbidity and mortality came from the effluent stack of the sulfur-recovery unit.

London, England--1952

Possibly the largest air pollution disaster to date in terms of the number of persons affected occurred around December 5-13, 1952 in London, England. Approximately 4,000 persons died and an unknown number of persons became ill in and around London as a dense fog enveloped the British Isles. A sharp increase in both respiratory and cardiovascular deaths was observed beginning on the first day of the fog. While the cardiovascular deaths fell abruptly as soon as the fog cleared,

respiratory deaths continued at a high level for several days afterward. A detailed analysis of the excess deaths that occurred during the week of December 7-13 showed a three-fold increase in deaths for babies under one year of age and for the elderly older than 55 years of age. For all other ages there was an approximate two-fold increase in the number of deaths. During the first week of the episode deathrates from bronchitis were 10 times as high as for the previous three weeks; for pulmonary tuberculosis, four to five times as high; for other respiratory diseases, six times as high; for lung cancer, two times as high; and for disorders of the heart and circulatory system, three times as high.

Medical investigators found some indication that the proportionate increase in the number of cases of illness was not as large as the increase in the number of deaths. Also, the illness rates did not rise as suddenly as the deathrates in the early days of the fog. The medical investigators postulated that the morbidity and mortality rates could possibly have been caused by the synergistic effect between sulfur dioxide and sulfuric acid or particulate matter and sulfur oxides. The major sources of the particulate matter and sulfur oxide emissions were identified as coal burning fireplaces used for domestic heating.

Other Air Pollution Episodes

Table 56 presents a listing of the four previously described air pollution disasters as well as of three additional disasters which, for one reason or another, were not investigated in the same detail by medical and scientific personnel in the areas affected. Where possible, an effort has been made to quantify the mortality and morbidity rates associated with each episode and to identify the causative agent. Between December 2-5, 1957 a fog similar to the one in 1952 over the British Isles caused an estimated 800-1,000 deaths in London. As in previous episodes, most of the deaths occurred on the first day. There was also a marked early increase in the number of acute illnesses requiring hospital treatment. Measurements of sulfur dioxide and particulate matter concentrations taken at the time indicated that the levels were critically high.

London continued to suffer from air pollution problems during the winter of 1958-1959. It has been estimated that about six or seven severe air pollution episodes caused from 200 to 250 excess deaths during this winter. An analysis of these deaths indicated that the victims were previously suffering with respiratory conditions or cardiovascular lesions. Analysis of the deaths also showed a high correlation between levels of particulate matter

Table 56

MAJOR AIR POLLUTION EPISODES

Year	Dates	Location	Reported Excess Deaths	Reported Illnesses	Reported Meteorological Conditions	Identified or Suspected Toxic Pollutants
1930	December 1-5	Meuse Valley, Belgium	60	6,000	High Pressure, Low Wind Speeds, Dense Fog	Sulfur Compounds
1948	October 27-31	Donora, Pennsylvania	20	6,000	Very Stable Atmosphere, Low Wind Speeds, Dense Fog	Sulfur Compounds and Particulate Matter
1950	November 24	Poza Rica, Mexico	22	320	Low Altitude, Temperature Inversion, Low Wind Speeds, Dense Fog	Hydrogen Sulfide
1952	December 5-13	London, England	4,000	Unknown	Very Stable Atmosphere, Low Wind Speeds, Dense Fog	Sulfur Compounds and Particulate Matter
1953	November 15-24	New York City, New York	165	Unknown	Very Stable Atmosphere, Low Wind Speeds, Dense Fog	Sulfur Compounds and Particulate Matter
1957	December 2-5	London, England	800-1,000	Unknown	Very Stable Atmosphere, Low Wind Speeds, Dense Fog	Sulfur Compounds and Particulate Matter
1963	January 29-February 12	New York City, New York	809	Unknown	Very Stable Atmosphere, Low Wind Speeds, Smoke	Sulfur Compounds and Particulate Matter

Source: SEWRPC.

and all causes of mortality, a slightly lower association between particulate matter and sulfur dioxide, and a negative association between particulate matter and visibility.

In New York City during the latter part of January and early part of February 1963, 809 excess deaths were recorded of individuals 28 years of age or older. Children and young adults were not considered in the tabulation of mortality rates. The most critical period was between January 29th and February 12th. During these 15 days, 7 had excessive suspended particulate, or Coefficient of Haze (COH), levels, and measured sulfur dioxide concentrations peaked on February 6th. When the effects of biological stresses other than air pollution were accounted for, an estimated 200 to 400 excess deaths were attributed to air pollutants. This increase in mortality rates occurred primarily in the older age groups.

Many other examples of air pollution episodes have been noted over the past two decades but few have been quantitatively examined. Details on such disasters, such as a worldwide episode which accounted for at least 1,000 excess deaths in November 1962 and one along the eastern seaboard of the United States in November 1966, are not documented sufficiently to provide enough data for a thorough analytical investigation.

Table 56 indicates, however, that there are many traits common to each severe episode. For instance, all of the disasters have occurred in the colder winter months, all have been in areas of heavy industrialization, and all have occurred under similar meteorological conditions such as a stable atmosphere and dense fog. In each of the disasters reviewed either sulfur compounds or sulfur oxides acting synergistically with particulate matter have been the suspected causative agents for the increase in morbidity and mortality rates. Due to the limited understanding of the nature of air pollution and its effect on exposed populations by the scientific and medical communities at the time of the disasters, the contribution to the excess deathrates from other pollutants, acting singly or synergistically, cannot be estimated.

AMBIENT AIR QUALITY

The detailed investigations of air pollution disasters, such as those described in the previous section, provided the first insights into the nature of air pollutants and firmly established the relationship between excessive pollutant concentrations and human morbidity and mortality. These after-the-fact studies, however, were limited to the analysis of specific events which occurred at fixed locations and times, and were not able to measure the effect of chronic exposure to lower pollutant levels commonly present in the urban environment.

Over the past two decades, the scientific and engineering communities, with the technical and financial assistance of federal, state, and local governmental agencies, have sought to identify the toxic agents in the atmosphere and their sources, quantify their presence in the ambient air, define the threshold concentrations at which they have deleterious effects on the environment, and provide economically and technologically feasible methods for their control. This effort had lead to the collation of a large body of evidence linking air pollution levels and adverse effects on public health through laboratory studies on animals, clinical studies of human individuals, and epidemiological studies which have shown direct correspondence between the incidence of disease and levels of air pollution experienced by large population groups over substantial time periods. In total, this body of evidence describing the damaging effects of air pollution provided the basis for the development of air quality criteria.

Air quality criteria are an expression of the scientific knowledge concerning the relationship between various concentrations of pollutants in the ambient air and their adverse affect on man, animals, vegetation, and materials. The primary function of air quality criteria is to provide the latest information on the consequences to human health and welfare of a given concentration of a specific pollutant in the ambient air.

National Standards

Air quality criteria are the basis on which the air quality standards are developed. The principal difference between air quality criteria and air quality standards is that air quality criteria are descriptive of the effects which can be expected to occur whenever and wherever the ambient air concentrations of a pollutant species reaches or exceeds a specific level for a specific period of time. Air quality standards, on the other hand, are prescriptive in that they prescribe pollutant levels which may not be legally exceeded during a specific time in a specific geographic area.

There are many factors which must be considered in the development of air quality criteria if they are to be readily converted to air quality standards which are effective in protecting human health and welfare and preventing damage to plants and animals and deterioration of artifacts. The physical and chemical properties of a suspected pollutant must be well known in order to establish its mechanisms of formation, residence time in the atmosphere, and final removal from the environment. It is essential that the biological response of human, animal, and plant life to given levels of the pollutant be well documented by measuring the diagnosable effects of pollutants, as well as their latent effects and their effects predisposing an organism to disease. In measuring these responses, the characteristics of the receptor must be taken into consideration, including such factors as the susceptibility of the individual, the general state of health of the individual, and the location at which an individual would be exposed to the pollutant and the duration of the exposure. Certain segments of the population are more susceptible to and adversely affected by lower air pollution levels. Air quality criteria, therefore, should be cognizant of and based on the effects of air pollutants on the most predisposed class of individuals. In addition, the effects of air pollution on human

comfort and on the soiling, corrosion, or other deterioration of materials and personal property must be considered. Finally, the development of air quality criteria must consider the effects of air pollution on atmospheric conditions such as solar radiation, temperature, visibility, and overall aesthetics. Inclusion of all these factors in the development of air quality criteria ensures a sound, comprehensive data base from which the air quality standards may be derived.

The derivation of air quality standards from the air quality criteria, however, remains a matter of interpreting the basic data. Often, a subjective determination must be made in the establishment of a standard to be adopted nationally as to the ability of that standard to uniformly protect all segments of the population and their property without placing undue constraints or immoderate restrictions on individuals or businesses where such limits are not necessary to provide for the public welfare. A standard based, for example, on the susceptibility of individuals who smoke to a given pollutant level would be more restrictive than a standard based on observations of the nonsmoking segments of the population. Also, a standard based on the low tolerance of certain cash crops grown only in the southern regions of the country would not have any applicability in northern states. The federal government has, therefore, promulgated standards to be adopted nationally as minimum levels to be attained and maintained to ensure protection of human health and welfare with an adequate margin of safety. The individual states are permitted to adopt alternative standards as long as they are more stringent than those set by the federal government.

The National Ambient Air Quality Standards (NAAQS) for the six pollutants for which air quality criteria have been developed are listed in Table 57. The criteria on which these standards are based are set forth in the following U.S. Department of Health, Education and Welfare, Public Health Service, and U.S. Environmental Protection Agency documents: AP-49, "Air Quality Criteria for Particulate Matter"; AP-60, "Air Quality Criteria for Sulfur Oxides"; AP-62, "Air Quality Criteria for Carbon Monoxide"; AP-63, "Air Quality Criteria for Photochemical Oxidants"; AP-64, "Air Quality Criteria for Hydrocarbons"; and AP-84, "Air Quality Criteria for Nitrogen Oxides." The air quality criteria document for photochemical oxidants was updated and superseded by a document entitled, "Air Quality Criteria for Ozone and Other Photochemical Oxidants," published by the U.S. Environmental Protection Agency in April 1978. As discussed later in this chapter, the updated document served as the basis for the change from the photochemical oxidant ambient air quality standard to an ozone ambient air quality standard.

The air quality criteria authorized by the Air Quality Act of 1967 were developed with full recognition that as more scientific and technical information became available it might be necessary to revise the criteria documents. Accordingly, the U.S. Environmental Protection Agency (EPA) established the National Air Quality Criteria Advisory Committee to make recommendations concerning the need to revise the criteria. Before the Committee was disbanded on June 30, 1976, it prepared a timetable for issuing draft copies of revised criteria documents. The documents will be issued over a three-year period in the following order: photochemical oxidants and related hydrocarbons–August 1977; nitrogen oxides–February 1978; carbon monoxide–August 1978; sulfur oxides and associated particulates–August 1979; and particulate matter–August 1979. These revised documents are scheduled to be published between 3 and 15 months after the designated dates, depending on whether or not development of a new or revised air quality standard is necessary.

The National Ambient Air Quality Standards, as listed in Table 57, consist of a primary and secondary standard for each pollutant, although in most cases the primary and secondary standards are the same concentration. The primary standard specifies the maximum level of the pollutant which should be permitted to occur to protect human health with an adequate margin of safety. The secondary standard specifies the maximum level of the pollutant which should be permitted to occur to protect animal and plant life and property from damage, and to thereby protect the public welfare from any known or anticipated adverse effect of an air pollutant. The attainment and maintenance of the National Ambient Air Quality Standards are the primary goals of the regional air quality maintenance plan.

Presented herein is a discussion of the six pollutants for which standards have been promulgated, including their physical and chemical characteristics and their effects on human health, plant and animal life, and materials and property, and any such influence each pollutant may have on additional facets of the environment.

Also, a number of pollutants which are suspected of having adverse effects on the environment, and for which air quality criteria have been developed, are reviewed. Air quality standards have not presently been promulgated for these contaminants but at least for one species, lead, are expected to be issued by the Environmental Protection Agency.

Particulate Matter

Particulate matter is a general term for a large variety of substances which have the ability to remain suspended in the ambient air for indefinite periods of time. It encompasses particles placed into the atmosphere from natural sources, including bacteria, viruses, fungi, molds, yeasts, pollen, and spores from live and decaying plant and animal life; particles caused by wind erosion, volcanic activity, and forest fires; and, in coastal areas, particles produced by the evaporation of salt-containing sea water. In addition, human activities and movements place substantial quantities of soot, dust, and fly ash into the atmosphere primarily as combustion products from space heating, industrial processes, and motor vehicle use. As considered in this report, particulate matter is undifferentiated as to the physical structure of its component parts and is treated as the composite mass of all suspended substances, both solid and liquid, which are larger than small molecules (about 0.0002 micron) but smaller in diameter than 500 microns (μ).[1] Particles

[1] *One micron is one millionth of a meter. For perspective, a human hair is about 100 microns in diameter.*

Table 57

SUMMARY OF NATIONAL AMBIENT AIR QUALITY STANDARDS ISSUED APRIL 30, 1971, AND REVISED SEPTEMBER 15, 1973 AND FEBRUARY 8, 1979[a]

Pollutant	Period of Measurement or Calculation	Concentration (weight of pollutant per cubic meter of ambient air corrected to 25°C and 760 millimeters of mercury)	
		Primary Standard	Secondary Standard
Particulate Matter (PM)	Annual (geometric mean)	75 micrograms	60 micrograms
	24 hour	260 micrograms[b]	150 micrograms[b]
The primary sources of particulate matter are industrial processes, power generation, space heating, and manmade or windblown fugitive dust. The primary and secondary standards have been exceeded in the Region.[c]			
Sulfur Oxides (SO_x) (measured as sulfur dioxide)	Annual (arithmetic mean)	80 micrograms (0.03 per million)	–
	24 hour	365 micrograms (0.14 per million)[b]	–
	3 hour	–	1,300 micrograms (0.5 parts per million)[b]
The primary sources of sulfur oxides are industrial processes, power generation, and space heating. The sulfur dioxide levels in the Region are not suspected to exceed the annual standard at the present time.			
Carbon Monoxide (CO)	8 hour	10 milligrams (9 parts per million)[b]	Same as Primary
	1 hour	40 milligrams (35 parts per million)[b]	Same as Primary
The primary source of carbon monoxide is gasoline-powered motor vehicles. The 8 hour primary air quality standard has been exceeded in the Region.			
Hydrocarbons (HC) (nonmethane measured as methane)	3 hour (6 a.m. to 9 a.m.)	160 micrograms (0.24 part per million)[b]	Same as Primary
The primary source of hydrocarbons is gasoline-powered motor vehicles. From a limited amount of hydrocarbon air quality data taken by a mobile monitoring van situated in Kenosha County during the summer of 1975 violations in the hydrocarbon standard have been shown to occur.			
Nitrogen Dioxide (NO_2)	Annual (arithmetic mean)	100 micrograms (0.05 part per million)	Same as Primary
The primary sources of nitrogen dioxide are gasoline-powered motor vehicles, industrial processes, power plants, and space heating. The nitrogen dioxide levels in the Region do not exceed the standard at the present time.			
Ozone[d] (O_x)	1 hour	235 micrograms (0.12 part per million)[e]	Same as Primary
The primary sources of pollutants which contribute toward the formation of ozone are gasoline-powered motor vehicles and industrial processes. The primary air quality standard has been exceeded in the Region.			

[a] *Ambient air quality standards for a seventh pollutant, lead, were promulgated by the Administrator of the U. S. Environmental Protection Agency on October 5, 1978. More detailed ambient air quality monitoring will be needed to determine whether the standard for this pollutant species is being exceeded in the Region and whether, in fact, a plan need be prepared to ensure the attainment and maintenance of the lead ambient air quality standard.*

[b] *Concentration not to be exceeded more than once per year.*

[c] *Although the air quality standards have been monitored and continue to be observed, ambient air particulate matter levels declined between 1970 and 1975.*

[d] *Formerly expressed as photochemical oxidants.*

[e] *Concentrations not to be exceeded more than one hour averaged over an consecutive three-year period.*

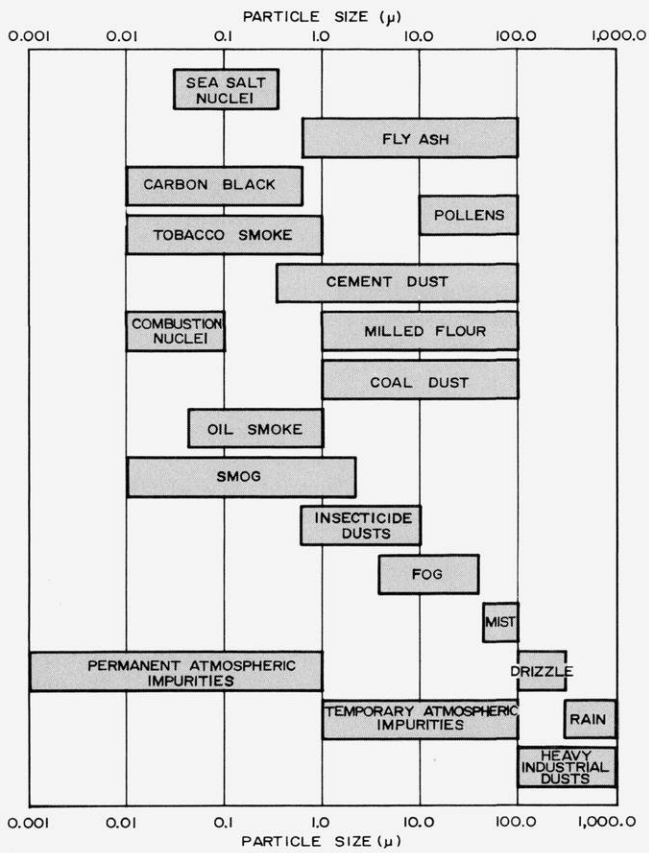
Source: Code of Federal Regulations Title 40, Part 50, 1973.

in this size range may stay suspended in the atmosphere anywhere from a few seconds to several months. Figure 27 presents the characteristic size distribution of selected particles between 0.005 μ and 500 μ. In general, particles smaller than 1.0 μ in diameter originate principally through condensation and combustion processes; particles between 1.0 μ and 10.0 μ arise principally from comminution or pulverization; and particles greater than 10.0 μ result from mechanical processes such as wind erosion, grinding and spraying, and the pulverization of surface materials by pedestrians and motor vehicles.

Particles in the atmosphere smaller than 0.1 μ in diameter are characterized by random motions produced by collisions with gas molecules. These particles, through sorption and nucleation of gas molecules and adhesion with other particles, quickly grow larger. Particles with diameters in excess of 1.0 μ have significant settling velocities and their motions may deviate significantly from the motion of the ambient air. With increasing size, particles become more subject to removal through the influence of gravity and are less likely to be held in suspension. Larger particles such as dust, therefore, are deposited relatively close to their source and primarily constitute a localized problem, while the smaller particles capable of long-range transport affect a greater area and may be more uniformly distributed through a large volume of air.

Figure 27

CHARACTERISTIC SIZE DISTRIBUTION OF SELECTED PARTICLES



Source: SEWRPC.

Effect of Particulate Matter on Human Health: Particulate matter may be injurious to human health in one or more of the following three ways: a particle may be chemically or physically toxic--that is, poisonous in the human system if it is absorbed or inhaled; a particle may act as a carrier of another toxic substance; or a particle may interfere with the cleansing mechanisms in the human respiratory tract. Particulate matter enters the human body principally through the respiratory system.

Figures 28 and 29 diagram the pathway by which particulate matter in the ambient air enters the body and is deposited and retained in the lungs. As air is drawn toward the lungs, filtering mechanisms in the nasal cavity trap the larger particles, but particles smaller than approximately 100 μ pass into the tracheal compartment. The trachea and bronchioles also have a filtering mechanism for removing particles greater than about 5.0 μ in diameter. Particles smaller than 5.0 μ may readily penetrate to the alveoli, or alveolar sacs, where the gaseous exchange between the ambient air and the body takes place.

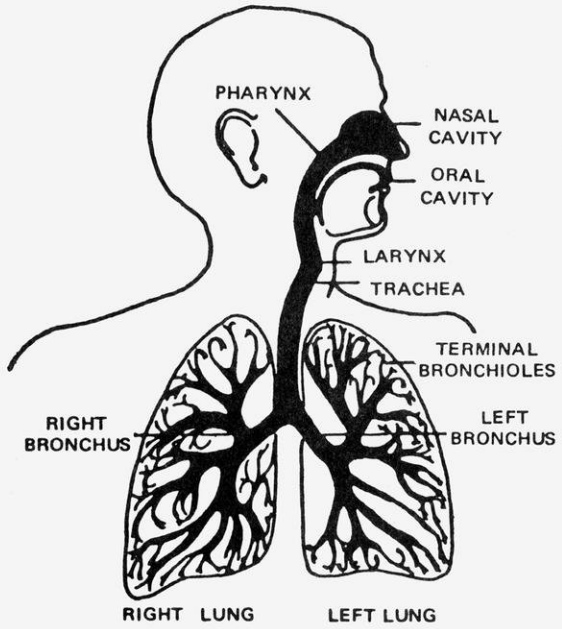
The efficiency of the body's natural particle filtering mechanisms is dependent on a number of factors, the most significant of which is the size distribution of the material entering the system. At normal breathing rates the nasal cavity is about 99 percent efficient in collecting particles on the order of 100 μ and larger, but is less than 20 percent efficient in collecting particles smaller than 1 micron. At the bottom end of the respiratory system in the pulmonary compartment where the alveoli reside, 90 percent of the deposited particles are smaller than 2 microns in diameter. Above 5.0 μ there is nearly 100 percent deposition in the nasal cavity and tracheal-bronchial regions of the lungs.

An average adult lung contains approximately 300 million alveoli and 14 million alveolar ducts. The size of the alveoli is between 150 and 400 μ in diameter, indicating a total surface area in the lungs of between about 320 and 860 square feet available for oxygen exchange. As this surface area is covered by small particles, the capability of the respiratory system to exchange oxygen for the body's waste gases is diminished proportionately.

The respiratory tract, however, does have a number of mechanisms by which deposited particles may be removed from the system. In the tracheal and bronchial regions of the lung, for example, a film of mucus is kept in continual upward movement by a lining of small hairs called cilia. The mucus, to which the inhaled particles adhere, is eventually swallowed and thereby enters the gastrointestinal tract. The significant increase in the occurrence of stomach cancer which has been observed in areas of high air pollution concentrations may be directly related to this respiratory removal process.

Figure 28

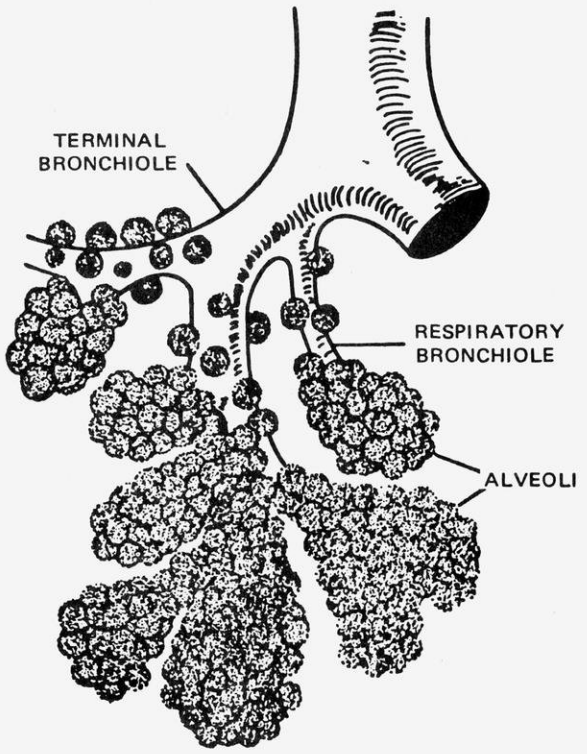
THE HUMAN RESPIRATORY SYSTEM



Source: U. S. Environmental Protection Agency.

Figure 29

THE GAS EXCHANGE AREA IN THE PULMONARY CHAMBER



Source: U. S. Environmental Protection Agency.

In addition to the mucus-cilia transport mechanism, particles in the respiratory system may be removed by direct absorption into the blood stream or into the body's lymph fluids. Particles entering the body in this manner may adversely affect remote organs, such as the kidneys or liver, in much the same way as the pollution-bearing mucus affects the stomach.

Another removal process which should be noted is the clearance of particles from alveoli surfaces by a type of cell which engulfs foreign materials. These cells, called macrophages, literally carry foreign particles from the alveoli to the bronchial area of the lung where cilia transport them upward out of the system. It has been suggested, however, that particles enclosed by macrophage cells might also be transported into the thin membrane lining of the lungs, thereby making the lungs vulnerable to such diseases as pneumonia and pleurisy.

Another area of uncertainty is the synergistic effect--that is, the combined effect of two substances acting together to produce a reaction more adverse than either substance alone--of pollutants simultaneously inhaled into the respiratory tract. For example, sulfur dioxide may impede the removal of particles from the bronchial region by slowing down or halting the transport of mucus. In such a situation, particulate matter would accumulate in the lungs at a far greater rate and to a much more severe health detriment than if sulfur dioxide were not present. More research is necessary before such interactions among pollutants may be fully described. It is evident, however, that particulate matter, acting either synergistically or unilaterally, may not only irritate existing respiratory conditions or initiate the onset of such diseases as pneumonia, bronchitis, emphysema, and lung cancer, but may cause or promote diseases in other bodily organs well removed from the respiratory tract.

Effect of Particulate Matter on Animals: Many of the observed effects of high particulate matter levels on animals are similar to human responses to such levels. In fact, much of the present understanding of the physiological effects of particles in the human respiratory system has evolved from laboratory studies of small animals. The different breathing patterns and overall living conditions of animals, however, limit the extent to which observed biological responses in animals to given particulate matter levels are useful in establishing sound cause effect-type relationships in humans. Field animals, for instance, may ingest more atmospheric pollutants by eating vegetation contaminated by particles settling out of the atmosphere than they inhale directly into their lungs. Where autopsies of domestic and commercial animals have been performed in the aftermath of

a severe air pollution episode, as in Donora, Pennsylvania, it has been shown that their mortality was due to respiratory inflamation similar to that occurring in humans. From such postmortem studies it seems reasonable to conclude that animals are affected by high concentrations of particulate matter, primarily through the respiratory tract, although specific responses to lower doses of this pollutant have not been ascertained.

Effect of Particulate Matter on Vegetation: Particulate matter has not been shown to have any direct toxic effects on vegetation. From a few studies of specific particle sources, however, such as particulate matter generated by cement kilns, certain mechanisms by which atmospheric solids may cause vegetation damage can be identified. For example, particles deposited in sufficient quantity on plant leaves may, in the presence of moisture, develop into a hard adherent crust. Such incrustations have been observed on bean plants and fir trees. The crust can potentially damage plant tissues and inhibit growth possibly by reducing the light necessary for photosynthesis and starch formation, causing the alkalinity of the tissue to increase, or preventing the normal gas exchange with the atmosphere. The overall alkalinity of the soil may also be changed by the deposition of particulate matter in a way which may favor one crop type but be detrimental to another. Further research will be necessary to determine the full extent of the impact of particulate matter on vegetation.

Effect of Particulate Matter on Artifacts: Particulate matter acts to soil and corrode materials. Soiling, although not generally an irreversible effect, necessitates increase cleaning and maintenance activities which may, in turn, accelerate deterioration of artifacts. Corrosion of materials may be induced by either the acid nature of the particles themselves or by corrosive chemicals carried by the particles. Laboratory and field studies have shown that metals were damaged by corrosion in the presence of particulate matter, sulfur dioxide, and relative humidities greater than 70 percent. The corrosion may be due in part to atmospheric moisture.

In addition to damaging metals, particulate matter may damage electrical equipment by corroding electrical contacts and connectors. Also, masonry and textiles, particularly cotton, linen, and nylon, are susceptible to corrosion by certain particulates. The principal agent of corrosion is probably sulfate particles, particularly sulfuric acid which forms from sulfur dioxide and water vapor.

Effect of Particulate Matter on Atmospheric Properties: Particulate matter may interact with the atmosphere by influencing both short-term meteorological events and long-term climatic trends, and by determining, in part, atmospheric visibility. In the short-term, atmospheric particulates provide the nucleus around which water vapor may condense. If the particles are sufficiently large--greater than 1.0 μ--enough water vapor may be condensed to form a cloud droplet which can fall under the influence of gravity. As the droplet falls it comes in contact with other droplets which increases its size. Under the proper conditions the droplet becomes massive enough to fall from the base of the cloud as rain. In a similar process, atmospheric particles may provide a nucleus around which water vapor may freeze and fall out of the cloud as snow.

Numerous studies have established significant relationships between increases in precipitation and human activities and industrial processes in urban areas. One example is the precipitation pattern at LaPorte, Indiana, 30 miles east of the heavily industrialized metropolitan Chicago area. The precipitation pattern at LaPorte between 1905 and 1965 has been shown by researchers to closely parallel both the trend in the annual number of days in Chicago with smoke and haze and the annual production rate at nearby steel mills. The "LaPorte Anomaly," as this pattern is termed, is attributed to the large concentrations of anthropogenic particles placed into the atmosphere in the Chicago urban area. Studies of a similar nature have been conducted for Tulsa, Oklahoma, Washington, D.C., Louisville, Kentucky, Pittsburgh, Pennsylvania, and Buffalo, New York. Each of these studies has concluded that urban centers influence precipitation patterns by either acting as a heat source which produces thermal currents and consequently precipitation, or as a source of nuclei around which cloud droplets may form.

Particulate matter may also intercept and scatter or absorb solar radiation passing through the atmosphere, thereby reducing the amount of sunlight reaching the earth's surface. It has been estimated that urban areas receive 15 to 20 percent less total solar radiation than do rural areas. In some cases the reduction may be considerably greater, with as much as one-third of the total sunlight lost in summer and two-thirds lost in winter. The higher loss in winter may be due to the increased particulate matter emissions from combustion for space heating.

In addition to seasonal cycles of solar radiation loss, diurnal, weekly, and yearly cycles have been observed in major urban areas. For example, a study of solar radiation reaching the ground in Washington, D.C. between 1903 and 1966 indicated a possible net decrease of about 3 percent in the amount of solar energy at the ground over the 63-year period due, in significant part, to the increase in atmospheric particles. Other factors, such as the increased population and urbanization, also contributed significantly to the decrease.

It should be noted that natural sources, such as volcanoes and major forest fires, generally reduce solar radiation to a much greater extent than do anthropogenic sources. Such events as an eruption of a large volcano, however, have only a temporary effect on the atmosphere. On the other hand, particulates placed into the atmosphere because of human activities are constantly being replenished. In the long-term, therefore, it is man-made emissions which produce the important decrease in total solar radiation reaching the ground.

The overall result of the scattering and absorption of solar radiation by atmospheric particles is, in theory, a reduction in the amount of heat energy at the surface

and, consequently, a lower mean temperature of the earth. Climatologists have identified a general cooling trend in the global mean annual temperature, estimated to be between 0.5°F and 3.0°F, starting around 1945. This cooling trend has been observed even though substantial increases in carbon dioxide emissions to the atmosphere were anticipated to raise the temperature. Carbon dioxide in the ambient air acts to trap the heat energy radiating from the earth. The fact that cooling is in progress indicates that the absorption and scattering of solar radiation by particulates, may be a more significant determinant of climatic trends than the trapping of the earth's heat energy by carbon dioxide.

Closer to the ground, particulate matter may reduce visibility by scattering and absorbing light from both an object and its background, thereby reducing the contrast between them. Moreover, particulates scatter light into the line of sight, illuminating the air between an object and observer and further degrading the visual contrast. In addition to lowering the aesthetic character of the landscape, reduced visibility may pose an obstacle to the safe operation of motor vehicles and aircraft. It may be mathematically shown that, on the average, visibility will be reduced to five miles when particulate matter concentrations approximate 150 micrograms per meter^3 ($\mu g/m^3$). At a level of 100 $\mu g/m^3$, the visibility will approximate 7.5 miles. Depending on other atmospheric conditions, these average concentration values could be higher or lower by a factor of two to achieve a similar visibility reduction.

Finally, it should be noted that particulate matter may be a significant source or carrier of irritating odors. Approximately one-fourth of the odors most frequently reported to state and local air pollution agencies are those which are known to be, or suspected to be, associated with particulate air pollution. The sources of these odors include gasoline and diesel exhausts and coffee-roasting operations, and paint spraying, street paving, and trash burning.

Air Quality Criteria and Standards for Particulate Matter: Since it has been established that particulate matter does produce adverse effects on human health and the environment, it is possible to relate such effects to specific concentrations of particulates suspended in the ambient air for a given time. As mentioned, the sum of all such relationships developed from laboratory, clinical, and epidemiological studies constitute the air quality criteria for particulate matter. These criteria are presented in Table 58. This table summarizes the scientific research which served as the basis for promulgating the ambient air quality standards for particulate matter.

It may be seen from Table 58 that the lowest particulate matter concentrations at which human health is affected begin around 80 $\mu g/m^3$ on an annual average basis and between 200 and 300 $\mu g/m^3$ on a 24-hour average basis. In mandating the primary standard for particulate matter, therefore, the U. S. Environmental Protection Agency established two time intervals. A concentration of 75 $\mu g/m^3$ (geometric mean) cannot be exceeded on an annual basis, and a concentration of 260 ug/m^3 can be exceeded only once per year on a 24-hour basis. These prescribed concentrations reflect the best available knowledge of the effects of particulate matter on human health with an additional margin of safety.

Because of the documented evidence that particulate matter adversely affects materials and degrades atmospheric properties and the overall aesthetics of the environment, the U. S. Environmental Protection Agency has mandated secondary standards. Corresponding to the time periods addressed under the primary standards, a concentration of 60 ug/m^3 (geometric mean) on an annual basis and a concentration of 150 ug/m^3 on a 24-hour basis, not to be exceeded more than once per year, were established as the secondary standards for particulate matter. These concentrations correspond to the lower threshold levels at which particulates accelerate corrosion and limit visibility. The standards for particulate matter, as well as for the other five pollutant species, are presented in Table 57.

Sulfur Oxides

The oxides of sulfur include sulfur monoxide (SO), sulfur dioxide (SO_2), sulfur trioxide (SO_3), sulfur sesquioxide (S_2O_3), sulfur heptoxide (S_2O_7), and sulfur tetroxide (SO_4). Sulfur monoxide, sulfur sesquioxide, sulfur heptoxide, and sulfur tetroxide are unstable compounds and difficult to form. Their presence in the atmosphere has not been confirmed, although it is speculated that sulfur heptoxide may be found in the ambient air as a result of the chemical reaction between sulfur dioxide and ozone. Sulfur dioxide and sulfur trioxide, however, form easily and are primarily products of combustion processes using fossil fuels. Of these two compounds, sulfur dioxide is the most predominant in the atmosphere since only about one part of sulfur trioxide is formed for every 40 to 80 parts of sulfur dioxide during the combustion process. Also, sulfur dioxide is relatively stable in free air, whereas sulfur trioxide is rapidly reduced to its hydrated form, sulfuric acid (H_2SO_4), in the presence of atmospheric moisture. Sulfur dioxide, because of its overwhelming predominance in the atmosphere, may therefore be used as an index of the total pollution from all sulfur compounds.

Sulfur dioxide is a nonflammable, nonexplosive, colorless gas that is highly soluble in water and that can act as either a reducing or an oxidizing agent.[2] Its physical characteristics are set forth in Table 59. Even concentrations as low as 0.3 to 1.0 parts per million (ppm) in the ambient air, the gas can be tasted by most people. In concentrations greater than 3.0 parts per million it has a pungent, irritating odor.

Sulfur dioxide is chemically very active. Through oxidation in the atmosphere this gaseous compound can be transformed into particulate matter, the principal com-

[2] *In general, an oxidizing process involves the depletion of elemental oxygen in the ambient air through chemical bonding in compounds, and a reducing process releases oxygen to the atmosphere.*

Table 58

SUMMARY OF AIR QUALITY CRITERIA FOR PARTICULATE MATTER

Particulate Matter Concentration ($\mu g/m^3$)	Time Period	Associated Pollutants	Biological or Physical Response	Category of Effect
750+	24 hours	With sulfur dioxide concentrations of 715 $\mu g/m^3$ and higher	Excess deaths and a considerable increase in illness	Health
300+	24 hours	With sulfur dioxide concentrations of 630 $\mu g/m^3$ and higher	Chronic bronchitis patients suffer acute worsening of symptoms	Health
200+	24 hours	With sulfur dioxide concentrations of 250 $\mu g/m^3$ and higher	Increased absences of industrial workers	Health
100 to 130+	Annual (arithmetic mean)	With sulfur dioxide concentrations of 120 $\mu g/m^3$ and higher	Children experience increase incidence of certain respiratory diseases	Health
100+	Annual (geometric mean)	With sulfation levels above 30 mg/cm^2 per month	Increased deathrates for persons over 50 years old are likely	Health
80 to 100	Annual (geometric mean)	With sulfation levels above 30 mg/cm^2 per month	Increased deathrates for persons over 50 years old may occur	Health
100 to 150	Annual (geometric mean)		Direct sunlight reduced in middle and high latitudes by as much as one-third in summer and two-thirds in winter	Solar Radiation
150	At Any Time	Relative humidity less than 70 percent	Visibility reduced to as low as five miles	Visibility
60 to 180	Annual (geometric mean)	In the presence of sulfur dioxide and moisture	Corrosion of steel and zinc is accelerated	Materials

Source: U.S. Department of Health, Education and Welfare, Public Health Service; and SEWRPC.

ponent of which is liquid droplets of sulfuric acid. Sulfur dioxide is oxidized in the atmosphere by two main processes--photochemical and catalytic. Both laboratory and field measurements have shown that sulfur dioxide will oxidize to sulfur trioxide in the presence of a catalyst such as manganese or iron salts. In the presence of water, sulfur trioxide is readily converted to sulfuric acid. Sulfur dioxide in a mixture of hydrocarbons and nitrogen oxides, and irradiated by sunlight, also produces sulfuric acid particles. A primary characteristic of the photo-oxidation of sulfur dioxide is the formation of a large number of very small particles with diameters on the order of 0.02 $/\mu$. In the presence of the hydrocarbons and nitrogen oxides these particles grow rapidly, with their final size distribution dependent upon, among other factors, relative humidity. From observational and experimental data it may be concluded that high relative humidity maximizes the ambient air concentrations of sulfuric acid in both the photochemical and catalytic processes of sulfur dioxide oxidation.

Effect of Sulfur Oxides on Human Health: Inhalation of sulfur dioxide through the mouth has been found to produce a constriction in human bronchial tubes in the lung causing a resistance to the normal flow of air. In a laboratory experiment on human subjects exposed to sulfur dioxide concentrations of either 43,000 $\mu g/m^3$ (15 ppm) or 80,000 $\mu g/m^3$ (28 ppm) for 10 minutes and inhaled both through the mouth and the nose in separate trials, a greater airway resistance was found in most

Table 59

PHYSICAL CONSTANTS OF SULFUR DIOXIDE

Molecular Weight	64.06
Density (grams per liter; gas)	2.927 at 0°C; 1 atmosphere
Specific Gravity (liquid)	1.434 at -10°C
Molecular Volume (milliliters; liquid)	44
Melting Point (°C)	-75.46
Boiling Point (°C)	-10.02
Critical Temperature (°C)	157.2
Critical Pressure (atmosphere)	77.7
Heat of Fusion (Kilocalories per mole)	1.769
Heat of Vaporization (Kilocalories per mole)	5.960
Dielectric Constant (Σ)	13.8 at 14.5°C
Viscosity (dyne section/centimeter^2)	0.0039 at 0°C
Molecular Boiling Point Constant (°C/1000 grams)	1.45
Dipole Moment (DeBye units)	1.61

Source: U.S. Department of Health, Education and Welfare, Public Health Service.

subjects when the gas at either concentration was breathed through the mouth. The increased airway resistance was readily reversible after exposure. Absorption of sulfur dioxide by tissue in the nasal cavity effectively removes about 90 to 95 percent of the pollutant at high concentrations.

Other laboratory experiments have shown that most individuals will experience a respiratory response to sulfur dioxide at concentrations of 14,000 $\mu g/m^3$ (5.0 ppm) and above. At concentrations of about 3,000 to 6,000 $\mu g/m^3$ (1.0 to 2.0 ppm) an effect can be detected only in certain sensitive individuals.

Most of the available information concerning the health effects of ambient air concentrations of sulfur dioxide is derived from mortality and morbidity studies following major air pollution episodes in the United States and globally. In general, such epidemiological studies are complicated by the presence of other pollutants, most notably particulate matter, which act synergistically to enhance the effect of either pollutant alone. This source of information, however, represents the most reliable basis for the promulgation of air quality standards for sulfur oxides.

One such epidemiological study, conducted in London, England,[3] detected a rise in the daily deathrate when the concentration of sulfur dioxide rose abruptly to about 715 $\mu g/m^3$ (0.25 ppm) in the presence of suspended particulate matter at 750 $\mu g/m^3$. The elderly and persons with cardiovascular or respiratory diseases were particularly affected. This study also found that when average daily concentrations of sulfur dioxide exceeded 1,500 $\mu g/m^3$ (0.52 ppm) with levels of particulate matter exceeding 2,000 $\mu g/m^3$, an increase in the deathrate of 20 percent or more over base line levels resulted. Increased mortality rates have also been noted in New York City at the same sulfur dioxide concentrations.

In Rotterdam, the Netherlands, a 24-hour mean sulfur dioxide concentration of 500 $\mu g/m^3$ (0.19 ppm) lasting for three to four days lead to an increased mortality rate. This observation is especially significant since particulate levels are very low in Rotterdam. Even lower levels of sulfur dioxide, which approximate 300 to 500 $\mu g/m^3$ (0.11 to 0.19 ppm) averaged over 24-hours, are thought possibly to increase mortality.

Human morbidity rates have increased in all episodes which have resulted in increased mortality. In the Rotterdam study, hospital admissions for respiratory disease, particularly in older persons, significantly increased when sulfur dioxide reached levels of 300 to 500 $\mu g/m^3$ (0.11 to 0.19 ppm). There was also an observed increase in absenteeism from work which reached 30 percent for persons under 45 years of age and over 50 percent for persons age 45 and older.

In a severe air pollution episode in New York City in November 1953, in which 165 deaths were directly attributable to the effects of the air pollutants, hospital admissions for respiratory infections and cardiac diseases showed a marked increase. During the period of November 12 to 24, sulfur dioxide levels ranged between 200 and 2,460 $\mu g/m^3$ (0.07 and 0.86 ppm), and hospital admissions had clearly increased by November 16, at which time concentrations had not yet exceeded 715 $\mu g/m^3$ (0.25 ppm).

Although the study of major air pollution episodes provides the most dramatic evidence associating high sulfur dioxide levels with significant increases in mortality and morbidity rates, additional statistical studies of lower and more persistent sulfur dioxide levels have indicated similar correlations. For example, a study made in Nashville, Tennessee showed a direct correlation between illnesses for all causes for housekeeping white females between 15 and 64 years of age and ambient sulfur dioxide levels. It also showed that morbidity from cardiovascular disease in persons of both sexes older than age 55 was twice as high in the area with the greatest sulfur dioxide levels than in the area with the lowest sulfur dioxide levels.

Several studies have noted a relationship between daily variations in air pollution levels and changes in the clinical condition of patients with chronic lung disease. It has been observed, for example, that an average level of about 600 $\mu g/m^3$ (0.21 ppm) of sulfur dioxide over a one-day period causes accentuation of symptoms in persons with chronic respiratory disease on the day following the high sulfur dioxide level if particulate matter at a similar concentration is also present.

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[3] *P.J. Lawther, Compliance with the Clean Air Act: Medical Aspects, J. Inst. Fuels (London), Vol. 36, 1963, pp. 341-344.*

The available laboratory and epidemiological studies have been able to identify a strong association between air pollution levels and human mortality and morbidity rates. Much further research is necessary, however, to establish the levels of sulfur dioxide at which physiological damage is produced both in the presence and absence of its synergistic effects with particulate matter.

Effect of Sulfur Oxides on Animals: Generally, the laboratory experiments on exposure of animals to sulfur oxides are performed at concentrations far in excess of those likely to be found in polluted atmospheres, and consequently have no direct relevance to criteria for atmospheric pollutants. Nevertheless, such experiments do indicate the kinds of physiological and pathological response of which animals and humans are capable.

Laboratory animals are far less sensitive to sulfur oxides than are humans. The guinea pig, for example, is apparently the most susceptible animal to sulfuric acid concentrations studied to date, although it can withstand levels which would be intolerable to man.

Sulfur dioxide and sulfuric acid may both produce constriction of the bronchial tubes in guinea pigs, but the effect is readily reversible. This observed airway resistance is detectable around 460 $\mu g/m^3$ (0.16 ppm) of sulfur dioxide. The increase resistance to air flow, however, is not considered as an indication of major physiological change and may not be extrapolated to human response.

Effect of Sulfur Oxides on Vegetation: Studies of the effects of sulfur oxides on vegetation have been made for more than 100 years. Two general types of plant injury have been found to be produced by sulfur oxides: acute and chronic. Acute injury results from the rapid absorption of toxic concentrations of sulfur dioxide. Immediately after exposure, plant tissues in a sharply defined area take on a dull water-soaked appearance and subsequently dry out and bleach to an ivory color. On some species the lesions finally turn brown to reddish-brown. This effect is quite similar between grass foliage and broad-leafed plants.

Acute injury in pine trees usually occurs in bands on the tips of needles, with the injured area taking on a reddish-brown color. The discoloration in conifers may involve the whole needle or limited areas of any portion.

As an example of the nature of the damage that may be suffered by cash crops, an experiment on barley was made under field conditions. It was found that if the barley was fumigated with 5.0 ppm of sulfur dioxide for one hour per day over six successive days, severe injury to the plant would occur. If the same dosage was applied for periods shorter than one hour during the six days, there was much less damage. The injury could be repaired if sufficient periods free of sulfur dioxide were provided. It was also found that injury to younger plants did not reduce final yield, whereas injury to older plants caused significant reductions. Also, no yield reductions occurred unless visible damage symptoms were detected on the foliage.

Chronic sulfur oxide injury to plants is characterized by a gradual yellowing of the foliage. The slow fading of green color over a period of several days suggests that the chlorophyll-making mechanism is being destroyed and the green pigment cannot be replenished. A large amount of sulfate is found in leaves with chronic injury which is not found in leaves with acute injury. Large quantities of sulfate may be accumulated in leaf tissue without causing injury. If excessive amounts are absorbed rapidly, however, acute injury results.

The mechanism by which sulfur dioxide causes injury to leaf tissue is not well understood. One possible explanation is that as the very water soluble sulfur dioxide is absorbed through the outer leaf covering it is oxidized, perhaps by the oxygen by-product of the photosynthesis process. Sulfuric acid is then formed which deleteriously reacts with the organic compounds in the leaf tissue.

The amount of injury a plant incurs is also dependent on such factors as temperature, relative humidity, light intensity, soil moisture, and nutrient supply. In general, plants are more resistant to sulfur dioxide at temperatures below about 40°F, possibly because of the lower physiological activity and, therefore, the reduced gaseous exchange of the plants in cool weather. Plants grown in low relative humidity and low soil moisture also show an increased resistance to sulfur dioxide damage, as do plants in darkness. It is evident, however, that factors which reduce the susceptibility of plants to injury from sulfur dioxide represent far from optimum growing conditions.

Injury to plants may be amplified by the synergistic effect of sulfur dioxide in the presence of photochemical oxidant products such as ozone or nitrogen dioxide. Combinations of sublethal concentrations of sulfur dioxide and ozone in two-hour fumigations produced injury in tobacco plants. When the exposure time was doubled to four hours, the severity of the injury was approximately doubled, but there was no response when fumigation consisted of either sulfur dioxide or ozone alone. Such a synergistic response between sulfur dioxide and ozone or other pollutants offers a partial explanation for occasional inconsistencies between laboratory findings with a single pollutant and findings on plant response in the natural environment.

Effect of Sulfur Oxides on Materials: Considerable material damage is caused by the conversion of sulfur oxides to the highly reactive sulfuric acid. Under normal conditions damage to metals increases with increasing relative humidity and temperature, which encourage sulfuric acid formation. Particulate matter in the air also contributes to the deleterious effects.

Atmospheres polluted with sulfur dioxide have been found to be among the most corrosive of all atmospheres studies, even more corrosive than some marine atmospheres. A striking example is the almost four-fold reduction in the corrosion rate of zinc in Pittsburgh associated with a three-fold reduction in sulfur dioxide and a two-fold reduction in dustfall between 1926 and 1960.

Carbon steels are apparently the metal most affected by polluted atmospheres, followed in descending order by zinc, copper, aluminum, and stainless steel. A study of corrosion in mild low-carbon steel panels exposed in the Chicago and St. Louis areas found a direct correlation between the degree of corrosion and ambient air levels of sulfur dioxide. In St. Louis, with the exception of one particularly polluted site, corrosion losses averaged 30 to 80 percent greater at urban sites than at nonurban sites. In Chicago, the corrosion loss rate was about 50 percent more at the most corrosive site than at the least corrosive site.

When sulfur dioxide is converted to sulfuric acid in the presence of moisture it is also capable of attacking a wide variety of building materials including limestone, marble, roofing slate, and mortar. The carbonate of any carbonate-containing stone is converted to relatively soluble sulfates and then is leached away by rainwater. Building stones are eroded to a greater or lesser degree depending on their chemical composition. Softer building stones, such as the limestones and dolomites, are attacked more readily by the acids than are granites, gneiss, and many sandstones, which do not contain carbonates.

Sulfur oxides, particularly the acids, are detrimental to textile fibers. Cotton, linen, hemp, jute, rayons, and synthetic nylons are especially prone to loss of tensile strength after exposure to the acids. Animal fibers, such as wool and furs, are much more resistant to acid damage. Animal skin, particularly leather, has a strong affinity for sulfur dioxide which ultimately causes a disintegration of the material. Discoloration of paper products and the fading of textile dyes, enhanced by the synergistic effect of particulates and oxidant products, are also caused by sulfur dioxide-polluted atmospheres.

Air Quality Criteria and Standards for Sulfur Oxides:
Table 60 presents a summary of selected air quality criteria for sulfur oxides. From this table it is evident that adverse health effects may be associated with both the short-term exposures to high sulfur dioxide levels and to long-term exposures at lower but more persistent sulfur dioxide levels, thus necessitating an annual and a 24-hour ambient air quality standard.

The available air quality criteria indicate that adverse health effects occur at a level as low as 115 $\mu g/m^3$ (0.04 ppm) of sulfur dioxide when accompanied by smoke concentration of 160 $\mu g/m^3$ averaged on an annual basis. In order to provide a margin of safety and to take into account possible deleterious effects occurring below that level, the primary annual ambient air quality standard for sulfur oxides was promulgated by the federal government at 80 $\mu g/m^3$ (0.03 ppm). Since this concentration is below the lowest level at which adverse effects on vegetation were found to occur, a secondary annual standard need not be established.

In the short term, adverse health effects were noted when the 24-hour average sulfur dioxide concentrations exceeded 300 $\mu g/m^3$ (0.11 ppm) for three to four days. Using this criterion, it was determined by the EPA that, on a statistical basis, the maximum 24-hour concentration of sulfur dioxide on any single day should not exceed 365 $\mu g/m^3$ (0.14 ppm). Also, in order to prevent adverse effects on vegetation and materials from large doses of sulfur dioxide within short-term periods, the EPA promulgated a secondary ambient air quality standard which limits the average three-hour sulfur dioxide concentration to a level below 1,300 $\mu g/m^3$ (0.5 ppm). Both the 24-hour primary standard and the three-hour primary standard are not to be exceeded more than once per year.

Carbon Monoxide
Carbon monoxide (CO) is a colorless, odorless, tasteless gas which is slightly lighter than air. It is a highly flammable gas but, by itself, will not support combustion. Certain select physical characteristics of carbon monoxide are presented in Table 61.

Carbon monoxide is the most widely distributed and most commonly occurring air pollutant, accounting, by weight, for more total atmospheric pollution than all the other pollutants combined. It is formed primarily by the incomplete combustion of carbonaceous materials used as fuels for motor vehicles, space heating, and industrial processes, or burned as refuse.

Carbon monoxide is a major product in the oxidation process associated with the general combustion of gaseous or liquid hydrocarbon fuels. Carbon monoxide then reacts with hydroxyl radicals (-OH) to form carbon dioxide (CO_2). This second reaction, however, is approximately 10 times slower than the first reaction. Although several factors may serve to mitigate the disproportionate formation rates of carbon monoxide to carbon dioxide, the primary variable determining the quantity of carbon dioxide produced is the amount of oxygen available for combustion. As the availability of oxygen increases, more complete conversion of carbon monoxide to carbon dioxide results. Increasing the post-burn residence time of the gaseous combustion products in the firing chamber lowers the level of carbon monoxide, since it provides a longer period for carbon monoxide to react with an available hydroxyl radical to form carbon dioxide.

Carbon monoxide emissions from the internal combustion engine in a motor vehicle are effectively determined by two factors: the concentration of carbon monoxide in the exhaust and the exhaust volume. The exhaust concentration, in turn, depends mainly on the air-to-fuel ratio entering the combustion chamber, while the exhaust volume depends on the power output. Figure 30 demonstrates the marked relationship between carbon monoxide concentrations in the exhaust gas and the air-fuel ratio as determined from tests. Carbon monoxide concentrations increase with lower (richer) air-fuel ratios, and decrease with higher (leaner) air-fuel ratios, reaching a saturation point around the 14.5 to 1 ratio. The exhaust flow rate increases with increasing engine power output. During the idle mode the power requirement and, therefore, exhaust flow is at a minimum; during full throttle it is at a maximum. During the idle mode, and at low speeds,

Table 60

SUMMARY OF SELECTED AIR QUALITY CRITERIA FOR SULFUR OXIDES

Sulfur Dioxide Concentration	Averaging Time	Associated Particulate Matter Levels	Observed Biological or Physical Response	Category of Effect
1,500 $\mu g/m^3$ (0.52 ppm)	24 Hours	6 Coefficient of Haze (COH) or greater	Increased mortality	Human Health
715 $\mu g/m^3$ (0.25 ppm)	24 Hours	750 $\mu g/m^3$	Increase in the daily deathrate	Human Health
500 $\mu g/m^3$ (0.19 ppm)	24 Hours	Low	Increased mortality	Human Health
300 to 500 $\mu g/m^3$ (0.11 to 0.19 ppm)	24 Hours	Low	Increased hospital admissions of older persons for respiratory disease; Increased absenteeism from work	Human Health
715 $\mu g/m^3$ (0.25 ppm)	24 Hours	Unknown	A sharp rise in illness rates for patients over age 54 with bronchitis	Human Health
600 $\mu g/m^3$ (0.21 ppm)	24 Hours	300 $\mu g/m^3$ (smoke)	Accentuation of symptoms in patients with chronic lung disease	Human Health
105 to 265 $\mu g/m^3$ (0.037 to 0.092 ppm)	Annual	185 $\mu g/m^3$ (smoke)	Increased frequency of respiratory symptoms and lung disease	Human Health
120 $\mu g/m^3$ (0.046 ppm)	Annual	100 $\mu g/m^3$ (smoke)	Increased frequency and severity of respiratory diseases in school children	Human Health
115 $\mu g/m^3$ (0.04 ppm)	Annual	160 $\mu g/m^3$ (smoke)	Increase in mortality from bronchitis and lung cancer	Human Health
85 $\mu g/m^3$ (0.03 ppm)	Annual	–	Chronic plant injury and excessive leaf drop	Vegetation
860 $\mu g/m^3$ (0.30 ppm)	8 Hours	–	Some species of trees and shrubs show injury	Vegetation
145 to 715 $\mu g/m^3$ (0.05 to 0.25 ppm)	4 Hours	–	Moderate to severe injury in sensitive plants when sulfur dioxide reacts synergistically with ozone or nitrogen dioxide	Vegetation
345 $\mu g/m^3$ (0.12 ppm)	Short-Term	High	Corrosion rate for steel panels may be increased by 50 percent	Materials
285 $\mu g/m^3$ (0.10 ppm)	Short-Term	285 $\mu g/m^3$	Visibility may be reduced to about five miles	Visibility

Source: U.S. Environmental Protection Agency and SEWRPC.

Table 61

PHYSICAL PROPERTIES OF CARBON MONOXIDE

Molecular Weight	28.01
Melting Point (°C)	-207
Boiling Point (°C)	-192
Specific Gravity (relative to air)	0.968
Density[a] (grams per liter)	1.25

[a] *At 0°C, 760 millimeters mercury.*

Source: U.S. Department of Health, Education and Welfare, Public Health Service.

however, the air-to-fuel ratio is low, thus maximizing carbon monoxide emissions. As travel speed increases, carbon monoxide emissions decrease—although exhaust volumes increase, because the air-to-fuel ratio is higher.

Among the natural sources of carbon monoxide may be included such physical sources as volcanoes, gas pockets as found in coal mines, and lightning-caused forest fires. It has also been reported to be formed during electrical storms in the lower atmosphere, and is suspected of being formed in the upper atmosphere above 40 miles by the photodissociation of carbon dioxide. Carbon monoxide is also emitted to the atmosphere by certain naturally occurring biological process. Small quantities are formed by vegetation during seed germination and seedling growth and it has been observed in injured, cut, or dried plants. Carbon monoxide has been found to be a component of marsh gas, and extremely high concentrations have been found in certain types of seaweed. Certain ocean-dwelling biological specimens such as jellyfish and the Portugese Man-of-War produce carbon monoxide, and the ocean itself is suspected of generating substantial quantities of carbon monoxide through as yet undetermined mechanisms.

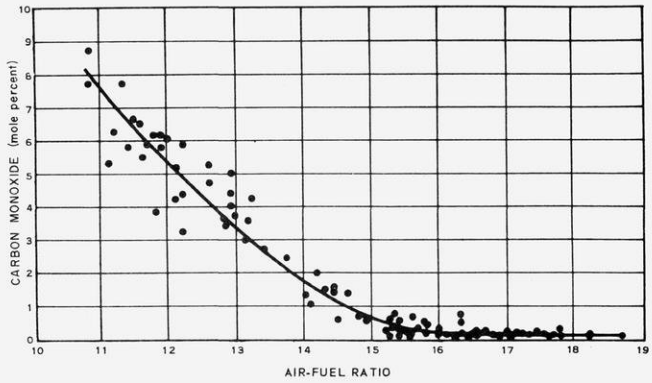
Globally, anthropogenic sources are estimated to release approximately 270 million tons of carbon monoxide into the atmosphere each year, about half of the 530 million tons which are normally present in the lowest layer of the atmosphere. Scientists at Argonne National Laboratory have suggested that natural sources may contribute more than 3.5 billion tons of carbon monoxide per year to the atmosphere in the northern hemisphere alone--more than 10 times the emissions from athropogenic sources.[4]

The Argonne study indicates that there are five isotropically different species of carbon monoxide which are generally produced seasonally according to the nature of their source. The principal species identified was the carbon monoxide produced by the chemical transformation of methane (CH_4) in the air. It has been estimated that a single acre of marshland emits about 3,000 pounds of methane per year. If this methane were converted in its entirety, as experiments indicate it may be, about 5,000

[4] *See "Carbon Monoxide: Natural Sources Dwarf Man's Output," Science, Vol. 177, pp. 338-339, July 28, 1972.*

Figure 30

RELATIONSHIP OF CARBON MONOXIDE EMISSIONS TO THE AIR-FUEL RATIO IN THE INTERNAL COMBUSTION ENGINE[a]



[a] *This figure is based on results obtained from testing three internal combustion engines.*

Source: U. S. Department of Health, Education and Welfare, Public Health Service.

pounds of carbon monoxide would be produced. From estimates of methane production in the northern hemisphere, the Argonne researchers conclude that greater than 3 billion tons of carbon monoxide are formed from this process alone per year. There was an increased abundance of this species found in summer, consistent with the methane production of swamps and marshland.

A second species of carbon monoxide, having its source also in the chemical transformation of methane, showed increased concentrations in the winter and spring seasons. This species was also found to be abundant in marine air of low northern latitudes.

The third species of carbon monoxide identified was found to have a seasonal increase in summer. The source of this species was associated with the growth of plants, and an estimated 200 million tons are produced during summer in the northern hemisphere. Also associated with vegetation was a fourth species, which was the predominant type the researchers found in the fall season. It was assumed to be caused by the degradation of chlorophyll from dying plants. The emissions of this species were approximated at 200-500 million tons for a six-week period in autumn in the northern hemisphere.

The last identifiable species of atmospheric carbon monoxide was the predominant type during the winter and early spring months, and was principally associated with automobile emissions and the combustion of fuel for space heating purposes. The Argonne study estimated that 30 to 60 million tons per month worldwide of this species were produced by such anthropogenic sources during the winter.

The residence time of carbon monoxide in the atmosphere has been subject to considerable speculation. Estimates range from around 0.1 year to five years. The Argonne

study indicates that the residence time decreases to about 10 days in summer due to the increase in solar radiation.

Measurements of background concentrations of carbon monoxide taken over a number of years and at numerous locations do not show any increase with time. Such an increase might be expected if carbon monoxide had a long residence time in the atmosphere. In measurements made in relatively unpolluted, clean air, the background levels of carbon monoxide ranged from 0.029 to 1.15 milligrams per liter^3 (mg/m^3). With global carbon monoxide emissions from anthropogenic sources estimated to be around 270 million tons per year, and in the absence of any removal processes, it has been calculated that the background levels should increase by approximately 0.03 mg/m^3 per year. The fact that this increase has not been observed indicates that natural removal processes must be actively scavenging the carbon monoxide from the atmosphere.

The atmospheric removal processes of carbon monoxide are not well known at the present time. Some of the atmospheric sinks discussed herein are so speculative that, in fact, they may contribute carbon monoxide to the atmosphere rather than remove it.

One removal process which has been postulated involves the upward migration of carbon monoxide from the lower atmosphere to the upper atmosphere, where it is oxidized to carbon dioxide in the presence of ultraviolet radiation. This reaction has been confirmed by laboratory experiment. It has also been shown, however, that ultraviolet radiation is capable of dissociating carbon dioxide into carbon monoxide and atomic oxygen. The photodissociation of carbon dioxide is considered to be relatively small at levels below about 60 miles since the intensity of solar radiation falls off rapidly at that level.

Another possible sink for carbon monoxide may be plants and microorganisms in the soil which have the ability to metabolize it. Laboratory experiments have demonstrated that several commonly occurring soil microorganisms have the capacity to convert carbon monoxide to methane and carbon dioxide in the presence of moisture. A study conducted by the Stanford Research Institute indicates that the microorganisms in average soil in temperate climates can convert about 210 tons of carbon monoxide per square mile per year. At this rate, the soil surface in the United States would have the capacity of removing about 600 million tons per year.

A third removal process which has been speculated involves the chemical binding of carbon monoxide to porphyrin compounds that are widely distributed in plants and animals. The hemoglobin compound in humans is one such porphyrin compound. This process temporarily removes carbon monoxide from the atmosphere. Permanent removal from the environment, however, depends on whether the carbon monoxide is converted to carbon dioxide in a subsequent chemical reaction when the porphyrin compounds break down.

Effect of Carbon Monoxide on Human Health: Carbon monoxide is the agent responsible for most of the poisoning deaths in the United States each year. Historically, carbon monoxide poisoning can be traced back through Greek and Roman literature, and it is probable that it extends even into prehistoric times for as long as wood, grasses, and other organic materials were used as fuel for combustion. During the Fifteenth Century, A.D., when coal was first used for domestic heating, carbon monoxide poisoning increased greatly. The introduction of illuminating gas, a mixture of hydrogen, carbon monoxide, methane, and other hydrocarbons, in the Nineteenth Century further increased this hazard. The widespread use of the internal combustion engine during the Twentieth Century has spread the emissions of carbon monoxide from the interior of dwelling units to the ambient air in the proximity of major transportation systems. Consequently, concern has shifted from the short-term exposure to fatal concentrations of carbon monoxide to the effects on human health from longer exposures to much lower concentrations.

Carbon monoxide is readily absorbed into the lungs and reacts with proteins in the blood, most notably hemoglobin, causing a reduction of the oxygen-carrying and -exchange mechanisms in the circulatory system. Normally, oxygen is attached to hemoglobin compounds, termed oxyhemoglobin (O_2Hb), and carried to tissues in the body where the oxygen is exchanged for waste gases. Hemoglobin, however, has an affinity for carbon monoxide over 200 times greater than for oxygen. When carbon monoxide is inhaled, therefore, carboxyhemoglobin (COHb) is preferentially formed. Carboxyhemoglobin is a much more stable compound than oxyhemoglobin and consequently does not permit the necessary exchange of gases in the body's tissues to occur. The result, if sufficient concentrations of carbon monoxide are inhaled, is to cause mortality by suffocation.

Human blood in nonsmokers normally carries approximately one-half of 1 percent carboxyhemoglobin due to internal chemical processes. At this level there are no apparent adverse physiological responses. Carboxyhemoglobin may, however, build up in the blood depending on such factors as the ambient air concentrations of carbon monoxide, length of exposure, and breathing rate. If the concentration of carbon monoxide remains constant, an equilibrium will be reached in the bloodstream. This equilibrium point is reached when the pressure of carbon monoxide in the blood is about equal to the opposing pressure of carbon monoxide in the alveolar sacs and the ambient air. Laboratory experiments have shown that the equilibrium point is generally reached after about eight or more hours of exposure, although physical activity can shorten this time period.

Figure 31 demonstrates the relationship between exposure to varying levels of carbon monoxide and the percentage of carboxyhemoglobin in the blood of healthy male test subjects engaged in sedentary activity. It may be seen from this figure that the carboxyhemoglobin

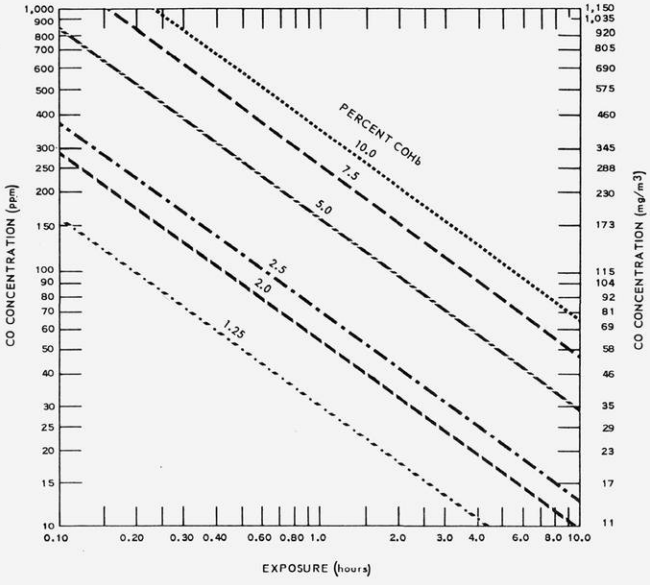
in the blood increases with either ambient air concentrations of carbon monoxide or length of exposure. It should be noted that the exposure times are given on a logarithmic axis. Figure 31, therefore, indicates that the buildup of carboxyhemoglobin in the bloodstream is initially taking place at a very rapid rate, but slows down considerably with an increase in periods of exposure.

From experimental exposures of humans to varying concentrations of carbon monoxide over a short term it has been determined that carboxyhemoglobin levels in the bloodstream of less than 1 percent do not produce any adverse health effects. At an estimated level of about 2.5 percent carboxyhemoglobin, however, the experimental subjects were unable to accurately determine the passage of fixed time intervals. When carboxyhemoglobin levels reached about 3 percent, changes in visual acuity and relative brightness threshold have been observed. At about the 5 percent level, performance of subjects in response and coordination tests was significantly impaired as were the subjects' visual discrimination functions.

Above the 5 percent level, significant changes in the functioning of the heart have been identified. Since the body's demand for oxygen remains constant for the same activity, the reduced amount of oxygen transported by the bloodstream in the presence of carbon monoxide requires the oxygen deficit to be made up by the pumping of a greater volume of blood from the lungs to the tissues. Persons having respiratory or circulatory problems, such as individuals with pulmonary emphysema or coronary heart disease, are unable to effectively compensate for carbon monoxide exposures by increasing the blood flow, and are thus particularly vulnerable. There is also some evidence that carbon monoxide is a factor in causing arteriosclerosis. In general, it may be concluded that the persons most sensitive to carbon monoxide exposures are those who are the most vulnerable to a decreased oxygen supply.

Figure 31

RELATIONSHIP BETWEEN CARBON MONOXIDE EXPOSURE AND CARBOXYHEMOGLOBIN LEVELS IN THE BLOOD



Source: U. S. Environmental Protection Agency.

It should be noted that cigarette smokers have been shown to have a median carboxyhemoglobin value of about 5 percent, compared to nonsmokers with a median value of 0.5 percent. Approximately 2 percent of cigarette smoke, or about 22,400 mg/m^3, is carbon monoxide. Of that amount, the average inhaled concentration approximates 460 to 575 mg/m^3. Cigarette smokers, therefore, would also seem to be particularly susceptible to ambient air carbon monoxide levels.

The developing fetus, which may be unusually sensitive to insufficient oxygen, and certain groups in the population that work in areas exposed to chronic long-term carbon monoxide concentrations, such as traffic policemen, may also be classified as sensitive individuals. Further, individuals requiring maximal judgment and functional ability, such as automobile drivers, should be considered as sensitive to low levels of carbon monoxide.

Other than its effect on human health, and its effect on animals with similar respiratory systems, carbon monoxide has not been shown to have any detrimental effect to vegetation, materials, or any atmospheric property at levels presently found in the ambient air. Moreover, certain plants and soil microorganisms may actually remove carbon monoxide from the air.

Air Quality Criteria and Standards for Carbon Monoxide: Table 62 presents a summary of the human health effects from exposure to varying carbon monoxide concentrations over different time intervals. Carbon monoxide exerts these adverse effects by combining with hemoglobin proteins in the blood, thereby reducing the oxygen-carrying capacity through the circulatory system. The buildup of carboxyhemoglobin in the bloodstream can be related directly to observed deterioration in the performance of certain body functions.

The blood of a nonsmoking individual normally contains about one-half of 1 percent carboxyhemoglobin due to internal body chemistry. As carbon monoxide is inhaled, however, the level of carboxyhemoglobin increases rapidly at first, until about 30 percent of the equilibrium point has been reached, whereupon the process proceeds at a slower rate. The equilibrium point, the value at which the external and internal pressures of carbon monoxide are about the same, is reached after between eight to 12 hours of continuous exposure.

As already mentioned, laboratory experiments have shown that when carboxyhemoglobin levels reach 2.5 percent in the blood, perception of time intervals is impaired, at levels of about 3 percent certain visual functions are impaired; and at levels in excess of 5 per-

Table 62

SUMMARY OF AIR QUALITY CRITERIA FOR CARBON MONOXIDE

Carbon Monoxide Level	Effect	Comment
35 mg/m^3 (30 ppm) for up to 12 hours	Equilibrium value of 5 percent blood COHb is reached in 8 to 12 hours; 80 percent of this equilibrium value (4 percent COHb) is reached within 4 hours	Experimental exposure of nonsmokers. Theoretical calculations suggest exposure to 23 (20 ppm) and 12 mg/m^3 (10 ppm) would result in COHb levels of about 3.7 and 2 percent, respectively, if exposure was continuous for 8 or more hours
58 mg/m^3 (50 ppm) for 90 minutes	Impairment of time-interval discrimination in nonsmokers	Blood COHb levels not available, but anticipated to be about 2.5 percent. Similar blood COHb levels expected from exposure to 10 to 17 mg/m^3 (10 to 15 ppm) for 8 or more hours
115 mg/m^3 (100 ppm) intermittently through a facial mask	Impairment in performance of some psychomotor tests at a COHb level of 5 percent	Similar results may have been observed at lower COHb levels, but blood measurements were not accurate
High concentrations of CO administered for 30 to 120 seconds, with 10 minutes then allowed for washout of alveolar CO before measuring blood COHb level	Exposure sufficient to produce blood COHb levels above 5 percent has been shown to place a physiologic stress on patients with heart disease	Data rely on COHb levels produced rapidly after short exposure to high levels of CO; this is not necessarily comparable to exposure over a longer time period or under equilibrium conditions

Source: U.S. Department of Health, Education and Welfare, Public Health Service.

cent, persons with coronary or respiratory ailments are unable to compensate for the decreased oxygen-carrying capacity of the blood by increasing the blood flow.

Based on these criteria, the air quality standards for carbon monoxide are intended to limit the formation of carboxyhemoglobin in the bloodstream to levels below 2 percent. Since, as mentioned, carboxyhemoglobin builds up rapidly during early exposures to carbon monoxide, and since it reaches equilibrium after about eight hours, a one-hour and an eight-hour standard have been promulgated. These standards, as shown in Table 57, are 40 mg/m^3 (35 ppm) and 10 mg/m^3 (9.0 ppm) for the one-hour and eight-hour periods, respectively, and are thought to be sufficiently adequate to protect the public health with an added margin of safety. Referring back to Figure 31, it may be seen that the promulgated standards will allow a buildup of between 1.25 and 2 percent carboxyhemoglobin--well below the level necessary to initiate adverse effects as presently understood from medical evidence. It should be noted that the primary and secondary standards for both time periods are the same since carbon monoxide has not been demonstrated to have any deleterious effects on vegetation, materials, or any atmospheric property.

Nitrogen Oxides

Nitrogen oxides are gaseous pollutants which include nitric oxide (NO), nitrogen dioxide (NO_2), nitrogen trioxide (NO_3), nitrous oxide (N_2), nitrogen sesquioxide (N_2O_3), nitrogen tetroxide (N_2O_4), and nitrogen pentoxide (N_2O_5). The only oxide of nitrogen naturally present in the atmosphere in appreciable quantities is nitrous oxide. Nitrous oxide is a colorless and odorless gas which is chemically inert at normal atmospheric temperatures and consequently is not considered to be an air pollutant. Nitrous oxide is primarily formed through the decomposition of nitrogen compounds by soil bacteria and from reactions between nitrogen and oxygen or ozone in the upper atmosphere.

Nitrogen trioxide, nitrogen sesquioxide, nitrogen tetroxide, and nitrogen pentoxide do not accumulate in the atmosphere in significant concentrations. These compounds are, however, important intermediate products in photochemical reactions in the atmosphere, even in small quantities.

Nitric oxide and nitrogen dioxide are the most important of the various oxides of nitrogen as air pollutants. The physical properties of these two compounds are presented in Table 63. Under the high temperature conditions accompanying the burning of fossil fuels, nitric oxide and, to a much lesser extent, nitrogen dioxide are formed when air is used as the oxidizing agent. Two molecules of nitric oxide, a colorless, odorless gas, are formed when atmospheric oxygen and nitrogen react through the absorption of heat energy. This reaction may be shown in equation form as follows:

$$N_2 + O_2 + \text{HEAT ENERGY} \rightarrow 2NO$$

Table 63

SELECTED PHYSICAL CONSTANTS OF NITRIC OXIDE AND NITROGEN DIOXIDE

	Nitric Oxide (NO)	Nitrogen Dioxide (NO_2)
Molecular Weight	30.01	46.01
Melting Point (°C)	-163.6	-11.2
Boiling Point (°C)	-151.8	21.2
Density (grams per liter)	1.3402	–
Specific Gravity (liquid)	–	1.4494

Source: U.S. Department of Health, Education and Welfare, Public Health Service.

Nitrogen dioxide may then be formed when two molecules of nitric oxide react with oxygen as shown by the following equation:

$$2NO + O_2 \rightarrow 2NO_2$$

These equations are a generalized view of the atmospheric chemistry leading to the production of nitrogen dioxide. In actuality, factors such as the ambient air temperature, the initial concentration of nitric oxide, and the presence of intermediate compounds like nitrogen trioxide all influence the rate of nitrogen dioxide formation.

Once in the atmosphere, nitrogen dioxide, a reddish orange-brown gas with a characteristic pungent odor, may chemically react with water vapor to form nitric acid (HNO_3) and either nitrous acid (HNO_2) or nitric oxide. These reactions may be shown in equation form as follows:

$$2NO_2 + H_2O \rightarrow HNO_3 + HNO_2$$

or

$$3NO_2 + H_2O \rightarrow 2HNO_3 + NO$$

These reactions, however, have not been found to be of major significance in the ambient air.

Natural sources of nitrogen oxides, referring hereinafter only to the nitric oxide and nitrogen dioxide compounds, emit about 10 times as much of the pollutant, principally from bacterial action, as are emitted from man-made sources. The distribution of natural emissions, however, is so globally uniform that the background levels of nitrogen oxides are quite small compared to the localized concentrations produced by man-made sources. It has been estimated that the average background levels on the North American continent are about 8.0 $\mu g/m^3$ (4.0 parts per billion [ppb]) for nitrogen dioxide, and about 2.0 $\mu g/m^3$ (2ppb) for nitric oxide. A comparison of global background levels and estimated annual emission rates indicates that the average residence time of nitrogen dioxide in the atmosphere is about three days and of nitric oxide, about four days. These residence times reflect the action of natural scavenging processes, including photochemical reactions which occur during daylight in any area where the ambient air contains nitrogen oxides and reactive hydrocarbons.

Nitrogen oxides are essential compounds in the atmospheric processes leading to the formation of photochemical oxidants. The mechanism by which nitrogen oxides photochemically react with hydrocarbons in the ambient air to yield oxidant products is outlined in the "Photochemical Oxidants" section of this chapter.

The combustion of fossil fuels is the principal source of man-made nitrogen oxide emissions. From a national emissions study made in 1968 it was determined that about 50 percent of the total nitrogen oxide emissions was generated by stationary combustion sources, primarily from power plants and industries, and that another 40 percent was attributable to transportation sources, overwhelmingly to motor vehicles. Only relatively small quantities of nitrogen oxides were found to be emitted from noncombustion industrial processes, mainly the manufacturing and use of nitric acid.

Both nitric oxide and nitrogen dioxide concentrations display distinct diurnal variations dependent on the intensity of solar ultraviolet energy and the amount of atmospheric mixing. These concentrations also vary with daily traffic patterns. Nitric oxide concentrations also show a seasonal variation, with higher mean values occurring during late fall and winter months when there is less overall atmospheric mixing and less ultraviolet energy for forming secondary products. The seasonal pattern for nitrogen dioxide is less distinct. Even though a greater amount of nitric oxide is converted to nitrogen dioxide during the summer months, the actual concentration of nitrogen dioxide may be greatest during other seasons of the year, when its removal from the atmosphere occurs at a slower rate.

Ambient air measurements of nitric oxide from across the United States have indicated that peak values above 1,230 $\mu g/m^3$ (1.0 ppm) are common. Nitrogen dioxide concentrations, however, have rarely been recorded at that level. Most nitrogen dioxide concentrations measured in urban areas have been lower than 940 $\mu g/m^3$ (0.5 ppm).

Effect of Nitrogen Oxides on Human Health: Both nitric oxide and nitrogen dioxide have been demonstrated to produce adverse health effects. The concentration at which nitric oxide produces such effects, however, is many times the level at which it is found in the ambient air. Nitric oxide, therefore, is not considered to have adverse health effects of itself; rather, its main toxic potential at ambient air concentrations results from its rapid oxidation to nitrogen dioxide.

The pungent odor of nitrogen dioxide is immediately perceptible in sensitive individuals beginning at concentrations of about 225 $\mu g/m^3$ (0.12 ppm). At higher

concentrations, about 835 $\mu g/m^3$ (0.42 ppm), nearly all individuals immediately perceive the distinctive odor. Laboratory experiments have found that the effects of nitrogen dioxide and sulfur dioxide were additive; that is, a lower concentration of each gas led to odor perception if both gases were present simultaneously.

Most of the laboratory experiments measuring the toxicological effects of nitrogen dioxide in man involve exposure to concentrations higher than found in the ambient air. Other information derived from occupational exposures to higher concentrations of nitric oxide/nitrogen dioxide mixtures is complicated by the presence of other pollutants. What data have been obtained from such sources indicate that humans, when exposed to nitrogen dioxide concentrations approximating 9,400 $\mu g/m^3$ (5.0 ppm) for 10 minutes, are affected by an increased airway resistance. This effect is readily reversible, however. At extremely high doses, around 169,000 $\mu g/m^3$ (90 ppm) for 30 minutes, nitrogen dioxide has been shown to produce pulmonary edema and other respiratory impairments. Accidental exposures to even higher concentrations for about five minutes have produced death within two days to five weeks.

The effect of long-term exposure to ambient air levels of nitrogen dioxide is best detailed in a study of school children in Chattanooga, Tennessee. In this study, four residential areas--one area near a large TNT plant and having high monitored nitrogen dioxide and low particulate matter levels, a second area with reversed conditions, and two "clean" areas--were selected for examination. Each area contained three elementary schools. The results of the study indicated that nitrogen dioxide exposure caused impaired respiratory functioning in elementary school children and accounted for an increase in the frequency of acute respiratory illness in family groups. Throughout the entire study period, the illness-incidence rates for each family segment in the high nitrogen dioxide area were consistently and significantly higher than the incidence rates for each family segment in the two clean areas. This increased incidence of acute respiratory disease was observed when the 24-hour nitrogen dioxide concentration, measured over a six-month period, ranged between 117 and 205 $\mu g/m^3$ (0.062 to 0.109 ppm).[5]

A second study of three areas in Chattanooga (the same areas as in the previous study cited with the exception of the high particulate matter area) found that exposure to intermediate and high levels of nitrogen dioxide was directly associated with a significant increase in acute bronchitis among infants exposed for three years, and among school children exposed for two and three years. This greater frequency of acute bronchitis was observed when the mean 24-hour nitrogen dioxide concentration, measured over a six-month period, ranged between 118 and 156 $\mu g/m^3$ (0.063 and 0.083 ppm). Although both of the Chattanooga studies were based on a six-month nitrogen dioxide average, the annual average would not be substantially different since nitrogen dioxide does not exhibit marked seasonal variations.

Effect of Nitrogen Oxides on Animals: Most of the available information concerning the physiological effects of nitrogen dioxide is derived from experiments on laboratory animals. As with humans, nitrogen dioxide exerts its primary toxic effect on the lung. Concentrations greater than 188,000 $\mu g/m^3$ (100 ppm) are lethal to most animal species, with 90 percent of the deaths attributed to pulmonary edema. At much lower concentrations, but still in excess of 1,500 $\mu g/m^3$ (0.08 ppm), adverse changes in pulmonary function have been observed in rats, guinea pigs, and monkeys.

Changes in the metabolic rate of the lung tissue in rabbits occurred at exposures as low as 470 $\mu g/m^3$ (.025 ppm) for four hours a day over six days. This effect was found to be reversible, however, after about seven days following the exposure period. Similar changes were observed in rabbits exposed to 1,900 $\mu g/m^3$ (1.0 ppm) of nitrogen dioxide for one to four hours. Again, these alterations were found to be reversible.

Long-term exposure of laboratory animals has shown that nitrogen dioxide inhalation increases susceptibility to bacterial pneumonia and influenza infections and may lead to pulmonary emphysema. Inhalation of nitrogen dioxide may also produce systemic effects, generally secondary to those on the lungs, including cellular changes in heart, liver, and kidney tissue.

Effect of Nitrogen Oxides on Vegetation: As with sulfur dioxide, certain types of vegetation are more susceptible to damage from nitrogen dioxide than others. In addition to varying levels of susceptibility, factors such as the stage of plan development and plant environment (temperature, light, humidity, soil moisture, and mineral nutrition) influence the degree of injury to vegetation by air pollutants. For example, in all species of plants, young leaves are the least injured when exposed to nitrogen dioxide while older leaves are the most sensitive. Depending on the kind of plant and its environment, one factor may be of greater importance than another.

Many kinds of plants develop acute leaf injury (lesions) when exposed to nitrogen dioxide concentrations greater than 47,000 $\mu g/m^3$ for a one-hour period. Under controlled growth conditions, the threshold value for nitrogen dioxide damage, that is, the level that injures 5 percent of the leaf area, for certain sensitive plants is 7,500 $\mu g/m^3$ to 15,000 $\mu g/m^3$ (4.0 to 8.0 ppm) for one hour. Increasing the duration of exposure lowers the injury threshold concentration so that only 1,900 $\mu g/m^3$ of nitrogen dioxide administered over 48 hours produces leaf damage.

The lesions on the plant leaves caused by nitrogen dioxide may be due principally to the chemical reaction of the pollutant with water. Nitrogen dioxide reacts

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[5] *These measured nitrogen dioxide concentrations were monitored using the Jacobs-Hochheiser method, which is no longer an EPA-approved monitoring procedure.*

with water to form a mixture of nitrous and nitric acids. This reaction probably occurs as the gas reaches the wet surfaces of the leaf tissue and thereby corrodes the leaf covering.

Effect of Nitrogen Oxides on Materials: Nitrogen oxides have been found to have significant effects on three classes of materials: textile dyes and additives, natural and synthetic textile fibers, and metals. The most pronounced problem is associated with textile dyes and additives. Fading of certain sensitive dyes used on cellulose acetate fibers has been caused by nitrogen dioxide at levels below 188,000 $\mu g/m^3$ (100 ppm). Loss of color, particularly in blue and green dyes in cotton and viscose rayon, has occurred in gas dryers where nitrogen oxide concentrations range from 1,100 to 3,700 $\mu g/m^3$ (0.6 to 2.0 ppm). Yellow discoloration in undyed white and pastel-colored fabrics has also been attributed to nitrogen oxides. Laboratory experiments have shown that, in addition to causing fading and discoloration, nitrogen oxides can deteriorate cotton and nylon textile fibers, but specific threshold limits have not yet been determined.

Particulate nitrates--a mixture of nitrous and nitric acid--are another form of nitrogen oxides. It has been found that particulate nitrates can corrode the nickel-brass wire springs used in electrical relay switches. Since particulate nitrates are formed when nitrogen dioxide chemically reacts with water, high relative humidity levels encourage nitrate production and accelerate corrosion.

Effect of Nitrogen Oxides on Atmospheric Properties: The primary adverse effect of nitrogen dioxide in the atmosphere lies in its ability to readily absorb sunlight and enter into and promote the photochemical process. The mechanism by which nitrogen oxides contribute to the formation of oxidant products is outlined in this chapter under the subtopic "Photochemical Oxidants."

Nitrogen dioxide is intensely colored and absorbs light over the entire spectrum of visible light, but primarily in the shorter wavelengths--violet, blue, and green. In the atmosphere it reduces the brightness and contrast of distant objects, and causes the horizon sky and white objects to appear pale yellow to reddish-brown. The presence of particulate matter tends to mask the coloration effect of nitrogen dioxide, but the two pollutants combined significantly reduce the visibility, contrast, and brightness of distant objects.

Air Quality Criteria and Standards for Nitrogen Oxides: A summary of selected air quality criteria for nitrogen oxides is presented in Table 64. It is evident that nitrogen dioxide is the most damaging of the oxides of nitrogen. With the exception of the nitrogen dioxide levels monitored in the two Chattanooga, Tennessee studies, however, the observed effects on human health have been due principally to accidental or occupational exposures to nitrogen dioxide concentrations far in excess of those normally occurring in the ambient air. Most urbanized areas do not exceed nitrogen dioxide levels of 940 $\mu g/m^3$ (0.5 ppm). Since short-term nitrogen dioxide levels do not occur at the magnitude necessary to produce irreversible damage to human health, the ambient air quality standard should be based on long-term exposures.

As Table 64 indicates, and as already discussed, at nitrogen dioxide levels ranging from 117 to 207 $\mu g/m^3$ (0.062 to 0.109 ppm) for a 24-hour average measured over six months, acute respiratory disease has been found to increase in family groups in one study in Chattanooga, and an increased frequency of bronchitis in infants and school children was found in a second study. Based primarily on these two studies, the EPA promulgated, and the U.S. Congress adopted, the limit of 100 $\mu g/m^3$ (0.05 ppm) of nitrogen dioxide levels averaged on an annual basis. Although the Chattanooga studies were based on six months of monitoring data, the lack of any significant seasonal variation in nitrogen dioxide concentrations permits the standard to be based on the annual average.

Hydrocarbons

Hydrocarbons are compounds whose molecules consist of hydrogen (H) and carbon (C) atoms only. They may exist in either a gaseous, liquid, or solid state depending on the number of carbon atoms and the way in which the carbon atoms are chemically bonded together. In general, hydrocarbons having more than 12 carbon atoms may be considered as particles and do not occur in the gaseous state in sufficient abundance to be measurable in the atmosphere. Hydrocarbons having between one and four carbon atoms are gaseous at ordinary temperatures, whereas those having five or more carbon atoms are liquids or solids in their pure state. Liquid mixtures of hydrocarbons, such as gasoline or cleaning solvents, include some compounds which, when apart from the mixture, would normally exist in either the gaseous or solid state. From an air pollution standpoint, the significant hydrocarbons are those which are present in the atmosphere in the gaseous state; that is, those containing less than 12 carbon atoms.

Hydrocarbons present a major air pollution problem because of their role in the photochemical formation of secondary pollutants. Hydrocarbons react with oxygen atoms, ozone molecules, and certain additional oxidation products generated by the action of sunlight on other components in the atmosphere, particularly nitrogen dioxide. Sunlight alone has no appreciable effect on hydrocarbons in the air, and without such reactive products as ozone hydrocarbons would not be involved in photochemical air pollution.

Not all of the numerous hydrocarbon compounds have the same reactivity in the presence of photochemical products. Methane (CH_4), for example, is the simplest hydrocarbon and is relatively inert in the atmosphere. Other hydrocarbon compounds may react very rapidly and be depleted in a parcel of air within a short time. In general, the reaction rates depend on the concentrations of the individual hydrocarbon compounds and the oxidation products. Theoretically, if a parcel of air

Table 64

SUMMARY OF SELECTED AIR QUALITY CRITERIA FOR NITROGEN OXIDES

Pollutant	Concentration	Duration of Exposure	Observed Biological or Physical Response	Category of Effect
Nitric Oxide	Normally occurring ambient air levels	–	No adverse health effects	Human Health
Nitrogen Dioxide	225 $\mu g/m^3$ (0.12 ppm)	–	Odor perception in sensitive individuals	Human Health
Nitrogen Dioxide	9,400 $\mu g/m^3$ (5 ppm)	10 minutes	Increased airway resistance (reversible)	Human Health
Nitrogen Dioxide	162,200 $\mu g/m^3$ (90 ppm)	30 minutes	Pulmonary edema produced 18 hours after accidental occupational exposure	Human Health
Nitrogen Dioxide	117 to 205 $\mu g/m^3$ (0.062 to 0.109 ppm)	Average 24-hour concentration measured over six months	Increased incidence of acute respiratory disease in family groups in Chattanooga, Tennessee	Human Health
Nitrogen Dioxide	118 to 156 $\mu g/m^3$ (0.063 to 0.083 ppm)	Average 24-hour concentration measured over six months	Frequency of acute bronchitis increased among infants and school children in Chattanooga, Tennessee	Human Health
Nitrogen Dioxide	7,500 to 15,000 $\mu g/m^3$ (4 to 8 ppm)	1 hour	Injury produced in over 5 percent of leaf area in sensitive plants	Vegetation
Nitrogen Dioxide	188,000 $\mu g/m^3$ (100 ppm)	Continuous	Lethal to most animal species, with 90 percent of the deaths attributable to pulmonary edema	Animals
Nitrogen Dioxide	470 $\mu g/m^3$ (0.25 ppm)	4 hours a day for six days	Changes in the metabolic rate of lung tissues in rabbits (reversible)	Animals
Nitrogen Dioxide	1,100 to 3,700 $\mu g/m^3$ (0.6 to 2.0 ppm)	Normal clothes-drying cycle	Loss of color in cotton and rayon fabrics in gas clothes dryers	Materials

Source: U.S. Environmental Protection Agency and SEWRPC.

received enough sunlight over a sufficiently long period, the hydrocarbons and oxidation products would react ultimately to form carbon dioxide and water vapor. No air parcel, however, retains its integrity in the atmosphere long enough for its hydrocarbons to be fully oxidized. The role of hydrocarbons in the formation of secondary pollutants is discussed in more detail in this chapter under the subtopic "Photochemical Oxidants."

Hydrocarbons are placed into the atmosphere by both natural and man-made sources. Of the natural sources, most of the hydrocarbons are produced by biological processes including the decomposition of organic material and the formation and release of certain hydrocarbons by vegetation. Other natural sources include emissions from coalfields, natural gas, and petroleum fields, and natural fires. Methane is the primary hydrocarbon compound released from natural sources and, in fact, accounts for more of the emissions than all other hydrocarbon compounds combined. Global methane production from natural sources is estimated at about 1.6 billion tons per year.

Man-made hydrocarbon emissions originate primarily from the incomplete combustion of fossil fuel, particularly gasoline, and from the use of hydrocarbons as solvents for many industrial purposes including chemical, drug, and pharmaceutical manufacturing, in paints, varnishes, and lacquers; and in the dry cleaning of clothes. Transportation-related sources account for

more than 50 percent of the total hydrocarbon emissions from all sources. The internal combustion engine in conventional automobiles can emit literally hundreds of different hydrocarbons, primarily in trace quantities, from four sources: engine exhaust, crankcase blowby, the carburetor, and the fuel tank. On uncontrolled automobiles about 60 percent of the unburned hydrocarbons comes from the exhaust, and another 20 percent comes from crankcase blowby. An additional 10 percent each results from the evaporation of gasoline in the carburetor and the fuel tank. Diesel engines, gas turbines, and jet aircraft engines are all fired with an excess of air and the fuel burns more efficiently, thereby producing fewer hydrocarbon emissions. Also, since fuel for these engines is not as volatile as gasoline, evaporative hydrocarbon emissions are very low.

The evaporation of hydrocarbons during the production, processing, storage, and transfer of petroleum products also contributes substantially to the air pollution problem. At each stage of the refinery process, from the oil field to the end use, hydrocarbons may potentially be evaporated into the ambient air.

Other stationary sources of hydrocarbon emissions include coke plants, refuse burned openly, and fuel-burning equipment of all types when improperly adjusted, inadequately maintained, or incorrectly operated. Miscellaneous sources of hydrocarbons from biological materials include industries using fermentation, food processing, organic fertilizer processing, wood distillation, and soap manufacturing.

As stated previously, methane is the most abundant of all hydrocarbons. Whereas all other hydrocarbon concentrations occasionally drop to unmeasurably low levels, methane does not. From numerous global measurements it has been indicated that there is a worldwide minimum concentration of methane of about 0.7 to 1.0 mg/m^3. In populated areas values of 4.0 mg/m^3 or more have been observed.

Nonmethane to methane ratios have been estimated for certain urbanized areas after allowing for the estimated background concentrations. The estimated ratios for several weeks averaged 0.6 in Cincinnati, Ohio, and 1.9 in Los Angeles, California, although the methane values were similar. The higher ratio in Los Angeles reflects the difference in automobile use between the two cities, since methane and the hydrocarbons with fewer carbon atoms are found only in trace amounts in automobile exhaust gases. Data on the diurnal patterns of nonmethane hydrocarbon concentrations in a number of cities indicate that concentrations reach a maximum level between 6 a.m. and 8 a.m. and diminish during the rest of the day. This 6 a.m. to 8 a.m. peak corresponds to a time of high automobile use.

It has proven difficult to develop a mathematical simulation model to relate hydrocarbon emissions to ambient air quality and then to the products of photochemical reactions. Because no model has achieved such a level of sophistication, the relationship between hydrocarbon emissions and maximum daily oxidant levels must be approached on an empirical basis. The adopted empirical approach has been to compare measured hydrocarbon levels averaged between 6 a.m. and 9 a.m. with hourly maximum oxidant values later in the day. When the oxidant values are plotted as a function of the early morning hydrocarbons, a complete range of oxidant values--starting near zero and approaching a finite level--is observed, indicating a strong dependence of oxidant formation on earlier hydrocarbon emissions. Figures 32 and 33 indicate this relationship of oxidants to total 6 a.m. to 9 a.m. average total hydrocarbons and to the 6 a.m. to 9 a.m. average nonmethane hydrocarbons, respectively, as determined from 326 days of data observed in five cities between 1966 and 1968. In Figure 33 it may be seen that the early morning nonmethane hydrocarbon concentrations must be below 200 $\mu g/m^3$ (0.3 ppm) if the maximum oxidant concentration is to be kept below 200 $\mu g/m^3$ (0.1 ppm). It should be noted that this empirical determination is on the conservative side and may be affected by unique local meteorological conditions or emission sources. It is, however, the only available guideline for relating hydrocarbon emissions to oxidant formation.

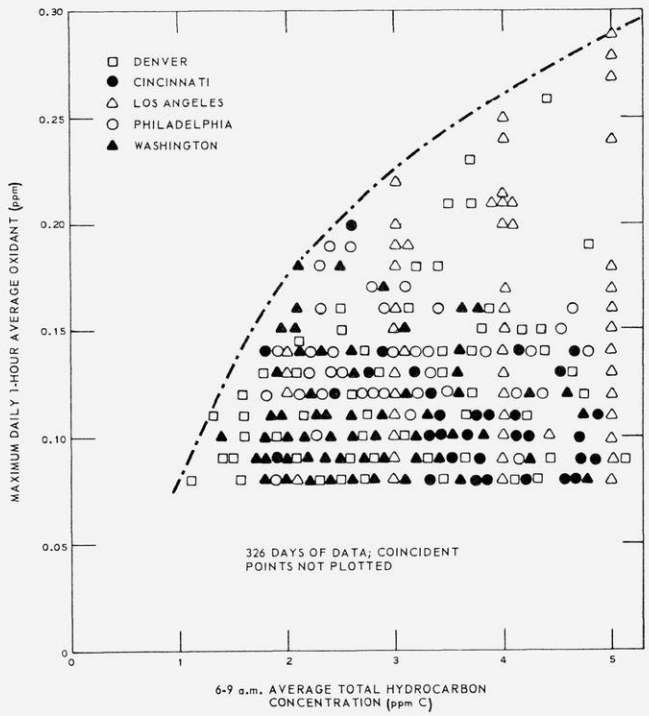
Effects of Hydrocarbons: Hydrocarbons of themselves have no direct effect on human health at levels found in the atmosphere. They do, however, enter into and promote the formation of photochemical oxidants and other compounds which have been shown to have a deleterious influence on the public welfare. The effect of such compounds is discussed in this chapter under the subtopic "Photochemical Oxidants."

Of the various hydrocarbon compounds, only ethylene (2 CH_2) has been shown to adversely affect vegetation in concentrations attained in the ambient air. Around the turn of the century it was observed that illuminating gas caused malformations of certain plants and injuries to flowers. Ethylene has been subsequently reported as responsible for considerable losses of flowers in California and of cotton in Texas. Research has shown that ethylene is produced internally within plant tissues where it serves as a hormone in regulating growth, development, and other processes in the ripening of fruit. It is therefore in a unique role of being both internally necessary for plant development and externally toxic. The present state of knowledge concerning the effects of ethylene indicate that, other than greenhouse crops, no significant damage should be sustained by vegetation growing within the Southeastern Wisconsin Region.

Air Quality Criteria and Standards for Hydrocarbons: Since hydrocarbons do not directly affect the health and welfare of the population, the only criterion upon which to promulgate a standard is the established relationship between early morning hydrocarbon concentrations and the formation of oxidants in the ambient air to levels known to be deleterious. In this sense, the air quality standard for hydrocarbons is only a guideline for achieving the air quality standard for ozone.

Figure 32

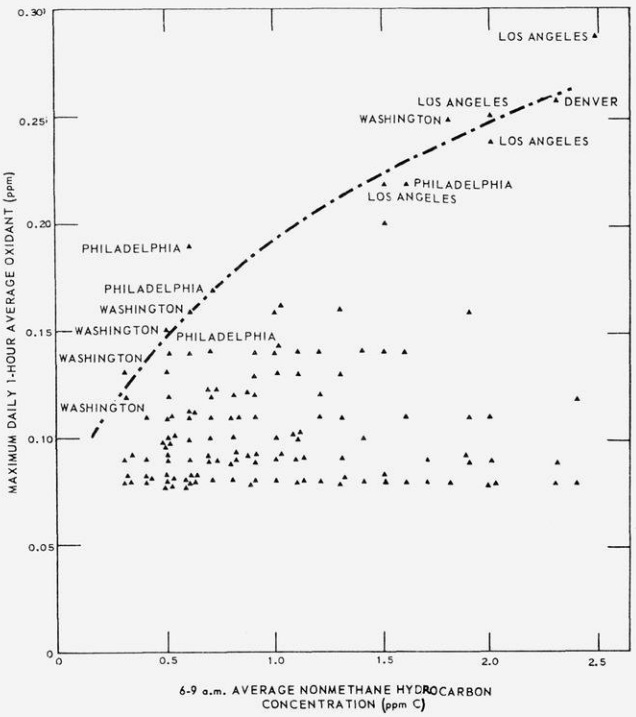
MAXIMUM ONE-HOUR AVERAGE OXIDANT LEVELS AS A FUNCTION OF 6:00 A.M. TO 9:00 A.M. AVERAGE TOTAL HYDROCARBON CONCENTRATIONS



Source: U. S. Environmental Protection Agency.

Figure 33

MAXIMUM ONE-HOUR AVERAGE OXIDANT LEVELS AS A FUNCTION OF 6:00 A.M. TO 9:00 A.M. AVERAGE NONMETHANE HYDROCARBON CONCENTRATIONS



Source: U. S. Environmental Protection Agency.

The ambient air quality standard for ozone initially was set at 160 $\mu g/m^3$ (0.08 ppm). Figure 33 shows that the 6 a.m. to 9 a.m. average nonmethane hydrocarbon concentration must, therefore, be lower than 160 $\mu g/m^3$ (0.24 ppm) if the oxidant standard is not to be exceeded. The hydrocarbon standard was consequently set at this level. It should be noted here that, because of certain air quality monitoring limitations, the hydrocarbon standard is expressed in terms of total hydrocarbons; that is, nonmethane compounds are measured as methane. The standard, therefore, has a margin of safety since it includes the concentration of nonreactive hydrocarbons as well as of the reactive compounds.[6]

Photochemical Oxidants

Photochemical oxidants are secondary pollution products, formed in the atmosphere from a series of reactions between hydrocarbons and nitrogen oxides in the presence of sunlight, which have the ability to combine with (oxidize) certain substances that are not readily oxidized by oxygen. The most common of the photochemical oxidants are ozone (O_3), peroxyacyl nitrates (PAN), and nitrogen dioxide (NO_2). Of these, ozone is found in the largest quantities in polluted atmospheres. Selected physical properties of ozone and peroxyacetyl nitrate, a member of the peroxyacyl nitrate family, are given in Table 65. The physical properties of nitrogen dioxide are presented in Table 63.

The chemical process by which oxidants are formed in the lower atmosphere involves literally hundreds of complex reactions which, within the scope of this report, can only be depicted in a generalized manner. First, it is necessary to distinguish between ozone formed in the upper atmosphere and that formed near the surface. There is a permanent layer of ozone in the atmosphere which acts as a shield to prevent harmful ultraviolet radiation from reaching the ground. Without this protective ozone layer, which reaches a maximum density at an elevation of from 12 to 20 miles, life could not have developed outside of the oceans. Stated simply, ozone in this region is formed when oxygen, normally a stable two-atom molecule--O_2, absorbs ultraviolet radiation, a form of energy, and breaks into two single atoms. When one of these atoms collides with a double-atom oxygen molecule, called diatomic oxygen, an energy-rich ozone molecule is formed. Being energy-rich, the ozone molecule is unstable and must rapidly transfer the excess energy to another neutral molecule if it is to stabilize. These reactions can be stated in equation form as follows:

[6] *No action has yet been undertaken by the U.S. Environmental Protection Agency to change the three-hour hydrocarbon air quality standard as a result of the change in the ozone standard from 160 $\mu g/m^3$ (0.08 ppm) to 235 $\mu g/m^3$ (0.12 ppm).*

Table 65

PHYSICAL PROPERTIES OF OZONE AND PEROXYACETYL NITRATE

	Ozone	Peroxyacetyl Nitrate
Physical State	Colorless Gas	Colorless Liquid
Chemical Formula	O_3	CH_3COONO_2
Molecular Weight	48	121
Melting Point	$-192.7 \pm 0.2^{\circ}C$	–
Boiling Point	$-111.9 \pm 0.3^{\circ}C$	–
Vapor Pressure	–	≈15 millimeters mercury
Vapor Density[a]	1.96 grams per liter	–

[a] *At 25°C, 760 millimeters mercury.*

Source: U.S. Environmental Protection Agency.

$$O_2 + \text{Ultraviolet Radiation (Energy)} \rightarrow O + O$$
and
$$O_2 + O + M \text{ (a neutral molecule)} \rightarrow O_3 + M$$

If the ozone molecule absorbs ultraviolet radiation, it becomes unstable and rapidly decomposes as follows:

$$O_3 + \text{ultraviolet Radiation} \rightarrow O_2 + O,$$
and ultimately
$$O_3 + O \rightarrow O_2 + O_2.$$

This production and destruction of ozone are continuous processes in the upper atmosphere.

The ozone layer is not a perfect filter of the energetic ultraviolet radiation, and some small quantities do penetrate to the surface. The amount which does reach the ground, however, is not enough to separate the oxygen molecules. Some other mechanism must, therefore, act to generate the ozone concentrations found in the ambient air near the ground.

Of all the major atmospheric pollutants, nitrogen dioxide is the most efficient absorber of ultraviolet radiation. Upon absorbing this energy, nitrogen dioxide breaks down to nitric oxide and a single oxygen atom. The single atom of oxygen may then join with diatomic oxygen, in the presence of a neutral molecule to remove the excess energy, to form ozone. The ozone may then react with the nitric oxide to form nitrogen dioxide and diatomic oxygen. This cyclic process is presented diagramatically in Figure 34.

Figure 34 implies that nitric oxide and ozone are formed and destroyed in equal quantities. If, on the other hand, ozone was destroyed at a rate slightly slower than that at which nitric oxide was being converted to nitrogen dioxide, ozone and nitrogen dioxide would build up in the atmosphere while nitric oxide would be depleted. Since ozone does accumulate in the ambient air, it is necessary to introduce an intermediate chemical reaction that would explain the conversion of nitric oxide to nitrogen dioxide without destroying an equal amount of ozone.

Laboratory experiments and atmospheric measurements indicate that hydrocarbons provide the necessary chemical reactants which lead to the accumulation of ozone in the ambient air. Figure 35 shows the photochemical oxidation process as it is influenced by the presence of hydrocarbon compounds. Again, nitrogen dioxide is broken down by sunlight into nitric oxide and an atom of oxygen. Most of the oxygen atoms thus released would combine with the diatomic oxygen in the air to form ozone. In the presence of hydrocarbons, however, some of the single oxygen atoms would oxidize the hydrocarbon compounds, producing energetic and very chemically active compounds called free radical hydrocarbons (RO_2). These free radicals undergo a series of changes whereby they rapidly react with diatomic oxygen and ultimately oxidize nitric oxide to nitrogen dioxide. Because each free radical hydrocarbon carries a number of oxygen atoms in an unstable bond, a single free radical can oxidize more than one molecule of nitric oxide. Nitrogen dioxide and ozone, therefore, build up quickly while nitric oxide is being depleted.

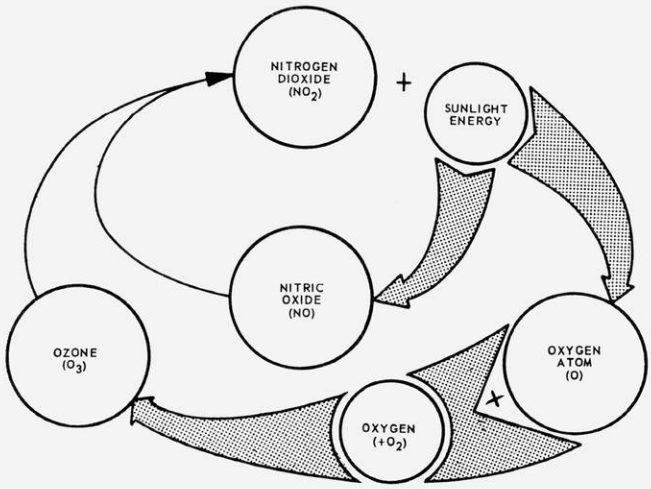
Free radical hydrocarbons may also react with oxygen and nitrogen compounds in the air to form other irritating oxidant compounds. Such a reaction with nitrogen dioxide, for example, produces peroxyacetyl nitrate. Thus, the principal determinant of the oxidation products formed is the chemical composition of the hydrocarbon mixture undergoing photochemical change.

The quantity of photochemical oxidants generated is strongly related to not only the presence of precursor emissions but to meteorological factors. The fundamental pattern of oxidant buildup closely follows the diurnal and annual cycle of peak solar radiation. Seasonally, oxidant concentrations are generally much higher in summer, when the ambient air temperature is warmer and sunlight intensity and duration are near maximum levels. The maximum oxidant concentrations on a daily basis generally occur in midafternoon shortly following the peak period of sunlight. The capability of oxidants to disperse in the atmosphere is determined by such meteorological variables as wind speed and stability.

Ozone may be found in the ambient air due to naturally occurring phenomena unrelated to the nature and amount of precursor emissions. Localized quantities of ozone are generated by lightning discharges in thunderstorms. Also, electrical energy loss to the atmosphere from high-voltage power lines may contribute fractionally to localized ozone concentrations. According to theoretical estimates, these naturally occurring sources of ozone formation do not account for any significant amount of observed concentrations.

Figure 34

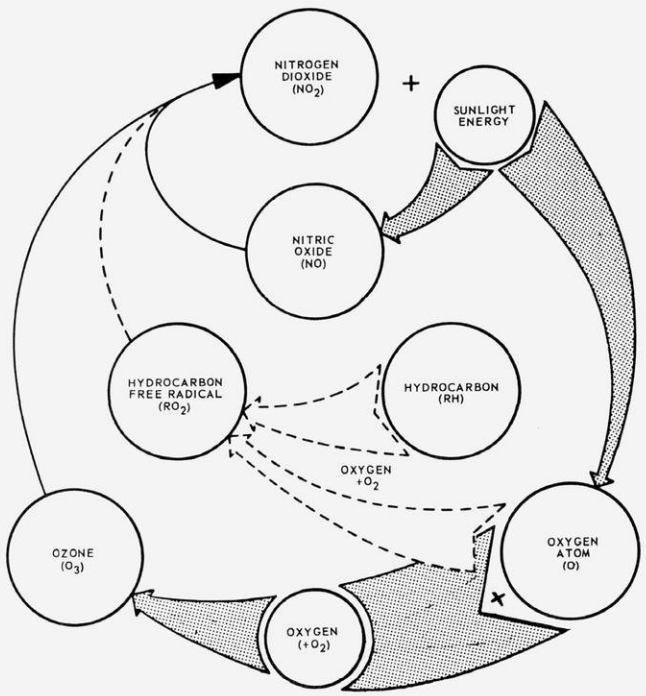
THE PHOTOCHEMICAL OXIDANT PROCESS WITH NITROGEN OXIDES



Source: U. S. Environmental Protection Agency.

Figure 35

THE PHOTOCHEMICAL OXIDANT PROCESS WITH NITROGEN OXIDES AND HYDROCARBONS



Source: U. S. Environmental Protection Agency.

As mentioned, ozone is naturally formed in the upper atmosphere. It has been suggested that some of this ozone may be transferred to the surface by certain meteorological mechanisms which cause subsidence. There are, however, many destructive processes in the lower atmosphere which could severely prohibit any significant amounts of ozone from being transported to the surface. It appears, therefore, that none of the naturally occurring processes of ozone formation measurably influence ambient air oxidant concentrations.

Effect of Photochemical Oxidants on Human Health: The adverse effects of photochemical oxidants on human health range from loss of sensory perception to death. The health effects of any one particular oxidant compound depend on the chemical nature of the compound, the concentration level, the duration of exposure, and the resistance or susceptibility of the individual. It is necessary, therefore, to separate the health effects of the principal oxidant products, whenever possible, as well as to define the health effects from the total body of photochemical oxidants.

As with the other pollutants discussed, photochemical oxidants enter the body primarily through the respiratory system. Being chemically active, oxidants may react with the mucus and tissue layers in all compartments of the respiratory tract, causing a deterioration of the cellular lining and consequently a restriction of normal pulmonary functions.

Ozone, in particular, appears to produce substantial damage in the respiratory tract. In one experiment a single subject was exposed to 2,940 to 3,920 $\mu g/m^3$ (1.5 to 2.0 ppm) of ozone for two hours. Following exposure, the subject was found to have a lack of physical coordination, an inability to express thoughts, and respiratory symptoms such as chest pain and cough. The subject also showed a 13 percent reduction in the breathing capacity of the lungs. In another experiment involving 10 men and 1 woman exposed to between 1,180 and 1,570 $\mu g/m^3$ (0.6 to 0.8 ppm) of ozone for two hours, the average breathing capacity fell by about 10 percent.

Additional experimentation has revealed that ozone concentrations up to 200 $\mu g/m^3$ (0.1 ppm) for one hour may be tolerated without significant effect. Even in lower concentrations, however, approximating 40 $\mu g/m^3$ (0.02 ppm), 9 out of 10 subjects were capable of perceiving the ozone odor. Although there is a lack of sound information on the effects of ozone between 200 and 780 $\mu g/m^3$ (0.1 to 0.4 ppm), it has been indicated that concentrations in this range may disturb some pulmonary functions. At exposures of 980 to 1,960 $\mu g/m^3$ for periods of from one to two hours, definite changes in pulmonary functions, including increased airway resistance and decreased breathing capacity, have been demonstrated to occur. At even higher concentrations of from 1,960 to 5,900 $\mu g/m^3$ over about two hours, experimental subjects have shown extreme fatigue and lack of coordination. Severe pulmonary edema and

possible acute bronchiolitis are caused by ozone concentrations of about 17,600 $\mu g/m^3$ (9.0 ppm).

From the very limited amount of experimental data on the health effects of peroxyacyl nitrates (PAN), it has been suggested that these oxidant products increase the oxygen uptake of subjects during exercise. This observed increase in oxygen uptake may be due to increased airway resistance caused by the PAN. It would appear, however, that at the concentrations found in the ambient air, PAN does not present any recognized health hazard.

The most obvious effect of photochemical oxidants is the development of eye irritation in human beings. Ozone itself is not an eye irritant, but PAN and certain oxidized hydrocarbons do produce this effect. Because eye irritation is not directly measurable but rather relies on subjective reports, it is not possible to define a specific dose-response relationship to various oxidant levels.

Effect of Photochemical Oxidants on Animals: Autopsies of experimental animals that have been subjected to lethal doses of ozone have shown that death was characterized by acute inflammation of the respiratory tract often accompanied by hemorrhage and edema. Certain pathological changes, including bronchitis, bronchiolitis, emphysema, and fibrosis, have been produced in animals by prolonged exposure to ozone concentrations ranging from 390 to 1,960 $\mu g/m^3$ (0.2 to 1.0 ppm). Changes in pulmonary functions, including decreased volume of air inhaled per breath, increased respiratory rates, and increased resistance to air flow, have been observed at ozone exposures of 590 $\mu g/m^3$ (0.3 ppm) for periods up to two hours. These changes were found to be reversible after the discontinuation of exposure.

At higher concentrations of 1,960 $\mu g/m^3$ (1.0 ppm) for a one-hour period, chemical changes were found to occur in the structural proteins of the animal lung. Chemical and biochemical changes have also been observed in the heart, liver, and brain of animals exposed to ozone levels between 1,960 and 11,800 $\mu g/m^3$ (1.0 to 6.0 ppm) for more than four hours. At much lower doses--160 $\mu g/m^3$ (0.08 ppm) for three hours--the defensive mechanism in animals for resisting bacterial infections was found to be significantly impaired. It has also been indicated that regular daily exposures of test animals to various ozone levels accelerates both the growth of lung tumors and the aging process.

Most of the physiological experimentation on the effects of photochemical oxidants in animals has been done with laboratory-prepared oxidant mixtures generated by irradiating automobile exhausts. Auto exhaust generally contains variable mixtures of carbon monoxide, hydrocarbons, and oxides of nitrogen, as well as other oxidants. Some of the damage caused by the oxidants, as observed in these experiments, may be due in part to the presence of these other pollutants. Ozone, however, appears to be the principal damage-producing pollutant in the oxidant mixture, although not enough information is yet available to determine the effects of PAN at concentrations which may be expected to occur in the ambient air.

Effect of Photochemical Oxidants on Vegetation: Damage to vegetation is one of the earliest manifestations of photochemical air pollution. The effects of oxidants on vegetation may be broken into three categories: acute injury, characterized by cell collapse; chronic injury, characterized by distinct patterns of dead leaf tissue; and physiological effects including growth alterations, reduced yields, and changes in the quality of plant products. The symptoms of acute injury are generally identifiable to a particular pollutant. Ozone, for example, causes a stippling or flecking effect on leaves, whereas PAN-produced injury is characterized by a glazing or bronzing on the underside of the leaf. As with most of the adverse effects produced by photochemical oxidants, ozone is the principal cause of damage. Not all varieties of plants are equally susceptible to oxidant damage. Certain plant strains may be highly resistant to injury while a slightly different strain may be extremely prone to damage even at relatively low oxidant concentrations.

Environmental factors, such as light, temperature, humidity, and the age of the leaf, also determine the extent to which a particular plant may be injured. It has been found that plants are generally more sensitive to PAN when grown under high-intensity light, but are more sensitive to ozone when grown under low-intensity light. Young leaves are more prone to PAN damage, while ozone damage generally appears on leaves nearing maturity. Higher temperatures and humidity levels also seem to increase oxidant damage.

Photochemical oxidants, and ozone in particular, have long been known for their ability to destroy bacteria and other microorganisms. The ozone concentration required to be effective as a germicide, however, is often adequate to kill certain small animals in a shorter period of time than it would take to eradicate the bacteria.

Effect of Photochemical Oxidants on Materials: Of all the oxidant products, only ozone is known to deteriorate materials. From an economic standpoint, rubber is probably the most important material sensitive to ozone. Antiozonant additives have been developed to protect rubber products from ozone destruction, and inherently resistant synthetic rubbers are also available. These additives and synthetics are relatively expensive, however, and add to the final cost of the end product. Moreover, increasing amounts of antiozonants are required as the amount of ozone to be encountered increases, and sometimes only temporary protection is provided since some chemicals such as oils and gasoline may remove the antiozonants from the rubber.

Ozone has also been found to deteriorate the cellulose in textile fabrics. Ozone acts in the presence of light and humidity to appreciably alter the breaking strength and fluidity of fibers. The susceptibility of different fibers to ozone deterioration is related to their chemical structure. In increasing order, the most susceptible fibers appear to be cotton, acetate, nylon, and polyester.

Certain dyes are also susceptible to fading due to the deterioration of their pigmentation by ozone. Experiments done by various cities around the country with high ozone levels have indicated that the amount of fading is dependent on the ozone concentration, length of exposure, type of material, and such factors as relative humidity and the presence or absence of other atmospheric pollutants. Selected combinations of fabrics, dyes, and processing techniques can eliminate or substantially reduce ozone fading, but the costs of such treatment are added to the cost of the end product.

Effect of Photochemical Oxidants on Atmospheric Properties: When mixed with combustion particles, photochemical oxidants may form a thick brownish haze termed smog--smoke-fog. In addition to having a generally offensive odor, smog acts to reduce the amount of sunlight reaching the earth's surface. As discussed in the section in this chapter on particulate matter, the absorption and reradiation of solar energy by atmospheric pollutants may contribute to climatic variations.

Air Quality Criteria and Standards for Photochemical Oxidants: Table 66 is a summary of selected air quality criteria for photochemical oxidants. This table shows the effects of oxidant products on human health, plant and animal life, and materials at the lowest concentrations for which the stated effect has been observed. From these criteria it may be seen that short-term exposures to photochemical oxidants at comparatively low levels produce a greater biological response than do long-term exposures at somewhat higher concentrations, indicating that a tolerance to the pollution may be acquired to some degree. Although tolerence to oxidants has not been demonstrated in humans, laboratory studies of small animals, and even plants, have shown that a limited resistance to this form of pollution may develop from short-term high-concentration exposures and last for several weeks or even for several months.

The air quality criteria listed in Table 66 indicate that most individuals can perceive oxidant products in the ambient air at a concentration of about 40 $\mu g/m^3$ (0.02 ppm), and also suggest that adverse health effects such as increased airway resistance may be incurred at concentrations of approximately 200 $\mu g/m^3$ (0.10 ppm). For three reasons, however, the clinical tests conducted at the 200 $\mu g/m^3$ (0.10 ppm) exposure level do not suggest any endangerment of public health. First, the subjects experienced no physical discomfort while exposed to this concentration level. Second, the observed changes in airway resistance were small. Third, smaller, nonsignificant increases in airway resistance were observed in the same subjects at an increased ozone exposure level of 780 $\mu g/m^3$ (0.40 ppm). Based on such findings, it appears that significant adverse health effects should not occur below at least an average ozone concentration of 200 $\mu g/m^3$ (0.10 ppm) over a one-hour period.

As mentioned, ozone is the major oxidant product, accounting for more of the total photochemical pollution than all other oxidant products combined. Since it is not feasible, either technologically or financially, to simultaneously monitor the ambient air for each individual oxidant product, ozone is used as the index of the total photochemical pollution. In recognition of ozone as the principal photochemical oxidant product, the Administrator of the U.S. Environmental Protection Agency redesignated the photochemical oxidant ambient air quality standard to an ozone ambient air quality standard on February 8, 1979. Moreover, the revised standard was established at 235 $\mu g/m^3$ (0.12 ppm) of ozone for a maximum one-hour average, which represents an increase of 50 percent over the prior photochemical oxidant standard of 160 $\mu g/m^3$ (0.08 ppm) of ozone for a maximum one-hour average. The revised standard also states that the 235 $\mu g/m^3$ (0.12 ppm) ozone level may not be exceeded for more than three hours over any three-year period. The Administrator increased the maximum allowable ambient air concentration of ozone to 235 $\mu g/m^3$ (0.12 ppm) on a one-hour average on the basis of more recent health data, which indicated that toxic ozone effects do not occur below a level of about 300 $\mu g/m^3$ (0.15 ppm) for that length of exposure. In the opinion of the Administrator, therefore, the establishment of the ambient air quality standard for ozone at 235 $\mu g/m^3$ (0.12 ppm) was sufficient to provide for the public health with an adequate margin of safety.

Hazardous Pollutants

Although air quality criteria and standards have been developed only for the six aforementioned pollutants, the U.S. Environmental Protection Agency is expected to eventually issue such documents and promulgate standards for an additional 30 pollutants. For one such pollutant, lead, draft copies of the air quality criteria document have already been issued for review.

There is, in addition to the above-mentioned pollutants, a class of air pollutants that represents a danger to public health but whose control may not be successfully achieved by the promulgation of ambient air standards since the concentrations of such pollutants tend to be high in the immediate vicinity of a point source rather than permeating very large areas. These contaminants are termed hazardous pollutants and five have been designated to date (1977): vinyl chloride, asbestos, mercury, beryllium, and benzene. A brief summary of the sources, effects, and emission limitations for these five pollutants, as well as for lead, are presented herein.

Vinyl Chloride: In January 1974 the B.F. Goodrich Chemical Company reported to the National Institute of Occupational Safety and Health that several of its employees had died from a rare form of cancer of the liver. The company thought that these deaths may have been related to occupational exposure to vinyl chloride gas. The EPA consequently established a task force to fully assess the impact of vinyl chloride on human health in both occupational exposures and in the general population. The task force determined that while air, water, and solid waste disposal were all possible entry routes of this pollutant into the environment, contamination of the air in the general vicinity of the production facilities posed the greatest environmental problem to the nearby population. Potential sources of vinyl chloride exposure to the general population, outside of proximity to a manufacturing facility, include aerosol containers and plastics used for containing or wrapping food products and drinking water.

As of June 1975 the National Cancer Institute confirmed that 27 cases of the rare liver cancer had occurred among workers who were occupationally exposed to vinyl chloride. In a survey by the American Cancer Society only one case of this type of cancer was recorded per 78,000 deaths. From these data it was concluded that workers exposed to vinyl chloride have a 3,000-time greater chance of developing this type of cancer than the general population. Further occupational exposure studies have implicated vinyl chloride as a human chemical carcinogen which causes tumors in many sites, only one of which is the liver.

Table 66

SUMMARY OF SELECTED AIR QUALITY CRITERIA FOR PHOTOCHEMICAL OXIDANTS

Oxidant	Concentration	Duration of Exposure	Observed Biological or Physical Response	Category of Effect
Ozone	40 $\mu g/m^3$ (0.02 ppm)	Less than 5 minutes	Distinctive odor perceived by 9 out of 10 subjects	Human Health
Ozone	200 to 1,960 $\mu g/m^3$ (0.10 to 1.00 ppm)	1 hour	Significant increase in airway resistance	Human Health
Ozone	3,900 $\mu g/m^3$ (2.00 ppm)	2 hours	Reduced breathing capacity, severe cough, inability to concentrate	Human Health
Ozone	390 $\mu g/m^3$ (0.20 ppm)	3 hours per day, six days per week for 12 weeks	No apparent effects observed. With an ozone level of 900 $\mu g/m^3$ (0.5 ppm) for the same exposure pattern, however, a change in pulmonary functioning was observed after only eight weeks	Human Health
Ozone	390 to 590 $\mu g/m^3$ (0.20 to 0.30 ppm)	Continuous during working hours	Small changes in pulmonary functions including reduced breathing capacity. Respiratory irritation and chest constriction observed at 590 $\mu g/m^3$	Human Health
All oxidants	Greater than 200 $\mu g/m^3$ (0.10 ppm)	Peak values	Eye irritation	Human Health
All oxidants	250 $\mu g/m^3$ (0.13 ppm)	Maximum daily value	Aggravation of respiratory diseases like asthma. Such a peak value would be statistically expected to be associated with a maximum hourly concentration of 100 to 120 $\mu g/m^3$ (0.05 to 0.06 ppm)	Human Health
Ozone	160 $\mu g/m^3$ (0.08 ppm)	3 hours	Increased susceptibility of laboratory animals to bacterial infection	Animals
All oxidants	1,960 to 7,470 $\mu g/m^3$ (1.00 to 3.81 ppm)	Continuous	Increased frequency of lung tumors found in laboratory animals after 24 weeks	Animals
Peroxyacyl nitrates	54 $\mu g/m^3$ (0.01 ppm)	5 hours	Leaf lesions occur in the most sensitive plant species under laboratory conditions	Vegetation
Ozone	60 $\mu g/m^3$ (0.03 ppm)	8 hours	Certain sensitive species of vegetation exhibited damage under laboratory conditions	Vegetation
All oxidants	100 $\mu g/m^3$ (0.05 ppm)	4 hours	Leaf injury to sensitive plants	Vegetation
Ozone	40 $\mu g/m^3$ (0.02 ppm)	1 hour	Cracking of stretched vulcanized natural rubber	Materials

Source: U.S. Department of Health, Education and Welfare, Public Health Service, and SEWRPC.

There are two major sources of vinyl chloride emissions: polyvinyl chloride plants, which are responsible for about 85 percent of the nationwide emissions, and ethylene dichloride-vinyl chloride plants, which account for about 11 percent of the national emissions. At the end of 1975, there were 41 existing plants in the former category and 17 existing plants in the latter operating in the United States. In addition, there are approximately 8,000 polyvinyl chloride fabrication plants and several other miscellaneous sources providing about 4 percent of the national emissions. In 1975 these plants produced in total about seven billion tons of polyvinyl chloride and an equal amount of ethylene dichloride (approximately half of which went for the production of vinyl chloride). This production is estimated to place more than 110,000 tons of vinyl chloride emissions into the atmosphere annually.

The chemical processes involved in the production of vinyl chloride are complex and diversified. The EPA, therefore, did not set a single emission standard but rather established separate standards for each process and company.[7] From its own assessment, the EPA concluded that emissions from a typical polyvinyl chloride plant would be reduced from 330 kilograms per hour to 16 kilograms per hour, about a 95 percent reduction, with the addition of the best available control technology. Also, vinyl chloride emissions from a typical ethylene dichloride-vinyl chloride plant would fall from 176 kilograms per hour to 10 kilograms per hour, about a 94 percent reduction, with the emission controls. Although the vinyl chloride emissions would not be totally eliminated, the standards would further the protection of human health by minimizing the emissions.

Asbestos: Asbestos is a term which refers to any of six naturally occurring crystalline mineral silicates. Although the six substances have different chemical and physical properties–from being resistant to fire to being resistant to attack by acids—as an air pollutant they are treated aggregately as asbestos.

Asbestos fibers enter the atmosphere from a wide variety of sources ranging from the weathering and disturbance of natural deposits of asbestos-bearing materials to the disposal of products containing asbestos. Other emission sources include asbestos mining and milling sites, manufacturing facilities, and construction sites using asbestos insulating, fireproofing, and structural materials. More than 3,000 commercial products contain asbestos. As these products are used, asbestos is frequently emitted to the ambient air. Among these products are automotive brake linings and asbestos-asphalt concrete for paving roadways. Between 1965 and 1969 the United States annually consumed about 800,000 tons of asbestos, approximately one-third of the world production, 74 percent of which was used in the construction industry.

Asbestos is extremely resistant to thermal and chemical change. Settled particles consequently retain their integrity in the environment and may also be reentrained into the atmosphere. By mechanical processes asbestos fibers may be broken down into particles of a size capable of remaining suspended in the air for long periods of time. These factors, together with the presence of a large number of emission sources, have lead to high background concentrations of asbestos in the atmosphere, particularly in urban areas.

The inhalation of asbestos fibers has been related to a number of human diseases among which is included asbestosis. Asbestosis is characterized by a buildup of fibrous tissue and scarring in the lungs which may interfere with normal respiratory or cardiovascular functions. Asbestosis was not recognized until 1900, 22 years after asbestos was first mined on a large-scale basis. The first victim, a British textile worker, inhaled asbestos dust stirred up by the machine he had operated for 14 years. Ten other men, all his co-workers, died before their thirtieth birthdays. Cases of asbestosis were not reported in this country until 1930. Asbestosis is one of the most debilitating of the lung diseases caused by dust inhalation. It generally erupts 20 to 30 years after exposure and exhibits no warning symptoms to mark its early stages. At present, asbestosis has no cure.

Certain cancers and tumor developments have been associated with the inhalation of asbestos. It has been recognized since 1947 that occupational exposure to asbestos can increase the risk of developing bronchial cancer. For the population in general--those exposed to asbestos only in the ambient air--there have been no data compiled to assess the risk. A study in South Africa in 1960 established the relationship of asbestos to the development of mesothelioma, a fatal malignant tumor in the lining of the lungs. This study was the first to suggest that nonoccupational exposures to asbestos were hazardous. One particular feature of mesothelioma which complicates the medical understanding of the disease is that the tumor characteristically appears 30 to 40 years after the initial exposure to asbestos.

Asbestos has also been suspected of producing cancer in the human gastrointestinal tract. This association was most recently suggested when large amounts of asbestos were found in the drinking water in Duluth, Minnesota near a mining operation which released the contaminant into Lake Superior. The exact biochemical processes by which asbestos causes lung and stomach cancers, however, have not yet been determined.

A quantitative definition of the asbestos air pollution problem cannot be formulated until specific dose-response relationships have been established between ambient air concentrations of the pollutant and the resulting human injury. Nevertheless, asbestos has been clearly implicated as a serious air pollution problem. This situation caused the EPA to specify control policies rather than promulgate ambient air quality standards. The EPA emission standard basically states that there shall be no visible emissions to the outside air unless

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[7] *Although beyond the scope of this report, the emission standards for various process operations are defined in the Federal Register, Vol. 40, No. 248.*

certain specific air filtering practices are followed. The emission standard applies only to asbestos mills, manufacturing plants, demolition operations, and spraying and roadway surfacing activities. Mining operations and dumps of asbestos tailings and open storage of asbestos ores are not covered by the EPA standard since the Bureau of Mines and the Occupational Safety and Health Administration (OSHA) regulations exercise this authority. The OSHA has promulgated a standard for levels of exposure to airborne asbestos fibers. This standard, which took effect on July 1, 1976, states that the concentration shall not exceed two fibers longer than five microns per cubic centimeter of air on an eight-hour time-weighted average.

Mercury: The term "mercury" is generally applied to all chemical and physical forms of the element mercury. Elemental mercury is commonly known as a liquid metal, but it can readily evaporate into the air as mercury vapor. Once in the air the vapor may adhere to airborne particles.

Mercury may enter the environment in a number of ways. The high volatility of mercury allows it to seep up through layers of earth to the surface. Such outgassing of mercury from rock and soil, along with its long-range transport abilities, produces a background concentration everywhere. Higher background levels have been found above ore deposits, in underground waters, in hot springs, and near other geothermally heated areas. An estimated 25,000 to 150,000 tons per year of mercury are placed into the atmosphere by outgassing. The estimated contribution of 230 tons per year of mercury from the agitation of the land by agriculture and increased surface exposure by mining is relatively insignificant.

The world industrial production of mercury is 8,800 tons annually, most of which is eventually lost as waste into streams and the atmosphere. In addition, up to 20,000 tons of mercury are released to the ambient air annually by the burning of fossil fuels. The annual global mercury emissions from man-made sources are estimated to approximate 31,000 tons. It should be emphasized, however, that there is little precise data available on the amount of mercury which enters the environment.

Airborne mercury may be inhaled by humans or it may settle out of the air or fall with rain. It has been demonstrated that when mercury concentrations of 50 to 350 $\mu g/m^3$ are inhaled, between 75 and 85 percent of the contaminant is absorbed. Lower concentrations may be absorbed more completely. The central nervous system is the area most susceptible to long-term exposure to mercury vapor. The vapor is absorbed into the blood from the lungs, where it is partially oxidized to mercuric ions. Carried by the blood the mercuric ions are widely distributed, but accumulate primarily in the kidney and liver. Elemental mercury can diffuse into the central nervous system and similar tissues, where more of it is oxidized to mercuric ions. Mercury can accumulate in the brain, testes, and thyroid because its elimination from these sites is slow. In cases of chronic exposure to mercury vapor, symptoms indicating damage to the central nervous system are commonly observed, including tremors, psychological disturbance, loss of appetite, loss of weight, and insomnia. In extreme cases, death from exhaustion may occur.

Mercury may also enter the human body from food and water intake, as well as through direct absorption through the skin. Although data on the quantities of mercury entering the body in such ways are scarce, it has been estimated that from average diets over a long period of time expected mercury intakes would average 10 μg/day.

A Swedish study on the effects of methyl mercury has concluded that an intake of 30 μg/day produces no harmful effects. An intake, however, of 10 times that amount, or 300 μg/day, may be expected to produce symptoms in the most sensitive individuals.[8] Based on estimates of the daily dietary intake–10 μg/day average–mercury intake would have to be limited to 20 μg/day if the total daily intake were to be kept below 30 μg/day. The average human inhales approximately 20 cubic meters of air each day. To remain below an intake of 20 μg/day of mercury, the ambient air levels should be no higher than 1.0 $\mu g/m^3$. Also, because chronic health effects occur with long-term exposure, the emission standard should be designed to restrict mercury concentrations to the 1.0 $\mu g/m^3$ level averaged over 30 days.

Of the major sources of mercury emissions, mercury-cell chlor-alkali plants and primary mercury-processing plants are the only two that are known to emit mercury in quantities and in a manner that will cause the ambient air concentration to exceed 1.0 $\mu g/m^3$, assuming a negligible background level. In consideration of atmospheric diffusion estimates of mercury and the availability of technology to control such emission, the EPA has restricted mercury emissions from these two types of facilities to five pounds per day. Also, the American Conference of Governmental Industrial Hygienists (ACGIH) has adopted maximum, time-weighted average values of 10 $\mu g/m^3$ for a particular mercury compound, alkyl mercury, and 50 $\mu g/m^3$ for all other forms of mercury. These concentrations are based on occupational exposure to mercury at the rate of an eight-hour day and a 40-hour week. The ACGIH standards are commonly adopted by the Bureau of Mines, U.S. Department of Labor, and other regulatory agencies.

Beryllium: Beryllium is one of the most toxic nonradioactive substances known. The health hazards of beryllium were first described in the 1930's, but in 1943 the National Institute of Health attributed its toxic effects to another element, fluoride (F_2), to which beryllium

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[8] *Because methyl mercury and mercury vapor appear to produce similar effects at the same levels, they may be considered equivalent.*

readily combined, rather than to beryllium itself. Subsequent exposure of workers to nonfluoride beryllium compounds indicated that this conclusion was in error.

Beryllium is obtained from beryl ore, most of which is imported into this country from Brazil, Argentina, and Africa. Beryl is the least toxic beryllium compound, and mining operations for this ore are not considered dangerous.

Beryllium may enter the atmosphere as a by-product of the extraction and refining processes which separate beryllium from its ores, or in the manufacturing of beryllium and its compounds for industrial use. Approximately 300 operations such as machine shops, ceramic plants, propellant plants, extraction plants, and foundries comprise the major uses of beryllium that could cause emissions to the atmosphere. The distribution of such sources, however, is such that dangerous ambient air levels have not been recorded except in a few instances.

Beryllium emissions also result from the use of the metal as a component for rocket fuel. Beryllium reacts with oxygen, fluorine and chlorine and gives off heat which adds to the thrust of the rocket motors. Since 1966, however, the U.S. Public Health Service, and later the EPA, has placed restrictions on the emissions of beryllium from rocket firings. Further restrictions were also imposed by the U.S. Department of Defense in a 1967 directive.

Another potential source of beryllium emissions is the combustion of coal. The beryllium content of various deposits of U.S. coal ranges from 1 to 30 parts per million. Although the concentrations are quite low, most of the beryllium becomes airborne upon combustion. The amount of coal presently consumed is not enough to cause a dangerous buildup of ambient air beryllium concentrations; but as coal is increasingly used as an energy source, more beryllium will enter the atmosphere.

The adverse effects of beryllium on human health were first noted in 1940 as a result of the occurrence of lung disease in occupationally exposed workers. Beryllium poisoning may either be acute, having symptoms with less than one year's duration, or it may be chronic, having symptoms which persist for more than a year. The acute effects include inflammation of the skin, areas around the eye, tracheal and bronchial tubes, and nasal mucous membranes, and may lead to chemical pneumonitis--a form of pneumonia. Very severe cases may lead to acute pulmonary edema, which may be fatal.

The chronic form of beryllium poisoning, generally referred to as berylliosis, is a progressive lung disease similar to pneumonia which is characterized by inflammation in the walls of the alveolar sacs. The chronic form has been observed in persons who have never been occupationally exposed to beryllium. Of 60 persons studied in relation to nonoccupationally incurred berylliosis, 27 were found to be exposed to beryllium by washing clothes soiled with beryllium dust, 18 were exposed to air pollution surrounding beryllium plants, 13 were exposed to both of the previous sources, and the remaining two exposures were unknown. There is little evidence for a lasting cure, and the disease progresses in spite of removing the patient from exposure.

Most of the cases of berylliosis involved exposure to beryllium when it was not recognized as a hazardous substance and when its ambient air concentrations were not measured. From retrospective case studies of nonoccupationally exposed persons who incurred berylliosis it has been determined that the lowest concentration which produced the disease was greater than 0.01 $\mu g/m^3$ and probably less than 0.10 $\mu g/m^3$. In 1949, the Atomic Energy Commission (AEC) promulgated a guideline of 0.01 $\mu g/m^3$ beryllium concentration in the ambient air averaged over 30 days in order to protect the public health. Since that time, no reported cases of berylliosis have resulted from ambient air exposure to beryllium.

Based on the maximum permissible beryllium concentration of 0.01 $\mu g/m^3$ averaged over 30 days, and in consideration of the dispersive capability of the atmosphere, it was determined that the beryllium emission standard for all processing facilities could not exceed 10 grams per day. This standard may also be met by the installation of an EPA-approved beryllium monitoring network surrounding the facility in order to demonstrate that ambient air beryllium concentrations do not exceed 0.01 $\mu g/m^3$ on a 30-day average.

A different type of standard was required to regulate the beryllium emissions during the firing of rocket motors. In this case, large quantities of beryllium are emitted within short time periods. The EPA standard states that beryllium emissions from intermittent beryllium sources (rocket firings) shall not exceed a time-weighted concentration of 75 μg-minutes per cubic meter within the limits of 10- to 60-minute intervals during a consecutive two-week period.

The recommended occupational exposure standard states that no worker shall be exposed to more than 2.0 $\mu g/m^3$ of beryllium determined as a time-weighted average for an eight-hour work day. Furthermore, no worker shall be exposed to beryllium levels greater than 25 $\mu g/m^3$ for any 30-minute time period. Questions concerning the total amount of beryllium retained in the body level have not been answered. The main justification for these standards is the lack of occurrence of disease after their enforcement.

Benzene: Benzene is the latest substance to be designated as a hazardous air pollutant by the EPA. On April 14, 1977, the Environmental Defense Fund (EDF) petitioned the EPA to add benzene to the list of hazardous pollutants since it had been shown to cause or contribute to adverse health effects at high levels of exposure. Scientific studies, including a report by

the National Institute for Occupational Safety and Health (NIOSH) released in April 1977, have strongly suggested that the incidence of leukemia, a form of blood cancer, was substantially higher in workers exposed to benzene than in the general population. Consequently, on June 8, 1977, the Administrator of the EPA designated benzene as a hazardous air pollutant which may cause or contribute to an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness.

Benzene is a colorless, highly flammable liquid which burns with a smoky flame. It is produced and used in large quantities throughout the United States mainly as a starting ingredient of many chemical reactions and as a solvent. The principal sources of benzene emissions include chemical manufacturing plants, petroleum refineries, gasoline storage and handling facilities, coke ovens, and automobiles.

Approximately 11 billion pounds of benzene were produced in the United States during 1976. Of this total an estimated 260 million pounds may have been released to the atmosphere. A large number of people are routinely exposed to measurable concentrations of benzene in the ambient air and, while these ambient exposures are at substantially lower levels than occupational exposures, there is reason to believe that such ambient exposures may increase the risk of cancer and should therefore be reduced.

The EPA is presently preparing an assessment of the health risk of benzene which is to be completed by November 1977. It has been the policy of the EPA to recognize that some health risks exist at any level of exposure to cancer-producing chemicals. Under this policy, benzene emissions and resultant ambient air concentrations should be reduced to the lowest possible level. The exact nature and degree of controls on benzene emissions, however, shall depend on the availability of control technology and the relative risk to the public before and after emission controls are applied.

Lead: Lead has not been designated as a hazardous air pollutant since its control to ensure the public health can best be achieved by the promulgation of ambient air standards. For this reason, the EPA is in the process of preparing the air quality criteria document for atmospheric lead.[9]

It has been known for millennia that the ingestion of lead can be lethal. Lead poisoning, sometimes known as "plumbism," was first described by the Greek poet-physician Nicander more than 2,000 years ago. Early Egyptian writings have also indicated an awareness of the toxic nature of lead compounds. More recently, the ingestion by young children of lead compounds in paint chips has emphasized the need to control lead in the environment.

Lead is a soft, dull gray, odorless and tasteless heavy metal. It is most commonly found in natural ores, particularly galena--a lead-sulfur mixture. The relative abundance of lead-containing ores plus the characteristics of lead, including a low melting point, malleability, and resistance to corrosion, all contributed to its use early in human history. Being a component of the earth's crust, lead occurs naturally in water and air as a result of erosion, dust formation from soil, and the diffusion of gases from within the earth to the atmosphere. In addition, large quantities of lead have been placed into the environment as a result of mining the occasional concentrated deposits of lead ores. Natural sources, however, only contribute slightly to the ambient air concentrations of lead. Recent estimates indicate a natural background level of lead at about 0.0005 $\mu g/m^3$, which results from airborne dust containing an average of 10 to 15 ppm of lead.

Lead consumption in the United States approximated 1.3 million tons in 1975. About 80 percent of this consumption was supplied by domestic mines. Commercially, lead is included in batteries, cables, plumbing, weights, metal products, ballast, paints and gasoline additives, and other chemicals. Lead or its compounds may enter the environment at any stage during its mining, smelting, processing, use, or disposal. Recent estimates of the contributions of major sources of lead emissions indicate that the atmosphere is the primary component of the environment contaminated from man-made sources. These estimates also indicate that the primary man-made contributor of lead emissions is motor vehicle exhaust as result of the combustion of lead additives in gasoline. About 180,000 tons, or 70 percent, of the 257,000 tons of lead used in gasoline, and about 90 percent of the total lead emissions are emitted directly into the atmosphere each year. The remaining 30 percent is stored as deposits in the engine and exhaust system where it is either removed in the waste oil or gradually flakes off as very large particles which rapidly fall to the road surface.

Stationary sources place about 18,000 tons of lead, or 10 percent of the total emissions, into the atmosphere each year. Most of these emissions are a result of waste incineration, metallurgical operations, and consumer product manufacturing.

Human exposure to lead may be through the air, water, soils and dusts, and food, and by direct contact with the metal or its compounds. Consequently, lead may be inhaled into the respiratory system, ingested into the gastrointestinal tract, or absorbed through the skin. For humans and animals the major source of lead intake is food. Daily intake of lead in foods, including water and beverage consumption, averages about 300 μg for adults, with a range of from 100 to 500 μg for most people. Generally, high levels of lead are found in relation to large food intakes and high seafood consumption, and to

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[9] *Draft copies of this document were released for public review in November 1976.*

the frequent consumption of fame containing lead shot. Of the total amount of lead ingested by adults, between 5 and 10 percent is absorbed.

Exposure to lead in the ambient air is variable in the general population. Since ambient air concentrations are directly related to motor vehicle emissions, persons residing in urbanized areas are likely to be exposed to high lead levels than persons residing in rural areas. Furthermore, the quantity of air inhaled varies markedly with such factors as age, sex, and amount of physical activity. It has been found, however, that less than 30 percent of the inhaled lead is actually absorbed by the adult body.

Of particular significance is the difference of lead intake patterns between adults and children. It has been found that exposures to ambient air concentrations of lead account for a much smaller proportion of the total absorption by children than by adults. Also, since children have the tendency to mouth or ingest nonfood products, the amounts of dust and other lead-containing materials, such as paint, are a much more significant source of lead than that inhaled.

The lead level in the blood generally reflects the exposure to lead from all sources. The level of lead in the blood can also be related, but with less certainty, to lead levels in other tissues and to physiological alterations or disturbances caused by lead. From numerous studies of various population groups it has been determined that the mean lead content of the normal adult is about 20 μg per 100 milliliters (ml) of blood. Groups living in urban areas always showed somewhat higher levels–about 20 percent. There is also a difference between male and female adult lead levels, with males having about 20 percent more lead than females.

Obvious symptoms of lead poisoning rarely appear until blood lead levels reach at least 80 μg/100 ml. Biological responses to lead around this level include anemia and intestinal cramps. At considerably higher levels, encephalitis, an inflammation of the brain, may occur. The brain, kidney, and blood are the most sensitive organs to the effects of lead. In the blood, subtle changes in chemical functions may occur at levels slightly higher than the mean population level of 20 μg/100 ml. When the blood lead level reaches 25 to 30 μg/100 ml in children and women, and 35 to 45 $\mu g/m^3$ in men, the formation of certain enzymes are significantly inhibited. The affected enzymes are of fundamental importance to the normal metabolism of the body. Also, hemoglobin levels have been shown to be lowered when blood lead levels range from 40 to 110 μg/100 ml.

The central nervous system is particularly sensitive to lead. Encephalopathy, a disease of the brain characterized by structural alterations, may occur from acute exposures to lead and be followed by coma and cardiorespiratory arrest. Lead encephalopathy usually does not occur until blood lead levels exceed 120 μg/100 ml. Those individuals who survive the disease show a high incidence of permanent brain damage which may cause periodic convulsions, irritability, hyperactivity, retardation of normal development, and impaired motor development. There is also evidence to suggest that neurological damage may occur in children who chronically have blood lead levels as low as 40 μg/100 ml. Hyperactivity has been observed in children with blood lead levels between 25 and 55 μg/100 ml.

Lead toxicity may produce structural and chemical changes in kidney cells. Although these kidney changes appear to be reversible when exposure to lead is mild, it is known that permanent kidney damage results from prolonged overexposures. The degree and duration of exposure necessary to produce such irreversible kidney damage, however, are not known.

There is no definitive evidence of adverse biological effects in the general adult population due to exposure to lead except in limited areas around smelters. The problem primarily involves children. Children are particularly susceptible since they ingest more lead than do adults exposed to similar environments, and their developing brains are more easily damaged than mature brains.

Based on these observed criteria, the EPA is recommending that the ambient air concentrations of lead and its compounds not exceed a level of 5.0 $\mu g/m^3$ averaged over at least three months. At this level the contribution of inhaled lead should not exceed 5.0 μg/100 ml of blood. Maintenance of the inhalation contribution at this recommended level will not eliminate the lead toxicity problem, particularly in children, but should help ensure that blood lead in the general population will not produce adverse biological responses provided lead absorbed through ingestion does not occur in abnormal exposure patterns. Removal of lead from paint and gasoline, as presently required by law, will greatly reduce further contamination of the environment.

AMBIENT AIR QUALITY MONITORING

Monitoring ambient air pollutant concentrations serves six general purposes: it defines the nature and geographic extent of the air pollution problem; it establishes relationships between air pollution levels and such factors as topography, meteorology, land use, and transportation system development and utilization; it relates air pollution levels to human health effects, plant and animal damage, property deterioration, and aesthetic losses; it provides a measure of the effectiveness of air pollution control programs; it identifies sources of air pollution which require the greatest controls; and it provides a direct comparison with established ambient air quality standards. Accordingly, a sound inventory of ambient air quality, which may be considered representative of the true atmospheric pollutant concentrations within the Region, is essential to any air quality maintenance planning effort.

Air quality monitoring may be categorized into two general areas according to the physical nature of the pollutants measured: measurements of solid materials in the atmosphere and measurements of gaseous materials in the atmosphere. The mass of solid particles is determined most often by directly weighing collection devices such as filter pads which have been exposed to a stream of ambient air. Since, however, the mass of gaseous pollutants cannot be directly weighed, measurements of their concentrations in the ambient air depend on observations of chemical reaction rates with a given substance. It has generally become acceptable to report particulate matter concentration levels in terms of unit mass per unit volume of air such as micrograms per cubic meter ($\mu g/m^3$), and to report gaseous pollutants in terms of the ratio of their volume to the volume of ambient air; that is, in parts per million (ppm). The two units of measure may be used interchangeably, however, with little loss of accuracy with the conversion factors given in Table 67 for selected pollutants. For convenience, this report presents all ambient air pollution levels in terms of the units of measurement used for the instrumentation concerned.

In order to satisfactorily characterize the nature and extent of the air pollution problems, a monitoring network must be established which is based on the development of standardized monitoring procedures and the use and maintenance of reliable instrumentation, as well as on the efficient placement of monitors to maximize the representativeness of collected air samples. In the following sections a review of the available technology for measuring ambient air pollutants is presented, with particular attention paid to those instruments and procedures recommended by the U.S. Environmental Protection Agency (EPA). Also, a historical examination of the air quality monitoring efforts in southeastern Wisconsin by federal, state, and local governmental agencies is provided to preface a summary of the findings and conclusions which may be drawn from the monitoring data collected within the Region.

Air Quality Sampling Procedures and Instrumentation

Monitoring Procedures for Particulate Matter: Air quality monitoring for particulate matter levels may be performed for either particles that settle out of the atmosphere close to their source and in a relatively short period of time, or for those particles which may remain in suspension over great distances from their source and for long periods of time. Both of these monitoring techniques have been used in the Region and are discussed below.

Settleable Particulate Matter: There are two methods by which particulate matter which is gravitationally removed from the atmosphere may be measured: sticky paper and dustfall jars. The use of the sticky paper sampling method, in which an adhesive-coated paper is weighed before and after exposure to the atmosphere for sustained periods to obtain a net deposition rate, never had widespread use in the Region. An alternative method based on a similar principle was the "dustfall jar" technique, which achieved much more widespread application. In this method, containers are placed in elevated locations where local obstructions do not interfere with the gravitational settling of atmospheric particles. The containers range from four to eight inches in diameter, are tall enough to accommodate expected monthly dust fall, and are normally partially filled with distilled water to which a solution of either alcohol or glycerin compounds is added to prevent evaporation or freezing under varying meteorological conditions. Collection of particulates is also done on a dry basis without the use of a fluid medium. In the wet method, algicides and fungicides are sometimes used to inhibit bacterial growth.

The advantages of dustfall jars are their relatively low cost and easy maintenance. The common practice is to use an approximate 30-day sampling period and report the net weight of the materials deposited in the jar, generally in equivalent units of tons per square mile per month. In some cases total solids are reported, and in others only the materials that are insoluble in the collecting medium are reported.

The disadvantage of using dustfall jars is that for many years there was no uniform procedure for the collection and analysis of settleable particulates and, therefore, results were not comparable from all areas of the country. It was not until 1962 that the American Society for Testing and Materials (ASTM) initially standardized the sampling, analytical, and reporting methods for measuring dustfall.

Table 67

CONVERSION FACTORS BETWEEN VOLUME AND MASS UNITS OF CONCENTRATION FOR SELECTED AIR POLLUTANTS

Pollutant[a]	To Convert from Micrograms[b] per Cubic Meter (mass) to Parts per Million (volume) Multiply by:	To Convert from Parts per Million (volume) to Micrograms[b] per Cubic Meter (mass) Multiply by:
Sulfur Dioxide	3.82×10^{-4}	2617.80
Carbon Dioxide	8.73×10^{-1}	1.15
Nitrogen Dioxide	5.32×10^{-4}	1879.70
Hydrocarbons (as methane)	1.53×10^{-2}	653.59
Ozone	5.10×10^{-4}	1960.78

[a] *At an atmospheric temperature of 25°C and a standard atmospheric pressure of 760 millimeters of mercury (mm Hg).*

[b] *For carbon monoxide the units are in milligrams per cubic meter.*

Source: A.C., Stern, Fundamentals of Air Pollution, Academic Press, New York, 1971, and SEWRPC.

The Milwaukee County dustfall sampling program obtained monthly samples between 1951 and 1971 from a minimum of 50 sites and, on occasion, from as many as 70 sites. Glass containers, six inches in diameter and eight inches high with a glycerin-water collecting solution, were used consistently from the onset of the program. The results were reported as total solids (solubles plus insolubles) in tons per square mile per month.

The dustfall monitoring sites were located in five characteristic land use areas or zones: agricultural, residential, commercial, local business, and industrial. Table 68 presents the average monthly deposition rates in these five zones for selected years between 1951 and 1971 for the 44 stations which were in continuous operation during that 20-year period. It may be seen from the table that substantial reductions in settleable particulates were achieved in the industrial zone, with a net decrease of nearly 60 percent in deposition rates between 1951 and 1971. The local business and commercial zones also indicated significant decreases of about 53 and 40 percent, respectively, between these two years. On the other hand, the deposition rates for the agricultural and residential areas decreased only slightly since 1951. Moreover, the percentage of the total deposition in the agricultural and residential zones rose from about 7 and 11 percent, respectively, in 1951, to about 12 and 17 percent, respectively, in 1971, indicating the encroachment of urban development into the more rural areas of the County. The recent trends in particulate matter concentrations over the entire Region are presented in more detail later in this chapter.

Suspended Particulate Matter: Two methods are commonly used to measure the quantity of small particles which remain indefinitely suspended in the air. The first, and most universally accepted method, is the high-volume, or hi-vol, gravimetric method.[10]

The hi-vol sampler, shown in Figure 36, draws air into a covered housing and through a filter by means of a high-flow-rate blower at a flow rate of 40 to 60 cubic feet of air per minute. Particles in the size range of from 0.1 micrometer (μ) to 100 μ are ordinarily collected on the glass surface of the filter. The mass concentration of suspended particles in the ambient air is computed by measuring the mass of collected particles and the volume of air sampled. The hi-vol sampler is generally operated for a 24-hour period, although in cases of very high particulate matter concentrations a representative sample may be taken in six to eight hours.

The hi-vol monitor is the sampling method against which the ambient air quality standards for particulate matter are measured. As such, the hi-vol monitoring technique is termed the "reference" method. The EPA has determined a reference method for each of the six pollutants for which ambient air quality standards have been pro-

[10] *Methods involving weighing to analyze a collected sample, whether it is for a particular size fraction, chemical constituents, or the total particulate, are termed gravimetric methods.*

Table 68

AVERAGE ANNUAL PARTICULATE DEPOSITION RATE IN MILWAUKEE COUNTY BY ZONING DISTRICT: SELECTED YEARS 1951-1971[a]

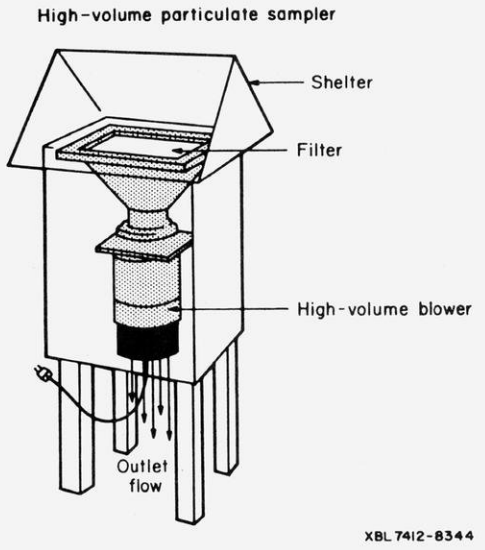
Zoning District	Number of Sites		Tons per Square Mile per Month												
	Minimum	Maximum	1951	1957	1960	1961	1962	1963	1965	1966	1967	1968	1969	1970	1971
Agricultural . .	4	5	14.0	15.4	13.5	14.1	14.0	20.4	25.2	26.0	29.5	24.0	18.3	21.4	13.4
Residential . . .	16	19	22.4	19.8	14.2	14.5	12.4	21.2	23.8	23.4	22.8	22.5	19.4	21.7	18.8
Commercial. . .	2	2	45.8	47.9	34.6	36.5	38.1	36.8	41.6	36.8	45.6	40.6	35.1	23.3	27.5
Local Business. .	9	12	36.5	27.1	23.4	23.8	24.4	29.8	25.4	26.1	29.2	29.6	23.1	23.4	17.1
Industrial . . .	13	15	82.1	56.3	36.0	35.3	41.6	41.3	45.4	41.7	43.1	42.4	40.8	37.5	33.6

[a] *Variations in land use and urban expansion are evident in the averages from these selected years. Emissions over the 20-year period have generally been reduced, but not in equal proportions. Industrial districts have shown the greatest proportionate decrease, while agricultural and residential zones have exhibited an overall rise in the percentage of the total emissions. This measure of particulate matter should be taken as an approximation since, unless extreme care is observed, extraneous contaminants easily bias the final value. Advances in instrumentation have produced more sophisticated and reliable techniques for monitoring particulate pollution.*

Source: Milwaukee County Department of Air Pollution Control.

Figure 36

HIGH-VOLUME PARTICULATE MATTER SAMPLER



Assembled sampler and shelter

Source: U. S. Environmental Protection Agency.

mulgated. In addition, the Administrator of the EPA has identified equivalent methods, that is, any method of sampling and analyzing for an air pollutant which has been satisfactorily demonstrated to be consistent with the reference method, which may be used alternatively to monitor air pollutant levels. The reference method for each pollutant species is presented in Table 69, along with representative equivalent methods.

It may be seen from Table 69 that there is no equivalent method for measuring ambient air concentrations of particulate matter. An alternative to the hi-vol method, however, has achieved widespread usage in the country although its results are not comparable to the ambient air quality standards. This method is the continuous tape sampler.

The tape sampler, as shown in Figure 37, basically consists of a vacuum pump, a filtering mechanism, and a timing device. The timing device allows the sampling period to be varied automatically from about five minutes to three hours, thereby making it possible to more accurately measure peak periods of pollution instead of an average value over a long sampling period as with the hi-vol method. The pump pulls air through the filter tape at a rate of between 0.1 and 0.5 cubic foot per minute for a preselected period of time, after

Table 69

REFERENCE AND EQUIVALENT METHODS FOR MEASURING AMBIENT AIR POLLUTANT CONCENTRATIONS

Pollutant	Reference Method	Equivalent Method(s)
Particulate Matter	High-Volume Sampler	None
Sulfur Dioxide	Pararosaniline[a]	Gas Chromatographic Separation-Flame Photometric Detection Flame Photometric Detection Coulometric Detection
Carbon Monoxide	Nondispersive Infrared Spectrometry	Gas Chromatographic Separation-Catalytic Conversion-Flame Ionization Detection
Nitrogen Dioxide	—[b]	Saltzman Method Christie Arsenite Method Chemiluminescence Method
Hydrocarbons	Gas Chromatographic Separation-Catalytic Conversion-Flame Ionization Detector	None
Ozone	Gas Phase Chemiluminescence	Potassium Iodide Colorimetric Detection Ultraviolet Photometric Detection of Ozone

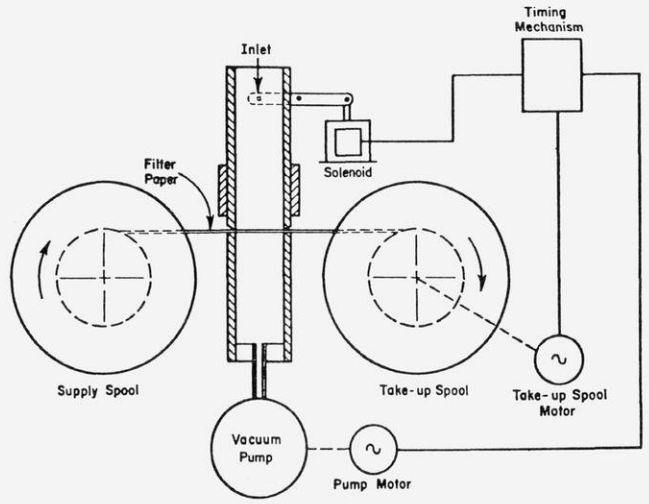
[a] *The pararosaniline method has recently been questioned as to its ability to reliably measure sulfur dioxide concentrations over a wide range of ambient temperature conditions. Of the 11 continuous sulfur dioxide monitoring sites in the Region, only two use the pararosaniline method. The remaining eight stations use the flame photometric detection method.*

[b] *The Jacobs-Hochheiser method was the EPA reference method for detecting nitrogen dioxide concentrations in the ambient air until the EPA rescinded its designation on June 8, 1973, after noting certain deficiencies which lead to unreliable measurements.*

Source: Federal Register, 36, No. 158, page 15486, August 14, 1971, and SEWRPC.

Figure 37

CONTINUOUS TAPE SAMPLER



Source: U. S. Environmental Protection Agency.

which the tape is advanced to a new spot. These spots are then analyzed for their particle content on the basis of the amount of light absorbed by the collected particles. The analysis is conducted by passing a beam of light through a clean area on the filter tape to a photoelectric cell. The intensity of the light beam incident on the cell is adjusted until a reading of 100 percent light transmittance is attained. The exposed spot on the filter is then placed between the light source and the photoelectric cell, and the reduction in the intensity of the light reaching the cell is measured. The standard unit for reporting these measurements is the coefficient of haze (COH).

Despite the flexibility of the tape sampler in monitoring short-term concentrations, there are a number of disadvantages associated with its use. The primary limitations of the tape sampler are its inability to collect other than very fine particles and the small quantity of material collected on each spot. Since the tape sampler cannot collect particles as large as those collected by the hi-vol method, its measurements cannot be considered as a direct indication of ambient air particulate matter concentrations. The small amount of material collected also does not permit other types of analyses, particularly chemical analyses, to be conducted.

Monitoring Procedures for Sulfur Dioxide: Monitors for ambient air sulfur dioxide concentrations may be of the static, mechanical, or continuous type. A static monitor is one which does not utilize any moving parts or fluids. A mechanical sulfur dioxide monitor takes a number of sequential samples by bubbling air into solution bottles. Both the static and mechanical monitoring samples are analyzed chemically in a laboratory. A continuous type of sulfur dioxide monitor, however, is capable of sampling and analyzing the ambient air at the point of observation without the need of a laboratory. Further, the results from a continuous monitor may be recorded on a strip chart and left unattended for extended periods depending on the need to calibrate and maintain the instrument. In the following sections, a review of the processes involved with each of the three sulfur dioxide monitoring devices is provided.

Static Sulfur Dioxide Monitoring: Static sulfur dioxide samplers are based on the lead dioxide (PbO_2) sulfation plate or candle which have been in use since the 1930's. The procedure fundamentally involves the reaction of sulfur dioxide with lead dioxide to form lead sulfate. This reaction may be written as, $SO_2 + PbO_2 \rightarrow PbSO_4$. The lead candle itself is made by painting a thin layer of lead dioxide paste on a gauze cylinder and allowing it to dry. After exposure to atmospheric sulfur dioxide the lead dioxide layer is removed and the sulfate content determined, commonly by a gravimetric procedure. The results are generally reported as a sulfation rate in units of milligrams of sulfur trioxide per 100 centimeters square per month or per day (mg SO_3/100 cm^2/month).[11]

The use of lead candles in determining sulfation rates is hindered by two types of interference. First, the reaction between lead dioxide and sulfur dioxide may be affected by the presence of other atmospheric contaminants. Such compounds as ammonium sulfate or hydrogen sulfate can contribute to the sulfation rate and lead to erroneously high measures of sulfur dioxide. Second, certain substances will inhibit or enhance the contact between sulfur dioxide and lead dioxide. Atmospheric soot particles, for instance, will occasionally cover the reaction rate. Atmospheric moisture, on the other hand, increases the sulfation rate. Despite these limitations, the lead candle technique is useful for relative measures of sulfur dioxide concentrations.

Mechanical Sulfur Dioxide Monitoring: The procedure followed in mechanical, or manual, sulfur dioxide monitoring is to bubble an air sample through an absorbing solution which is then analyzed in a laboratory, generally by the pararosaniline method. As may be seen in Table 69, the pararosaniline method is the monitoring procedure recommended by the EPA. The pararosaniline method, often referred to as the West-Gaeke method after its inventors, measures the color intensity of the pararosaniline dye at a fixed wavelength which is proportional to the concentration of sulfur dioxide. The color of the dye ranges from a light red to a deep purple with increasing sulfur dioxide concentrations. This procedure may also be adapted to a continuous mode of operation as will be seen in the next section.

Continuous Sulfur Dioxide Monitoring: There are numerous techniques for the continuous monitoring of ambient air sulfur dioxide concentrations. The techniques

[11] *This unit may be converted into units of sulfur dioxide by the formula: ppm (SO_2) = (0.03) mg SO_3/100 cm^2/month.*

may be classified into three general categories based on their underlying principle of operation: wet chemical, electrochemical, and physical. The wet chemical principle, consisting of the conductivity, colorimetry, and coulometry methods of detection, has been in widespread use for many years and has been thoroughly field-tested. The relatively new electrochemical devices, introduced around 1970, are based on measurements of an electrical current induced by the oxidation of sulfur dioxide. The physical methods of sulfur dioxide detection are even less dependent on chemical analysis and are based mainly on spectroscopy. A brief discussion of the characteristics of each major detection principle is presented below.

The Wet Chemical Technique: The first continuous sulfur dioxide monitor was invented in 1929 and measured the conductance of electricity by an absorbing solution into which sulfur dioxide has been dissolved by contact with the ambient air. The solution may either be distilled water or hydrogen peroxide. As increasing amounts of sulfur dioxide are absorbed by the solution, the resistance to the passage of electricity through the solution is reduced. The conductivity method is popular because of its high sensitivity, fast response time, minimal maintenance, and simple operation. It is, however, subject to interference from other atmospheric gases.

As mentioned under the section on mechanical sulfur dioxide monitors, the pararosanoline method is the EPA reference method for determining ambient air levels of this pollutant. The pararosaniline method is one of a number of similar procedures which measure sulfur dioxide concentrations through use of colored dyes. These procedures are termed colorimetric analyses. The original pararosaniline procedure as developed in 1956 by P. W. West and G. C. Gaeke has since been improved upon to eliminate interference from heavy metals, and from nitrogen oxides and ozone among other gases. In principle of operation the procedure is the same as the mechanical method with the exception that 24 one-hour air samples are bubbled through individual solution bottles sequentially prior to laboratory analysis. The pararosaniline method has lately come under question, however, as to the influence of ambient air temperatures during removal and transport of the solution bottles between the monitoring site and the laboratory. It has been suggested that nonrefrigerated solution bottles yield inaccurately low values of sulfur dioxide concentrations.

The coulometric method of ambient air sulfur dioxide detection measures the electrical current necessary to maintain a fixed concentration of a particular element, usually bromine or iodine, dissolved in water. This current is proportional to the amount of absorbed sulfur dioxide. Since it is the electrical current and not the electrical charge that is measured, this method is often referred to as the amperometric method. The change in electrical current may be continuously recorded on a strip chart. The primary advantage to this method is its low maintenance requirements. As shown in Table 69 the coulometric detection method is an equivalent method for monitoring sulfur dioxide concentrations.

The Electrochemical Technique: The electrochemical technique avoids the wet chemistry associated with the conductimetric, colorimetric, and coulometric methods. Electrochemical monitors measure the increase in electrical current flowing between the two materials, which takes place as the ambient air concentrations of sulfur dioxide increase. Commercially available electrochemical monitors are typically light in weight and low in power consumption. Replacement or rejuvenation of the sensing units, however, can be expensive and is generally required at six-month intervals. Also, since the sensing units deteriorate gradually, continuous calibration of the monitor is necessary.

The Physical Technique: The physical presence of sulfur dioxide in the ambient air may be directly measured by devices which use such sophisticated technology as lasers and microwaves. The most reliable of the physical measurement methods, however, is spectroscopy. Spectroscopy measures the absorption of light at certain wavelengths characteristic of the substance being monitored. Since each substance is unique as to its absorption characteristics, spectroscopy may be used to detect the presence of any gaseous pollutant.

A device known as a nondispersive infrared spectrometer has frequently been used to monitor sulfur dioxide concentrations. This instrument consists of two chambers separated by a flexible diaphragm, both of which are filled with sulfur dioxide. These chambers are heated by focusing a beam of infrared energy through a reference cell containing a gas, such as nitrogen or argon, which does not absorb the energy, and a second beam of infrared energy through a sample cell containing the ambient air. As each chamber is heated, the internal pressure rises. The pressure rise is greater in the chamber which has been heated by the infrared energy passing through the reference cell since some of the energy passing through the sample cell has been absorbed by the sulfur dioxide in the air before reaching the chamber. The result is that the diaphragm is displaced toward the sample cell. This displacement is directly proportional to the amount of sulfur dioxide in the ambient air. The nondispersive infrared spectometer can measure only one gas at a time—that with which the chambers have been filled. A refinement of this technique, known as the nondispersive infrared spectrometer can measure only one a single, preselected gas but is able to measure any gas within a wide range of wavelengths. Both of these techniques, however, are subject to interference from other atmospheric gases.

Another variation of spectroscopy for measuring sulfur dioxide in the ambient air uses a device called a flame photometric detector. With this device, ambient air is burned in a stream of hydrogen. The light which is produced is focused through a lens, filtered to eliminate all but the wavelength characteristic of sulfur, and measured for intensity by a photomultiplier tube. The intensity increases as ambient air concentrations of sulfur compounds increase.

The flame photometric detector is not capable of distinguishing sulfur dioxide from all other sulfur-containing compounds. In order to separate the various sulfur compounds a process of filtering known as gas chromatography may be used prior to the spectral analysis. Comparisons of the gas chromatographic-flame photometric detector field measurements and the simple flame photometric detector measurements have produced nearly identical results, indicating that measurements for total sulfur are probably synonymous with measurements for just sulfur dioxide. As may be seen in Table 69, both the flame photometric detector method and the gas chromatographic-flame photometric detection method are EPA-approved equivalent monitoring techniques for measuring sulfur dioxide concentrations.

Monitoring Procedures for Carbon Monoxide: As shown in Table 69, the EPA reference method for monitoring ambient air concentrations of carbon monoxide is the nondispersive infrared detection technique. This method is identical in procedure with that described for sulfur dioxide except that carbon monoxide is substituted into the measurement chambers. With some modifications, the dispersive infrared, colorimetric, coulometric, and electrochemical detection methods may also be used to monitor for carbon monoxide.

An equivalent method of carbon monoxide monitoring involves using gas chromatography with a catalytic converter and a flame ionization detector. This method may also be adapted to measure hydrocarbon concentrations. The first step in the procedure is to separate the carbon monoxide and the hydrocarbons from the other atmospheric gases in the air sample. This is done by gas chromatography. The carbon monoxide is then converted to methane by heating the gas in the presence of a catalyst. Finally, the methane is burned in a hydrogen flame and the combustion products, which carry an electrically negative charge, are attracted to a positive electrode in the combustion chamber. The buildup of the charged particles on the positive electrode produces an electrical current which may be directly measured. The current increases with increasing deposits of ionized particles which, in turn, are directly proportional to the original carbon monoxide concentration of the air sample. This procedure requires frequent calibration and maintenance.

Monitoring Procedures for Nitrogen Dioxide: As shown in Table 69, the EPA reference method for measuring ambient air concentrations of nitrogen dioxide was the Jacobs-Hochheiser method. On June 14, 1972, however, William D. Ruckelhaus, then Administrator of the EPA, stated that this method was suspected of being unreliable and would be reevaluated. Subsequently, on June 8, 1973, the EPA published its analysis of the Jacobs-Hochheiser method noting two particular deficiencies. First, the method overestimates nitrogen dioxide concentrations at low ambient levels and underestimates them at high ambient levels. Second, the method is subject to interference from nitric oxide. As a result of these deficiencies, the Jacobs-Hochheiser method is no longer the approved reference method for measuring nitrogen dioxide concentrations.

As an alternative to the Jacobs-Hochheiser method, the EPA has designated three equivalent methods: the Saltzman, Christie arsenite, and continuous chemiluminescence methods. The Saltzman method is a colorimetric procedure which measures the intensity of a red dye at a specific wavelength formed when nitrogen dioxide reacts chemically with a coupling reagent. Although similar in principle of operation to the pararosaniline method for the detection of sulfur dioxide, the Saltzman method is not as subject to interference from other chemical compounds found in the ambient air. One major disadvantage of the method, however, is that it cannot be used sucessfully because of color fading when the delay between sample collection and color measurement is more than four to six hours or when sampling periods are longer than one hour. Even with these limitations, the American Society for Testing and Materials has selected the Saltzman method as the standard method for monitoring nitrogen dioxide concentration in the air.

In the Christie arsenite method, nitrogen dioxide is bubbled through a sodium hydroxide-sodium arsenite solution to form a stage solution of sodium nitrate. This method is applicable to collection of 24-hour samples in the field and subsequent analysis in the laboratory. Collected samples are stable for at least six weeks. In the laboratory the sodium nitrate solution is chemically reacted with a reagent to form a dye which is proportional in color intensity to the amount of nitrogen dioxide initially absorbed. The Christie arsenite method is subject to interference from sulfur dioxide and nitric oxide but these interferences can, for the most part, be eliminated by chemical treatment of the sodium nitrate solution prior to the colorimetric analysis.

The chemiluminescence method may be used to detect both nitric oxide and nitrogen dioxide, though the measurement for the latter is made indirectly. In principle the chemiluminescence method is based on the reaction between nitric oxide and ozone which produces a radiant emission that is detected by a photomultiplier tube. This chemiluminescent reaction is applicable only to the direct measurement of nitric oxide. To detect the total oxides of nitrogen, conversion of nitrogen dioxide to nitric oxide is first required. Nitrogen dioxide is then recorded as the difference between the nitric oxide and total nitrogen oxide measurements. The advantages of chemiluminescent analyzers include direct continuous measurements, fast response time, minimal interferences from other gases, and an excellent sensitivity over a wide range of concentrations. In addition, the need for a laboratory to perform the wet chemical analysis as required by the Saltzman and Christie arsenite methods is eliminated. The size, weight, and cost of such analyzers may, however, be considered significant disadvantages.

Monitoring Procedures for Hydrocarbons: The flame ionization detection (FID) method is the most widespread hydrocarbon sensing method presently in use. Hydrocarbons containing nitrogen, oxygen, or halogen atoms give a reduced response, and therefore FID hydrocarbon analyzers are generally calibrated in terms of a gas

such as methane (CH_4). Consequently, the ambient air quality standard for hydrocarbons specifies that all nonmethane hydrocarbons be measured as methane.

Prior to measurement by the flame ionization detector, all other air pollutants except the hydrocarbon compounds are filtered from the air sample using the gas chromatographic separation technique. The remaining mixture of hydrocarbon compounds is then divided into two separate samples. The first sample is fed into a flame ionization detector, which operates under the same procedure described for measuring carbon monoxide, and the total hydrocarbons present are measured. The second sample is fed to a catalyst that selectively combusts all hydrocarbons but methane. The residual methane hydrocarbons are then fed to and measured by the flame ionization detector.

As shown in Table 69, the gas chromatographic-catalytic conversion-flame ionization method is the reference method for measuring ambient air hydrocarbon concentrations. At the present time, the EPA has not approved any equivalent method.

Monitoring Procedures for Ozone: Monitoring for ozone may be either manual, generally suing wet chemical techniques, or continuous, through automatic analyzers. Since the ambient air quality standards are given in terms of one—hour averages, manual techniques may be eliminated from discussion as being incapable of adequately monitoring the air for such short time periods.

As shown in Table 69, the EPA reference method for measuring ambient air ozone concentrations is the gas phase chemiluminescence method. This method is based on the principle that reactions of chemical species in the gas phase are accompanied by a characteristic emission of light. This light can be detected by a photomultiplier device and related to the ozone concentration in the air sample under investigation.

The technique utilized for the chemiluminescent detection of oxides of nitrogen involves the mixing of ozone with nitric oxide. In this procedure a constant source of ozone is reacted with a measured air sample containing nitric oxide. For the determination of ozone levels a constant source of nitric oxide is fed into the air sample and the resultant light emissions are monitored—a simple reversal of the first procedure.

There are two other chemiluminescent-type monitoring procedures which operate on the same principle as the above procedure but which replace nitric oxide with another reactant. One monitor is based on the light emission from the ozone-ethylene reaction, and the other on the light emission from the ozone-Rhodamine-B reaction. The response and operating characteristics of all three types of chemiluminescent monitors have shown good correlation and proved about equally reliable.

There are two additional methods, deemed by the EPA as equivalent to the chemiluminescence method, for measuring ambient air ozone concentrations. One method is based on the chemical reaction of ozone with a solution of water containing potassium iodide (3KI). As an air sample containing ozone is continuously bubbled through the solution, the ozone reacts with the potassium iodide to produce the tri-iodine ion (I_3), which may be determined by spectrometry and recorded on a strip chart.

The second equivalent method involves the ultraviolet photometric detection of ozone. This method is based on the principle that ozone is a very strong absorber of ultraviolet light at a characteristic wavelength. Procedurely, air samples alternately bypass and then pass through a catalytic converter which removes ozone selectively. The sample of air stripped of ozone enters a chamber where it is irradiated by ultraviolet light. The amount of light transmitted through the chamber is measured by a photodetector and serves as the reference measurement. The air sample containing ozone then enters the chamber. The photodetector now measures the reduction in ultraviolet light due to its absorption by the ozone. The difference is then recorded as the ozone concentration.

Air Quality Management and Monitoring Efforts in Southeastern Wisconsin

Air quality management, monitoring, and control efforts of various kinds are not new to the Southeastern Wisconsin Region. Such efforts have been carried out at various times in the past by two of the seven counties within the Region and three of the cities within the Region, as well as by the State of Wisconsin and the federal government. The first air pollution control legislation in the Region was passed by the City of Milwaukee in 1904 and was directed at the reduction of smoke emissions. In 1948 Milwaukee County assumed responsibility for air pollution control on a countywide basis in an effort to abate the nuisance-producing pollutants—smoke, soot, fly ash, dust, and other visible particulate pollution. The program was most successful and, through the enactment and strict enforcement of air pollution control regulations relating to marine power, railroad motive power, incineration, stationary power, and heating sources, achieved large decreases in the annual particulate deposition rates in the County.

With the exception of Milwaukee County, no other state or areawide air pollution control programs existed within the Region prior to 1969. Monitoring for air quality pollutant levels within the Region, however, was initiated during 1957 by the federal government. The Quality Assurance and Environmental Monitoring Laboratory (QAEML) of the EPA carries out a variety of air sampling activities to obtain information about ambient air quality throughout the United States. Part of the function of the QAEML is the operation of the National Air Surveillance Network (NASN). This network is comprised of three units: The Hi-Vol Network, which samples particulates, became operational in 1957; the Gas Sampling Network, monitoring nitrogen dioxide and sulfur dioxide, was initiated in 1959; and the Continuous Monitoring Projects (CAMP), which collects data on sulfur dioxide, oxides of nitrogen, carbon monoxide, total hydrocarbons, and ozone in selected cities across the country,

was begun in 1962.[12] Under the NASN program, which initially established 170 monitoring stations, a high-volume air sampler was located in downtown Milwaukee in 1957 to collect suspended particulate matter samples on a twice monthly basis for analysis and interpretation at the U.S. Public Health Service laboratories. In 1961, the sampler site was upgraded to include monitoring for sulfur dioxide and nitrogen dioxide. In 1963 similar stations were located above the police headquarters in the City of Racine and above the Municipal Building in the City of Kenosha. The data provided by these stations supplemented data on annual particulate deposition rates collected by the Milwaukee County Department of Air Pollution Control.

In 1967 Milwaukee County expanded its ambient air quality monitoring program by securing 10 additional hi-vol particulate samplers and instrumentation to monitor gaseous pollutants on a continuous basis. In 1969 a mobile air quality monitoring van which sampled for solid and gaseous pollutants and obtained data on wind speed and direction was placed into operation by Milwaukee County.

As the monitoring effort in Milwaukee County continued to expand, the Wisconsin Department of Natural Resources (DNR) began in 1970 to establish an air quality surveillance network in the other six counties within the Region. In January 1975, the DNR assumed responsibility for all monitoring activity within Milwaukee County and, with the exception of the Racine County Department of Air Pollution Control and the NASN surveillance sites, presently conducts all air quality sampling efforts in southeastern Wisconsin. Table 70 presents a historical summary of the air quality monitoring activities which have taken place within the Region over the past two decades. The existing monitoring network, as well as historical monitoring sites, are shown on Map 36.

As may be seen in Table 70, there were 61 stationary monitoring sites within the Region actively sampling for suspended particulate matter, and 12 stationary monitoring sites measuring sulfur dioxide, eight sites measuring carbon monoxide, nine sites measuring ozone, and five sites measuring nitrogen dioxide in 1977. At the close of 1977, however, 14 monitoring sites ceased sampling for suspended particulate matter, two ceased measuring sulfur suspended particulate matter, five ceased measuring sulfur dioxide, and two ceased monitoring photochemical oxidants. In addition, the three mobile monitoring vans operated by the DNR have been stationed within the Region at various times to measure all six of the criteria pollutants.

Table 71 presents a summary of the minimum number of monitoring sites, as determined by the EPA, necessary to adequately sample the atmosphere in regions having different populations and levels of air pollution. Generally, in Priority I areas the air quality is poorer than the primary standards, in Priority II areas pollutant concentrations are between the secondary and primary standards, and in Priority III areas pollutant concentrations are below the secondary standards. Since monitored particulate matter and ozone levels have been in excess of the applicable primary standards in the Southeastern Wisconsin Region, the EPA designated the seven-county area as a Priority I region for these pollutants on May 31, 1972. In the same action, the EPA designated southeastern Wisconsin as a Priority II area for sulfur dioxide, and a Priority III area for carbon monoxide and nitrogen dioxide. Based on these designations, and on a 1975 regional population of about 1,800,000 persons, the recommended minimum number of monitoring sites should be as follows: suspended particulates, 12 high-volume sites; sulfur dioxide, four continuous monitoring sites; and photochemical oxidants, four continuous monitoring sites. No monitoring sites are required for carbon monoxide or nitrogen dioxide based on the EPA designations. The existing air quality monitoring network in the Southeastern Wisconsin Region, therefore, consists of a substantially greater number of stations than the minimum defined by the EPA.

In addition to the number of monitoring sites, the placement of such sites throughout the Region is an important factor in characterizing the nature and extent of the regional air pollution problem. The air quality monitoring network should consist of stations that are situated primarily to document the highest pollution levels in the Region; to measure population exposure; to measure the pollution generated by specific classes of sources; and to record the nonurban levels of pollution. The monitoring sites within the network can be placed into four general groups: center city area; suburban area; rural area; and remote area. The center city and suburban areas can be further refined into four secondary categories depending on the dominating influence within a one-mile radius of the sampling site. These four subcategories consist of: industrial sites—implying the proximity of product-orientated establishments such as manufacturing plants, utilities, mining operations, or graneries; commercial sites—implying service and retail establishments where a unique traffic pattern into and out of the area exists; residential sites—implying a neighborhood community not influenced by a dominating industry or commercial center; and mobile sites—implying locations near truck, bus, or airport terminals or freeway and expressway interchanges. Rural sampling sites may also be further defined as near-urban sites—implying a rural area close enough to be influenced by a major urban center—or agricultural sites—implying an area surrounded by such activities and land uses as orchards, crop raising, and cattle grazing. A remote site is usually far enough removed from any activity to be primarily influenced only by naturally occurring sources of pollution. In Table 72 the active hi-vol particulate matter monitoring sites within the Region which meet all EPA sampling requirements are listed by county, along with the site description of the area in which they are situated. It may be seen in Table 72 that the moni-

[12] *In 1974, the responsibility for the maintenance and operation of the CAMP monitoring stations was turned over to state and local air pollution control agencies.*

Table 70

HISTORICAL SUMMARY OF AIR MONITORING ACTIVITIES IN THE REGION

Code Number on Map 36	Monitoring Site	Civil Division	Operator	Pollutant Monitored											
				Particulate Matter		Sulfur Dioxide		Carbon Monoxide		Hydrocarbons		Nitrogen Oxides		Ozone	
				Start	Finish	Start	Finish	Start	Finish	Start	Finish	Start	Finish	Start	Finish
	Kenosha County														
1	625 52nd Street	Kenosha	EPA-NASN[a]	May 1965	Active	–	–	–	–	–	–	–	–	–	–
2	6530 Sheridan Road	Kenosha	Department of Natural Resources	March 1970	April 1970	–	–	–	–	–	–	–	–	–	–
3	6729 18th Avenue	Kenosha	Department of Natural Resources	March 1970	September 1970	–	–	–	–	–	–	–	–	–	–
4	2401 60th Street	Kenosha	Department of Natural Resources	March 1970	September 1971	–	–	–	–	–	–	–	–	–	–
5	2204 Roosevelt Road	Kenosha	Department of Natural Resources	April 1970	January 1971	–	–	–	–	–	–	–	–	–	–
6	839 62nd Street	Kenosha	Department of Natural Resources	June 1970	September 1970	–	–	–	–	–	–	–	–	–	–
7	2213 56th Street	Kenosha	Department of Natural Resources	April 1971	July 1971	–	–	–	–	–	–	–	–	–	–
8	6415 35th Street	Somers	Department of Natural Resources	April 1971	Active	–	–	–	–	–	–	–	–	–	–
9	2401 S. 60th Street	Kenosha	Department of Natural Resources	September 1971	March 1975	–	–	–	–	–	–	–	–	–	–
10	2804 N. Pershing Boulevard	Kenosha	Department of Natural Resources	September 1971	November 1974	–	–	–	–	–	–	–	–	–	–
11	5934 8th Avenue	Kenosha	Department of Natural Resources	September 1971	August 1977	–	–	–	–	–	–	–	–	–	–
12	625 52nd Street	Kenosha	Department of Natural Resources	July 1975	Active	January 1976	December 1977	–	–	–	–	–	–	–	–
13	8518 22nd Avenue[b]	Kenosha	Department of Natural Resources	May 1975	September 1976[c]	May 1975	September 1975	May 1975	September 1975	July 1975	August 1975	June 1976	September 1976	May 1975	September 1976[c]
14	Kenosha Airport	Kenosha	Washington State University	–	–	–	–	August 1976	September 1976	August 1976	September 1976	–	–	August 1976	September 1976
15	720 59th Place	Kenosha	Department of Natural Resources	September 1977	Active	–	–	–	–	–	–	–	–	–	–
16	Kenosha Airport	Kenosha	Department of Natural Resources	–	–	–	–	–	–	–	–	–	–	May 1977	September 1977[c]
17	5805 Sheridan Road[b]	Kenosha	Department of Natural Resources	March 1977	May 1977	–	–	–	–	March 1977	May 1977[g]	April 1977	May 1977	–	–
	Milwaukee County														
1	814 W. Wisconsin	Milwaukee	EPA-NASN[a]	July 1957	June 1976	July 1957	June 1976	–	–	–	–	July 1957	June 1976	–	–
2	9722 W. Watertown Plank Road	Wauwatosa	Department of Natural Resources[d]	June 1967	Active	–	–	–	–	–	–	–	–	–	–
3	711 W. Wells Street	Milwaukee	Department of Natural Resources[d]	January 1970	Active	July 1976	Active	–	–	–	–	March 1975	Active	–	–
3a	711 W. Wells Street	Milwaukee	EPA-RASN	June 1967	September 1977	–	–	–	–	–	–	–	–	–	–
4	245 W. Lincoln Avenue[b]	Milwaukee	Milwaukee County	–	–	November 1968	January 1969	November 1968	January 1969	–	–	November 1968	January 1969	–	–
5	5330 W. Layton Avenue[b]	Greenfield	Milwaukee County	–	–	January 1969	April 1969	January 1969	April 1969	–	–	January 1969	April 1969	–	–
6	2040 S. 67th Place[b]	West Allis	Milwaukee County	–	–	April 1969	July 1969	April 1969	July 1969	–	–	April 1969	July 1969	–	–
7	4010 W. Forest Home Avenue	Milwaukee	Department of Natural Resources[d]	June 1969	January 1976	–	–	–	–	–	–	–	–	–	–
8	3245 N. 37th Street	Milwaukee	Milwaukee County	June 1969	March 1971	–	–	–	–	–	–	–	–	–	–
9	N. 37th Street and W. Wells Street[b]	Milwaukee	Milwaukee County	–	–	July 1969	April 1970	July 1969	April 1970	–	–	July 1969	April 1970	–	–
10	845 N. 35th Street	Milwaukee	Department of Natural Resources[d]	September 1969	October 1977	–	–	–	–	–	–	–	–	–	–
11	8885 S. 68th Street	Franklin	Department of Natural Resources[d]	September 1969	Active	–	–	–	–	–	–	–	–	–	–
12	319 W. Virginia Street	Milwaukee	Milwaukee County	October 1969	March 1970	–	–	–	–	–	–	–	–	–	–
13	230 S. Muskego Avenue	Milwaukee	Department of Natural Resources[d]	December 1969	Active	–	–	–	–	–	–	–	–	–	–
14	7510 W. National Avenue	West Allis	Milwaukee County	December 1969	March 1970	–	–	–	–	–	–	–	–	–	–
15	5100 N. 91st Street	Milwaukee	Department of Natural Resources[d]	January 1970	Active	–	–	–	–	–	–	–	–	–	–
16	1615 E. Locust Street	Milwaukee	Milwaukee County	January 1970	June 1972	–	–	–	–	–	–	–	–	–	–
17	3700 N. 35th Street	Milwaukee	Milwaukee County	January 1970	December 1971	–	–	–	–	–	–	–	–	–	–
18	340 E. Puetz Road	Oak Creek	Milwaukee County	–	–	February 1970	June 1970	–	–	–	–	–	–	–	–
19	2969 S. Howell Avenue	Milwaukee	Department of Natural Resources[d]	March 1970	Active	–	–	–	–	–	–	–	–	–	–
20	730 W. Lapham Street	Milwaukee	Milwaukee County	March 1970	July 1970	–	–	–	–	–	–	–	–	–	–
21	932 S. 60th Street	West Allis	Milwaukee County	March 1970	May 1970	–	–	–	–	–	–	–	–	–	–
22	W. Fond du Lac Avenue and W. Armitage Avenue[b]	Milwaukee	Milwaukee County	–	–	April 1970	November 1970	April 1970	November 1970	–	–	April 1970	November 1970	–	–
23	6213 W. Lapham Street	West Allis	Milwaukee County	May 1970	September 1970	–	–	–	–	–	–	–	–	–	–
24	725 W. Howard Avenue	Milwaukee	Milwaukee County	–	–	June 1970	September 1970	–	–	–	–	–	–	–	–
25	1001 15th Avenue	South Milwaukee	Department of Natural Resources[d]	September 1970	Active	–	–	–	–	–	–	–	–	–	–
26	9501 W. Cleveland Avenue	West Allis	Department of Natural Resources[d]	September 1970	Active	–	–	–	–	–	–	–	–	–	–
27	1640 S. 24th Street	Milwaukee	Department of Natural Resources[d]	October 1970	May 1977	September 1970	December 1973	–	–	–	–	–	–	–	–
28	N. Port Washington Road and W. Silver Spring Drive[b]	Glendale	Milwaukee County	–	–	November 1970	October 1972	November 1970	October 1972	–	–	November 1970	October 1972	November 1970	October 1972
29	1750 S. Kinnickinnic Avenue	Milwaukee	Department of Natural Resources[d]	December 1970	Active	–	–	–	–	–	–	–	–	–	–
30	330 E. Greenfield Avenue	Milwaukee	Department of Natural Resources[d]	March 1971	March 1975	–	–	–	–	–	–	–	–	–	–
30a	600 E. Greenfield Avenue	Milwaukee	Department of Natural Resources	March 1975	Active	–	–	–	–	–	–	–	–	–	–
31	7841 N. 47th Street	Brown Deer	Department of Natural Resources[d]	April 1971	Active	–	–	–	–	–	–	–	–	–	–
32	3281 N. 41st Street	Milwaukee	Department of Natural Resources[d]	April 1971	Active	–	–	–	–	–	–	–	–	–	–
33	606 W. Kilbourn Avenue	Milwaukee	Milwaukee County	–	–	–	–	June 1971	May 1973	–	–	–	–	–	–
34	1313 W. Reservoir Avenue	Milwaukee	Department of Natural Resources[d]	June 1972	Active	–	–	–	–	–	–	–	–	–	–
35	3201 N. Downer Avenue	Milwaukee	Department of Natural Resources[d]	June 1972	Active	–	–	–	–	–	–	–	–	–	–
36	7528 W. Appleton Avenue	Milwaukee	Department of Natural Resources	April 1972	Active	August 1975	Active	October 1973	Active	–	–	March 1976	Active	July 1973	Active
37	2114 E. Kenwood Boulevard	Milwaukee	Department of Natural Resources	October 1973	July 1977[e]	July 1973	Active	October 1973	November 1975	–	–	–	–	July 1973	Active
38	1020 W. Canal Street[b]	Milwaukee	Department of Natural Resources	–	–	December 1972	November 1973	December 1972	November 1973	–	–	December 1972	November 1973	December 1972	November 1973
39	606 W. Kilbourn Avenue	Milwaukee	Department of Natural Resources	April 1974	July 1977[e]	July 1973	Active	October 1973	Active	–	–	–	–	July 1973	April 1977
40	444 E. Clybourn Street	Milwaukee	Department of Natural Resources	–	–	–	–	May 1973	November 1973	–	–	–	–	–	–
41	9722 W. Watertown Plank Road	Wauwatosa	Department of Natural Resources	April 1974	November 1975	July 1973	November 1975	January 1974	November 1975	–	–	–	–	January 1974	November 1975
42	1225 S. Carferry Drive	Milwaukee	Department of Natural Resources	April 1974	July 1977[e]	January 1974	Active	January 1974	Active	–	–	January 1976	Active	January 1974	Active
43	3401 S. 39th Street	Milwaukee	Department of Natural Resources	April 1974	July 1977[e]	March 1974	Active	January 1974	Active	–	–	–	–	January 1974	Active
44	3716 W. Wisconsin Avenue	Milwaukee	Department of Natural Resources	April 1975	July 1977[e]	January 1975	Active	August 1975	Active	–	–	November 1975	Active	March 1975	Active
45	1550 S. Barclay Street[b]	Milwaukee	Department of Natural Resources	December 1974	March 1975	December 1974	March 1975	December 1974	March 1975	December 1974	March 1975	–	–	December 1974	March 1975
46	Ryan Road and Nicholson Avenue[b]	Oak Creek	Department of Natural Resources	September 1974	December 1974	–	–	September 1974	December 1974	September 1974	December 1974	–	–	September 1974	December 1974

Table 70 (continued)

Code Number on Map 36	Monitoring Site	Civil Division	Operator	Pollutant Monitored											
				Particulate Matter		Sulfur Dioxide		Carbon Monoxide		Hydrocarbons		Nitrogen Oxides		Ozone	
				Start	Finish	Start	Finish	Start	Finish	Start	Finish	Start	Finish	Start	Finish
	Milwaukee County (continued)														
47	5300 S. Howell Avenue	Milwaukee	Department of Natural Resources	January 1975	Active	–	–	–	–	–	–	–	–	–	–
48	2300 S. 51st Street	Milwaukee	Department of Natural Resources	January 1975	Active	–	–	–	–	–	–	–	–	–	–
49	3419 W. Wisconsin Avenue	Milwaukee	Department of Natural Resources	November 1977	Active	–	–	–	–	–	–	–	–	–	–
50	711 W. Wells	Milwaukee	Department of Natural Resources	May 1977	May 1978[f]	–	–	–	–	–	–	–	–	–	–
51	1640 S. 24th Street	Milwaukee	Department of Natural Resources	May 1977	May 1978[f]	–	–	–	–	–	–	–	–	–	–
52	2615 W. Greves Street	Milwaukee	Department of Natural Resources	April 1977	May 1978[f]	–	–	–	–	–	–	–	–	–	–
53	2011 W. Canal Street	Milwaukee	Department of Natural Resources	May 1977	May 1978[f]	–	–	–	–	–	–	–	–	–	–
54	Car Department Building	Milwaukee	Department of Natural Resources	May 1977	May 1978[f]	–	–	–	–	–	–	–	–	–	–
55	Muskego Marshalling Yard	Milwaukee	Department of Natural Resources	May 1977	May 1978[f]	–	–	–	–	–	–	–	–	–	–
56	340 W. Oregon Street	Milwaukee	Department of Natural Resources	June 1977	May 1978[f]	–	–	–	–	–	–	–	–	–	–
57	388 S. Muskego Avenue	Milwaukee	Department of Natural Resources	July 1977	May 1978[f]	–	–	–	–	–	–	–	–	–	–
	Ozaukee County														
1	408 N. Lake Street	Port Washington	Department of Natural Resources	December 1971	Active	–	–	–	–	–	–	–	–	–	–
2	Highways C and Q	Grafton	Department of Natural Resources	June 1975	September 1975	June 1975	June 1975	–	–	–	–	June 1975	September 1975[c]	June 1975	September 1976
	Racine County														
1	730 Washington Avenue	Racine	Racine County	November 1977	Active	January 1970	September 1977	–	–	–	–	–	–	–	–
2	208 E. Jefferson	Burlington	Racine County	February 1970	December 1975	–	–	–	–	–	–	–	–	–	–
3	1501 Albert	Racine	Racine County	February 1970	Active	–	–	–	–	–	–	–	–	–	–
4	925 15th Avenue	Union Grove	Racine County	February 1970	Active	–	–	–	–	–	–	–	–	–	–
5	Caledonia Town Hall	Husher	Racine County	February 1970	Active	–	–	–	–	–	–	–	–	–	–
6	Lakeview School	Wind Lake	Racine County	February 1970	December 1975	–	–	–	–	–	–	–	–	–	–
7	1648 N. Memorial Drive	Racine	Racine County	May 1970	July 1970	–	–	–	–	–	–	–	–	–	–
8	815 Dekoven Avenue	Racine	Racine County	October 1970	October 1970	–	–	–	–	–	–	–	–	–	–
9	3701 Durand Avenue	Racine	Racine County	October 1970	Active	–	–	–	–	–	–	–	–	–	–
10	2400 Rapids Drive	Racine	Racine County	October 1970	December 1975	–	–	–	–	–	–	–	–	–	–
11	4901 Washington Avenue	Racine	Racine County	October 1970	Active	–	–	–	–	–	–	–	–	–	–
12	730 Washington Avenue	Racine	EPA NASN[a]	January 1971	September 1977	–	–	–	–	–	–	–	–	–	–
13	1603 Washington Avenue	Racine	Racine County	April 1973	July 1977[e]	April 1973	August 1977	April 1973	August 1977	–	–	–	–	April 1973	August 1977[c]
14	2210 Rapids Drive	Racine	Racine County	January 1976	Active	–	–	–	–	–	–	–	–	–	–
15	1601 Washington Avenue	Racine	Racine County	January 1974	August 1977	–	–	–	–	–	–	–	–	–	–
16	1519 Washington Avenue	Racine	Racine County	August 1977	Active	–	–	–	–	–	–	–	–	–	–
17	1521 Washington Avenue	Racine	Racine County	–	–	August 1977	Active	August 1977	Active	–	–	–	–	–	–
	Walworth County														
1	Upham Hall	University of Wisconsin-Whitewater	Department of Natural Resources	February 1970	December 1975	February 1970	September 1977	–	–	–	–	November 1971	June 1972	November 1971	August 1972
2	723 Geneva Street	Lake Geneva	Department of Natural Resources	March 1970	June 1977	–	–	–	–	–	–	–	–	–	–
3	Consolidated School	Darien	Department of Natural Resources	–	–	–	–	–	–	–	–	–	–	June 1974	August 1974
	Washington County														
1	328 N. 8th Avenue	West Bend	Department of Natural Resources	January 1970	November 1972	–	–	–	–	–	–	–	–	–	–
	Waukesha County														
1	130 W. St. Paul Avenue	Waukesha	Department of Natural Resources	March 1970	Active	–	–	–	–	–	–	–	–	–	–
2	726 N. Grand Avenue	Waukesha	Department of Natural Resources	December 1974	July 1977[e]	December 1974	December 1975	December 1974	June 1977	–	–	–	–	December 1974	Active
3	N91 W16228 Pershing Avenue	Menomonee Falls	Department of Natural Resources	September 1975	November 1975	September 1975	November 1975	September 1975	November 1975	September 1975	November 1975	–	–	–	–
4	1344 White Rock Avenue	Waukesha	Department of Natural Resources	December 1976	Active	–	–	–	–	–	–	–	–	–	–
5	1335 Cleveland Court	Waukesha	Department of Natural Resources	December 1976	Active	–	–	–	–	–	–	–	–	–	–
6	1116 Adams Street	Waukesha	Department of Natural Resources	December 1976	Active	–	–	–	–	–	–	–	–	–	–
7	1230 The Strand	Waukesha	Department of Natural Resources	December 1976	Active	–	–	–	–	–	–	–	–	–	–
8	1301 E. Main Street	Waukesha	Department of Natural Resources	February 1977	Active	–	–	–	–	–	–	–	–	–	–
9	612 E. Main Street	Waukesha	Department of Natural Resources	August 1977	Active	–	–	–	–	–	–	–	–	–	–
10	225 N. Grand Avenue	Waukesha	Department of Natural Resources	–	–	–	–	July 1977	Active	–	–	–	–	–	–

[a] *U.S. Environmental Protection Agency, National Air Sampling Network.*

[b] *Location of mobile air quality monitoring van.*

[c] *Operates only from May through September.*

[d] *Responsibility for the operation of this site was assumed from Milwaukee County by the Wisconsin Department of Natural Resources on January 1, 1975.*

[e] *Collected suspended particulates measured as the reduction of transmitted light and defined in terms of optical density.*

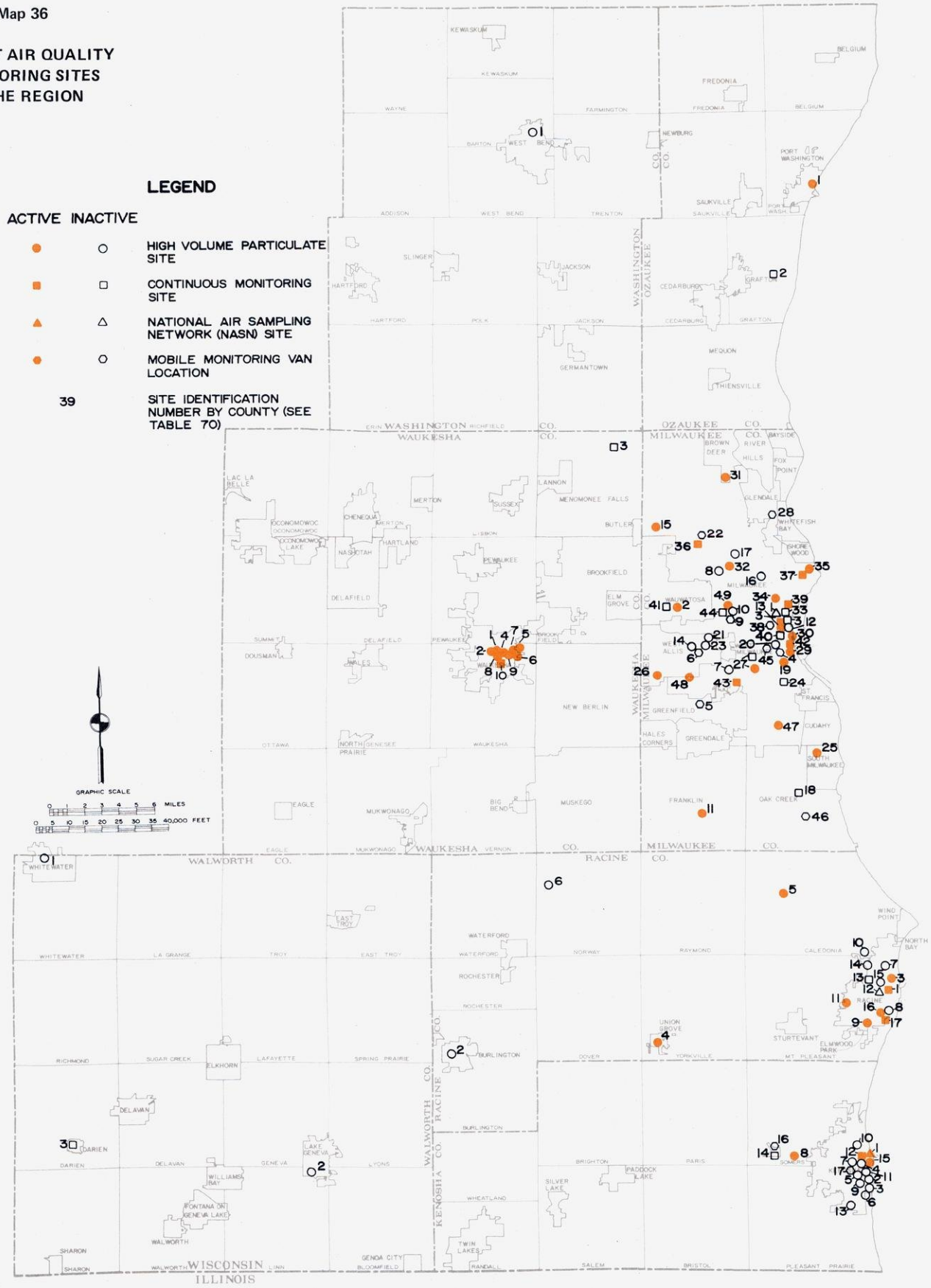
[f] *Indicates special project particulate matter sampling. Sites are not coded on Map 36.*

[g] *Monitoring of nonmethane hydrocarbons.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Map 36

AMBIENT AIR QUALITY MONITORING SITES IN THE REGION



The monitoring of ambient air for various pollutants in the Southeastern Wisconsin Air Quality Control Region is currently being conducted at 44 sites in the Region. This map identifies the location of the sites at which monitoring activity is occurring, indicates the extent of the monitoring effort, and the agency sponsoring or supervising the activity. In addition, this map identifies the location of all known inactive air quality monitoring sites.

Source: SEWRPC.

Table 71

EPA-RECOMMENDED MINIMUM NUMBER OF AIR QUALITY MONITORING SITES

Priority Classification of Region	Pollutant	Measurement Method	Minimum Frequency of Sampling	Population	Minimum Number of Air Quality Monitoring Sites
I	Suspended Particulates	High-Volume Sampler	One 24-hour sample every 6 days[c]	Less than 100,000 100,000 to 1,000,000 1,000,001 to 5,000,000 More than 5,000,000	4 4.0 + 0.6 per 100,000 population 7.5 + 0.25 per 100,000 population 12 + 0.16 per 100,000 population
	Sulfur Dioxide	Pararosaniline or Equivalent	Continuous	Less than 100,000 100,000 to 5,000,000 More than 5,000,000	1 1 + 0.15 per 100,000 population 6 + 0.05 per 100,000 population
	Carbon Monoxide	Nondispersive Infrared or Equivalent	Continuous	Less than 100,000 100,000 to 5,000,000 More than 5,000,000	1 1 + 0.15 per 100,000 population 6 + 0.05 per 100,000 population
	Nitrogen Dioxide	24-Hour Sampling Method (Jacobs-Hochheiser Method)[a]	One 24-hour sample every 14 days[b]	Less than 100,000 100,000 to 1,000,000 More than 1,000,000	3 4 + 0.6 per 100,000 population 10
	Photochemical Oxidants	Gas Phase Chemiluminescence or Equivalent	Continuous	Less than 100,000 100,000 to 5,000,000 More than 5,000,000	1 1 + 0.15 per 100,000 population 6 + 0.05 per 100,000 population
II	Suspended Particulates	High-Volume Sampler	One 24-hour sample every 6 days[c]	–	3
	Sulfur Dioxide	Pararosaniline or Equivalent	One 24-hour sample every 6 days[c]	–	3
III	Suspended Particulates	High-Volume Sampler	One 24-hour sample every 6 days[c]	–	1
	Sulfur Dioxide	Pararosaniline or Equivalent	One 24-hour sample every 6 days[c]	–	1

[a] *This method has been under dispute for many years; however, no alternative method has yet been approved.*

[b] *Equivalent to 26 random samples per year.*

[c] *Equivalent to 61 random samples per year.*

Source: U.S. Environmental Protection Agency and SEWRPC.

toring sites fall predominantly in the center city category. Of the 57 total sites, only 10 fall into the suburban category and 3 into the rural category. Due to the highly urbanized nature of the Region, no sites may be classified as remote.

Air Pollution Levels in Southeastern Wisconsin

The nature and extent of the air pollution problem in the Southeastern Wisconsin Region may be defined through the examination of available air quality monitoring data for each of the six major pollutants. As may be seen in Table 70, the air quality monitoring network in the Region has historically been flexible in response to a continuing reevaluation of instrument siting to best characterize regional air pollution levels. In the following sections the available air quality monitoring data from both active and inactive monitoring sites in the Region are summarized for the years 1973 through 1977 and related to the applicable ambient air quality standards.

Particulate Matter Concentrations: Ambient air levels of particulate matter may only be assessed against the air quality standards on total suspended particulates as measured by the high-volume gravimetric sampler. Table 73 presents the annual geometric and arithmetic means, along with the standard geometric deviations, for those hi-vol monitoring sites active in the Region between 1973 and 1977.

In 1973 there were 35 particulate matter monitoring sites in operation throughout the Region, over half of which were located in Milwaukee County. During that year, 7 of the 35 sites exceeded the primary annual standard of 75 $\mu g/m^3$ (geometric mean)—6 stations in Milwaukee County and 1 in Racine County. An additional 5 sites exceeded the secondary annual standard of 60 $\mu g/m^3$ (geometric mean)—2 in Milwaukee County and 3 in Kenosha County. Ozaukee, Walworth, and Waukesha Counties all exhibit air quality levels well below both the primary and secondary standards. Washington County does not have a particulate matter monitoring station but, based upon its predominantly agricultural nature, the ambient air quality standards are not expected to be exceeded.

Table 72

SITE DESCRIPTION FOR HI-VOL PARTICULATE MATTER AND CONTINUOUS MONITORING STATIONS

Monitoring Site	Civil Division	Site Description
Kenosha County		
625 52nd Street	Kenosha	Center City-Commercial
6415 35th Avenue	Somers	Center City-Commercial
720 59th Place	Kenosha	Center City-Industrial
5934 8th Avenue	Kenosha	Center City-Commercial
Milwaukee County		
3419 W. Wisconsin Avenue	Milwaukee	Center City-Commercial
845 N. 35th Street	Milwaukee	Center City-Commercial
230 S. Muskego Avenue	Milwaukee	Center City-Industrial
2969 S. Howell Avenue	Milwaukee	Center City-Commercial
1640 S. 24th Street	Milwaukee	Center City-Residential
5100 N. 91st Street	Milwaukee	Suburban-Residential
1750 S. Kinnickinnic Avenue	Milwaukee	Center City-Industrial
600 E. Greenfield Avenue	Milwaukee	Center City-Industrial
7841 N. 47th Street	Brown Deer	Suburban-Residential
3281 N. 41st Street	Milwaukee	Center City-Residential
1313 W. Reservoir Avenue	Milwaukee	Center City-Industrial
3201 N. Downer Avenue	Milwaukee	Suburban-Residential
711 W. Wells Street	Milwaukee	Center City-Commercial
8885 S. 68th Street	Franklin	Rural-Near Urban
1001 15th Avenue	South Milwaukee	Suburban-Residential
9722 W. Watertown Plank Road	Wauwatosa	Suburban-Residential
9501 W. Cleveland Avenue	West Allis	Suburban-Residential
7528 W. Appleton Avenue	Milwaukee	Suburban-Commercial
5300 S. Howell Avenue	Milwaukee	Center City-Industrial
2300 S. 51st Street	Milwaukee	Center City-Industrial
2615 W. Greves Street	Milwaukee	Center City-Industrial
1020 W. Canal Street	Milwaukee	Center City-Industrial
Car Department Building	Milwaukee	Center City-Industrial
Muskego Marshalling Yard	Milwaukee	Center City-Industrial
340 W. Oregon Street	Milwaukee	Center City-Industrial
388 S. Muskego Avenue	Milwaukee	Center City-Industrial
Ozaukee County		
408 N. Lake Avenue	Port Washington	Center City-Residential
Racine County		
2210 Rapids Drive	Racine	Suburban-Commercial
730 Washington Avenue	Racine	Center City-Commercial
3701 Durand Avenue	Racine	Center City-Commercial
4901 Washington Avenue	Racine	Center City-Residential
1501 Albert	Racine	Center City-Industrial
1519 Washington Avenue	Racine	Center City-Commercial
925 15th Avenue	Union Grove	Rural-Agricultural
Caledonia Town Hall	Husher	Rural-Agricultural
Walworth County		
723 Geneva Street	Lake Geneva	Center City-Residential

Table 72 (continued)

Monitoring Site	Civil Division	Site Description
Waukesha County		
1344 White Rock Avenue	Waukesha	Center City-Commercial
1335 Cleveland Court	Waukesha	Center City-Commercial
1116 Adams Street	Waukesha	Center City-Commercial
1230 The Strand	Waukesha	Center City-Commercial
1301 E. Main Street	Waukesha	Center City-Commercial
612 E. Main Street	Waukesha	Center City-Commercial
St. Paul Avenue	Waukesha	Center City-Commercial
Continuous Monitoring Stations		
Milwaukee County		
7528 W. Appleton Avenue	Milwaukee	Suburban-Commercial
606 W. Kilbourn Avenue	Milwaukee	Center City-Commercial
1225 S. Carferry Drive	Milwaukee	Center City-Industrial
2114 E. Kenwood Boulevard	Milwaukee	Center City-Residential
3401 S. 39th Street	Milwaukee	Suburban-Residential
3716 W. Wisconsin Avenue	Milwaukee	Center City-Residential
711 W. Wells Street	Milwaukee	Center City-Commercial
Racine County		
1521 Washington Avenue	Racine	Center City-Commercial
730 Washington Avenue	Racine	Center City-Commercial
Waukesha County		
726 N. Grand Avenue	Waukesha	Center City-Commercial

Source: Wisconsin Department of Natural Resources.

In 1974 every station exceeding either the primary or secondary annual standard in 1973 indicated a decrease in particulate matter levels. One notable change occurred at the station at 2400 Rapids Drive in Racine, where the concentration increased by approximately 13 $\mu g/m^3$ to 61.7 $\mu g/m^3$, exceeding the secondary annual standard. In total, however, only 5 sites exceeded the primary annual standard and 7 exceeded the secondary annual standard in 1974.

In 1975 the downward trend continued in Milwaukee County, while Racine and Kenosha Counties showed marked increases at nearly every monitoring site. In 1976 the reverse situation occurred, with particulate matter levels decreasing in Kenosha and Racine Counties—generally not to the 1973 levels, however—and increasing in Milwaukee County.

During 1977 4 monitoring sites in Milwaukee County exceeded the primary annual standard, and 10 stations, 5 in Milwaukee County, 2 in Kenosha County, 2 in Racine County, and the station in Walworth County, exceeded the secondary annual standard. In addition, 6 monitoring stations were set up in Waukesha County, of which 2 sites exceeded the primary annual standard and 3 sites exceeded the secondary annual standard.

Variances in meteorological conditions may contribute substantially to the observed differences in the annual particulate matter levels from year to year. Overall, however, particulate matter levels in the Region have generally been on the decline for the past few years. Figure 38 illustrates this pattern graphically for four monitoring stations in Milwaukee County from 1971 through 1976. This figure indicates that the most dramatic reductions in particulate matter concentrations occurred between 1971 and 1973, with the exception of the station at 1750 S. Kinnickinnic Avenue, a source-orientated site, where the sharpest decline occurred between 1972 and 1973. It should also be noted that the rates of decline at each site have slowed considerably since the initial decreases and have either leveled off or begun to increase. The monitoring sites shown in Figure 38 exemplify the effectiveness of early emission control regulations on numerous pollutant sources to rapidly reduce ambient air particulate matter concentrations, while demonstrating that those controls, mostly on major point sources, are not adequate to prevent the increase in ambient air particulate matter concentrations from other sources attendant to urban growth and development in the Region.

In addition to being influenced by emissions from local sources and prevailing meteorological conditions, particulate matter levels in the Southeastern Wisconsin Region are influenced by the natural background levels of particles in the atmosphere, by particles produced in the chemical transformation of gaseous pollutants, and by the transport of particulate matter into the Region from extraregional, anthropogenic sources. Natural sources of particles in the atmosphere—including wind erosion of soil and rock, forest fires, volcanoes, and sea salt—produce a substantially greater quantity of emissions than are produced by anthropogenic sources. Man-made particulate matter emissions, however, usually result in greater observed ambient air pollution levels in populated areas since the sources are generally concentrated within a small area. There are two sources of naturally

Table 73

AIR QUALITY MONITORING DATA FOR PARTICULATE MATTER CONCENTRATIONS IN THE REGION: 1973-1977

Monitoring Site	Civil Division	Particulate Matter Concentrations ($\mu g/m^3$) Annual Geometric Mean					Particulate Matter Concentrations ($\mu g/m^3$) Annual Arithmetic Mean					Particulate Matter Concentrations ($\mu g/m^3$) Standard Geometric Deviation				
		1973	1974	1975	1976	1977	1973	1974	1975	1976	1977	1973	1974	1975	1976	1977
Kenosha County																
625 52nd Street	Kenosha	66.6	40.7	63.7	50.6	57.1	70.0	N/A	71.7	55.4	57.7	N/A	N/A	1.65	1.50	1.50
6415 35th Avenue	Somers	53.5	48.4	56.7	59.5	68.4	61.8	53.9	63.4	72.1	75.3	N/A	N/A	1.67	1.70	1.60
2401 60th Street	Kenosha	63.5	62.4	117.1	–	–	70.4	69.5	117.8	–	–	1.65	1.63	1.14	–	–
5934 8th Avenue	Kenosha	72.6	62.4	71.3	65.5	50.3	77.4	N/A	79.2	77.2	68.8	N/A	N/A	1.60	1.60	1.70
720 59th Place	Kenosha	–	–	–	–	54.9	–	–	–	–	54.3	–	–	–	–	1.50
5805 Sheridan Road	Kenosha	–	–	–	–	72.6	–	–	–	–	85.9	–	–	–	–	1.50
8518 22nd Avenue	Kenosha	–	–	56.5	76.7	–	–	–	62.7	85.7	–	–	–	1.58	1.60	–
Milwaukee County																
814 W. Wisconsin Avenue	Milwaukee	82.7	78.0	66.4	41.1	–	N/A	88.0	74.2	45.9	–	N/A	N/A	1.63	1.60	–
4010 W. Forest Home Avenue	Milwaukee	53.6	48.8	53.5	38.4	–	59.1	53.8	59.2	40.7	–	1.56	1.58	1.56	1.50	–
845 N. 35th Street	Milwaukee	74.4	69.8	67.0	65.2	67.8	83.3	77.2	74.7	73.3	72.0	1.63	1.61	1.59	1.40	1.40
230 S. Muskego Avenue	Milwaukee	114.1	103.2	93.1	104.4	91.2	132.0	123.0	109.6	118.8	103.2	1.80	1.80	1.80	1.70	1.60
2969 S. Howell Avenue	Milwaukee	59.7	55.6	58.0	60.6	67.2	66.3	63.1	64.2	67.9	73.7	1.61	1.69	1.59	1.60	1.60
1640 S. 24th Street	Milwaukee	64.0	60.5	59.1	63.6	74.0	70.7	67.2	65.8	69.9	77.5	1.61	1.60	–	1.60	1.50
5100 N. 91st Street	Milwaukee	49.7	–	38.7	56.5	42.1	57.5	–	45.0	60.7	47.5	1.71	–	2.03	1.50	1.60
1750 S. Kinnickinnic Avenue	Milwaukee	120.8	112.6	108.5	107.4	93.6	133.0	125.0	120.3	119.7	104.3	1.60	1.60	1.56	1.50	1.60
330 E. Greenfield Avenue[a]	Milwaukee	105.4	101.6	117.0	–	–	126.0	119.0	144.7	–	–	1.80	1.80	1.92	–	–
7841 N. 47th Street	Brown Deer	49.2	39.1	43.7	45.6	41.4	56.0	45.0	51.4	50.7	53.7	1.70	1.70	1.81	1.60	1.70
3281 N. 41st Street	Milwaukee	45.9	46.1	48.4	51.2	47.4	53.3	53.2	54.4	56.2	53.5	1.80	1.71	1.62	1.60	1.60
1313 W. Reservoir Avenue	Milwaukee	75.7	66.0	71.1	67.0	58.6	92.0	77.0	84.0	73.8	66.1	1.80	1.80	1.75	1.60	1.60
3201 N. Downer Avenue	Milwaukee	49.5	45.5	44.6	44.3	48.5	56.6	52.6	51.3	53.9	54.0	1.74	1.74	1.74	1.60	1.60
711 W. Wells Street	Milwaukee	80.7	77.1	70.8	67.9	80.8	92.8	89.8	80.9	81.0	91.8	1.72	1.76	1.68	1.70	1.70
8885 S. 68th Street	Franklin	46.4	39.5	50.6	55.7	46.3	52.7	43.3	59.2	74.8	53.9	1.67	1.55	1.67	1.70	1.70
1001 15th Avenue	South Milwaukee	55.2	46.1	48.1	52.7	46.7	N/A	53.0	52.4	61.7	53.0	N/A	1.70	1.52	1.60	1.60
9722 W. Watertown Plank Road	Wauwatosa	52.0	50.6	52.0	59.8	61.9	60.1	57.7	58.5	71.1	68.1	1.77	1.70	1.65	1.60	1.50
9501 W. Cleveland Avenue	West Allis	50.0	50.0	51.3	55.2	47.1	57.0	56.0	56.0	59.9	50.1	1.70	1.60	1.53	1.40	1.60
5300 S. Howell Avenue	Milwaukee	–	–	49.4	69.3	70.4	–	–	N/A	82.7	79.1	–	–	1.65	1.70	1.60
2300 S. 51st Street	Milwaukee	–	–	60.1	–	48.3	–	–	66.0	–	53.5	–	–	1.54	–	1.50
3419 W. Wisconsin Avenue	Milwaukee	–	–	–	–	40.0	–	–	–	–	41.5	–	–	–	–	1.30
5100 S. 51st Street	Milwaukee	–	–	–	67.5	–	–	–	–	69.9	–	–	–	–	1.30	–
7528 W. Appleton Avenue	Milwaukee	–	–	48.9	68.0	55.1	–	–	–	63.0	60.8	–	–	1.59	1.30	1.60
600 E. Greenfield Avenue	Milwaukee	–	–	98.0	90.6	85.7	–	–	109.1	107.7	93.4	–	–	1.59	1.70	1.50
Ozaukee County																
408 N. Lake Street	Port Washington	46.2	36.9	41.0	37.4	40.5	59.9	46.4	50.4	52.8	49.0	2.02	1.98	1.96	2.00	1.70
Racine County																
730 Washington Avenue	Racine	–	–	58.5	50.4	33.8	–	–	64.2	54.7	37.7	–	–	1.54	1.50	1.60
3701 Durand Avenue	Racine	50.1	53.8	49.2	49.8	52.8	53.4	59.8	54.4	59.2	58.2	N/A	N/A	1.59	1.60	1.60
4901 Washington Avenue	Racine	46.6	38.3	50.2	47.9	45.8	49.2	41.5	57.3	56.1	49.8	1.40	1.51	1.69	1.50	1.50
2210 Rapids Drive	Racine	48.3	61.7	62.2	47.5	47.0	53.2	70.0	71.0	54.2	53.2	–	1.65	1.70	1.50	1.60
1501 Albert	Racine	82.1	72.0	89.4	72.9	63.3	97.5	87.0	103.0	84.1	74.6	1.89	1.94	1.74	1.70	1.80
1601 Washington Avenue	Racine	53.1	55.9	69.7	59.6	63.3	55.9	67.0	77.2	68.4	71.5	1.42	1.84	1.60	1.50	1.40
925 15th Avenue	Union Grove	39.8	39.1	48.1	–	46.2	46.8	43.7	52.3	–	45.0	1.78	1.59	1.51	–	1.60
Lakeview School	Wind Lake	29.4	31.0	44.8	–	–	32.2	35.8	50.0	–	–	1.52	1.68	1.65	–	–
Caledonia Town Hall	Husher	40.7	34.7	43.6	–	–	47.4	41.2	48.7	–	–	1.69	1.71	1.60	–	–
Police Station	Burlington	43.3	45.5	57.3	–	–	47.3	51.9	N/A	–	–	1.53	1.69	1.69	–	–
1519 Washington Avenue	Racine	–	–	–	–	54.3	–	–	–	–	54.6	–	–	–	–	1.50
Walworth County																
University of Wisconsin Whitewater, Upham Hall	Whitewater	31.8	28.0	37.8	37.4	–	36.1	32.1	41.5	40.2	–	1.77	1.77	1.55	1.60	–
723 Geneva Avenue	Lake Geneva	44.7	37.6	41.2	47.8	62.1	49.5	43.6	46.6	59.5	74.7	1.57	1.71	1.69	1.60	1.80
Waukesha County																
St. Paul Avenue	Waukesha	49.5	38.3	55.2	53.4	58.2	56.1	45.6	60.9	63.4	66.1	1.72	2.07	1.57	1.40	1.70
1344 White Rock Avenue	Waukesha	–	–	–	–	74.3	–	–	–	–	91.7	–	–	–	–	1.90
1335 Cleveland Court	Waukesha	–	–	–	–	82.2	–	–	–	–	100.6	–	–	–	–	1.90
1116 Adams Street	Waukesha	–	–	–	–	73.6	–	–	–	–	82.6	–	–	–	–	1.60
1230 The Strand	Waukesha	–	–	–	–	109.8	–	–	–	–	124.8	–	–	–	–	1.90
1301 E. Main Street	Waukesha	–	–	–	–	74.7	–	–	–	–	84.9	–	–	–	–	1.40
612 E. Main Street	Waukesha	–	–	–	–	54.9	–	–	–	–	58.8	–	–	–	–	1.50

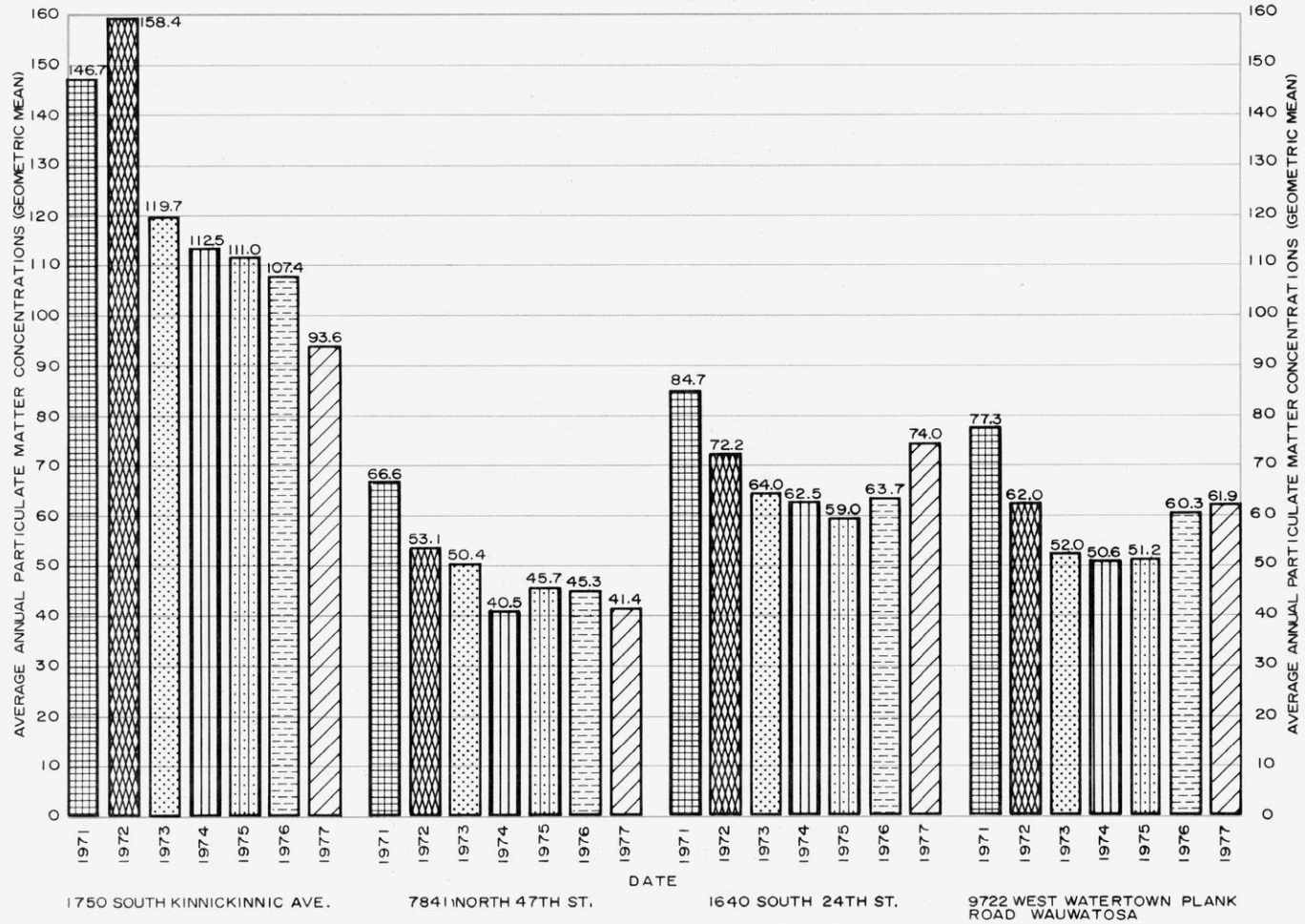
NOTE: N/A indicates data not available.

[a] *Station relocated to 600 E. Greenfield Avenue in 1975.*

Source: Wisconsin Department of Natural Resources.

Figure 38

PARTICULATE MATTER LEVELS FOR FOUR MONITORING STATIONS IN MILWAUKEE COUNTY: 1971-1977



Source: Wisconsin Department of Natural Resources and City of Milwaukee, Department of City Development.

occurring particulate matter: global sources and continental sources. The U.S. Environmental Protection Agency has estimated that the global annual average background levels of particulate matter range between 1 and 5 $\mu g/m^3$. Considering only the large land mass of the North American continent, the EPA has also estimated that background levels of particulate matter across the midwestern United States are about 14 $\mu g/m^3$ on an annual geometric average.[13]

Chemical transformations in the atmosphere lead to the formation of secondary particulates as gaseous pollutants, such as sulfur dioxide, nitric oxide, ammonia, and certain hydrocarbon compounds, which react with water vapor in the presence of sunlight. Depending on prevailing atmospheric conditions, such chemical transformations may occur near the source of the primary pollutant emissions or a substantial distance away from the source after the primary pollutants have been transported downwind.

Particulates formed through chemical reactions are generally smaller—in the range of 0.01μ to 1.0μ —than particles emitted directly from a source since they develop from gas molecules. Being smaller, these secondary particulates may remain suspended and have a longer residence time in the atmosphere and, consequently, may be transported a greater distance than direct particulate matter emissions. In fact, the EPA has concluded that, on an annual average, the transport of secondary particulates may contribute approximately 5 $\mu g/m^3$ to particulate matter levels in the midwestern United States, while the transport of primary particulate matter emissions may only have a minimal impact on long-term average concentrations.

The long-range transport of primary particulate matter emissions from wind-blown dust as a result of erosion or certain agricultural operations has been shown to contribute to violations of the short-term ambient air quality standards in the Midwest area under certain meteoro-

[13] *For more information concerning global and continental average particulate matter levels, see National Assessment of the Urban Particulate Problem, Volume 1, Summary of National Assessment, U.S. Environmental Protection Agency, EPA Report No. 450/3-76-024, July 1976.*

logical conditions.[14] Particulate matter emissions from major industrial operations, however, do not appear to contribute significantly to either the primary or secondary short-term particulate matter standard violations except possibly in the heavily industrialized region of the northeastern United States. The transport of secondary particles—most notably sulfates—from industrial operations may contribute substantially to local violations of the short-term particulate matter standards. Several research studies have indicated that the long-range transport of secondary particles may account for 13 to 25 $\mu g/m^3$ of the average daily particulate matter concentrations and may, on occasion, account for up to 50 $\mu g/m^3$ of such concentrations.

Map 37 presents the generalized distribution of annual particulate matter levels (geometric mean) within the Region for the base year, 1973. The area centering on the heavily industrialized portion of the Menomonee River Valley in the City of Milwaukee is shown to exceed the primary annual standard. The secondary standard is exceeded in Milwaukee County as far south as Mitchell Field, as far west as West Allis and the southeastern portion of Wauwatosa, and as far north as the junction of STH 41 and STH 57. The secondary annual standard is also exceeded over the intensely developed portions of the Racine and Kenosha urbanized areas.

Table 74 lists the first and second highest 24-hour average particulate matter concentrations recorded at each hi-vol monitoring site in the Region between 1973 and 1977, along with the number of days per year ambient air quality at each site exceed the primary and secondary short-term standards of 260 and 150 $\mu g/m^3$, respectively. Since only one violation of the 24-hour standard is allowed per year, it is the second highest value recorded which violates the ambient air quality standards. The highest and second highest 24-hour particulate matter levels observed in this five-year period were recorded at the station at 1230 The Strand in the City of Waukesha, with concentrations of 475 and 430 $\mu g/m^3$ in 1977.

It is apparent from the number of days of standard violations that only four monitoring stations account for nearly 90 percent of the total number of violations in Milwaukee County. These monitoring stations, all of which are close to major point sources, are located at 230 S. Muskego Avenue, 1750 S. Kinnickinnic Avenue, 330 E. Greenfield Avenue. (600 E. Greenfield Avenue as of 1975), and 711 W. Wells Street. These four stations recorded 40 out of 44 total violations of the primary 24-hour particulate matter standard in Milwaukee County between 1973 and 1977, and 376 out of 458 total violations of the secondary 24-hour standard over the same years.

[14] *See E.W. Klappenbach and S. Goranson, Long-Range Transport of Particulates: Case Study, October 15, 1976, presented at the 70th Annual Meeting of the Air Pollution Control Association, Toronto, Ontario, Canada, June 20-24, 1977.*

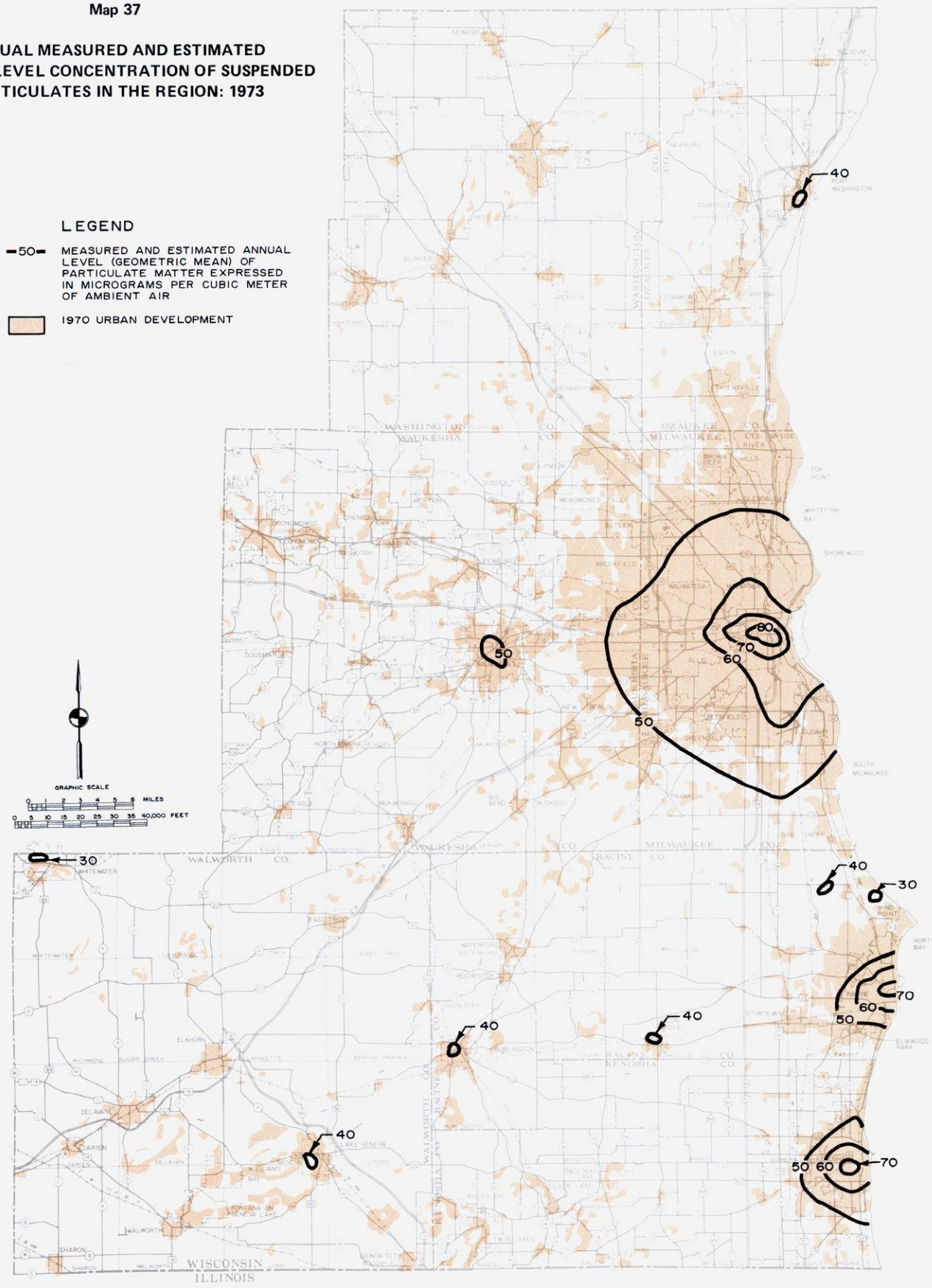
The total number of days exceeding either the primary or secondary 24-hour particulate matter standard has decreased markedly between 1973 and 1976. In 1973 there were 28 days of violation of the primary standard and 157 days of violation of the secondary standard throughout the Region. In 1974, this number had dropped to 11 and 149 days of violation of the primary and secondary standards, respectively. By 1975 only 7 days of primary standard violations and 110 days of secondary standard violations occurred throughout the Region, and in 1976 there were no days of primary standard violations and 44 days of secondary standard violations. In 1977 the downward trend in particulate matter concentrations continued in Milwaukee County while the number of days exceeding the 24-hour secondary standard increased in both Kenosha and Walworth Counties. During 1977 there were a total of 8 days of primary 24-hour standard violations and 90 days of violations of the 24-hour secondary standard in the Region.

Sulfur Dioxide Concentrations: As many as 11 monitoring stations have been sampling for sulfur dioxide concentrations in the ambient air of the Region since mid-1973. Data from only a few of these stations, however, can be used to represent ambient air concentrations of this pollutant in southeastern Wisconsin. Unfortunately, all sulfur dioxide monitoring data measured by the DNR prior to 1975 have been found to be invalid due to problems in converting the raw data as obtained from the monitors to accurate average concentrations. A second problem is that the pararosaniline method of monitoring for sulfur dioxide has come into question because of the effects of high temperatures on the resultant measurements. Two of the 11 sulfur dioxide monitoring sites employed this method. The remaining nine sites used the equivalent continuous flame photometric detection method. Finally, as with particulate matter observations, the EPA has established certain minimum criteria to evaluate the representativeness of the monitored data. These criteria require that each calendar quarter contain at least 20 percent of the total number of possible observations, and that at least 75 percent of the total possible observations in a year be available to be used to calculate summary statistics. In 1975 no sulfur dioxide monitoring site in the Region could meet these criteria. In 1976, however, four monitoring sites in Milwaukee County and one site in Racine County satisfactorily complied with the EPA requirements. The year 1976 was therefore selected as the base year for the sulfur dioxide analyses.

Table 75 presents a summary of the available 1976 and 1977 sulfur dioxide air quality data from the five valid monitoring stations. As may be seen from this table, no station has exceeded the National Ambient Air Quality Standards of 80 $\mu g/m^3$, 365 $\mu g/m^3$, and 1,300 $\mu g/m^3$ for the annual, 24-hour, and three-hour time scale, respectively. Although not indicated on this table, a monitoring station at 2114 E. Kenwood Boulevard in the City of Milwaukee did exceed the 24-hour standard on two occasions, reaching a level of 402 $\mu g/m^3$ in 1976

Map 37

ACTUAL MEASURED AND ESTIMATED GROUND-LEVEL CONCENTRATION OF SUSPENDED PARTICULATES IN THE REGION: 1973



The above map presents a generalized depiction of annual average particulate matter levels (geometric mean) over the Region as based on monitoring data from 1973. This isopleth analysis indicates that the primary annual average particulate matter ambient air quality standard (75 micrograms per cubic meter) was exceeded over an approximately eight-square mile area centered in the heavily industrialized area of the Menomonee River Valley in Milwaukee County in 1973, and that the secondary annual average standard (60 micrograms per cubic meter) was exceeded over an additional 40-square-mile area in Milwaukee County. The intensely developed portions of Kenosha and Racine Counties also exceeded the secondary standard over an approximate area of 11 and 9 square miles, respectively. Between 1973 and 1975, particulate matter levels in the Region showed a general downward trend. This decrease in regional particulate matter levels, however, was stabilized, or in some cases reversed, between 1976 and 1977.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Table 74

FIRST AND SECOND HIGHEST 24-HOUR MONITORED PARTICULATE MATTER CONCENTRATIONS AND NUMBER OF STANDARD VIOLATIONS BY SITE IN THE REGION: 1973-1977

Monitoring Site	Civil Division	Observed First and Second Highest Particulate Matter Concentrations ($\mu g/m^3$)										Number of Days Exceeding the 24-Hour Standards									
		1973		1974		1975		1976		1977		Primary					Secondary				
		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1973	1974	1975	1976	1977	1973	1974	1975	1976	1977
Kenosha County																					
625 52nd Street	Kenosha	–	–	110.0	110.0	150.0	128.0	123.0	111.0	158.0	125.0	–	0	0	0	0	–	0	1	0	0
6415 35th Avenue	Somers	113.7	109.3	116.8	91.0	134.0	130.0	180.0	140.0	170.0	153.0	0	0	0	0	0	0	0	0	0	2
2401 60th Street	Kenosha	147.5	119.1	151.6	133.0	168.8	108.5	–	–	–	–	0	0	0	–	–	0	1	0	–	–
5934 8th Avenue	Kenosha	145.6	144.8	–	–	183.2	180.1	199.0	177.0	193.0	133.0	0	–	0	0	0	0	–	2	1	0
720 59th Place	Kenosha	–	–	–	–	–	–	–	–	100.0	97.0	–	–	–	–	0	–	–	–	–	0
5805 Sheridan Road	Kenosha	–	–	–	–	–	–	–	–	206.0	193.0	–	–	–	–	0	–	–	–	–	3
8518 22nd Avenue	Kenosha	–	–	–	–	157.0	–	233.0	199.0	–	–	–	–	0	0	–	–	–	1	–	–
Milwaukee County																					
814 W. Wisconsin Avenue	Milwaukee	166.0	155.0	200.0	200.0	–	–	78.0	66.0	–	–	–	0	–	0	–	–	2	–	0	–
4010 W. Forest Home Avenue	Milwaukee	171.0	160.0	139.0	116.0	172.0	166.8	56.0	44.0	–	–	0	0	0	0	–	2	0	3	0	–
845 N. 35th Street	Milwaukee	193.0	190.0	174.0	168.0	221.5	203.4	134.0	123.0	193.0	166.0	0	0	0	0	0	9	3	6	0	1
230 S. Muskego Avenue	Milwaukee	365.0	338.0	411.0	408.0	359.4	290.4	278.0	241.0	348.0	228.0	8	4	4	0	0	28	26	18	13	7
2969 S. Howell Avenue	Milwaukee	166.0	134.0	171.0	133.0	152.6	–	141.0	140.0	263.0	140.0	0	0	0	0	0	2	1	1	0	0
1640 S. 24th Street	Milwaukee	195.0	188.0	199.0	135.0	190.1	164.7	159.0	152.0	143.0	136.0	0	0	0	0	0	2	1	2	1	0
5100 N. 91st Street	Milwaukee	211.0	161.0	–	–	71.0	–	124.0	112.0	155.0	118.0	0	–	0	0	0	2	–	0	0	0
1750 S. Kinnickinnic Avenue	Milwaukee	379.0	332.0	402.0	270.0	262.3	255.8	209.0	207.0	253.0	222.0	3	2	1	0	0	37	24	26	13	10
330 E. Greenfield Avenue[a]	Milwaukee	458.0	426.0	338.0	329.0	305.0	–	–	–	–	–	8	4	0	–	–	16	20	10	–	–
7841 N. 47th Street	Brown Deer	154.0	133.0	126.0	119.0	139.0	–	109.0	106.0	133.0	121.0	0	0	0	0	0	1	0	0	0	0
3281 N. 41st Street	Milwaukee	156.0	135.0	161.0	138.0	169.9	152.5	114.0	106.0	138.0	134.0	0	0	0	0	0	1	0	1	0	0
1313 W. Reservoir Avenue	Milwaukee	391.0	380.0	224.0	209.0	483.0	251.0	146.0	140.0	182.0	161.0	3	0	1	0	0	9	10	6	0	1
3201 N. Downer Avenue	Milwaukee	146.0	135.0	131.0	123.0	129.6	–	110.0	101.0	143.0	132.0	0	0	0	0	0	0	0	0	0	0
711 W. Wells Street	Milwaukee	304.0	297.0	244.0	241.0	259.6	247.3	212.0	178.0	208.0	197.0	5	0	0	0	0	36	51	22	2	5
8885 S. 68th Street	Franklin	136.0	119.0	99.0	89.0	168.4	–	147.0	145.0	185.0	151.0	0	0	0	0	0	0	0	1	0	1
1001 15th Avenue	South Milwaukee	184.0	143.0	240.0	113.0	118.3	–	126.0	124.0	145.0	134.0	0	0	0	0	0	1	0	0	0	0
9722 W. Watertown Plank Road	Wauwatosa	159.0	146.0	192.0	145.0	129.6	–	176.0	124.0	257.0	161.0	0	0	0	0	0	1	1	0	0	2
9501 W. Cleveland Avenue	West Allis	157.0	153.0	171.0	128.0	–	–	116.0	111.0	129.0	127.0	0	0	0	0	0	2	1	0	0	0
5300 S. Howell Avenue	Milwaukee	–	–	–	–	–	–	295.0	154.0	206.0	184.0	–	–	–	0	0	–	–	–	2	3
2300 S. 51st Street	Milwaukee	–	–	–	–	–	–	–	–	149.0	121.0	–	–	–	–	0	–	–	–	–	0
3419 W. Wisconsin Avenue	Milwaukee	–	–	–	–	–	–	–	–	59.0	51.0	–	–	–	–	0	–	–	–	–	0
5100 S. 51st Street	Milwaukee	–	–	–	–	–	–	120.0	108.0	–	–	–	–	–	0	–	–	–	–	0	–
7528 W. Appleton Avenue	Milwaukee	–	–	–	–	118.0	–	134.0	112.0	132.0	132.0	–	0	0	0	–	–	–	0	0	0
600 E. Greenfield Avenue	Milwaukee	–	–	–	–	223.0	–	377.0	302.0	213.0	190.0	–	–	–	1	0	–	–	–	8	4
Ozaukee County																					
408 N. Lake St.	Port Washington	359.4	173.0	166.1	161.9	157.8	151.7	124.0	123.0	158.0	110.0	1	0	0	0	0	2	2	2	0	0
Racine County																					
730 Washington Avenue	Racine	–	–	–	–	131.0	–	102.0	89.0	143.0	90.0	–	–	0	0	0	–	–	0	0	0
3701 Durand Avenue	Racine	54.4	52.2	117.3	115.0	113.8	–	121.0	121.0	149.0	113.0	0	0	0	0	0	0	0	0	0	0
4901 Washington Avenue	Racine	95.3	70.7	77.8	71.9	123.7	–	115.0	102.0	111.0	108.0	0	0	0	0	0	0	0	0	0	0
2210 Rapids Drive	Racine	97.7	62.2	195.5	148.5	209.0	–	127.0	108.0	134.0	114.0	0	0	0	0	0	0	1	1	0	0
1501 Albert	Racine	212.6	207.7	262.7	195.7	285.8	233.5	238.0	182.0	243.0	173.0	0	1	1	0	0	4	2	6	4	3
1601 Washington Avenue	Racine	76.9	73.9	193.5	163.2	151.0	147.2	118.0	117.0	167.0	131.0	0	0	0	0	0	0	2	1	0	0
925 15th Avenue	Union Grove	157.0	89.0	109.0	88.0	109.4	–	–	–	148.0	131.0	0	0	0	–	0	1	0	0	–	0
Lakeview School	Wind Lake	71.5	67.6	121.9	67.0	92.8	–	–	–	–	–	0	0	0	–	–	0	0	0	–	–
Caledonia Town Hall	Husher	140.3	129.9	163.9	113.0	112.5	–	–	–	–	–	0	0	0	–	–	0	1	0	–	–
208 E. Jefferson	Burlington	94.7	94.6	129.1	120.0	118.0	113.0	–	–	–	–	0	0	0	–	–	0	0	0	–	–
1519 Washington Avenue	Racine	–	–	–	–	–	–	–	–	125.0	107.0	–	–	–	–	0	–	–	–	–	0
Walworth County																					
University of Wisconsin Whitewater-Upham Hall	Whitewater	74.9	69.3	74.8	59.8	105.6	–	77.0	72.0	–	–	0	0	0	0	–	0	0	0	0	–
723 Geneva Street	Lake Geneva	151.7	116.4	138.4	109.0	118.0	–	150.0	112.0	196.0	154.0	0	0	0	0	0	1	0	0	0	2
Waukesha County																					
St. Paul Avenue	Waukesha	131.1	115.1	109.8	82.6	174.5	–	101.0	100.0	147.0	144.0	0	0	0	0	0	0	0	1	0	0
1344 White Rock Avenue	Waukesha	–	–	–	–	–	–	112.0	42.0	341.0	232.0	–	–	–	0	0	–	–	–	0	11
1335 Cleveland Court	Waukesha	–	–	–	–	–	–	88.0	49.0	330.0	301.0	–	–	–	0	2	–	–	–	0	13
1116 Adams Street	Waukesha	–	–	–	–	–	–	87.0	40.0	231.0	196.0	–	–	–	0	0	–	–	–	0	3
1230 The Strand	Waukesha	–	–	–	–	–	–	93.0	53.0	475.0	430.0	–	–	–	0	6	–	–	–	0	19
1301 E. Main Street	Waukesha	–	–	–	–	–	–	–	–	225.0	139.0	–	–	–	–	0	–	–	–	–	0
612 E. Main Street	Waukesha	–	–	–	–	–	–	–	–	135.0	95.0	–	–	–	–	0	–	–	–	–	0

[a] *Station relocated to 600 E. Greenfield Avenue in 1975.*

Source: Wisconsin Department of Natural Resources.

and 381 $\mu g/m^3$ in 1977. No monitoring station, however, exceeded the three-hour standard at any time during 1976.[15]

Since the sulfur dioxide monitoring data are limited to five sites, a limited isopleth analysis could not be performed. Map 38 presents the annual arithmetic mean level of concentration and the maximum 24-hour and three-hour average sulfur dioxide concentrations in Milwaukee County for 1976 and 1977. As indicated on the Milwaukee County map, which is the area experiencing the highest monitored values, it appears unlikely that any part of the Region is in violation of the annual sulfur dioxide air quality standard.

The level of sulfur dioxide in rural areas of the Region is anticipated to be substantially lower than the isopleth values shown on Map 38, since those areas lack the

[15] *Two violations of the three-hour sulfur dioxide standard were recorded during 1975—one at the monitoring station located at 3714 W. Wisconsin Avenue, Milwaukee, on July 31st, and one at the station located at 7528 W. Appleton Avenue, Milwaukee, on October 5th-6th. Both violations were attributable to impingement by a major point source.*

Table 75

SULFUR DIOXIDE AIR QUALITY MONITORING DATA: 1976-1977

Monitoring Site	Number of Hours Monitored		Maximum Three-Hour Average Concentration ($\mu g/m^3$)		Maximum 24-Hour Average Concentration ($\mu g/m^3$)		Annual Arithmetic Average Concentration ($\mu g/m^3$)		Annual Arithmetic Standard Deviation	
	1976	1977	1976	1977	1976	1977	1976	1977	1976	1977
Milwaukee County										
606 W. Kilbourn Avenue	6,839	7,416	453	793	152	246	42	44	42	44
1225 S. Carferry Drive	6,366	7,620	752	845	290	283	61	57	58	60
3401 S. 39th Street	6,776	6,872	979	882	141	287	37	44	45	63
3716 W. Wisconsin Avenue	7,449	7,352	979	1,252	200	340	45	43	45	64
Racine County										
1603 Washington Avenue[a]	6,764	7,619	363	337	107	118	37	38	21	22

[a] *Station relocated in August 1977 to 1521 Washington Avenue.*

Source: Wisconsin Department of Natural Resources.

characteristic sources of sulfur dioxide emissions. Sulfur dioxide also is not subject to long-range transport in large concentrations, since it is readily absorbed by plants, soils, and certain material substances. Moreover, sulfur dioxide is readily oxidized in the atmosphere and is thus chemically transformed to sulfate particles. Consequently, sulfur dioxide emissions from the more urbanized areas of the Region are not expected to significantly impinge on the more rural areas.

Carbon Monoxide Concentrations: Monitoring for carbon monoxide levels began in the Region in 1973 but, as with sulfur dioxide, the data obtained by the DNR prior to 1975 were found to be invalid due to problems in the reduction of the raw data to accurate average concentrations. Consequently, only the air quality monitoring data for carbon monoxide concentrations recorded after January 1, 1975, with the exception of a few days in 1973, can be considered representative of regional levels.

A summary of the available carbon monoxide air quality monitoring data for 1975 through 1977 is presented in Table 76 for both the one-hour and eight-hour standards. Based on the data in this table, Map 39 was prepared, which locates the carbon monoxide monitoring sites in the Region during 1976 and 1977. In 1975, there were nine monitoring sites sampling for carbon monoxide, but this number was reduced to seven sites in 1976 when two stations in Milwaukee County were discontinued. The highest one-hour average carbon monoxide concentration in the Region during 1975 was recorded at the station located at 2114 E. Kenwood Boulevard in the City of Milwaukee, followed closely by the station located in the City of Waukesha at 726 N. Grand Avenue. The maximum concentrations recorded at these two sites, however—18.9 and 18.0 mg/m^3, respectively—are less than half of the one-hour ambient air quality standard of 40 mg/m^3.

In 1976 only two of the seven remaining carbon monoxide monitoring sites showed a reduction in the maximum one-hour concentration. The site at 7528 W. Appleton Avenue registered an increase of nearly 8.5 mg/m^3 in the level of the maximum one-hour concentration over the 1975 level. In 1977 each monitoring site in Milwaukee County recorded increases over the previous year's maximum one-hour carbon monoxide concentrations, while the site in Racine County and the site in Waukesha County registered slightly lower levels than 1976. The greatest increase in one-hour average carbon monoxide levels in the Region between 1976 and 1977 was measured in Milwaukee County at 3401 S. 39th Street, where the level in 1976 was 7.3 mg/m^3 and rose to 17.5 mg/m^3 in 1977. Even with the increases, however, ambient air concentrations remained well below the established standard.

Several violations of the eight-hour carbon monoxide standard of 10 mg/m^3 were recorded between 1975 and 1977. The highest maximum eight-hour concentration occurred in the City of Waukesha in 1975, at the Appleton Avenue site in the City of Milwaukee in 1976, and at the Wisconsin Avenue site in the City of Milwaukee in 1977. Of the seven monitoring sites in operation in 1976, three in Milwaukee County exceeded the eight-hour standard, while the sites in Racine and Waukesha Counties were only marginally below the standard. In 1977 all of the monitoring sites in Milwaukee County, as well as the monitoring site in Waukesha County, had measured carbon monoxide levels in excess of the eight-hour standard. A problem with eight-hour average carbon monoxide concentrations remains within localized areas of the Region.

Nitrogen Dioxide Concentrations: Prior to 1976, all federal and state nitrogen dioxide monitoring stations in the Region used the Jacobs-Hochheiser sampling method.

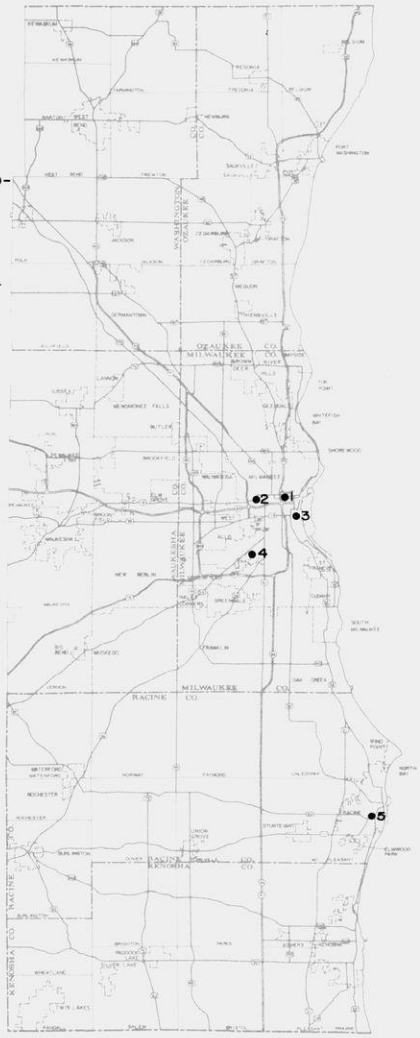
Map 38

SULFUR DIOXIDE MONITORING SITES IN THE REGION: 1976-1977

NOTE: PRIMARY ANNUAL AVERAGE STANDARD– 80μg/m^3.

PRIMARY 24-HOUR STANDARD– 365μg/m^3.

SECONDARY THREE-HOUR STANDARD– 1,300μg/m^3.



Site Number	Location	Year	Maximum Three-Hour Average (μg/m^3)	Maximum 24-Hour Average (μg/m^3)	Annual Arithmetic Average (μg/m^3)
1	606 W. Kilbourn Avenue	1976	453	152	42
		1977	793	246	44
2	3716 W. Wisconsin Avenue	1976	979	200	45
		1977	1,252	340	43
3	1225 S. Carferry Drive	1976	752	290	61
		1977	845	283	57
4	3401 S. 39th Street	1976	979	141	37
		1977	882	287	44
5	1521 Washington Avenue (Racine County)	1976	363	107	37
		1977	337	118	38

The National Ambient Air Quality Standard for sulfur oxides specifies that atmospheric levels shall not exceed the annual average level of 80 micrograms per cubic meter (0.03 part per million), and that the 24-hour average level of 365 micrograms per cubic meter (0.14 part per million), or the three-hour average level of 1,300 micrograms per cubic meter (0.50 part per million) shall not be exceeded more than once per year. As may be seen from this map, no station has exceeded these standards on either the annual, 24-hour, or three-hour time scale.

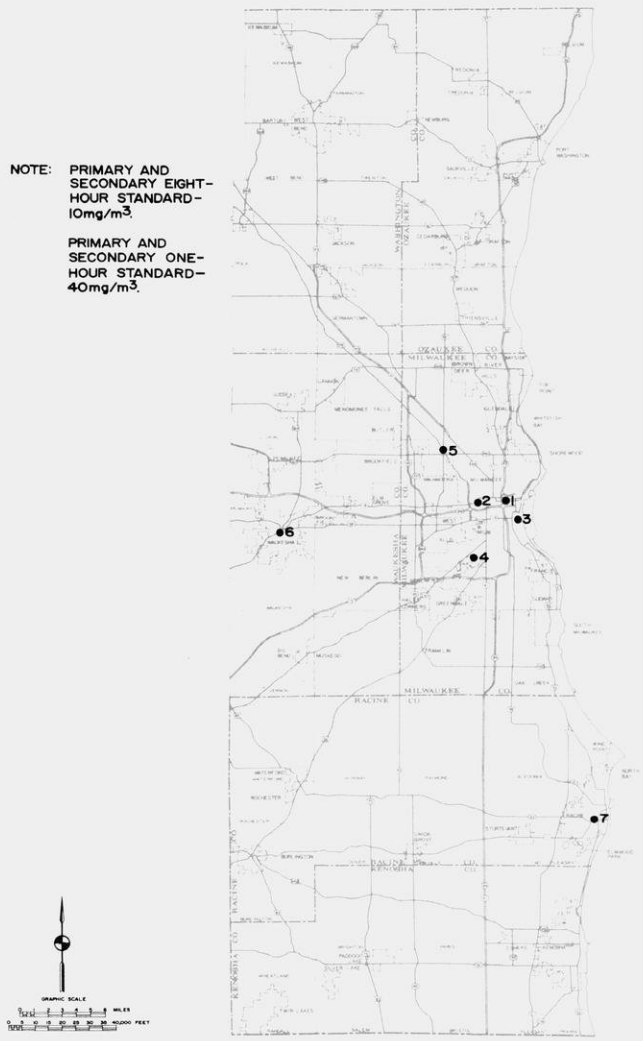
Source: Wisconsin Department of Natural Resources and SEWRPC.

Map 39

CARBON MONOXIDE MONITORING SITES IN THE REGION: 1976-1977

NOTE: PRIMARY AND SECONDARY EIGHT-HOUR STANDARD– 10mg/m^3.

PRIMARY AND SECONDARY ONE-HOUR STANDARD– 40mg/m^3.



Site Number	Location	Year	Highest One-Hour Average (mg/m^3)	Highest Eight-Hour Average (mg/m^3)
1	606 W. Kilbourn Avenue	1976	9.2	6.3
		1977	25.8	15.0
2	3716 W. Wisconsin Avenue	1976	19.3	10.2
		1977	23.3	17.3
3	1225 S. Carferry Drive	1976	12.3	12.0
		1977	18.6	10.7
4	3401 S. 39th Street	1976	7.3	4.0
		1977	17.5	11.4
5	7528 W. Appleton Avenue	1976	22.2	13.7
		1977	22.9	16.0
6	726 N. Grand Avenue (Waukesha County)	1976	19.5	9.7
		1977	15.9	11.5
7	1521 Washington Avenue (Racine County)	1976	19.9	9.9
		1977	17.0	9.6

The National Ambient Air Quality Standards for carbon monoxide specify that the second highest level of atmospheric carbon monoxide over a one-year period shall not exceed 10 milligrams per cubic meter (9.0 parts per million) over an eight-hour period and 40 milligrams per cubic meter (35.0 parts per million) over a one-hour period. Air sampling data gathered by the Wisconsin Department of Natural Resources reveal that in 1977 the monitoring sites in Racine County were the only ones recording eight-hour carbon monoxide levels less than the established standards.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Table 76

CARBON MONOXIDE AIR QUALITY MONITORING DATA: 1975-1977

Monitoring Site	Highest One-Hour Average (mg/m^3)			Highest Eight-Hour Average (mg/m^3)		
	1975	1976	1977	1975	1976	1977
Milwaukee County						
606 W. Kilbourn Avenue	13.0	9.2	25.8	9.0	6.3	15.0
1225 S. Carferry Drive	12.0	12.3	18.6	10.3	12.0	10.7
3401 S. 39th Street	8.3	7.3	17.5	5.9	4.0	11.4
3716 W. Wisconsin Avenue	17.3	19.3	23.3	8.7	10.2	17.3
7528 W. Appleton Avenue	13.8	22.2	22.9	7.4	13.7	16.0
2114 E. Kenwood Boulevard	18.9	–	–	7.4	–	–
9722 W. Watertown Plank Road	8.2	–	–	3.9	–	–
Racine County						
1603 Washington Avenue[a]	10.4	19.9	15.6	4.7	9.9	5.0
1521 Washington Avenue	–	–	17.0	–	–	9.6
Waukesha County						
726 N. Grand Avenue	18.0	19.5	15.9	11.3	9.7	11.5

[a] *Station relocated in August 1977 to 1521 Washington Avenue.*

Source: Wisconsin Department of Natural Resources.

After it was determined that this sampling method did not yield reliable data, it was replaced by the Christie arsenite method. Only four monitoring sites using the Christie arsenite method, however, met the minimum sampling requirements as defined by the EPA. The minimum sampling frequency for nitrogen dioxide is one 24-hour sample every 14 days, which is equivalent to 26 random samples per year. Table 77 lists the nitrogen dioxide monitoring sites, all in the City of Milwaukee, and summarizes the valid data for 1976 and 1977.

It may be seen in Table 77 that the highest annual value reported, 70.0 $\mu g/m^3$ at 711 W. Wells Street in 1977, is well below the standard of 100 $\mu g/m^3$ on an annual basis. Since the monitoring sites are all located in areas of high nitrogen dioxide emissions, particularly from motor vehicles, it is probable that these data are representative of the maximum nitrogen dioxide concentrations in southeastern Wisconsin. Map 40 identifies the location of the nitrogen dioxide monitoring sites in Milwaukee County.

Hydrocarbon Concentrations: There is only a limited amount of air quality monitoring data on regional hydrocarbon levels available to date. Under a special contract with the DNR, Washington State University collected data on average 6 a.m. to 9 a.m. hydrocarbon concentrations at the Kenosha Airport between August 4 and September 30, 1976. Of the 58 monitoring days, 43 registered violations of the hydrocarbon standard of 160 $\mu g/m^3$ (0.24 ppm). The highest three-hour (6 a.m. to 9 a.m.) average recorded was about 553 $\mu g/m^3$ (0.83 ppm) total nonmethane hydrocarbons measured on September 19, 1976, and the second highest was 420 $\mu g/m^3$ (0.63 ppm) measured on August 21, 1976. These levels are approximately 250 and 150 percent above the established standard, respectively.

The DNR also operated a hydrocarbon monitoring station at 3716 W. Wisconsin Avenue in the City of Milwaukee from August 1 to 19, 1975, sampling on 13 days. Samples from all 13 days monitored indicated violations of the 6 a.m. to 9 a.m. standard. The highest recorded three-hour total nonmethane hydrocarbon average was 509 $\mu g/m^3$ (0.763 ppm), and the second highest value was 389 $\mu g/m^3$ (0.584 ppm). These values are about 200 and 150 percent above the standard, respectively. From March through May 1977, the Department of Natural Resources operated a mobile air monitoring van in the City of Kenosha from which a limited amount of nonmethane hydrocarbon data were gathered. During this period a maximum three-hour nonmethane hydrocarbon reading of 755 $\mu g/m^3$ (0.39 ppm) was recorded. Although limited in quantity and spatial distribution, the available hydrocarbon air quality monitoring data indicate that numerous violations of the three-hour hydrocarbon standard are occurring over a broad area in the Region.

Photochemical Oxidant Concentrations: The number of monitoring sites in the Region sampling for ozone was increased from six during the summer of 1973 to 10 in both 1976 and 1977. Table 78 lists these monitoring sites, along with the highest one-hour ozone levels recorded at each site by year. Owing to equipment maintenance and repair requirements, not all monitoring sites were sampled continuously, or even on the same days, during the year. Consequently, a direct comparison of ozone concentrations monitored at all of the various sites, or at the same site from year to year, is not possible. Also, the limited period of record is insufficient to adequately identify significant trends in the data. Certain observations, however, can be made with respect to the regional ozone problem from the available sampling data.

Table 77

NITROGEN DIOXIDE AIR QUALITY MONITORING DATA: 1976-1977

Monitoring Site	Number of Samples		Maximum 24-Hour Level ($\mu g/m^3$)		Annual Average ($\mu g/m^3$)		Standard Deviation ($\mu g/m^3$)	
	1976	1977	1976	1977	1976	1977	1976	1977
City of Milwaukee								
1225 S. Carferry Drive	44	59	93	127	45.2	47.6	20.1	23.0
7528 W. Appleton Avenue	46	60	199	104	50.4	55.0	27.5	19.9
3716 W. Wisconsin Avenue	56	57	148	136	60.8	60.4	26.7	25.4
711 W. Wells Street	52	53	237	108	59.6	70.0	32.9	19.2

Source: Wisconsin Department of Natural Resources.

First, the highest one-hour average ozone concentration monitored in southeastern Wisconsin was 0.297 ppm, which occurred in Racine County in 1974--a level approximately 2.5 times the standard of 0.12 ppm. Until 1976 Racine County had consistently reported the highest one-hour maximum ozone concentrations over the period of record. In 1976 and 1977, however, the highest level was reported by the station located at 2114 E. Kenwood Boulevard in the City of Milwaukee.

Second, the lowest maximum one-hour ozone concentration over the period of record was 0.058 ppm, monitored in 1975 by the station located at 1225 S. Carferry Drive in the City of Milwaukee. This low value, however, reflects the results of only a very limited amount of ozone monitoring data available in the City of Milwaukee in 1975. It is probable that higher ozone levels would have been indicated had a greater number of hours been sampled during the year. With the exception of the 1975 data, therefore, Table 78 indicates that the monitoring site located in the City of Waukesha has generally recorded the lowest maximum one-hour ozone concentrations of all stations with a sufficient number of valid sampling hours in a given year.

The data demonstrate that high maximum ozone concentrations occur outside of the heavily populated area of the City of Milwaukee. In 1976, for example, monitoring sites in Kenosha, Racine, and Ozaukee Counties each experienced a higher one-hour maximum than any site in Milwaukee County with the exception of the station at 2114 E. Kenwood Boulevard in the City of Milwaukee. The fact that Waukesha County generally recorded relatively low maximum ozone levels indicates that there is a pronounced decline in ozone levels in an inland direction away from Lake Michigan. Confounding this indication, however, is the fact that high ozone levels have been measured at all locations throughout the State when continuing ozone monitoring has been conducted during the summer and fall months.

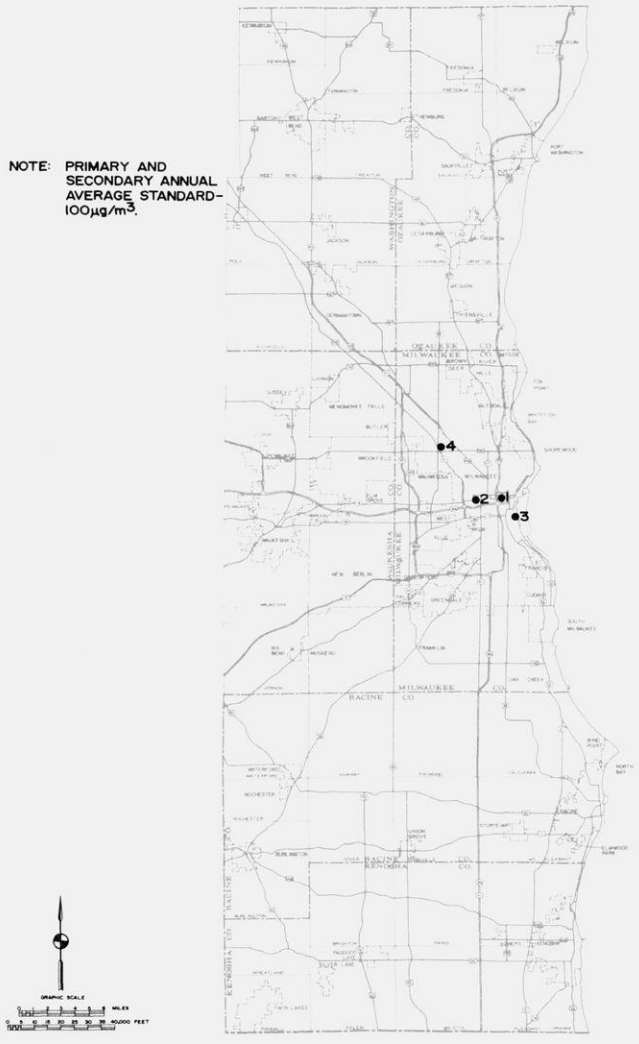
The number of hours each monitoring site exceeded the ambient air quality standard of 0.12 ppm from 1973 through 1977 is given in Table 79. The table indicates that the Racine County monitoring site recorded the greatest number of hours above 0.12 ppm in both 1973 and 1974; the Ozaukee County monitoring site recorded the greatest number of hours above 0.12 ppm in both 1975 and 1976; and the station at 2114 E. Kenwood Boulevard in the City of Milwaukee recorded the greatest number of hours above 0.12 ppm in 1977. Again, a direct comparison of the concentrations monitored at the various sites, or even at the same site in different years, is not possible because the number of violations at any monitoring site is a function of the number of hours the monitor is operating. Therefore, if a monitoring site is not operating during a sustained period of high ozone levels it may not record a large percentage of the annual values exceeding the standard. For this reason, monitoring stations in Milwaukee County in 1975 indicate little, if any, violations of the standard since much of the monitoring data for these sites were deemed invalid for that year.

The relatively large number of hours in which the ozone standard was exceeded in Kenosha County during 1975 and 1976 is probably indicative of Kenosha's proximity to the Chicago area, from where substantial quantities of oxidants and their precursor emissions may be transported into the Region. The ozone monitoring site in Kenosha was located approximately four miles north of the Wisconsin-Illinois border and is well removed from any major air pollution source which would influence the monitored ozone concentrations. The high levels of ozone concentrations monitored at the Kenosha site when the prevailing winds have a high southerly component may, therefore, be attributable to the migration of pollutants across the state boundaries. The relatively large number of hours over which the ozone standard in Racine County was exceeded also tends to support the conclusion that the ozone problem in Kenosha and Racine Counties is essentially due to the long-range transport of pollutants from extraregional sources.

In order to illustrate the diurnal buildup of ozone in the atmosphere, and to depict the relative contribution of local emission sources compared to the contribution from extraregional pollutant sources in the formation of regional ozone levels, Figures 39 through 47 graphically present an hour-by-hour display of the monitored

Map 40

NITROGEN DIOXIDE MONITORING SITES IN THE REGION WITH ANNUAL AVERAGE MONITORED LEVELS: 1976-1977



Site Number	Location	Year	Annual Average ($\mu g/m^3$)
1	711 W. Wells Street	1976	59.6
		1977	70.0
2	3716 W. Wisconsin Avenue	1976	60.8
		1977	60.4
3	1225 S. Carferry Drive	1976	45.2
		1977	47.6
4	7528 W. Appleton Avenue	1976	50.4
		1977	55.0

A total of four nitrogen dioxide monitoring sites, using the Christie arsenite sampling method, met the minimum sampling requirements as defined by the Environmental Protection Agency during 1976 and 1977. Since each site is located in an area of high nitrogen dioxide emissions, principally from vehicular traffic, it is probable that data from these sites are representative of the maximum nitrogen dioxide concentrations in southeastern Wisconsin. As shown above, the highest annual value reported, 60.8 micrograms per cubic meter at 3716 W. Wisconsin Avenue in 1976, and the highest annual value reported, 70.0 micrograms per cubic meter at 711 W. Wells Street in 1977, are well below the annual standard of 100 micrograms per cubic meter.

Source: Wisconsin Department of Natural Resources and SEWRPC.

ozone concentrations from nine sites in the Region on June 12, 1976, from 11:00 a.m. to 7:00 p.m. On this day, the highest one-hour average ozone concentration measured to date within the Region was recorded.

Figure 39 shows that by 11:00 a.m., pollutant concentrations in Kenosha were already far in excess of the 0.12 ppm standard, recording between 0.131 and 0.155 ppm of ozone. Racine was still somewhat lower--on the order of 0.106 to 0.130 ppm of ozone--while only one station in Milwaukee--that on the south side at Alverno College, 3401 S. 39th Street--recorded relatively elevated concentrations. By 12:00 noon, as shown in Figure 40, both Kenosha and Racine were recording ozone levels between 0.156 and 0.180 ppm. In Milwaukee, the recorded levels at Alverno College remained in the same range as the hour earlier, the Civic Center at 606 W. Kilbourn approached the standard, and the monitoring site at the University of Wisconsin-Milwaukee, north on Kenwood Boulevard, exceeded the standard. The dramatic increase observed between 11:00 a.m. and 12:00 noon at the UWM campus was probably due to the fact that the wind direction changed from a southerly direction to a southeasterly direction, allowing ozone-enriched air transported over Lake Michigan to reach the monitoring site location.

By 1:00 p.m., Figure 41, ozone levels at the Grafton monitoring site in Ozaukee County increased from below 0.080 ppm in the previous hour to a level between 0.156 and 0.180 ppm. Substantial concentration increases were also recorded at the UWM Campus, the Civic Center, Alverno College, and Jones Island in Milwaukee County, as well as at the Racine County and Kenosha County monitoring sites.

At 2:00 p.m., Figure 42, most of the daily high ozone concentrations at monitoring stations in Milwaukee County had been reached. Both the monitoring sites at Alverno College and at 3716 W. Wisconsin Avenue rose to the 0.181 to 0.205 ppm range, while the concentrations at the Civic Center and Jones Island reached the 0.206 to 0.230 level. The site on the UWM campus remained in excess of 0.230 ppm. In Ozaukee County, the monitor in Grafton also increased beyond the 0.230 ppm level. It should be noted that both the Kenosha County and Racine County monitors experienced reduced ozone concentrations within this hour, dropping to the 0.156 to 0.180 ppm and 0.181 to 0.205 ppm levels, respectively. These reductions in air pollution may be attributable to a marked decline in the transport of precursor pollutant compounds generated during the early morning rush-hour traffic flow in the Chicago urbanized area. The fact that the Milwaukee area is continuing to experience increases in oxidant concentrations in this hour is indicative of the continuing photochemical irradiation of early morning transported precursor emissions from a southerly direction.

A continuing decline of ozone concentrations is evident at 3:00 p.m., as shown in Figure 43, for both Kenosha and Racine Counties. Also, the monitoring sites at Jones Island and the Civic Center in Milwaukee County register their first decline in ozone levels during the day. All other stations remain in the same range as the previous hour.

Table 78

HIGHEST ONE-HOUR MONITORED
OZONE CONCENTRATIONS IN THE REGION: 1973-1977

Monitoring Site		Maximum Ozone Concentration (ppm)				
Street Address	Civil Division	1973	1974	1975[f]	1976	1977
Kenosha County						
8518 22nd Avenue	Kenosha	--	--	0.212	0.271	--
Kenosha Airport[a]	Kenosha	--	--	--	--	0.175
Milwaukee County						
9722 W. Watertown Plank Road	Wauwatosa	0.150	0.200	0.076	--	--
2114 E. Kenwood Boulevard	Milwaukee	0.217	0.270	0.094	0.290	0.204
1225 S. Carferry Drive	Milwaukee	0.151	0.125	0.058	0.214	0.165
3716 W. Wisconsin Avenue	Milwaukee	--	--	0.064	0.195	0.149
3401 S. 39th Street	Milwaukee	--	0.183	0.073	0.197	0.178
7528 W. Appleton Avenue	Milwaukee	0.128	0.152	0.162	0.146	0.169
606 W. Kilbourn Avenue	Milwaukee	0.208	0.187	0.163	0.218	0.057[c]
Ozaukee County						
Highways C and Q	Grafton	--	--	0.200	0.238	0.181[d]
Racine County						
1603 Washington Avenue[e]	Racine	0.257	0.297	0.227	0.232	0.181
1521 Washington Avenue	Racine	--	--	--	--	0.106
Waukesha County						
726 N. Grand Avenue	Waukesha	--	0.111[b]	0.101	0.108	0.148

[a] *Location of mobile air quality monitoring van.*

[b] *Operated only during the months of August through December 1974.*

[c] *Operated through April 1977.*

[d] *Operated through August 1977.*

[e] *Station relocated to 1521 Washington Avenue in August 1977.*

[f] *Due to faulty calibration, much of the ozone data recorded at monitoring sites in Milwaukee County during 1975 were deemed invalid. Thus, the maximum one-hour average ozone values indicated for this year may be anomalously low.*

Source: Wisconsin Department of Natural Resources.

In Figure 44, the first decline in oxidant levels on the north side of the City of Milwaukee is shown to occur around 4:00 p.m. The Jones Island and Civic Center monitoring sites remain constant, but a decline may be seen at the 3716 W. Wisconsin Avenue station. Alverno College did not report data for this hour. The Grafton site continued to experience an influx of oxidants from the south and remained above the 0.230 ppm level. It is particularly interesting to note that both Kenosha and Racine Counties registered an increase in ozone concentrations during this hour. Such an increase may be due to a combination of local emissions as the evening rush hour is approached and the transport of pollutants from the Chicago area by a secondary mid-morning traffic peak generated by shopping trips, industrial activity, and the increased use of commercial motor vehicles.

By 5:00 p.m., as shown in Figure 45, the Racine and Kenosha County monitoring sites resume their decline, and all sites in Milwaukee County, with the exception of the UWM campus, reported decreasing ozone levels. The Grafton site persisted in measurements above 0.230 ppm.

Table 79

NUMBER OF HOURS PER MONITORING SITE EXCEEDING
0.12 PPM OF MEASURED OZONE CONCENTRATIONS: 1973-1977

Monitoring Site		Number of Hours of Measured Ozone Levels in Excess of 0.12 ppm				
Street Address	Civil Division	1973	1974	1975	1976	1977
Kenosha County						
8518 22nd Avenue[a]	Kenosha	--	--	58	97	--
Kenosha Airport	Kenosha	--	--	--	--	14
Milwaukee County						
9722 W. Watertown Plank Road	Wauwatosa	4	11	0	--	--
2114 E. Kenwood Boulevard	Milwaukee	23	49	0	62	38
1225 S. Carferry Drive	Milwaukee	13	2	0	28	16
3716 W. Wisconsin Avenue	Milwaukee	--	--	0	11	7
3401 S. 39th Street	Milwaukee	--	21	0	21	16
7528 W. Appleton Avenue	Milwaukee	6	6	36	6	8
606 W. Kilbourn Avenue	Milwaukee	20	10	14	25	0[b]
Ozaukee County						
Highways C and Q	Grafton	--	--	65	115	6
Racine County						
1603 Washington Avenue[c]	Racine	43	58	41	87	32
Waukesha County						
726 N. Grand Avenue	Waukesha	--	0	0	0	6

[a] *Location of mobile air quality monitoring van.*

[b] *Operated through April 1977.*

[c] *Station relocated to 1521 Washington Avenue in August 1977.*

Source: Wisconsin Department of Natural Resources.

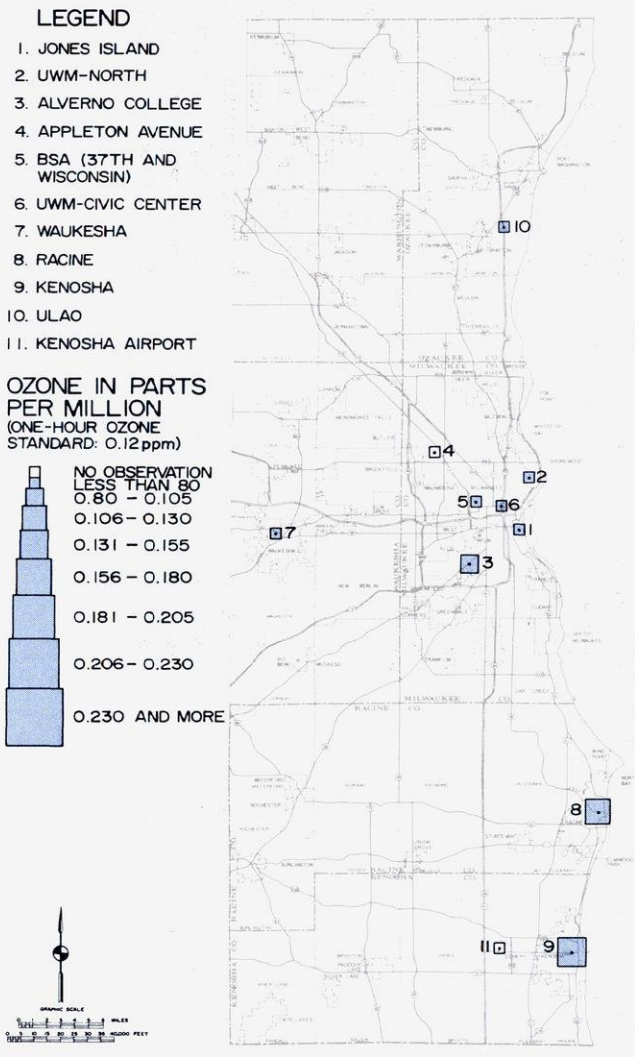
The first evidence of decreasing oxidant concentrations on the north side of Milwaukee appears by 6:00 p.m., as may be seen in Figure 46. The only reversal from a continuing decline in all of Kenosha, Racine, and Milwaukee Counties occurs at 3716 W. Wisconsin Avenue in the City of Milwaukee. The observed increase in ozone concentrations at this site is most probably due to a decrease in nitrogen oxide emissions caused by a decrease in local vehicle movement and reduced industrial activity. Again, the Grafton site records ozone concentrations above 0.230 ppm.

At 7:00 p.m., Figure 47, all monitoring stations to the south of the UWM campus in the City of Milwaukee report lower levels of oxidant concentrations. Waukesha also measured lower concentrations for the first time since the morning oxidant buildup. Grafton, on the other hand, had not yet realized a significant decrease since reaching its maximum ozone levels around 2:00 p.m.

In total, these nine figures indicate a northerly progression of the maximum oxidant concentrations during daylight hours from both local emission sources and extraregional emission sources. The high ozone levels monitored in Kenosha and Racine Counties in the mid-morning are predominantly related to the early morning hydrocarbon emissions in the Chicago metropolitan area and the influx of additional oxidants and their precursor emissions from areas much farther downwind. By early afternoon these transported emissions have reached Milwaukee County, producing substantial increases in the oxidant levels. The highest ozone concentrations during the day are observed on the north side of Milwaukee and in Ozaukee County, where the combination of local plus transported emissions compounds the oxidant levels. The area of maximum daily ozone levels also tends to retain the higher concentrations well into the evening, as exemplified by the persistence of values greater than 0.230 ppm of ozone in Grafton.

Figure 39

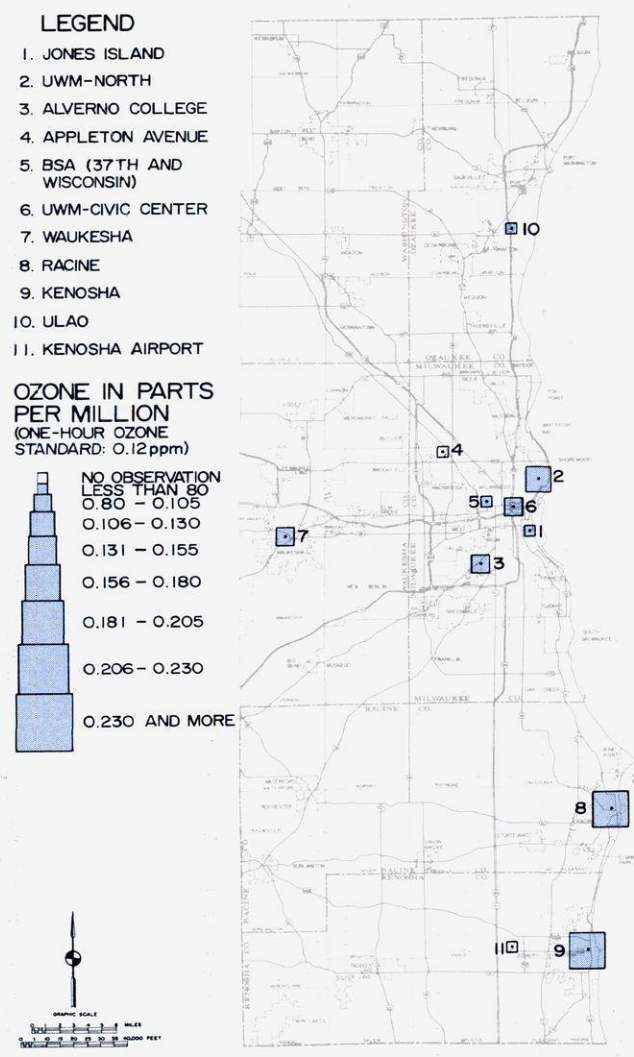
AVERAGE HOURLY OZONE CONCENTRATIONS AT SELECTED STATIONS IN THE REGION— JUNE 12, 1976: 11:00 A.M.



Source: Wisconsin Department of Natural Resources.

Figure 40

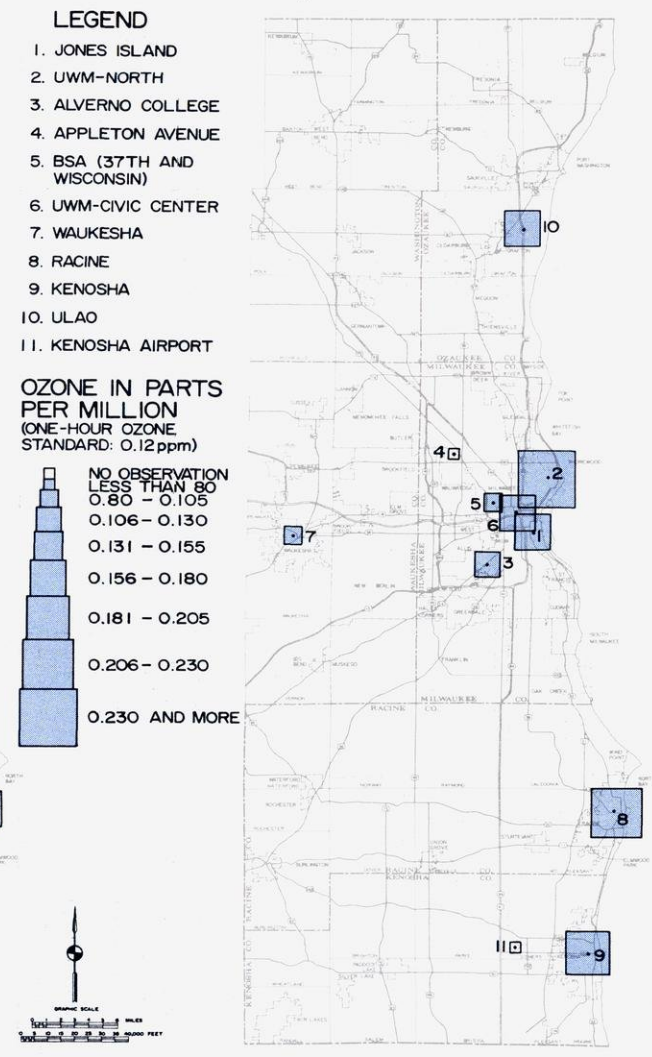
AVERAGE HOURLY OZONE CONCENTRATIONS AT SELECTED STATIONS IN THE REGION— JUNE 12, 1976: 12:00 P.M.



Source: Wisconsin Department of Natural Resources.

Figure 41

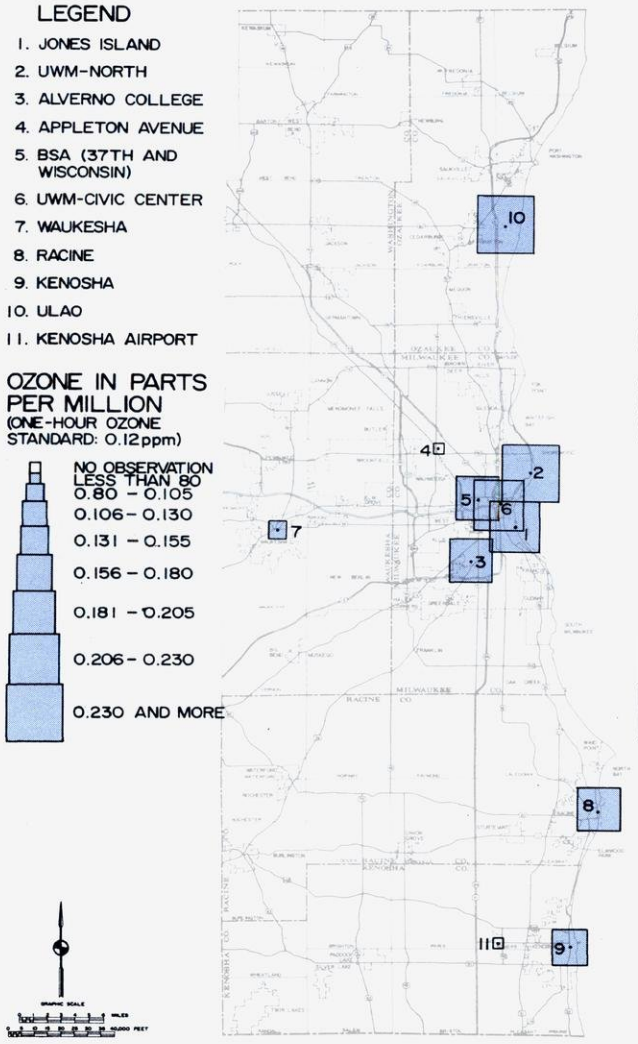
AVERAGE HOURLY OZONE CONCENTRATIONS AT SELECTED STATIONS IN THE REGION— JUNE 12, 1976: 1:00 P.M.



Source: Wisconsin Department of Natural Resources.

Figure 42

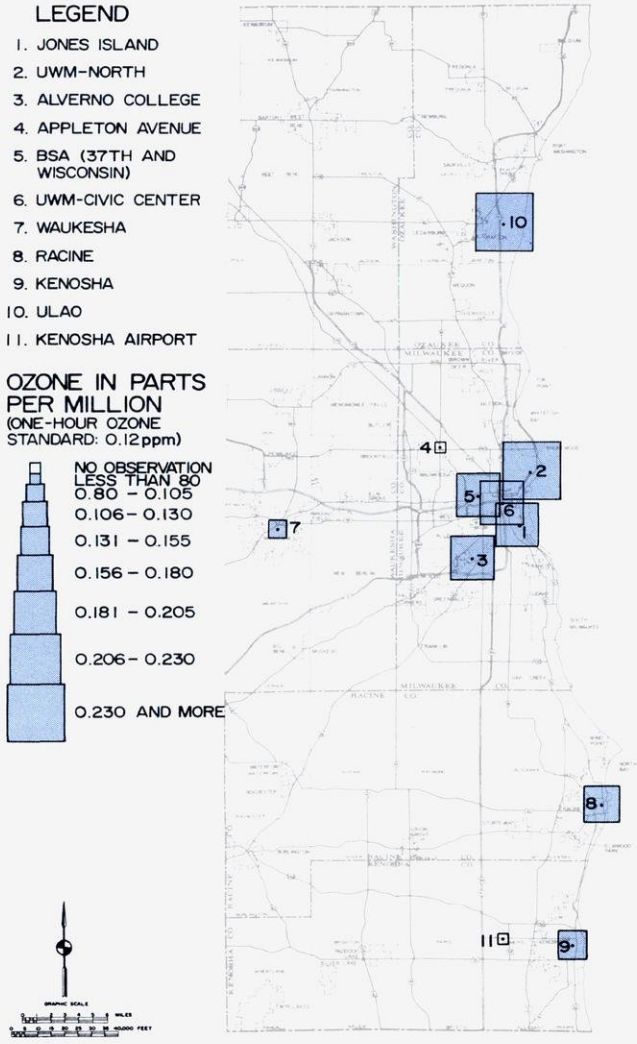
AVERAGE HOURLY OZONE CONCENTRATIONS AT SELECTED STATIONS IN THE REGION— JUNE 12, 1976: 2:00 P.M.



Source: Wisconsin Department of Natural Resources.

Figure 43

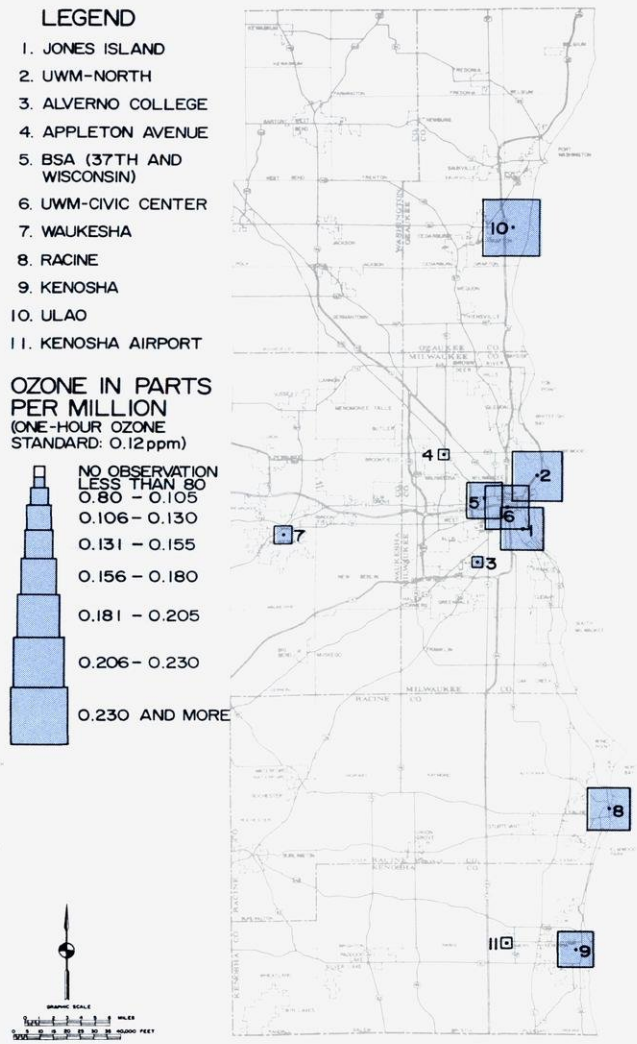
AVERAGE HOURLY OZONE CONCENTRATIONS AT SELECTED STATIONS IN THE REGION— JUNE 12, 1976: 3:00 P.M.



Source: Wisconsin Department of Natural Resources.

Figure 44

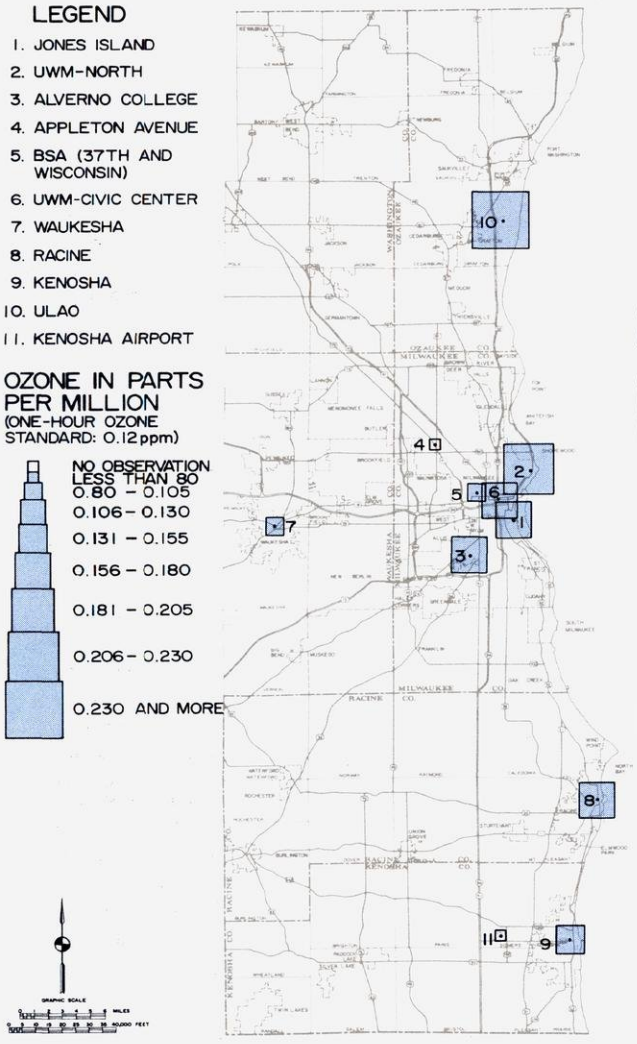
AVERAGE HOURLY OZONE CONCENTRATIONS AT SELECTED STATIONS IN THE REGION— JUNE 12, 1976: 4:00 P.M.



Source: Wisconsin Department of Natural Resources.

Figure 45

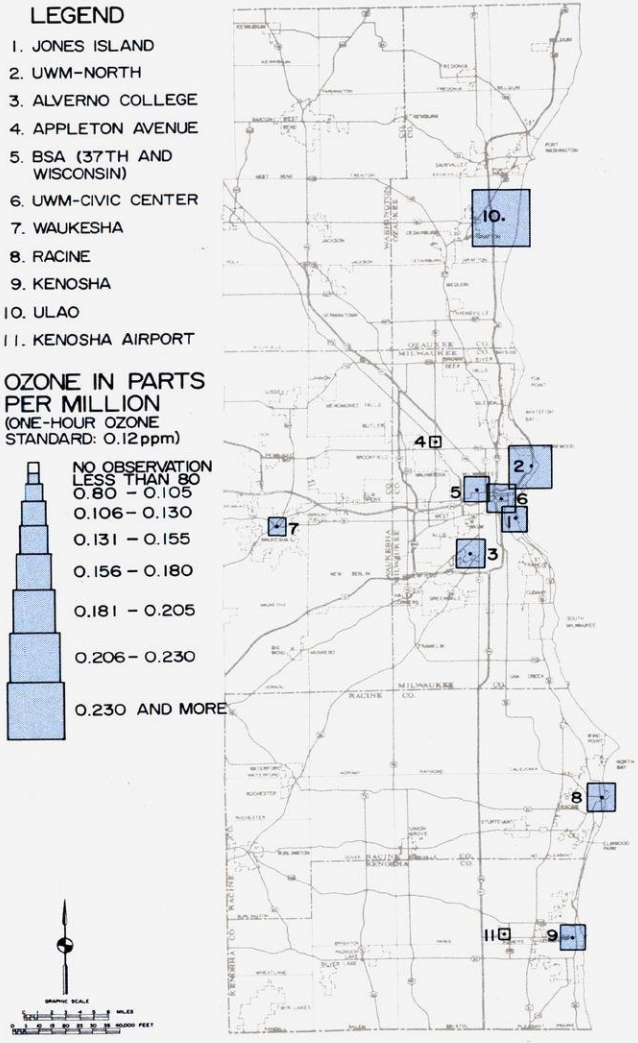
AVERAGE HOURLY OZONE CONCENTRATIONS AT SELECTED STATIONS IN THE REGION— JUNE 12, 1976: 5:00 P.M.



Source: Wisconsin Department of Natural Resources.

Figure 46

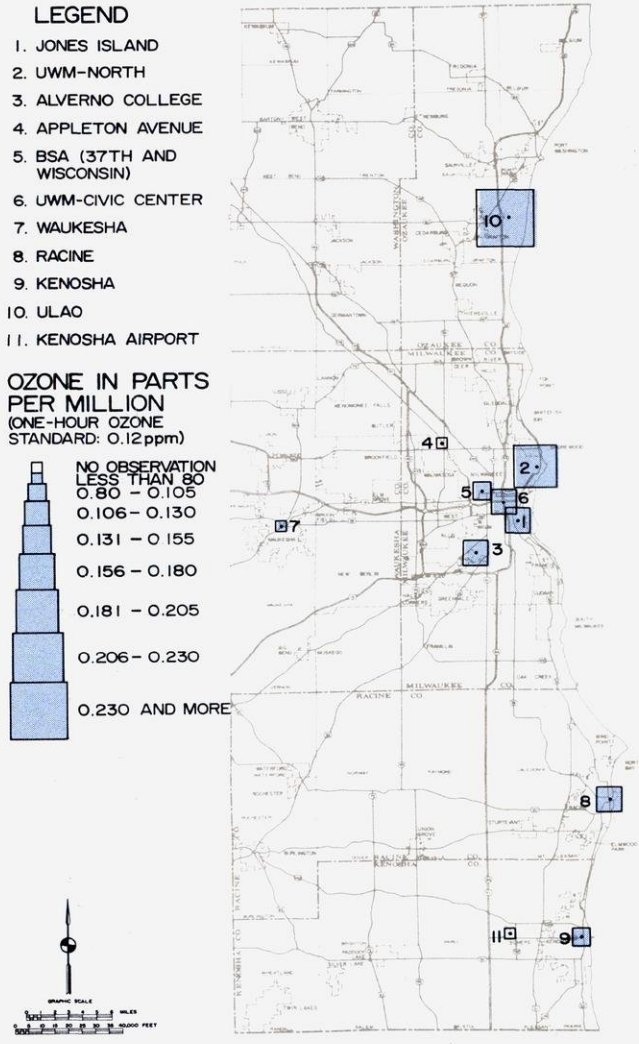
AVERAGE HOURLY OZONE CONCENTRATIONS AT SELECTED STATIONS IN THE REGION— JUNE 12, 1976: 6:00 P.M.



Source: Wisconsin Department of Natural Resources.

Figure 47

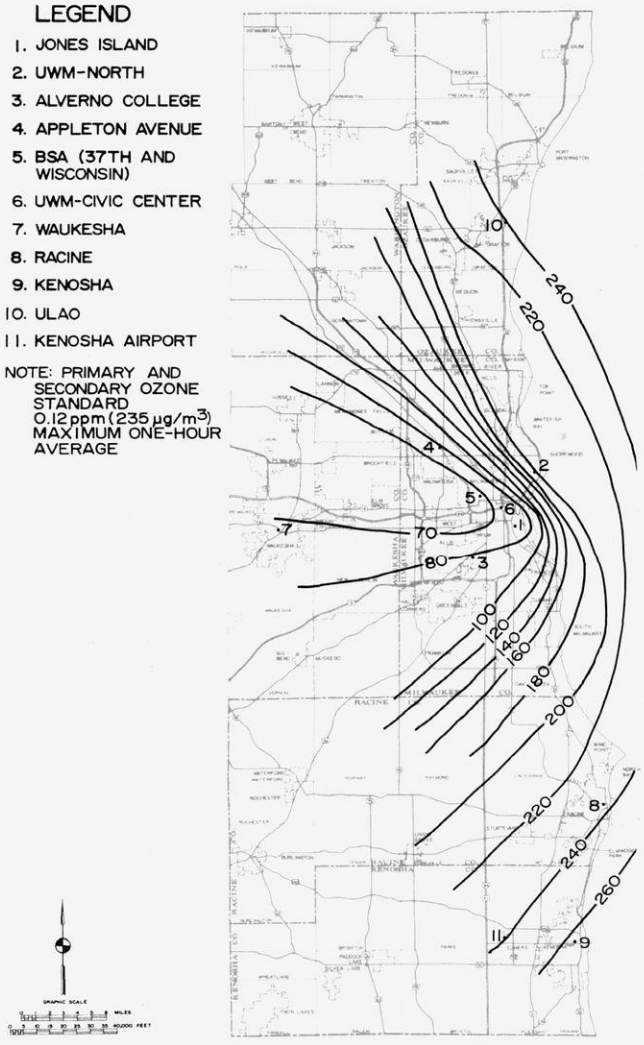
AVERAGE HOURLY OZONE CONCENTRATIONS AT SELECTED STATIONS IN THE REGION— JUNE 12, 1976: 7:00 P.M.



Source: Wisconsin Department of Natural Resources.

Figure 48

GENERALIZED ISOPLETHS OF MAXIMUM HOURLY OZONE VALUES FOR JULY 6, 1976 (PPM)



Source: Wisconsin Department of Natural Resources.

The significance of local versus transported precursor emissions may also be seen in Figure 48. This figure presents the generalized isopleths of maximum hourly ozone values for July 6, 1976. The maximum isopleth value is 0.260 ppm, occurring in Kenosha County. Proceeding northward, the isopleth values show a marked decrease until central Milwaukee County is reached. In the absence of any major precursor emission sources in southern Kenosha County, it may be concluded that this gradient of declining oxidant levels is evidence of transported pollutants crossing the state boundary and mixing with, and being diluted by, the relatively cleaner air over Kenosha, Racine, and southern Milwaukee Counties. To the north of central Milwaukee County high oxidant concentrations are sustained over a long time period, as evidenced by the data from the Grafton site. Therefore, the oxidant levels downwind of the Milwaukee urbanized area are attributable to both local precursor pollutant emissions and the much larger influx of both oxidants and their precursor emissions from extraregional sources.

Emergency Air Pollution Episode Levels

Existing air quality monitoring data indicate that violations of several of the air quality standards have, and still are, occurring in the Southeastern Wisconsin Region. Consequently, it has been necessary to establish a mechanism by which air pollution control measures may be implemented promptly and routinely when emergency air pollution episodes occur. Three emergency episode levels have been established, each defined by a particular level of specific pollutant concentrations, and each producing a specific set of responses to reduce pollutant emissions. Summary data defining these three emergency episode levels—alert, warning, and emergency—are presented in Table 80.

The initial stage, the alert level, is that concentration of pollutants at which control measures are to begin. An alert level is declared whenever any pollutant reaches the concentrations specified in Table 80 at any monitoring site and meteorological conditions are such that the pollutant concentrations may be expected to remain at alert levels or higher for 12 or more hours or, in the case of photochemical oxidants, to recur the following day at the same or higher levels, unless control actions are taken to reduce pollutant emissions. At the alert level the basic action is to prohibit all open burning operations and to restrict certain intermittent industrial operations, such as cleaning boilers or incinerating solid waste, to between 12:00 noon and 4 p.m., when atmospheric conditions are generally most favorable to dispersion.

The warning level indicates that air quality is continuing to degrade and that additional control measures are necessary. At this level both open burning and incineration of solid waste are prohibited at all times while the warning is in effect.

The emergency level indicates that air quality is continuing to degrade even with the control measures in effect under the alert and warning levels and that the most stringent control measure must be implemented. When the emergency level is reached, all nonessential commercial, institutional, and manufacturing operations are to cease and all motor vehicle use is prohibited except for emergency purposes.

Table 80

EMERGENCY AIR POLLUTION EPISODE LEVELS

Alert Level	Warning Level	Emergency Level
1. The sulfur dioxide dose is equal to or greater than 2.8 ppm per hour (7,500 μg-hr/m^3) for any consecutive eight-hour period in the preceding 16 hours	1. The sulfur dioxide dose is equal to or greater than 5.6 ppm per hour (15,000 μg-hr/m^3) for any consecutive eight-hour period in the preceding 16 hours	1. The sulfur dioxide dose is equal to or greater than 8.0 ppm per hour (21,500 μg-hr/m^3) for any consecutive eight-hour period in the preceding 16 hours
2. The particulates dose is equal to or greater than 28 COHs per hour (3,500 μg-hr/m^3) for any consecutive eight-hour period in the preceding 16 hours	2. The particulates dose is equal to or greater than 56 COHs per hour (7,000 μg-hr/m^3) for any consecutive eight-hour period in the preceding 16 hours	2. The particulates dose is equal to or greater than 72 COHs per hour (9,000 μg-hr/m^3) for any eight-hour period in the preceding 16 hours
3. The sulfur dioxide and particulate combined—product of sulfur dioxide ppm, 24-hour average, and COH, 24-hour average equal to 0.2 or product of sulfur dioxide μg/m^3, 24-hour average, and particulate μg/m^3, 24-hour average equal to 65 x 10^3	3. The sulfur dioxide and particulate combined—product of sulfur dioxide ppm, 24-hour average and COH, 24-hour average equal to 0.8 or product of sulfur dioxide μg/m^3, 24-hour average and particulate μg/m^3, 24-hour average equal to 261 x 10^3	3. The sulfur dioxide and particulate combined—product of sulfur dioxide ppm, 24-hour average and COH, 24-hour average equal to 1.2 or product of sulfur dioxide μg/m^3, 24-hour average and particulate μg/m^3, 24-hour average equal to 393 x 10^3
4. The carbon monoxide dose is equal to or greater than 120 ppm per hour (138 mg-hr/m^3) for any consecutive eight-hour period in the preceding 16 hours	4. The carbon monoxide dose is equal to or greater than 240 ppm per hour (275 mg-hr/m^3) for any consecutive eight-hour period in the preceding 16 hours	4. The carbon monoxide dose is equal to or greater than 320 ppm per hour (368 mg-hr/m^3) for any consecutive eight-hour period in the preceding 16 hours
5. The oxidant dose is equal to or greater than 0.4 ppm per hour (800 μg-hr/m^3) for any consecutive four-hour period in the preceding eight hours	5. The oxidant dose is equal to or greater than 1.2 ppm per hour (2,000 g-hr/m^3) for any consecutive four-hour period in the preceding 16 hours	5. The oxidant dose is equal to or greater than 1.4 ppm per hour (2,800 μg-hr/m^3) for any consecutive four-hour period in the preceding eight hours
6. The nitric oxide dose is equal to or greater than 2.4 ppm per hour (4,510 μg-hr/m^3) for any consecutive four-hour period in the preceding eight hours	6. The nitric oxide dose is equal to or greater than 4.8 ppm per hour (9,040 μg-hr/m^3) for any consecutive four-hour period in the preceding eight hours	6. The nitric oxide dose is equal to or greater than 6.4 ppm per hour (12,050 μg-hr/m^3) for any consecutive four-hour period in the preceding eight hours

Source: Wisconsin Administrative Code, Department of Natural Resources, NR 154.20.

In addition to the above-stated actions under the alert, warning, and emergency levels, any person responsible for the operation of an air pollution source which emits more than 0.25 ton per day of any air contaminant for which air quality standards have been established must prepare and submit to the DNR an emission control plan for reducing the amount of air contaminants released to the atmosphere in the event ambient air quality deteriorates to either the alert, warning, or emergency stage. The DNR has the responsibility to notify such pollutant sources to effect their adopted emission control plan whenever the air quality monitoring data and meteorological forecasts indicate that an air pollution episode level has been attained and will be sustained. Through such a program air pollutant concentrations are to be minimized in as timely and nondisruptive a fashion as possible, and the duration and severity of the episode conditions are to be substantially reduced.

Air Quality Index

Information regarding existing and forecast air pollution levels should be disseminated to the public in as rapid and meaningful manner as possible to enable sensitive individuals to avoid or lessen prolonged exposure to the contaminants. In order to simplify the reporting of air pollution problems to the general public, the EPA established a uniform method for reporting daily air quality levels in September 1976. The method, known as the Pollutant Standards Index (PSI), places maximum emphasis on protecting human health by advising the

Table 81

FEDERAL POLLUTANT STANDARDS INDEX

Pollutant Level	Pollutant Standards Index	Total Suspended Particulates	Sulfur Dioxide $\mu g/m^3$ 24 hours (ppm)	Carbon Monoxide mg/m^3 eight hours (ppm)	Ozone $\mu g/m^3$ one hour (ppm)	Nitrogen Oxide $\mu g/m^3$ one hour (ppm)	Total Suspended Particulates x Sulfur Dioxide $(\mu g/m^3)^2$ (ppm)
50 percent of Primary Short-Term NAAQS . . .	50	75[a]	80[a] (.03)	5.0 (4.5)	0.120 (0.06)	_[b]	_[b]
Primary Short-Term NAAQS	100	260	365 (.14)	10.0 (9.0)	0.235 (0.12)	_[b]	_[b]
Alert Level	200	375	800 (.30)	17.0 (15.0)	400[c] (0.20)	1,130 (0.60)	65×10^3 (22.727)
Warning Level	300	625	1,600 (.60)	34.0 (30.0)	800 (0.40)	2,260 (1.20)	216×10^3 (91.259)
Emergency Level	400	875	2,100 (.80)	46.0 (40.0)	1,000 (0.50)	3,000 (1.60)	393×10^3 (137.413)
Significant Harm Level	500	1000	2,620 (1.00)	57.5 (50.0)	1,200 (0.60)	3,750 (2.00)	490×10^3 (171.329)

[a] *Annual primary NAAQS.*

[b] *No index value reported at concentration levels below those specified by the alert level criteria.*

[c] *For the PSI index 400 $\mu g/m^3$ appears to be a more consistent breakpoint between the descriptor words "unhealthful" and "very unhealthful" than the oxidant alert level of 200 $\mu g/m^3$.*

Source: U.S. Environmental Protection Agency, Federal Register, Vol. 41, No. 174, September 7, 1976 and Vol. 44, No. 92, May 10, 1979.

public of any adverse effects which may be produced by an existing or forecast pollution level. In addition, the PSI emphasis is on short-term (less than 24 hours) acute health effects rather than on the long-term, chronic effects of air pollution. As a margin of safety, the PSI is concerned with the highest monitored pollutant concentrations and assumes that all other stations will experience similarly high values.

The PSI is based on five pollutants—particulate matter, sulfur dioxide, carbon monoxide, nitrogen dioxide, and ozone—for which there are either short-term health-related ambient air quality standards or federal episode criteria and significant harm levels. A sixth variable—the product of total suspended particulates and sulfur dioxide—is also taken into account in determining the index. The index uses a "segmented linear function" to convert each air pollutant concentration into a normalized number. A segmented linear function consists of two or more straight lines drawn between successive coordinates where each line may have a different slope. For each pollutant, the coordinates between which the lines are drawn consist of points at 50 percent of the primary short-term National Ambient Air Quality Standards (NAAQS), the primary short-term NAAQS, and the federal alert, warning, emergency, and significant harm levels. The concentrations at which each pollutant reaches these levels are presented in Table 81 with the corresponding Pollutant Standards Index value. The segmented linear functions for each pollutant from which a precise index value may be determined are shown in Figures 49 through 54.

The Pollutant Standards Index was intended to be used in conjunction with descriptor words characterizing the general health effects associated with a given index value and a cautionary statement emphasizing measures sensitive individuals should take to avoid excessive exposure. A comparison of the index values with pollutant concentrations, descriptor words, health effects, and cautionary statements is provided in Table 82.

In April 1976, about six months prior to the issuance of the federal Pollutant Standards Index, the Wisconsin Department of Natural Resources implemented a similar method of reporting air quality information to the public. This reporting method, which replaced the ozone advisory reports issued by the DNR for approximately three years, is known as the Air Quality Index (AQI) system. The AQI differs from the PSI only in that it does not include nitrogen dioxide and the descriptor words "moderate," "unhealthful," and "very unhealthful," are replaced by "unsatisfactory," "poor," and "very poor," respectively. The highest monitored value for any pollutant measured at any monitoring station in the Region is used, consistent with the federal procedure, and the same segmented linear functions are used to calculate the index. Nitrogen dioxide is not used in the AQI system since reliable monitoring procedures for this pollutant have not yet been established in the Region. When available, data on this pollutant species may be readily incorporated into the index.

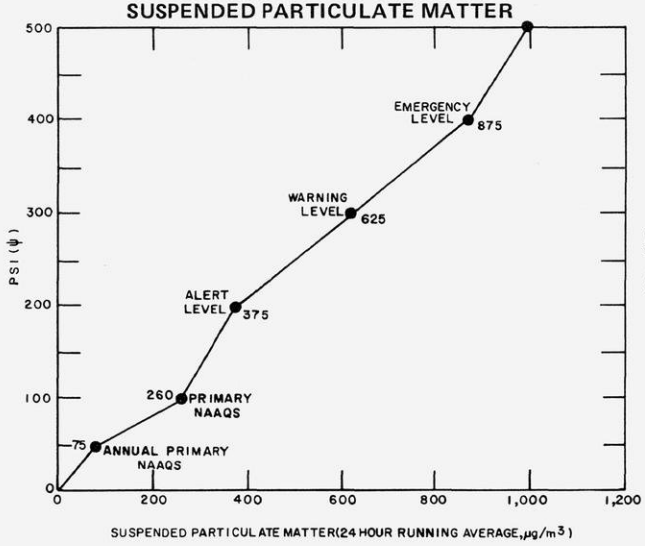
The Air Quality Index is issued twice daily, at 10:30 a.m. and 3:00 p.m., by the DNR Southeast District Office, with a forecast of the trend in the index over the following 24 hours. This information is available to the news media and the public on a recorded phone message by calling: 414/257-4461.

THE SOCIOECONOMIC IMPACT OF AIR POLLUTION

The adverse effects of air pollution have a definite economic impact on society through costs incurred in three general categories: the costs of direct effects, such as income lost and medical bills incurred as a result of air pollution-caused illness; adjustment costs, such as maintenance and cleaning operations necessitated by deterioration and soiling of materials and artifacts by air pollution; and market effect costs, such as increased prices for agricultural products when yields are reduced because of plant damage by air pollution. Estimates of

Figure 49

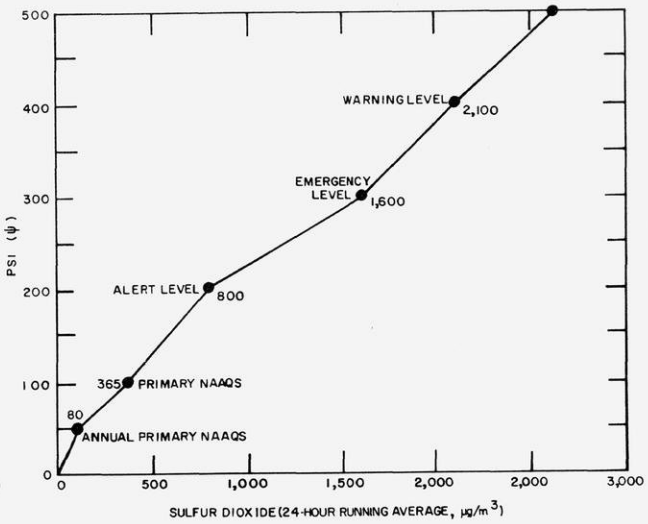
SEGMENTED LINEAR FUNCTION FOR SUSPENDED PARTICULATE MATTER



Source: Federal Register, Volume 41, No. 174.

Figure 50

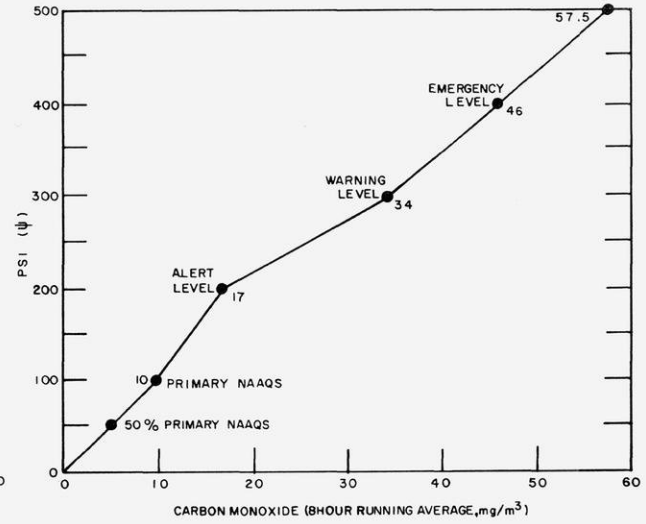
SEGMENTED LINEAR FUNCTION FOR SULFUR DIOXIDE



Source: Federal Register, Volume 41, No. 174.

Figure 51

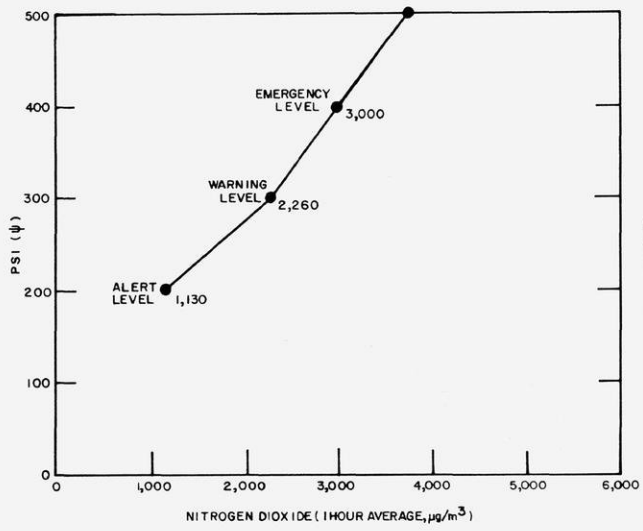
SEGMENTED LINEAR FUNCTION FOR CARBON MONOXIDE



Source: Federal Register, Volume 41, No. 174.

Figure 52

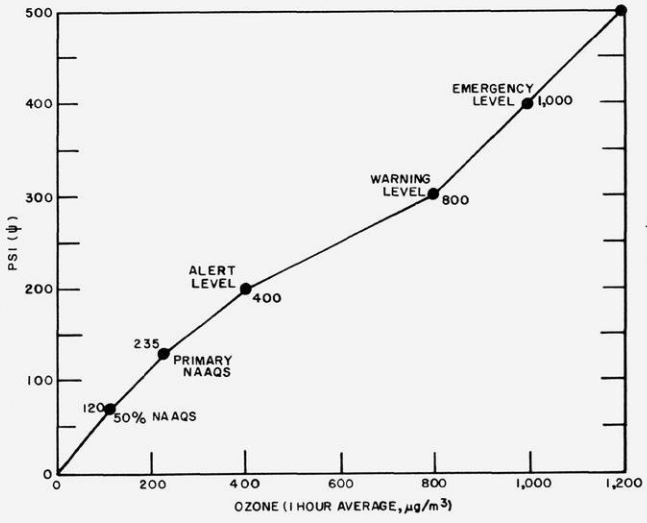
SEGMENTED LINEAR FUNCTION FOR NITROGEN DIOXIDE



Source: Federal Register, Volume 41, No. 174.

Figure 53

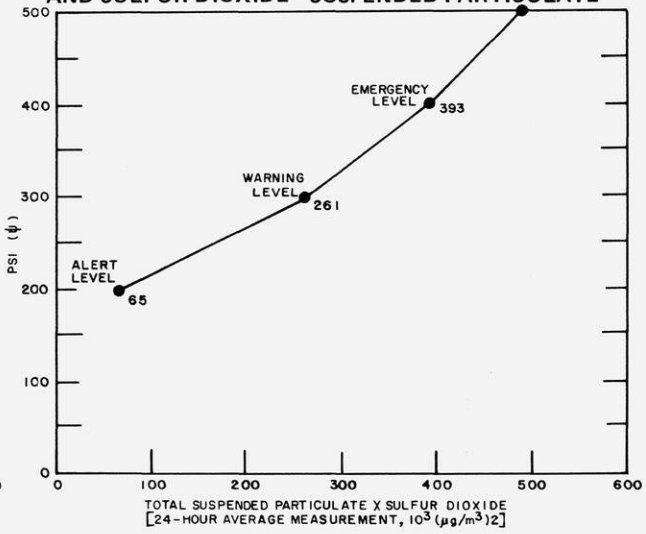
SEGMENTED LINEAR FUNCTION FOR OZONE



Source: Federal Register, Volume 44, No. 92.

Figure 54

SEGMENTED LINEAR FUNCTION FOR COMBINED MATTER AND SULFUR DIOXIDE SUSPENDED PARTICULATE



Source: Federal Register, Volume 41, No. 174.

Table 82

POLLUTANT INDEX VALUE WITH ASSOCIATED POLLUTANT LEVELS, DESCRIPTOR WORDS, AND CAUTIONARY STATEMENTS

Index Value	Air Quality Level	Pollutant Levels: Total Suspended Particulates (24-hour) $\mu g/m^3$	Sulfur Dioxide (24-hour) $\mu g/m^3$	Carbon Monoxide (eight-hour) mg/m^3	Ozone (one-hour) $\mu g/m^3$	Nitrogen Dioxide (one-hour) $\mu g/m^3$	Health Effect Descriptor	General Health Effects	Cautionary Statements
401-500	Significant Harm	876-1,000	2,101-2620	46.1-57.5	1,001-1,200	3,001-3,750	Hazardous	Premature death of ill and elderly. Healthy people will experience adverse symptoms that affect their normal activity	All persons should remain indoors, keeping windows and doors closed. All persons should minimize physical exertion and avoid traffic
301-400	Emergency	626-875	1,601-2,100	34.1-46.0	801-1,000	2,261-3,000		Premature onset of certain diseases in addition to significant aggravation of symptoms and decreased exercise tolerance in healthy persons	Elderly and persons with existing diseases should stay indoors and avoid physical exertion. General population should avoid outdoor activity
201-300	Warning	376-625	801-1,600	17.1-34.0	401-800	1,131-2,260	Very Unhealthful	Significant aggravation of symptoms and decreased exercise tolerance in persons with heart or lung disease, with widespread symptoms in the healthy population	Elderly and persons with existing heart or lung disease should stay indoors and reduce physical activity
101-200	Alert	261-375	366-800	10.1-17.0	241-400[c]	1,130	Unhealthful	Mild aggravation of symptoms in susceptible persons, with irritation symptoms in the healthy population	Persons with existing heart or respiratory ailments should reduce physical exertion and outdoor activity
81-100	NAAQS	76-260	81-365	6.0-10.0	121-240	–[a]	Moderate	--	--
0-80	50 percent of NAAQS	0-75	0-80[b]	0-5.0	120	–[a]	Good	--	--

[a] *No index values reported at concentration levels below those specified by alert level criteria.*

[b] *Annual primary NAAQS.*

[c] *400 $\mu g/m^3$ was used instead of the oxidant alert level of 200 $\mu g/m^3$.*

Source: Federal Register, Vol. 41, No. 174.

the dollar loss attendant to air pollution effects, however, are limited and general in nature since many other physical, social, and economic factors tend to be obscure in terms of the intrinsic influence of air pollution on personal day-to-day expenditures. For example, estimating the cost of the deleterious effects of air pollution on human health requires detailed information on such factors as the extent to which an air pollutant acted either singly or synergistically to produce an observed biological disorder; to what degree an individual may have been predisposed to air pollution effects due to prior illness or congenital defects; and what role was taken by possible cofactors, such as smoking, in augmenting the deleterious effects. Detailed relationships of this nature have not been established at the present time.

Problems of a similar nature are also encountered in estimating the economic impact of air pollution on materials since, in most cases, it is impossible to distinguish between natural deterioration caused by weathering processes and deterioration caused by air pollution. Even in a pollution-free environment certain materials, such as iron, will rust and tarnish, and other materials, such as stone, marble, and slate, will corrode in the presence of atmospheric moisture.

Economic damage to agricultural crops is equally difficult to measure. Losses due to the suppression of growth, delayed maturity, and reduced yields cannot reasonably be accounted for as a result of air pollution alone and independent from climatic and soil conditions. In a similar manner, aesthetic losses are often intangible but real nonetheless. This is perhaps best reflected by differences in property values in a heavily polluted neighborhood as compared to property values in an area with relatively clean air.

In the following sections, the economic losses in the Region due to the role of air pollution in household and business soiling, material deterioration, vegetation destruction, and human morbidity and mortality rates are appraised within the above-mentioned constraints and limitations. An estimate of the number of regional inhabitants adversely affected by air pollution levels which exceed the established standards is also provided, along with the demographic characteristics of affected inhabitants.

Impact of Air Pollution on Cleaning Costs

Soiling due to the settling of particulate matter prompts households, businesses, and industrial establishments to

increase cleaning activities and consequently forces additional costs for maintenance. The first attempt to quantify such added costs was made by the Mellon Institute for the Pittsburgh area in 1913.[16] The Mellon Institute study estimated that soiling costs about $20 per capita annually. Several additional studies were performed in the late 1960's but were often limited to a few specific cleaning operations or a small geographic area.

The most comprehensive study of soiling by particulate matter was undertaken in 1970 by researchers from Booz-Allen and Hamilton, Inc., for the Renjerdal area around Philadelphia.[17] Using sophisticated statistical survey techniques, the Booz-Allen study gathered data from area residents on 27 cleaning and maintenance operations and on personal attitudes toward cleaning. Of these 27 operations, 11 were found to be somewhat sensitive to particulate matter levels. Due to the lack of prerequisite data on two of the operations, only 9 were considered in the study. Table 83 lists these pollution-related cleaning tasks, along with an estimate of their unit cleaning costs.

Table 83

POLLUTION-RELATED CLEANING TASKS AND UNIT CLEANING COSTS: 1970

Task	Unit Market Value (dollars)
Replace Air Conditioner Filter	1.00
Wash Floor Surface	6.00
Wash Inside Window	0.50
Clean Venetian Blinds/Shades	3.50
Clean/Repair Screens	0.20
Wash Outside Window	1.50
Clean/Repair Storm Windows	2.00
Clean Outdoor Furniture	10.00
Clean Gutters	15.00

Source: Midwest Research Institute and Booz-Allen and Hamilton, Inc.

Utilizing the data base provided by the Booz-Allen study, a study by the Midwest Research Institute, sponsored by the U.S. Environmental Protection Agency, estimated the net soiling damage costs for each of the 9 tasks in 148 Standard Metropolitan Statistical Areas (SMSA's) across the country in 1970, including the Milwaukee SMSA.[18] The study found that the Chicago, New York, and Los Angeles SMSA's suffered the most in terms of total net soiling damages, with costs of $516 million, $418 million, and $388 million, respectively, in 1970. For the Milwaukee SMSA, total soiling damage costs were estimated to be about $44 million in 1970. Table 84 presents the net cost in 1970 by cleaning task for the Milwaukee SMSA and for the total of all 148 SMSA's studied. It should be noted that the costs of cleaning venetian blinds, shades, and draperies and of washing exterior windows in the Milwaukee SMSA were the largest expenditures, accounting for nearly $25 million, or 57 percent, of the total soiling damage cost estimates.

This study also provided an annual per capita net soiling damage cost for each SMSA in 1970. The 1970 per capita costs ranged from $104.65 in Cleveland, Ohio to $4.98 in San Antonio, Texas. For the Milwaukee SMSA, the per capita soiling damage cost was estimated at $31.27 in 1970. Extrapolating this cost to the 1970 county populations of the Region gives an overall estimate of nearly $55 million in soiling damages in the seven-county area as shown in Table 85.

Impact of Air Pollution on Deterioration of Materials and Artifacts

Among the adverse effects of air pollution on materials and artifacts are: the corrosion of metals; the deterioration of rubber; the fading of paint; and soiling of most substances. The most visible effect of particulate pollutants is the soiling of surfaces on which they are deposited. Particles may also act as catalysts, increasing the corrosive reactions between metals and other pollutants such as the sulfur oxides. Damages to surfaces and textiles are also incurred as a result of the wear and tear imposed by repetitive cleaning made necessary by particulate matter soiling. The intrinsic economic damage to materials caused by air pollution is difficult to ascertain because of the difficulty of distinguishing between natural and pollution-related deterioration, and because of the uncertainty regarding indirect costs of early replacement of materials worn out by excessive cleaning.

A comprehensive study of air pollution damage to materials was conducted by the Midwest Research Institute (MRI).[19] The MRI study presented a sys-

[16] *See John J. O'Connor, The Economic Cost of the Smoke Nuisance to Pittsburgh, Mellon Institute of Industrial Research and School of Specific Industries, University of Pittsburgh, Pittsburgh, Pennsylvania, 1913.*

[17] *See Booz-Allen and Hamilton, Incorporated, Study to Determine Residential Soiling Costs of Particulate Air Pollution, Washington, D.C., October 1970.*

[18] *See Ben-chieh Liu and Eden Siu-hung Yu, Physical and Economic Damage Functions for Air Pollutants by Receptor, Midwest Research Institute, Kansas City, Missouri, September 1976, EPA Report No. 600/5-76-011.*

[19] *See System Analysis of the Effects of Air Pollution on Materials, Midwest Research Institute, January 1970.*

tematic analysis of all the physical and chemical interactions between materials, pollutants, and environmental factors. Fifty-three economically important materials, representing about 40 percent of the economic value of all materials exposed to air pollution, were identified and selected for the study. The results of the study indicated that approximately $100 billion in 1970 dollars would be required annually in cleaning costs nationwide to keep these 53 materials in polluted areas as clean as they would be in a nonpolluted environment, and that the annual deterioration of these materials produces an economic loss each year of about $3.8 billion.

Table 84

ESTIMATED NET SOILING DAMAGE COSTS BY CLEANING TASK FOR 148 SMSA'S AND THE REGION: 1970

Task	Damage Costs in 148 SMSA's (millions of dollars)	Damage Costs in Milwaukee SMSA (millions of dollars)
Replace Air Conditioner Filter	11.8	0.1
Wash Floor Surface	558.8	4.8
Wash Inside Window	454.1	3.9
Clean Venetian Blinds/ Shades/Draperies	1,956.3	16.9
Clean/Repair Screens	13.6	0.1
Wash Outside Window	925.7	8.0
Clean/Repair Storm Windows	349.2	3.0
Clean Outdoor Furniture	275.1	2.7
Clean Gutters	488.9	4.2
Total	5,033.0	43.9

Source: Midwest Research Institute.

Table 85

ESTIMATED COSTS OF SOILING FROM THE DEPOSITION OF PARTICULATE MATTER BY COUNTY: 1970

County	1970 Population	Net Soiling Damage Costs
Kenosha	117,917	$ 3,687,265
Milwaukee	1,054,249	32,966,366
Ozaukee	54,461	1,702,995
Racine	170,838	5,342,104
Walworth	63,444	1,983,894
Washington	63,839	1,996,246
Waukesha	231,335	7,233,939
Region	1,756,083	$54,912,809

Source: SEWRPC.

Paint and zinc coatings are the two materials most affected by both soiling and deterioration caused by air pollution, accounting for more than half of the total losses in each category. About $35 billion and $24 billion of the estimated nationwide $100 billion soiling costs of the 53 materials are attributable to damage to paint and zinc coatings, respectively. Of the estimated $3.8 billion deterioration costs of the 53 materials, $1.2 billion damage is incurred by paint, and $0.8 billion damage is incurred by zinc coatings.

If it is assumed that the soiling and deterioration costs of materials are shared equally on a per capita basis, an estimate of the economic impact of air pollution-caused material damage can be made. Using the gross nationwide estimates of soiling and deterioration costs of $100 billion and $3.8 billion, respectively, and apportioning these values on the basis of the ratio of the 1970 regional county populations to the population of the United States in 1970, Table 86 was derived. It may be seen from Table 86 that approximately $864 million in soiling damage and about $32 million in deterioration damage are incurred in the Region annually.

Impact of Air Pollution on Vegetation

Since the predominant land use category in the Southeastern Wisconsin Region is agriculture, crops sensitive to certain atmospheric pollutants will produce a lower yield per acre than in clean air as air pollution levels from urban sources encroach upon rural areas and, consequently, economic losses may result.

Sulfur dioxide and oxidants are the principal atmospheric pollutants which damage vegetation. A study performed by the Stanford Research Institute (SRI) has provided a means by which the economic loss of agricultural crops from visible damage caused by these two pollutants may be estimated. This study, however, does not recognize real economic losses due to growth suppression, delayed maturity, reduced yields, and increased costs of crop production. Crop losses of this type are substantially more intangible than visible damage and therefore cannot be as readily translated into dollar amounts.

The Stanford Research Institute study estimates the dollar loss by first determining the value of a given crop, multiplying that value by an index of the sensitivity the crop displays to either oxidants or sulfur dioxide, and finally, multiplying that product by an index of the pollution potential a given agricultural area has for receiving deleterious levels of each of the two pollutants. This procedure may be expressed in equation form as follows:

Dollar Loss = Crop Value x Crop Sensitivity x Pollution Potential

The pollution potential index was derived on the basis of local emission data for sulfur dioxide, hydrocarbon to nitrogen oxide emission ratios for oxidants, the average percentage of days during the growing season occurring in stagnation periods of two or more successive days, and generalized climatic conditions. The pollution potential indices for 87 Standard Metropolitan Statistical Areas were determined and divided into nine class ranges for oxidants and six class ranges for sulfur dioxide, with the

Table 86

ESTIMATED COSTS OF SOILING AND DETERIORATION OF MATERIALS FROM AIR POLLUTION BY COUNT: 1970

County	County Population ÷ U.S. Population	Materials	Soiling Cost	Deterioration Cost	Total Cost
Kenosha	5.80×10^{-4}	Paint	$ 20,312,029	$ 696,412	$ 21,008,441
		Zinc	13,928,248	464,274	14,392,522
		Other Materials	23,794,091	1,044,618	24,838,709
Subtotal			$ 58,034,304	$ 2,205,304	$ 60,239,672
Milwaukee	5.18×10^{-3}	Paint	$181,601,773	$ 6,226,346	$187,828,119
		Zinc	124,526,930	4,150,897	128,677,827
		Other Materials	212,733,506	9,339,519	222,073,025
Subtotal			$518,862,209	$19,716,762	$538,578,971
Ozaukee	2.68×10^{-4}	Paint	$ 9,381,288	$ 321,644	$ 9,702,932
		Zinc	6,432,883	214,429	6,647,312
		Other Materials	10,989,509	482,466	11,471,975
Subtotal			$ 26,803,680	$ 1,018,539	$ 27,822,219
Racine	8.40×10^{-4}	Paint	$ 29,428,041	$ 1,008,961	$ 30,437,002
		Zinc	20,179,228	672,640	20,851,868
		Other Materials	34,472,849	1,513,442	35,986,291
Subtotal			$ 84,080,118	$ 3,195,043	$ 87,275,161
Walworth	3.12×10^{-4}	Paint	$ 10,928,673	$ 374,697	$ 11,303,370
		Zinc	7,493,947	249,798	7,743,745
		Other Materials	12,802,160	562,046	13,364,206
Subtotal			$ 31,224,780	$ 1,186,541	$ 32,411,321
Washington	3.14×10^{-4}	Paint	$ 10,996,714	$ 377,030	$ 11,373,744
		Zinc	7,540,604	251,353	7,791,957
		Other Materials	12,881,865	565,545	13,447,410
Subtotal			$ 31,419,183	$ 1,193,928	$ 32,613,111
Waukesha	1.14×10^{-3}	Paint	$ 39,849,590	$ 1,366,271	$ 41,215,861
		Zinc	27,325,433	910,847	28,236,280
		Other Materials	46,680,949	2,049,407	48,730,356
Subtotal			$113,855,972	$ 4,326,525	$118,182,497
Region	8.64×10^{-3}	Paint	$302,498,108	$10,371,361	$312,869,469
		Zinc	207,427,273	6,914,238	214,341,511
		Other Materials	354,354,929	15,557,043	369,911,972
Total	--	--	$864,280,310	$32,842,642	$897,122,952

Source: Midwest Research Institute and SEWRPC.

median for each successive class range being approximately twice the value of the prior class. The pollution potential indices for the Milwaukee area are presented in Table 87. Both the oxidant and sulfur dioxide indices fall within the fourth class range.

The crop sensitivity factor was determined by categorizing each particular crop type as being either sensitive, intermediate, or resistant to a pollutant, and by classifying the portion of the plant which was directly affected into a category of either high, medium, or none. For a given

intensity of pollution, therefore, there are nine possible variants of economic damage. Considering that the economic loss would be similar between several of the variants, the nine variants are reduced to five economic sensitivity classes. Using this technique, the Stanford Research Institute study classified more than 80 species or groups of vegetation into one of these five sensitivity classes for both oxidants and sulfur dioxide. Table 87 lists the five sensitivity classes with their equivalent factors for oxidants and sulfur dioxide. With the values for crop sensitivity and pollution potential it is possible to estimate the economic loss due to crop damage within the Region.

Table 87

CROP SENSITIVITY AND POLLUTION POTENTIAL FACTORS

Sensitivity Class	Pollutant	
	Oxidants	Sulfur Dioxide
A	0.025	0.040
B	0.020	0.022
C	0.016	0.008
D	0.013	0.004
E	0.010	0.000
Pollution Potential Index	0.331	1.413

Source: Stanford Research Institute, Assessment of Economic Impact of Air Pollutants on Vegetation in the United States: 1969 and 1971, July 1973, and SEWRPC.

The commercial value of crops grown in the Region during 1973 has been estimated from data provided by the Wisconsin Department of Agriculture on the number of acres in each crop type and the average dollar value per acre of each crop type. These values are presented in Table 88 by county, and indicate a total crop value of approximately $86.7 million for the entire Region for 1973. Each crop type was assigned a sensitivity factor to oxidants and sulfur dioxide according to the results of the Stanford Research Institute study and, using the pollution potential indices shown in Table 87, the estimated loss to each crop type was calculated by county. As shown in Table 89, agricultural damage in southeastern Wisconsin may be estimated at about $320,000 from oxidants, and about $194,000 from sulfur dioxide. The total estimated damage to all crops grown in the Region during 1973 represents approximately six-tenths of 1 percent of the total crop value. The Stanford Research Institute study results for 1971 estimated the crop loss for the entire United States to be $150 million, or slightly more than one-half of 1 percent of the total crop value. This close correspondence between the crop loss and total crop value for the Region and that for the country indicates that the estimated half million-dollar regional crop loss is a reliable order of magnitude measure of the economic impact of air pollution on vegetation.

Impact of Air Pollution on Mortality and Morbidity Costs

Air pollution episodes have previously been associated with significant increases in human morbidity and mortality rates. It has also been shown, however, that even at chronic exposures to pollution levels much lower than those experienced during episode conditions, symptoms in certain individuals susceptible to respiratory and cardiovascular disease may be aggravated. In severe instances, death may ensue. The only measure which may be used to assess the economic impact of the increase in human mortality rates due to air pollution is the loss of income.

In a study by the Midwest Research Institute (MRI), the mortality costs associated with the adverse health effects of particulate matter and sulfur dioxide, as expressed in terms of loss of income, were estimated for 40 Standard Metropolitan Statistical Areas (SMSA's) in the United States in 1970. This study was based on sophisticated statistical techniques which provided estimates on the number of deaths in excess of the conventional mortality rates in each of the 40 SMSA's labor force which could be attributed directly to ambient air particulate matter and sulfur dioxide concentrations. The calculated, pollution-caused premature deaths were then translated into economic loss estimates on the basis of 1970 median income, the expected family income growth rate, and the rate of inflation. Using these factors, the MRI study estimated that the total mortality costs due to sulfur dioxide in the 40 SMSA's approximated $887 million per year, and the total mortality costs due to total suspended particulates approximated $1,044 million per year. The total mortality costs attributable to air pollution were consequently about $1,931 million. The MRI estimated that the mortality costs without the influence of air pollution totaled about $60,221 million; therefore, the particulate matter and sulfur dioxide concentrations added about 3 percent to the total mortality costs.

The population of the 40 SMSA's in the MRI study was approximately 60 percent of the total population of the United States in 1970. Again assuming that the estimated mortality costs may be equally distributed throughout the population, extrapolating the estimate for the 40 SMSA's to the entire United States yields a mortality damage cost of $1,477 million due to sulfur dioxide and $1,739 million due to total suspended particulates. The United States mortality cost estimates may be apportioned to the seven counties within the Region on the basis of population ratios as given in Table 86. The results of this allocation are presented in Table 90. If air pollution were not a causative factor in mortality rates the mortality costs throughout the Region would have been approximately $866 million per year. Introducing air pollution as a contributing agent in premature deaths, however, increases the regional mortality cost estimates by about 3 percent, or by $28 million per year—$15 million due to total suspended particulates and $13 million due to sulfur dioxide.

In the same MRI study, estimates were made for the 40 SMSA's on the morbidity costs from air pollution. Morbidity costs may be classified as either direct costs

Table 88

ESTIMATED CROP ACREAGE AND CROP VALUE IN THE REGION BY COUNTY: 1973

Crop	Value of Crop in 1973 Dollars per Acre	Kenosha		Milwaukee		Ozaukee		Racine		Walworth		Washington		Waukesha		Region	
		Acres	Total Value	Acres	Total Value	Acres	Total Value	Acres	Total Value	Acres	Total Value	Acres	Total Value	Acres	Total Value	Acres	Total Value
Field Crops																	
Corn for Grain and Silage	199.20	32,100	6,394,320	1,600	318,720	18,000	3,585,600	35,300	7,031,760	102,000	20,318,400	42,600	8,485,920	37,600	7,489,920	269,200	53,624,640
Oats	49.20	6,300	309,960	1,000	49,200	11,800	580,560	7,700	378,840	13,500	664,200	21,500	1,057,800	10,200	501,840	72,000	3,542,400
Barley	57.33	400	22,932	100	5,733	300	17,199	1,250	71,663	750	42,998	100	5,733	150	8,600	3,050	174,858
All Wheat	125.26	1,550	194,153	1,000	125,260	850	106,471	4,250	532,355	950	118,997	1,350	169,101	950	118,997	10,900	1,365,334
Soybeans	135.00	14,700	1,984,500	3,300	445,500	1,100	148,500	24,700	3,334,500	19,200	2,592,000	850	114,750	4,350	587,250	68,200	9,207,000
All Hay	80.67	17,800	1,435,926	2,500	201,675	28,000	2,258,760	17,700	1,427,859	40,000	3,226,800	8,200	661,494	7,450	600,992	121,650	9,813,506
Potatoes	1,298.51	900	1,168,659	–	–	150	194,777	1,200	1,558,212	900	1,168,659	200	259,702	450	584,330	3,800	4,934,339
Vegetable Crops																	
Cabbage[a]	784.44	32	25,308	5	3,677	29	23,094	41	31,867	79	62,163	58	45,650	50	39,607	294	231,366
Carrots[a]	750.22	27	20,170	4	2,930	25	18,405	34	25,397	66	49,543	48	36,382	42	31,566	246	184,393
Onions[a]	1,614.29	8	13,503	1	1,962	8	12,321	11	17,002	21	33,166	15	24,355	13	21,132	77	123,441
Lettuce[a]	1,675.45	7	11,011	1	1,600	6	10,048	8	13,865	16	27,046	12	19,861	10	17,232	60	100,663
Sweet Corn	93.94	450	42,273	400	37,576	3,600	338,184	650	61,061	1,550	145,607	2,500	234,850	1,200	112,728	10,350	972,279
Snap Beans[a]	213.93	333	71,193	48	10,343	304	64,963	419	89,641	817	174,867	600	128,413	521	111,417	3,042	650,837
Beets[a]	240.61	39	9,488	6	1,378	36	8,658	50	11,946	71	23,304	71	17,114	62	14,848	361	86,736
Green Lima Beans[a]	149.19	44	6,596	6	958	40	6,019	56	8,305	109	16,201	80	11,897	69	10,323	404	60,299
Cucumbers[a] for Pickles	500.67	62	31,110	9	4,520	57	28,387	78	39,171	153	76,413	112	56,114	97	48,686	568	284,401
Green Peas	118.78	–	–	50	5,939	3,300	391,974	–	–	2,350	279,133	3,250	386,035	1,000	118,780	9,950	1,181,861
Fruits																	
Strawberries[a]	985.00	8	8,239	1	1,197	8	7,518	11	10,374	21	20,237	15	14,861	13	12,894	77	75,320
Flowers																	
All Ornamental Plants[b]	–[c]	–	19,250	–	2,797	–	17,566	–	24,239	–	47,283	–	34,722	–	30,127	–	175,984
Total Crop Acreage and Value		74,760	11,768,591	10,031	1,220,965	67,613	7,819,004	93,458	14,668,057	182,579	29,087,017	81,561	11,764,754	64,227	10,461,269	574,229	86,789,657

[a] *County data for crop not available. Data apportioned according to the ratio of county farmland to state farmland.*

[b] *Data are presented as value of sales at wholesale.*

[c] *The values of ornamental plants are determined by the nature of the plants.*

Source: Wisconsin Department of Agriculture, 1974 Wisconsin Agricultural Statistics, and SEWRPC.

Table 89

ESTIMATED 1973 REGIONAL CROP LOSS BY CROP, POLLUTANT, AND COUNTY (IN 1973 DOLLARS)

Crop	Sensitivity Factor		Kenosha		Milwaukee		Ozaukee		Racine		Walworth		Washington		Waukesha		Region	
	Oxidants	Sulfur Dioxide	Loss to Oxidants	Loss to Sulfur Dioxide	Loss to Oxidants	Loss to Sulfur Dioxide	Loss to Oxidants	Loss to Sulfur Dioxide	Loss to Oxidants	Loss to Sulfur Dioxide	Loss to Oxidants	Loss to Sulfur Dioxide	Loss to Oxidants	Loss to Sulfur Dioxide	Loss to Oxidants	Loss to Sulfur Dioxide	Loss to Oxidants	Loss to Sulfur Dioxide
Field Crops																		
Corn for Grain and Silage	E	E	21,165	–	1,055	–	11,868	–	23,275	–	67,254	–	28,086	–	24,792	–	117,495	–
Oats	C	C	1,642	3,504	261	556	3,075	6,563	2,006	4,282	3,518	7,508	5,602	11,957	2,658	5,673	18,762	40,043
Barley	C	C	121	259	30	65	91	194	380	810	228	486	30	65	46	97	926	1,976
All Wheat	C	C	1,028	2,195	663	1,416	564	1,204	2,819	6,018	630	1,345	896	1,912	630	1,345	7,230	15,435
Soybeans	D	C	8,539	22,433	1,917	5,036	639	1,679	14,348	37,693	11,153	29,300	494	1,297	2,527	6,638	39,617	104,076
All Hay	E	E	4,753	–	668	–	7,477	–	4,726	–	10,681	–	2,190	–	1,989	–	32,484	–
Potatoes	C	E	6,189	–	–	–	1,032	–	8,252	–	6,189	–	1,375	–	3,095	–	26,132	–
Subtotal			43,437	28,391	4,594	7,073	24,746	9,640	55,806	48,803	99,653	38,639	38,673	15,231	35,737	13,753	302,646	161,530
Vegetable Crops																		
Cabbage	D	B	109	787	16	114	99	718	137	991	267	1,932	196	1,419	170	1,231	994	7,192
Carrots	D	C	87	228	13	33	79	208	109	287	213	560	157	411	136	357	794	2,084
Onions	C	E	72	–	10	–	65	–	90	–	176	–	129	–	112	–	654	–
Lettuce	C	A	58	622	8	90	53	568	73	784	143	1,529	105	1,123	91	974	531	5,690
Sweet Corn	E	E	140	–	124	–	1,119	–	202	–	482	–	777	–	373	–	3,217	–
Snap Beans	C	C	377	805	55	117	344	734	475	1,013	926	1,977	680	1,452	590	1,259	3,447	7,357
Beets	C	C	50	107	7	16	46	98	63	135	123	263	91	193	79	168	459	980
Green Lima Beans	C	C	35	75	5	11	32	68	44	94	86	183	63	134	55	117	320	682
Cucumbers	E	E	103	–	15	–	94	–	130	–	253	–	186	–	161	–	942	–
Green Peas	D	D	–	–	26	34	1,687	2,215	–	–	1,201	1,578	1,661	2,182	511	671	5,086	6,680
Subtotal			1,031	2,624	279	415	3,618	4,609	1,323	3,304	3,870	8,022	4,045	6,912	2,278	4,777	16,444	30,665
Fruits																		
Strawberries	E	E	27	–	4	–	25	–	34	–	67	–	49	–	43	–	249	–
Subtotal			27	–	4	–	25	–	34	–	67	–	49	–	43	–	249	–
Flowers																		
All Ornamental Plants	B	C	127	218	19	32	116	199	160	274	313	534	230	393	199	341	1,164	1,991
Total by Pollutant	--		44,622	31,233	4,896	7,520	28,505	14,448	57,323	52,381	103,903	47,195	42,997	22,538	38,257	18,871	320,503	194,186
Total County Crop Loss	--		75,855		12,416		42,953		109,704		151,098		65,535		57,128		514,689	

Source: SEWRPC.

Table 90

ESTIMATED MORTALITY COSTS DUE TO SULFUR DIOXIDE AND TOTAL SUSPENDED PARTICULATE MATTER-40 SMSA'S, UNITED STATES, AND REGION: 1970

Area	Total Mortality Due to Sulfur Dioxide (millions of dollars)	Total Mortality Due to Total Suspended Particulates (millions of dollars)	Total Mortality Due to Air Pollution (millions of dollars)	Total Mortality without Air Pollution (millions of dollars)
40 SMSA's	886.6	1,044.0	1,930.6	60,221.4
United States	1,476.6	1,738.7	3,215.3	100,293.8
Region				
Kenosha	0.9	1.0	1.9	58.2
Milwaukee	7.7	9.0	16.7	519.5
Ozaukee	0.4	0.5	0.9	26.9
Racine	1.2	1.5	2.7	84.2
Walworth	0.5	0.5	1.0	31.3
Washington	0.5	0.5	1.0	31.5
Waukesha	1.7	2.0	3.7	114.3
Total	12.9	15.0	27.9	865.9

Source: Midwest Research Institute and SEWRPC.

including expenditures for the prevention, detection, and treatment of illness, or indirect costs including loss of output to the economy because of a disability or illness.

A number of assumptions were made in the MRI study on the estimated morbidity costs including: 1) that each pollution-related morbidity incident results in one visit to consult a physician; 2) that 1 out of 8.3 physician visits, or about 12 percent, results in hospitalization; 3) that drug costs run about 50 percent of the physician costs; and 4) that when hospitalization is required each patient stays one day in the facility. The average cost of one day in the hospital was estimated at $82 in 1970 dollars, and the average cost of the physician visit was placed at $14. Based upon these premises, the MRI estimated the total morbidity costs due to total suspended particulates in the 40 SMSA's at $141 million, and to sulfur dioxide at $103 million. Extrapolating these estimates for the 40 SMSA's to the United States, and then apportioning the national estimates to the Region on the basis of population, yields an estimated morbidity cost incurred in southeastern Wisconsin from total suspended particulates of about $2 million per year, and from sulfur dioxide of $1.5 million per year. These estimates are listed in Table 91 and Table 92 by county for both the direct and indirect morbidity costs. In total, the estimated morbidity costs in the Region due to the effects of air pollution are approximately $3.5 million per year. The cost resulting from the adverse effects of air pollution on human health in southeastern Wisconsin therefore, as expressed by mortality and morbidity costs, is estimated to total $31.5 million per year in 1970 dollars. When this dollar loss is combined with the estimated $54,912,809 in increased cleaning costs incurred by households and businesses, $897,122,952 in damage costs caused by soiling and deterioration of materials and artifacts, and $514,689 in costs due to crop damage, the total estimated cost of the effects of air pollution in the Southeastern Wisconsin Region is $983,957,450 annually.

Impact of Air Pollution on the Population of Southeastern Wisconsin

Beyond the estimates of the economic loss attributable to the adverse effects of air pollution is the much more critical estimate of the number of individuals who reside in areas where air pollution concentrations are above levels demonstrated to produce harmful health effects. Also, since young children and the elderly are particularly susceptible to the effects of air pollution, it is useful to examine the characteristics of those persons living in areas exceeding the ambient air quality standards.

Of the six pollutants for which ambient air quality standards have been established, only hydrocarbons have not been associated with any adverse health effects. Hydrocarbons, however, are precursor compounds essential to the formation of photochemical oxidants, whose deleterious effects on the human respiratory system have been documented. From the available monitoring data on ambient air ozone concentrations, it appears that much of the Region is subjected to photochemical oxidant levels that exceed the standards during the summer months and that can cause some degree of respiratory aggravation to residents.

Table 91

ESTIMATED MORBIDITY COSTS DUE TO SULFUR DIOXIDE—40 SMSA'S, UNITED STATES, AND THE REGION: 1970

Area	Direct Morbidity Costs Due to Sulfur Dioxide (thousands of dollars)			Indirect Morbidity Costs Due to Sulfur Dioxide (thousands of dollars)	Total Morbidity Costs Due to Sulfur Dioxide (thousands of dollars)	Total Morbidity Costs without Sulfur Dioxide (thousands of dollars)
	Physician Costs	Hospital Costs	Drug Costs			
40 SMSA's	15,104	10,617	7,558	69,637	102,916	783,202
United States	25,154	17,682	12,587	115,975	171,398	1,304,359
Region						
Kenosha	15	10	7	67	99	757
Milwaukee	130	92	65	601	888	6,757
Ozaukee	7	5	3	31	46	350
Racine	21	15	11	97	144	1,096
Walworth	8	6	4	36	54	407
Washington	8	6	4	36	54	410
Waukesha	29	20	14	132	195	1,487
Total	218	154	108	1,000	1,480	11,264

Source: Midwest Research Institute and SEWRPC.

Table 92

ESTIMATED MORBIDITY COSTS DUE TO PARTICULATE MATTER—40 SMSA'S, UNITED STATES, AND THE REGION: 1970

Area	Direct Morbidity Costs Due to Total Suspended Particulates (thousands of dollars)			Indirect Morbidity Costs Due to Total Suspended Particulates (thousands of dollars)	Total Morbidity Costs Due to Total Suspended Particulates (thousands of dollars)	Total Morbidity Costs without Total Suspended Particulates (thousands of dollars)
	Physician Costs	Hospital Costs	Drug Costs			
40 SMSA's	18,848	13,251	9,425	99,483	141,007	711,202
United States	31,390	22,068	15,697	165,681	234,836	1,184,449
Region						
Kenosha	18	13	9	96	136	687
Milwaukee	163	114	81	858	1,216	6,135
Ozaukee	8	6	4	44	62	317
Racine	26	19	13	139	197	995
Walworth	10	7	5	52	74	370
Washington	10	7	5	52	74	372
Waukesha	36	25	18	189	268	1,350
Total	271	191	135	1,430	2,027	10,226

Source: Midwest Research Institute and SEWRPC.

Nitrogen dioxide, another oxidant product, may also aggravate respiratory conditions. As indicated from the available, although limited, air quality monitoring data for nitrogen dioxide in Milwaukee County, annual levels of this pollutant are approximately 30 percent below the ambient air quality standard at the site recording the maximum level in 1977. Since the portion of Milwaukee County being sampled for nitrogen dioxide concentrations is the most highly urbanized and industrialized in the Region, it is not anticipated that any adverse health effects anywhere in the seven-county area may be attributable to excessively high levels of this pollutant.

Sulfur dioxide concentrations were monitored at five sites in the Region in 1976 and 1977—four sites in Milwaukee County and one site in Racine County—meeting the minimum EPA sampling requirements. No violations of either the three-hour, 24-hour, or annual sulfur dioxide ambient air quality standards were recorded at any of these five monitoring sites in 1976. The monitoring station at 2114 E. Kenwood Boulevard in the City of Milwaukee, which was only in partial operation, did measure a violation of the 24-hour standard on two occasions: once in 1976 and once in 1977. Also, in 1975 there was one violation of the three-hour secondary sulfur dioxide standard monitored at 3716 W. Wisconsin Avenue and one at 7528 W. Appleton Avenue, both in the City of Milwaukee. These violations, however, do not represent violations of the air quality standards since they occurred only on one occasion during the year and a second violation was not monitored at any of the sites. It may be concluded, therefore, that in the absence of any violation of the National Ambient Air Quality Standards, no regional inhabitant is subject to adverse health effects from exposure to detrimental sulfur dioxide levels.

Carbon monoxide has two health-related standards—a one-hour and an eight-hour concentration level. The available air quality monitoring data from 1975, 1976, and 1977 indicate that the one-hour carbon monoxide standard of 40 mg/m^3 has not been exceeded in the Region, and consequently, no adverse health effects should be incurred by the regional population from very short-term, high carbon monoxide levels. The eight-hour carbon monoxide standard of 10 mg/m^3 has been exceeded, or has almost been exceeded, at seven out of the eight monitoring sites operational in 1977, including stations in Racine and Waukesha Counties, as well as all stations in Milwaukee County. All of the monitoring sites are located in areas of high average daily traffic volume, the main source of the carbon monoxide emissions, and are generally removed from residential areas. Two additional factors act to limit the extent of the health-related problems stemming from the observed standard violations. First, carbon monoxide is readily absorbed by microorganisms in soils and by plants and, as a result, it moves toward lower concentrations rapidly where vegetation is present such as in residential neighborhoods. Second, most of the population exposed to carbon monoxide levels in excess of the eight-hour standard do not remain stationary in the affected area long enough to receive the harmful dosage of the pollutant. Considering these factors, it is unlikely that a substantial number of the regional population is adversely affected by excessively high exposures to carbon monoxide.

Of all the pollutants, only particulate matter may be shown to adversely affect definable geographic subareas of the Region over a long-term period. Map 37 indicates that both the primary and secondary annual particulate matter standards are exceeded over an approximately 48-square-mile area in Milwaukee County, and that the secondary annual standard is exceeded in an approximately 9-square-mile and 11-square-mile area in Racine and Kenosha Counties, respectively. The population residing within these areas is exposed to particulate matter levels which can adversely affect either its health or its general welfare.

Based upon 1970 population data it is estimated that about 73,400 persons, or about 7 percent of the Milwaukee County population and 4 percent of the total regional population, living within an approximately eight-square-mile area encompassing the central portion of the City of Milwaukee are exposed to dangerously high annual average concentrations of particulate matter. An additional 361,000 persons, or about 34 percent of the resident population of Milwaukee County and 21 percent of the total regional population, living in an area of approximately 40 square miles surrounding the area of the primary standard violation are exposed to particulate matter levels between 60 and 74 $\mu g/m^3$—the range of levels in excess of the secondary annual standard.

In Racine County approximately 68,100 persons, or nearly 40 percent of the county population and 4 percent of the total regional population, reside within the 9-square-mile area in which the secondary annual particulate matter standard is exceeded.

In Kenosha County approximately 59,800 persons, or nearly 51 percent of the county population and 3.4 percent of the total regional population, reside within the 11-square-mile area in which the secondary annual particulate matter standard is exceeded.

As mentioned, young children and the elderly are particularly susceptible to respiratory diseases caused or aggravated by air pollution. The area of Milwaukee County where the annual primary particulate matter standard is exceeded has a resident population age 65 and older of about 8,400 persons, about 11 percent of the areas's total population. This area also has a resident population nine years old and younger of about 9,900, about 13 percent of this areas's inhabitants. Together, young children and the elderly comprise nearly one-fourth of the population residing in that portion of Milwaukee County where particulate matter levels may cause health problems.

There are approximately 70,400 children and 42,100 elderly persons residing in that area of Milwaukee County where the secondary annual particulate matter standards are exceeded, comprising about 20 percent and 12 percent, respectively, of the total population in that

40-square-mile area. In the 129 square miles in Milwaukee and Waukesha Counties where particulate matter levels ranged from 50 to 59 $\mu g/m^3$ in 1973, an additional 93,100 children and 55,300 elderly persons reside.

Of the 68,100 persons living in that portion of Racine County where the annual secondary particulate matter standard is exceeded, approximately 14,500 persons are children and 7,700 are elderly, about 8.5 percent and 4.5 percent of the county's residents, respectively.

Residing in that portion of Kenosha County exceeding the secondary standard are about 9,900 children and 5,200 elderly persons, or about 8.4 percent and 5.3 percent of the total county population, respectively.

In 1970 the nonwhite population of Milwaukee County approximated 114,000 persons, or 10.8 percent of the county population. The number of nonwhite individuals living in that portion of Milwaukee County where the annual primary particulate matter standard is exceeded is only about 2,800 persons, or approximately 4 percent of the area's 73,400 residents and significantly lower than the percentage of the county's nonwhite population. In the area exceeding only the secondary standard, approximately 91,000 persons out of the area's 361,000 population, or about 25 percent, are nonwhite—a percentage well in excess of the county's overall nonwhite population.

The countywide composition of the nonwhite population of Racine is about 11,300 persons, or 6.6 percent of the total population. About 10,050 nonwhite persons, or about 89 percent of the county's entire nonwhite population and about 15 percent of the area's total residents, reside in that portion of Racine County where the secondary annual particulate matter standard is exceeded.

The number of nonwhite persons in Kenosha County is approximately 2,300 persons, or 1.9 percent of the total county population. About 1,600 nonwhite persons, or 70 percent of the total nonwhite population, live in that portion of Kenosha County which exceeds the secondary annual standard--about 3 percent of the total population of that area.

On the regional level, the 73,400 persons residing in that area of Milwaukee County where the primary annual particulate matter standard is exceeded comprise about 4 percent of the total seven-county population. The number of persons living in those areas of Kenosha, Milwaukee, and Racine Counties where the secondary annual standard is exceeded is 488,900 persons, about 28 percent of the total regional population. In total, therefore, about 562,300 persons, or about 32 percent of the total regional population, live in areas where annual particulate matter levels exceed 60 $\mu g/m^3$.

In 1970 there were about 336,500 children age nine and younger and 169,400 persons age 65 and older living in the Region, comprising 19.2 and 9.6 percent, respectively, of the total population. About 9,900 of those children and 8,400 of the elderly, about 3 percent of all the children and 5 percent of all the elderly in the Region, resided in the area exceeding the primary annual standard. An additional 94,800 children and 55,000 elderly persons, 28 percent and 32 percent, respectively, of their total numbers, lived in areas exceeding the secondary annual standard. In total, 104,700 children, or about 31 percent of the population under 10 years old, and 63,400 elderly persons, or about 37 percent of all persons 65 years of age and older, live in those areas of the Region where particulate matter levels are higher than 60 $\mu g/m^3$.

The nonwhite population of the Region in 1970 was 129,831 persons, or about 7.4 percent of the total population. Of that number, 2,800 nonwhite persons, or about 2 percent of the total nonwhite population, lived in the area exceeding the primary annual standard. An additional 102,600 nonwhite persons, or about 79 percent of the total nonwhite population, resided in those areas of the Region in which the secondary annual standard was exceeded. In total, 105,450 nonwhite persons, or about 81 percent of the total nonwhite population, live in those portions of the Region where annual particulate matter levels exceed 60 $\mu g/m^3$.

SUMMARY

The history of the air pollution problem parallels the history of the use of fossil fuels for combustion. Carbon monoxide poisonings and irritation from smoke and soot may be traced back to ancient times. The advent of the Industrial Revolution during the 18th century with its attendant demand for carbonaceous fuels vastly accelerated the rate at which pollutant emissions were deposited in the ambient air. Eventually unplanned and unchecked industrial growth, combined with the virtual lack of any controls on air pollutant emissions, led to a series of air pollution episodes during which local mortality and morbidity rates were dramatically increased. One of the first such recognizable air pollution episodes occurred in Meuse Valley, Belgium in 1930, where 60 persons died and 6,000 persons were taken ill during a five-day period in December. The first well-documented air pollution disaster in the United States occurred in Donora, Pennsylvania, between October 27 and October 31, 1948. In this episode, 20 persons died and 6,000 illnesses were reported. Together with other air pollution disasters, most notably those in Poza Rica, Mexico in 1950 and in London, England in 1952, the incident at Donora prompted action by both government officials and private citizens to investigate the relationships between the various components of air pollution, still not identified at the time, and its effects on human health and welfare.

Over the ensuing two decades, research by the scientific and engineering communities, with the technical and financial assistance of federal, state, and local governmental agencies, lead to the collation of a body of evidence which firmly linked air pollution levels with observed adverse effects on human health. Five primary

health-related air pollutants—particulate matter, sulfur oxides, carbon monoxide, nitrogen dioxide, and photochemical oxidants—were identified. A sixth pollutant species, hydrocarbons, was identified as having no demonstrable adverse health effects, but as being an essential precursor to photochemical oxidant formation and thus necessary to control.

The body of scientific evidence concerning the effects of each air pollutant species on human health, animal and plant damage, and the deterioration of materials is collectively referred to as air quality criteria. Air quality criteria are the basis on which the air quality standards are developed. The air quality standards prescribe the levels of each pollutant species in the ambient air which may not be legally exceeded during a specific time in a specific geographic area. Air quality criteria have been published by the U.S. Environmental Protection Agency (EPA), and air quality standards have been promulgated by the U.S. Congress under the Clean Air Act Amendments of 1970 for the six pollutant species named above.

The most visible of all the pollutant species is particulate matter. Particulate matter is a general term for a large variety of substances which have the ability to remain suspended in the ambient air for indefinite periods of time. It includes suspended particles from natural sources such as bacteria, viruses, fungi, molds, yeasts, pollen, and spores from live and decaying plant and animal life; and particles caused by wind erosion, volcanic activity, and forest fires, and by the evaporation of salt-containing sea water. In addition, particles from man-made sources such as the combustion products from space heating, industrial processes, and motor vehicles are included in the particulate matter pollutant species.

Particulate matter has been found to cover the surface of the alveolar sacs when inhaled into the lungs and thereby inhibit the exchange of oxygen with the body's waste gases. When inhaled in sufficient quantities over a long time period, or in even higher quantities within a much shorter duration, particulate matter may produce certain respiratory diseases in humans and animals. Particulate matter has also been found to cause indirect damage to plants by reducing the light necessary for photosynthesis due to the formation of incrustations on leaf surfaces. Also, either by the acid nature of the particles themselves or as carriers of acid chemicals, particulate matter may corrode electrical equipment, masonry, and textiles. The ability of particles in the atmosphere to absorb and scatter light has led to speculation that particulate matter may also cause long-term climatic changes.

Based upon the physical and chemical nature of particulate matter and the observed biological and material response to its presence in the atmosphere, a primary air quality standard, that is, the maximum level permissible to protect human health, and a secondary air quality standard, that is, the maximum level permissible to protect plant and animal life from injury and materials from damage, were promulgated. Also, since both long-term and short-term exposures to particulate matter produced adverse effects, an annual and a 24-hour air quality standard were established for both the primary and secondary levels. On an annual basis, the primary air quality particulate matter standard was limited to 75 $\mu g/m^3$ (geometric mean) in order to protect human health, and the secondary standard was limited to 60 $\mu g/m^3$ (geometric mean) to prevent damage to plants, animals, and materials. In order to protect the public health from excessive short-term exposures, the 24-hour primary standard was established at 260 $\mu g/m^3$, and to prevent other adverse effects, the secondary 24-hour standard was set at 150 $\mu g/m^3$.

It has been observed that the biological effects of particulate matter may be exacerbated when sulfur oxides are also present. The most common of the sulfur oxides is sulfur dioxide, a nonflammable, nonexplosive, colorless gas with a pungent odor. Sulfur dioxide is a product of combustion processes using fossil fuels. Sulfur dioxide is chemically very active and, through oxidation in the atmosphere, can be converted from the gaseous to the particulate stage, the principal component of which is liquid droplets of sulfuric acid.

Sulfur dioxide has been found to produce a constriction in the bronchial tubes thereby decreasing the airflow in the lungs. Both long-term and short-term exposures to this pollutant are associated with increased respiratory illnesses. An annual and a 24-hour standard were therefore promulgated to protect the public health. The primary annual standard was established at 80 $\mu g/m^3$, and the primary secondary standard was set at 365 $\mu g/m^3$. Since observed adverse effects on plants, animals, or materials had not been found to occur at ambient air concentrations below these levels, no annual or 24-hour secondary standards were deemed necessary. To prevent a short-term exposure to extremely high doses of sulfur dioxide, however, a three-hour secondary standard of 1,300 $\mu g/m^3$ was issued.

Carbon monoxide, a colorless, odorless, tasteless gas, is perhaps the most toxic of all the criteria pollutants. It is formed primarily by the incomplete combustion of carbonaceous materials used as fuels for motor vehicles, space heating, and industrial processes, and the burning of refuse. Carbon monoxide is readily absorbed into the lungs and reacts with proteins in the blood, most notably hemoglobin, to cause a reduction of the oxygen-carrying and -exchange mechanism in the circulatory system. Hemoglobin has an affinity for carbon monoxide over 200 times greater than for oxygen and, if sufficient quantities are inhaled, death by suffocation may occur.

Carbon monoxide builds up rapidly in the blood during the initial exposure but reaches an equilibrium point after about eight hours. As it is absorbed into the blood, carboxyhemoglobin is formed. The blood of a nonsmoking individual usually contains about one-half of 1 percent carboxyhemoglobin due to internal body chemistry. When the carboxyhemoglobin levels reach about 2.5 percent, certain visual functions are impaired and perceived time intervals are distorted. The air quality

standard for carbon monoxide is therefore designed to keep the carboxyhemoglobin levels in the blood below 2 percent. A one-hour primary standard limiting ambient air carbon monoxide concentrations to 40 mg/m^3 and an eight-hour primary standard of 10 mg/m^3 have, therefore, been promulgated to protect the public health from adverse carboxyhemoglobin levels.

Nitrogen dioxide, a reddish brown-orange gas with a characteristic pungent odor, and nitric oxide, a colorless, odorless gas, are the principal oxides of nitrogen. Under the high temperature conditions accompanying the burning of fossil fuels nitric oxide and, to a much lesser extent, nitrogen dioxide are formed when air is used as the oxidizing agent. The nitric oxide is chemically converted to nitrogen dioxide in the presence of oxygen in the free air.

Nitric oxide is not known to produce adverse health effects at concentrations normally occurring in the ambient air. Long-term exposures to nitrogen dioxide, however, have been shown to induce acute respiratory disease and produce an increased frequency of bronchitis in infants and school children. Nitrogen dioxide has also been identified as the cause of leaf injury to various plants, but only at concentrations above the levels at which human health is impaired. Also at higher concentrations than normal in the ambient air, nitrogen dioxide has been found to cause the fading of textile dyes and additives, the weakening of textile fibers, and the corrosion of metals. Nitrogen dioxide is also an essential precursor compound in the formation of photochemical oxidants.

Since long-term exposure to normally occurring ambient air concentrations is the cause of the observed adverse health effects in humans, the air quality standard for nitrogen dioxide has been promulgated only on an annual basis. Moreover, since adverse health effects occur at levels lower than those which cause injury and damage to plants and materials, the secondary annual air quality standard is the same as the primary standard. Based on studies of long-term nitrogen dioxide health effects, therefore, the primary annual average concentration of nitrogen dioxide has been limited to 100 $\mu g/m^3$.

Photochemical oxidants are secondary pollution products formed in the atmosphere from a series of reactions between hydrocarbons and nitrogen oxides. The principal photochemical oxidant product is ozone. Ozone, a colorless gas, is chemically active and may react with the mucus and tissue layers in all compartments of the respiratory tract to cause a deterioration of the cellular lining and consequently a restriction of normal pulmonary functions. Ozone also may produce damage to vegetation and contribute to the deterioration of certain materials.

Photochemical oxidants have been found to produce a greater biological response at comparatively low levels of exposure over short-term periods than higher concentrations over an extended interval, indicating that a tolerance to the pollutant may be acquired to some degree. From laboratory data it has been determined that adverse health effects are initiated when oxidant concentrations exceed about 200 $\mu g/m^3$ (0.10 ppm) averaged over a period of one hour. In order to protect the public health, therefore, the primary photochemical oxidant ambient air quality standard, measured as ozone, was initially set at 160 $\mu g/m^3$ (0.08 ppm) for a one-hour maximum concentration not to be exceeded more than once per year. Based on more recent clinical data on the health effects of ozone, however, the Administrator of the U.S. Environmental Protection Agency changed the photochemical oxidant standard to an ozone standard in February 1979, and increased the maximum allowable ambient air concentration of ozone from 160 $\mu g/m^3$ (0.08 ppm) to 235 $\mu g/m^3$ (0.12 ppm) on a one-hour average for the level of the primary standard. Since this prescribed maximum level should, according to the available evidence, also prevent injury to plants and damage to artifacts, the secondary standard is the same as the primary standard.

In addition to the six above-mentioned pollutants, there is a class of air pollutants that presents a danger to the public health but for which ambient air quality standards are not an effective means of control. Five of these contaminants, termed hazardous pollutants, have been designated to date (1977): vinyl chloride, asbestos, mercury, beryllium, and benzene. The adverse health effects associated with each of these five pollutants are abated through the control of their emissions from the responsible sources.

Ambient air quality monitoring data recorded at locations distributed throughout the Region have indicated that the seven-county area has exceeded, and is continuing to exceed, several of the National Ambient Air Quality standards. Particulate matter levels have been monitored at about 35 sites in the Region each year between 1973 and 1977. The data observed during 1973, the designated base year of the regional air quality maintenance planning program, have indicated that the primary annual air quality standard for particulate matter of 75 $\mu g/m^3$ was exceeded in an approximately eight-square-mile area of Milwaukee County centered on the central business district of the City of Milwaukee and the adjacent, heavily industrialized portion of the Menomonee River Valley. The maximum measured concentrations in that area averaged about 121 $\mu g/m^3$ (geometric mean), a level about 60 percent greater than the primary annual standard. The secondary annual particulate matter standard of 60 $\mu g/m^3$ was exceeded during 1973 in an additional approximately 40-square-mile area of Milwaukee County, principally in the City of Milwaukee. The secondary standard was also exceeded in an approximately 9-square-mile area of the City of Racine, and in an approximately 11-square-mile area of the City of Kenosha, the maximum measured concentrations in those areas reading 82 $\mu g/m^3$ and 73 $\mu g/m^3$, respectively. The maximum annual average concentration in the City of Racine, although above the primary annual standard, was measured only at a single point. From the

isopleth analysis of particulate matter concentrations in the City of Racine, the area exceeding the primary standard was determined to be limited to this single point.

Of the 18 particulate matter monitoring sites in Milwaukee County in operation in 1973, five indicated violations of the primary 24-hour particulate matter standard of 260 $\mu g/m^3$. All five of these sites were located in the City of Milwaukee, with the maximum measured concentration reading 458 $\mu g/m^3$. With the exception of the monitoring site in Port Washington in Ozaukee County, where the maximum measured concentration exceeded 359 $\mu g/m^3$, no particulate matter monitoring site in the Region recorded a violation of the primary 24-hour standard. The secondary 24-hour particulate matter standard of 150 $\mu g/m^3$, however, was exceeded during 1973 at most of the monitoring sites in Milwaukee County, at two sites in Racine County, at one site in Walworth County, and at the one site in Ozaukee County. From the decreasing number of violations of the primary and secondary 24-hour standards observed between 1973 and 1976, and from the general decrease in the annual average monitored concentrations at sites throughout the Region over the same period, a trend of decreasing particulate matter concentrations is apparent. This observed decline, however, is probably due to the application of emission control technology to the major point sources, and could be reversed in the near future solely through the effects of new urban growth and development. In fact, monitoring data for the year 1977 indicate that the decline has stabilized or may even be on the increase.

The air pollutant monitoring data gathered for 1977 indicate that there were 37 high-volume particulate matter air samplers meeting the EPA criteria for sampling frequency in operation in the Region for the year. During this period, five stations recorded particulate matter levels exceeding the primary 24-hour standard, and 18 recorded violations of the secondary standard.

Prior to 1975, all sulfur dioxide air quality monitoring data recorded in the Region by the Wisconsin Department of Natural Resources (DNR) were found to be invalid due to problems in data reduction. Of the nine sulfur dioxide monitoring sites operational in 1975, none met the Environmental Protection Agency minimum sampling requirements to be considered representative samples of existing sulfur dioxide levels. In 1976 five sulfur dioxide monitoring sites in the Region, four in Milwaukee County and one in Racine County, met all EPA sampling requirements and the data were deemed valid. No violations of the primary annual or the primary 24-hour sulfur dioxide standards of 80 and 365 $\mu g/m^3$, respectively, nor of the secondary three-hour standard of 1,300 $\mu g/m^3$, were recorded at any of these five sites during 1976 or 1977. Since the five monitoring sites were located in areas of heavy urbanization and industrialization, it is not anticipated that the sulfur dioxide ambient air quality standards were exceeded at any other point in the Region.

As with sulfur dioxide, all carbon monoxide air quality monitoring data recorded in the Region prior to 1975 by the DNR were found to be invalid due to problems of data reduction. During 1975 nine monitoring sites in the Region were operated to sample carbon monoxide levels, but this number was reduced to seven in 1976 when two stations in Milwaukee County were discontinued and remained at seven stations during 1977. The maximum measured one-hour carbon monoxide concentration in these three years was 25.8 mg/m^3, measured at the station located at 606 W. Kilbourn Avenue in the City of Milwaukee during 1977, a value approximately 65 percent of the one-hour standard of 40 mg/m^3. The eight-hour carbon monoxide standard of 10 mg/m^3, however, was exceeded at two monitoring sites in 1975—one located at 1225 S. Carferry Drive in the City of Milwaukee and one at 726 N. Grand Avenue in the City of Waukesha—at three monitoring sites in 1976—one located at 1225 S. Carferry Drive, one at 7528 W. Appleton Avenue, and one at 3716 W. Wisconsin Avenue, all in the City of Milwaukee— and at six monitoring sites in 1977—all five in Milwaukee County plus the Waukesha County site. It may be concluded, therefore, that a carbon monoxide problem does exist in localized areas of the Region.

Prior to 1976, the Jacobs-Hochheiser method was used in sampling nitrogen dioxide concentrations in the ambient air. This method was later found not to yield reliable data. During 1976 and 1977, however, four nitrogen dioxide monitoring sites using the newly approved Christie arsenite method met all EPA minimum sampling requirements. All four of these sites were located in the City of Milwaukee. The highest annual average nitrogen dioxide concentration measured was 70.0 $\mu g/m^3$ at the station located at 711 W. Wells Street. This level is well below the ambient air quality standard of 100 $\mu g/m^3$. It is unlikely, therefore, that a violation of the nitrogen dioxide ambient air quality standard occurred anywhere in the Region in 1976 or 1977.

Only a limited amount of ambient air quality monitoring data is available for hydrocarbons. As part of a special contract with the Wisconsin Department of Natural Resources, Washington State University collected data on hydrocarbon concentrations at the Kenosha Airport between August 4 and September 30, 1976. Of the 58 monitoring days, 43 were found to exceed the average three-hour (6 a.m. - 9 a.m.) hydrocarbon standard of 160 $\mu g/m^3$. The DNR also operated a hydrocarbon monitoring site at 3716 W. Wisconsin Avenue in the City of Milwaukee from August 1 to 19, 1975, sampling on 13 days. The three-hour hydrocarbon standard was exceeded on all 13 days in which monitoring took place. A limited amount of nonmethane hydrocarbon data was collected in 1977 from the operation of a mobile air quality monitoring van stationed in Kenosha County from March through May. During this period a maximum nonmethane hydrocarbon three-hour reading of 755 $\mu g/m^3$ (0.39 ppm) was recorded. Although limited in quantity and spatial distribution, the available hydro-

carbon air quality monitoring data indicate that violations of the three-hour hydrocarbon standard may be occurring over a broad area in the Region.

In both 1975 and 1976, the ozone monitoring site in Kenosha County recorded the greatest number of hours above the then established ambient air quality oxidant standard of 0.08 ppm, with 234 and 364 hours, respectively. The large number of hours during which the Kenosha monitoring site exceeded the oxidant standard, and the proximity of the site to the Wisconsin-Illinois border, is indicative of the probable transport of significant quantities of oxidant products and their precursor emissions from sources outside of the Southeastern Wisconsin Region.

Ozone monitoring in 1977 shows a continuing pattern of each sampling site in the Region recording concentrations above the national standard for oxidants of 0.08 ppm. During 1977 the highest ozone level of 0.204 ppm was recorded at 2114 E. Kenwood Boulevard in Milwaukee, while Racine County registered the greatest number of hours of measured ozone levels in excess of the standard.

Damage from the effects of air pollution has been estimated to cost approximately $1.0 billion per year in southeastern Wisconsin in 1970 dollars. The loss of income due to premature deaths possibly caused by air pollution-related illness is estimated to approximate $27.9 million per year. Another $3.5 million annually in lost income and medical expenses may be attributed to increased morbidity rates possibly induced by air pollution levels in southeastern Wisconsin. A total of about $31.4 million annually, therefore, is lost or expended because of the possible effects of air pollution on human health.

The soiling of households and businesses by air pollution adds an estimated $55 million annually to cleaning and maintenance expenses. The soiling and deterioration of materials and artifacts, particularly paint and zinc coatings, by air pollution produces about $897 million in damage annually. Crop losses due to the effects of air pollution on vegetation are estimated to account for about an additional $515,000 in lost income per year. The total estimated impact of air pollution on the economy of southeastern Wisconsin is, therefore, about $983,957,450 per year in 1970 dollars.

Based on 1970 population data, the latest year for which population characteristics may be disaggregated in subcounty units within the entire Region, and on the available ambient air quality monitoring data, it is estimated that about 73,400 persons, or about 4 percent of the total regional population, live within the approximate eight-square-mile area in Milwaukee County where the primary annual particulate matter ambient air quality standard is exceeded. An additional 361,000 persons living in a 40-square-mile area in Milwaukee County, 68,100 persons living in a 9-square-mile area in Racine County, and 59,800 persons in an 11-square-mile area in Kenosha County are exposed to particulate matter levels in excess of the secondary annual ambient air quality standard. Therefore, 488,900 persons, or about 28 percent of the total regional population, reside in the 60 square miles where the secondary annual standard is exceeded.

In the eight-square-mile area in Milwaukee County where the primary annual particulate matter standard is exceeded, the 1970 population included about 9,900 children age nine and younger, and about 8,400 persons age 65 and older, approximately 3 percent of all children and 5 percent of all elderly in the Region. Also, about 2,800 nonwhite persons, or about 2 percent of the total regional nonwhite population, resided in this area.

In the 60 square miles within Milwaukee, Racine, and Kenosha Counties where the secondary annual particulate matter standard is exceeded, the population included about 94,800 children and 55,000 elderly persons, or about 28 and 32 percent of their total regional numbers, respectively. Also, about 105,450 nonwhite persons, or about 81 percent of the total regional nonwhite population, resided in those portions of the Region which exceed the secondary annual standard.

Existing ambient air levels of sulfur dioxide and nitrogen dioxide do not adversely affect human health. There may be certain segments of the population, however, that are exposed to detrimentally high levels of carbon monoxide for periods of eight hours or longer. The number of persons exposed to such carbon monoxide levels cannot be determined due to limitations in the available air quality monitoring data, which prohibit the areal extent of the violations from being defined, and to uncertainties in quantifying the number of individuals remaining in the affected area for durations longer than eight hours. The number and spatial distribution of ambient air monitoring stations sampling for ozone concentrations also do not permit an estimate to be made of the number of individuals within the Region exposed to photochemical oxidant levels in excess of the one-hour standard. The frequent recurrence of ozone standard violations at every operational monitoring site within the Region, however, indicates that a substantial segment of the regional population may be exposed to potentially harmful oxidant levels intermittently throughout the summer season. It should again be noted that the long-range transport of photochemical oxidants and their precursor compounds from major metropolitan areas south of the Region contributes to the high levels experienced in southeastern Wisconsin.

From the available, although limited, ambient air quality monitoring data, it may be concluded that a significant air pollution problem does exist within the Region, particularly with regard to particulate matter, ozone, and hydrocarbon levels, and to a lesser extent, carbon monoxide levels. A need is evident, therefore, to address the abatement of existing air pollution levels within the Region through the regional air quality maintenance planning program in order that the protection of the public health from deleteriously high concentrations of atmospheric contaminants may be ensured.

Chapter VII

AIR POLLUTANT EMISSIONS INVENTORY FOR SOUTHEASTERN WISCONSIN: 1973 AND 1977

INTRODUCTION

Although air pollution levels in southeastern Wisconsin are influenced by pollutants transported into the Region from extraregional sources and, to a lesser extent, by the naturally occurring background levels of pollutants, an important factor in determining ambient air quality within the Region is the quantity of pollutant emissions released into the atmosphere by local sources. In order to effectively assess the regional ambient air quality problem, therefore, it is necessary to collate an accurate and complete air pollutant emissions inventory that identifies the location of all emission sources, and describes and quantifies the magnitude, frequency, and duration of pollutant discharge by these sources into the atmosphere. Such an air pollutant emissions inventory serves at least four purposes in any air quality maintenance planning effort. First, such an inventory is necessary to identify the major contributing sources of air pollution. Second, such an inventory is necessary to assess the potential effectiveness of legal and technical emission controls. Third, such an inventory is necessary to determine the compliance of emission sources with established state and federal emission standards. And fourth, such an inventory is necessary to properly calibrate and apply air quality simulation modeling techniques, and, using such techniques, to forecast probable future ambient air quality levels. A regional air pollutant emissions inventory is thus an essential part of any areawide air quality maintenance planning effort.

All sources of air pollutant emissions may be grouped into one of three general categories: point sources, line sources, or area sources. For the purposes of the regional air quality maintenance planning program, point sources are defined as large discrete sources, such as stacks associated with industrial operations; line sources are defined as transportation-related emission sources, predominantly motor vehicles operating over arterial streets and highways; and area sources are defined as the aggregation of the many small, highly diffused sources of pollutant emissions, such as residential space heating and agricultural tilling operations, which may not individually be major contributors of pollution but which may collectively have a significant impact on ambient air quality. In the following sections of this chapter, the procedures used in collating the point, line, and area source air pollutant emissions inventory for the Southeastern Wisconsin Region are reviewed, and the inventory findings are presented for each emission source category.

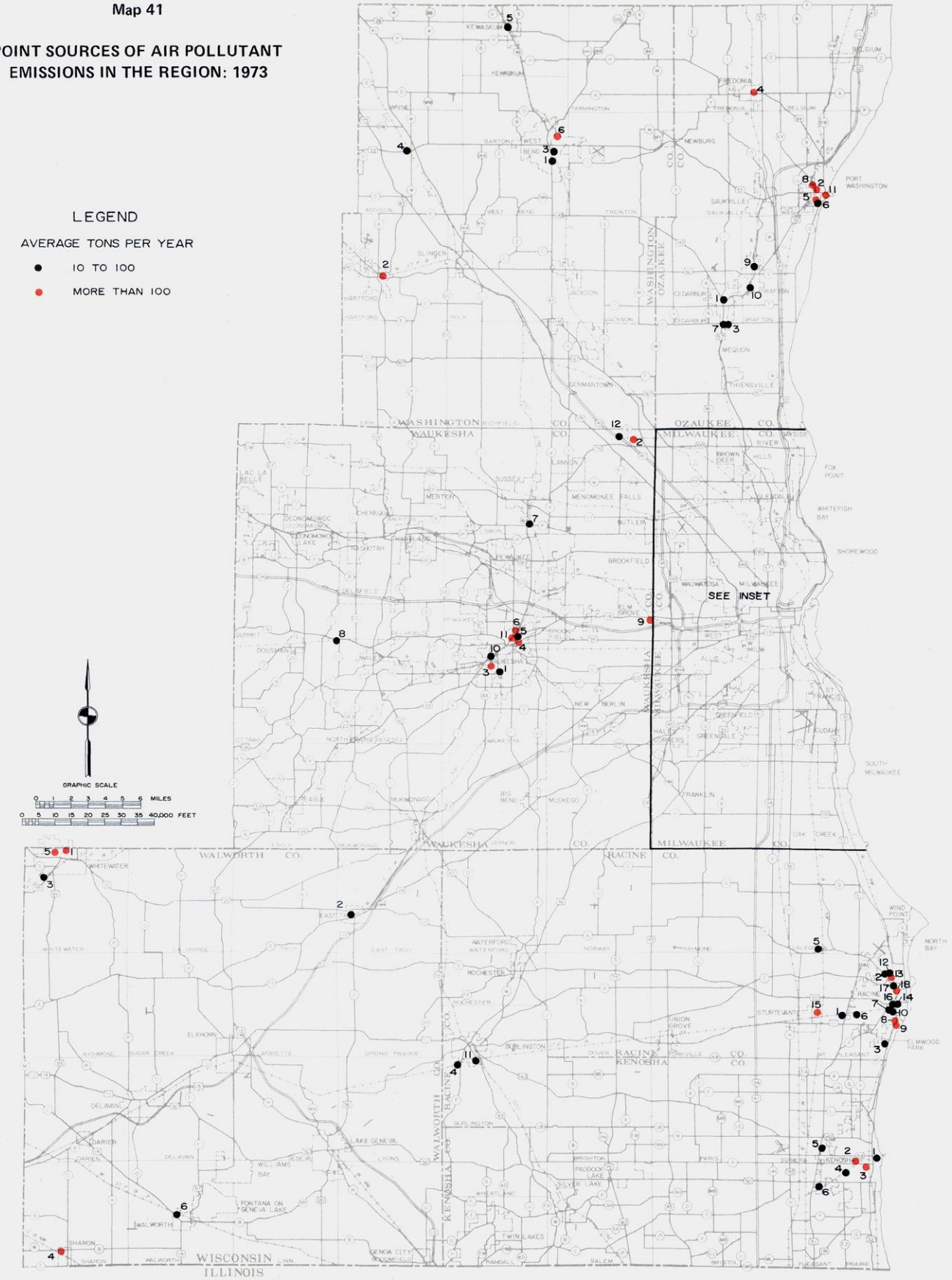
POINT SOURCE EMISSIONS INVENTORY: 1973

Data collection on air pollutant emissions from point sources in the State of Wisconsin, outside of Milwaukee County, was initiated in 1970 when a single engineer from the Wisconsin Department of Natural Resources (DNR) was assigned the task of visiting major industries throughout the State that had a potential for polluting the atmosphere. Milwaukee County conducted extensive source emission inventories in 1966 and again in 1970. In 1971 the DNR standardized the inventory procedures and increased the level of staff resources allocated to the basic data collection effort. The 1973 point source emissions inventory for the seven-county Southeastern Wisconsin Region is a product of this state agency data collection effort, under which data on emissions from all existing sources are reviewed annually and data on new sources added as they become operational. A list of those facilities in the Region that produced greater than 10 tons of pollutant emissions during 1973, extracted from the state inventory, is presented by county in Appendix B. The facilities listed in the Appendix are shown on Map 41 by two categories, those which released between 10 and 100 tons of pollutants per year and those which released more than 100 tons per year.

As a part of the existing State Implementation Plan (SIP) to Achieve Air Quality Standards, limitations were established in 1972 for certain categories of point source emissions. These limitations, as set forth in Chapter NR 154 of the Wisconsin Administrative Code by pollutant species, define the maximum allowable emission rate for specific types of industrial processes, fuel-burning installations, and incinerators. However, the maximum allowable emission rate for those sources that either existed or were under construction prior to April 1, 1972—the date on which the regulations took effect—is different from the rate for those that were constructed subsequent to that date. Generally, the emission limitations for those sources constructed prior to April 1, 1972, are less stringent than the limitations for sources constructed after the regulation date. Thus, air pollutant emissions from point sources in the Region during 1973 may be further identified as to the specific industrial process, the type of fuel-burning installation, or the size of incinerator from which the emissions were generated, and by the degree of control to which each source of emissions is subject. In the following sections, the findings of the 1973 point source emissions inventory for the seven-county Southeastern Wisconsin Region are presented disaggregated in this manner by pollutant species. The 1976 point source

Map 41

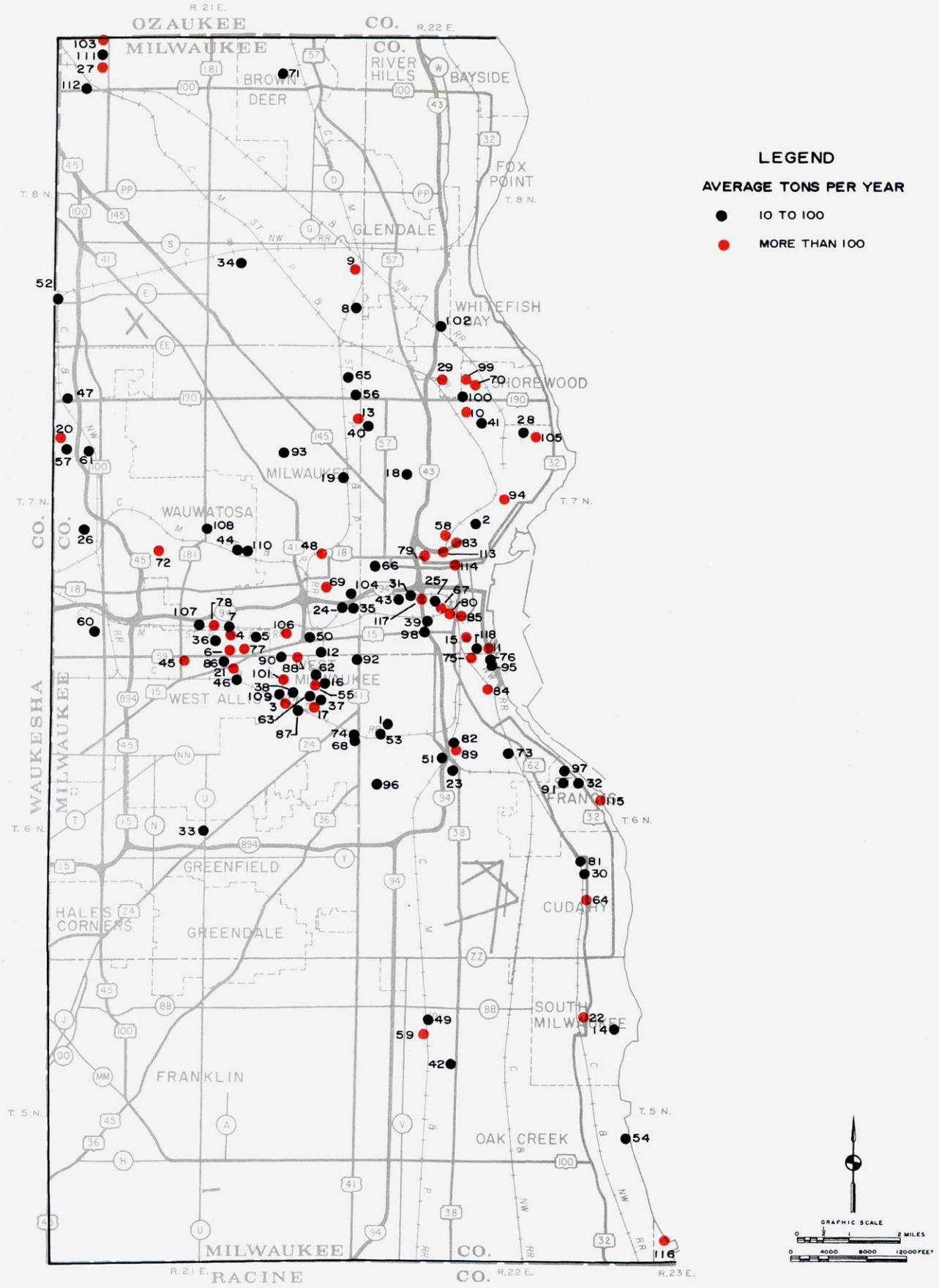
POINT SOURCES OF AIR POLLUTANT EMISSIONS IN THE REGION: 1973



The Wisconsin Department of Natural Resources identified 177 major industrial facilities, or point sources, in the Southeastern Wisconsin Region which emitted 10 or more tons of air pollution during 1973. Of these 177 major industrial facilities, 108 emitted between 10 and 100 tons of air pollution, and the other 69 emitted more than 100 tons of air pollution into the ambient air over the Region during that year. (Numbers on map correspond to facilities identified in Appendix B.)

Source: SEWRPC.

Map 41 (continued)



Source: SEWRPC.

emissions inventory for the Southeastern Wisconsin Region, which was used in the calibration of the air quality simulation model for sulfur dioxide, is presented later in this chapter and may be compared with the 1973 inventory to evaluate the change in regional point source emission levels as a result of the further implementation and enforcement of legal and technological pollution controls.

Particulate Matter

In 1973 there were 46 point sources in the Region that emitted between 10 and 100 tons of particulate matter, and 13 point sources that emitted more than 100 tons. These point sources, the geographic distribution of which is shown on Map 42, released a total of 18,110 tons of particulates into the atmosphere over the Region during the year. Table 93 indicates the distribution of these total emissions from point sources in the Region by county and by source of emissions. In 1973 particulate matter emissions from industrial processes accounted for about 37 percent of the total regional particulate matter emissions from point sources, while fuel burning and incineration accounted for about 63 percent and less than 1 percent, respectively. In terms of areal distribution, Table 93 indicates that the greatest amount of particulate matter emissions is released from sources in Milwaukee County, which contains approximately 63 percent of the total emission sources, which in turn emit 85 percent of the total emissions.

Sulfur Dioxide

In 1973 there were 28 point sources in the Region that emitted between 10 and 100 tons of sulfur dioxide, and an additional 14 point sources that emitted more than 100 tons of this pollutant species. In total, 191,171 tons of sulfur dioxide were emitted from the 42 sulfur dioxide point sources in the Region during 1973. The geographic distribution of these sources is shown on Map 43. Table 94 indicates the distribution of sulfur dioxide emissions from point sources in the Region by county and by source of emissions. The predominant source of sulfur dioxide emissions is fuel-burning installations, which account for approximately 98 percent of the regional sulfur dioxide emissions from all point sources. Incineration and industrial processes account for 0.1 percent and 2.3 percent of the total regional

Table 93

DISTRIBUTION OF PARTICULATE MATTER EMISSIONS FROM POINT SOURCES IN THE REGION BY COUNTY: 1973

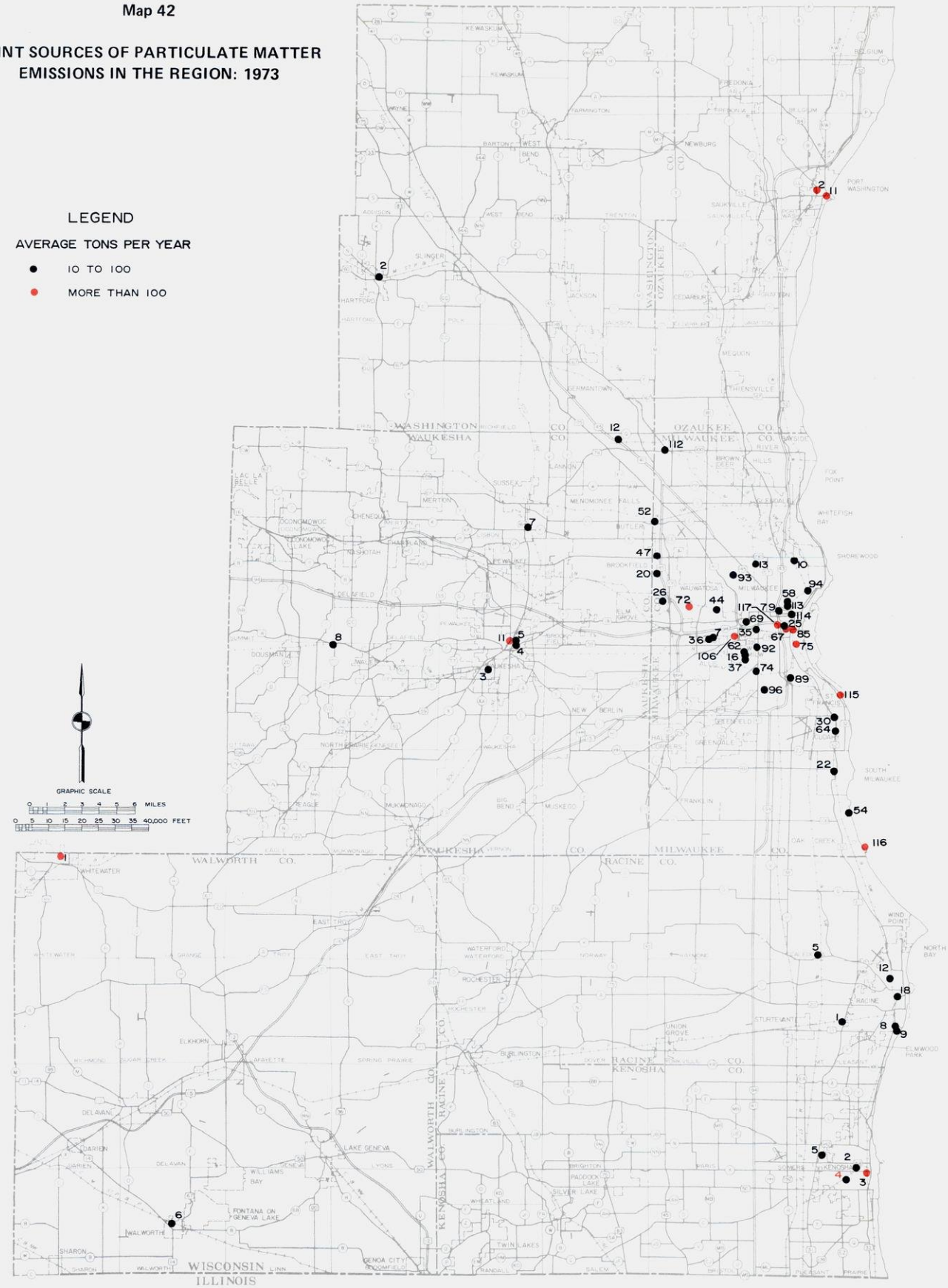
Source of Emissions	Emissions (tons)							
	Kenosha	Milwaukee	Ozaukee	Racine	Walworth	Washington	Waukesha	Region
Fuel-Burning Installation (boilers)								
5,000,000 BTU per Hour or Less	1	25	1	35	1	20	8	91
5,000,001 to 49,999,999 BTU per Hour	-- [a]	593	3	20	2	3	3	624
50,000,000 to 99,999,999 BTU per Hour	1,064	60	--	23	2	--	--	1,149
100,000,000 BTU per Hour or More	17	8,878	583	3	1	--	--	9,482
Subtotal	1,082	9,556	587	81	6	23	11	11,346
Incineration								
Less than 500 Pounds Waste per Hour	--	1	--	-- [a]	--	--	--	1
500-4,000 Pounds of Waste per Hour	-- [a]	9	4	--	--	--	15	28
More than 4,000 Pounds Waste per Hour	--	16	105	--	--	--	--	121
Subtotal	-- [a]	26	109	-- [a]	--	--	15	150
Industrial Process								
Coking Processes	--	4,839	--	--	--	--	--	4,839
Metal Processes	63	212	45	124	210	2	187	843
Painting Processes	-- [a]	35	-- [a]	-- [a]	--	1	2	38
Food Processing	--	--	--	3	--	--	--	3
Asphalt Products	49	114	--	13	--	1	7	184
Grain Handling and Processing	--	187	--	--	--	--	--	187
Printing and Lithography	--	2	--	-- [a]	--	--	1	3
Glassworks	--	24	--	7	--	--	--	31
Coating Operations	--	1	--	--	--	--	--	1
Heat Treating	2	50	2	1	--	--	1	56
Solvent and Adhesive Processes	--	1	--	--	--	--	--	1
Washing and Drying	--	41	-- [a]	-- [a]	1	--	-- [a]	42
Miscellaneous	3	320	2	3	-- [a]	11	47	386
Subtotal	117	5,826	49	151	211	15	245	6,614
Total	1,199	15,408	745	232	217	38	271	18,110

[a] *Less than one-half ton.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Map 42

POINT SOURCES OF PARTICULATE MATTER EMISSIONS IN THE REGION: 1973



The Wisconsin Department of Natural Resources identified 46 point sources in the Region that emitted between 10 and 100 tons of particulate matter, and an additional 13 point sources that emitted more than 100 tons of particulate matter into the ambient air over southeastern Wisconsin, during 1973. In total, these 59 point sources are estimated to have released more than 18,000 tons of particulate matter air pollution in that year. (Numbers on map correspond to facilities identified in Appendix B.)

Source: SEWRPC.

Table 94

DISTRIBUTION OF SULFUR DIOXIDE EMISSIONS FROM POINT SOURCES IN THE REGION BY COUNTY: 1973

Source of Emissions	Emissions (tons)							
	Kenosha	Milwaukee	Ozaukee	Racine	Walworth	Washington	Waukesha	Region
Fuel-Burning Installation (boilers)								
5,000,000 BTU per Hour or Less	1	51	--[a]	65	1	28	44	190
5,000,001 to 49,999,999 BTU per Hour	--[a]	348	--[a]	26	7	1	2	384
50,000,000 to 99,999,999 BTU per Hour	506	107	--	26	1	--	--	640
100,000,000 BTU per Hour or More	38	141,672	43,740	2	1	--	--	185,453
Subtotal	545	142,178	43,740	119	10	29	46	186,667
Incineration								
Less than 500 Pounds of Waste per Hour	--	--[a]	--	94	--	--	--	94
500 — 4,000 Pounds of Waste per Hour	1	--[a]	3	--	--	--	25	29
More than 4,000 Pounds of Waste per Hour	--	7	12	--	--	--	--	19
Subtotal	1	7	15	94	--	--	25	142
Industrial Process								
Coking Processes	--	816	--	--	--	--	--	816
Metal Processes	--	875	--[a]	--[a]	1	--[a]	--[a]	876
Painting Processes	--[a]	--[a]	--[a]	--	--	--[a]	--[a]	--[a]
Food Processing	--	--	--	--	--	--	--	--
Asphalt Products	--	17	--	--	--	2	2	21
Grain Handling and Processing	--	16	--	--	--	--	--	16
Printing and Lithography	--	--[a]	--	--	--	--	--[a]	--[a]
Glassworks	--	--	--	--[a]	--	--	--	--[a]
Coating Operations	--	--[a]	--	--	--	--	--	--[a]
Heat Treating	--[a]	2	--[a]	--[a]	--	--	--[a]	2
Solvent and Adhesive Processes	--	--[a]	--	--	--	--	--	--[a]
Washing and Drying	--	16	--	--	--	--	--[a]	16
Miscellaneous	--	2,609	2	--[a]	--	4	--	2,615
Subtotal	--[a]	4,351	2	--[a]	1	6	2	4,362
Total	546	146,536	43,757	213	11	35	73	191,171

[a] *Less than one-half ton.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

emissions, respectively. Within the fuel-burning category, the greatest amount of sulfur dioxide emissions results from the combustion of fossil fuels to generate electric power.

As of 1973, no point sources in the Region were subject to the sulfur dioxide emission limitations set forth in the Wisconsin Administrative Code. It cannot be stated, therefore, that any point source was not in compliance with the established emission standards. A ban on coal-burning installations having a heat input of less than 250 million British Thermal Units (BTU's) per hour, however, was in effect in 1973. Although this ban was enforced specifically for the control of particulate matter emissions, an indirect result of the ban was the minimization of sulfur dioxide emissions from point sources.

Carbon Monoxide

There were 21 point sources in the Region that produced between 10 and 100 tons of carbon monoxide during 1973, and 20 point sources that emitted more than 100 tons of carbon monoxide during the year. A total of approximately 20,718 tons of carbon monoxide were released into the atmosphere over the Region from these point sources in 1973. The geographic distribution of these sources within the Region is shown on Map 44.

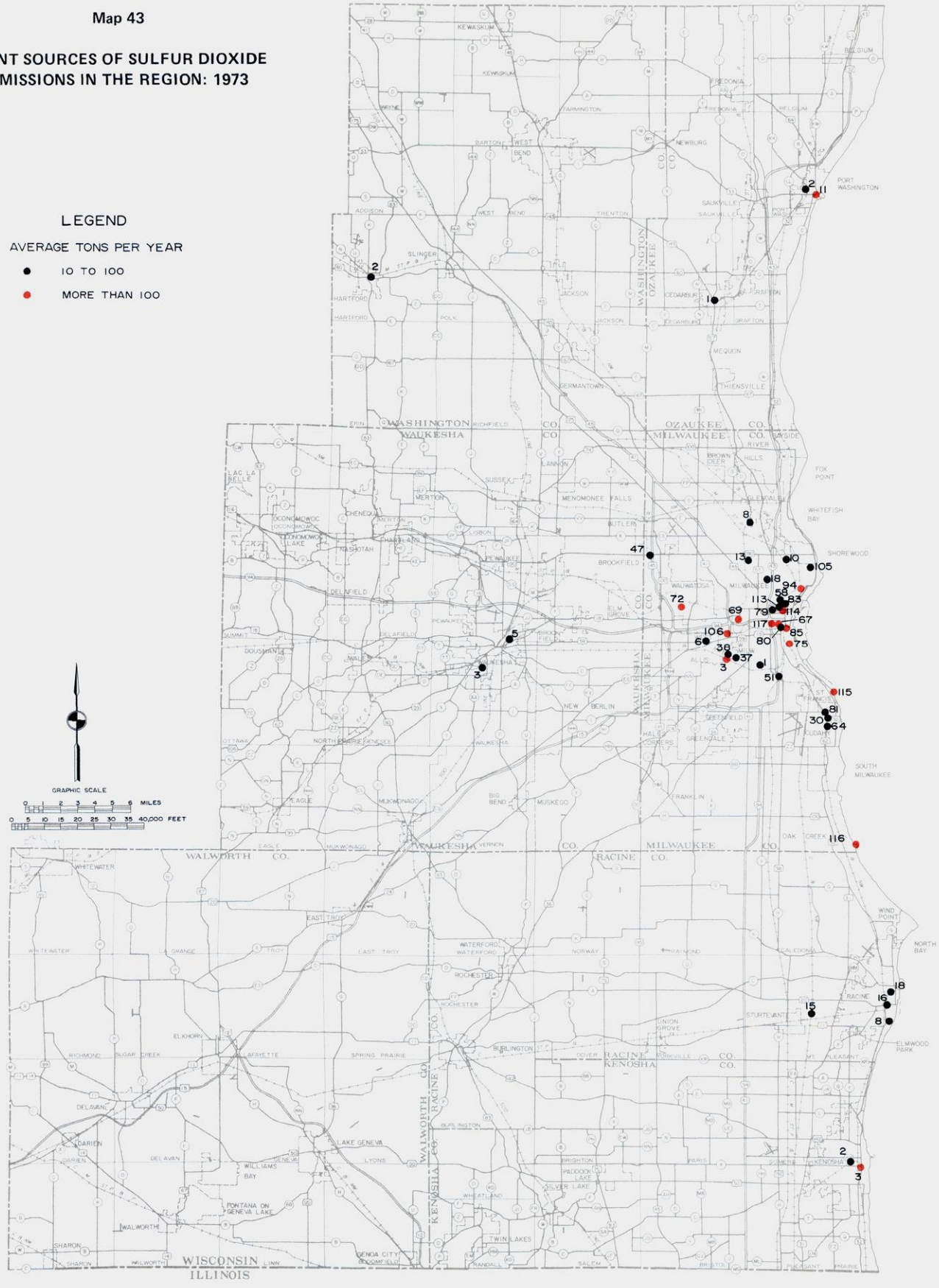
Table 95 indicates the distribution of carbon monoxide emissions from point sources in the Region by county and by source of emission. The primary source of carbon monoxide is industrial processes, specifically metal processes.

Nitrogen Oxides

In 1973 there were 87 point sources in the Region that emitted between 10 and 100 tons of nitrogen oxides and an additional 23 point sources that emitted more than 100 tons of this pollutant species. A total of 48,654 tons of nitrogen oxide emissions were released into the atmosphere over the Region from these point sources during 1973. The geographic distribution of these sources within the Region is shown on Map 45.

Map 43

POINT SOURCES OF SULFUR DIOXIDE EMISSIONS IN THE REGION: 1973



The Wisconsin Department of Natural Resources identified 28 point sources in the Region that emitted between 10 and 100 tons of sulfur dioxide, and an additional 14 point sources that emitted more than 100 tons of this pollutant species, during 1973. In total, these 42 point sources released more than 190,000 tons of sulfur dioxide into the ambient air over the Region in that year. These sulfur dioxide emissions may be attributed principally to the combustion of fossil fuels in large industrial boilers. (Numbers on map correspond to facilities identified in Appendix B.)

Source: SEWRPC.

Table 95

DISTRIBUTION OF CARBON MONOXIDE EMISSIONS FROM POINT SOURCES IN THE REGION BY COUNTY: 1973

Source of Emissions	Emissions (tons)							
	Kenosha	Milwaukee	Ozaukee	Racine	Walworth	Washington	Waukesha	Region
Fuel-Burning Installation (boilers)								
5,000,000 BTU per Hour or Less	1	11	1	3	1	7	1	25
5,000,001 to 49,999,999 BTU per Hour	--[a]	79	2	6	1	3	2	93
50,000,000 to 99,999,999 BTU per Hour	16	45	--	10	4	--	--	75
100,000,000 BTU per Hour or More	11	2,051	344	2	1	--	--	2,409
Subtotal	28	2,186	347	21	7	10	3	2,602
Incineration								
Less than 500 Pounds of Waste per Hour	--	1	--	--	--	--	--	1
500-4,000 Pounds of Waste per Hour	4	1	35	--	--	--	350	390
More than 4,000 Pounds of Waste per Hour	--	10	175	--	--	--	--	185
Subtotal	4	12	210	--	--	--	350	576
Industrial Process								
Coking Processes	--	210	--	--	--	--	--	210
Metal Processes	2	6,618	108	6,381	1,635	1	2,012	16,757
Painting Processes	1	8	--[a]	--	--	1	2	12
Food Processing	--	--	--	--[a]	--	--	--	--[a]
Asphalt Products	--[a]	2	--	--[a]	--	--[a]	--[a]	2
Grain Handling and Processing	--	15	--	--	--	--	--	15
Printing and Lithography	--	1	--	--[a]	--	--	1	2
Glassworks	--	--	--	7	--	--	--	7
Coating Operations	--	3	--	--	--	--	--	3
Heat Treating	2	51	3	--	--	--	1	57
Solvent and Adhesive Processes	--	1	--	1	--	--	--	2
Washing and Drying	--	3	--[a]	--[a]	--[a]	--	1	4
Miscellaneous	--	201	17	2	--	249	--	469
Subtotal	5	7,113	128	6,391	1,635	251	2,017	17,540
Total	37	9,311	685	6,412	1,642	261	2,370	20,718

[a] *Less than one-half ton.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Table 96 indicates the distribution of nitrogen oxide emissions from point sources in the Region by county and by source of emissions. It should be noted that nitrogen oxide emissions were not produced in any significant quantities from industrial processes or incineration within the Region in 1973, and that the only significant point source of nitrogen oxide emissions was the combustion of fossil fuels. There were no sources in the Region during 1973 to which nitrogen oxide emission standards were applicable.

Hydrocarbons

Map 46 indicates the geographic distribution of hydrocarbon point sources within the Region during 1973. Of the 86 sources shown on the map, 51 emitted between 10 and 100 tons of hydrocarbons and 35 emitted more than 100 tons of hydrocarbons. In total, these sources released approximately 24,650 tons of hydrocarbons into the atmosphere over the Region in 1973.

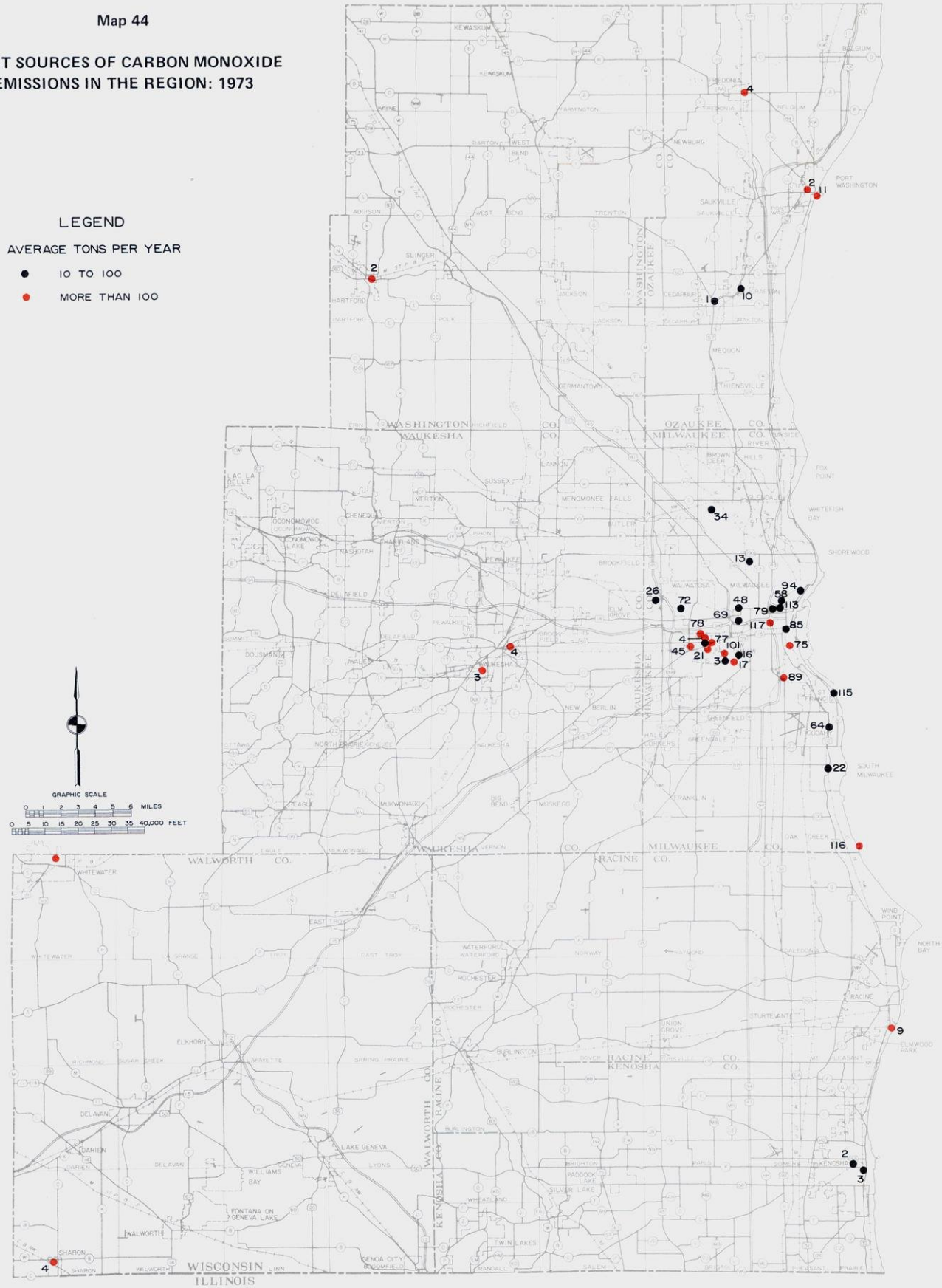
Table 97 indicates the distribution of hydrocarbon emissions from point sources in the Region by county and by source of emissions. Industrial processes accounted for 96.6 percent of the total regional hydrocarbon emissions from point sources, while fuel burning and incineration accounted for 3.3 percent and 0.1 percent of the total, respectively. Table 97 includes hydrocarbon emissions from point sources that were both in compliance and not in compliance with established emissions limitations.

LINE SOURCE EMISSIONS INVENTORY: 1973

The inventory of air pollutants emitted by line sources includes estimates of the quantity of particulate matter, sulfur dioxide, carbon monoxide, nitrogen oxides, and hydrocarbons released by automobiles, trucks, and buses operating on the street and highway system of the seven-county Southeastern Wisconsin Region during

Map 44

POINT SOURCES OF CARBON MONOXIDE EMISSIONS IN THE REGION: 1973

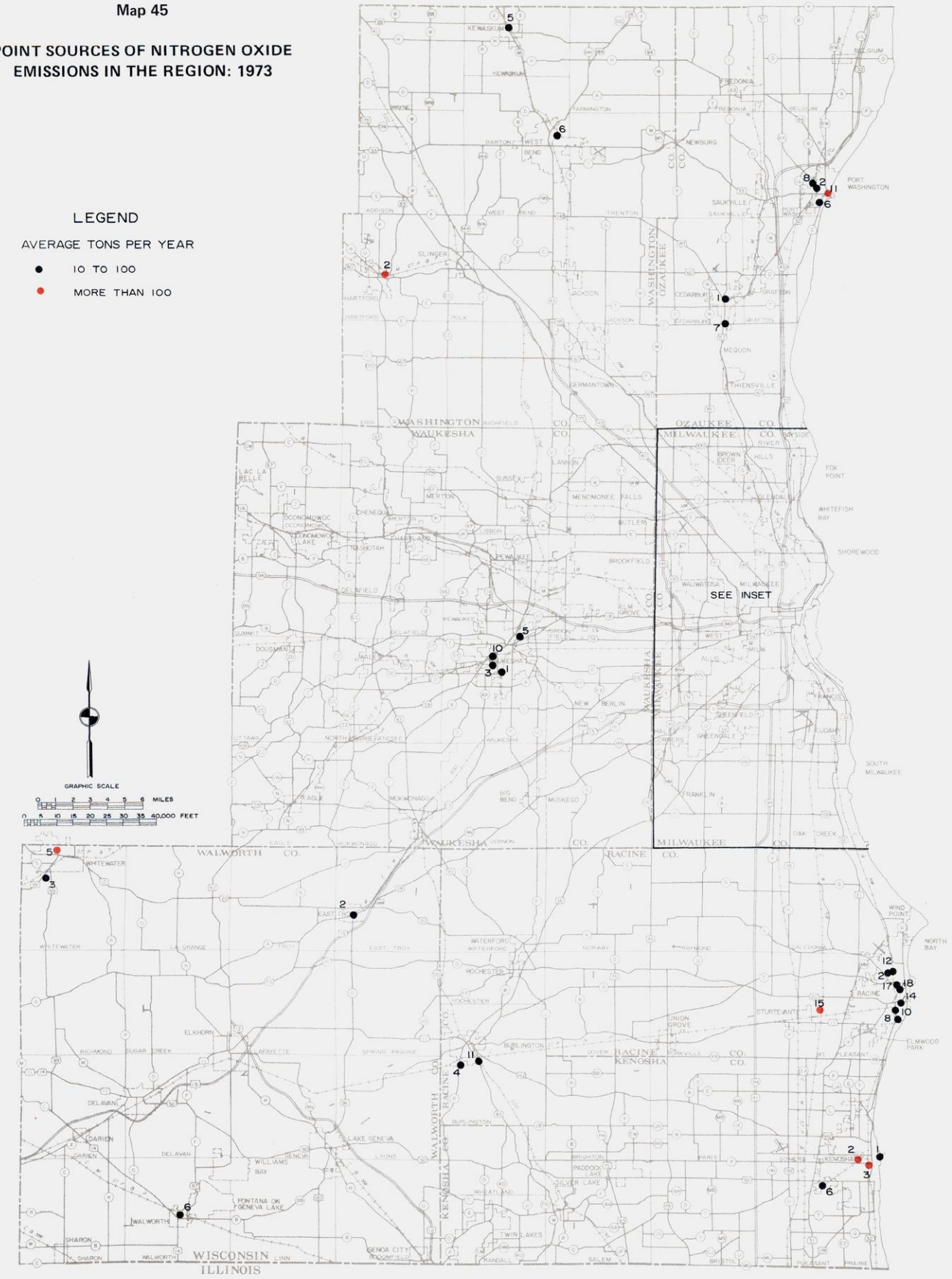


The Wisconsin Department of Natural Resources identified 21 point sources in the Region that emitted between 10 and 100 tons of carbon monoxide, and 20 point sources that emitted more than 100 tons of carbon monoxide, during 1973. In total, these 41 point sources emitted about 20,700 tons of carbon monoxide into the atmosphere over the Region during that year. The carbon monoxide emissions from point sources may be attributed principally to metal processing operations. (Numbers on map correspond to facilities identified in Appendix B.)

Source: SEWRPC.

Map 45

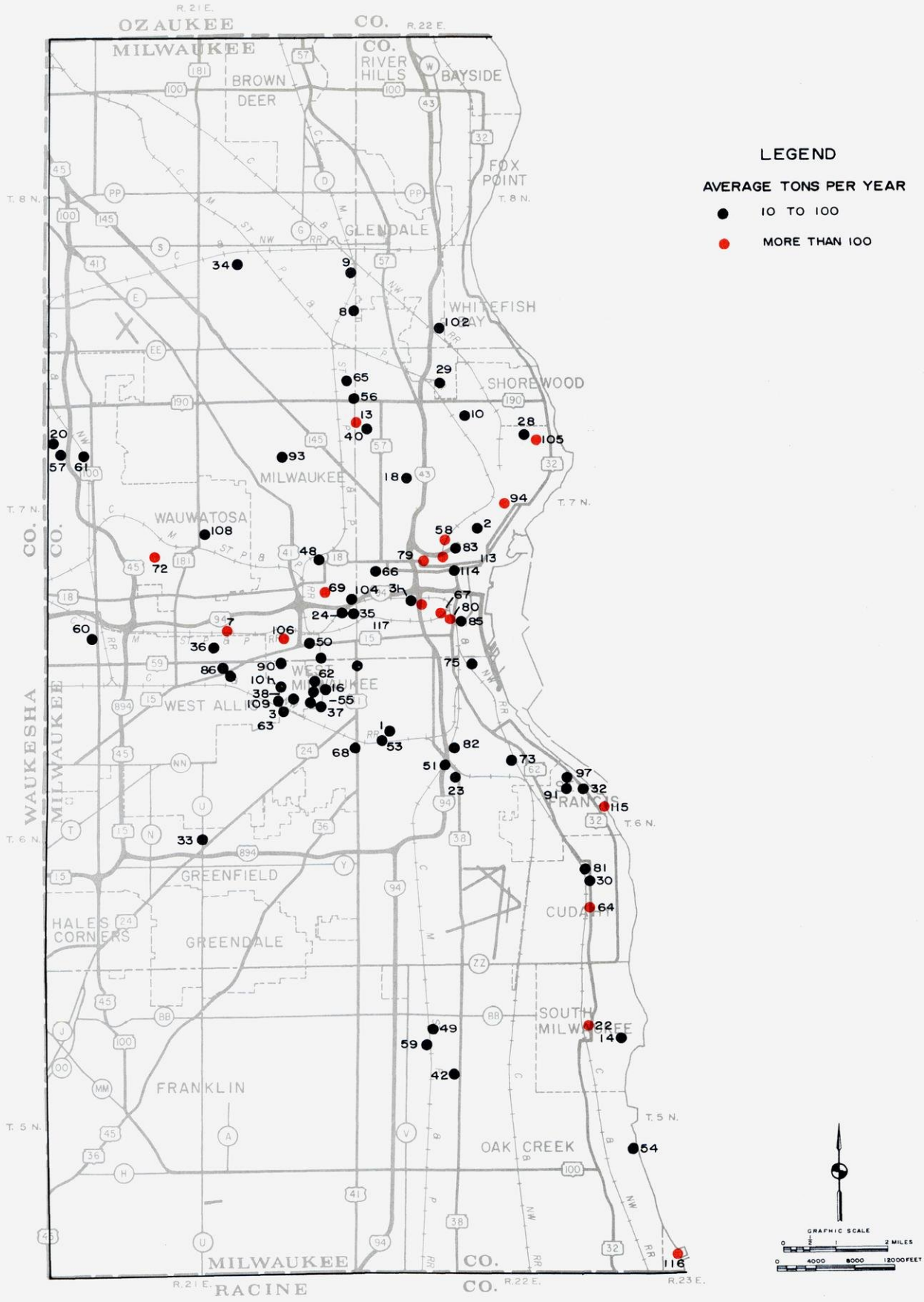
POINT SOURCES OF NITROGEN OXIDE EMISSIONS IN THE REGION: 1973



The Wisconsin Department of Natural Resources identified 87 point sources in the Region that emitted between 10 and 100 tons on nitrogen oxides, and an additional 23 point sources which emitted more than 100 tons of nitrogen oxides, during 1973. In total, these 110 point sources emitted about 48,600 tons of nitrogen oxides into the atmosphere over the Region in that year. The nitrogen oxide emissions from point sources may be attributed principally to the combustion of fossil fuels in very large industrial boilers. (Numbers on map correspond to facilities identified in Appendix B.)

Source: SEWRPC.

Map 45 (continued)



Source: SEWRPC.

Table 96

DISTRIBUTION OF NITROGEN OXIDE EMISSIONS FROM POINT SOURCES IN THE REGION BY COUNTY: 1973

Source of Emissions	Emissions (tons)							
	Kenosha	Milwaukee	Ozaukee	Racine	Walworth	Washington	Waukesha	Region
Fuel-Burning Installation (boilers)								
5,000,000 BTU per Hour or Less	9	78	14	39	10	9	15	174
5,000,001 to 49,999,999 BTU per Hour	5	864	27	67	37	32	25	1,057
50,000,000 to 99,999,999 BTU per Hour	241	734	--	120	58	--	--	1,153
100,000,000 BTU per Hour or More	128	37,514	6,185	24	24	--	--	43,875
Subtotal	383	39,190	6,226	250	129	41	40	46,259
Incineration								
Less than 500 Pounds of Waste per Hour	--	1	--	625	--	--	--	626
500-4,000 Pounds of Waste per Hour	1	3	3	--	--	--	30	37
More than 4,000 Pounds of Waste per Hour	--	8	15	--	--	--	--	23
Subtotal	1	12	18	625	--	--	30	686
Industrial Process								
Coking Processes	--	--	--	--	--	--	--	--
Metal Processes	18	223	13	5	15	2	17	293
Painting Processes	4	38	2	--	--	5	8	57
Food Processing	--	--	--	1	--	--	--	1
Asphalt Products	--[a]	13	--	--[a]	--	2	3	18
Grain Handling and Processing	--	84	--	--	--	--	--	84
Printing and Lithography	--	14	--	1	--	--	3	18
Glassworks	--	--	--	35	--	--	--	35
Coating Operations	--	4	--	--	--	--	--	4
Heat Treating	9	267	13	6	--	--	7	302
Solvent and Adhesive Processes	--	5	--	--	--	--	--	5
Washing and Drying	--	13	--[a]	--[a]	35	--	--	48
Miscellaneous	7	618	32	3	10	169	5	844
Subtotal	38	1,279	60	51	60	178	43	1,709
Total	422	40,481	6,304	926	189	219	113	48,654

[a] *Less than one-half ton.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

1973.[1] The inventory was conducted in three main phases: 1) emissions from automobile and truck operations on the arterial street and highway system were estimated; 2) emissions from automobile and truck operations on the collector and land access street system were estimated; and 3) emissions from urban mass transit vehicles operating on the street and highway systems within the Milwaukee, Kenosha, and Racine urbanized areas were estimated.

The initial step of each phase of the line source emissions inventory was to determine the type and number of vehicles operating on each link of the transportation system or within each traffic analysis zone of the Region. For the arterial street and highway system, estimates of vehicle miles of travel per average weekday were developed by utilizing the Commission's battery of traffic simulation models. These models, which simulate both the utilization and performance of the arterial street and highway and public transit systems, were developed from and calibrated to extensive travel inven-

[1] *All emission estimates were calculated following the procedures and using the emission factors set forth in the U. S. Environmental Protection Agency publication, Mobile Source Emission Factors—For Low-Altitude Areas Only, March 1978. These procedures differ from those used in the air quality analyses of alternative and recommended regional transportation plans for the year 2000 presented in SEWRPC Planning Report No. 25, A Regional Land Use Plan and a Regional Transportation Plan for Southeastern Wisconsin: 2000, in that the procedures and emission factors used in the plan evaluation predated the Clean Air Act Amendments of 1977 and the procedures and emission factors contained in Supplement No. 5 to AP-42. The procedures and emission factors found in Mobile Source Emission Factors were used in the regional air quality maintenance planning program to provide the most accurate and up-to-date estimate of the contribution of air pollutants from line sources to the total regional air pollution problem, given the 1977 legislative changes which provided for less stringent federal controls on automotive sources of pollution.*

Table 97

DISTRIBUTION OF HYDROCARBON EMISSIONS FROM POINT SOURCES IN THE REGION BY COUNTY: 1973

Source of Emissions	Emissions (tons)							
	Kenosha	Milwaukee	Ozaukee	Racine	Walworth	Washington	Waukesha	Region
Fuel-Burning Installation (boilers)								
5,000,000 BTU per Hour or Less	-- [a]	5	-- [a]	1	-- [a]	2	1	9
5,000,001 to 49,999,999 BTU per Hour	-- [a]	59	-- [a]	2	-- [a]	1	1	63
50,000,000 to 99,999,999 BTU per Hour	5	9	--	3	1	--	--	18
100,000,000 BTU per Hour or More	3	608	103	-- [a]	-- [a]	--	--	714
Subtotal	8	681	103	6	1	3	2	804
Incineration								
Less than 500 Pounds of Waste per Hour	--	-- [a]	--	--	--	--	--	-- [a]
500-4,000 Pounds of Waste per Hour	1	-- [a]	2	--	--	--	15	18
More than 4,000 Pounds of Waste per Hour	--	4	8	--	--	--	--	12
Subtotal	1	4	10	--	--	--	15	30
Industrial Process								
Coking Processes	--	677	--	--	--	--	--	677
Metal Processes	-- [a]	15	1	25	1	-- [a]	1	43
Vapor Degreasing	14	626	63	102	--	133	--	938
Painting Processes	1,518	12,061	190	521	--	407	420	15,117
Food Processing	--	--	--	1	--	--	--	1
Asphalt Products	-- [a]	1	--	-- [a]	--	-- [a]	-- [a]	1
Grain Handling and Processing	--	6	--	--	--	--	--	6
Printing and Lithography	--	1,971	--	31	--	--	169	2,171
Glassworks	--	--	--	3	--	--	--	3
Coating Operations	--	1,388	--	465	--	--	161	2,014
Heat Treating	1	22	1	-- [a]	--	1	1	26
Solvent and Adhesive Processes	--	33	--	--	--	--	43	76
Washing and Drying	--	9	-- [a]	--	-- [a]	--	-- [a]	9
Gasoline Storage and Loading	--	2,039	114	--	--	--	--	2,153
Miscellaneous	--	556	1	3	--	21	--	581
Subtotal	1,533	19,404	370	1,151	1	562	795	23,816
Total	1,542	20,089	483	1,157	2	565	812	24,650

[a] *Less than one-half ton.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

tories conducted by the Commission in 1972.[2] Utilizing the Commission simulation models, traffic assignments and vehicle miles of travel estimates were made for the following types of vehicle trips:

1. Light-duty gasoline vehicle trips comprised of internal auto driver, group-quartered person auto driver, nonresident internal auto driver, and external auto driver trips;[3]

2. Light-duty gasoline truck trips comprised of internal and external light truck trips;

3. Heavy-duty gasoline truck trips comprised of internal medium and heavy truck trips; and

4. Heavy-duty diesel truck trips comprised of internal nonresident truck trips and external medium and heavy truck trips.[4]

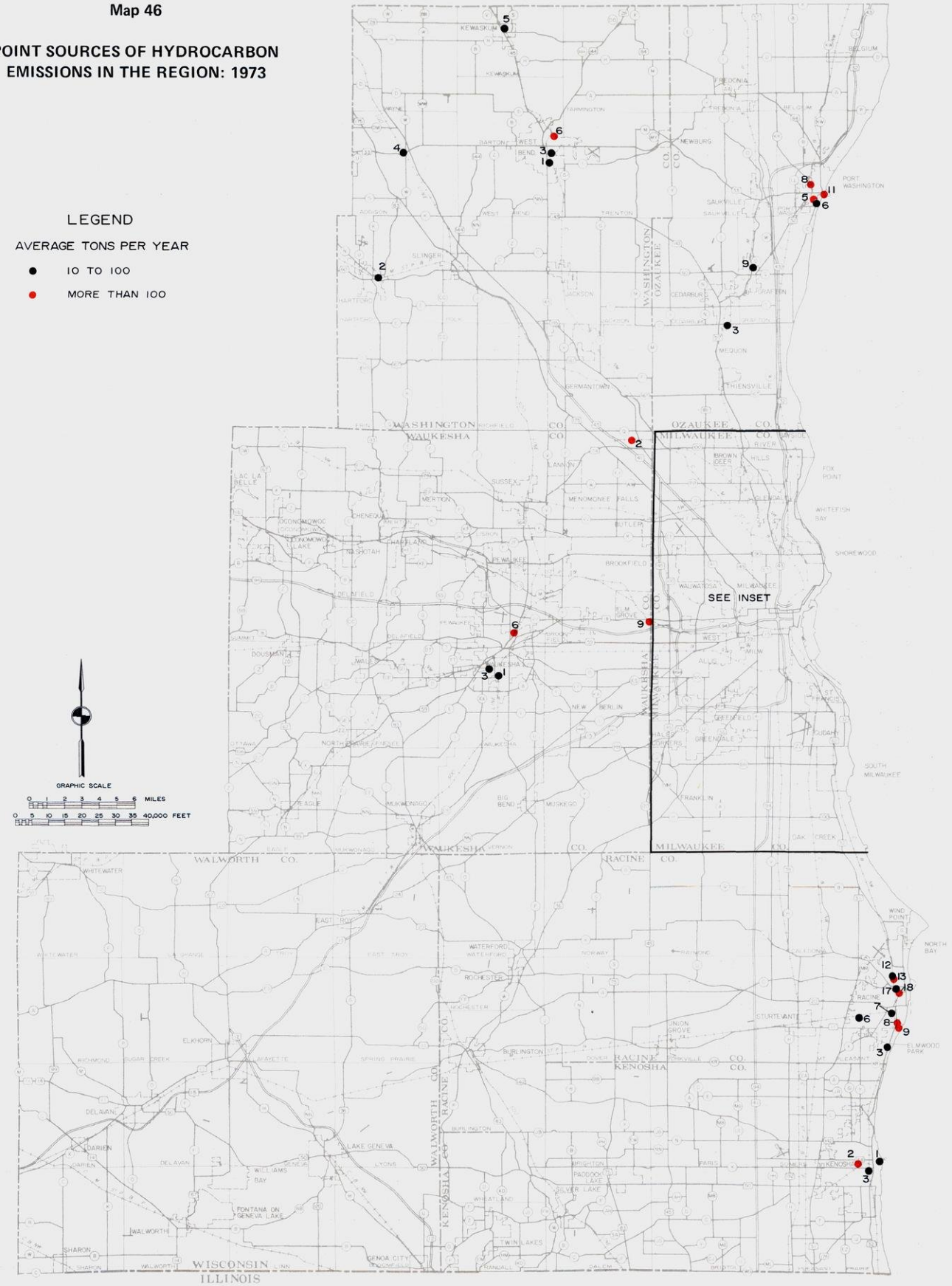
[2] *For a more detailed description of the development, calibration, and operation of the Commission traffic simulation models, see Chapter IV of SEWRPC Planning Report No. 25, A Regional Land Use Plan and a Regional Transportation Plan for Southeastern Wisconsin: 2000, Volume Two, Alternative and Recommended Plans.*

[3] *For a more detailed explanation of vehicle trip types, see Chapter IV of SEWRPC Planning Report No. 25, A Regional Land Use Plan and a Regional Transportation Plan for Southeastern Wisconsin: 2000, Volume Two, Alternative and Recommended Plans.*

[4] *Light-duty gasoline vehicles are defined as passenger automobiles. Light-duty gasoline trucks are defined as two-axle, four-tire vehicles having a gross vehicle weight of 8,000 pounds or less. Heavy-duty trucks are defined as vehicles having a gross vehicle weight in excess of 8,000 pounds and are further identified by the fuel used.*

Map 46

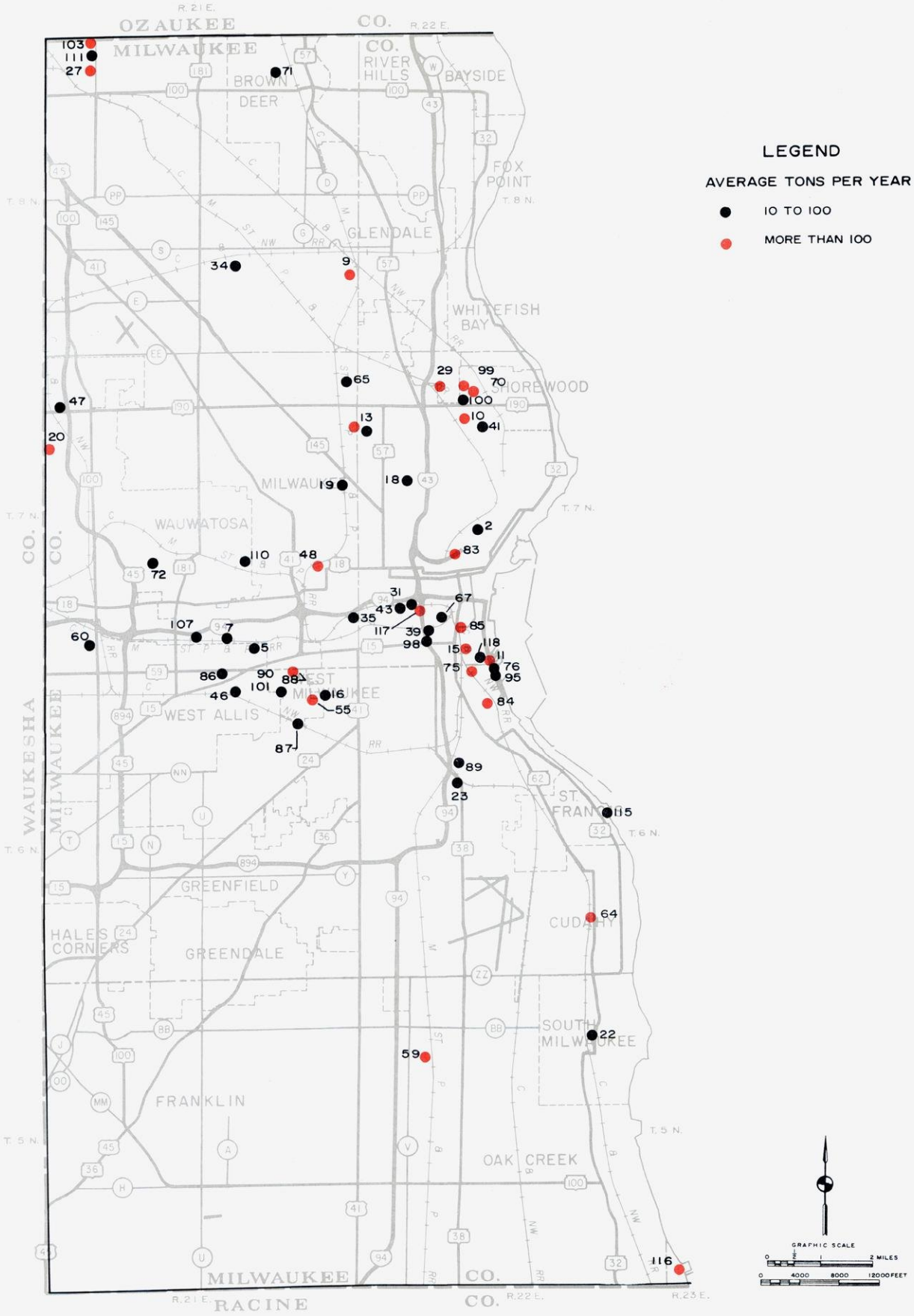
POINT SOURCES OF HYDROCARBON EMISSIONS IN THE REGION: 1973



The Wisconsin Department of Natural Resources identified 51 point sources in the Region that emitted between 10 and 100 tons of hydrocarbons, and an additional 35 point sources which emitted more than 100 tons of hydrocarbons, during 1973. In total, these 86 point sources emitted approximately 24,600 tons of hydrocarbons into the atmosphere over the Region in that year. The hydrocarbon emissions from point sources may be attributed principally to industrial processes, specifically painting operations. (Numbers on map correspond to facilities identified in Appendix B.)

Source: SEWRPC.

Map 46 (continued)



Source: SEWRPC.

In total, traffic assignments and vehicle miles of travel estimates for each of the above four vehicle types were made for the approximately 6,000 links in the arterial street and highway system within the seven-county Southeastern Wisconsin Region.

Estimates of the vehicle miles of travel on the collector and land access street system were not made on a link-by-link basis, but rather were calculated by traffic analysis zones. Traffic analysis zones are geographic areas roughly corresponding to neighborhood units used in transportation planning for the analysis of socioeconomic, land use, and traffic data. The Commission has delineated a total of 1,220 traffic analysis zones in the Region, the boundaries of which are shown on Map 47. The number of trip origins and destinations within each traffic analysis zone was derived from the results of the Commission's 1972 origin and destination survey. Also, for each of the 1,220 traffic analysis zones, an estimate of the average trip length and average trip speed was calculated based on the size, location, and internal development characteristics of the zone. The number of trips was then multiplied by the average trip length to provide the estimated vehicle miles of travel by vehicle type within each zone.

Estimates of the vehicle miles of travel by urban mass transit vehicles were calculated from the number of buses using each transit link per average weekday. Such estimates were made for approximately 4,000 transit links in Milwaukee County and 600 transit links in Racine and Kenosha Counties.

The estimated average weekday vehicle miles of travel in 1972 on the regional arterial street and highway system, local and land access street system, and urban mass transit system are set forth in Table 98 by vehicle type. As shown in the table, light-duty gasoline automobiles and trucks accounted for the predominant portion of the regional vehicle miles of travel on the average weekday, with 20,741,800 vehicle miles, or about 93 percent of the total vehicle miles of travel.

Since there were only minor changes in the regional transportation system between 1972 and 1973, the vehicle miles of travel estimates presented in Table 98 were considered representative of the traffic conditions in the Region during 1973. These estimates were therefore used with the emission factors for 1973 and earlier model vehicles in the 1973 line source emissions inventory. The following sections describe in detail the methodology used to collate the 1973 line source emissions inventory by vehicle type.

Table 98

AVERAGE WEEKDAY VEHICLE MILES OF TRAVEL ON THE REGIONAL STREET AND HIGHWAY SYSTEM BY VEHICLE TYPE: 1972

Vehicle Type	Average Weekday Vehicle Miles of Travel			
	Freeway	Standard Surface	Collector and Local Streets	Total
Light-Duty				
Gasoline Vehicles . . .	5,234,800	12,033,800	2,167,700	19,436,300
Gasoline Trucks	296,100	862,900	146,500	1,305,500
Heavy-Duty				
Gasoline Trucks	266,500	647,800	104,700	1,019,000
Diesel Trucks.	326,000	193,300	4,800	524,100
Total	6,123,400	13,737,800	2,423,700	22,284,900
Urban Mass Transit[a]	--	--	--	65,000

[a] *The average weekday vehicle miles of travel made by mass transit vehicles are not available by type of transportation system traversed.*

Source: SEWRPC.

Light-Duty Gasoline Vehicles

Air pollutant emissions from mobile sources, particularly automobiles, change with time as older vehicles without emission control equipment are replaced by vehicles with such control devices, and as the vehicles with control equipment gradually deteriorate as they accumulate age and mileage. In order to calculate the emissions from automobiles for those pollutant species that are controlled by federal law—carbon monoxide, nitrogen oxides, and hydrocarbons—for a specified calendar year, therefore, it is necessary to determine the distribution of vehicles by age and to compile associated data on the annual accumulation of mileage and relative proportion of total travel by vehicle age. Such information for automobiles operating within the Southeastern Wisconsin Region is presented in Table 99. In this table, automobiles are distributed in age categories between 1 and

Table 99

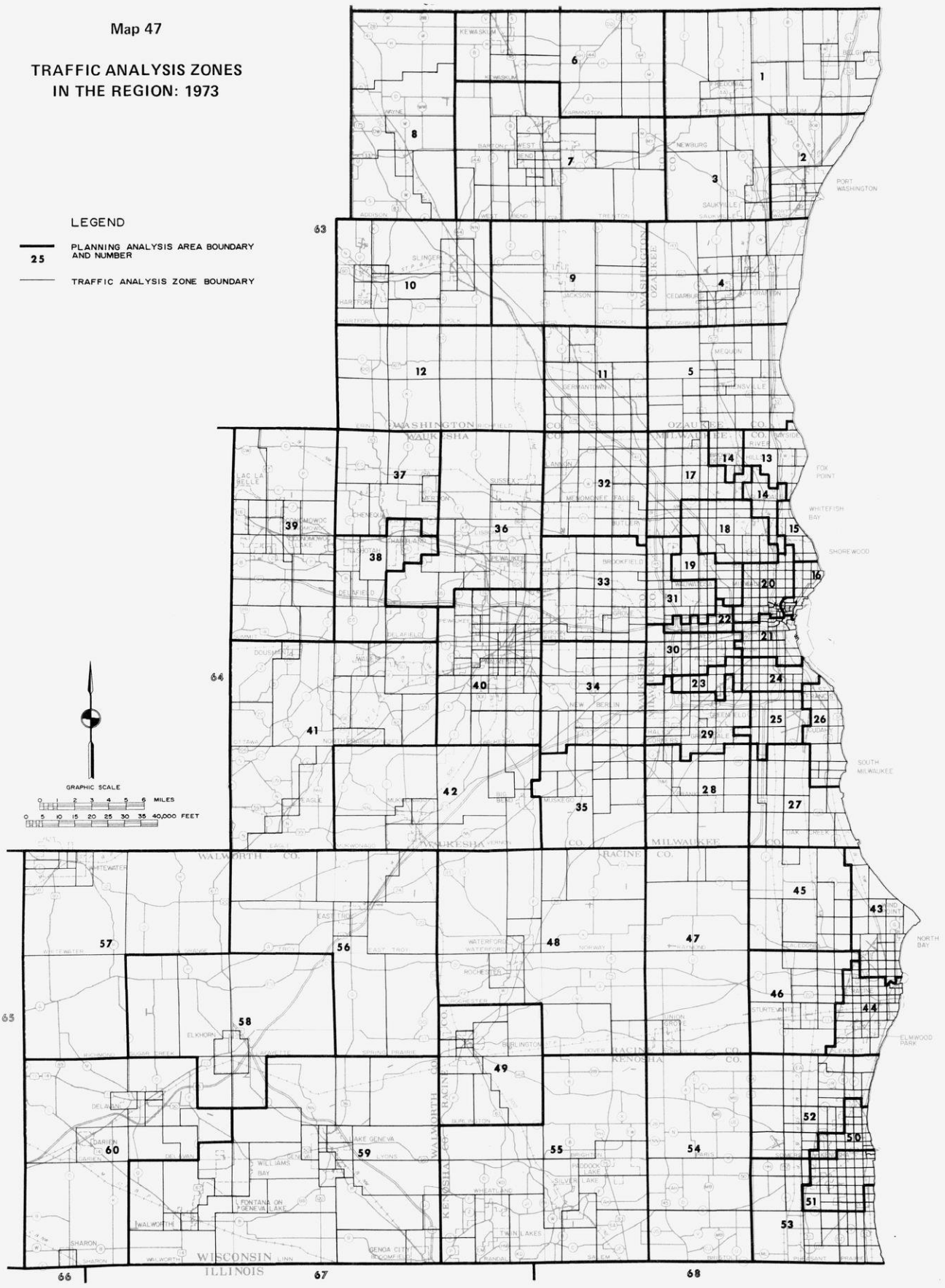
VEHICLE AGE DISTRIBUTION, ANNUAL MILEAGE ACCUMULATION RATE, AND PROPORTION OF TRAVEL FOR LIGHT-DUTY GASOLINE VEHICLES

Vehicle Age	Vehicle Age Distribution (a)	Annual Mileage Accumulation Rate (b)	Fractional Part Annual Mileage (a) x (b)	Travel Fraction ((a) x (b)/SUM)
1	0.100	15,900	1,590.0	0.136
2	0.105	15,000	1,575.0	0.135
3	0.107	14,000	1,498.0	0.128
4	0.107	13,100	1,401.7	0.120
5	0.104	12,200	1,268.8	0.108
6	0.099	11,300	1,118.7	0.096
7	0.091	10,300	937.3	0.080
8	0.080	9,400	752.0	0.064
9	0.068	8,500	578.0	0.049
10	0.052	7,600	395.2	0.034
11	0.035	6,700	234.5	0.020
12	0.014	6,700	93.8	0.008
13 and older	0.038	6,700	254.6	0.022
Total Vehicle Fleet	1.000	--	11,697.6 (SUM)	1.000

Source: U. S. Environmental Protection Agency and SEWRPC.

Map 47

TRAFFIC ANALYSIS ZONES IN THE REGION: 1973



As shown on this map, the Southeastern Wisconsin Region has been divided into 1,220 geographic areas termed traffic analysis zones. These zones, comprised of U. S. Public Land Survey quarter sections, are the basis for the preparation of the travel forecasts that permit the quantification of traffic flows on the various segments of the street and highway system within the Region. These traffic flows, in turn, provide the necessary information to calculate the line source pollutant emissions within the Region.

Source: SEWRPC.

13 years or older. This distribution was derived from vehicle registration data for 1973 obtained from the Wisconsin Department of Transportation. The annual mileage accumulation rate represents the national average determined by the U. S. Environmental Protection Agency (EPA) from five years of data compiled for the years from 1970 through 1975. The proportion of travel by vehicle age was calculated as shown in the table.

In addition to determining the vehicle miles of travel for automobiles and the relative proportion of travel by vehicle age, it is necessary to determine the average rate of pollutant emissions per vehicle mile of travel. For this purpose the EPA has established a standard Federal Test Procedure (FTP) to measure the pollutant emissions for vehicles by model year for each calendar year.[5] The FTP conditions under which light-duty gasoline vehicles were tested are indicated in Table 100. Based on the testing of light-duty gasoline vehicles under FTP conditions, the EPA has estimated the average exhaust emission rate of carbon monoxide, nitrogen oxides, and hydrocarbons from new vehicles. In addition, the EPA has determined the average deterioration rate of emissions control equipment with accumulated mileage, and these data are presented in Table 101 for automobiles of model year 1973 and earlier operated in 1973. Based upon these data, the EPA has prepared a table of exhaust emission factors for carbon monoxide, nitrogen oxides, and hydrocarbons for light-duty gasoline vehicles operating during 1973 and representative of vehicle travel as of July of that year. It was assumed that new model year vehicle sales begin in October of the previous year and that only three-eighths of the model year fleet annual mileage accumulation occurs by the month of July. Under these assumptions, the average exhaust emission factors for carbon monoxide, nitrogen oxides, and hydrocarbons for light-duty gasoline vehicles for calendar year 1973 are shown in Table 102.

Pollutant emission rates measured under the FTP conditions set forth in Table 100 are not in themselves adequate estimates of the actual emission rates since such conditions represent a vehicular operation scenario and meteorological conditions that do not occur uniformly throughout southeastern Wisconsin. The FTP-determined pollutant emission rates, as shown in Table 101, must, therefore, be adjusted to provide a more representative emission rate that considers localized traffic operation and meteorological conditions. The effects of adjusting the average emission rates to reflect local conditions are discussed in the following sections.[6]

Mode of Operation, Temperature, and Speed Correction Factors: As may be seen in Table 100, the FTP measures pollutant emissions during three modes of operation—hot start, cold start, and stabilized—and in an average ambient

[5] *Details on the emission testing of vehicles using the Federal Test Procedure may be found in the Federal Register, Volume 137, No. 211, November 15, 1972.*

Table 100

FEDERAL TEST PROCEDURE CONDITIONS FOR DETERMINING CARBON MONOXIDE, NITROGEN OXIDE, AND HYDROCARBON EXHAUST EMISSIONS FOR LIGHT-DUTY GASOLINE VEHICLES

Procedure Conditions
1. Ambient temperature = 75°F average (68°F-86°F)
2. Mixing ratio = 75 grains of water vapor per pound of dry air
3. Average speed = 19.6 mph, 18 percent idle operation
4. Average cold operation = 21 percent
5. Average hot start operation = 27 percent
6. Average stabilized operation = 52 percent
7. Air conditioning not in use
8. Car contains driver only; no passenger or luggage
9. Car is not pulling a trailer
10. Vehicles are not in an Inspection/Maintenance program
11. Vehicles receive typical in-use maintenance

Source: U. S. Environmental Protection Agency and SEWRPC.

Table 101

CARBON MONOXIDE, NITROGEN OXIDE, AND HYDROCARBON NEW VEHICLE EXHAUST FACTORS AND DETERIORATION RATES FOR LIGHT-DUTY GASOLINE VEHICLES: CALENDAR YEAR 1973

Pollutant	Model Year	New Vehicle Emission Factor (grams per mile)	Deterioration Rate per 10,000 Miles (grams per mile)
Carbon Monoxide	1968-1973	31.14	6.15
	Pre-1968	68.30	3.06
Nitrogen Oxides	1973	2.98	--
	1968-1972	4.43	--
	Pre-1968	3.58	--
Hydrocarbons	1968-1973	2.43	0.53
	Pre-1968	4.45	0.58

Source: U. S. Environmental Protection Agency and SEWRPC.

[6] *There are five principal correction factors that must be considered in the preparation of a light-duty gasoline vehicle emissions inventory: mode of operation, air conditioning usage, vehicle load, vehicle speed, and humidity. For a more detailed explanation of the development of these correction factors, see Mobile Source Emission Factors, U. S. Environmental Protection Agency, Office of Air and Waste Management, EPA-400/ 9-78-006, March 1978.*

Table 102

CARBON MONOXIDE, NITROGEN OXIDE, AND HYDROCARBON EXHAUST EMISSION FACTORS FOR LIGHT-DUTY GASOLINE VEHICLES CALENDAR YEAR 1973

Model Year	Emission Factor (grams per mile)		
	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
1973	34.8	3.0	2.7
1972	43.2	4.4	3.5
1971	52.3	4.4	4.3
1970	60.8	4.4	5.0
1969	68.7	4.4	5.7
1968	76.0	4.4	6.3
1967	94.0	3.6	9.3
1966	97.1	3.6	9.9
1965	99.9	3.6	10.4
1964	102.4	3.6	10.9
1963	104.7	3.6	11.3
1962 and earlier	106.7	3.6	11.7

Source: U. S. Environmental Protection Agency and SEWRPC.

air temperature of 75°F. The cold start mode of operation is representative of vehicle start-up after a long engine-off period. For the purpose of the 1973 line source emissions inventory, the cold start phase was defined as the first 505 seconds of vehicle operation following a four-hour or longer engine-off period. If the engine-off period, referred to as the "soak time," is less than four hours, the restarted vehicle is considered to be in the hot operating mode. The hot operating mode is again assumed to last for 505 seconds after start-up. After 505 seconds in either the cold or hot mode, the vehicle is considered to be in the stabilized mode.

The mode of operation is particularly significant in determining the vehicle emission rate of carbon monoxide and hydrocarbons. In order for ignition to occur in a gasoline engine, the fuel introduced into the combustion cylinders must be vaporized and an appropriate balance between the vaporized fuel and air in the chamber must be achieved. Gasoline does not vaporize as well at lower temperatures as it does in the relatively high temperature range associated with stabilized engine operation. When a cold engine is started an imbalance occurs in the air to fuel ratio as a result of the reduced efficiency of the gasoline vaporization. To compensate for this temporary imbalance, the fuel delivery system is equipped with a choke mechanism which restricts the flow of incoming air to the point where a partial vacuum is created in the intake manifold. The vacuum causes additional fuel to be delivered into the combustion chambers. The increased amount of fuel compensates for the lower rate of vaporization and ignition takes place. The reduced quantity of air, however, results in incomplete fuel combustion, two major products of which are carbon monoxide and unburned hydrocarbons. On most vehicles the choke mechanism is an automatic device actuated by a heat sensor which is built into a temperature-sensitive engine component such as the exhaust manifold. Laboratory tests have shown that the time the heat sensor holds the choke in the "on" position is a function of ambient air temperature. The choke-on time increases with decreasing ambient air temperature. The colder the air, therefore, the longer the choke will be activated and the greater will be the emissions of carbon monoxide and hydrocarbons until stabilized operating temperatures have been achieved.

Since the FTP ambient air temperature averaged 75°F, the conditions for determining light-duty gasoline vehicle emissions for the Southeastern Wisconsin Region had to be adjusted to reflect temperature conditions within the Region in 1973. Thus, an average seasonal temperature was calculated from the meteorological data observed at the National Weather Service office at General Mitchell Field in Milwaukee County. The ambient air temperatures assumed to be representative of the regional seasonal conditions in 1973 are: winter—26°F; spring—46°F; summer—73°F; fall—54°F. These temperature values, when used in conjunction with the national average of cold, hot, and stabilized modes of operation—21, 27, and 52 percent, respectively—acted to increase the pollutant emission estimates of carbon monoxide and hydrocarbons from the exhaust of light-duty gasoline vehicles over that estimate assuming only FTP conditions.[7]

At the same time the mode of operation and the ambient air temperature correction factors were applied, a correction factor for vehicle operating speed was also applied to adjust the carbon monoxide, hydrocarbon, and nitrogen oxide exhaust emission estimates. In general, carbon monoxide and hydrocarbon emissions decrease with increased operating speed while nitrogen oxide emissions increase. The rate of change in exhaust emissions with change in speed, however, varies with the vehicle model year.

The average vehicle speed over the entire FTP was 19.6 miles per hour (mph), as shown in Table 100. The average speed within each operational mode, however, varied. In both the cold and hot operating modes the average speed was 26 mph, while in the stabilized mode it was 16 mph. It was necessary, therefore, to

[7] *The relative percentage of hot, cold, and stabilized modes of operation may vary both geographically and temporally depending on land use types and day of the week, or even time of day. This variation may be attributed to the different travel characteristics, such as trip length and duration, associated with different trip purposes. Since the line source emissions inventory was developed on a regional basis, it was deemed necessary to use the national averages of hot, cold, and stabilized operating modes as representative of prevailing conditions over this broad geographic area.*

adjust the pollutant emission estimates to speeds that reflect the actual operating conditions over each link and traffic analysis zone in the regional transportation system. This adjustment was applied at the same time as the mode of operation factor, and resulted in a decrease in carbon monoxide and hydrocarbon emissions and an increase in nitrogen oxide emissions over the arterial street and highway system, which, considering the Region as a whole has an average speed of 55 mph. Inversely, this adjustment caused an increase in carbon monoxide and hydrocarbon emissions and a decrease in nitrogen oxide emissions on the collector and land access street system, which has an average regional operating speed of 30 mph.

Air Conditioning Correction Factor: Testing by the U. S. Environmental Protection Agency has shown that the use of air conditioners in light-duty gasoline vehicles increases hydrocarbon exhaust emissions by 13 percent, and carbon monoxide and nitrogen oxide exhaust emissions by 18 percent each. Correction factors must therefore be used to account for these significant increases in exhaust pollutant emissions when air conditioning systems are used.

In order to apply the air conditioning correction factors, it is necessary to estimate the percentage of vehicles that are equipped with air conditioning systems, as well as the percentage of time that the systems are in use. The EPA has determined from national statistics that approximately 81 percent of 1973 model vehicles, 75 percent of 1969-1972 model vehicles, 66 percent of 1966-1968 model vehicles, and 54 percent of pre-1966 model vehicles are equipped with air conditioning systems. It was assumed that these percentages were valid for the Region.

The percentage of vehicles actually using the air conditioning system was determined on the assumption that such systems would only be turned on when the ambient air temperature was 70°F or greater. Temperatures of this magnitude usually may be expected only between 9 a.m. and 7 p.m. in the summer months in the Region. Approximately 70 percent of the total average weekday travel on the urban arterial streets of the Region, and 63 percent of the total average weekday travel on the rural highways of the Region, occurs between those hours. Based on these percentages, and on the percentage of total vehicle miles of travel on both urban arterial streets and rural highways—60 percent and 40 percent, respectively—it was estimated that 67 percent of the vehicles equipped with air conditioning systems used such devices when temperatures reached or exceeded 70°F. It was further estimated that the use of air conditioning systems in light-duty gasoline vehicles resulted in a 5.5 percent increase in hydrocarbon exhaust emissions and an 8.9 percent increase in carbon monoxide and nitrogen oxide exhaust emissions during the summer months in the Region over the amount which would have been produced by those vehicles had the systems not been operating.

Vehicle Load Correction Factor: The FTP emission factors presented in Table 102 assume an average vehicle loading of 300 pounds, which accounts for the weight of the driver, the vehicle fuel, and other liquids. The EPA has estimated that an additional 500 pounds of weight would increase vehicle exhaust emissions of carbon monoxide by 20 percent, hydrocarbons by 6 percent, and nitrogen oxides by 3 percent. A correction factor that indicates the number of vehicles carrying an additional 500 pounds of passengers and/or luggage was therefore applied to the emissions calculations for these pollutant species.

The Commission's 1972 origin and destination survey indicated that 33 percent of all automobile trips were made in vehicles containing more than one person. Therefore, it was assumed that 33 percent of the total number of vehicle miles of travel was made by vehicles having an increased load of 500 pounds. Under this assumption, it is estimated that hydrocarbon exhaust emissions from light-duty gasoline vehicles increase by 2 percent, carbon monoxide emissions by 7 percent, and nitrogen oxide emissions by 1 percent over the FTP emission factors.

Humidity Correction Factor: The formation of nitrogen oxide emissions in light-duty gasoline vehicle exhaust is affected by humidity in the ambient air. The humidity, measured as the mixing ratio—the number of grains of water per pound of dry air—was normalized in the FTP to 75 grains per pound of dry air. At the FTP average ambient temperature of 75°F, this represents a relative humidity of approximately 62 percent. In order to account for local conditions, an average relative humidity was derived from the 1973 meteorological data for each season, which was then used with the average seasonal temperatures to estimate the average mixing ratios for the Region. The mean mixing ratio in the Region was thus determined to be 33 grains per pound of dry air in spring, 81 grains per pound of dry air in summer, 43 grains per pound of dry air in fall, and 14 grains per pound of dry air in winter. As a result, nitrogen oxide emissions were increased approximately 20 percent in spring, 29 percent in winter, and 15 percent in fall, and decreased by about 3 percent in summer.

Evaporative and Crankcase Hydrocarbon Emissions: In addition to being emitted in the exhaust of light-duty gasoline vehicles, hydrocarbons are emitted from the engine crankcase, and from the fuel tank and carburetor system as evaporative losses. Crankcase emissions have been eliminated since the 1964 model year vehicles were introduced and therefore could contribute only slightly to the 1973 line source emissions inventory. Evaporative losses from the fuel tank and carburetor system, however, are still major sources of hydrocarbon emissions.

Diurnal changes in temperature cause an expansion of the air-fuel mixture in a partially filled fuel tank and gasoline vapor is therefore released into the atmosphere. Losses from the fuel tank also occur as the fuel is heated by the road surface during driving. Evaporative losses from the carburetor system occur after engine shutdown at the end of a trip. These losses are from, for example, the carburetor vents, float bowl, and clearances around the throttle and choke shafts.

Crankcase and evaporative hydrocarbon losses are not assumed to increase with vehicle age or mileage, but rather are solely a function of the initial emission rate which, in turn, depends on the extent of the control equipment on the vehicle in a particular model year. Table 103 lists the crankcase and evaporative hydrocarbon emission factors for pre-1963 to 1973 model year light-duty gasoline vehicles.

Particulate Matter and Sulfur Oxide Emissions: Light-duty gasoline vehicles emit relatively small quantities of particulate matter and sulfur oxides. At the present time, there are no federal standards or controls regulating the emission of these two pollutant species from light-duty gasoline vehicles. [8] For this reason, particulate matter and sulfur oxide emissions are expressed in terms of average emission rates per vehicle miles of travel, and are not adjusted for either operating conditions or ambient meteorological conditions.

For particulate matter, the emission factor for 1973 and earlier model year vehicles is 0.54 gram per vehicle mile of travel. This emission factor is comprised of 0.34 gram of particles in the engine exhaust and 0.20 gram of particles attributable to tire wear. The emission factor for sulfur oxides for 1973 and earlier model year vehicles is 0.13 gram per vehicle mile of travel. Sulfur oxide emissions are contained entirely in the exhaust.

Total Pollutant Emissions From Light-Duty Gasoline Vehicles: Table 104 presents a county summary of air pollutant emissions from light-duty gasoline vehicles operating on the regional arterial street and highway system and on the collector and land access street system during 1973. This emission summary is shown by season to illustrate the influence of meteorological factors on the production of carbon monoxide, nitrogen oxide, and hydrocarbon emissions.

[8] *Although not directed at the control of particulate matter emissions from light-duty gasoline vehicles, federal regulations requiring the removal of lead compounds from gasoline will substantially reduce the quantity of particulates emitted from gasoline-powered motor vehicles.*

Table 103

CRANKCASE AND EVAPORATIVE HYDROCARBON EMISSION FACTORS FOR LIGHT-DUTY GASOLINE VEHICLES: CALENDAR YEAR 1973

Model Year	Emission Factor (grams per mile)
1973	0.4
1972	0.4
1971	0.6
1970	0.9
1969	0.9
1968	0.9
1967	1.7
1966	1.7
1965	1.7
1964	1.7
1963	1.7
Pre-1963	5.0

Source: U. S. Environmental Protection Agency and SEWRPC.

Table 104

SUMMARY OF LIGHT-DUTY GASOLINE VEHICLE EMISSIONS BY COUNTY BY SEASON: 1973

County	Season	Emissions (tons)				
		Particulate Matter	Sulfur Dioxide	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
Kenosha	Winter	68	16	8,831	755	872
	Spring	68	16	7,586	703	791
	Summer	68	16	7,057	626	755
	Fall	68	16	7,189	675	765
	Annual	272	64	30,663	2,759	3,183
Milwaukee	Winter	474	114	68,354	5,057	6,599
	Spring	474	114	58,794	4,703	5,981
	Summer	474	114	54,784	4,193	5,706
	Fall	474	114	55,747	4,518	5,780
	Annual	1,896	456	237,679	18,471	24,066
Ozaukee	Winter	35	8	3,978	413	407
	Spring	35	8	3,410	384	370
	Summer	35	8	3,163	343	353
	Fall	35	8	3,228	369	358
	Annual	140	32	13,779	1,509	1,488
Racine	Winter	78	19	10,566	866	1,035
	Spring	78	19	9,082	805	938
	Summer	78	19	8,455	718	895
	Fall	78	19	8,609	774	907
	Annual	312	76	36,712	3,163	3,775
Walworth	Winter	40	10	4,726	450	477
	Spring	40	10	4,053	419	434
	Summer	40	10	3,762	374	414
	Fall	40	10	3,838	403	419
	Annual	160	40	16,379	1,646	1,744
Washington	Winter	46	11	4,879	562	508
	Spring	46	11	4,178	522	462
	Summer	46	11	3,870	466	441
	Fall	46	11	3,954	502	447
	Annual	184	44	16,881	2,052	1,858
Waukesha	Winter	148	36	17,336	1,728	1,759
	Spring	148	36	14,866	1,607	1,598
	Summer	148	36	13,798	1,433	1,525
	Fall	148	36	14,079	1,544	1,546
	Annual	592	144	60,079	6,312	6,428
Region	Winter	889	214	118,670	9,831	11,657
	Spring	889	214	101,969	9,143	10,574
	Summer	889	214	94,889	8,153	10,089
	Fall	889	214	96,644	8,785	10,222
	Annual	3,556	856	412,172	35,912	42,542

Source: SEWRPC.

Light-Duty Gasoline Trucks

As with light-duty gasoline vehicles, the EPA has not extensively measured particulate matter and sulfur oxide emissions from light-duty gasoline trucks under varying operating conditions because of the relatively small quantities produced by motor vehicles as compared with carbon monoxide, nitrogen oxides, and hydrocarbons, and as compared to particulate matter and sulfur dioxide emissions from stationary sources. The light-duty gasoline truck emission factor for particulate matter is shown with the emission factor for sulfur oxides in Table 105. This factor is the same as for automobiles, comprised of 0.34 gram of particles in the exhaust and 0.20 gram of particles produced by tire wear per vehicle mile of travel. Although the EPA emission factor is the same, light truck tire wear is likely to result in greater particulate matter emissions than automobile tire wear because of larger tires and heavier loads on tires. The emission factor for sulfur oxides from light-duty gaoline trucks, 0.18 gram per vehicle mile of travel, is 0.05 gram higher than the factor for automobiles and is based on the estimated sulfur content of the fuel and the greater fuel consumption of light-duty trucks compared to automobiles. Although light-duty trucks may be expected to yield a higher rate of particulate matter emissions because of greater gasoline consumption, the U. S. Environmental Protection Agency has not yet established a relationship between fuel consumption and exhaust levels for this pollutant species.

Carbon monoxide, nitrogen oxide, and hydrocarbon emissions from light-duty gasoline trucks were calculated following essentially the procedures used to determine such emissions from light-duty gasoline vehicles. However, a departure from the EPA methodology was made for the purposes of the regional air quality maintenance planning program. In the EPA procedure, light-duty gasoline trucks were divided into two classes: trucks with a gross vehicle weight of 6,000 pounds or less and trucks with a gross vehicle weight of 6,001 to 8,500 pounds. Traffic data and, consequently, trip assignments for the Region are based on a single class of light trucks—those with a gross vehicle weight of 8,000 pounds or less. Therefore, the emission calculations for light-duty gasoline trucks operating on the regional transportation system during 1973 assumed only one class of that vehicle type—that of the lighter EPA class.

Data on the distribution of light-duty gasoline trucks by model year, annual mileage accumulation rate, and proportion of travel by vehicle age were obtained from the EPA and are shown in Table 106. Table 106 is reflective of the national statistics for light-duty trucks weighing less than 6,000 pounds. Since the EPA has determined that trucks in this weight class account for between 70 and 80 percent of the total nationwide light-duty gasoline truck fleet, such statistics are representative of the light-duty trucks operating in southeastern Wisconsin.

Although vehicle age and travel distributions for light-duty trucks were made by weight class, the EPA has issued a composite exhaust emission rate and a composite deterioration rate which are inclusive of both weight classes. These rates are presented in Table 107 for light-duty gasoline trucks of model year 1973 and older. The emission factors for carbon monoxide, nitrogen oxides, and hydrocarbons from 1973 model year and older light-duty trucks, based on the new vehicle emission and deterioration rates and again assuming that only three-eighths of the annual accumulated mileage occurs by July, are shown in Table 108 for calendar year 1973.

Table 105

PARTICULATE AND MATTER AND SULFUR OXIDE EMISSION FACTORS FOR LIGHT-DUTY GASOLINE TRUCKS: CALENDAR YEAR 1973

Pollutant	Emission Rate (grams per mile)
Particulate Matter	
Exhaust	0.34
Tire Wear	0.20
Total	0.54
Sulfur Oxides (SO_x as SO_2)	0.18

Source: U. S. Environmental Protection Agency and SEWRPC.

Table 106

VEHICLE AGE DISTRIBUTION, ANNUAL MILEAGE ACCUMULATION RATE, AND PROPORTION OF TRAVEL FOR LIGHT-DUTY GASOLINE TRUCKS

Vehicle Age	Vehicle Age Distribution (a)	Annual Mileage Accumulation Rate (b)	Fractional Part Annual Mileage (a) x (b)	Travel Fraction ((a) x (b)/SUM)
1	0.061	15,900	969.9	0.093
2	0.095	15,000	1,425.0	0.136
3	0.094	14,000	1,316.0	0.126
4	0.103	13,100	1,349.3	0.129
5	0.083	12,200	1,012.6	0.097
6	0.076	11,300	858.8	0.082
7	0.076	10,300	782.8	0.075
8	0.063	9,400	592.2	0.057
9	0.054	8,500	459.0	0.044
10	0.043	7,600	326.8	0.031
11	0.036	6,700	241.2	0.023
12	0.024	6,600	158.4	0.015
13 and older	0.192	5,000	960.0	0.092
Total Vehicle Fleet	1.000	--	10,452.0 (SUM)	1.000

Source: U. S. Environmental Protection Agency and SEWRPC.

Table 107

CARBON MONOXIDE, NITROGEN OXIDE, AND HYDROCARBON NEW VEHICLE EXHAUST EMISSION FACTORS AND DETERIORATION RATES FOR LIGHT-DUTY GASOLINE TRUCKS CALENDAR YEAR 1973

Pollutant	Model Year	New Vehicle Emission Factor (grams per mile)	Deterioration Rate per 10,000 Miles (grams per mile)
Carbon Monoxide	1970-1973	31.48	6.15
	1968-1969	42.08	5.44
	Pre-1968	70.38	3.06
Nitrogen Oxides	1973	3.56	--
	1970-1972	4.59	--
	1968-1969	4.90	--
	Pre-1968	4.16	--
Hydrocarbons	1970-1973	2.56	0.53
	1968-1969	3.25	0.54
	Pre-1968	4.76	0.58

Source: U. S. Environmental Protection Agency.

Table 108

CARBON MONOXIDE, NITROGEN OXIDE, AND HYDROCARBON EXHAUST EMISSION FACTORS FOR LIGHT-DUTY GASOLINE TRUCKS CALENDAR YEAR 1973

Model Year	Emission Factor (grams per mile)		
	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
1973	34.8	3.0	2.7
1972	43.2	4.4	3.5
1971	52.3	4.4	4.3
1970	60.8	4.4	5.0
1969	68.7	4.4	5.7
1968	76.0	4.4	6.3
1967	94.0	3.6	9.3
1966	97.1	3.6	9.9
1965	99.9	3.6	10.4
1964	102.4	3.6	10.9
1963	104.7	3.6	11.3
1962 and earlier	106.7	3.6	11.7

Source: U. S. Environmental Protection Agency and SEWRPC.

Correction Factors for Light-Duty Gasoline Trucks: The exhaust emission factors shown in Table 108 for light-trucks had to be modified to reflect local traffic and meteorological conditions in areas where the FTP conditions do not prevail. Adjustments to these exhaust emission factors were made for ambient air temperature, mode of operation, average speed, humidity, air conditioning, and vehicle load following the same procedures detailed for light-duty gasoline vehicles. Also, the crankcase and evaporative hydrocarbon emissions were added to the inventory at the same rate as that for light-duty gasoline vehicles.

Total Pollutant Emissions From Light-Duty Gasoline Trucks: The total quantity of pollutant emissions from light-duty gasoline trucks operating on the regional arterial street and highway system and on the collector and land access street system during 1973 is summarized by county by season in Table 109. In aggregate, pollutant emissions from light-duty gasoline trucks are substantially less than those produced by automobiles. Light-duty trucks generate approximately 94 percent less carbon monoxide emissions, 92 percent less nitrogen oxide emissions, and 91 percent less hydrocarbon emissions than do automobiles on a regional average because of the lesser number of light-truck trips.

Heavy-Duty Gasoline Trucks

Heavy-duty gasoline trucks include all trucks and buses with a gross vehicle weight in excess of 8,000 pounds and that are powered by gasoline-fueled, spark-ignited, internal combustion engines. The EPA test programs for determining the emission factors for in-use heavy-duty vehicles included both the FTP and an actual urban road test conducted in San Antonio, Texas. The San Antonio Road Route (SARR) test conditions for both heavy-duty gasoline trucks and heavy-duty diesel trucks are shown in Table 110.

The SARR test was conducted on 35 gasoline and 10 diesel heavy-duty trucks operating over freeway, arterial, local, and collector street segments of a total length of 7.24 miles. The average speed was found to be about 20 mph, with about 20 percent of the time spent at idle. The SARR test, however, made no attempt to account for the time trucks spend idling as a result of deliveries or special operations.

Data on the vehicle age distribution, annual mileage accumulation rate, and proportion of travel for heavy-duty gasoline trucks are shown in Table 111. The values shown in the table, based on national statistics obtained from the EPA, were used to determine emissions from heavy-duty gasoline trucks operating on the regional arterial street and highway system and local and land access street system. Table 112 presents the distribution of buses by vehicle age for Kenosha, Milwaukee, and Racine Counties. The values shown in this table were used to calculate emissions from gasoline buses operating on the urban mass transit network in the Region. In Milwaukee County all buses are diesel vehicles, all buses in Racine County are gasoline-powered, and Kenosha County buses are divided equally between the two fuel types.

The new heavy-duty gasoline truck emission rates and deterioration rates for carbon monoxide, nitrogen oxides, and hydrocarbons are shown in Table 113. The emission factors for heavy-duty gasoline trucks for the three pollutant species for 1973 model year and older trucks operating in calendar year 1973 were derived from these rates and are shown in Table 114.

Table 109

SUMMARY OF LIGHT-DUTY GASOLINE TRUCK EMISSIONS BY COUNTY BY SEASON: 1973

County	Season	Emissions (tons)				
		Particulate Matter	Sulfur Dioxide	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
Kenosha	Winter	5	1	647	70	84
	Spring	5	1	560	56	78
	Summer	5	1	527	65	76
	Fall	5	1	533	64	76
	Annual	20	4	2,267	255	314
Milwaukee	Winter	23	6	3,427	287	453
	Spring	23	6	2,976	230	423
	Summer	23	6	2,806	263	410
	Fall	23	6	2,832	262	413
	Annual	92	24	12,041	1,042	1,699
Ozaukee	Winter	3	1	304	39	38
	Spring	3	1	263	31	35
	Summer	3	1	247	36	34
	Fall	3	1	250	36	35
	Annual	12	4	1,064	142	142
Racine	Winter	6	1	801	80	103
	Spring	6	1	695	64	96
	Summer	6	1	654	73	93
	Fall	6	1	661	73	94
	Annual	24	4	2,811	290	386
Walworth	Winter	4	1	502	56	63
	Spring	4	1	434	45	59
	Summer	4	1	408	51	57
	Fall	4	1	413	51	58
	Annual	16	4	1,757	203	237
Washington	Winter	5	1	590	80	78
	Spring	5	1	511	64	72
	Summer	5	1	480	73	70
	Fall	5	1	485	73	71
	Annual	20	4	2,066	290	291
Waukesha	Winter	11	3	1,292	157	172
	Spring	11	3	1,119	126	160
	Summer	11	3	1,051	144	155
	Fall	11	3	1,063	144	156
	Annual	44	12	4,525	571	643
Region	Winter	57	14	7,563	769	991
	Spring	57	14	6,558	616	923
	Summer	57	14	6,173	705	895
	Fall	57	14	6,237	703	903
	Annual	228	56	26,531	2,793	3,712

Source: SEWRPC.

Table 110

SAN ANTONIO ROAD ROUTE CONDITIONS FOR DETERMINING CARBON MONOXIDE, NITROGEN OXIDE, AND HYDROCARBON EXHAUST EMISSIONS FROM HEAVY-DUTY VEHICLES

SARR Conditions
1. Ambient temperature = 75°F
2. Mixing ratio = 75 grains of water vapor per pound of dry air
3. Average speed = 20 mph
4. Average stabilized operation = 100 percent
5. Average operating weight = 17,000-20,000 pounds for gas, 40,000-50,000 pounds for diesel
6. Average weight over cubic inch displacement = 47-54 for gas, 57-67 for diesel
7. All testing performed in one low-altitude city
8. Vehicles receive typical in-use maintenance
9. Vehicles are not in an Inspection/Maintenance program

Source: U. S. Environmental Protection Agency.

Table 111

VEHICLE AGE DISTRIBUTION, ANNUAL MILEAGE ACCUMULATION RATE, AND PROPORTION OF TRAVEL FOR HEAVY-DUTY GASOLINE TRUCKS

Vehicle Age	Vehicle Age Distribution (a)	Annual Mileage Accumulation Rate (b)	Fractional Part Annual Mileage (a) x (b)	Travel Fraction ((a) x (b)/SUM)
1	0.037	19,000	703.0	0.061
2	0.070	19,000	1,330.0	0.116
3	0.078	17,900	1,396.2	0.122
4	0.086	16,500	1,419.0	0.124
5	0.075	15,000	1,125.0	0.098
6	0.075	13,500	1,012.5	0.088
7	0.075	12,000	900.0	0.079
8	0.068	10,600	720.8	0.063
9	0.059	9,500	560.5	0.049
10	0.053	8,600	455.8	0.040
11	0.044	7,800	343.2	0.030
12	0.032	7,000	224.0	0.020
13 and older	0.248	5,038	1,249.4	0.110
Total Vehicle Fleet	1.000	--	11,439.4 (SUM)	1.000

Source: U. S. Environmental Protection Agency and SEWRPC.

At the present time, the EPA has not determined any applicable correction factors for ambient meteorological conditions for heavy-duty trucks and therefore no such adjustments were made. Moreover, all vehicle activity of heavy-duty trucks was assumed to take place in the stabilized mode of operation and, consequently, emissions in the hot start or cold start phase of operation were not considered. The emission factors in Table 114 may be adjusted, however, for vehicle speeds differing from the SARR test conditions. The average speed of heavy-duty trucks along each traffic link and in each traffic analysis zone was used in preparing the 1973 inventory. The emission factors also assume that heavy-duty trucks are traveling at half rated load, because there are no local data to support any other assumption. Therefore, no correction factor was applied for empty trucks or trucks at full load. Thus, the only adjustment to the basic emission rates other than the speed correction factor was the inclusion of crankcase and evaporative

Table 112

VEHICLE AGE DISTRIBUTION FOR BUSES IN THE MILWAUKEE, KENOSHA, AND RACINE URBANIZED AREAS: 1973

Urbanized Area	Vehicle Age (years)	Number of Buses
Kenosha	2	4
	3	2
	22	12
Total	--	18
Milwaukee	6	30
	7	60
	8	63
	9	30
	10	75
	11	83
	13	40
	14	20
	16	22
	17	29
	18	25
	19	28
	20	20
	22	5
	23	2
Total	--	532
Racine	5	3
	6	10
	14	1
Total	--	14

Source: SEWRPC.

Table 113

CARBON MONOXIDE, NITROGEN OXIDE, AND HYDROCARBON NEW VEHICLE EXHAUST EMISSION FACTORS AND DETERIORATION RATES FOR HEAVY-DUTY GASOLINE TRUCKS CALENDAR YEAR 1973

Pollutant	Model Year	New Vehicle Emission Factor (grams per mile)	Deterioration Rate per 10,000 Miles (grams per mile)
Carbon Monoxide	1970-1973	212.70	6.15
	Pre-1970	272.90	3.06
Nitrogen Oxides	1970-1973	12.80	--
	Pre-1970	8.80	--
Hydrocarbons	1970-1973	18.54	0.53
	Pre-1970	23.90	0.58

Source: U. S. Environmental Protection Agency.

Table 114

CARBON MONOXIDE, NITROGEN OXIDE, AND HYDROCARBON EXHAUST EMISSION FACTORS FOR HEAVY-DUTY GASOLINE TRUCKS CALENDAR YEAR 1973

Model Year	Emission Factor (grams per mile)		
	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
1973	215.6	12.8	18.8
1972	224.4	12.8	19.5
1971	236.0	12.8	20.5
1970	247.0	12.8	21.5
1969	295.0	8.8	28.1
1968	299.6	8.8	29.0
1967	303.7	8.8	29.7
1966	307.4	8.8	30.4
1965	310.6	8.8	31.1
1964	313.6	8.8	31.6
1963	316.2	8.8	32.1
1962 and earlier	318.6	8.8	32.6

Source: U. S. Environmental Protection Agency.

hydrocarbon emissions at a rate of 2.0 grams per vehicle mile of travel for 1968 to 1973 model year heavy-duty gasoline trucks, and 7.7 grams per vehicle mile of travel for pre-1968 model year heavy-duty gasoline trucks.

Particulate matter emissions are again determined by particles in the exhaust and particles released as a result of tire wear. Exhaust particles are emitted from heavy-duty gasoline trucks at a rate of 0.91 gram per vehicle mile of travel. Tire wear emissions are based on data for light-duty gasoline vehicles, since no more specific data for heavy-duty trucks are available, and are adjusted for trucks having more than four tires. The truck classification data from the Commission's 1972 origin and destination study indicate that the average heavy-duty gasoline truck has eight tires. The average tire wear emission factor is therefore twice the rate for light-duty gasoline vehicles, or 0.40 gram per vehicle mile of travel. The total particulate matter emission rate for heavy-duty gasoline trucks is thus 1.31 grams per vehicle mile of travel.

Sulfur oxide emissions from heavy-duty gasoline trucks are released into the atmosphere at an estimated rate of 0.36 gram per vehicle mile of travel. This emission factor is based on an average fuel consumption of 6.0 miles per gallon and an average sulfur content in the fuel of 0.04 percent as determined by the Automobile Manufacturers Association and the U. S. Department of the Interior, Bureau of Mines.

The total pollutant emissions from heavy-duty gasoline trucks operating over the regional transportation system during 1973 are presented in Table 115. The total pollutant emissions from mass transit vehicles in the Region,

Table 115

SUMMARY OF HEAVY-DUTY GASOLINE TRUCK EMISSIONS BY COUNTY BY SEASON: 1973

County	Season	Emissions (tons)				
		Particulate Matter	Sulfur Dioxide	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
Kenosha	Winter	5	1	989	48	105
	Spring	5	1	989	48	105
	Summer	5	1	989	48	105
	Fall	5	1	989	48	105
	Annual	20	4	3,956	192	420
Milwaukee	Winter	60	17	11,125	538	1,151
	Spring	60	17	11,125	538	1,151
	Summer	60	17	11,125	538	1,151
	Fall	60	17	11,125	538	1,151
	Annual	240	68	44,500	2,152	4,604
Ozaukee	Winter	3	1	527	29	48
	Spring	3	1	527	29	48
	Summer	3	1	527	29	48
	Fall	3	1	527	29	48
	Annual	12	4	2,108	116	192
Racine	Winter	9	2	1,598	82	153
	Spring	9	2	1,598	82	153
	Summer	9	2	1,598	82	153
	Fall	9	2	1,598	82	153
	Annual	36	8	6,392	328	612
Walworth	Winter	6	2	924	53	88
	Spring	6	2	924	53	88
	Summer	6	2	924	53	88
	Fall	6	2	924	53	88
	Annual	24	8	3,696	212	352
Washington	Winter	6	2	946	54	86
	Spring	6	2	946	54	86
	Summer	6	2	946	54	86
	Fall	6	2	946	54	86
	Annual	24	8	3,784	216	344
Waukesha	Winter	25	7	4,148	234	369
	Spring	25	7	4,148	234	369
	Summer	25	7	4,148	234	369
	Fall	25	7	4,148	234	369
	Annual	100	28	16,592	936	1,476
Region	Winter	114	32	20,257	1,038	2,000
	Spring	114	32	20,257	1,038	2,000
	Summer	114	32	20,257	1,038	2,000
	Fall	114	32	20,257	1,038	2,000
	Annual	456	128	81,028	4,152	8,000

Source: SEWRPC.

Table 116

SUMMARY OF TRANSIT EMISSIONS BY COUNTY BY SEASON: 1973

County	Season	Emissions (tons)				
		Particulate Matter	Sulfur Dioxide	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
Kenosha	Winter	--[a]	--[a]	34	1	4
	Spring	--[a]	--[a]	34	1	4
	Summer	--[a]	--[a]	34	1	4
	Fall	--[a]	--[a]	34	1	4
	Annual	--[a]	--[a]	136	4	16
Milwaukee	Winter	7	12	227	105	24
	Spring	7	12	227	105	24
	Summer	7	12	227	105	24
	Fall	7	12	227	105	24
	Annual	28	48	908	420	96
Ozaukee	Winter	--	--	--	--	--
	Spring	--	--	--	--	--
	Summer	--	--	--	--	--
	Fall	--	--	--	--	--
	Annual	--	--	--	--	--
Racine	Winter	--[a]	--[a]	67	2	8
	Spring	--[a]	--[a]	67	2	8
	Summer	--[a]	--[a]	67	2	8
	Fall	--[a]	--[a]	67	2	8
	Annual	--[a]	--[a]	268	8	32
Walworth	Winter	--	--	--	--	--
	Spring	--	--	--	--	--
	Summer	--	--	--	--	--
	Fall	--	--	--	--	--
	Annual	--	--	--	--	--
Washington	Winter	--	--	--	--	--
	Spring	--	--	--	--	--
	Summer	--	--	--	--	--
	Fall	--	--	--	--	--
	Annual	--	--	--	--	--
Waukesha	Winter	--[a]	--[a]	2	1	--[a]
	Spring	--[a]	--[a]	2	1	--[a]
	Summer	--[a]	--[a]	2	1	--[a]
	Fall	--[a]	--[a]	2	1	--[a]
	Annual	--[a]	--[a]	8	4	--[a]
Region	Winter	7	12	330	109	36
	Spring	7	12	330	109	36
	Summer	7	12	330	109	36
	Fall	7	12	330	109	36
	Annual	28	48	1,320	436	144

[a] *Less than one-half ton.*

Source: SEWRPC.

including both gasoline-powered and diesel-powered buses, are presented in Table 116. As may be seen in these tables, the pollutant emissions from these vehicle types do not vary by season since meteorological factors are assumed not to influence the relative emission rates from heavy-duty vehicles.

Heavy-Duty Diesel Trucks

Heavy-duty diesel trucks have engines that allow more complete combustion and use less violatile fuels than spark-ignited engines. As a result, carbon monoxide and hydrocarbon emissions from diesel trucks are relatively low as compared to such emissions from gasoline trucks. Diesel engines, however, operate under high temperatures and with large excesses of oxygen, and nitrogen oxide emissions are therefore relatively high.

The procedure followed in calculating the emissions from heavy-duty diesel trucks is the same as that used for heavy-duty gasoline trucks. Data on the vehicle age distribution, annual mileage accumulation rate, and proportion of travel for heavy-duty diesel trucks are shown in Table 117. The new vehicle emission rates for carbon monoxide, nitrogen oxides, and hydrocarbons

Table 117

VEHICLE AGE DISTRIBUTION, ANNUAL MILEAGE ACCUMULATION RATE, AND PROPORTION OF TRAVEL FOR HEAVY-DUTY DIESEL TRUCKS

Vehicle Age	Vehicle Age Distribution (a)	Annual Mileage Accumulation Rate (b)	Fractional Part Annual Mileage (a) x (b)	Travel Fraction ((a) x (b)/SUM)
1	0.077	73,600	5,667.2	0.102
2	0.135	73,600	9,936.0	0.178
3	0.134	69,900	9,366.6	0.168
4	0.131	63,300	8,292.3	0.149
5	0.099	56,600	5,603.4	0.101
6	0.090	50,000	4,500.0	0.081
7	0.082	45,600	3,739.2	0.067
8	0.062	41,200	2,554.4	0.046
9	0.045	38,200	1,719.0	0.031
10	0.033	36,000	1,188.0	0.021
11	0.025	34,600	865.0	0.016
12	0.015	33,800	507.0	0.009
13 and older	0.072	25,738	1,753.2	0.031
Total Vehicle Fleet	1.000	--	55,691.3 (SUM)	1.000

Source: U. S. Environmental Protection Agency and SEWRPC.

Table 118

CARBON MONOXIDE, NITROGEN OXIDE, AND HYDROCARBON NEW VEHICLE EXHAUST EMISSION FACTORS AND DETERIORATION RATES FOR HEAVY-DUTY DIESEL TRUCKS CALENDAR YEAR 1973

Pollutant	Model Year	New Vehicle Emission Factor (grams per mile)	Deterioration Rate per 10,000 Miles (grams per mile)
Carbon Monoxide	1973	35.10	--
Nitrogen Oxides	1973	21.40	--
Hydrocarbons	1973	4.30	--

Source: U. S. Environmental Protection Agency and SEWRPC.

Table 119

CARBON MONOXIDE, NITROGEN OXIDE, AND HYDROCARBON EXHAUST EMISSION FACTORS FOR HEAVY-DUTY DIESEL TRUCKS CALENDAR YEAR 1973

Model Year	Emission Factor (grams per mile)		
	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
1973	35.1	21.4	4.3
1972	35.1	21.4	4.3
1971	35.1	21.4	4.3
1970	35.1	21.4	4.3
1969	35.1	21.4	4.3
1968	35.1	21.4	4.3
1967	35.1	21.4	4.3
1966	35.1	21.4	4.3
1965	35.1	21.4	4.3
1964	35.1	21.4	4.3
1963	35.1	21.4	4.3
1962 and earlier	35.1	21.4	4.3

Source: U. S. Environmental Protection Agency and SEWRPC.

are given in Table 118. Table 118 indicates that the deterioration rate for heavy-duty diesel trucks is zero for each pollutant species. With no deterioration, the emission factors are constant for all 1973 and earlier model year diesel trucks, as may be seen in Table 119.

As with heavy-duty gasoline trucks, emission factors for heavy-duty diesel trucks were adjusted only to account for speeds along each link that varied from the SARR average speed of 20 mph. Also, since diesel fuel is considerably less volatile than gasoline, crankcase and evaporative hydrocarbon emissions are not produced by heavy-duty diesel trucks and are not part of the inventory for this vehicle type.

Particulate matter is emitted from the exhaust of heavy-duty diesel trucks at a rate of 1.30 grams per vehicle mile of travel. To calculate tire wear particulate emissions, it was assumed that all diesel trucks had 18 tires and would therefore generate 0.90 gram of particles per vehicle mile of travel. The composite particulate matter emission factor for heavy-duty diesel trucks is thus 2.20 grams per vehicle mile of travel.

The sulfur oxide exhaust emission factor for heavy-duty diesel trucks is 2.80 grams per vehicle mile of travel. This factor was based on the assumption that the sulfur content of diesel fuel is 0.20 percent and that the fuel use rate is 4.6 miles per gallon as determined by the U. S. Environmental Protection Agency and the U. S. Department of Transportation.

The total pollutant emissions from heavy-duty diesel trucks operating over the regional transportation system during 1973 are presented in Table 120. As with heavy-duty gasoline trucks, meteorological factors do not cause a seasonal change in the level of heavy-duty diesel truck emissions.

Line Source Emissions Inventory: 1973 Summary

After the line source emissions were calculated for each vehicle type, the calculations were adjusted to distribute the pollutants by hour of day. Data from the Commission's 1972 origin and destination study were used to determine the hourly proportion of travel by vehicle type on the regional surface arterial, freeway, and local and land access street systems. The resultant distribution

Table 120

SUMMARY OF HEAVY-DUTY DIESEL TRUCK EMISSIONS BY COUNTY BY SEASON: 1973

County	Season	Emissions (tons)				
		Particulate Matter	Sulfur Dioxide	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
Kenosha	Winter	16	20	152	176	13
	Spring	16	20	152	176	13
	Summer	16	20	152	176	13
	Fall	16	20	152	176	13
	Annual	64	80	608	704	52
Milwaukee	Winter	28	35	264	282	26
	Spring	28	35	264	282	26
	Summer	28	35	264	282	26
	Fall	28	35	264	282	26
	Annual	112	140	1,056	1,128	104
Ozaukee	Winter	6	8	58	67	5
	Spring	6	8	58	67	5
	Summer	6	8	58	67	5
	Fall	6	8	58	67	5
	Annual	24	32	232	268	20
Racine	Winter	14	17	133	156	11
	Spring	14	17	133	156	11
	Summer	14	17	133	156	11
	Fall	14	17	133	156	11
	Annual	56	68	532	624	44
Walworth	Winter	6	8	56	57	6
	Spring	6	8	56	57	6
	Summer	6	8	56	57	6
	Fall	6	8	56	57	6
	Annual	24	32	224	228	24
Washington	Winter	13	17	131	152	11
	Spring	13	17	131	152	11
	Summer	13	17	131	152	11
	Fall	13	17	131	152	11
	Annual	52	68	524	608	44
Waukesha	Winter	15	20	151	174	13
	Spring	15	20	151	174	13
	Summer	15	20	151	174	13
	Fall	15	20	151	174	13
	Annual	60	80	604	696	52
Region	Winter	98	125	945	1,064	85
	Spring	98	125	945	1,064	85
	Summer	98	125	945	1,064	85
	Fall	98	125	945	1,064	85
	Annual	392	500	3,780	4,256	340

Source: SEWRPC.

of travel is shown in Table 121. As may be seen in the table, travel by light-duty gasoline trucks reaches a peak between 3:00 p.m. and 4:00 p.m. on each facility type, with a secondary peak occurring around 7:00 a.m. Travel by heavy-duty trucks peaks at approximately 10:00 a.m. on all facilities. However, travel by heavy-duty gasoline trucks on the regional freeway system reaches a peak at 3:00 p.m.

Buses operating over the urban mass transit system in the Region during 1973 were distributed by operating period—morning, midday, afternoon, and night—in Kenosha, Milwaukee, and Racine Counties, as shown in Table 122. The table indicates that the transit systems in all three counties operate at maximum levels during the morning and evening rush hours.

Hourly pollutant emissions from all vehicle types operating on the arterial street and highway system were allocated to U. S. Public Land Survey quarter sections by means of State Plane Coordinate data maintained for each link on the system. Each arterial street and highway link was envisioned as a straight line between two nodes geographically identified in the State Plane Coordinate System. The line source emissions were then allocated among quarter sections on the basis of the proportion of the total link contained in each quarter section. For the local and land access street system, pollutant emissions were allocated to U. S. Public Land Survey quarter sections by distributing those pollutants emitted within a traffic analysis zone on the basis of the proportion of transportation-related land use in the quarter sections lying within the zone.

The data presented in this section represent the inventory of particulate matter, sulfur oxides, carbon monoxide, nitrogen oxide, and hydrocarbon emissions produced by vehicular activity on the arterial street and highway system, the local and land access street system, and the urban mass transit system in the Region by hour of the day for an average weekday in each of the four seasons during 1973. The total seasonal pollutant emissions by hour of the day are obtained by multiplying the hourly emissions by 77.5—the average number of weekdays per season. The seasonal averages are then summed to provide the annual line source emissions for 1973 within the Region. Table 123 summarizes the 1973 line source pollutant emissions inventory by county by season.

AREA SOURCE EMISSIONS INVENTORY: 1973

The area source emissions inventory includes 22 separate categories of air pollution sources. These 22 categories all share one common characteristic: the sources within each category emit a relatively small amount of pollutants when considered individually but, when considered collectively, may contribute significantly to the total regional pollutant emissions burden. The nature of the 22 area source emission categories is diverse—ranging from agricultural sources to the operation of commercial Great Lakes vessels—and each required the development of a unique inventory methodology. In the following sections of this chapter, the procedures used to calculate and spatially and temporally allocate the individual area source emission categories are reviewed and the results presented.

Emissions From Agricultural Tilling Operations

Agricultural tilling involves the loosening and pulverization of soil in order to eradicate weeds and to create a suitable soil structure for use as a crop seedbed. During a tilling operation, small dust particles are injected into the atmosphere. Those particles which, because of their small size, do not settle out of the atmosphere near the source may be suspended in the air for an indefinite time and be transported over great distances.

Table 121

HOURLY DISTRIBUTION OF TRAVEL BY VEHICLE TYPE ON THE REGIONAL TRANSPORTATION SYSTEM

Hour	Proportion of Travel								
	Light-Duty Vehicles and Trucks			Heavy-Duty Trucks					
				Gasoline			Diesel		
	Surface Arterial	Freeway	Collector and Minor	Surface Arterial	Freeway	Collector and Minor	Surface Arterial	Freeway	Collector and Minor
1	0.015	0.020	0.004	0.012	0.013	--	0.022	0.035	--
2	0.010	0.019	0.002	0.013	0.014	--	0.017	0.037	--
3	0.009	0.015	0.002	0.015	0.017	--	0.026	0.040	--
4	0.007	0.011	0.002	0.017	0.020	0.003	0.025	0.038	0.003
5	0.025	0.025	0.008	0.020	0.026	0.015	0.025	0.048	0.015
6	0.044	0.052	0.041	0.024	0.040	0.037	0.040	0.042	0.037
7	0.075	0.090	0.072	0.052	0.058	0.075	0.057	0.041	0.075
8	0.046	0.058	0.047	0.077	0.067	0.103	0.064	0.047	0.103
9	0.041	0.037	0.042	0.090	0.072	0.106	0.073	0.049	0.106
10	0.042	0.032	0.051	0.092	0.070	0.114	0.081	0.054	0.114
11	0.047	0.035	0.054	0.089	0.065	0.104	0.068	0.049	0.104
12	0.052	0.039	0.059	0.068	0.054	0.083	0.069	0.050	0.083
13	0.048	0.037	0.051	0.078	0.057	0.102	0.062	0.048	0.102
14	0.062	0.054	0.058	0.090	0.081	0.094	0.065	0.049	0.094
15	0.082	0.092	0.088	0.080	0.085	0.076	0.070	0.046	0.076
16	0.090	0.085	0.095	0.055	0.077	0.051	0.057	0.043	0.051
17	0.073	0.074	0.078	0.040	0.048	0.020	0.038	0.040	0.020
18	0.054	0.051	0.063	0.027	0.033	0.007	0.027	0.035	0.007
19	0.044	0.036	0.059	0.016	0.025	0.004	0.015	0.033	0.004
20	0.035	0.030	0.041	0.009	0.021	0.002	0.022	0.033	0.002
21	0.030	0.031	0.034	0.007	0.016	0.002	0.022	0.033	0.002
22	0.029	0.027	0.022	0.008	0.014	0.001	0.022	0.041	0.001
23	0.023	0.025	0.017	0.009	0.013	0.001	0.018	0.031	0.001
24	0.017	0.023	0.010	0.012	0.013	--	0.015	0.038	--

Source: SEWRPC.

Table 122

DISTRIBUTION OF TRAVEL BY TRANSIT SYSTEM AND BY PERIOD OF OPERATION: 1973

Transit System	Proportion of Travel			
	Morning (hours 7-9)	Midday (hours 10-15)	Afternoon (hours 16-18)	Night[a]
Kenosha . . .	0.333	0.167	0.333	--
Milwaukee . .	0.333	0.167	0.333	0.143
Racine	0.333	0.167	0.333	0.250

[a] *There were variations in the amount of night service offered by the three transit systems. The Milwaukee transit system offered seven hours of night service; the Racine transit system, four hours; and the Kenosha transit system, no night service.*

Source: SEWRPC.

The quantity of particulate matter emissions generated by agricultural tilling is dependent upon the surface soil texture and soil moisture content, and is directly proportional to the land area tilled. Soil texture is a function of the relative proportion of clay, sand, and silt particles in the soil mixture. Soils that have a finer texture—that is, a higher silt content—have a higher rate of particulate emissions than the coarser, sandy soils, since the smaller particles are more aerodynamically suited to long-range atmospheric transport. Therefore, in order to calculate the particulate matter emissions from this area source category, it was necessary to estimate the silt content of the soils in the Region subject to tilling operations during 1973.

Data on the nature and location of the various soil types found within the Region were obtained from SEWRPC Planning Report No. 8, Soils of Southeastern Wisconsin, which documents the results of the detailed operational soil surveys conducted within the Region by the U. S. Soil Conservation Service under contract to the Commission. From this report, estimates of soil silt content were made on the basis of generalized soil

Table 123

TOTAL LINE SOURCE EMISSIONS INVENTORY FOR THE SOUTHEASTERN WISCONSIN REGION BY COUNTY BY SEASON: 1973

County	Season	Emissions (tons)				
		Particulate Matter	Sulfur Dioxide	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
Kenosha	Winter	94	38	10,653	1,050	1,078
	Spring	94	38	9,321	984	991
	Summer	94	38	8,759	916	953
	Fall	94	38	8,897	964	963
	Annual	376	152	37,630	3,914	3,985
Milwaukee	Winter	592	184	83,397	6,269	8,253
	Spring	592	184	73,386	5,858	7,605
	Summer	592	184	69,206	5,381	7,317
	Fall	592	184	70,195	5,705	7,394
	Annual	2,368	736	296,184	23,213	30,569
Ozaukee	Winter	47	18	4,867	548	498
	Spring	47	18	4,258	511	458
	Summer	47	18	3,995	475	440
	Fall	47	18	4,063	501	446
	Annual	188	72	17,183	2,035	1,842
Racine	Winter	107	39	13,165	1,186	1,310
	Spring	107	39	11,575	1,109	1,206
	Summer	107	39	10,907	1,031	1,160
	Fall	107	39	11,068	1,087	1,173
	Annual	428	156	46,715	4,413	4,849
Walworth	Winter	56	21	6,208	616	634
	Spring	56	21	5,467	574	587
	Summer	56	21	5,150	535	565
	Fall	56	21	5,231	564	571
	Annual	224	84	22,056	2,289	2,357
Washington	Winter	70	31	6,546	848	683
	Spring	70	31	5,766	792	631
	Summer	70	31	5,427	745	608
	Fall	70	31	5,516	781	615
	Annual	280	124	23,255	3,166	2,537
Waukesha	Winter	199	66	22,929	2,294	2,313
	Spring	199	66	20,286	2,142	2,140
	Summer	199	66	19,150	1,986	2,062
	Fall	199	66	19,443	2,097	2,084
	Annual	796	264	81,808	8,519	8,599
Region	Winter	1,165	397	147,765	12,811	14,769
	Spring	1,165	397	130,059	11,970	13,618
	Summer	1,165	397	122,594	11,069	13,105
	Fall	1,165	397	124,413	11,699	13,246
	Annual	4,660	1,588	524,831	47,549	54,738

Source: SEWRPC.

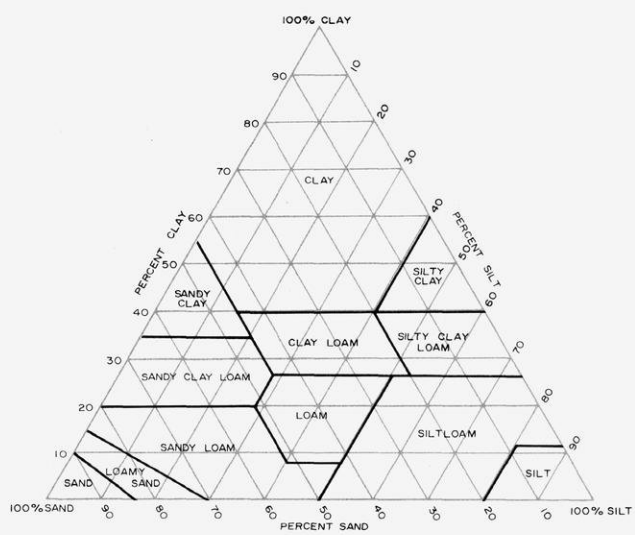
association groups.[9] For each soil association group in the Region, the relative percentage of the major and minor component soils was identified, and each soil type was classified according to texture. For example, the Ozaukee-Martinton-Saylesville association group is comprised of the major soils of Ozaukee—50 percent of the group, Martinton—10 percent, and Saylesville—8 percent, and the minor soils of Mequon—12 percent of the group, Aztalan—10 percent, and Montgomery—10 percent. Based on their relative mixture of sand, clay, and silt particles, all three of the major soils in this group and the Mequon soil are classified as silt-loams, the Aztalan soil is classified as a loam, and the Montgomery soil is classified as a silty clay loam. The average silt content for each soil texture class may be determined from Figure 55. As may be seen in this figure, the silt content of the silt-loam texture class ranges from 50 to 80 percent, with a median value of 65 percent. The loam texture class has a median silt content of approximately 40 percent, and the silty clay loam class has a median silt content of about 55 percent. Therefore, the average silt content for the Ozaukee-Martinton-Saylesville soil association group, weighted by the relative proportion of each soil texture class, is 62 percent.

In total, 32 distinct soil association groups have been identified in the Region. The average silt content for each of these 32 groups was determined in the same manner as illustrated above (see Table 124). It should be noted that since only the average silt content of each soil texture class has been determined, and since no soil association groups within the Region are 100 percent silt texture, the maximum silt content for any soil association group is 65 percent.

The amount of moisture in the soil being tilled is also an important determinant of the quantity of particulate matter emissions produced since water binds the soil particles together. Field measurements have indicated that the quantity of emissions produced are inversely

Figure 55

SOIL TEXTURE CLASSES BY PARTICLE SIZE



Source: John Wiley and Sons, Fundamentals of Soil Science, New York.

[9] *A soil association group is a landscape that has a distinctive proportional pattern of soils. It normally consists of one or more major soils and at least one minor soil and is named for the major soils. The soils in one association group may occur in another group but in a different pattern and proportion.*

Table 124

SOIL ASSOCIATION GROUPS WITH ESTIMATED SILT CONTENT

Soil Association Group	Silt Content (percent)
Rodman-Casco	10
Boyer-Oshtemo	13
Boyer-Granby	17
Hochheim-Sisson-Casco	36
Casco-Fabius	38
Colwood-Boyer-Sisson	40
Casco-Fox-Rodman	44
Warsaw-Lorenzo	44
Casco-Hochheim-Sisson	46
Fox-Casco	48
Hebron-Montgomery-Aztalan	48
Hochheim-Theresa	48
Warsaw-Plano	51
Miami-McHenry	52
Miami	53
Montgomery-Martinton-Hebron-Saylesville	58
Navan-Pella-Aztalan	61
Ozaukee-Martinton-Saylesville	58
Plano-Griswold	62
Varna-Elliot-Ashkum	62
Morley-Beecher-Ashkum	64
Brookston-Pella-Lumartine	65
Flagg-Pecatonica	65
Houghton-Adrian[a]	65
Houghton-Palms[a]	65
Houghton-Palms-Adrian[a]	65
Kewaunee-Manawa	65
Ozaukee-Mequon	65
Ozaukee-Morley-Mequon	65
Pella-Kendall-Elburn	65
Pella-Knowles	65
Plano	65

[a] *Muck-Peat type soils. Silt content estimated only.*

Source: U. S. Soil Conservation Service and SEWRPC.

proportional to the square of the soil moisture content. A small amount of water in the soil, therefore, can significantly reduce particulate matter emissions.

The amount of moisture in the soil is dependent on local precipitation and temperature conditions. A useful measure of the relationship between precipitation, temperature, and soil moisture content is the Thornthwaite precipitation-evaporation index. Developed by Dr. C. Warren Thornthwaite, this dimensionless index is determined from total annual rainfall and mean annual temperature. In the continental United States the value of the Thornthwaite precipitation-evaporation index ranges from 6 in southwestern Arizona, an extremely hot and arid climate, to 318 in western Washington, a cool climate with heavy rainfall. For the Southeastern Wisconsin Region the Thornthwaite index has a value of 100.

Soil moisture and silt content have been related to particulate matter emissions through an empirical formula developed from field measurements conducted under EPA contracts. This relationship may be expressed as:

$$E = \frac{1.4s}{(0.02PE)^2}$$

where: E = particulate matter emission factor (pounds per acre),
s = silt content of the surface soil (percent), and
PE = Thornthwaite's precipitation-evaporation index.

With a regional PE value of 100, the above equation is reduced to E = 0.35s, leaving the silt content as the only unknown variable in the emission factor.

Since particulate matter emissions from agricultural tilling operations depend on the silt content of the soil being worked, and since the number of specific fields being tilled as opposed to being left fallow in the Region during any given year cannot be readily determined, an indirect procedure for calculating and allocating emissions from this area source category was developed. Table 125 lists the number of acres by county that were subject to tilling operations during 1973 as determined from the 1974 Wisconsin Agricultural Statistics, the total area in croplands and pasture by county from the Commission 1970 land use inventory, and the percentage of the 1973 tilled land per acre of cropland and pasture in 1970 by county. Because croplands are not distinguished from pastures in the 1970 land use inventory, it was assumed that a portion of each acre in the cropland and pasture land use category was subject to tilling operations. It was further assumed that the cropland and pasture acreage in the Region did not appreciably change between 1970 and 1973. The portion of each acre devoted to tilling operations was determined by dividing the 1973 tilled acreage by the 1970 cropland and pasture acreage for each of the seven counties in southeastern Wisconsin to yield the percentage of tilled

Table 125

AMOUNT OF CROPLAND AND PASTURE TILLED IN THE REGION BY COUNTY: 1973

County	Acres in Cropland and Pasture (1970)	Acres Subject to Tilling	Percent Subject to Tilling
Kenosha	113,016	74,200	66
Milwaukee . . .	27,526	9,950	36
Ozaukee	99,132	67,100	68
Racine	143,121	92,750	65
Walworth. . . .	260,760	181,200	69
Washington . .	185,985	121,350	65
Waukesha . . .	198,854	86,900	44
Region	1,028,394	633,450	62

Source: U. S. Department of Agriculture and SEWRPC.

land to total cropland and pasture. These percentages were then used to estimate the number of acres in each U. S. Public Land Survey quarter section in the Region that produced particulate matter emissions from tilling operations. If, for example, a quarter section located in Racine County had 100 acres in cropland and pasture land use according to the 1970 inventory, only 65 acres were considered tilled during 1973 (see Table 125). The average silt content of the soils in the specific quarter section was then identified and used with the emission factor to estimate the pounds of particulate matter emissions that were generated by tilling in 1973.

The procedure detailed above assumed that tilling operations only occurred once per year on any tract of tillable land. Not all tilling operations occur within the same season, however. Some tilling occurs in all seasons except winter. A seasonal allocation factor, set forth in Table 126, was therefore used to distribute the emissions by quarter section by season. A summary of the particulate matter emissions produced by agricultural tilling operations in 1973 is presented in Table 127 by county by season.

Emissions From Agricultural Equipment

Agricultural equipment used for tilling and other farming-related operations may also be a source of pollutant emissions if powered by an internal combustion engine. Four such agricultural equipment types are included in this area source category: wheeled tractors, self-propelled combines, pick-up balers, and forage harvesters. These four farm implements account for more than 75 percent of all the power used in agricultural operations on a national average.

Pollutant emissions from each type of agricultural equipment depend on the number of units in operation, the fuel used for power, and the number of hours the implement is in service. Certain farm equipment, such as tractors and self-propelled combines, may be powered by either gasoline or diesel fuel. Pick-up balers, on the other hand, are always gasoline-powered, while forage harvesters are always diesel-powered. It is necessary, therefore, to determine not only the number of units for each equipment type in operation within the Region, but the distribution of the units by fuel type for those implements that may use either gasoline or diesel fuel.

Table 126

SEASONAL ALLOCATION FACTOR FOR AGRICULTURAL TILLING EMISSIONS

Season	Factor (percent)
Winter	--
Spring	85
Summer	5
Fall	10

Source: SEWRPC.

Table 127

SUMMARY OF PARTICULATE MATTER EMISSIONS FROM TILLING OPERATIONS BY COUNTY BY SEASON: 1973

County	Season	Particulate Matter Emissions (tons)
Kenosha	Winter	--
	Spring	633
	Summer	37
	Fall	74
	Annual	744
Milwaukee	Winter	--
	Spring	95
	Summer	6
	Fall	11
	Annual	112
Ozaukee	Winter	--
	Spring	547
	Summer	32
	Fall	64
	Annual	643
Racine	Winter	--
	Spring	805
	Summer	47
	Fall	94
	Annual	946
Walworth	Winter	--
	Spring	1,427
	Summer	83
	Fall	167
	Annual	1,677
Washington	Winter	--
	Spring	918
	Summer	54
	Fall	108
	Annual	1,080
Waukesha	Winter	--
	Spring	633
	Summer	37
	Fall	74
	Annual	744
Region	Winter	--
	Spring	5,058
	Summer	296
	Fall	592
	Annual	5,946

Source: SEWRPC.

Table 128 lists the number of tractors, self-propelled combines, pick-up balers, and forage harvesters in operation in the Region by county as reported in the U. S. Department of Agriculture publication, United States Census of Agriculture-1969, the latest year of available data prior to 1973. The work-life of farm equipment is such that the four-year difference between the census data and the base year would not significantly change the number of units in operation. The tractors and self-propelled combines shown in Table 128 have also been distributed by fuel type—25 percent gasoline-powered and 75 percent diesel-powered for both equipment types—based on the results of a telephone survey of farm implement dealers conducted in the Region by the Commission.

The emission factors for gasoline and diesel farm tractors, and for gasoline and diesel nontractor farm equipment, are presented in Table 129. These factors were determined from studies conducted by the Southwest Research Institute under contract to the EPA. The EPA has also determined that the average annual usage of tractors and other farm machinery is approximately 550 hours. This value was used to calculate the total pollutant emissions from the operation of agricultural equipment.

After the total pollutant emissions had been calculated by equipment type, seasonal usage factors were determined, based again on the results of a telephone survey of farm implement dealers conducted in the Region by the Commission. These factors, shown by equipment type in Table 130, were the basis for the distribution of the annual emissions to each season within the year. A summary of pollutant emissions generated from the operation of agricultural equipment by county by season for 1973 is provided in Table 131.

The pollutant emissions shown in Table 131 were allocated to the U. S. Public Land Survey quarter sections within the Region by first determining the average emission rate for particulate matter, sulfur dioxide, carbon monoxide, nitrogen oxides, and hydrocarbons per acre of land tilled during 1973. This determination was made by dividing the pollutant emissions for each season by the acres of land tilled within each county during 1973, as shown in Table 125. These pollutant emission rates were then assigned to quarter sections on the basis of the percentage of cropland and pasture, as inventoried by the Commission for each county in 1970, subject to tilling in 1973. These percentages by county are also presented in Table 125.

Emissions From Aircraft Operations

Pollutant emissions from aircraft operations were calculated on the basis of the estimated number of landing and takeoff cycles (LTO's) occurring at the 20 major public airports, shown on Map 48, in operation within emissions were then assigned to quarter sections on the basis of the percentage of cropland and pasture, as inventoried by the Commission for each county in 1970, subject to tilling in 1973. These percentages by county are also presented in Table 125.

Table 128

AGRICULTURAL EQUIPMENT INVENTORY FOR SOUTHEASTERN WISCONSIN: 1973

County	Number of Tractors		Number of Self-Propelled Combines		Number of Pick-Up Balers (gasoline)	Number of Forage Harvesters (diesel)
	Gasoline	Diesel	Gasoline	Diesel		
Kenosha	443	1,331	36	109	333	187
Milwaukee	123	369	8	23	79	14
Ozaukee	500	1,500	37	113	397	246
Racine	658	1,975	53	160	421	217
Walworth	898	2,694	68	205	749	438
Washington	918	2,755	57	172	656	514
Waukesha	722	2,166	33	99	674	337
Region	4,262	12,790	292	881	3,309	1,953

Source: U. S. Department of Agriculture, U. S. Census of Agriculture—1969.

Table 129

EMISSION FACTORS FOR AGRICULTURAL EQUIPMENT

Equipment	Emission Factor (grams per hour)						
	Particulate Matter	Sulfur Oxides	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons		
					Exhaust	Crankcase	Evaporative
Diesel Farm Tractor	61.8	42.2	161	452	77.8	--	--
Gasoline Farm Tractor	8.33	5.56	3,380	157	128	26.0	15,600 grams per unit per year
Diesel Farm Equipment (nontractor)	34.9	21.7	95.2	210	38.6	--	--
Gasoline Farm Equipment (nontractor)	7.94	6.34	4,360	105	143	0.063	1,600 grams per unit per year

Source: U. S. Environmental Protection Agency.

Table 130

SEASONAL EQUIPMENT USAGE FACTORS FOR AGRICULTURAL EQUIPMENT

Season	Usage Factor (percent)			
	Tractors	Self-Propelled Combines	Pick-Up Balers	Forage Harvesters
Winter	10	--	--	--
Spring	60	--	--	--
Summer	15	100	100	--
Fall	15	--	--	100
Total	100	100	100	100

Source: SEWRPC.

the Region during 1973.[10] An LTO may be defined as all the operational transitions of an aircraft below an altitude of 3,500 feet, and includes taxi-idle, takeoff, climbout, approach and landing, and taxi-idle prior to engine shutdown.

Table 132 lists the number of aircraft by type based at each of the airports considered in this study, with the exception of General Mitchell Field, and presents the estimated number of operations occurring annually at each facility. Data on aircraft activity at General Mitchell Field are provided in Table 133, and are distributed according to common air carrier, air taxi, military, and general aviation operations by aircraft type. The table also indicates the number of engines associated with each aircraft type.

For common air carriers and air taxis operating at General Mitchell Field, and for general aviation aircraft at all airports, the pollutant emissions were determined by multiplying the number of aircraft engines by the number of LTO's, and subsequently by the emission factor appropriate to the aircraft engine type, as shown in Table 134. Military operations at Mitchell Field were distributed as 60 percent C-130 aircraft—a turboprop

Table 131

SUMMARY OF AGRICULTURAL EQUIPMENT EMISSIONS BY COUNTY BY SEASON: 1973

County	Season	Emissions (tons)				
		Particulate Matter	Sulfur Dioxide	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
Kenosha	Winter	5	4	104	41	11
	Spring	31	21	624	244	67
	Summer	12	8	1,138	98	58
	Fall	12	8	167	85	21
	Annual	60	41	2,033	468	157
Milwaukee	Winter	1	1	30	12	3
	Spring	9	6	178	70	19
	Summer	3	2	287	27	15
	Fall	3	2	47	23	6
	Annual	16	11	542	132	43
Ozaukee	Winter	5	4	104	41	11
	Spring	31	21	623	244	67
	Summer	11	8	989	91	52
	Fall	9	6	159	67	18
	Annual	56	39	1,875	443	148
Racine	Winter	8	6	169	66	18
	Spring	51	35	1,014	397	109
	Summer	19	13	1,923	160	98
	Fall	20	13	274	145	36
	Annual	98	67	3,380	768	261
Walworth	Winter	11	7	210	82	23
	Spring	63	43	1,262	494	136
	Summer	24	17	2,487	202	125
	Fall	25	17	341	179	44
	Annual	123	84	4,300	957	328
Washington	Winter	11	7	215	84	23
	Spring	65	44	1,290	505	139
	Summer	23	16	2,217	194	114
	Fall	27	18	352	192	47
	Annual	126	85	4,074	975	323
Waukesha	Winter	8	6	169	66	18
	Spring	51	35	1,015	397	109
	Summer	18	13	2,128	157	104
	Fall	20	13	273	142	35
	Annual	97	67	3,585	762	266
Region	Winter	49	35	1,001	392	107
	Spring	301	205	6,006	2,351	646
	Summer	110	77	11,169	929	566
	Fall	116	77	1,613	833	207
	Annual	576	394	19,789	4,505	1,526

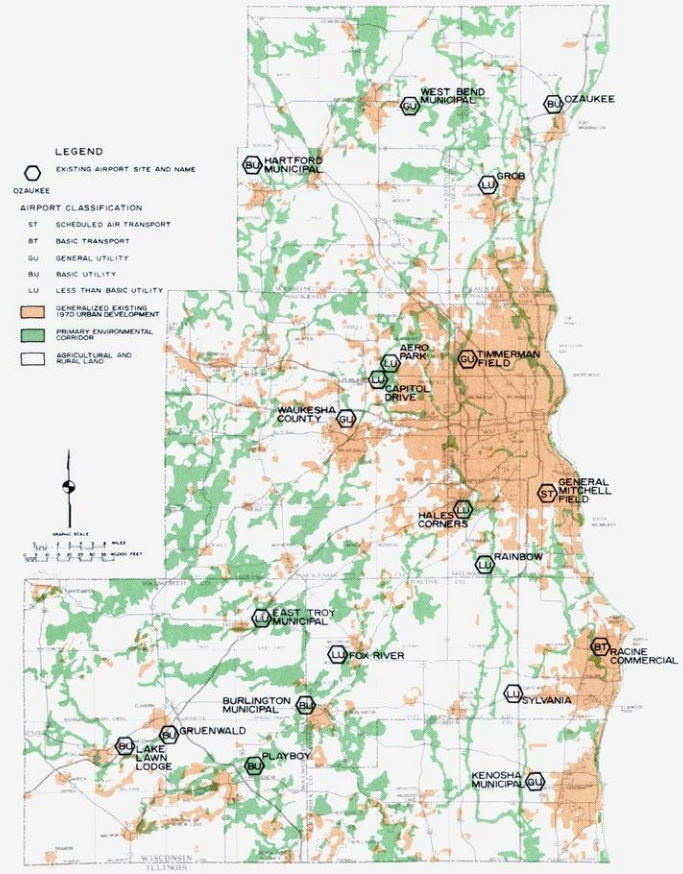
Source: SEWRPC.

transport-type aircraft—and 40 percent KC-97 aircraft—a piston engine cargo tanker transport-type aircraft with two auxiliary jet engines—based on interviews with U. S. Air Force operations personnel. All KC-97 operations were considered to be itinerant—that is, other than local operations—and were assumed to have the emission characteristics of nonmilitary piston transport class aircraft. The two auxiliary jet engines on the KC-97 were assumed to emit pollutants characteristic of military transport aircraft engines. Fifty percent of the C-130 operations were considered to be local, and an adjusted LTO based on actual operating conditions was used to develop the emission factors for these operations. The

[10] *Of a total of 46 publicly and privately owned airports within the Region in 1973, only 20 were considered in this study. These 20 airports account for 99 percent of all general, commercial, and military aviation operations within the Region. Moreover, of the general commercial and military aviation aircraft operating within the Region, approximately 92 percent is based at these 20 airports. Most of the 26 airports not considered in this study were small, privately owned, turf-surfaced landing strips at which only one single engine aircraft was usually based. Such airports supported only a very few local and itinerant operations per day. For more detailed information on all airports within the Region, see SEWRPC Planning Report No. 21, A Regional Airport System Plan for Southeastern Wisconsin.*

Map 48

SELECTED AIRPORTS IN THE REGION: 1973



The 20 airports indicated on the above map account for 99 percent of all general, commercial, and military aviation operations within the Region. Approximately 92 percent of the general, commercial, and military aviation aircraft operating within the Region is based at these 20 airports. Aircraft operations at these 20 airports contributed an estimated 60 tons of particulate matter, 56 tons of sulfur dioxide, 6,432 tons of carbon monoxide, 524 tons of nitrogen oxides, and 928 tons of hydrocarbons to the regional emissions burden in 1973.

Source: SEWRPC.

remaining 50 percent of the C-130 operations were considered to be itinerant, and the emissions from these operations were calculated using the emission factors shown in Table 134.

The pollutant emissions found to result from aircraft operations at each of the 20 selected airports in the Region during 1973 were assigned to the U. S. Public Land Survey quarter sections in which the individual airports were located. For those airports located in more than one quarter section, the pollutant emissions were assigned equally to all quarter sections encompassing the airport. Pollutant emissions from aircraft operations were also distributed uniformly by season, since an investigation of the monthly flight activity at General Mitchell Field indicated less than a 5 percent variance in the number of seasonal operations. A summary of the pollutant emissions from aircraft operations by county by season is presented in Table 135.

Emissions From Small Commercial-Institutional and Industrial Operations

Emissions from small commercial-institutional operations and from small industrial operations are discussed jointly since the procedures used to calculate the emissions from these sources are essentially the same. It should be noted that these sources were not included in the point source emissions inventory because they do not individually emit more than 10 tons per year of any pollutant species.

Small commercial establishments, institutions, and industries in the Region rely on four fuel types for process heat, space heating, and water heating: fuel oil or kerosene, natural gas, liquified petroleum gas, and coal or coke. With the exception of natural gas data, fuel use data are not directly available by county. Data on natural gas use for commercial-institutional combustion and for industrial combustion were provided by the Wisconsin Gas Company, the Wisconsin Natural Gas Company, and the Wisconsin Southern Gas Company for 1973 for counties within their respective service areas. State fuel sale totals for 1973 are available for fuel oil, liquified petroleum gas, and coal from the U. S. Department of the Interior, Bureau of Mines.[11]

The natural gas consumption by small industries and commercial and institutional establishments for each county in the Region in 1973 was estimated by subtracting the natural gas use quantified by county in the 1973 point source inventory for operations emitting more than 10 tons per year of any pollutant species from the county data on commercial-institutional and industrial consumption provided by the three natural gas suppliers. The residential use for each county was then subtracted from this difference, and the results were considered the natural gas available for consumption by these small operations by county.

State sales totals of liquified petroleum gas (LPG) as obtained from the Bureau of Mines are disaggregated into two categories: residential and commercial-institutional use, and industrial use. In order to establish the proportion of the residential and commercial fuel use category attributable to the commercial sector, the annual use of liquified petroleum gas for residential space heating and water heating purposes had to be estimated. This estimate was based on the number of housing units in each county of the State using LPG for space heating and the number of housing units using LPG for water heating, as determined from the U. S. Bureau of the

[11] *See the following U. S. Department of the Interior, Bureau of Mines, publications: Sales of Fuel Oil and Kerosene in 1973, Sales of Liquified Petroleum Gases and Ethane in 1973, and Bituminous Coal and Lignite Distribution-Calendar Year: 1973.*

Table 132

ESTIMATED AIRCRAFT OPERATIONS AT SELECTED AIRPORTS IN THE REGION BY AIRCRAFT TYPE: 1973

Airport	County	Number of Based Aircraft					Number of Annual Operations by Aircraft Type					Number of LTO's by Aircraft Type				
		Single Engine	Twin Engine	Turboprop	Turbojet	Total	Single Engine	Twin Engine	Turboprop	Turbojet	Total	Single Engine	Twin Engine	Turboprop	Turbojet	Total
Kenosha-Municipal	Kenosha	81	11	2	--	94	62,484	6,006	2,310	--	70,800	31,242	3,003	1,155	--	35,400
Aero Park	Waukesha	7	--	--	--	7	2,526	--	--	--	2,526	1,263	--	--	--	1,263
Capitol Drive	Waukesha	66	--	--	--	66	40,185	--	--	--	40,185	20,092	--	--	--	20,092
Hales Corners	Milwaukee	26	--	--	--	26	22,960	--	--	--	22,960	11,480	--	--	--	11,480
Timmerman	Milwaukee	155	29	--	--	184	145,566	15,834	--	--	161,400	72,783	7,917	--	--	80,700
Rainbow	Milwaukee	45	1	--	--	46	28,390	541	--	--	28,931	14,195	270	--	--	14,465
Grob	Ozaukee	11	--	--	--	11	3,674	--	--	--	3,674	1,837	--	--	--	1,837
Ozaukee	Ozaukee	4	--	--	--	4	3,950	--	--	--	3,950	1,975	--	--	--	1,975
Burlington-Municipal	Racine	34	5	--	--	39	6,270	2,730	--	--	9,000	3,135	1,365	--	--	4,500
Fox River	Racine	9	--	--	--	9	4,600	--	--	--	4,600	2,300	--	--	--	2,300
Racine-Commercial	Racine	23	12	3	1	39	28,388	6,552	3,465	595	39,000	14,194	3,276	1,732	298	19,500
Sylvania	Racine	42	2	--	--	44	12,318	1,082	--	--	13,400	6,159	541	--	--	6,700
East Troy-Municipal	Walworth	14	6	1	--	21	1,974	3,276	1,150	--	6,400	987	1,638	575	--	3,200
Gruenwald	Walworth	5	--	--	--	5	4,760	--	--	--	4,760	2,380	--	--	--	2,380
Lake Lawn Lodge	Walworth	2	--	--	--	2	1,600	--	--	--	1,600	800	--	--	--	800
Playboy	Walworth	4	5	--	--	9	3,670	2,730	--	--	6,400	1,835	1,365	--	--	3,200
Hartford-Municipal	Washington	57	4	--	--	61	62,516	2,184	--	--	64,700	31,258	1,092	--	--	32,350
West Bend-Municipal	Washington	62	12	1	--	75	92,298	6,552	1,150	--	100,000	46,149	3,276	575	--	50,000
Waukesha County	Waukesha	152	38	1	--	191	104,900	20,750	1,150	--	126,800	52,450	10,375	575	--	63,400
	Region	799	125	8	1	933	633,029	68,237	9,225	595	711,086	316,514	34,118	4,612	298	355,542

Source: SEWRPC.

Table 133

ESTIMATED AIRCRAFT OPERATIONS AT GENERAL MITCHELL FIELD BY AIRCRAFT TYPE: 1973

Aircraft Group	Number of Engines	Number of Operations	Number of LTO's
Common Air Carrier and Commuter			
Boeing 747	4	2,327	1,164
DC-10, L-1011	3	2,326	1,163
DC-8 Stretch	4	--	--
DC-8, Boeing 707, Boeing 720	4	6,205	3,103
DC-9, Boeing 727	2-3	40,332	20,166
CV-580, F-227	2	26,371	13,186
Subtotal	--	77,561	38,781
Air Taxi			
Turboprop	2	6,360	3,180
General Aviation			
Single Engine	1	118,518	59,259
Light Twin Engine	2	18,564	9,282
Heavy Twin Engine	2	5,164	2,584
Light Turboprop	2	5,775	2,888
Heavy Turboprop	2	3,810	1,905
Turbojet	2	4,165	2,082
Subtotal	--	155,996	78,000
Military			
KC-97	6	5,610	2,805
C-130	4	8,414	4,207
Subtotal	--	14,024	7,012
Total	--	253,941	126,973

Source: SEWRPC.

Census publication, Census of Housing: 1970. The heating demand for 1973 was estimated from the number of "heating degree-days" experienced in each county as reported by the National Weather Service. Total LPG consumption for residential space heating in the State was then calculated by multiplying the number of LPG housing units by an EPA-determined fuel use factor of 0.232 gallon of LPG per heating degree-day per housing unit. For residential water heaters the EPA-determined fuel use factor is 382 gallons of LPG per housing unit per year. When these totals were subtracted from the total amount of LPG sold in Wisconsin for residential and commercial-institutional consumption, the remaining value was assumed to be used solely by statewide commercial-institutional establishments during 1973. This remaining value was then apportioned among individual counties within the State on the basis of the county population to the total state population. The annual LPG use by large commercial and institutional facilities in each county of the Region, identified in the 1973 point source emissions inventory, was then subtracted from the above value for each county in the Region to yield the estimated LPG fuel use by small commercial and institutional establishments in the Region during 1973.

The total sales of LPG for industrial use in Wisconsin in 1973 were apportioned among the counties of the State on the basis of the ratio of manufacturing employees in each county to manufacturing employees in the State. The LPG fuel use by major industries in the Region was extracted from the 1973 point source emissions inventory by county and was subsequently subtracted from the county estimates apportioned from the statewide sales total.

Table 134

EMISSION FACTORS FOR AIRCRAFT OPERATIONS BY AIRCRAFT TYPE

Aircraft Group	Emission Factor (pounds per engine per LTO cycle)				
	Particulate Matter	Sulfur Oxides	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
Common Air Carrier					
Boeing 747	1.30	1.82	46.80	31.40	12.20
DC-10, L-1011	1.30	1.82	46.80	31.40	12.20
DC-8 Stretch	--	--	--	--	--
DC-8, Boeing 707, Boeing 720	1.21	1.56	47.40	7.90	41.20
DC-9, Boeing 727	0.41	1.01	17.00	10.20	4.90
CV-580, F-227	1.10	0.40	6.60	2.50	2.90
Air Taxi	0.20	0.18	3.10	1.20	1.10
Military					
KC-97 (Jet)	1.10	0.41	5.70	2.20	2.70
KC-97 (Piston)	0.56	0.28	304.00	0.40	40.70
C-130 (Itinerant)	1.10	0.41	5.70	2.20	2.70
C-130 (Local)[a]	0.57	0.24	2.20	1.91	0.82
General Aviation					
Single Engine	0.02	0.014	12.20	0.047	0.40
Light Twin Engine	0.02	0.014	12.20	0.047	0.40
Heavy Twin Engine	0.28	0.14	152.00	0.20	20.40
Light Turboprop	0.20	0.18	3.10	1.20	1.10
Heavy Turboprop	1.10	0.40	6.60	2.50	2.90
Turbojet	0.11	0.37	15.80	1.60	3.60

[a] *LTO cycle includes 7.0-minute taxi time, 0.5-minute takeoff, 2.5-minute climb, and 4.5-minute approach based on observations and analysis of actual operations conducted at General Mitchell Field.*

Source: U. S. Environmental Protection Agency and SEWRPC.

The total sales of distillate oil and kerosene in Wisconsin in 1973 for commercial-institutional use were apportioned among the counties in the State, and, thereby, among the seven counties in the Region, following the same procedure as outlined above for LPG. However, data on fuel oil consumption by small industrial operations were disaggregated into two categories: distillate fuel oil sales and residual fuel oil sales. Each fuel oil type was allocated among the counties of the State, and thereby the Region, on the basis of the ratio of manufacturing employees in the county to the total number of manufacturing employees in the State. Again, the distillate fuel oil and the residual fuel oil consumed by major industries in the Region were subtracted from the apportioned county totals.

The total sales of coal in Wisconsin in 1973 for commercial-institutional and industrial use were also apportioned among the counties in the State. The total coal used by all major point sources in the State was first subtracted from the total sales, and the coal used for residential fuel consumption was then subtracted to yield the total state sales of coal to small commercial-institutional and industrial operations. Except for Milwaukee County, where actual coal consumption for commercial-institutional and industrial use was determined from an inventory of all coal suppliers, the state coal sales were apportioned to counties within the State, and thus the Region, on the basis of the ratio of county population to the total state population.

The estimated amount of natural gas, liquified petroleum gas, fuel oil, and coal used by small commercial-institutional operations in the Region during 1973 is presented by county and by season in Table 136. The seasonal allocation factor for commercial-institutional fuel use is based on two assumptions: that approximately 25 percent of the annual consumption is attributable to water heating and other nonspace heating uses, which are distributed evenly throughout the year, and that 75 percent of the consumption is attributable to space heating uses, which vary according to the annual distribution of heating degree-days.[12] Commercial-institutional fuel use was apportioned among U. S. Public Land Survey

[12] *Assumptions pertaining to the relative use of fuel for either space heating, water heating, or process use were determined from data provided by the natural gas utilities serving the Southeastern Wisconsin Region.*

Table 135

SUMMARY OF AIRCRAFT EMISSIONS BY COUNTY BY SEASON: 1973

County	Season	Emissions (tons)				
		Particulate Matter	Sulfur Dioxide	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
Kenosha	Winter	-- [a]	-- [a]	59	1	2
	Spring	-- [a]	-- [a]	59	1	2
	Summer	-- [a]	-- [a]	59	1	2
	Fall	-- [a]	-- [a]	59	1	2
	Annual	-- [a]	-- [a]	236	4	8
Milwaukee	Winter	15	14	1,192	127	217
	Spring	15	14	1,192	127	217
	Summer	15	14	1,192	127	217
	Fall	15	14	1,192	127	217
	Annual	60	56	4,768	508	868
Ozaukee	Winter	-- [a]	-- [a]	3	-- [a]	-- [a]
	Spring	-- [a]	-- [a]	3	-- [a]	-- [a]
	Summer	-- [a]	-- [a]	3	-- [a]	-- [a]
	Fall	-- [a]	-- [a]	3	-- [a]	-- [a]
	Annual	-- [a]	-- [a]	12	-- [a]	-- [a]
Racine	Winter	-- [a]	-- [a]	58	1	3
	Spring	-- [a]	-- [a]	58	1	3
	Summer	-- [a]	-- [a]	58	1	3
	Fall	-- [a]	-- [a]	58	1	3
	Annual	-- [a]	-- [a]	232	4	12
Walworth	Winter	-- [a]	-- [a]	19	-- [a]	1
	Spring	-- [a]	-- [a]	19	-- [a]	1
	Summer	-- [a]	-- [a]	19	-- [a]	1
	Fall	-- [a]	-- [a]	19	-- [a]	1
	Annual	-- [a]	-- [a]	76	-- [a]	4
Washington	Winter	-- [a]	-- [a]	132	1	4
	Spring	-- [a]	-- [a]	132	1	4
	Summer	-- [a]	-- [a]	132	1	4
	Fall	-- [a]	-- [a]	132	1	4
	Annual	-- [a]	-- [a]	528	4	16
Waukesha	Winter	-- [a]	-- [a]	145	1	5
	Spring	-- [a]	-- [a]	145	1	5
	Summer	-- [a]	-- [a]	145	1	5
	Fall	-- [a]	-- [a]	145	1	5
	Annual	-- [a]	-- [a]	580	4	20
Region	Winter	15	14	1,608	131	232
	Spring	15	14	1,608	131	232
	Summer	15	14	1,608	131	232
	Fall	15	14	1,608	131	232
	Annual	60	56	6,432	524	928

[a] *Less than one-half ton.*

Source: SEWRPC.

Table 136

ESTIMATED TOTAL FUEL CONSUMPTION BY SMALL COMMERCIAL-INSTITUTIONAL OPERATIONS IN THE REGION BY COUNTY BY SEASON: 1973

County	Season	Fuel Type				
		Natural Gas (cubic feet)	Coal (tons)	LPG Propane (gallons)	Residual Fuel Oil (gallons)	Distillate Fuel Oil (gallons)
Kenosha	Winter	818,070,300	3,948	1,811,300	453,330	4,330,718
	Spring	629,810,000	2,057	943,597	236,162	2,256,088
	Summer	181,933,900	24	10,842	2,714	25,923
	Fall	209,719,000	1,357	622,401	155,774	1,488,127
	Annual	1,839,533,200	7,386	3,388,140	847,980	8,100,856
Milwaukee	Winter	2,456,705,200	19,025	13,886,629	3,435,436	32,261,381
	Spring	1,845,594,600	9,911	7,234,243	1,789,691	16,806,574
	Summer	561,413,500	114	83,122	20,564	193,110
	Fall	806,761,300	6,538	4,771,743	1,180,489	11,085,701
	Annual	5,670,474,600	35,588	25,975,737	6,426,180	60,346,766
Ozaukee	Winter	161,760,300	1,316	603,767	151,110	1,443,573
	Spring	124,085,400	686	314,532	78,721	752,030
	Summer	36,914,800	8	3,614	905	8,641
	Fall	57,314,800	452	207,467	51,925	496,043
	Annual	380,075,300	2,462	1,129,380	282,661	2,700,287
Racine	Winter	1,244,208,100	5,072	2,415,066	604,440	5,774,291
	Spring	932,578,600	2,642	1,258,129	314,883	3,008,118
	Summer	274,729,500	30	14,456	3,618	34,564
	Fall	323,511,900	1,743	829,868	207,699	1,984,170
	Annual	2,775,028,100	9,487	4,517,519	1,130,640	10,801,143
Walworth	Winter	367,940,800	1,316	603,767	151,110	1,385,836
	Spring	264,570,600	686	314,532	78,721	721,952
	Summer	81,262,400	8	3,614	905	8,295
	Fall	115,717,000	452	207,467	51,925	476,203
	Annual	829,490,800	2,462	1,129,380	282,661	2,592,286
Washington	Winter	191,453,700	2,632	1,207,533	302,220	2,887,145
	Spring	145,154,400	1,371	629,065	157,442	393,604
	Summer	39,861,700	16	7,228	1,809	4,523
	Fall	63,788,400	904	414,934	103,849	259,623
	Annual	440,258,200	4,923	2,258,760	565,320	3,544,895
Waukesha	Winter	1,645,226,500	6,580	3,018,832	755,550	7,217,863
	Spring	1,065,570,400	3,428	1,572,651	393,604	3,760,148
	Summer	318,606,400	40	18,070	4,523	43,205
	Fall	416,878,500	2,261	1,037,336	259,623	2,480,212
	Annual	3,446,281,800	12,309	5,646,899	1,413,300	13,501,428
Region	Winter	6,885,364,900	39,889	23,546,894	5,853,196	55,300,807
	Spring	5,007,364,000	20,781	12,266,749	3,049,224	27,698,514
	Summer	1,494,722,200	240	140,946	35,038	318,261
	Fall	1,993,690,900	13,707	8,091,216	2,011,284	18,270,079
	Annual	15,381,142,000	74,617	44,045,805	10,948,742	101,587,661

Source: SEWRPC.

quarter sections in each county on the basis of the ratio of commercial and institutional land area in the individual quarter sections to the county total.

The estimated amount of natural gas, liquified petroleum gas, fuel oil, and coal used by small industrial operations in the Region during 1973 is presented in Table 137 by county by season. The seasonal distribution of industrial fuel use is based on the assumption that 10 percent of the annual consumption is attributable to space heating, distributed according to the heating degree-days throughout the year, and that 90 percent is attributable to fuel consumed for industrial processes, which is allocated equally throughout the year. Industrial fuel consumption was allocated among U. S. Public Land Survey quarter sections in each county on the basis of the ratio of manufacturing land area within the individual quarter sections to the county total.

Air pollutant emissions from both small commercial-institutional operations and small industrial operations were calculated by multiplying the estimated fuel consumption by quarter section by season by the EPA-determined emission factors shown in Table 138. The total pollutant emissions from small commercial-institutional operations and from small industrial operations in the Region in 1973 are shown in Tables 139 and 140, respectively, by county by season.

Table 137

ESTIMATED TOTAL INDUSTRIAL FUEL CONSUMPTION: 1973

County	Season	Fuel Type				
		Natural Gas (cubic feet)	Residual Fuel Oil (gallons)	Distillate Fuel Oil (gallons)	LPG Propane (gallons)	LPG Butane (gallons)
Kenosha	Winter	276,751,176	49,128	113,531	--	31,991
	Spring	286,294,320	32,160	74,319	--	20,941
	Summer	190,862,880	45,477	105,094	--	29,613
	Fall	200,406,024	36,235	83,736	--	23,595
	Annual	954,314,400	163,000	376,680	--	106,140
Milwaukee	Winter	6,799,947,104	632,398	1,296,388	1,973,832	318,628
	Spring	6,162,452,063	413,975	848,631	1,292,094	208,578
	Summer	4,037,468,593	585,398	1,200,040	1,827,138	294,948
	Fall	4,249,966,940	466,430	956,161	1,455,816	235,007
	Annual	21,249,834,700	2,098,201	4,301,220	6,548,880	1,057,161
Ozaukee	Winter	365,356,860	165,830	122,284	220,770	21,327
	Spring	333,119,490	108,555	80,049	144,518	13,961
	Summer	150,441,060	153,506	113,196	204,362	19,742
	Fall	225,661,590	122,310	90,192	162,830	15,730
	Annual	1,074,579,000	550,201	405,721	732,480	70,760
Racine	Winter	520,460,950	271,441	121,512	405,275	63,981
	Spring	474,537,925	177,688	79,544	265,298	41,883
	Summer	244,922,800	251,267	112,482	375,155	59,226
	Fall	290,845,825	200,203	89,623	298,914	47,190
	Annual	1,530,767,500	900,599	403,161	1,344,642	212,280
Walworth	Winter	333,392,476	45,240	61,142	110,385	10,664
	Spring	311,883,284	29,615	40,024	72,259	6,981
	Summer	193,582,728	41,878	56,598	102,181	9,871
	Fall	236,601,112	33,367	45,096	81,415	7,865
	Annual	1,075,459,600	150,100	202,860	366,240	35,381
Washington	Winter	490,780,728	165,830	76,471	220,770	21,327
	Spring	340,819,950	108,555	50,059	144,518	13,961
	Summer	204,491,970	153,506	70,788	204,362	19,742
	Fall	327,187,152	122,310	56,402	162,830	15,730
	Annual	1,363,279,800	550,201	253,720	732,480	70,760
Waukesha	Winter	909,849,765	125,503	139,982	436,415	42,654
	Spring	827,136,150	82,156	91,634	285,683	27,922
	Summer	468,710,485	116,176	129,579	403,981	39,484
	Fall	551,424,100	92,566	103,245	321,882	31,460
	Annual	2,757,120,500	416,401	464,440	1,447,961	141,520
Region	Winter	9,696,539,059	1,455,370	1,931,310	3,367,447	510,572
	Spring	8,736,243,182	952,704	1,264,260	2,204,370	334,227
	Summer	5,490,480,516	1,347,208	1,787,777	3,117,179	472,626
	Fall	6,082,092,743	1,073,421	1,424,455	2,483,687	376,577
	Annual	30,005,355,500	4,828,703	6,407,802	11,172,683	1,694,002

Source: SEWRPC.

Emissions From Dry Cleaning Operations

Certain clothing and textile articles may be cleaned only by treating them with organic solvents in a process referred to as dry cleaning. Organic solvents are usually a by-product of petroleum, which is a complex mixture of hydrocarbons. The dry cleaning process involves the agitation of clothing in a solvent bath followed by a rinsing with clean solvent and drying with warm air. Drying causes the solvent to vaporize. As a consequence, hydrocarbon compounds are released into the ambient air through evaporation.

According to a dry cleaning plant survey conducted by the Michigan Department of Health in 1965, about 18 pounds of clothes per person are dry-cleaned per year in moderate climates, and about 25 pounds per person are dry-cleaned per year in colder areas. Based on this information and on the average rate of solvent use per pound of clothing, the EPA has determined that approximately 2.0 pounds of evaporative hydrocarbon emissions per person are released per year into the atmosphere in moderate climatic areas, and that about 2.7 pounds per person are released per year in colder climates.

Evaporative hydrocarbon emissions from dry cleaning operations in the Southeastern Wisconsin Region during 1973 were determined by multiplying the estimated 1973 county populations by the factor 2.7 pounds per person. The total hydrocarbon emissions from dry cleaning operations during 1973 by county by season are presented in Table 141. These emissions were distributed among U. S. Public Land Survey quarter sections in each county on the basis of the ratio of commercial land area in a quarter section to the total county commercial land area as determined from the Commission's 1970 regional land use inventory.

Emissions From Forest Wildfires

A forest wildfire is a large-scale combustion process that consumes various ages, sizes, and types of botanical specimens growing outdoors in a defined geographical area. The occurrence, size, and intensity of a forest wildfire is dependent on such variables as meteorological conditions, the species of trees and brush and their moisture content, and the weight of consumable fuel per unit of land. Forest wildfires are intermittent, generally short-term, sources of emissions rather than continuous emitters, but have the potential to produce large quantities of pollutants for several hours or even days.

The Counties of Kenosha, Ozaukee, Racine, Walworth, Washington, and Waukesha are outside of the organized fire protection and control areas of the Wisconsin Department of Natural Resources. Milwaukee County, however, does have a state office of fire control. In the counties without an organized program, the wildfire problem has not been severe enough to justify the establishment of such a program, and the responsibility for the suppression of wildfires is carried by the local municipalities with state assistance. As a result, data collection on wildfires in these counties is of a general nature, with no finer spatial resolution available than a summary of the number of fires and the acreage burned in each county. Table 142 lists the number of forest wildfires in each county of the Region in 1973, along with the total acreage burned.

In addition to the number of acres burned, an important factor in determining pollutant emissions from forest wildfires is the mass of forest fuel per unit of land area burned, termed the fuel loading factor. Estimates provided by the Fire Management Office of the U. S. Forest Service have indicated that, given the relative scarcity of densely forested areas within the Region, only about three tons of material, mostly scrub and brush, would be consumed per acre of land burned.

Table 138

EMISSION FACTORS FOR COMMERCIAL-INSTITUTIONAL AND INDUSTRIAL FUEL USE: 1973

Fuel Type	Emission Factor (grams)				
	Particulate Matter	Sulfur Oxides	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
Commercial-Institutional					
Natural Gas (per cubic foot)	0.00454	0.0002724	0.01	0.05	0.003632
Residual Oil (per gallon)	10.442	71.278	1.816	27.240	1.362
Distillate Oil (per gallon)	6.810	64.468	1.816	27.240	1.362
LPG Propane (per gallon)	0.82	0.0004086	0.86	4.994	0.32
LPG Butane (per gallon)	0.86	0.0004086	0.91	5.45	0.36
Coal (per ton)	7,945.00	25,878.00	22,700.00	2,043.00	5,221.00
Industrial					
Natural Gas (per cubic foot)	0.00454	0.0002724	0.01	0.08	0.001362
Residual Oil (per gallon)	10.442	71.278	1.816	27.240	1.362
Distillate Oil (per gallon)	6.810	64.468	1.816	27.240	1.362
LPG Propane (per gallon)	0.77	0.0004086	0.68	5.08	0.14
LPG Butane (per gallon)	0.82	0.0004086	0.73	5.49	0.14
Coal (per ton)	44,265.00	25,878.00	908.00	6,810.00	454.00

Source: U. S. Environmental Protection Agency and SEWRPC.

The emission factors for forest wildfires are presented in Table 143. Based on these emission rates, a fuel loading factor of three tons per acre, and the number of acres burned in each county, the amount of pollutants emitted from forest wildfires in the Region were calculated for 1973. In the absence of specific information on the temporal occurrence of wildfires in the Region, emissions were seasonally allocated on the basis of the number of forest wildfires within the entire State by season, as shown in Table 144.

Total pollutant emissions from forest wildfires are presented in Table 145 by county by season for 1973. Since the exact location of the forest wildfires could not be identified, these emissions were allocated among U. S. Public Land Survey quarter sections in each county of the Region according to the percentage of total woodlands in the county within each quarter section, as determined from the Commission's 1970 land use inventory. Based on trends in land use changes as derived from land use inventories conducted by the Commission in 1963, 1967, and 1970, it was assumed that no significant change in county woodland areas occurred between 1970 and 1973.

Emissions From Gasoline Marketing

Emissions from gasoline marketing are those emissions that result from the evaporation of hydrocarbon compounds during the filling of service station storage tanks and motor vehicle gasoline tanks. The quantity of evaporative hydrocarbon losses is directly dependent on the amount of gasoline loaded into such tanks. Data on gasoline sales are not available by county, but the Wisconsin Department of Revenue does report state totals of gasoline sales which, in 1973, amounted to approximately 2.2 billion gallons. This statewide gasoline sales volume was allocated among the individual counties in the Southeastern Wisconsin Region on the basis of vehicle miles of travel. Table 146 sets forth the estimated gasoline consumption by county for 1973 as determined by this allocation.

Evaporative hydrocarbon emission factors for gasoline marketing operations are shown in Table 147. As may be seen in this table, the quantity of hydrocarbons released to the atmosphere during the loading of service station storage tanks depends on the method used to fill such tanks. The "splash" loading method involves the direct discharge of gasoline into the upper part of an underground tank through a short filler spout. This freefall of liquid encourages both evaporation and entrainment loss caused by the formation of gasoline droplets which are expelled through the vapor vent line. Lower hydrocarbon emissions are achieved with the "submerged" loading method because the gasoline is delivered directly to the bottom of the storage tank through a tightly connected pipe without splashing. Inventory records maintained by the Wisconsin Department of Natural Resources indicate that 79 percent of the service station tanks in Milwaukee County were splash filled and 21 percent were submerged filled. Since similar data were not available for the other six counties in the Region, a "worst case" assumption of 100 percent splash fill method was used to maximize the emissions.

The total evaporative hydrocarbon emissions released from gasoline marketing operations in the Region during 1973 are presented in Table 148 by county by season. These emissions were allocated among U. S. Public Land Survey quarter sections in each county on the basis of the ratio of the number of gasoline service stations within the quarter section to the total number of service stations

Table 139

SUMMARY OF POLLUTANT EMISSIONS FROM SMALL COMMERCIAL-INSTITUTIONAL OPERATIONS BY COUNTY BY SEASON: 1973

County	Season	Emissions (tons)				
		Particulate Matter	Sulfur Dioxide	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
Kenosha	Winter	68	396	105	186	30
	Spring	41	232	63	117	18
	Summer	10	55	15	30	4
	Fall	29	171	44	73	12
	Annual	148	854	227	406	64
Milwaukee	Winter	412	2,693	513	1,168	156
	Spring	243	1,577	305	706	93
	Summer	59	377	74	176	23
	Fall	177	1,164	219	491	66
	Annual	891	5,811	1,111	2,541	338
Ozaukee	Winter	22	132	34	56	10
	Spring	13	77	20	34	6
	Summer	3	19	5	9	1
	Fall	10	57	14	24	4
	Annual	48	285	73	123	21
Racine	Winter	90	523	137	256	39
	Spring	54	306	82	161	24
	Summer	13	73	20	41	6
	Fall	38	226	57	99	16
	Annual	195	1,128	296	557	85
Walworth	Winter	23	128	36	66	10
	Spring	14	75	22	41	6
	Summer	3	18	5	11	2
	Fall	10	55	15	26	4
	Annual	50	276	78	144	22
Washington	Winter	44	264	66	105	18
	Spring	26	154	39	63	11
	Summer	6	37	9	15	3
	Fall	19	114	28	44	8
	Annual	95	569	142	227	40
Waukesha	Winter	115	659	177	326	51
	Spring	68	386	105	196	30
	Summer	17	92	26	50	8
	Fall	48	285	73	125	21
	Annual	248	1,422	381	697	110
Region	Winter	774	4,795	1,068	2,163	314
	Spring	459	2,807	636	1,318	188
	Summer	111	671	154	332	47
	Fall	331	2,072	450	882	131
	Annual	1,675	10,345	2,308	4,695	680

Source: SEWRPC.

Table 140

SUMMARY OF POLLUTANT EMISSIONS FROM SMALL INDUSTRIAL OPERATIONS BY COUNTY BY SEASON: 1973

County	Season	Emissions (tons)				
		Particulate Matter	Sulfur Dioxide	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
Kenosha	Winter	3	11	3	29	1
	Spring	3	10	4	30	1
	Summer	2	9	2	21	-[a]
	Fall	2	10	3	22	1
	Annual	10	40	12	102	3
Milwaukee	Winter	52	133	80	665	13
	Spring	47	121	73	603	12
	Summer	34	107	49	409	9
	Fall	37	116	51	432	9
	Annual	170	477	253	2,109	43
Ozaukee	Winter	5	20	5	42	1
	Spring	4	18	4	38	1
	Summer	3	16	2	21	1
	Fall	4	18	3	28	1
	Annual	16	72	14	129	4
Racine	Winter	7	28	7	60	1
	Spring	6	25	6	54	1
	Summer	5	23	4	32	1
	Fall	5	24	4	37	1
	Annual	23	100	21	183	4
Walworth	Winter	3	7	4	33	1
	Spring	3	7	4	31	1
	Summer	2	6	2	20	-[a]
	Fall	2	7	3	24	1
	Annual	10	27	13	108	3
Washington	Winter	5	17	6	51	1
	Spring	4	16	4	37	1
	Summer	3	14	3	25	1
	Fall	4	15	4	36	1
	Annual	16	62	17	149	4
Waukesha	Winter	7	19	11	90	2
	Spring	7	17	10	82	2
	Summer	5	15	6	50	1
	Fall	5	16	7	57	1
	Annual	24	67	34	279	6
Region	Winter	82	235	116	970	20
	Spring	74	214	105	875	19
	Summer	54	190	68	578	13
	Fall	59	206	75	636	15
	Annual	269	845	364	3,059	67

[a] *Less than one-half ton.*

Source: SEWRPC.

within the county. The locations of gasoline service stations within the Region in operation during 1973 were identified from data provided by the Wisconsin Department of Revenue.

Emissions From General Utility Engines

The category of general utility engines includes those pollutant emissions that are produced by small 2-stroke and 4-stroke, air-cooled, gasoline-powered motors used in lawnmowers, snowthrowers, small electric generators, compressors, pumps, minibikes, and garden tractors. Of the more than 44 million engines of this type in service in the United States, approximately 89 percent are used in lawn and garden applications.

Since specific data concerning the sales and applications of the various types of general utility engines in the Region are not available, two major assumptions were made regarding the operation of such equipment. First, it was assumed that every residential building in the

Table 141

SUMMARY OF HYDROCARBON EMISSIONS FROM DRY CLEANING OPERATIONS BY COUNTY BY SEASON: 1973

County	Season	Hydrocarbon Emissions (tons)
Kenosha	Winter	41
	Spring	41
	Summer	41
	Fall	41
	Annual	164
Milwaukee	Winter	352
	Spring	352
	Summer	352
	Fall	352
	Annual	1,408
Ozaukee	Winter	20
	Spring	20
	Summer	20
	Fall	20
	Annual	80
Racine	Winter	59
	Spring	59
	Summer	59
	Fall	59
	Annual	236
Walworth	Winter	22
	Spring	22
	Summer	22
	Fall	22
	Annual	88
Washington	Winter	24
	Spring	24
	Summer	24
	Fall	24
	Annual	96
Waukesha	Winter	84
	Spring	84
	Summer	84
	Fall	84
	Annual	336
Region	Winter	602
	Spring	602
	Summer	602
	Fall	602
	Annual	2,408

Source: SEWRPC.

Table 142

SUMMARY OF FOREST WILDFIRES IN THE REGION BY COUNTY: 1973

County	Number of Fires	Total Acreage Burned
Kenosha	89	306
Milwaukee	--	--
Ozaukee	23	39
Racine	75	79
Walworth	46	48
Washington	52	168
Waukesha	85	230
Region	370	870

Source: Wisconsin Department of Natural Resources, Wisconsin 1973 Forest Fire Report.

Table 143

EMISSION FACTORS FOR FOREST WILDFIRES

Pollutant	Emission Factor (pounds per ton forest material consumed)
Particulate Matter	17
Sulfur Oxides	Negligible
Carbon Monoxide	140
Nitrogen Oxides	4
Hydrocarbons	24

Source: U. S. Environmental Protection Agency.

Table 144

STATEWIDE SEASONAL ALLOCATION FACTORS FOR FOREST WILDFIRES

Season	Factor (percent)
Winter	--
Spring	60
Summer	23
Fall	17

Source: Wisconsin Department of Natural Resources.

Table 145

SUMMARY OF POLLUTANT EMISSIONS FROM FOREST WILDFIRES BY COUNTY BY SEASON: 1973

County	Season	Emissions (tons)				
		Particulate Matter	Sulfur Dioxide	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
Kenosha	Winter	--	--	--	--	--
	Spring	5	--	39	1	7
	Summer	2	--	15	--[a]	3
	Fall	1	--	11	--[a]	2
	Annual	8	--	65	1	12
Milwaukee	Winter	--	--	--	--	--
	Spring	--[a]	--	2	--[a]	--[a]
	Summer	--[a]	--	1	--[a]	--[a]
	Fall	--[a]	--	1	--[a]	--[a]
	Annual	--[a]	--	4	--[a]	--[a]
Ozaukee	Winter	--	--	--	--	--
	Spring	1	--	2	--[a]	--[a]
	Summer	--[a]	--	1	--[a]	--[a]
	Fall	--[a]	--	--[a]	--[a]	--[a]
	Annual	1	--	3	--[a]	--[a]
Racine	Winter	--	--	--	--	--
	Spring	1	--	8	--[a]	1
	Summer	--[a]	--	3	--[a]	1
	Fall	--[a]	--	2	--[a]	--[a]
	Annual	1	--	13	--[a]	2
Walworth	Winter	--	--	--	--	--
	Spring	1	--	6	--[a]	1
	Summer	--[a]	--	2	--[a]	--[a]
	Fall	--[a]	--	2	--[a]	--[a]
	Annual	1	--	10	--[a]	1
Washington	Winter	--	--	--	--	--
	Spring	3	--	21	1	4
	Summer	1	--	8	--[a]	1
	Fall	1	--	6	--[a]	1
	Annual	5	--	35	1	6
Waukesha	Winter	--	--	--	--	--
	Spring	4	--	29	1	5
	Summer	1	--	11	--[a]	2
	Fall	1	--	8	--[a]	1
	Annual	6	--	48	1	8
Region	Winter	--	--	--	--	--
	Spring	15	--	107	3	18
	Summer	4	--	41	--[a]	7
	Fall	3	--	30	--[a]	4
	Annual	22	--	178	3	29

[a] *Less than one-half ton.*

Source: SEWRPC.

Table 146

ESTIMATED GASOLINE CONSUMPTION IN THE REGION BY COUNTY: 1973

County	Gasoline Consumed (gallons)
Kenosha	42,331,772
Milwaukee	322,075,760
Ozaukee	19,827,443
Racine	50,404,398
Walworth	30,367,094
Washington	22,540,062
Waukesha	98,790,621
Region	586,337,150

Source: Wisconsin Department of Revenue.

Table 147

EVAPORATIVE HYDROCARBON EMISSION FACTORS FOR GASOLINE MARKETING IN THE REGION: 1973

Emission Source	Emission Factor (pounds per 1,000 gallons)	
	Milwaukee County	All Other Counties
Underground Tank Filling	10.6[a]	11.5[b]
Underground Tank Breathing	1.0	1.0
Vehicle Refueling Displacement Losses (uncontrolled)	9.0	9.0
Vehicle Refueling Spillage	0.7	0.7
Total	21.3	22.2

[a] *Assumes 79 percent splash fill and 21 percent submerged fill.*

[b] *Assumes 100 percent splash fill.*

Source: U. S. Environmental Protection Agency and SEWRPC.

Region would operate at least one type of general utility engine for lawn and garden applications and that approximately 11 percent of the residential buildings would operate an additional engine for miscellaneous purposes. Second, it was assumed that the smaller 2-stroke engines would be used in urban areas while the larger 4-stroke engines would be used in the rural areas of the Region. The EPA-determined emission factors for general utility engines, as contained in AP-42, Compilation of Air Pollutant Emission Factors, were modified to reflect these assumptions. The resulting composite emission factors are presented in Table 149.

The number of residential buildings within each U. S. Public Land Survey quarter section in the Region was determined as a part of the residential fuel use emissions inventory. All quarter sections lying within cities or villages were identified as urban, and all quarter sections lying within towns were identified as rural. The appropriate emission factor was then multiplied by the number of residential buildings in each quarter section to obtain the estimated pollutant emissions from general utility engines. These emissions were seasonally allocated, based on a telephone survey of lawn and garden implement dealers in the Region, as follows: 60 percent to

Table 148

SUMMARY OF EVAPORATIVE HYDROCARBON EMISSIONS FROM GASOLINE MARKETING BY COUNTY BY SEASON: 1973

County	Season	Hydrocarbon Emissions (tons)
Kenosha	Winter	118
	Spring	118
	Summer	118
	Fall	118
	Annual	472
Milwaukee	Winter	858
	Spring	858
	Summer	858
	Fall	858
	Annual	3,432
Ozaukee	Winter	55
	Spring	55
	Summer	55
	Fall	55
	Annual	220
Racine	Winter	140
	Spring	140
	Summer	140
	Fall	140
	Annual	560
Walworth	Winter	84
	Spring	84
	Summer	84
	Fall	84
	Annual	336
Washington	Winter	63
	Spring	63
	Summer	63
	Fall	63
	Annual	252
Waukesha	Winter	274
	Spring	274
	Summer	274
	Fall	274
	Annual	1,096
Region	Winter	1,592
	Spring	1,592
	Summer	1,592
	Fall	1,592
	Annual	6,368

Source: SEWRPC.

the summer season, 20 percent to the spring season, and 10 percent to both the fall and winter seasons. The estimated pollutant emissions resulting from the operation of general utility engines in the Region are presented by county by season in Table 150.

Table 149

EMISSION FACTORS FOR GENERAL UTILITY ENGINES

Engine Type	Emission Factor (grams per unit per year)				
	Particulate Matter	Sulfur Oxides	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
Urban Lawn and Garden 2-Stroke	470	38	33,400	108	14,813
Rural Lawn and Garden 4-Stroke	31	26	19,100	217	1,703
Urban and Rural Miscellaneous 4-Stroke	34	30	19,300	384	1,460
Urban Utility 2-Stroke	473.74	41.30	35,523	150.24	14,973.60
Rural Utility 4-Stroke	34.74	29.30	21,223	259.24	1,863.60

Source: U. S. Environmental Protection Agency.

Emissions From Incinerators

The quantity of air pollutant emissions generated by the disposal of solid waste in incinerators depends on the amount of material burned and the design of the incinerator. For the purpose of the area source emissions inventory, incinerators are classified into two categories: commercial-industrial and residential. Municipal incinerators were included in the point source emissions inventory.

In 1973 Milwaukee County published the results of an inventory of solid waste disposal practices in the County, including a summary of all the residential and commercial-industrial incinerators installed between 1948 and 1972.[13] Included in this summary is a detailed breakdown of the number of incinerators installed by year by category and by rated capacity in pounds per hour. [14] These data were updated to 1973 by the Wisconsin Department of Natural Resources and are presented in Table 151 along with an estimate of the total tons of refuse burned by incinerator type. The emission factors corresponding to the incinerator types shown in Table 151, as determined by the EPA, are presented in Table 152. The total air pollutant emissions released from residential and commercial-industrial incinerators in Milwaukee County were calculated using the total tons of refuse burned from Table 151 and the emission factors from Table 152.

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[13] *Milwaukee County Department of Air Pollution Control, 1973 Solid Waste Disposal Inventory-Milwaukee County, September 1973.*

[14] *Milwaukee County implemented its commercial and domestic incinerator permit program in August 1965. Prior to that time, only a plan review and approval was required for commercial incinerators, and domestic incinerators were not reviewed at all.*

Table 150

SUMMARY OF POLLUTANT EMISSIONS FROM GENERAL UTILITY ENGINES BY COUNTY BY SEASON: 1973

County	Season	Emissions (tons)				
		Particulate Matter	Sulfur Dioxide	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
Kenosha	Winter	1	--[a]	106	1	37
	Spring	2	--[a]	213	1	73
	Summer	7	--[a]	638	4	220
	Fall	1	--[a]	106	1	37
	Annual	11	--[a]	1,063	7	367
Milwaukee	Winter	12	1	865	4	365
	Spring	23	2	1,731	7	730
	Summer	70	6	5,192	22	2,189
	Fall	12	1	865	4	365
	Annual	117	10	8,653	37	3,649
Ozaukee	Winter	1	--[a]	47	--[a]	17
	Spring	1	--[a]	94	1	34
	Summer	3	--[a]	283	2	100
	Fall	1	--[a]	47	--[a]	17
	Annual	6	--[a]	471	3	168
Racine	Winter	2	--[a]	143	1	48
	Spring	3	--[a]	285	2	96
	Summer	9	1	856	5	288
	Fall	2	--[a]	143	1	48
	Annual	16	1	1,427	9	480
Walworth	Winter	1	--[a]	59	--[a]	17
	Spring	1	--[a]	117	1	33
	Summer	3	--[a]	352	3	99
	Fall	1	--[a]	59	--[a]	17
	Annual	6	--[a]	587	4	166
Washington	Winter	--[a]	--[a]	49	--[a]	14
	Spring	1	--[a]	98	1	29
	Summer	3	--[a]	293	2	86
	Fall	--[a]	--[a]	49	--[a]	14
	Annual	4	--[a]	489	3	143
Waukesha	Winter	2	--[a]	198	1	72
	Spring	5	1	396	2	144
	Summer	13	1	1,188	7	432
	Fall	2	--[a]	198	1	72
	Annual	22	2	1,980	11	720
Region	Winter	19	1	1,467	7	570
	Spring	36	3	2,934	15	1,139
	Summer	108	8	8,802	45	3,414
	Fall	19	--[a]	1,467	7	570
	Annual	182	12	14,670	74	5,693

[a] *Less than one-half ton.*

Source: SEWRPC.

Since local data on solid waste incinerators were not available for the other six counties in the Region, it was assumed that the pollutant emissions from domestic incinerators would be produced in proportion to the ratio of the county population to the Milwaukee County population. Similarly, it was assumed that pollutant emissions from commercial-industrial incinerators would be produced in proportion to the ratio of the number of county manufacturing employees to the number of manufacturing employees in Milwaukee County.

Table 151

CHARACTERISTICS OF RESIDENTIAL AND COMMERCIAL-INDUSTRIAL INCINERATORS IN MILWAUKEE COUNTY: 1973

Incinerator Classification[a]	Number Installed	Number in Use	Average Rated Capacity (pounds per hour)	Total Refuse Burned (tons)
Flue Fed Single Chamber and Regular Single Chamber	N/A	2,000	50	8,800
Commercial and Industrial—Rated at over 500 pounds per hour and installed from 1965 through 1973	45	41	750	5,412
Commercial and Industrial—Rated at over 500 pounds per hour and installed from 1948 through 1964	85	26	825	2,831
Commercial and Industrial—Rated at less than 500 pounds per hour and installed from 1965 through 1973	577	519	125	11,418
Commercial and Industrial—Rated at less than 500 pounds per hour and installed from 1948 through 1964	1,291	387	125	6,386
Domestic Incinerators—Installed from 1965 through 1973	1,455	1,091	15	655
Domestic Incinerators—Installed from 1948 through 1964	765	191	15	115
Domestic Incinerators—Installed before 1948. Includes old pot-bellied stoves and cast iron trash burners	N/A	400	15	240

NOTE: N/A indicates data not available.

[a] *The nine municipal incinerators in Milwaukee County were shut down prior to 1973.*

Source: Wisconsin Department of Natural Resources.

The emissions from domestic incinerators were allocated among U. S. Public Land Survey quarter sections in each county on the basis of the ratio of housing units within the quarter section to the total number of housing units in the county. For emissions from commercial-industrial incinerators, this allocation was made on the basis of the ratio of commercial and industrial land area per quarter section to the total commercial and industrial land area in the county. All emissions were distributed equally among seasons. Table 153 indicates the pollutant emissions generated by the incineration of solid waste in the Region by county by season during 1973.

Emissions From Power Boat Operations

Power boats operating on lakes and waterways within the Region are a source of sulfur oxide, carbon monoxide, nitrogen oxide, and hydrocarbon emissions. The quantity of emissions produced by power boats is dependent on the horsepower of the engine used for propulsion and the number of hours the engine is operated. During the summer of 1974, the Commission conducted an "Existing Outdoor Recreation User Survey," which in part sought to identify the location and time of boating activity in the Region.[15] As a part of this survey, ques-

[15] *For more detailed information on the "Existing Outdoor Recreation Users Survey" see SEWRPC Planning Report No. 27, A Regional Park and Open Space Plan for Southeastern Wisconsin: 2000.*

Table 152

EMISSION FACTORS FOR INCINERATORS

Incinerator Classification	Emission Factor (grams per ton)				
	Particulate Matter	Sulfur Oxides	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
Flue Fed Single Chamber and Regular Single Chamber.	30.0	0.05	20.0	3.0	15.0
Commercial and Industrial—Rated at over 500 pounds per hour and installed from 1965 through 1973.	4.76	1.9	4.0	7.2	1.2
Commercial and Industrial—Rated at over 500 pounds per hour and installed from 1948 through 1964.	7.0	2.5	10.0	3.0	3.0
Commercial and Industrial—Rated at less than 500 pounds per hour and installed from 1965 through 1973.	7.0	2.5	10.0	3.0	3.0
Commercial and Industrial—Rated at less than 500 pounds per hour and installed from 1948 through 1964.	7.0	2.5	10.0	3.0	3.0
Domestic Incinerators—Installed from 1965 through 1973 . . .	7.0	0.05	Negligible	2.0	2.0
Domestic Incinerators—Installed from 1948 through 1964 . . .	35.0	0.5	300.0	1.0	100.0
Domestic Incinerators—Installed before 1948. Includes old pot-bellied stoves and cast iron trash burners	29.43	0.05	240.31	1.2	80.5

Source: U. S. Environmental Protection Agency.

tionnaires were sent to approximately 11 percent of the 92,043 registered boat owners in the Region. The data obtained from returned questionnaires were used to identify the location and the amount of time power boats were in use, and the average maximum horsepower rating for boats operating within the Region during 1973. The results of the sample response were extrapolated to the total population of registered power boats to obtain the estimated total number of such craft operating on each lake in the Region.

The survey response indicated that 50 horsepower was the average maximum horsepower rating for boats registered in the Region. However, boat engines are rarely operated at the maximum rating for sustained periods and, consequently, the average horsepower output of the engines had to be estimated. A study by the Southwest Research Institute sponsored by the EPA indicates that the average horsepower produced by such craft is only 9.1 horsepower. According to personnel at the Outboard Marine Corporation, the average size engine sold in the United States is rated at a maximum of 40 horsepower. Assuming that the ratio of the national average engine size of 40 horsepower to the average 9.1 horsepower of work produced during operation remains constant as engine size increases, then the average work output from boats in southeastern Wisconsin, with an average maximum rating of 50 horsepower, would be 11.4 horsepower.

Since the survey data did not account for the average number of hours of power boat operation per year, the EPA-determined national average of 50 hours per boat per year was assumed. Each boat operating within the Region during 1973, therefore, produced an annual average of 570 horsepower-hours of work. This value was multiplied by the pollutant emission factors given in Table 154, and subsequently by the number of power boats using each lake in the Region, to obtain the total estimated pollutant emissions from power boat operations in the Region. These emissions were distributed by county seasonally, based on an allocation factor, shown in Table 155, determined from interviews with recreational site managers. Table 156 presents the total estimated pollutant emissions from power boat operations within the Region during 1973 by county by season.

Emissions From Railroad Line Sources

There are three major railroad companies providing freight or passenger service in the Southeastern Wisconsin Region: the Soo Line, the Chicago & North Western Railway, and the Chicago, Milwaukee, St. Paul & Pacific Railroad Company (Milwaukee Road). Map 49 and Table 157 indicate the location of the rail lines within the Region and the railroad route mileage maintained by these three major railroad companies during 1973. For the purpose of the regional ambient air quality planning program, this rail network was broken down into 314 operational links. Minor rail operations such as the Municipality of East Troy, Wisconsin, Railroad, the Grand Trunk & Western Railroad, and the Chesapeake & Ohio Railroad were considered of negligible importance and omitted from the inventory.

Air pollutant emissions are produced along the regional rail network at a rate that depends on the type of locomotive engine operating on each link in the network and the amount of diesel fuel consumed by each engine type. There are five general locomotive engine categories into which all rail propulsion units operating in the Region may be classified: 2-stroke supercharged switch engine, 4-stroke switch engine, 2-stroke supercharged road engine, 2-stroke turbocharged road engine, and 4-stroke road engine. Estimates of the average fuel consumption rate, annual accumulated mileage, and total annual fuel consumption for each of these five engine types for 1973 for each link in the rail network were developed by SEWRPC based on operating information provided by representatives of the three major railroad companies. These data are summarized in Table 158.

Table 153

SUMMARY OF POLLUTANT EMISSIONS FROM INCINERATORS BY COUNTY BY SEASON: 1973

County	Season	Emissions (tons)				
		Particulate Matter	Sulfur Dioxide	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
Kenosha	Winter	5	1	4	2	3
	Spring	5	1	4	2	3
	Summer	5	1	4	2	3
	Fall	5	1	4	2	3
	Annual	20	4	16	8	12
Milwaukee	Winter	56	8	41	16	29
	Spring	56	8	41	16	29
	Summer	56	8	41	16	29
	Fall	56	8	41	16	29
	Annual	224	32	164	64	116
Ozaukee	Winter	3	1	3	1	2
	Spring	3	1	3	1	2
	Summer	3	1	3	1	2
	Fall	3	1	3	1	2
	Annual	12	4	12	4	8
Racine	Winter	10	1	7	3	5
	Spring	10	1	7	3	5
	Summer	10	1	7	3	5
	Fall	10	1	7	3	5
	Annual	40	4	28	12	20
Walworth	Winter	2	--[a]	2	1	1
	Spring	2	--[a]	2	1	1
	Summer	2	--[a]	2	1	1
	Fall	2	--[a]	2	1	1
	Annual	8	--[a]	8	4	4
Washington	Winter	4	1	3	1	2
	Spring	4	1	3	1	2
	Summer	4	1	3	1	2
	Fall	4	1	3	1	2
	Annual	16	4	12	4	8
Waukesha	Winter	8	1	7	2	4
	Spring	8	1	7	2	4
	Summer	8	1	7	2	4
	Fall	8	1	7	2	4
	Annual	32	4	28	8	16
Region	Winter	88	13	67	26	46
	Spring	88	13	67	26	46
	Summer	88	13	67	26	46
	Fall	88	13	67	26	46
	Annual	352	52	268	104	184

[a] *Less than one-half ton.*

Source: SEWRPC.

Table 154

EMISSION FACTORS FOR POWER BOATS

Pollutant	Emission Factor (grams per unit per hour)
Sulfur Oxides	0.49
Carbon Monoxide	250.00
Hydrocarbons.	85.00
Nitrogen Oxides	0.50

Source: U. S. Environmental Protection Agency.

Table 155

SEASONAL ALLOCATION FACTORS FOR POWER BOATS IN THE REGION

Season	Factor (percent)
Winter	- -
Spring	5
Summer	80
Fall	15

Source: SEWRPC.

Table 156

SUMMARY OF POLLUTANT EMISSIONS FROM POWER BOAT OPERATIONS BY COUNTY BY SEASON: 1973

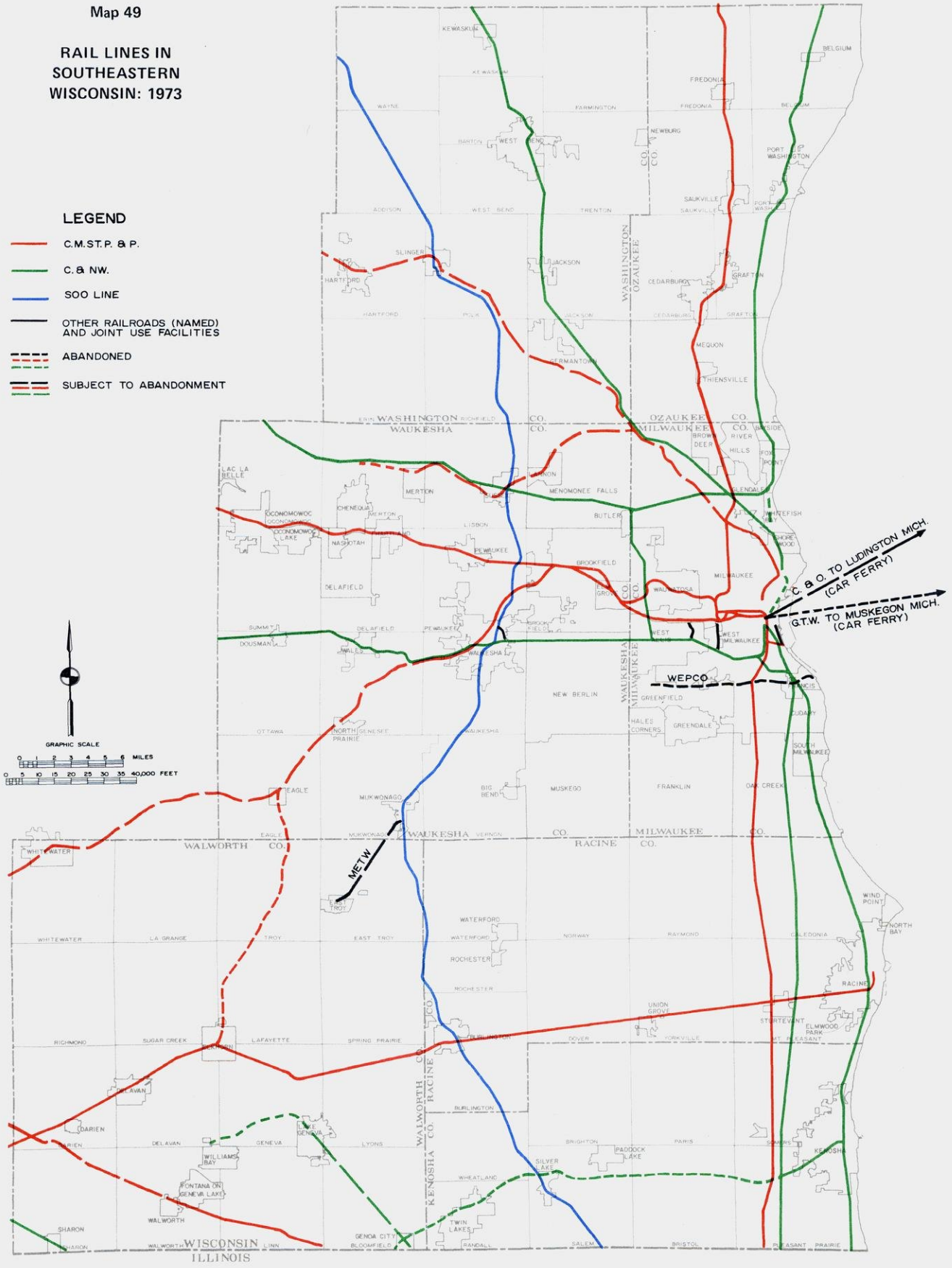
County	Season	Emissions (tons)				
		Particulate Matter	Sulfur Dioxide	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
Kenosha	Winter	- -	- -[a]	- -	- -[a]	- -
	Spring	- -	- -[a]	71	- -[a]	24
	Summer	- -	2	1,142	2	388
	Fall	- -	- -[a]	214	- -[a]	73
	Annual	- -	2	1,427	2	485
Milwaukee	Winter	- -	- -[a]	- -	- -[a]	- -
	Spring	- -	- -[a]	140	- -[a]	48
	Summer	- -	4	2,238	5	761
	Fall	- -	1	420	1	143
	Annual	- -	5	2,798	6	952
Ozaukee	Winter	- -	- -[a]	- -	- -[a]	- -
	Spring	- -	- -[a]	31	- -[a]	11
	Summer	- -	1	499	1	170
	Fall	- -	- -[a]	94	- -[a]	32
	Annual	- -	1	624	1	213
Racine	Winter	- -	- -[a]	- -	- -[a]	- -
	Spring	- -	- -[a]	118	- -[a]	40
	Summer	- -	4	1,883	4	640
	Fall	- -	1	353	1	120
	Annual	- -	5	2,354	5	800
Walworth	Winter	- -	- -[a]	- -	- -[a]	- -
	Spring	- -	- -[a]	138	- -[a]	47
	Summer	- -	4	2,201	4	748
	Fall	- -	1	413	1	140
	Annual	- -	5	2,752	5	935
Washington	Winter	- -	- -[a]	- -	- -[a]	- -
	Spring	- -	- -[a]	116	- -[a]	40
	Summer	- -	4	1,859	4	632
	Fall	- -	1	349	1	119
	Annual	- -	5	2,324	5	791
Waukesha	Winter	- -	- -	- -	- -	- -
	Spring	- -	1	412	1	140
	Summer	- -	13	6,584	13	2,239
	Fall	- -	2	1,235	3	420
	Annual	- -	16	8,231	17	2,799
Region	Winter	- -	- -	- -	- -	- -
	Spring	- -	1	1,026	1	350
	Summer	- -	32	16,406	33	5,578
	Fall	- -	6	3,078	7	1,047
	Annual	- -	39	20,510	41	6,975

[a] *Less than one-half ton.*

Source: SEWRPC.

Map 49

RAIL LINES IN SOUTHEASTERN WISCONSIN: 1973



There were about 595 route miles of railway in operation within the Southeastern Wisconsin Region during 1973. The operation of locomotive engines over this railway system contributed approximately 216 tons of particulate matter, 484 tons of sulfur dioxide, 1,300 tons of carbon monoxide, 2,804 tons of nitrogen oxides, and 308 tons of hydrocarbons to the regional emissions burden during 1973.

Source: SEWRPC.

Table 157

RAILWAY ROUTE MILEAGE IN SOUTHEASTERN WISCONSIN: 1973

County	Railroad								Total		Subject to Abandonment	
	Chicago, Milwaukee, St. Paul & Pacific		Chicago & North Western		Soo Line		Municipality of East Troy, Wisconsin					
	Mileage	Percent of Total in Region	Mileage	Percent of Total in Region	Mileage	Percent of Total in Region	Mileage	Percent of Total in Region	Mileage	Percent of Total in Region	Mileage	Percent of Total in Region
Kenosha	12.5	2.1	29.1	5.0	10.6	1.8	--	--	52.2	8.8	--	--
Milwaukee	52.7	8.9	67.1	11.6	--	--	--	--	119.8	20.2	8.6[a]	1.5
Ozaukee	25.0	4.2	25.0	4.3	--	--	--	--	50.0	8.4	--	--
Racine	40.5	6.8	24.6	4.2	14.0	2.4	--	--	79.1	13.3	--	--
Walworth	51.8	8.7	13.4	2.3	3.8	0.7	6.0[a]	1.0	75.0	12.6	31.9[a]	5.5
Washington	22.7	3.8	27.2	4.7	25.0	4.3	--	--	74.9	12.6	22.7[a]	3.9
Waukesha	66.8	11.3	47.7	8.2	26.9	4.6	1.2[a]	0.2	142.6	24.0	20.1[a]	3.5
Region	272.0	45.8	234.1	40.3	80.3	13.8	7.2	1.2	593.6	100.0	83.3[a]	14.3
Subject to Abandonment	66.2[a]	11.4	9.9[a]	1.7	--	--	7.2	1.2	83.3[a]	14.3	--	--

NOTE: Percentage figures may not sum exactly due to rounding.

[a] *Approximation.*

Source: Wisconsin Department of Transportation and SEWRPC.

Table 158

FUEL CONSUMPTION RATE, ANNUAL ACCUMULATED MILEAGE, AND TOTAL FUEL CONSUMPTION BY RAILROAD ENGINE TYPE: 1973

Engine Type	Fuel Consumption Rate (gallons per mile)	Annual Accumulated Mileage	Annual Fuel Consumption (gallons)
2-Stroke Supercharged Switch	3	5,044	15,132
4-Stroke Switch	4	--	--
2-Stroke Supercharged Road	3	307,632	922,896
2-Stroke Turbocharged Road	4.6	3,127,124	14,384,770
4-Stroke Road	4	101,400	405,600

Source: SEWRPC.

Table 159

EMISSION FACTORS FOR RAILROAD ENGINES

Engine Type	Emission Factor (grams per mile)				
	Particulate Matter	Sulfur Oxides	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
2-Stroke Supercharged Switch	7.60	17.34	25.55	76.05	57.79
4-Stroke Switch	45.04	103.51	690.08	889.84	265.14
2-Stroke Supercharged Road	34.05	77.63	89.89	476.70	201.58
2-Stroke Turbocharged Road	52.21	119.04	334.14	689.17	58.48
4-Stroke Road	45.50	103.51	326.88	853.52	179.78

Source: U. S. Environmental Protection Agency.

Emission rates in terms of pounds of pollutants generated per thousand gallons of fuel consumed were determined for each of the five locomotive engine types through an EPA-sponsored study conducted by the Southwest Research Institute. Using the data on the average fuel use rate for each engine type provided by the railroad companies, these emission factors were converted to grams of pollutants produced per engine mile of travel. Table 159 lists both the EPA-developed and the equivalent SEWRPC-developed emission factors for the five engine types. For each link in the regional railroad network, the annual accumulated mileage for each engine type was multiplied by the corresponding emission factor for each pollutant species considered in this inventory to calculate the total annual pollutant emissions. The total annual pollutant emissions from locomotive engine activity along each link were assigned to U. S. Public Land Survey quarter sections on the basis of the percentage of the total length of each link within a particular quarter section. Emissions were distributed equally among seasons since most rail activity is conducted following generally rigid and constant schedules. The estimated pollutant emissions released from locomotive engine operations along the regional railroad network during 1973 are presented in Table 160.

Emissions From Railroad Yards

In addition to the locomotives used for road haul service

Table 160

SUMMARY OF POLLUTANT EMISSIONS FROM RAILROAD ENGINES OPERATING ALONG THE REGIONAL RAIL NETWORK BY COUNTY BY SEASON: 1973

County	Season	Emissions (tons)				
		Particulate Matter	Sulfur Dioxide	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
Kenosha	Winter	8	18	48	103	10
	Spring	8	18	48	103	10
	Summer	8	18	48	103	10
	Fall	8	18	48	103	10
	Annual	32	72	192	412	40
Milwaukee	Winter	17	39	109	228	21
	Spring	17	39	109	228	21
	Summer	17	39	109	228	21
	Fall	17	39	109	228	21
	Annual	68	156	436	912	84
Ozaukee	Winter	3	8	22	46	5
	Spring	3	8	22	46	5
	Summer	3	8	22	46	5
	Fall	3	8	22	46	5
	Annual	12	32	88	184	20
Racine	Winter	10	22	59	126	13
	Spring	10	22	59	126	13
	Summer	10	22	59	126	13
	Fall	10	22	59	126	13
	Annual	40	88	236	504	52
Walworth	Winter	2	4	11	22	3
	Spring	2	4	11	22	3
	Summer	2	4	11	22	3
	Fall	2	4	11	22	3
	Annual	8	16	44	88	12
Washington	Winter	5	11	25	63	11
	Spring	5	11	25	63	11
	Summer	5	11	25	63	11
	Fall	5	11	25	63	11
	Annual	20	44	100	252	44
Waukesha	Winter	9	19	51	113	14
	Spring	9	19	51	113	14
	Summer	9	19	51	113	14
	Fall	9	19	51	113	14
	Annual	36	76	204	452	56
Region	Winter	54	121	325	701	77
	Spring	54	121	325	701	77
	Summer	54	121	325	701	77
	Fall	54	121	325	701	77
	Annual	216	484	1,300	2,804	308

Source: SEWRPC.

along the regional rail line network, engines used for switching operations in railroad yards must be considered as a source of air pollutant emissions. As with road locomotives, pollutant emissions from switch yard operations depend on the type of engine and the quantity of fuel consumed.

Data provided by the three major railroad companies operating within the Region show that there were 16 yards in Milwaukee County and one yard in Waukesha County with regularly scheduled switching activities ongoing during 1973. The railroad companies also provided data concerning the types of engines in use and the average number of hours per day and days per week that each engine was in operation during 1973. Based on these data it was found that the 2-stroke supercharged switch engine was the predominant engine type used in yard activities, and that under general operating conditions each such engine consumed diesel fuel at a rate of approximately 20 gallons per hour. Using this hourly fuel consumption rate, the total quantity of fuel consumed during 1973 for railroad yard operations was estimated based on the average number of engine-hours of work per week extended to 52 weeks at each switching yard. The air pollutant emissions from this consumption were then determined by multiplying this consumption by the emission factors for 2-stroke supercharged switch engines, shown in Table 159.

The air pollutant emissions generated by railroad yard operations in the Region during 1973 are listed by county by season in Table 161. Since the emission calculations were based on average weekly operating characteristics, the emissions were allocated equally among seasons. These emissions from each yard were then allocated directly to the U. S. Public Land Survey quarter section in which the yard was located.

Emissions From Residential Fuel Use

Air pollutant emissions from occupied housing units are produced primarily by various fuels consumed for space heating and water heating purposes. Emissions from residential fuel use are calculated by collating data on the number of occupied housing units in the Region, the type of building in which each housing unit is contained, the type of fuel used for combustion, and the quantity of each fuel type consumed.

Table 161

SUMMARY OF POLLUTANT EMISSIONS FROM RAILROAD YARD OPERATION IN THE REGION BY SEASON– MILWAUKEE AND WAUKESHA COUNTIES: 1973

County	Season	Emissions (tons)				
		Particulate Matter	Sulfur Dioxide	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
Milwaukee	Winter	16	34	170	253	98
	Spring	16	34	170	253	98
	Summer	16	34	170	253	98
	Fall	16	34	170	253	98
	Annual	64	136	680	1,012	392
Waukesha	Winter	--[a]	1	7	9	3
	Spring	--[a]	1	7	9	3
	Summer	--[a]	1	7	9	3
	Fall	--[a]	1	7	9	3
	Annual	--[a]	4	28	36	12
Region	Winter	16	35	177	262	101
	Spring	16	35	177	262	101
	Summer	16	35	177	262	101
	Fall	16	35	177	262	101
	Annual	64	140	708	1,048	404

[a] *Less than one-half ton.*

Source: SEWRPC.

The number of occupied year-round housing units in the Region was identified from the census tract data contained in the 1970 Census of Housing, published by the U. S. Bureau of the Census. These housing units were subsequently allocated to U. S. Public Land Survey quarter sections during the Commission's 1970 land use inventory. Census data also provided the estimated percentages of housing units using either natural gas, bottled gas, fuel oil and kerosene, coal and coke, wood, electricity, other fuels, or no fuel for residential space heating and water heating purposes within each census tract. Each housing unit within a quarter section was assigned to a particular fuel type on the basis of the distribution of fuel use within the census tract in which the quarter section is located. When a quarter section was located in more than one census tract, housing units within the quarter section were allocated among each census tract according to the relative percentage of the quarter section land area within each tract. The number of housing units within each of the eight space heating fuel categories as determined in this manner are summarized for the Region by county for 1970 in Table 162. Although there are eight categories of residential fuel use listed in the table, only natural gas, bottled gas, fuel oil, coal, and wood produce onsite air pollutant emissions. Therefore, housing units using electricity, other fuel, and no fuel for space heating were not considered in the area source emissions inventory.

The rate at which a housing unit will consume fuel for space heating purposes depends, among other factors, on the type of building in which the housing unit is located. The EPA had determined that an average single-family dwelling requires approximately 17,000 British Thermal Units (BTU's) of heat energy for every heating degree-day.[16] The EPA, using data supplied by the Chicago Department of Environmental Control, has also determined that the fuel requirements for an individual housing unit decrease as the number of housing units in a building increase. This reduced energy demand is due principally to the interchange of heat between attached housing units and to the generally smaller area contained within individual multiple-unit dwellings. Table 163 lists the relative fuel requirements by fuel type for housing units in multiple-unit buildings normalized to an average single-family dwelling. In order to account for these differences in relative fuel requirements for housing units in buildings of various size, all housing units in the Region in 1970 were assigned by fuel type to one of the six structure categories listed in Table 164. This assignment was accomplished through use of census tract data on building sizes, supplemented with a review of the 1970 aerial photographs of the Region.

[16] *A heating degree-day is defined as the number of degrees the average daily (24-hour) air temperature is below 65°F.*

Table 162

DISTRIBUTION OF HOUSING UNITS IN THE REGION BY COUNTY AND BY FUEL TYPE: 1970

County	Number of Units per Fuel Type							
	Natural Gas	Bottled Gas	Fuel Oil and Kerosene	Coal and Coke	Wood	Electric	Other	No Fuel
Kenosha . . .	26,391	1,307	7,882	454	--	285	84	29
Milwaukee . .	243,562	2,112	82,327	8,422	83	6,359	2,640	41
Ozaukee . . .	7,649	315	6,808	170	19	213	--	--
Racine	31,230	1,104	17,224	341	15	708	109	--
Walworth. . .	11,367	775	8,451	99	--	272	46	17
Washington .	6,932	600	9,839	24	35	188	19	6
Waukesha . .	31,262	855	29,369	368	--	623	90	15
Region	358,393	7,068	161,900	9,878	152	8,648	2,988	108

Source: SEWRPC.

Table 163

RELATIVE FUEL REQUIREMENTS FOR RESIDENTIAL STRUCTURES BY FUEL TYPE

Building Size (units)	Relative Fuel Requirement[a]				
	Natural Gas	Bottled Gas	Fuel Oil and Kerosene	Coal and Coke	Wood
1	1.00	1.00	1.00	1.00	1.0
2-4	0.90	0.90	0.90	0.90	1.0
5-9	0.78	0.74	0.78	0.78	1.0
10-19.	0.64	0.64	0.68	0.68	1.0
20-49.	0.49	0.49	0.57	0.57	1.0
50 or More. . .	0.44	0.44	0.51	0.51	1.0

[a] *All terms expressed as a fraction of fuel use required by a single-family dwelling.*

Source: U. S. Environmental Protection Agency.

Table 164

ESTIMATED NUMBER OF HOUSING UNITS IN THE REGION BY FUEL TYPE AND BY STRUCTURE TYPE: 1970

Building Size (units)	Number of Units per Fuel Type				
	Natural Gas	Bottled Gas	Fuel Oil and Kerosene	Coal and Coke	Wood
1	189,972	6,333	125,468	5,008	132
2-4	97,469	574	27,751	2,300	20
5-9	21,998	92	3,143	758	--
10-19.	17,361	69	2,190	462	--
20-49.	21,568	--	2,694	918	--
50 or More. . .	10,025	--	654	432	--
Total	358,393	7,068	161,900	9,878	152

Source: SEWRPC.

Assuming that a single-family dwelling unit requires approximately 17,000 BTU's of heat energy per degree-day, it is necessary to determine the heating value for each fuel type in order to estimate the quantity of fuel that must be burned to meet that demand. The heating value for each fuel type is the product of the heat content of the fuel times the efficiency at which heat is released during the combustion process. The heat content, heating efficiency, and resultant heating value for all of the fuel types considered in this inventory but wood are shown in Table 165.

Based on the heating value for each fuel type, the quantity of fuel consumed by the average single-family dwelling to meet the 17,000 BTU's per degree-day may be determined. This unit of fuel consumption, termed the fuel use factor, may then be adjusted to reflect the lower heating requirements of multiple-unit buildings. Table 166 lists the fuel use factors by structure type for each type of fuel. Assuming that the number of housing units in the Region did not significantly change between 1970 and 1973, the total amount of fuel consumed for residential space heating may be estimated by multiplying the number of housing units per structure type in each fuel type category by the corresponding fuel use factor and subsequently by the number of heating degree-days experienced in 1973. The number of heating degree-days in 1973 was determined from temperature observations taken at the National Weather Service office at General Mitchell Field in Milwaukee County, and are presented in Table 167 by season.

The above technique was used to approximate total fuel consumption for space heating for fuel oil, bottled gas, and wood in all counties of the Region in 1973, and for coal consumption in all but Milwaukee County. Data on the consumption of natural gas by season in the Southeastern Wisconsin Region during 1973 were provided by the Wisconsin Gas Company, the Wisconsin Natural Gas Company, and the Wisconsin Southern Gas Company for those counties, or portions thereof, within their respective service areas. Also, the tonnage of coal consumed in Milwaukee County during 1973 was determined from a survey of all coal suppliers serving the County.

In addition to space heating, water heating accounts for a significant amount of residential fuel use. The number of water heaters by fuel type by county, again based on data derived from the 1970 Census of Housing, are presented in Table 168. As may be seen by comparing Table 168 with Table 162, the number of water heaters does not correspond to the number of housing units. This difference is due to the fact that many large multiple-unit buildings use a common water heating system for all units, as well as the fact that the fuel type used for space heating may not be the same fuel used for water heating. It was necessary, therefore, to estimate the fuel used by water heaters on a county level, and then to allocate this fuel use to individual quarter sections under the assumption that a housing unit using one fuel type for space heating would use the same fuel type for water heating.

The fuel use factors for water heaters, based on EPA estimates of average hot water use, are presented in Table 169 by fuel type. These fuel use factors are multiplied by the number of water heaters of each fuel type from Table 168 to obtain an estimate of the total fuel consumed for residential water heating purposes.

Table 165

HEAT CONTENT, HEATING EFFICIENCY, AND HEATING VALUE FOR SELECTED FUEL TYPES

Fuel Type	Heat Content	Heating Efficiency (percent)	Heating Value
Natural Gas	1,333 BTU per cubic foot	75	1,000 BTU per cubic foot
Fuel Oil and Kerosene	186,667 BTU per gallon	75	140,000 BTU per gallon
Coal and Coke	22,000 BTU per pound	65	14,300 BTU per pound
Bottled Gas	122,063 BTU per gallon	75	91,547 BTU per gallon

Source: SEWRPC.

Table 166

RESIDENTIAL FUEL USE FACTORS PER HEATING DEGREE-DAY BY STRUCTURE TYPE

Structure Size (units)	Fuel Use Factor				
	Natural Gas (cubic feet per degree-day)	Bottled Gas (pounds per degree-day)	Fuel Oil (gallons per degree-day)	Coal (pounds per degree-day)	Wood (pounds per degree-day)
1	21.25	0.232	0.162	1.83	3.40
2-4	19.13	0.209	0.146	1.65	3.40
5-9	15.73	0.172	0.126	1.43	3.40
10-19	13.60	0.149	0.110	1.24	3.40
20-49	10.41	0.114	0.092	1.04	3.40
50 or More	9.35	0.102	0.083	0.93	3.40

Source: U. S. Environmental Protection Agency.

Table 167

NUMBER OF HEATING DEGREE-DAYS AT GENERAL MITCHELL FIELD BY SEASON: 1973

Season	Number of Heating Degree-Days
Winter	3,561
Spring	1,854
Summer	21
Fall	1,223
Annual	6,659

Source: U. S. Department of Commerce, National Weather Service.

Table 168

NUMBER OF WATER HEATERS IN THE REGION BY FUEL TYPE AND BY COUNTY: 1970

County	Number of Water Heaters				
	Natural Gas	Bottled Gas	Fuel Oil	Coal	Wood
Kenosha	27,356	1,154	455	36	--
Milwaukee . . .	267,944	3,901	4,935	2,746	--
Ozaukee	6,596	335	527	--	--
Racine	33,412	1,311	1,013	81	--
Walworth. . . .	8,661	1,125	293	--	--
Washington . .	6,006	1,010	602	--	--
Waukesha . . .	25,516	1,317	976	37	--
Region	375,491	10,153	8,801	2,900	--

Source: SEWRPC.

Table 169

FUEL USE FACTORS FOR WATER HEATERS BY FUEL TYPE

Fuel Type	Factor
Natural Gas . . .	3.5×10^4 cubic feet per water heater unit per year
Bottled Gas . . .	382 gallons per water heater unit per year
Fuel Oil	250 gallons per water heater unit per year
Coal.	1.25 tons per water heater unit per year
Wood	--

Source: U. S. Environmental Protection Agency.

The estimated fuel used for water heaters was assigned to quarter sections on the basis of the ratio of the number of housing units of a particular fuel type in a quarter section to the total number of housing units in the county of that fuel type. Fuel use for water heating was distributed equally among all seasons and added to the seasonal totals of fuel use for space heating. The total estimated fuel use for residential space heating and water heating purposes in the Region during 1973 as determined in this manner is presented in Table 170.

The EPA-determined emission factors contained in Table 171 were used to calcuate the emissions generated by residential fuel use. The emissions thus calculated are presented in Table 172 by county by season.

Emissions From Rock Handling and Storage

Rock handling and storage operations include the excavation, processing, storage and transportation of rock, stone, sand, and gravel. Particulate matter emissions may result during each phase of these operations, depending on the amount of material processed, the moisture content of the raw material, the method of transfer of the material from the excavation area, and the degree to which the transfer, processing, and storage areas are enclosed.

Table 170

ESTIMATED FUEL CONSUMPTION FOR RESIDENTIAL SPACE HEATING AND WATER HEATING IN THE REGION BY COUNTY: 1973

County	Fuel Consumption				
	Natural (cubic feet)	Bottled Gas (gallons)	Fuel Oil (gallons)	Coal (pounds)	Wood (pounds)
Kenosha	4,574,687,232	2,437,119	8,532,800	5,484,562	--
Milwaukee . . .	39,416,098,816	4,572,231	85,500,560	88,972,640	1,879,166
Ozaukee	1,256,252,928	598,765	7,425,886	2,038,050	430,171
Racine	5,323,210,752	2,129,754	18,314,368	3,932,315	339,609
Walworth. . . .	1,889,138,176	1,508,765	9,106,541	1,190,623	--
Washington . .	1,124,211,200	1,139,883	10,686,352	292,463	792,421
Waukesha . . .	5,153,001,472	1,634,378	31,279,104	4,467,470	--

Source: SEWRPC.

Table 171

EMISSION FACTORS FOR RESIDENTIAL FUEL USE

Fuel Type	Emission Factor (grams)				
	Particulate Matter	Sulfur Oxides	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
Natural Gas (per cubic foot) . . .	0.00454	0.0002724	0.00908	0.03632	0.003632
Bottled Gas (per gallon).	0.8172	0.0004086	0.8626	3.178	0.3178
Fuel Oil (per gallon)[a]	4.54	19.34	2.27	5.448	1.362
Coal (per pound)[b].	4.20	12.939	11.35	1.0215	2.6105
Wood (per pound)	6.81	0.3405	7.037	2.27	8.172

[a] *Assumes a 0.3 percent sulfur content.*

[b] *Assumes a 1.5 percent sulfur content and an 8.5 percent ash content.*

Source: U. S. Environmental Protection Agency.

In the Southeastern Wisconsin Region, the primary materials extracted are sand and gravel and crushed limestone. The locations of active facilities in the seven-county area that mine and process such materials were identified from an unpublished SEWRPC report entitled, Mineral Extraction in Southeastern Wisconsin—Special Quarry Study: 1970. From a telephone survey of sand and gravel processing facilities thus identified in the Region and from information contained in the 1973 point source emissions inventory prepared by the Wisconsin Department of Natural Resources, it was determined that 102 sand and gravel operations were active in the Region during 1973. Based on an EPA-determined compound emission rate of 0.1 pound of particulates per ton of sand and gravel mined, processed, transferred, and stored, it was calculated that 29 tons of particulate matter were emitted from rock handling and storage operations in 1973. These emissions were distributed proportionately among the U. S. Public Land Survey quarter sections in the Region in which there were sand and gravel operations.

From a telephone survey of crushed limestone-producing facilities and from the information contained in the 1973

Table 172

SUMMARY OF POLLUTANT EMISSIONS FROM RESIDENTIAL FUEL USE BY COUNTY BY SEASON: 1973

County	Season	Emissions (tons)				
		Particulate Matter	Sulfur Dioxide	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
Kenosha	Winter	47	139	68	109	23
	Spring	27	73	40	75	14
	Summer	3	1	5	19	2
	Fall	18	49	26	48	9
	Annual	95	262	139	251	48
Milwaukee	Winter	343	1,066	357	903	158
	Spring	198	560	234	621	97
	Summer	21	8	40	156	16
	Fall	121	371	126	324	56
	Annual	683	2,005	757	2,004	327
Ozaukee	Winter	31	100	34	58	14
	Spring	17	52	19	38	8
	Summer	1	1	2	7	1
	Fall	11	35	12	21	5
	Annual	60	188	67	124	28
Racine	Winter	74	238	79	168	33
	Spring	42	125	48	114	20
	Summer	4	2	7	27	3
	Fall	25	83	26	53	11
	Annual	145	448	160	362	67
Walworth	Winter	33	113	30	71	13
	Spring	18	59	18	45	8
	Summer	1	--[a]	2	9	1
	Fall	11	39	11	24	5
	Annual	63	211	61	149	27
Washington	Winter	36	124	28	68	16
	Spring	20	65	16	42	9
	Summer	1	1	2	7	1
	Fall	13	43	10	24	6
	Annual	70	233	56	141	32
Waukesha	Winter	110	391	102	223	44
	Spring	61	205	60	143	26
	Summer	4	2	7	28	3
	Fall	40	136	34	72	15
	Annual	215	734	203	466	88
Region	Winter	674	2,171	698	1,600	301
	Spring	383	1,139	435	1,078	182
	Summer	35	15	65	253	27
	Fall	239	756	245	566	107
	Annual	1,331	4,081	1,443	3,497	617

[a] *Less than one-half ton.*

Source: SEWRPC.

point source emissions inventory, it was determined that limestone quarries in the Region generated approximately 292 tons of particulate matter emissions during 1973. Again, these emissions were distributed among the U. S. Public Land quarter sections in which the limestone quarries were located.

Collectively, the mining and processing of sand and gravel and crushed limestone in the Region during 1973 emitted approximately 321 tons of particulate matter. The amount of emissions produced by county by season is shown in Table 173.

Table 173

SUMMARY OF PARTICULATE MATTER EMISSIONS FROM ROCK HANDLING AND STORAGE OPERATIONS BY COUNTY BY SEASON: 1973

County	Season	Particulate Matter Emissions (tons)
Kenosha	Winter	--[a]
	Spring	--[a]
	Summer	1
	Fall	1
	Annual	2
Milwaukee	Winter	5
	Spring	7
	Summer	12
	Fall	10
	Annual	34
Ozaukee	Winter	2
	Spring	4
	Summer	10
	Fall	7
	Annual	23
Racine	Winter	4
	Spring	5
	Summer	6
	Fall	5
	Annual	20
Walworth	Winter	--[a]
	Spring	1
	Summer	2
	Fall	1
	Annual	4
Washington	Winter	2
	Spring	5
	Summer	12
	Fall	9
	Annual	28
Waukesha	Winter	23
	Spring	41
	Summer	83
	Fall	63
	Annual	210
Region	Winter	36
	Spring	63
	Summer	126
	Fall	96
	Annual	321

[a] *Less than one-half ton.*

Source: SEWRPC.

Emissions From Small Point Sources

In collating the 1973 point source emissions inventory for the Southeastern Wisconsin Region, only those facilities that emitted more than 10 tons of any one pollutant species per year were included. Those facilities emitting pollutants at a lower rate were assumed to have only a minor impact on local ambient air quality. In total, there were 94 such facilities operating within the Region during 1973. Although each of these facilities individually constituted relatively small sources of pollutant emissions, collectively these sources represent an important part of the total regional emissions inventory. In order to account for these emissions, therefore, pollutants generated from small point sources were considered as a category of area source emissions. Table 174 presents a county summary by season of the pollutant emissions produced by the 94 small point sources operating within the Region during 1973.

Emissions From Snowmobile Operations

The amount of pollutant emissions produced by the internal combustion engines used in snowmobiles depends on the number of snowmobile units and their hours of operation. During the winter of 1974, the Commission conducted an "Existing Outdoor Recreation User Survey" which in part sought to identify the location and time of snowmobile use.[17] Based on the response to that survey, pollutant emissions from snowmobiles were calculated and allocated to U. S. Public Land Survey quarter sections.

Table 175 lists the number of registered snowmobiles in the Region by county for 1973. The 1974 survey sent questionnaires to approximately 15 percent of the 39,951 registered snowmobile owners in the Region. From this response, the average number of snowmobile outings and the average number of hours of snowmobile use per outing were determined by county. These averages were expanded from the survey response to the entire population of snowmobile owners in the Region to estimate the total number of hours of snowmobile use by county. The survey response was also used to identify the locations of snowmobile use. Based upon the sites defined by the respondents of the questionnaire, an estimate of the total number of hours of snowmobile use by U. S. Public Land Survey quarter section was calculated for those areas falling within the regional boundaries.

The average number of hours of snowmobile use in each quarter section was multiplied by the pollutant emission factors, given in Table 176, to obtain the total annual snowmobile emissions. These emissions were allocated seasonally, with 85 percent attributed to the winter season and 15 percent to the spring season, based on the relative occurrence of snowfall on the ground in excess of one inch during 1973. The total pollutant emissions from snowmobile use in the Region during 1973 thus calculated are presented in Table 177 by county by season.

Emissions From Commercial Vessels

Included in this area source category are the pollutant emissions generated by inboard-powered vessels using regional port facilities for the commercial transport of materials. Vessel activities at the ports of Kenosha, Milwaukee, and Port Washington, the Wisconsin Electric

Table 174

SUMMARY OF POLLUTANT EMISSIONS FROM SMALL POINT SOURCES IN THE REGION BY COUNTY BY SEASON: 1973

County	Season	Emissions (tons)				
		Particulate Matter	Sulfur Dioxide	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
Kenosha	Winter	1	-- [a]	-- [a]	5	-- [a]
	Spring	1	-- [a]	-- [a]	5	-- [a]
	Summer	1	-- [a]	-- [a]	5	-- [a]
	Fall	1	-- [a]	-- [a]	5	-- [a]
	Annual	4	-- [a]	-- [a]	20	-- [a]
Milwaukee	Winter	11	7	2	20	22
	Spring	11	7	2	20	22
	Summer	11	7	2	20	22
	Fall	11	7	2	20	22
	Annual	44	28	8	80	88
Ozaukee	Winter	8	--	1	4	3
	Spring	8	--	1	4	3
	Summer	8	--	1	4	3
	Fall	8	--	1	4	3
	Annual	32	--	4	16	12
Racine	Winter	6	2	-- [a]	5	--
	Spring	6	2	-- [a]	5	--
	Summer	6	2	-- [a]	5	--
	Fall	6	2	-- [a]	5	--
	Annual	24	8	-- [a]	20	--
Walworth	Winter	1	-- [a]	--	-- [a]	--
	Spring	1	-- [a]	--	-- [a]	--
	Summer	1	-- [a]	--	-- [a]	--
	Fall	1	-- [a]	--	-- [a]	--
	Annual	4	-- [a]	--	-- [a]	--
Washington	Winter	2	1	-- [a]	3	-- [a]
	Spring	2	1	-- [a]	3	-- [a]
	Summer	2	1	-- [a]	3	-- [a]
	Fall	2	1	-- [a]	3	-- [a]
	Annual	8	4	-- [a]	12	-- [a]
Waukesha	Winter	4	1	2	4	-- [a]
	Spring	4	1	2	4	-- [a]
	Summer	4	1	2	4	-- [a]
	Fall	4	1	2	4	-- [a]
	Annual	16	4	8	16	-- [a]
Region	Winter	33	11	5	41	25
	Spring	33	11	5	41	25
	Summer	33	11	5	41	25
	Fall	33	11	5	41	25
	Annual	132	44	20	164	100

[a] *Less than one-half ton.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

[17] *For more detailed information on the "Existing Outdoor Recreation Users Survey" see SEWRPC Planning Report No. 27, A Regional Park and Open Space Plan for Southeastern Wisconsin: 2000.*

Table 175

NUMBER OF REGISTERED SNOWMOBILES IN THE REGION BY COUNTY: 1973

County	Number of Registered Snowmobiles
Kenosha	2,990
Milwaukee	9,460
Ozaukee	3,435
Racine	5,121
Walworth	3,565
Washington	5,709
Waukesha	9,671
Region	39,951

Source: Wisconsin Department of Transportation and SEWRPC.

Table 176

EMISSION FACTORS FOR SNOWMOBILE USE

Pollutant	Emission Factor (grams per hour)
Particulate Matter	27.90
Sulfur Oxides	0.85
Carbon Monoxide	978.00
Nitrogen Oxides	10.00
Hydrocarbons	630.00

Source: U. S. Environmental Protection Agency.

Power Company facilities in Oak Creek, Milwaukee, and Port Washington, and the docking facilities utilized by the Chesapeake & Ohio Railroad and the Grand Trunk & Western Railroad carferries were inventoried for 1973. The port of Racine was not included in this inventory because records of vessel activity are not maintained by any public or private agency for that facility. Also not included in this inventory were the two emergency vessels stationed in Milwaukee and one emergency vessel stationed in Kenosha operated by the U. S. Coast Guard. These vessels receive dockside power from onshore facilities and would, therefore, not contribute significantly to regional air pollutant emissions.

The inventory data collected for each facility were comprised of the number of vessels per month utilizing the port, the length of stay for each vessel, the type of fuel used by each vessel, and the rate of fuel consumption. These data were readily obtained from public and private shipping records as well as from personal communications with public officials and corporate representatives. The number of ships using port facilities within

Table 177

SUMMARY OF POLLUTANT EMISSIONS FROM SNOWMOBILE USE BY COUNTY BY SEASON: 1973

County	Season	Emissions (tons)				
		Particulate Matter	Sulfur Dioxide	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
Kenosha	Winter	1	--[a]	28	--[a]	18
	Spring	--[a]	--[a]	5	--[a]	3
	Summer	--	--[a]	--[a]	--[a]	--[a]
	Fall	--	--[a]	--[a]	--[a]	--[a]
	Annual	1	--[a]	33	--[a]	21
Milwaukee	Winter	--[a]	--[a]	12	--[a]	8
	Spring	--[a]	--[a]	2	--[a]	1
	Summer	--[a]	--[a]	--[a]	--[a]	--[a]
	Fall	--[a]	--[a]	--	--[a]	--[a]
	Annual	--[a]	--[a]	14	--[a]	9
Ozaukee	Winter	--[a]	--[a]	17	--[a]	11
	Spring	--[a]	--[a]	3	--[a]	2
	Summer	--[a]	--[a]	--[a]	--[a]	--[a]
	Fall	--[a]	--[a]	--[a]	--[a]	--[a]
	Annual	--[a]	--[a]	20	--[a]	13
Racine	Winter	1	--[a]	40	--[a]	26
	Spring	--[a]	--[a]	7	--[a]	5
	Summer	--[a]	--[a]	--[a]	--[a]	--[a]
	Fall	--[a]	--[a]	--[a]	--[a]	--[a]
	Annual	1	--[a]	47	--[a]	31
Walworth	Winter	1	--[a]	26	--[a]	17
	Spring	--[a]	--[a]	5	--[a]	3
	Summer	--[a]	--[a]	--[a]	--[a]	--[a]
	Fall	--[a]	--[a]	--[a]	--[a]	--[a]
	Annual	1	--[a]	31	--[a]	20
Washington	Winter	1	--[a]	36	--[a]	23
	Spring	--[a]	--[a]	6	--[a]	4
	Summer	--[a]	--[a]	--[a]	--[a]	--[a]
	Fall	--[a]	--[a]	--[a]	--[a]	--[a]
	Annual	1	--[a]	42	--[a]	27
Waukesha	Winter	2	--[a]	70	--[a]	44
	Spring	--[a]	--[a]	12	--[a]	8
	Summer	--[a]	--[a]	--[a]	--[a]	--[a]
	Fall	--[a]	--[a]	--[a]	--[a]	--[a]
	Annual	2	--[a]	82	--[a]	52
Region	Winter	6	--[a]	229	--[a]	147
	Spring	--[a]	--[a]	40	--[a]	26
	Summer	--[a]	--[a]	--[a]	--[a]	--[a]
	Fall	--[a]	--[a]	--[a]	--[a]	--[a]
	Annual	6	--[a]	269	--[a]	173

Source: SEWRPC.

the Region and the amount of fuel consumed while in port by fuel type are provided in Table 178 by county by season.

The emission factors used in this calculation are listed in Table 179 and are representative of the rate pollutants are produced by commercial motorships operating on the Great Lakes. Since the emission factors are given as pounds of pollutant per thousand gallons of fuel, a conversion factor of 7.12 pounds per gallon was used to change the tons of diesel fuel consumed to the corresponding units. Similarly, tons of coal consumed were converted to the equivalent energy content of diesel fuel at the rate of one ton of coal to every 274 gallons of

Table 178

NUMBER OF COMMERCIAL VESSELS UTILIZING REGIONAL PORT FACILITIES AND ESTIMATED FUEL CONSUMPTION BY COUNTY BY SEASON: 1973

County	Winter	Spring	Summer	Fall	Annual
Kenosha					
Number of Ships	--	7	12	12	31
Tons of Fuel Consumed					
Fuel Oil or Diesel Fuel	--	27	59	45	131
Diesel Fuel	--	--	--	--	--
Coal	--	--	--	--	--
Total	--	27	59	45	131
Milwaukee					
Number of Ships	198	266	420	323	1,207
Tons of Fuel Consumed					
Fuel Oil or Diesel Fuel	258	448	785	794	2,285
Diesel Fuel	15	94	82	60	251
Coal[a]	135	149	276	152	712
Total	408	691	1,143	1,006	3,248
Ozaukee					
Number of Ships	--	17	18	22	57
Tons of Fuel Consumed					
Fuel Oil or Diesel Fuel	--	47	105	45	197
Diesel Fuel	--	--	--	--	--
Coal[a]	--	31	37	--	68
Total	--	78	142	45	265
Racine	N/A	N/A	N/A	N/A	N/A

NOTE: N/A indicates data not available.

[a] *The tons of coal consumed were converted to oil equivalent units.*

Source: SEWRPC.

Table 179

EMISSION FACTORS FOR COMMERCIAL VESSELS OPERATING ON THE GREAT LAKES

Pollutant	Emission Factor (pounds per thousand gallons of fuel)
Particulate Matter	97.5
Sulfur Oxides	57
Carbon Monoxide	110
Nitrogen Oxides	260
Hydrocarbons	59

Source: U. S. Environmental Protection Agency.

diesel fuel, then converted to the corresponding units. The emissions produced by commercial vessels operating within the coastal waters of the Region during 1973 are presented in Table 180 by county by season.

The Menomonee River Valley Emission Inventories

Concurrent with the preparation of the air pollutant emissions inventory for southeastern Wisconsin under the regional air quality maintenance planning program, the City of Milwaukee, Department of City Development, undertook a particulate matter emissions inventory for the heavily industrialized area of the Menomonee River Valley. In particular, the City of Milwaukee examined four sources of particulate matter emissions: aggregate storage piles, travel on unpaved roads, travel on unpaved automobile parking lots, and travel on unpaved truck lots. These four categories are referred to as "fugitive dust" sources, which is a general term for particulate matter emissions made airborne through wind forces or abrasive anthropogenic activities. The procedures and findings of the localized fugitive dust emissions inventory conducted by the City of Milwaukee and incorporated into the regional air quality maintenance planning program are summarized in the following sections.[18]

Table 180

SUMMARY OF POLLUTANT EMISSIONS FROM COMMERCIAL VESSELS OPERATING WITHIN THE REGION BY COUNTY BY SEASON: 1973

County	Season	Emissions (tons)				
		Particulate Matter	Sulfur Dioxide	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
Kenosha	Winter	--	--	--	--	--
	Spring	--[a]	--[a]	--[a]	1	--[a]
	Summer	--[a]	--[a]	1	2	--[a]
	Fall	--[a]	--[a]	1	2	--[a]
	Annual	--[a]	--[a]	2	5	--[a]
Milwaukee	Winter	7	4	1	5	1
	Spring	9	5	5	15	3
	Summer	15	6	10	27	6
	Fall	9	6	10	26	5
	Annual	40	21	26	73	15
Ozaukee	Winter	--[a]	--[a]	1	2	--[a]
	Spring	2	--[a]	2	4	1
	Summer	2	1	3	7	2
	Fall	--[a]	--[a]	1	3	1
	Annual	4	1	7	16	4
Region	Winter	7	4	2	7	1
	Spring	11	5	7	20	4
	Summer	17	7	14	36	8
	Fall	9	6	12	31	6
	Annual	44	22	35	94	19

[a] *Less than one-half ton.*

Source: SEWRPC.

[18] *For a more detailed description of the inventory procedures used by the City of Milwaukee, Department of City Development, see the following Department publications: Fugitive Dust Emissions from the Uncovered Storage Piles in the Menomonee River Valley, June 20, 1976, Estimating Fugitive Dust Emissions from Unpaved Roads in the Menomonee River Valley, June 30, 1976; Fugitive Dust Emissions from Unpaved Automobile Parking Lots, December 31, 1975; and Fugitive Dust Emissions from the Unpaved Trucking Lots in the Menomonee River Valley, May 9, 1976. With the exception of the aggregate storage piles document, these publications have been updated as of June 30, 1978.*

Aggregate Storage Piles: The Department of City Development, through field observations and telephone surveys, determined that there were at least 10 types of materials stored in uncovered outdoor piles in the Menomonee River Valley—clinker, coal, coarse lime, coke, gypsum, limestone, pig iron, rock salt, sand, and scrap including scrap metal, scrap lumber, machine parts, and metal turnings—which together average more than two million tons per year in storage. Most of these materials are untreated for dust prevention since they are subject to frequent loading and unloading operations: The quantity of each type of material stored in the industrialized area of the Menomonee River Valley is shown in Table 181.

Research on fugitive dust emissions has only been undertaken within the last few years. Consequently, emission factors for many of the material types stored in aggregate piles have not yet been determined. In order to circumvent this lack of detailed information, the Department of City Development consulted the available, although limited, literature on fugitive dust emissions and surveyed industry representatives and local environmental officials to establish a "best estimate" emission factor for each of the material types stored in the Valley. Based on this survey, the estimated fugitive dust emission factors shown in Table 182 were determined. These emission factors were used to estimate the quantity of particulate matter emissions produced by the stored materials. The annual fugitive dust emissions thus calculated were then allocated among the seasons according to the distribution of precipitation throughout the year. Precipitation acts to bind aggregate materials together and thereby limit their release to the atmosphere. The amount of particulate matter emissions released from aggregate storage piles in the industrialized area of the Menomonee River Valley is shown in Table 183 by season.

Table 181

QUANTITY OF MATERIALS STORED IN THE INDUSTRIALIZED AREA OF THE MENOMONEE RIVER VALLEY

Type of Material	Estimated Quantity Stored (tons per year)
Clinker	12,000
Coal	1,030,000
Coarse Lime	55,000
Coke	5,000
Gypsum	300,000
Limestone	10,000
Pig Iron	20,000
Rock Salt	380,000
Sand	65,000
Scrap	193,000

Source: City of Milwaukee, Department of City Development.

Table 182

ESTIMATED EMISSION FACTORS FOR AGGREGATE STORAGE PILES BY MATERIAL TYPE

Type of Material	Emission Factor (pounds per ton stored)
Clinker	0.22
Coal	0.45
Coarse Lime	0.45
Coke	0.13
Gypsum	0.45
Limestone	0.22
Pig Iron	0.13
Rock Salt	0.13
Sand	0.22
Scrap	0.13

Source: City of Milwaukee, Department of City Development.

Table 183

PARTICULATE MATTER EMISSIONS FROM AGGREGATE STORAGE PILES IN THE MENOMONEE RIVER VALLEY BY SEASON: 1973

Season	Particulate Matter Emissions (tons)
Winter	57
Spring	80
Summer	115
Fall	108
Annual	360

Source: City of Milwaukee, Department of City Development.

Travel on Unpaved Roads: Vehicle travel on unpaved roads is the source of particulate matter emissions in the form of fugitive dust from the pulverization and abrasion of the surface material and the entrainment of dust particles by the action of turbulent air currents. In the heavily industrialized area of the Menomonee River Valley, there are approximately six miles of unpaved roads that release fugitive dust emissions in this manner.

The factors influencing the quantity of particulate emissions from unpaved roads have been related in the following equation developed by the Midwest Research Institute under an EPA-sponsored contract:

$$E = 0.81s \left(\frac{S}{30}\right)\left(\frac{365\text{-}w}{365}\right) \times VMT$$

where: E = total estimated fugitive dust emissions,
s = silt content of the underlying road surface,[19]
S = average vehicle speed,
w = number of days with precipitation equal to or in excess of 0.01 inch or snow cover on the ground equal to or in excess of one inch, and
VMT = vehicle miles of travel on the unpaved roads.

The City of Milwaukee, through laboratory tests of road samples, determined that the average silt content of the unpaved road surfaces in the Menomonee River Valley was approximately 6.62 percent. Also, meteorological observations taken at the National Weather Service office at General Mitchell Field indicated that during 1973, there were 166 days in which precipitation was equal to or in excess of 0.01 inch, or snow cover was equal to or in excess of one inch. The City further conducted a special vehicle count on each of the unpaved roads in the Valley during the spring of 1976, which provided an estimate of the number of vehicles operating over each link, the vehicle mix, the average trip length on the road, and the average vehicle speed. The results of this inventory indicated that approximately 5,700 vehicles per day, as adjusted for vehicles with more than four tires, traveled about 253,000 vehicle miles on unpaved roads in the Menomonee River Valley annually at an assumed average speed of 25 miles per hour. At this assumed speed the emission factor is equal to 2.43 pounds per vehicle mile of travel. Based on these findings, the total emissions produced were then calculated by season to account for changes in precipitation and snow cover throughout the year. The particulate matter emissions from vehicle travel on unpaved roads in the industrialized area of the Menomonee River Valley are shown by season in Table 184.

Table 184

PARTICULATE MATTER EMISSIONS FROM TRAVEL ON UNPAVED ROADS IN THE MENOMONEE RIVER VALLEY BY SEASON: 1973

Season	Particulate Matter Emissions (tons)
Winter	52
Spring	71
Summer	105
Fall	99
Annual	327

Source: City of Milwaukee, Department of City Development.

Travel on Unpaved Automobile Parking Lots: The City of Milwaukee, Department of City Development, has identified 389 unpaved automobile parking lots in the industrialized area of the Menomonee River Valley. Vehicle activity on these lots produces particulate matter emissions in the same manner as travel on unpaved roads. As with unpaved roads, the quantity of emissions released depends on the vehicle miles of travel on the parking lots, the silt content of the underlying surface, the average vehicle speed, and the number of days with precipitation equal to or in excess of 0.01 inch or snow cover on the ground equal to or in excess of one inch. The equation developed by the Midwest Research Institute for travel on unpaved roads is, therefore, also applicable to travel on unpaved automobile parking lots.

Based on the size of the individual automobile parking lots and the average number of vehicles using each lot, as determined through an inventory conducted by the Department of City Development during the summer of 1976, it was estimated that approximately 537 vehicle miles of travel per day occurred over the 389 unpaved parking lots. It was assumed that the average speed of the automobiles on these lots was approximately eight miles per hour and, from laboratory tests, it was found that the average silt content of the lot surfaces was 5.83 percent. The resulting emission factor is, therefore, 0.69 pound per vehicle mile of travel. Under these conditions, and accounting for temporal variations in precipitation and snow cover levels, the Department of City Development estimated that travel on unpaved automobile parking lots in the Menomonee River Valley in 1973 produced approximatey 49 tons of particulate matter emissions, as shown in Table 185.

Travel on Unpaved Truck Lots: The City of Milwaukee, Department of City Development, during an inventory conducted in the spring of 1976, identified 80 unpaved lots in the industrialized area of the Menomonee River Valley that are used by large trucks in the transport of commercial materials. Based on this inventory, the Department has estimated that, when trucks are adjusted to the equivalent of four-tire vehicles, approximately 122,000 vehicle miles of travel are experienced over the 80 unpaved truck lots annually. Again using the Midwest Research Institute's equation for fugitive dust emissions, an average silt content of 9.7 percent on the road surface as determined from field tests, and an average vehicle speed of eight miles per hour, and thus an emission factor of 1.14 pounds of pollutant per vehicle mile of travel, trucks traveling over unpaved lots in the industrialized area of the Menomonee River Valley released about 77 tons of particulate matter into the atmosphere in 1973, as shown by season in Table 186.

Area Source Emissions Inventory: 1973 Summary
Table 187 presents the total estimated air pollutant emissions for each of the 22 identified area source

[19] *The silt content is defined here as the percentage of particles that are less than or equal to 30 μ in size.*

Table 185

PARTICULATE MATTER EMISSIONS FROM TRAVEL ON UNPAVED AUTOMOBILE PARKING LOTS IN THE MENOMONEE RIVER VALLEY BY SEASON: 1973

Season	Particulate Matter Emissions (tons)
Winter	8
Spring	11
Summer	16
Fall	14
Annual	49

Source: City of Milwaukee, Department of City Development.

Table 186

PARTICULATE MATTER EMISSIONS FROM TRAVEL ON UNPAVED TRUCK LOTS IN THE MENOMONEE RIVER VALLEY BY SEASON: 1973

Season	Particulate Matter Emissions (tons)
Winter	13
Spring	17
Summer	25
Fall	22
Annual	77

Source: City of Milwaukee, Department of City Development.

Table 187

QUANTITY OF AIR POLLUTANT EMISSIONS FROM AREA SOURCES IN THE REGION: 1973

Source Category	Pollutant									
	Particulate Matter		Sulfur Dioxide		Carbon Monoxide		Nitrogen Oxides		Hydrocarbons	
	Tons	Percent	Tons	Percent	Tons	Percent	Tons	Percent	Tons	Percent
Agricultural Equipment	576	4.80	394	2.39	19,789	28.98	4,505	21.87	1,526	5.76
Agricultural Tilling	5,946	49.51	--	--	--	--	--	--	--	--
Aircraft Operations	60	0.50	56	0.34	6,432	9.42	524	2.54	928	3.51
Commercial-Institutional Fuel Use	1,675	13.95	10,345	62.64	2,308	3.38	4,695	22.78	680	2.57
Dry Cleaning Operations	--	--	--	--	--	--	--	--	2,408	9.09
Forest Wildfires	22	0.18	--	--	178	0.26	3	0.01	29	0.11
Gasoline Marketing	--	--	--	--	--	--	--	--	6,368	24.05
General Utility Engines	182	1.52	12	0.07	14,670	21.48	74	0.36	5,693	21.50
Incineration	352	2.93	52	0.31	268	0.39	104	0.50	184	0.70
Industrial Fuel Use	269	2.24	845	5.12	364	0.53	3,059	14.84	67	0.25
Power Boat Operations	--	--	39	0.24	20,510	30.03	41	0.20	6,975	26.34
Travel by Railroad Engines	216	1.80	484	2.93	1,300	1.90	2,804	13.60	308	1.16
Railroad Yard Work	64	0.53	140	0.85	708	1.04	1,048	5.08	404	1.53
Residential Fuel Use	1,331	11.08	4,081	24.71	1,443	2.11	3,497	16.96	617	2.33
Rock Handling and Storage	321	2.67	--	--	--	--	--	--	--	--
Small Point Sources	132	1.10	44	0.27	20	0.03	164	0.80	100	0.38
Snowmobile Operations	6	0.05	--[a]	--	269	0.40	--[a]	--	173	0.65
Travel on Unpaved Roads	327	2.72	--	--	--	--	--	--	--	--
Unpaved Auto Lots	49	0.41	--	--	--	--	--	--	--	--
Unpaved Truck Lots	77	0.64	--	--	--	--	--	--	--	--
Aggregate Storage Piles	360	3.00	--	--	--	--	--	--	--	--
Commercial Vessels	44	0.37	22	0.13	35	0.05	94	0.46	19	0.07
Total	12,009	100.00	16,514	100.00	68,294	100.00	20,612	100.00	26,479	100.00

[a] *Less than one-half ton.*

Source: SEWRPC.

categories in the Region during 1973. The table also indicates the relative contribution of the individual area source emission categories to the total area source pollutant emissions for each pollutant species. As may be seen in this table, about 12,000 tons of particulate matter were emitted from area sources in the Region during 1973. Of this 12,000 tons, about 8,952 tons, or nearly 75 percent, are attributable to only three area source emission categories—agricultural tilling, commercial-institutional fuel use, and residential fuel use. The fact that agricultural tilling alone accounts for nearly 50 percent of the particulate matter emissions in the 1973 area source inventory not only indicates the ability of plowing operations to inject large quantities of soil particles into the atmosphere, but also reflects the intensely agricultural nature of the Region.

It should also be noted, however, that agricultural tilling operations are distributed over a broad geographic area and, consequently, may not impact ambient air quality to the same extent as commercial-institutional and residential fuel use emissions, which are generally concentrated within urban centers.

The commercial-institutional and residential fuel use categories are the largest area sources of sulfur dioxide emissions in the 1973 inventory. These two categories accounted for 14,426 tons, or about 87 percent, of the total 16,514 tons of sulfur dioxide emissions from area sources in the Region during 1973. This finding is not surprising since sulfur dioxide emissions are principally the by-product of the combustion of fossil fuels, and the commercial-institutional and residential fuel use categories represent the largest consumers of primary energy fuels of all the area source categories.

Carbon monoxide emissions from area sources—also principally a by-product of the combustion of fossil fuels—totaled about 68,294 tons in the Region during 1973. The primary area source categories producing these emissions are power boat operations, agricultural equipment, and general utility engines. Collectively, these three categories accounted for about 54,969 tons, or approximately 81 percent, of the total carbon monoxide emissions from area sources in the Region during 1973. In the case of power boats and general utility engines, many of which use two-stroke-cycle engines, the high levels of carbon monoxide emissions may be attributed to a combination of relatively low operating temperatures, as compared to commercial boilers or residential furnaces, and the rich fuel mixture that such engines must use for smooth performance. Because the predominant type of tractors and other machinery used for agricultural operations in the Region are diesel-powered (see Table 128), with engines that operate at high temperatures and utilize large amounts of air for complete combustion, it was initially assumed that agricultural operations would not be a significant source of carbon monoxide. However, the predominance of diesel-powered equipment notwithstanding, gasoline-powered agricultural engines using richer fuel mixtures emit 20 to 45 times more carbon monoxide than do diesel-powered engines, as may be seen in Table 129. Therefore, agricultural equipment operations, particularly the gasoline-powered equipment operations, did contribute substantially to the total carbon monoxide emissions from area sources in the Region during 1973.

Conversely, the fraction of agricultural equipment that is diesel-powered is a significant contributor to the 1973 inventory of nitrogen oxide emissions from area sources in the Region. Of the approximate 20,600 tons of nitrogen oxide emissions from area sources in the Region during 1973, about 18,553 tons, or about 90 percent, were attributable to agricultural equipment, railroad engines, and commercial-institutional, industrial, and residential fuel use. The diesel-powered agricultural equipment engines and railroad engines operate under conditions conducive to the formation of nitrogen oxide emissions; that is, oxidation occurring in the combustion chamber at high temperatures. Similarly, the high operating temperatures associated with commercial-institutional, industrial, and residential boilers or furnaces—again using air as the oxidizing agent—promote the formation of nitrogen oxides.

In addition to contributing significant amounts of carbon monoxide emissions, general utility engines and power boats account for a major portion of the hydrocarbon emissions from area sources in the Region during 1973. These two categories emitted about 12,668 tons, or nearly 48 percent, of the total area source hydrocarbon emissions during 1973. The relatively low operating temperatures and rich fuel mixtures characteristic of these two-stroke-cycle engines are the principal cause of the high hydrocarbon emission rates. Another area source category, gasoline marketing, also contributed substantially to the regional hydrocarbon burden during 1973, with about 6,368 tons, or about 24 percent, of the total area source hydrocarbon emissions being attributable to the transfer of gasoline to submerged service station storage tanks and transferred again from the submerged tanks to vehicle fuel tanks.

Table 188 presents the total area source emissions inventory for the Region for 1973 distributed by county and by season. As may be expected, Milwaukee County, which has the largest concentration of urban development and the largest resident population, produces the largest absolute and relative quantity of emissions for each pollutant species, ranging from about 28 percent of the total regional area source particulate matter emissions to about 53 percent of the sulfur dioxide emissions during 1973.

The total regional area source emissions inventory exhibits a distinct seasonal distribution for four of the five pollutant species. Particulate matter emissions, for example, are at a maximum in the spring season when agricultural tilling operations occur to the greatest extent. Sulfur dioxide emissions from area sources reach a peak during the winter season, when fossil fuel combustion is used most for space heating purposes. Both carbon monoxide and hydrocarbon area source emissions are released in the largest quantities during the summer months, when the two-stroke-cycle engines used in power boats and general utility engines attain maximum operation. Only nitrogen dioxide exhibits a reduced seasonal peak in the temporal distribution of emissions. This finding may be explained by the fact that most combustion processes, whether for space heating purposes in the winter or the operation of agricultural equipment in the spring, occur under conditions that encourage the formation of nitrogen oxides; that is, high temperatures in the combustion chamber and the use of air as the oxidizing agent. As winter fuel consumption for space heating declines, comsumption by agricultural equipment begins to increase. Nitrogen dioxide emissions from area sources are therefore more uniformly distributed between the winter and spring seasons.

Table 188

COUNTY SUMMARY OF TOTAL AREA SOURCE EMISSIONS BY SEASON: 1973

County	Season	Emissions (tons)				
		Particulate Matter	Sulfur Dioxide	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
Kenosha	Winter	139	569	525	477	294
	Spring	756	355	1,170	580	381
	Summer	88	94	3,067	287	849
	Fall	152	257	683	342	329
	Annual	1,135	1,275	5,445	1,686	1,853
Milwaukee	Winter	1,077	4,000	3,372	3,401	2,301
	Spring	925	2,373	4,184	2,666	2,600
	Summer	596	612	9,405	1,466	4,616
	Fall	738	1,763	3,253	1,945	2,247
	Annual	3,336	8,748	20,214	9,478	11,764
Ozaukee	Winter	80	265	271	250	149
	Spring	634	177	827	410	215
	Summer	79	54	1,813	189	412
	Fall	120	125	359	194	163
	Annual	913	621	3,270	1,043	939
Racine	Winter	212	820	699	686	385
	Spring	993	516	1,692	863	516
	Summer	129	141	4,820	404	1,257
	Fall	215	372	983	471	452
	Annual	1,549	1,849	8,194	2,424	2,610
Walworth	Winter	77	259	397	275	192
	Spring	1,533	188	1,604	635	346
	Summer	123	49	5,083	272	1,086
	Fall	222	123	876	277	322
	Annual	1,955	619	7,960	1,459	1,946
Washington	Winter	110	425	560	376	199
	Spring	1,053	292	1,750	717	341
	Summer	114	85	4,551	315	942
	Fall	192	204	958	365	300
	Annual	1,469	1,006	7,819	1,773	1,782
Waukesha	Winter	288	1,097	939	835	615
	Spring	891	667	2,251	951	848
	Summer	199	158	10,162	434	3,173
	Fall	274	474	2,040	529	949
	Annual	1,652	2,396	15,392	2,749	5,585
Region	Winter	1,983	7,435	6,763	6,300	4,135
	Spring	6,785	4,568	13,478	6,822	5,247
	Summer	1,328	1,193	38,901	3,367	12,335
	Fall	1,913	3,318	9,152	4,123	4,762
	Annual	12,009	16,514	68,294	20,612	26,479

Source: SEWRPC.

Table 189

SUMMARY OF TOTAL EMISSIONS FOR THE SOUTHEASTERN WISCONSIN REGION BY COUNTY BY SEASON: 1973

County	Season	Emissions (tons)				
		Particulate Matter	Sulfur Dioxide	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
Kenosha	Winter	533	743	11,187	1,632	1,758
	Spring	1,150	530	10,500	1,670	1,758
	Summer	482	268	11,835	1,308	2,187
	Fall	546	432	9,590	1,412	1,677
	Annual	2,711	1,973	43,112	6,022	7,380
Milwaukee	Winter	5,521	40,818	89,097	19,790	15,576
	Spring	5,369	39,191	79,898	18,644	15,227
	Summer	5,040	37,430	80,939	16,967	16,955
	Fall	5,182	38,581	75,775	17,771	14,664
	Annual	21,112	156,020	325,709	73,172	62,422
Ozaukee	Winter	313	11,222	5,309	2,374	768
	Spring	867	11,134	5,256	2,497	794
	Summer	312	11,011	5,979	2,240	973
	Fall	353	11,083	4,594	2,271	729
	Annual	1,845	44,450	21,138	9,382	3,264
Racine	Winter	377	912	15,467	2,103	1,984
	Spring	1,158	608	14,870	2,204	2,011
	Summer	294	233	17,330	1,666	2,706
	Fall	380	465	13,654	1,790	1,915
	Annual	2,209	2,218	61,321	7,763	8,616
Walworth	Winter	187	283	7,015	938	827
	Spring	1,643	212	7,482	1,256	934
	Summer	233	73	10,643	854	1,651
	Fall	332	146	6,518	889	893
	Annual	2,395	714	31,658	3,937	4,305
Washington	Winter	189	465	7,171	1,279	1,023
	Spring	1,133	332	7,581	1,564	1,113
	Summer	193	125	10,043	1,115	1,691
	Fall	272	243	6,540	1,200	1,057
	Annual	1,787	1,165	31,335	5,158	4,884
Waukesha	Winter	555	1,181	24,460	3,157	3,131
	Spring	1,158	751	23,130	3,121	3,191
	Summer	466	242	29,904	2,448	5,438
	Fall	541	559	22,076	2,655	3,236
	Annual	2,720	2,733	99,570	11,381	14,996
Region	Winter	7,675	55,624	159,706	31,273	25,067
	Spring	12,478	52,758	148,717	30,956	25,028
	Summer	7,020	49,382	166,673	26,598	31,601
	Fall	7,606	51,509	138,747	27,988	24,171
	Annual	34,779	209,273	613,843	116,815	105,867

Source: SEWRPC.

Total Air Pollutant Emissions in the Region: 1973 Summary

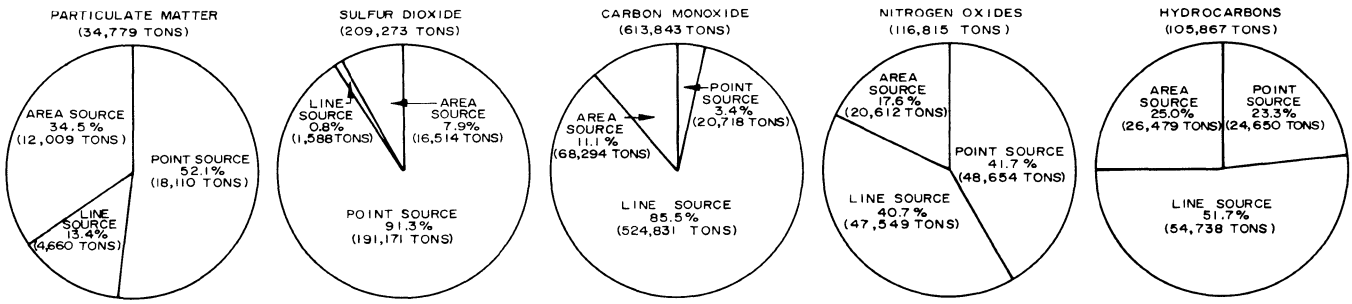
Table 189 provides a summary by season and by county of the total estimated air pollutant emissions from all point, line, and area sources in the Region during 1973. As may be seen in the table, about 34,800 tons of particulate matter, 209,300 tons of sulfur dioxide, 613,800 tons of carbon monoxide, 116,800 tons of nitrogen oxides, and 105,900 tons of hydrocarbons—approximately one million tons altogether—were released into the atmosphere over the Region during this year from all sources within the Region.

Figure 56 indicates the relative contribution of point, line, and area sources to the total regional emissions of each pollutant species during 1973. As the figure indicates, point sources accounted for about 52 percent of the total 34,800 tons of particulate matter emissions in the Region during 1973. Area sources contributed about 35 percent of the total particulate matter emissions, and line sources contributed about 13 percent.

Point sources, as shown in the figure, were the predominant emitter of sulfur dioxide in the Region, accounting for over 91 percent of the emissions of this pollutant

Figure 56

RELATIVE CONTRIBUTION FROM POINT, LINE, AND AREA SOURCES TO TOTAL POLLUTANT BURDEN: 1973



Source: Wisconsin Department of Natural Resources and SEWRPC.

species during 1973. Area sources contributed about 8 percent of the total sulfur dioxide emissions, and line sources contributed virtually no sulfur dioxide emissions, accounting for less than 1 percent of the total burden.

Line sources were the major generator of carbon monoxide and hydrocarbon emissions in the Region during 1973. As shown in the figure, line sources accounted for about 86 percent of the total regional carbon monoxide emissions and about 52 percent of the total hydrocarbon emissions. Point sources and line sources, meanwhile, contributed nearly equal amounts of nitrogen oxides during 1973, 42 percent and 41 percent, respectively. Nitrogen oxides, therefore, is the only pollutant species for which there is no single predominant source of emissions.

It should be noted that the emissions data summarized in Table 189 and in Figure 56 are representative only of those pollution sources in the Region that could be identified and quantified with some degree of precision and accuracy. There are, however, certain sources of emissions that have not been included in this inventory either because the pollutant source was not identified as such during the inventory or because the rate at which pollutant emissions were generated by a process, operation, or event could not be defined. Fugitive dust emissions from industrial sources are an example of a source category that was not identified during the collation of the 1973 inventory. This category, which is comprised of those emissions that are released inside industrial facilities by some process or operation and that may be subsequently released to the ambient air through open windows or vents, has only been recognized as a significant source of pollution since about 1976. Consequently, industrial fugitive dust emissions were not included in the 1973 inventory but have been included in the 1977 inventory. Structural fires, on the other hand, are an example of an air pollutant emissions source that may be identified and precisely located both temporally and spatially. Emissions from structural fires, however, cannot be estimated with any precision or accuracy because the rate at which pollutant species are emitted during such fires depends on the type of material being consumed—a factor which varies too substantially between individual structures to allow ready quantification of an average emission rate. The amount of air pollutant emissions in the Region due to structural fires, therefore, is not included in the emissions inventory.

Although unidentifiable or unquantifiable emission sources are not represented in the pollutant inventory summaries, the collective impact of such sources on ambient air quality in the Region may be evaluated as a part of the air quality simulation modeling effort. Such an evaluation is made during model calibration, when the modeling results are adjusted by adding a uniform "background" level of pollutant concentration to the predicted concentration. This background concentration—the value of which is inferred from the "y" intercept in a least squares regression analysis of the differences between the observed and calculated pollutant concentrations (see Chapter X)—is representative of the joint contribution of unidentified or unquantified local emissions, long-range pollutant transport, chemical transformations, and naturally occurring pollutant levels to the monitored pollutant concentrations. As local air pollutant emission sources are better defined and as emission rates for various operations, processes, and events are more firmly established through further research, the adjustment for background pollutant levels will probably be lowered.

SULFUR DIOXIDE EMISSIONS INVENTORY: 1976

As mentioned in Chapter VI of this report, all ambient air quality monitoring data for sulfur dioxide measured in the Region prior to 1975 were deemed invalid because of the use of a monitoring technique that has since come into question and because of problems in reducing the raw data to average concentrations. It was necessary, therefore, to select a year other than 1973, and subsequent to 1975, as the base year for calibrating and validating the air quality simulation model for sulfur dioxide. Accordingly, the year 1976, during which a maxi-

mum of five valid sulfur dioxide monitoring sites were operated, was chosen as the base year for measuring this pollutant species, and an updated inventory of sulfur dioxide emissions from point, line, and area sources in the Region was prepared.

As in the 1973 inventory, the sulfur dioxide emissions from point sources in the Region during 1976 were collated by personnel from the Wisconsin Department of Natural Resources. These point source emissions, presented by county in Table 190, totaled about 236,600 tons in 1976, approximately 24 percent more than the 191,200 tons of sulfur dioxide emissions from point sources inventoried in 1973. Nearly 85 percent of this 45,500-ton increase occurred in Milwaukee County and may be attributed to an increase in demand for fossil fuels for electrical power generation and industrial processes.

The 1976 sulfur dioxide emissions from line sources in the Region were derived from the 1977 line source emissions inventory conducted by the Commission, which was prepared following the same U. S. EPA recommended procedures used in the 1973 line source inventory. It should be noted that the rate of sulfur dioxide emissions from vehicles operating on the street and highway system in the Region did not change between 1976 and 1977. Thus, the 1976 emissions were calculated by reducing the 1977 emissions by the estimated growth in vehicle miles of travel experienced between 1976 and 1977. As indicated in Table 191, line sources generated about 1,800 tons of sulfur dioxide during 1976, an increase of about 200 tons, or approximately 13 percent, over the 1,600 tons of sulfur dioxide emitted by line sources in the Region during 1973.

Sulfur dioxide emissions from area sources are predominantly generated by the combustion of fossil fuels in commercial-institutional, industrial, and residential boilers or furnaces. These three categories accounted for over 92 percent of the sulfur dioxide area source emissions during 1973. Because other area sources of sulfur dioxide emissions are relatively small, and because little change may be anticipated in these small emission categories, only the three major area source categories of sulfur dioxide emissions were reinventoried for 1976. The

Table 190

SULFUR DIOXIDE EMISSIONS FROM POINT SOURCES IN THE REGION BY COUNTY: 1976

County	Sulfur Dioxide Emissions (tons)
Kenosha	392
Milwaukee	184,788
Ozaukee	51,136
Racine	208
Walworth	32
Washington	8
Waukesha	84
Region	236,648

Source: Wisconsin Department of Natural Resources and SEWRPC.

Table 191

SUMMARY OF TOTAL LINE SOURCE SULFUR DIOXIDE EMISSIONS BY COUNTY BY SEASON: 1976

County	Season	Sulfur Dioxide Emissions (tons)
Kenosha	Winter	45
	Spring	45
	Summer	45
	Fall	45
	Annual	180
Milwaukee	Winter	192
	Spring	192
	Summer	192
	Fall	192
	Annual	768
Ozaukee	Winter	28
	Spring	28
	Summer	28
	Fall	28
	Annual	112
Racine	Winter	45
	Spring	45
	Summer	45
	Fall	45
	Annual	180
Walworth	Winter	31
	Spring	31
	Summer	31
	Fall	31
	Annual	124
Washington	Winter	30
	Spring	30
	Summer	30
	Fall	30
	Annual	120
Waukesha	Winter	77
	Spring	77
	Summer	77
	Fall	77
	Annual	308
Region	Winter	448
	Spring	448
	Summer	448
	Fall	448
	Annual	1,792

Source: SEWRPC.

same procedures were followed in collating the 1976 inventory of sulfur dioxide emissions from commercial-institutional, industrial, and residential fuel use as were used in the 1973 inventories. However, the rate of fuel consumption by these three sources was determined from the prevailing meteorological conditions during 1976, and the type of fuel consumed was determined from a telephone survey of local suppliers in the Region. The sulfur dioxide emissions resulting from commercial-institutional, industrial, and residential fuel use in the Region during 1976 are presented in Tables 192, 193, and 194, respectively. The total regional sulfur dioxide emissions from area sources during 1976 approximated 11,400 tons (see Table 195), about 31 percent less than the 16,500 tons of sulfur dioxide emitted from area sources in 1973. This significant decrease can be attributed principally to a substantial reduction in the quantity of coal used for space heating and water heating purposes in the Region from 1973 to 1976.

The total estimated sulfur dioxide emissions from all point, line, and area sources in the Region are presented by county by season in Table 196. As shown in the table, approximately 250,000 tons of sulfur dioxide emissions were released from all sources in the Region during 1976, an increase of 41,000 tons, or about 20 percent, over the 209,000 tons of sulfur dioxide emitted in the Region during 1973. This 41,000-ton increase was due almost entirely to an approximate 45,000-ton increase in sulfur dioxide emissions from point sources, which was slightly offset by a 5,000-ton decrease in sulfur dioxide emissions from area sources.

AIR POLLUTANT EMISSIONS INVENTORY: 1977

Since the collation of the 1973 regional inventory of air pollutant emissions from point, line, and area sources, both governmental agencies and the private sector have been researching ways in which to more accurately identify and quantify emission sources and pollutant discharge rates. In particular, additional research conducted by the U. S. EPA into the actual on-road operational characteristics of motor vehicles has led to substantial revisions in the calculation procedures used to determine pollutant emissions in automotive exhaust gases. Moreover, more detailed investigations of the physical and chemical processes associated with the formation of ozone in the lower atmosphere have led to advances in the simulation procedures for defining the cause and effect relationships between precursor emissions and ambient ozone levels. The Empirical Kinetics Modeling Approach (EKMA)—described in Chapter X—is one such modeling procedure that has been developed since the collation of the 1973 regional air pollutant emissions inventory. The Clean Air Act Amendments of 1977, however, prescribe that the use of the EKMA, or any other modeling approach for photochemical oxidants, be based on current—circa 1977—ambient air quality monitoring data for ozone and a complementary hydrocarbon emissions inventory. A comprehensive air pollutant emissions inventory for the year 1977 was, therefore, deemed essential for the regional air quality maintenance planning program.

The 1977 air pollutant emissions inventory has several advantages over the 1973 inventory in addition to providing a more recent identification of the existing air pollution problem in the Region. First, the 1977 inventory includes emission source categories that were not identified in the 1973 inventory collation process and,

Table 192

SUMMARY OF SULFUR DIOXIDE EMISSIONS FROM COMMERCIAL-INSTITUTIONAL FUEL USE BY COUNTY BY SEASON: 1976

County	Season	Sulfur Dioxide Emissions (tons)
Kenosha	Winter	227
	Spring	115
	Summer	32
	Fall	118
	Annual	492
Milwaukee	Winter	1,086
	Spring	548
	Summer	151
	Fall	564
	Annual	2,349
Ozaukee	Winter	76
	Spring	38
	Summer	11
	Fall	39
	Annual	164
Racine	Winter	298
	Spring	150
	Summer	41
	Fall	154
	Annual	643
Walworth	Winter	75
	Spring	38
	Summer	10
	Fall	39
	Annual	162
Washington	Winter	151
	Spring	76
	Summer	21
	Fall	79
	Annual	327
Waukesha	Winter	379
	Spring	191
	Summer	53
	Fall	196
	Annual	819
Region	Winter	2,292
	Spring	1,156
	Summer	319
	Fall	1,189
	Annual	4,956

Source: SEWRPC.

thus, is more comprehensive. Second, the 1977 inventory provides the means by which the Wisconsin Atmospheric Diffusion Model (WIS-ATMDIF) modeling procedures[20] and results may be validated through the successful computer simulation of pollutant concentrations in the Region under meteorological and emission source conditions that may vary substantially from the base year, 1973, conditions. Finally, changes in the spatial distribution of emission sources and in the quantity of pollutants discharged by each source category may be identified, and possible trends observed, through comparison of the 1973 and 1977 inventories. This comparison is provided in the following sections.

[20] *For a detailed explanation of the Wisconsin Atmospheric Diffusion Model, see Chapter X.*

Table 193

SUMMARY OF SULFUR DIOXIDE EMISSIONS FROM INDUSTRIAL FUEL USE BY COUNTY BY SEASON: 1976

County	Season	Sulfur Dioxide Emissions (tons)
Kenosha	Winter	6
	Spring	5
	Summer	5
	Fall	5
	Annual	21
Milwaukee	Winter	105
	Spring	92
	Summer	83
	Fall	92
	Annual	372
Ozaukee	Winter	15
	Spring	13
	Summer	12
	Fall	13
	Annual	53
Racine	Winter	23
	Spring	20
	Summer	18
	Fall	20
	Annual	81
Walworth	Winter	5
	Spring	4
	Summer	4
	Fall	4
	Annual	17
Washington	Winter	14
	Spring	12
	Summer	11
	Fall	12
	Annual	49
Waukesha	Winter	12
	Spring	11
	Summer	10
	Fall	11
	Annual	44
Region	Winter	180
	Spring	157
	Summer	143
	Fall	157
	Annual	637

Source: SEWRPC.

Table 194

SUMMARY OF SULFUR DIOXIDE EMISSIONS FROM RESIDENTIAL FUEL USE BY COUNTY BY SEASON: 1976

County	Season	Sulfur Dioxide Emissions (tons)
Kenosha	Winter	153
	Spring	67
	Summer	3
	Fall	69
	Annual	292
Milwaukee	Winter	1,182
	Spring	519
	Summer	28
	Fall	537
	Annual	2,266
Ozaukee	Winter	110
	Spring	48
	Summer	3
	Fall	50
	Annual	211
Racine	Winter	262
	Spring	115
	Summer	6
	Fall	119
	Annual	502
Walworth	Winter	124
	Spring	54
	Summer	3
	Fall	56
	Annual	237
Washington	Winter	136
	Spring	60
	Summer	3
	Fall	62
	Annual	261
Waukesha	Winter	429
	Spring	188
	Summer	9
	Fall	194
	Annual	820
Region	Winter	2,396
	Spring	1,051
	Summer	55
	Fall	1,087
	Annual	4,589

Source: SEWRPC.

Point Source Emissions Inventory: 1977

Particulate Matter: The particulate matter emissions from point sources in the Region as obtained from the Wisconsin Department of Natural Resources' records for 1977 are provided in Table 197. As shown in the table, point sources emitted 7,432 tons of particulate matter in the Region during 1977, a decrease of 10,678 tons, or 59 percent, from the particulate matter emissions from point sources during 1973 (see Table 93). With the exception of Racine and Waukesha Counties, which experienced a small absolute growth in emissions, all other counties in the Region exhibited a decrease in

Table 195

SUMMARY OF TOTAL AREA SOURCE SULFUR DIOXIDE EMISSIONS BY COUNTY BY SEASON: 1976

County	Season	Sulfur Dioxide Emissions (tons)
Kenosha	Winter	408
	Spring	227
	Summer	70
	Fall	220
	Annual	925
Milwaukee	Winter	2,481
	Spring	1,275
	Summer	383
	Fall	1,305
	Annual	5,444
Ozaukee	Winter	212
	Spring	129
	Summer	44
	Fall	117
	Annual	502
Racine	Winter	613
	Spring	345
	Summer	109
	Fall	333
	Annual	1,400
Walworth	Winter	215
	Spring	144
	Summer	42
	Fall	121
	Annual	522
Washington	Winter	320
	Spring	205
	Summer	67
	Fall	183
	Annual	775
Waukesha	Winter	849
	Spring	448
	Summer	120
	Fall	440
	Annual	1,857
Region	Winter	5,098
	Spring	2,773
	Summer	835
	Fall	2,719
	Annual	11,425

Source: SEWRPC.

Table 196

TOTAL SULFUR DIOXIDE EMISSIONS FROM POINT, LINE, AND AREA SOURCES IN THE REGION BY COUNTY BY SEASON: 1976

County	Season	Sulfur Dioxide Emissions (tons)
Kenosha	Winter	551
	Spring	370
	Summer	213
	Fall	363
	Annual	1,497
Milwaukee	Winter	48,870
	Spring	47,664
	Summer	46,772
	Fall	47,694
	Annual	191,000
Ozaukee	Winter	13,024
	Spring	12,941
	Summer	12,856
	Fall	12,929
	Annual	51,750
Racine	Winter	710
	Spring	442
	Summer	206
	Fall	430
	Annual	1,788
Walworth	Winter	254
	Spring	183
	Summer	81
	Fall	160
	Annual	678
Washington	Winter	352
	Spring	237
	Summer	99
	Fall	215
	Annual	903
Waukesha	Winter	947
	Spring	546
	Summer	218
	Fall	538
	Annual	2,249
Region	Winter	64,708
	Spring	62,383
	Summer	60,445
	Fall	62,329
	Annual	249,865

Source: Wisconsin Department of Natural Resources and SEWRPC.

the total quantity of particulate matter emissions from point sources between 1973 and 1977. The greatest absolute decrease occurred in Milwaukee County, where emissions declined from 15,408 tons in 1973 to 6,095 tons in 1977, a decline of about 60 percent over the five-year period. This 9,313-ton reduction in particulate matter emissions from point sources in Milwaukee County represents about 87 percent of the 10,678-ton decrease observed in the Region between 1973 and 1977, and may be attributed principally to the change in emissions from the Milwaukee Solvay Coke Company and the Wisconsin Electric Power Company's Oak Creek plant. In 1973 the Milwaukee Solvay Coke Company generated an estimated 4,845 tons of particulate matter emissions. Through the retirement of about one-half of the coke ovens at the facility, and the provision of pollution control equipment for the remaining coke ovens, the company reduced particulate matter emissions to about 473 tons by 1977, a reduction of about 4,372 tons, or more than 90 percent, from the 1973 level. Increases in the efficiency of pollution control equipment and the burning of coal with a lower ash content resulted in a reduction of particulate matter emissions from the Oak Creek power plant—from about 7,292 tons in 1973 to 3,223 tons in 1977, a decrease of nearly 56 percent over the five-year period.

The greatest relative reduction in particulate matter emissions from point sources between 1973 and 1977 occurred in Kenosha County. In 1973 point sources in Kenosha County produced about 1,199 tons of particulate matter. By 1977 these emissions were reduced to about 49 tons, a decrease of about 96 percent. This decrease may be attributed almost entirely to the addition of air pollution controls on the boilers at the Anaconda American Brass Company, which resulted in about a 98 percent reduction in particulate matter emissions—from 1,082 tons in 1973 to about 18 tons in 1977.

The Milwaukee Solvay Coke Company, the Oak Creek power plant, and the Anaconda American Brass Company jointly accounted for about 9,504 tons, or about 89 percent, of the total 10,678-ton reduction in particulate

Table 197

DISTRIBUTION OF PARTICULATE MATTER EMISSIONS FROM POINT SOURCES IN THE REGION BY COUNTY: 1977

Source of Emissions	Emissions (tons)							
	Kenosha	Milwaukee	Ozaukee	Racine	Walworth	Washington	Waukesha	Region
Fuel-Burning Installation (boilers)								
5,000,000 BTU per Hour or Less	-- [a]	12	-- [a]	-- [a]	1	-- [a]	3	16
5,000,001 to 49,999,999 BTU per Hour	-- [a]	73	-- [a]	4	-- [a]	1	1	79
50,000,000 to 99,999,999 BTU per Hour	17	38	--	32	16	--	1	104
100,000,000 BTU per Hour or More	7	4,816	499	2	-- [a]	--	--	5,324
Subtotal	24	4,939	499	38	17	1	5	5,523
Incineration								
Less than 500 Pounds of Waste per Hour	--	-- [a]	--	--	--	--	--	-- [a]
500-4,000 Pounds of Waste per Hour	-- [a]	13	--	--	--	--	--	13
More than 4,000 Pounds of Waste per Hour	--	19	--	--	--	--	43	62
Subtotal	-- [a]	32	--	--	--	--	43	75
Industrial Process								
Coking Processes	--	473	--	--	--	--	--	473
Metal Processes	7	231	34	119	33	8	40	472
Painting Processes	1	28	-- [a]	-- [a]	1	1	-- [a]	31
Food Processing	--	--	--	3	--	--	--	3
Asphalt Products	13	85	--	6	8	--	38	150
Grain Handling and Processing	--	93	--	--	--	--	--	93
Printing and Lithography	--	1	--	-- [a]	--	--	-- [a]	1
Glassworks	--	3	--	124	--	--	--	127
Coating Operations	--	-- [a]	--	--	--	--	-- [a]	-- [a]
Heat Treating	4	110	--	2	--	--	1	117
Solvent and Adhesive Processes	--	--	--	--	--	--	--	--
Washing and Drying	--	-- [a]	-- [a]	--	--	--	121	121
Miscellaneous	--	100	3	1	68	-- [a]	74	246
Subtotal	25	1,124	37	255	110	9	274	1,834
Total	49	6,095	536	293	127	10	322	7,432

[a] *Less than one-half ton.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

matter emissions from point sources in the Region between 1973 and 1977. The remaining 11 percent of the observed particulate matter emissions reduction essentially reflects the addition of pollution controls on smaller facilities throughout the Region.

Sulfur Dioxide: Table 198 presents the county distribution of sulfur dioxide emissions from point sources in the Region during 1977 by source of emissions. As shown in the table, point source sulfur dioxide emissions in 1977 totaled 196,839 tons, an increase of 5,668 tons, or 3 percent, over the 191,171 tons emitted during 1973 (see Table 94). The greatest absolute increase in sulfur dioxide emissions from point sources occurs in Milwaukee County in the fuel-burning category, in particular, from boilers with a rated capacity of 100 million BTU's or more per hour. The operation of these large boilers, principally associated with the Oak Creek power plant, resulted in a 13,700-ton, or 10 percent, increase in sulfur dioxide emissions—from 141,672 tons in 1973 to 155,364 tons in 1977. This increase in sulfur dioxide emissions may be attributed to the greater quantity of coal used at the Oak Creek plant in 1977, and to a higher average sulfur content in the coal burned in 1977. Coal use at the plant increased by about 63,000 tons, or over 2 percent, between 1973 and 1977—from approximately 2.845 million tons during 1973 to about 2.908 million tons in 1977. At the same time, the average sulfur content of the coal used rose from about 1.80 percent in 1973 to about 1.95 percent in 1977, which caused an overall increase in sulfur dioxide emissions of about 8 percent.

The increase in sulfur dioxide emissions in Milwaukee County was offset somewhat by a decrease in emissions in Ozaukee County. Between 1973 and 1977, the Port Washington power plant reduced sulfur dioxide emissions by 5,745 tons, or about 13 percent—from 43,740 tons to 37,995 tons. This observed decrease may be attributed entirely to the reduction in the average sulfur content of the coal used of from 3.35 percent in 1973 to 2.85 percent in 1977.

Further offsetting the Milwaukee County increase was the reduction in sulfur dioxide emissions from miscellaneous industrial processes. In 1973 nearly all of the 2,615 tons of sulfur dioxide emissions from miscellaneous processes (see Table 94) were attributable to the Marquette Cement Manufacturing Company, which contributed about 2,604 tons from a coal-fired cement

Table 198

DISTRIBUTION OF SULFUR DIOXIDE EMISSIONS FROM POINT SOURCES IN THE REGION BY COUNTY: 1977

Source of Emissions	Emissions (tons)							
	Kenosha	Milwaukee	Ozaukee	Racine	Walworth	Washington	Waukesha	Region
Fuel-Burning Installation (boilers)								
5,000,000 BTU per Hour or Less	-- [a]	36	--	--	-- [a]	3	26	65
5,000,001 to 49,999,999 BTU per Hour	-- [a]	578	-- [a]	40	-- [a]	4	5	627
50,000,000 to 99,999,999 BTU per Hour	306	299	--	221	4	--	2	832
100,000,000 BTU per Hour or More	133	155,364	37,995	34	1	--	--	193,527
Subtotal	439	156,277	37,995	295	5	7	33	195,051
Incineration								
Less than 500 Pounds of Waste Per Hour	--	-- [a]	--	--	--	--	--	-- [a]
500-4,000 Pounds of Waste per Hour	1	2	--	--	--	--	--	3
More than 4,000 Pounds of Waste per Hour	--	7	--	--	--	--	33	40
Subtotal	1	9	--	--	--	--	33	43
Industrial Process								
Coking Processes	--	704	--	--	--	--	--	704
Metal Processes	4	684	-- [a]	72	38	--	31	829
Painting Processes	-- [a]	-- [a]	-- [a]	--	--	-- [a]	--	-- [a]
Food Processing	--	--	--	-- [a]	--	--	--	-- [a]
Asphalt Products	--	9	--	6	2	--	5	22
Grain Handling and Processing	--	79	--	--	--	--	--	79
Printing and Lithography	--	-- [a]	--	--	--	--	-- [a]	-- [a]
Glassworks	--	--	--	-- [a]	--	--	--	-- [a]
Coating Operations	--	-- [a]	--	--	--	--	-- [a]	-- [a]
Heat Treating	-- [a]	4	--	-- [a]	--	--	-- [a]	4
Solvent and Adhesive Processes	--	--	--	--	--	--	--	--
Washing and Drying	--	-- [a]	--	--	--	--	7	7
Miscellaneous	--	84	9	1	-- [a]	1	5	100
Subtotal	4	1,564	9	79	40	1	48	1,745
Total	444	157,850	38,004	374	45	8	114	196,839

[a] *Less than one-half ton.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

kiln. The cessation of operations at this facility prior to 1977 resulted in a 99 percent reduction in sulfur dioxide emissions from industrial processes—from 4,362 tons in 1973 to 1,745 tons in 1977.

Carbon Monoxide: Table 199 presents a county distribution of the carbon monoxide emissions from point sources in the Region during 1977 by source category. As may be seen in Table 199, about 8,570 tons of carbon monoxide were emitted by point sources during 1977, which represents a decrease of about 12,148 tons, or nearly 59 percent, from the emission level of 20,718 tons during 1973 (see Table 95). In both 1973 and 1977, the predominant source category for carbon monoxide was metal processing. Within this source category, cupolas, or cylindrical melting furnaces, were principally responsible for the carbon monoxide pollution. Since 1973, however, many cupola operations have been controlled—such as the J. I. Case Corporation in Racine County and the General Castings Corporation in Waukesha County—or have either reduced the level of activity or have added afterburners to control the exhaust emissions. As a result of these changes, carbon monoxide emissions from metal processing operations have been reduced by about 12,090 tons, or about 72 percent—from 16,757 tons in 1973 to 4,667 tons in 1977. This reduction in emissions from metal processing operations, therefore, explains the significant decrease in the quantity of carbon monoxide released from point sources in the Region between 1973 and 1977.

Nitrogen Oxides: The county distribution of nitrogen oxide emissions from point sources in the Region during 1977 is presented in Table 200 by source category. As shown in the table, nitrogen oxide emissions from point sources during 1977 totaled 46,296 tons, a decrease of about 2,358 tons, or nearly 5 percent, from the 48,654 tons produced during 1973 (see Table 96). Much of this relatively small decrease may be attributed to changes in the types and amounts of fuel used at certain Wisconsin Electric Power Company facilities—the Valley plant, the Lakeside plant, the Commerce Street plant, and the Wells Street plant, all located in Milwaukee County—during 1977. The most important of these changes was less use of coal at the Valley plant in 1977. These four intermediate and peaking plants collectively reduced nitrogen oxide emissions by more than 1,500 tons in the five-year period. The Oak Creek power plant was the only

Table 199

DISTRIBUTION OF CARBON MONOXIDE EMISSIONS FROM POINT SOURCES IN THE REGION BY COUNTY: 1977

Source of Emissions	Emissions (tons)							
	Kenosha	Milwaukee	Ozaukee	Racine	Walworth	Washington	Waukesha	Region
Fuel-Burning Installation (boilers)								
5,000,000 BTU per Hour or Less	-- [a]	12	-- [a]	-- [a]	2	-- [a]	1	15
5,000,001 to 49,999,999 BTU per Hour	-- [a]	65	1	5	-- [a]	2	2	75
50,000,000 to 99,999,999 BTU per Hour	12	37	--	15	13	--	1	78
100,000,000 BTU per Hour or More	11	2,038	349	1	1	--	--	2,400
Subtotal	23	2,152	350	21	16	2	4	2,568
Incineration								
Less than 500 Pounds of Waste per Hour	--	-- [a]	--	--	--	--	--	-- [a]
500-4,000 Pounds of Waste per Hour	2	5	--	--	--	--	--	7
More than 4,000 Pounds of Waste per Hour	--	27	--	--	--	--	459	486
Subtotal	2	32	--	--	--	--	459	493
Industrial Process								
Coking Processes	--	181	--	--	--	--	--	181
Metal Processes	--	4,173	2	1	489	-- [a]	2	4,667
Painting Processes	4	8	-- [a]	-- [a]	-- [a]	1	-- [a]	13
Food Processing	--	--	--	-- [a]	--	--	--	-- [a]
Asphalt Products	-- [a]	1	--	-- [a]	-- [a]	--	-- [a]	1
Grain Handling and Processing	--	21	--	--	--	--	--	21
Printing and Lithography	--	4	--	-- [a]	--	--	1	5
Glassworks	--	1	--	6	--	--	--	7
Coating Operations	--	1	--	--	--	--	-- [a]	1
Heat Treating	4	28	--	3	--	--	2	37
Solvent and Adhesive Processes	--	-- [a]	--	--	--	--	--	-- [a]
Washing and Drying	--	1	-- [a]	--	--	--	1	2
Miscellaneous	--	236	27	-- [a]	1	289	21	574
Subtotal	8	4,655	29	10	490	290	27	5,509
Total	33	6,839	379	31	506	292	490	8,570

[a] *Less than one-half ton.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

major commercial electrical power generation station in Milwaukee County to exhibit an increase in nitrogen oxide emissions—from about 25,780 tons in 1973 to about 26,260 tons in 1977—because of an increase in coal consumption. Also contributing to the net reduction in nitrogen oxide emissions from point sources was a decrease in emissions from the Allis Chalmers power plant—from 537 tons in 1973 to 265 tons in 1977.

Most of the reduction in nitrogen oxides from point sources in the incineration source category can be attributed to the closing of the small industrial and commercial incinerators in Racine County. Emissions decreased by 623 tons—from 686 tons in 1973 to 63 tons in 1977. In the industrial process source category, the cessation of operations at the Marquette Cement Manufacturing Company led to a reduction of about 498 tons in nitrogen oxide emissions. This reduction, however, was more than offset by an increase in the emissions from the heat treating operations at the Ladish Company from 154 tons of nitrogen oxides in 1973 to 739 tons in 1977. Industrial processes were, therefore, the only point source to demonstrate an increase in nitrogen dioxide emissions over the five-year period, rising from 1,709 tons in 1973 to 2,176 tons in 1977, or by 27 percent.

Hydrocarbons: Hydrocarbon emissions from point sources in the Region during 1977 are quantified in Table 201 by county and by source of emissions. The table indicates that point source emissions during 1977 totaled 32,127 tons, an increase of 7,477 tons, or about 30 percent, from the 24,650 tons emitted from point sources during 1973 (see Table 97). In both the 1973 and 1977 point source inventories, paint processes contributed the most hydrocarbon emissions, releasing approximately 15,117 tons in 1973 and 13,144 tons in 1977. The largest absolute decrease between 1973 and 1977 paint processes occurred in Milwaukee County, which was the largest contributor in both point source inventories. Milwaukee County paint processes contributed 49 percent of the hydrocarbon point source emission total in the Region in 1973, but only 25 percent of the total in 1977.

Table 200

DISTRIBUTION OF NITROGEN OXIDE EMISSIONS FROM POINT SOURCES IN THE REGION BY COUNTY: 1977

Source of Emissions	Emissions (tons)							
	Kenosha	Milwaukee	Ozaukee	Racine	Walworth	Washington	Waukesha	Region
Fuel-Burning Installation (boilers)								
5,000,000 BTU per Hour or Less	3	40	2	1	17	1	16	80
5,000,001 to 49,999,999 BTU per Hour	4	692	7	47	15	15	14	794
50,000,000 to 99,999,999 BTU per Hour	116	432	--	175	64	--	8	795
100,000,000 BTU per Hour or More	96	35,976	6,279	15	22	--	--	42,388
Subtotal	219	37,140	6,288	238	118	16	38	44,057
Incineration								
Less than 500 Pounds of Waste per Hour	--	--[a]	--	--	--	--	--	--[a]
500-4,000 Pounds of Waste per Hour	1	15	--	--	--	--	--	16
More than 4,000 Pounds of Waste per Hour	--	8	--	--	--	--	39	47
Subtotal	1	23	--	--	--	--	39	63
Industrial Process								
Coking Processes	--	--	--	--	--	--	--	--
Metal Processes	2	279	9	45	20	1	25	381
Painting Processes	18	43	2	1	--	5	1	70
Food Processing	--	--	--	1	--	--	--	1
Asphalt Products	--[a]	4	--	2	2	--	1	9
Grain Handling and Processing	--	122	--	--	--	--	--	122
Printing and Lithography	--	18	--	1	--	--	5	24
Glassworks	--	5	--	32	--	--	--	37
Coating Operations	--	4	--	--	--	--	1	5
Heat Treating	27	768	--	15	--	--	11	821
Solvent and Adhesive Processes	--	--[a]	--	--	--	--	--	--[a]
Washing and Drying	--	5	--[a]	--	35	--	4	44
Miscellaneous	--	473	56	7	17	1	108	662
Subtotal	47	1,721	67	104	74	7	156	2,176
Total	267	38,884	6,355	342	192	23	233	46,296

[a] *Less than one-half ton.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Table 201

DISTRIBUTION OF HYDROCARBON EMISSIONS FROM POINT SOURCES IN THE REGION BY COUNTY: 1977

Source of Emissions	Emissions (tons)							
	Kenosha	Milwaukee	Ozaukee	Racine	Walworth	Washington	Waukesha	Region
Fuel-Burning Installation (boilers)								
5,000,000 BTU per Hour or Less	--[a]	3	--[a]	--[a]	1	--[a]	--[a]	4
5,000,001 to 49,999,999 BTU per Hour	--[a]	13	--[a]	1	--[a]	--[a]	--[a]	14
50,000,000 to 99,999,999 BTU per Hour	2	7	--	3	3	--	--[a]	15
100,000,000 BTU per Hour or More	2	596	105	--[a]	--[a]	--	--	703
Subtotal	4	619	105	4	4	--[a]	--[a]	736
Incineration								
Less than 500 Pounds of Waste per Hour	--	--[a]	--	--	--	--	--	--[a]
500-4,000 Pounds of Waste per Hour	--[a]	3	--	--	--	--	--	3
More than 4,000 Pounds of Waste per Hour	--	8	--	--	--	--	20	28
Subtotal	--[a]	11	--	--	--	--	20	31
Industrial Process								
Coking Processes	--	584	--	--	--	--	--	584
Metal Processes	1	56	1	44	9	--[a]	11	122
Vapor Degreasing	291	5,719	363	821	231	293	715	8,433
Painting Processes	3,502	7,965	222	430	266	509	250	13,144
Food Processing	--	--	--	--[a]	--	--	--	--[a]
Asphalt Products	--[a]	--[a]	--	--[a]	--[a]	--	--[a]	--[a]
Grain Handling and Processing	--	8	--	--	--	--	--	8
Printing and Lithography	--	1,554	--	48	--	--	264	1,866
Glassworks	--	--[a]	--	3	--	--	--	3
Coating Operations	--	2,118	--	311	--	--	140	2,569
Heat Treating	1	223	--	1	--	--	1	226
Solvent and Adhesive Processes	--	30	--	--	--	--	43	73
Washing and Drying	--	--[a]	--[a]	--	--	--	--	--[a]
Bulk Petroleum Storage	58	2,888	245	119	143	156	141	3,750
Miscellaneous	--	425	2	20	1	96	38	582
Subtotal	3,853	21,570	833	1,797	650	1,054	1,603	31,360
Total	3,857	22,200	938	1,801	654	1,054	1,623	32,127

[a] *Less than one-half ton.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

American Can Company and American Motors Corporation together produced approximately 3,207 tons fewer hydrocarbon emissions from painting processes in Milwaukee County in 1977. This reduction is primarily attributable to a decrease in paint products used between 1973 and 1977, a difference of 930,300 gallons. In addition, A. O. Smith, Joseph Schlitz Brewing Company—Container Division, Inryco, Inc., and PPG Industries together reduced paint process emissions by 881 tons between 1973 and 1977. American Motors Corporation was responsible for all of Kenosha County's painting process hydrocarbon emissions in both 1973 and 1977. An increase in hydrocarbon emissions in the County from 1,518 tons in 1973 to 3,502 tons in 1977 resulted from an increase in paint product use of over 300,000 gallons by 1977. In Walworth County, hydrocarbon emissions from painting processes increased from zero in 1973 to 266 tons in 1977 solely as the result of a new source, Sta-Rite Industries.

Hydrocarbon emissions from coating operations increased between 1973 and 1977 by 730 tons in Milwaukee County and 555 tons in the Region. Ninety-one percent of the net increase in Milwaukee County of 669 tons was the result of two new sources, Miller Brewing Company—Can plant and W. H. Brady Company—Florist Avenue plant, which together produced 1,218 tons of hydrocarbon emissions. This increase was offset by a 519-ton reduction in emissions from Inryco, Inc. The 30-ton difference in emissions was accounted for by other Milwaukee County point sources. The 154-ton reduction in emissions from coating operations in Racine County was the result of lower solvent use at the principal source of hydrocarbons from coating operations in the County, Rainfair, Inc.

Degreasing operations and gasoline storage losses show increases of 7,495 tons and 1,597 tons, respectively, from 1973 to 1977. These increases are attributable to additions in the point source inventory as identified by Booz, Allen and Hamilton, Inc.

While industrial processes, specifically evaporative losses from painting, vapor degreasing, coating, bulk petroleum storage, and printing operations, are significant contributors of point source hydrocarbon emissions, indus-

trial and electric power generation boilers contribute relatively small amounts of hydrocarbon emissions, both relatively and absolutely. This contribution is principally attributable to the low emissions from fossil fuels when burned in large units under proper combustion conditions.

Line Source Emissions Inventory: 1977

The 1977 regional line source emissions inventory was calculated following the same U. S. EPA-approved methodology used in the 1973 regional line source emissions inventory. Assumptions pertaining to vehicle age distribution, the mode of vehicle operation, and vehicle operating speeds, as well as the correction factors for air conditioning use and vehicle loads, for the year 1977 are consistent with the initial conditions defined for the year 1973. The 1977 regional line source emissions inventory, however, was prepared under revised assumptions concerning the estimated vehicle miles of travel, by vehicle type, over the arterial street and highway system and the collector and local street system in the Region, the vehicle emission rates for model year 1977 and earlier vehicles, and the prevailing meteorological conditions during 1977—particularly average seasonal temperatures and average seasonal humidity levels—that influence the rate of pollutant formation from line sources.

The estimated average weekday vehicle miles of travel on the street and highway system in the Region during 1977 are shown in Table 202 by vehicle type. The average weekday vehicle miles of travel, assuming an average annual growth rate determined from the 1985 stage of the "no build" transportation plan and the 1972 regional vehicle miles of travel, are shown in Table 98. A comparison of Table 98 and Table 202 indicates that the total average weekday vehicle miles of travel in the Region increased by an estimated 2.9 million miles, or nearly 13 percent—from about 22.3 million miles on an average weekday in 1972 to about 25.2 million miles on an average weekday in 1977. Therefore, it would be logical to assume that air pollutant emissions from line sources in the Region, in the absence of the effects of other factors, would have increased by about 13 percent in 1977 over the base year levels.

One such other factor affecting emissions—particularly of carbon monoxide, nitrogen oxides, and hydrocarbons—is the difference in the average seasonal temperature and average seasonal humidity conditions between 1973 and 1977. Table 203 sets forth the temperature and humidity conditions used in calculating both the 1973 and 1977 line source emissions inventories. As shown in the table, the average temperature in each season during 1977, except spring, was somewhat colder than in the corresponding season in 1973. Since colder ambient air temperatures promote the formation of carbon monoxide and hydrocarbons in the exhaust from light-duty gasoline vehicles and light-duty gasoline trucks, it may be expected that the emissions of these two pollutant species from line sources would be greater in the winter, summer, and fall seasons, and lower in the spring season, during 1977 than if the temperatures experienced in 1973 had prevailed. Because of the complex interrelationship between ambient air temperature, operational model, and vehicle speed, however, it is not possible to precisely quantify the increase in carbon monoxide and hydrocarbon emissions resulting from the lower ambient air temperatures experienced during 1977.

As with the average seasonal temperature, the average seasonal humidity levels during 1977 were lower than during 1973 in each season except spring. Since lower humidity levels encourage the formation of nitrogen oxides in the exhaust from light-duty gasoline vehicles and light-duty gasoline trucks, it may be expected that the emissions of this pollutant species from line sources should be higher in 1977 than in 1973 if all other condi-

Table 202

AVERAGE WEEKDAY VEHICLE MILES OF TRAVEL ON THE REGIONAL STREET AND HIGHWAY SYSTEM BY VEHICLE TYPE: 1977

Vehicle Type	Average Weekday Vehicle Miles of Travel			
	Freeway	Standard Surface	Collector and Local Streets	Total
Light-Duty				
Gasoline Vehicles . . .	7,387,400	12,191,800	2,087,900	21,667,100
Gasoline Trucks	482,600	1,000,000	152,900	1,635,500
Heavy-Duty				
Gasoline Trucks	376,800	804,900	122,700	1,304,400
Diesel Trucks.	469,600	149,000	9,300	627,900
Total	8,716,400	14,145,700	2,372,800	25,234,900
Urban Mass Transit[a]				68,700

[a] *The average weekday vehicle miles of travel made by mass transit vehicles are not available by type of transportation system traversed.*

Source: SEWRPC.

Table 203

METEOROLOGICAL CONDITIONS USED IN THE CALCULATION OF THE 1973 AND 1977 REGIONAL LINE SOURCE EMISSION INVENTORIES

Season	Average Seasonal Temperature (^{o}F)		Average Seasonal Humidity (measured as the mixing ratio-grains per pound of dry air)	
	1973	1977	1973	1977
Winter	26	18	14	10
Spring	46	50	33	34
Summer	73	68	81	72
Fall	54	49	43	38

Source: U. S. National Weather Service and SEWRPC.

tions remained constant. In 1973 the humidity correction factor resulted in an increase in nitrogen oxide emissions of about 29 percent in winter, 20 percent in spring, and 15 percent in fall, and a decrease of about 3 percent in summer. In 1977, however, the humidity correction factor resulted in an increase of about 31 percent in winter, 19 percent in spring, 17 percent in fall, and 2 percent in summer. On an annual basis, therefore, humidity levels in the Region during 1977 resulted in a level of nitrogen oxide emissions from light-duty gasoline vehicles and light-duty gasoline trucks approximately 8 percent higher than the humidity levels experienced during 1973.

Offsetting the increase in air pollutant emissions from line sources in the Region is the influence of more stringent restrictions on the permissible pollutant emission rates for certain types of motor vehicles that took effect after 1973. Since such emission restrictions vary by vehicle type, the impact of these limitations are discussed individually in the following sections.

Light-Duty Gasoline Vehicles: Table 204 presents the carbon monoxide, nitrogen oxide, and hydrocarbon exhaust emission factors, which represent the new vehicle emission rate plus deterioration, for light-duty gasoline vehicles of model year 1977 and earlier in calendar year 1977. This table may be compared with Table 102, which provides the exhaust emission factors for model year 1973 and earlier vehicles in calendar year 1973. As indicated in Table 102, a new model year vehicle in calendar year 1973 would emit 34.8 grams of carbon monoxide per mile of travel, 3.0 grams of nitrogen oxides per mile of travel, and 2.7 grams of hydrocarbons per mile of travel. A new model year vehicle in calendar year 1977, however, would emit only 20.3 grams of carbon monoxide, 1.6 grams of nitrogen oxides, and 1.3 grams of hydrocarbons for each mile of travel, as shown in Table 204. In other words, a new model vehicle in 1977 would emit about 42 percent less carbon monoxide, about 47 percent less nitrogen oxides, and about 52 percent less hydrocarbons than a comparable new model vehicle in 1973. Similar emission reductions are also evident in the comparison of exhaust emission rates from vehicles that were two and three years old in calendar year 1977 and vehicles that were two and three years old in 1973. Vehicles four years old and older generally emit pollutants at about the same rate in both calendar years. However, since light-duty gasoline vehicles three years old and less account for about 40 percent of the total vehicle miles of travel in any calendar year (see Table 99), carbon monoxide, nitrogen oxide, and hydrocarbon emissions from line sources should be significantly reduced by the lower, more stringent emission rates applicable to later model year vehicles.

Table 204

CARBON MONOXIDE, NITROGEN OXIDE, AND HYDROCARBON EXHAUST EMISSION FACTORS FOR LIGHT-DUTY GASOLINE VEHICLES CALENDAR YEAR 1977

Model Year	Emission Factor (grams per mile)		
	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
1977	20.3	1.6	1.3
1976	24.1	2.6	1.6
1975	28.2	2.7	1.9
1974	60.8	3.0	5.0
1973	68.7	3.0	5.7
1972	76.0	4.4	6.3
1971	82.8	4.4	6.9
1970	89.0	4.4	7.4
1969	94.7	4.4	7.9
1968	99.8	4.4	8.3
1967	104.7	3.6	11.3
1966	106.7	3.6	11.7
1965 and earlier	108.7	3.6	12.1

Source: U. S. Environmental Protection Agency and SEWRPC.

The amount of air pollutant emissions released from light-duty gasoline vehicles operating on the street and highway system in the Region, estimated from the estimated vehicle miles of travel, the prevailing meteorological conditions, and the exhaust emission rates for 1977, are presented in Table 205 by county by season. In comparing the emissions from light-duty gasoline vehicles in 1977, shown in Table 205, with the emissions from such vehicles in 1973, shown in Table 104, it is evident that emissions for all pollutant species except sulfur dioxide declined over the five-year period. Sulfur dioxide emissions from light-duty gasoline vehicles are solely a function of vehicle miles of travel and are not affected by such external factors as prevailing meteorological conditions. Consequently, because the vehicle miles of travel for light-duty gasoline vehicles increased by about 2.2 million miles, or about 12 percent—from 19.4 million miles to 21.6 million miles (see Tables 98 and 202—between 1973 and 1977, the sulfur dioxide emissions increased by about 12 percent—from 856 tons to 956 tons—between the two years.

Particulate matter emissions from light-duty gasoline vehicles decreased from 3,556 tons in 1973 to 3,100 tons in 1977, a 456-ton, or 13 percent, decrease. This reduction may be attributed to the placement of catalytic converters on automobiles beginning with 1974 model year vehicles. Since lead compounds are the principal source of particulate matter emissions in automobile exhaust, the use of unleaded gasoline in catalytic converter-equipped vehicles, required to prevent contamination of the catalytic agent, reduces the emission factor for this pollutant species by about 54 percent—from 0.54 gram per vehicle mile of travel to 0.25 gram per vehicle mile of travel. Assuming that all light-duty gasoline vehicles of model year 1975 and later are equipped with catalytic converters, about 40 percent of the total light-duty gasoline vehicle miles of travel in 1977 were made using unleaded fuel (see the travel fractions in Table 99). With 40 percent of the travel fraction having a particulate matter emission rate of

0.25 gram per mile, and the remaining 60 percent of the travel fraction having an emission rate of 0.54 gram per mile, the overall weighted emission rate in 1977 was approximately 0.42 gram per vehicle mile of travel. This weighted emission rate is about 22 percent less than the 1973 emission rate of 0.54 gram per mile, which more than offsets the approximately 12 percent increase in travel by light-duty gasoline vehicles over the five-year period.

Table 205 indicates that light-duty gasoline vehicles emitted 394,895 tons of carbon monoxide emissions in 1977, a decrease of about 17,277 tons, or over 4 percent, from the 1973 level of 412,172 tons. This 4 percent reduction was achieved despite the increased vehicle miles of travel in the Region in 1977 and the colder temperatures because of the more stringent exhaust pollutant emission limitations on later year model automobiles. Similarly, hydrocarbon emissions from light-duty gasoline vehicles demonstrated a 7,857-ton, or more than 18 percent, reduction by 1977—from about 42,542 tons in 1973 to about 34,685 tons in 1977. Again reflecting the influence of the more stringent exhaust emission limitations, nitrogen oxide emissions from light-duty gasoline vehicles were reduced by 2,294 tons, or over 6 percent, between 1973 and 1977—from 35,912 tons in 1973 to 33,618 tons in 1977. This 6 percent reduction was achieved in spite of the fact that humidity levels during 1977 resulted in about 8 percent more nitrogen oxide emissions than would have been produced had the humidity levels of 1973 prevailed.

Table 205

SUMMARY OF LIGHT-DUTY GASOLINE VEHICLE EMISSIONS BY COUNTY BY SEASON: 1977

County	Season	Emissions (tons)				
		Particulate Matter	Sulfur Dioxide	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
Kenosha	Winter	62	19	9,391	746	771
	Spring	62	19	7,002	681	641
	Summer	62	19	6,814	636	630
	Fall	62	19	7,055	670	644
	Annual	248	76	30,262	2,733	2,686
Milwaukee	Winter	380	118	65,253	4,368	5,241
	Spring	380	118	48,935	3,990	4,354
	Summer	380	118	47,756	3,724	4,284
	Fall	380	118	49,298	3,926	4,375
	Annual	1,520	472	211,242	16,008	18,254
Ozaukee	Winter	36	11	5,078	448	422
	Spring	36	11	3,773	410	351
	Summer	36	11	3,666	382	345
	Fall	36	11	3,803	403	352
	Annual	144	44	16,320	1,643	1,470
Racine	Winter	74	23	11,332	886	928
	Spring	74	23	8,455	810	771
	Summer	74	23	8,230	756	758
	Fall	74	23	8,519	797	774
	Annual	296	92	36,536	3,249	3,231
Walworth	Winter	39	12	5,386	475	448
	Spring	39	12	4,002	434	372
	Summer	39	12	3,888	405	365
	Fall	39	12	4,033	427	374
	Annual	156	48	17,309	1,741	1,559
Washington	Winter	44	13	6,046	533	503
	Spring	44	13	4,491	487	418
	Summer	44	13	4,362	455	411
	Fall	44	13	4,526	480	420
	Annual	176	52	19,425	1,955	1,752
Waukesha	Winter	140	43	19,844	1,716	1,646
	Spring	140	43	14,754	1,567	1,368
	Summer	140	43	14,336	1,463	1,344
	Fall	140	43	14,867	1,543	1,375
	Annual	560	172	63,801	6,289	5,733
Region	Winter	775	239	122,330	9,172	9,959
	Spring	775	239	91,412	8,379	8,275
	Summer	775	239	89,052	7,821	8,137
	Fall	775	239	92,101	8,246	8,314
	Annual	3,100	956	394,895	33,618	34,685

Source: SEWRPC.

Light-Duty Gasoline Trucks: As may be seen by comparing Table 98 and Table 202, the average weekday vehicle miles of travel for light-duty gasoline trucks increased by 330,000 miles, or about 25 percent, between 1973 and 1977—from 1.3 million miles per day in 1973 to about 1.6 million miles per day in 1977. The amount of air pollutant emissions released from light-duty gasoline trucks operating over the street and highway system in the Region during 1977, assuming this increase in vehicle miles of travel, is presented in Table 206 by county by season.

Table 206 indicates that light-duty gasoline trucks emitted 244 tons of particulate matter emissions during 1977—an increase of about 16 tons, or more than 6 percent, over the 1973 emissions of 228 tons. As with light-duty gasoline vehicles, light-duty gasoline trucks of model year 1975 and later were assumed to be equipped with catalytic converters and therefore to require the use of unleaded fuel. Because trucks of model year 1975 and later accounted for about 35 percent of the total travel for this vehicle type in 1977 (see the travel fractions in Table 106), the overall weighted particulate matter emission rate was approximately 0.44 gram per mile of travel, a decrease of about 19 percent from the 0.54 gram per mile emission rate in 1973. The 25 percent growth in vehicle miles of travel, however, offset this 19 percent reduction in the particulate matter emission rate and, consequently, light-duty gasoline trucks released about 6 percent more emissions of this pollutant species in 1977 than in 1973.

Sulfur dioxide emissions from light-duty gasoline trucks were also reflective of the increased vehicle miles of travel. Emissions increased from 56 tons in 1973 to 76 tons in 1977, or by 36 percent.

Carbon monoxide and hydrocarbon emissions from light-duty gasoline trucks both exhibited increases in 1977. Carbon monoxide emissions rose to 31,513 tons in 1977, an increase of about 4,982 tons, or nearly 19 percent, over the 26,531 tons emitted during 1973. Hydrocarbon emissions increased by about 177 tons, or approximately 5 percent—from 3,712 tons in 1973 to 3,891 tons in 1977. Although the exhaust emission factors for these two pollutant species were substantially

reduced for vehicles of model year 1975 and later, as may be seen by comparing Table 207 with Table 108, the increase in vehicle miles of travel more than offset the benefits gained by this reduction. Only for nitrogen oxides was the emission factor reduction capable of providing a net decrease in emissions—from 2,793 tons in 1973 to 2,598 tons in 1977, a 7 percent decrease.

Heavy-Duty Gasoline Trucks: As indicated in Table 202, heavy-duty gasoline trucks accounted for about 1.30 million vehicle miles of travel in the Region on an average weekday in 1977, an increase of about 285,000 miles, or nearly 28 percent, over the corresponding vehicle miles of travel in 1973 (see Table 98). The air pollutant emissions released from heavy-duty gasoline trucks operating over the regional street and highway system in 1977 are quantified in Table 208 by county by season.

Particulate matter emissions from heavy-duty gasoline trucks in the Region during 1977 totaled 580 tons, an increase of 124 tons, or about 27 percent, over the 456 tons emitted during 1973. Such an increase is to be expected since the particulate matter emissions from heavy-duty gasoline trucks are strictly a function of travel, and are, as modeled, independent of external factors such as meteorological conditions. Consequently, emission quantities may be expected to change in direct proportion to the change in the vehicle miles of travel. Similarly, sulfur dioxide emissions from heavy-duty gasoline trucks increased by 32 tons, or by 25 percent, over the 128 tons emitted in 1973.

Carbon monoxide emissions from heavy-duty gasoline trucks during 1977 increased by about 8,216 tons, or slightly more than 10 percent, over the 81,028 tons emitted in 1973. This 10 percent increase in emissions, which is less than may have been anticipated considering a 28 percent increase in vehicle miles of travel, is a result of slightly lower overall fleet exhaust emission factors and a significant change in the rate of pollutant emissions for later model year trucks, as well as of a slight increase in vehicle operating speed for all trucks. The exhaust emission factors for heavy-duty gasoline trucks in calendar year 1977 are shown in Table 209. Comparison of Table 209 with Table 114 indicates that the carbon monoxide emission factor for a new vehicle in 1977 increased slightly over the emission factor for a new vehicle in calendar year 1973. In fact, this increase is evident in the comparison of the latest four model years between calendar year 1977 and calendar year

Table 206

SUMMARY OF LIGHT-DUTY GASOLINE TRUCK EMISSIONS BY COUNTY BY SEASON: 1977

County	Season	Emissions (tons)				
		Particulate Matter	Sulfur Dioxide	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
Kenosha	Winter	5	2	756	60	85
	Spring	5	2	574	54	75
	Summer	5	2	564	51	74
	Fall	5	2	578	54	75
	Annual	20	8	2,472	219	309
Milwaukee	Winter	24	7	4,226	269	469
	Spring	24	7	3,229	246	412
	Summer	24	7	3,180	230	409
	Fall	24	7	3,251	242	414
	Annual	96	28	13,886	987	1,704
Ozaukee	Winter	3	1	348	31	38
	Spring	3	1	264	28	33
	Summer	3	1	258	27	33
	Fall	3	1	265	28	33
	Annual	12	4	1,135	114	137
Racine	Winter	6	2	927	68	105
	Spring	6	2	705	62	92
	Summer	6	2	693	58	92
	Fall	6	2	710	61	93
	Annual	24	8	3,035	249	382
Walworth	Winter	5	1	660	58	70
	Spring	5	1	500	53	61
	Summer	5	1	490	49	60
	Fall	5	1	504	52	61
	Annual	20	4	2,154	212	252
Washington	Winter	5	2	752	63	84
	Spring	5	2	570	58	73
	Summer	5	2	559	54	73
	Fall	5	2	574	57	74
	Annual	20	8	2,455	232	304
Waukesha	Winter	13	4	1,951	160	221
	Spring	13	4	1,481	146	194
	Summer	13	4	1,453	136	193
	Fall	13	4	1,491	143	195
	Annual	52	16	6,376	585	803
Region	Winter	61	19	9,620	709	1,072
	Spring	61	19	7,323	647	940
	Summer	61	19	7,197	605	934
	Fall	61	19	7,373	637	945
	Annual	244	76	31,513	2,598	3,891

Source: SEWRPC.

Table 207

CARBON MONOXIDE, NITROGEN OXIDE, AND HYDROCARBON EXHAUST EMISSION FACTORS FOR LIGHT-DUTY GASOLINE TRUCKS CALENDAR YEAR 1977

Model Year	Emission Factor (grams per mile)		
	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
1977	19.3	2.4	1.4
1976	26.6	2.4	1.9
1975	34.5	2.4	2.5
1974	60.8	3.0	5.0
1973	68.7	3.0	5.7
1972	76.0	4.4	6.3
1971	82.8	4.4	6.9
1970	89.0	4.4	7.4
1969	94.7	4.4	7.9
1968	99.8	4.4	8.3
1967	104.7	3.6	11.3
1966	106.7	3.6	11.7
1965 and earlier	108.7	3.6	12.0

Source: U. S. Environmental Protection Agency and SEWRPC.

Table 208

SUMMARY OF HEAVY-DUTY GASOLINE TRUCK EMISSIONS BY COUNTY BY SEASON: 1977

County	Season	Emissions (tons)				
		Particulate Matter	Sulfur Dioxide	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
Kenosha	Winter	7	2	1,108	66	111
	Spring	7	2	1,108	66	111
	Summer	7	2	1,108	66	111
	Fall	7	2	1,108	66	111
	Annual	28	8	4,432	264	444
Milwaukee	Winter	71	20	11,776	650	1,177
	Spring	71	20	11,776	650	1,177
	Summer	71	20	11,776	650	1,177
	Fall	71	20	11,776	650	1,177
	Annual	284	80	47,104	2,600	4,708
Ozaukee	Winter	5	1	721	49	68
	Spring	5	1	721	49	68
	Summer	5	1	721	49	68
	Fall	5	1	721	49	68
	Annual	20	4	2,884	196	272
Racine	Winter	11	3	1,661	103	161
	Spring	11	3	1,661	103	161
	Summer	11	3	1,661	103	161
	Fall	11	3	1,661	103	161
	Annual	44	12	6,644	412	644
Walworth	Winter	9	3	1,281	90	117
	Spring	9	3	1,281	90	117
	Summer	9	3	1,281	90	117
	Fall	9	3	1,281	90	117
	Annual	36	12	5,124	360	468
Washington	Winter	8	2	1,103	76	104
	Spring	8	2	1,103	76	104
	Summer	8	2	1,103	76	104
	Fall	8	2	1,103	76	104
	Annual	32	8	4,412	304	416
Waukesha	Winter	34	9	4,661	320	430
	Spring	34	9	4,661	320	430
	Summer	34	9	4,661	320	430
	Fall	34	9	4,661	320	430
	Annual	136	36	18,644	1,280	1,720
Region	Winter	145	40	22,311	1,354	2,168
	Spring	145	40	22,311	1,354	2,168
	Summer	145	40	22,311	1,354	2,168
	Fall	145	40	22,311	1,354	2,168
	Annual	580	160	89,244	5,416	8,672

Source: SEWRPC.

Table 209

CARBON MONOXIDE, NITROGEN OXIDE, AND HYDROCARBON EXHAUST EMISSION FACTORS FOR HEAVY-DUTY GASOLINE TRUCKS CALENDAR YEAR 1977

Model Year	Emission Factor (grams per mile)		
	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
1977	221.7	10.5	22.3
1976	230.5	10.5	23.0
1975	242.1	10.5	24.0
1974	253.1	10.5	25.0
1973	257.1	12.8	22.4
1972	266.3	12.8	23.2
1971	274.6	12.8	23.9
1970	282.0	12.8	24.5
1969	310.6	8.8	31.1
1968	313.6	8.8	31.6
1967	316.2	8.8	32.1
1966	318.6	8.8	32.6
1965 and earlier	320.7	8.8	33.0

Source: U. S. Environmental Protection Agency and SEWRPC.

1973. However, the fifth through eighth model years in calendar year 1977 indicate a substantial decrease in the carbon monoxide exhaust emission factor when compared with the corresponding vehicles in calendar year 1973. When weighted for the fraction of travel by model year (see Table 111), the overall fleet carbon monoxide emission factor for heavy-duty gasoline trucks is about 3 percent lower in calendar year 1977 than in calendar year 1973.

Of greater significance in reducing carbon monoxide emissions from heavy-duty gasoline trucks is the change in the speed adjustment factor with the change in vehicle speed. As discussed in Chapter VI of this report, carbon monoxide emissions from internal combustion gasoline engines decrease nonlinearly with increasing speed. A small increase in the average operational speed would, therefore, yield a substantial reduction in carbon monoxide exhaust emissions. Such operational speed increases occurred on the regional street and highway system between 1973 and 1977 due to such improvements in the system as the opening to traffic of STH 15 and IH 43. This speed increase resulted in an approximate 15 percent reduction in the carbon monoxide emissions from heavy-duty gasoline trucks in 1977. In total, therefore, the effect of the 28 percent increase in travel is offset by a 3 percent decrease in the average fleet carbon monoxide rate and a 15 percent reduction due to increased operational speeds to yield a net increase of about 10 percent in the carbon monoxide emissions from heavy-duty gasoline trucks between 1973 and 1977.

Hydrocarbon emissions from heavy-duty gasoline trucks between 1973 and 1977 exhibit a pattern similar to the carbon monoxide emission. In 1977 this vehicle type emitted 8,672 tons of hydrocarbon emissions, an increase of 672 tons, or over 8 percent, over the 8,000 tons emitted during 1973. For this pollutant species, the increase in vehicle miles of travel was offset by a combination of lower overall fleet exhaust emission rates, increased operating speeds, and lower evaporative emission rates for later model year vehicles.

Nitrogen oxide emissions from heavy-duty gasoline trucks demonstrated an increase of 1,264 tons, or more than 30 percent, between 1973 and 1977—from 4,152 tons in 1973 to 5,416 tons in 1977. Unlike their effect on hydrocarbon and carbon monoxide emissions from mobile sources, increased operating speeds increase the emission rate of nitrogen oxides. Notwithstanding the

decrease in exhaust emission rates for nitrogen oxides in later model year vehicles, the increase in travel and in the average operating speeds together resulted in the observed 30 percent increase in emissions between 1973 and 1977.

Heavy-Duty Diesel Trucks: As shown in Table 202, heavy-duty diesel trucks accounted for about 627,900 vehicle miles of travel on an average weekday in the Region in 1977. This level of travel represents an increase of 103,800 miles, or nearly 20 percent, over the 524,100 vehicle miles of travel by heavy-duty diesel trucks on an average weekday in 1972 (see Table 98). The air pollutant emissions produced by heavy-duty diesel trucks operating over the regional street and highway system in 1977 are quantified in Table 210 by county by season.

In 1977, 468 tons of particulate matter were emitted from heavy-duty diesel trucks, an increase of 76 tons, or 19 percent, over the 1973 emission level of 392 tons. Like sulfur dioxide emissions from heavy-duty gasoline trucks, sulfur dioxide emissions from heavy-duty diesel trucks increased in correspondence with increased vehicle miles of travel. Emissions increased from 500 tons in 1973 to 596 tons in 1977, or by 19 percent.

A total of 3,284 tons of carbon monoxide emissions were released from heavy-duty diesel trucks in 1977, a decrease of 496 tons, or 13 percent, from the 1973 emission level of 3,780 tons. This decrease is in part attributable to an increase in average operating speeds over the regional street and highway system in 1977, as compared with average operating speeds in 1973. Also contributing to this reduction is the significant decrease in the carbon monoxide exhaust emission rates in later model year vehicles—27.0 grams per mile of travel in 1977, as shown in Table 211, compared to 35.1 grams per mile in 1973, as indicated in Table 119.

As is also evident in comparing Tables 119 and 211, the exhaust emission factor for hydrocarbons increases for vehicles of model year 1974 through 1977 over the 1973 and carlier model year vehicle exhaust emission rate. This increase, plus the substantial increase in vehicle miles of travel for heavy-duty diesel trucks, provided for an increase in hydrocarbon emissions of 212 tons, or over 62 percent between 1973 and 1977—from 340 tons in 1973 to 552 tons in 1977.

The small decrease in the exhaust emissions rate of nitrogen oxides from later model year vehicles indicated in Table 209 was insufficient to offset the effect of the increase in vehicle miles of travel and increased operating speeds. Nitrogen oxide emissions from heavy-duty diesel trucks consequently rose by 1,280 tons, or 30 percent, between 1973 and 1977—from 4,256 tons in 1973 to 5,536 tons in 1977.

Mass Transit Vehicles: As may be seen in Table 202, mass transit vehicles in the Region accounted for about 68,700 miles of travel on an average weekday in 1977, an increase of 3,700 miles, or nearly 6 percent, over the

Table 210

SUMMARY OF HEAVY-DUTY DIESEL TRUCK EMISSIONS BY COUNTY BY SEASON: 1977

County	Season	Emissions (tons)				
		Particulate Matter	Sulfur Dioxide	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
Kenosha	Winter	18	23	122	219	21
	Spring	18	23	122	219	21
	Summer	18	23	122	219	21
	Fall	18	23	122	219	21
	Annual	72	92	488	876	84
Milwaukee	Winter	31	40	236	354	39
	Spring	31	40	236	354	39
	Summer	31	40	236	354	39
	Fall	31	40	236	354	39
	Annual	124	160	944	1,416	156
Ozaukee	Winter	12	15	80	154	14
	Spring	12	15	80	154	14
	Summer	12	15	80	154	14
	Fall	12	15	80	154	14
	Annual	48	60	320	616	56
Racine	Winter	14	18	95	178	16
	Spring	14	18	95	178	16
	Summer	14	18	95	178	16
	Fall	14	18	95	178	16
	Annual	56	72	380	712	64
Walworth	Winter	13	16	90	145*	15
	Spring	13	16	90	145	15
	Summer	13	16	90	145	15
	Fall	13	16	90	145	15
	Annual	52	64	360	580	60
Washington	Winter	11	14	73	121	12
	Spring	11	14	73	121	12
	Summer	11	14	73	121	12
	Fall	11	14	73	121	12
	Annual	44	56	292	484	48
Waukesha	Winter	18	23	125	213	21
	Spring	18	23	125	213	21
	Summer	18	23	125	213	21
	Fall	18	23	125	213	21
	Annual	72	92	500	852	84
Region	Winter	117	149	821	1,384	138
	Spring	117	149	821	1,384	138
	Summer	117	149	821	1,384	138
	Fall	117	149	821	1,384	138
	Annual	468	596	3,284	5,536	552

Source: SEWRPC.

65,000 vehicle miles of travel on an average weekday in 1973 (see Table 98). In 1973 the regional mass transit fleet was comprised of a mix of gasoline-powered and diesel-powered vehicles. Because of the purchase of new mass transit vehicles and the attendant retirement of older vehicles, however, the regional fleet in 1977 was comprised solely of diesel-powered vehicles. The air pollutant emissions from mass transit vehicles operating in the Region during 1977 are quantified in Table 212 by county by season.

As gasoline-powered vehicles are replaced by diesel-powered vehicles, the use of the less volatile diesel fuel may be expected to lead to an increase in particulate

Table 211

CARBON MONOXIDE, NITROGEN OXIDE, AND HYDROCARBON EXHAUST EMISSION FACTORS FOR HEAVY-DUTY DIESEL TRUCKS CALENDAR YEAR 1977

Model Year	Emission Factor (grams per mile)		
	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
1977	27.0	20.1	4.5
1976	27.0	20.1	4.5
1975	27.0	20.1	4.5
1974	27.0	20.1	4.5
1973	35.1	21.4	4.3
1972	35.1	21.4	4.3
1971	35.1	21.4	4.3
1970	35.1	21.4	4.3
1969	35.1	21.4	4.3
1968	35.1	21.4	4.3
1967	35.1	21.4	4.3
1966	35.1	21.4	4.3
1965 and earlier	35.1	21.4	4.3

Source: U. S. Environmental Protection Agency and SEWRPC.

matter, sulfur dioxide, and nitrogen oxide emissions and a decrease in carbon monoxide and hydrocarbon emissions. Such changes are evident in comparing the transit emissions in 1973, shown in Table 116, and in 1977, shown in Table 212. As shown in Table 212, particulate matter emissions from transit vehicles in 1977 totaled 32 tons, an increase of 4 tons, or over 14 percent, over the 1973 emission level of 28 tons. Sulfur dioxide emissions from transit vehicles also increased in 1977—from 48 tons in 1973 to 64 tons in 1977, a 33 percent increase. Similarly, nitrogen oxide emissions from transit vehicles increased by 64 tons between 1973 and 1979, from 436 tons in 1973 to 500 tons in 1977, a 15 percent increase.

Diesel-powered engines produce much less carbon monoxide than gasoline-powered engines because diesels operate with high air-to-fuel ratios which allow for more complete combustion. As a result, carbon monoxide emissions from mass transit vehicles in 1977 totaled 852 tons, a decrease of 468 tons, or more than 35 percent, from the 1973 emission level of 1,320 tons. Also, since diesel fuel is less volatile than gasoline, evaporative hydrocarbon emissions from this vehicle type are negligible. The lower evaporative hydrocarbon emissions and the lower exhaust hydrocarbon emissions due to more complete combustion resulted in about 112 tons of total hydrocarbon emissions from mass transit vehicles in 1977, a decrease of 36 tons, or 25 percent, from the 144 tons emitted in 1973.

Line Source Emissions Inventory—1977 Summary: Table 213 presents a summary of the quantity of air pollutant emissions from all line sources—light-duty gasoline vehicles, light-duty gasoline trucks, heavy-duty gasoline trucks, heavy-duty diesel trucks, and mass transit vehicles—operating over the regional street and highway system in 1977. As may be seen by comparing Table 213 with Table 123, particulate matter, carbon monoxide, and hydrocarbon emissions decreased over this five-year period, while sulfur dioxide and nitrogen oxide emissions increased.

The total particulate matter emissions in the Region from all vehicle types in 1977 totaled 4,424 tons, a decrease of 236 tons, or about 5 percent, from the 1973 emission level of 4,660 tons. This decrease is due solely to the reduction in particulate matter emissions from light-duty

Table 212

SUMMARY OF TRANSIT EMISSIONS BY COUNTY BY SEASON: 1977

County	Season	Emissions (tons)				
		Particulate Matter	Sulfur Dioxide	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
Kenosha	Winter	--[a]	1	10	6	1
	Spring	--[a]	1	10	6	1
	Summer	--[a]	1	10	6	1
	Fall	--[a]	1	10	6	1
	Annual	--[a]	4	40	24	4
Milwaukee	Winter	8	14	190	112	26
	Spring	8	14	190	112	26
	Summer	8	14	190	112	26
	Fall	8	14	190	112	26
	Annual	32	56	760	448	104
Ozaukee	Winter	--[a]	--[a]	--[a]	--[a]	--[a]
	Spring	--[a]	--[a]	--[a]	--[a]	--[a]
	Summer	--[a]	--[a]	--[a]	--[a]	--[a]
	Fall	--[a]	--[a]	--[a]	--[a]	--[a]
	Annual	--[a]	--[a]	--[a]	--[a]	--[a]
Racine	Winter	--[a]	1	11	6	1
	Spring	--[a]	1	11	6	1
	Summer	--[a]	1	11	6	1
	Fall	--[a]	1	11	6	1
	Annual	--[a]	4	44	24	4
Walworth	Winter	--	--	--	--	--
	Spring	--	--	--	--	--
	Summer	--	--	--	--	--
	Fall	--	--	--	--	--
	Annual	--	--	--	--	--
Washington	Winter	--	--	--	--	--
	Spring	--	--	--	--	--
	Summer	--	--	--	--	--
	Fall	--	--	--	--	--
	Annual	--	--	--	--	--
Waukesha	Winter	--[a]	--[a]	2	1	--[a]
	Spring	--[a]	--[a]	2	1	--[a]
	Summer	--[a]	--[a]	2	1	--[a]
	Fall	--[a]	--[a]	2	1	--[a]
	Annual	--[a]	--[a]	8	4	--[a]
Region	Winter	8	16	213	125	28
	Spring	8	16	213	125	28
	Summer	8	16	213	125	28
	Fall	8	16	213	125	28
	Annual	32	64	852	500	112

[a] *Less than one-half ton.*

Source: SEWRPC.

Table 213

TOTAL LINE SOURCE EMISSIONS INVENTORY FOR THE SOUTHEASTERN WISCONSIN REGION BY COUNTY BY SEASON: 1977

County	Season	Emissions (tons)				
		Particulate Matter	Sulfur Dioxide	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
Kenosha	Winter	92	47	11,387	1,097	989
	Spring	92	47	8,816	1,026	849
	Summer	92	47	8,618	978	837
	Fall	92	47	8,873	1,015	852
	Annual	368	188	37,694	4,116	3,527
Milwaukee	Winter	514	199	81,681	5,753	6,951
	Spring	514	199	64,366	5,352	6,007
	Summer	514	199	63,138	5,070	5,934
	Fall	514	199	64,751	5,284	6,030
	Annual	2,056	796	273,936	21,459	24,922
Ozaukee	Winter	56	28	6,227	682	542
	Spring	56	28	4,838	641	466
	Summer	56	28	4,725	612	460
	Fall	56	28	4,869	634	467
	Annual	224	112	20,659	2,569	1,935
Racine	Winter	105	47	14,026	1,241	1,211
	Spring	105	47	10,927	1,159	1,041
	Summer	105	47	10,690	1,101	1,028
	Fall	105	47	10,996	1,145	1,045
	Annual	420	188	46,639	4,646	4,325
Walworth	Winter	66	32	7,417	768	650
	Spring	66	32	5,873	722	565
	Summer	66	32	5,749	689	557
	Fall	66	32	5,908	714	567
	Annual	264	128	24,947	2,893	2,339
Washington	Winter	68	31	7,974	793	703
	Spring	68	31	6,237	742	607
	Summer	68	31	6,097	706	600
	Fall	63	31	6,276	734	610
	Annual	272	124	26,584	2,975	2,520
Waukesha	Winter	205	79	26,583	2,410	2,318
	Spring	205	79	21,023	2,247	2,013
	Summer	205	79	20,577	2,133	1,988
	Fall	205	79	21,146	2,220	2,021
	Annual	820	316	89,329	9,010	8,340
Region	Winter	1,106	463	155,295	12,744	13,364
	Spring	1,106	463	122,080	11,889	11,548
	Summer	1,106	463	119,594	11,289	11,404
	Fall	1,106	463	122,819	11,746	11,592
	Annual	4,424	1,852	519,788	47,668	47,908

Source: SEWRPC.

gasoline vehicles as a result of the use of unleaded fuels in later model year automobiles. All other vehicle types demonstrated an increase in particulate matter emissions, generally reflecting the increase in the vehicle miles of travel between 1973 and 1977.

The total sulfur dioxide emissions in the Region from all vehicle types in 1977 totaled 1,852 tons, an increase of about 264 tons, or nearly 17 percent, over the 1973 emission level of about 1,588 tons. This increase may be attributed solely to the increase in vehicle miles of travel between 1973 and 1977.

The total carbon monoxide emissions in the Region from all vehicle types in 1977 totaled 519,788 tons, a decrease of 5,043 tons, or slightly less than 1 percent, from the 1973 emission level of 524,831 tons. This decrease may be attributed principally to the effect of more stringent limitations on carbon monoxide emissions from later model year light-duty gasoline vehicles and, to a lesser extent, to reductions in carbon monoxide emissions from heavy-duty diesel trucks and mass transit vehicles. These reductions, however, were offset by increased carbon monoxide emissions from light-duty gasoline trucks and heavy-duty gasoline trucks.

The total nitrogen oxide emissions in the Region from all vehicle types in 1977 totaled 47,668 tons, an increase of 119 tons, or about one-quarter of 1 percent, over the 1973 emission level of 47,549 tons. Although both light-duty gasoline vehicles and light-duty gasoline trucks exhibited a decrease in nitrogen oxide emissions between 1973 and 1977, principally because of more stringent emission controls on later model year vehicles, nitrogen oxide emissions exhibited a slight net increase in 1977 because of a significant increase in travel levels and in average operating speeds on the part of heavy-duty diesel trucks and mass transit vehicles.

The total hydrocarbon emissions in the Region from all vehicle types in 1977 totaled 47,908 tons, a decrease of about 6,830 tons, or more than 12 percent, from the 1973 emission level of about 54,738 tons. This decrease is again principally due to the more stringent controls on later model year light-duty gasoline vehicles.

Area Source Emissions Inventory: 1977

The 1973 regional area source emissions inventory considered 22 sources of air pollutant emissions. Because of the efforts of the Wisconsin Department of Natural Resources and two private consulting firms—Pacific Environmental Services, Inc. and Booz, Allen and Hamilton, Inc.—under contract to the U. S. Environmental Protection Agency, an additional source category of particulate matter emissions and seven additional source categories of hydrocarbon emissions were identified for the Southeastern Wisconsin Region and were incorporated into the 1977 area source inventory.[21] In total, therefore, the 1977 regional area source inventory was comprised of 30 individual categories of emissions.

Table 214 lists the air pollutant emissions from each of the 30 area source categories included in the 1977 regional inventory and, where applicable, provides a comparison with the corresponding emission levels

[21] *The 22 individual area source emission categories utilized in the 1973 inventory are listed in Table 186; the additional source category of particulate matter emissions used in the 1977 inventory is industrial fugitive dust. The seven additional hydrocarbon emission categories are architectural coatings, miscellaneous solvent use, automobile refinishing, cutback asphalt, construction equipment, industrial equipment, and off-highway motorcycles.*

Table 214

PERCENT CHANGE BETWEEN 1973 AND 1977 AIR POLLUTANT EMISSIONS FROM AREA SOURCES IN THE REGION

Source Category	Pollutant														
	Particulate Matter			Sulfur Dioxide			Carbon Monoxide			Nitrogen Oxides			Hydrocarbons		
	Tons		Percent	Tons		Percent	Tons		Percent	Tons		Percent	Tons		Percent
	1973	1977	Change	1973	1977	Change	1973	1977	Change	1973	1977	Change	1973	1977	Change
Agricultural Equipment	576	589	2.26	394	400	1.52	19,789	16,884	- 14.68	4,505	4,481	- 0.53	1,526	1,399	- 8.32
Agricultural Tilling	5,946	5,848	- 1.65	--	--	--	--	--	--	--	--	--	--	--	--
Aircraft Operations	60	68	13.30	56	64	17.86	6,432	8,772	36.38	524	580	10.69	928	1,204	29.74
Commercial-Institutional Fuel Use	1,675	750	- 55.22	10,345	4,760	- 53.99	2,308	1,830	- 20.71	4,695	2,849	- 39.32	680	443	- 34.85
Dry Cleaning Operations	--	--	--	--	--	--	--	--	--	--	--	--	2,408	2,420	0.50
Forest Wildfires	22	106	381.82	--	--	--	178	865	385.96	3	22	633.33	29	146	403.45
Gasoline Marketing	--	--	--	--	--	--	--	--	--	--	--	--	6,368	6,568	3.14
General Utility Engines	182	207	13.74	12	18	50.00	14,670	16,844	14.82	74	85	14.86	5,693	6,459	13.45
Incineration	352	360	2.27	52	60	15.38	268	276	2.99	104	108	3.85	184	188	2.17
Industrial Fuel Use	269	384	42.75	845	651	- 22.96	364	387	6.32	3,059	3,064	0.16	67	58	- 13.43
Power Boat Operations	--	--	--	39	39	--	20,510	20,510	--	41	41	--	6,975	6,975	--
Travel by Railroad Engines	216	216	--	484	484	--	1,300	1,300	--	2,804	2,804	--	308	308	--
Railroad Yard Work	64	64	--	140	140	--	708	708	--	1,048	1,048	--	404	404	--
Residential Fuel Use	1,331	835	- 37.27	4,081	5,533	35.58	1,443	1,748	21.14	3,497	4,906	40.29	617	530	- 14.10
Rock Handling and Storage	321	321	--	--	--	--	--	--	--	--	--	--	--	--	--
Small Point Sources	132	68	- 48.48	44	28	- 36.36	20	16	- 20.00	164	216	31.71	100	100	--
Snowmobile Operations	6	6	--	--[a]	--[a]	--	269	269	--	--[a]	--[a]	--	173	173	--
Travel on Unpaved Roads	327	262	- 19.88	--	--	--	--	--	--	--	--	--	--	--	--
Unpaved Auto Lots	49	36	- 26.53	--	--	--	--	--	--	--	--	--	--	--	--
Unpaved Truck Lots	77	61	- 20.78	--	--	--	--	--	--	--	--	--	--	--	--
Aggregate Storage Piles	360	360	--	--	--	--	--	--	--	--	--	--	--	--	--
Commercial Vessels	44	45	2.27	22	34	54.55	35	47	34.29	94	121	28.72	19	26	36.84
Industrial Fugitive Dust	--	8,056	N/A	--	--	--	--	--	--	--	--	--	--	--	--
Architectural Coating	--	--	--	--	--	--	--	--	--	--	--	--	--	3,916	N/A
Miscellaneous Solvent Use	--	--	--	--	--	--	--	--	--	--	--	--	--	7,996	N/A
Automobile Refinishing	--	--	--	--	--	--	--	--	--	--	--	--	--	424	N/A
Cutback Asphalt	--	--	--	--	--	--	--	--	--	--	--	--	--	10,549	N/A
Construction Equipment	--	--	--	--	--	--	--	--	--	--	--	--	--	398	N/A
Industrial Equipment	--	--	--	--	--	--	--	--	--	--	--	--	--	1,152	N/A
Off-Highway Motorcycles	--	--	--	--	--	--	--	--	--	--	--	--	--	556	N/A
Total	12,009	18,642	55.23	16,514	12,211	- 26.06	68,294	70,456	3.17	20,612	20,325	- 1.39	26,479	52,395	97.87

NOTE: N/A indicates data not available.

[a] *Less than one-half ton per year.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

during 1973. Except where noted, the procedures followed in collating the 1977 regional area source emissions inventory were the same as those described for the 1973 regional air source emissions inventory. The findings of the 1977 regional area source emissions inventory are described in the following sections.

Emissions From Agricultural Equipment: Table 214 indicates that the particulate matter emissions from agricultural equipment operations in 1977 totaled 589 tons, an increase of about 13 tons, or about 2 percent, over the 1973 emission level of 576 tons. Similarly, sulfur dioxide emissions from this source category totaled 400 tons in 1977, an increase of 7 tons, or less than 2 percent, over the 1973 emission level of about 394 tons. Carbon monoxide, nitrogen oxides, and hydrocarbons, however, all exhibited a decrease in emission levels over this five-year period.

Table 215 presents the agricultural equipment inventory by county as used to calculate the 1977 emissions from this source category. Comparing Table 215 with Table 128 indicates that over the five-year period the number of tractors and pick-up bailers in the Region decreased, while the number of self-propelled combines and forage harvesters increased. Moreover, while tractors and self-propelled combines in 1973 were assumed to be 75 percent diesel-powered and 25 percent gasoline-powered, by 1977 the fuel mix was assumed to be 80 percent diesel-powered and 20 percent gasoline-powered, reflecting a trend toward a totally diesel-powered implement fleet by the year 2000. This increase in the number of farm tractors and other machinery using diesel fuel increases the particulate matter, sulfur dioxide, and nitrogen oxide emission rates, as evidenced in Table 129, while decreasing the carbon monoxide and hydrocarbon emission rates. The small net increase in total particulate matter and sulfur dioxide emissions in the Region in 1977, as well as the small net decrease in nitrogen oxide emissions, may be attributed to the reduction in gasoline-powered farm equipment—particularly tractors and pick-up bailers—which offset the increase in the emission rates for these three pollutant species caused by the increased use of diesel fuel. Both the decrease in the number of gasoline-

Table 215

AGRICULTURAL EQUIPMENT INVENTORY FOR SOUTHEASTERN WISCONSIN: 1977

County	Number of Tractors		Number of Self-Propelled Combines		Number of Pick-Up Balers (gasoline)	Number of Forage Harvesters (diesel)
	Gasoline	Diesel	Gasoline	Diesel		
Kenosha	338	1,354	31	122	309	223
Milwaukee	87	347	6	23	77	40
Ozaukee	352	1,408	29	118	346	338
Racine	491	1,964	47	186	382	277
Walworth	685	2,738	57	230	707	519
Washington	714	2,856	52	207	689	734
Waukesha	531	2,126	31	126	593	438
Region	3,198	12,793	253	1,012	3,103	2,569

Source: U. S. Department of Agriculture, U. S. Census of Agriculture—1974.

Table 216

SUMMARY OF AIRCRAFT OPERATIONS AT SELECTED AIRPORTS IN THE REGION: 1977

Airport	Number of Operations	Number of LTO's
Kenosha-Municipal	89,700	44,850
Aero Park	2,526	1,263
Capitol Drive	40,185	20.093
Hales Corners[a]	22,960	11,480
Timmerman	190,752	95,376
Rainbow	29,931	14,965
Grob	3,674	1,837
Ozaukee	29,000	14,500
Burlington-Municipal	42,156	21,078
Fox River	4,600	2,300
Racine-Commercial	53,000	26,500
Sylvania	38,100	19,050
East Troy-Municipal	44,000	22,000
Gruenwald	21,600	10,800
Lake Lawn Lodge	1,600	800
Playboy	6,400	3,200
Hartford-Municipal	81,468	40,734
West Bend-Municipal	86,116	43,058
Waukesha County	165,658	82,829
Total	953,426	476,713

[a] *Hales Corners Airport ceased operation on August 16, 1977.*

Source: SEWRPC.

powered machines and the increase in the use of diesel-powered machines acted to reduce carbon monoxide emissions by 15 percent and hydrocarbon emissions by 8 percent between 1973 and 1977.

Emissions From Agricultural Tilling Operations: Table 214 indicates that particulate matter emissions from agricultural tilling operations in the Region totaled 5,848 tons during 1977, a decrease of 98 tons, or less than 2 percent, from the 1973 emission level of 5,946 tons. This decrease reflects the loss of farmland in the Region through conversion to urban uses.

Since particulate matter emissions from agricultural tilling operations had to be determined on a quarter section-by-quarter section basis because of changes in the estimated silt content of the underlying soil between individual quarter sections, the use of computer processing was required to perform the numerous attendant calculations. In the absence of a detailed computer-readable file on agricultural land area by quarter section specific to the year 1977, it was necessary to estimate the area of each section in the Region in such use by interpolating between the land area in agricultural and related purposes based on the 1970 regional land use inventory and the 1985 stage of the adopted land use plan. Although the areas of each quarter section in agricultural land uses thus estimated for 1977 may not correspond precisely to the actual land area subjected to tilling operations in that year, this procedure is believed to provide a valid estimate of the location and extent of agricultural land area in the Region in 1977 while facilitating machine processing of the emissions inventory.

Emissions From Aircraft Operations: As with the 1973 inventory, the air pollutant emissions from aircraft operations in 1977 were calculated on the basis of the number of landing and takeoff cycles (LTO's) occurring at the 20 major airports within the Region. Table 216 lists the estimated number of operations and the corresponding number of landing and takeoff cycles at the 19 general aviation airports in operation within the Region during 1977. The corresponding data for General Mitchell Field is provided in Table 217 disaggregated by aircraft type. Comparing Table 216 with Table 132 indicates that the number of LTO's has increased by about 121,200 cycles, or about 34 percent, between 1973 and 1977—from about 355,500 cycles in 1973 to about 476,700 cycles in 1977. The total number of LTO's at General Mitchell Field, however, declined by about 7,200 cycles, or about 6 percent, between 1973 and 1977—from about 127,000 cycles in 1973 to about 119,800 cycles in 1977, as shown in Tables 133 and 217. The increase in the number of LTO's by the large jet aircraft in the common carrier classification between 1973 and 1977—about 4,000 LTO's, or 10 percent—offset the loss of LTO's by general aviation aircraft. In addition, because of the higher pollutant emission rates for jet aircraft, as shown in Table 134, the total emissions at General Mitchell Field increased between 1973 and 1977.

Emissions From Small Commercial-Institutional and Industrial Operations: Between 1973 and 1977 the number of persons employed in the commercial and institutional sectors of the regional economy increased by 5.8 percent. At the same time, the number of persons employed in the manufacturing sector of the regional economy increased by 3.8 percent. The fuel consumed by small commercial-institutional and industrial sources

Table 217

ESTIMATED AIRCRAFT OPERATIONS AT GENERAL MITCHELL FIELD BY AIRCRAFT TYPE: 1977

Aircraft Group	Number of Engines	Number of Operations	Number of LTO's
Common Air Carrier and Commuter			
Boeing 747	4	2,181	1,091
DC-10, L-1011	3	2,273	1,136
DC-8 Stretch	--	2,611	1,306
DC-8, Boeing 707	4	2,766	1,383
DC-9, Boeing 727	2-3	48,607	24,303
CV-580, F-227	2	27,041	13,521
Subtotal	--	85,479	42,740
Air Taxi			
Turboprop	2	2,464	1,232
General Aviation			
Light Twin Engine	2	74,175	37,088
Heavy Twin Engine	2	9,699	4,849
Light Turboprop	2	30,872	15,436
Heavy Turboprop	2	12,567	6,284
Turbojet	2	9,289	4,644
Subtotal	--	136,602	68,301
Military			
KC-97	6	6,040	3,020
C-130	4	9,060	4,530
Subtotal	--	15,100	7,550
Total	--	239,645	119,823

Source: SEWRPC.

Table 218

ESTIMATED TOTAL FUEL CONSUMPTION BY SMALL COMMERCIAL-INSTITUTIONAL OPERATIONS IN THE REGION BY COUNTY BY SEASON: 1977

County	Season	Fuel Type				
		Natural Gas (cubic feet)	Coal (tons)	LPG Propane (gallons)	Fuel Oil Residual (gallons)	Fuel Oil Distillate (gallons)
Kenosha	Winter	1,124,140,210	4,266	2,070,495	518,201	4,950,440
	Spring	388,272,112	1,473	715,138	178,984	1,709,856
	Summer	55,078,199	209	101,446	25,390	242,551
	Fall	378,735,604	1,437	697,573	174,588	1,667,859
	Annual	1,946,226,125	7,385	3,584,652	897,163	8,570,706
Milwaukee	Winter	3,465,231,565	9,419	15,873,794	3,927,043	36,877,957
	Spring	1,196,872,744	3,253	5,482,725	1,356,380	12,737,452
	Summer	169,781,948	461	777,750	192,409	1,806,867
	Fall	1,167,475,870	3,173	5,348,061	1,323,066	12,424,602
	Annual	5,999,362,127	16,306	27,482,330	6,798,898	63,846,878
Ozaukee	Winter	232,264,320	1,422	690,165	172,734	1,650,147
	Spring	80,222,874	491	238,379	59,661	569,952
	Summer	11,379,986	70	33,815	8,463	80,850
	Fall	78,252,487	479	232,524	58,196	555,953
	Annual	402,119,667	2,462	1,194,883	299,054	2,856,902
Racine	Winter	1,695,821,892	5,480	2,760,659	690,935	6,600,586
	Spring	585,727,956	1,893	953,517	238,645	2,279,808
	Summer	83,088,226	268	135,261	33,853	323,401
	Fall	571,341,656	1,846	930,098	232,784	2,223,813
	Annual	2,935,979,730	9,487	4,779,535	1,196,217	11,427,608
Walworth	Winter	506,902,491	1,422	690,165	172,734	1,584,148
	Spring	175,081,453	491	238,379	59,661	547,156
	Summer	24,836,115	70	33,815	8,463	77,617
	Fall	170,781,207	479	232,524	58,196	533,718
	Annual	877,601,266	2,462	1,194,883	299,054	2,742,639
Washington	Winter	269,042,138	2,844	1,380,330	172,734	3,300,293
	Spring	92,925,738	982	476,759	59,661	1,139,904
	Summer	13,181,947	139	67,630	8,463	161,701
	Fall	90,643,353	958	465,049	58,196	1,111,906
	Annual	465,793,176	4,923	2,389,768	299,054	5,713,804
Waukesha	Winter	2,106,025,565	7,109	3,450,824	863,669	8,250,734
	Spring	727,410,146	2,455	1,191,897	298,307	2,849,760
	Summer	103,186,502	348	169,076	42,316	404,252
	Fall	709,543,932	2,395	1,162,622	290,980	2,779,766
	Annual	3,646,166,145	12,307	5,974,419	1,495,272	14,284,512
Region	Winter	9,399,428,181	31,962	26,916,432	6,518,050	63,214,305
	Spring	3,246,513,023	11,038	9,296,794	2,251,299	21,833,888
	Summer	460,532,923	1,565	1,318,793	319,357	3,097,239
	Fall	3,166,774,109	10,767	9,068,451	2,196,006	21,297,617
	Annual	16,273,248,236	55,332	46,600,470	11,284,712	109,443,049

Source: SEWRPC.

in the Region during 1977 was initially estimated by applying these growth rates to the 1973 level of fuel consumption. However, it was determined from a telephone survey of coal suppliers in Milwaukee County conducted by the Wisconsin Department of Natural Resources that coal use had significantly declined from the level identified in the 1973 inventory. It was therefore necessary to reduce the coal consumption for small commercial-institutional and industrial operations in Milwaukee County to a level reflecting the findings of the 1977 DNR survey, and to maintain constant the coal consumption in the remaining six counties. The total estimated fuel use for small commercial-institutional operations during 1977, based on the above assumptions, is shown in Table 218, and, for small industrial operations during 1977, in Table 219.

Subsequent to the preparation of the 1973 inventory of air pollutant emissions from small commercial-institutional and industrial operations, the U. S. Environmental Protection Agency revised the emission factors for distillate fuel oil and residual fuel oil combustion. These revised emission factors, shown in Table 220 for commercial-institutional fuel use and in Table 221 for industrial fuel use, have the effect of reducing the average emission rate for all pollutant species with the exception of carbon monoxide. It should also be noted that the change in the sulfur dioxide and nitrogen oxide emission factors only affects distillate fuel oil combustion.

As shown in Table 214, the emissions of each of the five pollutant species from commercial-institutional fuel use exhibited a significant decrease from 1973 to 1977. This decrease may be attributed in part to the change in the emission factors for fuel oil combustion, and in part to a reduction in the amount of coal consumed in 1977. Table 214 also indicates that only sulfur dioxide and hydrocarbon emissions from industrial fuel use decreased since 1973. This may be attributed to the fact that fuel oil is not as significant a component of the total industrial fuel consumption as it is of commercial-

Table 219

ESTIMATED TOTAL FUEL CONSUMPTION BY SMALL INDUSTRIAL OPERATIONS IN THE REGION BY COUNTY BY SEASON: 1977

County	Season	Fuel Type				
		Natural Gas (cubic feet)	Fuel Oil Residual (gallons)	Fuel Oil Distillate (gallons)	LPG Propane (gallons)	LPG Butane (gallons)
Kenosha	Winter	572,158,053	97,727	225,838	--	63,636
	Spring	197,620,380	33,754	78,003	--	21,979
	Summer	28,033,367	4,788	11,065	--	3,118
	Fall	192,766,546	32,925	76,088	--	21,440
	Annual	990,578,346	169,194	390,994	--	110,173
Milwaukee	Winter	12,740,313,074	1,257,974	2,578,791	3,926,373	633,819
	Spring	4,400,437,082	434,497	890,701	1,356,148	218,918
	Summer	624,222,403	61,635	126,350	192,376	31,054
	Fall	4,292,356,171	423,826	868,824	1,322,840	213,541
	Annual	22,057,328,730	2,177,932	4,464,666	6,797,737	1,097,332
Ozaukee	Winter	644,262,550	329,872	243,249	439,157	42,424
	Spring	222,524,894	113,936	84,017	151,683	14,653
	Summer	31,566,188	16,162	11,918	21,517	2,079
	Fall	217,059,370	111,138	81,953	147,957	14,293
	Annual	1,115,413,002	571,108	421,137	760,314	73,449
Racine	Winter	917,769,818	539,954	241,714	806,177	127,272
	Spring	316,992,865	186,497	83,487	278,449	43,959
	Summer	44,966,908	26,455	11,843	39,499	6,236
	Fall	309,207,075	181,917	81,436	271,610	42,880
	Annual	1,588,936,666	934,823	418,480	1,395,735	220,347
Walworth	Winter	644,790,513	89,992	121,625	219,579	21,212
	Spring	222,707,249	31,083	42,008	75,841	7,326
	Summer	31,592,056	4,409	5,959	10,758	1,039
	Fall	217,237,247	30,320	40,977	73,979	7,147
	Annual	1,116,327,065	155,804	210,569	380,157	36,724
Washington	Winter	817,352,768	329,872	152,117	439,157	42,424
	Spring	282,309,344	113,936	52,541	151,683	14,653
	Summer	40,046,889	16,162	7,453	21,517	2,079
	Fall	275,375,431	111,138	51,250	147,957	14,293
	Annual	1,415,084,432	571,108	263,361	760,314	73,449
Waukesha	Winter	1,653,028,287	249,652	278,455	868,123	84,848
	Spring	570,947,270	86,228	96,177	299,845	29,306
	Summer	80,991,518	12,232	13,643	42,534	4,157
	Fall	556,924,004	84,111	93,814	292,480	28,586
	Annual	2,861,891,079	432,223	482,089	1,502,982	146,897
Region	Winter	17,989,675,063	2,895,043	3,841,789	6,698,566	1,015,635
	Spring	6,213,539,084	999,931	1,326,934	2,313,649	350,794
	Summer	881,419,329	141,843	188,231	328,201	49,762
	Fall	6,060,925,844	975,375	1,294,342	2,256,823	342,180
	Annual	31,145,559,320	5,012,192	6,651,296	11,597,239	1,758,371

NOTE: Industrial coal consumption is considered commercial/institutional fuel consumption.

Source: SEWRPC.

institutional fuel consumption and, consequently, the reduction in coal use is the predominant influencing factor rather than the change in the emission factors for fuel oil combustion.

Emissions From Dry Cleaning Operations: As in the 1973 area source emissions inventory, the evaporative hydrocarbon losses from dry cleaning operations in the Region were estimated on the basis of an assumed solvent use of 2.7 pounds per person. Regional population data for the year 1975 compiled in a special population census conducted in the City of Milwaukee during that year were used to calculate the evaporative hydrocarbon emissions from dry cleaning operations since these data were deemed to provide the most reliable estimate available of the number of regional inhabitants. It was assumed that such fluctuations as may exist in regional population levels from year to year would not significantly influence the level of dry cleaning operations.

The estimated hydrocarbon emissions resulting from the evaporation of solvents used in dry cleaning operations in the Region during 1977 totaled 2,420 tons. This level is essentially the same as the 2,408 tons of evaporative hydrocarbon emissions from dry cleaning operations estimated for the year 1973.

Emissions From Forest Wildfires: In 1973 there were about 370 forest wildfires in the Region which damaged about 870 acres of woodland and brushland, as shown in Table 142. As may be seen in Table 222, however, there were 606 forest wildfires in the Region during 1977 which damaged over 4,100 acres of woodlands and brushlands. This approximately four-fold increase in the acreage burned by wildfires in the Region produced a corresponding increase in the level of emissions from this source category in 1977.

Emissions From Gasoline Marketing: In the 1973 regional area source emissions inventory, it was estimated that 546 million gallons of gasoline were consumed by vehicles operating over the street and highway system in southeastern Wisconsin, and that an additional 40 million gallons of gasoline were consumed for miscellaneous purposes such as the operation of general utility engines

Table 220

EMISSION FACTORS FOR COMMERCIAL-INSTITUTIONAL FUEL USE: 1977

Fuel Type	Emission Factor (grams)				
	Particulate Matter	Sulfur Oxides	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
Natural Gas (per cubic foot)	0.00454	0.0002724	0.01	0.05	0.003632
Residual Oil (per gallon)	4.54	71.278	2.27	27.24	0.454
Distillate Oil (per gallon)	0.908	19.34	2.27	9.99	0.454
LPG Propane (per gallon)	0.82	0.0004086	0.86	4.994	0.32
LPG Butane (per gallon)	0.86	0.0004086	0.91	5.45	0.36
Coal (per ton)	7,945.00	25,878.00	22,700.00	2,043.00	5,221.00

Source: U. S. Environmental Protection Agency.

Table 221

EMISSION FACTORS FOR INDUSTRIAL FUEL USE: 1977

Fuel Type	Emission Factor (grams)				
	Particulate Matter	Sulfur Oxides	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
Natural Gas (per cubic foot)	0.00454	0.0002724	0.01	0.08	0.001362
Residual Oil (per gallon)	5.90	71.278	2.27	27.24	0.454
Distillate Oil (per gallon)	0.908	19.34	2.27	9.99	0.454
LPG Propane (per gallon)	0.77	0.0004086	0.68	5.08	0.14
LPG Butane (per gallon)	0.82	0.0004086	0.73	5.49	0.14
Coal (per ton)	44,265.00	25,878.00	908.00	6,810.00	454.00

Source: U. S. Environmental Protection Agency.

Table 222

SUMMARY OF FOREST WILDFIRES IN THE REGION BY COUNTY: 1977

County	Number of Fires	Total Acreage Burned
Kenosha	130	984
Milwaukee	--	--
Ozaukee	24	228
Racine	194	450
Walworth	92	1,826
Washington	40	180
Waukesha	126	460
Region	606	4,128

Source: Wisconsin Department of Natural Resources, Wisconsin 1977 Forest Fire Report.

in the seven-county area. Based on an estimate of the increase in vehicle miles of travel in the Region and on the average fleet fuel use rate, it was estimated that 616 million gallons of gasoline were consumed by automobiles and trucks in southeastern Wisconsin during 1977, an increase of about 70 million gallons, or about 13 percent, over the amount consumed in 1973. As in the 1973 inventory, the Wisconsin Department of Natural Resources estimated the statewide consumption of gasoline for miscellaneous purposes during 1977, and allocated that consumption among individual counties of the State, and thus the Region, on the basis of the county population to the total state population. Using this procedure, it was estimated that approximately 42 million gallons of gasoline were consumed for miscellaneous purposes in the Region during 1977, an increase of about two million gallons, or about 5 percent, over the 1973 consumption level. In total, therefore, about 657 million gallons of gasoline were consumed in southeastern Wisconsin during 1977, an increase of about 71 million gallons, or 12 percent, over the 1973 estimated gasoline consumption level of 586 million gallons. The estimated gasoline consumption in the Region by county for 1977 is presented in Table 223.

From a telephone survey of gasoline service stations in the Region conducted by the Wisconsin Department of Natural Resources during 1978, it was determined that approximately one-half of all service stations had switched from the splash method of filling underground storage tanks to the lower emission-producing submerged method. It was accordingly assumed that 50 percent of the gasoline service stations in the Region used the submerged filling method during 1977. The overall emission factors for gasoline marketing in 1977, as shown in Table 224, is thus lower than the overall emission factors used in the 1973 inventory, which assumed a mix of 21 percent submerged method and 79 percent splash method in Milwaukee County, and 100 percent splash method in all other counties of the Region (see Table 147). Based on the estimated regional gasoline consumption of 657 million gallons, and assuming total submerged filling, the hydrocarbon emissions from gasoline marketing in the Region during 1977 totaled 6,568 tons, an increase of 200 tons, or about 3 percent, over the 1973 emission level of 6,368 tons.

Emissions From General Utility Engines: As in the 1973 area source emissions inventory, each residential structure identified in the 1977 regional housing unit inventory was assumed to operate at least one type of general utility engine for lawn and garden applications, and it was assumed that approximately 11 percent of the residential buildings would operate an additional engine for miscellaneous purposes. Also like the 1973 inventory, it was assumed that 2-stroke engines would be used primarily in urban areas, and that 4-stroke engines would be used primarily in the more rural areas of the Region. Table 214 indicates that the air pollutant emissions from general utility engines increased by a minimum of about 14 percent for particulate matter and a maximum of 50 percent for sulfur oxides between 1973 and 1977.

Emissions From Incinerators: The air pollutant emissions from commercial and industrial incinerators in the

Table 223

ESTIMATED GASOLINE CONSUMPTION IN THE REGION BY COUNTY: 1977

County	Gasoline Consumed (gallons)
Kenosha	52,848,105
Milwaukee	313,364,709
Ozaukee	30,731,522
Racine	65,193,349
Walworth	34,989,559
Washington	39,027,536
Waukesha	120,696,200
Region	656,850,980

Source: Wisconsin Department of Revenue and Wisconsin Department of Natural Resources.

Table 224

EVAPORATIVE HYDROCARBON EMISSION FACTORS FOR GASOLINE MARKETING IN THE REGION: 1977

Emission Source	Emission Factor (pounds per 1,000 gallons)
Underground Tank Filling	9.3[a]
Underground Tank Breathing	1.0
Vehicle Refueling Displacement Losses (uncontrolled)	9.0
Vehicle Refueling Spillage	0.7
Total	20.0

[a] *Assumes 50 percent submerged fill and 50 percent splash fill.*

Source: U. S. Environmental Planning Agency and SEWRPC.

Region during 1977 were estimated assuming that the quantity of refuse burned would be proportional to the number of persons employed in the manufacturing sector. Similarly, it was assumed that the quantity of refuse burned in domestic incinerators would be proportional to the number of residential structures. Accordingly, the air pollutant emissions generated by incinerators in the Region during 1977, as shown in Table 214, reflect the change in manufacturing employment and housing units between 1973 and 1977 as estimated based on regional growth patterns.

Emissions From Power Boat Operations: After a review of the findings and results of the 1973 inventory and forecast of power boat activities in southeastern Wisconsin, it was determined that the level of this activity had reached near saturation in the Region by 1973 and that any future increase in power boating activities would be of such small magnitude so as not to appreciably alter the level of air pollutant emissions estimated in the 1973 inventory. The air pollutant emissions inventory for power boat operations in the Region during 1977, consequently, was held constant at about 40 tons of sulfur dioxide, 20,500 tons of carbon monoxide, 41 tons of nitrogen oxides, and 6,970 tons of hydrocarbons.

Emissions From Railroad Engines: As indicated in Table 214, air pollutant emissions from railroad engines, both for yard work and for travel on the regional rail network, were assumed to remain unchanged from the 1973 emissions. This assumption is based on the premise that the normal level of engine activity both in yards and on the regional rail network is determined by a fixed schedule that has varied little over the recent past. Moreover, it was assumed that any decrease in passenger train service within the Region, such as occurred between 1973 and 1977, would be offset by an increase in freight train movements.

Emissions From Residential Fuel Use: The total number of housing units in the Region in 1977 was estimated by interpolating between the number of housing units identified in the 1970 land use inventory and the number of housing units forecast in the 1985 stage of the adopted land use plan. This interpolative method was used in order to obtain the housing unit data in a format suitable for computer processing. Under this procedure the total number of housing units in the Region during 1977 was estimated to be 615,580 units. This represents an increase of about 66,500 units, or 12 percent, over the 549,140 housing units identified in the 1970 inventory.

Table 225 gives the distribution of the 1977 housing units in the Region by fuel type. This distribution may be compared with the distribution of housing units by fuel type as determined in the 1970 inventory and shown in Table 162. It is significant to note that the number of housing units in the Region using coal for space heating purposes declined from about 9,900 units in 1970 to about 2,900 units in 1977, a decrease of about 7,000 coal-burning units, or about 71 percent, over this eight-year period. This reduction was estimated from data provided by a survey of coal suppliers in Milwaukee County conducted by the Wisconsin Department of Natural

Table 225

DISTRIBUTION OF HOUSING UNITS IN THE REGION BY COUNTY AND BY FUEL TYPE: 1977

County	Number of Units per Fuel Type							
	Natural Gas	Bottled Gas	Fuel Oil and Kerosene	Coal and Coke	Wood	Electric	Other	No Fuel
Kenosha	27,603	1,307	11,893	454	--	1,506	84	29
Milwaukee	255,354	2,112	97,137	1,440	83	11,180	2,640	41
Ozaukee	8,469	315	9,602	170	19	1,042	--	--
Racine	32,385	1,104	21,175	341	15	1,866	109	--
Walworth	12,059	775	11,075	99	--	966	46	17
Washington	8,043	600	13,529	24	35	1,315	19	6
Waukesha	34,086	855	38,625	368	--	3,453	90	15
Region	377,999	7,068	203,036	2,896	152	21,328	2,988	108

Source: SEWRPC.

Resources in 1977, which indicated that residential coal use had declined substantially since the initial coal use inventory in 1974. Based on this survey finding, the number of coal-burning units in Milwaukee County was estimated to have decreased to that level which could be accommodated under the total coal sales and heating demand in 1977. It was also determined that the number of coal-burning housing units in the other six counties had remained at the 1970 level. The coal-burning housing units removed from the Milwaukee County inventory and the new housing units developed after 1970 in all seven counties were assigned to fuel types on the following assignment schedule: 60 percent to fuel oil, 20 percent to natural gas, and 20 percent to electricity. A water heater of the same fuel type as used for space heating purposes was also assigned to each new heating unit. Ninety percent of the total available dwelling units were assumed to be single-family dwellings and 10 percent two- to four-unit dwellings. The assignment of new housing units constructed between 1970 and 1977 to the above schedule was intended to provide a conservative over-estimate of fuel consumption for residential space heating purposes.

The heating demand in the Region during 1977 was significantly greater than during 1973. Table 226 lists the heating degree-days at General Mitchell Field in 1977. Comparing Table 224 with Table 167 indicates that, on an annual average, 1977 had an approximately 9 percent greater demand for heat energy than did 1973. Correspondingly, fuel use for space heating was estimated to have increased by about 9 percent over this period.

Subsequent to the 1973 inventory of emissions from residential fuel use, the U. S. EPA revised the fuel oil combustion emission factors shown in Table 171. As a result of this revision, the particulate matter emission factor was reduced from 4.54 grams per gallon to 1.135 grams per gallon, a decrease of about 3.4 grams, or about 75 percent; the hydrocarbon emission factor was reduced from 1.362 grams per gallon to 0.454 gram per gallon, a decrease of about 0.91 gram, or about 67 percent; and the nitrogen oxide emission factor was increased from 5.448 grams per gallon to 8.172 grams per gallon, an increase of about 2.72 grams, or 50 percent.

Table 226

NUMBER OF HEATING DEGREE-DAYS AT GENERAL MITCHELL FIELD BY SEASON: 1977

Season	Number of Heating Degree-Days
Winter	4,208
Spring	1,453
Summer	206
Fall	1,418
Annual	7,285

Source: U. S. Department of Commerce, National Weather Service.

The impact of the revised fuel oil combustion emission factors for residential fuel use is most evident when comparing the particulate matter emissions from this source category for 1973 and for 1977, as shown in Table 214. In 1977 the total particulate matter emissions from residential fuel use totaled 835 tons, a decrease of about 495 tons, or about 37 percent, from the 1973 emission level of 1,331 tons. This substantial decrease is attributed principally to the reduction in the particulate matter emission factor, which more than offset the increase in emissions that might have been expected from the 12 percent increase in the number of housing units and 9 percent increase in heating demand. Total hydrocarbon emissions from residential fuel use in the Region also decreased as a result of the new emission factor—from 617 tons in 1973 to 530 tons in 1977, a 14 percent decrease. Sulfur dioxide and carbon monoxide emissions were not influenced by the revised fuel oil combustion emission factors, and increased in accordance with the increased number of housing units and greater heating demand in 1977. Nitrogen oxide emissions, for which the emission factor was increased, demonstrated the largest relative increase of the five pollutant species, increasing by about 1,410 tons, or over 40 percent, between 1973 and 1977—from 3,497 tons in 1973 to 4,906 tons in 1977.

Emissions From Rock Handling and Storage: The particulate matter emissions from rock handling and storage in the Region during 1977 were held constant at the 1973 level of pollutant production. This determination was based upon the observation that the land area for mineral extraction and quarrying operations in southeastern Wisconsin remained essentially the same between 1970 and 1975—the date of the Commission's most recent aerial photography. It was accordingly concluded that the level of excavation, processing, storage, and transport of rock, stone, sand, and gravel should not have appreciably changed over the period, and that emissions from this source category would not vary perceptibly between 1973 and 1977.

Emissions From Small Point Sources: As in the 1973 inventory, there were a number of sources in the Wisconsin Department of Natural Resources 1977 point source emissions inventory that were considered too small to have a significant impact on ambient air quality in the Region when considered individually. Consequently, these small point sources, which emit less than 10 tons per year of each pollutant species, were included in the area source emissions inventory. In the 1973 inventory there were 94 individual small point sources. In 1977, however, there were only 88 small point sources. Many of the small point sources of the 1973 inventory remained in this classification in 1977, but several had ceased operations and were deleted from the inventory. Others had increased their emission rate to greater than 10 tons per year of one or more pollutant species and were subsequently placed in the major point source inventory. As a result of such changes in the composition of the small point source inventory, particulate matter, sulfur dioxide, and carbon monoxide emissions from this source category exhibited a decrease

between 1973 and 1977, while hydrocarbon emissions remained essentially the same and nitrogen oxide emissions increased.

Emissions From Snowmobile Operations: As indicated in Table 214, air pollutant emissions from snowmobile operations in the Region during 1977 are assumed to have remained at the same level as that estimated for 1973. This assumption is based on the premise that the normal climatic conditions in southeastern Wisconsin do not favor the persistence of the snow cover on the ground necessary to maintain the integrity of established snowmobile trails, and that increasing urbanization in the Region is reducing the nondelineated areas of snowmobile use in more rural locations. Both of these conditions would tend to inhibit snowmobile use in much of the seven-county area.

Emissions From Commercial Vessels: Table 227 presents a county summary of the commercial vessel activity at port facilities in the Region during 1977. Table 227 may be compared with Table 178, which summarizes the port activity during 1973. As may be seen from this comparison, the number of commercial vessels using port facilities in Milwaukee County decreased by about 20 percent between 1973 and 1977. The number of vessels using ports in Kenosha and Ozaukee Counties increased by about 61 percent and 37 percent, respectively. On a regional basis, there were 205 fewer commercial vessels using port facilities in southeastern Wisconsin in 1977 than there were in 1973, a decrease of about 16 percent.

Although there were fewer vessels in 1977, the total quantity of fuel consumed by such ships during dockside activities actually increased over the 1973 level of consumption. As shown in Table 227, the fuel consumed of both fuel types—diesel fuel and coal—by commercial vessels in the Region during 1977 totaled 3,915 tons, an increase of about 271 tons, or about 7 percent, over the 1973 total fuel consumption of 3,644 tons. This increase in fuel consumption may be attributed to a longer average period of time spent at dockside by commercial vessels during 1977. As a result of this higher fuel consumption, air pollutant emissions from commercial vessels using regional port facilities during 1977 increased over the comparable 1973 level of emissions for each pollutant species, as shown in Table 214.

The Menomonee River Valley Emission Inventories: As a part of a fugitive dust study being conducted by the City of Milwaukee, Department of City Development, the City reevaluated its original 1973 inventory of particulate matter emissions from vehicle travel on unpaved roads, unpaved automobile parking lots, and unpaved truck lots, and from aggregate storage piles in the heavily industralized area of the Menomonee River Valley. This reevaluation was conducted in order to determine the effects of the different meteorological conditions between 1973 and 1977 and to ascertain the extent to which unpaved roads and lots had been paved since the initial inventory period. The results and findings of this reevaluation process are summarized in the following sections.

Table 227

NUMBER OF COMMERCIAL VESSELS UTILIZING REGIONAL PORT FACILITIES AND ESTIMATED FUEL CONSUMPTION BY COUNTY BY SEASON: 1977

County	Winter	Spring	Summer	Fall	Annual
Kenosha					
Number of Ships	4	6	17	23	50
Tons of Fuel Consumed					
Fuel Oil or Diesel Fuel	11	14	53	88	166
Diesel Fuel	--	--	--	--	--
Coal	--	--	--	--	--
Total	11	14	53	88	166
Milwaukee					
Number of Ships	171	210	300	281	962
Tons of Fuel Consumed					
Fuel Oil or Diesel Fuel	122	222	402	623	1,369
Diesel Fuel	152	250	332	285	1,019
Coal[a]	176	180	240	188	784
Total	450	652	974	1,096	3,172
Ozaukee					
Number of Ships	8	18	31	21	78
Tons of Fuel Consumed					
Fuel Oil or Diesel Fuel	27	94	211	245	577
Diesel Fuel	--	--	--	--	--
Coal	--	--	--	--	--
Total	27	94	211	245	577
Racine	N/A	N/A	N/A	N/A	N/A

NOTE: N/A indicates data not available.

[a] *The tons of coal consumed were converted to oil equivalent units.*

Source: SEWRPC.

Aggregate Storage Piles: The Department of City Development has determined that the particulate matter emissions from aggregate storage piles remained essentially constant between 1973 and 1977. No significant differences in the number, size, or location of such storage piles were observed during the 1977 inventory reevaluation process. As indicated in Table 214, therefore, 360 tons of particulate matter emissions from aggregate storage piles in the Menomonee River Valley were included in the 1977 area source emissions inventory.

Travel on Unpaved Roads: Approximately 6.1 linear miles of unpaved road surface in the Menomonee River Valley were identified by the Department and included in the 1973 and 1977 fugitive dust emission inventories. Although the number of vehicles and the average vehicle speed on such unpaved roads were assumed to remain constant from 1973 to 1977, the Department determined that the fugitive dust emissions from this source category in 1977 totaled 262 tons, a decrease of 65 tons, or about 20 percent, from the 1973 emission level of 327 tons. As with unpaved truck lots, the principal cause for this emission reduction is the increase in the number of days with precipitation during 1977.

Travel on Unpaved Automobile Lots: In 1973 there were 389 unpaved automobile parking lots in the Menomonee River Valley. In the 1977 reevaluation, the Department found 341 such lots in the Valley, a decrease of 48 lots, or about 12 percent. These 48 lots were either paved or converted to other land uses. This reduction in the number of unpaved automobile parking lots explains, in part, the 27 percent decrease in particulate matter emissions from this source category—from 49 tons in 1973 to 36 tons in 1977, as shown in Table 214. This decrease may be further explained by the fact that 1977 had a greater number of days with precipitation than did 1973. In 1977 there were 198 days during which precipitation events equaled or exceeded 0.01 inch or during which snow cover on the ground exceeded one inch. This represents an increase of 32 days, or 19 percent, over the 166 days with equivalent precipitation amounts in 1973. The greater number of days with precipitation events in 1977 acted to increase the binding of loose surface materials and to decrease fugitive dust emissions. The 198 days with precipitation events during 1977 represent approximately 54 percent of the 365-day year, while the 166 days with precipitation events in 1973 represent about 45 percent of the year. The difference—about 9 percent—is reflected in a reduction in fugitive dust emissions between 1973 and 1977.

Travel on Unpaved Truck Lots: In both the 1973 and 1977 fugitive dust emission inventories, the City of Milwaukee, Department of City Development, found 80 unpaved truck lots in the Menomonee River Valley. The Department determined that the particulate matter emissions from such lots during 1977 totaled about 61 tons, a decrease of about 16 tons, or nearly 21 percent, from the 1973 emission level of 77 tons. This decrease may be attributed principally to the increased number of days with precipitation in 1977 as compared with 1973.

Industrial Fugitive Dust Emissions: Industrial fugitive dust emissions may be defined as particulate matter which either escapes from a defined process flow stream due to leakage, material handling, or inadequate operations control, or which becomes airborne due to the forces of wind or human activity. During 1978 the Wisconsin Department of Natural Resources completed an inventory of the estimated quantity of fugitive dust emissions that escaped through windows, doors, and roof vents located in proximity to manufacturing operations and industrial processes in the Southeastern Wisconsin Region. This inventory was conducted through field investigations, conducted by personnel from the Department, which established the type of process and the quantity of throughput associated with the generation of fugitive dust emissions. Based on these field investigations, and on the U. S. Environmental Protection Agency-recommended emission factors for each process category, the Department estimated that approximately 8,056 tons of particulate matter emissions are released annually into the atmosphere from fugitive dust sources in southeastern Wisconsin.[22]

Special Hydrocarbon Emissions Inventories: Subsequent to the preparation of the 1973 regional air pollutant emissions inventory, the Wisconsin Department of Natural Resources, with the assistance of Pacific Environmental Services, Inc. (PES) and Booz, Allen and Hamilton, Inc., completed a hydrocarbon emissions inventory including such previous unquantified sources as architectural coatings, miscellaneous solvent use, automobile refinishing, cutback asphalt, construction equipment, industrial equipment, and off-highway motorcycles. Other hydrocarbon emission sources collated during this procedure, such as printing and lithography sources, are comprised essentially of stack emissions and were therefore included in the point source inventory for 1977. The aforementioned seven hydrocarbon sources, however, are more areally diffuse and are therefore considered in the area source inventory. The procedures and underlying assumptions used to estimate the hydrocarbon emissions from these seven source categories are discussed in the following sections.[23]

Architectural Coatings: Architectural coatings consist of paints, stains, varnishes, and other protective or decorative coatings. These coatings are collectively termed trade paints. Trade paints may be classified as either being solvent-based or water-based coatings. Solvent-based paints contain approximately 53 percent hydrocarbon solvent by volume, while water-based paints contain about 3.5 percent hydrocarbon solvent by volume. Although several types of solvents may be used in trade paints, the average solvent density is about 7.3 pounds per gallon.

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[22] *The U. S. EPA-recommended emission factors are contained in the document, Technical Guidance for Control of Industrial Process Fugitive Particulate Emissions, PEDCo Environmental, Inc., EPA-450/3-77-010, March 1977.*

[23] *The seven hydrocarbon inventories referenced were developed by the consulting firms as a part of a larger effort to estimate the emissions of this pollutant species in 47 counties within six states in the midwestern area of the United States. Most often the hydrocarbon emissions were estimated by the consultant on a statewide basis and allocated to the counties within each state by an apportionment factor. It is probable that a more local-specific inventory would provide a more representative depiction of the true level of emissions from these seven sources in the Southeastern Wisconsin Region. Although the Commission can endorse neither the accuracy of these seven inventories nor, in particular, the allocation techniques used to apportion the emissions to the county level, the results of the inventory are included herewith as a preliminary estimate of the possible hydrocarbon emissions burden which may be contributed by these sources and which may influence ozone formation in the Region.*

From data provided by the U. S. Bureau of Census, and from a survey conducted by the National Paint and Coatings Association, Pacific Environmental Services, Inc. has estimated an average per capita consumption rate of 1.02 gallons of solvent-based paint, and 1.239 gallons of water-based paint per person per year in Wisconsin.[24] Thus, with an estimated regional population of about 1.778 million persons in 1977, approximately 181,350 gallons of solvent-based paint and 2.203 million gallons of water-based paint were consumed in southeastern Wisconsin during the year. The hydrocarbon emissions resulting from this trade paint consumption level in the Region—assuming that all of the solvent contained in the paint evaporates to the atmosphere as it dries—would consequently be on the order of 3,900 tons during 1977.

Miscellaneous Solvent Use: Miscellaneous solvent use includes those types of organic solvents that are essentially associated with such products as shoe polish, nail polish, hair spray, and numerous other household items. This source category is intended to account for the differences between national solvent production data and the lower levels of solvent use that are specifically accounted for in most local air pollutant emission inventories. Due to the widespread use of solvents in many diverse applications, it is not possible to accurately identify the amount of solvent consumed in each end use category. However, based on estimates provided by the U. S. Environmental Protection Agency, the Wisconsin Department of Natural Resources has determined that a best estimate of miscellaneous solvent use is about nine pounds per person per year. Under the assumption that all of the solvent is released into the ambient air, the Department multiplied this nine pounds annual per capita solvent use rate by the population estimates for each county in southeastern Wisconsin in 1977, and estimated that approximately 8,000 tons of hydrocarbon emissions were released as a result of miscellaneous solvent use in the Region during 1977.

Automobile Refinishing: From data provided by the Wisconsin Automobile Collision Technician's Association, the Wisconsin Department of Natural Resources determined that there are approximately 1,750 automobile body repair shops in the State of Wisconsin. The Department, through a telephone survey, also determined that, on the average, each automobile body repair shop uses about 175 gallons of paint per year. As with architectural coating, the solvent content of the paint was assumed to be about seven pounds per gallon. Based on these assumptions, the Department estimated that 1,072 tons of hydrocarbon emissions from automobile refinishing operations were released throughout the entire State during 1977. These hydrocarbon emissions were apportioned to each county in the Region on the basis of the county's population to the state population. In southeastern Wisconsin in 1977, the Department has estimated that about 425 tons of hydrocarbons were emitted from automobile refinishing.

Cutback Asphalt: Cutback asphalt is a commonly used asphalt cement that has been diluted, or "cutback," with organic solvents to facilitate handling. This type of asphalt is most often used for paving roadways. After the cutback asphalt is applied to the road, much of the added solvent evaporates to the atmosphere. There are three basic types of cutback asphalt used in street and highway improvement—slow cure, medium cure, and rapid cure—which are defined by the reactivity of the solvent base used for dilution—heavy distillate oil, kerosene, and light distillate oil, respectively. Depending on the type of solvent used for dilution, the hydrocarbon emission rate ranges from 156 pounds per ton of asphalt to 418 pounds per ton of asphalt.

From data provided by the U. S. Department of the Interior, Bureau of Mines, Pacific Environmental Services, Inc. determined that 83,000 tons of slow cure cutback asphalt, 65,000 tons of medium cure cutback asphalt, and 35,000 tons of rapid cure cutback asphalt were used in the State of Wisconsin during 1976—the latest year for which data were available. Based on these consumption data, Booz, Allen and Hamilton, Inc. estimated that 27,200 tons of hydrocarbon emissions were released to the atmosphere in the State of Wisconsin as a result of the use of cutback asphalt. This statewide emission total—which was assumed to be representative of the emissions from cutback asphalt use in 1977—was apportioned among individual counties in the Southeastern Wisconsin Region on the basis of the ratio of the 1977 county population to the total state population in that year. The hydrocarbon emissions resulting from the use of cutback asphalt in the Region during 1977 were estimated to total 10,530 tons.

Construction Equipment: Construction equipment includes such vehicles as tracklaying tractors, motor graders, wheel loaders, rollers, and scrapers that are used in road-building or structure-building activities. The latest inventory of heavy construction equipment is a national estimate provided by the U. S. Environmental Protection Agency for the year 1973. As the EPA has noted, however, the amount of heavy construction equipment has not increased significantly over the past 10 to 15 years, but rather has shown variations about a typical value. The national estimate of 1,181,400 units of heavy construction equipment may, therefore, be considered representative of the construction equipment inventory for 1977.

Pacific Environmental Services, Inc. (PES) apportioned a fraction of this national heavy construction equipment inventory to the State of Wisconsin based on the ratio of employees in the contract construction industry in the State to the total number of contract construction employees in the nation. Similarly, statewide heavy construction equipment estimates were apportioned among individual counties in southeastern Wisconsin on the basis of the number of contract construction employees in each county to the total state employment

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[24] *For more information, see Pacific Environmental Services, Inc., Forty-Seven County Hydrocarbon Area Source Emissions Inventory, February 1978.*

in contract construction. Based on this apportionment, and on a composite hydrocarbon emission factor of about 230 pounds per unit per year, PES estimated that 400 tons of hydrocarbons were emitted from the operation of heavy construction equipment in the Southeastern Wisconsin Region during 1977.

Industrial Equipment: Industrial equipment is comprised of such machinery as forklifts, portable generators, pumps, small tractors and wheel loaders, and any other fuel-burning mobile equipment that may be used at an industrial plant. The Southwest Research Institute collated a national inventory of such industrial equipment by fuel type—light-duty gasoline, heavy-duty gasoline, and heavy-duty diesel—for the year 1974. This inventory was updated to the year 1975 by PES on the basis of the change in industrial activity as indicated by the change in mining, wholesale trade, and manufacturing employment levels. PES subsequently apportioned the estimated national population of industrial equipment to individual counties on the basis of the ratio of the county employment in these three categories to the corresponding total employment in the country. A composite emission factor for each fuel type—developed from test results on typical engines used in each fuel type category—was used to calculate the hydrocarbon emissions from the estimated county population of industrial equipment. Assuming that the industrial equipment stock within the Region did not change significantly between 1975 and 1977, the hydrocarbon emissions in the Region from this source category during 1977 were estimated to be 1,150 tons.

Off-Highway Motorcycles: Based on data provided by the Motorcycle Industry Council, Inc., Pacific Environmental Services, Inc. estimated the number of motorcycles used for off-road riding in Wisconsin during 1975. The statewide total of off-highway motorcycles was allocated among counties on the basis of the ratio of the county population to the total state population. A composite emission factor developed under assumptions concerning the type of engine—2-stroke cycle or 4-stroke cycle—engine size, fuel tank volume, and length of the riding season was used to estimate the total emissions from the operation of off-highway motorcycles in the Region during 1977. Assuming that the use of off-highway motorcycles in the Region did not significantly change between 1975 and 1977, the total hydrocarbon emissions from this source category totaled 555 tons in 1977.

Area Source Emissions Inventory—1977 Summary: Table 228 presents the total regional area source emissions inventory for 1977 disaggregated by county and by season. As shown in the table, particulate matter emissions from area sources in the Region totaled 18,642 tons during 1977, an increase of 6,633 tons, or 55 percent, over the 1973 emission level of about 12,009 tons. This increase is due almost entirely to the addition of the industrial fugitive dust emission category. About 13,904 tons, or over 74 percent, of the total particulate matter area source emissions in 1977 are attributable to only two source categories: industrial fugitive dust—about 8,056 tons, or 43 percent—and agricultural tilling operations—about 5,848 tons, or 31 percent. Of the remaining 18 area sources of particulate matter emissions, none accounted for more than 5 percent of the total area source inventory for this pollutant species. It is significant to note that Waukesha County, which has shown substantial industrial development while maintaining an overall mixed rural-urban character, exhibits the largest county total of particulate matter emissions from area sources, accounting for 6,663 tons, or nearly 36 percent, of the total 1977 inventory. For all other pollutant species Milwaukee County is indicated as the predominant location of area source emissions.

Table 228

COUNTY SUMMARY OF TOTAL AREA SOURCE EMISSIONS BY SEASON: 1977

County	Season	Emissions (tons)				
		Particulate Matter	Sulfur Dioxide	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
Kenosha	Winter	113	483	572	502	545
	Spring	731	222	1,194	517	920
	Summer	91	86	3,103	287	1,414
	Fall	143	205	696	357	859
	Annual	1,078	996	5,565	1,663	3,738
Milwaukee	Winter	1,223	2,855	3,834	3,497	4,138
	Spring	1,264	1,218	4,532	2,165	6,588
	Summer	1,134	483	10,357	1,527	8,683
	Fall	1,147	1,197	3,761	2,119	6,271
	Annual	4,768	5,753	22,484	9,308	25,680
Ozaukee	Winter	56	262	298	259	302
	Spring	604	132	796	386	519
	Summer	74	58	2,065	204	745
	Fall	114	120	393	243	473
	Annual	848	572	3,552	1,092	2,039
Racine	Winter	285	688	753	690	745
	Spring	1,063	320	1,522	717	1,249
	Summer	260	129	4,400	387	1,994
	Fall	324	297	995	481	1,198
	Annual	1,932	1,434	7,670	2,275	5,186
Walworth	Winter	54	262	424	306	324
	Spring	1,543	143	1,694	613	671
	Summer	132	52	5,048	278	1,418
	Fall	217	117	887	306	610
	Annual	1,946	574	8,053	1,503	3,023
Washington	Winter	82	387	552	379	390
	Spring	1,018	205	1,540	691	695
	Summer	121	84	4,673	332	1,335
	Fall	186	179	930	398	665
	Annual	1,407	855	7,695	1,800	3,085
Waukesha	Winter	1,508	1,021	1,016	868	1,159
	Spring	2,104	439	2,141	812	1,987
	Summer	1,505	155	10,205	428	4,398
	Fall	1,546	412	2,075	576	2,097
	Annual	6,663	2,027	15,437	2,684	9,641
Region	Winter	3,321	5,958	7,449	6,501	7,603
	Spring	8,327	2,679	13,419	5,901	12,629
	Summer	3,317	1,047	39,851	3,443	19,987
	Fall	3,677	2,527	9,737	4,480	12,173
	Annual	18,642	12,211	70,456	20,325	52,392

Source: SEWRPC.

Table 228 indicates that sulfur dioxide emissions from area sources in the Region totaled 12,211 tons in 1977, a decrease of 4,303 tons, or about 26 percent, from the 1973 emission level of 16,514 tons. As in the 1973 area source inventory, commercial-institutional and residential fuel use were the largest area sources of sulfur dioxide emissions. These two categories accounted for 10,293 tons, or 84 percent, of the total area source sulfur dioxide emissions in the Region during 1977. The lower amount of coal used in these two source categories is the main reason for the overall reduction in sulfur dioxide emissions from area sources between 1973 and 1977.

Carbon monoxide emissions from area sources in the Region during 1977, as shown in Table 228, totaled 70,456 tons. This represents an increase of 2,162 tons, or slightly more than 3 percent, over the 1973 emission level of 68,294 tons. Most of this increase may be attributed to the increase in aircraft operations in the Region, which produced 8,772 tons of carbon monoxide emissions in 1977, an increase of about 2,340 tons over the corresponding 1973 emission level of 6,432 tons.

Nitrogen oxide emissions from area sources in the Region during 1977 totaled 20,325 tons. This represents a slight decrease of 287 tons, or about 1 percent, from the 1973 emission level of 20,612 tons. This net decrease is a result of a large decrease in nitrogen oxide emissions from commercial-institutional fuel use—from about 4,695 tons in 1973 to about 2,849 tons in 1977, a reduction of about 1,846 tons. This decrease was offset, however, by an increase in nitrogen oxide emissions from residential fuel use—from 3,497 tons in 1973 to 4,906 tons in 1977, an increase of 1,409 tons.

The 1977 regional hydrocarbon emissions from area sources totaled 52,395 tons, or more than 97 percent over the 1973 emission level of 26,479 tons. Most of this increase is due to the addition of the seven hydrocarbon emission sources as estimated by Pacific Environmental Services, Inc. and Booz, Allen and Hamilton, Inc. The seven additional sources jointly accounted for 24,991 tons of hydrocarbon emissions in the 1977 regional area source emissions inventory.

Volatile Organic Compound Emissions

Although an ambient air quality standard for hydrocarbons was established as a guideline for attaining and maintaining the ozone standard, not all of the numerous hydrocarbon compounds emitted into the atmosphere are equally reactive and, consequently, not all hydrocarbon compounds promote the formation of oxidants. Some hydrocarbon compounds, in fact, react so slowly in the atmosphere that they may be considered chemically inert. Alternatively, there are hydrocarbon compounds that are extremely reactive in the presence of sunlight, and it is this group of hydrocarbons—collectively termed volatile organic compounds—that is primarily responsible for ozone formation in the lower atmosphere. It is specifically the volatile organic compound emissions, therefore, that must be controlled in order to attain and maintain the ozone standard in the Region.

Table 229 lists the percentage of volatile organic compounds contained in the total hydrocarbon mixture emitted by selected air pollution sources. As shown in the table, volatile organic compounds constitute from a low of 45 percent of the total hydrocarbon emissions from the combustion of natural gas to a high of 100 percent of the total hydrocarbon emissions from agricultural equipment and dry cleaning operations. Table 230 provides the volatile organic compound emissions inventory for the Region for 1977. The emission totals are based on the relative proportion of reactive compounds in the total hydrocarbon emission mixture for each source category.

The estimated 118,330 tons of volatile organic compounds emitted in the Region during 1977 represent about 89 percent of the 132,427 tons of hydrocarbons emitted during that year. Of the 118,330 tons of volatile organic compound emissions, 63,267 tons, or more than 53 percent, were produced by stationary sources—primarily industrial processes. Mobile sources, principally vehicular traffic on the regional street and highway system, accounted for 55,063 tons, or about 46 percent, of the 1977 volatile organic compound emissions inventory. It is interesting to note that the automobile alone accounts for about 30,500 tons, or more than 25 percent, of the total 1977 volatile organic compound emissions inventory.

Table 229

PERCENT OF VOLATILE ORGANIC COMPOUNDS CONTAINED IN TOTAL HYDROCARBON EMISSIONS FROM SELECTED AIR POLLUTION SOURCES

Source Category	Volatile Organic Compound Emissions (percent)
Agricultural Equipment	100
Aircraft	
Piston	88
Jet	97
Dry Cleaning (petroleum base)	100
Forest Wildfires	62
Fuel Combustion	
Natural Gas	45
Fuel Oil	89
Coal	85
Wood	62
Highway Vehicles	
Light-Duty Gasoline Vehicles	88
Light-Duty Gasoline Trucks	88
Heavy-Duty Gasoline Trucks	93
Heavy-Duty Diesel Trucks	98
Mass Transit Vehicles	98
Incineration	62
Power Boats	88
Railroad Engines	98
Snowmobiles	88
Commercial Vessels	90

Source: U. S. Environmental Protection Agency and Wisconsin Department of Natural Resources.

Table 230

QUANTITY OF VOLATILE ORGANIC COMPOUND EMISSIONS IN THE REGION: 1977

Source	County Emissions (tons)							
	Kenosha	Milwaukee	Ozaukee	Racine	Walworth	Washington	Waukesha	Region
Stationary Sources								
Storage, Transportation, and Marketing of Petroleum Products								
Gasoline and Crude Oil Storage	--	601	74	--	--	--	--	675
Bulk Gasoline Terminals	--	2,181	125	--	--	--	--	2,306
Gasoline Bulk Plants	58	106	46	119	143	156	141	769
Service Station Loading	246	1,457	143	303	163	181	561	3,054
Underground Service Station Tank Breathing	26	157	15	33	17	20	60	328
Service Station Unloading	256	1,520	149	316	170	189	586	3,186
Subtotal	586	6,022	552	771	493	546	1,348	10,318
Industrial Processes								
Paint Manufacturing	--	637	--	--	--	--	--	637
Industrial Surface Coating								
Automobiles	3,502	2,029	--	--	--	--	--	5,531
Cans	--	4,017	--	17	--	--	259	4,293
Metal Coils	--	26	--	--	--	--	--	26
Paper	--	2,005	--	--	--	--	--	2,005
Fabric	--	--	--	321	--	--	--	321
Wood Furniture	--	8	--	--	--	--	--	8
Miscellaneous Metal Products	--	2,636	204	367	266	415	179	4,067
Miscellaneous Surface Coating	--	360	--	--	--	--	--	360
Subtotal	3,502	11,718	204	705	266	415	438	17,248
Nonindustrial Surface Coating								
Architectural Coatings	279	2,179	150	385	151	178	589	3,911
Auto Refinishing	30	234	16	41	16	19	63	419
Subtotal	309	2,413	166	426	167	197	652	4,330
Solvent Use								
Degreasing	291	5,719	363	821	231	293	715	8,433
Dry Cleaning	171	1,367	88	241	91	103	355	2,416
Graphic Arts	--	47	--	--	--	--	155	202
Cutback Asphalt	747	5,908	392	1,055	401	461	1,588	10,552
Miscellaneous Solvent Use	565	4,390	308	802	310	365	1,253	7,993
Subtotal	1,774	17,431	1,151	2,919	1,033	1,222	4,066	29,596
Miscellaneous Stationary Sources								
Fuel Combustion	84	987	127	121	33	46	146	1,544
Solid Waste Disposal (incineration)	7	83	5	13	3	5	23	139
Forest Fires	22	--	5	10	41	4	10	92
Subtotal	113	1,070	137	144	77	55	179	1,775
Stationary Sources Subtotal	6,284	38,654	2,210	4,965	2,036	2,435	6,683	63,267
Mobile Sources								
Highway Vehicles								
Light-Duty Automobiles	2,362	16,064	1,294	2,843	1,372	1,542	5,045	30,522
Light-Duty Trucks	272	1,500	120	335	223	267	708	3,425
Heavy-Duty Gasoline Trucks	414	4,378	253	597	435	387	1,601	8,065
Heavy-Duty Diesel Trucks	81	153	53	63	60	49	82	541
Mass Transit Buses	5	100	--	6	--	--	1	112
Subtotal	3,134	22,195	1,720	3,844	2,090	2,245	7,437	42,665
Off-Highway Vehicles								
Agricultural Equipment	145	34	155	204	307	315	234	1,394
General Utility Engines	76	433	36	101	46	43	141	876
Snowmobiles	19	8	11	27	17	24	46	152
Construction Equipment	23	183	17	31	11	16	95	376
Industrial Equipment	35	792	33	109	23	42	114	1,148
Off-Highway Motorcycles	75	147	27	46	66	30	102	493
Subtotal	373	1,597	279	518	470	470	732	4,439
Railroad Lines	40	84	18	53	10	43	53	301
Railroad Yards	--	385	--	--	--	--	10	395
Aircraft	10	1,034	3	15	7	16	20	1,105
Commercial Vessels	1	18	4	--	--	--	--	23
Power Boats	427	837	187	704	823	695	2,462	6,135
Mobile Sources Subtotal	3,985	26,150	2,211	5,134	3,400	3,469	10,714	55,063
Total	10,269	64,804	4,421	10,099	5,436	5,904	17,397	118,330

Source: Pacific Environmental Services, Inc., Booz, Allen and Hamilton, Inc., Wisconsin Department of Natural Resources, and SEWRPC.

Total Air Pollutant Emissions in the Region: 1977 Summary

Table 231 provides a summary by county and by season of the total estimated air pollutant emissions from all point, line, and area sources in the Region during 1977. As may be seen by comparing Table 231 with Table 189, particulate matter emissions decreased by 4,277 tons, or by about 12 percent, between 1973 and 1977—from 34,779 tons in 1973 to 30,502 tons in 1977. This decrease may be attributed to a decrease of about 10,678 tons in particulate matter emissions from point sources, and a decrease of about 236 tons in particulate matter from line sources, which were partially offset by an increase in particulate matter emissions from area sources on the order of 6,633 tons.

Sulfur dioxide emissions in the Region increased by about 1,600 tons, or less than 1 percent, between 1973 and 1977—from 209,273 tons in 1973 to 210,902 tons in 1977. This increase may be attributed to an increase of 5,668 tons in sulfur dioxide emissions from point sources plus an increase of 264 tons in emissions from line sources, which were offset by a decrease of 4,303 tons of sulfur dioxide emissions from area sources.

Carbon monoxide emissions in the Region demonstrated an overall decrease of about 15,000 tons, or more than 2 percent, between 1973 and 1977—from 613,843 tons in 1973 to 598,817 tons in 1977. Most of this net decrease is attributable to a reduction of 12,148 tons in carbon monoxide emissions from point sources. A reduction of 5,043 tons in carbon monoxide emissions from line sources also contributed to the overall decrease estimated for this pollutant species between 1973 and 1977. The reduction in carbon monoxide emissions from point and line sources, however, was partially offset by an increase in emissions from area sources of 2,162 tons.

Like carbon monoxide emissions, nitrogen oxide emissions in the Region decreased by about 2 percent between 1973 and 1977. In 1977 approximately 114,289 tons of nitrogen oxide emissions were released from point, line, and area sources in the Region—about 2,500 tons less than the 116,815 tons of this pollutant species generated during 1973. A reduction of 2,358 tons in nitrogen oxide emissions from point sources, accompanied by a 287-ton reduction in nitrogen oxide emissions from area sources, accounts for this net decrease between 1973 and 1977. The reduction was slightly offset by a 119-ton increase in emissions from line sources.

The regional hydrocarbon emissions inventory increased by 26,560 tons, or about 25 percent, between 1973 and 1977—from 105,867 tons in 1973 to 132,427 tons in 1977. This increase is principally due to the identification of several additional point and area source emission categories that were not included in the 1973 regional hydrocarbon emissions inventory. The significant change between the 1973 and 1977 hydrocarbon emission inventories, therefore, is more a result of the inventory procedures than of regional growth and development patterns.

Table 231

SUMMARY OF TOTAL EMISSIONS FOR THE SOUTHEASTERN WISCONSIN REGION BY COUNTY BY SEASON: 1977

County	Season	Emissions (tons)				
		Particulate Matter	Sulfur Dioxide	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
Kenosha	Winter	217	641	11,967	1,666	2,498
	Spring	835	380	10,018	1,610	2,733
	Summer	195	244	11,729	1,332	3,215
	Fall	247	363	9,577	1,438	2,676
	Annual	1,494	1,628	43,291	6,046	11,122
Milwaukee	Winter	3,261	42,516	87,225	18,971	16,639
	Spring	3,302	40,879	70,608	17,238	18,145
	Summer	3,172	40,145	75,205	16,318	20,167
	Fall	3,185	40,859	70,222	17,124	17,851
	Annual	12,920	164,399	303,260	69,651	72,802
Ozaukee	Winter	246	9,791	6,620	2,530	1,078
	Spring	794	9,661	5,729	2,616	1,219
	Summer	264	9,587	6,885	2,405	1,440
	Fall	304	9,649	5,357	2,465	1,175
	Annual	1,608	38,688	24,591	10,016	4,912
Racine	Winter	463	828	14,787	2,017	2,406
	Spring	1,241	460	12,457	1,962	2,740
	Summer	438	270	15,098	1,573	3,472
	Fall	502	438	12,000	1,711	2,694
	Annual	2,644	1,996	54,342	7,263	11,312
Walworth	Winter	152	305	7,967	1,122	1,137
	Spring	1,641	186	7,694	1,383	1,399
	Summer	230	95	10,923	1,015	2,139
	Fall	315	161	6,922	1,068	1,341
	Annual	2,338	747	33,506	4,588	6,016
Washington	Winter	153	420	8,599	1,178	1,358
	Spring	1,089	238	7,850	1,439	1,567
	Summer	192	117	10,843	1,044	2,198
	Fall	257	212	7,279	1,137	1,536
	Annual	1,691	987	34,571	4,798	6,659
Waukesha	Winter	1,794	1,128	27,721	3,336	3,882
	Spring	2,390	546	23,287	3,117	4,406
	Summer	1,791	263	30,904	2,619	6,792
	Fall	1,832	520	23,344	2,855	4,524
	Annual	7,807	2,457	105,256	11,927	19,604
Region	Winter	6,286	55,629	164,886	30,820	28,998
	Spring	11,292	52,350	137,643	29,365	32,209
	Summer	6,282	50,721	161,587	26,306	39,423
	Fall	6,642	52,202	134,701	27,798	31,797
	Annual	30,502	210,902	598,817	114,289	132,427

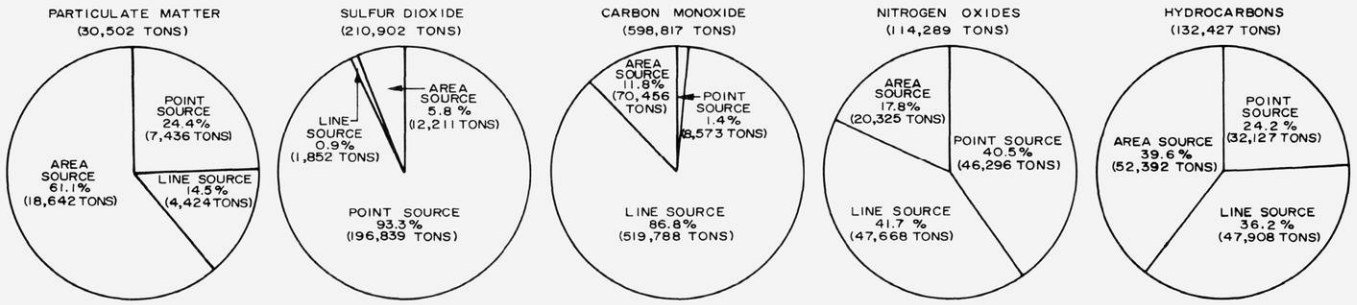
Source: SEWRPC.

The 1977 regional air pollutant emissions inventory also included an estimate of that fraction of the total hydrocarbon emissions that promotes the formation of ozone in the lower atmosphere. Those reactive hydrocarbons—termed volatile organic compounds—were estimated to constitute 118,330 tons, or about 89 percent, of the 132,427 tons of total hydrocarbons emitted in the Region during 1977.

Figure 57 presents a schematic representation of the relative contribution of point, line, and area sources to

Figure 57

RELATIVE CONTRIBUTION FROM POINT, LINE, AND AREA SOURCES TO TOTAL POLLUTANT BURDEN: 1977



Source: Wisconsin Department of Natural Resources and SEWRPC.

the total regional emissions burden for each pollutant species. As may be seen in the figure, area sources accounted for more than 61 percent of the total particulate matter emissions in the Region in 1977. In 1973 area sources accounted for less than 35 percent of the emissions for this pollutant species (see Figure 56). The dominance of area sources in 1977 is a result of the decrease in particulate matter emissions from point sources and the addition of industrial fugitive dust emissions to the 1977 area source inventory. As in 1973, point sources were the predominant contributor of sulfur dioxide emissions in 1977, accounting for over 93 percent of the total regional burden for this pollutant species. Area sources, with less than 6 percent of the total sulfur dioxide emissions, and line sources, with less than 1 percent of the total sulfur dioxide emissions, are relatively insignificant contributors to the total regional burden.

The relative contribution of point, line, and area sources to the total carbon monoxide emissions burden remains essentially constant between 1973 and 1977. Line sources constitute about 87 percent of the carbon monoxide emissions in 1977 as compared with about 86 percent in 1973. Similarly, the relative contribution of point, line, and area sources to the total nitrogen oxide emissions burden in the Region in 1977 is essentially the same as that in 1973. Point, line, and area sources contributed about 41 percent, 42 percent, and 18 percent, respectively, to the 1977 regional nitrogen oxide emissions burden as compared to about 42 percent, 41 percent, and 18 percent, respectively, in 1973.

With the inclusion of additional hydrocarbon emission sources in the 1977 regional inventory, the relative contribution from point, area, and line sources to the emissions burden for this pollutant species changed significantly from the 1973 distribution. Whereas line sources contributed about 52 percent of the total regional hydrocarbon emissions in 1973, this relative proportion had decreased to about 36 percent in 1977. The largest increase in the relative contribution of hydrocarbon emissions occurred in the area source category. Emissions from area sources rose from about 25 percent of the total emissions burden in 1973 to 40 percent of the total emissions burden in 1977.

SUMMARY

This chapter has set forth the procedures followed in the collation of the air pollutant emissions inventory for the Southeastern Wisconsin Region, and has detailed the results and findings of this inventory process for the years 1973 and 1977. It has been estimated that more than one million tons of air contaminants—particulate matter, sulfur dioxide, carbon monoxide, nitrogen oxides, and hydrocarbons—were released from local sources into the atmosphere over the Region in both 1973 and 1977. These air pollutant emissions, supplemented by those pollutants that are transported into the Region from extraregional sources, are the primary determinant of ambient air quality in southeastern Wisconsin. The impact that local emission sources have on ambient air quality in the Region may be described through use of air quality simulation modeling techniques, the results of which are presented in Chapter XI of this report.

Chapter VIII

AIR POLLUTION METEOROLOGY OF SOUTHEASTERN WISCONSIN

INTRODUCTION

A good understanding of the air pollution problem of an area is facilitated by consideration of three aspects of the problem: 1) the specific pollutant species involved and the potential effects of these pollutants on receptors—human, plant, and animal forms of life—and on artifacts; 2) the amount and spatial distribution of pollutant emissions from all sources; and 3) the mechanisms which govern the transport and diffusion of pollutants from their sources to the receptor. The first two phases have been discussed in Chapters VI and VII of this report, respectively. This chapter discusses the physical processes in the atmosphere that are responsible for the dispersion of the contaminants through the air and that thereby contribute to determining ambient air quality. Since diffusion of air pollutants occurs on a scale ranging from the localized dispersion of a single plume to the long-range transport of a pollutant-laden air mass over broad geographic areas, both the microscale and mesoscale diffusion characteristics of the atmosphere are discussed herein.

The ultimate disposition of a chemically inactive pollutant in the atmosphere is determined by the sum of all the physical forces acting upon it in both the horizontal and vertical directions. For most very small particles and all gases the primary force of dispersion is the wind. This chapter, therefore, examines the general wind field over the Region and the mechanisms by which it is established. A discussion of localized circulation patterns generated by the presence of terrain features such as valleys, urban centers, and large bodies of water is also presented in this chapter because of the potential which these patterns may have for aggravating air pollution problems.

EXISTING REGIONAL METEOROLOGICAL OBSERVATION NETWORK

Information concerning meteorological conditions in the Region relative to air pollution dispersion is limited. One first order National Westher Service observation station recording detailed meteorological data on a continuous basis is located within the Southeastern Wisconsin Region—General Mitchell Field in Milwaukee County. This first order station is situated approximately three miles west of Lake Michigan. The effects that such a large body of water may exert on certain atmospheric variables, such as temperature and humidity, and the unique wind field patterns, such as the so called lake breeze, which may be generated due to temperature differentials between land and adjacent water surfaces may be reflected in the meteorological data recorded at General Mitchell Field. Since the influence of Lake Michigan diminishes in an inland direction, however, the meteorological observations from General Mitchell Field may not be considered totally representative of prevailing atmospheric conditions throughout the entire Region.

In addition to this first order observation station, cooperative volunteers record daily maximum and minimum temperatures and precipitation amounts at 15 locations within the Region, and precipitation amounts only at two locations within the Region, as shown on Map 50. Only five of these 17 partial record stations are located along the approximately 81 miles of Lake Michigan shoreline within the Region.

Although data on the horizontal variations in atmospheric conditions within the Region are limited, the lack of data on vertical variations in atmospheric conditions within the Region probably constitutes the most serious deficiency of the existing meteorological data for the Region, particularly with respect to regional air quality maintenance planning. In some instances, certain upper air conditions may be indirectly assessed from surface level data using procedures which rely on the principle that certain meteorological conditions and events are interdependent and interrelated. Regular monitoring of the prevailing meteorological conditions through the full height of the lower atmosphere, however, would provide a more satisfactory depiction of the pollutant diffusion capabilities of the atmosphere over the Region and would enable more accurate forecasts of localized pollutant concentrations to be made under various meteorological regimes.

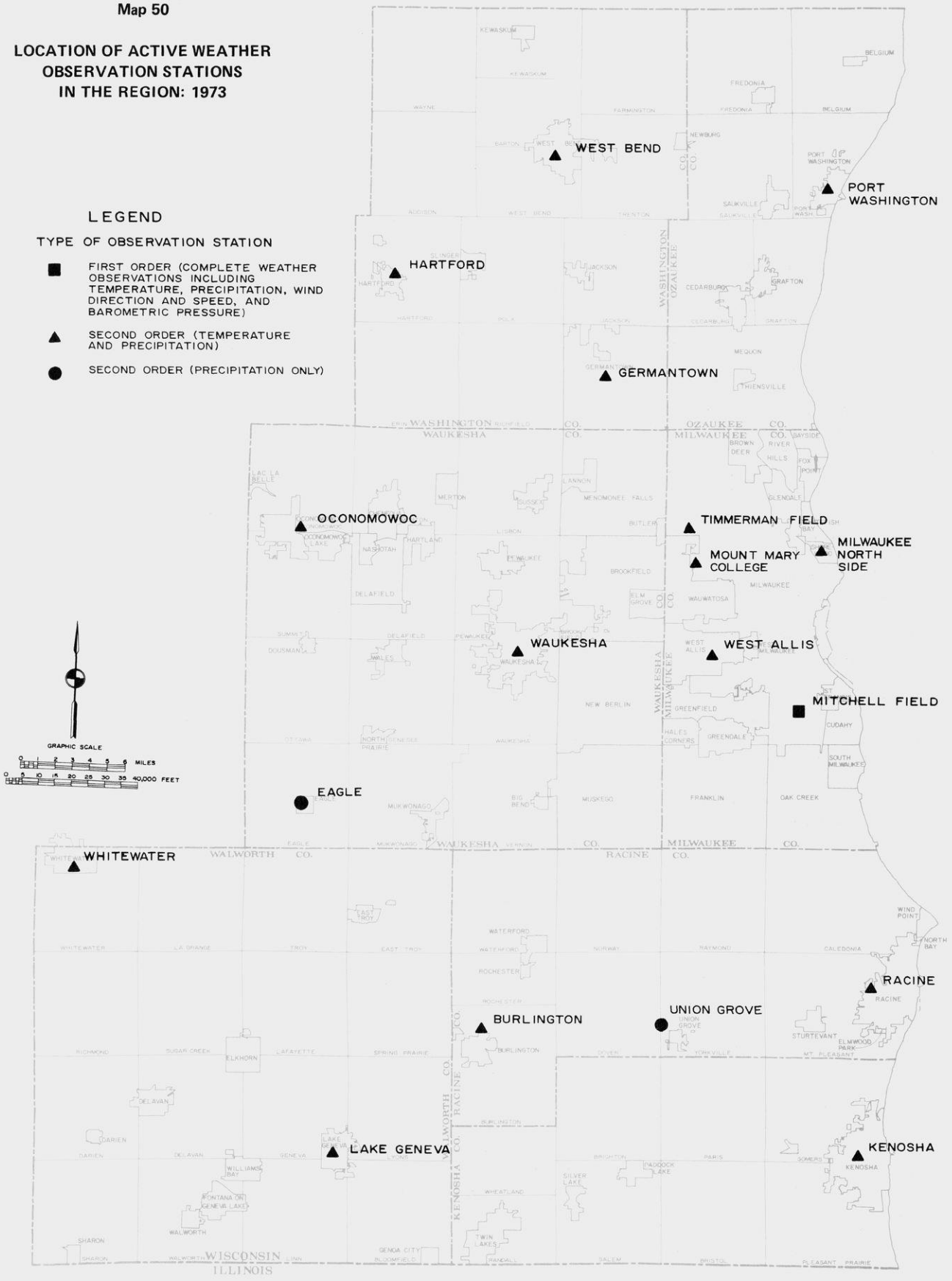
METEOROLOGIC FUNDAMENTALS OF AIR POLLUTION TRANSPORT AND DIFFUSION

The atmosphere is a mixture of gases. The relative proportion of these gases and the remaining atmospheric constituents by weight and volume for a dry parcel of "clean" air are presented in Table 232, along with an estimate of their residence time in the atmosphere.[1] In addition to this dry mixture of permanent and semi-

[1] *It is significant to note that the figures in Table 232 represent only estimates of the composition of unpolluted dry air. By the time scientists had the capability to identify and measure atmospheric components, air pollution had been proceeding for several thousands of years so that even in remote locations, such as at the poles, in deserts, on mountains, or at sea, pollutants had become a common constituent of the ambient air. It may only be assumed, therefore, that the level of pollution measured at such remote locations approaches the true background concentration and does not appreciably alter the estimate of the composition of the unpolluted atmosphere.*

Map 50

LOCATION OF ACTIVE WEATHER OBSERVATION STATIONS IN THE REGION: 1973



A network of meteorological stations, utilizing uniform observation and data collection techniques, provides information for compiling the climatological regime prevalent over the Region. Data collected at these stations are collated and published by the National Climatic Center, National Oceanic and Atmospheric Administration.

Source: National Weather Service and SEWRPC.

Table 232

COMPOSITION OF DRY AIR

Element	Volume (parts per million)	Micrograms per Meter^3	Percent of Total Volume	Calculated Residence Time
Nitrogen	780,900	8.95×10^8	78.1	Continuous
Oxygen	209,400	2.74×10^8	20.9	Continuous
Argon	9,300	1.52×10^7	0.9	Continuous
Carbon Dioxide	315	5.67×10^5	0.03	2 to 4 years
Neon	18	1.49×10^4	< 0.01	Continuous
Helium	5.2	8.50×10^2	< 0.01	2×10^6 years
Methane	1.0 - 1.2	$6.56\text{-}7.87 \times 10^2$	< 0.01	4 to 7 years
Krypton	1.0	3.43×10^3	< 0.01	Continuous
Nitrous Oxide	0.5	9.00×10^2	< 0.01	4 years
Hydrogen	0.5	4.13×10^2	< 0.01	Unknown
Xenon	0.08	4.29×10^2	< 0.01	Continuous
Other	ca. 0.02	--	< 0.01	--

Source: Adapted from A.C. Stern, et.al., Fundamentals of Air Pollution, Academic Press, New York, 1973, and J. Brockis, Environmental Chemistry, Plenum Press, New York, 1977.

permanent gases, the atmosphere contains spatially and temporally varying quantities of water and organic vapors as well as particles held in suspension.

The atmosphere has a total mass of about 5,600 trillion tons. Nearly 75 percent of the atmosphere by weight, and almost all of the water vapor and dust particles, is contained within the lowest seven miles in an atmospheric layer known as the troposphere.[2] There are several additional layers in the atmosphere which may be defined by their vertical temperature characteristics but, from the standpoint of air pollution, the most important is the troposphere since that is the layer into which essentially all air pollutants are directly emitted. It is also the layer in which nearly all the atmospheric phenomena that are collectively referred to as "weather" occur, and where most receptors are located.

The transport and diffusion of air pollutants is primarily determined by the meteorological conditions prevailing in the troposphere at the time and the location of their release to the atmosphere. The primary meteorological variables that influence the transport and diffusion of air pollutants include atmospheric stability, wind speed and wind direction, mechanical and thermal turbulence, and the height of the mixing layer. In the following sections, each of these factors is examined as to its effect on the dispersion of atmospheric contaminants.

[2] *The height of the troposphere varies both spatially and temporally. Under average conditions it extends from an altitude of about 5 miles at the poles to about 10 miles at the equator, but 7 miles is a good approximation for all latitudes.*

Atmospheric Stability

Atmospheric stability may be defined as the tendency of an air parcel to migrate through the atmosphere in a vertical direction. In terms of dispersion, atmospheric stability determines the degree to which a given quantity of an air pollutant will be mixed and diluted with relatively cleaner air as it moves up or down through the atmosphere from its point of origin.

The tendency of an air parcel to rise or fall is principally a function of its temperature relative to the ambient air. A parcel of air warmer than its immediate environs will be less dense than the surrounding air and will rise until the temperature, and consequently the density, have reached an equilibrium. In a similar manner, a parcel of air that is colder, and therefore more dense, than the surrounding air will sink until both the air parcel and its environs have equal temperatures and densities.

A notable characteristic of the troposphere is that, generally, temperatures through this layer decrease uniformly with increasing height. The rate of change of temperature over a unit distance is termed the lapse rate of temperature. The global average temperature lapse rate through the troposphere is about 3.6°F per 1,000 feet. The environmental lapse rate existing at any one location at any one time, however, is dependent on the prevailing meteorological conditions and must be related to the dry adiabatic lapse rate temperature in order to assess atmospheric stability conditions. The dry adiabatic lapse rate is the constant rate of temperature change which occurs as unsaturated air expands during ascent or contracts during descent in the atmosphere. This lapse rate of temperature is approximately 5.4°F per 1,000 foot change in altitude. An unsaturated, or dry, parcel of air which ascends 1,000 feet will expand and therefore

experience a temperature drop of 5.4°F per 1,000 feet.[3] Conversely, a dry parcel of air which descends 1,000 feet will compress and experience a rise in temperature of 5.4°F. Basically, if the environmental lapse rate is greater than the dry adiabatic lapse rate, an air parcel will have a tendency to rise if given impetus; but if the environmental lapse rate is lower than the dry adiabatic lapse rate, an air parcel will have a tendency to resist upward movement.

The effect of the temperature lapse rate on the dispersion capabilities of the atmosphere is illustrated in Figure 58. In each illustration in the figure, the diagram at the left indicates the existing atmospheric lapse rate—solid line—and the dry adiabatic lapse rate—dashed line. The diagram at the right represents the characteristic dispersion of a smoke plume from an elevated source under the prevailing stability conditions.

[3] *This temperature lapse rate is constant for a dry parcel of air. If the air parcel were saturated with water vapor, however, lifting it would initiate the condensation process, which releases heat energy and consequently retards the rate of cooling. The temperature lapse rate for a wet parcel of air, therefore, is not constant but varies in relation to the amount of condensation taking place, which, in turn, is a function of temperature and pressure.*

In 1961, Dr. F. Pasquill of the British Meteorological Office devised a methodology by which atmospheric stability could be classified indirectly on an hourly basis using readily available meteorological data. Stability near the ground is determined primarily by wind speed and net solar radiation. Net solar radiation is, in turn, a function of time of day, time of year, and latitude, as well as total cloud cover. In the system devised by Dr. Pasquill, net solar radiation is estimated by solar altitude and modified for existing conditions of total cloud cover and cloud ceiling height.

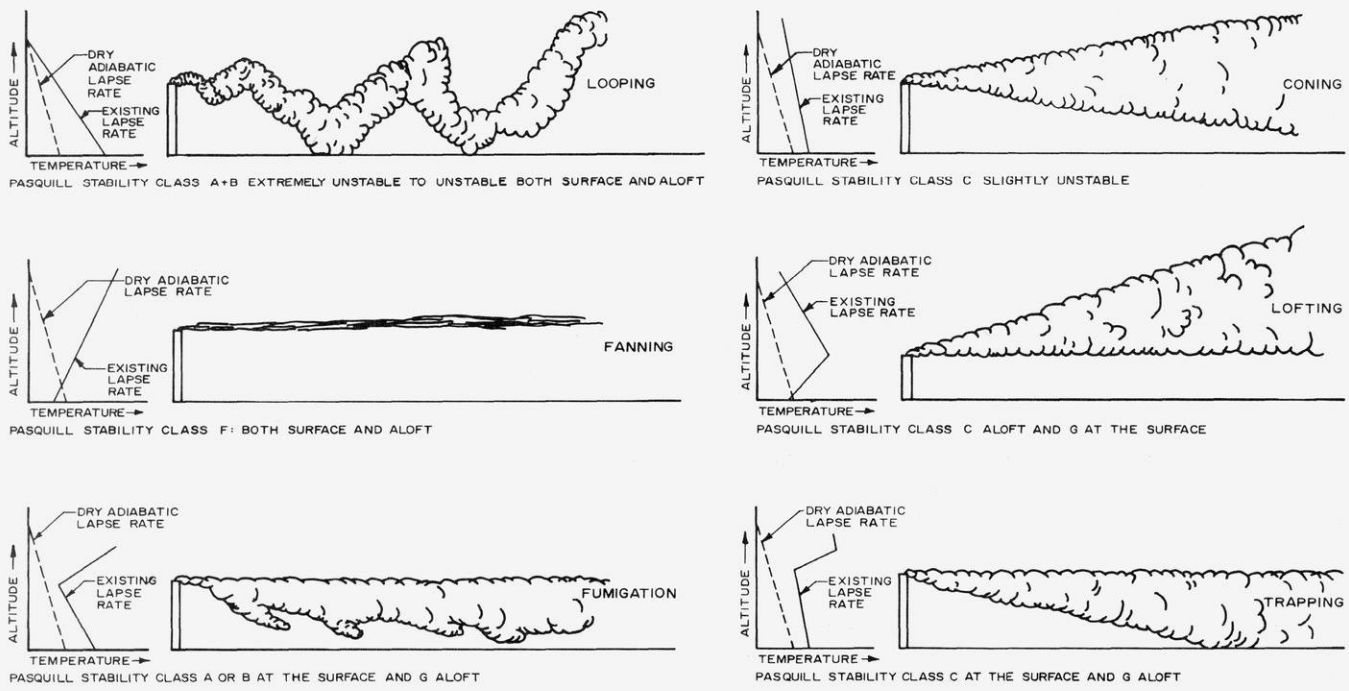
There are seven stability classes defined by the Pasquill system: A) extremely unstable, B) unstable, C) slightly unstable, D) neutral,[4] E) slightly stable, F) stable, and G) extremely stable. The step-by-step procedure for calculating the stability class is provided in Appendix C. As a general rule, however, instability occurs with high levels of incoming solar radiation and low wind speed, stability with high net radiative losses and light winds, and neutral conditions with cloudy skies or high wind speeds.

In Pasquill stability classes A and B, the existing atmospheric temperature lapse rate is much greater than the dry adiabatic lapse rate. An air parcel emitted to such

[4] *The neutral stability classification may be further defined as either neutral/day or neutral/night.*

Figure 58

THE EFFECTS OF VARYING TEMPERATURE LAPSE RATES ON PLUME BEHAVIOR



Source: U. S. Environmental Protection Agency and SEWRPC.

ambient conditions would follow the dry adiabatic temperature lapse rate and would at any point be warmer than the surrounding air. Since the air parcel is warmer it would tend to rise through the atmosphere, generating thermally induced eddy currents. The eddy currents developed in the unstable air may force portions of plume to the ground for short time intervals, but over extended periods would lead to good dispersion. This type of smoke plume behavior is termed looping. The unstable lapse rates associated with looping occur only with light winds and strong solar heating.

In Pasquill stability class C, the existing temperature lapse rate is slightly less than the dry adiabatic lapse rate but is not quite isothermal. Under this condition the atmosphere is only slightly unstable and consequently only a small amount of mixing occurs. The mixing which does occur as the plume moves away from the source produces a cone-shaped appearance, and hence the term coning is applied to this type of plume behavior. Coning is generally prevalent on cloudy or windy days or nights.

In Pasquill stability class F, the existing lapse rate indicates that the ambient air temperature is steadily increasing from the ground upward through the atmosphere. Under such conditions, referred to as a ground level inversion, thc air is very stable and vertical motion is suppressed. There may be mixing in the horizontal plane providing some dispersion along that axis, but vertical mixing is essentially negligible. Pollutant concentrations in the plume are high due to the lack of mixing, but the pollutants do not impact on the ground. This type of plume behavior is termed fanning, and is generally produced during nights with clear skies and light winds.

The three types of plume behavior discussed above are products of an atmospheric temperature lapse rate which remains constant from the ground past the point of effluent discharge at the top of the stack. There are conditions, however, which lead to a reversal of the temperature lapse rate between the ground and the top of the stack. One such case is shown in Pasquill stability classes C aloft and G at surface where an initial ground level inversion reverts to a near dry adiabatic lapse rate below the point of discharge. Under this condition, the air near the ground is extremely stable while the air above the inversion is at least slightly unstable. Below the inversion there is no vertical mixing which prohibits the air pollutants from impacting the surface. Vertical mixing, however, is occurring in the unstable air above the inversion, causing the pollutants to be carried higher in the atmosphere. This type of plume behavior is known as lofting and frequently occurs near sunset on a clear evening in open country. Lofting is generally only a transitional situation which is replaced by fanning as the inversion layer deepens.

When an inversion aloft overlays a very unstable layer of air at the surface, the smoke plume behaves as shown in Pasquill stability classes A or B at the surface and G aloft. This condition is termed fumigation and is characterized by the turbulent transport of pollutants to the ground along the full length of the plume. Fumigation is favored under clear skies and light winds and has a higher frequency of occurrence in summer because of increased solar heating. Fumigation may also be established as stable air from rural areas moves into an urbanized area during the early evening hours and is modified in the lowest layer by the heat generated within the city. The fumigation in this case persists until the city has lost enough heat so that the unstable lapse conditions at the surface cannot be maintained. Fumigation conditions are also associated with the transition from stable nocturnal lapse rates to more unstable day time lapse rates, and with the onset of the lake breeze effect as it moves inland.

Also characterized by an inversion aloft is the behavior of a smoke plume known as trapping. As shown in Pasquill stability class C at the surface and G aloft in Figure 58, trapping is similar to fumigation with the exception that in the trapping condition, pollutants are emitted below the base of the inversion and are contained beneath this level. Even if the diffusion is good underneath the inversion, as is the case with high winds, pollutant concentrations in the plume and at ground level will increase due to the lack of vertical mixing.

It is evident that atmospheric stability may be readily estimated if the vertical temperature profile in the lower troposphere is known. Obtaining such data, however, requires the use of expensive meteorological equipment. The National Weather Service does operate a nationwide network of 62 stations which routinely send radiosondes aloft twice daily to measure, among other meteorological elements, the temperature structure of the atmosphere. These stations are spaced roughly 250 miles apart: the closest to the Southeastern Wisconsin Region is at Green Bay, Wisconsin. Although the data obtained from such observations are useful in many areas of meteorology, their applicability to local air pollution studies are of limited value because of poor spatial and temporal resolution.

The absolute and relative frequency of occurrence of the seven Pasquill stability classes, as calculated from meteorological observations taken eight times per day at the National Weather Service office at General Mitchell Field in the City of Milwaukee from 1964 through 1973, are presented in Table 233. The table provides both the seasonal and annual distribution. It may be seen from this table that the occurrence of neutral atmospheric conditions predominates in all seasons—ranging from nearly 81 percent of the observations in winter, a period of peak cloud cover, to about 47 percent in summer. Unstable conditions occur most frequently in the summer months—about 25 percent of the time—and least frequently during the winter—about 3 percent of the time. Such seasonal variation in the occurrence of the different stability classes is indicative of the direct relationship between atmospheric instability and strong solar heating at the surface. Stable conditions occur more uniformly throughout the seasons, ranging from about 28 percent in summer to about 16 percent in winter. This relatively small seasonal range is due in part to the fact that conditions favorable to the formation of a stable atmosphere—that is, high radiative heat loss and low wind speeds—

Table 233

ABSOLUTE AND RELATIVE FREQUENCY OF OCCURRENCE OF PASQUILL STABILITY CLASSES BY SEASON—MILWAUKEE: 1964-1973

Stability Class	Winter		Spring		Summer		Fall		Annual	
	Absolute Number of Occurrences	Relative Frequency of Occurrence[a]	Absolute Number of Occurrences	Relative Frequency of Occurrence[a]	Absolute Number of Occurrences	Relative Frequency of Occurrence[a]	Absolute Number of Occurrences	Relative Frequency of Occurrence[a]	Absolute Number of Occurrences	Relative Frequency of Occurrence[a]
Extremely Unstable	--	--	8	0.001087	26	0.003533	1	0.000137	35	0.001199
Unstable	22	0.003056	202	0.027446	542	0.073641	99	0.013599	865	0.029624
Slightly Unstable	219	0.030421	702	0.095380	1,287	0.174864	447	0.061401	2,655	0.090928
Neutral	5,796	0.805112	4,887	0.663994	3,447	0.468342	4,771	0.655358	18,901	0.647316
Slightly Stable	725	0.100708	800	0.108696	914	0.124185	1,045	0.143544	3,484	0.119319
Stable	343	0.047646	543	0.073777	758	0.102989	640	0.087912	2,284	0.078222
Extremely Stable	94	0.013057	218	0.029620	386	0.052446	277	0.038049	975	0.033392
Total	7,199	1.000000	7,360	1.000000	7,360	1.000000	7,280	1.000000	29,199	1.000000

[a] *Relative frequency of occurrence is presented as a dimensionless number.*

Source: National Climatic Center and SEWRPC.

generally occur during the nighttime hours independent of seasonal variation. The winter low in the frequency of occurrence of stable atmospheric conditions may be attributed to the general increase in cloud cover, which limits the nocturnal radiative heat loss. Variability in the seasonal wind pattern also influences atmospheric stability and is discussed in the following section.

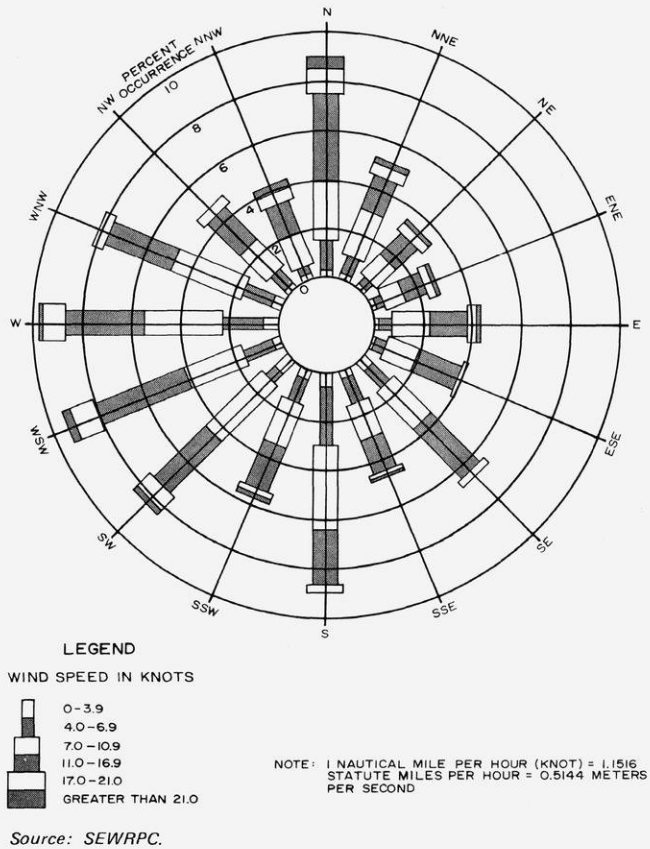
Wind Speed and Direction

The dispersion of a pollutant-laden parcel of air in the horizontal plane is primarily a function of wind speed and direction. The time it takes for a pollutant to travel from a source to a given receptor is directly related to the wind speed. Wind speed also determines the volume of air into which a pollutant will be discharged or, in other words, the degree to which the pollutant concentration is initially diluted. For example, if a continuous source is emitting a certain pollutant at a rate of 10 grams per second and the wind speed is one meter per second, then each unit volume—one cubic meter of air—that passes over the source will contain 10 grams of the pollutant. If, however, the emission rate remains constant but the wind speed increases to five meters per second, each unit volume of air passing over the source will contain only two grams of the pollutant. In general, the concentration of a pollutant near its source of emission is inversely proportional to the wind speed.

The distribution of wind speeds and directions over a long period at a particular site may be graphically depicted through use of a "wind rose," as shown in Figure 59. Figure 59 was derived by computing the relative frequency of occurrence of wind directions from 16 compass points, and of wind speeds in six class intervals, from data recorded every three hours during 1973 at the National Weather Service office at General Mitchell

Figure 59

WIND ROSE FOR GENERAL MITCHELL FIELD: 1973



Source: SEWRPC.

Field. In this figure, wind speed intervals are identified by the width and shading of a bar segment, with the length of the bar segment indicating the relative frequency of occurrence of such wind speeds from a given compass direction. The relative frequency of calm observations when the wind was not measurable has been distributed among the 16 directions in direct proportion to their relative frequency of occurrence.

As may be seen from Figure 59 and Table 234, the prevailing wind direction—that is, the direction having the highest frequency of occurrence—was from the west at General Mitchell Field during 1973. Out of a total of 2,900 observations, 278 observations, or about 9.8 percent with distributed calms, recorded the wind from due west. It may also be seen that the wind directions having a high westerly component, from southwest through west-northwest, cumulatively account for about 36 percent of all observations. Winds from due north and due south also occur with substantial frequency, accounting for 9.2 and 9.1 percent of the annual total, respectively.

A seasonal pattern of changes in the wind speed and direction distribution is evident in Table 234. In winter the predominant wind direction is west to west by northwest. The strongest winds, however, come out of the northern quadrant from north by northwest to east by northeast. In spring, the wind from the south-southwest through the north-northwest quadrant shows an increase in average speed but a large decrease in overall frequency of occurrence. The predominant winds are from the north to north by northeast, and demonstrate only a slight decrease in average speed over the winter season. In the summer there is a general decrease in average wind speeds from all directions, with south to west-by-southwest winds predominating. Southerly and westerly winds prevail in fall, with little change in average wind speeds from those in the summer.

The relationship between wind speed, wind direction, and atmospheric stability is indicated on the stability wind roses shown in Figures 60 through 62. These figures illustrate the frequency of occurrence of wind speed intervals and wind directions observed at General Mitchell Field in 1973 for unstable atmospheric conditions (Pasquill stability classes A, B, and C), neutral atmospheric conditions (Pasquill stability class D), and stable atmospheric conditions (Pasquill stability classes E, F, and G). Numerical data on the relative frequency of occurrence of these stability groups are presented in Table 235.

Figure 60 and Table 235 indicate that about 25 percent of the unstable atmospheric conditions are associated with winds from the west and west-by-southwest. For neutral stability conditions, Figure 61, winds from the north dominate slightly but winds in the southwest to west-by-northwest quadrant also contribute significantly. Winds from the due south figure predominantly in the occurrence of stable atmospheric conditions, Figure 62, accounting for about 18 percent of Pasquill stability classes E, F, and G, but winds from the west and west-by-northwest directions jointly account for about 23 percent of these classes. It may be concluded, therefore, that there is a slight predisposition for unstable conditions to occur more often with westerly winds, neutral conditions to occur more often with northerly winds, and stable conditions to occur more often with southerly winds. Also, westerly winds are generally associated with all maxima.

Table 234

ABSOLUTE AND RELATIVE FREQUENCY OF OCCURRENCE OF WIND DIRECTIONS WITH AVERAGE WIND SPEED—GENERAL MITCHELL FIELD: 1973

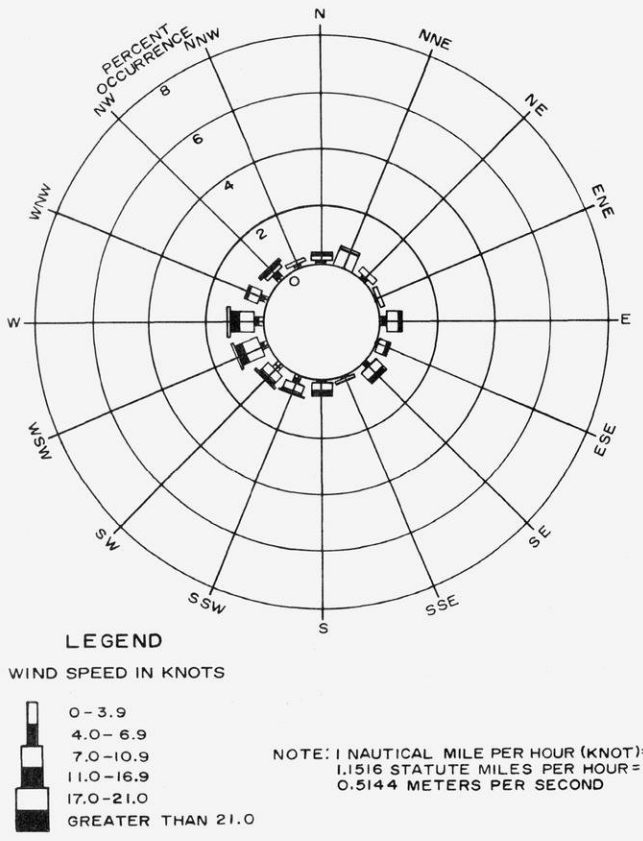
Wind Direction	Winter			Spring			Summer			Fall			Annual		
	Number of Observations	Relative Frequency (percent)	Average Wind Speed (knots)	Number of Observations	Relative Frequency (percent)	Average Wind Speed (knots)	Number of Observations	Relative Frequency (percent)	Average Wind Speed (knots)	Number of Observations	Relative Frequency (percent)	Average Wind Speed (knots)	Number of Observations	Relative Frequency (percent)	Average Wind Speed (knots)
North	39	5.5	12.5	132	18.3	12.6	50	7.0	10.6	40	5.6	10.7	261	9.2	11.9
North by Northeast	11	1.5	15.0	82	11.4	10.8	29	4.0	9.0	21	2.9	9.1	143	5.0	10.5
Northeast	23	3.3	13.0	34	4.7	11.4	14	2.0	9.1	19	2.7	9.1	90	3.1	10.9
East by Northeast	23	3.3	14.3	27	3.8	12.4	7	1.0	10.7	23	3.2	8.9	80	2.8	11.8
East	35	4.9	11.7	33	4.6	9.8	22	3.0	9.5	25	3.5	8.8	115	4.0	10.1
East by Southeast	31	4.3	11.8	29	4.1	9.1	27	3.8	9.1	28	3.9	10.6	115	4.0	10.2
Southeast	28	4.0	11.0	61	8.5	10.3	60	8.3	9.9	43	6.1	9.1	192	6.7	10.0
South by Southeast	20	2.8	11.5	41	5.7	10.2	38	5.4	7.8	35	5.0	8.6	134	4.8	9.3
South	45	6.4	9.9	50	7.0	10.2	75	10.6	7.7	87	12.3	8.4	257	9.1	8.8
South by Southwest	39	5.6	11.1	23	3.2	11.0	62	8.7	9.2	41	5.8	9.8	165	5.8	10.0
Southwest	66	9.3	11.6	34	4.7	12.6	94	12.9	10.6	46	6.4	10.9	240	8.4	11.2
West by Southwest	66	9.3	11.3	48	6.6	14.4	101	14.0	11.1	52	7.3	10.2	267	9.3	11.5
West	88	12.5	11.1	39	5.4	12.6	62	8.7	9.7	89	12.6	9.3	278	9.8	10.4
West by Northwest	78	11.1	10.4	37	5.1	11.2	33	4.6	9.9	89	12.5	9.9	237	8.3	10.3
Northwest	59	8.3	10.2	33	4.6	11.3	28	3.9	8.5	47	6.6	10.0	167	5.8	10.0
North by Northwest	56	7.9	12.4	17	2.3	15.7	15	2.1	8.1	26	3.6	11.0	114	3.9	12.0
Calms	13			16			19			17			65		
Total	720	100.0	11.2[a]	736	100.0	11.3[a]	736	100.0	9.4[a]	728	100.0	9.4[a]	2920	100.0	10.3[a]

[a] *Average.*

Source: National Climatic Center and SEWRPC.

Figure 60

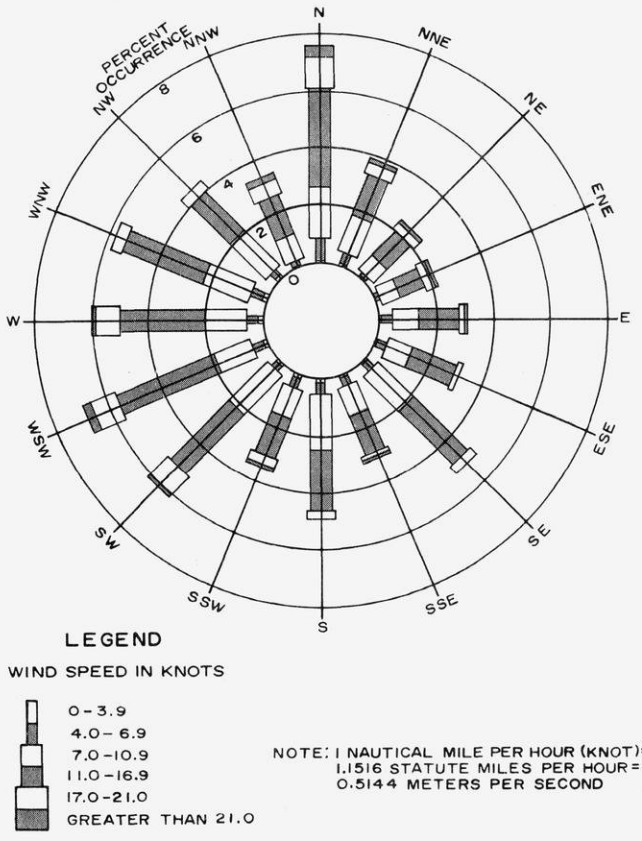
STABILITY WIND ROSE FOR
GENERAL MITCHELL FIELD: 1973
UNSTABLE ATMOSPHERIC CONDITIONS



Source: SEWRPC.

Figure 61

STABILITY WIND ROSE FOR
GENERAL MITCHELL FIELD: 1973
NEUTRAL ATMOSPHERIC CONDITIONS



Source: SEWRPC.

The interrelationship between wind speed and stability is evident in Table 236. In this table, the relative frequency of occurrence of the six wind speed categories is presented by stability class for the 1973 wind observations at General Mitchell Field. The wind speed was between 7 and 16 knots for nearly 70 percent of the total annual observations during this year, with all wind speeds in excess of 11 knots occurring with neutral and, to a lesser extent, slightly unstable atmospheric conditions. In no instance did wind speeds in excess of 6 knots occur with the stable or extremely stable classes.

Thermal and Mechanical Turbulence

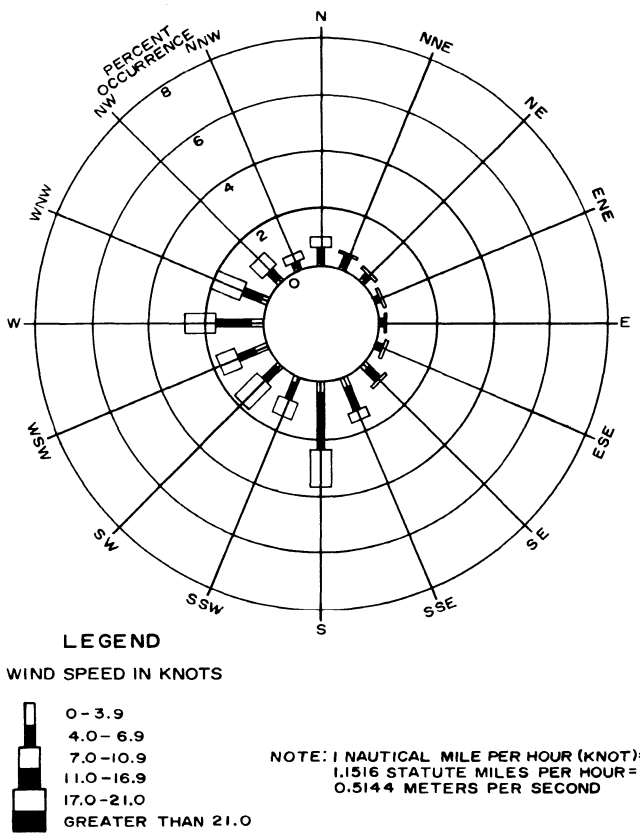
In the above discussion on wind speed and direction it was assumed that the wind flow was laminar; that is, that it flowed smoothly in the horizontal plane without perturbations. In actuality, however, there are physical forces which act on the wind to produce deviations such as eddy currents in the mean speed and direction of the wind field. The random motions so produced are of widely different scales and periods and are essentially responsible for the movement and diffusion of pollutants in the direction perpendicular to the mean wind flow. Collectively referred to as atmospheric turbulence, these random motions are due to thermal or mechanical influences near the surface acting either independently or jointly to deflect the straight-line motion of the wind.

Mechanical turbulence is the induced eddy structure of the atmosphere caused by the impaction, and consequent displacement, of the wind on surface objects such as buildings and trees and other terrain features. The amount of mechanical turbulence produced in the atmosphere is directly related to the height and spacing of the impaction objects as well as to the speed of the wind. Although the relationship between mechanical turbulence and atmospheric diffusion is difficult to quantify precisely, it may be approximated by the surface roughness parameter. The surface roughness parameter, Z_o, may be calculated according to the following formula:

$$Z_o = \frac{\overline{Ha}}{2A}$$

Figure 62

STABILITY WIND ROSE FOR GENERAL MITCHELL FIELD: 1973 STABLE ATMOSPHERIC CONDITIONS



Source: SEWRPC.

Table 235

RELATIVE FREQUENCY OF OCCURRENCE OF UNSTABLE, NEUTRAL, AND STABLE ATMOSPHERIC CONDITIONS BY WIND DIRECTION IN MILWAUKEE COUNTY: 1973

Wind Direction	Stability Class (percent)			Total
	Unstable (A, B, C)	Neutral (D)	Stable (E, F, G)	
North	0.4	7.7	1.1	9.2
North by Northeast	0.7	3.8	0.5	5.0
Northeast	0.4	2.4	0.3	3.1
East by Northeast	0.3	2.2	0.3	2.8
East	0.6	3.1	0.3	4.0
East by Southeast	0.5	3.1	0.4	4.0
Southeast	0.8	5.0	0.9	6.7
South by Southeast	0.2	3.0	1.6	4.8
South	0.5	4.9	3.7	9.1
South by Southwest	0.6	3.7	1.5	5.8
Southwest	0.7	5.9	1.8	8.4
West by Southwest	1.1	6.5	1.7	9.3
West	1.2	5.9	2.7	9.8
West by Northwest	0.7	5.6	2.0	8.3
Northwest	0.5	4.2	1.1	5.8
North by Northwest	0.2	3.2	0.5	3.9
Total	9.4	70.2	20.4	100.0

Source: National Climatic Center and SEWRPC.

Table 236

RELATIVE FREQUENCY OF WIND SPEED INTERVALS BY STABILITY CLASS–GENERAL MITCHELL FIELD: 1973

Wind Speed Interval (knots)	Stability Class							Total
	Extremely Unstable (A)	Unstable (B)	Slightly Unstable (C)	Neutral (D)	Slightly Stable (E)	Stable (F)	Extremely Stable (G)	
0-3	0.03	0.32	0.51	1.16	--	1.16	1.85	5.03
4-6	0.03	0.45	0.99	5.00	3.97	5.42	--	15.86
7-10	--	0.86	4.45	21.16	7.81	--	--	34.28
11-16	--	--	1.44	33.97	--	--	--	35.41
17-21	--	--	0.17	7.60	--	--	--	7.77
Greater Than 21	--	--	0.07	1.58	--	--	--	1.65
Total	0.06	1.63	7.63	70.47	11.78	6.58	1.85	100.0

Source: National Climatic Center and SEWRPC.

where:

$\overline{H}$ = the effective height of the roughness elements,

a = the frontal or silhouette area seen by the wind, and

A = the total area of the region divided by the number of roughness elements.

The units of the surface roughness parameter are expressed in meters and represent the mean diameter of the eddy currents produced by the underlying terrain. Typically, the surface roughness parameter ranges from 0.02 to 0.1 meter for open country, 0.1 to 1.0 meter for forested areas, and 0.5 meter to 10.0 meters for urban areas.

The surface roughness parameter may also be viewed as a measure of the stress, or frictional drag, exerted on the wind flow by ground-level obstacles. Because of the effects of frictional forces at the surface, wind speed is generally found to increase, and the wind direction to veer (turn clockwise in the northern hemisphere), with height in the friction layer.

Figure 63 presents a schematic representation of the change in wind speed and direction that may be experienced under varying terrain conditions. In all three of the diagrams the surface wind is from due south. Over smooth terrain, the speed of the wind measured near the surface[5] is approximately 90 percent of the wind speed as measured around 3,000 feet, and the degree of veering is about 10°. Over average terrain with only small changes in elevation and with some trees and shrubs, the surface wind speed is only about 80 percent of the upper wind speed and the amount of veering with height is about 15° to 20°. Over rough terrain, such as in urban areas or in hilly or mountainous regions, the surface wind speed may only be 50 percent of the upper wind speed, and the amount of veering may be as great as 40° to 45°.

The second form of turbulence, thermal turbulence, is that induced by the stability of the atmosphere. When heating of the earth's surface, particularly under light winds, causes the lower layer of the atmosphere to become unstable, thermal turbulence increases. On clear nights with light winds, as heat is rapidly lost by the surface of the earth, the air immediately above the surface also cools and causes the atmosphere to become extremely stable and, as a result, thermal turbulence is at a minimum. It is the vertical motion of air parcels rising and falling in response to atmospheric stability conditions that determines the magnitude of thermal turbulence.

In general, thermal turbulence may be associated with unstable atmospheric conditions because any fluctuations so produced in the wind flow will be enhanced by the temperature gradient through the atmosphere. By the same reasoning, mechanical turbulence may be associated with neutral stability because fluctuations in the wind flow produced by impaction with surface objects are neither enhanced nor surpressed by the thermal structure of the atmosphere. Laminar wind flow is associated with extreme stability conditions since any fluctuations are immediately damped out.

Since atmospheric instability is produced by strong solar heating, it follows that thermal turbulence will be at a maximum during daylight hours. This means that vertical motion will also be at a maximum during daylight hours. Consequently, the difference between wind speed at the surface and upper level wind speeds is the least during the daytime, as is the degree of veering. Mechanical turbulence predominates when wind speeds are brisk and in periods of reduced solar heating such as cloudy days or in the evening hours. Laminar flow occurs only on clear nights with very low wind speeds.

Mixing Height

The mixing height (or depth) may be defined as the height above the surface through which relatively vigorous vertical mixing occurs. In effect, the mixing height defines the upper limit on the volume of air through which pollutants may be dispersed. The height of the mixing layer is, itself, defined by the temperature structure through the atmosphere and is directly related to prevailing atmospheric stability conditions. The "fumigation" and "trapping" plume illustrations in Figure 58 graphically illustrate the effect of the mixing height on the pollutant dispersion capabilities of the atmosphere. In all of these classes, the mixing height extends from the surface to the base of the upper air inversion. The air above the initial point of inversion is extremely stable and any attempt at further vertical motion is quickly damped out. Air pollutants are therefore trapped beneath this lid and may only mix and dilute in the shallow layer near the ground.

The method for calculating the height of the mixing layer requires data on the existing vertical temperature structure through the lower atmosphere. The network of 62 meteorological stations across the continental United States which make such measurements twice daily, however, does not provide the spatial resolution necessary for local air pollution studies. In characterizing the mixing heights occurring within the Southeastern Wisconsin Region, therefore, statistical techniques must be applied to the observed data to estimate actual conditions throughout the Region.

The U. S. Environmental Protection Agency sponsored a work effort which resulted in a statistical representation of the seasonal average heights of the mixing layer

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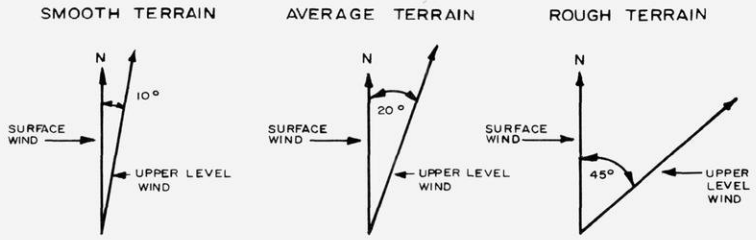
[5] *In meteorological terminology, the expression "near the surface" means that layer of the atmosphere between the ground and a height of about 10 meters (about 33 feet). Accordingly, the surface wind speed would be the velocity of the wind measured at ground level or at any height up to 10 meters.*

Figure 63

EFFECT OF SURFACE ROUGHNESS ON WIND SPEED AND DIRECTION



Source: U. S. Environmental Protection Agency and SEWRPC.

in the morning and in the afternoon across the continental United States[6]. Maps 51 and 52 are a partial product of that effort and represent the winter morning and afternoon average mixing heights, respectively, based on a five-year period of record from 1960 through 1964. It may be seen on these isopleth maps that the morning mixing height over southeastern Wisconsin on a typical winter day averages between 500 and 600 meters. As solar heating progresses during the day, the mixing layer increases to about 700 meters on an average winter afternoon, which corresponds to the diurnal peak of thermal turbulence and atmospheric instability.

Maps 53 and 54 represent the average summer morning and afternoon mixing heights, respectively. The average summer morning mixing height over southeastern Wisconsin is 300 to 400 meters, which is considerably lower than the average winter morning value. This difference is due to the deep inversions produced during the early morning hours in summer from strong nocturnal radiational cooling at the earth's surface and lower average wind speeds in summer as compared to winter. The average summer afternoon mixing height increases to approximately 1,600 meters due to the intense solar heating at the surface which maximizes the occurrence and magnitude of unstable atmospheric conditions. Because of the strong diurnal heating and cooling cycle experienced during summer in the Region, this season exhibits the greatest change between the average morning and afternoon mixing heights.

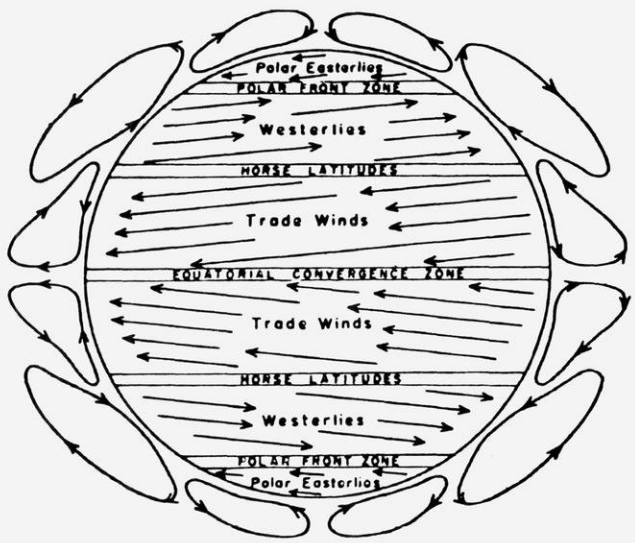
The seasonal variation of average mixing heights is much greater between winter and summer afternoons than between winter and summer mornings, particularly at inland locations well removed from large bodies of water. The oceans and the Great Lakes have a moderating effect on weather systems which reduces the range of variation in meteorological elements both seasonally and diurnally. This point is exemplified by noting that on each of the four maps presented, the average mixing height over the Region is always within 100 meters of the level at Green Bay despite the latitudinal difference.

MESOSCALE CIRCULATION AND AIR POLLUTION

Small-scale fluctuations in wind motion as caused by prevailing atmospheric stability and turbulence conditions take place within larger circulatory patterns. Fundamentally, global circulation, as shown in Figure 64, is established by the transport of heat energy from the

Figure 64

SCHEMATIC REPRESENTATION OF GENERAL GLOBAL CIRCULATION

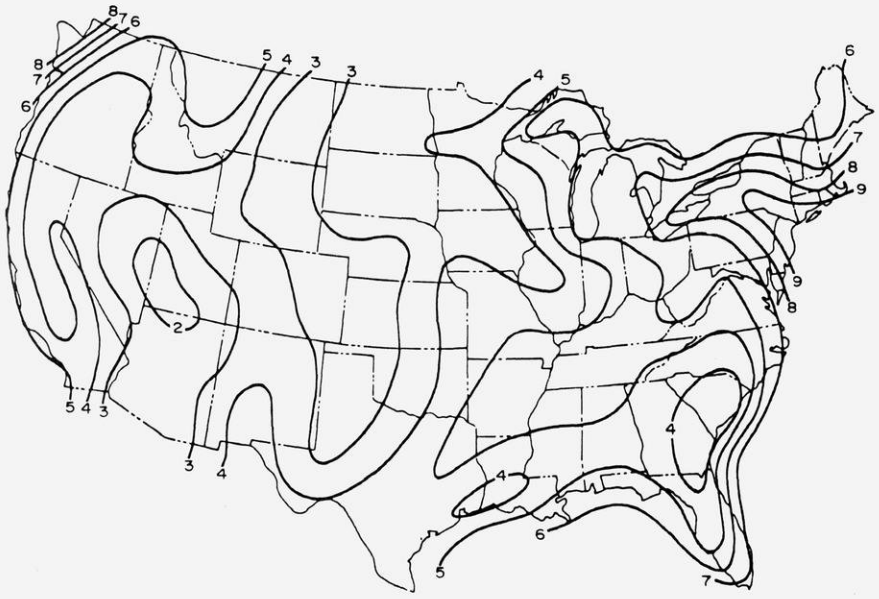


Source: H. R. Byers, General Meteorology, McGraw Hill, New York, 1959.

[6] *See George C. Holyworth, Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution Throughout the Contiguous United States, U. S. Environmental Protection Agency, AP-101, January 1972.*

Map 51

MEAN WINTER MORNING MIXING HEIGHTS (HUNDREDS OF METERS)

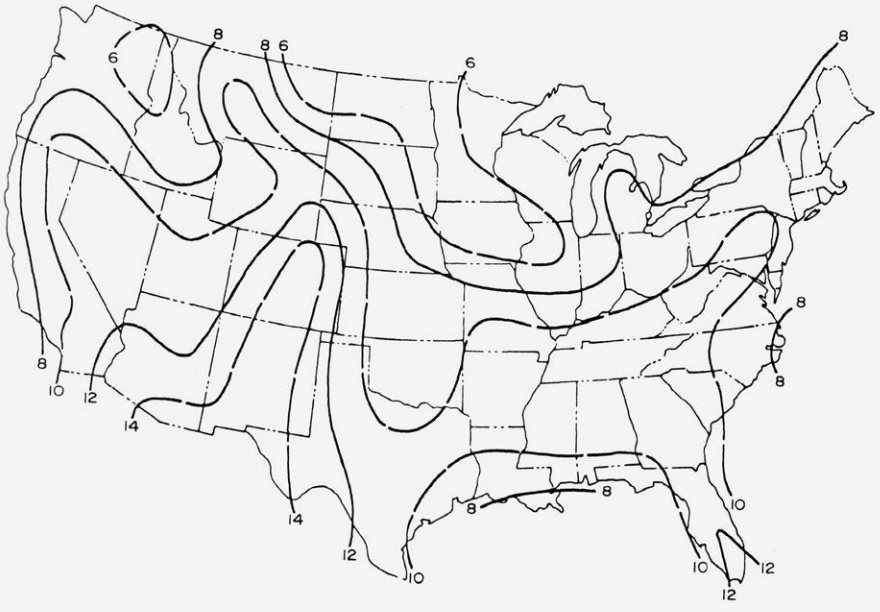


Mean morning mixing heights in the United States usually range from about 300 meters to 900 meters (approximately 1,000 to 3,000 feet during the winter season as shown on the map above). The higher mixing height values are generally found adjacent to large bodies of water such as along the coasts and over the Great Lakes. Areas near large bodies of water often experience high relative humidities and/or low cloudiness, which inhibit formation of the intense radiation inversions that tend to lower the height of the mixing layer. Along the Lake Michigan coast of the Region, the mean morning mixing height is about 600 meters (about 2,000 feet) during the winter season.

Source: George C. Holzworth, Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution Throughout the Contiguous United States, U. S. Environmental Protection Agency, AP-101, January 1972.

Map 52

MEAN WINTER AFTERNOON MIXING HEIGHTS (HUNDREDS OF METERS)

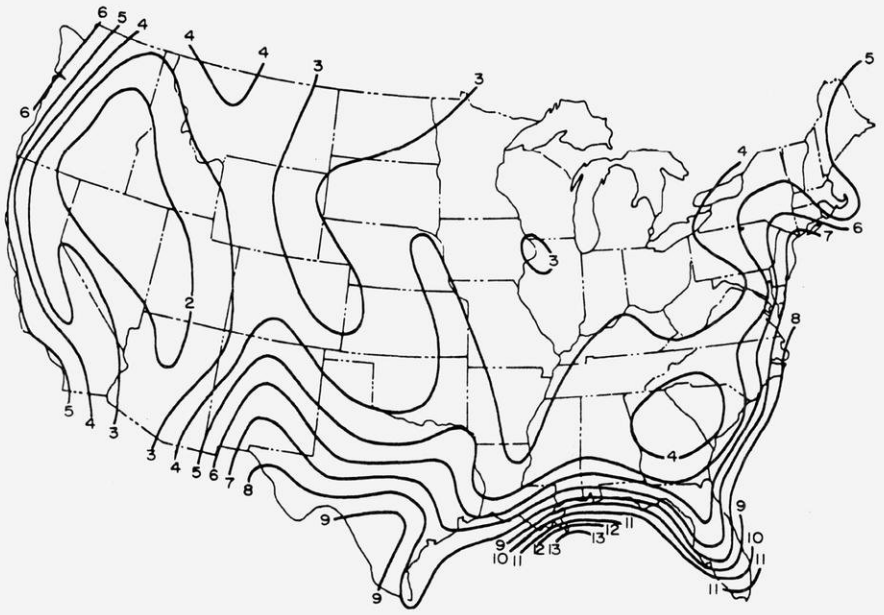


Mean afternoon mixing heights in winter in the United States generally exhibit a pattern opposite to that for mornings in that afternoon heights tend to be relatively low along the coasts and over the Great Lakes as compared with more inland areas. This pattern is due primarily to the moderating effect that large bodies of water have on maximum ambient air temperatures. Mean afternoon mixing heights in the Region during the winter season, as may be seen on the accompanying map, average between 600 to 800 meters (about 2,000 to 2,600 feet).

Source: George C. Holzworth, Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution Throughout the Contiguous United States, U. S. Environmental Protection Agency, AP-101, January 1972.

Map 53

MEAN SUMMER MORNING MIXING HEIGHTS (HUNDREDS OF METERS)

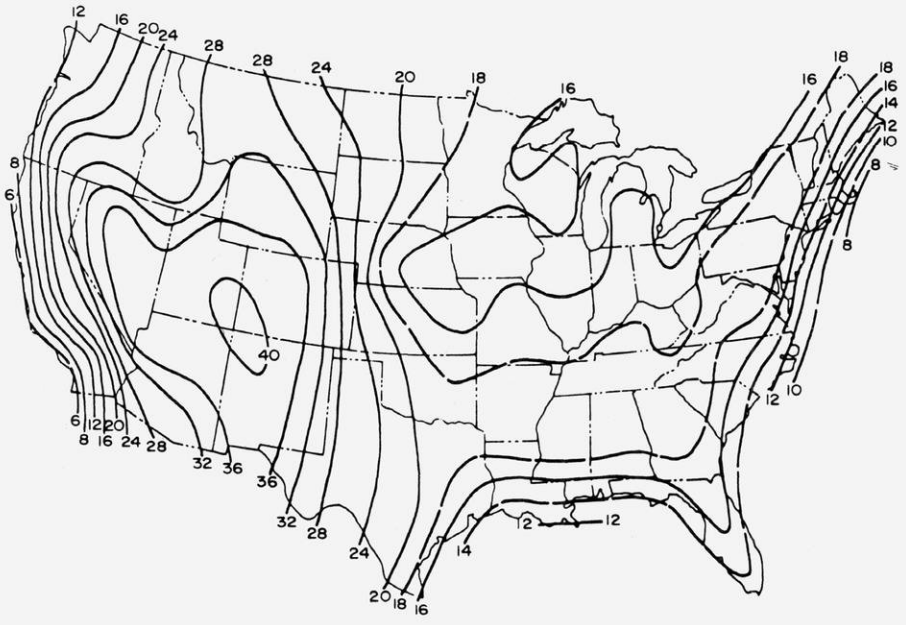


The mean morning mixing height over southeastern Wisconsin is the lowest for the year during the summer season. As may be seen on the accompanying map, the mean morning mixing height in the Region during the summer season is between 300 to 400 meters (about 1,000 to 1,300 feet). Such low morning mixing heights are generally caused by intense radiation inversions whose formulation is enhanced by the dry, low-density air frequently experienced in summer months.

Source: George C. Holzworth, Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution Throughout the Contiguous United States, U. S. Environmental Protection Agency, AP-101, January 1972.

Map 54

MEAN SUMMER AFTERNOON MIXING HEIGHTS (HUNDREDS OF METERS)



The highest mean mixing heights across the United States are experienced in the afternoon during the summer season. The summer season also exhibits the greatest diurnal variation in mean mixing heights. Seasonally, the mean mixing heights vary much more for afternoons than for mornings, although this variation is always greater at inland locations because of the moderating effect of the oceans along coastal areas. In southeastern Wisconsin the mean afternoon mixing height averages about 1,600 meters (about 5,250 feet).

Source: George C. Holzworth, Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution Throughout the Contiguous United States, U. S. Environmental Protection Agency, AP-101, January 1972.

warm equatorial regions to the cold polar regions. During the poleward migration the tropical air cools and subsides to the surface and tends to move back toward the equator, creating a cellular-type circulation pattern. As air subsides, however, the temperature increases in accordance with the dry adiabatic lapse rate of 5.4°F per 1,000 feet of descent. Some of this heated air, therefore, continues poleward until it interfaces with cold air moving down from the poles. A secondary circulatory cell is formed when the warmer air from the mid-latitudes is forced upward by the colder and denser polar air. The heat exchanged at the junction of these two air masses warms the polar air and it too rises, forming the third major circulatory cell.

Because the earth rotates on its axis there is an apparent deflection in the straight-line motion of the wind between the poles and the equator. In the northern hemisphere this deflection, known as the Coriolis force, acts to produce a deviation to the right of the direction of travel. A wind moving equatorward from the north pole would therefore appear to be coming from an easterly direction and a wind moving poleward in the mid-latitudes would appear to be coming from a westerly direction. It is within this band of westerly air flow that the weather systems affecting meteorological conditions in southeastern Wisconsin are carried.

General weather conditions in southeastern Wisconsin are caused by the migration of alternating low pressure systems (cyclones) and high pressure systems (anticyclones) through the midwestern United States. These macroscale weather systems are extremely large in areal extent, ranging between hundreds and thousands of miles in size. Low pressure systems are often associated with fronts; that is, a narrow band of rapidly changing meteorological conditions generally accompanied by strong winds, precipitation, and atmospheric instability. High pressure systems, on the other hand, are generally accompanied by low winds and very stable atmospheric conditions. Periods of excessive air pollution levels are often related to the occurrence of a high pressure system which remains stationary, or stagnant, for several days over a given area. In such a situation, low wind speeds, stable air, and shallow mixing heights permit air pollutants to accumulate to relatively high concentrations.

High pressure systems and low pressure systems both may dominate the general circulatory pattern over a broad area for several days. Within this macroscale pattern, however, there may exist various mesoscale circulations introduced by the presence of certain topographic or man-made features. These mesoscale circulatory patterns range in areal extent from several hundreds of feet to several tens of miles and are discussed in the following sections.

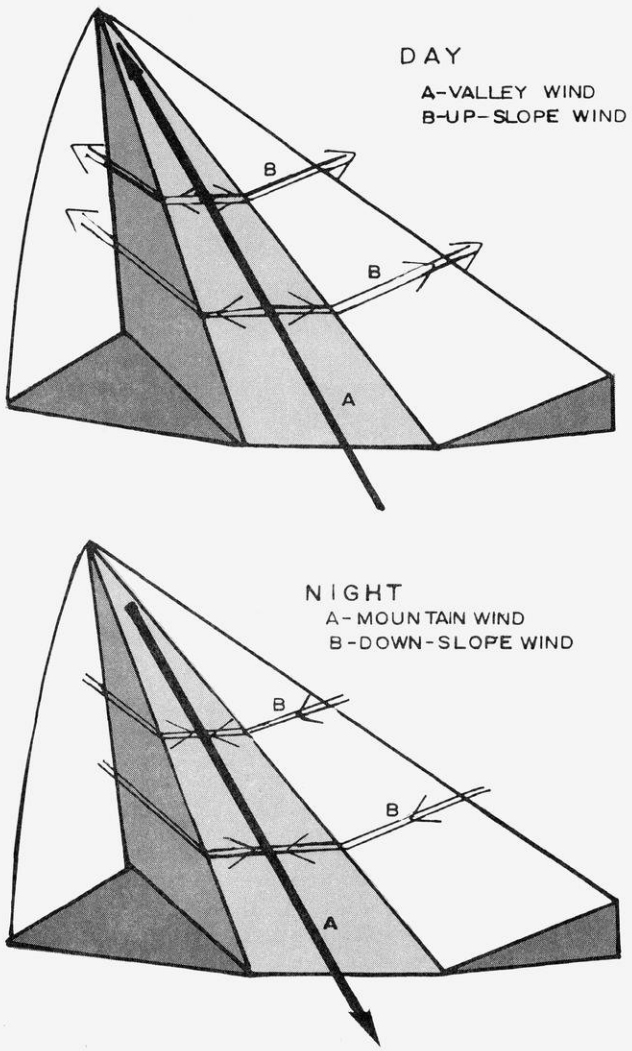
Valley Effects

Valleys may affect the general wind flow in two ways: by channeling the wind along the valley axis and by establishing a mesoscale circulation through differential heating and cooling between the valley floor and the valley slopes. Valley effects are the greatest when mean wind speeds are light.

Figure 65 illustrates the circulation pattern generated during the day—the valley wind—and during the night—the mountain or canyon wind—by the thermally driven winds. During a day with clear skies and light winds the slope of the valley receives more solar radiation than does the valley floor. Being warmer than the air over the valley floor, air above the slopes rises and moves toward the center of the valley, where it cools and subsides. The air thus displaced over the slopes is replaced by air moving upward from the valley floor, thereby completing the cellular circulatory flow. At night the air over the slopes cools most rapidly and a reverse circulation from that established during the day is formed. As the cold

Figure 65

SCHEMATIC REPRESENTATION OF TYPICAL WIND CIRCULATION PATTERNS IN VALLEYS DURING THE DAY AND DURING THE NIGHT



Source: Compendium of Meteorology, American Meteorological Society, Boston, Massachusetts, 1951.

air drainage winds move down the slopes an inversion is created, which intensifies and deepens with time. Any air pollutants emitted into this cold air will therefore have very limited vertical motion. The air pollution disaster at Donora, Pennsylvania and in Meuse Valley, Belgium, see Chapter VI, are examples of this condition. In addition, if the valley floor has some slope, the cold air will move downhill along the valley axis. The steeper the slope of the valley the stronger the wind will be. Heating the valley during the day may cause a wind to move up the valley, but such winds are not as strong nor frequent as the downslope winds.

The Southeastern Wisconsin Region is fairly uniform in topography, with only slight variations in elevation. One notable area of local relief in the Region is the heavily industrialized portion of the Menomonee River Valley in the City of Milwaukee. As discussed in Chapter VII, this area contains some of the largest industrial sources of air pollutant emissions in the Region. The Valley varies in elevation from a floor level of about 585 feet above mean sea level to a maximum height of approximately 650 feet at the southern rim. This maximum change in elevation of about 65 feet, however, is not thought to be of sufficient magnitude to generate valley wind circulation patterns which would significantly alter the mean wind flow, although this relief may act to locally channel near surface winds along the major axis of the valley floor.

Urban Effects

The presence of a large urbanized area produces an urban-rural circulation pattern due, as in the case of the valley winds, to differential heating of nearby surfaces. Urbanized areas have many anthropogenic heat sources such as furnaces, factories, and automobiles, which are not present in such quantity or density in rural areas. Cities are also made of materials that quickly absorb heat and only slowly reradiate it back to the atmosphere. The shape of cities, with their numerous structures, promotes the multiple absorption and emission of heat energy between buildings. As a result, warm air rises over cities and is replaced by cooler air from rural areas.

Figure 66 presents a schematic representation of urban-rural circulation under conditions of calm winds and light winds. With calm winds, a roughly circular city surrounded by characteristically rural environs would form a dome of relatively warm air. As warm air rises over the central city and moves outward, it is replaced by cooler air from the rural areas. With light winds, the relatively weak urban-rural circulation pattern is limited to the downwind direction. This urban "heat island" effect, as it is known, may be responsible in part for the increase of pollutant levels measured in rural areas in the Region.

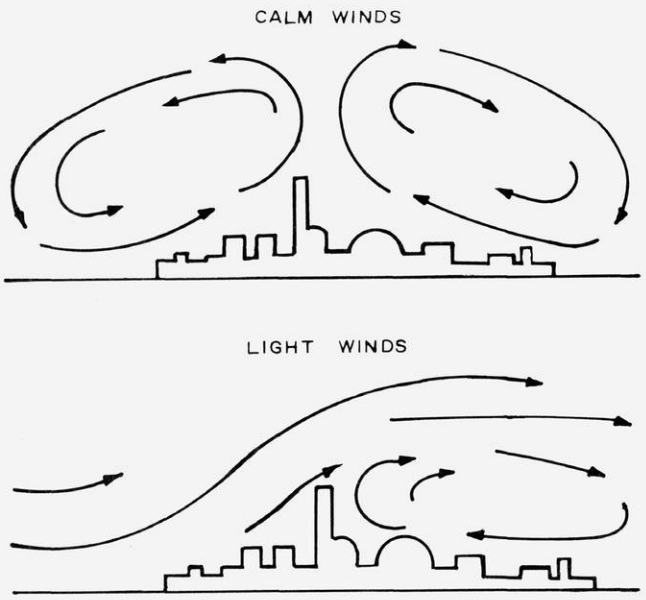
In addition to occasionally generating a localized wind circulation, cities also influence most of the other meteorological elements. Table 237 lists the representative values of urban-rural contrast for several meteorological variables. As the table indicates, urban temperatures are higher, particularly in terms of the minimum winter temperatures. During the period immediately after sunset, the city air does not cool as rapidly as does the rural air because of the heat content of buildings and structures which radiate toward each other rather than directly to the atmosphere. Between sunrise and noon the urban and rural temperatures are about the same, but the city is almost invariably warmer in the afternoon. The city influences temperatures in the vertical direction on the order of three times the average height of its buildings. The average heat island effect over major urban areas has been observed to extend as high as 1,500 feet. The temperature lapse rate is also quite different over cities, especially at night. Rural areas generally form very stable lapse rates due to radiational cooling at the surface. Urban areas often maintain neutral to slightly unstable conditions at low levels through the night, with an inversion layer above.

Variations between urban and rural temperatures are very noticeable at northern latitudes in winter when snow covers the countryside but has melted in the city. One result of urban areas being warmer than rural areas is that the city's heating requirements are about 10 percent less than those of rural areas.

Urban centers also have lower relative and absolute humidity than do rural areas. Lower humidities in the city may be due to the more rapid runoff of precipitation. Moreover, the absence of substantial vegetation cover in cities means they acquire little moisture from the evapotranspiration process in plants.

Figure 66

URBAN CIRCULATIONS



Source: SEWRPC.

Table 237

REPRESENTATIVE VALUES OF URBAN-RURAL CONTRAST FOR SEVERAL METEOROLOGICAL VARIABLES

Variable	Urban Compared With Rural
Temperature	
Annual Mean Temperature	1.5°F more
Mean Winter Minimum Temperature	3.0°F more
Humidity	
Annual Mean Relative Humidity	6 percent less
Seasonal Mean Relative Humidity	8 percent less in summer; 2 percent less in winter
Wind	
Annual Mean Wind Speed	25 percent less
Speed of Extreme Wind Gusts	15 percent less
Frequency of Calms	15 percent more
Radiation	
Solar Radiation on Horizontal Surfaces	15 percent less
Ultraviolet Radiation	15 percent less in summer; 30 percent less in winter
Precipitation	
Total Annual Precipitation	10 percent more
Days With Less Than 0.2 Inch (5 millimeters) Precipitation	10 percent more
Cloudiness	
Cloudiness Frequency and Amount	10 percent more
Frequency of Fog	30 percent more in summer; 100 percent more in winter

Source: Adopted from H. Landsberg, Physical Climatology, Gray Company, *DuBois, Pennsylvania, 1969.*

Wind speeds are substantially lower in cities than in rural areas because of the size and number of the surface roughness elements. In addition, there is channeling of the wind in the canyons formed by alternating streets and groups of buildings.

Solar radiation, particularly in the ultraviolet portion of the spectrum, is also less in cities because of the presence of higher concentrations of particulates and gases in the urban atmosphere which absorb, reflect, and scatter the energy. These particles and gases are primarily the result of air pollution. The loss of ultraviolet radiation may have a significant, but indirect, impact on human health since solar radiation in this area of the spectrum has been identified as a bactericide. Less ultraviolet radiation may, therefore, encourage the growth and development of harmful bacterial agents.

The particles in the atmosphere may also act as condensation nuclei and lead to an increase in precipitation in and downwind of the urban environment. Increased turbulence over cities from both increased surface roughness and release of heat may also contribute to the observed precipitation increase. Although some water vapor is added to the urban atmosphere from combustion sources, it does not appear that any significant increase in precipitable water results from this source.

The more frequent occurrence of fog and cloudiness in the urban environment may also be attributed to particulate air pollutants acting as condensation nuclei. In addition, smoke and haze have been shown to occur more frequently in urban areas than in rural areas. The lower visibility in cities is probably the most noticeable of the meteorological differences between urban and rural environments.

The aforementioned effects of air pollution on local meteorology within urban areas may also extend to and impact upon surrounding rural areas. As noted, for example, particles released to the atmosphere as air pollution may serve as condensation nuclei for precipitation that forms many miles downwind of the urban center from which they originate. More significant perhaps is the formation of ozone in rural areas downwind and well removed from the major hydrocarbon and nitrogen oxide sources—such as motor vehicles and fossil fuel power plants—that are frequently associated with urban areas. It may be concluded, therefore, that the influence of air pollution on meteorological elements, although more pronounced in an urban envionment where the emission sources are generally the most abundant, does extend into rural areas.

Lake Breeze Effect

At different seasons of the year and also at different times of the day the temperatures of large bodies of water and adjacent land masses may be quite dissimilar. For example, during late spring, large bodies of water are still cold relative to adjacent land surfaces; this difference is greatest in mid-afternoon because of the more rapid diurnal heating of the land. Particularly during the warmer seasons, onshore flow is associated with a significant modification of the temperature structure in the lower layer. The cold water surfaces cool the air immediately above, forming an inversion. Air pollutants emitted into this stable layer will have essentially the characteristics of a fanning plume, as shown in Figure 58. As the air moves inland, the warm land surface heats the air above and erodes the inversion near the surface, replacing it with a more unstable lapse rate. This lapse rate becomes deeper as the air moves over more heated land surface. If the inversion is increased to a depth at which an elevated stack is emitting pollutants, fumigation, such as may be seen in Figure 58, will occur. Further penetration of the unstable layer eventually would lead to a trapping type of plume behavior, and then to a looping type of plume behavior, as the inversion is gradually lifted and eliminated (see Figure 58). When the water is warmer than the adjacent land surface, such as in late fall, offshore wind flow will result in fumigation over the water.

On summer days the land-water temperature difference is at a maximum. On such days, when winds are light and the skies are clear, the intense and rapid heating of a land surface next to a large body of water may set up a circu-

lation pattern extending over both surfaces. The air above the land surface is heated and rises, while the air over the water is cooled and subsides. The cool air moves inland replacing the rising warm air, which travels out over the water and subsides. This type of thermally induced cellular circulation is termed the "lake breeze" and is schematically depicted in Figure 67. If the lake breeze is particularly strong, air from quite some distance out over the water may be brought toward the land. Over a long distance, however, the Coriolis force may deflect the straight-line motion of the breeze so that the resulting flow is nearly parallel to the shoreline by the time of impaction. This generally occurs after the lake breeze is the strongest and results in decreasing the inland flow and, subsequently, in breaking down the lake breeze circulation.

Figure 67 also indicates the probable behavior of pollutants entrapped and circulating in a well-developed lake breeze and accompanying temperature inversion. The arrows indicate the probable trajectories of both large and small particles and gaseous pollutants from sources located in proximity to the Lake Michigan shoreline. The lake breeze inland flow depth may extend to about 3,000 feet, and is overlayed by a return flow of air toward the lake which may reach an altitude of 6,000 to 7,000 feet above the surface. Air pollutants that are trapped in this circulation pattern may be carried repeatedly over the lake and the land until relatively high concentrations accumulate. These concentrations may be many times higher than the normal concentrations within the Region even though the pollutant emission rates in the area remain constant.

Conditions favorable to the formation of a lake breeze in southeastern Wisconsin are estimated to occur during about one-third of the summer days, or about 15 percent of the total time. The onset of the lake breeze is usually after 8:00 a.m., and the breeze most often abates at sunset. The inland penetration of the lake breeze may, on occasion, reach 20 to 25 miles but is usually limited to two or three miles from shore.

SUMMARY

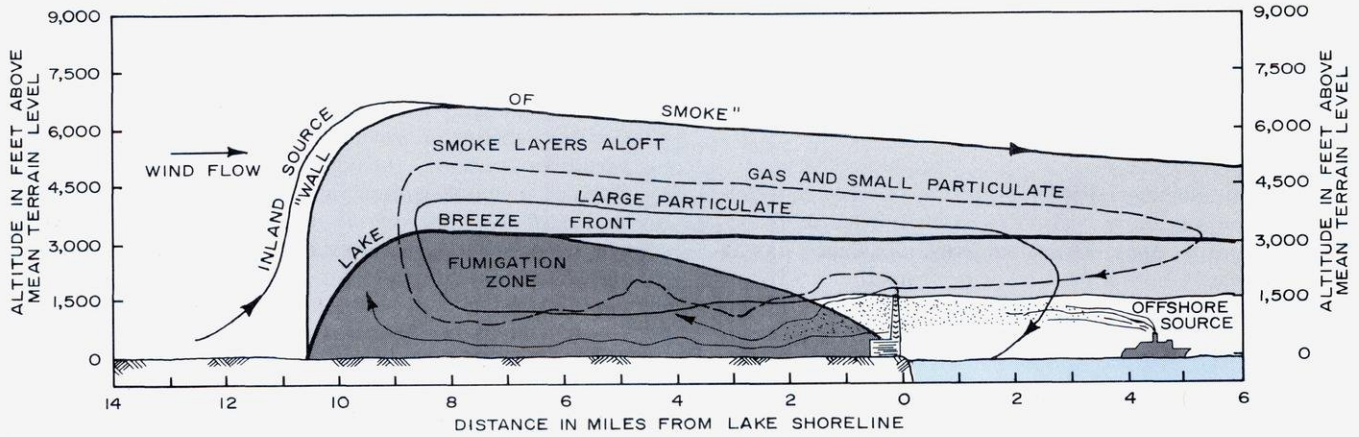
There is one first order National Weather Service observation station in the Region. The station, located at General Mitchell Field in Milwaukee County, provides detailed meteorological data on a continuous basis. This station is supplemented by 16 partial record stations, 14 of which report daily maximum and minimum temperatures and precipitation levels and two of which report precipitation levels only. All stations in the regional meteorological observation network, however, provide only surface data and do not measure weather variables in the upper air. Such upper air data are essential for determining the transport and diffusion of atmospheric pollutants.

Most air pollutants are emitted directly into the lowest layer of the atmosphere, a layer termed the troposphere. A notable characteristic of the troposphere is that air temperatures decrease with increasing height at a rate of about 3.6°F per 1,000 feet. This condition, termed the normal temperature lapse rate, is the basis on which atmospheric stability is determined.

Atmospheric stability is a measure of the tendency of an air parcel to migrate through the atmosphere in a vertical direction. The degree to which the atmosphere is stable or unstable influences whether air pollutants will be concentrated at the level of emission or dispersed vertically. Layers of air having different temperature structures and, therefore, different stability conditions, may override each other and enhance or limit dispersion of pollutants at ground level.

Figure 67

SCHEMATIC REPRESENTATION OF THE LAKE BREEZE EFFECT



Source: Adapted by SEWRPC from Original Drawing by Air Pollution Analysis Laboratory, University of Wisconsin-Milwaukee.

Neutral atmospheric conditions occur when the ambient temperature of the atmosphere decreases with height at the dry adiabatic temperature lapse rate—the constant rate of temperature change which occurs as unsaturated air expands during ascent or contracts during descent. Under such conditions, vertical motion in the atmosphere is neither helped nor hindered by thermal stability. Unstable atmospheric conditions are characterized by a temperature profile which decreases more rapidly with height than does the dry adiabatic temperature lapse rate. In this condition, any small vertical fluctuation is enhanced. When the ambient temperature increases with height or remains constant, the atmosphere is stable, and any vertical fluctuations that may be experienced are quickly damped out. As a general rule, instability occurs with high incoming solar radiation and low wind speeds, stability with high net radiation loss and light winds, and neutral conditions with cloudy skies or high wind speeds.

The condition where temperature increases with height is known as an inversion. An inversion acts as an effective lid on the extent to which vertical mixing may occur and is often responsible for excessive pollutant concentrations in the lower atmosphere.

Atmospheric stability may be readily determined if the vertical temperature profile is known. Such observations, however, are only made twice daily at 62 meteorological stations across the country spaced roughly 250 miles apart. The closest such station to the Southeastern Wisconsin Region is located at Green Bay, Wisconsin. An indirect method for classifying atmospheric stability was devised in 1961 by Dr. F. Pasquill of the British Meteorological Office, and may be applied to the readily available meteorological data from General Mitchell Field.

Using Dr. Pasquill's method and meteorological data from General Mitchell Field for the period 1964 through 1973, it was found that neutral atmospheric conditions occur approximately 65 percent of the time on an annual basis, with a maximum frequency of occurrence in winter, about 81 percent of the seasonal observations, and a minimum frequency in summer, about 47 percent of the seasonal observations.

Unstable conditions are the most frequent during the summer, occurring about 25 percent of the time, and the least frequent during the winter, occurring about 3 percent of the time. Stable conditions occur more uniformly throughout the year, ranging from about 28 percent in summer to 16 percent in winter.

Wind speed and wind direction are the primary determinants of the motion of pollutants in the horizontal plane. In the Southeastern Wisconsin Region, winds having a high westerly component—that is, from the southwest through the west-northwest directions—had the highest annual frequency of occurrence during 1973, cumulatively accounting for about 36 percent of all observations. In winter the predominant wind direction is west to west by northwest, although the strongest winds come out of the north by northwest to east by northeast quadrant. In spring the predominant winds are from the north to north by northeast. Average wind speeds decrease in summer over the winter and spring values, and south to west-by-southwest winds prevail. Southerly and westerly winds prevail in fall, with little change in average wind speeds from those in the summer.

From an analysis of the joint frequency of occurrence of atmospheric stability classes and wind direction, it was determined that there is a slight predisposition for unstable conditions to occur more often with westerly winds, neutral conditions to occur more often with northerly winds, and stable conditions to occur more often with southerly winds. Wind speeds at General Mitchell Field during 1973 averaged between 7 and 16 knots for nearly 70 percent of the total annual observations. All wind speeds that measured in excess of 11 knots occurred with neutral and, to a far lesser extent, slightly unstable atmospheric conditions. In no instance did wind speeds in excess of 6 knots occur with the stable or extremely stable classes.

Mechanical and thermal turbulence in the atmosphere act to disturb the laminar, or straight-line, motion of the wind. Mechanical turbulence is the induced eddy structure of the atmosphere caused by the impaction of the wind on surface objects such as buildings and trees and other terrain features. The relationship between mechanical turbulence and atmospheric diffusion may be approximated by the surface roughness parameter. The surface roughness parameter represents the mean diameter of the eddy currents produced by the underlying terrain, and typically ranges from 0.02 to 0.1 meter for open country, 0.1 to 1.0 meter for forested areas, and 0.5 meter to 10.0 meters for urban areas.

Thermal turbulence is the induced eddy structure of the atmosphere produced by the surface heating of air parcels which rise and are replaced by sinking, cooler air parcels. In general, thermal turbulence is associated with unstable atmospheric conditions. Since atmospheric instability is produced by strong solar heating, it follows that thermal turbulence will be at a maximum during daylight hours. Mechanical turbulence predominates when wind speeds are brisk and in periods of reduced solar heating. Laminar flow is generally found only on clear nights with very low wind speeds.

The mixing height is defined as the height above the surface through which relatively vigorous vertical mixing occurs. Because of the lack of data on the vertical temperature structure through the atmosphere over the Region, a more general and statistical approach must be used to characterize the depth of the regional mixing layer. A U. S. Environmental Protection Agency-sponsored study of the 62 meteorological stations recording upper air data between 1960 and 1964 produced seasonal maps of average morning and afternoon mixing heights. Based on these maps, it was determined that the average morning mixing height over the Southeastern Wisconsin Region in winter was between 500 and 600 meters. By the afternoon of a typical winter day, the

average mixing height increased slightly to about 700 meters over the Region. In summer, the average morning mixing height over southeastern Wisconsin is between 300 and 400 meters. The average summer afternoon mixing height over the Region is approximately 1,600 meters.

Although the daily weather experienced in southeastern Wisconsin is attributable to the migration of alternating high and low pressure systems through the Midwest, localized mesoscale circulation may be produced in the Region as a result of certain terrain features. For example, valleys may affect the general wind flow in two ways: by channeling the wind along the valley axis and by forming a cellular circulation pattern as a result of differential heating between the valley slopes and the valley floor when regional winds are light. This type of mesoscale circulation does not occur significantly in southeastern Wisconsin since the Region is fairly uniform in topography, with only slight variations in elevation. The heavily industrialized area of the Menomonee River Valley does exhibit some local relief—about 65 feet from the valley floor to the southern rim—but it is not thought to be of sufficient magnitude to generate a significant valley wind circulation pattern, although this relief may act to channel near surface winds along the major axis of the valley floor.

The presence of large urban areas also produces a mesoscale circulation due to thermal differences between the city and rural areas. Cities have many heat sources which are not present in such quantity and density in rural areas. In addition, the structure of cities and the materials from which they are made combine to make urbanized areas significantly warmer than the surrounding countryside. Under calm regional winds, warm air over urbanized areas rises and moves aloft toward the rural areas, while cooler air from the countryside moves into the cities at low levels. When regional winds are light, the urban-rural circulation pattern is limited to the downwind side of the urbanized area.

Cities also influence most of the meteorological elements. Urban temperatures, for example, are significantly warmer than rural temperatures, particularly in terms of minimum temperatures. Urban humidity, both relative and absolute, is lower than rural humidity because of increased precipitation runoff and the absence of vegetation. In addition, wind speeds are lower in cities and calms are less frequent because of the size and number of surface roughness elements. Particles in the urban atmosphere reduce the amount of solar radiation at the surface of a city, particularly in the ultraviolet portion of the spectrum. The same particles may serve as condensation nuclei and increase the amount of precipitation and the occurrence of fog in the urban environment.

Differential heating of land surfaces and large water bodies produces a general mesoscale circulation pattern known as the lake breeze. During the summer, when the difference between the warm land surface and cool lake waters is at a maximum, air rises over the land surface, moves over the lake, and subsides. Cool air from over the lake moves shoreward and penetrates inland. If the lake breeze is particularly strong, air from quite some distance out over the lake may be brought toward the land. Over a long distance this air is deflected by the Coriolis force, and the resulting flow is thus nearly parallel to the shoreline by the time of impaction.

Air pollutants trapped in the lake breeze circulation pattern may be repeatedly carried over the lake and land until relatively high concentrations accumulate, even though emission rates remain constant. Conditions favorable to the formation of the lake breeze along the Lake Michigan shoreline in Wisconsin are estimated to occur during about one-third of the summer days, or about 15 percent of the total time.

As is evident in this chapter, air pollution meteorology involves an understanding of atmospheric motions in the microscale, mesoscale, and macroscale. Often the physical forces acting in these ranges may not be readily quantified, or are not measured routinely at all meteorological observation stations. It should, therefore, be recognized that regional air quality maintenance planning must frequently rely on generalized meteorological data representative of a broad geographic area in simulating and replicating the dynamic atmospheric processes of air pollutant transport and diffusion.

Chapter IX

AIR POLLUTION CONTROL TECHNOLOGY

INTRODUCTION

Air pollution levels have generally been decreasing in major urban areas of the United States over the past five years. This decrease can be largely attributed to the development and application of emission control technology to major emission sources such as electric power generation plants, industrial sources, and automobiles. A great deal of expense has been incurred, primarily in the private sector, for the purchase, installation, operation, and maintenance of pollution control devices.

The purpose of this chapter is to review the technology that is available for the direct control of air pollutant emissions. The direct control of air pollutants involves the treatment of emissions by equipment that uses mechanical, chemical, and/or electrical processes. Changes in production processes may also directly reduce the initial generation or the escape of emissions into the atmosphere. Indirect methods of air pollution control, such as reducing mobile source emissions through a reduction in vehicle miles of travel, are discussed in Chapter XIII of this report.

This chapter presents the major means available for the direct reduction of air pollutant emissions from point, area, and line sources. For each of these three categories of emissions, the major pollutants are discussed, as applicable, in terms of combustion and process (industrial) sources together with the possible means of control, the effectiveness of those means, and the attendant costs.

CONTROL TECHNOLOGY FOR POINT SOURCES

A number of control equipment alternatives are available for the direct control of gas stream emissions from point sources. The criteria used to select the appropriate types of gas-cleaning equipment are presented in Figure 68. The degree of collection efficiency required is dependent upon the relationship between emissions and emission standards. The required collection efficiency is an important factor in choosing a control equipment alternative from among those available. What also must be considered are the gas stream and particle characteristics and the characteristics associated with individual plant facilities. The emission control alternatives that meet the efficiency and plant facility requirements can then be evaluated in terms of costs, and the appropriate control system may be selected.

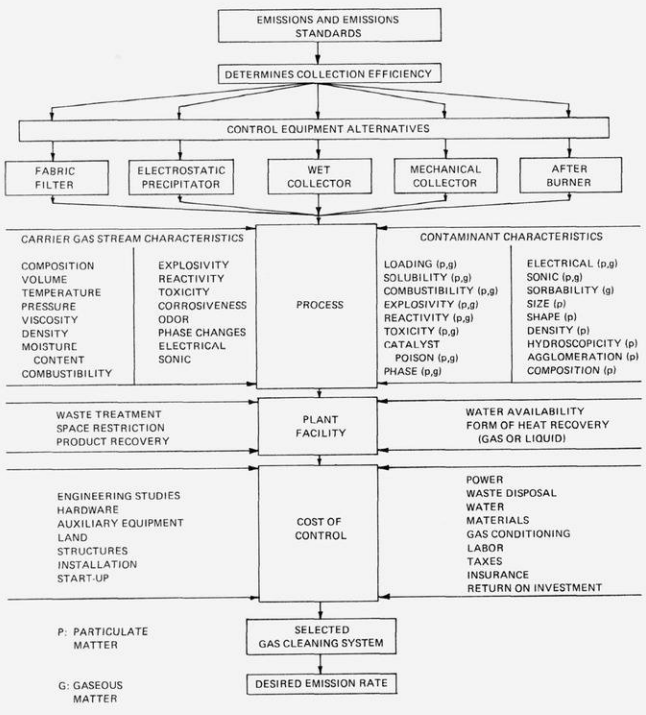
Particulate Matter Control

Control equipment for the gas cleaning of particulate matter generated by point sources may be classified into several types, including mechanical collectors (settling chambers), inertial separators (cyclones), wet collectors (scrubbers), electrostatic precipitators, fabric filters (baghouses), and equipment in which the pollutant is burned as a control means (afterburners). Some control systems incorporate elements of more than one type of control device into the same piece of equipment, and more than one type of control device may be used in a series in order to prolong the useful life of the equipment and to achieve the desired level of emissions control.

Removal of particulate matter from point sources may be required for both combustion operations—such as electric power generation plants, incinerators, and boilers—and processing operations—such as grain mills, cement plants, or steel mills. The choice of collection equipment for removing particulate matter from a gas stream depends on a number of factors related to the gas stream and particle characteristics: particle size, physical and chemical properties of the particles, concentration and mass of the particles to be handled, total volume of the gas stream, temperature and humidity of the gas stream, and

Figure 68

PROCESS OF SELECTION OF GAS-CLEANING EQUIPMENT



Source: U. S. Environmental Protection Agency.

the collection efficiency required.[1] Average collection efficiencies for various particulate control equipment are presented in Table 238.

Settling Chambers: A settling chamber is a mechanical device wherein the velocity of the gas stream is reduced enough to allow gravitational settling of suspended particles and mist. The chamber is most efficient for the removal of coarse particles, those greater than 40 microns (μ) in size, and becomes less efficient for smaller particles. Advantages of settling chambers include low pressure drop loss, low energy cost, simple design and maintenance, and the ability to handle large particles and high dust loads. Disadvantages include low collection efficiency, especially of small particles, and sensitivity to variable flow rates. Because of the inherent low efficiency, the simple settling chamber has limited use as a single collection device to meet air quality standards. The chamber is used primarily to provide low efficiency but economical precleaning of gas streams containing high loads of large particles prior to cleaning by a secondary device. Some major applications include kilns, furnaces, and feed mills. Settling chamber efficiencies for natural-draft coal-burning units, such as underfeed stokers, are estimated to be 50 to 60 percent.

Inertial Separators: Inertial separators operate by imparting centrifugal force to the particles that are to be removed from the exhaust gas stream. This centrifugal force is produced by directing the gas in a circular path or by effecting an abrupt change in the direction of the gas.

The most basic type of inertial separator is the single cyclone. A cyclone, which is an inertial separator without moving parts, separates particulate matter from a carrier gas by transforming the straight-line motion of a gas stream into a double vortex. In the double vortex the entering gas spirals downward at the outside and upward at the inside of the cyclone, as shown schematically in Figure 69. Because of the conical shape of the cyclone, the gas in the center vortex is compressed and has a greater velocity than the gas in the exterior vortex which, in fact, approaches zero near the cyclone wall. The centrifugal force produced by the spiraling motion of the gas stream carries the accompanying particulate matter toward the cyclone wall, where the slow-moving particles are removed by the force of gravity. The particles are then collected by a receiving container at the base of the cyclone.

The percentage of the particulate matter removed by the single cyclone from the exhaust gas stream—termed the collection efficiency—is between 95 and 99 percent for particle sizes larger than 40 μ. Collection efficiency declines rapidly for smaller particles, however, becoming less than 50 percent for particles smaller than 5 μ. The collection efficiency of the cyclone also decreases as the cyclone diameter and gas density increase, and as the inlet velocity of the gas, the density of the particulate matter, the cyclone body length, and the smoothness of the inner cyclone wall decrease. The poor collection efficiency of single cyclones in removing smaller parti-

[1] *Henry C. Perkins, Air Pollution, McGraw-Hill Book Company, New York, New York, 1974.*

Table 238

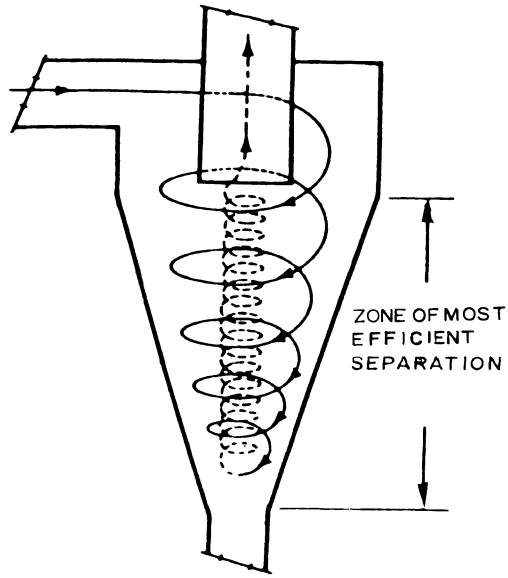
DISTRIBUTION BY PARTICLE SIZE OF AVERAGE COLLECTION EFFICIENCIES FOR VARIOUS PARTICULATE CONTROL EQUIPMENT

Type of Collector	Efficiency (percent)					
		Particle Size Range (microns)				
	Overall	0 to 5	6 to 10	11 to 20	21 to 44	>44
Baffled Settling Chamber	58.6	7.5	22	43	80	90
Simple Cyclone	65.3	12	33	57	82	91
Long-Cone Cyclone	84.2	40	79	92	95	97
Multiple Cyclone (12-inch diameter)	74.2	25	54	74	95	98
Multiple Cyclone (6-inch diameter)	93.8	63	95	98	99.5	100
Irrigated Long-Cone Cyclone	91.0	63	93	96	98.5	100
Electrostatic Precipitator	97.0	72	94.5	97	99.5	100
Irrigated Electrostatic Precipitator	99.0	97	99	99.5	100	100
Spray Tower	94.5	90	96	98	100	100
Self-Induced Spray Scrubber	93.6	85	96	98	100	100
Disintegrator Scrubber	98.5	93	98	99	100	100
Venturi Scrubber	99.5	99	99.5	100	100	100
Wet-Impingement Scrubber	97.9	96	98.5	99	100	100
Baghouse	99.7	99.5	100	100	100	100

Source: U.S. Environmental Protection Agency.

Figure 69

PATH OF GAS STREAM IN A CYCLONE



Source: U. S. Environmental Protection Agency.

cles is a limiting factor for many industrial applications, particularly combustion processes. This type of collector is best used to recover pneumatically transported material within an industrial facility or to capture large, coarse, nontoxic particles.

An improvement in the collection efficiency for smaller particles—in the range of 5 to 10 μ—is achieved by the multiple-cyclone collector. The multiple-cyclone, or multiclone, consists of a number of small diameter cyclones operating in parallel, having a common inlet and outlet for the gas stream. The flow patterns of the gas in a multiclone differ from that in a single cyclone in that the gas, instead of entering at the side to initiate the rotary motion, enters at the top of the collecting tube and has a swirling action imparted to it by a stationary vane positioned in its path. Individual tubes within the multiclone have diameters that usually range from one foot to as small as two inches. Well-designed multiclone collectors can achieve a collection efficiency as high as 90 percent for particles ranging in size from 5 to 10 μ.

Both the initial cost and the operating cost of a multiclone are higher than those of a single cyclone collector, and power requirements are correspondingly larger. The multiclone, however, still represents a low initial capital expenditure relative to wet scrubbers, electrostatic precipitators, or baghouses. The multiclone has been used on wood waste and coal boilers with a rated output of 250 million British Thermal Units (BTU's). However, this collector is not efficient enough to meet new source emission standards for coal-fired boilers. With respect to new sources, therefore, the multiclone is limited to use on wood-fired boilers with a rated output of less than 100 million BTU's, or as a primary collector preceding a more efficient secondary collector.

Wet Scrubbers: Wet collection devices use a variety of methods to wet particular matter and/or aerosols in order to facilitate their removal from the gas stream of combustion devices. Wet scrubbers are typically used when 1) fine particles are to be removed at high efficiency rates, 2) cooling may be desired and moisture is not objectionable, 3) gases are combustible, or 4) gaseous as well as particulate matter need to be removed.[2]

One of the objectives of wet scrubbers is adequate dispersion of the liquid, usually water, in order to achieve good contact between the particulate phase and the liquid phase. The simplest type of scrubber is a spray chamber in which spray nozzles inject the liquid into the gas stream at the top of the chamber. The stream velocity decreases as it enters the chamber. The particulate is captured by inertial impingement or diffusion, with the larger droplets falling to the bottom by gravity settling and being collected. A mist eliminator may be placed at the top of the tower to remove both excess clean water droplets and dirty droplets that are very small.

The collection efficiency of a well-designed spray chamber is approximately 90 percent for particle sizes down to 5 to 10 μ. Below this particle size the efficiency decreases rapidly. The spray chamber is extensively used as a primary collector for large, coarse particulate matter and as a gas cooler for high temperature gas streams. After the gas stream has been cooled and freed of large particles, a more efficient secondary collector may be used to complete the cleaning process. A variation of the simple spray tower is the baffled spray tower, which usually consists of vertical impingement baffle screens that are wetted by flushing sprays or overflow weirs. Applications of baffled spray towers on municipal incinerators have produced particulate removal efficiencies ranging from 10 to 50 percent. In its simplest form, the cyclone wet scrubber is achieved by installing nozzles in a ring inside a conventional dry cyclone. This scrubber features a tangential inlet in a cylindrical body where the spray acts on the particles in the outer vortex. The rotating gas containing the particulate matter is forced outward by centrifugal force against the wet inner wall of the cyclonic tower. Since centrifugal force is the principal collecting mechanism, efficiency is promoted by relatively high gas velocities. In general, wet cyclone scrubbers have a collection efficiency of from 90 to 98 percent for droplets between 5 and 50 μ and of 99 percent for those larger than 50 μ.[3]

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[2] *Kenneth Wark and Cecil F. Warner, Air Pollution: Its Origin and Control, Thomas Y. Crowell Company, New York, New York, 1976.*

[3] *Ibid.*

Other types of scrubbers include the orifice and venturi types. The orifice scrubber utilizes the air velocity to provide liquid contact. The flow of the air through a restricted, and usually curved, passage partially filled with water causes dispersion of the water. In turn, centrifugal forces, impingement, and turbulence cause wetting of the particles and their collection. This scrubber uses a large quantity of water, but most of it can be recirculated without pumps or spray nozzles.

A venturi scrubber has a rectangular or circular flow path which converges to a narrow throat and then diverges back into its original cross-sectional area. As the gas stream passes through the venturi tube, low pressure water is added at the venturi throat. Although contact time is relatively short, the extreme turbulence promotes very intimate contact. The wetted particles and droplets are then collected in a cyclone spray separator. The venturi scrubber is the most expensive wet collector and has the highest power requirement, but it also has the highest collection efficiency. This scrubber will collect particles in the 1 to 5 μ range with an efficiency of 99 percent.

A negative factor associated with wet scrubber units is maintenance and repair costs resulting from water-induced metal corrosion, and the water pollution problem attendant to such units. Wet scrubbers are widely used to control particulate matter in paper mills, foundries, and fertilizer plants.

Electrostatic Precipitators: Electrostatic precipitators are devices which remove particulate matter and liquid aerosols from a gas stream by using high-intensity electric fields to impart an electrical charge to the particles to be removed. The charged particles are forced to a grounded collecting surface, which may be wet or dry, and thus removed from the gas stream. Generally, the efficiency of the device increases with the length of passage through and the retention time in the precipitator.

The electrical field in an industrial precipitator is provided through application of high direct current voltage to a dual electrode system. One electrode is an electrical corona; the other electrode is usually a plate parallel to the plane of the corona wires. The corona generated in the high field region supplies the charge necessary for collection. The charged particles enter the region of the electric field and migrate toward the electrode with the opposite polarity. The charge on the particle is neutralized by the collecting electrode. The collected particles are commonly dislodged from the collector plates by periodic rapping or flushing. The deposit is then collected in a hopper or sump for later disposal.

Precipitators are appropriately utilized when 1) high efficiencies are required for removing fine dust, 2) very large volumes of gas are to be handled, or 3) valuable material may need to be recovered from the gas stream.[4]

Electrostatic precipitators are considered to be among the best available control technology. Overall collection efficiency can be as high as 99.9 percent, and there is no theoretical lower limit to the size of a particle that can be collected.

The advantages of precipitation include 1) relatively little maintenance is required, 2) high-temperature gas streams can be cleaned without affecting efficiency, 3) large-volume gas flows can be handled by varying the physical dimensions of the collection equipment, and 4) power requirements for large-volume gas streams are low in comparison to other types of collectors. Disadvantages include high initial investment costs and the limited ability of the precipitator to adequately handle a variable flow rate. Because of the large physical dimensions of the device, space requirements may preclude the retrofitting to older emission sources.

If the original gas stream contains a high dust load, a precleaner, usually a cyclone, may be used to reduce the dust loading to the precipitator. In order to achieve a higher efficiency rate than that possible with a single unit, two or more precipitators may be employed in a series or in multiple field sections.

Baghouses: The method used most widely to remove small particles with high efficiency consists of separating dust from the air stream by means of a fabric filter. The fabric is made into bags of tubular or envelope shape, then housed in a structure called a baghouse. Fabric filters are typically utilized in particulate control when 1) very high removal efficiencies are demanded, 2) the gas stream is above its dew point (in order to prevent condensation), 3) volumes are relatively low, or 4) temperatures are reasonably low.

In a baghouse, which acts as a large vacuum cleaner, the filtration process is achieved by the instantaneous effect of the particulate matter being trapped by the fabric filter, the characteristics of which are enhanced by the cumulative effect of the dust captured by the filter through time. The filters normally used have relatively large interstices and cannot achieve high collection efficiencies by simple sieving. Small particles are initially captured and retained by the filter by means of interception, impingement, diffusion, gravitational settling, and electrostatic attraction. The filter media must be compatible with the temperature and pH of the effluent, and include, in order of increasing cost, cotton, nylon, orlon, dacron, fiberglass, wool, and teflon. The dust accumulates in the fabric filter, producing a cake that further increases the collection efficiency of the sieving. In order to prevent extreme pressure drops across the collector, however, the accumulated dust must be periodically removed from the filter. Removal methods include mechanical shaking, jet-pulsing, and reverse-jet dedusting. Bags with mechanical shaking are used on large-scale installations.

Filtration is among the most efficient and reliable methods for the control of particulate matter from gas streams. Efficiency rates of 100 percent are possible for

[4] *Kenneth Wark and Cecil F. Warner, Air Pollution: Its Origin and Control, Thomas Y. Crowell Company, New York, New York, 1976.*

particles 5 to 10 μ in size. For particles 0 to 5 μ in size, the efficiency rate is 99.5 percent. Some disadvantages of filtration include sensitivity to filtering velocity and high temperatures, susceptibility of fabric to chemical attack, and negative reactions to high relative humidity.

Afterburners: The afterburner—direct flame or catalytic—is usually considered a control device for gaseous pollutants, but may be used to control particulate residue-free vapors, mists, smoke, and relatively small combustible particles. Afterburners are usually used when small volumes of gases and low concentrations of particulate matter are involved.[5] Because afterburners are used primarily to control gaseous emissions, they are discussed in a later section.

Applications of Particulate Controls: Air pollution emission control requirements virtually mandate the use of a highly efficient control system for the reduction of point source-generated particulate emissions. The viable alternatives for collection control include venturi wet scrubbers, electrostatic precipitators, and baghouses, possibly preceded by a primary collector to remove large particles. These three particulate control devices are generally considered to meet reasonably available control technology (RACT) standards. Some specific pollutant sources and the usual type of collection equipment used with these sources are discussed below.

Hot-mix asphalt plants, either portable or stationary, are common sources of dust emissions, which are principally released from the rotary drier. Dust emissions up to 6,700 pounds per hour have been measured. A variety of control equipment may be employed, including single or multiple cyclones plus multiple centrifugal spray chambers, baffled spray towers, baghouses, and medium draft loss venturi scrubbers. Overall collection efficiencies generally range from 95 to 100 percent.

Grain elevators handling large quantities of barley, rye, wheat, and corn emit dust as a result of loading and unloading operations, conveyance operations, and cleaning operations. Because of air pollution emissions and the potential explosion hazard of fine airborne particles, emissions control measures must be of the highest possible efficiency. This generally dictates that baghouse collectors be used for the collection of the particulate matter. Pneumatic connections to the baghouse are normally used in all emission areas.

Incineration has conventionally been utilized as a method of disposing of combustible waste products. Incinerators may use a variety of emissions collection equipment depending on size, fuel type, and design. Industrial and commercial installations have used a box-like single chamber incinerator to consume up to several tons of refuse per day. Refuse from apartment houses has been burned in chute-fed, single-chamber incinerators. An initial step in controlling incineration emissions is to ban open fires and single-chamber incinerators. Another step is multiple-chamber incineration, which burns refuse continuously or in a batch on grates. With multiple-chamber incineration, the exhaust gas stream is forced through several vertical and horizontal turns as it goes through the chambers. These chambers mix the gases and provide secondary combustion to decrease the amount of particulate emissions. Municipal incinerators may be controlled by baffled spray chamber scrubbers, medium to high draft loss venturi scrubbers, or electrostatic precipitators. High exhaust temperatures generally preclude use of a baghouse without auxiliary precooling equipment. Large incinerator installations may use electrostatic precipitators that are capable of handling large gas stream volumes with 99 percent efficiency.

Boilers may be classified as industrial or utility. Industrial boilers generally have a rated heat input of less than 250 million BTU's per hour. Utility boilers generally have a rated heat input of more than 250 million BTU's per hour and, owing to economies of scale, usually have an actual input of 1,000 million BTU's per hour and larger. Boilers fired on natural gas do not need particulate control equipment, and oil-fired units generally do not if fired with distillate fuels. Stringent control requirements may dictate the use of a collector with some high ash residual oils. This collector may be a multiclone with small diameter cones or a venturi scrubber.

Boilers with a rated heat input of 100 million BTU's per hour or less sometimes use wood and woodwaste, such as sander dust, wood shavings, and sawdust, for fuel. If the fuel is fed to the boiler by stoker and is carefully mixed to make it as homogeneous as possible, the boiler emissions may be adequately controlled by a well-designed multiclone collector. If fuel is fed to the firebox by windswept spouts and fuel homogeneity cannot be ensured, a high-efficiency wet scrubber or even a baghouse may be needed to meet emission limits. Removal efficiencies of between 98 and 99 percent are possible using these control devices.

Large coal-fired boilers are not able to meet particulate emission limits without collection equipment. Small industrial coal-fired boilers are able to meet existing source standards with a multiclone collector if the operation of the boiler is carefully monitored to ensure efficient combustion. Underfeed stoker-fired boilers can meet existing emission limitations when provided with settling chambers. A venturi scrubber may be used to control emissions but is not in common use on a source of this type. New source standards require the use of an electrostatic precipitator or even a baghouse.

Utility boilers are almost invariably controlled by an electrostatic precipitator because of its high control efficiency, low maintenance and reliability, and low power requirements, and because of the ready supply of electricity. With the introduction of sulfur dioxide scrubbers, some utilities have chosen to scrub the particulate emissions and sulfur dioxide in the same unit. Sulfur

[5] *Frank L. Gross, Jr., Handbook on Air Pollution Control, 1973.*

dioxide scrubbers are discussed in the next section. Utilities are also starting to use baghouse collectors to control particulates. Although expensive, the baghouse is, in some cases, the only means to collect emissions from some low resistivity, low sulfur western coals. The cost of the equipment is offset by not having to scrub sulfur oxides from the exhaust gas stream.

Other Control Methods: Several control methods other than interception and collection in a carrier gas stream may be used to reduce particulate matter from stationary point sources. These methods include energy substitution, energy conservation, operational changes, and modification or replacement of equipment.

Energy substitution may result in a reduction in more than one category of pollutant emissions. For example, a switch in boiler fuel from high sulfur coal to natural gas would result in a reduction in not only particulate matter, but sulfur oxides as well. As a result of periodic seasonal acute shortages of natural gas combined with long-term decreasing domestic reserves and increasing prices, however, this alternative may become unattractive. In fact, in many locations new large boilers cannot be served with natural gas fuel due to allocation restrictions. Finally, coal- or oil-generated power or heat may, in some cases, be replaced by hydro- or nuclear-generated electricity.

By increasing the efficiency of combustion or process operations, and by reducing the demand for process or space heating, energy generation requirements can be lowered, thereby reducing the initial pollutant generation. Changing the mode of operation of process equipment may result in the prevention of pollutant formation. Finally, the use of different processes, raw materials, or new equipment may produce fewer emissions. For example, a foundry cupola that needs control equipment to comply with emission standards might be replaced by electric induction melting, which usually does not require particulate control equipment.

Costs: Although cost elements vary from one installation to another, the basic elements involved in air pollution control equipment installation include:

1. Capital base costs of control equipment;
2. Depreciation of all control equipment;
3. Overhead costs, including taxes, insurance, and interest for control equipment;
4. Operation and maintenance costs;
5. Collected waste material disposal costs; and
6. Other capital for research and development and land and engineering studies to determine and design optimum control systems.[6]

[6] *Based on information from the U. S. Environmental Protection Agency.*

The "installed costs" of air pollution control equipment, including auxiliary equipment, usually run from two to three times the base price of the equipment, with the cost of the basic control device varying from 25 to 90 percent of the total capital costs. The "installed costs" generally include control hardware costs, auxiliary hardware costs, and costs for site installation. Cost differences may result from variations in factors such as auxiliary equipment, local code requirements, gas stream characteristics, and plant location.

When considering the costs of a given pollution control system, one should consider 1) raw materials and fuels used in the process, 2) alterations in process equipment, 3) control hardware and auxiliary equipment, and 4) disposal of collected emissions. In general, as control efficiency improves, the quantity of emissions is reduced and the cost of control increases. Also, as the cost of control increases, greater increments of cost are usually required for corresponding increments of emission reduction.

In Figures 70, 71, and 72, economic information is provided on the costs of some particulate control equipment. The costs are expressed in 1975 dollars. Although substantial variations from the average costs cited should be expected in individual installations, the relative costs between the different control methods should be valid. Table 239 presents installed costs for particulate control equipment for 1972. The annual operating costs of particulate control equipment will depend on 1) the volume of gas to be cleaned, 2) system pressure drop, 3) operating time, 4) consumption and cost of electricity, 5) fan efficiency, and 6) when required, the costs of scrubbing liquor.

The basic operating costs of mechanical collectors are electrical power costs, which vary with unit size and pressure drop. In gravitational collectors, the pressure drop is low and therefore operation costs are insignificant. Wet collectors require power and scrubbing liquor, and power costs vary with equipment size, liquor circulation, and pressure drop. Liquor consumption, in turn, varies with equipment size and stack temperatures. Figure 70 presents the capital and operating costs of venturi scrubbers.

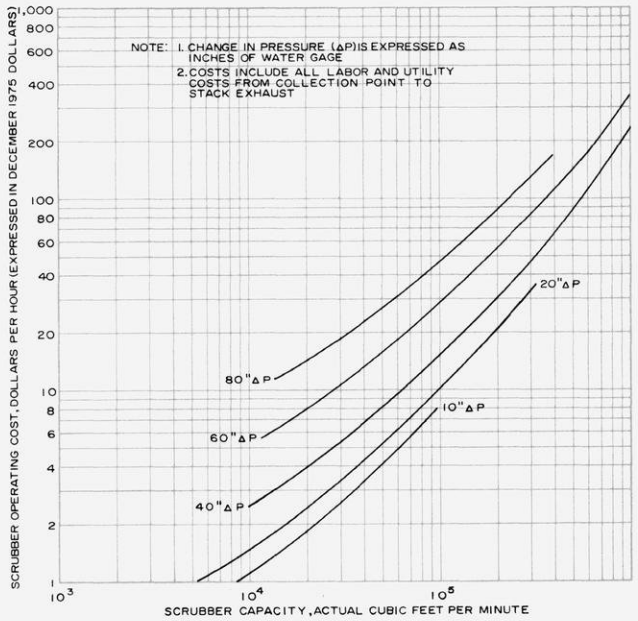
The major operating costs of electrostatic precipitators include the power costs for gas ionization and fan operation. Power costs vary with the efficiency and size of the equipment. In addition to requiring regular maintenance personnel, electrostatic precipitators require the services of an engineer or highly trained operator. The cost of a basic electrostatic precipitator is a function of the plate area, and the size of the plate area is a function of the removal efficiency required. Figure 71 presents the capital and operating costs of high-voltage electrostatic precipitators.

The most efficient collection mechanism for controlling many types of particulate emissions is a filtering device. The operation costs for fabric filters vary directly with equipment size and pressure drop and include power costs for fan operation and bag cleaning. Major maintenance costs include the costs of servicing the fan and

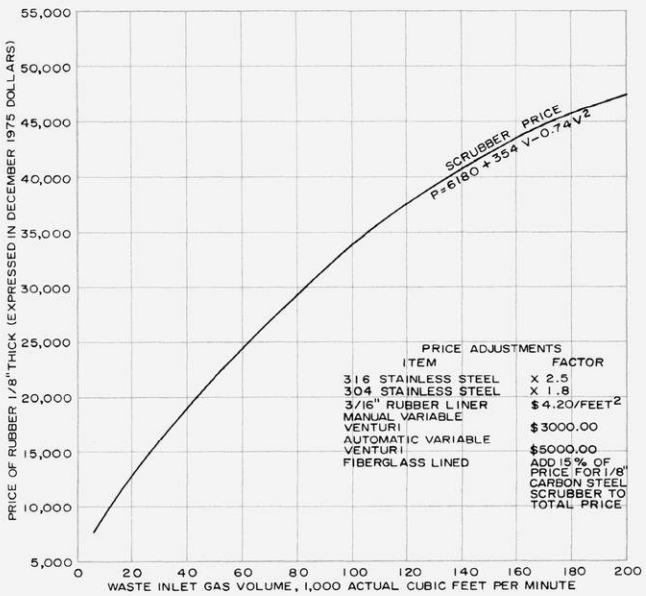
Figure 70

CAPITAL AND OPERATION COSTS OF VENTURI SCRUBBERS

VENTURI SCRUBBER OPERATING COSTS
VERSUS VOLUME AND PRESSURE DROP



ONE-EIGHTH THICK CARBON STEEL FABRICATED
SCRUBBER PRICE VERSUS VOLUME

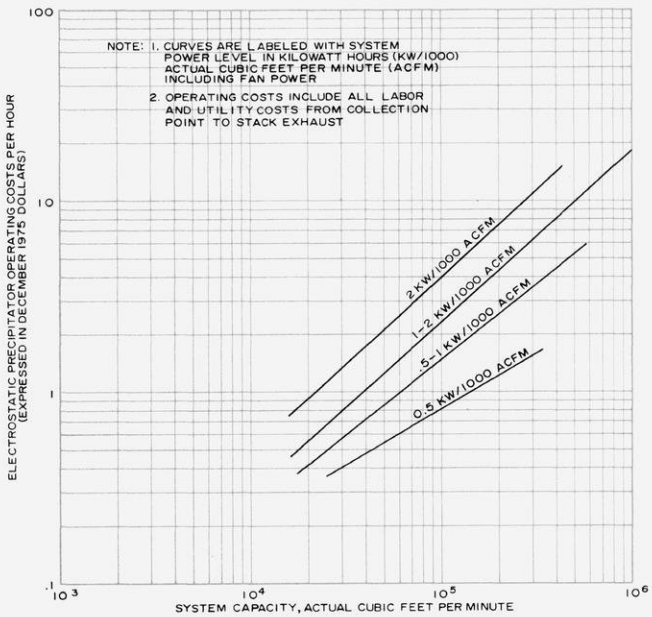


Source: U. S. Environmental Protection Agency, Capital and Operating Costs of Selected Air Pollution Control Systems, EPA 450/3-76-014, May 1976.

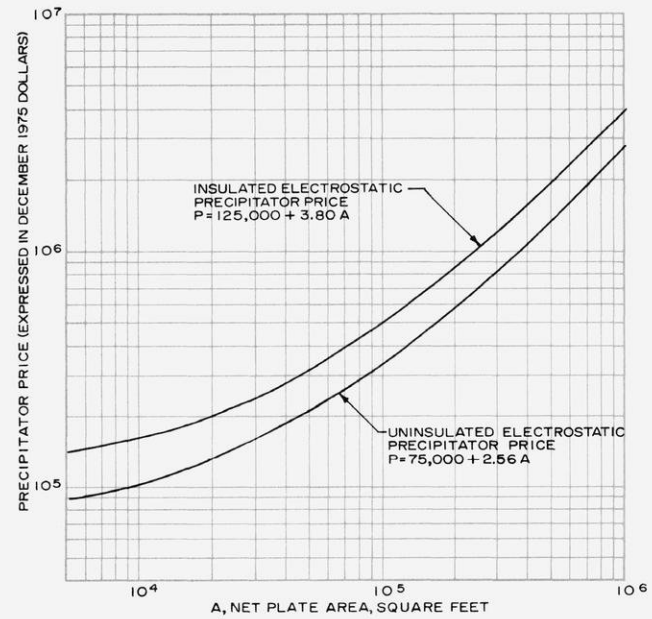
Figure 71

CAPITAL AND OPERATION COSTS OF HIGH-VOLTAGE ELECTROSTATIC PRECIPITATORS

ELECTROSTATIC PRECIPITATOR OPERATING COSTS
VERSUS VOLUME AND POWER CONSUMPTION



DRY TYPE ELECTROSTATIC PRECIPITATOR
PURCHASE PRICES VERSUS PLATE AREA



Source: U. S. Environmental Protection Agency, Capital and Operating Costs of Selected Air Pollution Control Systems, EPA 450/3-76-014, May 1976.

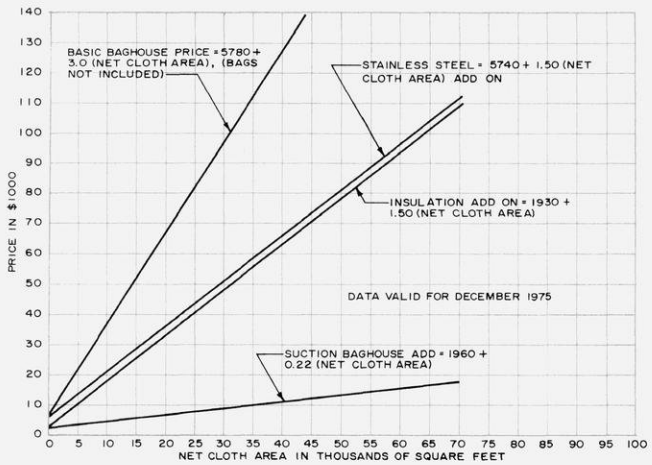
shaking mechanisms, emptying the collection bin, and replacing worn bags. The capital costs for fabric filter baghouses, presented in Figure 72, are based on net cloth area—the total filter area available for filtration. The operating costs are related to volume and pressure drop.

Most particulate matter collected by air pollution control systems has little economic value, but must, nonetheless, be disposed of in an economically and environmentally acceptable manner. Among the alternatives for handling the collected material are returning it to the process

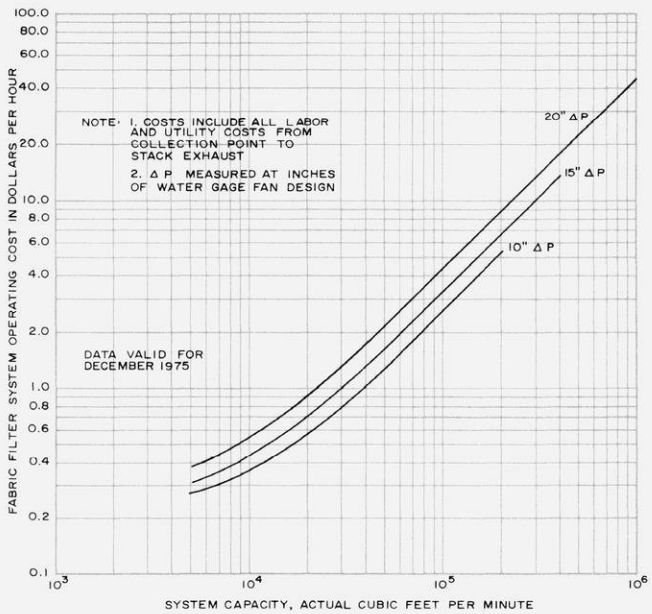
Figure 72

CAPITAL AND OPERATION COSTS OF FABRIC FILTERS

CONTINUOUS, PRESSURE, MECHANICAL SHAKER
BAGHOUSE PRICES VERSUS NET CLOTH AREA



FABRIC FILTER OPERATING COSTS
VERSUS VOLUME AND PRESSURE DROP



Source: U. S. Environmental Protection Agency, Capital and Operating Costs of Selected Air Pollution Control Systems, EPA 450/3-76-014, May 1976.

stream, selling it in the form collected, converting it to a marketable product, or discarding it in the most economical manner.

Sulfur Oxides Control

Sulfur oxides from man-made point sources are produced either by combustion processes, principally those of electric power generation plants and boilers, and or by industrial processes, such as oil refineries, petrochemical plants, and sulfuric acid plants. The single most important man-made source of atmospheric sulfur oxides is the burning of coal and oil in electric power generation plants. The amount of sulfur dioxide, the principal sulfur compound emission produced in the combustion process, varies with the nature of the fossil fuel—the sulfur content of oil and coal varying from 0.1 to over 5 percent by weight—and with the total quantities of fossil fuels burned. During the combustion process, most of the sulfur in the fuel is converted to sulfur dioxide. In some combustion processes, up to 5 percent of the sulfur may be converted to sulfur trioxide, the anhydride of sulfuric acid.

Potential methods for the control of sulfur dioxide emissions from fossil fuel combustion include:

1. The use of flue-gas desulfurization systems,
2. The use of desulfurized coal and oil,
3. The use of low sulfur fuel, and
4. Increased stack height to increase atmospheric dispersion.[7]

Currently, the principal approach to flue-gas desulfurization involves absorption or scrubbing, through which the contaminant is transformed into a liquid state. The liquid removes the sulfur emissions from the gas stream and the cleaned gas is exhausted to the ambient air. This type of flue-gas desulfurization (FGD) process is generally applicable to flue gases from coal and oil combustion in medium to large boilers and power plants. More than 50 sulfur dioxide removal processes have been tested to find effective, reliable, and economical ways to remove dilute sulfur dioxide emissions from flue gases. Flue-gas desulfurization processes that have been demonstrated to be effective include magnesium oxide, lime and limestone, Wellman-Lord, double alkali, Chiyoda, and catalytic oxidation systems.

Magnesium Oxide Systems: The magnesium oxide system is regenerable, and uses magnesium oxide (MgO) to remove sulfur dioxide from the emission stream. Magnesium oxide has a relatively high reactivity with sulfur dioxide, and the system offers a removal efficiency of greater than 90 percent.

The regenerative process requires that the fly ash in the flue gas be removed before scrubbing with magnesium oxide slurry. Before the flue gas is fed into an aqueous slurry of magnesium oxide, magnesium sulfate, and magnesium sulfite, it is sent through a venturi absorber scrubber to reduce the load of particular matter. The major reaction in the absorber is the formation of magnesium sulfite from sulfur dioxide and magnesium oxide. Magnesium sulfite from the scrubber loop is dried and then calcined to drive off a stream of 10 to 15 percent

[7] *Kenneth Wark and Cecil F. Warner, Air Pollution: Its Origin and Control, Thomas Y. Crowell Company, New York, New York, 1976.*

Table 239

INSTALLED COSTS OF CONTROL EQUIPMENT
FOR GAS STREAM PARTICULATE CONTROL: 1972

Type of Collector	Approximate Installed Cost in 1972 Dollars by Gas Flow Rates (actual cubic feet per minute)			
	2,000	5,000	10,000	40,000
Centrifugal Precipitator	4,315	8,540	10,788	55,738
Cyclone	6,230	12,331	15,576	80,476
High-Voltage Electrical Precipitator	25,987	51,433	64,968	335,668
Low-Voltage Electrical Precipitator	17,477	34,589	43,692	225,742
Multiple Cyclone	1,680	3,325	4,200	21,700
Automatic Cloth Filter	3,379	6,688	8,448	43,648

NOTE: Installed dust collector cost includes purchased cost of dust collector (motor and drive for applicable types), handling and setting, piping and ductwork, concrete, steel, instrumentation, electrical insulation (if required), paint, and indirect costs (prime contractor engineering and construction overhead).

Source: U.S. Environmental Protection Agency.

sulfur dioxide. The regenerated magnesium oxide is then returned to the scrubber.[8] This regeneration can be accomplished at the plant site or at some remote location since magnesium sulfite and magnesium oxide are chemically stable enough to be transported. The sulfur dioxide generated in the calcining process is most commonly converted into sulfuric acid, which may be sold as a by-product.

An operational advantage of this system is the ability to operate during extended outages of the regeneration facility if adequate supplies of magnesium oxide are maintained. Unlike the lime/limestone system, the magnesium oxide regenerator system produces no waste sludge and, therefore, no attendant solid waste disposal problem. But, as with the lime/limestone system, additional heat may be required to increase the temperature of the flue gas for proper buoyancy in the stack. Although efficiencies of over 90 percent have been demonstrated with this system, the high costs have inhibited widespread application.

Lime/Limestone Systems: Original designs of lime/limestone removal systems called for limestone to be injected directly into the boiler. The high temperatures converted the limestone into more reactive lime which then combined with the sulfur dioxide produced by the combustion process. Problems with this system included plugging and erosion of the boiler.

Improved processes utilizing a lime slurry scrubbing system have proved more successful. In this process, the gas stream is scrubbed with a 5 to 15 percent slurry containing lime (CaO) and limestone ($CaCO_3$). The sulfur dioxide reacts with the slurry to form sulfite and sulfate salts. The solids, including coal fly ash, are separated from the slurry and discharged into a settling pond. The sulfur dioxide removal efficiency of the lime/limestone system is determined by the reactivity of the scrubbing liquid, amount of gas-liquid contact, gas-to-liquid flow ratio, gas residence time, and number of scrubber stages.

The system has achieved sulfur dioxide removal rates of between 90 and 92 percent and a particulate removal efficiency of about 99 percent. The reliability, as well as availability, of these systems is controversial, but is generally considered to be about 80 percent. However, the use of a battery of scrubber modules allows the modules to be rotated in service so that regular maintenance can be provided without reducing boiler loads. Because of the cooling of the gas stream caused by the scrubbing, some type of gas reheating system may be required to obtain adequate buoyancy for plume rise from the stack. When only part of the sulfur oxide needs to be removed in order to meet emission standards, the simplest method now used is to bypass part of the flue gas around the scrubbers and recombine the gas stream before it goes to the stack.

A major drawback to the use of the lime/limestone scrubber is the generation of large amounts of sludge composed of aqueous calcium sulfate or calcium sulfite. One approach to disposal is oxidation of the calcium sulfite to calcium sulfate, which can be readily dewatered. Calcium sulfate is water soluble, however, so further treatment is necessary if leaching is a problem. Another approach is to dewater the sludge and deposit it in alternate layers with fly ash. This arrangement allows good drainage and restricts rewatering of the sludge.

[8] *Ibid.*

Commercial processes involving the addition of fly ash and lime are now available to chemically fix the sludge. The mixture, when compressed, sets up into a hard durable mass.

Lime/limestone scrubbing is the best understood technology for sulfur dioxide removal and is expected to be the prevalent control method into the 1980's. Scrubbers are very expensive, both in capital and operating costs, because high-grade steels that are resistant to wear and corrosion must be used in the construction of the devices. For a 500-megawatt (MW) generating plant, up to 25 percent of the total capital cost may be expended for sulfur dioxide scrubbing equipment, including multiple modules and backup equipment. With the rising cost of the very low sulfur coal needed to meet present federal emission standards without scrubbers, the system may pay for itself within half the life of the plant.

Wellman-Lord System: The Wellman-Lord system, a regenerative system, uses a solution of sodium sulfite to remove sulfur dioxide from flue-gas streams. After thorough removal of particulate matter by a precleaning device, the gas stream enters a simple two-stage contacting device. Flue gas is contacted by a sodium sulfite solution and passes out the top of the absorber after the sulfur oxide level has been reduced to the desired level. The reaction between sulfur dioxide and sodium sulfite is:

$$SO_2 + Na_2SO_3 + H_2O \rightarrow 2NaHSO_3.$$

The solution leaving the bottom of the tower, now rich in bisulfite, is sent to a surge tank, then to a forced circulation evaporator-crystallizer system. In the evaporator-crystallizer system, heat is applied by a low-pressure exhaust system. In an evaporator, the bisulfite is thermally decomposed into sulfur dioxide and sulfur sulfite, the latter of which can be recovered and reused.

An advantage of this system is that it is a regenerative system and thus does not produce a sludge disposal problem. In addition, the system is adaptable to rapidly varying load conditions. Another advantage, if physical placement near the stack is limited, is that the absorption part of the process can be separated from the regeneration part by a considerable distance. This allows one regeneration system to service several absorbers on several stacks.

Collection efficiencies of this system have been reported at 90 percent or above, but the technology has not proven to be highly reliable. The capital cost of the Wellman-Lord system is substantially more than that of the lime/limestone system.

Double Alkali Systems: The double alkali system uses two alkalies, one for absorbing the sulfur dioxide and one for regenerating the spent absorbing liquor. A sodium alkali such as sodium hydroxide or sodium sulfite is usually the absorbing agent and calcium hydroxide is usually the regenerating agent.

With this system, the scrubbing solution and exhaust gas stream are contacted counter-currently in an exhaust gas tower. The sodium hydroxide combines with sulfur dioxide to form sodium sulfite. The active sulfite reacts further to form sodium bisulfite or sodium sulfate. The scrubber gases are discharged through the top of the absorber and to the stack while the scrubber solution is discharged through the bottom of the tank into a recycle container. Because of the formation of sodium sulfate, the regeneration process must be capable of regenerating both the sulfate and sulfite, although the sulfate reaction is complicated by the solubility of calcium sulfate. Thus, the solution chemistry must be carefully monitored to provide a dilute hydroxide concentration while maintaining sufficient sulfate levels to cause precipitation of the calcium sulfate.

The large amount of lime added to dissolve out the sodium sulfate increases the level of calcium ions in the return scrubber stream. These calcium ions may form insoluble calcium salts and precipitate in the scrubber, causing scaling problems. Sodium carbonate and carbon dioxide are added to the regenerated solution, producing sodium hydroxide and insoluble calcium carbonate. The calcium carbonate formed is used as a pretreatment for the scrubber effluent; calcium carbonate reacts with the sodium bisulfite in the effluent stream to form insoluble calcium sulfite and sodium sulfite. Finally, calcium sulfite from the regeneration process is pumped to a batch holding tank and dewatered by vacuum filtration. The waste material is then transported to a landfill for disposal.

The double alkali system has the advantage over the lime/limestone system of eliminating many of the scaling problems involved in the latter. The double alkali system is also more efficient in scrubbing out sulfur dioxide and can, therefore, operate at lower liquid-to-gas ratios. In addition, the double alkali system requires a lower pressure drop in the absorber, and has fewer absorber stages. The costs of the double alkali system appear to be competitive with lime/limestone systems.

The sodium alkali used in this system has received competition from ammonia as an absorber for sulfur dioxide. One disadvantage of ammonia is the fume produced by the more volatile ammonia cation. However, ammonia has the advantage of producing ammonium sulfate, a more desirable side product, which can be regenerated or sold as a fertilizer.

Chiyoda Systems: Chiyoda International Corporation, a Japanese firm, has developed a flue-gas desulfurization system based on scrubbing with dilute sulfuric acid. The exhaust gases are first pretreated in a venturi wet scrubber to remove particulates and chlorides and reduce gas temperature. The gases are then treated in a packed absorption tower with a dilute sulfuric acid (about 2 percent by weight) solution. The sulfur dioxide in the flue gas dissolves in the scrubbing solution and combines with water to form sulfurous acid. The scrubbed gas passes out the tower and into the stack. The absorber

effluent is sent to an oxidizing tower where air is blown into the solution. A ferric iron catalyst (as iron sulfate in the scrubber effluent) is used to convert the sulfurous acid to sulfuric acid. Most of the adsorbed liquid is then recycled to the absorption tower. To keep the sulfuric acid concentration low, a purge stream is bled to a crystallizer and treated with limestone. The sulfuric acid and limestone react to form carbon dioxide, water, and insoluable calcium sulfate. Vacuum filtration is used to remove the precipitate, and the sludge is transferred to a landfill.

On commercial boilers in Japan, the system has achieved sulfur dioxide removal efficiencies of over 90 percent, with 94 percent reliability on oil-fired boilers. A pilot experiment on a coal-fired plant has produced encouraging results in controlling sulfur dioxides.

Catalytic Oxidation: A number of desulfurization processes are based on the principle of absorption—for example, the magnesium oxide and double alkali systems. In contrast, the catalytic oxidation process converts sulfur oxides to sulfuric acid by passing the flue gases over a vanadium pentoxide catalyst, which promotes the conversion of sulfur dioxide to sulfur trioxide. The sulfur trioxide then reacts with water vapor to produce a low concentration of sulfuric acid.

As indicated in Figure 73, the flue gas from the boiler is passed through a high-efficiency particulate separator (for example, an electrostatic precipitator) to remove the fly ash. After the gas stream passes through the catalyst bed, the gas is cooled and passed through a heat exchanger where this acid is condensed. A mist eliminator is used to remove the sulfuric acid mist from the gas stream, which is fan-ejected to the stack. This system is simple, requires no recycling of the vanadium pentoxide, and is capable of removal efficiencies of 85 percent or greater. Disadvantages of catalytic oxidation include high temperature gas cleaning and corrosion problems. Also, the process is feasible only on new plants.[9]

Because electric generating power plants are major sources of sulfur dioxide emissions, flue-gas desulfurization systems have been used mainly to control emissions from these large sources. Flue-gas desulfurization systems have also been developed to fit smaller industrial boilers, both new and retrofit units. Sulfur dioxide control systems have been designed for more than 200 industrial boilers in the United States with exhaust volumes ranging from more than one million down to as low as 6,000 cubic feet per minute. Sodium scrubbing and double alkali systems are currently the most commonly used flue-gas desulfurization systems on industrial-size boilers, although more than 10 other control systems are also used.

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[9] *Henry C. Perkins, Air Pollution, McGraw-Hill Book Company, New York, New York, 1974.*

In addition to wet sulfur dioxide scrubber systems, dry scrubber systems with removal efficiencies exceeding 90 percent and utilizing soda ash or lime as reagents have been developed for small boilers. The reagent is sprayed into an absorber chamber where contact is made with the boiler flue gas. The gas stream is then directed to a particle collector, either an electrostatic precipitator or baghouse, where the fly ash and the powder containing the absorbed sulfur dioxide are removed and disposed of in a dry form. This system has the advantages of removing both the particulate matter and sulfur dioxide in a combined operation and of eliminating the wet sludge disposal problem.

Active research continues on ways to improve the efficiency and reliability of flue-gas desulfurization systems. Of particular note is preliminary evidence which indicates that the addition of adipic acid, an inexpensive food additive, to flue gas scrubbers increases the efficiency of sulfur dioxide removal. Use of this acid promises more efficient and consistent removal of sulfur dioxide, with average removal rates of up to 95 to 97 percent, plus an estimated 10 percent reduction in operating costs.

None of these flue-gas desulfurization systems has been proven to be trouble-free, with problems including scale formation and plugging in absorber units and associated equipment; plugging of mist eliminators, lines, and some types of absorbers; and failure of pumps, piping, reheaters, fans, and stack linings. In addition, with the nonregenerative scrubber systems, serious problems exist in achieving economical and environmentally acceptable means of disposing of waste sludge containing calcium sulfite, gypsum, and fly ash.

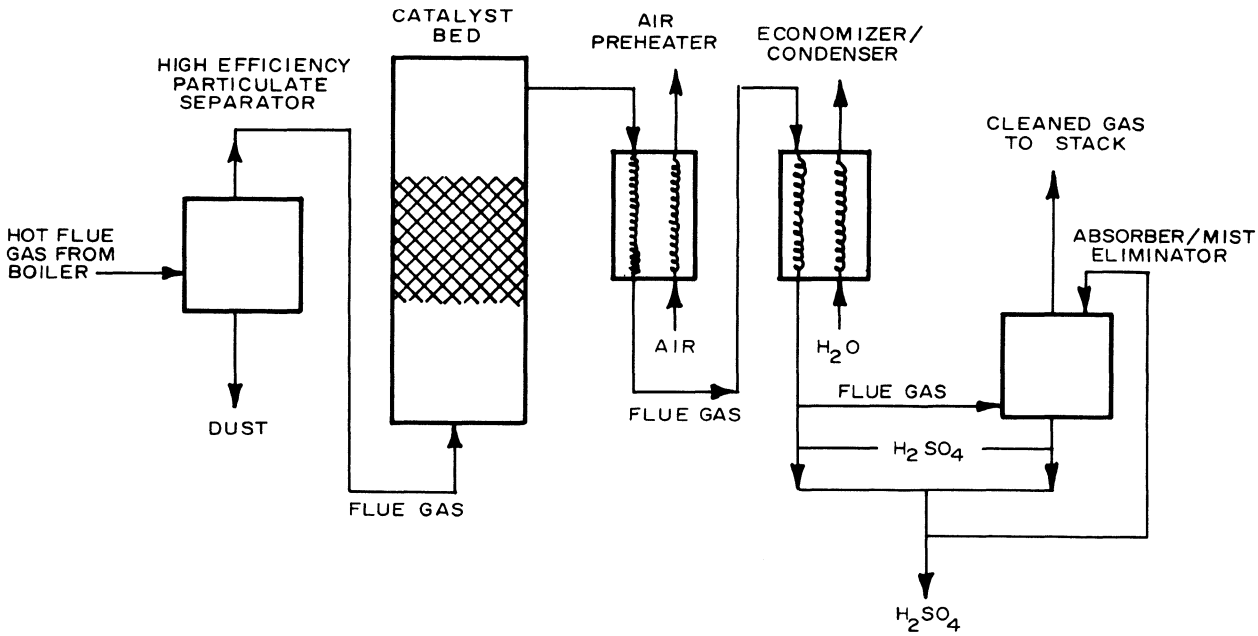
Desulfurization of Coal and Oil: A second approach to the reduction of sulfur oxide is to remove part of the sulfur in the fuel before it is burned. Sulfur occurs in coal in both organic and inorganic forms. Iron pyrite (FeS_2), the inorganic form, is present as discrete particles and therefore subject to physical removal by gravity washing. The sulfur in pyritic form is generally 40 percent or less of the total sulfur in coal, and water washing may reduce this total by one-third. In the organic form sulfur is chemically bound in the coal and therefore more costly and more difficult to remove. A removal process might involve coal gasification or conversion to synthetic oil.

The desulfurization of oil is now technically possible with commercially available but expensive processes. As reserves of oil and natural gas are consumed, the desulfurization of coal may become economically attractive, and competitive with the desulfurization of flue gases.

Change to Lower Sulfur Fuels: In both large and small combustion units, sulfur dioxide reduction can be achieved by the use of fuels that are naturally low in sulfur. The option of switching to inherently low-sulfur natural gas is limited as a long-term alternative, however, because of limited domestic supplies, and the establishment of priorities for various use categories set by the federal regulatory agency.

Figure 73

CATALYTIC OXIDATION PROCESS



Source: U. S. Environmental Protection Agency.

Crude oil varies in its sulfur content from below 0.25 to over 2.0 percent by weight. As a result of the refining process, most of the sulfur remains in the heavier distillate fuels, resulting in residual fuel oils which may have four to six times the sulfur content of crude oil. The residual fuel oil commonly burned in power plants contains between 0.75 and 2.5 percent sulfur. Refining processes have been developed which reduce the sulfur content in residual fuel oil to less than 1.0 percent. A simple way to reduce the sulfur content of fuel oil is to blend high-sulfur residual oils with low-sulfur distillate oils. Changes in fuel oil grades and sulfur levels usually do not present problems in firing, although special equipment is needed to burn certain residual oils. A reduction in sulfur content does not change the firing characteristics of the fuel oil, so sulfur dioxide control can be readily accomplished if a lower sulfur fuel is available.

Because much of the coal used by industry and electrical utilities in the United States has generally had a high sulfur content, a reduction in sulfur oxide emissions can be accomplished by changing to low-sulfur coal. Problems occur when the coal being fired is not compatible with the stoker in small boilers. For example, western low-sulfur coal cannot be fired in certain types of boiler stokers. Coal size, ash content, and the slagging properties of the coal determine which coals can be used with which stokers.

A switch to low-sulfur coal can reduce sulfur dioxide emissions but at the same time increase particulate matter emissions if the ash content of the coal is higher than that of the original coal. Low-sulfur coal may affect the electrical resistivity of the electrostatic precipitator and result in a reduction in particulate removal in the precipitator. Therefore, when considering different types of coal, the boiler compatibility, as well as emission performance, of the coal must be considered.

Tall Stack Dispersion: Tall stack dispersion is a controversial approach to the reduction of ground-level sulfur emissions. This method is based on the increased dispersion at high altitudes so that ground-level concentrations are acceptable at all times. This control strategy does not rely on fuel desulfurization systems, which have not been reasonably proven to be practicable to date, or on sulfur removal processes.

Desulfurization Costs: The costs of effluent desulfurization from electric power generation plants vary in large part with the sulfur content of the fuel and plant generation capacity. Capital investment and operating costs for several leading desulfurization processes are presented in Table 240.

Nitrogen Oxide Control

The two most important forms of nitrogen oxide pollutants are nitric oxide (NO) and nitrogen dioxide (NO_2).

Table 240

CAPITAL INVESTMENT AND OPERATING COSTS FOR EFFLUENT DESULFURIZATION SYSTEMS

Coal-Fired Power Unit (90 percent sulfur dioxide removal)

Generating Capacity	Unit Status	Sulfur Content (percent)	Costs Time Period (years)	Type of Costs	Limestone Systems		Lime Systems		Magnesium Oxide Systems		Sodium Systems		Catalytic Oxidation Systems	
					Costs (dollars)	Dollars per Kilowatt Mills per Kilowatt Hour	Costs (dollars)	Dollars per Kilowatt Mills per Kilowatt Hour	Costs (dollars)	Dollars per Kilowatt Mills per Kilowatt Hour	Costs (dollars)	Dollars per Kilowatt Mills per Kilowatt Hour	Costs (dollars)	Dollars per Kilowatt Mills per Kilowatt Hour
200 Megawatts	New	3.5	30	Capital Operating	13,031,000 3,921,500	65.2 2.80	11,749,000 4,163,900	58.7 2.97	14,139,000 4,776,800	70.7 3.41	16,198,000 5,971,700	81.0 4.27	19,537,000 4,232,700	97.7 3.02
200 Megawatts	Existing	3.5	20	Capital Operating	11,344,000 3,867,100	56.7 2.76	13,036,000 4,822,000	65.2 3.44	14,372,000 5,091,200	71.9 3.64	17,149,000 7,377,700	85.7 5.27	17,735,000 5,849,400	88.7 4.18
500 Megawatts	Existing	3.5	25	Capital Operating	23,088,000 7,892,600	46.2 2.26	26,027,000 9,612,400	52.1 2.75	26,026,000 9,607,900	52.1 2.75	31,208,000 14,658,000	62.4 4.19	37,907,000 12,399,600	75.8 3.54
500 Megawatts	New	2.0	30	Capital Operating	22,600,000 6,774,700	45.2 1.94	20,232,000 6,915,100	40.5 1.98	22,958,000 7,523,400	45.9 2.15	26,706,000 9,101,700	53.4 2.60	42,520,000 8,801,200	85.0 2.51
500 Megawatts	New	3.5	30	Capital Operating	25,163,000 7,702,700	50.3 2.20	22,422,000 8,101,900	44.8 2.31	26,406,000 9,210,800	52.8 2.63	30,491,000 11,601,500	61.0 3.31	42,736,000 8,873,900	85.5 2.54
500 Megawatts	New	5.0	30	Capital Operating	27,343,000 8,522,200	54.7 2.43	24,272,000 9,170,100	48.5 2.62	29,355,000 10,768,500	58.7 3.08	33,709,000 13,983,300	67.4 4.00	42,928,000 8,940,500	85.9 2.55
1,000 Megawatts	Existing	3.5	25	Capital Operating	35,133,000 12,752,900	35.1 1.82	38,133,000 15,301,400	38.1 2.19	38,717,000 15,481,900	38.7 2.21	47,721,000 15,118,500	47.7 3.59	62,913,000 21,460,800	62.9 3.07
1,000 Megawatts	New	3.5	30	Capital Operating	37,725,000 11,874,100	37.7 1.70	32,765,000 12,553,100	32.8 1.79	38,865,000 14,347,000	38.9 2.05	45,832,000 18,391,300	45.8 2.63	69,889,000 13,957,600	69.9 1.99

Oil-Fired Power Unit (90 percent sulfur dioxide removal)

Generating Capacity	Unit Status	Sulfur Content (percent)	Costs Time Period (years)	Type of Costs	Limestone Systems		Lime Systems		Magnesium Oxide Systems		Sodium Systems		Catalytic Oxidation Systems	
					Costs (dollars)	Dollars per Kilowatt Mills per Kilowatt Hour	Costs (dollars)	Dollars per Kilowatt Mills per Kilowatt Hour	Costs (dollars)	Dollars per Kilowatt Mills per Kilowatt Hour	Costs (dollars)	Dollars per Kilowatt Mills per Kilowatt Hour	Costs (dollars)	Dollars per Kilowatt Mills per Kilowatt Hour
200 Megawatts	New	2.5	30	Capital Operating	8,263,000 2,842,000	41.3 2.03	9,482,000 3,413,500	47.4 2.44	8,861,000 3,204,400	44.3 2.29	10,324,000 4,269,200	51.6 3.05	13,069,000 2,750,100	65.3 1.96
500 Megawatts	New	1.0	30	Capital Operating	12,935,000 4,732,500	25.9 1.35	15,961,000 5,748,600	31.9 1.64	12,695,000 4,633,100	25.4 1.32	15,198,000 5,854,700	30.4 1.67	28,067,000 5,743,600	56.1 1.64
500 Megawatts	New	2.5	30	Capital Operating	15,473,000 5,564,400	30.9 1.59	18,148,000 6,852,800	36.3 1.96	16,080,000 6,092,700	32.2 1.74	18,949,000 8,305,100	37.9 2.37	28,277,000 5,677,500	56.6 1.62
500 Megawatts	New	4.0	30	Capital Operating	17,481,000 6,281,800	35.0 1.79	19,861,000 7,742,300	39.7 2.21	18,765,000 7,393,500	37.5 2.11	21,893,000 10,640,500	43.8 3.04	28,449,000 5,565,100	56.9 1.59
500 Megawatts	Existing	2.5	25	Capital Operating	18,657,000 6,587,300	37.3 1.88	21,817,000 8,001,500	43.6 2.29	20,376,000 7,308,700	40.8 2.09	24,445,000 10,261,600	48.9 2.93	32,824,000 11,126,100	65.6 3.18
1,000 Megawatts	New	2.5	30	Capital Operating	23,384,000 8,987,400	23.4 1.28	26,341,000 10,795,200	26.3 1.54	23,656,000 9,715,900	23.7 1.39	28,765,000 13,686,200	28.8 1.96	46,356,000 8,911,900	46.4 1.27

NOTE: Capital investment costs are for a Midwest plant location project beginning mid-1972 and ending mid-1975. Annual operating costs assume a power unit on-stream time of 7,000 hours per year for 1975 with a midwestern plant location. Investment and operating costs do not include costs for disposal of fly ash or credit for by-products. Onsite solid disposal is assumed.

Source: U. S. Environmental Protection Agency, Detailed Cost Estimates for Advanced Effluent Desulfurization Process, EPA 600/2-75-006, January 1975.

Nitric oxide, a precursor to the formation of nitrogen dioxide, is formed through the direct combination of nitrogen and oxygen from the air in the intense heat of combustion processes. Fuels containing nitrogen in their structure may also be responsible for a part of the nitrogen oxides produced in the combustion process. In the presence of sunlight in the atmosphere, nitric oxide is able to combine with additional oxygen to form nitrogen dioxide.

As with particulate matter and the sulfur oxides, nitrogen oxides are produced primarily by the combustion of fuel. Stationary sources, primarily electric power generation plants and industrial combustion, are responsible for the production of more than 50 percent of the man-made nitrogen oxides in the United States. However, while the control of sulfur oxides and particulate matter is conventionally attempted by using emission stream "clean-up" devices, nitrogen oxide control is usually accomplished through the regulation of the combustion process. Nitrogen oxide emissions from combustion equipment result from the fixation of atmospheric nitrogen in the burner primary flame zone. The reaction occurs in power plant furnaces at high temperatures, with the rate of oxidation of nitrogen to nitrogen oxides being very low at 500°F and very high at 4,000°F.

Because they contribute a substantial amount of nitrogen oxide emissions, electric power generation plant boilers have been the object of developed control techniques. While the total nitrogen oxides emitted from smaller industrial and commercial boilers are often considerable for a given area, the emissions from a few large power plants can readily equal or exceed the total of all other stationary combustion sources. Also, the emissions from power plants are concentrated in small geographical areas, and thus can cause high ground-level concentrations. Consequently, control technology has been directed toward reducing the emissions from larger sources.

Reductions in nitrogen oxide emissions from both existing boilers and new installations can be achieved by the modification of operating conditions and by modification of design features. The following modifications of operating conditions have proved to be effective:

1. Low excess air firing—Combustion in the presence of low excess air is one of the most promising and commonly applicable methods of reducing nitrogen oxides by combustion modifications. Special control equipment supplies as close to stoichiometric requirements of air for complete burnout of fuel as is permitted by the nature of the combustion process.[10] In some coal boilers, 70 percent reductions in nitrogen oxides have been achieved, with reductions of from 25 percent excess air to 1.4 percent excess air. However, this was accompanied by a decrease in carbon combustion efficiency from 99.5 percent to 92 percent. Reduction in excess air from 10 percent to 5 percent in natural gas-fired boilers has produced a 30 percent reduction in nitrogen oxides.

2. Two stage combustion—By supplying substoichiometric quantities of primary air to the burners in oil- or gas-fired combustion, a substantial reduction in nitrogen oxide emissions can be achieved. Complete burnout of the fuel is accomplished by injecting secondary air at lower temperatures. Because the temperatures are reduced, the formation of nitrogen oxide is lowered. This control method is less readily adaptable to coal-burning plants because hazardous fuel-air distributions may occur. This may also lead to unburned fuel and possible increases in carbon monoxide production.

3. Flue-gas recirculation—This technique lowers the peak flame temperature by diluting the primary flame zone with cool flue gas, which is recirculated back into the combustion zone. The cooler gas absorbs heat and lowers the combustion temperature. The oxygen concentration is also lowered, an effect which favors reduction in nitrogen oxide emissions. A disadvantage of this system is the increased cost of the duct work associated with large volumes of gas.

4. Steam or water injection—Steam or water injections have the same effect as flue-gas recirculation; that is, a thermal dilution of the flame. Because this method lowers thermal efficiencies, it has limited use.

Nitrogen oxide reduction can also be achieved by modification of design features as follows:

1. Burner configuration, location, and spacing—Variations in nitrogen oxide levels occur with differences in burner configuration. Cyclone burners in coal-fired plants promote turbulent combustion and yield high levels of nitrogen oxides. One design feature that reduces nitrogen oxide formation is the spacing of burners so that radiant heat transfer is increased. Thus, flame temperatures can be reduced by rapid heat transfer from the flame to the water tube surfaces.

2. Tangential firing—In tangential firing the burners are located in the corners of the boiler, firing on a tangent to a circle at the center of the furnace. Because the resulting flames have little interaction with each other, peak temperatures are reduced and so are the nitrogen oxide emissions.

[10] *A stoichiometric reaction is one in which the input equals the output. In a combustion reaction it produces a complete conversion of carbon to carbon dioxide and hydrogen to water.*

3. Fluidized bed combustion—This technique, which brings granular solids, gases, or fluids in contact with one another, although still under development, promotes high heat transfer rates and hence low average combustion bed temperatures. It also offers the potential advantage of controlling sulfur dioxide emissions if limestone or similar material is added directly into the combustion zone.

Some other methods of nitrogen oxide control include:

1. Delayed mixing—Burners can be designed to delay mixing between the fuel and the air and to promote entrainment of bulk gas before complete combustion occurs. Combustion occurs over a longer period and in the center of the furnace. The bulk gas is entrained and adiabatic flame temperatures are prevented because of the better radiant heat transfer from flame to water tube surfaces.

2. Off-stoichiometric flame premixing—In this process, fuel and air within the burner are premixed at off-stoichiometric mixture ratios. The overall furnace stoichiometry is preserved by operating half of the burners fuel-rich and the remaining half correspondingly air-rich. Primary zone combustion occurs at off-stoichiometric flame conditions with lower flame temperatures. Unburned hydrocarbons from fuel-rich burners mix with the oxygen from air-rich burners. This secondary combustion occurs at lower gas temperatures and does not form additional nitrogen oxides. A limitation of this method is that it is difficult to design fuel burners that can operate both fuel-rich and air-rich over a wide load range.

3. Off-stoichiometric diffusion flame operation—In this type of operation, the burners are operated at off-stoichiometric mixture ratios without premixing the fuel and air. This can be accomplished in various ways. Some or all of the top burners can be taken out of service, with the associated air registers opened to simulate two stage combustion, or several burners can be taken out of service within the matrix of the burner system. Under the second method, some of the remaining burners are operated fuel-rich, with the other burners operated either air-rich or on air alone to maintain the desired overall furnace stoichiometry with secondary combustion. Total formation of nitrogen oxides depends upon the burner mixture ratios. For fuel-rich ratios, the rate of nitrogen oxide formation is reduced because of the increase in oxygen concentration. For air-rich mixtures, the temperature decrease reduces the nitrogen oxide formation rate.

To date, the reduction of nitrogen oxides from power plants has been accomplished by operation changes or combustion modification. Power plants emit large volumes of flue gas which present engineering problems in gas contracting, equipment sizing, temperature control, and pressure drop. Nitrogen oxide, being a relatively stable gas, has proved difficult to remove from flue gases. The wet scrubbing limestone process, used to control sulfur dioxide, can remove about 20 percent of the nitrogen oxides in a flue gas stream, but the major thrust of control research has been directed toward combustion modification techniques.

A small proportion of man-made nitrogen oxide emissions are the result of industrial and chemical processes, exclusive of combustion. The most prominent of these sources is related to the manufacture and use of nitric acid. In the manufacturing process, the chemical gas is commonly a process stream which must be recycled with maximum efficiency in order for the process to be economical. Among the techniques used to control industrial process emissions are:

1. Catalytic reduction, using a reducing gas such as methane, hydrogen, or carbon monoxide to reduce nitrogen dioxide to nitrogen oxide. The best catalysts to date have been the noble metals, which are extremely sensitive to sulfur.

2. Catalytic reduction and power recovery, using fuel oxidation to reduce nitrogen dioxide to colorless and nonirritant nitric oxide. Recovery of heat energy helps to make this process economical.

3. Nonselective catalytic abatement, which requires adding reducing fuel to burnout the oxygen in the tailgas and thus reduce both the nitrogen dioxide and nitric oxide present to nitrous oxide. Small amounts of nitrogen oxides are also lost from acid concentration operation condensation systems, but these low totals can be controlled by inexpensive absorbers.

Carbon Monoxide Control

Carbon monoxide, the product of incomplete combustion of carbon and its compounds, is emitted by fossil fuel combustion in greater quantities, by weight, than any other air pollutant type. In 1970 stationary point sources contributed approximately 13 percent of an estimated 147 million tons of man-made carbon monoxide emissions in the United States. The major stationary source categories are fuel combustion, solid waste disposal, and industrial process losses.[11]

Combustion control is one way to reduce carbon monoxide emissions from stationary combustion sources. Emissions can be minimized by the design and maintenance of combustion systems for 1) a high combustion temperature, 2) intimate contact among fuel oxygen and combustion gases, 3) sufficient reaction time, and 4) low effluent temperature. Proper design to meet specific

[11] *According to information compiled by the U. S. Environmental Protection Agency.*

load conditions is critical because firing in excess of the design rate of the combustion system is perhaps the greatest cause of excessive carbon monoxide from a stationary source. Two aspects of combustion control equipment are also significant; namely, adjustment of the fuel supply under variable loads and correction and control of the air-fuel ratio corresponding to the fuel supply.

In addition to combustion control, a change in fuel type or energy source may result in reduced carbon monoxide emissions. Accepted emission factors for burning coal, oil, and gas show decreasing carbon monoxide emissions for these fuels, in the order given. Because emissions from boilers and furnaces comprise a relatively small portion of total carbon monoxide emissions, a fuel change here is rarely justified.

Waste incineration and other burning are important sources of carbon monoxide emissions. High temperature incineration with excess air reduces emissions of particulates, carbon monoxide, and smog-forming compounds such as aldehydes, hydrocarbons, and organic acids—which are typical of open burning—but tends to increase nitrogen oxide emissions. High temperature incineration using excess air or other waste disposal methods not involving burning are ways to reduce carbon monoxide emissions. When incineration is used for waste disposal, auxiliary burners can be used to increase the incineration temperature from 1,600°F to 1,800°F. Temperature control systems can be used to facilitate consistent emission reduction.

Process sources of carbon monoxide include the iron and steel industry, petroleum refineries, and the chemical industry. A typical emission control system, for example, that applied to an iron cupola used for melting metals, includes an efficient particulate collecting system with an afterburner for burning carbon monoxide. Proper afterburner design can also result in a decrease in the amount of coke required for melting and in the amount of combustion products.

Hydrocarbon Emissions Control

Stationary sources of hydrocarbon emissions include gasoline distribution, fuel burning, waste disposal, degreasing and cleaning of metal parts, printing, painting operations, and the manufacture of chemicals. Control devices to control hydrocarbon emissions are based on the principles of incineration, adsorption, absorption, and condensation.

Hydrocarbon Emissions Control Principles: Incineration or afterburning devices utilize combustion to completely oxidize vapors and gases containing hydrocarbons which are emitted from a process or operation. These devices are useful for controlling not only hydrocarbons, but also combustible particulate matter in a gas stream. Afterburners burn hydrocarbons or particulate matter in a gas stream through the addition of fuel to complete the combustion process. In the direct flame afterburning process, additional fuel is injected into the gas stream in order to raise the temperature to a level sufficient to complete the oxidation of hydrocarbon emissions into carbon dioxide and water. Direct gas flame incineration has proved to be successful in controlling hydrocarbon emissions produced by coil coating lines, core ovens, lithographing ovens, metal coating ovens, paint-baking ovens, printing presses, solvent degreasing, and wire enameling operations. A second type of incineration device, the catalytic afterburner, is similar in design to the direct flame device but employs a solid active surface on which the combustion reaction takes place. Since the catalytic device operates at lower temperatures, lower fuel costs are frequently achieved. The catalytic afterburner is handicapped by higher maintenance costs and susceptibility to catalytic poisons, but has proven effective in controlling hydrocarbon emissions from paint and enamel bake ovens, varnish kettles, foundry core baking, and fabric coating operations.

Adsorption, the process of adhesion of a gas to a solid surface, is used as the basis for the control of some types of hydrocarbon emissions. In the event that an afterburner cannot be used and/or the hydrocarbon compounds need to be recovered from the gas stream, an adsorption device is an effective control. Activated carbon has been proven to be the most suitable adsorbent for the removal of hydrocarbon compounds from an exhaust gas stream. The carbon adsorbs hydrocarbon compounds from the gas stream at ambient temperatures regardless of the variation in hydrocarbon concentration or in humidity. Because adsorbed compounds have very low vapor pressure at ambient temperatures, the carbon system is particularly adapted to high-efficiency recovery of hydrocarbon solvents in small concentrations. This means that the system can be designed for operation without hazard because the vapor concentration is always below the flammable range.

Adsorption of a vapor by activated carbon has the added feature of being able to recover the adsorbed solvents by regeneration. To remove the adsorbed material from the carbon, the carbon may be heated to a temperature above that at which the solvents are adsorbed. A hot carrier gas is then used to remove the released vapors. Saturated steam at low pressures may also be used to remove high boiling organic compound constituents. The carrier gas is then sent to a condenser. The collected compounds may be recycled back into the process or sent to a reclamation plant for processing.

A problem in using activated carbon is that the adsorption bed must be protected from particulate matter, which can coat the surface of the carbon and render the bed useless. Also, when steam is used to regenerate the adsorption bed, the adsorber should be made of stainless steel or lined with a phenolic resin to inhibit corrosion.

The third method of air pollution control for hydrocarbon process sources is absorption. In gas absorption, one or more constituents in a gas stream are removed by dissolving them in a selective liquid solvent. This control method is used for light hydrocarbons. For

example, natural gas is removed from wellhead gas streams by absorption in a special hydrocarbon oil. Because the process is useful only with light organic compounds and another organic compound must be used as a solvent, absorption has only limited application for air pollution control.

Because of their relatively high boiling points, many hydrocarbon compounds are readily subject to condensation. Gaseous hydrocarbons may be converted to the liquid state by either increasing pressure or extracting heat. In general, solvent condensers operate by extracting heat from the vapor, the principal difference in condensers being in the method used in cooling the gas stream.

Condensers may be classified as surface or contact type. Surface condensers keep the coolant and the hydrocarbon vapors separate, usually with the use of a tube and shell design. Cooling water or air is used as the coolant in a surface condenser. In contact condensers, the vapor, coolant, and condensate are intimately mixed. Water is normally used as the coolant, and the process equipment may be a simple baffled spray chamber or a set of high velocity jets. Compared with surface condensers, contact condensers are simpler, more flexible, and less expensive. Condensate from contact devices cannot be reused directly and must be sent to a solvent recovery plant for reclamation. Otherwise, the condensate may pose a solid waste disposal problem. Surface condensers can be used to recover a relatively pure condensate, which may be recycled back into the process or sold.

Applications of Hydrocarbon Emissions Control: A significant amount of hydrocarbon emissions may result from the distribution and storage of gasoline and petroleum products. The products are normally stored in large closed tanks in the shape of a cylinder, sphere, or spheroid. Hydrocarbon losses from these tanks are of two types, breathing losses and working losses. Breathing loss is the loss of hydrocarbons from an open surface of the stored fuel, with the rate of loss dependent on the exposed surface area, the vapor pressure of the hydrocarbons, and the ambient temperature. Working losses result from the turnover of the inventory in the storage tank. Exposure of the fuel-coated walls as the tank is drained results in a larger surface area for evaporation. Even if filling of the tank is done exclusively by the underfill, or submerged fill method, the displacement of vapor by the liquid forces out large amounts of vapor.

The most effective method of control for both types of emission losses from a closed storage tank is the floating roof. Floating roofs have been used for more than 40 years, although not with wide acceptance. The modern floating roof uses pontoon sections for increased stability. Some pontoon roof designs include a vapor trap on the underside of the roof to retain vapors formed as a result of localized boiling and convert the dead vapor space into an insulation medium. A center drain conveys any liquid forming on the roof back into the main body of the liquid. To achieve high-efficiency control over storage of light hydrocarbons such as those in gasoline, a vapor recovery system may be added to the tank vent. The recovered vapors are compressed and sent to an absorption unit for recovery of any condensable hydrocarbons.

If combustion of fuels is not complete, the emission of hydrocarbons and other organic material may result. A major technique for controlling these emissions is the maintenance of proper combustion conditions, especially a high degree of fuel and air turbulence. When properly operated and designed, stationary fuel combustion equipment may not require control equipment.

Industrial processes which produce hydrocarbon air pollutant emissions include printing, can and paper coating, paint spraying, and metal degreasing operations. In printing, coating, and painting processes, the organic compound is evaporated and exhausted to the ambient air. The major factor affecting these emissions is the amount of volatile matter contained in the coating. The volatile portion of most common surface coatings averages about 50 percent, and most, if not all, of this is emitted into the air during the application and drying phases. Compounds released include aliphatic and aromatic hydrocarbons, alcohols, ketones, esters, alkyl and aryl hydrocarbon solvents, and mineral spirits.

A reduction in volatile organic compounds from conventional coating applications can be achieved through the use of spray or dip powder, water-borne solvent, high-solid coatings, carbon adsorption, and incineration. Where feasible, the use of low organic solvent coatings—those which contain less organic solvents than the conventional coatings used by an industry—may reduce volatile organic compound emissions. In some industrial applications, the use of water-borne coatings, which are low in organic solvents, may achieve hydrocarbon reductions of 70 to 90 percent over conventional coatings. In order to meet future air pollution control standards, coatings which are low in organic solvent may see increased use over add-on control devices such as afterburners or adsorbers.

Other industrial hydrocarbon emissions result from solvent metal cleaning (degreasing) operations which employ organic solvents to remove soluble impurities from metal surfaces, usually in preparation for painting, coating, or plating operations. Depending on the size and design of the degreasing system, reasonably available control technology (RACT) can be as simple as a manual cover or as complicated as a carbon adsorption system. Important control procedures include proper use of solvents, rapid equipment repair, reduction of solvent loss from cleaned parts (carry-out emissions), and proper disposition of cleaning wastes which contain volatile organic compounds. The primary emission control devices applicable to solvent-base emission reductions include improved covers, high freeboards, refrigerated chillers, carbon adsorption, and safety switches. An estimated one-third of the total metal degreasing emissions result from the disposal of used solvent, much of which is lost to the atmosphere by evaporation. Reclamation of the waste solvent is the most environ-

mentally acceptable means of handling spent solvent. The use of stills is fairly common for reclamation in large-use facilities.

Control Technology for Area Sources

Area source emissions result basically from four types of processes: 1) combustion (incineration, forest wildfires, and space and water heating), 2) internal combustion engines (agricultural equipment, general utility engines, power boats, snowmobiles, vessels, aircraft, and railroad engines), 3) particulate generation (agricultural tilling, rock handling and storage, construction and demolition, and vehicle traffic on unpaved roads and parking lots), and 4) evaporation (dry cleaning and gasoline marketing).

Little control technology has been developed to reduce the air pollutant emissions from most area sources. These sources, on an individual basis, produce relatively small emission totals. Hence, it has been economically or technically impractical to reduce their emissions by direct application of control devices. However, emissions from rock handling and storage, fugitive dust, dry cleaning, and gasoline marketing may be reduced by the application of control technology.

Each phase in the production and storage of rock material offers the opportunity for the generation of particulate matter. To reduce emissions, conveyer systems and transfer operations may be enclosed by hoods, covers, or canopies. Fabric filters or wet collection devices are useful in reducing particulate matter associated with grinding and crushing operations. Wet suppression by water, chemicals, or foam may prove effective in reducing dust emissions.

Other sources of fugitive dust include dirt roads, agricultural tilling, and demolition and construction activities. Methods used to control dust include the establishment of vegetation, the erection of windbreaks, and the stabilization of dust sources. From an air pollution standpoint, the first method is only useful in a small number of cases, such as to control emissions from abandoned waste material or long-term storage piles. With respect to agricultural operations, if a crop harvest exposes the soil to weather conditions which encourage fugitive dust generation, another appropriate crop may be seeded which will protect the soil from wind erosion. The establishment of windbreaks can also reduce fugitive dust by protecting materials from wind erosion. Windbreaks vary from a line of natural vegetation such as trees to an enclosed storage bin or silo. Natural vegetation is the least expensive windbreak but offers the least protection.

Construction of roadways and residential/commercial/industrial structures inevitably results in the exposure of the soil and hence susceptibility to the generation of fugitive dust. This dust may be produced by excavation activities, by vehicle traffic, and by the action of wind over bare soil surfaces. Wetting of unpaved access trails used by construction vehicles has reduced dust emissions up to 60 to 70 percent when a wet surface was maintained. A drawback to this control method is that it results in the creation of mud transfer to adjacent streets, thus creating a new dust source which may require street cleaning control measures. Dust generated by soil exposure at construction sites may be reduced through stabilization of the soil by either the establishment of a vegetative cover through temporary seeding or the use of a chemical palliative. Chemicals that have been used for dust control include mixtures of petroleum resin and light hydrocarbon solvents, polyvinyl acetate resin diluted with water, and a urea-formaldehyde resin in a water solution.

Demolition activities have the potential to produce large amounts of fugitive dust emissions from falling walls and other structural parts. Control methods for emissions produced by falling brick, plaster, and concrete walls involve spraying the structure before teardown and immediately after the fall. Fugitive dust air pollutant emissions from masonry demolition may be reduced 10 to 20 percent by using a water spray control.

Fugitive dust from unpaved roads may be controlled by the application of road oils, waste oils, or crankcase drainings. However, oil is not held tightly by soil or other materials and may percolate into the soil or be displaced by rain. Petroleum oils, on the other hand, are toxic to plants and may cause water pollution, limiting their use.

Paving is, of course, a common but relatively expensive technique for controlling fugitive dust generated from unpaved roads and parking lots. In a study in Seattle, Washington, paving was found to be the most cost-effective method for effectively reducing traffic-generated fugitive dust from gravel roads with an average daily vehicle count of over 15.[12] The reduction of vehicle speed on unpaved roads can reduce the amount of suspended dust, but this requires a very low speed limit to be effective.

An area source of hydrocarbon emissions is the use of organic solvents in dry cleaning operations. The dry cleaning process involves agitating the material to be cleaned in a solvent bath, rinsing with clean solvent, and drying with warm air. There are basically two types of dry cleaning operations, those using petroleum solvents and those using chlorinated synthetic solvents. The trend in dry cleaning operations today is toward smaller package operations located in shopping centers and suburban business districts. These plants almost exclusively use perchloroethylene, whereas the older, larger dry cleaning plants use petroleum solvents. The major source of hydrocarbon emissions in dry cleaning is the tumbler through which hot air is circulated to dry the clothes. Drying leads to vaporization of the solvent and, unless

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[12] *John W. Roberts, et al, "Costs and Benefits of Road Dust Control in Seattle's Industrial Valley," Journal of Air Pollution Control Association, Vol. 25, September 1975, pp. 948-952.*

control equipment is used, consequent emissions to the atmosphere. The primary control element used in synthetic solvent plants is a water-cooled condenser that is an integral part of the closed cycle in the tumbler or drying system. Up to 95 percent of the solvent which is evaporated from the clothing may be recovered in this process. Approximately half of the remaining solvent may then be recovered in an activated carbon absorber, producing an overall control efficiency of 97 to 98 percent.

Retail gasoline service stations are a major area source of hydrocarbon emissions. At these stations, gasoline is received by tank truck, stored in underground tanks, and dispensed to vehicle fuel tanks. Unless a vapor collection system is provided, hydrocarbons in the storage tank vapor space are displaced as the tank is filled with gasoline from the tank truck. The quantity of these emissions is dependent on the filling rate, filling method, vapor pressure of the fuel, and system temperature. Breathing losses from underground gasoline storage tanks are another source of hydrocarbon emissions but because these are underground, such losses are small.

Vehicle refueling is another source of hydrocarbon emissions from gasoline marketing operations. As with the filling of underground storage tanks, the hydrocarbon emissions are generated from the saturated gasoline vapors displaced as the fuel tank is filled. Emission control of underground tank filling operations has been designated as Stage I control, and control of vehicle refueling operations has been designated as Stage II control.

In Stage I control technology, a submerged fillpipe is used to discharge a gasoline load below the surface of the liquid in an underground tank. Submerged loading eliminates the excess vapors which would be generated from discharging the gasoline at the top of the tank, because free-fall of the gasoline droplets promotes evaporation and results in liquid entrainment of some gasoline droplets in the expelled vapors.

About 95 percent of the vapors displaced from underground tank refilling can be recovered by simply returning the displaced vapors to the tank truck. Two basic approaches are used to collect displaced vapors from underground tank refilling, single and dual point systems. The dual systems employ two tank fittings—one for product delivery and one for vapor collection. The single point systems employ one fitting—a coaxial or concentric fuel-vapor coupler. The advantage of the coaxial-type fitting is that an interlock system can be incorporated which will prohibit product delivery unless the vapor return line is connected. A disadvantage of the coaxial coupler is that it will result in lower product delivery rates. Truck inspections are a necessary and integral part of any vapor recovery program, because leaks in the truck will allow collected vapors to escape to the atmosphere and thus reduce the recovery efficiency.

Stage II controls, those used during vehicle refueling, basically consist of vapor displacement and vacuum assist. The vapor displacement, or vapor balance, system operates by transferring vapors to an underground tank, where they are stored until final transfer to a tank truck. The pressure created in the vehicle tank and vacuum created in the undergound tank are the principal agents of vapor transfer. The main pieces of equipment associated with a vapor balance system are a specifically designed nozzle which is designed to form a vapor tight seal at the fill neck interface, a flexible hose, and an underground piping system to transport the vapors to the underground storage tank. From this tank a vent line can either be open to the atmosphere or equipped with a pressure-vacuum valve to aid in retaining a vacuum in the tank.

Vacuum assist systems employ a blower or vacuum pump and a secondary recovery device. The vacuum device creates a negative pressure in the vehicle fillneck that transports hydrocarbon vapors either directly to the secondary unit, or to the underground tank with the excess vapors going to a secondary unit. The amount of vapor collected by this type of system is greater than that which would be displaced by the balance system. The additional air ingested causes the evaporation of additional hydrocarbons.

Control Technology for Line Sources

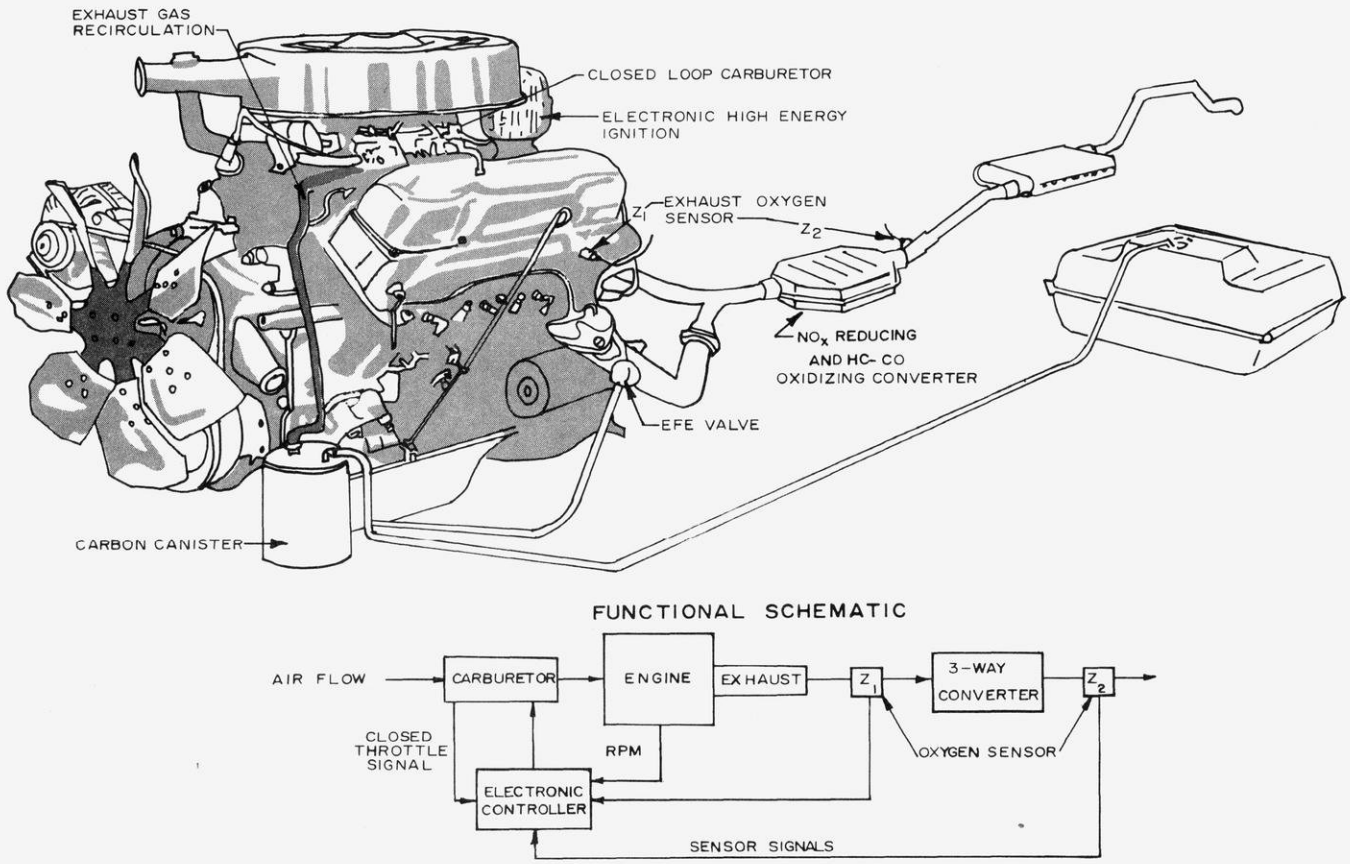
Mobile source air pollutant emissions are produced primarily by automobiles, trucks, and buses, most of which are powered by gasoline or diesel internal combustion engines. Because of the potential for significant impact of vehicular emissions on air quality, federally mandated emission standards for 1979 light-duty gasoline vehicles require that emission levels not exceed 1.5 grams of hydrocarbons per mile, 15.0 grams of carbon monoxide per mile, and 2.0 grams of nitrogen oxide per mile. These emissions originate principally from the carburetor, fuel tank, crankcase, and engine exhaust. The control technology discussed in this section is centered on manufacturer engine design modifications and physical control techniques to reduce air pollutant emissions from light-duty gasoline vehicles.

Hydrocarbon emissions from gasoline-powered motor vehicles result from 1) fuel vaporization in the carburetor, 2) vaporization due to increases in fuel temperature in the fuel tank, 3) blowby past the piston rings, and 4) incomplete fuel combustion. Evaporative hydrocarbon losses are associated with evaporation from the carburetor and fuel tank vents. Control systems are utilized to collect and contain fuel vapors from these sources until they can be returned to the combustion system. As shown in Figure 74, evaporative losses are commonly collected from the fuel tank and stored in an activated carbon canister. When the engine is operated after an inactive period, the hydrocarbon vapors are purged from the carbon bed and ducted to the air cleaner, from where they are directed into the combustion chamber of the engine, where they are burned.

Current internal combustion engines produce small amounts of blowby gases which escape past the piston rings into the crankcase. In order to prevent these gases

Figure 74

THREE-WAY CATALYST EMISSION CONTROL SYSTEM



Source: U. S. Environmental Protection Agency.

from entering the atmosphere, while simultaneously allowing proper crankcase ventilation, all engines now use a positive crankcase ventilation system. This system prevents the blowby gases from entering the atmosphere by routing them into the intake manifold, where they are mixed with the regular air-fuel mixture and burned in the combustion chamber. This system has reduced initial uncontrolled hydrocarbon emissions by approximately 20 percent.

Almost 100 percent of the carbon monoxide and nitrogen oxide emissions and 60 percent of the hydrocarbon emissions from an automobile not equipped with emission controls are found in the exhaust. To meet increasingly stringent federal automobile emission standards, automobile manufacturers have used a variety of techniques to reduce exhaust emissions. Air injection systems have been used to aid in minimizing carbon monoxide and hydrocarbon levels in vehicle exhaust streams. The air injection pump has been used on six-cylinder and eight-cylinder engines. The belt-driven pump compresses air and injects it through a series of hoses and air injection tubes—one for each cylinder—into the exhaust system near the exhaust valves. The injected fresh air then burns with the unburned portion of the exhaust gases in an exhaust manifold reactor, thereby effectively reducing carbon monoxide and hydrocarbon levels in the exhaust. In some cases, notably four-cylinder engines, a pulse air system—a simplified reed valve system—is used in place of the air pump when smaller amounts of air are required to help oxidize unburned exhaust hydrocarbons and carbon monoxide.

Nitrogen oxide emissions from internal combustion engines are the result of operating pressure, temperature, reaction time, and amounts of reactants present. One approach to the control of nitrogen oxides is exhaust gas recirculation (EGR). By recirculating a small amount of exhaust gas into the fuel mixture, peak combustion temperatures, and hence nitrogen oxide formation, can be reduced. An EGR valve is normally mounted on the intake manifold and is usually vacuum operated.

Other engine design modifications have been made to the conventional internal combustion engine in order to meet air pollutant emission standards and maintain acceptable performance and fuel economy. Modification involves using the "lean-burn" system, which mixes more air with the fuel than is required for complete fuel combustion. An air-fuel ratio close to the stoichiometric ratio for complete combustion is necessary to limit carbon monoxide and hydrocarbon emissions. Two problems associated with this system are a reduction in maximum power, and hence performance, and an increase in nitrogen oxides. Another application of the lean-burn principle is the stratified charge engine. The basic intent of this application is to supply a small amount of rich-fuel mixture near the point of ignition inside the cylinder while the remainder of the mixture is kept lean. This produces a stable slow burn on the power stroke and a maximum combustion temperature low enough to minimize the formation of nitrogen oxides but high enough and of sufficient duration to minimize the formation of hydrocarbons and carbon monoxide.

When engine design modifications and other emission control devices are not adequate to reduce emissions to the federal standards, catalytic reactors may be used on the vehicle exhaust system. To meet current federal standards, most U. S. automobile manufacturers have elected to use a catalytic converter to oxidize hydrocarbons and carbon monoxide in the exhaust stream. The oxidizing catalytic converter is commonly placed on the exhaust pipe away from the engine. The catalytic agent is contained in a metal casing, which directs the exhaust gases through the catalyst bed and protects the agent from mechanical damage. A thin layer of catalytically active material, usually platinum or a combination of transition metal oxides, is supported on small pellets or by a honeycomb monolith structure. As the exhaust gases pass through the catalytic bed, the carbon monoxide and hydrocarbons are oxidized into carbon dioxide and water. A major problem with the oxidation catalyst system is its susceptibility to contamination by fuels with very low levels of lead, phosphorus, or sulfur. Small amounts of these substances, particularly lead contamination through the use of leaded gasoline, can produce rapid deterioration in the efficiency of the converter.

In addition to the standard oxidation catalyst system, other exhaust control reactors have been developed. Monolithic start catalysts are used on some automobiles sold in California, where emission standards are more stringent than federal standards. These platinum and palladium catalysts provide for the conversion of hydrocarbons and carbon monoxide during the first two minutes of engine warmup, when emissions are highest, and before the primary catalyst has reached optimum operating temperature.

Reducing converters, using the metal rhodium, have been developed for use on the exhaust system. These converters, which break down nitrogen oxides in the exhaust gas into nitrogen and oxygen, are placed between the engine exhaust manifold and the oxidizing converter. Three-way catalyst emission control systems, which integrate the nitrogen oxide-reducing converter and the hydrocarbon-carbon monoxide oxidizing converter into one physical unit, have been utilized. A diagram of the major components of this system is presented in Figure 74. These converter systems, in order to be most effective, usually include an oxygen sensor. Because of the narrow tolerances under which most three-way catalysts operate, the oxygen sensor, a platinum-coated ceramic device located in the exhaust system, provides a feedback loop to an electronic control unit. The electronic control unit is used to maintain an air-fuel ratio at or near stoichiometric. The electronic control unit may also have sensor input for controlling modulated spark advance and modulated exhaust gas recirculation.

Existing design modifications and emission control devices have resulted in automobiles which are capable of meeting current federal air pollutant emission standards while operating with acceptable fuel efficiencies under normal operating conditions. Although the exact consumer cost of light-duty vehicle air pollution control is difficult to determine, and varies with the size, design, and manufacturer of the vehicle, recent model year costs are estimated by the U. S. Environmental Protection Agency to be about $200 to $300 per vehicle. Because emission standards for both light-duty gasoline vehicles and light-duty and heavy-duty gasoline- and diesel-fueled trucks will become increasingly more stringent, the cost and complexity of air pollutant control systems are expected to increase.

It should be noted that in order for an engine to operate properly and at optimum efficiency, proper maintenance and adjustment of the engine and its emission control components are usually necessary. Because of the recurring nature of these maintenance requirements, periodic inspection and maintenance of the engine and its pollution control systems have been found to be necessary in order that the vehicle retain its intrinsic pollution control capability. The merits of mandatory vehicle inspection and maintenance (I/M) are discussed in Chapter XIII of this report.

SUMMARY

There are many variables to be considered in the application of control technology to air pollution emissions. Among the most important are the emissions standards which must be met, technical feasibility and availability of control technology, alternatives to installation of control devices including process changes, and economic costs and benefits of the application of control technology.

Particulate emissions from point sources may be controlled by a number of physical devices, including settling chambers, inertial separators, wet collectors, electrostatic precipitators, and baghouses. These direct control devices are based on mechanical or electrical processes for particulate removal. Overall control efficiencies range from approximately 60 percent for baffled settling chambers to over 99 percent for fabric baghouses. Costs generally increase with decreasing particle size to be

removed and increasing gas volumes to be treated. Settling chambers are economical devices for removing particles larger than 40 microns in diameter. Electrostatic precipitators have high initial costs but are characterized by overall collection efficiencies of 97 percent at below average maintenance costs. Baghouses achieve collection efficiencies of 99.7 percent, but operational costs can be high if high temperature gas streams are to be controlled. Electrostatic precipitators, wet venturi scrubbers, and baghouses generally meet the criteria for reasonably available control technology (RACT) applications for particulate matter.

Sulfur oxide emissions from stationary point sources are principally the result of electric power generation. Control technology has centered on desulfurization of flue gases using magnesium oxide, lime/limestone, Wellman-Lord, double alkali, Chiyoda, and catalytic oxidation systems. Although each of these systems has achieved sulfur dioxide emission reduction efficiencies of about 90 percent, the lime/limestone system has the lowest capital installation costs and is the most commonly used system on large boilers in the United States. In addition, the use of dry scrubber technology and the application of wet flue-gas desulfurization processes to small- and medium-sized industrial boilers have been shown to be practical.

A reduction in nitrogen oxide emissions from stationary combustion sources is achieved by proper burner design, control of combustion processes, and recirculation of flue gases. Up to 80 percent reductions in nitrogen oxide emissions can be achieved through the reduction of excess air and recirculation of part of the flue gas. The costs of controlling nitrogen oxide emissions from large combustion sources vary greatly, with the costs for flue-gas recirculation being high, and the costs for two-stage combustion being low. Furthermore, the use of low excess air may show a net return.

Carbon monoxide generation from stationary point sources is primarily the result of fuel combustion, solid waste burning, and industrial processes. The most practical technique for the control of carbon monoxide emissions involves proper equipment design, installation, operation, and maintenance of combustion devices. Poorly adjusted equipment may produce emissions several hundred times as great as those from a well-adjusted unit. Because the physical control of carbon monoxide emissions may entail the removal of particulate matter or waste gas, the control costs are difficult to determine.

Hydrocarbon emissions from stationary sources are controlled using the principles of incineration, adsorption, absorption, and condensation. Removal efficiencies of incinerators, or afterburners, can be high, but operational costs are also high unless heat-recovery equipment is available. The capital and operational costs of high-efficiency adsorbing systems are high, but the recovery of valuable materials may offset some operational costs. Absorbers are not widely used when hydrocarbon or organic solvent emissions are low because large and expensive equipment is required to achieve high removal efficiencies. Finally, because condensers cannot achieve high removal efficiencies with low gas stream concentrations, they are most useful as preliminary devices to be followed by a more efficient device such as an afterburner or absorber.

Many area source emissions, because of their individually small size, are not readily controlled. Those emissions which originate from discrete points—for example, small incineration devices—may be controlled by techniques applicable to large stationary point sources, but unit costs are usually much higher when measured on a gas-volume basis. Fugitive dust emissions can be controlled using chemical palliatives or oils, or by paving unpaved roads and using windbreaks or vegetative cover. Water or chemical palliatives are useful for controlling fugitive particulate emissions from construction activities.

Line source air pollutant emissions result principally from tailpipe exhaust from automobiles, trucks, and buses. Because motor vehicles are major contributors of hydrocarbon, carbon monoxide, and nitrogen oxide emissions in most urban areas, control technology has centered on the reduction of these three pollutant species. Major reductions have been achieved in hydrocarbon emissions from fuel vaporization through the use of fuel vapor control systems and, to control blowby gases, the use of a positive crankcase ventilation system.

Carbon monoxide and hydrocarbon tailpipe emissions can be controlled by engine design modifications, particularly more precise control of the air-fuel ratios, and the use of oxidizing catalytic converters which change the hydrocarbon and carbon monoxide emissions into carbon dioxide and water. Nitrogen oxide emissions have been reduced through the use of exhaust gas recirculation systems and reducing converters on exhaust systems. To achieve and maintain the inherent capacity of emission control components in highway vehicle engines, proper maintenance and adjustment of such components are required throughout the operating life of the vehicles.

Chapter X

AIR QUALITY SIMULATION MODELING

INTRODUCTION

A quantitative analysis of the relationships among air pollutant emissions, prevailing meteorological conditions, and resulting air pollutant concentrations is a fundamental requirement of any comprehensive air quality maintenance planning effort. Such an analysis is necessary not only to assist in estimating the existing pollutant levels in the ambient air but also to enable sound forecasts of pollutant levels and estimates of required pollution abatement requirements to be made for a variety of alternative regional growth and development patterns and attendant pollution control strategies. In order to make a quantitative assessment of those factors which influence ambient air quality, the use of an analytical tool capable of measuring the impact of land use development, transportation systems development and operation, fuel utilization, and the implementation of proposed pollution abatement strategies is required. Recent developments in the fields of computer science and air quality simulation modeling have provided this necessary analytical tool.

The purpose of this chapter is to describe the air quality simulation models used in the regional air quality maintenance planning program. More specifically, this chapter discusses the need for and nature of air quality simulation modeling, the criteria used in selecting the models appropriate for realizing the objectives of this planning program, and the theoretical basis and operating characteristics of the air quality simulation models selected.

AIR QUALITY SIMULATION MODELING: BACKGROUND

Need For Modeling

In planning for the attainment and maintenance of the established ambient air quality standards, the pollutant levels throughout the Region should be quantified in order to estimate the magnitude and areal extent of the regional air pollution problem. The cost of installing, operating, and maintaining the elaborate network of air quality monitoring instruments necessary to achieve this ideal spatial and temporal resolution of pollutant levels, however, is prohibitive. Moreover, even if such an air quality monitoring network were feasible, the data thus obtained would reflect only existing conditions and, consequently, would be of limited value for relating changes in land use or in the transportation network to changes in ambient air quality. Also, a monitoring network generally cannot distinguish the effects of one type of pollutant source from another to assist in the investigation of control strategies. It is evident, therefore, that any regional air quality maintenance planning process must rely on the use of some analytical tool to serve as an adjunct to and an extension of the existing ambient air quality monitoring network. Air quality simulation modeling is the primary analytical tool available to meet this need.

Monitoring and modeling have complementary roles in the air quality maintenance planning process. Ambient air quality monitoring is best suited for determining the absolute values of pollutant concentrations at any given location, but has limited capability for addressing the variability of pollutant levels due to changes in emissions and meteorological conditions. Air quality simulation modeling, on the other hand, has a limited capability for accurately determining absolute levels of pollutants in the ambient air, but is well suited for evaluating spatial and temporal patterns of pollutant concentrations, as well as the impacts of specified emissions and meteorological conditions. Because of their complementary nature, air quality monitoring data and air quality simulation modeling techniques allow comprehensive air quality maintenance planning to be achieved at a regional level under varying alternative growth and development forecasts.

NATURE OF MODELING

The first attempt to numerically quantify the diffusion process in the atmosphere was made by Adolph Fick, a German physiologist, in 1855. This quantification, known as Fick's Law, related the change over time in the mean value of some conservative air property, such as the amount of an air pollutant, per unit mass of air to the distance the air parcel traveled from its original position times an eddy-diffusivity coefficient which was assumed to be constant. In 1926, L. F. Richardson, a British mathematician who is often referred to as the founder of "numerical weather forecasting," generalized Fick's Law for three dimensions, each with independent diffusion coefficients. Richardson's mathematical approach to describing atmospheric diffusion is known as the "K-theory" or "gradient transport theory." The major constraint on the practical application of this theory in air pollution modeling is the fact that the wind and diffusivity of an air parcel must be exactly defined for a particular period of time if accurate results are to be obtained. Since the precise quantity of a pollutant species in an air parcel and the wind and diffusivity acting on that parcel are not readily determined, resultant errors in the diffusion calculations are common.

A second approach to the numerical description of the atmospheric diffusion process was developed by Sir Geoffrey I. Taylor, a British mathematician, in 1921. Taylor's approach, known as the statistical theory of turbulent diffusion, consisted of defining the cross-wind

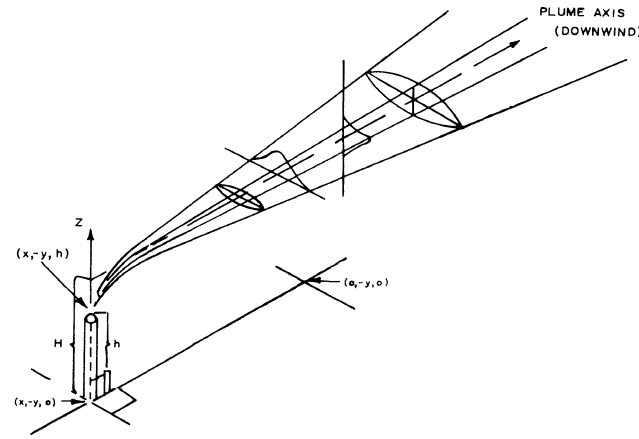
distribution of particles based on the generalized properties of the initial air parcel and the downwind distance of the parcel from the source at a single point in time. The statistical theory was refined in 1932 by O. G. Sutton, a British meteorologist, who developed an equation to compute air pollutant concentrations for both instantaneous and continuous emissions from point sources. Sutton's diffusion equation assumed a Gaussian distribution of pollutant concentration in the dispersing air parcel.[1]

Figure 75 provides a schematic representation of the dispersion of continuous pollutant emissions from an elevated source as the emissions are diffused in the horizontal and vertical planes according to the Gaussian distribution equation.

The σy and σz terms in the Gaussian distribution equation, which may be considered analogous to the eddy-diffusivity coefficients in the gradient transport equation, vary according to prevailing meteorological conditions, particularly atmospheric stability. The relationship between the σy and σz dispersion coefficients and atmospheric stability was initially addressed in "Project Prairie Grass"[2] conducted over a large flat plain in the Midwest during the summer of 1956. From the data collected in this project, Dr. F. Pasquill developed a family of σy and σz dispersion curves which defined the horizontal and vertical standard deviations of an emissions plume as a function of downwind distance for various atmospheric stability categories. These dispersion curves are presented in Figure 76 for vertical dispersion and Figure 77 for horizontal dispersion.

Figure 75

SCHEMATIC REPRESENTATION OF PLUME DISPERSION ACCORDING TO A GAUSSIAN DISTRIBUTION



Source: U. S. Environmental Protection Agency.

The statistical theory of diffusion and the gradient theory of diffusion have provided the mathematical basis for two generic classes of air quality simulation models: Gaussian and numerical grid models, respectively. In addition, there are two modeling classes which rely less extensively on rigorous mathematical techniques for numerically describing the dispersion capabilities of the atmosphere. The first is the statistical/empirical generic class of models. Statistical/empirical models attempt to establish either linear or nonlinear relationships between changes in ambient air pollutant concentrations and changes in emission rates. These types of models are used whenever scientific understanding of the physical and chemical processes in the atmosphere is incomplete, making the use of the more sophisticated mathematical models impractical. The second is the physical class of models. Physical models involve the use of wind tunnels, smog chambers, or fluid modeling facilities. These types of models may be very effective in evaluating the air quality impact of a single source or a small group of sources in a limited geographic area or in areas where complex terrain influences the diffusion process.

All of the air quality simulation models presently available may be categorized into one of the four above-described generic classes—Gaussian, numerical, statistical/empirical, or physical. Within some of these generic classes, a large number of individual "computational algorithms" may exist, each with its own specific applica-

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[1] *A Gaussian, or normal, distribution can be depicted by a symmetric bell-shaped curve representing a typical, normal distribution of events or occurrences. The most generalized form of the Gaussian distribution equation for atmospheric diffusion in three dimensions is expressed as:*

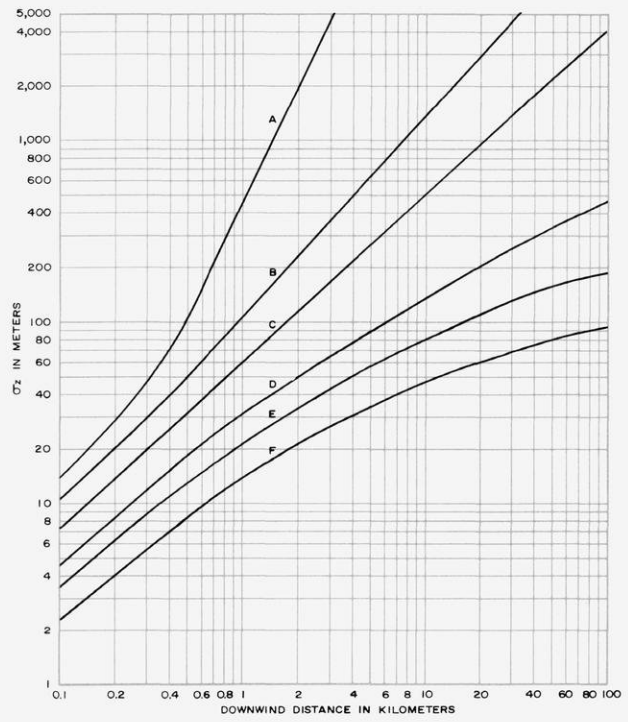
$$C = \frac{Q}{2\pi\sigma y\sigma z\mu} \exp\left[-1/2\left(\frac{y}{\sigma y}\right)^2\right] \left[\exp\left[-1/2\left(\frac{z-H}{\sigma z}\right)^2\right] + \exp\left[-1/2\left(\frac{z+H}{\sigma z}\right)^2\right]\right]$$

where: C = *predicted pollutant concentration* (g/m^3)
Q = *stack emissions* (g/m)
y = *crosswind distance between point source and receptor* (m)
z = *vertical distance from ground to receptor* (m)
H = *effective stack height (stack height + plume rise)* (m)
σy = *horizontal Gaussian dispersion coefficient* (m)
σz = *vertical Gaussian dispersion coefficient* (m)
μ = *wind speed* (m/s)

[2] *H. E. Cramer, "A Practical Method for Estimating the Dispersal of Atmospheric Contaminants," presented at the Proceedings of the First National Conference on Applied Meteorology, Hartford, Connecticut, 1957.*

Figure 76

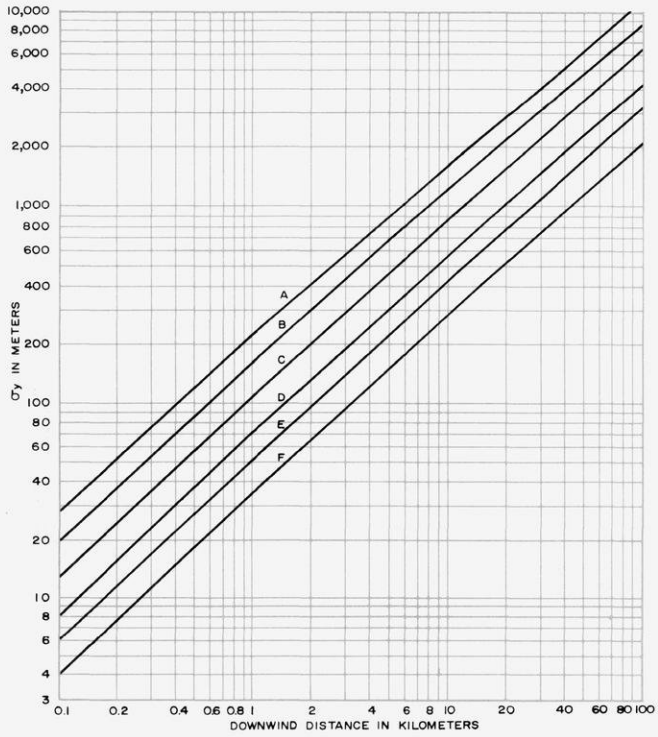
STANDARD DEVIATIONS OF VERTICAL DISPERSION AS A FUNCTION OF DOWNWIND DISTANCE



Source: U. S. Environmental Protection Agency.

Figure 77

STANDARD DEVIATIONS OF HORIZONTAL DISPERSION AS A FUNCTION OF DOWNWIND DISTANCE



Source: U. S. Environmental Protection Agency.

tions.[3] It has become common practice, however, to refer to each individual computational algorithm as a separate "model." In many cases, the only real difference between models within the same generic class is the degree of detail considered in the input or output data.

Table 241 presents the characteristics of a selected cross-section of available air quality models. Most of the models presented in Table 241 have been used in air pollution studies conducted by governmental agencies and the private sector. This table serves primarily to indicate the many applications of available simulation models—depending on such factors as the pollutant species to be examined and the averaging period to be considered—and to note differences in the input data requirements and the usefulness of the resultant calculations.

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[3] *It is important to distinguish between "models" and "computational algorithms." A model may be defined as a set of mathematical relationships which are based on scientific principles and often use adjustable parameters. A computational algorithm, on the other hand, is a set of detailed instructions for implementing a model.*

For the purpose of the regional air quality maintenance planning program, it was deemed essential to select the most reliable simulation model available under the existing state-of-the-art, based on a consideration of all of the factors listed in Table 241. From an initial review of the state-of-the-art of simulation modeling, it was evident that the most reliable models were those which utilized complex numerical equations to replicate the dynamic processes of atmospheric diffusion and thus required the use of a digital computer. It is important to emphasize that the model used in the regional air quality maintenance planning program, or more specifically the mathematical computations and logic decisions executed during the operation of that model, is no more and no less sophisticated or valid than the computations which could, with virtually unlimited personnel and time, be accomplished manually. The only advantage of digital computer simulation over manual computations is the rapidity of the computer computations and logic operations relative to the manual approach. Because of the staff and time requirements and associated monetary costs, it would have been impractical to manually execute the computations necessitated in a single application of the model used in the regional air quality maintenance planning program.

Table 241

CHARACTERISTICS OF SELECTED AIR QUALITY SIMULATION MODELS

Model Name	Model Technique	Pollutant Specification	Averaging Time Specification	Input		Concentration Estimates	Reliability
				Emission Data	Meteorological Data		
Rollback	Proportional reduction	Any pollutant	Any	Areawide emission totals	None	One estimate applicable to entire Air Quality Maintenance Area	Questionable
Miller-Holzworth	Integration of Gaussian dispersion across an urban area	Sulfur dioxide, particulate matter	1 Hour, Annual	Areawide emission totals	Average wind speed and mixing height	One estimate applicable to entire Air Quality Maintenance Area	Can be verified and calibrated
Hanna-Gifford	Simplified dispersion equation over an area	Sulfur dioxide, particulate matter, carbon monoxide	Annual	Areawide emission totals	Average wind speed	One estimate applicable to entire Air Quality Maintenance Area	Can be verified and calibrated
Hanna-Gifford with Point Source	Addition of specific point source calculations to basic Hanna-Gifford	Sulfur dioxide, particulate matter	1-24 Hour	Detailed point, area, line	Hourly variations of wind direction, wind speed, and mixing height	At any specified point	Can be verified and calibrated
Hanna-Gifford with HIWAY	Addition of line source calculations to basic Hanna-Gifford	Carbon monoxide	1-24 Hour	Detailed point, area, line	Hourly variations of wind direction, wind speed, and mixing height	At any specified point	Can be verified and calibrated
Air Quality Display Model (AQDM); Climatological Display Model (CDM)	Gaussian plume concentration calculations for annual averages	Sulfur dioxide, particulate matter	Annual	Detailed point, area, line	Frequency distribution of wind direction, wind speed, stability, and mixing height	At any specified point	Can be verified and calibrated
Sampled Chronological Input Model (SCIM); Realtime Air Quality Simulation Model (RAM)	Gaussian plume concentration calculations for 1-hour averages	Sulfur dioxide, particulate matter	1-24 Hour	Detailed point, area, line	Hourly variations of wind direction, wind speed, and mixing height	At any specified point	Verification incomplete; uncertain possibility of calibration
APRAC-1A	Line source calculations for highway and street links	Carbon monoxide	1-24 Hour	Detailed point, area, line	Hourly variations of wind direction, wind speed, and mixing height	At any specified point	Verification incomplete; uncertain possibility of calibration
SAI	Photochemical reaction and dispersion calculations	Carbon monoxide, nitrogen dioxide, ozone	1-10 Hour	Total emissions distributed as finite area sources	Hourly variations of wind direction, wind speed, and mixing height	One estimate for each area source grid	Verification incomplete; uncertain possibility of calibration
Empirical Kinetics Modeling Approach (EKMA)	Simulates ozone formation in urban atmospheres	Ozone	1 Hour	Precursors of ozone	Mixing height, solar intensity	One maximum concentration as a function of ozone precursors	Verification and calibration by Environmental Sciences Research Laboratory
Wisconsin Atmospheric Diffusion Model (WIS*ATMDIF)	Gaussian plume and numeric model computes concentration from up to 500 sources at up to 1,000 receptor points	Sulfur dioxide, particulate matter, carbon monoxide, nitrogen oxide, hydrocarbons	Short-term, Annual	Detailed point, area, line; stack height, stack diameter, stack gas exit volume, stack gas exit temperature	Stability class, wind direction, wind speed, mixing height, ambient air temperature	At any specified point	Can be verified and calibrated for nonreactive pollutant species
Texas Climatological Model (TCM)	Long-term mean concentrations for point and area sources; conceptually similar to CDM	Sulfur dioxide, particulate matter	24-Hour, Season, Annual	Single average emission rate for the averaging time period	Stability class, wind direction, wind speed	At any specified point	Self-calibrating with input of field receptor observations
Texas Episodic Model (TEM)	Short-term Gaussian plume model	Sulfur dioxide, particulate matter	10-Minute-24-Hour	Unique emission rate for each source	Stability class, wind direction, wind speed	At any specified point	Can be verified and calibrated
Point Source Dispersion Model (CRSTR)	Gaussian plume model applicable in uneven terrain for a point source with up to 19 stacks	Sulfur dioxide, particulate matter	1-24 Hour	Unique emission rate for each stack	Hourly variation of wind direction, wind speed, and mixing height	Highest 1-hour and 24-hour concentrations for the year and each day	No calibration option; work in progress
Point Source Dispersion Model (PTDIS)	Gaussian plume model estimates concentrations directly downwind of a point source with up to 50 receptors	Sulfur dioxide, particulate matter	1-24 Hour	Single point source emission rate	Stability class, wind direction, wind speed	One at each specified point	No calibration option
Point Source Dispersion Model (PTMAX)	Gaussian plume model determines downwind distance to ground-level maximum concentration	Sulfur dioxide, particulate matter	Less than 1 Hour	Single point source emission rate	Wind direction implicit; internally defined wind speed values	At specified point	No calibration option
Point Source Dispersion Model (PTMTP)	Gaussian plume model estimates concentrations for up to 25 sources	Sulfur dioxide, particulate matter	1-24 Hour	Point sources	Hourly wind direction, hourly wind speed, stability class, mixing height, ambient air temperature	At specified points	No calibration option

Source: U.S. Environmental Protection Agency and SEWRPC.

SIMULATION MODELS USED IN THE REGIONAL AIR QUALITY MAINTENANCE PLANNING PROGRAM

Model Selection Criteria

Prior to the selection of an air quality simulation model for use in the regional air quality maintenance planning program, the scope of the proposed planning program as well as the air quality problems within the Region were examined in order to determine the applicability of simulation modeling. Based on that examination, it was determined that the "ideal" air quality simulation model should have the following capabilities or features:

1. It should be able to accurately and reliably simulate the dispersion of atmospheric pollutants for short-term time periods—ranging from one hour to 24 hours—and also for periods as long as one year in order to establish the existing levels of air pollution within the Southeastern Wisconsin Region and, ultimately, to ascertain the geographic extent of those areas which exceed the National Ambient Air Quality Standards for the prescribed periods of measurement corresponding to each pollutant species.

2. It should be able to accurately and reliably simulate the chemistry of reactive pollutant species during transport within the Region.

3. It should be able to accurately and reliably simulate the effects of unique meteorological phenomena, such as the "lake breeze," on the dispersion of atmospheric pollutants within the Region.

4. It should be able to identify those meteorological conditions which most restrict the diffusion capabilities of the atmosphere and which may lead to the excessive accumulation of pollutant levels in the ambient air.

5. It should permit an assessment of the impact on ambient air quality of the emissions from point sources of air pollution such as major industrial facilities.

6. It should permit an assessment of the impact on ambient air quality of the emissions from mobile sources of air pollution such as automobiles, trucks, and buses operating over the regional transportation system.

7. It should permit an assessment of the impact on ambient air quality of the emissions from those individually small, but numerous, areawide sources of air pollution such as residential space heating and agricultural tilling operations.

8. It should permit an assessment of the impact on ambient air quality of changes in existing land use due to regional growth and development patterns, and of changes in the attendant transportation system designed to meet anticipated travel demand in the Region in future years.

9. It should permit an assessment of the impact on ambient air quality of the implementation of certain transportation control measures and selected transportation systems management elements.

10. It should permit an assessment of the impact on ambient air quality of proposed emission limitations on either existing or new major point sources of air pollution.

The above 10 criteria pertain directly to the needs of the regional air quality maintenance planning program. The model selection process, however, also considered the applicability of air quality simulation modeling techniques to other ongoing or proposed Commission work programs. For example, while various air quality simulation models were being considered for use in the regional air quality maintenance planning program, the Commission was in the process of reevaluating and updating the regional land use and transportation system plans. Early in this plan reevaluation process, it was recognized that air quality concerns should be an overriding consideration in the final selection, adoption, and implementation of the updated plans. The primary analytical tool available to compare the relative impact of the alternative land use and transportation plans on ambient air quality is an air quality simulation model with the capacity to forecast relative pollution levels over large-scale geographic areas.

The period of model selection also coincided with the advent of several regulations promulgated by the U. S. Environmental Protection Agency (EPA) concerning emission limitations for major new stationary sources and the prevention of significant deterioration in areas presently meeting the National Ambient Air Quality Standards. These regulations, which are discussed in Chapters II and III of this report, focused on the air pollutant emissions discharged by sources or facilities in any one of 28 industrial categories. On the basis of these regulations, it was apparent that the selected air quality model would have to be able to forecast the air quality impact of single sources of air pollution on a much more localized geographic area than the Region. This was particularly true in the areawide water quality management planning program, in which an estimation of the impact of potential wastewater management facilities- including sludge incineration facilities- on ambient air quality was necessary as a part of the environmental assessment of the plan. Since it was anticipated that the air quality simulation model would be applied in both the land use and transportation planning programs and in the areawide water quality management planning program, as well as in other Commission planning programs, it was deemed desirable to select a flexible model which could be refined and adapted to meet the needs of a wide cross-section of environmental planning activities.

Model Selection

There is no single digital computer model capable of meeting all of the selection criteria. In particular, there is no single simulation model that can adequately replicate the transport and diffusion of reactive pollutant species from their source through the atmosphere while also accounting for the photochemical reactions leading to the generation of oxidant products in the ambient air. Moreover, no single computer model can simulate both the required long-term and short-term averaging periods, or the diffusion of point, area, and line source emissions simultaneously. Therefore, it was necessary to first select a model for photochemical oxidants, and to then ascertain the best available "package" of models for simulating the transport and diffusion of the nonreactive pollutant species.

The Photochemical Oxidant Model: The primary purpose of photochemical oxidant models is to determine the reduction in precursor emissions necessary to attain the ambient air quality standard for ozone. To this end, the EPA has allowed the use of four alternative analytical techniques for establishing fundamental relationships between ozone levels in the lower atmosphere and the estimated quantity of precursor emissions: proportional rollback, statistical modeling, photochemical dispersion models, and the Empirical Kinetics Modeling Approach (EKMA). These four techniques are intended to replace the "Appendix J" approach—so-called because the procedure was originally documented in Appendix J to Title 40, Part 51, of the Code of Federal Regulations—which has been summarily abandoned.

Reflecting the state-of-the-art of photochemical oxidant modeling, each of these alternative analytical techniques has certain inherent limitations which preclude the establishment of exact, precisely quantified relationships between ozone levels and precursor emissions. Proportional rollback, for example, assumes a simple linear relationship between ambient concentrations of ozone and precursor emissions. Under this assumption, a 10 percent reduction in precursor emissions in a specific area would produce a corresponding 10 percent reduction in the concentration of ozone in the same area. Such an assumption does not take into account the complex and numerous ongoing chemical reactions in the atmosphere which vary under the influence of external factors such as the amount and duration of irradiation by sunlight. Moreover, the proportional rollback technique, as generally applied by the EPA, considers only the change in hydrocarbon levels in determining ozone concentrations and neglects the contributing influence of other pollutants—such as nitrogen dioxide—which are essential to oxidant formation in the ambient air. The proportional rollback technique may be useful, however, in determining the minimum level of hydrocarbon emissions control needed to attain the oxidant standard.

Statistical modeling techniques represent an improvement over proportional rollback in that a broader range of factors influencing ambient air oxidant concentrations is included in a more sophisticated analysis. Examples of such techniques include simple log linear regression equations, empirically derived envelope curves for individual cities, stochastic models, and complex multiple regression systems. Statistical modeling techniques may be used to relate pollutant emission rates and meteorological conditions to observed oxidant levels at a specified site, but they cannot be used to demonstrate a definitive cause-effect relationship. Therefore, the simulation results are of questionable reliability when used to extrapolate oxidant levels beyond the range of conditions from which the model was derived. Statistical models are thus more appropriately used to indicate the direction of change of oxidant levels under varying emission rates and meteorological conditions than to make absolute numerical predictions.

Photochemical dispersion models, which include procedures for quantifying the chemical mechanisms active in the atmosphere, have the potential to be theoretically more sound than the other oxidant modeling alternatives. Moreover, photochemical dispersion models provide a greater temporal and spatial resolution than may be achieved through use of the alternative approaches. Such resolution is an important feature since it allows for a greater flexibility in estimating the benefit of alternative control strategies. The widespread use of photochemical dispersion models is hindered, however, by several significant limitations. First, the data base required for such models is extremely detailed and intense and often is not readily obtainable. In order to achieve the spatial and temporal resolution of oxidant concentrations as output from these models, the input data must have a high spatial and temporal resolution. Moreover, a much greater knowledge of the mix of organic compounds in the atmosphere, as well as a fairly large oxidant monitoring network, must be available to operate and validate the model. Second, photochemical dispersion models are subject to several of the same shortcomings as the less data-intensive approaches in that the appropriate boundary and initial conditions must be accurately determined if the diffusion and chemical reactions within an air parcel are to be reliably simulated. Finally, photochemical dispersion models have not been extensively verified and, therefore, their ability to simulate oxidant formation and transport has not been widely demonstrated nor accepted.

The Empirical Kinetics Modeling Approach (EKMA) represents a compromise between rigorous treatment of chemical and physical principles underlying the formation and dispersion of oxidants and the representation of those principles in a photochemical dispersion model, which would require the use of extensive data. The EKMA is not as accurate or flexible as photochemical dispersion modeling but it simulates actual conditions in the atmosphere to a greater extent than the statistical or rollback approaches.

Conceptually, the EKMA examines the changes in a column of air—extending from the ground to the base of an upper air inversion and containing an initial concentration of ozone and precursor compounds—as it is trans-

ported along an assumed trajectory. As the column moves along the trajectory, it encounters fresh emissions which are assumed to be uniformly mixed throughout the column. In effect, the column is assumed to act like a large smog chamber in which the precursors react to form ozone.

EKMA is best suited to determining the sensitivity of maximum hourly ozone concentrations within or downwind of a large urban area to changes in ambient levels of nonmethane hydrocarbon (NMHC) and nitrogen oxide (NO_X) precursor emissions. This method is thus useful for determining the areawide reduction in precursor emissions necessary to attain the ambient air quality standard for photochemical oxidants, although it is less suitable for estimating the air quality impact of controlling the emissions from a single source or small group of sources. The fact that oxidant products and their precursors are subject to long-range transport, however, tends to diminish the importance of single sources of emissions and enhance the need to adopt an areawide approach in the development and evaluation of alternative control strategies. Since the EKMA was determined to meet that need in the most cost-effective manner, that model was selected for use in the regional air quality maintenance planning program.

Theoretical Basis for the EKMA: The EKMA was developed through work contracted for and done by the U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. The relationships among oxidants (expressed as ozone) and their precursor compounds that underlie this approach are based on the application of a chemical kinetics mechanism which is used to represent a detailed sequence of chemical reactions that has been advanced for a mixture of certain hydrocarbons, most notably propylene and n-butane, and nitrogen oxides.[4] The chemical mechanism used in the kinetics model is based on data obtained from smog chamber experiments with this simplified hydrocarbon-nitrogen oxide mixture conducted primarily at the University of California at Riverside. These data were matched against the U. S. Bureau of Mines smog chamber data obtained by irradiating automobile exhaust gases. Initial proportions of propylene and n-butane were then adjusted in the EKMA to obtain consistently close agreement with the Bureau of Mines smog chamber data. This adjustment was made because the smog chamber experiments are thought to use a mixture of reactive compounds more representative of that found in the urban atmosphere. There are generally no data, however, on the relative mix of hydrocarbon compounds that may be found in individual urban areas. Even in those few cases where such data are available, the EKMA could not use it directly because the detailed chemical kinetics of each hydrocarbon species is insufficiently understood at the present time. The EKMA uses the chemical mechanism for n-butane and propylene, which have been more reliably established, as representative of the two principal hydrocarbon classes found in automobile exhaust—paraffins and olefins, respectively. The only atmospheric mix for which a corresponding butane-propylene mix has been established is the automotive mix used in the Bureau of Mines smog chamber. This mix has been determined to be best represented by a three-to-one butane-propylene ratio.

Also incorporated into the EKMA are the physical transport and diffusion of the oxidants and precursors. The model considers an imaginary column of air—generally centered over the central business district of a major urban area—which extends from the ground to the base of an upper air inversion, such as that shown conceptually in Figure 78. The diameter of the column is large enough so that the horizontal exchange of air into and out of the column may be disregarded. Also, air within the column is assumed to be mixed uniformly at all times. The column of air is moved along a specified trajectory at a given speed as determined by the prevailing wind field. As the column moves, the volume changes in accordance with the diurnal change in the height of the inversion. Along the trajectory, the column also encounters precursor emissions, which are assumed to be instantaneously and homogeneously mixed within the column. The column may then be considered as a large reaction vessel wherein the chemical kinetics mechanisms simulate the transformation of precursors into ozone.

Operational Characteristics of the EKMA: There are two variations of EKMA. The first utilizes a standard set of ozone isopleths in which fixed assumptions have been made about sunlight intensity, initial precursor concentrations, atmospheric dilution rate, reactivity of precursor pollutants, and diurnal and spatial emission patterns. The second utilizes data for the same variables but determined for a specific urban area to produce a set of ozone isopleths depicting maximum afternoon concentrations of ozone downwind of that area. Since it was deemed desirable to use data from the Southeastern Wisconsin Region in the EKMA, the second variation was selected for use in the regional air quality maintenance planning program.

The EPA-developed computer program associated with the city-specific version of EKMA has the file name of Ozone Isopleth Plotting Package (OZIPP). The OZIPP operates in two principal stages. The first stage performs computer simulations to calculate maximum ozone concentrations as a function of the initial conditions specified by the user. The second stage provides the interpolation schemes that are used to draw the ozone isopleth diagram that is OZIPP's major output. Table 242 summarizes the major data input requirements for the OZIPP program to enable a city-specific isopleth diagram to be drawn. It should be noted that if the initial input

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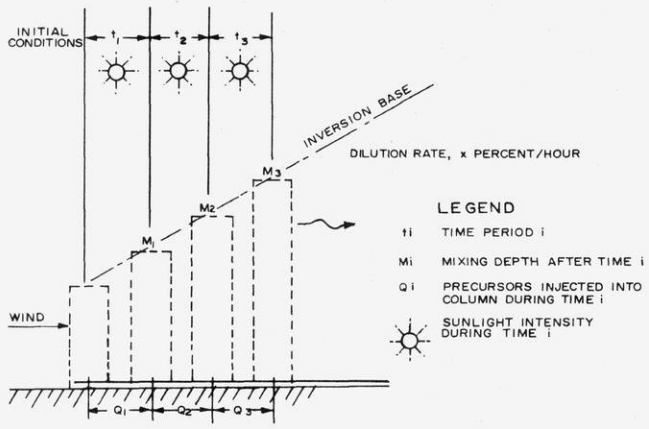
[4] *A chemical kinetics mechanism is a set of chemical reactions and rate constants that is intended to describe some chemical process. From a kinetic mechanism, it is possible to derive coupled, first-order, nonlinear differential equations that describe the rates of change of pollutant concentrations with time.*

Figure 78

CONCEPTUAL REPRESENTATION OF THE OPERATING PRINCIPLE OF THE EMPIRICAL KINETICS MODELING APPROACH



Source: U. S. Environmental Protection Agency.

conditions are not specified the default values indicated in Table 242 will apply, thereby reproducing the isopleth diagram corresponding to the standard variation of the EKMA.

As shown in Table 242, the first data set provides the amount of sunlight to which the column of air will be exposed along its trajectory. Termed the average photolytic rate constant, this value is calculated internally in the program based on the geographic location of the center of the urban area under consideration and on the precise time of year for which the analysis is being conducted. The photolytic rate constant is adjusted for each hour of the simulation period. If local conditions are not specified, the default option computes the average photolytic rate constant for the City of Los Angeles, California on June 21, 1975.

The change in the volume of the initial column of air with time is defined by the dilution rate. A city-specific dilution rate is determined in the OZIPP program when the height of the early morning mixing layer and the mid-afternoon mixing layer are provided as input along with the start and stop hour for the inversion rise. The default options are an initial mixing layer of 510 feet and a final mixing layer of 630 feet beginning at 8:00 a.m. and ending at 3:00 p.m.

Data on precursor emissions are input into the program in terms of relative emission rates. The emissions considered are nonmethane hydrocarbons (NMHC's) and nitrogen oxides (NO_X). The emission rates are based on the estimated spatial and temporal distribution of NMHC and NO_X emissions encountered by the imaginary column of air as it moves out from the central city area along a given trajectory. Following simulation, the rates are normalized relative to the emissions present in the air column at the beginning of the simulation period. Basic assumptions in the EKMA are that the column of air remains stationary over the central city area prior to 8:00 a.m. and that the level of emissions to which all other emission rates are normalized both spatially and temporally is the sum of the midnight to 8:00 a.m. emissions in that area. If post-8:00 a.m. NMHC and NO_X relative emission rate data are not specified, the OZIPP default option assumes that there are no new emissions encountered by the column along its trajectory.

The reactivity of the precursor emissions is assumed by the basic OZIPP program to be that of a three-to-one initial n-butane-propylene mix, a nitrogen dioxide (NO_2) to NO_X ratio of one-to-four, and an initial aldehyde concentration of 5 percent of the total hydrocarbon mix. If more specific knowledge of the relative mix of any of these pollutant species is available for a given urban area, the reaction rates in the chemical mechanism within the OZIPP program may be adjusted accordingly. For example, most NO_X emissions are largely nitric oxide (NO). The fraction that is NO_2, however, is increased both by photochemically induced organic reactions and by reaction with ozone. If it can be determined that a high background level of ozone is present at the start of the simulation period, that ozone may be assumed to have generated a greater fraction of NO_2 than the default value of 0.25. Adjustments of this nature, however, may significantly influence the calculated level of the maximum average hourly ozone concentrations and, consequently, should be made only when exact local information is available.

One of the major advantages of the EKMA model is its ability to include the effects of transported ozone and precursor compounds from upwind sources in the determination of maximum ozone concentrations downwind of an urban area. Transported ozone and precursors may be assumed to travel within two atmospheric layers: the layer between the surface and the height of the morning inversion, called surface layer transport, and the layer between the base of the morning inversion but below the base of the afternoon inversion, called transport aloft. From tests conducted by the EPA it has been determined that the long-distance transport of precursor emissions, both at the surface and aloft, does not have a significant impact on the maximum ozone levels downwind of an urban area.[5] This is due primarily to the fact that the transported hydrocarbon mix is substantially lower in reactivity than local emissions because of prior reactions occurring during transport. Scavenging of ozone near the ground during the nighttime and early morning

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[5] *U.S. Environmental Protection Agency, Uses, Limitations, and Technical Basis of Procedures for Quantifying Relationships Between Photochemical Oxidants and Precursors, EPA 450/2-77-021a, February 1978, and Procedures for Quantifying Relationships Between Photochemical Oxidants and Precursors: Supporting Documentation, EPA 450/2-77-02b, February 1977.*

Table 242

PRINCIPAL DATA INPUT REQUIREMENTS FOR THE OZONE ISOPLETH PLOTTING PACKAGE

Data Set	Parameter	Units	Default Value
Intensity of Sunlight	Latitude	Decimal Degrees North of Equator	34.058
	Longitude	Decimal Degrees West of Greenwich Meridian	118.250
	Time Zone	Hours From Greenwich Mean Time	8.0
	Year	–	1975
	Month	–	6.0
	Day	–	21
Dilution Rate	Initial Inversion Height	Feet	510
	Final Inversion Height	Feet	630
	Starting Time of Inversion Rise	24-Hour Daylight Time	0800
	Ending Time of Inversion Rise	24-Hour Daylight Time	1500
Nonmethene Hydrocarbon and Nitrogen Oxide Emission Rates	Number of Hours for Which Emission Fractions are to be Input From 1.0 to 10.0	–	–
	Nonmethene Hydrocarbon and Nitrogen Oxide Emission Fraction for Hours 1 to 10	–	–
Pollutant Reactivity	Initial Fraction of Carbon Atoms in the Form of Propylene	–	0.25
	Initial Nitrogen Dioxide/Nitrogen Oxide Ratio	–	0.25
	Fraction of Initial Nonmethene Hydrocarbon Added as Aldehyde	Parts per Million Carbon	0.05
Transport of Pollutants	Concentration of Ozone Transported in the Surface Layer	Parts per Million	–
	Concentration of Ozone Transported Aloft	Parts per Million	–
	Concentration of Nonmethene Hydrocarbon Transported in the Surface Layer	Parts per Million Carbon	–
	Concentration of Nonmethene Hydrocarbon Transported Aloft	Parts per Million Carbon	–
	Concentration of Nitrogen Oxide Transported in the Surface Layer	Parts per Million	–
	Concentration of Nitrogen Oxide Transported Aloft	Parts per Million	–
Plotting Accuracy	Number of Constant Nonmethene Hydrocarbon Nitrogen Oxide Ratio Lines on which Simulations are to be Performed	–	11
	Number of Simulations per Ratio Line	–	5.0
Plotting Scale	Length of the Abscissa	Inches	8.50
	Length of the Ordinate	Inches	5.95

Source: U.S. Environmental Protection Agency and SEWRPC.

also diminishes the influence of surface layer transport in the determination of the maximum ozone levels found downwind in the afternoon. Transport of ozone aloft, however, has been found by the EPA to have a measurable impact on maximum afternoon ozone concentrations on the ground.

Figure 79 depicts the entrainment of ozone aloft into the imaginary column of air as the column moves along its trajectory. As the base of the inversion increases during the course of the day, the ozone transported aloft, which is virtually unscavenged, is mixed with the air in the surface layer. The higher the dilution rate—that is, the faster the inversion rises—the greater the entrainment of ozone aloft into the surface layer. The impact of ozone transported aloft is more significant in the surface layer if local emissions are reduced since less ozone scavenging will occur. It is necessary, therefore, to reduce both local precursor emissions and transported ozone and precursor emissions in order to effectively reduce the urban ozone problem.

The last of the major input variables to the OZIPP computer program, as indicated in Table 242, define the accuracy and scale of the ozone isopleth diagram produced for the locally observed conditions. The isopleth

Figure 79

SCHEMATIC REPRESENTATION OF OZONE ENTRAINMENT FROM ALOFT INTO THE EKMA AIR COLUMN

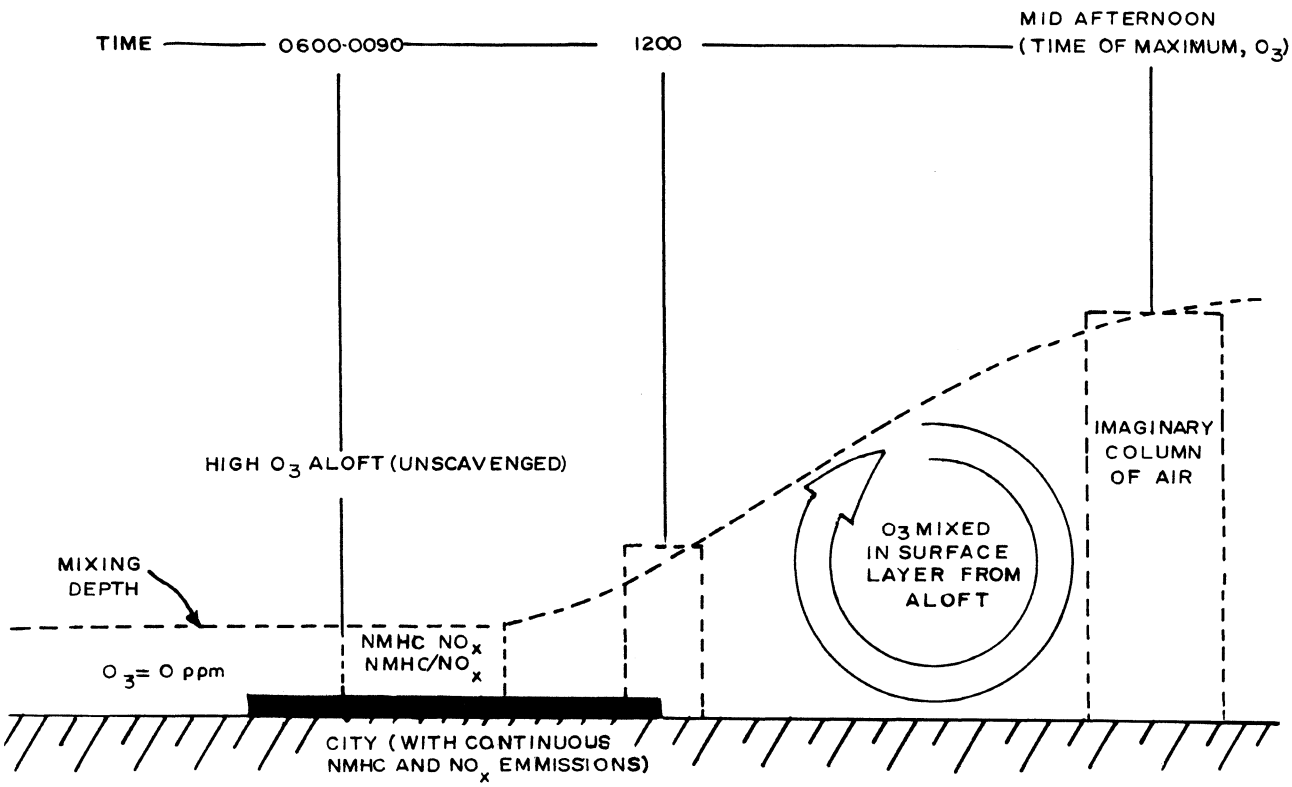


diagram of maximum average hourly ozone concentrations specific for the Southeastern Wisconsin Region is presented and discussed in Chapter XI.

The Nonreactive Pollutant Modeling "Package": As may be seen in Table 241, most of the available air quality simulation models for nonreactive pollutant species—such as particulates, sulfur dioxide, and carbon monoxide—are based on the Gaussian distribution. Whereas use of the Gaussian class of models is considered good practice with respect to stationary point sources having elevated discharges, their use is considered less adequate in simulating the diffusion of the near-surface emissions from line and area sources. Moreover, Gaussian models are generally applicable over relatively short distances and are therefore ill-suited for regional analyses. Numerical simulation models are less subject to these same limitations and represent a significant advance in the analysis of regional ambient air quality problems.

The Wisconsin Atmospheric Diffusion Model was selected for use in the regional air quality maintenance planning program since, in its present state of development, it is one of the most advanced simulation models available in the United States. This nonproprietary model, initially developed by the Air Quality Modeling Group at the University of Wisconsin-Madison between 1972 and mid-1974, combines the use of a Gaussian distribution technique to simulate ambient air pollutant concentrations due to point sources and a numerical technique to simulate ambient air pollution due to line and area sources. Although the responsibility for the operation of the Wisconsin Atmospheric Diffusion Model and its applications in the regional air quality maintenance planning program rested with the University of Wisconsin-Madison under a contractual agreement with the Commission, the model was installed on the SEWRPC computer facilities in 1978.

The computer program for the Wisconsin Atmospheric Diffusion Model, identified by the file name WIS*ATMDIF, consists of three submodels identified by the file names MLTPT, URBAN, and URBANT. Each of these submodels is discussed in the following sections.

MLTPT Submodel: The principal function of the MLTPT (an acronym for multiple point sources) submodel is to compute both the long- and short-term average concentrations of nonreactive pollutant species due to emissions from one or more point sources. In its present configuration MLTPT can simulate the dispersion of pollutant emissions from a maximum of 500 point sources and compute the ambient air pollutant concentrations at

a maximum of 1,000 receptors. The numerous equations used in the MLTPT submodel are presented in Appendix D of this report. In this section, a more generalized overview of the operational characteristics of the MLTPT submodel is presented.

The basic input data to the MLTPT are the geographic location of all point sources and receptor points to be considered in the analysis—identified graphically by a two-dimensional coordinate gridding system, the annual emissions of each pollutant species for each source, the physical characteristics of the stacks from which the pollutants are discharged, and the meteorological data corresponding to the period of analysis. The MLTPT submodel functions by computing the concentrations of a specified pollutant species at a given receptor resulting from the emissions of that pollutant species from all identified point sources. The program then performs the same calculations for a second receptor and continues to reiterate until the pollutant concentration at all receptors has been computed.

One of the preliminary calculations performed in the MLTPT program is the determination of the height at which the pollutant emissions cease to rise vertically above the stack and assume a trajectory with the mean wind flow. This point, termed the effective stack height, is equal to the physical height of the stack plus the distance of plume rise. The distance of plume rise is dependent on both the characteristics of the stack—including the stack diameter, stack gas volume flow rate, and stack gas exit temperature—and prevailing meteorological conditions—including ambient air temperature, wind speed, and atmospheric stability.[6] Five separate equations are used in the MLTPT program to calculate the plume rise depending on the stack characteristics and the stability of the atmosphere (see Appendix E).[7]

The Gaussian distribution equation, such as that used in the MLTPT program, assumes that wind speed remains constant with height. It was noted in Chapter VIII, however, that the wind speed near the surface is slower than the wind speed aloft due to frictional forces at ground level. The standard level for wind speed and wind direction measurements is set at 10 meters (approximately 33 feet)—considerably below the height of pollutant emission discharges from most elevated stacks. To obtain the wind speed at stack height, therefore, the MLTPT program uses the following power law equation:

$$U_s = U_{10}(h_s/10)p$$

where: U_s = the wind speed at stack height,
U_{10} = the wind speed at 10 meters,
h_s = the height of the stack, and
p = the power law exponent as a function of atmospheric stability.

The values of the exponent p contained in the MLTPT program are presented in Table 243 by Pasquill stability class. The wind speed at stack height thus calculated is used for determining the plume rise from a stack, and is considered the mean wind speed parameter in the Gaussian equation.

The pollutant emissions for each point source are input into the MLTPT program as an annual total. The computer program converts this annual total into an average emission rate expressed in terms of grams of pollutant emitted per second. As these emissions are transported from the effective stack height along the wind trajectory, they are assumed to exhibit a Gaussian distribution about the centerline of the wind direction, both in the vertical and horizontal, as depicted in Figure 75. On a long-term basis, however, the pollutant concentration may be considered to be distributed uniformly in the horizontal plane within a sector having an angle of 22.5°. This 22.5° sector corresponds to the angle of wind direction defined by the 16 compass points. For annual periods, it is assumed that all wind directions within each sector occur with equal probability and, therefore, concentrations are distributed uniformly in the horizontal direction of the sector. Under this assumption, only the vertical dispersion coefficient, σ_z, is significant in the determination of pollutant concentrations. The vertical dispersion coefficient is a function of atmospheric stability and downwind distance from the source. The derivation of the values σ_z may assume is discussed in Appendix D.

The annual average concentration at the receptor due to the emissions from one point source is obtained by summing the concentrations calculated by the Gaussian distribution equation for each of six wind speed categories and six atmospheric stability classes expressed in terms of their relative frequency of joint occurrence

Table 243

POWER LAW EXPONENTS USED IN MLTPT SUBMODEL FOR DETERMINING THE WIND PROFILE

Pasquill Stability Class	Exponent (p)
Extremely Unstable (A)	0.10
Unstable (B)	0.15
Slightly Unstable (C)	0.20
Neutral (D)	0.25
Slightly Stable (E)	0.25
Stable-Extremely Stable (F-G)	0.30

Source: Air Quality Modeling Group, University of Wisconsin-Madison.

[6] *A discussion of the effect of prevailing meteorological conditions on plume behavior was presented in Chapter VIII of this report.*

[7] *For more information on the development of these equations, see G. A. Briggs, Plume Rise, U. S. Atomic Energy Commission, Office of Information Services, 1969.*

for the wind direction oriented between the receptor and source. This process is repeated for each receptor point. The concentrations from all point sources are then summed at each receptor point to yield the annual average concentration due to all point sources in the Region.

For determining short-term average pollutant concentrations, the hourly meteorological data are used in place of the relative frequency distributions for wind speed and atmospheric stability in solving the Gaussian equation. Again, the process is repeated for each receptor, and the concentrations from all point sources are summed at each receptor for the averaging time period.

URBAN Submodel: The principal function of the URBAN submodel is to compute the annual average concentrations of nonreactive pollutant species due to the emissions from line and area sources. This submodel is based upon a three-dimensional numerical solution of the conservation of mass for a diffusing species. The URBAN submodel is addressed in more rigorous mathematical detail in Appendix F.

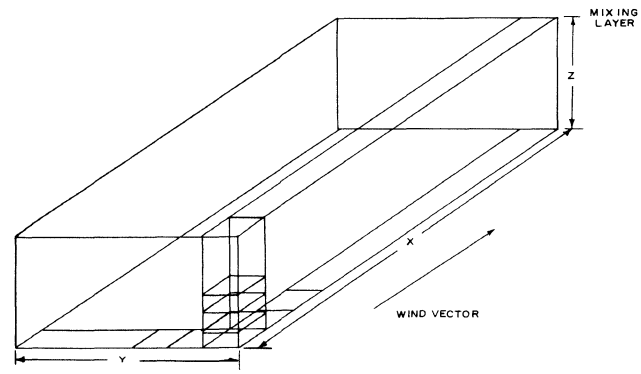
The URBAN submodel may be conceptualized as a series of boxes gridding the Region both vertically and horizontally. This three-dimensional box structure is pictured schematically in Figure 80, where the x-axis is defined by the direction of the mean wind, the y-axis is defined as the crosswind direction, and the z-axis as the vertical direction between the surface and the top of the mixing layer. In this type of model, known as an Eulerian model, pollutant concentrations are determined by computing the flow of mass into and out of each box or cell.[8]

The URBAN cell network established for the Southeastern Wisconsin Region consists of 52 one-mile divisions in the east-west direction, 72 one-mile divisions in the north-south direction, and 12 divisions in the vertical direction of variable size depending on the distance between the ground and the mixing height. The individual boxes, each covering a one-square-mile area, correspond to the U. S. Public Land Survey sections in the Region.

Pollutant emissions are input into the URBAN program by summing the annual line source and area source emissions—either separately or jointly at the option of the user—in each of the four quarter sections comprising a one-square-mile cell. These emissions are then converted internally in the program to an average emission rate expressed in terms of grams of pollutant emitted per second.

Figure 80

SCHEMATIC REPRESENTATION OF THE CELL STRUCTURE SIMULATED BY THE URBAN SUBMODEL



The URBAN program calculates annual average pollutant concentrations within each box at a specified level. This calculation involves determining the mass flow between the cells under various combinations of three atmospheric stability categories, eight wind directions, and three wind speed groups. In total, therefore, there are 72 possible combinations of stability, wind direction, and wind speed for which the mass flow may have to be determined in the URBAN program. Certain combinations of these meteorological factors—such as high wind speeds with stable atmospheric conditions—are not probable events, however, and the number of iterations performed in the URBAN program is generally reduced to about 50 sets of conditions. After the pollutant concentrations have been calculated for each cell under each set of meteorological conditions, the concentrations are summed to yield the annual average.

URBANT Submodel: The principal function of the URBANT submodel is to compute the short-term—one-hour, three-hour, eight-hour, and 24-hour—average concentrations of nonreactive pollutant species due to emissions from line and area sources. The URBANT submodel is a time-dependent version of the URBAN submodel and is identical in operation except that emission rates and meteorological conditions are step-changed hourly.

LIMITATIONS TO AIR QUALITY SIMULATION MODELING AND AMBIENT AIR QUALITY MONITORING

Previous sections of this chapter have discussed the nature and operational mechanics of air quality simula-

[8] *An Eulerian type of model has a fixed multiple-cell structure for which pollutant concentrations may be determined in each cell at a specified time. Eulerian models, therefore, are able to provide a synoptic "picture" of pollutant levels over a broad geographic area. Alternatively, there are Lagrangian type of models, such as the EKMA, in which pollutant concentrations are determined within an individual cell as it is moved along a predetermined trajectory. Although Eulerian models are more expensive to use than Lagrangian models, they are better suited for use in regional air pollution studies since they provide the most complete spatial and temporal analyses of the impact of varying emission levels.*

tion models in general, and the EKMA and WIS*ATMDIF models in particular. It must be emphasized, however, that numerical simulation models, including the EKMA and WIS*ATMDIF, cannot in themselves provide a complete definition of the existing air quality problem in an area, nor can such models offer total resolution to the problem of identifying future air quality problems. Air quality simulation models are merely a tool—an analytical device- which may be used within certain limitations to approximate the distribution and magnitude of existing pollutant concentrations and to indicate the probable rate of progress toward the attainment of the ambient air quality standards stemming from the application of pollution abatement measures or, conversely, the probable rate at which the ambient air is being degraded and existing problems exacerbated. Since an understanding of the limitations of air quality simulation modeling aids in the interpretation of the modeling results and, consequently, improves the decision-making process based on these results, a review of the limitations inherent in the modeling approach is presented herein.

Fundamentally, air quality simulation modeling is limited by the fact that numerical models attempt to reduce the complex physical and chemical processes occurring continuously and ubiquitously in the atmosphere into a set of predictive mathematical equations. Of necessity, these equations represent a simplification of the actual dispersion mechanisms and chemical reactions taking place in the ambient air. It is not possible, for instance, to mathematically quantify the precise motion of an air parcel in three dimensions because of the numerous short-term, small-scale perturbations experienced by the parcel due to mechanical and thermal turbulence. It is possible, however, to characterize the mean wind field by considering only the average wind speed and direction over a broad geographic area irrespective of minor fluctuations. Although some precision is lost and accuracy may be compromised by generalizing such meteorological variables, air quality simulation models must use such a simplified approach if a numerical solution to the dispersion equations is to be practically and economically feasible.

Besides such variables as wind speed and wind direction, which are directly measurable quantities, many air quality simulation models incorporate such parameters as eddy-diffusivity coefficients or horizontal and vertical dispersion coefficients, which may only be indirectly estimated—most often from experimental observations under ideal conditions. For example, both the horizontal spread and vertical spread of an emission plume downwind of a source under various atmospheric stability categories, shown in Figures 76 and 77, respectively, were developed on the basis of observations carried out under a single research project. Air quality simulation models which use these or similarly developed dispersion curves, such as the WIS*ATMDIF multiple point sources submodel, are limited by the accuracy of the experimental data provided by this project. It has been estimated by Dr. F. Pasquill that the maximum downwind ground level concentrations predicted by such models may be expected to be within 10 to 20 percent of the observed concentrations for a near-surface level emission source, and within 20 to 40 percent for an elevated emission source, under ideal circumstances including level terrain and steady meteorological conditions.

The combination of level terrain and steady meteorological conditions does not occur frequently in the routine application of air quality simulation models for maintenance planning purposes in major urban areas. Consequently, the accuracy of pollutant concentrations calculated by simulation models for urban areas will likely be somewhat less than that which would be achieved under idealized conditions. It is generally accepted that air quality simulation models are only accurate within a factor of two for such routine applications; that is, maximum pollutant concentrations in an urban area could range from one-half to twice the values indicated by the modeling results.

Modeling results may be even less accurate under certain "exceptional" conditions. These exceptional conditions would include the special wind field patterns generated by mountainous terrain, the helical wind flow associated with the "lake breeze" effect, wake flows produced by buildings, stacks, and highway vehicles, and the "canyon" flow effect caused by blocks of adjacent and opposing tall buildings. Dispersion modeling for extremely unstable or extremely stable atmospheric conditions and for great downwind distances—that is, more than about five miles, particularly when the characteristics of the underlying terrain change significantly with distance—may reduce accuracy by more than a factor of two.

The nature of the pollutant species being simulated also contributes to the uncertainties in air quality modeling. Chemical processes such as the transformation of gaseous sulfur dioxide to sulfate particles, for example, affect the monitored pollutant concentrations but are not adequately accounted for by most simulation models. Physical processes such as dry deposition, resuspension, and precipitation scavenging are also not accounted for by most simulation models and may contribute to uncertainties in the predicted ambient air pollutant concentrations. These chemical and physical processes may add emissions to the atmosphere, as with resuspension, or may remove pollutants, as with dry deposition, in a manner that the emissions inventory or forecast cannot adequately replicate. Since the emissions data are subject to some initial error due to assumptions inherent in the estimation techniques by which they are prepared, unaccounted atmospheric processes may compound the inaccuracies in the input emissions and, hence, the modeling results.[9]

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[9] *A discussion of the accuracy and precision associated with the preparation of the individual air pollutant emission inventories is presented in Chapter VII of this report. A further discussion of the accuracy and precision of the mathematical models used to prepare necessary input data for certain emission estimates—particularly with regard to the transportation-related data required for the line source inventory—may be found in Chapter IV of SEWRPC Planning Report No. 25, A Regional Land Use Plan and a Regional Transportation Plan for Southeastern Wisconsin: 2000, Volume Two, Alternative and Recommended Plans.*

Many of the aforementioned sources of inaccuracy and imprecision inherent in air quality simulation modeling may be taken into account, and thereby given a lesser impact on the modeling results, through calibration and correlation of the predicted concentrations to the pollutant levels measured by air quality monitors. The calibration procedure allows the modeling results to be adjusted for both systematic errors, such as small-scale spatial and temporal variations in the overall wind field, and background errors, such as chemical reactions in the atmosphere. It is important to note, however, that the calibration of the air quality simulation model is only as valid as the air quality monitoring data itself.

It is evident that air quality monitoring data have a significant, two-fold influence on the development and application of air quality simulation models. First, monitoring data are used as an integral part of the experimental data base for establishing the dispersion coefficients used by air quality simulation models. Second, monitoring data are used as the basis for adjusting the calculated pollutant levels in order to account for, and reduce the impact of, limitations inherent in the modeling effort. In considering limitations to air quality simulation models, therefore, it is necessary to recognize the limitations inherent in ambient air quality monitoring.

Limitations to ambient air quality monitoring are perhaps best exemplified by noting the sources of sampling error associated with hi-vol particulate matter monitors. As described in Chapter VI, the hi-vol monitor draws air through filter paper which captures particles contained in the air stream. The monitor itself has a basically square design with a gabled roof which protects the filter pad from adverse meteorological conditions and which permits particles of between 0.1 and 100 microns to be drawn onto the filter surface. The upper limit to the size of the particles collected, however, is determined by the inlet velocity of the air stream. As the inlet velocity is increased, the capture rate of large particles is also increased, and, as a result, higher levels of total suspended particulate matter in the ambient air are recorded.

The inlet velocity of a hi-vol monitor is dependent on the volumetric flow rate—that is, the volume of air brought through the filter pad by the blower motor—and the cross-sectional area of the inlet on the gabled roof of the monitor. The U. S. Environmental Protection Agency allows considerable latitude in the operational design of hi-vol monitors, particularly with regard to the volumetric flow rate and the inlet area. It is permissible for the volumetric flow rate to be as low as 40 cubic feet per minute (cfm) to as high as 60 cfm. Similarly, the sampler inlet area may range from 60 to 120 square inches. At either extreme, sampler design allows for an inlet velocity of from about 10 inches per second with a flow rate of 40 cfm and a cross-sectional area of 120 square inches, to about 29 inches per second with a flow rate of 60 cfm and a cross-sectional area of 60 square inches. It is evident, therefore, that considerable variation in measured ambient air particulate matter concentrations may be observed depending on the design of the monitor.

A study of hi-vol monitors conducted in the State of Illinois found that a sampler with an inlet velocity of about 14.4 inches per second recorded average particulate matter levels approximately 50 percent higher than an adjacent sampler with an inlet velocity of about 11.8 inches per second.[10] In this study, two hi-vol monitors were operated concurrently for 24-hour periods on 21 sampling days over a three-month period. The monitor operating with an inlet velocity of about 14.4 inches per second had a measured geometric average of 60 micrograms per cubic meter ($\mu g/m^3$)—the level of the secondary annual ambient air quality standard—for the experiment period, while the adjacent monitor with the inlet velocity of 11.8 inches per second measured a geometric average of 40 $\mu g/m^3$. This difference in monitored particulate matter levels may be significant in delineating the location and extent of nonattainment areas and even in identifying the existence of an air pollution problem.

The study of hi-vol monitors in Illinois also noted two additional sources of error in particulate matter sampling: the orientation of the monitor relative to the wind flow and passive loading of the filter pads. To quantify the effect of directional wind bias, two hi-vol monitors were placed adjacent to each other in an area where ambient particulate matter levels were primarily influenced by a single emission source. One monitor was oriented directly toward the source, and the other was positioned at a 45-degree angle. On sampling days when the wind flow was not along a path between the predominant emission source and the hi-vol monitors, both monitors recorded particulate matter levels of nearly the same magnitude—within 1 percent. When the emission source did impact on the monitoring site, however, the monitor oriented at 45 degrees to the wind flow recorded particulate matter levels about 13 percent higher on the average than the monitor perpendicular to the wind flow. The lower measurements recorded by the perpendicular monitor were due to the turbulent wind fields generated by the square sampler head acting as an obstacle to the air flow pattern. The oblique monitor allowed for a freer passage of the wind stream and provided a more accurate sample of the ambient air particulate matter concentrations. This directional bias effect was determined to have the most pronounced impact in industrial areas, where many monitors are source-oriented, and to be less of a concern in rural areas, where emission sources are more diffuse.

Passive loading may be defined as the deposition of airborne particles on a filter pad before or after the collection of the particulate matter sample. Passive loading results from the fact that sampled filters are removed and

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[10] *T. A. Sweitzer and H. E. Hesketh, The Effect of the Hi-Vol Methodology on Air Quality Modeling, The American Society of Mechanical Engineers, Air Pollution Control Division, 78-WA/APC-11, December 1978.*

replaced only once during the normal six-day sampling schedule. A clean filter may be allowed five days in the monitor prior to the sampling date, or conversely, a sampled filter may remain five days in the monitor prior to removal. During the period the filter stands idle it is still exposed to airborne particulate matter. The Illinois study found that passive loading may contribute up to 16 percent of the total particulate matter on filters in industrial areas. In areas with relatively unpolluted air, passive loading was found to account for about 7 percent of the total particulate matter concentrations.

Inlet velocity, wind directional bias, and passive loading are three potential sources of error in particulate matter monitoring. Other physical, chemical, and mechanical sources of error, such as flow rate determination errors, evaporation of volatile matter, motor voltage variations, and changes in relative humidity during the filter weighing process, may also influence the accuracy of the monitored data. Recognizing the limitations inherent in ambient air quality monitoring, the Comptroller General of the United States expressed the concern of the Government Accounting Office on the use of such data in a report to the Congress in October 1978. The report stated:

> In many instances monitoring is too sparse or biased by local conditions to give accurate indications of air quality. Further, some of the monitoring techniques themselves leave much to be desired. Some are being corrected, but others are still highly suspicious. Given these difficulties, trend analysis of pollutants becomes more a guessing game than a reasonable assessment. Even where corrections have taken place, the necessary data base for trends will stretch out for years. Monitoring techniques must be refined or corrected so that air quality can be accurately measured and improvements ascertained. Until monitoring reaches the state where it is an accurate indicator of air quality, EPA should be exceedingly cautious in applying costly and disruptive controls. Where the severity of the problem or even the existence of a problem is also uncertain the end effect becomes riddled with doubt.[11]

The limitations inherent in air quality simulation modeling and in ambient air quality monitoring as discussed in this section indicate that neither device, by itself, constitutes an adequate measure of the air pollution problem in the Southeastern Wisconsin Region. When used in conjunction, however, modeling and monitoring may be mutually supportive and act to ameliorate some of the deficiencies to which each procedure is subject. Calibration of modeling results with monitoring data, for example, reduces the systematic error associated with the reduction of complex physical and chemical atmospheric processes to simplified numerical representations. Alternatively, modeling results, which are not hindered by the vagaries of inlet velocity, directional bias, and passive loading, extend the capabilities of the monitoring network and may provide a more graphic depiction—at least in relative terms—of the distribution of pollutant concentrations throughout the Region. The regional air quality maintenance planning program has, therefore, attempted to carefully integrate both the air quality simulation modeling results and the existing ambient air quality monitoring data in defining the existing air pollution problems in southeastern Wisconsin.

[11] *Sixteen Air and Water Pollution Issues Facing the Nation, Report to the Congress by the Comptroller General of the United States, General Accounting Office, GED-78-148A, October 11, 1978.*

SUMMARY

Air quality simulation modeling, used as an adjunct to and an extension of the existing ambient air quality monitoring network, provides the primary analytical tool in the identification of existing and probable future regional air pollution problems and in the evaluation of the effectiveness of alternative control measures for pollution abatement. As such, air quality simulation modeling and ambient air quality monitoring have complementary roles in the regional air quality maintenance planning process.

Two generic classes of mathematically rigorous air quality simulation models are presently in use: numerical and Gaussian. In addition, there are two alternative, less mathematically rigorous, generic classes of air quality models in use. The first is the statistical/empirical generic class of models. Such models attempt to establish linear or nonlinear relationships between observed ambient air pollutant concentrations and emission rates. The second is the physical generic class of models. These models involve the use of wind tunnels, smog chambers, or fluid modeling procedures. All air quality simulation models presently available may be grouped into one of these four generic classes.

During the process of selecting an air quality simulation model for use in the regional air quality maintenance planning program, it became evident that no single simulation model available could fully meet all of the basic selection criteria. In particular, no air quality simulation model was found that could adequately replicate the transport and diffusion of reactive pollutant species while also accounting for the chemistry leading to the formation of oxidant products in the atmosphere. Moreover, no single simulation model was found that could simulate both the required long-term and short-term averaging periods, or which could simulate the diffusion of point, area, and line sources of emissions simultaneously. It was necessary, therefore, to select one air quality simulation model for photochemical oxidants, and to then ascertain the best available "package" of models for simulating the diffusion of nonreactive pollutant species.

There are four alternative analytical techniques available for establishing fundamental relationships between ozone levels in the lower atmosphere and precursor emissions:

proportional rollback, statistical modeling, photochemical dispersion models, and the Empirical Kinetics Modeling Approach (EKMA). Although each of these four alternative techniques has certain inherent limitations—reflecting the state-of-the-art of photochemical oxidant modeling—the EKMA was selected for use in the regional air quality maintenance planning program since it was determined that this approach was the best available for quantifying the relationship between oxidants and precursors on a regional basis.

The EKMA method, developed by the U. S. Environmental Protection Agency, is based on the application of a chemical kinetics mechanism which is used to represent a detailed sequence of chemical reactions for a mixture of selected hydrocarbon species. The EKMA may be conceptually viewed as a column of air which contains an initial concentration of ozone and precursor compounds. As the column is moved along a predefined trajectory, it encounters precursor emissions which are assumed to be instantaneously and homogeneously mixed within the column. The column may then be considered as a large reaction vessel wherein the transformation of precursors into ozone is simulated.

There are two variations of the EKMA. The first utilizes a standard set of ozone isopleths derived from fixed assumptions concerning meteorological, chemical, and emission rate factors. The second variation utilizes data for the same factors, but determined for a specific urban area. Since it was deemed more appropriate to use locally derived data, the second variation, or the city-specific version, of the EKMA was selected for use in the regional air quality maintenance planning program.

For the simulation of nonreactive pollutant species, the Wisconsin Atmospheric Diffusion Model was determined to be the best available modeling package since, in its present state of development, it is one of the most advanced simulation models in the United States. The Wisconsin Atmospheric Diffusion Model, identified by the file name WIS*ATMDIF, is comprised of three submodels: MLTPT (multiple point sources), URBAN, and URBANT.

The purpose of the MLTPT submodel is to calculate both the long- and short-term average pollutant concentrations due to emissions from point sources. This submodel uses the Gaussian distribution technique, considered to represent good practice for point source modeling, to compute the pollutant concentrations at as many as 1,000 receptors resulting from emissions from a maximum of 500 point sources. The principal function of the URBAN submodel is to compute the annual average concentrations of nonreactive pollutant species due to the emissions from line and area sources. This submodel is based on a three-dimensional numerical solution of the conservation of mass equation for a diffusing species. The URBANT submodel computes the short-term concentrations of nonreactive pollutant species due to emissions from line and area sources. The operation of the URBANT submodel is identical to that of the URBAN submodel except that emission rates and meteorological conditions are step-changed hourly.

Although air quality simulation models are the primary analytical tool available for long-term maintenance planning, all such models are subject to certain inherent limitations. Essentially, these limitations may be attributed to the inaccuracies associated with attempting to reduce the complex physical and chemical processes occurring continuously and ubiquitously in the atmosphere into a set of predictive, and necessarily simplistic, mathematical equations. Because of their inherent limitations, air quality simulation models cannot be used to establish or enforce specific regulations for controlling air pollution. Simulation models, however, are an important supplement to any ambient air quality monitoring network for identifying existing problem areas in the Region, and an excellent indicator of the relative direction and rate of change in air pollution levels over extended forecasting periods. Accordingly, the regional air quality maintenance planning program has attempted to carefully integrate ambient air quality simulation modeling results and existing ambient air quality monitoring data in devising and evaluating plans for the abatement of air pollution in southeastern Wisconsin through the year 2000.

Chapter XI

EXISTING PROBLEM IDENTIFICATION

INTRODUCTION

It was noted in Chapter X that air quality simulation models, when used as an extension of, and an adjunct to, ambient air quality monitoring data, can serve to help define the magnitude and areal extent of existing air pollution problems. This chapter presents the results and findings of the base year air quality simulation modeling effort for the Southeastern Wisconsin Region conducted under the regional air quality maintenance planning program. In particular, this chapter details the calibration and application of the Wisconsin Atmospheric Diffusion Model (WIS*ATMDIF) for estimating ambient regional levels of particulate matter and sulfur dioxide on an annual and short-term basis, and carbon monoxide levels for both eight-hour and one-hour averaging periods. In addition, the results of applying the Empirical Kinetics Modeling Approach (EKMA) to estimate the reduction in hydrocarbon emissions necessary to attain the photochemical oxidant standard in the Region are presented. The EKMA simulation effort is supplemented with estimates of nitrogen dioxide levels in the ambient air of the Region on an annual and short-term basis, and of short-term hydrocarbon levels using the Wisconsin Atmospheric Diffusion Model under the assumption that dispersion is occurring in the absence of photochemical reactions.

In addition to identifying prevailing air pollution levels within the Region, this chapter presents estimates of the number of regional inhabitants who are exposed to the deleterious health effects of adverse pollutant concentrations, utilizing the results of the air quality simulation modeling effort. This chapter also provides an estimate of the regional population residing in those areas of the Region where the secondary ambient air quality standard for a pollutant species has been exceeded.

PARTICULATE MATTER CONCENTRATIONS

There are two averaging periods for which atmospheric particulate matter levels in the Region must be evaluated against the established state and federal ambient air quality standards: the annual average, with a primary standard of 75 micrograms per cubic meter ($\mu g/m^3$) and a secondary standard of 60 $\mu g/m^3$, both expressed as a geometric mean, and the 24-hour average, with a primary standard of 260 $\mu g/m^3$ and a secondary standard of 150 $\mu g/m^3$. As may be seen in Table 73 in Chapter VI, ambient air quality data as monitored in southeastern Wisconsin between 1973 and 1977 have indicated that, although particulate matter levels in the Region have generally been decreasing over the five-year period, the primary annual ambient air quality standard has continued to be exceeded each year in parts of Milwaukee County, and the secondary annual standard has continued to be exceeded in parts of Kenosha, Milwaukee, and Racine Counties. Moreover, a special monitoring study conducted by the Wisconsin Department of Natural Resources during 1977 has indicated that parts of the City of Waukesha exceed the primary and secondary ambient air quality standards for particulate matter on an annual basis.

The fact that particulate matter levels have generally been decreasing in the Region is evident from a review of Figure 38 in Chapter VI, which depicts the annual geometric average at four monitoring stations in Milwaukee County between 1971 and 1977. As may be seen in this figure, the monitoring station located at 1750 S. Kinnickinnic Avenue in the City of Milwaukee, which recorded a maximum annual geometric average particulate matter level of about 158 $\mu g/m^3$ in 1972, has steadily recorded a year-to-year decline in such pollutant levels to about 94 $\mu g/m^3$ in 1977—a reduction of about 64 $\mu g/m^3$, or more than 40 percent, over this six-year period. Although this monitoring station has experienced the largest decline in particulate matter levels, a similar trend has been observed at many other monitoring sites in the Region for which data are available over a long term.

Table 74 in Chapter VI indicates that particulate matter levels have exceeded the primary 24-hour ambient air quality standard in parts of Milwaukee and Waukesha Counties, and have exceeded the secondary standards in parts of all counties in the Region except Washington County, for which no monitoring data are available, based on the pollutant concentrations measured between 1973 and 1977. It is evident from the air quality monitoring data, therefore, that both long-term and short-term concentrations of particulate matter presently occur in areas of the Region at levels potentially detrimental to human health.

The available ambient air quality monitoring data for particulate matter concentrations in the Region serve to identify the existence of adverse conditions, but may not indicate the true magnitude of the problem since the monitoring sites may not correspond to the actual location of the maximum pollutant concentrations. Monitoring data can also be an incomplete indicator of the spatial extent of the particulate matter problem. The Wisconsin Atmospheric Diffusion Model, therefore, was used as an adjunct to the monitoring data in order to more fully define the particulate matter problem in the Southeastern Wisconsin Region. The results and findings of this air quality simulation modeling effort for the annual average and 24-hour average particulate matter concentrations are presented in the following sections.

Annual Average Levels

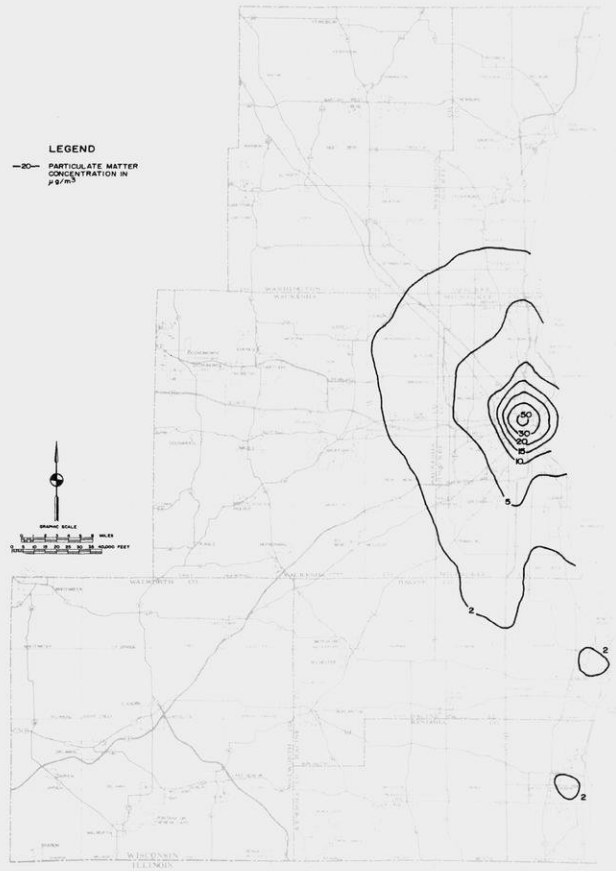
As was noted in Chapter X, the Wisconsin Atmospheric Diffusion Model is comprised of three submodels, each of which represents a computational algorithm for numerically simulating the diffusion processes in the atmosphere. Since these algorithms are mathematical approximations of these rather complex diffusion processes, it is necessary to calibrate the model—that is, to compare initial simulation model results to actual monitoring data and, if necessary, make adjustments in the model so as to calibrate it to the specific characteristics of the Region. Once calibrated, the simulation model may be used to project future ambient air pollutant levels based on forecast emission levels. In the case of particulate matter, the year 1973 was used both for calibrating the model and for defining the magnitude and areal extent of the problem within the Region. Moreover, because the Wisconsin Department of Natural Resources conducted an inventory of fugitive dust emissions from industrial sources which significantly increased the total quantity of identified area source emissions, and because the Department expanded the number of particulate matter monitoring stations in the City of Waukesha during 1977, the regional point, area, and line source emissions inventory for the year 1977 was also simulated and the calibrated results used to validate the application of the WIS*ATMDIF model for the Southeastern Wisconsin Region.

Point Source Concentrations—1973: As may be seen in Table 93 in Chapter VII, approximately 18,100 tons of particulate matter emissions were discharged from point sources in the Region during 1973. The ambient air particulate matter concentrations resulting from these point source emissions were simulated for the prevailing meteorological conditions in 1973 using the multiple point sources (MLTPT) submodel. The prevailing meteorological conditions in the Region during 1973 as input to the MLTPT submodel are summarized in Table 244, and include the relative frequency of occurrence of six wind speed categories, 16 wind directions, and six Pasquill stability classes, and the average mixing height associated with each stability class. The uncalibrated results of this modeling effort are shown on Map 55.

As may be seen on Map 55, the maximum particulate matter concentration isopleth has a value of 50 $\mu g/m^3$, expressed as an annual arithmetic average—with a single point maximum of 60 $\mu g/m^3$—and is centered over the heavily industrialized area of the Menomonee River Valley. The point sources of particulate matter emissions have a significant impact only in Milwaukee County, with the other six counties in the Region having ambient air particulate matter concentrations from point sources generally below 2.5 $\mu g/m^3$ on an annual arithmetic average basis in 1973. This finding may be attributable to four principal factors. First, as evidenced in Table 93 in Chapter VII, approximately 85 percent of all particulate matter emissions from point sources within the Region in 1973 were discharged in Milwaukee County. Second, about 38 percent of the particulate matter emissions from point sources in Milwaukee County were from facilities located in the heavily industrialized area of the Menomonee River Valley. Third, about 99 percent of the particulate matter emissions from point sources in the Menomonee River Valley were attributable to four facilities: Milwaukee Solvay Coke Company, Wisconsin Electric Power Company—Valley Plant, Marquette Cement Manufacturing Company, and PPG Industries. Of these facilities, only one, the Valley Plant, was in compliance with the existing particulate matter emission limitations established by the State. Finally, the Solvay Coke Company, which accounted for about 82 percent of the particulate matter emissions from point sources

Map 55

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE PARTICULATE MATTER CONCENTRATIONS DUE TO EMISSIONS FROM POINT SOURCES IN THE REGION: 1973



This map illustrates the impacts on ambient air quality of particulate matter emissions from point sources—that is, major industrial facilities or fuel-burning installations—in the Region during 1973. As may be seen on this map, the most significant impacts occur in Milwaukee County, where the concentration of particulate matter in the ambient air reaches a level as high as 50 micrograms per cubic meter ($\mu g/m^3$). Ambient air particulate matter concentrations due to point sources in the other six counties of the Region are generally below 2 $\mu g/m^3$ on an annual arithmetic average. The maximum particulate matter concentration isopleth indicated has a value of 50 $\mu g/m^3$, expressed as an annual arithmetic average, and is centered over the heavily industrialized area of the Menomonee River Valley.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Table 244

METEOROLOGICAL DATA USED FOR ANNUAL AVERAGE POINT SOURCE SIMULATION MODELING EFFORT: 1973

Data Group	Parameter	Variable Group	Frequency of Occurrence (percent)	Mixing Heights Associated with Atmospheric Stability Classes
Wind	Speed (knots)	0-3	5.0	--
		4-6	15.8	
		7-10	34.3	
		11-16	35.5	
		17-21	7.8	
		> 21	1.6	
		Total	100.00	
	Direction	North	5.51	--
		North-Northeast	1.55	
		Northeast	3.22	
		East-Northeast	3.19	
		East	4.95	
		East-Southeast	4.35	
		Southeast	4.09	
		South-Southeast	2.83	
		South	6.41	
		South-Southwest	5.54	
		Southwest	9.28	
		West-Southwest	9.38	
		West	12.46	
		West-Northwest	11.13	
		Northwest	8.29	
		North-Northwest	7.82	
		Total	100.00	
Atmospheric Stability	Pasquill Stability Class	A—Extremely Unstable	0.07	1,500
		B—Unstable	1.60	1,500
		C—Slightly Unstable	7.60	1,170
		D—Neutral	70.54	1,000
		E—Slightly Stable	11.77	
		F—Stable	8.42	--
		Total	100.00	--

Source: National Climatic Center; Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

in the Menomonee River Valley, discharged emissions relatively close to ground level, thereby inhibiting dispersion and significantly increasing the potential impact on ambient air quality.

Line and Area Source Concentrations—1973: Annual average particulate matter concentrations due to emissions from line and area sources in the Region during 1973 were simulated using the URBAN submodel of the Wisconsin Atmospheric Diffusion Model. The regional line and area source emission inventories have been summarized in Chapter VII in Tables 123 and 188. The meteorological conditions for 1973, as used in the URBAN submodel, are summarized in Table 245, and include the relative frequency of occurrence of eight wind direction sectors for three atmospheric stability classes, along with the associated value for both the net heat flux and the mean wind speed. As simulated by the URBAN submodel under these meteorological conditions, the uncalibrated ambient air particulate matter concentrations in the Region—expressed as annual arithmetic averages—due to emissions from line sources during 1973 are shown on Map 56, and such concentrations due to emissions from area sources during 1973 are shown on Map 57.

As indicated on Map 56, the highest simulated particulate matter concentration in the Region due to line source emissions on an annual arithmetic average basis is 20 $\mu g/m^3$ and occurs along IH 94 in the area of the Marquette Interchange in the City of Milwaukee. The particulate matter isopleths generally decrease in value

Table 245

METEOROLOGICAL DATA USED FOR ANNUAL AVERAGE LINE AND AREA SOURCE SIMULATION MODELING EFFORT: 1973

Stability Class	Heat Flux (langleys per minute)	Wind Speed (meters per second)	Percent Frequency by Wind Direction								
			North	Northeast	East	Southeast	South	Southwest	West	Northwest	Total
Unstable	0.18	5	0.10	0.10	0.23	0.37	0.22	0.45	0.47	0.37	2.31
	0.18	10	0.67	0.70	0.85	0.82	0.68	1.06	1.59	0.53	6.90
Neutral	--	5	1.17	0.49	0.72	0.76	0.87	0.58	0.96	0.61	6.16
	--	10	2.89	1.73	1.76	2.69	2.98	3.01	3.01	3.08	21.15
	--	15	7.13	3.23	3.29	4.65	4.43	7.42	8.07	4.98	43.20
Stable	- 0.04	5	1.56	0.77	0.57	1.86	5.21	3.41	4.55	2.35	20.28
Total	--	--	13.52	7.02	7.42	11.15	14.39	15.92	18.65	11.93	100.00

Source: National Climatic Center; Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

with increasing distance away from the Marquette Interchange in a pattern closely corresponding to the configuration of the regional freeway system. The influence of vehicular traffic in the Cities of Kenosha and Racine is also evident on this map, although the impact of line sources on ambient air particulate matter concentrations is far less in these two urbanized areas than in Milwaukee County.

Simulated isopleths of particulate matter concentrations due to area source emissions in the Region during 1973, as shown on Map 57, indicate that the highest concentration is 50 $\mu g/m^3$, on an annual arithmetic average basis, and occurs over the heavily industrialized area of the Menomonee River Valley. This finding may be attributed principally to the large quantity of fugitive dust emissions which emanate from this area. Area source emissions in smaller urban areas, such as the Cities of Kenosha, Racine, Waukesha, and West Bend, also have a measurable impact on the ambient air particulate matter concentrations, but to a far lesser extent than the area source emissions in the east-central portion of Milwaukee County.

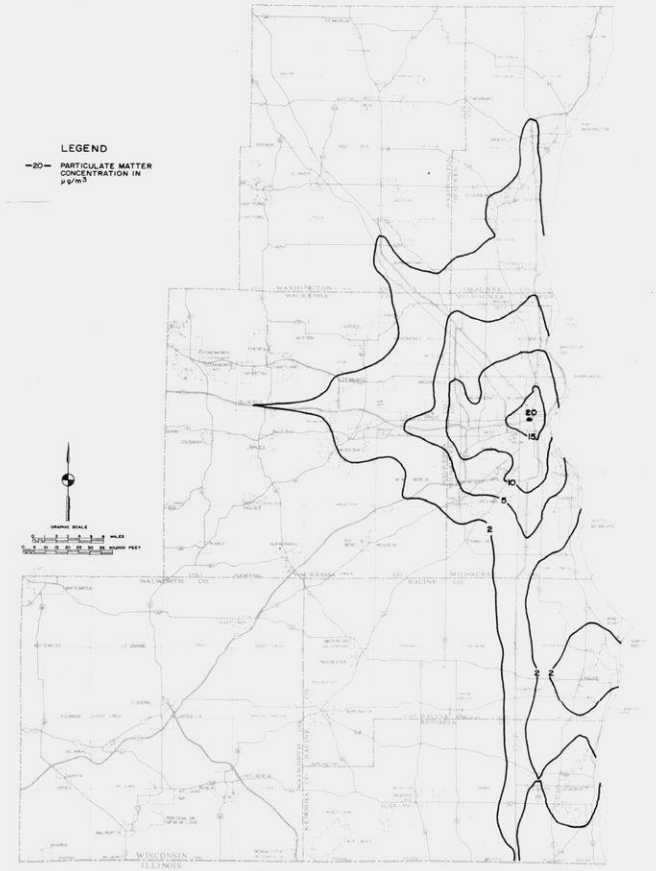
The impact of the identified sources of fugitive dust emissions in the Menomonee River Valley on particulate matter ambient air quality during 1973 is indicated on Map 58. As may be seen on this map, the four sources of fugitive dust emissions inventoried by the City of Milwaukee, Department of City Development—unpaved automobile parking lots, unpaved truck parking lots, travel on unpaved roads, and aggregate storage piles—are estimated to have contributed a maximum of about 30 $\mu g/m^3$ of particulate matter, expressed as an annual arithmetic average, to ground level particulate matter concentrations in the heavily industrialized portion of the Menomonee River Valley. Although the fugitive dust emissions inventory for the Menomonee River Valley is representative of only a small area within the Region, it does serve to indicate the impact that such sources of particulate matter emissions can have on ambient air quality .

Model Calibration and Validation—1973: In order to calibrate the simulated particulate matter concentrations in the Region as estimated by the Wisconsin Atmospheric Diffusion Model to the particulate matter concentrations actually measured during 1973, it is necessary to compare the model predictions with the monitored values at each site meeting the minimum U. S. Environmental Protection Agency (EPA) requirements for sampling frequency.[1] In 1973, there were 20 monitoring sites in the Region which met the minimum sampling requirements for determining annual average particulate matter concentrations. Table 246 provides a comparison of the annual arithmetic average particulate matter concentrations from point, area, and line sources—as computed by the WIS*ATMDIF model—with the concentrations measured at each of these 20 monitoring sites. The relationship between the monitored data and the mathematically simulated values is also presented schematically in Figure 81. Figure 81 was developed by plotting a point on the graph corresponding to the value of the annual arithmetic average at the monitoring site (the vertical axis) and the computer-simulated value (the horizontal axis) for each of the 20 sets of data presented in Table 246. A least-squares regression analysis was then performed in order to determine the equation of the line which provided the "best fit"—that is, the line which described the distribution of points with the minimal error. As indicated in Figure 81, the "best fit" is obtained from a line having a slope of 0.926 and an intercept of approximately 45.

[1] *The U. S. EPA requirements for minimum sampling frequency for particulate matter hi-vol gravimetric monitors have been set forth in Chapter VI. Monitoring stations not meeting these minimum sampling frequency requirements were not used in the calibration of the simulation model, since the data recorded at such monitoring stations could not be considered representative of particulate matter concentrations on an annual average basis.*

Map 56

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE PARTICULATE MATTER CONCENTRATIONS DUE TO EMISSIONS FROM LINE SOURCES IN THE REGION: 1973

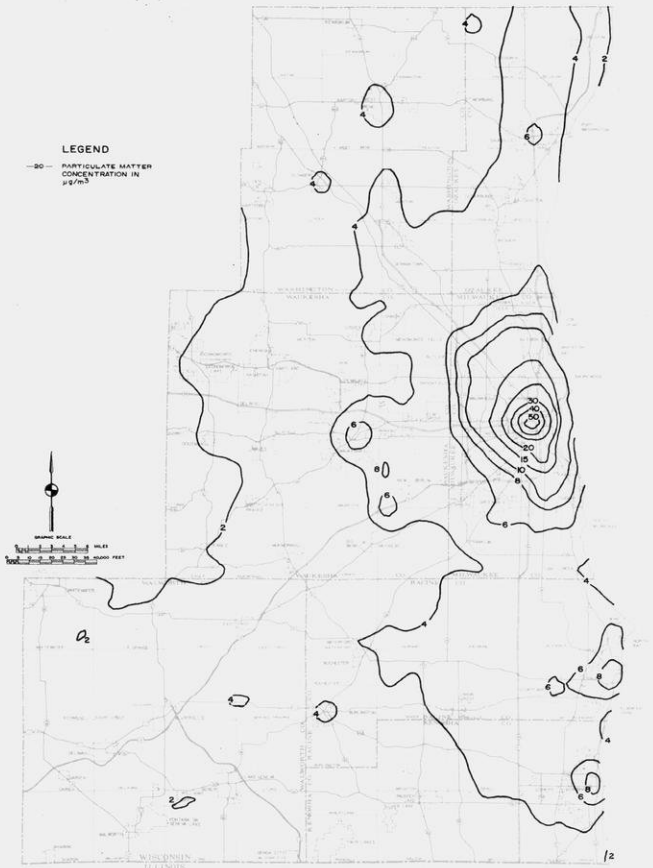


In 1973 the highest particulate matter concentration simulated in the Region due to line source emissions was 20 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average. This concentration occurred along IH 94 in the area of the Marquette Interchange in the City of Milwaukee. The particulate matter isopleth values generally decrease with increasing distance from the Marquette Interchange in a pattern closely corresponding to the configuration of the regional freeway system. The influence of vehicular traffic in the Cities of Kenosha and Racine is also evident, although the impact of line sources on ambient air particulate matter concentrations is far less in these two areas than in Milwaukee County.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 57

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE PARTICULATE MATTER CONCENTRATIONS DUE TO EMISSIONS FROM AREA SOURCES IN THE REGION: 1973



This map illustrates the contribution of area sources of particulate matter emissions to regional ambient air quality in 1973. The highest particulate matter concentration due to such sources was 50 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and was located over the heavily industrialized area of the Menomonee River Valley. Area source emissions in smaller urban areas, such as the Cities of Kenosha, Racine, Waukesha, and West Bend, also have a measurable impact on the ambient air particulate matter concentrations, but to a far lesser extent than the area source emissions in Milwaukee County.

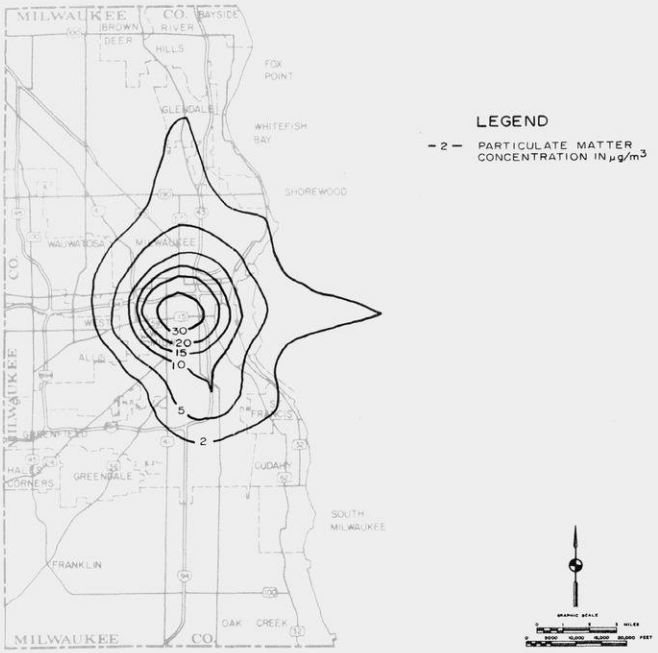
Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

The slope of the line is indicative of the relationship between the total particulate matter concentrations simulated by the WIS*ATMDIF model separately for the source categories and the monitored concentrations as measured at 20 sampling sites. It should also be noted that the slope of the line indirectly indicates the validity of the relationship between monitored particulate emissions and predicted concentrations. If, for example, the slope of the line were significantly greater than 1.0, an increase in the input emissions would produce a disproportionately large increase in the predicted concentrations. Conversely, if the slope of the line were significantly less than 1.0, an increase in the input emissions would produce a disproportionately small increase in the predicted concentrations. Such very large or very small slopes are evidence of systematic errors which prohibit the model from accurately accounting for variation in emissions or dispersion. The fact that the results of the WIS*ATMDIF modeling effort for annual average particulate matter levels in the Region during 1973 yield a slope of near unity indicates that the model is not subject to such systematic errors, and that spatial variations in emission patterns and temporal variations in atmospheric diffusion processes are accounted for in the model with only a minimal adjustment. Attendant to this finding is the conclusion that variations in topography within the Region, and atmospheric phenomena such as the "lake breeze" effect, do not significantly influence the annual average particulate matter levels on a regional scale.

In addition to systematic errors, there is a second type of error which indicates that, although the model is accounting for variations properly, the computed annual concentrations are in error by some uniform quantity at

Map 58

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE PARTICULATE MATTER CONCENTRATIONS DUE TO FUGITIVE DUST EMISSION SOURCES IN THE MENOMONEE RIVER VALLEY: 1973



This map illustrates the contribution of fugitive dust sources in the Menomonee River Valley to particulate matter pollution in Milwaukee County during 1973. As may be seen on this map, the maximum particulate matter concentration due to these fugitive dust sources—which included travel on unpaved roads, unpaved automobile and truck parking lots, and aggregate storage piles—was 30 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, during 1973. As may be seen by comparing this map with Map 57, fugitive dust emission sources in the Menomonee River Valley accounted for about 60 percent of the annual arithmetic average particulate matter concentrations due to area source emissions in Milwaukee County during 1973.

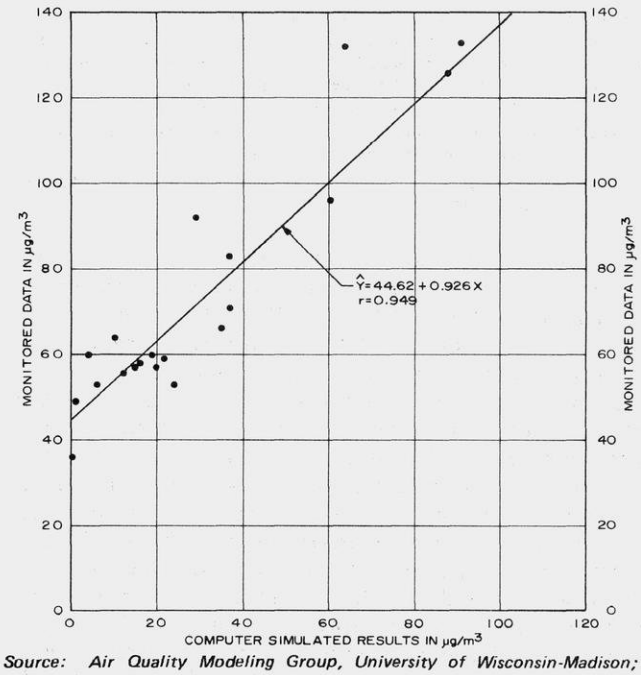
Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

all points. This type of error may be attributable to a background level of pollution which has not been accounted for in the emissions inventory, and includes unidentifiable local emissions, the chemical transformation of gaseous pollutants to solids in the atmosphere, long-range transport, and natural levels of the pollutant residing in the atmosphere. The magnitude of this type of error is quantified by the intercept value in the regression equation. In the case of the regression analysis for the annual arithmetic average particulate matter levels in the Region during 1973, the line intersects the y-axis at about 45 $\mu g/m^3$. Although it may be concluded that there were particulate matter concentrations of about 45 $\mu g/m^3$ on an annual arithmetic average basis present in the Southeastern Wisconsin Region during 1973 which could not be attributed to local point, area, or line sources of emissions, the specific contribution of unidentifiable local emission sources, chemical transformations, long-range transport, or natural particulate matter levels may not be quantified individually with any precision at the present time. It must suffice, therefore, to place an upper limit on the total annual contribution from all four of these possible sources combined. For that purpose, an adjustment factor of 45 $\mu g/m^3$ was added to the sum of the predicted particulate matter annual concentrations from point, area, and line sources.

Although the slope and intercept of the least-squares regression line may be used to identify and adjust errors in the simulation model or, in other words, to calibrate the model, the validity of the model predictions is best determined by performing a correlation analysis. In such an analysis, a coefficient of correlation (r), which is a measure of data-scatter about the regression line, such as that shown in Figure 81, is calculated and compared with the maximum theoretical value that could arise due to chance. The correlation coefficient may assume a value between ± 1.0, indicating a completely inverse linear relationship, to $+1.0$ indicating a completely direct linear relationship. A value of zero would indicate the total absence of any relationship. For the 20 sets of monitored and modeled annual arithmetic average particulate matter concentrations set forth in Table 246, the correlation coefficient was calculated to be 0.949. The maximum theoretical value which this coefficient would assume at the 1 percent confidence level—that is, at the level at

Figure 81

COMPARISON OF MONITORED AND COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE PARTICULATE MATTER CONCENTRATIONS IN THE REGION: 1973



Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Table 246

COMPARISON OF MONITORED AND COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE PARTICULATE MATTER CONCENTRATIONS IN THE REGION: 1973

Location of Monitoring Site		Computer-Simultated Data ($\mu g/m^3$)				Monitored Data ($\mu g/m^3$)
Address	County	Point	Line	Area	Total	
9722 W. Watertown Plank Road	Milwaukee	4	8	7	19	60
4010 W. Forest Home Avenue	Milwaukee	6	7	9	22	59
8885 S. 68th Street	Milwaukee	2	1	3	6	53
845 N. 35th Street	Milwaukee	10	12	15	37	83
2969 S. Howell Avenue	Milwaukee	15	6	14	35	66
1001 15th Avenue	Milwaukee	3	3	4	10	64
1640 S. 24th Street	Milwaukee	12	8	17	37	71
9501 W. Cleveland Avenue	Milwaukee	3	8	4	15	57
5100 W. 91st Street	Milwaukee	4	6	6	16	58
7841 N. 47th Street	Milwaukee	3	4	5	12	56
3281 N. 41st Street	Milwaukee	6	9	9	24	53
3201 N. Downer Avenue	Milwaukee	7	5	8	20	57
711 N. Wells Street	Milwaukee	14	16	30	60	96
230 S. Muskego Avenue	Milwaukee	18	9	37	64	132
1750 Kinnickinnic Avenue	Milwaukee	60	11	20	91	133
330 E. Greenfield Avenue	Milwaukee	32	13	43	88	126
1313 W. Reservoir Street	Milwaukee	9	7	13	29	92
408 N. Lake Street	Ozaukee	2	1	1	4	60
Upham Hall	Walworth	0	0	0	0	36
723 Geneva Street	Walworth	0	1	0	1	49

Source: Air Quality Modeling Group, University of Wisconsin-Madison; Wisconsin Department of Natural Resources; and SEWRPC.

which there is less than one chance in 100 that a correlation coefficient as high as this value would arise due to random sampling variation—is 0.561. The correlation between the monitored and simulated annual particulate matter concentrations may therefore be considered significant, and the WIS*ATMDIF model valid for use in the Southeastern Wisconsin Region.

Annual Geometric Average Particulate Matter Levels—1973: Since the annual average primary and secondary particulate matter ambient air quality standards are based on the geometric mean—in order to reduce the impact of extremely high and infrequently occurring values—the arithmetic mean must be converted to the geometric mean if existing levels are to be evaluated against the standards. The geometric mean may be related to the arithmetic mean by the following equation:

$$Mg = \frac{M}{\exp.\ (0.5 \ln^2 Sg)}$$

where: Mg = geometric mean,
M = arithmetic mean, and
Sg = standard deviation of the geometric mean.

A review of the particulate matter monitoring data from 1973 indicated that the average standard deviation of the geometric mean was approximately 1.7 $\mu g/m^3$. Using this value for Sg in the above equation, the geometric mean is therefore related to the arithmetic mean by the equation:

$$Mg = 0.869\ M$$

This factor of 0.869, therefore, was used to adjust the slope and intercept values—0.926 and 45, respectively—of the linear calibration equation. The adjusted linear calibration equation for determining the annual geometric average thus takes the form:

$$Y = 0.805X + 39.1$$

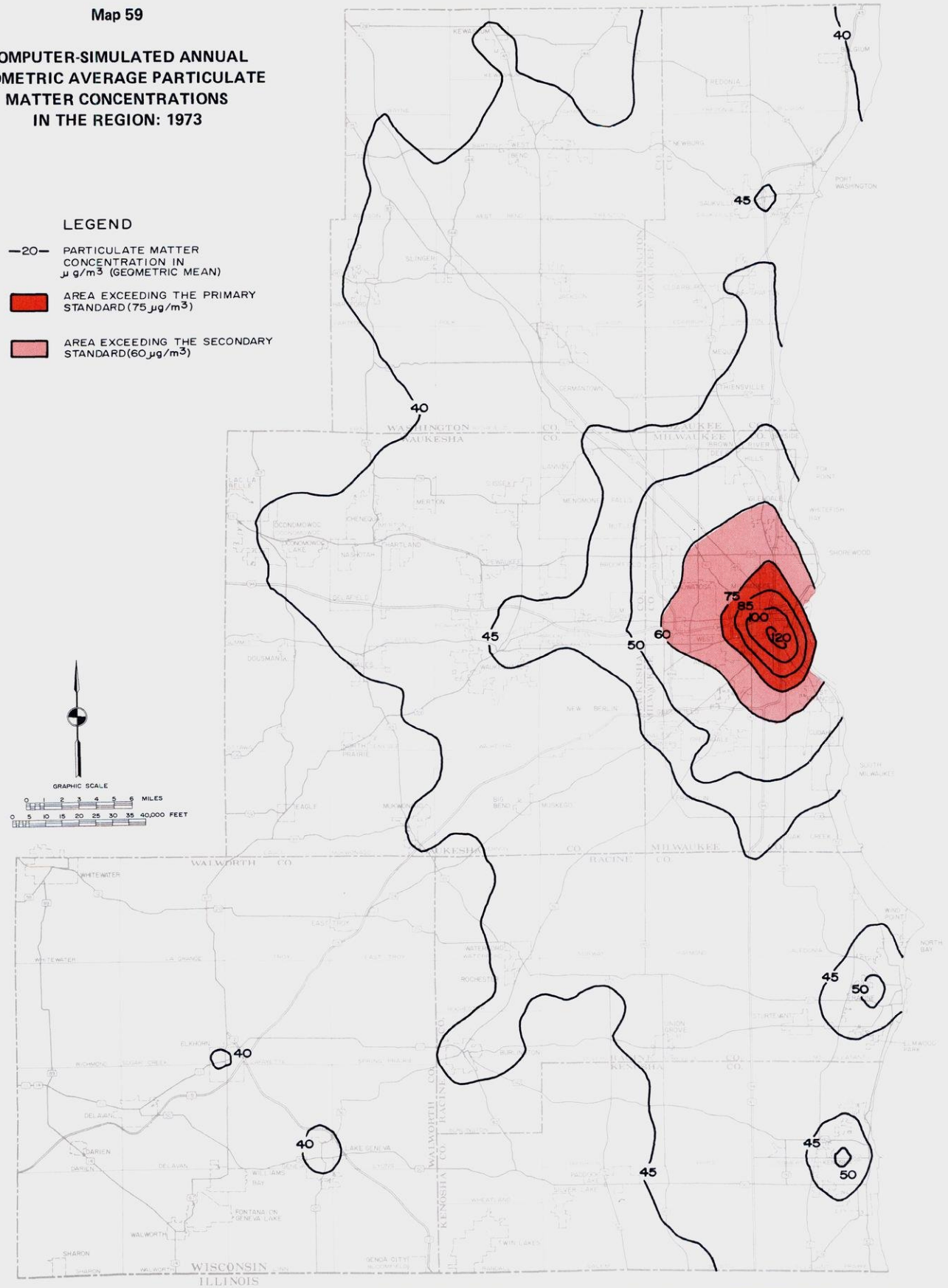
where: Y = the equivalent geometric mean of the combined point, area, and line source annual arithmetic average concentrations, X, at each receptor site.

The annual geometric average particulate matter concentrations at ground level in the Region during 1973 are shown on Map 59.

As may be seen on Map 59, the primary annual average particulate matter ambient air quality standard of 75 $\mu g/m^3$ is estimated to have been exceeded over a 24-square-mile area in Milwaukee County in 1973. Moreover, the secondary annual average standard of 60 $\mu g/m^3$ is estimated to have been exceeded over an additional 50 square miles in Milwaukee County. The highest isopleth value indicated on Map 59 is 120 $\mu g/m^3$, a value approximately 60 percent higher than the primary annual average standard.

Map 59

COMPUTER-SIMULATED ANNUAL GEOMETRIC AVERAGE PARTICULATE MATTER CONCENTRATIONS IN THE REGION: 1973



Point sources, line sources, and area sources of emissions all contribute to regional particulate matter concentrations. In 1973, particulate matter concentrations in an area of approximately 24 square miles in Milwaukee County are estimated to have exceeded the primary annual average standard of 75 micrograms per cubic meter ($\mu g/m^3$), and the concentrations in an additional area of 50 square miles are estimated to have exceeded the secondary annual average standard of 60 $\mu g/m^3$. The highest particulate matter concentration is estimated to have been 120 $\mu g/m^3$, or approximately 60 percent higher than the primary annual average standard. An estimated 671,900 persons resided in the area impacted by particulate matter concentrations in the ambient air greater than the primary, or health-related, and secondary, or welfare-related, standards.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

An estimated 285,000 persons resided in that portion of Milwaukee County exceeding the primary, or health-related, annual average particulate matter standard during 1973. In addition, about 386,900 persons resided in that portion of Milwaukee County exceeding the secondary, or welfare and property-related, standard during 1973.

Model Calibration and Validation—1977: Although the WIS*ATMDIF model was successfully calibrated and validated for particulate matter concentrations based on the 1973 regional emissions inventory, two factors made it desirable to recalibrate and revalidate the model using the more comprehensive data base available for the year 1977: the addition of a fugitive dust emission inventory prepared by the Wisconsin Department of Natural Resources, which substantially increased the quantity of identifiable sources of particulate matter emissions, and the addition of five monitoring sites in the City of Waukesha during 1977, which provided evidence of previously unsuspected violations of the particulate matter ambient air quality standards in that area. The successful recalibration and revalidation of the model for the later year serves not only to define particulate matter levels in the Region for a more recent period, but also to more fully substantiate the reliability of the forecast ambient air particulate matter levels as estimated through use of the WIS*ATMDIF model.

The prevailing meteorological conditions during 1977 as used in the MLTPT submodel for estimating the dispersion of particulate matter emissions from point sources are summarized in Table 247. Under these meteorological

Table 247

METEOROLOGICAL DATA USED FOR ANNUAL AVERAGE POINT SOURCE SIMULATION MODELING EFFORT: 1977

Data Group	Parameter	Variable Group	Frequency of Occurrence (percent)	Mixing Heights Associated with Atmospheric Stability Classes
Wind	Speed (knots)	0-3	5.4	--
		4-6	18.2	
		7-10	36.9	
		11-16	30.9	
		17-21	6.9	
		> 21	1.7	
		Total	100.00	
	Direction	North	7.34	--
		North-Northeast	5.65	
		Northeast	3.69	
		East-Northeast	1.87	
		East	2.38	
		East-Southeast	3.08	
		Southeast	6.70	
		South-Southeast	4.65	
		South	9.28	
		South-Southwest	5.68	
		Southwest	7.85	
		West-Southwest	10.82	
		West	13.84	
		West-Northwest	9.23	
		Northwest	4.58	
		North-Northwest	3.36	
		Total	100.00	
Atmospheric Stability	Pasquill Stability Class	A—Extremely Unstable	0.14	1,500
		B—Unstable	1.75	1,500
		C—Slightly Unstable	10.14	1,170
		D—Neutral	67.36	1,000
		E—Slightly Stable	12.60	--
		F—Stable	8.01	--
		Total	100.00	--

Source: National Climatic Center; Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

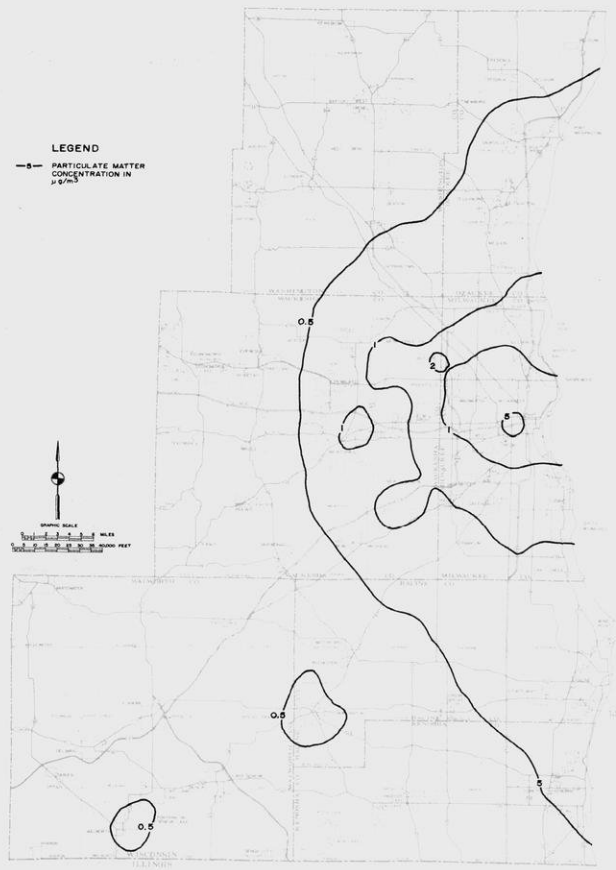
conditions, the particulate matter emissions from point sources during 1977, as summarized in Table 197 in Chapter VII, are estimated to have produced the uncalibrated ambient air concentrations shown on Map 60. It is evident, particularly when comparing Map 60 with Map 55, that the level of particulate matter concentrations in the Region due to point sources decreased significantly in Milwaukee County between 1973 and 1977. The highest isopleth value in Milwaukee County indicated on Map 60 is 5 $\mu g/m^3$, expressed as an annual arithmetic average. This value extends over the same approximate area enveloped by the 30 $\mu g/m^3$ isopleth in 1973. The highest isopleth value indicated in 1973 was 50 $\mu g/m^3$. This reduction in particulate matter levels between 1973 and 1977 may be attributed principally to the combined effect of several factors, including: the cessation of operations at the Marquette Cement Manufacturing Company; the relocation of PPG Industries; the reduction of emission sources and the application of control technology on remaining sources at the Milwaukee Solvay Coke Company; and the further control of particulate matter emissions from other diverse industries in and around the Menomonee River Valley which brought such sources into compliance with existing emission limitations mandated by the State. The cessation of operations at the Marquette Cement Manufacturing Company and the relocation of PPG Industries together accounted for about a 410-ton reduction in particulate matter emissions in the Menomonee River Valley between 1973 and 1977. More significantly, controls effected at the Milwaukee Solvay Coke Company between 1973 and 1977 yielded a reduction of about 4,400 tons of particulate matter from this source. The reduction in emissions from the Milwaukee Solvay Coke Company are of particular importance since the coking operations are a near-ground level source and thus impact ambient air quality more adversely than elevated sources.

The ambient air particulate matter concentrations in the Region due to the emissions from line and area sources during 1977, indicated in Tables 213 and 228 in Chapter VII, were simulated using the URBAN submodel under the prevailing 1977 meteorological conditions summarized in Table 248. The resulting pattern of uncalibrated particulate matter concentrations due to line source emissions during 1977 is shown on Map 61. Particulate matter emissions from line sources decreased slightly between 1973 and 1977—from about 4,660 tons in 1973 to about 4,424 tons in 1977, or by approximately 5 percent—as a result of a proportionate increase in the use of unleaded gasoline which, when burned, produces fewer particulates than leaded gasoline. However, Map 61 indicates a small increase in the size of the area encompassed by the isopleth value of 20 $\mu g/m^3$ in 1977 over the area encompassed by the same isopleth in 1973. For both years, the 20 $\mu g/m^3$ isopleth occurs in the vicinity of the Marquette Interchange in Milwaukee County. This observed increase may be attributable to a moderate increase in the frequency of stable atmospheric conditions in 1977 as compared with 1973 (see Tables 245 and 248), which would act to inhibit the dilution and dispersion of the line source emissions.

Map 62 presents the uncalibrated distribution of particulate matter concentrations due to emissions from area sources in the Region during 1977. The addition of the industrial fugitive dust emissions inventory in the modeling effort for the year 1977 accounts for the most notable differences from the particulate matter concentrations due to area source emissions in 1973, shown on Map 57. Map 62 indicates that three areas in Waukesha County—the City of Waukesha vicinity, the Village of

Map 60

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE PARTICULATE MATTER CONCENTRATIONS DUE TO EMISSIONS FROM POINT SOURCES IN THE REGION: 1977



This map illustrates the contribution of point sources of particulate matter emissions to regional ambient air quality in 1977. The maximum particulate matter isopleth has a value of 5 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and is centered over the same approximate area enveloped by the 30 $\mu g/m^3$ isopleth in 1973. Emissions of particulate matter from point sources were reduced by nearly 4,800 tons between 1973 and 1977. This reduction may be attributed principally to the combined effect of the cessation of operations at the Marquette Cement Manufacturing Company, the relocation of PPG Industries, the emission controls effected at the Milwaukee Solvay Coke Company, and the further control of particulate matter emissions from other industries in and around the Menomonee River Valley.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Table 248

METEOROLOGICAL DATA USED FOR ANNUAL AVERAGE LINE AND AREA SOURCE SIMULATION MODELING EFFORT: 1977

Stability Class	Heat Flux (langleys per minute)	Wind Speed (meters per second)	Percent Frequency by Wind Direction								
			North	Northeast	East	Southeast	South	Southwest	West	Northwest	Total
Unstable	0.18	5	0.47	0.32	0.22	0.39	0.46	0.31	0.37	0.10	2.64
	0.18	10	0.77	1.54	1.20	1.25	0.72	1.42	1.73	0.65	9.28
Neutral	--	5	0.81	0.96	0.80	0.97	1.24	0.76	1.03	0.44	7.01
	--	10	2.61	1.63	1.04	2.75	4.65	3.73	4.13	2.23	22.77
	--	15	5.21	1.87	1.03	3.81	3.52	5.96	11.54	4.76	37.70
Stable	- 0.04	5	2.15	1.10	0.56	1.37	3.86	3.92	4.97	2.67	20.60
Total	--	--	12.02	7.42	4.85	10.54	14.45	16.10	23.77	10.85	100.00

Source: National Climatic Center; Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Pewaukee, and the Villages of Delafield, Dousman, and Wales—two areas in Milwaukee County—the heavily industrialized area of the Menomonee River Valley and the City of Franklin—and an area at the northern boundary of the City of Racine experience relatively high levels of particulate matter concentrations on an annual arithmetic average basis due to area sources of emissions. The principal area sources of emissions contributing to these concentrations are mining operations, the use of unpaved roads, automobile parking lots and truck terminal lots, and untreated aggregate storage piles in the Menomonee River Valley, all of which contribute fugitive dust emissions.

Table 249 presents a comparison of the results of the simulation modeling effort for the annual arithmetic average particulate matter levels in the Region in 1977 with the concentrations monitored at the 28 monitoring sites meeting the minimum sampling requirements during that year. The relationship between the monitored data and the computer-simulated particulate matter concentrations is 1977 is presented schematically on Figure 82. As shown in Figure 82, the least-squares regression analysis indicates that the "best fit" linear equation has a slope of 0.986 and an intercept of about 44 $\mu g/m^3$. These values are approximately the same as the slope and intercept values determined for the calibration of the model for 1973.

The validity of the simulation model predictions for annual particulate matter levels in the Region is supported by a correlation analysis of the monitored and simulated concentrations for 1977. The correlation coefficient for the 28 sets of monitored and modeled particulate matter concentrations in 1977 was calculated to be 0.853. The maximum theoretical value which this correlation coefficient would assume at the 1 percent confidence level is 0.478. The correlation between the monitored and simulated annual particulate matter concentrations in 1977 may, therefore, be considered significant.

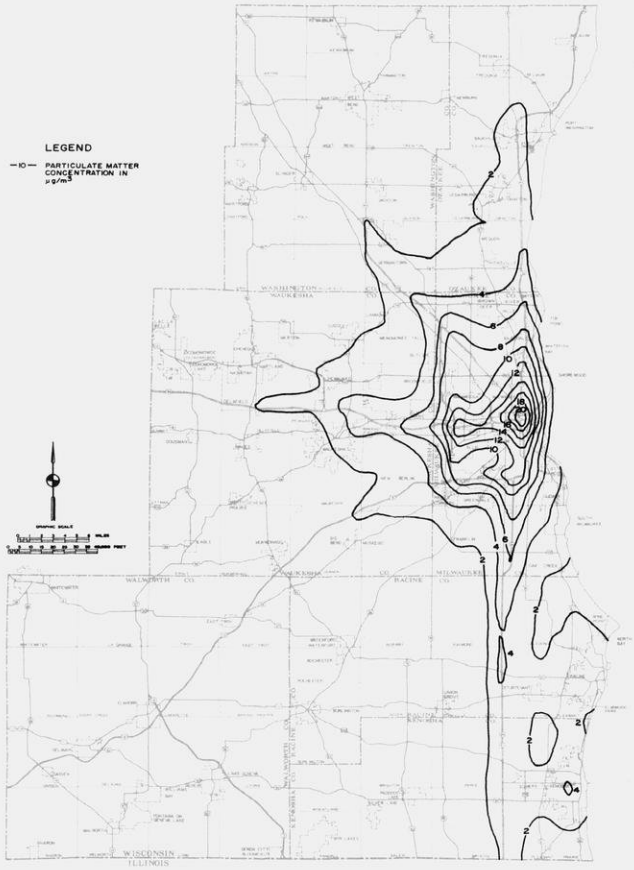
The annual geometric average particulate matter concentrations in the Region in 1977 were determined from the arithmetic average in the same manner as for 1973 levels—by combining the point, area, and line source concentrations, adding the background adjustment factor of 44 $\mu g/m^3$ at each receptor location, and correcting for the relationship between the geometric mean and the arithmetic mean. Thus calculated, the annual geometric average particulate matter concentrations in the Region for 1977 are shown on Map 63.

As may be seen on Map 63, the primary annual average ambient air quality standard for particulate matter of 75 $\mu g/m^3$ is estimated to have been exceeded over a 5-square-mile area in Milwaukee County and a 12-square-mile area in Waukesha County during 1977. In Milwaukee County, the area exceeding the primary annual particulate matter standard is centered over the heavily industrialized portion of the Menomonee River Valley. In Waukesha County, the primary annual particulate matter standard is exceeded in parts of the Cities of Menomonee Falls and Waukesha and in parts of the Towns of Lisbon, Pewaukee, and Wales.

The secondary annual average ambient air quality standard for particulate matter of 60 $\mu g/m^3$ is estimated to have been exceeded over a 24-square-mile area in Milwaukee County, a 23-square-mile area in Waukesha County, and a 0.1-square-mile area in Racine County during 1977. The areas in the Cities of Milwaukee, Menomonee Falls, and Waukesha and in the Towns of Lisbon and Pewaukee in which this secondary standard is exceeded basically encompass, and are an extension of, areas exceeding the primary standard. Areas exceeding the secondary standard in the City of Franklin in Milwaukee County, and just north of the City of Racine, however, are not associated with areas exceeding the primary standard. With the exception of the area within the City of Milwaukee, areas shown on Map 63 as exceeding either the primary or secondary annual average

Map 61

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE PARTICULATE MATTER CONCENTRATIONS DUE TO EMISSIONS FROM LINE SOURCES IN THE REGION: 1977

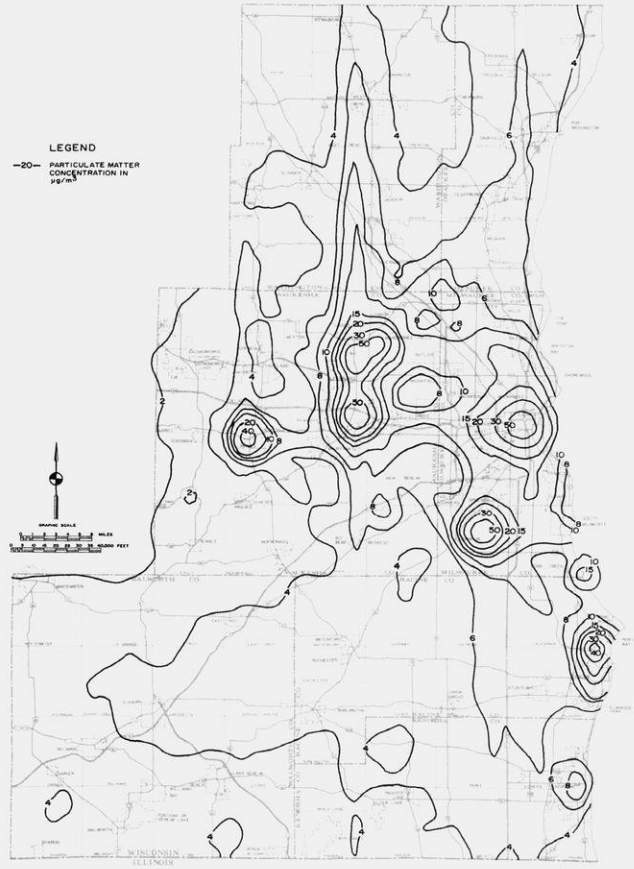


In 1977 the highest particulate matter concentration simulated in the Region due to line source emissions was 20 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average. This concentration occurs in the vicinity of the Marquette Interchange in Milwaukee County. Although 4,424 tons of particulate matter emissions from line sources were released, or about 5 percent less emissions than were released from line sources in 1973, a small increase in the size of the area encompassed by the highest isopleth value over the area encompassed by the same isopleth in 1973 can be observed. This increase may be attributable to a moderate increase in the frequency of stable atmospheric conditions in 1977 as compared with 1973, which would act to inhibit the dilution and dispersion of line source emissions.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 62

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE PARTICULATE MATTER CONCENTRATIONS DUE TO EMISSIONS FROM AREA SOURCES IN THE REGION: 1977



This map illustrates the contribution of area sources of particulate matter emissions to regional ambient air quality in 1977. The highest concentration attained was 50 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and was located over three areas in Waukesha County—the vicinity of the City of Waukesha, the Village of Pewaukee, and the Villages of Delafield, Dousman, and Wales—and two areas in Milwaukee County—the industrialized area of the Menomonee River Valley and the City of Franklin. The principal area sources contributing to these concentrations are mining operations, unpaved roads, parking lots, truck terminal lots, and untreated aggregate storage piles in the Menomonee River Valley, all of which contribute fugitive dust emissions.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; Wisconsin Department of Natural Resources; and SEWRPC.

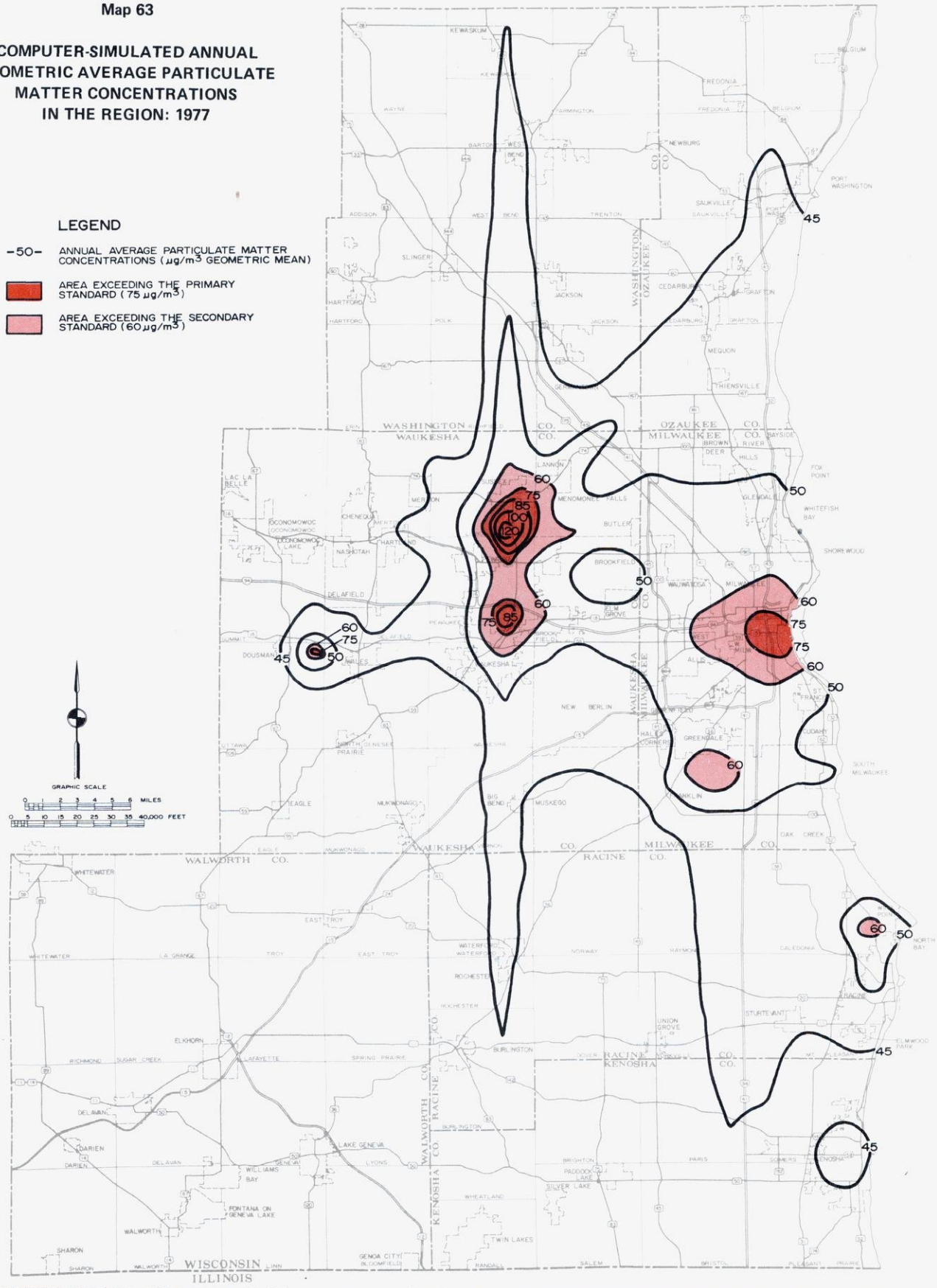
ambient air quality standard for particulate matter are closely identified with mineral extraction operations.

An estimated 54,800 persons resided in that portion of Milwaukee County which exceeded the primary annual standard in 1977. An additional 208,800 persons are estimated to have resided in that portion of Milwaukee County which exceeded the secondary standard during 1977. About 10,800 persons resided in those areas of Waukesha County where the primary annual standard was exceeded in 1977. An additional 20,000 persons in Waukesha County and about 70 persons in Racine County are estimated to have been exposed to particulate matter concentrations at levels exceeding the secondary annual average standard.

In total, therefore, approximately 17 square miles in the Region, or about six-tenths of 1 percent of the total area of the Region, experienced particulate matter concentrations at or above the primary annual average standard of 75 $\mu g/m^3$ in 1977. Furthermore, approximately

Map 63

COMPUTER-SIMULATED ANNUAL GEOMETRIC AVERAGE PARTICULATE MATTER CONCENTRATIONS IN THE REGION: 1977



The above map presents annual geometric average particulate matter concentration values resulting from regional point, line, and area sources of emissions derived from 1977 inventory data. The primary annual average air quality standard of 75 micrograms per cubic meter ($\mu g/m^3$) is estimated to have been exceeded over a 5-square-mile area in Milwaukee County and a 12-square-mile area in Waukesha County. The secondary annual average standard of 60 $\mu g/m^3$ is estimated to have been exceeded over a 24-square-mile area in Milwaukee County, a 23-square-mile area in Waukesha County, and a 0.1-square-mile area in Racine County. An estimated 294,500 persons resided in the area impacted by particulate matter concentrations in the ambient air greater than the primary, or health-related, and secondary, or welfare-related, standards.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Table 249

COMPARISON OF MONITORED AND COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE PARTICULATE MATTER CONCENTRATIONS IN THE REGION: 1977

Location of Monitoring Site		Computer-Simulated Data ($\mu g/m^3$)				Monitored Data (ug/m^3)
Address	County	Point	Line	Area	Total	
625 52nd Street	Kenosha	0.7	3	8	22.7	57.70
6415 35th Avenue	Kenosha	0.7	3	6	9.7	75.28
845 N. 35th Street	Milwaukee	4.3	12	20	36.3	72.01
230 S. Muskego Avenue	Milwaukee	3.8	10	43	56.8	103.17
2969 S. Howell Avenue	Milwaukee	5.1	10	19	34.1	73.67
5100 N. 91st Street	Milwaukee	2.8	2	11	15.8	47.46
1750 S. Kinnickinnic Avenue	Milwaukee	5.7	12	31	48.7	104.34
3281 N. 41st Street	Milwaukee	3.5	8	10	21.5	53.54
5300 S. Howell Avenue	Milwaukee	2.3	4	14	20.3	79.13
1313 W. Reservoir Street	Milwaukee	3.1	7	10	20.1	66.17
3201 N. Downer Avenue	Milwaukee	2.7	5	7	14.7	54.00
7528 W. Appleton Avenue	Milwaukee	2.6	6	11	19.6	60.77
600 E. Greenfield Avenue	Milwaukee	5.7	8	39	52.7	93.40
2300 S. 51st Street	Milwaukee	2.9	6	15	23.9	53.53
711 W. Wells Street	Milwaukee	3.8	18	41	62.8	91.77
9722 W. Watertown Plank Road	Milwaukee	2.8	8	6	16.8	68.11
1001 15th Avenue	Milwaukee	1.7	3	6	10.7	53.14
408 N. Lake Street	Ozaukee	2.3	4	2	8.3	49.00
925 15th Avenue	Racine	0.6	1	4	5.6	45.00
3701 Durand Avenue	Racine	0.9	2	4	6.9	58.24
4901 Washington Avenue	Racine	1.1	2	6	9.1	49.80
2210 Rapids Avenue	Racine	1.8	2	19	22.8	53.23
1501 Albert Street	Racine	0.8	3	20	23.8	74.55
130 W. St. Paul Avenue	Waukesha	4.1	3	9	16.1	66.10
1344 White Rock Avenue	Waukesha	13.9	3	34	50.9	91.74
1335 Cleveland Court	Waukesha	13.9	3	34	50.9	100.56
1116 Adams Street	Waukesha	13.9	3	34	50.9	82.64
1230 The Strand	Waukesha	13.9	3	34	50.9	124.84

Source: Air Quality Modeling Group, University of Wisconsin-Madison; Wisconsin Department of Natural Resources; and SEWRPC.

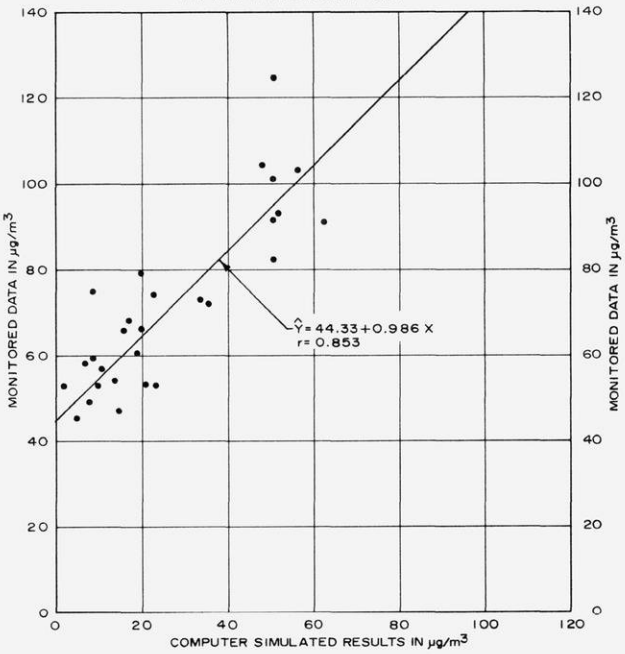
47 square miles in the Region, or about 1.7 percent of the total area of the Region, experienced concentrations at or above the secondary annual average standard of 60 $\mu g/m^3$ in 1977. Within the area exceeding the primary standard, an estimated 65,600 persons, or 3.7 percent of the total regional population in 1977, were subject to the potentially deleterious health effects of sustained exposure to such adverse pollutant levels. An additional 228,900 persons, or about 12.9 percent of the total regional population in 1977, resided in those areas in the Region in which the secondary annual average standard was exceeded. It may be concluded, therefore, that annual average particulate matter concentrations in southeastern Wisconsin have occurred and are occurring at levels which represent a hazard to the health and a detriment to the welfare of a significant portion of the regional population, and that measures for the control of particulate matter emissions must be devised and implemented to attain the primary and secondary annual average ambient air quality standards for this pollutant.

24-Hour Average Levels

The use of any air quality simulation model to estimate maximum 24-hour average particulate matter concentrations, particularly on a regional basis, is hindered by several severe limitations characteristic to some degree of all available numerical models. First, meteorological parameters, most notably wind speed and wind direction, demonstrate much greater temporal and spatial variation over a short-term averaging period than on an annual basis. Most air quality simulation models, including the WIS*ATMDIF model, can numerically replicate atmospheric diffusion only under a single set of meteorological conditions for any incremental short-term time unit, such as an hour, and are not capable of considering variations in those conditions due to either topography, differential heating, or unique wind flow patterns associated with such phenomena as the lake breeze effect. Second, whereas the total pollutant emissions from a source may be quantified with some measure of reliability, the day-to-day, or even hour-to-hour, operation of a source

Figure 82

COMPARISON OF MONITORED AND COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE PARTICULATE MATTER CONCENTRATIONS IN THE REGION: 1977



Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

is dependent on numerous and diverse factors which influence or govern the process rate or facility use of that unique source. Also, those factors which might cause one source to emit pollutants at its maximum rate may also act to diminish the emission rate from another source. For example, the peak-use period for emissions from electric power generation, which occurs in the summer when air-conditioning demand is greatest, would probably correspond to a low level of activity in such emission sources as agricultural processes or general utility engine use. It is improbable that an air pollutant emissions inventory could be prepared for a short-term basis which would accurately account for all such interrelated emission levels. Third, just as it is difficult to define short-term variation in local emission rates, the hourly or daily background level of pollutant concentrations are dependent on such variable factors as the source of the air mass transported into the Region, the level of pollutant-generating activity upwind, and changes in the rate of chemical reactions in the atmosphere. For these reasons, the air quality simulation modeling effort for short-term averaging periods must be viewed as a generalized depiction of the maximum pollutant levels which may be anticipated in the Region as a result of local emissions and catholic meteorological conditions. The calibration and validation of the WIS*ATMDIF model for the 24-hour average particulate matter concentrations in the Region is, therefore, precluded.

Within the constraints defined above, however, the short-term modeling effort for 24-hour average particulate matter concentrations in the Region serves to identify those areas where there is a potential for the primary and secondary air quality standards to be exceeded. Also, comparison of the short-term modeling results for two or more years provides an indication of the relative change in particulate matter levels in the Region resulting, in part, from changes in the magnitude and spatial distribution of local emission sources with time. The maximum 24-hour particulate matter concentrations in the Region, as estimated by the WIS*ATMDIF model, are shown on Map 64 for 1973 and on Map 65 for 1977.

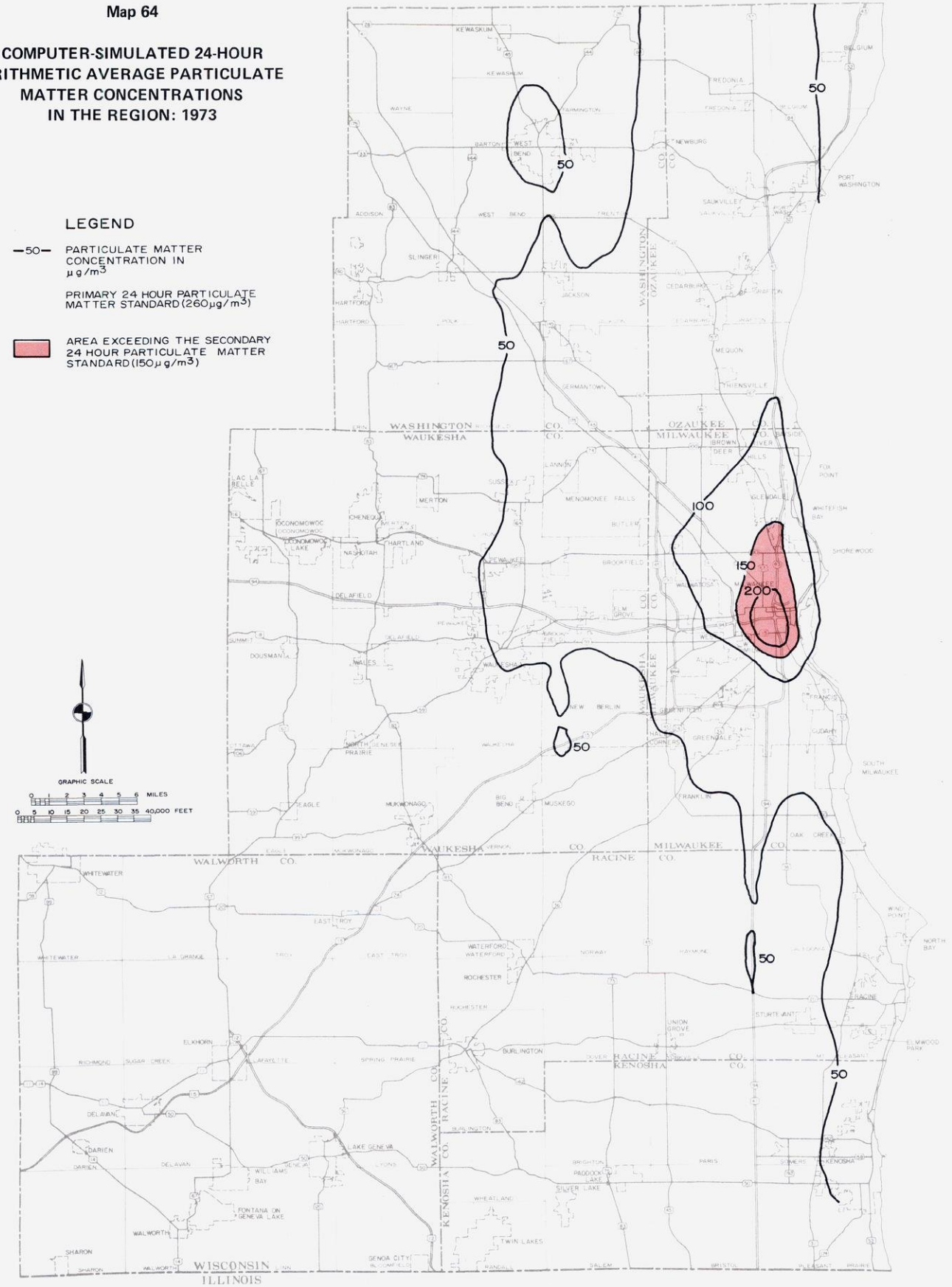
The meteorological conditions under which the 24-hour particulate matter concentrations were simulated assumed winds from the south at a ground level speed of about 5.6 miles per hour, slightly unstable atmospheric conditions for 12 hours of daylight, and slightly stable atmospheric conditions for 12 hours during the night. These meteorological assumptions are consistent with atmospheric conditions observed when the Region is dominated by a slow-moving high-pressure system attended by clear skies during the day and low wind speeds.

The highest particulate matter isopleth value indicated on Map 64, expressed as a 24-hour average, is 200 $\mu g/m^3$, and occurs over the heavily industrialized portion of the Menomonee River Valley. Although the primary ambient air quality standard of 260 $\mu g/m^3$ is estimated not to have been exceeded, the secondary standard of 150 $\mu g/m^3$ is estimated to have been exceeded over a 19-square-mile area in Milwaukee County from the Menomonee River Valley northward to the City of Glendale. It should be noted again, however, that background concentrations have not been considered in the preparation of Maps 64 and 65, and that the particulate matter levels shown on these maps could increase both in magnitude and areal extent if such factors as the effect of the long-range transport of particulates not accounted for in the modeling were sufficiently well known so as to be quantified and included as part of the modeling effort.

The modeling for 24-hour average particulate matter concentrations in 1977, as shown on Map 65, included point sources and industrial fugitive dust emissions—predominantly in areas outside the Menomonee River Valley—which were not available for 1973. As may be seen on Map 65, there are two areas in Waukesha County—the City of Waukesha and the Town of Lisbon—in which both the primary and secondary 24-hour average ambient air quality standards were exceeded due to local emissions alone. In addition, the secondary standard is estimated to have been exceeded just north of the City of Racine, in the City of Franklin, and in the Menomonee River Valley in the City of Milwaukee. Again, the magnitude and geographic extent of the particulate matter levels shown on Map 65 would increase if background concentrations were taken into account.

Map 64

COMPUTER-SIMULATED 24-HOUR ARITHMETIC AVERAGE PARTICULATE MATTER CONCENTRATIONS IN THE REGION: 1973

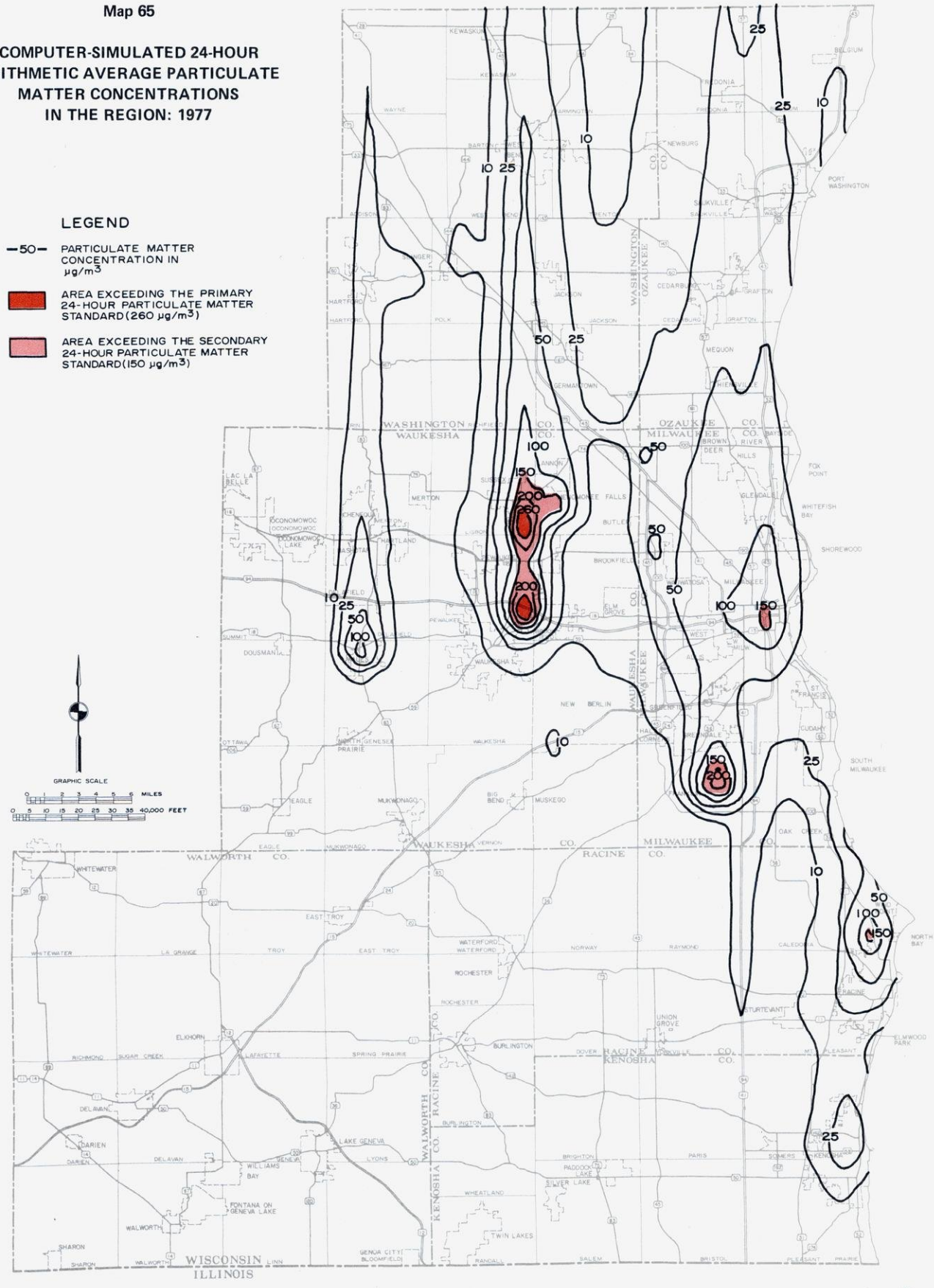


In 1973, simulated particulate matter concentration values, expressed as a 24-hour average, reached a maximum value of 200 micrograms per cubic meter ($\mu g/m^3$) over the heavily industrialized portion of the Menomonee River Valley. Although the primary 24-hour standard of 260 $\mu g/m^3$ is not estimated to have been exceeded, the secondary 24-hour standard of 150 $\mu g/m^3$ is estimated to have been exceeded by 50 $\mu g/m^3$, or about 33 percent, over a 19-square-mile area in Milwaukee County from the Menomonee River Valley northward to the City of Glendale. It should be noted that particulate matter concentrations dependent upon variable factors such as air mass transport, changes in the rate of atmospheric chemical reactions, and background pollutant concentrations are not reflected in the simulation modeling. Therefore, short-term averaging period isopleth analyses must be viewed as a generalized depiction of the maximum pollutant levels which may be anticipated in the Region as a result of local emissions, and actual levels may be somewhat higher both in magnitude and areal extent.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 65

COMPUTER-SIMULATED 24-HOUR ARITHMETIC AVERAGE PARTICULATE MATTER CONCENTRATIONS IN THE REGION: 1977



In 1977, simulated particulate matter concentration values, expressed as a 24-hour average, reached a maximum value of 300 micrograms per cubic meter (µg/m^3) over areas closely identified with mineral extraction operations. Both the primary and secondary 24-hour average standards are estimated to have been exceeded in two areas in Waukesha County—the City of Waukesha and the Town of Lisbon—due to local emissions alone. The secondary standard is estimated to have been exceeded in Milwaukee County—in the City of Franklin and in the City of Milwaukee over the Menomonee River Valley. It should be noted that the estimated 24-hour average particulate matter concentration over the heavily industrialized area of the Menomonee River Valley decreased significantly between 1973 and 1977. This estimated decrease may be attributed principally to the decrease in point source emissions as a result of the closing or relocation of several major industrial facilities in the Valley or the application of particulate matter emission control devices. It should be noted that particulate matter concentrations dependent upon variable factors such as air mass transport, changes in the rate of atmospheric chemical reactions, and background pollutant concentrations are not affected in the simulation modeling. Therefore, short-term averaging periods isopleth analyses must be viewed as a generalized depiction of the maximum pollutant level which may be anticipated in the Region as a result of local emissions, and actual levels may be somewhat higher both in magnitude and areal extent.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

A comparison of the estimated 1973 and 1977 24-hour average particulate matter concentrations indicates a significant decrease over this period in the level of particulates in the heavily industrialized area of the Menomonee River Valley. This estimated decrease may be attributed principally to the decrease in point source emissions as a result of the closing or relocation of several major industrial facilities in the Valley, and the application of control technology. This finding is supported by available particulate matter monitoring data, as summarized in Table 74 in Chapter VI. For example, of the 15 particulate matter monitoring sites in Milwaukee County which were operational both in 1973 and 1977, four sites recorded maximum 24-hour average particulate matter levels in excess of the primary standard of 260 $\mu g/m^3$ during 1973. But in 1977, only one monitoring site recorded a maximum 24-hour average particulate matter level in excess of the primary standard. It is apparent, however, that additional control measures will be required in Milwaukee, Racine, and Waukesha Counties in order to attain and maintain the primary and secondary 24-hour average particulate matter ambient air quality standards.

SULFUR DIOXIDE CONCENTRATIONS

It was noted in Chapter VI that the ambient air quality monitoring data for sulfur dioxide as measured in the Region prior to 1975 were found invalid due to errors inherent in the measurement technique and, consequently, could not be used to calibrate and validate the air quality simulation model. Accordingly, it was necessary to use data collected in 1976 to calibrate and validate the ambient air quality simulation model for sulfur dioxide. In 1976 five monitoring sites were operated within the Region—four in Milwaukee County and one in Racine County—using sulfur dioxide monitoring procedures meeting U. S. Environmental Protection Agency (EPA) requirements for sampling frequency. In the following sections, the results and findings of the sulfur dioxide air quality simulation modeling effort for the base year 1976 are reviewed for the annual, 24-hour, and three-hour averaging periods for which ambient air quality standards for sulfur dioxide have been established.

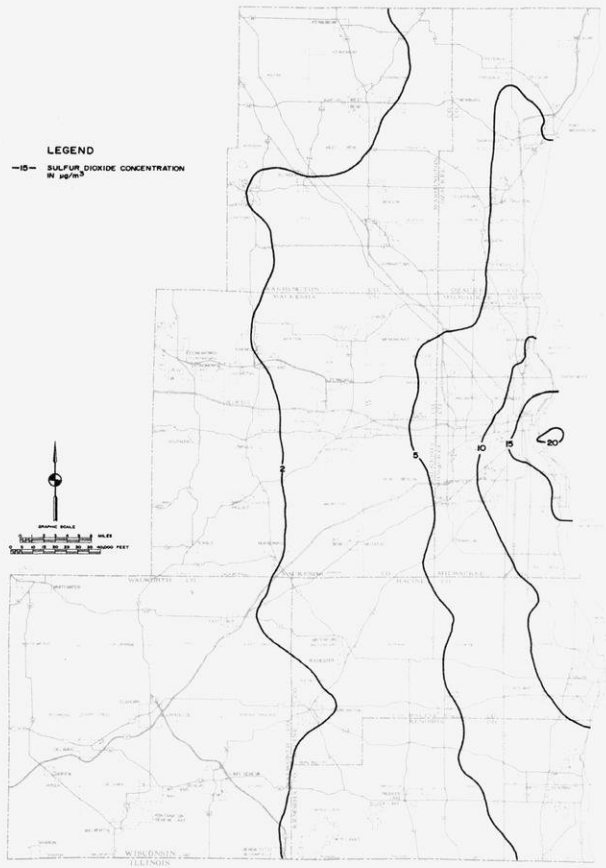
Annual Average Levels

For the annual average time period only a primary sulfur oxide ambient air quality standard—measured as sulfur dioxide and set at 80 micrograms per cubic meter ($\mu g/m^3$) for the arithmetic mean—has been promulgated by the EPA. Within the three-year period from 1975 through 1977, none of the five monitoring sites in the Region has recorded sulfur dioxide levels in excess of this standard. Since only five monitoring sites are available for determining annual average sulfur dioxide levels, however, it is necessary to use the simulation model in order to ascertain whether levels of sulfur dioxide in excess of the standard might exist in other areas of the Region.

The annual average sulfur dioxide concentrations in the Region due to emissions from point sources during 1976 were first simulated using the uncalibrated multiple point sources (MLTPT) submodel under the prevailing meteorological conditions as summarized in Table 250. The sulfur dioxide emissions from point sources during 1976 are summarized in Table 190 in Chapter VII. The uncalibrated annual average sulfur dioxide ambient air concentrations due to point sources, based on the 1976 meteorological and emissions data, are shown on Map 66. As may be seen on Map 66, the maximum isopleth value is 20 $\mu g/m^3$, or 25 percent of the annual standard, and extends out over Lake Michigan from a point on the

Map 66

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE SULFUR DIOXIDE CONCENTRATIONS DUE TO EMISSIONS FROM POINT SOURCES IN THE REGION: 1976



This map illustrates the impact of sulfur dioxide emissions from point sources on ambient air quality in the Region during 1976. The maximum sulfur dioxide concentration shown on the map is 20 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and is located along the Lake Michigan shoreline in central Milwaukee County. This relatively high sulfur dioxide concentration is associated principally with emissions from the Milwaukee Solvay Coke Company plant, which releases pollutants from coke ovens at near ground level. Larger sources of sulfur dioxide emissions, such as major fuel-burning installations, generally release their emissions from elevated stacks, and therefore do not impact ambient air quality at the surface to the same extent as do ground-level emission sources.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Table 250

METEOROLOGICAL DATA USED FOR ANNUAL AVERAGE POINT SOURCE SIMULATION MODELING EFFORT: 1976

Data Group	Parameter	Variable Group	Frequency of Occurrence (percent)	Mixing Heights Associated with Atmospheric Stability Classes
Wind	Speed (knots)	0-3	6.9	--
		4-6	14.7	
		7-10	34.9	
		11-16	33.0	
		17-21	8.7	
		> 21	1.8	
		Total	100.00	
	Direction	North	8.97	--
		North-Northeast	4.90	
		Northeast	3.87	
		East-Northeast	1.76	
		East	2.25	
		East-Southeast	2.00	
		Southeast	4.13	
		South-Southeast	3.28	
		South	8.16	
		South-Southwest	6.30	
		Southwest	8.73	
		West-Southwest	10.44	
		West	12.87	
		West-Northwest	10.11	
		Northwest	7.71	
		North-Northwest	4.52	
		Total	100.00	
Atmospheric Stability	Pasquill Stability Class	A—Extremely Unstable	0.14	1,500
		B—Unstable	3.08	1,500
		C—Slightly Unstable	9.04	1,170
		D—Neutral	64.07	1,000
		E—Slightly Stable	13.29	
		F—Stable	10.38	--
		Total	100.00	--

Source: National Climatic Center; Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

shoreline in central Milwaukee County. This isopleth value may be attributed to sulfur dioxide emissions from the Milwaukee Solvay Coke Company, which accounted for about 700 tons of this pollutant species during 1976. Sulfur dioxide concentrations may be observed to generally decrease with distance inland and with distance north and south of the heavily industrialized Menomonee River Valley.

The annual average sulfur dioxide concentrations in the Region due to emissions from line and area sources during 1976 were simulated using the URBAN submodel under the prevailing meteorological conditions summarized in Table 251. The resultant sulfur dioxide concentrations due to line source emissions are presented in Table 191 in Chapter VII and are shown on Map 67. As with particulate matter, the highest sulfur dioxide concentration from line sources is centered over the Marquette Interchange in Milwaukee County, with the concentrations generally decreasing radially away from this interchange in a pattern closely corresponding to the regional freeway system. The maximum isopleth value on Map 67 is 8 $\mu g/m^3$, or 10 percent of the primary annual standard.

Table 251

METEOROLOGICAL DATA USED FOR ANNUAL AVERAGE LINE AND AREA SOURCE SIMULATION MODELING EFFORT: 1976

Stability Class	Heat Flux (langleys per minute)	Wind Speed (meters per second)	Percent Frequency by Wind Direction								
			North	Northeast	East	Southeast	South	Southwest	West	Northwest	Total
Unstable	0.18	5	0.46	0.35	0.37	0.29	0.33	0.41	0.49	0.33	3.03
	0.18	10	0.72	1.52	1.15	1.03	0.60	1.03	2.31	0.82	9.18
Neutral	--	5	0.67	0.51	0.24	0.51	0.44	0.65	0.89	0.67	4.58
	--	10	2.19	1.13	1.05	1.78	2.14	2.52	3.99	3.26	18.06
	--	15	6.89	2.62	0.94	2.19	4.81	7.96	9.25	6.82	41.48
Stable	- 0.04	5	2.75	1.04	0.38	0.95	4.67	4.53	6.25	3.10	23.67
Total	--	--	13.68	7.17	4.13	6.75	12.99	17.10	23.18	15.00	100.00

Source: National Climatic Center; Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

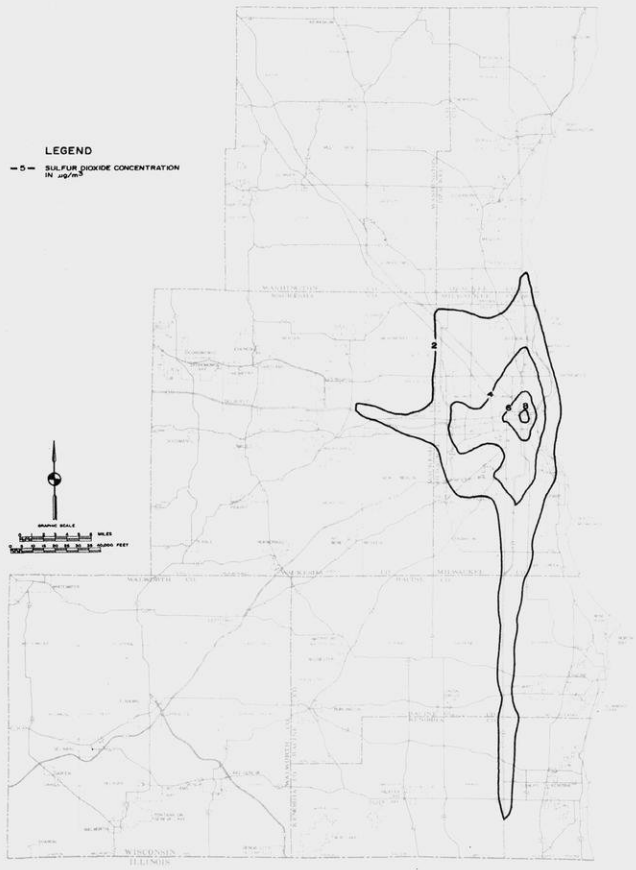
Map 68 shows the annual average sulfur dioxide concentrations in the Region due to the emissions from area sources during 1976, which are summarized in Table 195 in Chapter VII. The maximum isopleth value on Map 68 is 20 $\mu g/m^3$ and covers an approximate 26-square-mile area in central Milwaukee County. A second isopleth with a value of 10 $\mu g/m^3$ envelopes much of the remaining portion of the heavily urbanized area of Milwaukee County, as well as relatively small areas in the central portions of the Cities of Kenosha and Racine.

A comparison of the sulfur dioxide concentrations monitored in the Region during 1976 with the results of the simulation modeling effort is provided in Table 252, and shown graphically in Figure 83. A least-squares linear regression analysis (see the section in this chapter on particulate matter concentrations for an explanation of such an analysis, pages 398-400) performed for the five monitored-modeled data pairs of annual average sulfur dioxide concentrations yields a "best fit" line with a slope of 0.984 and an intercept, or background, value of 9.7 $\mu g/m^3$. The fact that the slope of the line is close to unity indicates that the model is relatively free of systematic error and that it adequately accounts for both the quantity and spatial variation in the distribution of sulfur dioxide emissions. The estimated background sulfur dioxide concentration of 9.7 $\mu g/m^3$ may be attributed principally to emissions which were not included in the 1976 inventory, and to other factors which may contribute to background values such as long-range transport.

The correlation coefficient (r) calculated for the five pair of monitored-modeled sulfur dioxide concentrations in 1976 is 0.770. (For an explanation of the correlation coefficient, refer to the section in this chapter on particulate matter concentrations, pages 400-401.) The maximum theoretical value which the correlation coefficient would assume at the 5 percent confidence level is 0.878. The correlation between the monitored and the predicted sulfur dioxide concentrations is not, therefore, significant in a strict mathematical sense. The maximum theoretical value the correlation coefficient may assume, however, increases rapidly with the number of data pairs available for the analysis. The fact that only five monitoring sites could be used to establish a relationship between the

Map 67

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE SULFUR DIOXIDE CONCENTRATIONS DUE TO EMISSIONS FROM LINE SOURCES IN THE REGION: 1976

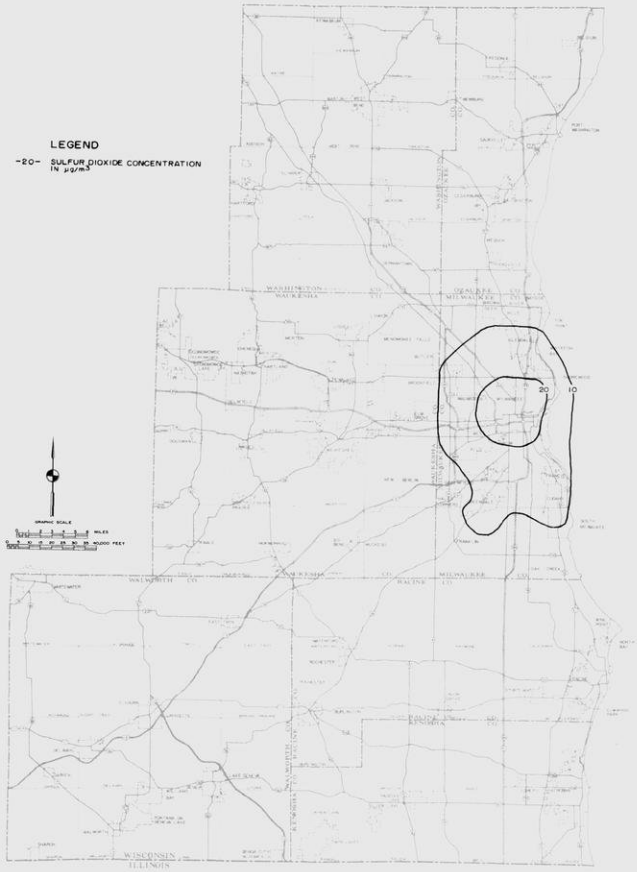


This map illustrates the impact of sulfur dioxide emissions from line sources on ambient air quality in the Region during 1976. The maximum sulfur dioxide concentration shown on the above map is 8 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and occurs in the area of the Marquette Interchange in Milwaukee County. As may be expected, the spatial distribution of sulfur dioxide concentrations due to line source emissions during 1976 closely parallels the pattern of the regional freeway system.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 68

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE SULFUR DIOXIDE CONCENTRATIONS DUE TO EMISSIONS FROM AREA SOURCES IN THE REGION: 1976



This map illustrates the impact of sulfur dioxide emissions from area sources on ambient air quality in the Region during 1976. As may be seen on this map, the maximum sulfur dioxide concentration due to area source emissions was 20 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and was located in central Milwaukee County. Sulfur dioxide emissions from area sources result principally from the combustion of fossil fuels for residential, commercial-institutional, and small industrial space heating and water heating purposes, and thus may be expected to reflect the pattern of intensive urban development within the Region as indicated on this map.

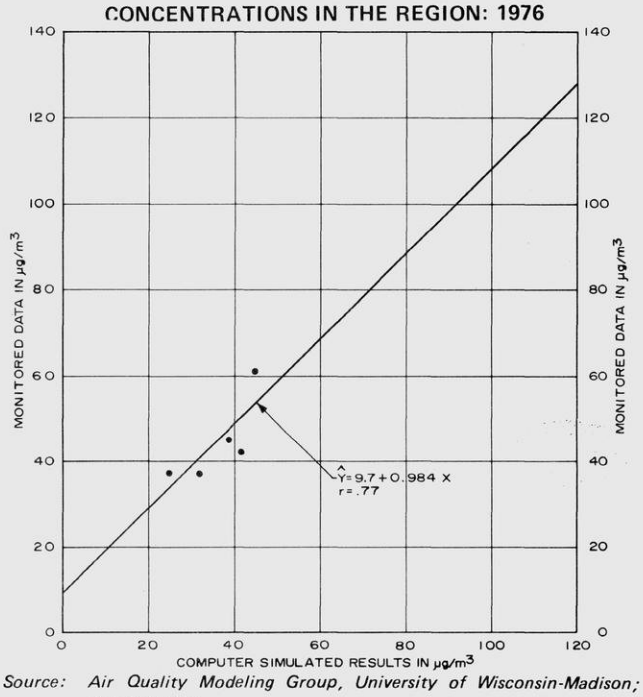
Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

monitored and predicted sulfur dioxide concentrations—as compared with 20 sites in 1973 and 28 sites in 1977 for particulate matter—places a rigorous constraint not only on the degree of error permissible in the model's numerical algorithm, but also on the allowable error in identifying and quantifying emission sources and in summarizing the prevailing meteorological conditions. Within these constraints, a correlation coefficient of 0.770, although not mathematically significant, is high from a practical standpoint.

In examining the monitored data and predicted values presented in Table 252, it is evident that the simulation model accounted for all of the monitored sulfur dioxide

Figure 83

COMPARISON OF MONITORED AND COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE SULFUR DIOXIDE CONCENTRATIONS IN THE REGION: 1976



Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Table 252

COMPARISON OF MONITORED AND COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE SULFUR DIOXIDE CONCENTRATIONS IN THE REGION: 1976

Location of Monitoring Site		Computer-Simulated Data ($\mu g/m^3$)				Monitored Data ($\mu g/m^3$)
Address	County	Point	Line	Area	Total	
606 W. Kilbourn Avenue.	Milwaukee	12	7	23	42	42
1225 S. Carferry Drive	Milwaukee	18	4	23	45	61
3401 S. 39th Street	Milwaukee	12	4	16	32	37
3716 W. Wisconsin Avenue . . .	Milwaukee	9	6	24	39	45
1601 Washington Avenue	Racine	13	2	10	25	37

Source: Air Quality Modeling Group, University of Wisconsin-Madison; Wisconsin Department of Natural Resources; and SEWRPC.

levels at 606 W. Kilbourn Avenue in the City of Milwaukee. Moreover, the model accounted for over 85 percent of the annual average sulfur dioxide levels measured at 3401 S. 39th Street and at 3716 W. Wisconsin Avenue, also in the City of Milwaukee. Only in the City of Racine did the modeling effort fail to account for more than 70 percent of the observed levels, and at that, 68 percent of the monitored concentrations were identified by the model. In spite of the 0.770 correlation coefficient, the WIS*ATMDIF model represents the best analytical tool available for determining annual average sulfur dioxide concentrations in the Southeastern Wisconsin Region.

Map 69 depicts the distribution of average annual sulfur dioxide concentrations from the combined point, area, and line sources of emissions in the Region during 1976 as estimated using the WIS*ATMDIF modeling results calibrated according to the "best fit" linear regression equation. Consistent with the findings for the five air quality sulfur dioxide monitoring sites in the Region during 1976, the simulation modeling results shown on Map 69 indicate that the primary sulfur dioxide ambient air quality standard of 80 $\mu g/m^3$, expressed as an annual arithmetic average, has not been exceeded anywhere in the Region. The maximum isopleth value indicated on Map 69 is 50 $\mu g/m^3$, or only 63 percent of the primary annual standard. It may, therefore, be concluded that sulfur dioxide in southeastern Wisconsin does not presently occur on an annual average basis in sufficient concentrations to constitute a danger to the health and welfare of regional inhabitants.

24-Hour Average Levels

Air quality simulation modeling of the 24-hour average sulfur dioxide concentrations is subject to the same limitations and impedances as 24-hour average particulate matter modeling. The extent to which background levels of sulfur dioxide are influenced by long-range transport is not precisely known at the present time. It is known, however, that sulfur dioxide can be readily absorbed by vegetation and by impaction upon certain surfaces, such as stone or other masonry, and can be chemically transformed to sulfate particles—a principal agent contributing to the precipitation phenomenon known as acid rain. As with the short-term particulate matter modeling effort, the WIS*ATMDIF model cannot take such removal processes or chemical reactions into account in simulating the 24-hour average sulfur dioxide concentrations in the Region. The modeling results for the 24-hour average sulfur dioxide concentrations in southeastern Wisconsin during 1976 as presented herein are thus based on the dispersion of this pollutant species from local emission sources only and in the assumed absence of physical or chemical removal processes.

The maximum 24-hour average sulfur dioxide concentrations in the Region during 1976 as estimated using the WIS*ATMDIF model are shown on Map 70. These results are based on assumed meteorological conditions of light wind speed—about 5.6 miles per hour (mph), slightly unstable atmospheric conditions for 12 hours of daylight, and slightly stable atmospheric conditions for 12 hours of night. The maximum isopleth value indicated on Map 70 is 200 $\mu g/m^3$, or approximately 55 percent of the primary ambient air quality standard of 365 $\mu g/m^3$, and is located in central Milwaukee County. The 200 $\mu g/m^3$ sulfur dioxide isopleth is in the area of two of the sulfur dioxide monitoring sites which were active during 1976—606 W. Kilbourn Avenue and 3716 W. Wisconsin Avenue, both in the City of Milwaukee. The maximum 24-hour average sulfur dioxide concentrations recorded during 1976 were 152 $\mu g/m^3$ and 200 $\mu g/m^3$ at the Kilbourn Avenue and Wisconsin Avenue monitoring sites, respectively. Thus, the simulation modeling results for this portion of the City of Milwaukee agree well with the monitored sulfur dioxide concentrations on a 24-hour average basis. Therefore it may be concluded that, based on both the available ambient air quality monitoring data and the air quality simulation modeling results, the 24-hour average ambient air quality standard for sulfur dioxide was not exceeded in the Region during 1976.

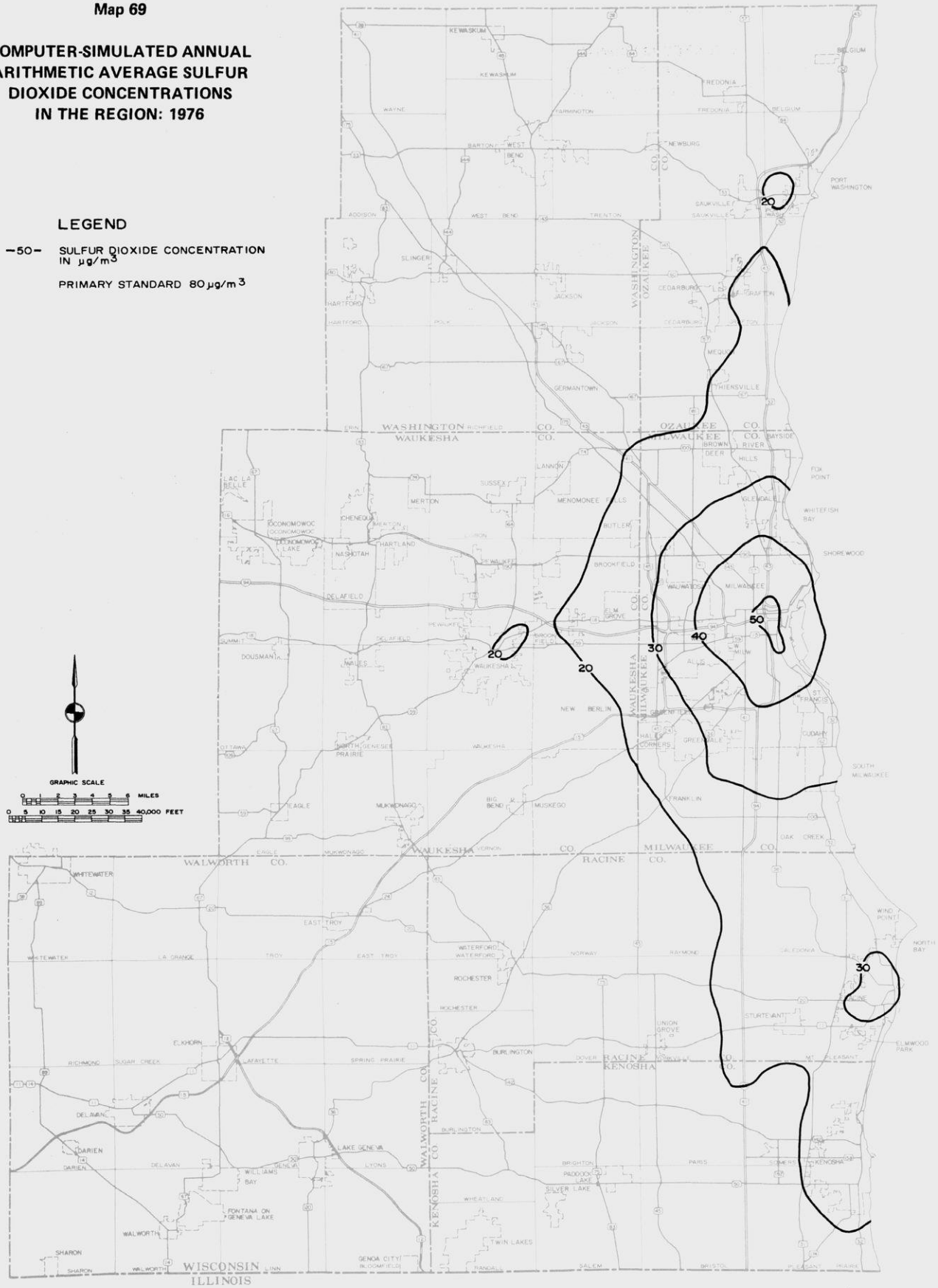
Three-Hour Average Levels

In order to prevent damage to vegetation from exposure to high concentrations of sulfur dioxide over relatively short periods, the U. S. EPA has established a secondary ambient air quality standard for sulfur dioxide at 1,300 $\mu g/m^3$ for a three-hour average. A review of the available monitoring data indicates that the three-hour standard was not exceeded during 1976, but that violations were recorded on two occasions in 1975 and on one occasion in 1977. On the 1977 occasion, only one monitoring site measured the violation, while the other sites recorded sulfur dioxide levels lower than the peak by a factor of 10. This observation suggests that the violation was caused by the impingement of a plume from a single point source for a sustained period.

For the purpose of simulating the maximum three-hour average sulfur dioxide concentrations in the Region during 1976, meteorological conditions were selected that would cause a plume from a point source to be driven to the ground as rapidly as possible, thereby minimizing the dispersion of the plume and maximizing the ground-level pollutant concentrations. Such an effect is achieved by simulating dispersion under extremely unstable atmospheric conditions with a wind speed of about 10 mph. The maximum three-hour sulfur dioxide concentrations in the Region during 1976 as estimated using the WIS*ATMDIF model and assuming the above conditions are shown on Map 71. As may be seen on Map 71, the maximum isopleth value is 500 $\mu g/m^3$ and is associated with the dispersion of sulfur dioxide emissions from the Wisconsin Electric Power Company Oak Creek Plant. To a lesser extent, the electrical generation plants in the Menomonee River Valley and in Port Washington may also be identified as major contributors to the maximum three-hour sulfur dioxide levels in the Region. Even under the "worst case" conditions postulated in this modeling effort, however, the maximum isopleth value of 500 $\mu g/m^3$ is only about 38 percent of the 1,300 $\mu g/m^3$ secondary three-hour average sulfur dioxidc standard.

Map 69

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE SULFUR DIOXIDE CONCENTRATIONS IN THE REGION: 1976

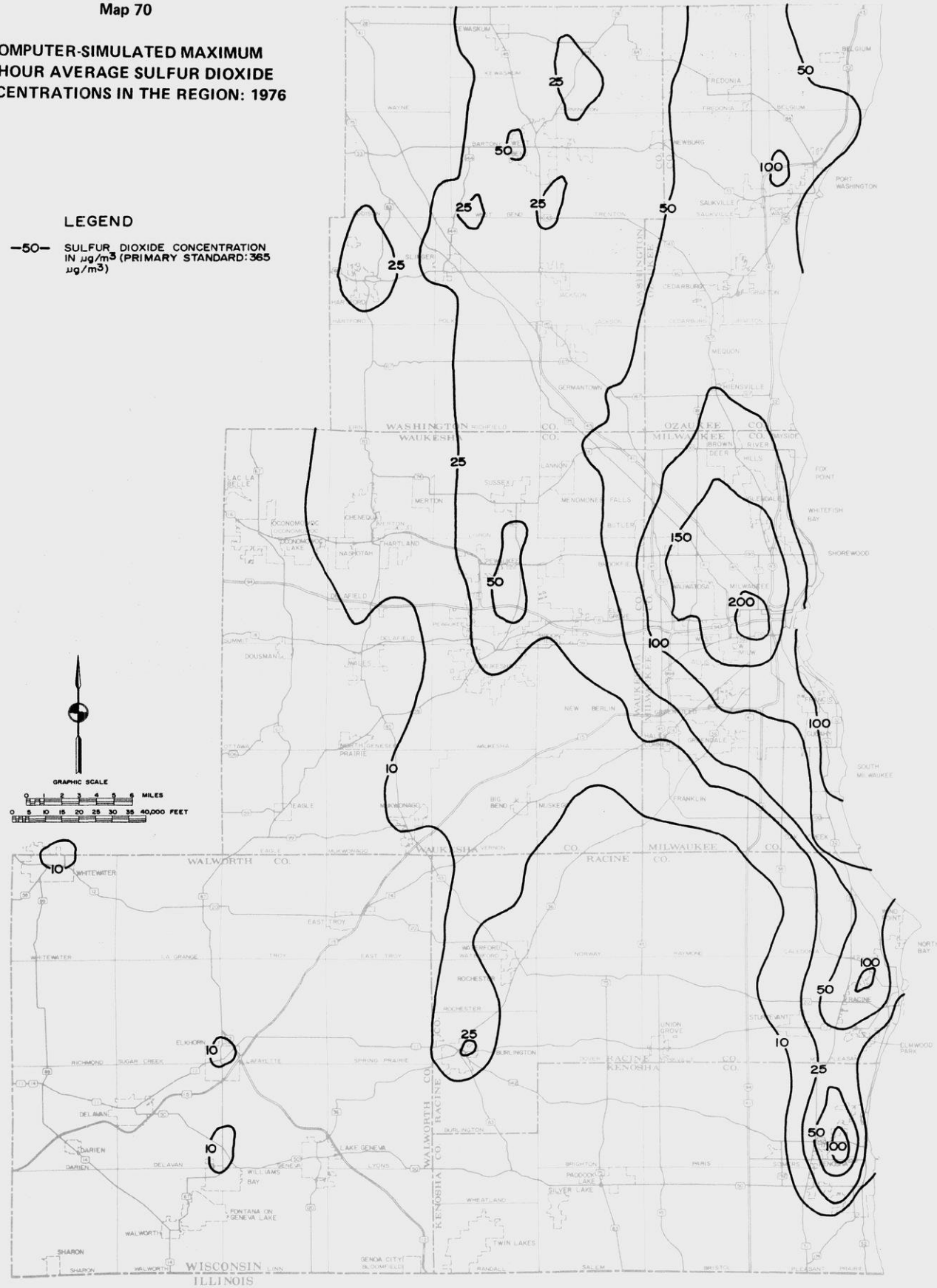


This map illustrates the composite impact of point, line, and area sources of sulfur dioxide emissions on ambient air quality in the Region during 1976 as determined using the Wisconsin Atmospheric Diffusion Model. The computer-simulated sulfur dioxide concentrations shown on this map were calibrated to available ambient air quality monitoring data for the year 1976, and adjusted to reflect the influence of long-range transport, unidentified local emission sources, and naturally occurring levels of sulfur dioxide in the ambient air. The highest sulfur dioxide concentration in the Region in 1976 as determined by this modeling effort was 50 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and was located in and around the central business district of the City of Milwaukee. The 50 $\mu g/m^3$ sulfur dioxide concentration isopleth is approximately 63 percent of the annual arithmetic average sulfur dioxide ambient air quality standard of 80 $\mu g/m^3$. It may, therefore, be concluded that this standard was not exceeded in the Region during 1976.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 70

COMPUTER-SIMULATED MAXIMUM 24-HOUR AVERAGE SULFUR DIOXIDE CONCENTRATIONS IN THE REGION: 1976

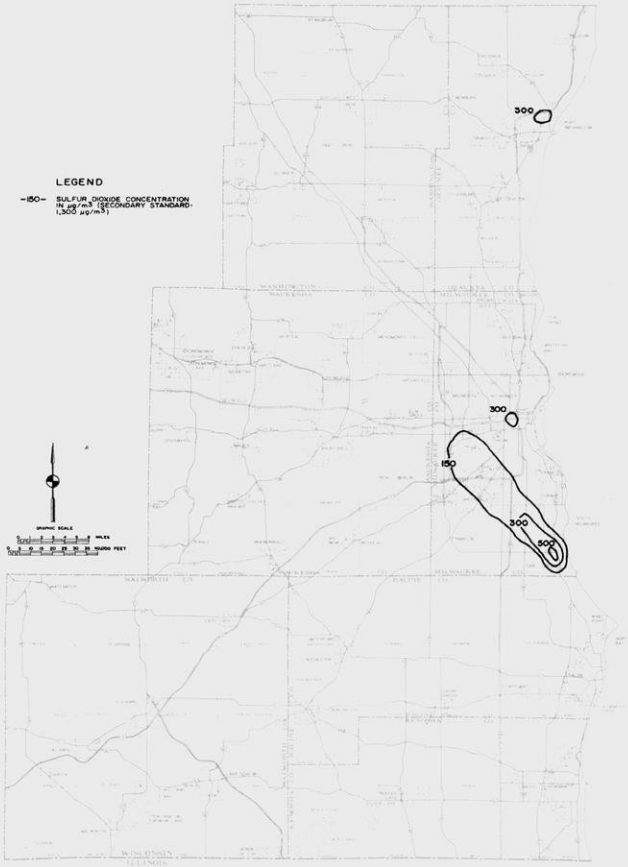


This map illustrates the composite impact of point, line, and area sources of sulfur dioxide emissions on the 24-hour average levels of sulfur dioxide concentrations in the Region during 1976. As may be seen on this map, the maximum sulfur dioxide concentration isopleth value of 200 micrograms per cubic meter ($\mu g/m^3$), expressed as a 24-hour arithmetic average, occurs in the central portion of Milwaukee County. The next highest isopleth values of 150 $\mu g/m^3$ and 100 $\mu g/m^3$ occur in Milwaukee County and in areas in the Cities of Racine and Kenosha and near the City of Port Washington. It is important to note, however, that the sulfur dioxide simulation modeling results for the 24-hour averaging period do not reflect the influence of long-range transport, unidentified local emission sources, or naturally occurring sulfur dioxide levels in the ambient air. Since such factors exhibit extreme day-to-day variations, it was not possible to account for their influence in the modeling effort for short-term averaging periods.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 71

COMPUTER-SIMULATED MAXIMUM THREE-HOUR AVERAGE SULFUR DIOXIDE CONCENTRATIONS IN THE REGION: 1976



This map illustrates the maximum three-hour average sulfur dioxide concentrations in the Region during 1976 under adverse meteorological conditions. Such adverse meteorological conditions would include an extremely unstable atmosphere and moderate, but persistent, southeasterly winds. As indicated on this map, the maximum three-hour average sulfur dioxide concentration isopleth has a value of 500 micrograms per cubic meter ($\mu g/m^3$), and is located near the Wisconsin Electric Power Company's Oak Creek Plant. To a lesser extent, the impact of Wisconsin Electric Power Company's Valley Plant and Port Washington Plant are also evident on this map. These three electric power generation facilities accounted for about 184,700 tons of sulfur dioxide emissions, or about 74 percent of the total 249,900 tons of emissions of this pollutant species in the Region, during 1976.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Available monitoring data for 1976 indicate that the maximum three-hour average sulfur dioxide concentration which occurred in the Region during that year was 979 $\mu g/m^3$, or about 75 percent of the 1,300 $\mu g/m^3$ standard. This level was recorded at two stations, one located at 3716 W. Wisconsin Avenue and one at 3401 S. 39th Street in the City of Milwaukee. As with the simulation modeling results for the maximum 24-hour average sulfur dioxide concentrations in the Region, the simulation modeling results for the maximum three-hour average sulfur dioxide concentrations are approximately one-half of the monitored levels. Again, this difference between the monitoring data and modeling results may be attributed, in part, to the influence of long-range transport, or to significant deviations from the average operating characteristics of major sulfur dioxide emission sources—a factor which may not adequately be accounted for in the simulation modeling effort. It should also be noted that elevated levels of sulfur dioxide concentrations over short-term averaging periods are thought to be associated with certain meteorological conditions which have a relatively low joint frequency of occurrence. In particular, such meteorological conditions include an extremely unstable atmosphere which quickly forces stack plumes to the ground, moderate wind speeds—on the order of 10 to 12 mph—which inhibit plume rise, and a high degree of wind persistence which acts to prevent the plume impaction point from drifting at ground level. Considering only the relative frequency of occurrence of extremely unstable atmospheric conditions—less than 1 percent of the time during 1976—there is a low probability that adverse meteorological conditions would have combined with high levels of transported sulfur dioxide or a large, anomalous increase in sulfur dioxide emissions from local sources to produce ambient air sulfur dioxide concentrations in excess of the three-hour average standard. Therefore, both the available monitoring data and the simulation modeling results indicate that the three-hour average sulfur dioxide ambient air quality standard of 1,300 $\mu g/m^3$ was not exceeded in the Region during 1976.

CARBON MONOXIDE CONCENTRATIONS

Air quality monitoring for carbon monoxide levels in the Region began in 1973. Much of the data obtained prior to 1975, however, were found to be invalid because of problems in the reduction of the raw data to average concentrations. There are, however, sufficient monitoring data available for selected days in 1973 through 1975 to enable the "worst case" carbon monoxide levels in the Region to be estimated using the Wisconsin Atmospheric Diffusion Model (WIS*ATMDIF).

Carbon monoxide is not subject to long-range transport and may not, in fact, be carried over significant distances within the Region, since it is readily absorbed by vegetation and directly into the earth by microorganisms. The carbon monoxide levels monitored in the Region, therefore, are predominantly influenced by the localized emissions in the proximity of the monitor. The WIS* ATMDIF model, however, is best suited for evaluating pollutant concentrations over broad geographic areas rather than microscale, "hotspot" areas of high carbon monoxide levels. Therefore, rather than attempting to separately calibrate the model to each monitor to reflect the influence of local emissions, the simulation effort for carbon monoxide was directed toward determining those meteorological conditions which would yield the maximum concentrations on a regional basis. Once the "worst case" conditions were determined for 1973, the 1977 carbon monoxide emissions inventory could be used to simulate ambient air quality under similar

Table 253

HOURLY METEOROLOGICAL DATA USED BY THE URBANT SUBMODEL TO SIMULATE CARBON MONOXIDE CONCENTRATIONS

Date	Hour	Wind Speed (meters per second)	Wind Direction	Cloud Cover (percent)	Net Heat Flux (langleys per minute)
December 7, 1973	04	3.2	West	--	- 0.04
	05	3.2	West	--	- 0.04
	06	4.2	West	--	- 0.04
	07	2.0	West	--	- 0.02
	08	1.5	West	--	- 0.02
	09	1.7	West	--	--
	10	2.0	West	--	0.06
	11	5.9	West	--	0.12
	12	4.3	West	--	0.12
December 12, 1973	04	2.0	West	10	- 0.04
	05	2.0	West	30	- 0.04
	06	1.5	West	40	- 0.02
	07	1.5	West	60	- 0.02
	08	1.5	West	100	--
	09	1.5	West	90	--
	10	1.5	West	80	--
	11	2.0	West	70	0.03
	12	7.4	West	60	0.06
February 12, 1974	04	3.3	Southwest	60	- 0.02
	05	2.0	Southwest	40	- 0.02
	06	2.0	Southwest	40	- 0.02
	07	2.0	Southwest	50	- 0.02
	08	2.0	Southwest	70	- 0.02
	09	2.0	Southwest	50	--
	10	2.5	Southwest	20	0.06
	11	2.0	Southwest	--	0.12
	12	2.0	Southwest	50	0.12
December 11, 1974	04	3.3	Southwest	--	- 0.04
	05	3.3	Southwest	--	- 0.04
	06	3.3	Southwest	--	- 0.04
	07	3.0	Southwest	100	- 0.02
	08	4.0	Southwest	100	--
	09	5.2	Southwest	100	--
	10	5.2	Southwest	100	--
	11	5.2	Southwest	100	--
	12	6.1	Southwest	100	--
January 27, 1975	04	2.0	Southwest	30	- 0.04
	05	2.0	Southwest	30	- 0.04
	06	2.0	Southwest	30	- 0.02
	07	2.0	Southwest	70	--
	08	2.0	Southwest	100	--
	09	2.0	Southwest	100	--
	10	4.1	Southwest	100	--
	11	5.2	Southwest	100	--
	12	5.2	Southwest	100	--

Source: Air Quality Modeling Group, University of Wisconsin-Madison.

Table 254

COMPARISON OF MONITORED AND COMPUTER-SIMULATED HOURLY CARBON MONOXIDE CONCENTRATIONS AT SELECTED SITES—MILWAUKEE COUNTY: 1973-1975

Address	Date	Milligrams per Cubic Meter															
		5:00 a.m.-6:00 a.m.		6:00 a.m.-7:00 a.m.		7:00 a.m.-8:00 a.m.		8:00 a.m.-9:00 a.m.		9:00 a.m.-10:00 a.m.		10:00 a.m.-11:00 a.m.		11:00 a.m.-12:00 p.m.		12:00 p.m.-1:00 p.m.	
		Computer-Simulated Data	Monitored Data	Computer-Simulated Data	Monitored Data	Computer-Simulated Data	Monitored Data	Computer-Simulated Data	Monitored Data	Computer-Simulated Data	Monitored Data	Computer-Simulated Data	Monitored Data	Computer-Simulated Data	Monitored Data	Computer-Simulated Data	Monitored Data
7528 W. Appleton Avenue	December 7, 1973	1	2	2	6	3	7	4	6	3	7	2	4	1	3	1	2
606 W. Kilbourn Avenue	December 7, 1973	4	--	9	--	14	--	15	--	13	--	7	--	3	--	3	--
1225 S. Carferry Drive	December 7, 1973	2	2	4	2	5	5	4	--	4	--	2	--	1	--	1	--
2114 E. Kenwood Boulevard	December 7, 1973	1	1	2	2	5	4	4	6	4	5	4	4	1	3	1	2
3401 S. 39th Street	December 7, 1973	1	--	2	--	3	--	3	--	3	--	2	--	1	--	1	--
9722 W. Watertown Plank Road	December 7, 1973	1	1	1	1	3	4	3	--	3	4	2	2	1	2	1	2
7528 W. Appleton Avenue	December 12, 1973	1	--	1	--	3	--	4	--	3	--	3	--	2	--	1	--
606 W. Kilbourn Avenue	December 12, 1973	2	1	6	4	11	7	12	11	10	6	9	4	6	3	3	4
1225 S. Carferry Drive	December 12, 1973	2	1	4	2	4	5	3	5	3	3	3	2	3	2	1	2
2114 E. Kenwood Boulevard	December 12, 1973	1	--	4	--	4	--	4	--	4	--	3	--	3	--	2	--
3401 S. 39th Street	December 12, 1973	1	--	2	--	3	--	3	--	2	--	2	--	2	--	1	--
9722 W. Watertown Plank Road	December 12, 1973	1	2	2	2	2	5	2	6	2	7	1	5	1	3	1	2
7528 W. Appleton Avenue	February 12, 1974	1	--	3	--	6	--	6	--	4	--	2	--	1	--	1	--
606 W. Kilbourn Avenue	February 12, 1974	3	1	7	2	13	12	16	13	11	13	5	14	2	11	2	3
1225 S. Carferry Drive	February 12, 1974	1	2	4	4	8	7	10	10	6	4	2	4	1	5	1	3
2114 E. Kenwood Boulevard	February 12, 1974	2	--	6	--	11	--	--	--	9	--	3	--	2	--	2	--
3401 S. 39th Street	February 12, 1974	1	--	2	--	3	--	5	--	3	--	1	--	1	--	1	--
9722 W. Watertown Plank Road	February 12, 1974	1	1	2	3	4	8	5	9	2	7	1	7	0	3	0	1
7528 W. Appleton Avenue	December 11, 1974	1	1	5	6	10	14	7	12	1	8	1	10	1	6	1	6
606 W. Kilbourn Avenue	December 11, 1974	2	--	6	--	13	--	10	--	4	--	3	--	3	--	3	--
1225 S. Carferry Drive	December 11, 1974	1	1	3	3	7	7	5	8	1	7	1	4	1	2	1	2
2114 E. Kenwood Boulevard	December 11, 1974	2	1	5	4	9	7	7	10	2	12	1	9	1	5	1	3
3401 S. 39th Street	December 11, 1974	1	1	2	2	3	4	2	4	1	2	1	2	1	1	1	1
9722 W. Watertown Plank Road	December 11, 1974	1	1	1	1	3	5	3	--	1	3	1	2	1	1	1	1
7528 W. Appleton Avenue	January 27, 1975	1	2	2	7	5	12	5	11	3	7	2	6	1	--	1	3
606 W. Kilbourn Avenue	January 27, 1975	2	--	7	--	13	--	12	--	7	--	5	--	3	--	3	--
1225 S. Carferry Drive	January 27, 1975	1	--	4	--	8	--	6	--	3	4	2	--	1	--	1	1
2114 E. Kenwood Boulevard	January 27, 1975	2	1	6	3	12	5	8	4	4	2	3	3	2	3	2	1
3401 S. 39th Street	January 27, 1975	1	2	2	4	4	5	3	4	2	2	1	2	1	1	1	1
9722 W. Watertown Plank Road	January 27, 1975	1	1	2	2	4	4	3	--	2	--	1	--	1	--	1	--

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

meteorological conditions, and conclusions could be drawn concerning the pattern in carbon monoxide levels throughout the Region. The results and findings of this simulation modeling effort are presented in the following sections.

"Worst Case" Carbon Monoxide Concentrations: 1973

There are two averaging periods against which the maximum carbon monoxide levels in the Region must be evaluated: an eight-hour average, with a primary and secondary standard of 10 milligrams per cubic meter (mg/m^3); and a one-hour average, with a primary and secondary standard of 40 mg/m^3. For both averaging periods, carbon monoxide levels in the Region were estimated through use of the time-dependent version of the WIS*ATMDIF model—the URBANT submodel. Emissions from point, line, and area sources were utilized in the application of the URBANT submodel. These sources accounted for the total of 613,800 tons of carbon monoxide emissions released in the Region in 1973. Point sources, which emitted about 20,700 tons of carbon monoxide, or approximately 3 percent of the total, were found to have a negligible effect on ambient air quality at the gound. Although area sources emitted only about 68,300 tons of carbon monoxide, or only about 11 percent of the total, such sources were considered to be significant because they released carbon monoxide emissions at ground level. Because line sources were found to have the most significant impact on ambient air quality, the URBANT submodel simulated the maximum carbon monoxide concentrations which would be associated with the emissions generated during peak periods of vehicle use within the Region. For the one-hour carbon monoxide average, this peak period corresponded to the hour from 7:00 a.m. to 8:00 a.m., and for the eight-hour average period to the hours from 5:00 a.m. to 1:00 p.m. For both averaging periods, carbon monoxide emissions during the winter season were used since cold ambient air temperatures increase the amount of carbon monoxide produced in the internal combustion engine.

Five monitoring days were selected for the purpose of comparing the uncalibrated simulation model results with measured ambient air data. These five days—Friday, December 7, 1973; Wednesday, December 12, 1973; Tuesday, February 12, 1974; Wednesday, December 11, 1974; and Monday, January 27, 1975—were selected on the criteria that at least three monitoring stations were operating, that the wind was from the south to west, and that the carbon monoxide concentrations were high compared to other days. For each of these five days, the model simulated the carbon monoxide concentrations for nine hours—from 4:00 a.m. to 1:00 p.m. The hour 4:00 a.m. to 5:00 a.m. was simulated to provide an initial background concentration for the model. The hourly meteorological data for each day as used in the URBANT submodel are presented in Table 253.

Table 254 provides a comparison of the hourly carbon monoxide concentrations as predicted by the uncalibrated URBANT submodel and the actual monitored data for each sampling site in operation on one or more of the five selected days. There were a total of six monitoring sites available for this comparative analysis. A correlation analysis between the monitored and predicted concentrations was performed for each of these six sites, the results of which are presented in Table 255. As may be seen in Table 255, the highest correlation between the monitored and predicted carbon monoxide concentrations, 0.91, occurred at 3401 S. 39th Street, and the lowest correlation, 0.33, at 2114 E. Kenwood Boulevard. The average correlation coefficient for all six monitoring sites was 0.68. (For an explanation of the correlation coefficient, refer to the section in this chapter on particulate matter concentrations, pages 400-401.) Considering all 141 matched monitored-modeled data pairs in Table 254, the maximum theoretical value the correlation coefficient would assume at the 1 percent confidence level is 0.22. The correlation between the monitored and the predicted carbon monoxide concentrations may, therefore, be considered significant.

Table 255

CORRELATION COEFFICIENTS BETWEEN MONITORED AND COMPUTER-SIMULATED HOURLY CARBON MONOXIDE CONCENTRATIONS AT SELECTED SITES—MILWAUKEE COUNTY: 1973-1975

Address	Correlation Coefficient
7528 W. Appleton Avenue	0.77
606 W. Kilbourn Avenue	0.60
1225 S. Carferry Drive	0.71
2114 E. Kenwood Boulevard	0.33
3401 S. 39th Street	0.91
9722 W. Watertown Plank Road	0.77
Average	0.68

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

On the basis of this initial modeling effort, a representative "worst case" scenario of hourly meteorological conditions was postulated which would yield maximum carbon monoxide levels in the Region for both an eight-hour and one-hour period. These hourly "worst case" meteorological conditions are set forth in Table 256. The resulting maximum eight-hour carbon monoxide levels in 1973 under these meteorological conditions as simulated using the URBANT submodel are shown on Map 72. As may be seen on Map 72, the eight-hour primary and secondary carbon monoxide standard of 10 mg/m^3 was exceeded in Milwaukee County in 1973 over a nine-square-mile area approximately centered on the Marquette Interchange. In addition, as shown on Map 73, the one-hour primary and secondary carbon monoxide standard of 40 mg/m^3 is estimated to have been exceeded over a two-square-mile area in the Region

during 1973, again centered on the Marquette Interchange. Based on these findings, it is estimated that 142,900 persons resided in that portion of the City of Milwaukee in which the eight-hour carbon monoxide ambient air quality standard was exceeded in 1973, and that 39,600 persons resided in that portion of the City of Milwaukee in which the one-hour carbon monoxide ambient air quality standard was exceeded in 1973.

Table 256

"WORST CASE" HOURLY METEOROLOGICAL DATA FOR CARBON MONOXIDE SIMULATIONS

Hour	Wind Speed (meters per second)	Wind Direction	Net Heat Flux (langleys per minute)
04	2.0	South	- 0.04
05	2.0	South	- 0.04
06	2.0	South	- 0.04
07	2.0	South	- 0.02
08	2.0	South	- -
09	2.0	South	- -
10	2.0	South	0.06
11	2.0	South	0.12
12	2.0	South	0.12

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

"Worst Case" Carbon Monoxide Concentrations: 1977

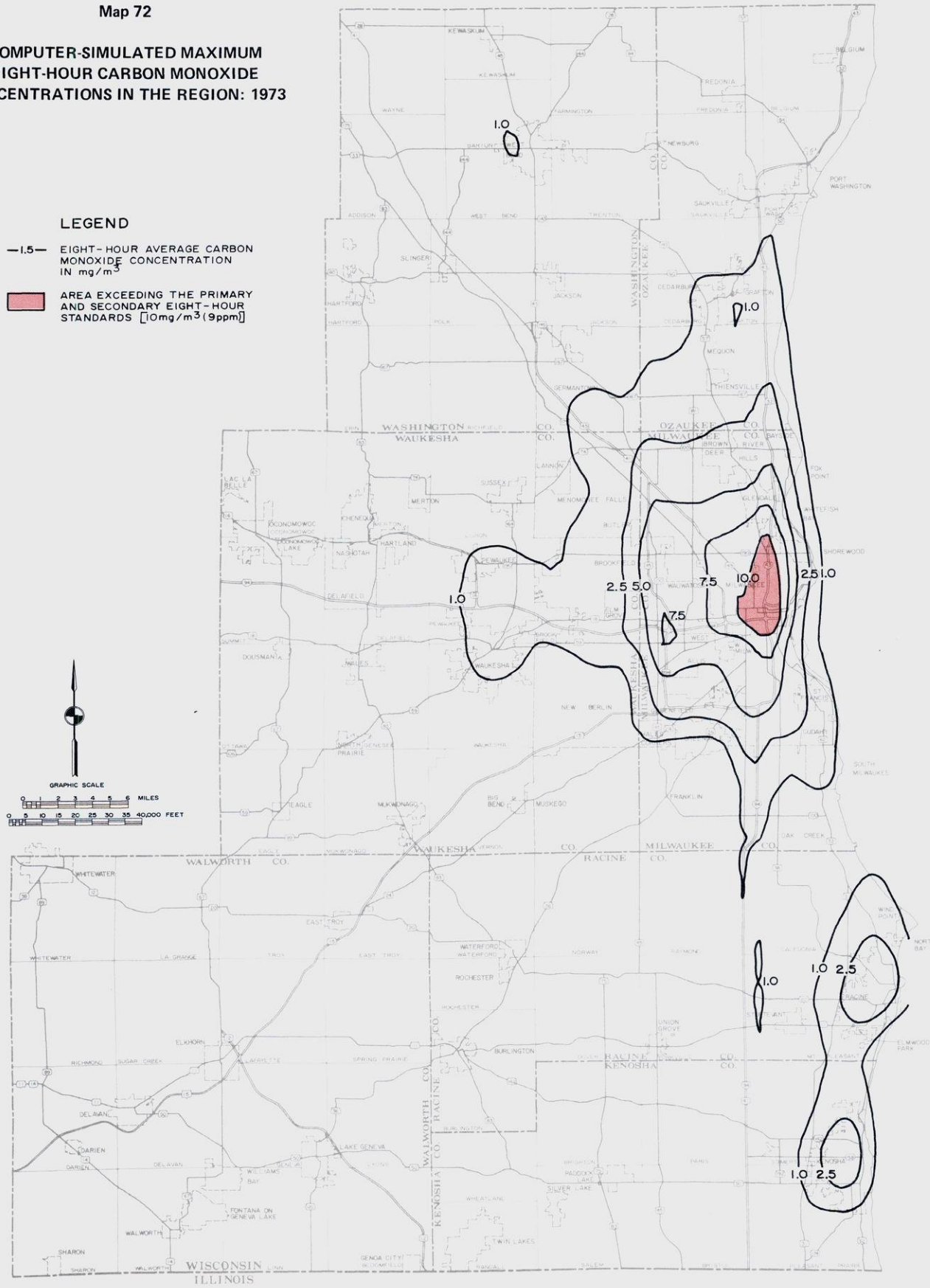
The maximum carbon monoxide concentrations in the Region in 1977 were simulated by the URBANT submodel using the "worst case" meteorological conditions determined for the base year, 1973, in order to provide an indication of the trend in carbon monoxide levels in the Region over the recent past. Map 74 shows the maximum eight-hour average carbon monoxide concentrations in the Region during 1977 under these "worst case" conditions. The maximum isopleth on Map 74 has a value of 14 mg/m^3, or approximately 40 percent higher than the primary and secondary ambient air quality standard of 10 mg/m^3. It is evident from a comparison of the maximum eight-hour carbon monoxide levels in the Region in 1973 and 1977, as shown on Map 72 and Map 74, respectively, that the area exceeding the 10 mg/m^3 ambient air quality standard in 1977 is substantially larger than the area exceeding the standard in 1973. The area shown on Map 74 as exceeding the eight-hour standard during 1977 encompasses approximately 21 square miles, an increase of about 12 square miles, or about 125 percent, over the area exceeding the standard in 1973. Based on these simulation modeling results, it is estimated that 267,800 persons resided in that portion of Milwaukee County in which the eight-hour carbon monoxide standard was exceeded during 1977, an increase of about 124,900 persons, or about 87 percent, over the 142,900 persons residing in the area in which the standard was exceeded during 1973. It should be noted that the 125 percent increase in the area exceeding the eight-hour average carbon monoxide standard coincides with a net decrease of about 5,000 tons, or about 1 percent, in carbon monoxide emissions from line sources—from about 524,800 tons in 1973 to about 519,800 tons in 1977—principally as a result of the federal motor vehicle emissions control program. This apparent anomaly may be explained, however, by the change in the spatial distribution of travel induced by the construction of new facilities between 1973 and 1977, and by the differing impact of emission controls on various vehicle types. For example, most of the additional area exceeding the eight-hour standard in 1977 extends northward along a centerline corresponding to the location of IH 43—a transportation facility constructed between 1973 and 1977. The utilization of this facility may have had a significant impact on the spatial redistribution of carbon monoxide emissions from line sources over this five-year period. Moreover, carbon monoxide emissions from light- and heavy-duty gasoline trucks in the Region increased by about 13,200 tons, or more than 12 percent, between 1973 and 1977—from about 107,500 tons in 1973 to about 120,700 tons in 1977. Thus, the increased use of these vehicle types, particularly in the area indicated as exceeding the eight-hour carbon monoxide standard during 1977, may be responsible, in part, for the excessive concentrations indicated by the simulation modeling effort.

The change in transportation facilities and utilization may also be responsible for the reduction in the maximum one-hour average carbon monoxide concentrations in the Region between 1973 and 1977. As was shown on Map 73, a two-square-mile area in Milwaukee County exceeded the one-hour average carbon monoxide ambient air quality standard of 40 mg/m^3 in 1973. As may be seen on Map 75, however, this one-hour average carbon monoxide standard was not exceeded anywhere in the Region in 1977. This reduction in maximum carbon monoxide levels on a one-hour average basis may be attributed to the combined effect of more stringent emission limitations on automobiles and a redistribution of travel, particularly in areas outside the central business district of the City of Milwaukee.

Available carbon monoxide ambient air quality monitoring data for 1977 support the findings of the corresponding simulation modeling effort. During 1977, all five of the operating carbon monoxide monitoring stations in Milwaukee County recorded maximum eight-hour average carbon monoxide concentrations in excess of the 10 mg/m^3 ambient air quality standard—the highest maximum being 17.3 mg/m^3, recorded at 3716 W. Wisconsin Avenue. None of the five monitoring sites, however, recorded maximum one-hour average carbon monoxide concentrations in excess of the 40 mg/m^3 ambient air quality standard during 1977. The highest maximum one-hour average carbon monoxide concentration measured during 1977 was 25.8 mg/m^3—or about 65 percent of the standard—at 606 W. Kilbourn Avenue.

Map 72

COMPUTER-SIMULATED MAXIMUM EIGHT-HOUR CARBON MONOXIDE CONCENTRATIONS IN THE REGION: 1973

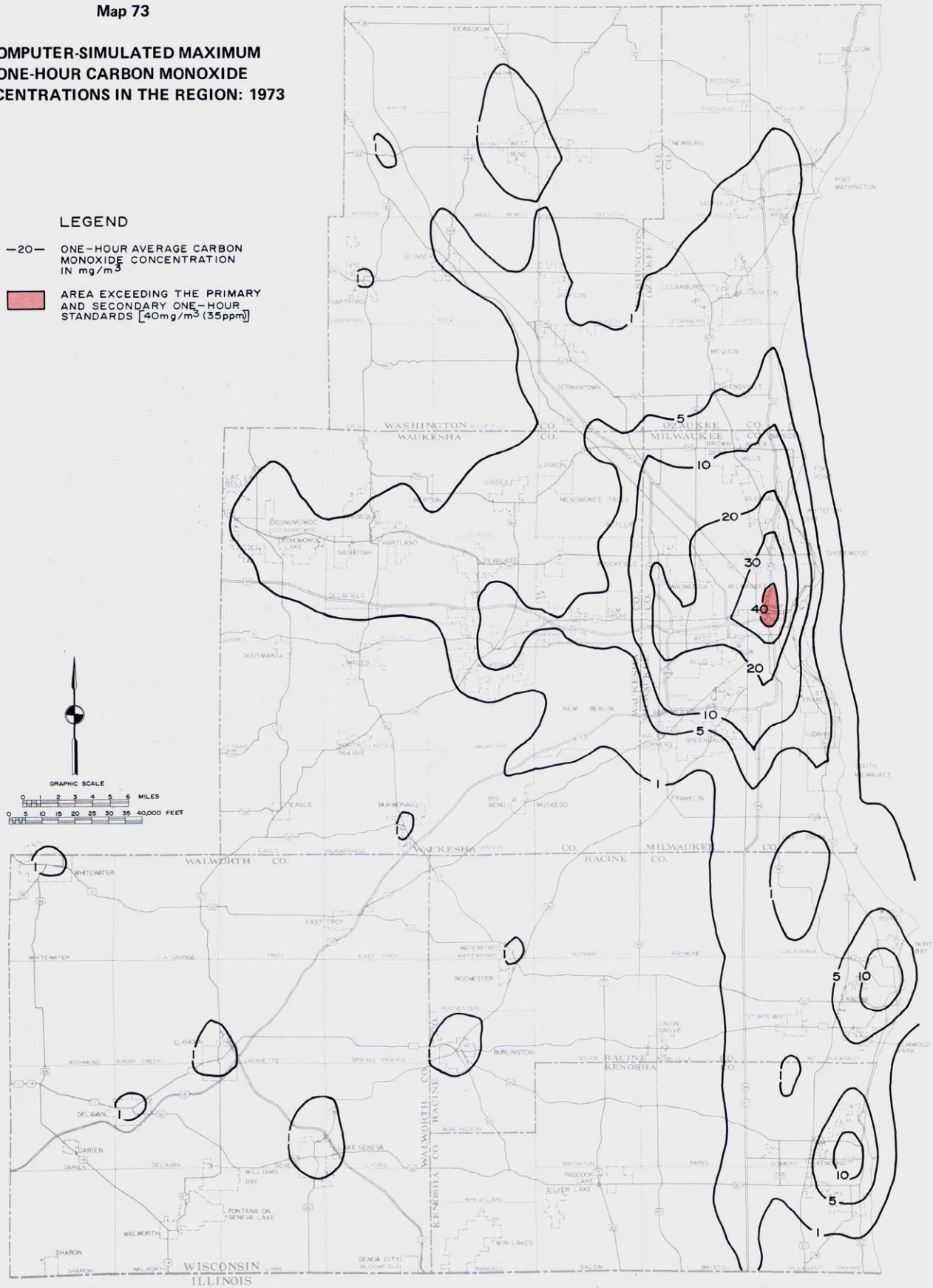


The isopleths of carbon monoxide concentrations shown on the above map represent the maximum eight-hour average of this pollutant which were estimated to have been experienced under the most adverse meteorological conditions during 1973. The eight-hour period for which the conditions are represented on this map is from 5:00 a.m. to 1:00 p.m. on a weekday, a period of heavy traffic flow, and the meteorological conditions are those of a light southerly wind (two meters per second or about four miles per hour). Under these conditions, the eight-hour ambient air quality standard for carbon monoxide may be expected to be exceeded in a nine-square-mile area in central Milwaukee County.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 73

COMPUTER-SIMULATED MAXIMUM ONE-HOUR CARBON MONOXIDE CONCENTRATIONS IN THE REGION: 1973

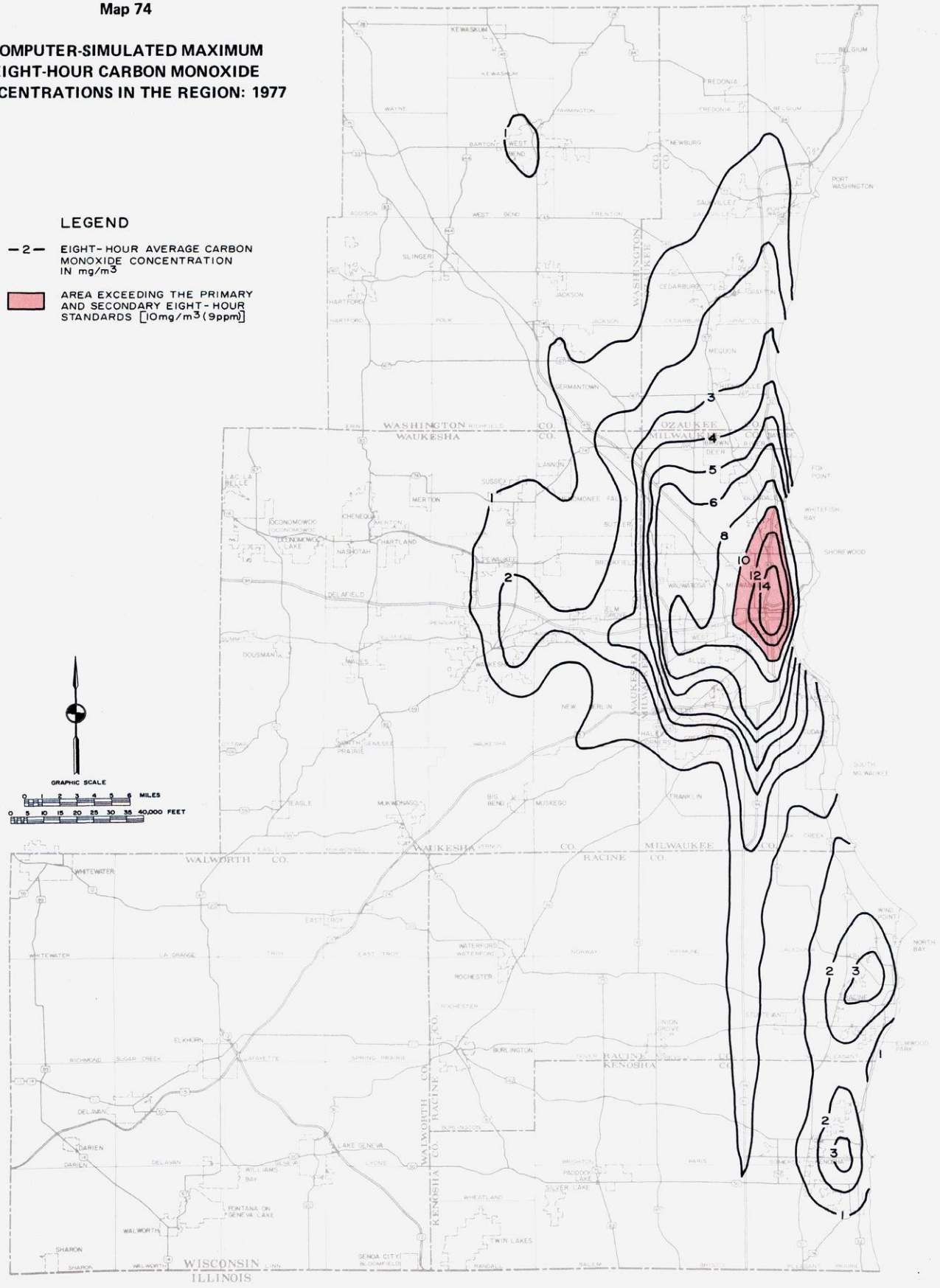


Maximum one-hour carbon monoxide concentrations in the Region may be expected to occur on a weekday between 7:00 a.m. and 8:00 a.m., when traffic volumes are heavy, and under the most adverse of meteorological conditions. Based on these "worst case" conditions, an area of approximately two square miles in and around the central business district of the City of Milwaukee may be expected to exceed the one-hour carbon monoxide air quality standard of 40 mg/m^3.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 74

COMPUTER-SIMULATED MAXIMUM EIGHT-HOUR CARBON MONOXIDE CONCENTRATIONS IN THE REGION: 1977

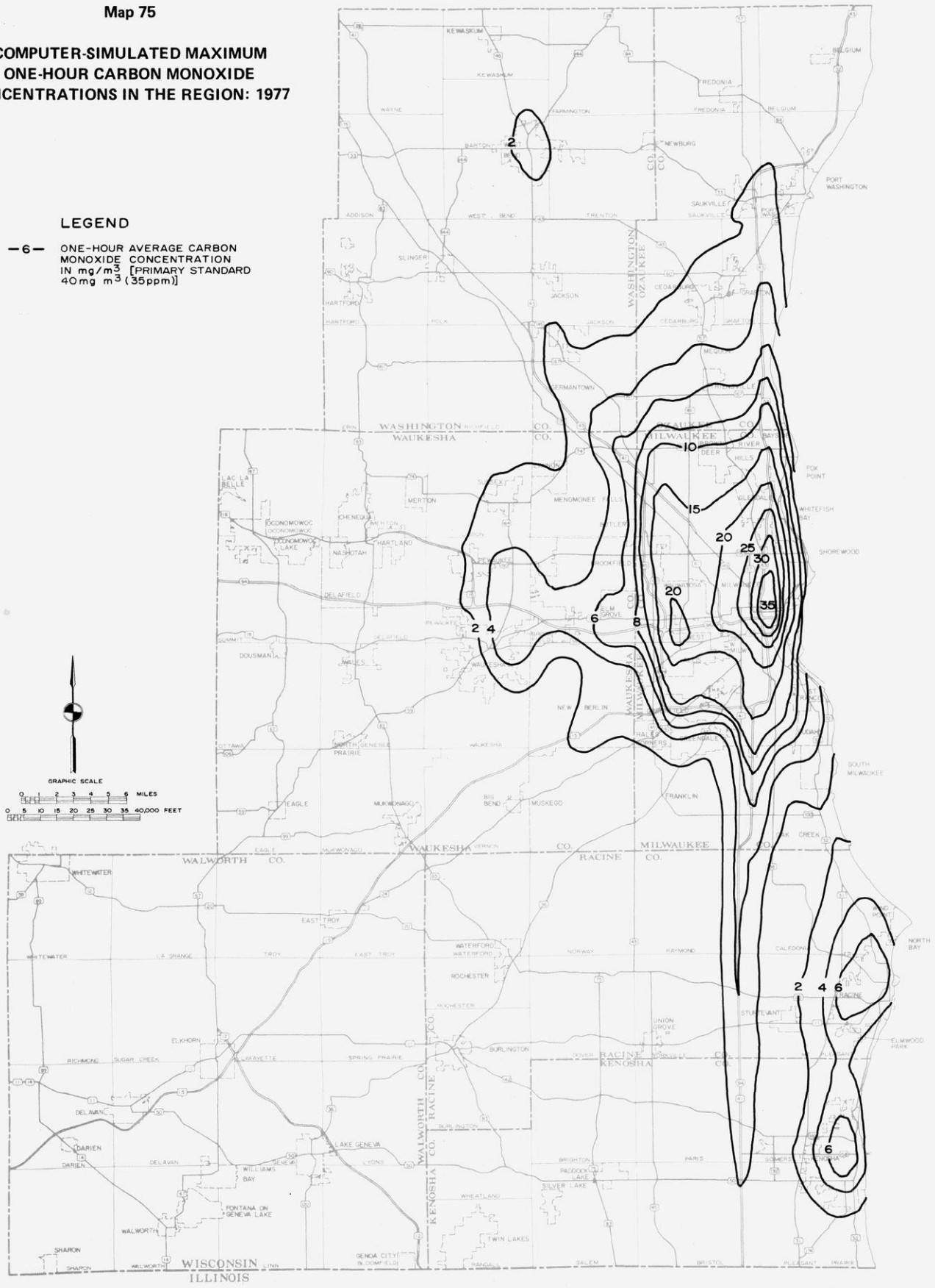


This map illustrates the composite impact of point, line, and area sources of emissions on eight-hour average carbon monoxide concentrations in the Region during 1977. This simulation modeling effort was conducted under emission conditions representative of a period of heavy traffic flow, from 5:00 a.m. to 1:00 p.m. on a weekday, and under meteorological conditions least favorable to pollutant dispersion. Under these "worst case" conditions, the eight-hour average carbon monoxide ambient air quality standard of 10 milligrams per cubic meter (mg/m^3) is estimated to have been exceeded over a 21-square-mile area in Milwaukee County during 1977. This area has an estimated resident population of 267,800 persons.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 75

COMPUTER-SIMULATED MAXIMUM ONE-HOUR CARBON MONOXIDE CONCENTRATIONS IN THE REGION: 1977



This map illustrates the composite impact of point, line, and area sources of emissions on one-hour average carbon monoxide concentrations in the Region during 1977. This simulation modeling effort was conducted under emission conditions representative of the peak morning travel hour, from 7:00 a.m. to 8:00 a.m., and under meteorological conditions least favorable to pollutant dispersion. Under these "worst case" conditions, the maximum carbon monoxide concentration isopleth has a value of 35 milligrams per cubic meter (mg/m^3), expressed as a one-hour arithmetic average, and is located in the area of the Marquette Interchange. Thus, the simulation modeling results, in agreement with available monitoring data, indicate that the one-hour average carbon monoxide ambient air quality standard of 40 mg/m^3 was not exceeded in the Region during 1977.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

NITROGEN DIOXIDE CONCENTRATIONS

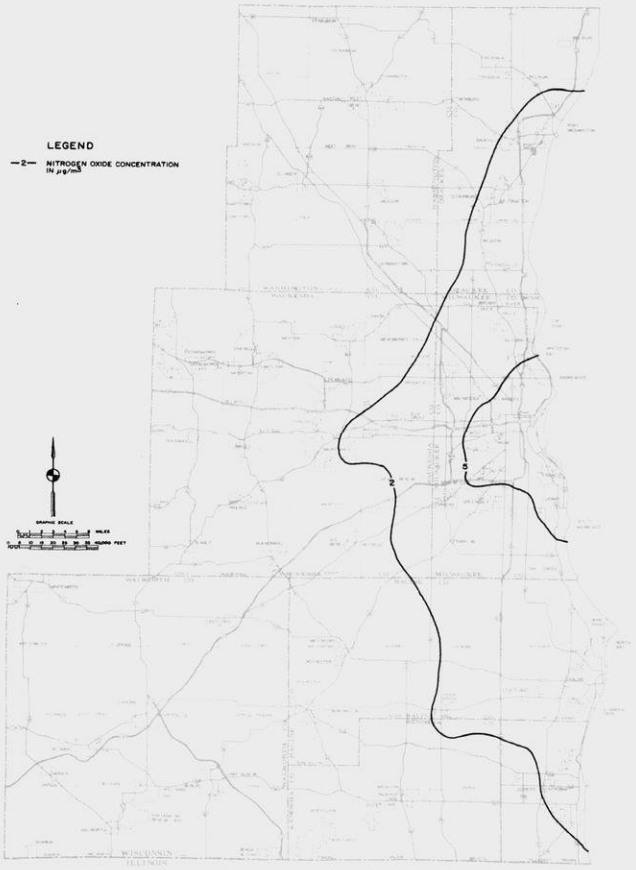
As was discussed in Chapter VI, prior to 1976 all federal and state nitrogen dioxide monitoring stations in the Region used the Jacobs-Hochheiser sampling method, which has subsequently been found to yield unreliable data. Since 1976, however, four monitoring sites—all in the City of Milwaukee—have produced reliable data on the ambient air levels of nitrogen dioxide in the Region using the approved Christie arsenite method. The results of this air quality monitoring effort have indicated that the maximum annual arithmetic average nitrogen dioxide concentration in the Region—70 micrograms per cubic meter ($\mu g/m^3$) measured at 711 W. Wells Street—is well below the ambient air quality standard of 100 $\mu g/m^3$ established for both the primary and secondary levels.

Annual average nitrogen dioxide concentrations are difficult to numerically simulate because nitrogen oxides are photochemically reactive. Nearly all emissions of this pollutant species are in the form of nitric oxides (NO) which are oxidized to nitrogen dioxide (NO_2) in the atmosphere. Not all of the nitric oxide emissions from local sources, however, are converted to nitrogen dioxide within the boundaries of the Region. The ratio of NO levels in the ambient air to NO_2 levels is an important parameter to monitor but, unfortunately, this information is not available for the Region. In the absence of such information, the air quality simulation effort is, of necessity, limited to modeling the dispersion of total nitrogen oxide emissions under the assumption that there are no ongoing chemical reactions taking place in the atmosphere. Although calibration and validation of the model are precluded by such an assumption, the modeling results are nevertheless useful in that they identify areas of maximum nitrogen oxide concentrations in the Region—which may be expected to correspond to areas of maximum nitrogen dioxide concentrations—and provide a base for the relative measure of the increase or decrease in nitrogen dioxide concentrations which may be anticipated attendant to future growth and change in the Region. For this reason, the uncalibrated findings and results of the air quality simulation modeling effort for annual average nitrogen oxide levels in the Region are presented herein.

The uncalibrated results obtained by the multiple point sources (MLTPT) submodel, assuming the meteorological conditions prevailing for 1977 as summarized in Table 247, indicate that annual average nitrogen oxide concentrations in the Region due to point source emissions, set forth in Table 200 in Chapter VII, will be distributed as shown on Map 76. The maximum isopleth on Map 76 has a value of 5 $\mu g/m^3$ which, even if it were assumed that the concentrations were all nitrogen dioxide, would only be 5 percent of the annual average standard of 100 $\mu g/m^3$. It may be concluded, therefore, that point sources do not appreciably contribute to nitrogen dioxide levels in the Region.

Map 76

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE NITROGEN OXIDE CONCENTRATIONS DUE TO EMISSIONS FROM POINT SOURCES IN THE REGION: 1977



This map illustrates the impact of nitrogen oxide emissions from point sources on ambient air quality in the Region during 1977. As may be seen on the map, the maximum nitrogen oxide isopleth has a value of 5 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and encompasses the central portion of Milwaukee County. It should be noted, however, that the simulation modeling effort for nitrogen oxides was conducted in the assumed absence of photochemical reactions. Such photochemical reactions affect the rate of conversion of nitric oxide to nitrogen dioxide, and influence the rate of ozone formation in the ambient air.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

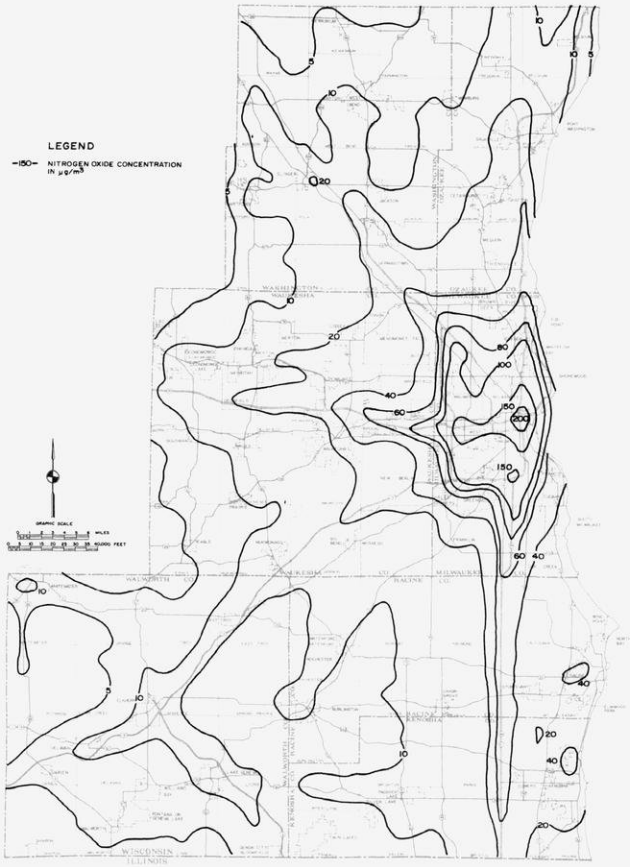
The URBAN submodel was used to estimate the annual average nitrogen oxide concentrations in the Region due to emissions from line and area sources in 1977. The line and area source emissions of nitrogen oxides during 1977 are presented in Tables 213 and 228 in Chapter VII, respectively, and the prevailing meteorological conditions for 1977 as used in the URBAN submodel are summarized in Table 248. The uncalibrated results of the simulation modeling effort for annual average nitrogen oxide concentrations in the Region due to line sources of emissions are presented on Map 77, and the concentrations attributable to area sources of emissions are presented on Map 78.

The maximum isopleth value shown on Map 77, is 200 $\mu g/m^3$, and is centered over the Marquette Interchange in Milwaukee County. This finding is consistent with previous observations that pollutant concentrations due to emissions from line sources are highest in the Region over this interchange. As with the other pollutant species, the nitrogen oxide concentrations shown on Map 77 generally decrease with distance from the Marquette Interchange in a pattern reflecting the configuration of the regional freeway system.

Map 78 indicates that the maximum annual average nitrogen oxide concentration in the Region due to area source emissions in 1977 was 100 $\mu g/m^3$ and was centered over the western edge of the heavily industrialized portion of the Menomonee River Valley. The correlation between urbanization and nitrogen oxide levels is readily apparent in areas outside Milwaukee County on Map 78, with isopleths ranging from about 5 $\mu g/m^3$ to 20 $\mu g/m^3$ over many of the major population centers. Also notable on Map 78 is the 60 $\mu g/m^3$ isopleth centered over General

Map 77

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE NITROGEN OXIDE CONCENTRATIONS DUE TO EMISSIONS FROM LINE SOURCES IN THE REGION: 1977

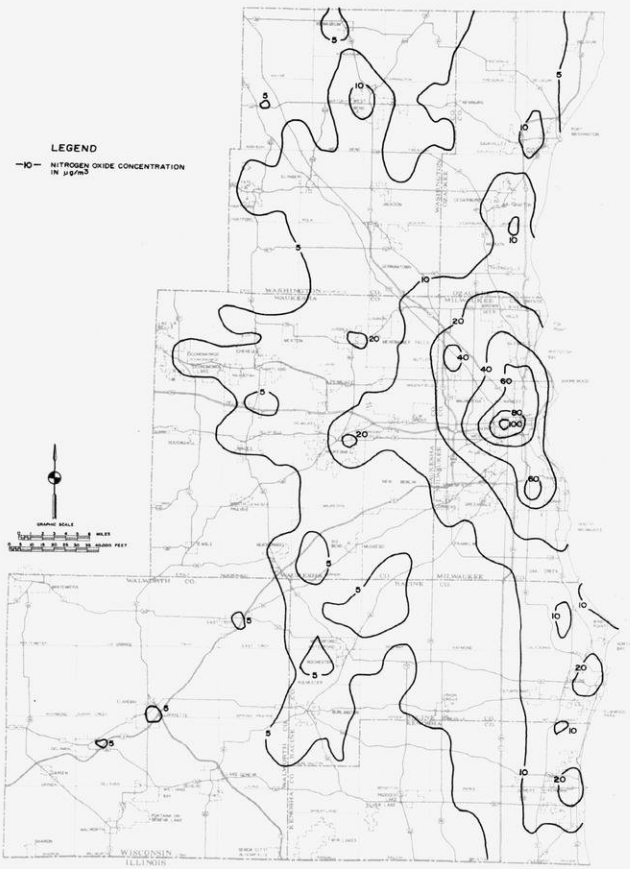


This map illustrates the impact of nitrogen oxide emissions from line sources on ambient air quality in the Region during 1977. As may be seen on this map, the maximum nitrogen oxide isopleth has a value of 200 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and is located in the area of the Marquette Interchange in Milwaukee County. The spatial distribution of the nitrogen oxide concentrations, which have been computer-simulated in the assumed absence of photochemical reactions, generally conforms to the pattern of the regional freeway system.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 78

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE NITROGEN OXIDE CONCENTRATIONS DUE TO EMISSIONS FROM AREA SOURCES IN THE REGION: 1977



This map illustrates the impact of nitrogen oxide emissions from area sources on ambient air quality in the Region during 1977. As may be seen on this map, the maximum nitrogen oxide isopleth has a value of 100 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and is located in central Milwaukee County. Nitrogen oxide emissions from area source categories result principally from the combustion of fossil fuels for residential, commercial-institutional, and small industrial space heating and water heating purposes.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Mitchell Field in Milwaukee County. This isopleth may be attributed principally to the operation of jet planes for commercial and military aviation purposes.

The total annual average nitrogen oxide concentrations in the Region during 1977 resulting from all point, area, and line sources of emissions are shown on Map 79. It should be noted that the nitrogen oxide concentrations indicated on Map 79 assume no chemical reactions in the atmosphere leading to the formation of nitrogen dioxide, nor is the transport of nitric oxide or nitrogen dioxide into the Region considered. It is evident, however, that only in Milwaukee County would annual average nitrogen dioxide levels be expected to exceed the 100 ug/m^3 standard. Since the monitoring data have indicated no such violations of the standard in Milwaukee County, not even near the area of the highest concentration of nitrogen oxides indicated by the WIS*ATMDIF model, it may be concluded that no area in southeastern Wisconsin presently exhibits nitrogen dioxide concentrations at levels detrimental to human health.

HYDROCARBON AND OZONE CONCENTRATIONS

The primary and secondary one-hour average ozone standard of 0.12 part per million (ppm) has consistently been exceeded at all monitoring sites in the Region since the first monitor became operational in 1973. Moreover, the limited hydrocarbon monitoring data available—13 days during 1975 in Milwaukee County and 58 days during 1976 in Kenosha County—indicate that the ambient air quality standard for this pollutant species of 160 $\mu g/m^3$, which is to be used as a guideline for achieving the ozone standard, may be exceeded by a factor of two to three in the Region. Since ozone and other photochemical oxidants are formed through chemical reactions in the atmosphere, the abatement of oxidant levels is best achieved through control of their precursor emissions, most notably hydrocarbons and, in particular, of that group of very reactive hydrocarbons referred to collectively as volatile organic compounds. The level of control on volatile organic compound emissions necessary to attain the ozone standard in the Region may be estimated through use of the Empirical Kinetics Modeling Approach (EKMA). The theoretical basis and operational characteristics of the EKMA, and its associated computer program—the Ozone Isopleth Plotting Package (OZIPP)—were described in Chapter X of this report. The OZIPP model input data requirements, and the results and findings of the city-specific version of the EKMA as applied to the Milwaukee urbanized area, are detailed in the following sections.

Determination of City-Specific Data Requirements

The principal function of the city-specific version of the EKMA is to estimate the reduction in volatile organic compound emissions required to reduce the observed maximum violation of the ozone standard downwind of the major urban center under consideration to the attainment level. The maximum one-hour average ozone concentration which violated the ambient air quality standard downwind of the Milwaukee urbanized area had a value of 0.232 ppm, and was measured on June 12, 1976, at the monitoring site located in the City of Grafton in Ozaukee County. It is this maximum violation which is considered in the EKMA modeling as the "design value."

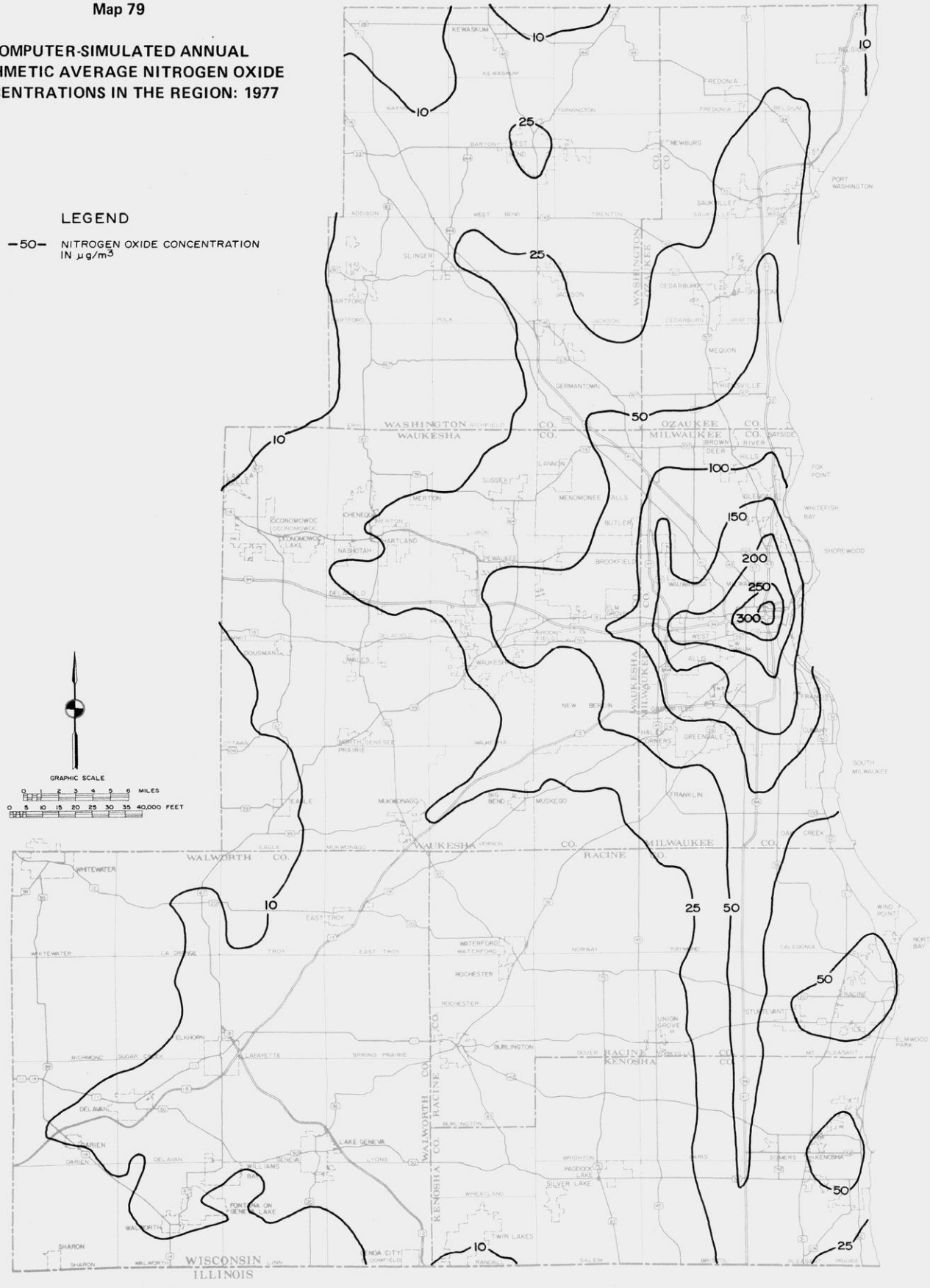
In addition to the design value, the OZIPP computer program also requires data on certain meteorological conditions—such as the amount of sunlight and the change in the mixing height with time, on local emission rates of nonmethane hydrocarbons and nitrogen oxides, and on the transport of nonmethane hydrocarbons, nitrogen oxides, and ozone, both at the surface and aloft. These data should be characteristic of the day on which the design value was measured. The data as used in the OZIPP program for the Milwaukee urbanized area are summarized in Table 257.

As may be seen in Table 257, the intensity of sunlight is calculated in the OZIPP program for the specific location of the Milwaukee urbanized area and for the exact time of year at which the design value was measured. Table 257 also indicates that the mixing height in the Region was assigned an initial value of 200 meters at 8:00 a.m. and a value of 1,000 meters at 3:00 p.m., corresponding to an average dilution rate of about 20 percent per hour. No change in the mixing height is assumed to occur prior to 8:00 a.m. or after 3:00 p.m.

The nonmethane hydrocarbon and nitrogen oxide emission rates as input into the OZIPP program are expressed as the fraction of new emissions encountered along the trajectory of the air column to the nonmethane hydrocarbon and nitrogen oxide emissions in the column prior to 8:00 a.m. As explained in Chapter X, the conceptual basis of the EKMA is a column of air which remains stationary over a central city area until 8:00 a.m., at which time the column moves according to the trajectory established by the prevailing winds. For the Milwaukee urbanized area, a column of air having a base area of nine square miles was selected for the determination of the pre-8:00 a.m. hydrocarbon and nitrogen oxide emissions. This nine-square-mile area encompassed the central business district of the City of Milwaukee and the Marquette Interchange, and was considered large enough to enable the exchange of pollutants into and out of the column to be treated as a negligible quantity. Map 80 shows the location of this nine-square-mile area in the City of Milwaukee as Box A. The total hydrocarbon and total nitrogen oxide emissions within this area were determined by summing the 1977 hourly line source emissions and the average hourly point and area source emissions as estimated in the 1977 inventory for the period from 12:00 midnight to 8:00 a.m. These emissions constitute the base emissions for estimating the relative emission rate. As the air column moves out of the central city area after 8:00 a.m., it follows the trajectory and speed of the prevailing wind and encounters new hydrocarbon and nitrogen oxide emissions between 8:00 a.m. and 9:00 a.m. In accordance with the hourly meteorological data observed at the National Weather Service Office at General Mitchell Field on June 12, 1976, by 9:00 a.m.

Map 79

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE NITROGEN OXIDE CONCENTRATIONS IN THE REGION: 1977



This map indicates the composite impact of point, line, and area sources of nitrogen oxide emissions on ambient air quality in the Region during 1977. The maximum nitrogen oxide isopleth has a value of 300 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and is located in and around the central business district of the City of Milwaukee. Although this simulation modeling effort was conducted in the assumed absence of photochemical reactions in the atmosphere leading to the conversion of nitric oxide to nitrogen dioxide and thus may not be related directly to the standard, available nitrogen dioxide monitoring data indicate that the air quality standard for this pollutant species was not exceeded in the Region during 1977.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Table 257

DATA INPUT FOR THE OZONE ISOPLETH PLOTTING PACKAGE

Data Group	Parameter	Units	Input Value
Intensity of Sunlight	Latitude	Decimal Degrees North of Equator	43.0
	Longitude	Decimal Degrees West of Greenwich Meridian	88.0
	Time Zone	Hours From Greenwich Mean Time	6.0
	Year	--	1976
	Month	--	6
	Day	--	12
Dilution Rate	Initial Inversion Height	Meters	200
	Final Inversion Height	Meters	1,000
	Starting Time of Inversion Rise	24-Hour Daylight Time	0800
	Ending Time of Inversion Rise	24-Hour Daylight Time	1500
Nonmethane Hydrocarbon and Nitrogen Oxide Emission Rates	Number of Hours for which Emission Factors Are to be Input	--	3
	Hydrocarbon Emission Fraction for Simulation Hour 1	--	0.041
	Hydrocarbon Emission Fraction for Hour 2	--	0.0051
	Hydrocarbon Emission Fraction for Hour 3	--	0.0031
	Nitrogen Oxide Emission Fraction for Simulation Hour 1	--	0.0125
	Nitrogen Oxide Emission Fraction for Hour 2	--	0.002
	Nitrogen Oxide Emission Fraction for Hour 3	--	0.002
Pollutant Reactivity	Initial Fraction of Carbon Atoms in the Form of Propylene	--	0.25
	Initial Nitrogen Dioxide/Nitrogen Oxide Ratio	--	0.25
	Fraction of Initial Nonmethane Hydrocarbons Added as Aldehyde	Parts per Million Carbon	0.05
Transport of Pollutants	Concentration of Ozone Transported in the Surface Layer	Parts per Million	0.069
	Concentration of Ozone Transported Aloft	Parts per Million	0.172
	Concentration of Nonmethane Hydrocarbons Transported in the Surface Layer	Parts per Million Carbon	0.58
	Concentration of Nonmethane Hydrocarbons Transported Aloft	Parts per Million Carbon	0.23
	Concentration of Nitrogen Oxide Transported in the Surface Layer	Parts per Million	0.025
	Concentration of Nitrogen Oxide Transported Aloft	Parts per Million	0.007
Plotting Accuracy	Number of Constant Nonmethane Hydrocarbons/Nitrogen Oxide Ratio Lines on which Simulations are to be Performed	--	11
	Number of Simulations per Ratio Line	--	5
Plotting Scale	Length of the Abscissa[a]	Inches	8.50
	Length of the Ordinate[b]	Inches	5.95
	Number of Ozone Isopleths to be Drawn	--	5

[a] *Width of the graph.*

[b] *Height of the graph.*

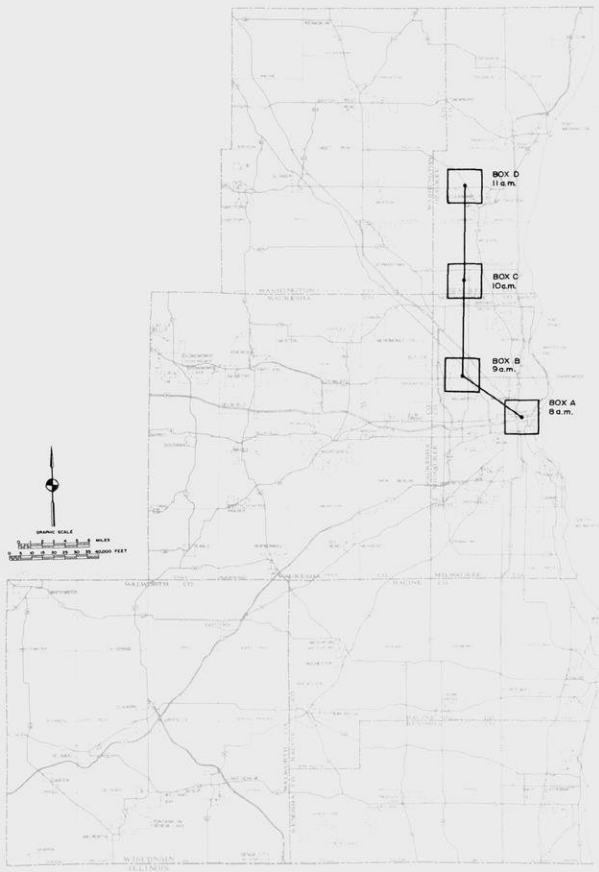
Source: U. S. Environmental Protection Agency and SEWRPC.

the column would have moved from downtown Milwaukee, Box A, to the area designated Box B on Map 80. By 10:00 a.m. the column would have moved to Box C at the border of Milwaukee and Ozaukee Counties, and by 11:00 a.m. the column would be situated just west of the City of Grafton. Only three hours of relative precursor emission rates are required, therefore, as input to the OZIPP program. These hydrocarbon and nitrogen oxide emission rates are expressed as the fraction of the hourly emissions in the area presently encompassed by the nine-square-mile box to the base emission totals, and are presented in Table 257 for each of the three simulation hours.

Local-specific data concerning the constituents of the hydrocarbon mix and the prevailing nitrogen dioxide to total nitrogen oxides ratio are virtually nonexistent for this Region. Thus, the default conditions specified in the OZIPP program for the fraction of carbon atoms in the form of propylene, the nitrogen dioxide to total

Map 80

POSTULATED TRAJECTORY OF THE EKMA AIR COLUMN ON JUNE 12, 1976



This map represents a generalized depiction of the trajectory that a column of air with a nine-square-mile base area may have followed on June 12, 1976, from the central business district in the City of Milwaukee at 8:00 a.m., Box A, to Ozaukee County at 11:00 a.m., Box D. This trajectory has been postulated based upon wind field data obtained from the National Weather Service Office at General Mitchell Field in Milwaukee County. As this column of air, with an initial concentration of ozone and precursor compounds, moves out of the central business district of the City of Milwaukee, new emissions are added, and ozone and other oxidant products are formed upwind of the major urban area.

Source: SEWRPC.

nitrogen oxides ratio, and the fraction of nonmethane hydrocarbons added as aldehyde were used in the simulation effort for southeastern Wisconsin.

From available ozone monitoring data gathered routinely by the Wisconsin Department of Natural Resources (DNR) in Kenosha County and from a special monitoring study conducted by Washington State University for the Wisconsin Public Service Commission at the Kenosha Airport for the purpose of estimating the air quality impact of the Pleasant Prairie Power Plant, it is possible to make certain generalizations concerning the quantity of ozone, nonmethane hydrocarbons, and nitrogen oxides transported into the Region both at the surface and aloft. As a rule, the transport of ozone and its precursor emissions at the surface may be approximated by the average concentrations measured upwind of the major urban area between 6:00 a.m. and 9:00 a.m. Also, as a result of experiments sponsored by the U. S. Environmental Protection Agency (EPA), it has been determined that average ozone and precursor concentrations monitored between 11:00 a.m. and 1:00 p.m. upwind of a major urban area are indicative of transport aloft. The surface transport value for ozone at ground level, as indicated in Table 257, was determined to be 0.069 ppm by averaging the 6:00 a.m. to 9:00 a.m. hourly ozone levels measured in Kenosha County on June 12, 1976. The transport value for ozone aloft, 0.172 ppm, was determined by averaging the hourly ozone values measured between 11:00 a.m. and 1:00 p.m. at the Kenosha monitoring site on the same day. Although comparable monitoring data are not available for nonmethane hydrocarbons and nitrogen oxides on June 12, 1976, these pollutant species were monitored by Washington State University under contract to the DNR between August 4 and September 30, 1976. Because of the similarity in prevailing meteorological conditions on June 12, 1976, and August 10, 1976, it was determined that the nonmethane hydrocarbon and nitrogen oxide monitoring results for this later date could be used to represent the transport of these oxidant precursor compounds at ground level and aloft. The surface transport value for nonmethane hydrocarbons was thus estimated to be 0.58 part per million of carbon (ppmC), and for nitrogen oxides, 0.025 ppm, based on the average values monitored between 6:00 a.m. and 9:00 a.m. on August 10, 1976. Based on the average values monitored between 11:00 a.m. and 1:00 p.m. on the same day, the transport value for nonmethane hydrocarbons aloft was estimated to be 0.23 ppmC, and for nitrogen oxides aloft, 0.007 ppm.

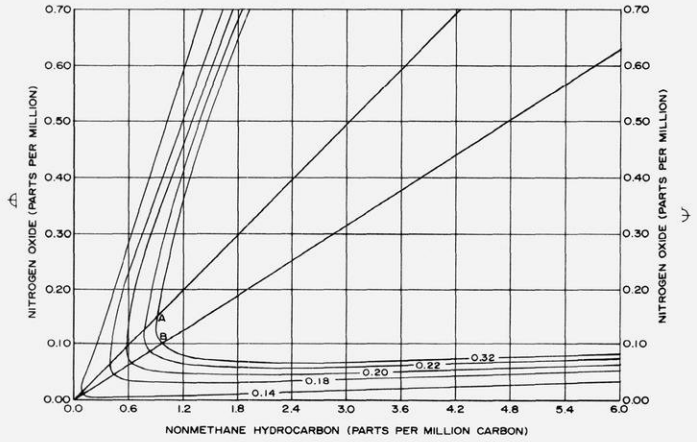
Results and Findings of the EKMA Simulation

Based on the prevailing meteorological conditions, relative emission rates, and estimated transport of ozone and its precursor emissions at ground level and aloft, the OZIPP computer model generated the ozone isopleth diagram shown in Figure 84. Figure 84 depicts the maximum afternoon ozone value that may occur under two assumptions concerning nonmethane hydrocarbon to nitrogen oxide ratios, assumptions which significantly affect the levels of emissions control required to attain and maintain the ozone ambient air quality standard. Since neither nonmethane hydrocarbons nor total nitrogen oxides have been monitored in the Region on a regular basis, a range of feasible ratios had to be assumed for this modeling effort. A study conducted by the EPA of 14 urban and suburban cities throughout the United States found that the ratio of nonmethane hydrocarbons to nitrogen oxides ($NMHC/NO_X$) varied between 6.0:1.0 and 16.0:1.0. The EPA also determined that the best estimate for this ratio was 9.5 ppmC of nonmethane hydrocarbons to 1.0 ppm of nitrogen oxides. Because of the uncertainties concerning the actual $NMHC/NO_X$ ratio occurring in southeastern Wisconsin, and because of the important implications that this value has in determining the level of control required on local emission sources, it was determined to use the range of $NMHC/NO_X$ ratios

from 6.0:1.0 to 9.5:1.0 as representative of this Region. Accordingly, a line corresponding to the 6.0:1.0 NMHC/NO_X ratio, and a second line corresponding to the 9.5:1.0 NMHC/NO_X ratio, were overlayed on Figure 84. The point at which the 6.0:1.0 NMHC/NO_X ratio line intersects the ozone isopleth having the value of 0.232 ppm, or the design value—labeled Point A in Figure 84—and the intersection of the 9.5:1.0 ratio line with the 0.232 ppm isopleth—labeled Point B in Figure 84—represent the range of base values from which nonmethane hydrocarbons are assumed to have to be reduced in order to attain and maintain the ozone standard.

Figure 84

OZONE ISOPLETH DIAGRAM REPRESENTATIVE OF EXISTING PRECURSOR COMPOUND RATIOS AND MAXIMUM AFTERNOON OZONE LEVELS IN THE REGION



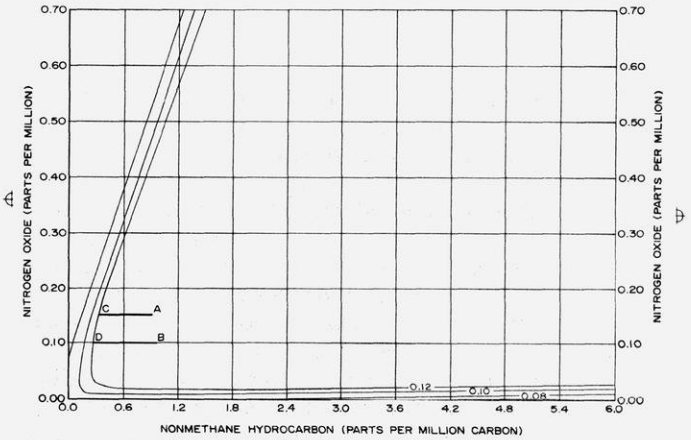
Source: U. S. Environmental Protection Agency and SEWRPC.

Since the abatement of excessive ozone levels in southeastern Wisconsin requires controls on volatile organic compound emissions, not only from local sources but from extraregional sources upwind, the degree to which local controls are necessary must be determined under the assumption that the ozone levels in the Region will not exceed the standard of 0.12 ppm due to the long-range transport of ozone or its precursor compounds. Under this assumption, the OZIPP model yields the ozone isopleths shown in Figure 85. Point A in Figure 85 represents the location at which the nonmethane hydrocarbon to nitrogen oxide ratio line of 6.0 to 1.0 intersects the ozone isopleth having the design value of 0.232 ppm, as shown in Figure 84. This point corresponds to a nonmethane hydrocarbon value of 0.88 ppmC, as indicated on the horizontal axis. In order to attain and maintain the ozone standard of 0.12 ppm under the assumption of a 6.0:1.0 NMHC/NO_X ratio, the nonmethane hydrocarbon level must be reduced from 0.88 ppmC to 0.33 ppmC (Point C in Figure 85), which represents a reduction of approximately 62 percent in the local volatile organic compound emissions contributing to the ozone problem in summer. The reduction in the level of nonmethane hydrocarbons required under the assumption of a 9.5:1.0 NMHC/NO_X ratio may be determined from line BD in Figure 85. Point B in Figure 85 represents the point at which the NMHC/NO_X ratio line of 9.5:1.0 intersects the ozone isopleth having the design value of 0.232 ppm, as shown in Figure 84. This point corresponds to a nonmethane hydrocarbon value of 0.95 ppmC. In order to attain and maintain the ozone standard under this assumption for the NMHC/NO_X ratio, the nonmethane hydrocarbon level must be reduced from 0.95 ppmC to 0.25 ppmC (Point D in Figure 85) which represents a reduction of approximately 74 percent in the local volatile organic compound emissions contributing to the ozone problem in summer.

Based on the preceding analysis, it may be concluded that if the ozone ambient air quality standard is to be attained and maintained in the Region, volatile organic compound emissions from local sources must be reduced by 62 percent at a minimum, to 74 percent optimally. As indicated in Table 230 in Chapter VII, an estimated 118,300 tons of volatile organic compound emissions were released by stationary and mobile sources in the seven-county Southeastern Wisconsin Region during 1977. Not all of these emissions, however, contributed to the high ozone concentrations observed during the summer season. In particular, certain miscellaneous volatile organic compound emission sources which are characteristically located in rural areas or which have a predominant use during the winter season have little or no effect on ozone formation within and downwind of major urban areas. Accordingly, the volatile organic compound emissions from agricultural equipment, snowmobiles, power boats, off-highway motorcycles, and miscellaneous solvent use—sources which jointly accounted for about 16,200 tons of volatile organic emissions during 1977—were not considered in the analysis of the results of the EKMA modeling effort. Thus, the EKMA modeling results indicate that a 62 to 74 percent reduction in the approxi-

Figure 85

OZONE ISOPLETH DIAGRAM REPRESENTATIVE OF THE REDUCTION IN NONMETHANE HYDROCARBONS NECESSARY TO ATTAIN THE PHOTOCHEMICAL OXIDANT STANDARD IN THE REGION UNDER FUTURE CONDITIONS



Source: U. S. Environmental Protection Agency and SEWRPC.

mately 102,100 tons of volatile organic compound emissions released in the Region during 1977 is required to attain and maintain the ozone ambient air quality standard. It may be concluded, therefore, that volatile organic compound emissions in the Region must be reduced to a maximum annual rate of 38,800 tons from all sources—which corresponds to a 62 percent reduction—or, more desirably, to a maximum annual rate of 26,600 tons—which corresponds to a 74 percent reduction.

Although the EKMA modeling effort indicated the general level of control required on sources of volatile organic compound emissions to achieve the ambient air quality standards, it did not provide any information on the spatial distribution of excessive precursor compound concentrations. In order to identify areas in the Region which require the greatest control of volatile organic compound emissions, the total point, area, and line source hydrocarbon emissions inventory for the Region during 1977 was simulated using the WIS*ATMDIF model under the "worst case" meteorological conditions for the three-hour period 6:00 a.m. to 9:00 a.m.—corresponding to the averaging period of the established standard. It should be noted that this simulation modeling effort was conducted in the assumed absence of photochemical reactions, and was intended only to identify areas with relatively high hydrocarbon concentrations in the ambient air. The results of this simulation modeling effort are shown on Map 81. As may be seen on Map 81, the guideline hydrocarbon standard of 160 $\mu g/m^3$ is exceeded on a three-hour average over an approximate 90-square-mile area in Milwaukee County. The maximum isopleth shown on Map 81 has a value of 500 micrograms per cubic meter ($\mu g/m^3$), indicating that the guideline ambient air quality standard for hydrocarbons may be exceeded in portions of the Region by more than a factor of three. The total hydrocarbon concentrations shown on this map may be attributable principally to line sources, since the inventory findings have indicated that automobiles and trucks contribute approximately 90 percent of the hydrocarbon emissions between 6:00 a.m. and 9:00 a.m.

From the available monitoring data, it may be concluded that persons residing in Kenosha, Milwaukee, Ozaukee, Racine, and Waukesha Counties have been and continue to be exposed to ozone concentrations detrimental to human health. Ozone concentrations have not been monitored in either Washington or Walworth Counties. Nevertheless, based on the fact that ozone levels in excess of the ambient air quality standard have been measured at all monitoring sites throughout the State of Wisconsin, it may be inferred that residents of these two counties in southeastern Wisconsin are also being exposed to ozone concentrations detrimental to human health.

NONATTAINMENT AREAS IN SOUTHEASTERN WISCONSIN

The air quality simulation modeling results as presented in this chapter have indicated that an air pollution problem exists in the Region with respect to particulate matter concentrations, carbon monoxide concentrations, and hydrocarbon/ozone concentrations. The results of this simulation modeling effort have been supported in all cases by available ambient air quality monitoring data. Based on the results of both the monitoring and modeling effort, and in compliance with requirements set forth in the Clean Air Act Amendments of 1977, the Wisconsin Department of Natural Resources has proposed that all or portions of certain counties in the Southeastern Wisconsin Region be designated as nonattainment areas—that is, as areas having ambient air quality worse than the prescribed standards—for one or more pollutant species. Pollutants for which nonattainment areas have been designated in the Region include particulate matter, carbon monoxide, and ozone.

Both the simulation modeling effort and the air quality monitoring data indicated that the ambient air quality standards for sulfur dioxide were not exceeded in the Region during 1976. Violations of the 24-hour average sulfur dioxide ambient air quality standards, however, were monitored in parts of Milwaukee County during 1977 and 1978. On the basis of this monitoring data, the Wisconsin Department of Natural Resources has proposed that a portion of Milwaukee County be designated as a nonattainment area for sulfur dioxide.

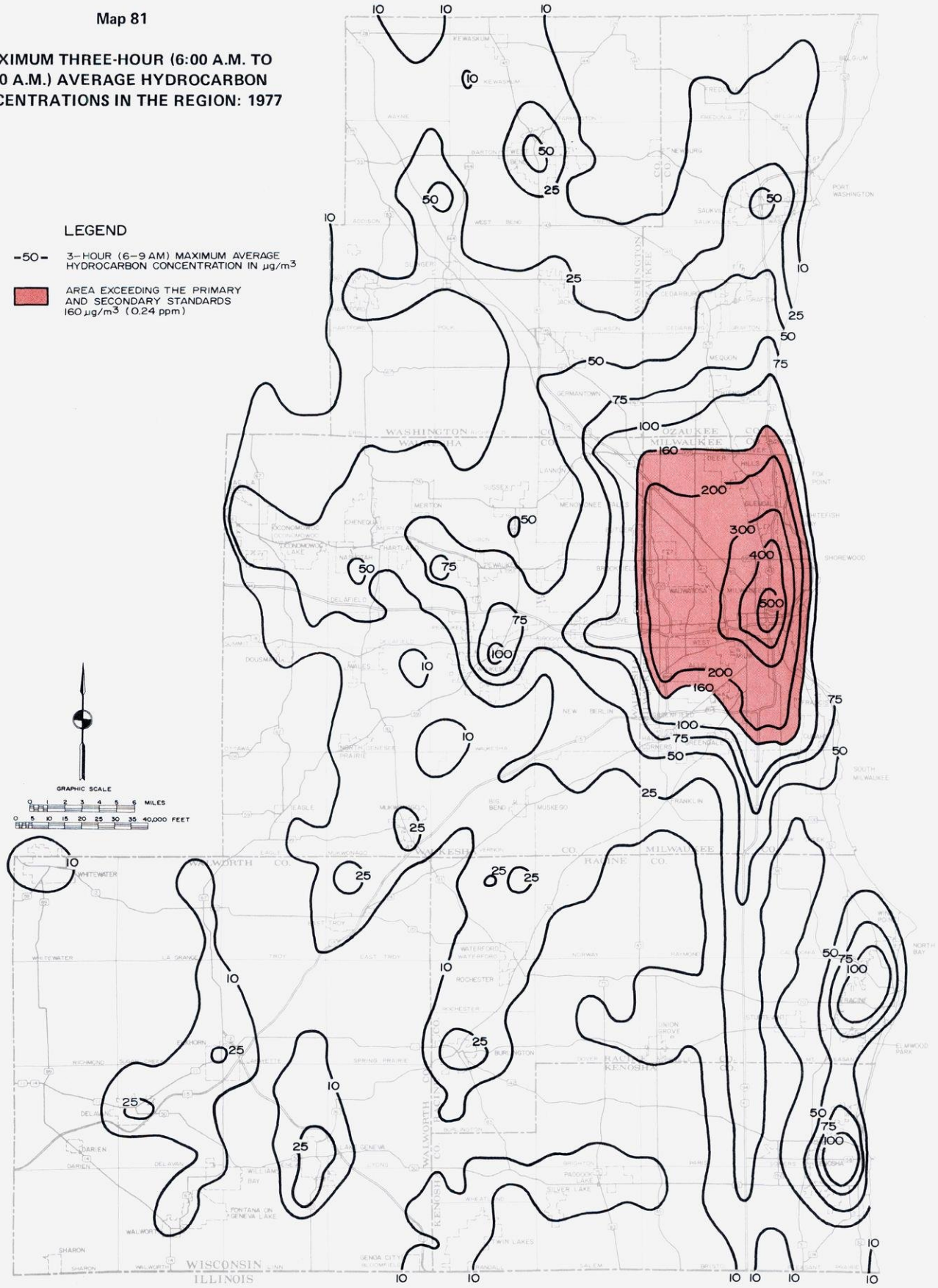
Nonattainment areas are designated by street boundaries and thus appear to follow a regular pattern, unlike the modeling results which are not constrained by such boundaries. Street boundaries are used in nonattainment area designations solely to facilitate identification of the problem areas and thereby eliminate any uncertainties concerning the boundaries of the geographic area within which enforcement of more stringent emission control regulations is required.

It should be noted that the nonattainment areas as presently designated or proposed for the Southeastern Wisconsin Region have been incorporated into the regional air quality attainment and maintenance planning program since such designations are required by federal regulations. There is, however, considerable disagreement in both the governmental and private sectors as to which areas should be designated as nonattainment areas. Such disagreement may ultimately lead to the elimination or redesignation of the existing nonattainment areas in the Region. Moreover, the boundaries of the nonattainment areas in the Region as presently defined may change in the future—either expanding because of additional monitoring or modeling information indicating a more geographically widespread problem, or contracting if attainment of the established standards is achieved through the implementation of air pollution control measures. The nonattainment areas in southeastern Wisconsin as presently (March 1980) defined or proposed are described herein.

Nonattainment areas for particulate matter may be categorized as either primary areas—that is, areas wherein the health-related standards are not being met—or secondary areas—that is, areas wherein the welfare-related standards are not being met. The primary and secondary particulate

Map 81

MAXIMUM THREE-HOUR (6:00 A.M. TO 9:00 A.M.) AVERAGE HYDROCARBON CONCENTRATIONS IN THE REGION: 1977



This map represents a generalized depiction of the maximum three-hour average, 6:00 a.m. to 9:00 a.m., hydrocarbon concentrations in the ambient air over the Region during 1977 in the assumed absence of photochemical reactions. Under this assumption, the three-hour average hydrocarbon ambient air quality standard of 160 micrograms per cubic meter ($\mu g/m^3$) is indicated to have been exceeded over a 90-square-mile area in Milwaukee County. Since hydrocarbons have no known adverse effects on human health in themselves, the hydrocarbon ambient air quality standard has been promulgated only as a surrogate measure for ozone. It has been observed that the ozone standard is generally violated during afternoon hours within and downwind of areas exhibiting high hydrocarbon concentrations in the early morning hours.

Source: SEWRPC.

matter nonattainment areas in southeastern Wisconsin as designated by the U. S. Environmental Protection Agency on October 5, 1978, are shown on Map 82. As may be seen on this map, there are two primary particulate matter nonattainment areas in the Region: one in and around the heavily industrialized portion of the Menomonee River Valley in the City of Milwaukee and one in the northeast portion of the City of Waukesha. In total, these two primary nonattainment areas comprise about three square miles, or about one-tenth of 1 percent of the total area of the Region. In addition, there are five secondary particulate matter nonattainment areas in the Region: one each surrounding the primary nonattainment areas in the Cities of Milwaukee and Waukesha, one centered in and around General Mitchell Field in Milwaukee County, and one each in the Cities of Kenosha and Racine. These five secondary particulate matter nonattainment areas comprise a total of about 38 square miles, or about 1.4 percent of the total area of the Region. About 20,200 persons reside in the primary particulate matter nonattainment areas in the Region, and an additional 335,300 persons reside in the secondary nonattainment areas.

Since both the primary and secondary ambient air quality standards for carbon monoxide have been established at the same level, all carbon monoxide nonattainment areas may be considered to be primary. As shown on Map 83, the carbon monoxide nonattainment area in the Region as designated by the U. S. Environmental Protection Agency on March 3, 1978, lies entirely within Milwaukee County and encompasses portions of the municipalities of Glendale, Greenfield, Milwaukee, Wauwatosa, West Allis, West Milwaukee, and Whitefish Bay. In total, approximately 85 square miles, or about 3 percent of the total area of the Region, have been designated as a nonattainment area. An estimated 730,600 persons reside in this nonattainment area.

As with carbon monoxide, the primary and secondary ozone ambient air quality standards have been established at the same level, and, therefore, all nonattainment areas for this pollutant species may be considered to be primary. In the Southeastern Wisconsin Region all of the area within the Counties of Kenosha, Milwaukee, Ozaukee, Racine, and Waukesha, as indicated on Map 84, was designated as a nonattainment area for ozone by the U. S. Environmental Protection Agency on March 3, 1978. In total, therefore, approximately 1,675 square miles, or more than 62 percent of the total area of the Region, lie within the designated ozone nonattainment area. Approximately 1,629,000 persons, or about 92 percent of the total regional population, reside within the five counties designated as a nonattainment area for ozone. Walworth and Washington Counties are presently designated as "unclassifiable" since ambient air quality monitoring for ozone has not been conducted to date in these two counties.

As noted earlier, available ambient air quality monitoring data have indicated that parts of Milwaukee County experienced violations of the 24-hour average ambient air quality standard for sulfur dioxide during 1977 and 1978. Based upon this monitoring data, the Wisconsin Department of Natural Resources has proposed that a 7.4-square-mile area in Milwaukee County, as shown on Map 85, be designated as a nonattainment area for sulfur dioxide. An estimated 62,500 persons reside within this proposed nonattainment area. To date, however, the U. S. Environmental Protection Agency has not formally designated this proposed sulfur dioxide nonattainment area.

The annual average ambient air quality standard for nitrogen dioxide has not been exceeded in the Region since monitoring for this pollutant species began in 1975. Accordingly, there are no proposed or designated nonattainment areas for this pollutant species in the Region.

SUMMARY

This chapter has presented the results and findings of the air quality simulation modeling effort as used as an adjunct to, and extension of, the available air quality monitoring data in defining the magnitude and areal extent of ambient air quality problems in southeastern Wisconsin. Two separate air quality simulation models were used for this purpose. The Wisconsin Atmospheric Diffusion Model (WIS*ATMDIF)—composed of the multiple point sources (MLTPT) submodel for simulating long-term concentrations due to point source emissions, the URBAN submodel for simulating long-term concentrations due to line and area source emissions, and a time-dependent version of the URBAN submodel, the URBANT submodel, for simulating short-term concentrations due to point, area, and line sources of emissions simultaneously—was used to numerically replicate the dispersion of chemically inert pollutant species through the atmosphere. The Empirical Kinetics Modeling Approach (EKMA) with its associated computer program—the Ozone Isopleth Plotting Package (OZIPP)—was used to determine the reduction in local volatile organic compound emissions necessary to achieve the ozone ambient air quality standard in the Region. The Wisconsin Atmospheric Diffusion Model was also used to simulate the dispersion of photochemically reactive pollutants—hydrocarbons and nitrogen oxides—in the assumed absence of such reactions, in order to help identify those areas within the Region which have the potential to experience pollutant concentrations in excess of the established standards.

Particulate matter concentrations in the Region must be evaluated against established ambient air quality standards for both long-term and short-term averaging periods. On an annual average, the primary, or health-related, particulate matter standard has been set at 75 micrograms per cubic meter ($\mu g/m^3$), and the secondary, or welfare-related, standard has been set at 60 $\mu g/m^3$. For the 24-hour average, the primary particulate matter standard has been promulgated at 260 $\mu g/m^3$, and the secondary standard at 150 $\mu g/m^3$, neither of which may be exceeded more than once per year. Air quality monitoring data available in the Region for the years 1973 through 1977 have indicated repeated violations of the primary and secondary particulate matter

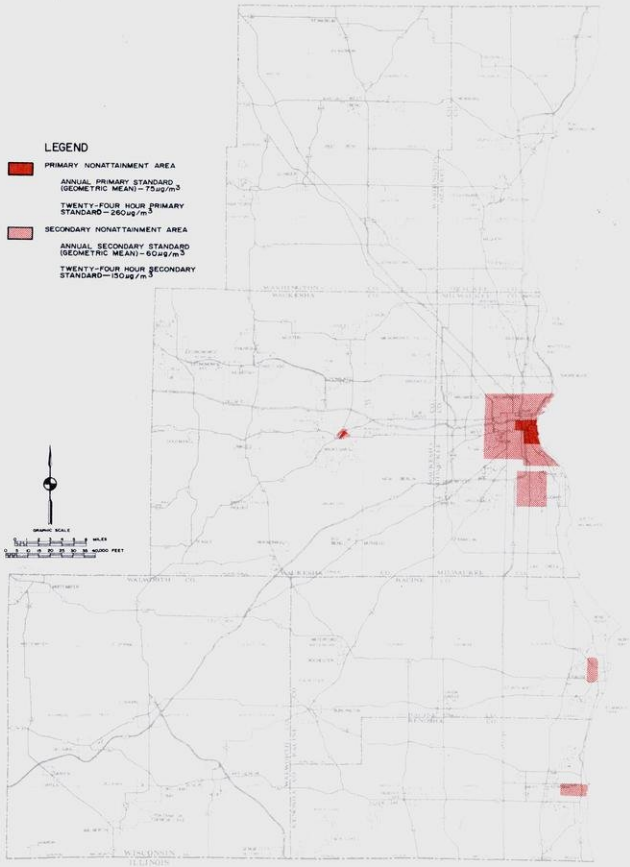
ambient air quality standards for both the annual and 24-hour averaging periods. Based on the successful calibration and validation of the WIS*ATMDIF model for annual particulate matter levels in the Region during 1973, it is estimated that the primary standard of 75 $\mu g/m^3$ was exceeded over an area of 24 square miles in Milwaukee County. Moreover, the secondary annual average standard of 60 $\mu g/m^3$ is estimated to have been exceeded over an additional 50 square miles in Milwaukee County during 1973.

The WIS*ATMDIF model was successfully recalibrated and validated for use in the Region using the 1977 point, area, and line source particulate matter emission inventories and prevailing meteorological conditions. The recalibration effort was undertaken because more extensive monitoring data had become available for the City of Waukesha, and because an industrial fugitive dust emissions inventory had been conducted by the Wisconsin Department of Natural Resources in 1977 which substantially increased the quantity of identifiable sources of particulate matter emissions in the Region. Based on this modeling effort, it is estimated that the primary annual average particulate matter ambient air quality standard of 75 $\mu g/m^3$ was exceeded in 1977 over a 5-square-mile area in Milwaukee County and a 12-square-mile area in Waukesha County. It is further estimated that the secondary annual average particulate matter ambient air quality standard was exceeded in 1977 over a 24-square-mile area in Milwaukee County, a 23-square-mile area in Waukesha County, and a 0.1-square-mile area in Racine County. An estimated 54,800 persons resided in that portion of Milwaukee County which exceeded the primary annual particulate matter standard in 1977, and an additional 208,800 persons resided in that portion of the County which exceeded the secondary annual average standard. In Waukesha County an estimated 10,800 persons resided in the areas exceeding the primary annual standard, and an additional 20,000 persons resided in the areas exceeding the secondary annual standard. Seventy persons resided in the Racine area exceeding the secondary annual standard. Therefore, in 1977 approximately 65,600 persons resided in those areas of the Region which exceeded the primary annual standard for particulate matter, and about 228,800 persons resided in those areas of the Region which exceeded the secondary annual standard.

For several reasons, the WIS*ATMDIF model cannot be calibrated and validated for the analysis of 24-hour average particulate matter levels in the Region. First, meteorological parameters demonstrate much greater temporal and spatial variation over a short-term averaging period than on an annual basis. Second, unlike total pollutant emissions from a source, the day-to-day or hour-to-hour emissions can fluctuate considerably depending on numerous and diverse factors which influence or govern the process rate or facility use of a particular source. And third, the hourly or daily background levels of pollutant concentrations are dependent on several variable factors—for example, changes in the rate of chemical reactions in the atmosphere. Within these constraints, however, the short-term modeling effort for 24-hour average particulate matter concentrations in the Region may serve to identify those areas in which there is the potential for the primary and secondary air quality standards to be exceeded.

Map 82

DESIGNATED PRIMARY AND SECONDARY PARTICULATE MATTER NONATTAINMENT AREAS IN THE REGION

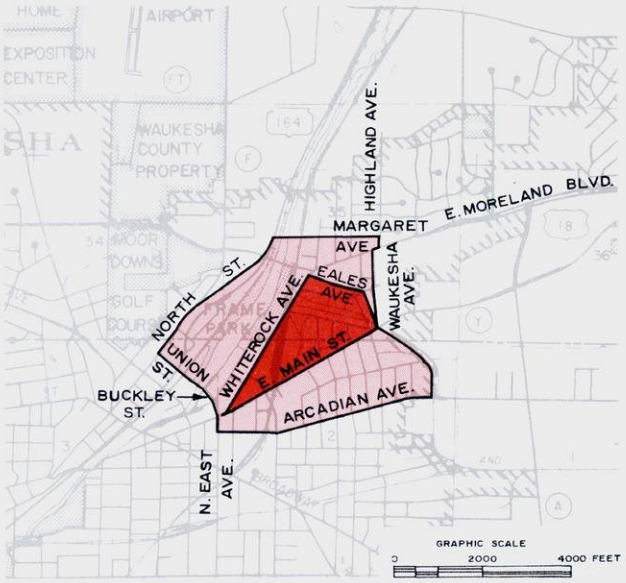


This map indicates the location of the primary and secondary particulate matter nonattainment areas in the Region as designated by the Wisconsin Department of Natural Resources in 1978. As may be seen on this map, there are two primary particulate matter nonattainment areas in the Region: one over a three-square-mile area in and around the heavily industrialized portion of the Menomonee River Valley in the City of Milwaukee comprising an estimated resident population of 16,500 persons, and one over a less than one-square-mile area in the northeast portion of the City of Waukesha comprising an estimated resident population of 3,700 persons. In addition, there are five secondary particulate matter nonattainment areas in the Region: one each surrounding the primary nonattainment areas in the Cities of Milwaukee and Waukesha, one in and around General Mitchell Field in Milwaukee County, and one each in the Cities of Kenosha and Racine. In total, these secondary particulate matter nonattainment areas encompass an area of approximately 38.4 square miles and an estimated resident population of 335,300 persons.

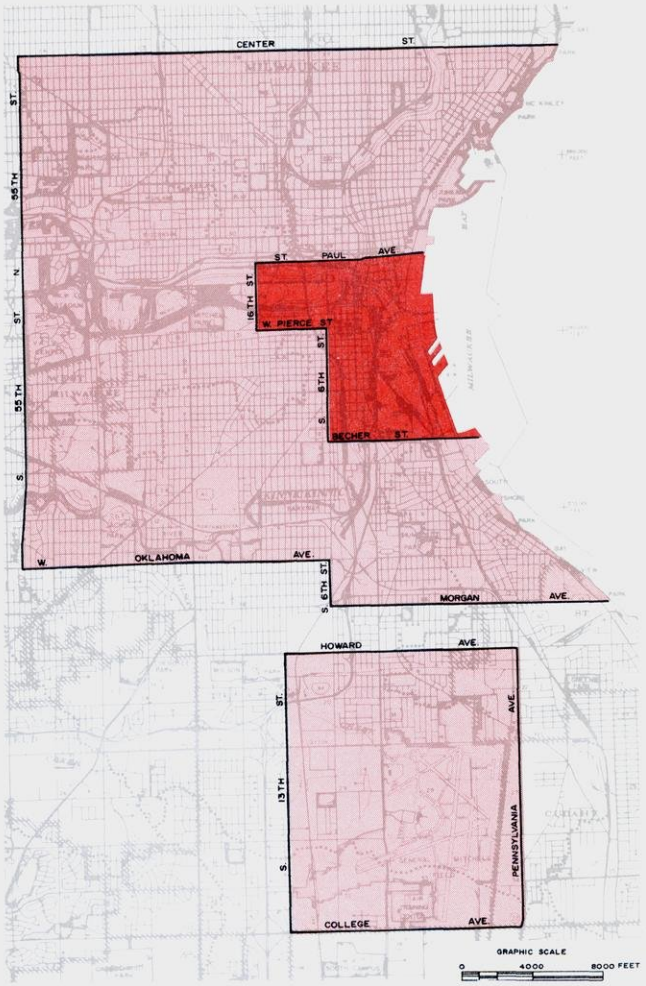
Source: U. S. Environmental Protection Agency and Wisconsin Department of Natural Resources.

Map 82 (continued)

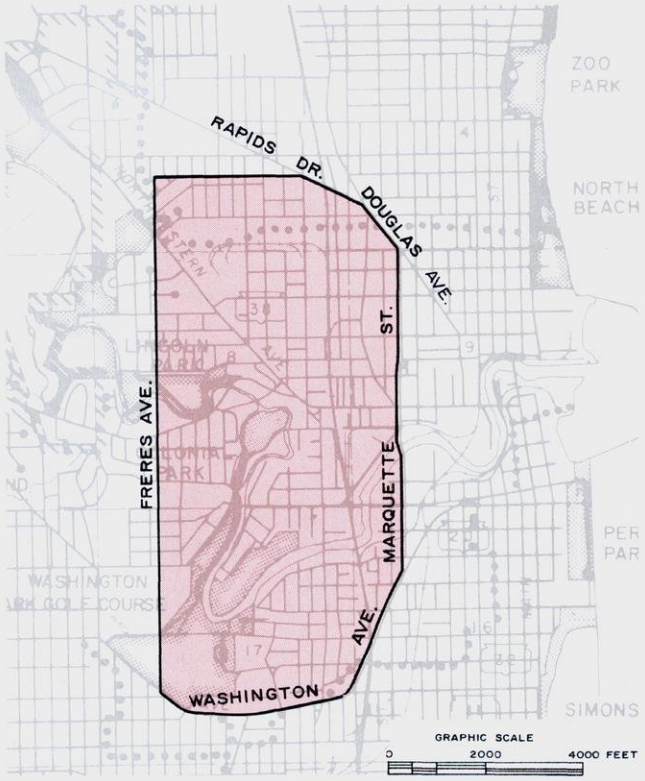
WAUKESHA PRIMARY AND SECONDARY NONATTAINMENT AREA



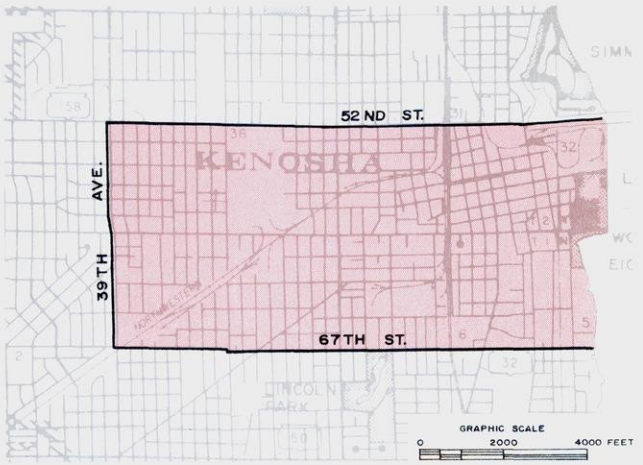
MILWAUKEE PRIMARY AND SECONDARY NONATTAINMENT AREA



RACINE SECONDARY NONATTAINMENT AREA



KENOSHA SECONDARY NONATTAINMENT AREA



Source: U. S. Environmental Protection Agency and Wisconsin Department of Natural Resources.

The maximum 24-hour average particulate matter concentration estimated by the WIS*ATMDIF model for 1973 was 200 $\mu g/m^3$. Although the primary ambient air quality standard of 260 $\mu g/m^3$ is not estimated to have been exceeded based on this modeling result, the secondary standard of 150 $\mu g/m^3$ is estimated to have been exceeded over a 19-square-mile area in Milwaukee County from the Menomonee River Valley northward to the City of Glendale. The modeling results for the 24-hour average particulate matter concentrations during 1977, which are based on the inclusion in the model of additional point sources and the industrial fugitive dust inventory not available for 1973, indicated that the primary and secondary air quality standards had been exceeded in the City of Waukesha and the Town of Lisbon in Waukesha County. Moreover, the secondary standard is estimated to have been exceeded just north of the City of Racine, in the City of Franklin, and in the Menomonee River Valley in the City of Milwaukee during 1977. All of these areas have been so identified solely on the basis of presently quantifiable local emission sources without consideration of background particulate matter levels. The influence of background particulate matter concentrations, such as may be due to long-range transport, would further exacerbate the excessively high pollutant levels attributable to these local emissions sources.

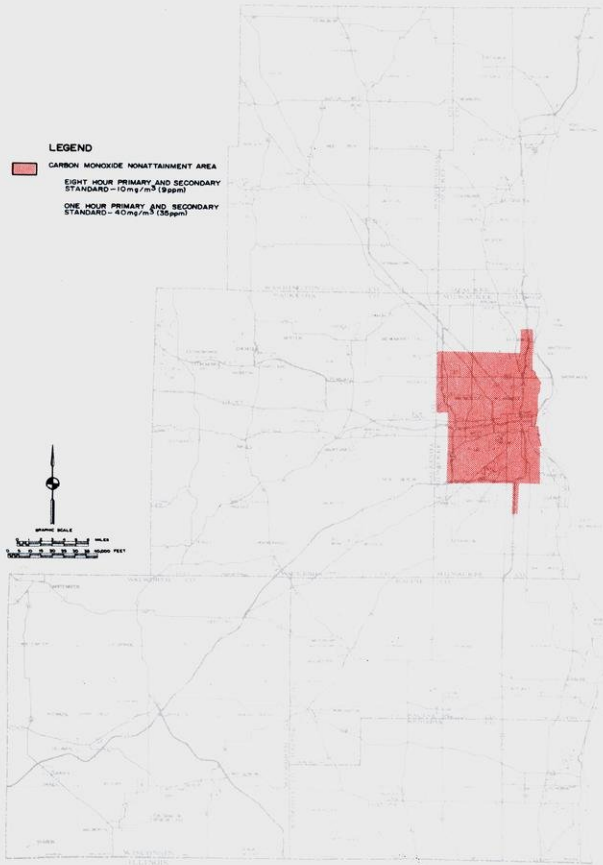
Ambient air sulfur dioxide levels in the Region must be evaluated against the established air quality standards for three averaging periods: the annual average, with a primary standard of 80 $\mu g/m^3$; the 24-hour average, with a primary standard of 365 $\mu g/m^3$; and a three-hour average, with a secondary standard of 1,300 $\mu g/m^3$. The results of the simulation modeling effort for the regional point, line, and area source emissions inventory for 1976 were used for this evaluation process since that year provided the greatest amount of monitoring data for the calibration and validation of the WIS*ATMDIF model. However, in 1976 only five sulfur dioxide monitoring sites in the Region met the minimum sampling frequency requirements of the U. S. Environmental Protection Agency (EPA) for determining the annual average. With only these five monitoring sites, it was not possible to achieve a mathematically significant correlation coefficient between the monitored and computer-simulated annual average sulfur dioxide concentrations. However, the high degree of predictability exhibited by the model, as evidenced by the fact that the simulated concentrations accounted for 68 percent to 100 percent of the total monitored concentrations, is believed to justify the use of the WIS*ATMDIF model as an analytical tool for determining annual average sulfur dioxide concentrations in the Southeastern Wisconsin Region, and for identifying the relative change in the levels of this pollutant species that may be anticipated under future conditions in the Region.

Annual average sulfur dioxide concentrations, as estimated by the calibrated WIS*ATMDIF model, did not exceed the primary standard of 80 $\mu g/m^3$ anywhere in the Region during 1976, a finding which is supported by the observed monitoring data. The maximum annual average sulfur dioxide concentration simulated for 1976 was 50 $\mu g/m^3$, or about 63 percent of the standard. It may be concluded, therefore, that sulfur dioxide levels in southeastern Wisconsin do not presently occur on an annual average basis in sufficient concentrations to constitute a danger to the health and welfare of the regional inhabitants.

As with the 24-hour average particulate matter modeling effort, the results and findings of the 24-hour average sulfur dioxide simulation may not be calibrated or validated because of uncertainties about local emission rates

Map 83

CARBON MONOXIDE NONATTAINMENT AREA IN THE REGION

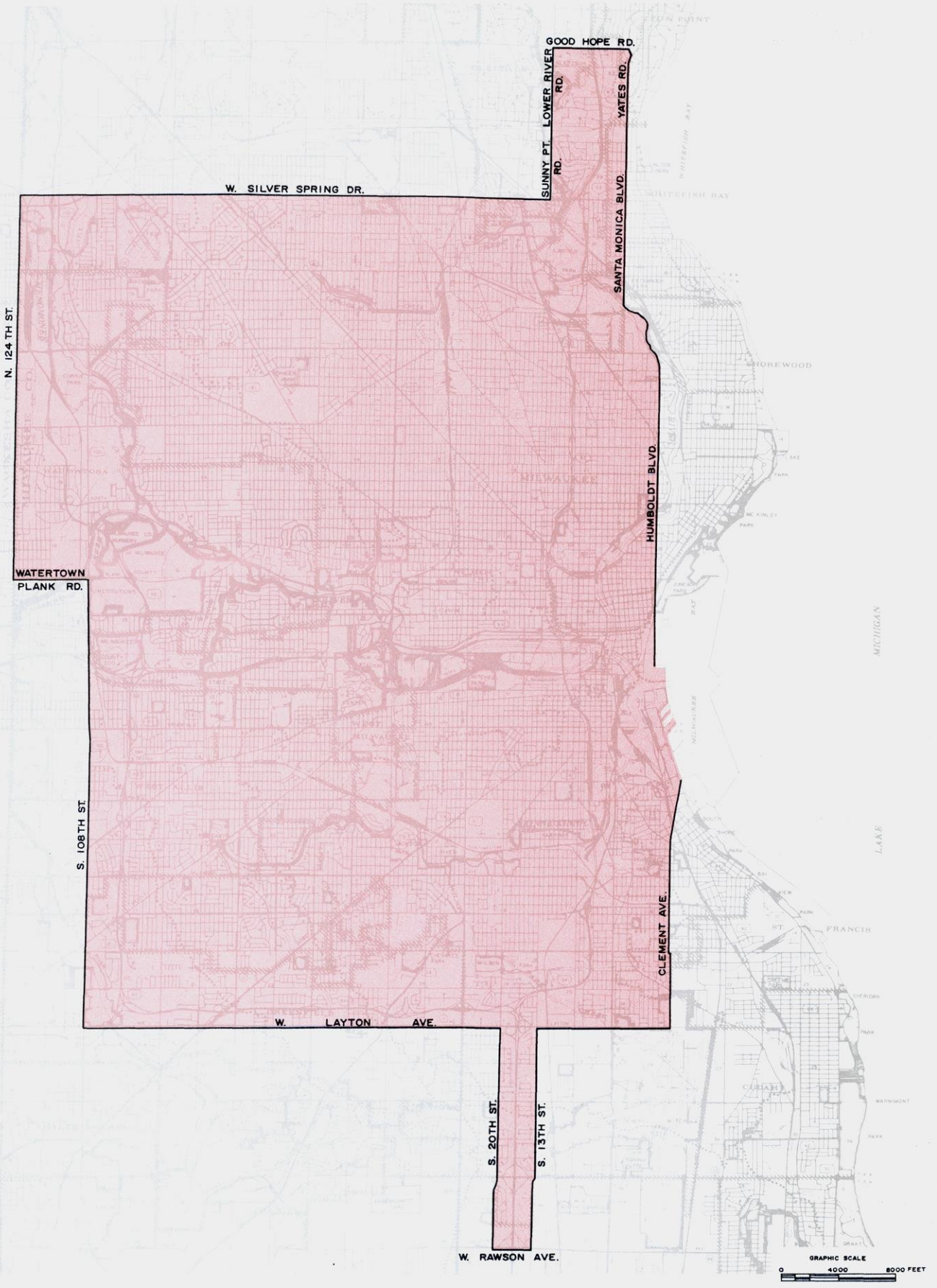


This map identifies that portion of Milwaukee County which was designated by the U. S. Environmental Protection Agency in March 1978 as a nonattainment area for carbon monoxide. Ambient air quality monitoring data from stations located within this designated nonattainment area indicate that the eight-hour average carbon monoxide ambient air quality standard has been violated on one or more occasions each year since monitoring for this pollutant species was initiated in 1973. The designated carbon monoxide nonattainment area encompasses approximately 85 square miles and an estimated resident population of 730,600 persons.

Source: SEWRPC.

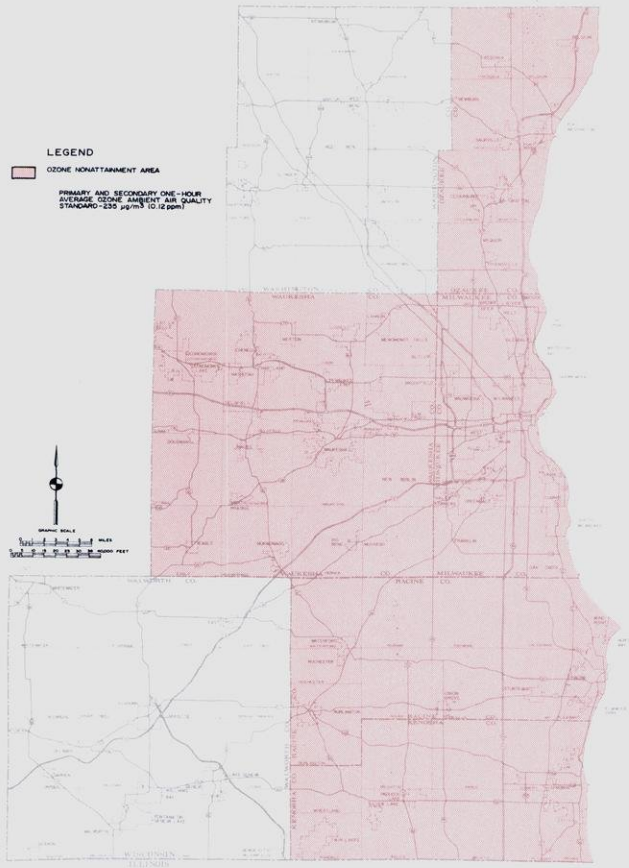
Map 83 (continued)

CARBON MONOXIDE NONATTAINMENT AREA IN MILWAUKEE COUNTY



Map 84

OZONE NONATTAINMENT AREA IN THE REGION



As may be seen on the above map, five counties in the Region—Kenosha, Milwaukee, Ozaukee, Racine, and Waukesha—were designated in 1978 by the U. S. Environmental Protection Agency as a nonattainment area for ozone. Walworth and Washington Counties are presently designated as "unclassifiable" with respect to the attainment of the ozone ambient air quality standard because there are no monitoring data for these two counties. The designated five-county ozone nonattainment area encompasses approximately 1,675 square miles, or about 62 percent of the total area of the Region, and a resident population of about 1,629,000 persons, or about 92 percent of the total regional population.

Source: SEWRPC.

and background concentrations for specific short-term periods. The modeling effort for the 24-hour average sulfur dioxide concentrations in the Region must, therefore, be viewed as a generalization of the maximum levels which may be anticipated under the influence of "worst case" meteorological conditions on local emissions. The maximum 24-hour average sulfur dioxide level simulated for 1976 under these "worst case" conditions was 200 $\mu g/m^3$ and was located in central Milwaukee County in the area of the two sulfur dioxide monitoring sites which were active during 1976—606 W. Kilbourn Avenue and 3716 W. Wisconsin Avenue, both in the City of Milwaukee. This 200 $\mu g/m^3$ level is approximately 55 percent of the primary standard of 365 $\mu g/m^3$. Therefore, it may be concluded that 24-hour average sulfur dioxide concentrations in excess of the standard did not occur in the Region during 1976. It is important to note, however, that violations of the 24-hour average sulfur dioxide standards were monitored in parts of Milwaukee County during 1977 and 1978.

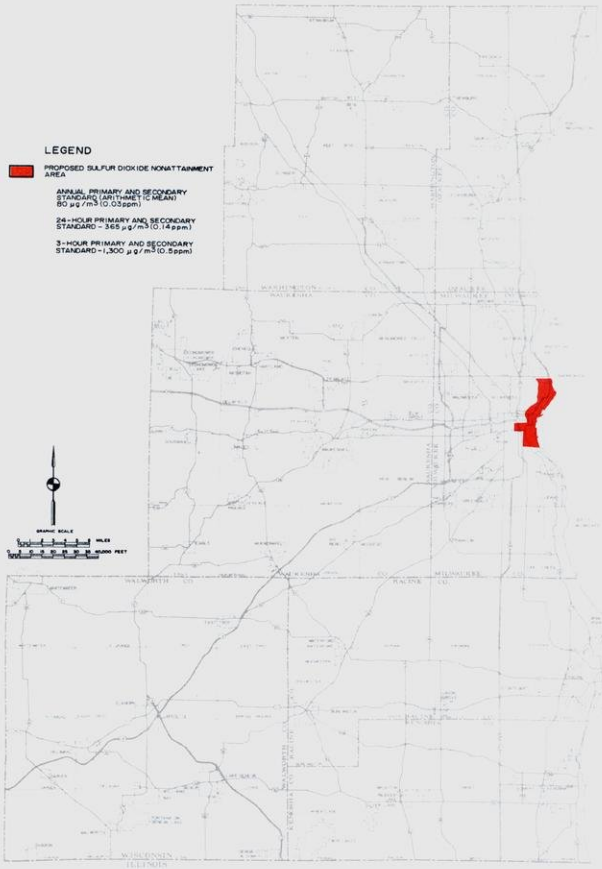
A review of the available monitoring data indicates that the three-hour average secondary sulfur dioxide standard of 1,300 $\mu g/m^3$ was not exceeded in the Region during 1976, although two violations were recorded in 1975 and one in 1977. The meteorological conditions which would tend to produce such violations have been postulated to include very unstable atmospheric conditions—which would drive a sulfur-laden plume rapidly to the ground, moderate wind speeds—around 10 miles per hour, and very high persistence of wind direction which would prevent the plume from drifting at the point of impaction. Under such conditions, the maximum three-hour average sulfur dioxide concentration during 1976, estimated using the WIS*ATMDIF model, was about 500 $\mu g/m^3$ and occurred in the vicinity of the Wisconsin Electric Power Company Oak Creek Plant. Since the frequency of occurrence of the meteorological conditions most likely to produce such high sulfur dioxide concentrations is less than 1 percent, it is unlikely that the maximum three-hour average sulfur dioxide standard would be exceeded more than once per year in southeastern Wisconsin.

Carbon monoxide levels in the Region must be evaluated against the established standards for two short-term averaging periods: an eight-hour average with a primary and secondary standard of 10 milligrams per cubic meter (mg/m^3), and a one-hour average with a primary and secondary standard of 40 mg/m^3. Monitored carbon monoxide levels are predominantly influenced by the emissions from sources in the vicinity of the monitoring site since carbon monoxide is not subject to long-range transport. Thus, the modeling results for carbon monoxide cannot be calibrated on a regional basis. The modeling effort for carbon monoxide, therefore, was directed toward determining the "worst case" meteorological conditions which would yield the maximum carbon monoxide levels for both the eight-hour and one-hour averaging periods. Thus determined, these "worst case" meteorological conditions were used to simulate the maximum carbon monoxide levels in the Region during 1973 and, for comparative purposes, 1977.

Based on this modeling effort, it is estimated that the eight-hour primary and secondary carbon monoxide standard of 10 mg/m^3 was exceeded in Milwaukee County in 1973 over a nine-square-mile area centered on and to the north of the Marquette Interchange. In addition, the one-hour primary and secondary carbon monoxide standard of 40 mg/m^3 is estimated to have been exceeded over a two-square-mile area in Milwaukee County, again centered on and to the north of the Marquette Interchange. Pursuant to these findings, it is estimated that 142,900 persons resided in that portion of the City of Milwaukee where the eight-hour average carbon monoxide standard was exceeded in 1973, and

Map 85

PROPOSED SULFUR DIOXIDE NONATTAINMENT AREA IN THE REGION

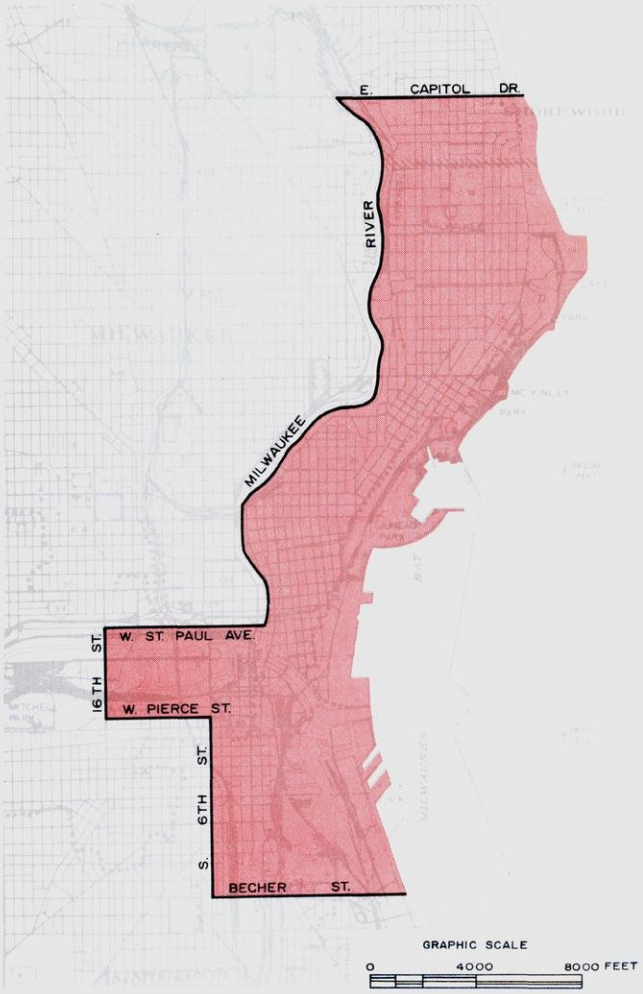


This map identifies the 7.4-square-mile area in Milwaukee County which the Wisconsin Department of Natural Resources in 1979 proposed be designated as a sulfur dioxide nonattainment area based upon monitored violations of the 24-hour average sulfur dioxide ambient air quality standard in 1977 and 1978. An estimated resident population of 62,500 persons reside within the boundaries of this proposed sulfur dioxide nonattainment area.

Source: Wisconsin Department of Natural Resources.

Map 85 (continued)

PROPOSED SULFUR DIOXIDE NONATTAINMENT AREA IN MILWAUKEE



Source: Wisconsin Department of Natural Resources.

that 39,600 persons resided in that portion of the City of Milwaukee where the one-hour average carbon monoxide standard was exceeded in 1973.

The "worst case" simulation modeling effort for carbon monoxide levels during 1977 indicated that the eight-hour average standard was exceeded over an area of about 21 square miles in Milwaukee County—an area with an estimated resident population of about 267,800 persons. However, the simulation modeling effort also indicated that attainment of the one-hour average carbon monoxide standard had been achieved throughout the Region by 1977. Available carbon monoxide monitoring data for 1977 support the findings of the simulation modeling effort, indicating violations of the eight-hour average standard only at five "hotspots" in Milwaukee County and no violations of the one-hour average standard.

Although nitrogen dioxide is photochemically reactive, a primary and secondary standard of 100 $\mu g/m^3$ has been promulgated for this pollutant for an annual averaging period. Most nitrogen oxide emissions, however, are in the form of nitric oxides (NO), which are oxidized in the atmosphere to nitrogen dioxide (NO_2). Since the WIS*ATMDIF model is not able to simulate the atmospheric chemistry of such reactions, the modeling effort for the 1977 annual nitrogen dioxide levels in the Region was limited to identifying areas of maximum nitrogen oxide concentrations in order to provide an indication of where the annual nitrogen dioxide standard may potentially be exceeded. In the assumed absence of such chemical reactions, the uncalibrated modeling results indicate that the maximum nitrogen oxide concentration in the Region during 1977 was about 300 $\mu g/m^3$ and

was located in and around the central business district of the City of Milwaukee. Since the available nitrogen dioxide monitoring data indicate no violations of the standard during 1977—particularly near the area of highest nitrogen oxide concentrations as estimated by the WIS*ATMDIF model—it may be concluded that no area in southeastern Wisconsin presently experiences nitrogen dioxide concentrations at levels detrimental to human health.

The primary and secondary ozone standard—established at 0.12 part per million (ppm) for a one-hour average—has consistently been exceeded at all monitoring sites in the Region since the first monitor became operational in 1973. Since ozone is formed through chemical reactions in the atmosphere, the abatement of this pollutant species is best achieved through the control of precursor emissions, most notably that group of reactive hydrocarbons referred to as volatile organic compounds. The level of control on volatile organic compound emissions necessary to attain the ozone standard in the Region has been determined through use of the Empirical Kinetics Modeling Approach (EKMA).

The main product of the computer program for the EKMA—the Ozone Isopleth Plotting Package (OZIPP)—is an isopleth diagram which depicts the maximum ozone levels that may be anticipated downwind of a major urbanized area for varying values of the nonmethane hydrocarbon to total nitrogen oxide ratio specific to that area. To simulate the pollutant emission rates and meteorological conditions leading to the maximum ozone concentration violating the established standard downwind of the Milwaukee urbanized area, the OZIPP program was operated under ambient conditions representative of the day on which this maximum violation was measured. This day was determined to be June 12, 1976, when an hourly ozone average of 0.232 ppm was recorded at the monitoring site in the City of Grafton in Ozaukee County.

The EKMA modeling effort for ozone was based on the assumption that controls will be required on volatile organic compound emissions from not only local sources but also extraregional sources upwind in order to prevent the ozone standard from being exceeded because of the long-range transport of ozone or its precursor emissions. The results of the EKMA simulations thus performed indicate that volatile organic compound emissions from local sources which contribute to the summer ozone problem need to be reduced by 62 percent at a minimum to 74 percent at a maximum to attain and maintain the ozone standard in the Region.

This range in the percent reduction necessary to attain and maintain the ozone standard reflects the uncertainties regarding the prevailing nonmethane hydrocarbon to nitrogen oxide ratios in the Region. A study conducted by the EPA of 14 urban and suburban cities throughout the United States found that the ratio of nonmethane hydrocarbons to nitrogen oxides varied between 6.0:1.0 and 16.0:1.0. In addition, the EPA determined that the best estimate for this ratio is 9.5:1.0. With a nonmethane hydrocarbon to nitrogen oxide ratio of 6.0:1.0, the local volatile organic compound emissions considered in the EKMA modeling analysis—about 102,100 tons in 1977—would have to be reduced by 62 percent to an annual maximum emission rate of about 38,800 tons if the ozone standard is to be attained and maintained in the Region. If the prevailing nonmethane hydrocarbon to nitrogen oxide ratio is 9.5:10, then a 74 percent reduction in local volatile organic compound emissions—to a maximum annual emission rate of about 26,600 tons—would be required to attain and maintain the ozone standard.

In order to determine where controls would be the most effective, the total hydrocarbon emissions inventory for 1977 was simulated using the WIS*ATMDIF model. Because of the limitations of the model, this simulation modeling effort was conducted in the assumed absence of photochemical reactions. The results of this simulation modeling effort indicate that a 90-square-mile area in Milwaukee County exceeded the ambient air quality standard for hydrocarbons—160 $\mu g/m^3$ on a three-hour, 6:00 a.m. to 9:00 a.m., average—during 1977.

Based on available ambient air quality monitoring data, the Wisconsin Department of Natural Resources (DNR) has proposed to the EPA that certain areas of the Region be designated as nonattainment areas—that is, areas having air pollutant levels in excess of established standards—for one or more pollutant species. Specifically, a three-square-mile area in Milwaukee County and a one-quarter-square-mile area in Waukesha County have been designated by the EPA as primary particulate matter nonattainment areas. In addition, a two-square-mile area in Kenosha County, a 34-square-mile area in Milwaukee County, a two-square-mile area in Racine County, and a less than one-square-mile area in Waukesha County have been designated as secondary particulate matter nonattainment areas. In total, about 20,200 persons, or about 1.1 percent of the total regional population, reside in the designated primary particulate matter nonattainment areas, and 335,300 persons, or about 18.9 percent of the total regional population, reside in the secondary nonattainment areas.

An 85-square-mile area in Milwaukee County, encompassing portions of the municipalities of Glendale, Greenfield, Milwaukee, Wauwatosa, West Allis, West Milwaukee, and Whitefish Bay, has been designated by the EPA as a carbon monoxide nonattainment area. This area has an estimated resident population of 730,600 persons, or 41.1 percent of the total regional population.

Five counties in the Southeastern Wisconsin Region—Kenosha, Milwaukee, Ozaukee, Racine, and Waukesha—have together been designated by the EPA as a nonattainment area for ozone. Walworth and Washington Counties have been designated as "unclassifiable" for this pollutant species since ozone monitoring has not been conducted to date in these two counties. The five counties presently designated as a nonattainment area

for ozone encompass approximately 1,675 square miles and a resident population of about 1,629,000 persons, or 92 percent of the total regional population.

The DNR has also proposed that a 7.4-square-mile area in Milwaukee County be designated as a nonattainment area for sulfur dioxide based upon monitored violations of the 24-hour average standard for this pollutant species during 1977 and 1978. This area encompasses a resident population of approximately 62,500 persons, or 3.5 percent of the total regional population.

In summary, this chapter has identified significant ambient air quality problems in the Region with respect to existing particulate matter, sulfur dioxide, carbon monoxide, and hydrocarbon/ozone concentrations. The findings may be summarized as follows:

Particulate Matter

- The air quality simulation modeling effort has indicated that 17 square miles in the Region with a resident population of about 65,600 persons experienced annual average concentrations of this pollutant species in excess of the primary, or health-related standard, and an additional 47 square miles in the Region with a resident population of about 228,800 persons experienced concentrations in excess of the secondary, or welfare-related, annual average standard during 1977.

- The Wisconsin Department of Natural Resources has designated a three-square-mile area in the Region with a resident population of about 20,200 persons as a primary particulate matter nonattainment area, and an additional 38-square-mile area in the Region with a resident population of about 335,300 persons as a secondary particulate matter nonattainment area. The differences between the simulation modeling results and the nonattainment designations are expected to be resolved as the modeling results are verified through increased monitoring activities.

Sulfur Dioxide

- The air quality simulation modeling effort has indicated that no area within the Region experienced violations of the annual, 24-hour, or three-hour average sulfur dioxide ambient air quality standards during 1976. This finding was supported by available sulfur dioxide ambient air quality monitoring data for that year.

- Based upon violations of the 24-hour average sulfur dioxide ambient air quality standard monitored during 1977 and 1978, the Wisconsin Department of Natural Resources has proposed that a 7.4-square-mile area in Milwaukee County be designated as a nonattainment area for this pollutant species. This 7.4-square-mile area has an estimated resident population of 62,500 persons.

Carbon Monoxide

- The air quality simulation modeling effort has indicated that the eight-hour average carbon monoxide ambient air quality standard was exceeded over a 21-square-mile area in Milwaukee County during 1977, an area having a resident population of approximately 267,800 persons. The simulation modeling results also indicated that the one-hour average carbon monoxide standard was not exceeded anywhere in the Region during 1977.

- Based upon the simulation modeling results and available ambient air quality monitoring data, which have indicated the presence of localized carbon monoxide "hotspots" outside the problem area as depicted by the modeling results, the Wisconsin Department of Natural Resources has designated an 85-square-mile area in Milwaukee County as a nonattainment area for carbon monoxide. This 85-square-mile area has an estimated resident population of 730,600 persons.

Nitrogen Dioxide

- The air quality simulation modeling effort has indicated that the annual average nitrogen dioxide ambient air quality standard was not exceeded in the Region during 1977.

- Since available ambient air quality monitoring data support the conclusion that the nitrogen dioxide standard has not been exceeded in the Region, it was deemed unnecessary to designate a nonattainment area for this pollutant species.

Hydrocarbons/Ozone

- The results of the EKMA simulation modeling effort have indicated that local volatile organic compound emissions must be reduced by 62 to 74 percent in order to attain and maintain the ozone ambient air quality standard in the Region. Quantitatively, the 1977 level of volatile organic compound emissions in the Region—about 102,100 tons—must be reduced to a maximum annual rate of between 26,600 and 38,800 tons.

- The U. S. Environmental Protection Agency has designated all of the area within the Counties of Kenosha, Milwaukee, Ozaukee, Racine, and Waukesha as an ozone nonattainment area. Both Walworth and Washington Counties have been designated as "unclassifiable" for this pollutant species since ozone concentrations have not been monitored in these two counties. The five counties in the Region designated as an ozone nonattainment area encompass approximately 1,675 square miles, or about 62 percent of the total area within the Region, and a resident population of about 1,629,000 persons, or about 92 percent of the total population of the Region.

Chapter XII

ANTICIPATED GROWTH AND CHANGE AND POTENTIAL PROBLEM IDENTIFICATION

INTRODUCTION

The existence, character, magnitude, and areal extent of the air pollution problem in the Region, specifically with regard to prevailing particulate matter, sulfur dioxide, carbon monoxide, and ozone levels, were determined from available air quality monitoring data, supplemented by ambient air quality simulation modeling studies, as documented in Chapter XI of this report. In comparing the observed and simulated air pollutant levels in the Region in 1973 with those in 1977, however, it is evident that ambient air quality in the Region has changed measurably over this four-year period. Particulate matter and carbon monoxide levels, for instance, declined between 1973 and 1977, while sulfur dioxide levels increased somewhat. These changes in ambient air quality in the Region may be attributed both to the increased application of air pollution control technology on existing sources, and to changes in the size, distribution, activities, and movements of the regional population. Moreover, future growth and development in the Region may be expected to produce further changes in regional ambient air quality. The purpose of this chapter is to provide an overview of the regional growth and development that may be anticipated to take place by the year 2000, and to estimate the effect of that growth and development on future regional ambient air quality. In so doing, the nature and extent of the air pollution abatement measures necessary to attain and maintain the national ambient air quality standards in southeastern Wisconsin will be defined.

Specifically, this chapter describes the probable future level, distribution, and age characteristics of the regional population to the year 2000. Forecast regional employment levels are also presented since employment is an important indicator of economic activity which, in turn, determines air pollutant emissions from major industrial sources. Also, important to any consideration of probable future air pollutant emissions from point sources are the type and quantity of primary fuels which may be expected to be available within the Region for industrial operations. Accordingly, the energy-related assumptions underlying the preparation of the air pollutant emission forecasts are also discussed. The adopted regional land use and transportation system plans for the year 2000 provide the basis for characterizing anticipated human activities and movements in the Region, which in turn are used to forecast the magnitude and distribution of future air pollutant emissions. Because of their importance to long-term air quality maintenance planning, these plans are described for the design year 2000 and for the intermediate stage year 1985.

In addition to being made for the design year 2000 and the intermediate stage year 1985, air pollutant emissions forecasts for point, line, and area sources have been made for the year 1982. These forecasts were made because the federal Clean Air Act Amendments of 1977 mandate that all primary, or health-related, ambient air quality standards are to be attained by that year. Only in the case of carbon monoxide and ozone may an extension of time be granted to achieve the standards if it can be demonstrated that, even with the application of Reasonably Available Control Technology, attainment is improbable. A discussion of the procedures followed in forecasting air pollutant emissions from point, line, and area sources is presented in this chapter, along with summary emission tables for the years 1982, 1985, and 2000.

This chapter concludes with an analysis of the future ambient air pollutant levels anticipated in the Region as determined through air quality simulation modeling. The air quality simulation modeling effort, which is based on the emission forecasts for the years 1982, 1985, and 2000, and on generalized meteorological conditions, is used to evaluate the impact of regional growth and development on ambient air quality in the Region, and to measure the ability of existing air pollution abatement controls and regulations to attain and maintain the ambient air quality standards. Through this modeling effort, the nature, magnitude, and areal extent of probable future air pollution problems in the Region are identified, and the nature and extent of required air pollution abatement controls and measures defined.

POPULATION GROWTH IN THE REGION: 1970-2000

Forecast Change

The size, character, and distribution of the resident population of an area have important implications for air quality planning. Population affects, and is affected by, air pollution. The size and distribution of the resident population determines the number of persons exposed to air pollution, with attendant hazards to health. The character of the population—in particular, the age distribution—determines the severity of the health risks associated with exposure to polluted air. In the absence of further air pollution control measures, shifts, as well as increases, in population, with the attendant changes in human activities and movements, may be expected to result in an increase in pollutant emissions and thereby exacerbate existing air pollution problems or create entirely new problems. Any air quality maintenance planning effort, therefore, requires consideration of probable future, as well as of existing, population levels, characteristics, and distribution. Data on the level, character, and distribution of the existing resident population

of the Region were provided in Chapter IV of this report. Data on the probable levels, characteristics, and distribution of the regional population in the years 1985 and 2000 are presented in this section of this chapter.

As a part of its ongoing regional planning effort, the Commission has prepared detailed projections and forecasts of the size, composition, and distribution of the regional population to the year 2000. The use of these basic forecasts for air quality management planning is not only cost-effective but helps to assure full coordination of areawide land use, transportation, and water quality management planning efforts with air quality management planning efforts. In any consideration of the following forecasts, it must be recognized that no one can "predict" the future and that all forecasts, however made, involve uncertainty. Forecasts cannot take into account events that are unpredictable but which may have a major effect on future conditions. Such events include wars, epidemics, major social, political, and economic upheavals, and radical institutional changes. Moreover, both public and private decisions of a less radical nature may significantly affect the ultimate accuracy of any forecast. Indeed, the very act of preparing forecasts which present a distasteful situation to society may lead to actions which will negate those very forecasts. For these reasons, therefore, forecasting, like planning, must be a continuing process. As otherwise unforeseeable events unfold, forecast results must be revised and, in turn, plans which are based on such forecasts must be reviewed and revised as necessary.

The basic procedure followed in the preparation of the regional population forecasts presented herein can be summarized as follows. Independent projections were made of the regional population to the year 2000 using four different demographic techniques.[1] These included a regression technique which converted independently prepared national population projections to regional projections; a technique developed by C. Horace Hamilton and Josef Perry[2]; a basic cohort survival technique; and a modified cohort survival technique. Utilizing the basic cohort survival technique alone, 15 population projections were prepared, each based upon different assumptions concerning trends in fertility and migration rates as shown in Table 258. These population projections were converted to employment projections and compared to independently prepared employment projections. A single "best" projection was then selected from the complete array of projections as the forecast to be used for planning purposes. This selection was made by the Commission staff with the assistance of the Commission advisory committees concerned.

The overall regional population forecast so prepared was utilized as a control total in developing population projections and forecasts for each of the seven counties comprising the Region. While the individual county projections were based on assumptions concerning fertility and migration rates specific to each county, the county forecasts finally selected were normative ones based upon the Commission's adopted land use development objectives, and assume that the continued diffusion of urban development into the outlying areas of the Region will be curtailed in the public interest through the exercise of land use controls and other public policy actions. The individual county forecasts assume that the present trends in population decentralization will be stabilized and, in fact, reversed in the mid to late 1980's, and that the central areas of the Region will again experience population growth. While at variance with existing trends, this assumption is consistent with federal policies which seek to discourage urban sprawl and protect critical environmental areas and prime agricultural lands.

Based on the above-described procedure, a resident population of approximately 2.22 million persons is forecast for the Region in the year 2000—an increase of about 460,000 persons, or about 26 percent, over the 1970 enumerated regional population of about 1.76 million persons (see Figure 86 and Table 259). The forecast change in population levels within each of the seven counties comprising the Region between 1970 and 2000 is shown in Table 259 and in Figures 87 through 93. In general, the county population forecasts indicate continued and relatively rapid population growth in Ozaukee, Washington, and Waukesha Counties, with slower rates of population growth in Kenosha, Racine, and Walworth Counties. Only Milwaukee County, which is presently exhibiting a loss of population, is forecast to experience a net population decline in the year 2000 from the 1970 population level. Milwaukee County is forecast to continue to lose population until about 1985, when the population, based on the Commission's normative land use plan, is expected to begin increasing again. The population increase forecast for Milwaukee County between 1985 and 2000, however, will not entirely offset the decrease forecast for 1970 to 1985, resulting in a small absolute decline in population between 1970 and the year 2000 of about 5,000 persons, or about one-half of 1 percent. Ozaukee and Washington Counties are expected to show the largest relative population gains, increasing by about 60,000 persons and 79,000 persons, or about 109 and 124 percent, respectively, from 1970 to 2000. Waukesha County is expected to experience the largest absolute gain in population, increasing by approximately 189,000 persons, or by about 82 percent, between 1970 and 2000.

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[1] *For a more complete description of the population forecasting methodology used and the results obtained, see SEWRPC Technical Report No. 11, The Population of Southeastern Wisconsin, and Chapter III of SEWRPC Planning Report No. 25, A Regional Land Use Plan and a Regional Transportation Plan for Southeastern Wisconsin: 2000, Volume Two, Alternative and Recommended Plans.*

[2] *C. Horace Hamilton and Josef Perry, "A Short Method for Projecting Population by Age from One Decennial Census to Another," Social Forces, Vol. 41, No. 2, December 1962.*

Table 258

PROJECTED REGIONAL POPULATION IN THE YEAR 2000 USING VARIOUS COMBINATIONS OF FERTILITY AND MIGRATION ASSUMPTIONS

Projection Number	Fertility and Migration Assumptions	2000 Population
1	Continuation of current fertility and mortality rates to 2000; migration rates at 1950-60 level	3,756,400
2	Reduction in fertility to replacement level from 1975 to 2000; migration rates at 1950-60 level; current mortality	3,532,000
3	Continuation of current fertility and mortality rates to 2000; migration rates at 1950-70 level	3,167,700
4	Reduction in fertility to replacement level from 1975 to 2000; migration rates at 1950-70 level; current mortality	2,968,400
5	Continuation of current fertility and migration rates through 1980, then replacement level fertility to 2000; migration rates between the current 1950-70 levels to 2000; current mortality	2,701,700
6	Continuation of current fertility, mortality, and migration rates to 2000	2,684,100
7	Continuation of current fertility rates to 1985 then replacement level fertility to 2000; continuation of current mortality and migration rates to 2000	2,590,100
8	Continuation of current fertility rates to 1980, then replacement level fertility to 2000; continuation of current mortality and migration rates to 2000	2,560,300
9	Reduction in fertility rates to replacement level from 1975 to 2000; continuation of current mortality and migration rates	2,506,800
10	Reduction in fertility rates to below replacement level from 1975 to 1985, then replacement level fertility to 2000; reversal of net out-migration the 1960's to net in-migration from 1970 to 2000; current mortality	2,427,000[a]
11	Continuation of current fertility and migration rates to 1985, then replacement level fertility and no migration to 2000; current mortality	2,380,800
12	Continuation of current fertility and mortality rates to 2000; no migration	2,338,300
13	Reduction in fertility to below replacement level from 1975 to 1985, then replacement level fertility to 2000; slowdown in the out-migration of the 1960's to a slight net in-migration by 2000; current mortality	2,219,300[b]
14	Reduction in fertility rates to replacement level from 1975 to 2000; continuation of current mortality rates; no migration	2,175,200
15	Reduction in fertility to below replacement level from 1975 to 1985, then replacement fertility to 2000; continuation of current out-migration and current mortality	1,971,800[c]

[a] *Selected by the Commission staff and advisory committees as the probable upper limit of regional population in 2000.*

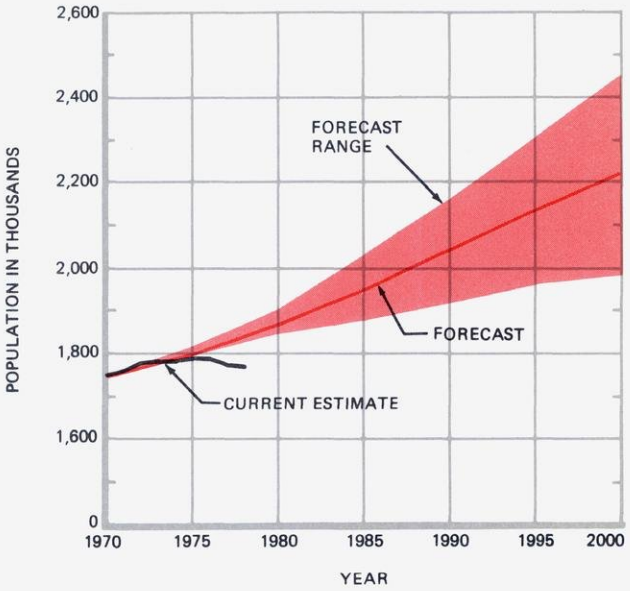
[b] *Selected by the Commission staff and advisory committees as the best forecast of regional population in 2000.*

[c] *Selected by the Commission staff and advisory committees as the probable lower limit of regional population in 2000.*

Source: SEWRPC.

Figure 86

POPULATION FORECAST AND CURRENT POPULATION ESTIMATE FOR THE REGION



Source: SEWRPC.

As may be seen in Table 260 and Figure 94, the forecast population growth rate of about 26 percent over the 30-year period from 1970 to 2000 is expected to be somewhat higher than the national growth rate—about 24 percent—and somewhat lower than the growth rate for the State of Wisconsin—about 32 percent. The regional population forecast assumes that the rural pool of migrants, which have in the past moved into the urban areas of the eastern, north-central, and midwestern parts of the nation, will essentially have disappeared. It also assumes that the migration presently characterized by a shift of population from the mature industrialized areas of the eastern, north-central and midwestern states to the southern and western states in response to the newly developing industrial economies there will diminish as per unit labor costs in the South and West approach those existing in the east, north-central, and midwestern states, thus stabilizing much of the out-migration currently occurring from the latter areas. The forecast thus visualizes an underlying national trend of redistribution and equalization of economic activity, per capita income, and population concentrations, rather than a long-term absolute decline of the older metropolitan areas of the United States.

It should be noted that the Commission forecasts meet the requirements outlined in the Federal Register of September 27, 1978. These U. S. Environmental Protection Agency requirements state that, to be used in areawide water quality management planning, forecast population levels for a region cannot exceed state population forecasts for the same region by more than 10 percent. The Commission's forecast for the year 2000 of 2.22 million persons varies only 2.2 percent from the Wisconsin Department of Administration's independently

Table 259

REGIONAL POPULATION FORECAST BY COUNTY: 1970-2000

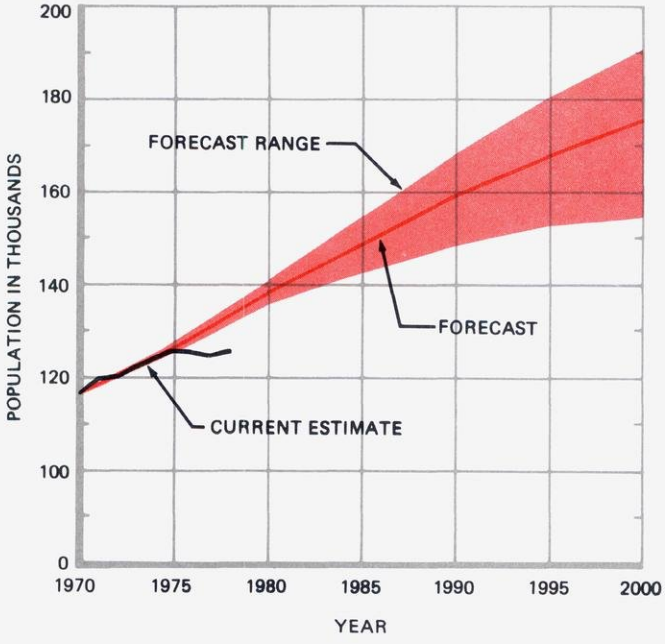
County	Population					
	Estimated 1970[a]	Forecast			Change: 1970-2000	
		1980	1990	2000	Number	Percent
Kenosha	117,917	139,200	159,900	174,800	56,883	48.2
Milwaukee	1,054,249	1,014,500	1,022,200	1,049,600	- 4,649	- 0.4
Ozaukee	54,461	76,200	97,400	114,000	59,539	109.3
Racine.	170,838	185,600	203,600	217,700	46,862	27.4
Walworth.	63,444	74,700	86,600	99,600	36,156	57.0
Washington . . .	63,839	90,900	117,600	143,000	79,161	124.0
Waukesha.	231,335	292,300	356,600	420,600	189,265	81.8
Region	1,756,083	1,873,400	2,043,900	2,219,300	463,217	26.4

[a] *These figures represent final 1970 Census of Population and Housing county totals after all adjustments and reallocations have been made by the Census Bureau. As such, these totals may not agree with county population totals shown in other tables in this publication. Adjusted population totals give no information about the social and economic characteristics of the reallocated population, making it impossible to recompile tables of population characteristics to reflect adjusted totals. However, in no county in the Southeastern Wisconsin Region does the final county population total differ from the preliminary county population total by more than 0.1 percent. This is not sufficient to affect the reliability of any table containing the preliminary population totals.*

Source: U. S. Bureau of the Census and SEWRPC.

Figure 87

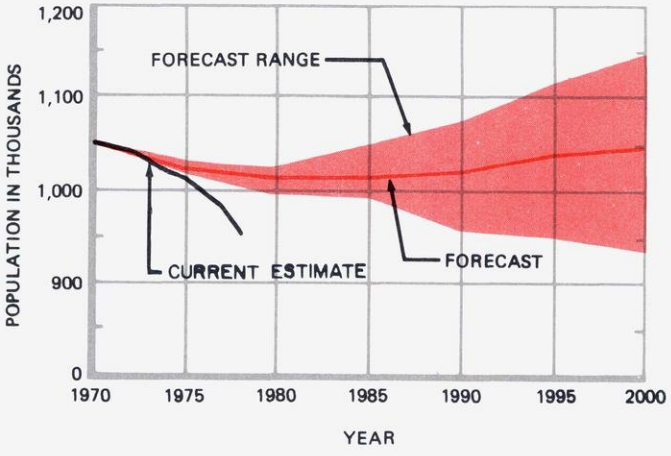
POPULATION FORECAST AND CURRENT POPULATION ESTIMATE FOR KENOSHA COUNTY



Source: SEWRPC.

Figure 88

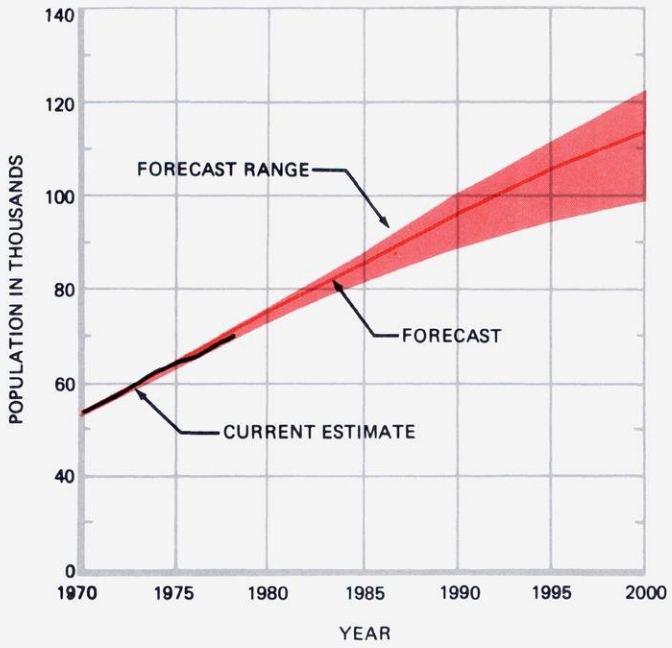
POPULATION FORECAST AND CURRENT POPULATION ESTIMATE FOR MILWAUKEE COUNTY



Source: SEWRPC.

Figure 89

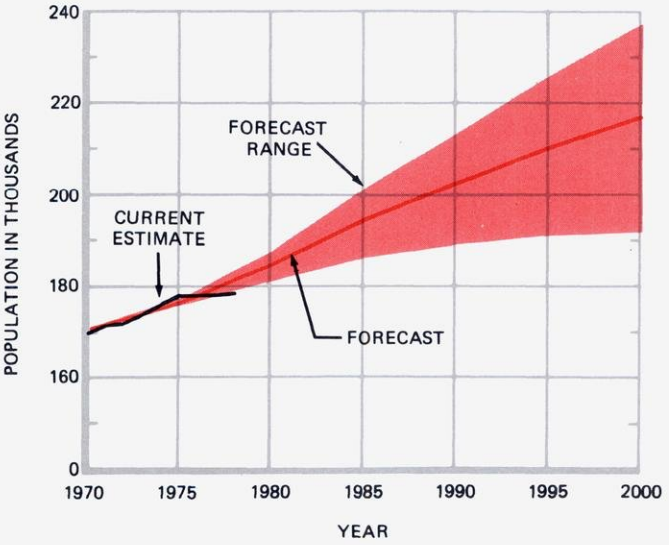
POPULATION FORECAST AND CURRENT POPULATION ESTIMATE FOR OZAUKEE COUNTY



Source: SEWRPC.

Figure 90

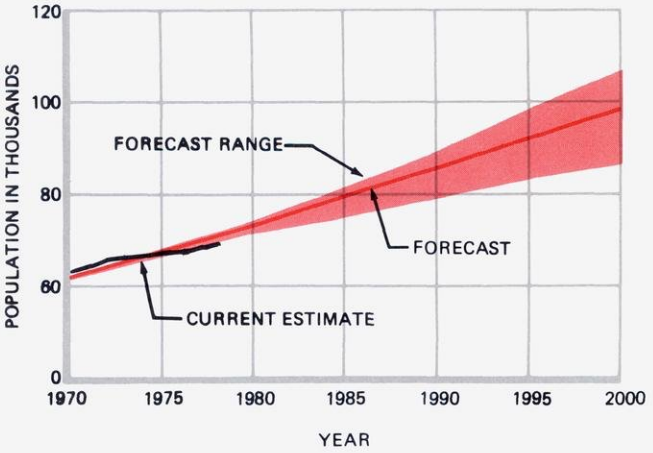
POPULATION FORECAST AND CURRENT POPULATION ESTIMATE FOR RACINE COUNTY



Source: SEWRPC.

Figure 91

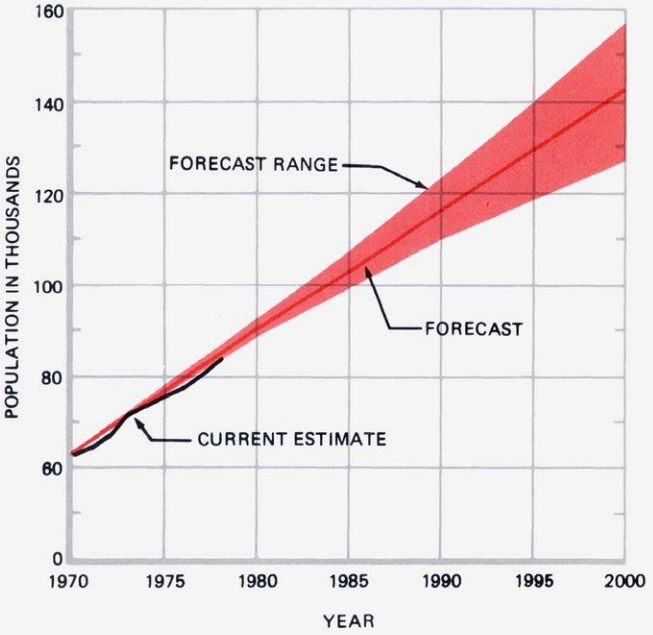
POPULATION FORECAST AND CURRENT POPULATION ESTIMATE FOR WALWORTH COUNTY



Source: SEWRPC.

Figure 92

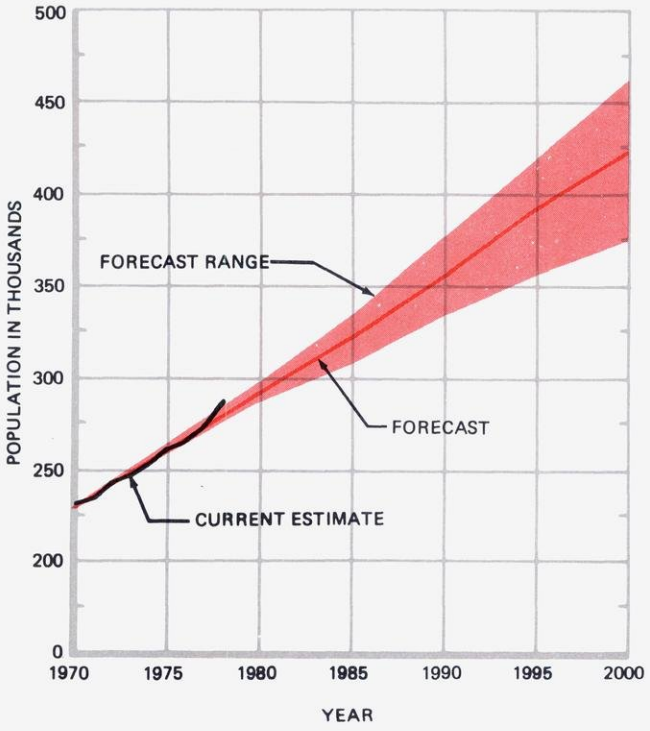
POPULATION FORECAST AND CURRENT POPULATION ESTIMATE FOR WASHINGTON COUNTY



Source: SEWRPC.

Figure 93

POPULATION FORECAST AND CURRENT POPULATION ESTIMATE FOR WAUKESHA COUNTY



Source: SEWRPC.

prepared forecast of 2.27 million persons for the same year. The year 2000 Commission population forecast for the Milwaukee Standard Metropolitan Statistical Area of 1.73 million varies only 2.2 percent from the state forecast of 1.77 million for the same year. Federal requirements also specify that the state forecasts cannot vary from forecasts prepared jointly by the U. S. Department of Commerce, Office of Business Economics, and the U. S. Department of Agriculture, Economic Research Service (BEA-OBERS), by more than 5 percent. The Wisconsin Department of Administration forecast of 5.78 million residents for the State in the year 2000 exceeds the BEA-OBERS forecast of 5.55 million by 4.1 percent.

Because certain segments of the population are more susceptible to the adverse health effects of air pollution than others, particularly the elderly and the very young, the anticipated age composition of an area is of great importance to air quality planning. The age composition of the regional population is expected to change in accordance with anticipated declines in birthrates and changes in migration patterns. Based on such assumptions, the expected change in the age composition of the regional population between 1970 and 2000 is shown graphically in Figure 95 and may be summarized as follows:

1. The age group from 0-4 years of age, representing the preschool population, is expected to increase

Table 260

POPULATION PROJECTIONS AND FORECASTS FOR THE REGION, WISCONSIN, AND THE UNITED STATES: 1970-2000

Year	Population (in thousands)		
	Region[a]	Wisconsin[b]	United States[c]
1970	1,756	4,418	204,800
1980	1,873	4,820	220,664
1990	2,044	5,384	237,678
2000	2,219	5,841	254,502
Percent Change 1970-2000	26.4	32.2	24.3

[a] *SEWRPC projections.*

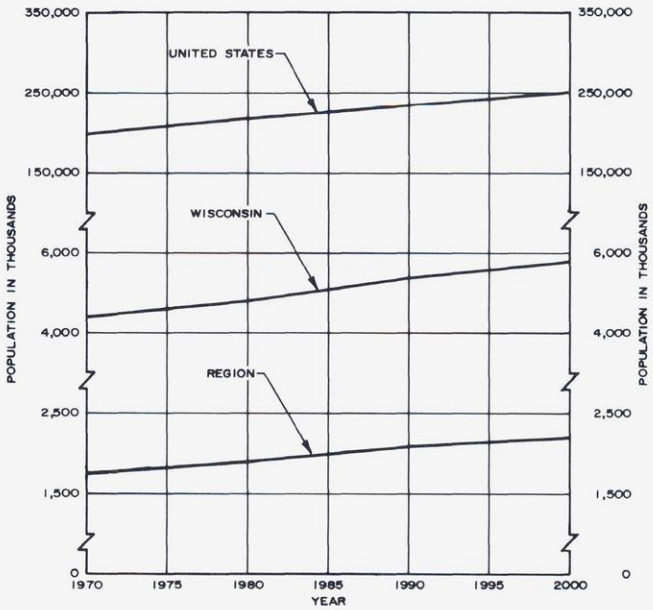
[b] *Wisconsin Department of Administration, Wisconsin Population Projections, Third Edition, June 1975.*

[c] *Figures include armed forces abroad and are Series V projections with immigration, published by the U. S. Bureau of the Census in Current Population Report Series P-25, No. 480, April 1972.*

Source: U. S. Bureau of the Census, Wisconsin Department of Administration, and SEWRPC.

Figure 94

COMPARISON OF POPULATION PROJECTIONS AND FORECASTS FOR THE REGION, WISCONSIN, AND THE UNITED STATES: 1970-2000



Source: U. S. Bureau of the Census, Wisconsin Department of Administration, and SEWRPC.

only slightly—from about 152,000 persons in 1970 to nearly 161,000 persons in the year 2000, an increase of 9,000 persons, or 6 percent, over the forecast period.

2. The age group from 5-14 years of age, representing the elementary school-age population, is expected to decrease in size by about 30,600 persons, or by 8 percent—from about 367,900 persons in 1970 to about 337,300 persons in the year 2000.

3. The age group from 15-19 years of age, representing the high school-age population, is expected to decrease by about 10,500 persons, or by 6 percent—from about 162,200 persons in 1970 to about 151,700 persons in the year 2000.

4. The age group from 20-64 years of age, representing the working-age population of the Region, is expected to increase by about 401,800 persons, or by 45 percent—from about 894,600 persons in 1970 to about 1,296,400 persons in the year 2000.

5. The age group 64 years of age and older, representing the elderly population of the Region, is expected to increase by about 104,200 persons, or by 62 percent—from about 168,700 persons in 1970 to about 272,900 persons in the year 2000.

These forecast changes in the age composition of the regional population have important implications for long-range air quality planning. In addition to envisioning a small increase in the number of young children and a large increase in the number of elderly persons, forecast age changes indicate that the labor force may be expected to increase substantially. Accordingly, the number of persons seeking work within the Region may be expected to increase, as will the need to provide jobs for these persons. This anticipated employment increase may lead to higher air pollution levels as major employment facilities expand or locate in the Region and as transportation demand increases, particularly in relation to trips to and from work.

The number of households in the Region is expected to increase at a somewhat greater rate than the population. Forecast increases in the number of households have important implications for long-range air quality planning since it is the household population which creates nearly all of the demand for certain land uses and for transportation facilities and which requires a significant expenditure of energy resources for heating purposes. As may be seen in Table 261, the number of households in the Region is expected to increase from about 536,500 in 1970 to about 747,700 in the year 2000, an increase of about 39 percent. Implicit in this forecast are the assumptions that the same proportion of the total population will reside in households in 2000 as did in 1970, and that the average household size will continue to decline from its 1970 level.

Recent Trends

Estimates of actual population levels within the Region through 1978 indicate that the most recent trends in population growth within the Region are deviating from the forecasts. This deviation is reflected not only in the relative populations of the central cities and mature suburbs of the Region and the newer suburbs and outlying rural-urban areas of the Region—a deviation to be expected since the regional land use plan has not yet been fully implemented—but also in the overall level of population of the Region. The actual population trends are shown in Figure 86 for the Region as a whole and in Figures 87 through 93 by county, and are summarized in Table 262. The estimated 1978 resident population of the Region of 1.77 million is about 4 percent below the forecast level of 1.85 million for that year. As indicated in Table 263, the largest discrepancy occurs in Milwaukee County. However, as is discussed in the next section, the underlying economic base of the Region appears to be relatively sound, and employment growth has exceeded Commission forecasts. Thus, these additional jobs are apparently being absorbed by dual wage earners and single-person households and, therefore, are attended by smaller population increases than expected. Although there are indications that the Commission population forecasts may be high, revision of those forecasts at this time is not warranted since no solid basis exists for making different fertility, migration, and labor force participation rate estimates until 1980 federal census data become available in 1982.

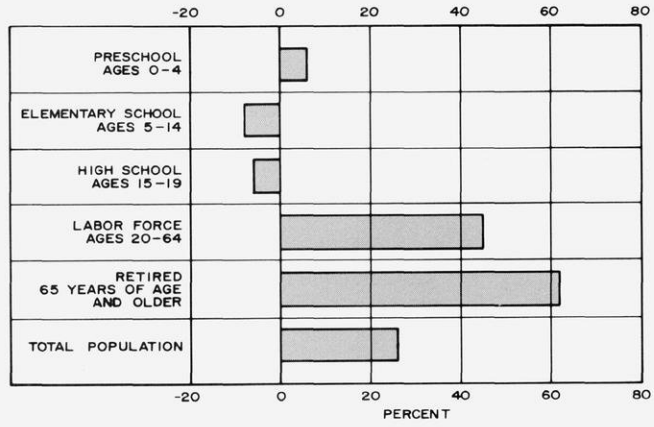
ECONOMIC GROWTH IN THE REGION: 1970-2000

Forecast Change

Population and employment levels in the Region have historically followed quite similar patterns because population migrations between geographic areas are largely dependent upon the availability of jobs in these areas. The rapid historic growth of population in the Region, therefore, may be attributed in part to the increasing economic activity in the Region since the early 1900's.

Figure 95

PERCENT CHANGE IN POPULATION OF THE REGION BY SELECTED AGE GROUP: 1970-2000



Source: U. S. Bureau of the Census and SEWRPC.

Table 261

ESTIMATED AND FORECAST HOUSEHOLDS IN THE REGION BY COUNTY: 1970-2000

County	1970			1980			1990			2000		
	Number of Households	Household Population	Persons per Household	Number of Households	Household Population	Persons per Household	Number of Households	Household Population	Persons per Household	Number of Households	Household Population	Persons per Household
Kenosha	35,468	115,712	3.26	42,800	136,574	3.19	50,400	156,860	3.11	56,800	171,466	3.02
Milwaukee	338,605	1,029,375	3.04	358,900	990,344	2.76	376,600	997,671	2.65	400,300	1,024,335	2.56
Ozaukee	14,753	53,999	3.66	21,200	75,546	3.56	27,500	96,558	3.51	32,500	113,012	3.48
Racine	49,796	167,016	3.35	55,100	181,406	3.29	61,800	198,963	3.22	67,800	212,727	3.14
Walworth	18,544	58,553	3.16	22,000	68,890	3.13	25,800	79,811	3.09	30,200	91,768	3.04
Washington	17,385	63,167	3.63	25,300	89,937	3.55	33,800	116,344	3.44	42,300	141,468	3.34
Waukesha	61,935	226,776	3.66	80,200	286,491	3.57	98,700	349,457	3.54	117,800	412,149	3.50
Region	536,486	1,714,598	3.20	605,500	1,829,188	3.02	674,600	1,995,664	2.95	747,700	2,166,925	2.90

Source: U. S. Bureau of the Census and SEWRPC.

Table 262

POPULATION DISTRIBUTION IN THE REGION BY COUNTY: 1970-1978

County	1970	1977[a]	1978[a]	Change: 1970-1978	
				Number	Percent
Kenosha	117,917	125,655	125,808	7,891	6.69
Milwaukee	1,054,249	981,618	960,993	- 93,256	- 8.85
Ozaukee	54,461	67,866	69,914	15,453	28.37
Racine	170,838	178,164	177,337	6,499	3.80
Walworth	63,444	68,589	69,058	5,614	8.85
Washington	63,839	80,367	83,282	19,443	30.46
Waukesha	231,335	275,640	285,100	53,765	23.24
Region	1,756,083	1,777,899	1,771,492	15,409	0.88

[a] *Wisconsin Department of Administration final estimates.*

Source: U. S. Bureau of the Census, Wisconsin Department of Administration, and SEWRPC.

Table 263

COMPARISON OF THE FORECAST AND ESTIMATED POPULATION: 1978

County	1978 Population		Change (estimate-forecast)	
	Forecast	Estimate	Number	Percent
Kenosha	134,640	125,808	- 8,832	- 6.56
Milwaukee	1,020,020	960,993	- 59,027	- 5.79
Ozaukee	71,840	69,914	- 1,926	- 2.68
Racine	182,320	177,337	- 4,983	- 2.73
Walworth	72,420	69,058	- 3,362	- 4.64
Washington	85,460	83,282	- 2,178	- 2.55
Waukesha	280,260	285,100	4,840	1.73
Region	1,846,960	1,771,492	- 75,468	- 4.09

Source: Wisconsin Department of Administration and SEWRPC.

Economic activity is often highly related to the degree of industrialization occurring within an area, since many large industries are labor-intensive. The change in economic activity in the Region, therefore, may be used as an indicator of the change in the level of industrial process throughput and, consequently, in the level of air pollutant emissions from point sources. Employment patterns in the Region, as a surrogate measure of economic activity, thus have particularly important implications for long-range air quality planning.

The anticipated employment levels in the Region for selected years between 1970 and 2000 are shown by county in Table 264 and Figure 96. As may be seen in Table 264, regional employment is expected to increase to 833,000 jobs by 1980, to 924,500 jobs by 1990, and to 1,016,000 jobs by 2000. The year 2000 regional employment forecast thus represents an increase of about 274,000 jobs, or approximately 37 percent, over the 1970 employment level. This indicates an annual average increase of 9,150 jobs, or 1.2 percent, over the 30-year period.

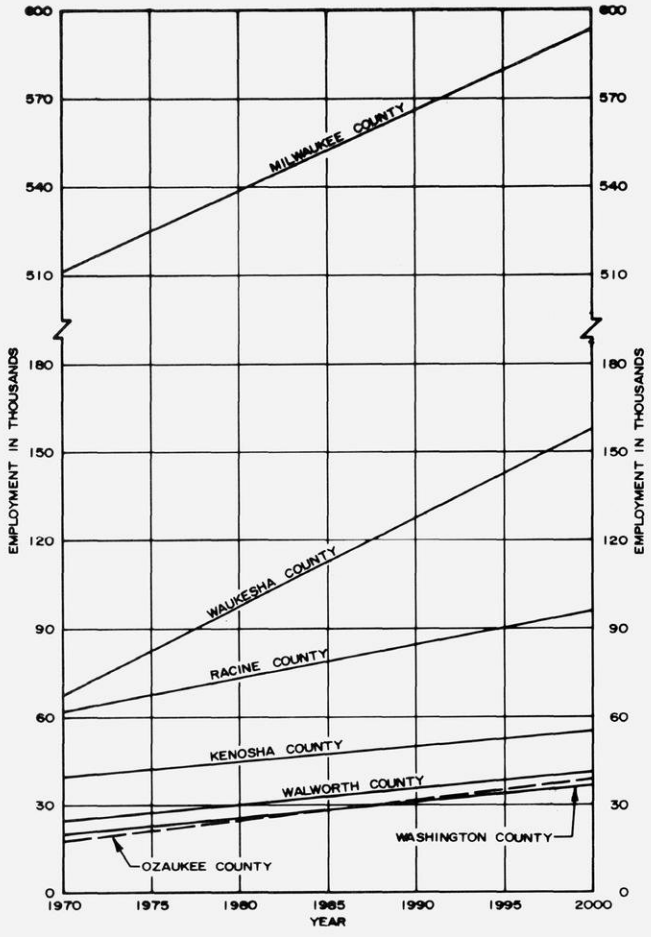
Milwaukee and Waukesha Counties are expected to have the largest absolute increases in employment—82,700 and 90,200 jobs, respectively—while Kenosha and Washington Counties are expected to have the smallest absolute increases—15,100 and 15,700 jobs, respectively. The largest relative rates of employment growth are expected in Ozaukee and Waukesha Counties—112 percent and 134 percent, respectively—while the smallest relative rate of employment growth, 16 percent, is expected in Milwaukee County. Employment in Milwaukee County is expected to decline in relation to the regional total, reflecting a continued decentralization of economic activity from the highly urbanized areas of the Region. While Milwaukee County's employment is expected to increase from 510,900 jobs in 1970 to 593,600 jobs in the year 2000, the County's share of total regional jobs is expected to decline from 69 percent to 58 percent.

The proportion of regional jobs in Waukesha County is expected to increase from 67,200 jobs, or 9 percent of total regional employment in 1970, to 157,400 jobs, or 15 percent of total regional employment in the year 2000. Meanwhile, Ozaukee, Racine, Walworth, and Washington Counties are all expected to experience increases in their share of the regional employment of from slightly less than 1 percent to slightly more than 1 percent between 1970 and 2000, and Kenosha County is expected to maintain its share of the regional employment at about 5 percent over the forecast period.

These expected trends in county employment between 1970 and 2000 are generally consistent with expected population increases, which reflect an overall decentralization of population and economic activity from the established urban areas of the Region to suburban and rural locations. This phenomenon is not unique to the Southeastern Wisconsin Region, but is now characteristic of many of the older established urbanized areas of the nation. It should be emphasized that the forecasts reflect the use of certain documented data and certain assump-

Figure 96

FORECAST EMPLOYMENT LEVELS IN THE REGION BY COUNTY: 1970-2000



Source: SEWRPC.

Table 264

EXISTING AND FORECAST REGIONAL EMPLOYMENT BY COUNTY: 1970-2000

County	Existing 1970	Forecast 1980	Forecast 1990	Forecast 2000	Change: 1970-2000 Number	Change: 1970-2000 Percent
Kenosha	39,200	44,200	49,300	54,300	15,100	38.5
Milwaukee	510,900	538,400	566,000	593,600	82,700	16.2
Ozaukee	17,900	24,600	31,300	38,000	20,100	112.3
Racine	61,900	73,100	84,300	95,500	33,600	54.3
Walworth	24,200	29,900	35,500	41,200	17,000	70.2
Washington	20,300	25,500	30,800	36,000	15,700	77.3
Waukesha	67,200	97,300	127,300	157,400	90,200	134.2
Region	741,600	833,000	924,500	1,016,000	274,400	37.0

Source: SEWRPC.

tions and judgments concerning trends in economic activity within the Region. As new data reveal new trends, revisions will undoubtedly have to be made to the forecasts in order to maintain their usefulness. Furthermore, the forecasts presented do not take into account variations caused by short-term business cycles or any unpredictable economic dislocation. The use of such forecasts in regional air quality maintenance planning, therefore, is necessarily limited to providing a general estimate of the trend toward growth or decline in certain industry groups and, within the constraints defined above, to quantifying the changes in industrial process throughput which may be expected by the year 2000 under conditions presently envisioned. As the economic forecast is revised, forecast air pollutant emissions from point sources will summarily have to be revised.

As presently forecast, employment by major industry groups to the year 2000 is shown in Table 265 and Figure 97. Between 1970 and 2000, employment in the trade, government and education services and private services groups may be expected to show relative increases greater than the regional employment increase of 37 percent. Manufacturing, while increasing at a rate approximately 10 percent below the regional employment rate increase, may be expected to continue to be the largest employment group with 320,300 jobs, or about 32 percent of the total regional employment, in the year 2000. Private services may be expected to constitute the second largest employment group with 276,800 jobs, or about 27 percent of the total regional employment, in the year 2000. Only one industry group—agriculture—is expected to decline in employment between 1970 and the year 2000. As may be seen in Table 265, agricultural employment in the Region is expected to decrease by 3,100 jobs, or 29 percent—from 10,600 jobs in 1970 to 7,500 jobs in the year 2000. This expected decline in agricultural employment in the Region is a continuation of an established trend and is due in part to the mechanization of farming processes, but more importantly to the loss of farmland in the Region through the conversion of land from agricultural to urban use.

Generally, the rapid increases in employment expected in the service and other consumer-oriented industry groups, and the corresponding slower rates of employment growth expected in the manufacturing industry groups to the year 2000, are continuations of already established trends. These trends represent a change in the orientation of the regional economy over the past 20 years and were probably brought about by the maturation of the Region's manufacturing base and subsequent increases in consumer spending for services and retail goods. It should be noted, however, that recently enacted business and industry tax changes in Wisconsin, which are intended to provide investment incentives, especially to manufacturing industries, may encourage existing manufacturing industries to expand and new manufacturing industries to locate in the Region.

The manufacturing industry group not only represents the largest single regional employer but also accounts for more point sources of air pollutant emissions than any other industry group. A breakdown of forecast employment levels by major manufacturing industry group is presented in Table 266 and Figure 98. As may be seen in Table 266 and Figure 98, the largest relative increase in employment from 1970 to the year 2000 is expected in the fabricated metals industry. The forecast employment level in this industry is expected to increase by 16,800 jobs, or by 68 percent—from 24,600 jobs in 1970 to 41,400 jobs in the year 2000. The expected

Table 265

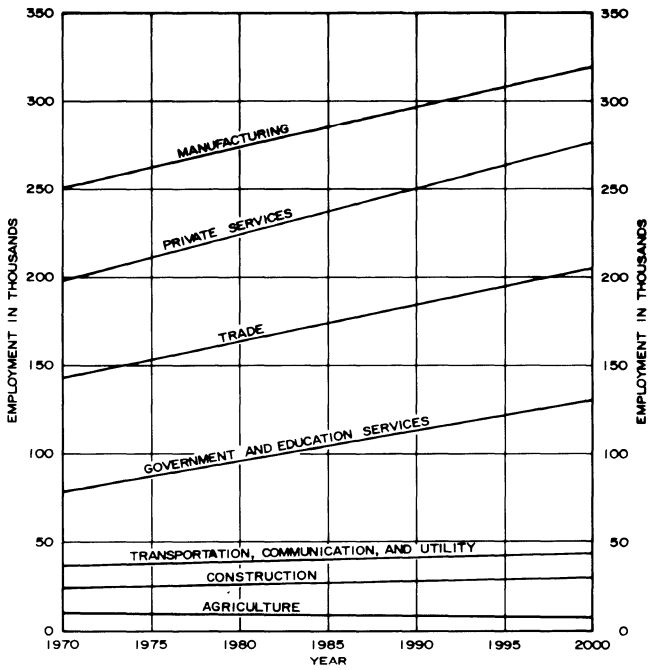
FORECAST EMPLOYMENT LEVELS IN THE REGION BY MAJOR INDUSTRY GROUP: 1970, 1980, 1990, AND 2000

Major Industry Group	Employment (in thousands)				Change 1970-2000	
	1970	1980	1990	2000	Number	Percent
Agriculture	10.6	9.5	8.3	7.5	- 3.1	- 29.2
Construction	24.0	26.0	28.0	30.1	6.1	25.4
Manufacturing	251.0	274.1	297.2	320.3	69.3	27.6
Trade	143.2	164.3	185.4	206.4	63.2	44.1
Transportation, Communication, and Utilities	36.0	38.5	41.2	43.7	7.7	21.4
Private Services	198.1	224.4	250.7	276.8	78.7	39.7
Governmental and Educational Services	78.7	96.2	113.7	131.2	52.5	66.7
Total	741.6	833.0	924.5	1,016.0	274.4	37.0

Source: SEWRPC.

Figure 97

FORECAST EMPLOYMENT LEVELS IN THE REGION BY MAJOR INDUSTRY GROUP: 1970-2000



Source: SEWRPC.

growth in employment in the fabricated metals industry is based on an increasing demand for such products as metal cans and containers used in food packaging.

The printing and publishing industry shows the next largest relative employment increase from 1970 to the year 2000. Employment in this industry is expected to increase by 8,400 jobs, or by 56 percent—from 14,900 jobs in 1970 to 23,300 jobs in the year 2000. The anticipated growth in this industry may be expected to be stimulated by increases in the number of households, rising educational attainment levels, and increased demands for paper products and publications from the business and government sectors.

The primary metals industry is expected to show an employment increase of 9,900 jobs, or 44 percent, by the year 2000—from 22,500 jobs in 1970 to 32,400 jobs in the year 2000. This expected increase in employment is based upon a projected 3 percent annual increase in the demand for primary metal products, such as ferrous castings, through the 1970's.

The Region's largest manufacturing employer—nonelectrical machinery and equipment—is expected to show an increase of 23,800 jobs, or 35 percent, by the year 2000—from 68,100 jobs in 1970 to 91,900 jobs in the year 2000. Nationally, growth in the output of this industry is projected to range from 5 to 6 percent annually through the 1970's. In addition, national employment projections in this industry show an annual rate of growth of 1.5 percent to the year 2000. Within the Region, the nonelectrical machinery industry has shown locational disadvantages, and the Region has not participated significantly in the rapidly growing computer industry. Thus, increases in regional employment in this industry are considered to be relatively modest.

One industry group—food and related products—is expected to experience a decline in employment between 1970 and 2000. This industry is expected to show absolute declines in employment of 1,300 employees, or 7 percent—from 18,900 jobs in 1970 to 17,600 jobs in the year 2000. The forecast decline in this industry is based on employment trends in the Region which show slow but steady declines in employment over the past two decades. In addition, many of the processes involved in food processing, such as those used in the brewing industry, are becoming highly mechanized. This forecast level represents a virtual stabilization of employment in this industry over the next two decades.

Recent Trends

As already noted, recent trends in economic activity within the Region indicate that employment within the Region is increasing at a faster rate than envisioned in the forecasts (see Table 267 and Figure 99). The 1977 employment level of the Region was anticipated to total 805,600 jobs. However, the number of jobs existing within the Region in 1977 was estimated at 835,100—29,500 jobs, or 3.5 percent, more than forecast. As shown in Table 268, most of the difference occurs in Milwaukee County, where the current estimate is nearly 21,800 jobs greater than forecast.

LAND USE DEVELOPMENT IN THE REGION: 1970-2000

A fundamental and basic consideration in any air quality attainment and maintenance planning effort is the probable future land use pattern of the planning area. The future density and distribution of the various urban and rural land uses determine to a large extent the character, magnitude, and distribution of air pollutant emissions and the practicality of, as well as the need for, various air quality management measures. Under the Commission's approach, the assessment of probable future land use patterns for air quality attainment and maintenance planning is based upon a normative land use plan.

In a planning effort conducted concurrently with the areawide air quality attainment and maintenance planning effort, the Commission prepared and on December 19, 1977, adopted a new regional land use plan for the design year 2000. This plan is set forth in SEWRPC Planning Report No. 25, A Regional Land Use Plan and a Regional Transportation Plan for Southeastern Wisconsin: 2000, Volume One, Inventory Findings, and Volume Two, Alternative and Recommended Plans. In addition, the Commission prepared and adopted on December 1, 1977, a regional park and open space plan, also for the design

Table 266

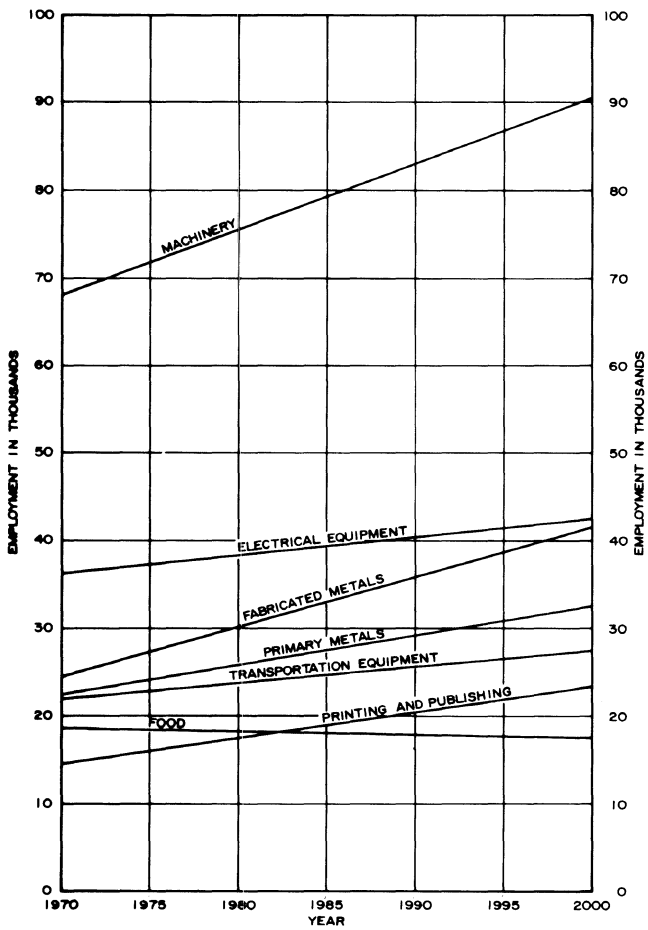
FORECAST MANUFACTURING EMPLOYMENT LEVELS IN THE REGION BY MANUFACTURING INDUSTRY GROUP: 1970, 1980, 1990, AND 2000

Manufacturing Industry Group	Employment (in thousands)				Change 1970-2000	
	1970	1980	1990	2000	Number	Percent
Food and Related Products	18.9	18.5	18.1	17.6	- 1.3	- 6.9
Printing and Publishing	14.9	17.7	20.5	23.3	8.4	56.4
Primary Metals	22.5	25.8	29.1	32.4	9.9	44.0
Fabricated Metals	24.6	30.2	35.8	41.4	16.8	68.3
Machinery	68.1	76.0	83.9	91.9	23.8	34.9
Electrical Equipment	36.5	38.5	40.5	42.6	6.1	16.7
Transportation Equipment	22.0	23.9	25.8	27.6	5.6	25.4
Miscellaneous Manufacturing	43.5	43.5	43.5	43.5	- -	- -
Total	251.0	274.1	297.2	320.3	69.3	27.6

Source: SEWRPC.

Figure 98

FORECAST MANUFACTURING EMPLOYMENT LEVELS IN THE REGION BY MANUFACTURING INDUSTRY GROUP: 1970-2000



Source: SEWRPC.

Table 267

EMPLOYMENT DISTRIBUTION IN THE REGION BY COUNTY: 1970, 1976, AND 1977

County	1970	1976	1977	Change 1970-1977	
				Number	Percent
Kenosha	39,200	43,200	44,300	5,100	13.0
Milwaukee	510,900	539,800	552,000	41,100	8.0
Ozaukee	17,900	22,800	23,400	5,500	30.7
Racine	61,900	70,100	72,600	10,700	17.3
Walworth	24,200	28,500	28,400	4,200	17.4
Washington	20,300	23,600	24,200	3,900	19.2
Waukesha	67,200	87,200	90,200	23,000	34.2
Region	741,600	815,200	835,100	93,500	12.6

Source: SEWRPC.

Table 268

COMPARISON OF FORECAST AND ESTIMATED REGIONAL EMPLOYMENT: 1977

County	1977 Employment		Change (estimate-forecast)	
	Forecast	Estimate	Number	Percent
Kenosha	42,700	44,300	1,600	3.6
Milwaukee	530,200	552,000	21,800	3.9
Ozaukee	22,600	23,400	800	3.4
Racine	69,700	72,600	2,900	4.0
Walworth	28,200	28,400	200	0.7
Washington	23,900	24,200	300	1.2
Waukesha	88,300	90,200	1,900	2.1
Region	805,600	835,100	29,500	3.5

Source: SEWRPC.

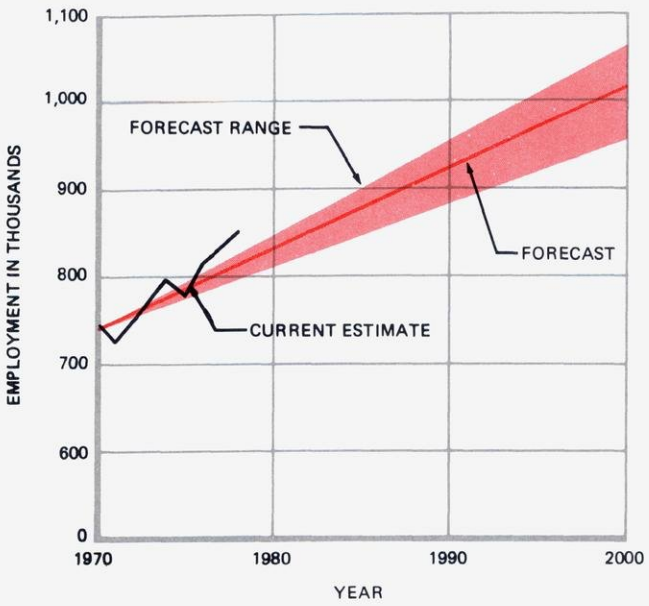
year 2000. This plan, which is set forth in SEWRPC Planning Report No. 27, A Regional Park and Open Space Plan for Southeastern Wisconsin: 2000, refines and details the land use plan with respect to the reservation of park and open space areas, which has important implications for air quality planning. Because of the basic importance of the land use plan to air quality maintenance planning, a brief description of this plan is provided herein.

Basic Land Use Development Concepts

The adopted design year 2000 land use plan for the Southeastern Wisconsin Region is shown in graphic summary form on Map 86. The regional land use plan seeks to centralize land use development within the Region to the greatest degree practicable; to encourage new urban development to occur at densities consistent with the provision of public centralized sanitary sewer, water supply, and urban mass transit facilities and services; to encourage new development to occur only in areas covered by soils well suited to urban use and not subject to special hazards, such as flooding; and to encourage new urban development and redevelopment to occur in areas in which essential urban facilities and services are available—particularly the existing urban centers of the Region—or into which such facilities and services can be readily and economically extended. While the plan recognizes the importance of the urban land market in determining the location, intensity, and character of future development within the Region, it proposes to regulate to a greater degree than in the past the effect of this market on development in order to promote a more orderly and economic settlement pattern; to avoid further intensification of the existing, and the creation of new, areawide developmental and environmental problems; and to generally channel the results of market forces into better conformance with sound areawide land use development objectives.

Figure 99

ESTIMATED AND FORECAST EMPLOYMENT IN THE REGION: 1970-2000



Source: SEWRPC.

Urban Land Use and Density

The adopted land use plan for the Region is designed to accommodate the forecast year 2000 resident population of about 2.22 million persons and the forecast year 2000 regional employment level of about 1.02 million jobs. This increase in population and employment would be accommodated by the in-filling of existing urban areas and by the conversion of about 113 square miles of land from rural to urban use by the year 2000. This proposed conversion is substantially less than the 235 square miles of land which would be converted from rural to urban use under a continuation of the existing trends toward decentralization of urban development within the Region. The degree of centralization envisioned in the new plan is indicated by the fact that more than 60 percent of all new urban residential land and about 49 percent of the incremental resident population increase would be located within 20 miles of the central business district of the City of Milwaukee. The plan envisions that new urban development would occur primarily in planned neighborhood units at medium-density population levels; that is, at about four dwelling units per net residential acre, or about 5,000 persons per gross square mile. In this respect, the plan is fully consistent with recently promulgated national urban policy.

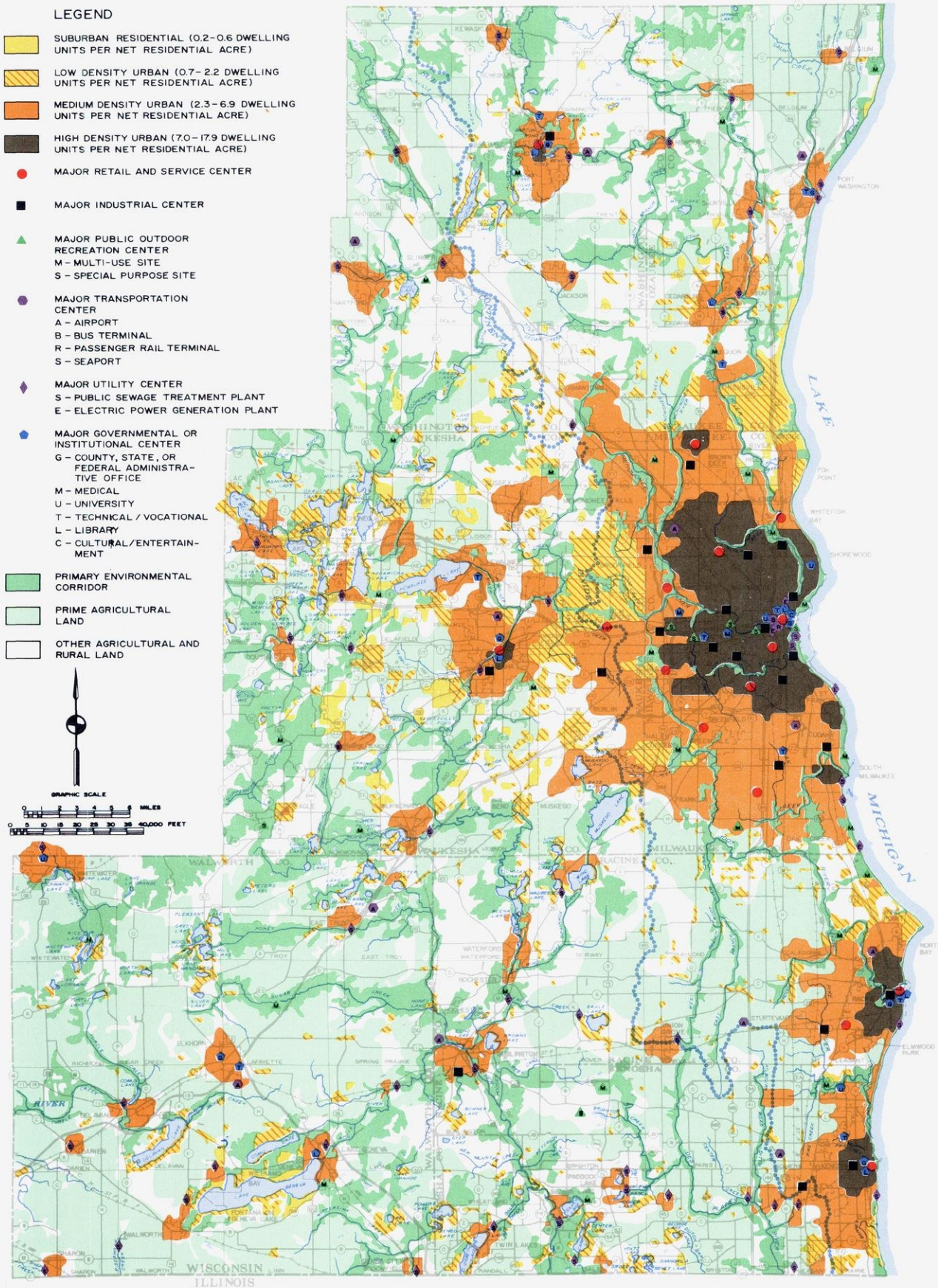
Two staging periods, the first ending in 1985 and the second in 2000, are incorporated into the regional land use plan to facilitate its implementation, to ensure that the conversion of rural land to urban use will occur in such a fashion as to stem the proliferation of scattered low-density urban development, and to facilitate functional planning in such areas as transportation, water pollution abatement, and air quality maintenance. The first staging period represents a period of proposed "in-filling"; that is, of intensifying residential land use in already platted and partially developed areas of the Region. The second staging period emphasizes new urban development as necessary to meet the new population and employment growth within the Region. As adopted, the land use plan for the Region at the end of the first staging period, 1985, is shown on Map 87; and at the end of the second stage, the year 2000, on Map 86. The adopted land use plan is quantitatively summarized for 1985 and 2000 in Table 269. A brief discussion of the changes in the major land use categories in the Region which may be expected under the adopted land use plan by the year 2000 follows.

Residential Development

The adopted land use plan proposes that about 60,900 acres be added to the existing stock of residential land within the Region in order to meet the additional housing needs forecast for the Region for the plan design year. As indicated in Table 269, the plan proposes an additional 38,600 acres of urban residential land—that is, residential land to be developed at high, medium, low, or suburban density—and an additional 22,300 acres of rural residen-

Map 86

ADOPTED REGIONAL LAND USE PLAN FOR SOUTHEASTERN WISCONSIN: 2000

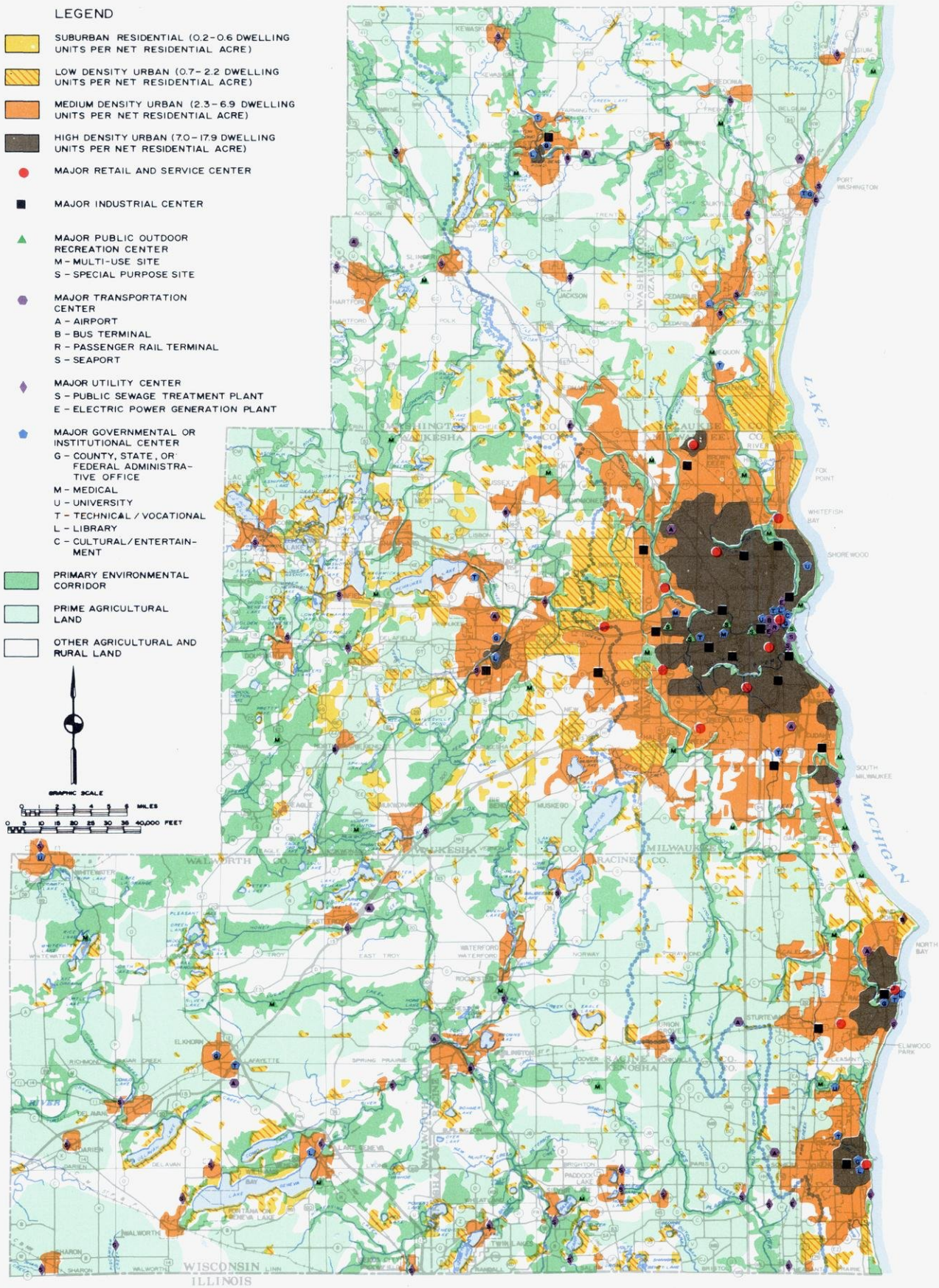


The recommended regional land use plan envisions converting about 113 square miles of land from rural to urban use over the period 1970 to 2000 to accommodate the forecast 463,000-person increase in the regional population expected over this time period. The degree of centralization of the recommended plan is indicated by the fact that over 60 percent of all new urban residential land and about 49 percent of the incremental resident population would be located within 20 miles of the central business district of the City of Milwaukee. Even with this emphasis on centralization of land use development, the average population density of the developed urban area of the Region would decline from about 4,350 persons per square mile in 1970 to about 3,500 persons per square mile in the year 2000.

Source: SEWRPC.

Map 87

ADOPTED REGIONAL LAND USE PLAN FOR SOUTHEASTERN WISCONSIN: 1985 STAGE



By 1985 it is expected that the regional population will increase by about 200,000 persons over the 1970 level and that an additional area of 53 square miles will have to be converted from rural to urban use to bring the total land in urban use within the Region to more than 565 square miles. It is also envisioned that by 1985 proposed new major commercial facilities would be provided in the Cities of Milwaukee and Racine and that proposed new industrial centers would be fully developed in the Cities of Milwaukee, Waukesha, and Oak Creek.

Source: SEWRPC.

tial land, or very-low residential development, on lot sizes exceeding five acres. Most of the additional housing required in the Region by the year 2000 would be developed in urban residential areas, predominantly at medium density. A typical single-family lot size would be one-quarter acre and a typical multiple-family development would average about 10 dwelling units per net acre. While rural residential development accounts for a substantial proportion, 37 percent, of the total proposed increase in residential land, such development would accommodate only a small proportion, approximately 10 percent, of the incremental population because of the large lot size involved.

Waukesha County is expected to experience the largest increase in urban residential land—13,700 acres—under the adopted land use plan. Milwaukee County would also experience a relatively large increase in urban residential land, approximately 7,900 acres. In fact, more than one-half of the total increase in urban residential land in the Region would occur in Waukesha and Milwaukee Counties. The smallest increase in urban residential land among the seven counties in the Region would occur in Walworth County, where an increase of approximately 2,000 acres is planned.

In addition to experiencing the largest increase in urban residential land, Waukesha County would experience the largest increase in rural residential land—approximately 8,300 acres—while Washington County would experience the second largest increase—about 7,300 acres. In comparison, the amount of rural residential development proposed in each of the other five counties is small, less than 2,200 acres, with no rural residential land proposed in Milwaukee County whatsoever.

Commercial Development

The adopted land use plan proposes the development of approximately 700 acres of new commercial land within the Region over the plan design period, increasing the total stock of commercial land in the Region to more than 7,200 acres by the year 2000. This development would meet the anticipated increases in retail and service employment and the demands of a growing population within the Region, and would be distributed so as to make the operation of business and the provision of goods and services to the people of the Region both efficient and convenient. It is proposed that this increase be accomplished through the development of planned, integrated commercial centers properly located near existing and proposed transportation system and residen-

Table 269

EXISTING AND PROPOSED LAND USE IN THE REGION: 1970, 1985, AND 2000 ADOPTED LAND USE PLAN

Land Use Category	Existing 1970		1985 Plan Stage				2000 Plan Stage					
			Planned Increment 1970-1985		Total 1985		Planned Increment 1985-2000		Planned Increment 1970-2000		Total 2000	
	Acres	Percent of Major Category	Acres	Percent Change	Acres	Percent of Major Category	Acres	Percent Change	Acres	Percent Change	Acres	Percent of Major Category
Urban Land Use												
Residential												
Urban High Density	24,389	7.4	152	0.6	24,541	6.8	219	0.9	371	1.5	24,760	6.2
Urban Medium Density	37,092	11.3	16,846	45.4	53,938	14.9	24,200	44.9	41,046	110.7	78,138	19.5
Urban Low Density	72,701	22.2	- 5,663	- 7.7	67,038	18.5	- 2,026	- 3.0	- 7,689	- 10.6	65,012	16.2
Suburban Density	22,079	6.7	5,647	25.6	27,726	7.7	- 785	- 2.8	4,862	22.0	26,941	6.7
Subtotal	156,261	47.6	16,982	10.9	173,243	47.9	21,608	12.5	38,590	24.7	194,851	48.6
Commercial	6,517	2.0	362	5.6	6,879	1.9	336	4.9	698	10.7	7,215	1.8
Industrial	10,038	3.1	3,542	35.3	13,580	3.7	3,130	23.0	6,672	66.5	16,710	4.2
Governmental and Institutional	16,628	5.1	324	1.9	16,952	4.7	627	3.7	951	5.7	17,579	4.4
Transportation, Communication, and Utilities[a]	109,430	33.4	10,690	9.8	120,120	33.2	10,751	9.0	21,441	19.6	130,871	32.7
Recreational	28,982[b]	8.8	2,293[c]	7.9	31,275	8.6	1,873[c]	6.0	4,166[c]	14.4	33,148	8.3
Urban Land Use Subtotal	327,856	100.0	34,193	10.4	362,049	100.0	38,325	10.6	72,518	22.1	400,374	100.0
Rural Land Use												
Residential	--[d]	--	8,165	--	8,165	0.6	14,141	173.2	22,306	--	22,306	1.7
Agricultural	1,040,119	74.7	- 35,090	- 3.4	1,005,029	73.9	- 44,689	- 4.5	- 79,779	- 7.7	960,340	72.7
Other Open Lands[e]	353,125	25.3	- 7,268	- 2.1	345,857	25.5	- 7,777	- 2.2	- 15,045	- 4.3	338,080	25.6
Rural Land Use Subtotal	1,393,244	100.0	- 34,193	- 2.5	1,359,051	100.0	- 38,325	- 2.8	- 72,518	- 5.2	1,320,726	100.0
Total	1,721,100	--	--	--	1,721,100	--	--	--	--	--	1,721,100	--

[a] *Includes off-street parking uses.*

[b] *Includes net site area of public and nonpublic recreation sites.*

[c] *Includes only that net site area recommended for public recreational use.*

[d] *Included in land use inventory as part of urban residential land use.*

[e] *Includes woodlands, water, wetlands, unused lands, and quarries.*

Source: SEWRPC.

tial areas; through the discouragement of strip commercial development along major streets and highways; through the encouragement of the provision of adequate off-street parking and loading facilities; and through the efficient provision of adequate utility services.

There were 12 major commercial centers in the Region during 1970, as shown on Map 88. These 12 centers comprise a total of 390 acres of commercial land uses—excluding related off-street parking—and provide employment for more than 99,000 persons, or about 33 percent of the total retail and service employment in the Region. The adopted land use plan proposes to retain 11 of these 12 retail and service centers as major commercial areas through the year 2000 and, furthermore, proposes the expansion of certain of these centers. It is anticipated that, by the year 2000, the 11 existing major commercial centers which are retained under the adopted land use plan would provide employment for an additional 8,000 persons.

As may be seen on Map 88, five new major commercial centers are proposed for development. These new centers would provide employment for more than 20,000 persons and would be located in the Cities of Milwaukee, Oak Creek, Racine, Waukesha, and West Bend. Each of these new centers would serve a market area of 100,000 persons or more, have a net site area of at least 20 acres, and contain a full range of commercial and service enterprises necessary to serve the surrounding trade area. In addition to these five new major centers, the adopted plan provides for more than 400 additional acres of commercial and service land for neighborhood and community commercial development. This new neighborhood and community commercial area, together with the area in such existing uses, would provide employment for nearly 308,000 persons by the year 2000, an increase of 49 percent over the employment level for neighborhood and community commercial areas in 1972.

Industrial Development

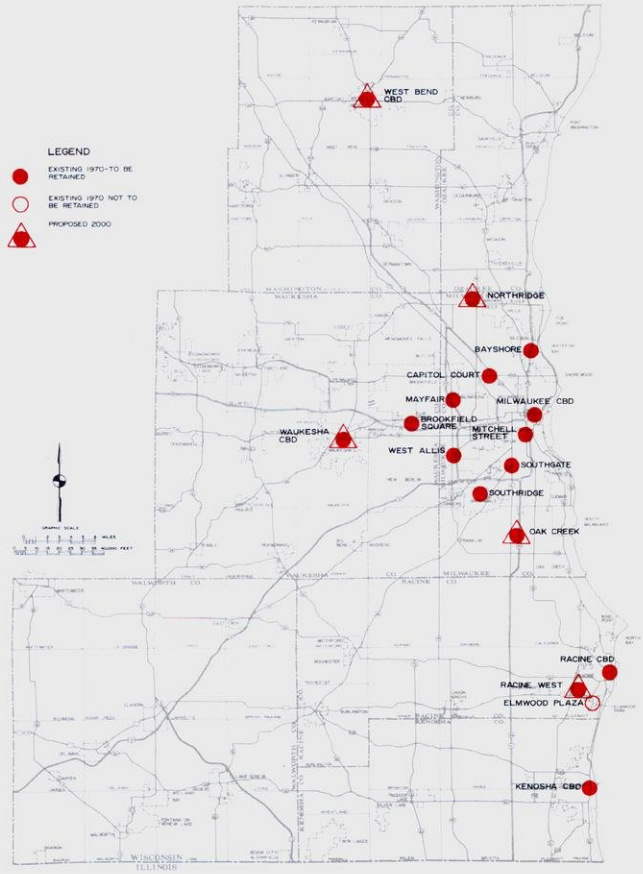
The adopted land use plan proposes that more than 6,600 acres of industrial land be added in the Region by the year 2000, increasing the total stock of such land to more than 16,700 acres by the plan design year. This increase would meet the land requirements of the forecast manufacturing and wholesaling employment within the Region, and would be distributed so as to protect and enhance the most important components of the economic base of the Region. This increase is proposed to be accomplished through the development of planned industrial centers properly located near existing and proposed transportation system facilities; through the protection and enhancement of existing industrial areas; and through the efficient provision of adequate utility services. The plan provides adequate sites for industrial development which meet the full array of criteria for such development, including ready access to high-speed, all-weather arterial highway facilities; soils which are suitable for industrial development; adequate power and water supply; sanitary sewer service and storm water drainage; reasonable access to airport and railway facilities; and ready access to labor supply.

As shown on Map 89, there were 17 major industrial centers within the Region in 1970. These 17 centers encompassed a total area of about 4,000 acres, excluding off-street parking, and provided employment for about 179,000 persons, or about 60 percent of the total regional employment in the manufacturing and wholesaling industries. The adopted land use plan proposes that these 17 centers be retained as major industrial areas through the year 2000, and furthermore proposes the expansion of certain of these existing centers. Under the plan, it is anticipated that the 17 major industrial areas will provide employment for about 198,000 persons by the year 2000, an increase of about 10 percent over the estimated 1972 employment level.

As may also be seen on Map 89, the plan proposes that five new major industrial centers be added within the Region by the year 2000. These centers would be located in or near the Cities of Burlington, Kenosha, Milwaukee, Oak Creek, and Waukesha, and provide employment for more than 41,000 persons by the plan design year. These five new centers would comprise an area of at least 250 acres and would be developed according to an integrated plan for use by a community of industries.

Map 88

MAJOR RETAIL AND SERVICE CENTERS IN THE REGION 2000 ADOPTED LAND USE PLAN



The recommended land use plan envisions that 16 major retail and service centers will be provided to serve the needs of the Region through the year 2000. Twelve of these centers existed in 1970, 11 of which are to be retained. Five are proposed new centers. The proposed new centers have a minimum gross site area of 70 acres each and are to be located in or near the Cities of Milwaukee, Oak Creek, Racine, West Bend, and Waukesha.

Source: SEWRPC.

In addition to providing for new major industrial areas, the plan provides for more than 2,700 acres of new industrial land for smaller industrial areas within local communities. The new industrial area, together with the existing local industrial areas, would employ more than 159,000 persons by the year 2000, an increase of 32 percent over the estimated 1972 employment level.

Governmental and Institutional Land Use

As indicated in Table 269, the adopted land use plan proposes that 951 acres of new governmental and institutional land be added to the existing stock of such land within the Region, which would result in a total of about 17,600 acres of governmental and institutional land in the year 2000. Most of the additional governmental and institutional lands proposed would be of neighborhood and community, rather than major regional, significance. Specifically, of the additional 951 acres of governmental and institutional land, 897 acres would be developed for such neighborhood and community uses as new schools, hospitals, and churches; for public facilities including police and fire stations; and for city, village, and town halls. The remaining 54 acres would be developed as major governmental centers including county seats, state and federal office buildings, and medical complexes, along with major institutional centers including universities, technical schools, libraries, and cultural centers.

Transportation, Communication, and Utility Land Use

As indicated in Table 269, the adopted land use plan proposes that approximately 21,400 acres of new transportation, communication, and utility land be added to the existing stock of such land within the Region by the year 2000. A total of about 130,900 acres of land in the Region would, therefore, be devoted to transportation, communication, and utility uses by the plan design year, an increase of about 20 percent over the 1970 level.

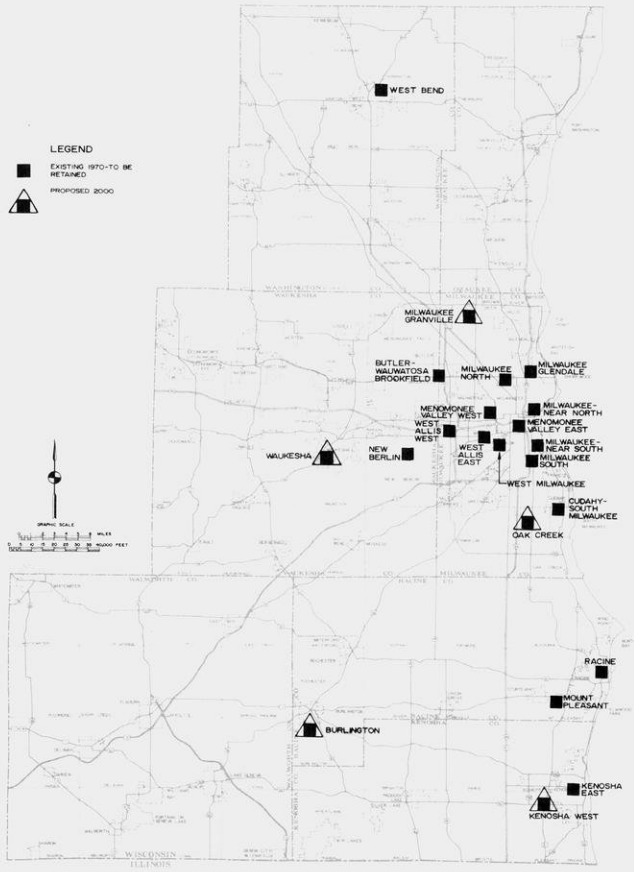
Under the plan, the land for major transportation centers—including major bus and rail terminals and major airports—and for major utility plants—including public sewage treatment plants and electric power generation plants—would increase from about 3,500 acres in 1970 to almost 6,700 acres by the year 2000, primarily to accommodate airport expansion recommended as a part of the regional airport system plan and the construction or expansion of sewage treatment plants recommended under the regional sanitary sewerage system plan. In addition to the foregoing major transportation and utility land uses, the plan calls for the provision of about 18,300 additional acres of land for other transportation, communication, and utility uses in the Region by the year 2000. Most of this additional land would be required for rights-of-way for new and improved arterial, collector, and minor streets needed to serve new land use development or to provide adequate transportation service to existing urban development.

Open Space-Recreational Land Use

Under the adopted land use plan, about 3,300 acres of land would be added to the existing stock of gross recreational land. This represents an increase of about 6 percent over the 1973 acreage. In 1973 there were about 16.3 acres of public park and outdoor recreation land per thousand population in the Region. The proposed increment of about 3,300 acres of public parkland would be needed to serve the expanded regional population, and would result in a slight decrease in the number of acres of public parkland per thousand population by the year 2000; there would be 14.6 acres per thousand population. It should be noted, however, that the amount of public parkland provided under the adopted land use plan would still exceed the Commission-recommended standard for this use of 14.0 acres per thousand population.

Map 89

MAJOR INDUSTRIAL CENTERS IN THE REGION 2000 ADOPTED LAND USE PLAN



The recommended land use plan envisions that 22 major industrial centers will be provided to serve the needs of the Region through the year 2000. Seventeen of these centers existed in 1970 and are to be retained and enlarged while five are proposed new centers. The five proposed new centers, each having a minimum gross site area of 320 acres, are Burlington, Kenosha-West, Milwaukee-Granville, Oak Creek, and Waukesha.

Source: SEWRPC.

With the addition of the proposed 3,300 acres of public parkland, there would be a total of 29 major parks in southeastern Wisconsin by the plan design year. Moreover, the plan would expand by 983 acres the gross area devoted to other public outdoor recreational uses, including major special-use outdoor recreation sites and neighborhood parks.

Open Space-Environmental Corridors

The adopted land use plan proposes that none of the net primary environmental corridor area be developed except to accommodate compatible park and outdoor recreation land uses, since maintenance of environmental corridor lands in a natural state is considered vital to the protection of the natural resource base and to the maintenance of the overall quality of the regional environment. Of the total net corridor area of about 322,000 acres, more than 42,000 acres, or about 13 percent, are covered by surface water. The balance of 280,000 acres of net corridor lands, representing 16 percent of the total land area of the Region, is that corridor area requiring protection through appropriate public action—that is, through public acquisition or protection through appropriate land use controls including the use of rural estate residential zoning districts.

Open Space-Agriculture and Other Open Land Use

There were approximately 1,393,000 acres, or 2,177 square miles, of open land within the Region in 1970, including 1,040,000 acres of agricultural land and 353,000 acres of other open lands (see Table 269). In an urbanizing area such as the Southeastern Wisconsin Region, it is inevitable that the demands of a growing urban population will require some conversion of rural land to urban land. Under the adopted land use plan, the expansion of urban activities into presently rural areas would result in the conversion of about 72,500 acres, or about 113 square miles, of rural land to urban land uses between 1970 and the year 2000. This would be equivalent to an average annual rate of conversion of about 2,400 acres, or about 3.8 square miles. In addition to the conversion of rural land to urban land uses, about 22,300 acres, or 35 square miles, would be developed for rural estate use. Because of the very low density recommended, however, such rural estate development would maintain the basic natural state of the open land. Much of the urban expansion and rural estate development proposed under the adopted land use plan—79,800 acres—would take place on lands now in agricultural use and would result in a decrease of about 8 percent in the existing stock of agricultural land within the Region. Of the seven counties, the greatest decline in agricultural land—27,900 acres—would occur in Waukesha County. In Milwaukee County, expanding urban development would require the conversion of about 8,400 acres, or about 30 percent of the remaining agricultural acreage, to urban use by the year 2000. It is important to note that only those prime agricultural lands which were already committed to urban development because of their proximity to existing and expanding concentrations of urban uses and the prior commitment of heavy capital investments and utility extensions were recommended for conversion under the adopted plan.

As already noted, there were about 353,000 acres of other open lands in the Region in 1970, including woodlands, water, wetlands, quarries, and unused land. Under the adopted land use plan, about 15,000 acres, or about 4 percent of these lands, would be converted to urban use or to rural estate residential use by the year 2000. Most of this acreage, it should be mentioned, would consist of individual woodlots located directly in the path of urban growth. Most of these lots are of insufficient size or quality to warrant permanent preservation.

FORECAST TRANSPORTATION SYSTEMS DEVELOPMENT AND UTILIZATION IN THE REGION: 1972-2000

The development and utilization of transportation facilities within the Region over the next two decades are the most significant factors determining the magnitude and spatial distribution of air pollutant emissions from mobile sources within the Region, and, as such, are important considerations in planning for the attainment and maintenance of the national ambient air quality standards. Moreover, the transportation planning process itself may serve as a tool for achieving the attainment of these standards in the short-term, and their maintenance in the long-term.

In May 1978, the Commission completed a reevaluation of its initial regional land use and regional transportation system plans, adopted in 1966 for the plan design year 1990. In keeping with federal regulations concerning transportation system planning, and as dictated by good planning and engineering practice, the year 2000 was selected as the new plan design year in the reevaluation process in order to provide an approximately 20- to 25-year design period for major transportation facilities. During this plan reevaluation process, three transportation alternatives—a highway-intensive transit-supported alternative, a transit-intensive highway-supported alternative, and a "no build" alternative—were assessed under both a controlled centralization land use plan and a controlled decentralization land use plan for their impact on ambient air quality in the Region in the year 2000. This assessment indicated that the magnitude and spatial distribution of the ambient air pollutant concentrations under each of the six alternative plans were so similar as to preclude air quality considerations in the selection of one alternative plan over another. However, the analysis did identify potential violations of the particulate matter, hydrocarbon, and photochemical oxidant ambient air quality standards within the Region and an attendant need under any combination of land use and supporting transportation system plans to consider air quality management measures. A much more detailed analysis of the adopted transportation plan for the year 2000, particularly with regard to emission rates from forecast vehicle use, is presented later in this chapter.

The adopted transportation plan for the year 2000 as evolved from the extensive plan reevaluation process was staged to the year 1985 in order to coordinate regional transportation planning with regional air quality maintenance planning, as well as to facilitate plan implemen-

tation. Further, since one possible course of action would be to make no major improvements to the existing transportation system, a "do nothing," or "no build," alternative transportation plan was analyzed for the years 1985 and 2000. This "no build" alternative transportation plan for the design and staged years—which attempts to meet future travel demand using the existing arterial street and highway and mass transit facilities augmented only with those facilities planned or committed for implementation as of January 1, 1975—serves as a point of departure for investigating a range of transportation improvements which would not only meet the probable future travel demand in the Region, but also lead to improvements in ambient air quality.

The adopted regional transportation system plan for 1985 and the year 2000, along with the corresponding "no build" alternative for both the design and staged years, provides the forecasts of transportation facility capacity and utilization from which estimates of future air pollutant emissions from line sources and attendant ambient air quality can be computed. The transportation facility and utilization forecasts for 1985 and 2000 also serve as end points for the estimation of future line source emissions in intermediate years such as 1982 and 1987—years corresponding to the time period prescribed by Congress in the Clean Air Act Amendments of 1977 for the attainment of all prescribed ambient air quality standards. These emission estimates for intermediate years must be made through use of interpolative techniques in the absence of year-specific transportation forecasts. Because of their importance to sound regional air quality maintenance planning, therefore, selected data characterizing the development of the transportation system in the Region, and the utilization of that system, between 1972 and 2000 are presented and discussed in the following sections.[3]

Development of Surface Transportation Facilities

Surface transportation facilities, as considered in this section, are limited to arterial streets and highways, including freeways and expressways, collector and land access streets, and mass transit facilities.[4] The changes within each of these facility types as they have occurred or are proposed to occur between 1972 and 2000 are reviewed individually below.

Arterial Streets and Highways: The proposed additions and changes to the arterial street and highway system in the Region are summarized by county in Table 270 for the years 1985 and 2000 under both the adopted transportation plan and the "no build" alternative plan. As may be seen in Table 270, and as depicted on Map 90, the 1985 stage of the adopted transportation plan includes about 3,395 miles of arterial streets and highways in the Region, representing an increase of 386 miles, or nearly 13 percent, over the 1972 arterial system. Of the 386-mile increase, 93 miles would be in the form of new freeways.[5] Therefore, under the 1985 stage of the adopted transportation plan, freeways would comprise 255 miles, or about 8 percent, of the total arterial system, while standard arterials would comprise about 3,140 miles, or the remaining 92 percent, of the total arterial system.

As also indicated in Table 270, 81 miles of freeways and 50 miles of standard arterials would be added to the regional arterial system between 1985 and 2000. Thus, under the adopted transportation plan, the arterial street and highway system mileage would total 3,526 miles in the year 2000, of which 336 miles, or about 9 percent, would consist of freeways, and 3,190 miles, or 89 percent, would consist of standard arterials (see Map 91). By the year 2000, therefore, the freeway mileage in the Region would increase by about 174 miles, or about 107 percent, over the 1972 freeway mileage, and the standard arterial mileage would increase by about 343 miles, or about 12 percent, over the 1972 standard arterial mileage.

Under the "no build" alternative transportation plan all development of the regional arterial street and highway system would be completed prior to 1985, as indicated in Table 270. The "no build" alternative plan, shown on Map 92, would add only about 75 miles of committed freeways and 224 miles of committed standard arterials to the existing 1972 arterial system. The total arterial street and highway mileage under the "no build" alternative is approximately 3,310 miles, or about 97 percent of the 3,395 miles planned under the 1985 stage of the adopted plan, and 94 percent of the 3,526 miles proposed under the adopted transportation system plan for the year 2000.

Collector and Land Access Streets: The primary purpose of the collector street system is, as the name implies, to collect and distribute traffic to and from the land access streets, conveying such traffic to and from the arterial system. The primary purpose of the land access street system is, as the name implies, to provide vehicular access

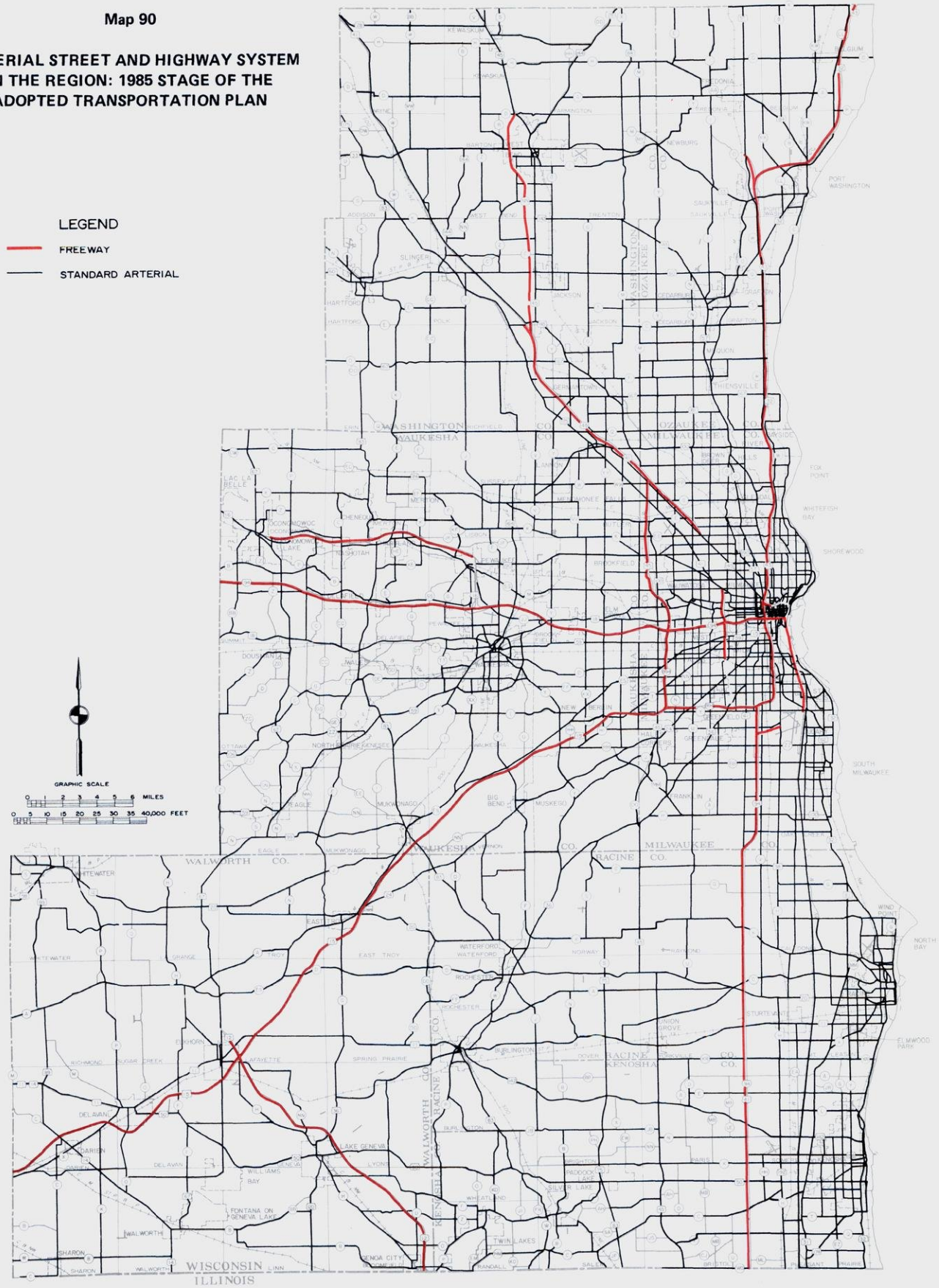
[3] *For a more detailed presentation of the recommended transportation plan for the Region for the year 2000, and of the alternatives analyzed, see SEWRPC Planning Report No. 25, A Regional Land Use Plan and a Regional Transportation Plan for Southeastern Wisconsin: 2000, Volume Two, Alternative and Recommended Plans.*

[4] *Other transportation facilities—including the railroad network and air and water transportation facilities in the Region—are discussed under the area source emissions forecasts presented later in this chapter.*

[5] *Of this total, 58.9 miles of new freeway have been opened to traffic as of January 1, 1979, including the Rock Freeway, the Daniel Hoan Bridge, the Airport Spur, IH 43, and USH 16.*

Map 90

ARTERIAL STREET AND HIGHWAY SYSTEM IN THE REGION: 1985 STAGE OF THE ADOPTED TRANSPORTATION PLAN

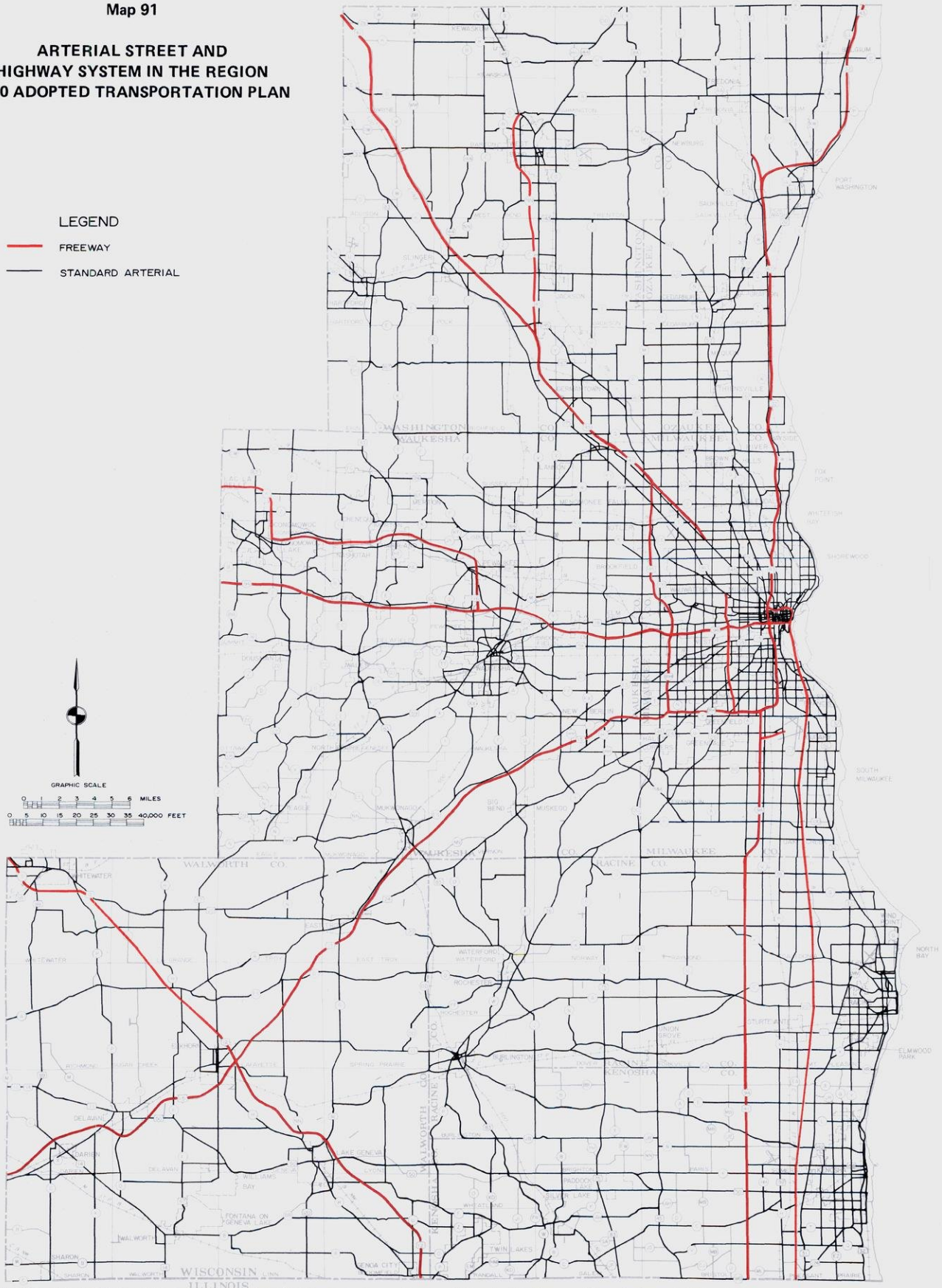


Under the 1985 stage of the adopted transportation plan, arterial street and highway system mileage within the Region would total about 3,395 miles by the year 1985, an increase of about 386 miles, or nearly 13 percent, over 1972. Freeways would comprise about 255 miles, or almost 8 percent, of the total arterial system in the year 1985, an increase of 93 miles over 1972. Of this increase, nearly 17 miles represent planned new freeways.

Source: SEWRPC.

Map 91

ARTERIAL STREET AND HIGHWAY SYSTEM IN THE REGION 2000 ADOPTED TRANSPORTATION PLAN

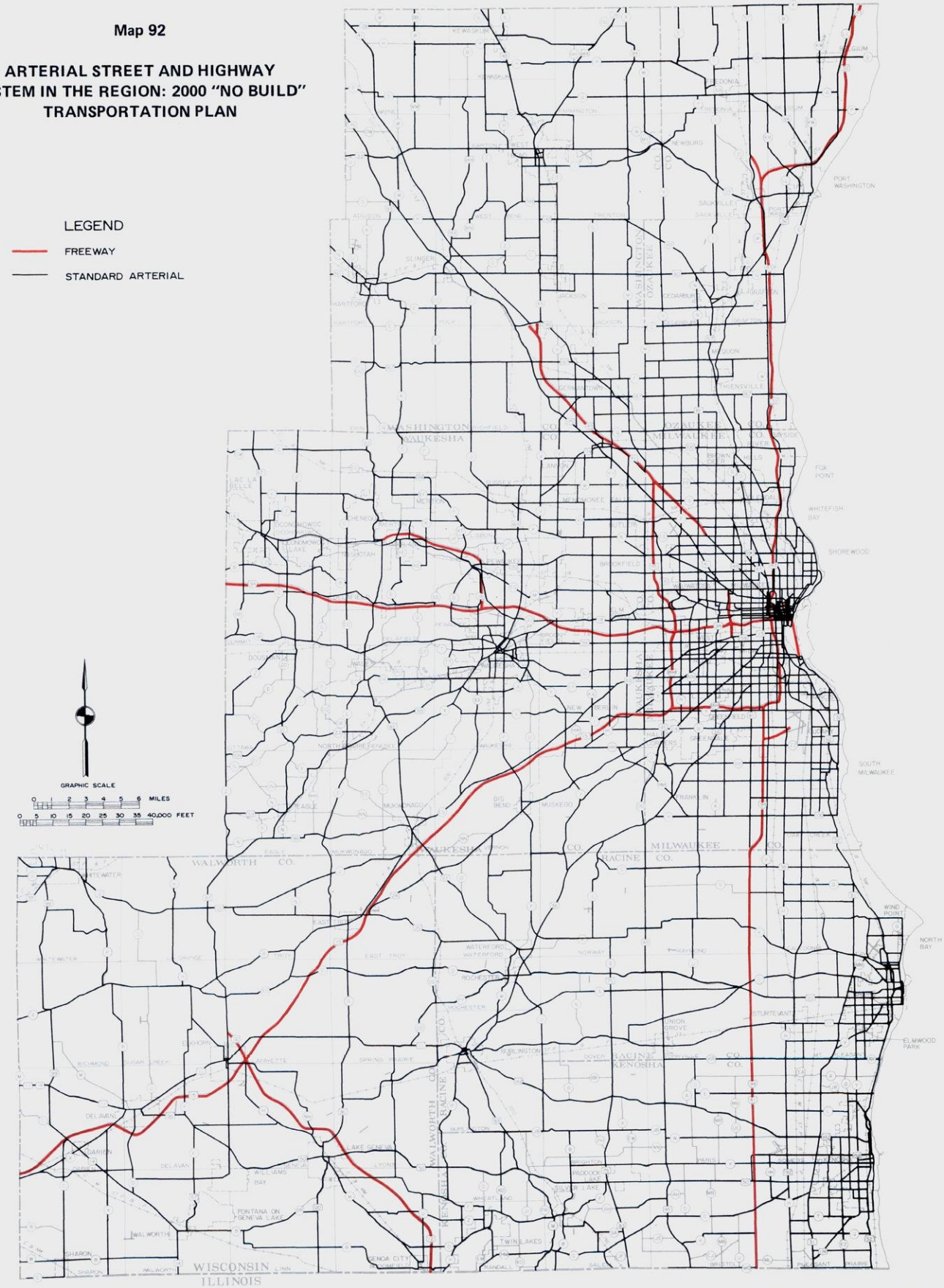


Under the adopted transportation plan, arterial street and highway system mileage within the Region would total about 3,526 miles by the year 2000, an increase of about 516 miles, or about 17 percent, over 1972. Freeways would comprise 336 miles, or about 9 percent, of the total arterial system in the year 2000, an increase of 174 miles over 1972. Such freeways would, however, be expected to carry about 42 percent of the average daily traffic load. Of this increase, 97 miles represent seven planned new freeways. Of this total system about 2,650 miles, or about 75 percent, would fall into the system preservation category, including facilities for which no work, resurfacing, or reconstruction for same capacity is proposed; about 707 miles, or 20 percent, would fall into the system improvement category, for which reconstruction for additional capacity or new construction of replacement facilities is proposed; and about 176 miles, or 5 percent, would fall into the system expansion category, wherein the construction of new facilities is proposed.

Source: SEWRPC.

Map 92

ARTERIAL STREET AND HIGHWAY SYSTEM IN THE REGION: 2000 "NO BUILD" TRANSPORTATION PLAN



Under the "no build" alternative transportation plan, arterial street and highway system mileage within the Region would total about 3,310 miles by the year 2000, an increase of 300 miles, or about 10 percent, over 1972. Of these additional 300 miles, 80 miles, or 27 percent, represent existing nonarterial collector and land access facilities that would be converted to arterial facilities as land use development and attendant increases in traffic demand occurred within the Region. Freeways would comprise 238 miles, or 7 percent, of the total arterial system in the year 2000, an increase of 75 miles over 1972. This increase in freeway mileage is represented entirely by freeways either actually under construction in 1972—such as the STH 15-Rock Freeway in Walworth County—or considered to be fully committed to construction in 1972—such as the Airport Spur Freeway in Milwaukee County.

Source: SEWRPC.

Table 270

ARTERIAL AND STREET AND HIGHWAY FACILITIES IN THE REGION BY TYPE OF ARTERIAL AND BY COUNTY: 1972, 1985 STAGE AND "NO BUILD" TRANSPORTATION PLANS, AND 2000 ADOPTED AND "NO BUILD" TRANSPORTATION PLANS

Miles of Arterial Facilities									
		1985 Stage Plan		1985 "No Build" Plan		2000 Adopted Plan		2000 "No Build" Plan	
County	1972	Increment (1972-1985)	Total	Increment (1972-1985)	Total	Increment (1985-2000)	Total	Increment (1985-2000)	Total
Kenosha									
Freeway	12.1	--	12.1	--	12.1	12.2	24.3	--	12.1
Standard Arterial	267.7	68.9	336.6	51.9	319.6	- 1.4	335.2	--	319.6
Subtotal	279.8	68.9	348.7	51.9	331.7	10.8	359.5	--	331.7
Milwaukee									
Freeway	63.8	9.2	73.0	5.4	69.2	12.8	85.8	--	69.2
Standard Arterial	670.4	17.6	688.0	- 3.0	667.4	1.3	689.3	--	667.4
Subtotal	734.2	26.8	761.0	2.4	736.6	14.1	775.1	--	736.6
Ozaukee									
Freeway	10.8	16.8	27.6	16.8	27.6	--	27.6	--	27.6
Standard Arterial	239.5	36.2	275.7	36.6	276.1	7.6	283.3	--	276.1
Subtotal	250.3	53.0	303.3	53.4	303.7	7.6	310.9	--	303.7
Racine									
Freeway	12.0	--	12.0	--	12.0	12.1	24.1	--	12.0
Standard Arterial	337.4	70.5	407.9	40.2	377.6	10.3	418.2	--	377.6
Subtotal	349.4	70.5	419.9	40.2	389.6	22.4	442.3	--	389.6
Walworth									
Freeway	19.1	31.1	50.2	31.2	50.3	17.0	67.2	--	50.3
Standard Arterial	389.1	6.3	395.4	11.1	400.2	20.6	416.0	--	400.2
Subtotal	408.2	37.4	445.6	42.3	450.5	37.6	483.2	--	450.5
Washington									
Freeway	6.8	14.6	21.4	1.8	8.6	21.0	42.4	--	8.6
Standard Arterial	332.4	63.8	396.2	69.2	401.6	- 1.0	395.2	--	401.6
Subtotal	339.2	78.4	417.6	71.0	410.2	20.0	437.6	--	410.2
Waukesha									
Freeway	37.8	21.4	59.2	20.2	58.0	5.4	64.6	--	58.0
Standard Arterial	610.7	29.3	640.0	18.9	629.6	12.8	652.8	--	629.6
Region	648.5	50.7	699.2	39.1	687.6	18.2	717.4	--	687.6
Region									
Freeway	162.4	93.1	255.5	75.4	237.8	80.5	336.0	--	237.8
Standard Arterial	2,847.2	292.6	3,139.8	224.9	3,072.1	50.3	3,190.1	--	3,072.1
Total	3,009.6	385.7	3,395.3	300.3	3,309.9	130.7	3,526.0	--	3,309.9

Source: SEWRPC.

to the abutting land uses. The collector and land access street system required to support the year 2000 adopted regional land use plan is estimated to total 8,550 miles. This represents a 1,850-mile, or 28 percent, increase over the 1972 system.

Mass Transit Facilities: The adopted regional transportation plan includes transit system development proposals for the three urbanized areas of the Region—Milwaukee, Kenosha, and Racine. The base transit fare is recommended to remain at the relative levels of $0.50 in the Milwaukee urbanized area and $0.25 in the Kenosha and Racine urbanized areas. If general price inflation continues, increases in the base transit fare should be anticipated in order to offset the effects of such inflation.

Transit Service in the Milwaukee Urbanized Area: In the Milwaukee urbanized area, the plan envisions the provision of three levels of transit service. The primary level of service is intended to link the major activity centers—such as commercial, industrial, institutional, and recreational centers—to each other and to the various residential communities in the area. Primary service is characterized by relatively high operating speeds but relatively low acces-

sibility. The primary service envisioned in the plan would include no true rapid transit; that is, transit service provided over exclusive, fully grade-separated rights-of-way. All of the primary service in the plan would be of the modified rapid transit type; that is, provided by the operation of motor buses in mixed traffic on freeways and, in some cases, over surface arterial streets on freeway route extensions. The primary transit service would be supported by the recommended implementation of a comprehensive freeway traffic management system for the Milwaukee urbanized area, including freeway mainline and ramp traffic monitoring, ramp metering with traffic signals operating from a centralized control, traffic accident detection and management, and driver information systems. Buses and other high-occupancy vehicles, such as carpools and vanpools, would be accorded preferential access to the freeways via exclusive ramps or lanes. The object of the system would be to enable the provision of a high-quality transit service on free-flowing, uncongested freeways.

The secondary level of transit service envisioned in the plan would provide express bus service over arterial streets, with stops generally located at intersecting transit routes. Secondary service is distinguished from primary service in that it provides a greater degree of accessibility at somewhat slower operating speeds. Under the adopted transportation plan, secondary service would be provided over 14 individual transit routes, with exclusive transit lanes—traffic lanes where only buses would be allowed during specified hours of the day—on six arterial streets. The exclusive transit lanes would total nearly 10 miles by the year 2000. Shared secondary transit service would be provided over about 146 miles of arterial facilities in the design year.

The tertiary level of mass transit service envisioned in the adopted transportation plan consists of local transit service provided primarily over arterial and collector streets, with frequent stops for passenger boarding and alighting. Under the adopted plan, extensive additions to the tertiary or local transit service routes would be provided. The plan envisions the ultimate extension of tertiary transit service to all of the Milwaukee urbanized area, including low-density urban residential areas in southern Ozaukee and Washington Counties and eastern Waukesha County. In these areas, the tertiary level of service would be either the traditional fixed-route service or some form of nontraditional transit service, such as route deviation, subscription, dial-a-ride, or shared-ride taxi service.

The mass transit system as it is envisioned for the Milwaukee urbanized area under the adopted transportation plan is shown on Maps 93 and 94 for the years 1985 and 2000, respectively. The number of round-trip route miles proposed to be provided by the primary, secondary, and tertiary levels of transit service, along with the miles of special transit facilities to be provided in the Milwaukee urbanized area for 1985 and 2000, are summarized in Table 271. Table 271 also indicates the number of buses required to provide the level of transit

Table 271

MASS TRANSIT FACILITIES IN THE MILWAUKEE URBANIZED AREA: 1972, 1985, AND 2000

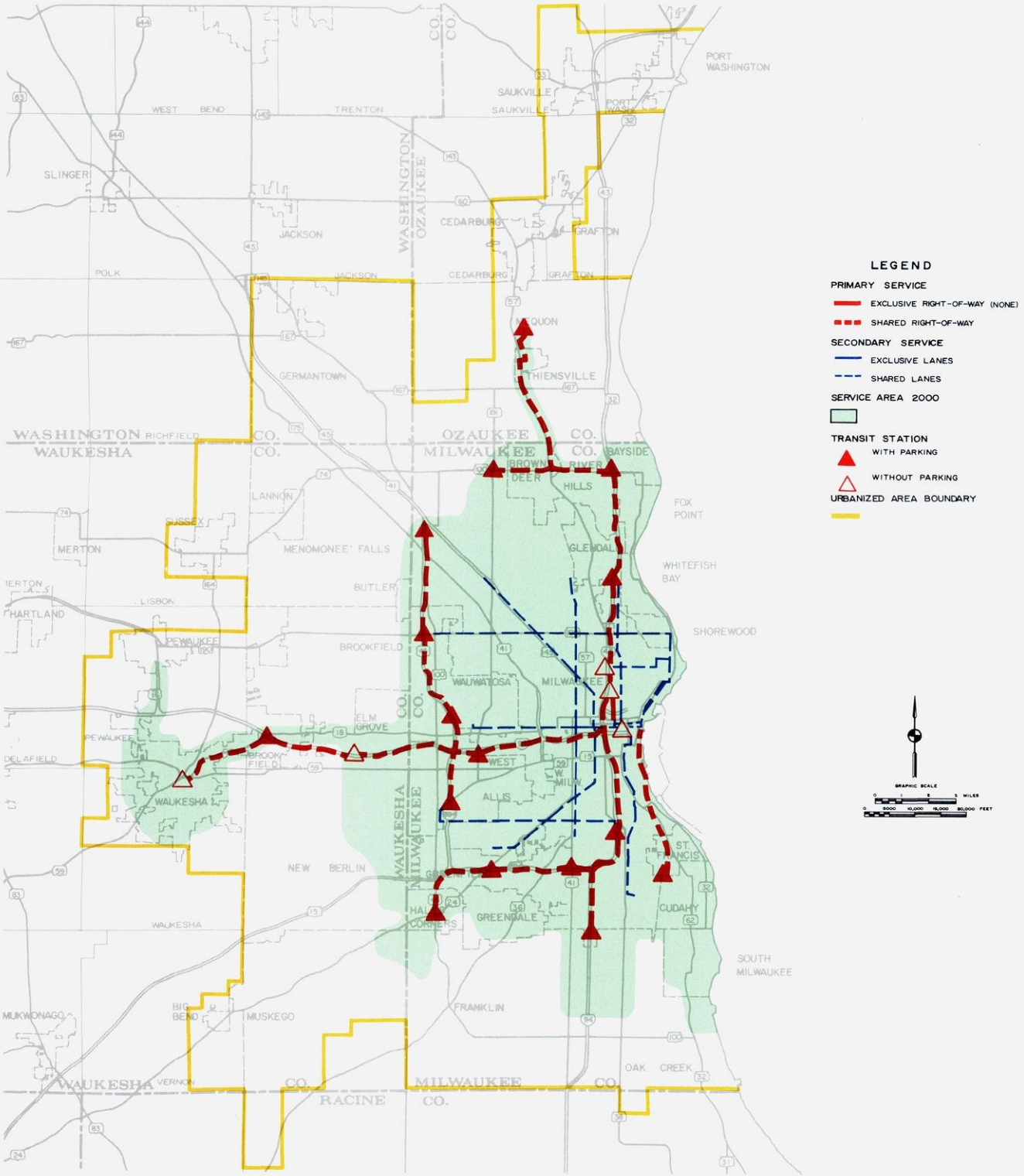
Transit Facility Characteristics	Existing 1972	Planned Increment 1972-1985	Total 1985	Planned Increment 1985-2000	Total 2000
Round-Trip Route Miles					
Primary	150	283	433	619	1,052
Secondary	56	98	154	207	361
Tertiary	855	613	1,468	192	1,660
Total	1,061	994	2,055	1,018	3,073
Special Facilities					
Transitway (miles)	--	--	--	--	--
Exclusive Lanes (miles)	--	2.0	2.0	7.5	9.5
Stations	--	21	21	17	38
Number of Buses Required	442	263	705	322	1,027
Basic Fare	$0.40	$0.10	$0.50[a]	--	$0.50[a]

[a] *In constant 1975 dollars.*

Source: SEWRPC.

Map 93

TRANSIT SYSTEM IN THE MILWAUKEE URBANIZED AREA: 1985 STAGE OF THE ADOPTED TRANSPORTATION PLAN

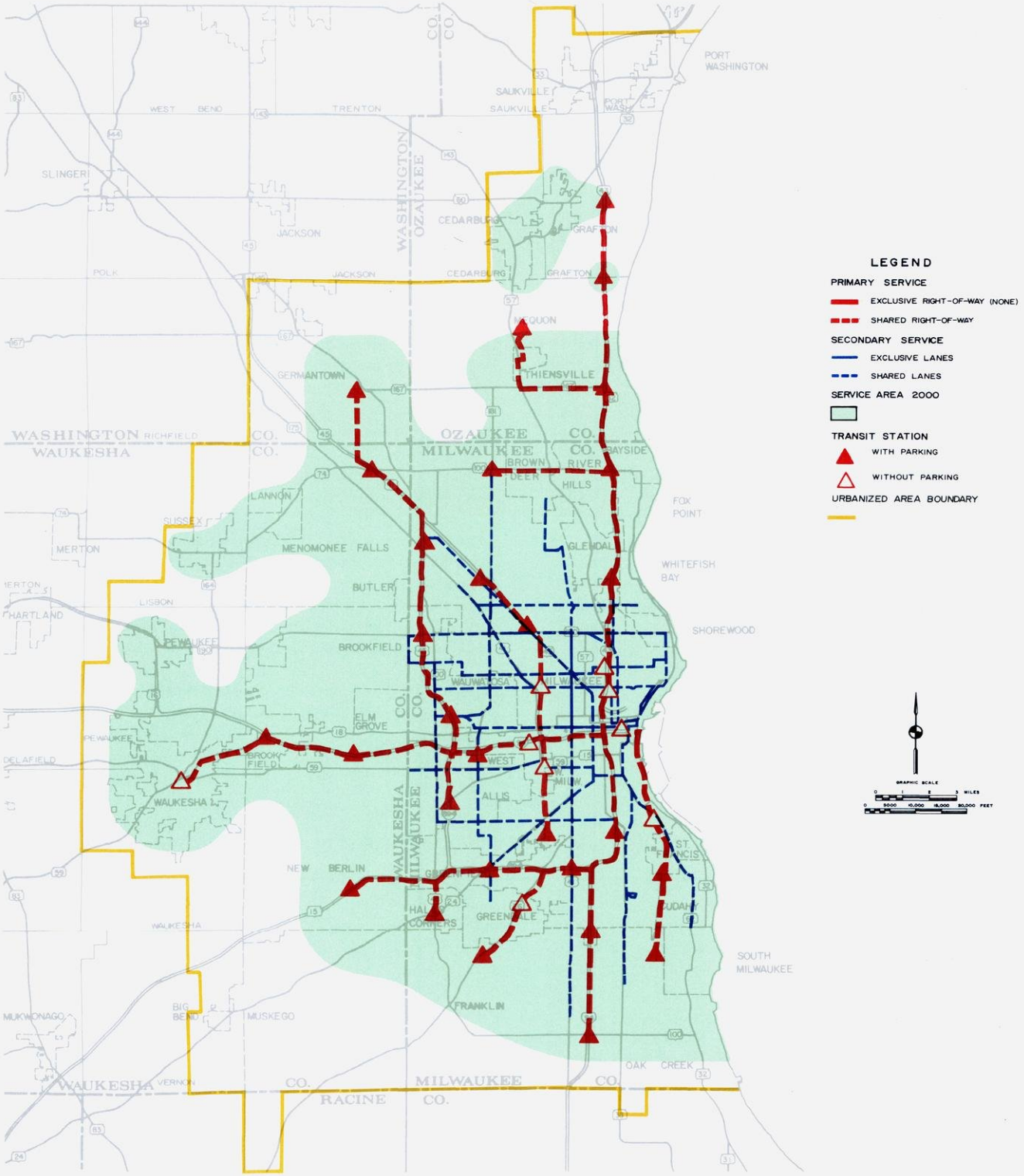


Under the 1985 stage of the adopted transportation plan, transit service would be provided over 2,055 round-trip route miles of transit line in the Milwaukee urbanized area. Of this total, 433 route miles would provide primary service, 154 route miles secondary service, and 1,468 route miles tertiary service. The system would require the operation of about 705 buses during peak ridership periods. This would represent an increase of 994 round-trip route miles and 263 buses over 1972. The plan also recommends the provision of 21 public transit stations, an increase of 17 over 1972.

Source: SEWRPC.

Map 94

TRANSIT SYSTEM IN THE MILWAUKEE URBANIZED AREA: 2000 ADOPTED TRANSPORTATION PLAN



Under the adopted transportation plan, transit service would be provided over 3,073 round-trip route miles of transit line in the Milwaukee urbanized area. Of this total, 1,052 route miles would provide primary service, 361 route miles secondary service, and 1,660 route miles tertiary service. The system would require the operation of about 1,027 buses during peak ridership periods. This would represent an increase of 2,012 round-trip route miles and 585 buses over 1972. The plan also recommends the provision of 38 public park and ride transit stations, an increase of 34 stations over 1972.

Source: SEWRPC.

service envisioned for the Milwaukee urbanized area and the transit fare recommended under the transportation plan.

Transit Service in the Kenosha and Racine Urbanized Areas: As envisioned in the adopted transportation plan, only the tertiary or local level of mass transit service would be provided in the Kenosha and Racine urbanized areas. Since mass transit service has significantly improved in these two urbanized areas in recent years in accordance with transit development programs prepared by the Commission in cooperation with the Cities of Kenosha and Racine, only relatively minor route extensions and changes to the existing systems have been proposed to reflect the anticipated expansion of these urbanized areas between 1972 and 2000. Map 95 and Map 96 identify the proposed transit service areas and suggested route systems for the Kenosha and Racine urbanized areas for the years 1985 and 2000. The number of round-trip route miles, the number of buses, and the basic fare envisioned in the mass transit system plan for the Kenosha and Racine urbanized areas in 1985 and 2000 are summarized in Table 272.

Future Travel Demand and System Utilization

Future Motor Vehicle Availability: As indicated in Table 273, automobile availability in the Region under the recommended transportation plan is expected to increase from 704,600 vehicles in 1972 to about 814,000 vehicles in 1985 and to about one million vehicles in the year 2000, a total increase of about 42 percent over this 28-year period. Based on this forecast of automobile availability, the number of persons per automobile on a regional average would decrease from 2.6 in 1972 to 2.3 in 1985 and to 2.2 in the year 2000.

The number of motor trucks available in the Region is projected to increase from 79,700 in 1972 to about 144,000 in 2000, an increase of 64,300, or approximately 81 percent. An analysis of growth trends in each of the various truck classifications indicates that a large proportion of truck growth between 1972 and 2000 will probably occur in the lightweight truck classification. Data on the existing and projected number of motor trucks available in the Region for selected years between 1950 and 2000 are presented in Table 274, and graphically depicted for this 50-year period in Figure 100.

Forecast Internal Person and Vehicle Trips: Under the adopted plan the number of internal person trips generated in the Region on an average weekday is expected to increase from 4.46 million in 1972 to 5.75 million in the year 2000, an increase of 1.29 million trips per day, or nearly 29 percent, over the 28-year period. The number of internal person trips generated on an average weekday in the Region is presented by trip purpose and mode of travel in Table 275 for the years 1972 and 2000. It is interesting to note in Table 275 that the number of internal person trips using mass transit as the mode of travel is anticipated to increase from about 184,000 trips in 1972 to about 335,000 trips in the year 2000, excluding transit trips made to and from school, for an increase of nearly 151,000 trips, or 82 percent. This increase in transit tripmaking assumes full implementation of both the adopted land use plan and the adopted transit system plan, including such recommended transportation systems management actions as a freeway operational control system. Even given this large increase in transit tripmaking, transit trips may be expected to constitute only about 6 percent of the total internal person trips made on an average weekday in the Region in the year 2000. Achieving a level of transit ridership of approximately 335,000 trips per average weekday would mean a return to the level of transit ridership that existed within the Region in 1963, and will require a reversal of long-term trends (see Figure 101).

The number of vehicle trips generated on an average weekday in the Region is anticipated to increase from 3.43 million in 1972 to 4.48 million in the year 2000,

Table 272

MASS TRANSIT FACILITIES IN THE KENOSHA AND RACINE URBANIZED AREAS: 1972, 1985, AND 2000

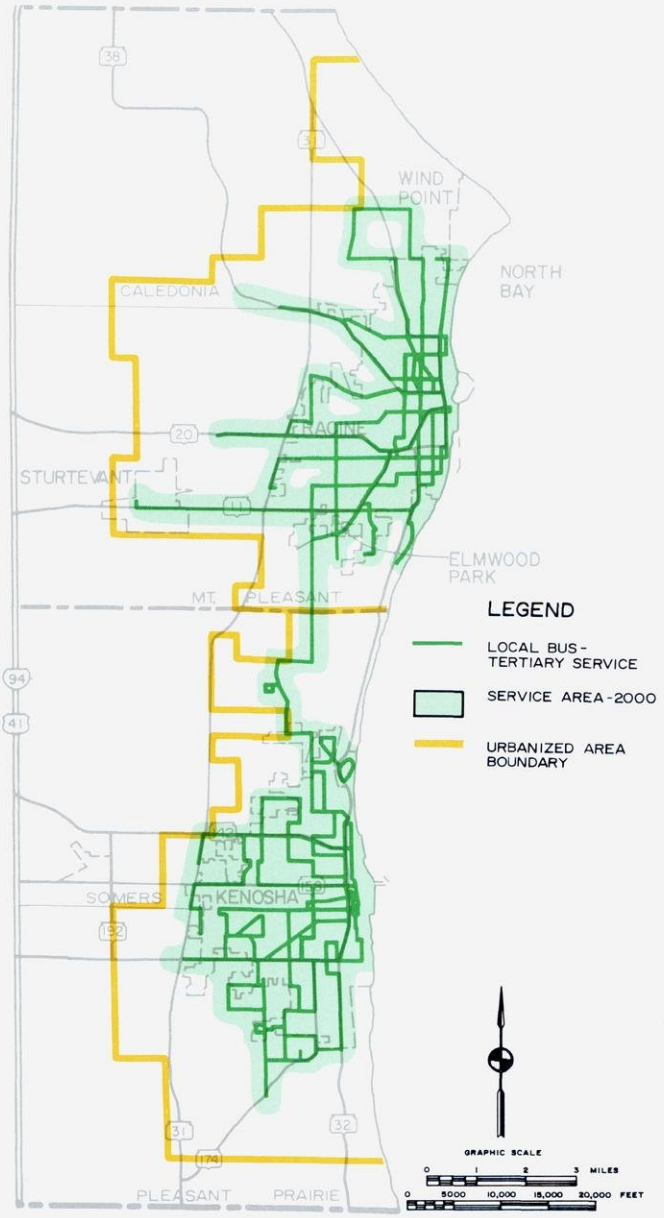
Transit Facility Characteristics	Existing 1972	Planned Increment 1972-1985	Total 1985	Planned Increment 1985-2000	Total 2000
Kenosha Urbanized Area					
Round-Trip Route Miles	59	80	139	8	147
Number of Buses Required	12	20	32	1	33
Basic Fare	$0.25	--	$0.25[a]	--	$0.25[a]
Racine Urbanized Area					
Round-Trip Route Miles	81	61	142	11	153
Number of Buses Required	10	14	24	14	38
Basic Fare	$0.40	- $0.15	$0.25[a]	--	$0.25[a]

[a] *In constant 1975 dollars.*

Source: SEWRPC.

Map 95

TRANSIT SYSTEM IN THE KENOSHA AND RACINE URBANIZED AREAS: 1985 STAGE OF THE ADOPTED TRANSPORTATION PLAN

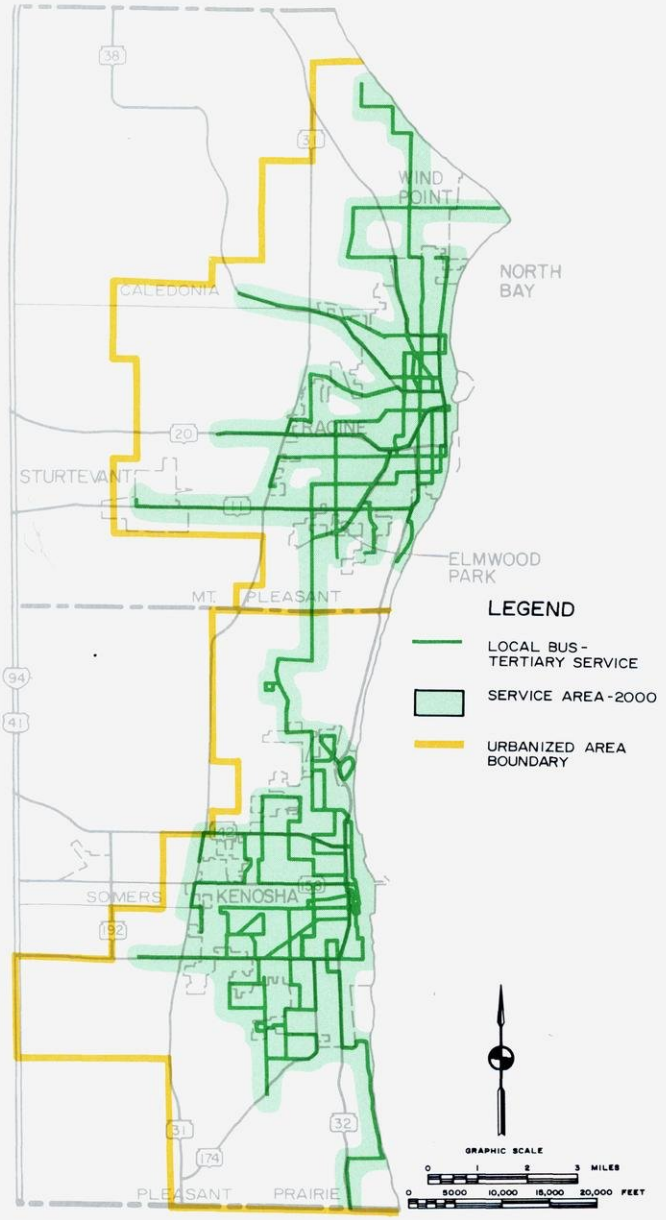


Under the 1985 stage of the adopted transportation plan, the transit system for the Kenosha urbanized area would consist of approximately 139 round-trip route miles of transit line, and the transit system for the Racine urbanized area would consist of 142 round-trip route miles of transit line, requiring a total of 32 buses in the Kenosha urbanized area and 24 buses in the Racine urbanized area for service during peak ridership periods. This would represent an increase of 80 round-trip route miles and 20 buses in the Kenosha area and 61 round-trip route miles and 14 buses in the Racine area over 1972.

Source: SEWRPC.

Map 96

TRANSIT SYSTEM IN THE KENOSHA AND RACINE URBANIZED AREAS 2000 ADOPTED TRANSPORTATION PLAN



Under the adopted transportation plan, the transit system for the Kenosha urbanized area would consist of approximately 147 round-trip route miles of transit line, and the transit system for the Racine urbanized area would consist of 153 round-trip route miles of transit line, requiring a total of 33 buses in the Kenosha urbanized area and 38 buses in the Racine urbanized area for service during peak ridership periods. This would represent an increase of 88 round-trip route miles and 21 buses in the Kenosha area and 72 round-trip route miles and 28 buses in the Racine area over 1972.

Source: SEWRPC.

an increase of about 1.05 million trips, or approximately 31 percent, over the 28-year period. The total vehicle trips generated on an average weekday in the Region are disaggregated by vehicle class in Table 276 for the years 1972 and 2000.

Forecast Average Weekday Vehicle Miles of Travel: Under the adopted transportation plan, vehicle miles of travel on the arterial street and highway system in the Region is expected to increase from about 20.1 million per average weekday in 1972 to about 24.1 million in

Table 273

COMPARISON OF AUTOMOBILES AVAILABLE IN THE REGION BY COUNTY: 1972, 1985, AND 2000

County	Existing 1972			Planned Increment 1972-1985		Total 1985			Planned Increment 1985-2000		Total 2000		
	Household Population	Automobiles	Persons per Automobile	Household Population	Automobiles	Household Population	Automobiles	Persons per Automobile	Household Population	Automobiles	Household Population	Automobiles	Persons per Automobile
Kenosha	122,700	48,700	2.5	24,300	19,400	147,000	68,100	2.2	24,500	18,900	171,500	87,000	2.0
Milwaukee	1,060,500	386,600	2.7	-69,800	-6,900	990,700	379,700	2.6	33,600	48,800	1,024,300	428,500	2.4
Ozaukee	61,400	27,300	2.2	24,700	15,000	86,100	42,300	2.0	26,900	15,300	113,000	57,600	2.0
Racine	177,100	70,900	2.5	14,000	13,300	191,100	84,200	2.3	21,600	18,200	212,700	102,400	2.1
Walworth	72,300	32,000	2.3	1,900	6,200	74,200	38,200	1.9	17,600	11,100	91,800	49,300	1.9
Washington	71,400	28,900	2.5	31,400	20,100	102,800	49,000	2.1	38,700	23,500	141,500	72,500	2.0
Waukesha	245,300	110,200	2.2	70,800	42,000	316,100	152,200	2.1	96,000	53,000	412,100	205,200	2.0
Total	1,810,700	704,600	2.6	97,300	109,100	1,908,000	813,700	2.3	258,900	188,800	2,166,900	1,002,500	2.2

Source: SEWRPC.

Table 274

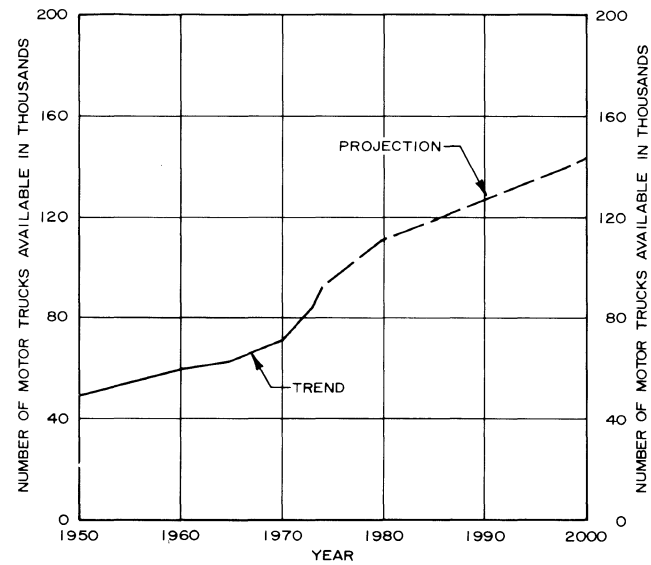
MOTOR TRUCK AVAILABILITY IN THE REGION SELECTED YEARS 1950-2000

Year	Motor Trucks Available in Region
1950	49,400
1955	54,100
1960	59,500
1965	63,400
1970	71,700
1975	97,000
1980	112,000
1985	120,000
1990	128,000
1995	136,000
2000	144,000

Source: Wisconsin Department of Transportation and SEWRPC.

Figure 100

MOTOR TRUCK AVAILABILITY IN THE REGION: 1950-2000



Source: SEWRPC.

Table 275

COMPARISON OF THE DISTRIBUTION OF INTERNAL PERSON TRIPS IN THE REGION BY TRIP PURPOSE: 1972 AND 2000

Trip Purpose	Internal Person Trips Generated on an Average Weekday															
	Transit				Automobile Driver				Automobile Passenger				Total			
	1972		2000		1972		2000		1972		2000		1972		2000	
	Number of Trips	Percent of Total	Number of Trips	Percent of Total	Number of Trips	Percent of Total	Number of Trips	Percent of Total	Number of Trips	Percent of Total	Number of Trips	Percent of Total	Number of Trips	Percent of Total	Number of Trips	Percent of Total
Home-Based Work	70,900	19.8	135,300	21.7	840,800	29.2	1,098,400	29.2	143,800	11.8	130,900	9.6	1,055,500	23.7	1,364,600	23.7
Home-Based Shopping	18,800	5.2	41,700	6.7	444,500	15.4	571,300	15.1	210,300	17.3	235,700	17.3	673,600	15.1	848,700	14.8
Home-Based Other	28,300	7.9	91,500	14.7	976,300	33.8	1,252,800	33.3	528,000	43.4	604,300	44.3	1,532,600	34.3	1,948,600	33.9
Nonhome-Based	13,100	3.7	10,800	1.7	555,700	19.3	751,600	20.0	211,000	17.3	238,900	17.5	779,800	17.5	1,001,300	17.4
School	226,700[a]	63.4	344,300[b]	55.2	67,400	2.3	90,000	2.4	124,800	10.2	153,400	11.3	418,900	9.4	587,700	10.2
Total	357,800[a]	100.0	623,600[b]	100.0	2,884,700	100.0	3,764,100	100.0	1,217,900	100.0	1,363,200	100.0	4,460,400	100.0	5,750,900	100.0

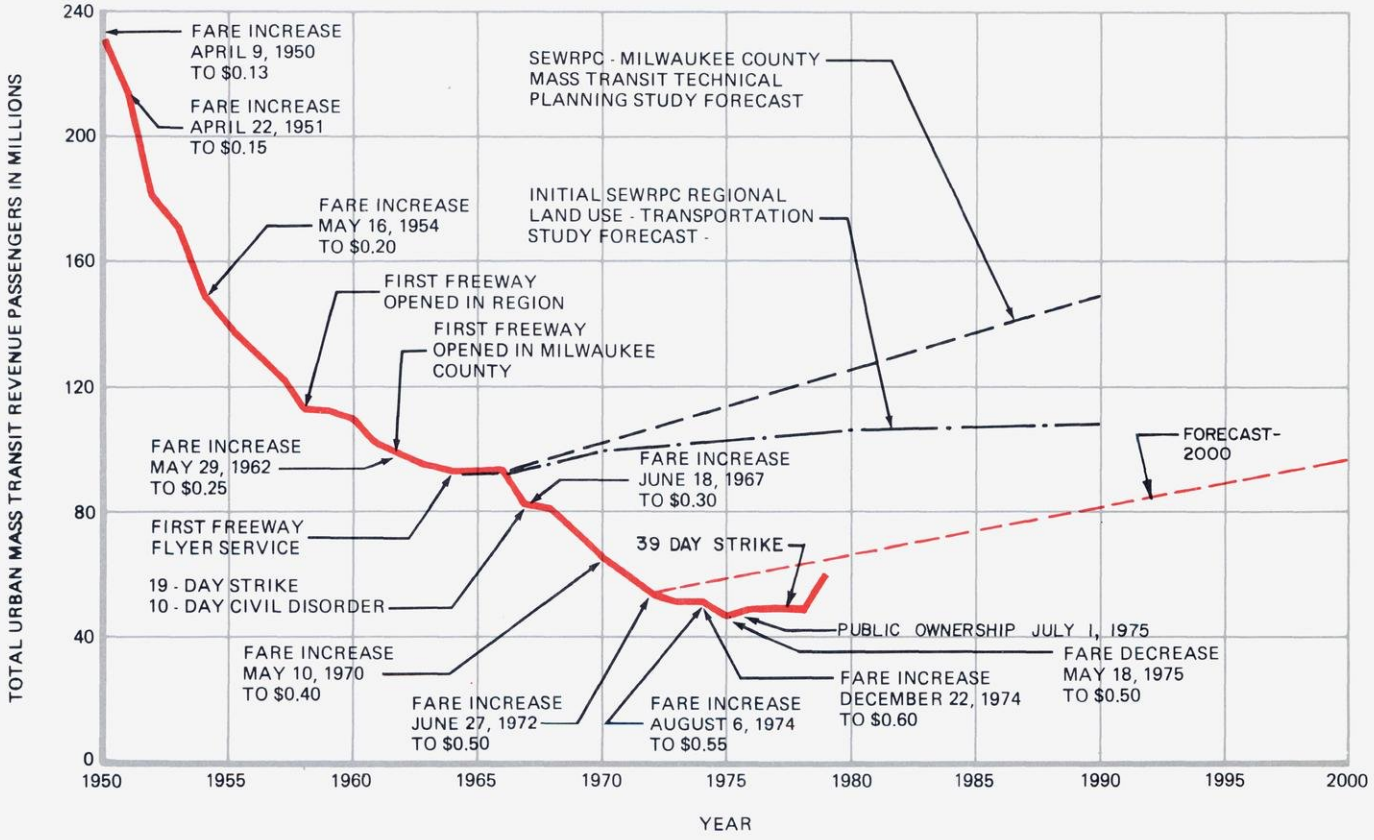
[a] *Includes 173,600 school trips made on school buses.*

[b] *Includes 288,600 school trips made on school buses.*

Source: SEWRPC.

Figure 101

HISTORICAL TREND IN MASS TRANSIT RIDERSHIP IN THE REGION



NOTE: FARE INCREASES AND DECREASES SHOWN IN THIS FIGURE REFER ONLY TO THE MILWAUKEE COUNTY TRANSIT SYSTEM AND TO THE SINGLE-RIDE ADULT CASH FARE.

Source: SEWRPC.

Table 276

COMPARISON OF THE DISTRIBUTION OF TOTAL VEHICLE TRIPS IN THE REGION BY VEHICLE CLASS: 1972 AND 2000

Vehicle Class	Total Vehicle Trips Generated on an Average Weekday					
	Existing 1972		Planned Increment		Total 2000	
	Number of Trips	Percent of Total	Number of Trips	Percent Change	Number of Trips	Percent of Total
Automobile						
Internal	2,884,700	84.0	879,400	30.5	3,764,100	84.0
External[a]	100,800	2.9	58,500	58.0	159,300	3.6
Other[b]	34,200	1.0	6,200	18.1	40,400	0.9
Subtotal	3,019,700	87.9	944,100	31.3	3,963,800	88.5
Truck						
Internal	383,600	11.2	89,000	23.2	472,600	10.5
External	25,000	0.7	15,800	63.2	40,800	0.9
Other[b]	6,000	0.2	- -	- -	6,000	0.1
Subtotal	414,600	12.1	104,800	25.3	519,400	11.5
Total	3,434,300	100.0	1,048,900	30.5	4,483,200	100.0

[a] *Includes light trucks, i.e., those under 6,000 pounds gross weight.*

[b] *Includes vehicle trips made by persons residing in group quarters and by nonresidents of the Region.*

Source: SEWRPC.

1985 and to about 30.1 million per average weekday in the year 2000, an increase of nearly 50 percent over the 28-year period. As summarized in Table 277, about 12.6 million, or 42 percent, of the vehicle miles of travel in the Region in the year 2000 could be expected to be made on freeways, with an additional 17.5 million, or about 58 percent of the total, being made on standard arterials. Travel on the collector and minor street system could be expected to account for about 2.3 million vehicle miles of travel on an average weekday in 1985 and 2.7 million vehicle miles of travel on an average weekday in the year 2000. In total, therefore, vehicle miles of travel in the Region would approximate 26.4 million miles on an average weekday in 1985 and 32.8 million miles on an average weekday in the year 2000.

System Utilization: Anticipated traffic volumes on the arterial street and highway system are shown on Map 97 for the year 1985 and on Map 98 for the year 2000. As evidenced on these maps, the greatest traffic volumes both in 1985 and 2000 will be experienced in Milwaukee County, particularly on the freeway system. Of the approximately 3,526 miles of arterial street and highway facilities in the Region in the year 2000, only

Table 277

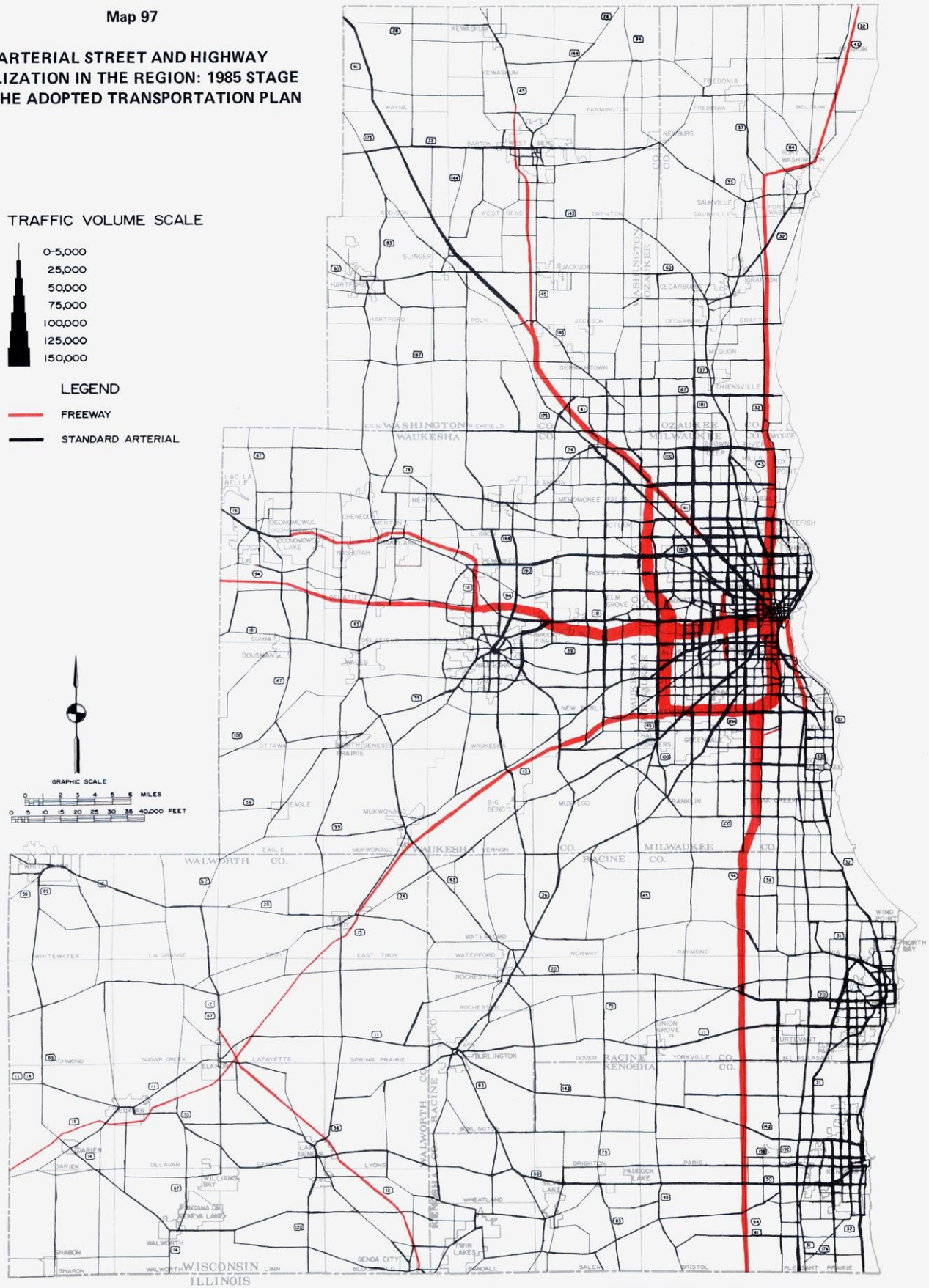
VEHICLE MILES OF TRAVEL ON THE ARTERIAL STREET AND HIGHWAY SYSTEM IN THE REGION BY COUNTY: 1972 AND 2000

County	Arterial Vehicle Miles of Travel on An Average Weekday (in thousands)					
	1972		Change 1972-2000		2000	
	Number	Percent of Total	Number	Percent	Number	Percent of Total
Kenosha						
Freeway	382	26.8	499	130.6	881	31.1
Standard Arterial	1,046	73.2	902	86.2	1,948	68.9
Subtotal	1,428	100.0	1,401	98.1	2,829	100.0
Milwaukee						
Freeway	3,977	37.2	1,917	48.2	5,894	47.6
Standard Arterial	6,718	62.8	- 241	- 3.6	6,477	52.4
Subtotal	10,695	100.0	1,676	15.7	12,371	100.0
Ozaukee						
Freeway	223	26.2	459	205.8	682	44.9
Standard Arterial	627	73.8	210	33.5	837	55.1
Subtotal	850	100.0	669	78.7	1,519	100.0
Racine						
Freeway	415	22.9	762	183.6	1,177	38.2
Standard Arterial	1,398	77.1	505	36.1	1,903	61.8
Subtotal	1,813	100.0	1,267	69.9	3,080	100.0
Walworth						
Freeway	56	6.4	1,180	2,107.1	1,236	50.4
Standard Arterial	817	93.6	397	48.6	1,214	49.6
Subtotal	873	100.0	1,577	180.6	2,450	100.0
Washington						
Freeway	190	16.5	662	348.4	852	42.6
Standard Arterial	961	83.5	186	19.4	1,147	57.4
Subtotal	1,151	100.0	848	73.7	1,999	100.0
Waukesha						
Freeway	970	29.3	917	94.5	1,887	32.1
Standard Arterial	2,344	70.7	1,653	70.5	3,997	67.9
Subtotal	3,314	100.0	2,570	77.5	5,884	100.0
Region						
Freeway	6,213	30.9	6,396	102.9	12,609	41.8
Standard Arterial	13,911	69.1	3,612	26.0	17,523	58.2
Total	20,124	100.0	10,008	49.7	30,132	100.0

Source: SEWRPC.

Map 97

ARTERIAL STREET AND HIGHWAY UTILIZATION IN THE REGION: 1985 STAGE OF THE ADOPTED TRANSPORTATION PLAN

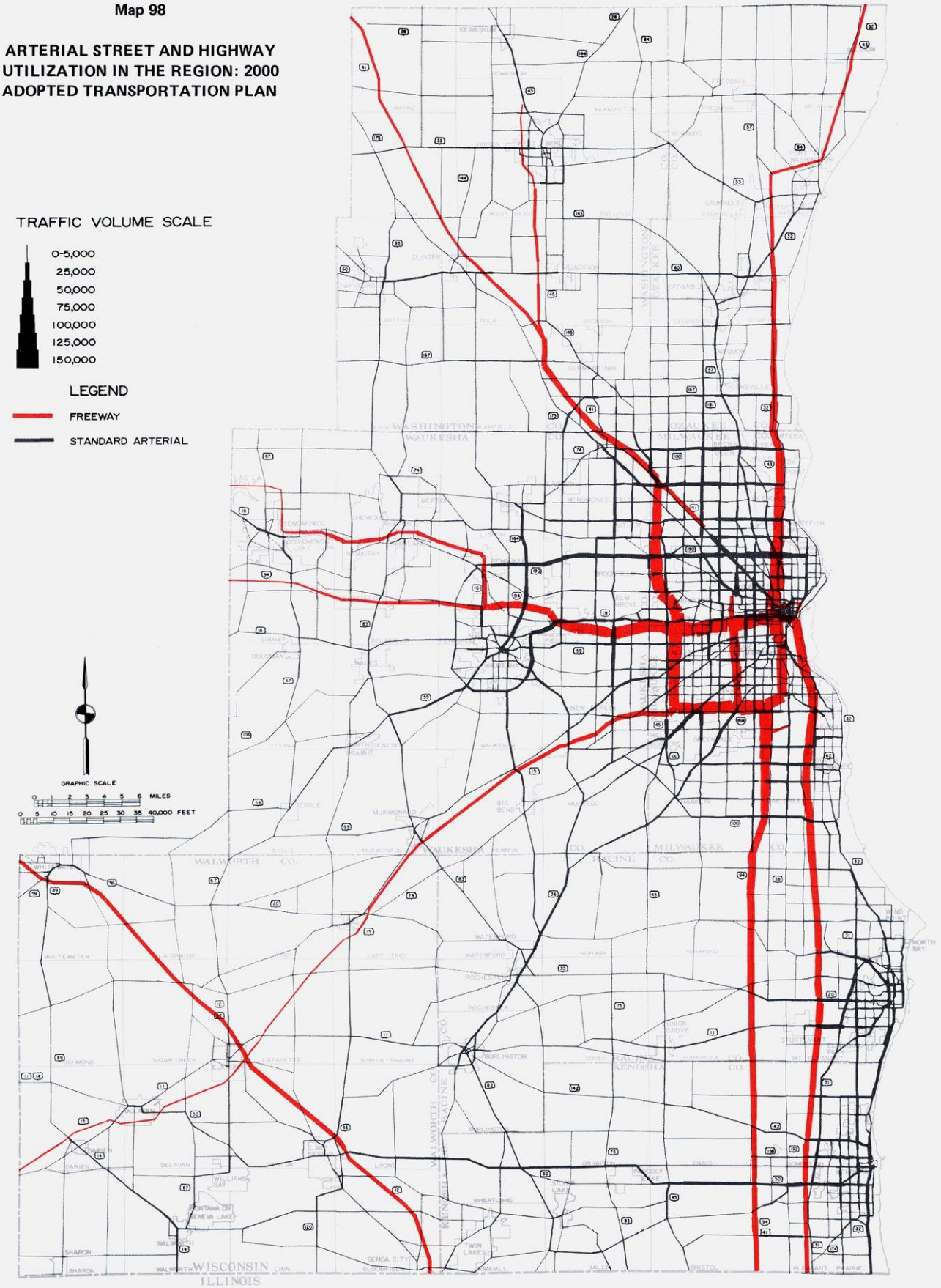


Weekday arterial street and highway system utilization in the Region may be expected to increase to 24.1 million vehicle miles of travel by the year 1985 under the adopted transportation plan, an increase of 4.0 million vehicle miles, or nearly 20 percent, over the 1972 level of 20.1 vehicle miles. About 8.9 million vehicle miles of travel, or nearly 37 percent of the total, could be expected to occur on the freeway system, as compared with 31 percent in 1972.

Source: SEWRPC.

Map 98

ARTERIAL STREET AND HIGHWAY UTILIZATION IN THE REGION: 2000 ADOPTED TRANSPORTATION PLAN



Weekday arterial street and highway system utilization in the Region may be expected to increase to 30.1 million vehicle miles of travel by the year 2000 under the adopted transportation plan, an increase of 10 million vehicle miles, or about 50 percent, over the 1972 level of 20.1 million vehicle miles. About 12.6 million vehicle miles of travel, or nearly 42 percent of the total, could be expected to occur on the freeway system, as compared with 31 percent in 1972.

Source: SEWRPC.

about 39 miles, or approximately 1 percent, may be expected to operate over design capacity. This represents a decrease from the 166 miles of facilities which operated over design capacity in 1972. The number of miles of facilities operating at design capacity, however, is expected to increase from about 155 miles, or about 5 percent of the total system in 1972, to about 344 miles, or about 10 percent of the total system in the year 2000.

Maps 99 and 100 present the arterial street and highway system utilization for the years 1985 and 2000, respectively, under the "no build" alternative transportation plan. Under the "no build" plan, approximately 439 miles of facilities, or about 13 percent of the total facilities under this plan, may be expected to operate over capacity in the year 2000, and an additional 369 miles of facilities, or about 11 percent, may be expected to operate at design capacity. This increase in miles of arterial system facilities operating at or over design capacity is evident in the comparison of traffic volumes indicated on Map 97 and Map 99 for the year 1985 under the adopted and "no build" transportation plans, respectively, and similarly on Map 98 and Map 100 for the year 2000. The larger traffic volumes indicated on the existing facilities under the "no build" plan for both years are a result of the fewer new and improved facilities planned under this alternative to meet the anticipated travel demand.

Under the adopted transportation plan, transit utilization in the Milwaukee urbanized area may be expected to increase from 1.2 million passenger miles in 1972 to 1.6 million passenger miles in the year 2000. This represents a 33 percent increase in utilization over the 28-year period. Of the 1.6 million passenger miles in the year 2000, approximately 37 percent can be expected to occur on the primary system, about 40 percent on the secondary system, and about 23 percent on the tertiary system. The area served by the transit system is proposed to increase from 165 square miles in 1972 to 436 square miles in the year 2000, an increase of approximately 164 percent. The recommended increase in transit service in the Milwaukee urbanized area is expected to result in an attendant increase in the number of daily revenue passengers—from 177,800 persons in 1972 to about 294,600 persons in the year 2000, an increase of about 66 percent. The anticipated transit ridership volumes for the primary and secondary service in the Milwaukee urbanized area are shown on Map 101.

Transit utilization in the Kenosha and Racine urbanized areas may be expected to increase significantly under the recommended plan over the 1972 levels. In the Kenosha area, transit utilization may be expected to increase from about 9,600 passenger miles per average weekday in 1972 to nearly 42,000 in the year 2000. In the Racine area, transit travel may be expected to increase from about 10,900 passenger miles per average weekday in 1972 to about 46,300 in the year 2000. The area served by the transit system in Kenosha would be increased from about 20 square miles in 1972 to about 39 square miles in the year 2000, an increase of about 92 percent. The transit service area in Racine may also be expected to increase significantly—from 17.5 square miles in 1972 to nearly 43 square miles in the year 2000, an increase of 143 percent. With the recommended increase in transit service, daily revenue passengers may be expected to increase from 2,800 to 18,700 in the Kenosha urbanized area and from 3,100 to 20,700 in the Racine urbanized area between 1972 and 2000. The anticipated transit ridership volumes for the Kenosha and Racine urbanized areas are shown on Map 102.

FORECAST ENERGY USE IN THE REGION: 1982-2000

The natural resource base of the State of Wisconsin does not have any known primary fuel deposits, reserves, or supplies. Consequently, the State and the Region must rely exclusively on the importation of primary fuels—such as coal, natural gas, petroleum, and uranium—to meet the energy needs of transportation, electrical power generation, industrial operations, and general domestic consumption, including space heating and water heating.[6] Moreover, both domestic and foreign supplies of the primary fuels in most common usage today—petroleum and natural gas—are being depleted to the extent that attendant rising costs as well as potential shortages require the development of alternative energy sources to meet the growing energy needs of an expanding economy. Necessary conversions to alternative energy sources may have important implications for long-range air quality planning.

In order to determine how the ambient air quality standards, once achieved in the short-term, can be maintained in the long-term, the probable future, as well as existing, pollutant emissions within the Region must be estimated. Since in many instances the pollutant emission rate is related to the type of fuel consumed, a forecast of the demand and availability of primary energy sources is a prerequisite to identifying and quantifying probable future air quality problems in the Region.

Whereas the probable future demand for energy may be estimated by mathematically projecting existing consumption, determination of the type of fuel which may be used to meet the projected demand requires the exercise of judgment, a difficult task given the uncertain-

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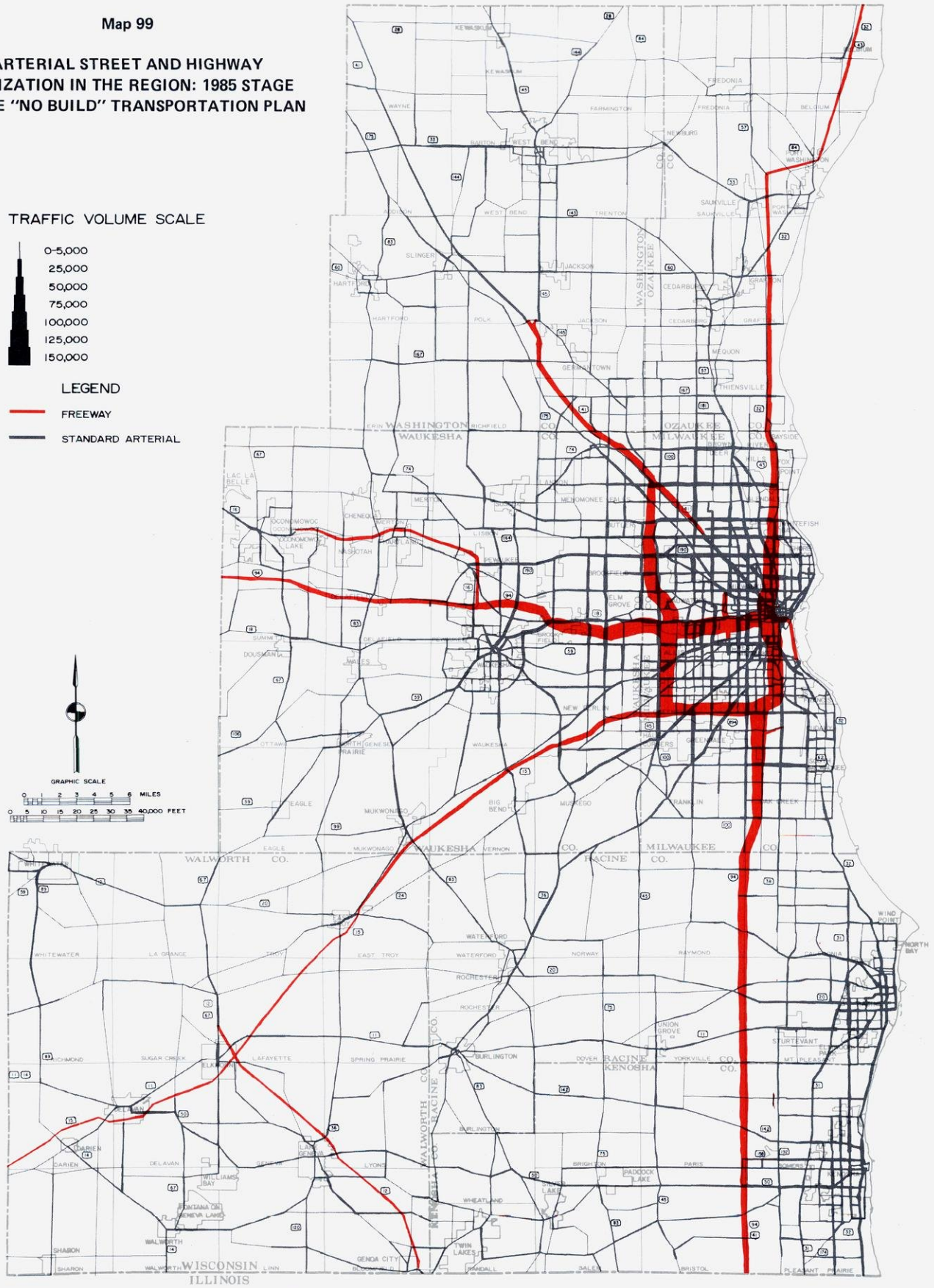
[6] *Recent studies have indicated that wood may have the potential to partially meet the fuel demand in northern portions of the State of Wisconsin. Because the Region does not have the same abundance of harvestable wood supplies as is found in other areas of the State, and because of the cost of preparation and transport, the use of wood as a primary fuel type for other than residential space heating would not appear likely in southeastern Wisconsin, particularly for industrial purposes. Moreover, the stringent air pollution control regulations in effect in southeastern Wisconsin generally offer a disincentive to the use of wood, with its high ash content.*

Map 99

ARTERIAL STREET AND HIGHWAY UTILIZATION IN THE REGION: 1985 STAGE OF THE "NO BUILD" TRANSPORTATION PLAN

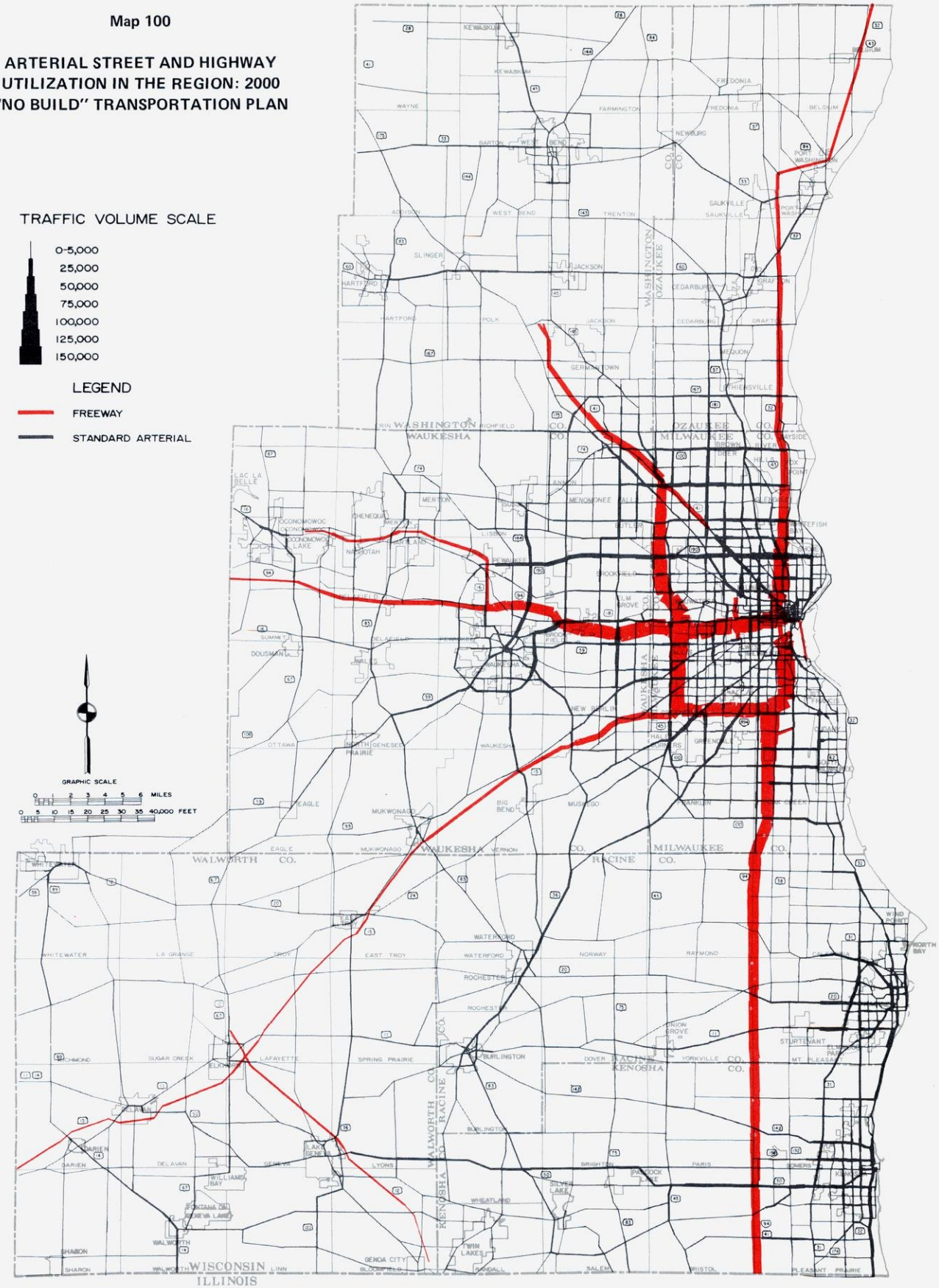


Weekday arterial street and highway system utilization in the Region may be expected to increase to 24.9 million vehicle miles of travel by the year 1985 under the "no build" alternative to the adopted transportation plan, an increase of 4.8 million vehicle miles, or about 24 percent, over the 1972 level of 20.1 million vehicle miles. About 9.4 million vehicle miles of travel, or nearly 38 percent of the total, could be expected to occur on the freeway system, as compared with 31 percent in 1972.

Source: SEWRPC.

Map 100

ARTERIAL STREET AND HIGHWAY UTILIZATION IN THE REGION: 2000 "NO BUILD" TRANSPORTATION PLAN

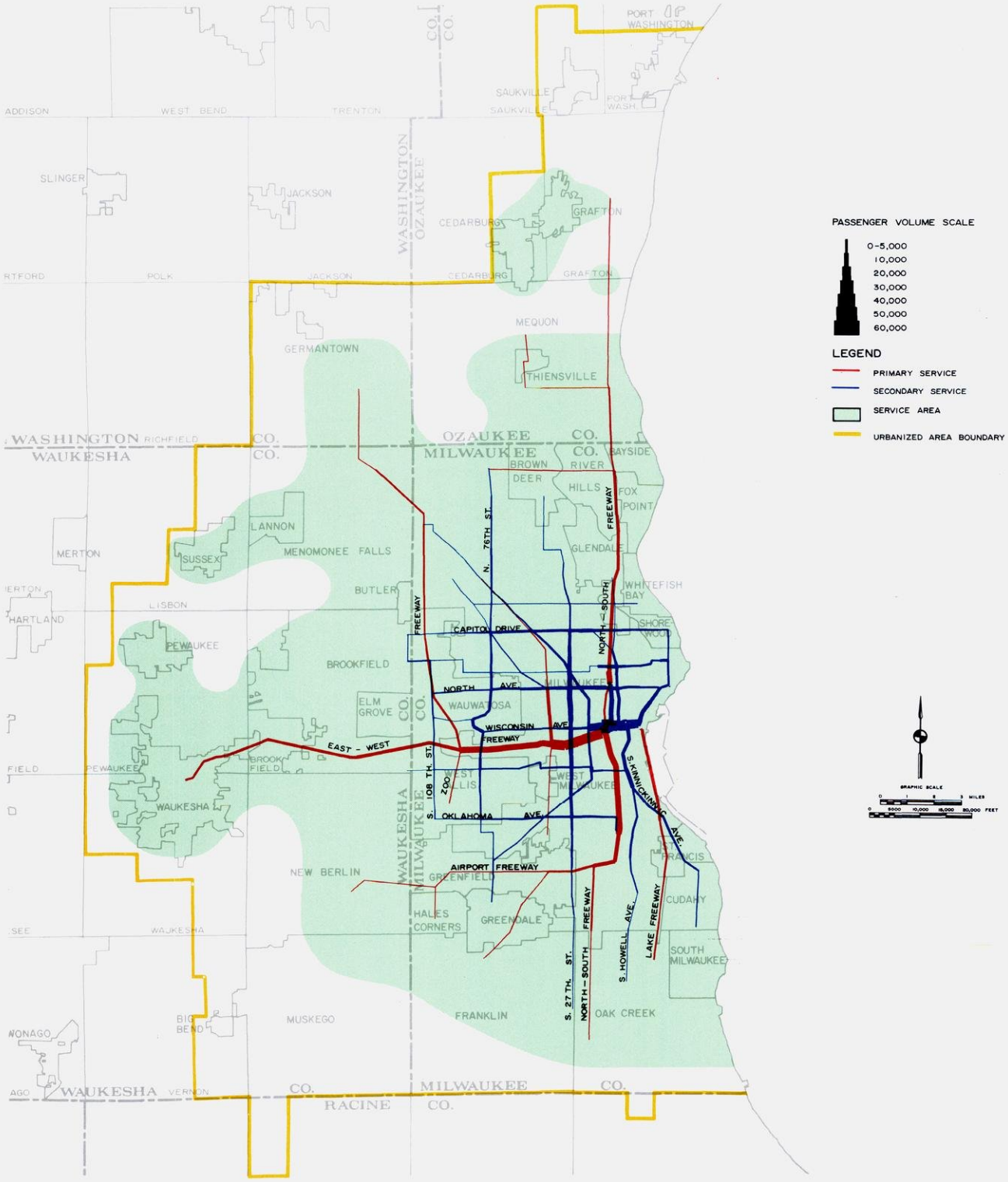


Weekday arterial street and highway system utilization in the Region may be expected to increase to 31.4 million vehicle miles of travel by the year 2000 under the "no build" alternative transportation plan, an increase of 11.3 million vehicle miles, or about 56 percent, over 1972. About 11.3 million vehicle miles of travel, or 36 percent of the total, could be expected to occur on the freeway system, as compared with 31 percent in 1972.

Source: SEWRPC.

Map 101

TRANSIT SYSTEM UTILIZATION IN THE MILWAUKEE URBANIZED AREA: 2000 ADOPTED TRANSPORTATION PLAN

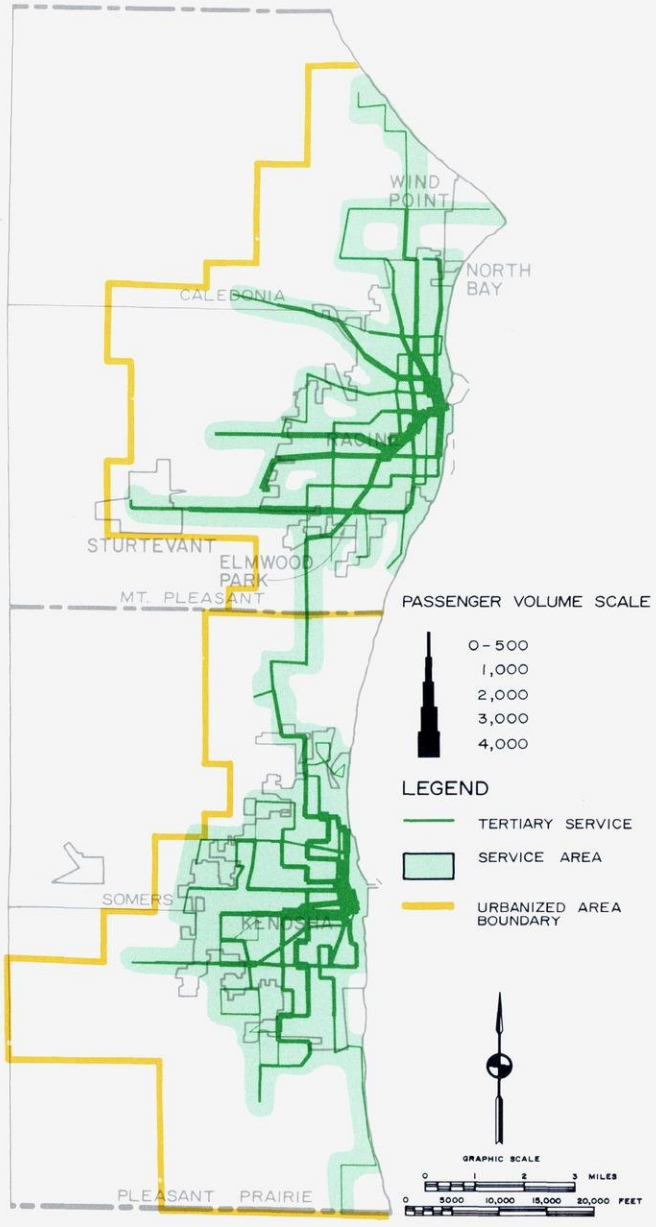


Under the adopted transportation plan, transit utilization in the Milwaukee area could be expected to increase from about 1.2 million passenger miles per average weekday in 1972 to about 1.6 million in the plan design year. About 37 percent of the transit travel could be expected to take place on the primary system, about 40 percent on the secondary system, and about 23 percent on the tertiary system. The base transit fare in Milwaukee would be $0.50 under the adopted plan.

Source: SEWRPC.

Map 102

TRANSIT SYSTEM UTILIZATION IN THE KENOSHA AND RACINE URBANIZED AREAS 2000 ADOPTED TRANSPORTATION PLAN



Under the adopted transportation plan, transit utilization in the Kenosha and Racine urbanized areas could be expected to increase significantly over the 1972 levels. In the Kenosha area, the expected increase would be from about 9,600 passenger miles per average weekday in 1972 to nearly 42,000 by the year 2000. In the Racine area, transit travel could be expected to increase from about 10,900 passenger miles per average weekday in 1972 to about 46,300 by the year 2000. Under the adopted plan, the base transit fare in Kenosha and Racine is assumed to remain at $0.25.

Source: SEWRPC.

ties involved. The availability of petroleum and natural gas in future years, for example, depends on such factors as the amount of reserves, the effectiveness of present conservation efforts, changing climatological conditions, and the willingness of foreign sources to release fuel for export. With all these uncertainties, precise forecasts of primary fuel availability cannot be made. Of necessity, therefore, forecasts of ambient air quality in the Region must be based on certain predefined assumptions concerning the future availability of primary fuel supplies and alternative fuel conversions by major industrial users. For the most part, these assumptions are intended to provide a "worst case" emissions profile in that the use of "dirtier" fuels is emphasized. In planning for the "worst case" situation, it is assumed that the ambient air quality standards may still be attained and maintained in the Region regardless of adverse developments in the long-range availability of any particular fuel type. The energy-related assumptions inherent in the forecast of air pollutant emissions from point, area, and line sources in the Region are presented in this section.

Fuel Availability Forecast—Point Sources

Natural gas is the most commonly used fuel for industrial processes in southeastern Wisconsin. Natural gas supplies from domestic sources in the continental United States, however, have been steadily decreasing since 1967. The continued availability of natural gas in Wisconsin is, therefore, uncertain over the length of the planning period. In the short-term major suppliers have refused to accept new industrial customers, and it is possible that no new residential customers may be accepted under some conditions in the future. The long-term outlook for natural gas supplies is dependent on several factors, including: the deregulation of prices at the wellhead to encourage exploration for new sources as well as to make it more profitable to extract the gas from more difficult existing sources; the development of large-scale coal gasification plants—a factor which is dependent on technological feasibility; and the completion of pipeline facilities to bring natural gas to Wisconsin from Alaskan and Mexican fields. Even under the most optimistic forecast of new sources of natural gas, it is unlikely that the supply will keep up with the demand over the entire 20-year planning period. It is probable, therefore, that industry in southeastern Wisconsin will have to become more reliant on other forms of primary fuel, either because of actual shortages or because of rising costs.

Forecasts of air pollutant emissions from point sources in the Region for the years 1982, 1985, and 2000 were based on two scenarios of primary fuel availability: a fuel oil-intensive energy scenario and a coal-intensive energy scenario. In addition, for point source emissions forecasts for the year 1982, an existing trend, or natural gas-intensive, energy scenario was used under the assumption that, at least in the near term, natural gas supplies would be adequate to meet industrial demand. For each alternative energy scenario other than the existing trends scenario, utilization of natural gas supplies was assumed to decrease at a rate of 1 percent per year—a rate considered to be representative of the depletion rate of domestic supplies—beginning in 1980 and continuing thereafter until all industries using natural gas had converted to either coal or fuel oil. The rate of conversion of industrial natural gas users was based on a priority schedule established by the Federal Power Commission wherein the sale of natural gas is curtailed first to the largest consumers—those having a maximum day requirement of three million cubic feet or more—followed by smaller commercial and industrial users and finally by residential customers.

Table 278

EXISTING AND FORECAST MAJOR ELECTRIC POWER GENERATION PLANTS IN THE REGION: 1970-2000

Power Plant	Year of Initial Operation or Major Addition	Expected Retirement Date[a]	Maximum Rated Capacity (megawatts fossil steam)	Maximum Rated Capacity (megawatts combustion units)
Existing or Under Construction				
E. Wells Street	1898-1938	January 1, 1989	12	--
Commerce Street	1903-1941	January 1, 1992	31	--
Lakeside	1920-1968	January 1, 1982	261	40 (gas turbine)
Port Washington[b]	1935-1969	1991-2001	376	23 (gas turbine)
Oak Creek	1953-1968	--[f]	1,514	25 (gas turbine)
Valley	1968-1969	--[f]	268	3 (diesel)
Germantown	1978	--[f]	--	264 (combustion turbine)
Pleasant Prairie[c]	1980-1983	--[f]	1,160	--
Proposed				
Ozaukee County[d]	1991	--[f]	400-800	--
Downtown Milwaukee[e]	1993	--[f]	510	--

[a] *For planning purposes, the Wisconsin Electric Power Company establishes retirement dates for generation units on the basis of 50 to 60 years of operation for steam units and 40 years of operation for combustion turbine units. No retirement dates have been established for the combustion units listed. Operating and economic conditions influence the actual dates of retirement, and all dates listed are subject to review.*

[b] *All units were omitted from the year 2000 point source emissions forecast, although the latest available retirement schedule from the Wisconsin Electric Power Company calls for the retirement of Unit 1 on January 1, 1991, Unit 2 on January 1, 1994, Unit 3 on January 1, 1999, Unit 4 on January 1, 2000, and Unit 5 on January 1, 2001.*

[c] *One unit was included in the 1982 point source emissions forecast and two units in the 1985 and 2000 forecasts. Wisconsin Electric Power Company's long-range plans call for the first unit to become operational in 1980 and the second unit to become operational in 1983.*

[d] *Included in year 2000 point source emissions forecast and in the Wisconsin Electric Power Company's long-range plans. Year of initial operation expected to fall between 1989 and 1997. Total capacity could range from 400 megawatts to 800 megawatts, depending upon the number of units to be located at the site.*

[e] *Included in year 2000 point source emissions forecast but has been deleted from Wisconsin Electric Power Company's long-range plans.*

[f] *Retirement date has not yet been established.*

Source: Wisconsin Electric Power Company and SEWRPC.

Also underlying the preparation of the air pollutant emissions forecasts from point sources in the Region were assumptions concerning the location, capacity, and time of on-line operation of new electric power generation plants. Based on the most recent (1978) estimates provided by the Wisconsin Electric Power Company, Table 278 identifies the known or anticipated location, year of initial operation, year of retirement, and maximum rated capacity for the existing and proposed major electric power plants in the Region through the year 2000.

Fuel Availability Forecast—Area Sources

The findings of the 1973 fuel use inventory indicated that approximately 65 percent of the housing units in the Region used natural gas for space heating. Because of the uncertainties concerning the future availability of natural gas supplies for either residential or industrial use, it was assumed that this natural gas dependency would be curtailed in the near term. Accordingly, in forecasting pollutant emissions resulting from residential fuel use it was assumed that no housing units constructed during or after 1980 would be permitted to burn natural gas for either space heating or water heating.[7] Also, based on trends in coal sales observed in the Region between

[7] *The assumption that natural gas supplies would not be available for new residential purposes was based upon energy forecasts as prepared between 1975 and 1977. As with all other energy forecasts, the presumed lack of adequate natural gas supplies to meet demand during the 1980's may not be realized because of new discoveries, innovative technology, or successful conservation measures.*

1973 and 1977, it was assumed that no housing units constructed after 1973 would use coal as a primary fuel. The residential fuel demand brought about by the development of new housing, therefore, was assumed to be met by fuel oil and electricity on an 80-20 basis, respectively. This four-to-one ratio was intended to maximize pollutant emissions while remaining consistent with observed trends in electrical power use.

Energy for small industrial, commercial, and institutional establishments for space heating and water heating purposes was considered to be provided by fuel oil and electricity in the same proportion as for new residential use. Unlike the point source forecasts, however, fuel-type conversions from natural gas to either coal or fuel oil were not assumed for existing area sources because of their individually small size. In addition, it was assumed unlikely that the energy requirements of expansion or new development would be met by either coal or natural gas.

Fuel Availability Forecast—Line Sources

In the absence of practical alternatives, the automobile fleet operating on the regional arterial street and highway system between 1980 and 2000 was assumed to remain powered by the internal combustion engine. Moreover, it was assumed that the automobile fleet would consist primarily of gasoline-fueled engines, with no significant proportion of the total vehicle fleet being comprised of diesel-fueled vehicles by the year 2000. It should be noted, however, that several automobile manufacturers are intensifying their research on the diesel-powered motor vehicle. One company, General Motors, Inc., estimates that as much as 25 percent of the vehicle fleet in the year 2000 may be diesel-powered. Nevertheless, since diesel engines are cleaner-burning than are gasoline engines with respect to all pollutants except particulate matter and sulfur oxides, the assumption that gasoline engines will predominate in the year 2000 represents a "worst case" scenario of the major transportation-related pollutant species.

A significant energy-related assumption concerns the fuel economy to be achieved by motor vehicles in future years. The Energy Policy and Conservation Act (Public Law 94-162, December 22, 1975), under "Title V-Improving Automotive Efficiency, Part A—Automotive Fuel Economy," has set forth certain minimum levels of average fleet fuel economy which must be attained by passenger automobiles manufactured subsequent to 1978. This legislation has mandated that passenger automobiles manufactured in 1978 will operate at 18.0 miles per gallon (mpg) of gasoline; in 1979, at 19.0 mpg; in 1980, at 20.0 mpg; and in 1985 and thereafter, at 27.5 mpg. Gasoline consumption in the design and intermediate years was, therefore, forecast on the basis of these mandated fuel economy levels.

FORECAST POINT SOURCE EMISSIONS IN THE REGION: 1982, 1985, AND 2000

The forecast of air pollutant emissions from point sources in the Region is dependent on the anticipated change in the level of process throughput activity from the base year through intermediate years to the design year. It was previously indicated that one measure of future process activity may be derived from the forecast of change in employment within specific industry groups. As forecast by the Commission, employment levels by major industry groups to the year 2000 have been presented in Table 265 and Figure 97. These employment forecasts actually represent summaries of employment forecasts by more specific industry groups. For classification purposes, the U. S. Department of Labor has grouped together industries with certain common characteristics and has identified each group by a Standard Industrial Classification (SIC) code. The actual and forecast employment levels in the Region by major two-digit SIC codes are presented in Table 279 for selected years between 1970 and 2000. It should be noted that the employment data for 1977 contained in Table 279 are based on the Commission's long-range employment forecasts. Employment estimates for 1977 indicate an actual regional employment level of approximately 835,100 jobs, or about 29,500 more jobs than forecast for that year. This represents about a 3.5 percent difference between the forecast as prepared in 1972 and the estimated actual number of jobs in the Region in 1977. For consistency, it was determined to use the forecast 1977 employment levels rather than the estimated 1977 employment levels, together with forecast 1982, 1985, and 2000 levels, to develop emission growth rates for point sources in the Region.

The change in employment levels in the Region, as indicated in Table 279, was used to gage the growth rate in process throughput activity—and hence, in air pollutant emissions—which may be anticipated within each industrial source category. The growth rate was determined using the employment data for the year 1977 as the base for measuring future change. The year 1977 was selected as the base year since it corresponded to the most recent point source emissions inventory available from the Wisconsin Department of Natural Resources prior to the calculation of the forecast emissions. For each of the forecast years, the level of activity of a process or facility as identified in the 1977 point source emissions inventory was increased or decreased according to the growth rate corresponding to the process or facility SIC code. These calculations provided the initial forecasts of emissions from point sources in the Region for the years 1982, 1985, and 2000.

During 1976, the Wisconsin Department of Natural Resources and SEWRPC staff members conducted personal interviews with representatives of the operators of the largest point sources of air pollutant emissions in southeastern Wisconsin. At the same time, a questionnaire was mailed to all other facility operators identified in the Department's most recent point source inventory. A copy of this questionnaire is contained in this report as Appendix G. The purpose of the interviews and questionnaire was to establish a more source-specific growth rate, where possible, rather than rely on industry-wide employment forecasts. Approximately 120 of the nearly 250 questionnaires mailed were returned to the

Table 279

ACTUAL AND FORECAST EMPLOYMENT IN THE REGION: 1970, 1982, 1985, AND 2000

Employment Category	Standard Industrial Classification Code	Actual Employment 1970 (in thousands)	Forecast Employment (in thousands)			
			1977	1982	1985	2000
Industrial						
Construction and Mining	10-17	24.0	25.4	26.4	27.0	30.1
Manufacturing						
Food and Related Products	20	18.9	18.6	18.4	18.2	17.6
Printing and Publishing	27	14.9	16.9	18.3	19.1	23.3
Primary Metals	33	22.5	24.8	26.5	27.5	32.4
Fabricated Metals	34	24.6	28.5	31.3	33.0	41.4
Nonelectrical Machinery	35	68.1	73.6	77.6	80.0	91.9
Electrical Equipment	36	36.5	37.9	38.9	39.6	42.6
Transportation Equipment	37	22.0	23.4	24.3	24.8	27.6
Other Manufacturing	--[a]	43.5	43.5	43.5	43.5	43.5
Wholesale Trade	50-51	32.0	35.8	38.5	40.1	48.2
Subtotal	--	307.0	328.4	343.7	352.8	398.6
Commercial						
Retail Trade	52-59	111.2	122.2	130.0	134.7	158.2
Finance, Insurance, and Real Estate	60-67	31.2	34.9	37.6	39.2	47.2
Private Services, Except Education	70-81, 83-89	166.9	181.6	192.1	198.3	229.6
Subtotal	--	309.3	338.7	359.7	372.2	435.0
Institutional						
Educational Services	82	51.7	59.6	65.3	68.7	85.7
Public Administration	91-97	27.0	31.3	34.4	36.3	45.5
Subtotal	--	78.7	90.9	99.7	105.0	131.2
Other Employment						
Agricultural	01-09	10.6	9.8	9.3	9.0	7.5
Transportation, Communication, and Utilities	40-49	36.0	37.8	39.0	39.8	43.7
Subtotal	--	46.6	47.6	48.3	48.8	51.2
Total	--	741.6	805.6	851.4	878.8	1,016.0

[a] *This category consists of SIC codes 19, 21-26, 28-32, and 38-39.*

Source: SEWRPC.

Commission. Those facilities which either incompletely or incorrectly filled out the questionnaire, or which indicated a growth rate below the corresponding industrywide growth rate as determined from regional employment forecasts, were assigned the growth factor developed on the basis of the employment forecasts by SIC code. Only for those facilities indicating a growth rate in excess of the industrywide value were the point source emissions forecasts for the years 1982, 1985, and 2000 recalculated. Approximately 80 facilities, or two-thirds of all respondents, indicated no growth or a growth rate below the industrywide value. Fifteen sources, however, did indicate a growth rate in excess of the growth rate estimated from the industry group employment forecasts. An additional five sources—all electrical power generation plants operated by the Wisconsin Electric Power Company—were assumed to be presently operating at or near maximum capacity and no further growth was attributed to these facilities. The remaining 20 respondents were classified as small point sources—that is, sources having a total pollutant emission rate of less than 10 tons per year—and were addressed under the forecast of area source emissions.

A final adjustment to the point source emissions forecasts was the addition of new facilities planned for construction and operation within the forecast period, and the deletion of sources having either a fixed retirement schedule or an anticipated shutdown date within the forecast period. This adjustment primarily affected the emissions forecasts for electrical power generation plants in the Region, the construction and retirement schedules of which have been presented in Table 278.

Once the growth rate of industrial process throughput had been estimated by major industrial category, and anticipated new industrial facilities had been located, the air pollutant emissions from forecast point sources in the Region were determined under the three alternative energy scenarios described in the previous section. As noted earlier, it was assumed that natural gas supplies would decrease at a rate of 1 percent per year beginning in 1980, and that this loss of supply would be accommodated through the conversion by major industrial users—first by the largest consumers and then by the smaller users in descending order as natural gas supplies are forecast to decrease—to either fuel oil or coal as

a primary fuel for combustion. Under this assumption, the heat value in British Thermal Units (BTU's) of the annual natural gas consumption for those point source facilities being converted to an alternative fuel type was used to determine the gallons of fuel oil or the tons of coal required to provide an equivalent amount of heat energy. The air pollutant emissions resulting from the forecast fuel conversions were then calculated using the emission factors appropriate to the alternative fuel type. Table 280 presents by county the air pollutant emissions forecast under the natural gas-intensive energy scenario (existing trend) for the year 1982, and the fuel oil-intensive and coal-intensive energy scenarios for the years 1982, 1985, and 2000.

As may be seen in Table 280, the coal-intensive energy scenario consistently indicates the highest forecast of air pollutant emissions from point sources in the design and intermediate years. Particulate matter emissions in the Region in the year 2000, for example, are forecast to total 11,700 tons under the coal-intensive energy scenario as compared with 9,900 tons under the fuel oil-intensive energy scenario. For the purpose of air quality maintenance planning, therefore, the coal-intensive energy scenario provides the potentially "worst case" pollutant conditions in the future years and will be the basis upon which the evaluation of anticipated growth in industrial emissions will be made.

The forecast 11,700 tons of particulate matter emissions from point sources in the year 2000 represents an increase of about 4,300 tons, or about 58 percent, over the 1977 emission level of about 7,400 tons. The largest absolute increase is forecast to occur in Milwaukee County, where particulate matter emissions are forecast to increase by about 2,300 tons, or 38 percent—from about 6,100 tons in 1977 to about 8,400 tons in the year 2000. In part, this increase may be attributed to the fact that Milwaukee County has the largest number of point sources in the Region converting to coal use under the forecast energy scenario. Also, a new steam generation plant has been included in the year 2000 forecast and has been located near the Lake Michigan shoreline in the vicinity of the North Harbor Tract in the City of Milwaukee. New electric power generation plants in Kenosha County—the Pleasant Prairie Power Plant, the first unit of which is scheduled for operation by 1982 and the second unit by 1984—in Ozaukee County—a new coal-fired power plant scheduled for operation by 1987—and in Washington County—the peaking plant located in Germantown which came on-line in 1978—also contribute to the increase in particulate matter emissions from point sources over the planning period.[8]

Sulfur dioxide emissions from point sources are forecast to total 205,800 tons in the year 2000, an increase of about 9,000 tons, or about 5 percent, over the 1977 emission level of 196,800 tons. This increase is due in part to the forecast industrial growth in the Region, accompanied by the conversion to coal. The largest absolute and relative change in sulfur dioxide emissions is forecast to occur in Ozaukee County, where sulfur dioxide emissions are expected to decrease by about 35,000 tons, or more than 92 percent—from about 38,000 tons in 1977 to about 2,900 tons in the year 2000. This forecast change may be attributed to the retirement of the Port Washington Power Plant in 1986.

Carbon monoxide emissions from point sources in the Region are forecast to increase by about 5,200 tons, or by over 60 percent—from 8,600 tons in 1977 to 13,800 tons in the year 2000. As with the increase forecast for particulate matter and sulfur dioxide emissions from point sources, this increase may be attributed to forecast industrial growth in the Region and to the postulated conversion from natural gas to coal as a primary energy source. For the same reasons, hydrocarbon emissions from point sources are forecast to increase by about 11,300 tons, or more than 35 percent— from 32,100 tons in 1977 to 43,400 tons in the year 2000.

The largest absolute and relative increase in forecast emissions from point sources in the Region over the planning period is demonstrated by nitrogen oxides. Nitrogen oxide emissions are forecast to increase by about 44,200 tons, or more than 95 percent—from about 46,300 tons in 1977 to about 90,500 tons in the year 2000. The principal factor underlying this large increase is the assumed addition of new power plants in the Region over the planning period.

FORECAST LINE SOURCE EMISSIONS IN THE REGION: 1982, 1985, AND 2000

Air pollutant emissions from line sources in the Region were forecast for the years 1982, 1985, and 2000, following the methodology approved by the U. S. Environmental Protection Agency (EPA) set forth in Chapter VII of this report. Assumptions for the forecast years pertaining to vehicle age distribution and the mode of vehicle operation, and the correction factors for air-conditioning use and vehicle loads, were consistent with the initial conditions defined for the 1973 and 1977 inventories.

For the years 1985 and 2000, separate line source emissions forecasts were prepared for the adopted regional transportation plan and for the "no build" alternative regional transportation plan in order to provide a comparison of the operating characteristics of each alternative plan as they may affect ambient air quality. The 1982 line source emissions forecast was developed on the basis of an assumed growth rate in average weekday vehicle miles of travel between the 1972 inventory and the 1985 stage of the "no build" alternative transportation plan. In order to focus on the impact of the development

[8] *This forecast of electric power generation facilities was based upon the Wisconsin Electric Power Company's (WEPCO) Advance Plan as prepared during 1977 and 1978. The forecast of electric power generation facilities as presently (1980) envisioned by WEPCO, insofar as it differs from the forecast used for estimating future air pollutant emissions, is presented in Table 278.*

Table 280

EXISTING AND FORECAST AIR POLLUTANT EMISSIONS FROM POINT SOURCES UNDER NATURAL GAS, FUEL OIL, AND COAL-INTENSIVE SCENARIOS: 1977, 1982, 1985, AND 2000

County	Energy Scenario	Particulate Matter (tons per year)				Sulfur Dioxide (tons per year)				Carbon Monoxide (tons per year)				Nitrogen Oxides (tons per year)				Hydrocarbons (tons per year)			
		1977	1982	1985	2000	1977	1982	1985	2000	1977	1982	1985	2000	1977	1982	1985	2000	1977	1982	1985	2000
Kenosha	Existing	49	--	--	--	444	--	--	--	33	--	--	--	267	--	--	--	3,857	--	--	--
	Natural Gas	--	411	--	--	--	9,966	--	--	--	531	--	--	--	7,255	--	--	--	4,197	--	--
	Fuel Oil	--	413	419	793	--	10,505	10,606	20,325	--	539	545	1,050	--	7,348	7,406	14,473	--	4,197	4,281	4,921
	Coal	--	527	545	945	--	11,112	11,291	21,186	--	543	547	1,055	--	7,668	7,776	14,946	--	4,199	4,290	4,926
Milwaukee	Existing	6,095	--	--	--	157,850	--	--	--	6,839	--	--	--	38,884	--	--	--	22,200	--	--	--
	Natural Gas	--	5,221	--	--	--	157,512	--	--	--	7,068	--	--	--	37,411	--	--	--	24,288	--	--
	Fuel Oil	--	5,267	6,246	6,997	--	161,817	164,000	167,543	--	7,124	7,288	9,112	--	38,166	38,699	48,359	--	24,303	24,985	29,979
	Coal	--	5,990	7,299	8,418	--	166,553	171,029	176,632	--	7,144	7,303	9,115	--	40,823	42,888	54,055	--	24,317	25,117	30,166
Ozaukee	Existing	536	--	--	--	38,004	--	--	--	379	--	--	--	6,355	--	--	--	938	--	--	--
	Natural Gas	--	538	--	--	--	38,004	--	--	--	376	--	--	--	6,355	--	--	--	1,026	--	--
	Fuel Oil	--	538	541	888	--	38,004	38,012	2,848	--	376	376	1,745	--	6,355	6,359	16,797	--	1,026	1,147	1,722
	Coal	--	538	542	897	--	38,004	38,022	2,896	--	376	376	1,745	--	6,355	6,361	16,831	--	1,026	1,147	1,732
Racine	Existing	293	--	--	--	374	--	--	--	31	--	--	--	342	--	--	--	1,801	--	--	--
	Natural Gas	--	316	--	--	--	413	--	--	--	31	--	--	--	368	--	--	--	1,949	--	--
	Fuel Oil	--	316	367	472	--	502	984	1,537	--	33	41	55	--	368	485	668	--	1,949	1,982	2,311
	Coal	--	339	464	648	--	606	1,601	2,843	--	33	46	66	--	409	871	1,482	--	1,951	1,999	2,331
Walworth	Existing	127	--	--	--	45	--	--	--	506	--	--	--	192	--	--	--	654	--	--	--
	Natural Gas	--	134	--	--	--	48	--	--	--	542	--	--	--	207	--	--	--	632	--	--
	Fuel Oil	--	135	143	166	--	190	246	298	--	542	565	673	--	208	227	271	--	632	631	774
	Coal	--	156	182	213	--	285	465	567	--	544	568	674	--	237	301	361	--	634	632	775
Washington	Existing	10	--	--	--	8	--	--	--	292	--	--	--	23	--	--	--	1,054	--	--	--
	Natural Gas	--	125	--	--	--	983	--	--	--	374	--	--	--	2,256	--	--	--	1,109	--	--
	Fuel Oil	--	125	128	137	--	983	1,012	1,112	--	374	401	531	--	2,256	2,271	2,296	--	1,109	1,182	1,370
	Coal	--	125	133	162	--	983	1,045	1,253	--	374	401	532	--	2,256	2,295	2,390	--	1,109	1,182	1,377
Waukesha	Existing	322	--	--	--	114	--	--	--	490	--	--	--	233	--	--	--	1,623	--	--	--
	Natural Gas	--	342	--	--	--	116	--	--	--	500	--	--	--	244	--	--	--	1,807	--	--
	Fuel Oil	--	342	359	425	--	116	119	280	--	500	508	562	--	244	244	319	--	1,807	1,794	2,143
	Coal	--	342	359	441	--	116	230	428	--	500	508	564	--	244	245	421	--	1,807	1,794	2,144
Region	Existing	7,432	--	--	--	196,839	--	--	--	8,570	--	--	--	46,296	--	--	--	32,127	--	--	--
	Natural Gas	--	7,087	--	--	--	207,042	--	--	--	9,422	--	--	--	54,096	--	--	--	35,008	--	--
	Fuel Oil	--	7,136	8,203	9,878	--	212,117	214,979	193,943	--	9,488	9,724	13,728	--	54,945	55,691	83,183	--	35,023	36,002	43,220
	Coal	--	8,017	9,524	11,724	--	217,659	223,683	205,805	--	9,514	9,749	13,751	--	57,992	60,737	90,486	--	35,043	36,161	43,451

Source: Wisconsin Department of Natural Resources and SEWRPC.

of transportation facilities and their utilization in the Region over the planning period, all emissions forecasts were made under the meteorological conditions used in the 1977 inventory. This served to eliminate changes in emission levels due to changes in external correction factors.

Table 281 summarizes the air pollutant emissions from line sources as forecast for each vehicle type for the years 1982, 1985, and 2000. The results of the emissions forecasts are discussed by vehicle type in the following sections.

Light-Duty Gasoline Vehicles

Table 282 presents by functional classification the average weekday vehicle miles of travel forecast for light-duty gasoline vehicles in the Region in 1982, 1985, and the year 2000. As may be seen in Table 282, the average weekday vehicle miles of travel for light-duty gasoline vehicles is expected to increase from approximately 21.7 million miles in 1977 to 28.1 million miles in the year 2000 under the adopted transportation plan. This represents an increase of 6.4 million miles, or more than 29 percent, over the planning period. Under the "no build" alternative, average weekday vehicle miles of travel is expected to total 29.6 million miles in the year 2000, an increase of 7.9 million miles, or about 36 percent, over the 1977 level of travel. In the absence of further emission controls on mobile sources, therefore, air pollutant emissions from light-duty gasoline vehicles may be expected to increase by at least 36 percent over the 1977 emission level by the year 2000.

Table 281

EXISTING AND FORECAST AIR POLLUTANT EMISSIONS FROM LINE SOURCES IN THE REGION: 1977, 1982, 1985, AND 2000

Source	Year	Emissions (tons)				
		Particulate Matter	Sulfur Dioxide	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
Light-Duty Gasoline Vehicles	1977	3,100	956	394,895	33,618	34,685
	1982	1,904	990	235,860	23,625	18,186
	1985 "No Build" Plan	1,992	1,036	158,974	20,022	13,029
	1985 Adopted Plan	1,915	996	151,648	19,311	12,425
	2000 "No Build" Plan	2,520	1,310	115,979	22,227	14,438
	2000 Adopted Plan	2,403	1,249	108,071	21,484	13,451
Light-Duty Gasoline Trucks	1977	244	76	31,513	2,598	3,891
	1982	148	77	28,489	2,170	2,699
	1985 "No Build" Plan	161	84	25,522	2,073	2,148
	1985 Adopted Plan	160	83	25,435	2,071	2,142
	2000 "No Build" Plan	194	101	11,546	2,049	1,195
	2000 Adopted Plan	168	88	10,036	1,783	1,054
Heavy-Duty Gasoline Trucks	1977	580	160	89,244	5,416	8,672
	1982	587	161	87,017	5,352	5,854
	1985 "No Build" Plan	594	163	70,506	5,036	4,082
	1985 Adopted Plan	593	163	70,333	5,030	4,069
	2000 "No Build" Plan	679	187	42,816	4,173	2,433
	2000 Adopted Plan	812	223	50,473	5,050	2,624
Heavy-Duty Diesel Trucks	1977	468	596	3,284	5,536	552
	1982	485	618	2,745	6,396	511
	1985 "No Build" Plan	503	641	2,737	6,269	409
	1985 Adopted Plan	503	640	2,733	6,293	408
	2000 "No Build" Plan	706	898	3,644	2,560	394
	2000 Adopted Plan	703	895	3,583	2,645	386
Mass Transit	1977	32	64	852	500	112
	1982	35	61	853	502	118
	1985 "No Build" Plan	35	61	853	502	114
	1985 Adopted Plan	65	114	1,408	862	183
	2000 "No Build" Plan	35	62	779	136	77
	2000 Adopted Plan	101	177	2,045	376	204
Total	1977	4,424	1,852	519,788	47,668	47,912
	1982	3,159	1,907	354,964	38,045	27,368
	1985 "No Build" Plan	3,285	1,985	258,592	33,902	19,782
	1985 Adopted Plan	3,236	1,996	251,557	33,567	19,227
	2000 "No Build" Plan	4,134	2,558	174,764	31,145	18,537
	2000 Adopted Plan	4,187	2,632	174,208	31,338	17,719

Source: SEWRPC.

Vehicle emission rates for carbon monoxide, nitrogen oxides, and hydrocarbons are mandated through the year 1981 by the federal motor vehicle emissions control program. As the vehicle fleet becomes increasingly populated by newer and more controlled vehicles, the average fleet emission rate may be expected to decline substantially. This fact is evidenced by the carbon monoxide, nitrogen oxide, and hydrocarbon exhaust emission rates for light-duty gasoline vehicles operating in calendar years 1982, 1985, and 2000, as shown in Table 283. This table indicates that for later calendar years, a vehicle of a given age generally emits a lower quantity of a particular pollutant species than a vehicle of the same age in an earlier calendar year. Thus, even with the 36 percent increase in average weekday vehicle miles of travel under the "no build" alternative transportation plan in the year 2000, carbon monoxide emissions from light-duty gasoline vehicles are expected to decrease from about 395,000 tons in 1977 to about 116,000 tons in the year 2000, a decline of about 279,000 tons, or about 71 percent, over the planning period. Similarly, nitrogen oxide emissions are expected to decrease by about 11,400 tons—from about 33,600 tons in 1977 to about 22,200 tons in the year 2000—under the "no build" plan. Hydrocarbons also are expected to decrease—from about 34,700 tons in 1977 to about 14,400 tons in the year 2000 under the "no build" plan, a decrease of about 20,300 tons, or 59 percent. Because of the improved traffic flow and lower average weekday vehicle miles of travel anticipated under the adopted transportation plan—due principally to recommended increases in mass transit usage—the carbon monoxide, nitrogen oxide, and hydrocarbon emissions forecasts for this vehicle type are lower under the adopted regional transportation plan than under the "no build" alternative.

The sulfur dioxide emissions from light-duty gasoline vehicles are forecast to increase in proportion to the rate of increase in average weekday vehicle miles of travel in the Region. The sulfur dioxide emissions in the year 2000 under the "no build" alternative transportation plan are forecast to total about 1,310 tons, an increase of about 350 tons, or 36 percent, over the 1977 level of emissions. This forecast increase in sulfur dioxide emissions parallels the 36 percent increase in average weekday vehicle miles of travel expected under the "no build" alternative regional transportation plan.

Due to the decreed elimination of lead additives in gasoline, particulate matter emissions from light-duty gasoline vehicles in the Region are expected to decrease

Table 282

EXISTING AND FORECAST AVERAGE WEEKDAY VEHICLE MILES OF TRAVEL FOR LIGHT-DUTY GASOLINE VEHICLES IN THE REGION BY FUNCTIONAL CLASSIFICATION 1977, 1982, 1985, AND 2000

Year	Average Weekday Vehicle Miles of Travel			
	Freeway	Standard Arterial	Collector and Local Streets	Total
1977	7,387,400	12,191,800	2,087,900	21,667,100
1982	7,625,000	12,683,000	2,090,200	22,398,200
1985 "No Build" Plan	7,941,000	13,346,900	2,092,800	23,380,700
1985 Adopted Plan	7,482,100	13,049,200	1,988,700	22,520,000
2000 "No Build" Plan	9,571,700	17,496,300	2,499,500	29,567,500
2000 Adopted Plan	10,584,100	15,149,600	2,381,300	28,115,000

Source: SEWRPC.

Table 283

CARBON MONOXIDE, NITROGEN OXIDE, AND HYDROCARBON EXHAUST EMISSION FACTORS FOR LIGHT-DUTY GASOLINE VEHICLES: CALENDAR YEARS 1982, 1985, AND 2000

Vehicle Age	Emission Factor (grams per mile)								
	Carbon Monoxide			Nitrogen Oxides			Hydrocarbons		
	1982	1985	2000	1982	1985	2000	1982	1985	2000
1	2.6	2.6	2.6	0.4	0.4	0.4	0.3	0.3	0.3
2	5.3	5.3	5.3	0.7	0.7	0.7	0.6	0.6	0.6
3	10.9	8.3	8.3	2.0	1.0	1.0	0.9	0.9	0.9
4	32.1	11.0	11.0	2.3	1.3	1.3	2.2	1.2	1.2
5	35.7	13.6	13.6	2.5	1.6	1.6	2.5	1.5	1.5
6	39.0	19.8	16.0	2.7	2.7	1.9	2.8	1.8	1.8
7	42.1	42.1	18.2	3.1	2.8	2.1	3.1	3.1	2.1
8	45.0	45.0	20.2	3.2	3.0	2.4	3.3	3.3	2.3
9	94.7	47.5	22.1	3.0	3.2	2.6	7.9	3.5	2.5
10	99.8	49.8	23.7	3.0	3.3	2.7	8.3	3.7	2.7
11	104.3	51.9	25.2	4.4	3.4	2.9	8.7	3.9	2.9
12	108.4	108.4	26.5	4.4	3.0	3.1	9.1	9.1	3.0
13 and Older	112.4	112.4	27.8	4.4	3.0	3.2	9.4	9.4	3.2

Source: U. S. Environmental Protection Agency.

from about 3,100 tons in 1977 to about 2,500 tons in the year 2000 under the "no build" alternative transportation plan. As noted in Chapter VII, lead additives are the principal source of particulate matter in automobile exhaust. By substituting lead-free gasoline for regular gasoline, the particulate matter emission rate decreases from 0.54 gram per vehicle mile to 0.25 gram per vehicle mile. The impact of the removal of lead additives from gasoline is most pronounced between 1977 and 1982, but this emission reduction is gradually offset by the increase in travel by the year 2000.

Light-Duty Gasoline Trucks

Table 284 presents by functional classification the average weekday vehicle miles of travel forecast for light-duty gasoline trucks in the Region for the years 1982, 1985, and 2000. As may be seen in Table 284, the average weekday vehicle miles of travel for this vehicle type is expected to total 2.3 million miles in the year 2000 under the "no build" plan, an increase of about 0.7 million miles, or 44 percent, over the 1977 level of travel.

The carbon monoxide, nitrogen oxide, and hydrocarbon exhaust emission rates for the light-duty gasoline truck fleet are presented in Table 285 for calendar years 1982, 1985, and 2000. As may be seen in Table 285, there is a significant reduction between 1982 and 1985 in the exhaust emission rate for each pollutant species for vehicles between one and three years of age. This reduction is attributable to the implementation of more stringent emission limitations on this vehicle type beginning in 1983.

Based on the emission rates shown in Table 285 and the forecast travel shown in Table 284, carbon monoxide emissions from light-duty gasoline trucks are forecast to decrease by about 20,000 tons, or about 63 percent—from 31,500 tons in 1977 to 11,500 tons in the year 2000—under the "no build" plan (see Table 281). Nitrogen oxide emissions from this vehicle type are forecast to decrease by about 550 tons, or about 21 percent—from 2,600 tons in 1977 to about 2,050 tons in the year 2000—under the "no build" plan. And finally, hydrocarbon emissions from light-duty gasoline trucks are forecast to decrease by about 2,700 tons, or 69 percent—from about 3,900 tons in 1977 to about 1,200 tons in the year 2000—under the "no build" plan.

The forecast particulate matter and sulfur oxide emissions from light-duty gasoline trucks follow a pattern similar to that found in the forecast of such emissions from light-duty gasoline vehicles. Particulate matter emissions are forecast to decrease markedly between 1977 and 1982—from about 245 tons to about 150 tons—due to the removal of lead compounds from gasoline, and to gradually increase with increasing travel to about 195 tons in the year 2000 under the "no build" plan. Sulfur oxide emissions are forecast to increase by about 25 tons, or more than 33 percent—from 76 tons in 1977 to about 101 tons in the year 2000—under the "no build" plan, reflecting the growth in average weekday vehicle miles of travel anticipated for this vehicle type.

Table 284

FORECAST AVERAGE WEEKDAY VEHICLE MILES OF TRAVEL FOR LIGHT-DUTY GASOLINE TRUCKS IN THE REGION BY FUNCTIONAL CLASSIFICATION 1977, 1982, 1985, AND 2000

Year	Average Weekday Vehicle Miles of Travel			
	Freeway	Standard Arterial	Collector and Local Streets	Total
1977	482,600	1,000,000	152,900	1,635,500
1982	513,500	1,075,200	156,500	1,745,200
1985 "No Build" Plan	556,000	1,179,400	157,200	1,892,600
1985 Adopted Plan	551,300	1,183,000	157,200	1,891,500
2000 "No Build" Plan	684,900	1,410,400	179,400	2,274,700
2000 Adopted Plan	760,400	1,030,700	179,400	1,970,500

Source: SEWRPC.

Heavy-Duty Gasoline Trucks

Table 286 presents by functional classification the average weekday vehicle miles of travel forecast for heavy-duty gasoline trucks in the Region for the years 1982, 1985, and 2000. As may be seen in Table 286, travel by heavy-duty gasoline trucks is expected to increase by about 212,500 miles per average weekday, or about 14 percent—from 1,304,400 miles in 1977 to about 1,516,900 miles in the year 2000—under the "no build" alternative transportation plan.

The carbon monoxide, nitrogen oxide, and hydrocarbon exhaust emission rates for heavy-duty gasoline trucks are presented in Table 287 for calendar years 1982, 1985, and 2000. As with light-duty gasoline trucks, more stringent exhaust emission limitations for heavy-duty gasoline trucks are scheduled for implementation in 1983. The impact of these limitations is evident in Table 287 for trucks between one and three years of age in 1985 as compared with trucks of similar age in 1982.

Based on the forecast increase in vehicle miles of travel by heavy-duty gasoline trucks in the Region, and on the exhaust emission factors shown in Table 287, carbon monoxide, nitrogen oxide, and hydrocarbon emissions from this vehicle type are expected to decrease over the planning period. As indicated in Table 281, carbon monoxide emissions are forecast to decrease by about 46,400 tons, or 52 percent—from about 89,200 tons in 1977 to about 42,800 tons in the year 2000—under the "no build" plan. Nitrogen oxide emissions are forecast to decrease by about 1,200 tons, or about 22 percent—from about 5,400 tons in 1977 to about 4,200 tons in the year 2000—under the "no build" plan. And finally, hydrocarbon emissions are forecast to decrease by about 6,300 tons, or nearly 72 percent—from about 8,700 tons in 1977 to about 2,400 tons in the year 2000—under the "no build" plan.

Particulate matter and sulfur oxide emissions from heavy-duty gasoline trucks are forecast to increase in proportion to the increase in average weekday vehicle miles of travel over the planning period. Particulate matter emissions from this vehicle type are expected to increase by about 100 tons, or 17 percent—from about 580 tons in 1977

Table 285

CARBON MONOXIDE, NITROGEN OXIDE, AND HYDROCARBON EXHAUST EMISSION FACTORS FOR LIGHT-DUTY GASOLINE TRUCKS: CALENDAR YEARS 1982, 1985, AND 2000

Vehicle Age	Emission Factor (grams per mile)								
	Carbon Monoxide			Nitrogen Oxides			Hydrocarbons		
	1982	1985	2000	1982	1985	2000	1982	1985	2000
1	17.7	5.1	5.1	1.8	0.5	0.5	1.2	0.4	0.4
2	25.0	7.8	7.8	1.9	1.9	0.8	1.7	0.8	0.8
3	32.9	10.7	10.7	2.1	2.1	1.2	2.3	1.1	1.0
4	40.2	40.2	13.5	2.3	2.3	1.5	2.9	2.9	1.4
5	48.7	47.1	16.1	2.4	2.4	1.7	3.6	3.4	1.7
6	55.1	53.5	18.5	2.4	2.5	2.0	4.1	3.9	2.0
7	61.0	59.4	20.7	2.4	2.7	2.3	4.6	4.4	2.2
8	66.4	66.4	22.7	2.4	2.4	2.5	5.0	5.0	2.5
9	94.7	71.3	24.5	3.0	2.4	2.7	7.9	5.3	2.7
10	99.8	75.7	26.2	3.0	2.4	2.5	8.3	5.7	2.9
11	104.3	79.6	27.7	4.4	2.4	2.9	8.7	6.0	3.0
12	108.4	108.4	29.0	4.4	3.0	3.2	9.1	9.1	3.2
13 and Older	112.4	112.4	30.3	4.4	3.0	3.3	9.4	9.4	3.3

Source: U. S. Environmental Protection Agency.

to about 680 tons in the year 2000—under the "no build" plan. Sulfur oxide emissions are forecast to increase by about 27 tons, or about 17 percent—from 160 tons in 1977 to 187 tons in the year 2000—under the "no build" plan.

Heavy-Duty Diesel Trucks

Table 288 presents by functional classification the average weekday vehicle miles of travel forecast for heavy-duty diesel trucks in the Region for the years 1982, 1985, and 2000. As may be seen in Table 288, the average weekday vehicle miles of travel by this vehicle type is expected to increase from 627,900 miles in 1977 to 868,600 miles in the year 2000 under the "no build" alternative transportation plan. This represents an increase of about 240,700 miles, or about 38 percent, over the planning period. The carbon monoxide, nitrogen oxide, and hydrocarbon exhaust emission rates for heavy-duty diesel trucks are presented in Table 289 for calendar years 1982, 1985, and 2000. Through a close review of Table 289, it may be seen that the only significant emission rate reduction for this vehicle type occurs in 1983 for hydrocarbons and in 1985 for nitrogen oxides.

Since carbon monoxide exhaust emission rates remain essentially constant throughout the planning period, the emissions of this pollutant species are expected to increase with increasing travel. Table 281 indicates that carbon monoxide emissions from heavy-duty diesel trucks are forecast to increase by about 360 tons, or nearly 11 percent—from about 3,280 tons in 1977 to about 3,640 tons in the year 2000—under the "no build" plan. Table 281 also indicates that nitrogen oxide emissions are forecast to decrease by about 2,900 tons, or about 53 percent—from about 5,500 tons in 1977 to about 2,600 tons in the year 2000—under the "no build" plan. And finally, hydrocarbon emissions from this vehicle type are forecast to decrease by about 155 tons, or 28 percent—from about 550 tons in 1977 to about 395 tons in the year 2000—under the "no build" plan.

Table 286

EXISTING AND FORECAST AVERAGE WEEKDAY VEHICLE MILES OF TRAVEL FOR HEAVY-DUTY GASOLINE TRUCKS IN THE REGION BY FUNCTIONAL CLASSIFICATION 1977, 1982, 1985, AND 2000

Year	Average Weekday Vehicle Miles of Travel			
	Freeway	Standard Arterial	Collector and Local Streets	Total
1977	376,800	804,900	122,700	1,304,400
1982	381,200	813,100	122,900	1,317,200
1985 "No Build" Plan	386,700	823,400	122,900	1,333,000
1985 Adopted Plan	397,300	812,400	122,900	1,332,600
2000 "No Build" Plan	446,400	933,900	136,600	1,516,900
2000 Adopted Plan	503,200	1,178,500	136,600	1,818,300

Source: SEWRPC.

As with heavy-duty gasoline trucks, the particulate matter and sulfur oxide emissions from heavy-duty diesel trucks are forecast to increase in proportion to the increase in average weekday vehicle miles of travel. Particulate matter emissions are expected to increase by about 235 tons, or 50 percent—from about 470 tons in 1977 to about 705 tons in the year 2000—under the

Table 287

CARBON MONOXIDE, NITROGEN OXIDE, AND HYDROCARBON EXHAUST EMISSION FACTORS FOR HEAVY-DUTY GASOLINE TRUCKS: CALENDAR YEARS 1982, 1985, AND 2000

Vehicle Age	Emission Factor (grams per mile)								
	Carbon Monoxide			Nitrogen Oxides			Hydrocarbons		
	1982	1985	2000	1982	1985	2000	1982	1985	2000
1	194.8	20.4	20.4	9.1	4.2	4.2	5.5	2.0	2.0
2	203.6	35.4	35.4	9.1	9.1	4.6	6.2	3.5	3.5
3	215.2	55.3	55.3	9.1	9.1	5.3	7.2	5.5	5.5
4	226.2	226.2	74.1	9.1	9.1	5.9	8.2	8.2	7.4
5	263.2	236.3	91.5	10.5	9.1	6.4	25.8	9.0	9.1
6	272.4	245.5	107.3	10.5	9.1	7.0	26.6	9.8	10.7
7	280.7	253.8	121.5	10.5	9.1	7.4	27.4	10.6	12.1
8	288.1	288.1	134.2	10.5	10.5	7.8	28.0	28.0	13.4
9	294.7	294.7	145.4	10.5	10.5	8.2	28.6	28.6	14.5
10	294.4	300.5	155.4	12.8	10.5	8.5	25.6	29.1	15.5
11	299.7	305.8	164.5	12.8	10.5	8.8	26.0	29.5	16.5
12	304.5	310.6	172.7	12.8	10.5	9.1	26.5	29.9	17.3
13 and Older	308.8	308.8	180.1	12.8	12.8	9.3	26.8	26.8	18.0

Source: U. S. Environmental Protection Agency and SEWRPC.

Table 288

EXISTING AND FORECAST AVERAGE WEEKDAY VEHICLE MILES OF TRAVEL FOR HEAVY-DUTY DIESEL TRUCKS IN THE REGION BY FUNCTIONAL CLASSIFICATION 1977, 1982, 1985, AND 2000

Year	Average Weekday Vehicle Miles of Travel			
	Freeway	Standard Arterial	Collector and Local Streets	Total
1977	469,600	149,000	9,300	627,900
1982	483,300	154,500	9,700	647,500
1985 "No Build" Plan	500,600	161,000	9,900	671,500
1985 Adopted Plan	471,600	191,300	9,900	672,800
2000 "No Build" Plan	633,200	225,200	10,200	868,600
2000 Adopted Plan	761,100	164,600	10,200	935,900

Source: SEWRPC.

"no build" plan. Sulfur oxide emissions are forecast to increase by about 300 tons, or 50 percent—from about 600 tons in 1977 to about 900 tons in the year 2000—under the "no build" plan.

Mass Transit Vehicles

As may be seen in Table 290, under the adopted regional transportation plan average weekday vehicle miles of travel by mass transit vehicles are forecast to increase by about 129,900 miles, or 189 percent—from about 68,700 miles in 1977 to 198,600 miles in the year 2000. Under the "no build" alternative transportation plan, the average weekday vehicle miles of travel by mass transit vehicles are expected to decline by about 1 percent, to 68,000 miles, in the year 2000. Air pollutant emissions from mass transit vehicles may, therefore, be expected to be higher under the adopted transportation plan than under the "no build" alternative plan (see Table 281).

Under the year 2000 "no build" alternative plan, carbon monoxide emissions are forecast to total about 780 tons, as compared with 2,045 tons under the adopted plan. Similarly, nitrogen oxide and hydrocarbon emissions from mass transit vehicles are forecast to total about 135 tons and 75 tons, respectively, under the year 2000 "no build" plan, as compared with about 375 tons and 205 tons, respectively, under the adopted transportation plan. However, the decrease in total pollutant emissions forecast under the adopted regional transportation plan, which would result principally from increased transit use, would more than offset the small absolute increase in pollutant emissions from mass transit vehicles expected under this plan.

FORECAST AREA SOURCE EMISSIONS IN THE REGION: 1982, 1985,AND 2000

Emissions From Agricultural Equipment

A basic assumption underlying the preparation of the forecast of pollutant emissions from agricultural equipment use for the years 1982, 1985, and 2000 is that, although some agricultural land within the Region will be converted to other land uses, the amount of such conversion will be minimized through implementation of the adopted regional land use plan. Accordingly, the amount of farm machinery was assumed to remain essentially at 1973 levels. There has also been an observed trend toward the use of diesel engines rather than gasoline engines for tractors and self-propelled combines. In

Table 289

CARBON MONOXIDE, NITROGEN OXIDE, AND HYDROCARBON EXHAUST EMISSION FACTORS FOR HEAVY-DUTY DIESEL TRUCKS: CALENDAR YEARS 1982, 1985, AND 2000

Vehicle Age	Emission Factor (grams per mile)								
	Carbon Monoxide			Nitrogen Oxides			Hydrocarbons		
	1982	1985	2000	1982	1985	2000	1982	1985	2000
1	27.0	27.0	27.0	19.9	5.3	5.3	4.5	2.8	2.8
2	27.0	27.0	27.0	19.9	19.9	5.3	4.5	2.8	2.8
3	27.0	27.0	27.0	19.9	19.9	5.3	4.5	2.8	2.8
4	27.0	27.0	27.0	19.9	19.9	5.3	4.5	4.5	2.8
5	27.0	27.0	27.0	20.1	19.9	5.3	4.5	4.5	2.8
6	27.0	27.0	27.0	20.1	19.9	5.3	4.5	4.5	2.8
7	27.0	27.0	27.0	20.1	19.9	5.3	4.5	4.5	2.8
8	27.0	27.0	27.0	20.1	20.1	5.3	4.5	4.5	2.8
9	27.0	27.0	27.0	20.1	20.1	5.3	4.5	4.5	2.8
10	35.1	27.0	27.0	21.4	20.1	5.3	4.3	4.5	2.8
11	35.1	27.0	27.0	21.4	20.1	5.3	4.3	4.5	2.8
12	35.1	27.0	27.0	21.4	20.1	5.3	4.3	4.5	2.8
13 and Older	35.1	35.1	27.0	21.4	21.4	5.3	4.3	4.3	2.8

Source: U. S. Environmental Protection Agency and SEWRPC.

Table 290

EXISTING AND FORECAST AVERAGE WEEKDAY VEHICLE MILES OF TRAVEL FOR URBAN MASS TRANSIT VEHICLES IN THE REGION: 1977, 1982, 1985, AND 2000

Year	Average Weekday Vehicle Miles of Travel
1977	68,700
1982	69,500
1985 "No Build" Plan	70,300
1985 Adopted Plan	134,300
2000 "No Build" Plan	68,000
2000 Adopted Plan	198,600

Source: SEWRPC.

1973 approximately 75 percent of the tractors and self-propelled combines were powered by diesel engines. In 1977 approximately 80 percent of these vehicles were diesel-powered. This trend is assumed to continue through the year 2000, when all tractors and self-propelled combines are estimated to be diesel-powered. Reflecting this trend, the fuel mix was postulated to be 85 percent diesel-15 percent gasoline in 1982; 90 percent diesel-10 percent gasoline in 1985; and 100 percent diesel in the year 2000. As in 1973 and 1977, all pickup bailers were assumed to be gasoline-powered and all forage harvesters were assumed to be diesel-powered throughout the forecasting period.

As indicated in Table 129 in Chapter VII, increasing the use of diesel equipment would serve to increase particulate matter, sulfur oxide, and nitrogen oxide emission rates and decrease the carbon monoxide and hydrocarbon emission rates. The forecast pollutant emissions from agricultural equipment for the years 1982, 1985, and 2000—presented in Table 291—exhibit this influence of increased diesel fuel use. Between 1977 and 2000, particulate matter emissions from agricultural equipment operations are forecast to increase by about 73 tons, or about 12 percent, over the 1977 level of about 589 tons. Similarly, sulfur oxide emissions are expected to increase by about 51 tons, or 13 percent—from 400 tons in 1977 to 451 tons in the year 2000, and nitrogen oxide emissions are forecast to increase by about 370 tons, or 8 percent—from 4,500 tons in 1977 to about 4,850 tons in the year 2000. Conversely, hydrocarbon emissions are forecast to decrease between 1977 and 2000 by about 300 tons, or about 21 percent—from about 1,400 tons to 1,100 tons. Carbon monoxide emissions are expected to show both the greatest absolute and the greatest relative decrease over the 23-year planning period, declining by about 7,200 tons, or 42 percent—from about 16,900 tons in 1977 to about 9,700 tons in the year 2000. This large decrease in carbon monoxide emissions is attributable to the difference in the emission factors for gasoline-powered and diesel-powered agricultural equipment. Table 129 in Chapter VII shows that the carbon monoxide emission rates for gasoline-powered tractors and nontractor farm equipment are 3,380 grams and 4,360 grams, respectively, for each hour of use. For diesel-powered tractors and diesel-powered nontractor farm equipment, the carbon

Table 291

EXISTING AND FORECAST AIR POLLUTION EMISSIONS FROM AREA SOURCES IN THE REGION: 1977, 1982, 1985, AND 2000

Source Category	Emissions (tons)											
	Particulate Matter				Sulfur Dioxide				Carbon Monoxide			
	1977	1982	1985	2000	1977	1982	1985	2000	1977	1982	1985	2000
Agricultural Equipment	589	616	639	662	400	418	434	451	16,884	15,534	13,677	9,719
Agricultural Tilling	5,848	5,791	5,756	5,532	--	--	--	--	--	--	--	--
Aircraft Operations	68	81	91	151	64	80	93	175	8,772	10,527	11,514	23,761
Commercial-Institutional Fuel Use	750	771	787	864	4,760	5,079	5,351	6,700	1,830	1,869	1,897	2,028
Dry Cleaning Operations	--	--	--	--	--	--	--	--	--	--	--	--
Forest Wildfires	106	30	30	30	--	--	--	--	865	245	245	245
Gasoline Marketing	--	--	--	--	--	--	--	--	--	--	--	--
General Utility Engines	207	212	218	251	18	21	22	26	16,844	17,804	18,405	21,647
Incineration	360	368	378	394	60	60	63	76	276	302	315	379
Industrial Fuel Use	384	403	424	528	651	859	1,149	2,598	387	406	423	505
Power Boat Operations	--	--	--	--	39	39	39	39	20,510	20,510	20,510	20,510
Travel by Railroad Engines	216	216	216	216	484	484	484	484	1,300	1,300	1,300	1,300
Railroad Yard Work	64	64	64	64	140	140	140	140	708	708	708	708
Residential Fuel Use	835	863	885	1,006	5,533	6,007	6,391	8,464	1,748	1,801	1,844	2,085
Rock Handling and Storage	321	321	321	321	--	--	--	--	--	--	--	--
Small Point Sources	68	54	54	62	28	22	23	25	16	6	7	8
Snowmobile Operations	6	6	6	6	[a]	[a]	[a]	[a]	269	269	269	269
Travel on Unpaved Roads	262	327	327	327	--	--	--	--	--	--	--	--
Unpaved Auto Lots	36	49	49	49	--	--	--	--	--	--	--	--
Unpaved Truck Lots	61	77	77	77	--	--	--	--	--	--	--	--
Aggregate Storage Piles	360	360	360	360	--	--	--	--	--	--	--	--
Commercial Vessels	45	5	5	5	34	10	10	10	47	39	39	39
Industrial Fugitive Dust	8,056	8,056	8,056	8,056	--	--	--	--	--	--	--	--
Architectural Coating	--	--	--	--	--	--	--	--	--	--	--	--
Miscellaneous Solvent Use	--	--	--	--	--	--	--	--	--	--	--	--
Auto Refinishing	--	--	--	--	--	--	--	--	--	--	--	--
Cutback Asphalt	--	--	--	--	--	--	--	--	--	--	--	--
Construction Equipment	--	--	--	--	--	--	--	--	--	--	--	--
Industrial Equipment	--	--	--	--	--	--	--	--	--	--	--	--
Off-Highway Motorcycles	--	--	--	--	--	--	--	--	--	--	--	--
Total	18,642	18,670	18,743	18,961	12,211	13,219	14,199	19,188	70,456	71,320	71,153	83,203

Source Category	Emissions (tons)							
	Nitrogen Oxides				Hydrocarbons			
	1977	1982	1985	2000	1977	1982	1985	2000
Agricultural Equipment	4,481	4,664	4,781	4,852	1,399	1,360	1,294	1,127
Agricultural Tilling	--	--	--	--	--	--	--	--
Aircraft Operations	580	747	875	1,719	1,204	1,356	1,613	3,519
Commercial-Institutional Fuel Use	2,849	3,057	3,202	3,897	443	452	458	485
Dry Cleaning Operations	--	--	--	--	2,420	2,576	2,645	2,996
Forest Wildfires	22	6	6	6	146	42	42	42
Gasoline Marketing	--	--	--	--	6,568	5,491	5,563	4,581
General Utility Engines	85	93	96	118	6,459	6,782	6,984	8,037
Incineration	108	111	114	130	188	199	203	223
Industrial Fuel Use	3,064	3,225	3,347	3,959	58	60	63	80
Power Boat Operations	41	41	41	41	6,975	6,975	6,975	6,975
Travel by Railroad Engines	2,804	2,804	2,804	2,804	308	308	308	308
Railroad Yard Work	1,048	1,048	1,048	1,048	404	404	404	404
Residential Fuel Use	4,906	5,109	5,265	6,132	530	538	546	594
Rock Handling and Storage	--	--	--	--	--	--	--	--
Small Point Sources	216	135	139	161	100	60	62	71
Snowmobile Operations	[a]	[a]	[a]	[a]	173	173	173	173
Travel on Unpaved Roads	--	--	--	--	--	--	--	--
Unpaved Auto Lots	--	--	--	--	--	--	--	--
Unpaved Truck Lots	--	--	--	--	--	--	--	--
Aggregate Storage Piles	--	--	--	--	--	--	--	--
Commercial Vessels	121	91	91	91	26	21	21	21
Industrial Fugitive Dust	--	--	--	--	--	--	--	--
Architectural Coating	--	--	--	--	3,916	4,060	4,169	4,732
Miscellaneous Solvent Use	--	--	--	--	7,996	8,304	8,332	9,986
Auto Refinishing	--	--	--	--	424	444	452	509
Cutback Asphalt	--	--	--	--	10,552	10,552	10,552	10,552
Construction Equipment	--	--	--	--	398	414	423	470
Industrial Equipment	--	--	--	--	1,152	1,201	1,234	1,355
Off-Highway Motorcycles	--	--	--	--	556	589	614	727
Total	20,325	21,131	21,809	24,958	52,395	52,361	53,330	57,967

[a] *Less than one-half ton per year.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

monoxide emission rates are reduced to 161 grams and 95.2 grams, respectively, for each hour of use. The shift toward the increased use of diesel-powered farm equipment, therefore, is expected to yield significant reductions in carbon monoxide and hydrocarbon emissions, while providing only slight to moderate increases in particulate matter, sulfur dioxide, and nitrogen oxide emissions.

The forecast agricultural equipment emissions for 1982, 1985, and 2000 were temporally allocated based on the seasonal equipment usage factors shown in Table 130 in Chapter VII. The forecast emissions were then spatially allocated to the U. S. Public Land Survey quarter sections in the Region according to the ratio of agricultural land in each section to the total agricultural land in the respective counties for each year.

Emissions From Agricultural Tilling Operations

The particulate matter emissions which are forecast to result from agricultural tilling operations in the years 1982, 1985, and 2000 are presented in Table 291. These emissions are based both on the amount of land in the Region projected to be devoted to agricultural crop production and on the total emissions generated in 1973, set forth in Table 127 in Chapter VII. The 1973 base-year emissions were multiplied by a growth factor obtained by dividing the number of forecast acres devoted to agricultural crop production by the number of acres in the same class of land use in the 1973 base year. The 1982 cropland acreage was derived by the interpolation between the 1970 regional land use inventory and the 1985 stage of the adopted land use plan for the year 2000. The acres subject to agricultural tilling operations in the year 2000 were calculated using the 2000 land use forecast.

Since the quantity of particulate matter emissions from agricultural tilling operations is directly proportional to the area tilled, and because the acreage devoted to agricultural crops is projected to decrease over the forecast period, particulate matter emissions from this source are forecast to decrease from about 5,800 tons in 1977 to about 5,500 tons in the year 2000. This decrease of about 300 tons, or about 5 percent, reflects the anticipated loss of farmland in the Region. Although both an absolute and a relative decrease in particulate matter emissions from this source is forecast, tilling operations will continue to be a major contributor of particulate matter, producing approximately 30 percent of the area source particulate matter emissions for each of the three projection years.

Emissions From Aircraft Operations

Pollutant emissions from aircraft operations were calculated for the years 1982, 1985, and 2000 on the basis of the number of operations anticipated at the public airports over the forecast period.[9] Between 1977 and 2000, significant regional growth is anticipated in the general aviation sector, with the number of general aviation aircraft expected to increase from approximately 1,500 to over 4,000 and the number of annual general aviation operations from approximately 953,000 to over 3,200,000. A summary of forecast aircraft operations at selected airports is presented in Table 292.

Data on operations anticipated at General Mitchell Field for 1982, 1985, and 2000 are presented in Table 293. A large increase in operations is expected in the first three common carrier groups listed in the table, the larger multi-engine passenger carriers—from approximately 14,300 in 1982 to over 68,600 in the year 2000. A decrease of about 30,100 operations in the fifth and sixth common carrier groups listed, the smaller jet and turboprop passenger planes, is expected. The number and type of military aircraft and the number of military aircraft operations are expected to remain constant at 15,100 operations annually over the forecast period. As in the base year, aircraft operations at General Mitchell Field may be expected to account for the majority of air pollutant emissions from this source category in future years.

Forecasts of emissions from aircraft operations for the years 1982, 1985, and 2000 are presented in Table 291. As in 1973 and 1977, these emissions were assigned to

Table 292

FORECAST AIRCRAFT OPERATIONS AT SELECTED AIRPORTS IN THE REGION 1977, 1982, 1985, AND 2000

Airport	Number of Operations			
	1977	1982	1985	2000
Kenosha-Municipal	89,700	110,700	123,300	318,424
Aero Park	2,526	2,526	2,526	2,526
Capitol Drive	40,185	40,185	40,185	40,185
Hales Corners[a]	22,960	--	--	--
Timmerman	190,752	228,753	251,553	385,895
Rainbow[b]	29,931	--	--	--
Grob	3,674	3,674	3,674	3,674
Ozaukee	29,000	84,000	117,000	305,706
Burlington-Municipal	42,156	70,286	87,164	270,069
Fox River	4,600	4,600	4,600	4,600
Racine-Commercial	53,000	68,000	77,000	202,596
Sylvania	38,100	81,600	107,700	201,600
East Troy-Municipal	44,000	94,000	124,000	256,788
Gruenwald	21,600	59,100	81,600	190,146
Lake Lawn Lodge	1,600	9,619	9,619	9,619
Playboy	6,400	18,205	18,205	18,205
Hartford-Municipal	81,468	101,358	113,300	266,630
West Bend-Municipal	86,116	98,546	106,000	350,960
Waukesha County	165,658	205,873	230,000	380,631
Total	953,426	1,281,025	1,497,426	3,208,254

[a] *Ceased operation August 16, 1977.*

[b] *Expected to cease operation before 1982.*

Source: R. Dixon Speas Associates, Inc., and SEWRPC.

[9] *For the years 1982 and 1985, the number of operations was taken directly from SEWRPC Planning Report No. 21, A Regional Airport System Plan for Southeastern Wisconsin. For the year 2000 the number of annual operations was calculated on the basis of a straight-line projection from the Commission estimates. No change in the number of aircraft operations was assumed from 1982 to 2000 for the very small private airports in the Region. These smaller, private airports are expected to produce approximately 1 percent of the total year 2000 regional aircraft pollutant emissions.*

the U. S. Public Land Survey quarter sections in which the individual airports were located. For those airports located in more than one quarter section, the pollutant emissions were assigned equally to all quarter sections encompassing the airport.

Annual increases are expected in each of the five emission categories as the number of aircraft and annual aircraft operations increase. Because of this growth and the high carbon monoxide emission factor for aircraft operations, such operations are projected to contribute over 25 percent of the area source carbon monoxide emissions by the year 2000, more than doubling from approximately 10,500 tons to 23,800 tons between 1982 and 2000. Between 1977 and 2000, hydrocarbon emissions from aircraft operations are projected to increase from approximately 1,200 tons to about 3,500 tons, or about 6 percent of the year 2000 total area source hydrocarbon emissions.

Emissions From Small Commercial-Institutional and Industrial Operations

As in 1977, emissions from small commercial-institutional operations and from small industrial operations were considered together. The emissions forecasts presented in Table 291 were determined from fuel estimates based on the assumption that commercial-institutional activity in the Region will increase by 7.4 percent between the 1977 base year and 1982, by 11.9 percent between 1977 and 1985, and by 34.0 percent between 1977 and the year 2000. The growth factor for each forecast period was determined by dividing the forecast year employment by the 1977 employment for the appropriate Standard Industrial Classification (SIC) codes.

Because of the uncertainty regarding future natural gas supplies, a "worst case" assumption was made that beginning in 1980 no new natural gas service would be installed for use in this category. Natural gas consumption was projected to increase between 1977 and 1980 and to remain constant between 1980 and 1982. The increase in natural gas consumption that would have taken place between 1980 and 1982 was reallocated to fuel oil, proportioned between residual and distillate fuel oil using the same ratio used in preparing such emissions estimates in 1977. The forecast fuel consumption for small commercial-institutional operations for the years 1982, 1985, and 2000 is presented in Table 294.

The emissions from small commercial-institutional operations were calculated using the same emission factors as were used in the 1977 base year inventory. The emissions were apportioned seasonally on the basis of two assumptions: that 25 percent of the annual fuel consumption is attributable to water heating and other nonspace heating purposes, which are distributed evenly by season, and that 75 percent of the consumption is attributable to space heating uses, which vary according to the annual distribution of heating degree-days. The average heating degree-days determined from meteorological data recorded at the General Mitchell Field weather station for the 10-year period from 1965 through 1974 were used to seasonally allocate space heating demand (see Table 295). The emissions were allocated as they were in the base year inventory and are presented in Table 291.

Table 293

FORECAST AIRCRAFT OPERATIONS AT GENERAL MITCHELL FIELD BY AIRCRAFT TYPE: 1982, 1985, AND 2000

Aircraft Group	Number of Operations		
	1982	1985	2000
Common Air Carrier and Commuter			
Boeing 747	4,576	6,164	15,134
DC-10, L-1011	5,648	7,514	24,916
DC-8 Stretch	4,118	7,360	28,594
DC-8, Boeing 707	1,646	2,342	2,014
DC-9, Boeing 727	49,792	49,792	38,940
CV-580, F-227	24,256	21,832	4,964
Total	90,036	95,004	114,562
Air Taxi			
Turboprop	2,976	3,340	4,298
General Aviation			
Light Twin	74,324	74,984	142,266
Heavy Twin	9,718	9,805	18,602
Light Turboprop	30,934	31,209	59,212
Heavy Turboprop	12,593	12,704	24,104
Turbojet	9,308	9,390	17,816
Total	136,877	138,092	262,000
Military			
KC-135	6,040	6,040	6,040
C-130	9,060	9,060	9,060
Total	15,100	15,100	15,100

Source: SEWRPC.

Natural gas consumption by small commercial-institutional operations was projected to increase by approximately 4 percent between 1977 and 1980, when all projected growth was allocated to dirtier fuels—in particular, residual and distillate fuel oils. Between 1977 and the year 2000, liquid propane gas consumption by small commercial-institutional operations is forecast to increase by approximately 32 percent, residual fuel oil consumption by 64 percent, and distillate fuel oil consumption by about 60 percent. Because the emission factors for liquid fuels, especially for sulfur dioxide and nitrogen oxides, are higher than natural gas emission factors, sulfur dioxide and nitrogen oxide emissions from small commercial-institutional operations are forecast to increase between 1977 to 2000 by 41 and 37 percent, respectively. Particulate matter emissions are forecast to increase by 15 percent between 1977 and 2000, and carbon monoxide and hydrocarbon emissions are forecast to increase by 11 and 10 percent, respectively, over the forecast period.

The forecast fuel consumption for small industrial operations is presented in Table 296. These forecasts were based on the assumption that industrial activity in the Region will increase by 4.7 percent between 1977 and 1982, by 7.4 percent between 1977 and 1985, and by 21.4 percent between 1977 and 2000.

Under the assumption of industrial growth without additional natural gas supplies after 1980, the use of residual

Table 294

FORECAST TOTAL FUEL CONSUMPTION BY SMALL COMMERCIAL-INSTITUTIONAL OPERATIONS IN THE REGION: 1982, 1985, AND 2000

County	Fuel Type				
	Natural Gas (cubic feet)	Coal (tons)	LPG Propane (gallons)	Fuel Oil Residual (gallons)	Fuel Oil Distillate (gallons)
Kenosha					
1982	2,029,005,120	7,385	3,835,374	997,629	9,529,858
1985	2,029,005,120	7,385	3,984,453	1,092,165	10,432,030
2000	2,029,005,120	7,385	4,726,453	1,562,693	14,922,385
Milwaukee					
1982	6,254,533,484	12,647	29,404,534	7,391,849	69,420,068
1985	6,254,533,484	12,647	30,547,467	7,852,744	73,755,714
2000	6,254,533,484	12,647	36,236,153	10,146,747	95,335,407
Ozaukee					
1982	419,223,056	2,462	1,278,458	327,764	3,131,041
1985	419,223,056	2,462	1,328,151	352,024	3,362,610
2000	419,223,056	2,462	1,575,485	472,775	4,515,195
Racine					
1982	3,060,855,994	9,487	5,113,832	1,336,781	12,769,501
1985	3,060,855,994	9,487	5,312,602	1,472,855	14,068,019
2000	3,060,855,994	9,487	6,301,939	2,150,130	20,531,096
Walworth					
1982	914,928,352	2,462	1,278,458	337,652	3,095,939
1985	914,928,352	2,462	1,328,151	376,914	3,454,989
2000	914,928,352	2,462	1,575,485	572,336	5,242,082
Washington					
1982	485,604,795	4,923	2,556,916	648,969	6,199,531
1985	485,604,795	4,923	2,656,302	687,538	6,567,768
2000	485,604,795	4,923	3,150,970	879,510	8,400,581
Waukesha					
1982	3,801,248,825	12,308	6,392,290	1,670,515	15,957,477
1985	3,801,248,825	12,308	6,640,753	1,839,907	17,573,948
2000	3,801,248,825	12,308	7,891,374	2,683,018	25,619,566
Region					
1982	16,965,399,630	51,674	49,859,862	12,711,159	120,103,415
1985	16,965,399,630	51,674	51,797,879	13,674,147	129,215,078
2000	16,965,399,630	51,674	61,457,859	18,467,209	174,566,312

Source: SEWRPC.

Table 295

NUMBER OF HEATING DEGREE-DAYS AT GENERAL MITCHELL FIELD BY SEASON: 1965-1974

Season	Number of Heating Degree-Days
Winter	3,758
Spring	2,016
Summer	- -
Fall	1,428
Annual	7,202

Source: U. S. Department of Commerce, National Weather Service.

fuel oil by small industrial operations is projected to increase by approximately 350 percent between 1977 and 2000, with distillate fuel oil increasing by about 410 percent. As indicated in Table 291, sulfur dioxide emissions are expected to show the largest relative increase of the five pollutants—from about 650 tons in 1977 to about 2,600 in the year 2000, an increase of almost 300 percent.

Emissions From Dry Cleaning Operations

Evaporative hydrocarbon emissions from dry cleaning operations in the Region for 1982, 1985, and 2000 were calculated by multiplying the population forecast for each county in the Region by an assumed hydrocarbon loss of 2.7 pounds per person for each of the three forecast years. These emissions forecasts are presented in Table 291. Between 1977 and the year 2000, hydrocarbon emissions from dry cleaning operations are forecast to increase from about 2,400 tons to about 3,000 tons, an increase of about 24 percent. These emissions were assigned to U. S. Public Land Survey quarter sections on the basis of the ratio of commercial land area in a quarter section to the total county commercial land area as determined from the land use inventories and interpolated land use inventories for each forecast year.

Emissions From Forest Wildfires

For the three forecast years, estimates of forest wildfire emissions were based on the mean number of acres burned in each county during the six-year period 1970 through 1975. Seasonal allocation factors were based on the statewide seasonal distribution of forest wildfires for a 10-year average (1964-1973) by month. The fuel loading factor of three tons per acre and the emission factors used in the 1977 base year inventory were used in calculations for the projection years.

As indicated in Table 291, forest fire emissions for the three projection years show a significant decrease from the 1977 base year inventory. Since the total acreage burned over a six-year period was used as the basis for wildfire emissions forecasts, and without a basis for a more reliable forecast, the emissions forecast for 1982 was also used for 1985 and 2000.

Emissions From Gasoline Marketing

In order to calculate the evaporative hydrocarbon emissions from gasoline marketing operations for the forecast years, the gasoline consumption for vehicle and general utility engine use needed to be estimated. The vehicle use estimates were based on forecasts of vehicle miles of travel prepared by applying the Commission's traffic simulation models. Gasoline consumed for vehicle use in 1982 was determined by interpolating between 1977 gasoline consumption and 1985 estimated gasoline consumption. The amount of gasoline consumed by general utility engines in the forecast years was estimated by multiplying the 1977 general utility engine gasoline consumption by a growth factor which was determined for each county by dividing the 1977 population into the forecast population for 1982, 1985, and 2000. Total gasoline consumption forecast for vehicle and general utility engine use in the Region is presented in Table 297.

Table 296

FORECAST TOTAL INDUSTRIAL FUEL CONSUMPTION: 1982, 1985, AND 2000

County	Fuel Type					
	Natural Gas (cubic feet)	Fuel Oil Residual (gallons)	Fuel Oil Distillate (gallons)	LPG Propane (gallons)	LPG Butane (gallons)	Coal (tons)
Kenosha						
1982	1,019,207,779	217,416	502,332	--	115,374	--
1985	1,019,207,779	283,554	655,022	--	118,452	--
2000	1,019,207,779	614,244	1,418,469	--	133,843	--
Milwaukee						
1982	22,694,823,780	3,250,140	6,664,889	7,118,633	1,149,133	3,660
1985	22,694,823,780	4,790,592	9,826,172	7,308,550	1,179,791	3,660
2000	22,694,823,780	12,492,855	25,632,591	8,258,138	1,333,079	3,660
Ozaukee						
1982	1,147,650,372	682,675	503,494	796,206	76,916	--
1985	1,147,650,372	827,770	610,618	817,448	78,968	--
2000	1,147,650,372	1,553,242	1,146,237	923,657	89,228	--
Racine						
1982	1,634,859,690	1,122,485	502,585	1,461,624	230,748	--
1985	1,634,859,690	1,367,678	612,494	1,500,618	236,904	--
2000	1,634,859,690	2,593,644	1,162,042	1,695,591	267,685	--
Walworth						
1982	1,148,590,853	226,381	306,024	398,103	38,458	--
1985	1,148,590,853	327,230	442,430	408,724	39,484	--
2000	1,148,590,853	831,478	1,124,461	461,829	44,614	--
Washington						
1982	1,455,982,826	724,807	334,268	796,206	76,916	--
1985	1,455,982,826	934,209	430,877	817,448	78,968	--
2000	1,455,982,826	1,981,214	913,919	923,657	89,228	--
Waukesha						
1982	2,994,604,694	632,308	705,220	1,573,933	153,832	--
1985	2,944,604,694	918,635	1,024,522	1,615,923	157,936	--
2000	2,944,604,694	2,350,267	2,621,034	1,825,878	178,457	--
Region						
1982	11,620,378,590	6,856,212	9,518,812	12,144,705	1,841,377	3,660
1985	11,620,378,590	9,449,668	13,602,135	12,468,711	1,890,503	3,660
2000	11,620,378,590	22,416,944	34,018,753	14,088,750	2,136,134	3,660

Source: SEWRPC.

The emissions factors used for the projection years, presented in Table 298, are based on the assumption that all underground storage tanks will be filled by the submerged loading method. This assumption is based on the present air pollution control regulations that require all gasoline service stations and other organic compound storage tanks in the Southeastern Wisconsin Air Quality Control Region to have submerged fill pipes. It was also assumed that there would be no control of hydrocarbon displacement losses at any gasoline service station in the Region. Gasoline use for general utility engines is forecast to slowly increase during the forecast years. In addition, because the fuel efficiency of the future vehicle fleet will increase, gasoline consumption based on vehicle miles of travel is forecast to decrease. Thus, total gasoline use in the Region is projected to decrease by approximately 7 percent between 1977 and 1982, and by about 23 percent between 1977 and the year 2000. This reduction in gasoline marketing is reflected in Table 291, which indicates that hydrocarbon emissions in the Region will decrease from about 6,600 tons in 1977 to about 4,600 tons in the year 2000.

Emissions From General Utility Engines

Pollutant emissions for the forecast years of 1982, 1985, and 2000 were based on the projected growth in the number of residential buildings in the Region. The forecast number of residential buildings within each U. S. Public Land Survey quarter section was determined as part of the forecast residential fuel use inventory, and the procedure used to make those projections is discussed in the section in this chapter on emissions from residential fuel use. In preparing the forecast of emissions from general utility engines and the composite emission factors, the two major assumptions used in the base year inventory regarding the operation of such engines were applied to the three projection years (see Chapter VII of this report).

Table 297

FORECAST GASOLINE CONSUMPTION IN THE REGION BY COUNTY: 1982, 1985, AND 2000

County	Gasoline Consumed (gallons)		
	1982	1985	2000
Kenosha	46,926,793	49,383,000	43,648,000
(Utility Engine Gasoline Consumption)	3,195,190	3,336,643	3,899,684
Total	50,121,983	52,719,643	47,547,684
Milwaukee	267,581,460	257,300,000	185,194,000
(Utility Engine Gasoline Consumption)	23,224,221	23,105,972	23,815,469
Total	290,805,681	280,405,972	209,009,469
Ozaukee	25,724,808	28,148,000	23,002,000
(Utility Engine Gasoline Consumption)	1,808,577	1,952,659	2,564,666
Total	27,533,385	30,100,659	25,566,666
Racine	54,924,095	57,753,000	47,337,000
(Utility Engine Gasoline Consumption)	4,288,346	4,403,390	4,927,036
Total	59,212,441	62,156,390	52,264,036
Walworth	33,423,735	34,937,000	37,231,000
(Utility Engine Gasoline Consumption)	1,713,043	1,790,167	2,211,383
Total	35,136,778	36,727,167	39,442,383
Washington	31,042,160	34,410,000	30,380,000
(Utility Engine Gasoline Consumption)	2,141,101	2,320,460	3,182,026
Total	33,183,261	36,730,460	33,562,026
Waukesha	107,295,573	112,003,000	92,163,000
(Utility Engine Gasoline Consumption)	6,875,613	7,302,530	9,465,203
Total	114,171,186	119,305,530	101,628,203
Region	566,918,624	573,934,000	458,955,000
(Utility Engine Gasoline Consumption)	43,246,091	44,211,821	50,065,467
Total	610,164,715	618,145,821	509,020,467

Source: SEWRPC.

Table 298

EVAPORATIVE HYDROCARBON EMISSION FACTORS FOR FORECAST GASOLINE MARKETING IN THE REGION

Emission Source	Emission Factor (pounds per 1,000 gallons)
Underground Tank Filling	7.3[a]
Underground Tank Breathing	1.0
Vehicle Refueling Displacement Losses (uncontrolled)	9.0
Vehicle Refueling Spillage	0.7
Total	18.0

[a] *Assumes 100 percent submerged fill.*

Source: U. S. Environmental Protection Agency and SEWRPC.

Because of the projected increase in the number of residential buildings in the Region, an increase in each of the five emission categories is to be expected with an increase in utility engine use. Each of the five pollutants shows an increase in excess of 20 percent between 1977 and 2000 (see Table 291).

Emissions From Incinerators

The air pollutant emissions generated for the forecast years by commercial and industrial incinerators in the Region were calculated and allocated employing the same methodology used in the 1977 inventory. The air pollutant emissions projected for 1982, 1985, and 2000, as shown in Table 291, reflect the expected increase in the quantity of refuse burned, assuming a positive correlation between refuse and the number of employees in manufacturing and the number of residential structures. Between 1977 and 2000, sulfur dioxide and carbon monoxide emissions were projected to increase from 60 tons to 76 tons, and from 276 tons to 379 tons, respectively, or by 27 and 37 percent, respectively. Meanwhile, nitrogen oxides were projected to increase from 108 tons to 130 tons, or by approximately 20 percent.

Emissions From Power Boat Operations

As was discussed in Chapter VII, it is assumed that the level of power boat activities in southeastern Wisconsin has approached the saturation point and that any increase in this activity will be limited. Therefore, for each of the projection years, the air pollutant emissions were held at the 1977 level of approximately 40 tons of sulfur dioxide, about 20,500 tons of carbon monoxide, about 40 tons of nitrogen oxides, and about 7,000 tons of hydrocarbons.

Emissions From Railroad Yards

No significant change was forecast for air pollutant emissions generated by railroad yard activities (see Table 291). This assumption is based on the premise that engine use for both yard work and for travel on the regional rail network is based on a fixed schedule that has shown only minor variations in the recent past.

Emissions From Residential Fuel Use

The air pollutant emissions generated by the combustion of fuel for water heating and space heating in the Region were estimated based on the number of housing units in each fuel-type category (fuel oil, natural gas, coal, wood, electricity), the appropriate fuel use factor for each structure type (see Table 163), and a heating requirement factor as measured by the heating-degree day. The mean heating-degree day values recorded at the weather station at General Mitchell Field for the 10-year period 1965 through 1974 were used to compute the residential fuel demand for each of the projection years (see Table 295).

The number of housing units forecast to use each fuel type was determined by a linear interpolation between the Commission's 1970 land use inventory and the 2000 forecast heating unit fuel and structure inventory. All heating units forecast to be built between 1970 and the projection years were assigned a fuel type. Because of the uncertainty regarding future natural gas supplies,

it was assumed that no new natural gas connections for residential use would be made after the end of 1979.[10] Therefore, the assignment of new residential heating units by fuel type is different for the years 1970 through 1979 than for the years from 1980 through 2000. The residential heating units forecast to be installed between 1970 and 1980 were assigned the following fuel types: fuel oil, 60 percent; natural gas, 20 percent; and electricity, 20 percent. No wood, coal, or propane gas residential heating units were forecast to be installed between 1970 and 1980. Eighty percent of all new forecast residential heating units built after 1980 were assumed to use fuel oil, and 20 percent electricity.

The residential heating units were allocated by structure type, with 90 percent assumed to be single-family structures and 10 percent to be 2- to 4-unit structures. This constitutes a "worst case" assumption, since small structures generally consume more fuel per heating unit and degree-day than do the larger multiple-unit structures.

Table 299 indicates the distribution of housing units forecast for the Region by fuel type for 1982, 1985, and 2000. A comparison with the distribution of housing units for 1977, shown in Table 225 in Chapter VII, indicates that the number of housing units using fuel oil will increase by 60 percent between 1977 and 2000, and that units heated with electricity will increase by 145 percent. Units using natural gas are forecast to increase during the same period by less than 1 percent.

Forecasts of fuel consumption for water heating use for the projection years were based on the assumption that no new residential natural gas-fired water heaters would be installed after the end of 1980. Beginning in 1981 all new water heaters were assumed to be electric, with a new water heater being installed with each new projected residential housing unit.

The forecast residential fuel use emissions, calculated on the basis of the foregoing assumptions, are presented in Table 291. Sulfur dioxide emissions exhibit the largest increase—from a 1977 level of about 5,500 tons to a 2000 level of about 8,500 tons, a 53 percent increase. This increase reflects, in part, the higher sulfur content in fuel oil, which is forecast to replace natural gas in new residential structures. Particulate matter emissions show a 20 percent increase between 1977 and 2000, carbon monoxide shows a 19 percent increase, nitrogen oxides a 25 percent increase, and hydrocarbons a 12 percent increase.

Emissions From Rock Handling and Storage

The particulate matter emissions generated by rock handling and storage operations are assumed to remain constant over the forecast period at approximately 320 tons, the amount generated in the 1977 base year. The available inventory data indicate that rock handling and storage operations have remained relatively constant, and no basis for quantifying a projected growth pattern could be identified.

Emissions From Small Point Sources

The forecast emissions for small point sources were based on the 1977 point source emissions inventory conducted by the Wisconsin Department of Natural Resources. The 88 facilities included in this category were each found to emit less than 10 tons per year of each pollutant species.

The emissions generated by each individual small point source for the three forecast years were calculated by multiplying the 1977 base year emissions by a growth factor for each forecast period, 1977-1982, 1977-1985, and 1977-2000. The growth factors were obtained by interpolating the forecast employment—based on Commission estimates for the Region—in the applicable Standard Industrial Classification (SIC) code. For each of the three forecast years, if a small point source's emissions, with appropriate growth factor applied, exceeded the criteria for small point emissions, that

Table 299

FORECAST NUMBER OF HOUSING UNITS IN THE REGION BY COUNTY AND BY FUEL TYPE: 1982, 1985, AND 2000

County	Number of Units per Fuel Type							
	Natural Gas	Bottled Gas	Fuel Oil and Kerosene	Coal and Coke	Wood	Electric	Other Fuel	No Fuel
Kenosha								
1982	27,921	1,304	14,221	454	--	2,175	84	29
1985	27,890	1,304	15,921	454	--	2,610	84	29
2000	27,751	1,304	23,786	454	--	4,545	84	29
Milwaukee								
1982	255,621	2,112	102,637	1,440	83	12,643	2,640	41
1985	255,193	2,112	106,662	1,440	83	13,544	2,640	41
2000	254,871	2,112	132,433	1,440	83	19,914	2,640	41
Ozaukee								
1982	8,814	315	11,708	170	19	1,684	--	--
1985	8,859	315	13,228	170	19	2,073	--	--
2000	8,736	315	19,835	170	19	3,699	--	--
Racine								
1982	32,566	1,104	23,097	341	15	2,391	109	--
1985	32,529	1,104	24,472	341	15	2,730	109	--
2000	32,393	1,104	31,361	341	15	4,435	109	--
Walworth								
1982	12,129	775	12,132	99	--	1,256	46	17
1985	12,118	775	12,883	99	--	1,447	46	17
2000	12,041	775	17,119	99	--	2,480	46	17
Washington								
1982	8,457	600	16,278	24	35	2,081	19	6
1985	8,475	600	18,188	24	35	2,586	19	6
2000	8,512	600	28,408	24	35	5,125	19	6
Waukesha								
1982	34,922	855	44,735	368	--	5,173	90	15
1985	34,937	855	49,062	368	--	6,324	90	15
2000	34,859	855	71,680	368	--	11,984	90	15
Region								
1982	380,430	7,065	224,808	2,896	152	27,403	2,988	108
1985	380,001	7,065	240,416	2,896	152	31,314	2,988	108
2000	379,163	7,065	324,622	2,896	152	52,182	2,988	108

Source: SEWRPC.

[10] *This assumption represents a "worst case" scenario in terms of air pollutant emissions.*

source was removed from the area source inventory and placed in the point source inventory. The emissions calculated to be produced by small point sources are presented in Table 291. Owing to the application of growth factors and subsequent transfer of a number of small point sources to the point source inventory, a decrease was found in each pollutant species between 1977 and 1982. However, small increases were found in each pollutant species between 1982 and 1985 and 1985 and 2000.

Emissions From Snowmobile Operations

As may be seen in Table 291, emissions from snowmobile operations in the forecast years of 1982, 1985, and 2000 are assumed to remain at the same level as estimated for 1977. This assumption is based on the premise that climatic conditions will not significantly alter the typical snow cover conditions in southeastern Wisconsin.

Emissions From Commercial Vessels

The air pollutant emissions forecasts for commercial transport inboard-powered vessels are based on the 1977 vessel survey and emission inventory prepared by the Commission. For each port facility in the Region, an inventory was prepared consisting of the number of vessels using the port per month, the length of stay of each vessel, vessel fuel type, and the rate of fuel consumption. Ferry activity on Lake Michigan was not included in the inventory. With the exception of ferry activity, the level of commercial vessel activity is not anticipated to change from the base-year levels. Because the Chesapeake & Ohio Railroad and the Grand Truck Western Railroad, operators of rail-automobile ferries across Lake Michigan, have petitioned the Interstate Commerce Commission for permission to abandon ferry service, operations were assumed to be discontinued during the projection years. Therefore, the annual emissions attributed to ferries, 40 tons of particulate matter, 24 tons of sulfur dioxide, 8 tons of carbon monoxide, 30 tons of nitrogen oxides, and 5 tons of hydrocarbons, were removed from the vessel emissions forecasts for 1982, 1985, and 2000 as depicted in Table 291.

Menomonee River Valley Emissions: The fugitive dust emissions forecast for the Menomonee River Valley, consisting of emissions from aggregate storage piles, travel on unpaved automobile lots, travel on unpaved truck lots, and travel on unpaved roads, was based on the 1973 emissions inventory conducted by the City of Milwaukee Department of City Development. The 1973 inventory attributed 360 tons of particulate matter emissions to aggregate storage piles, 327 tons to unpaved roads, 49 tons to unpaved automobile parking lots, and 77 tons to unpaved truck lots. The totals for the latter three emission categories are higher than the 1977 totals and were therefore used as "worst case" estimates because the 1977 climatic factor included an above average number of days with measurable precipitation or snow cover, which act to reduce the level of fugitive dust emissions. Therefore, the 1973 emissions inventory, deemed more representative of Menomonee River Valley fugitive dust emissions, was used for each of the three forecast years.

Industrial Fugitive Dust Emissions

Industrial fugitive dust emissions, generated by industrial processes, wind, and various human activities, were estimated in 1978 by the Wisconsin Department of Natural Resources to total approximately 8,100 tons annually in the Region. Because of the availability of this field survey-based inventory and the uncertainties inherent in any attempt to forecast these emissions, the 1978 emissions total for industrial fugitive dust emissions was used for the forecast years of 1982, 1985, and 2000. This emissions total of about 8,100 tons constitutes over 42 percent of the year 2000 area source particulate matter total of approximately 19,000 tons.

Special Hydrocarbon Emissions

As discussed in Chapter VII of this report, a special hydrocarbon emissions inventory consisting of seven categories of pollutant sources was conducted by the Wisconsin Department of Natural Resources (DNR) with the assistance of Pacific Environmental Services, Inc. (PES) and Booz, Allen and Hamilton, Inc. The emissions totals for these seven diffuse hydrocarbon sources, consisting of architectural coatings, miscellaneous solvent use, automobile refinishing, cutback asphalt, construction equipment, industrial equipment, and off-highway motorcycles, were estimated by the DNR for 1982 and 1987. The 1987 forecast was prepared by the DNR in order to determine whether the ozone standards would be attained by 1987. The 1985 hydrocarbon emissions forecasts for these seven categories, presented in Table 291, were prepared by the Commissions staff by interpolating between the 1982 and 1987 emissions forecasts, and the year 2000 forecasts were prepared by using the growth rates for the 10-year period between 1977 and 1987.

Hydrocarbon emissions from these seven categories in the Region are forecast to increase from approximately 25,000 tons to 28,300 tons between 1977 and the year 2000, an increase of approximately 13 percent over the 23-year period. During each of the three forecast years, these seven categories are forecast to account for approximately 49 percent of the total forecast hydrocarbon emissions from area sources, with cutback asphalt emissions maintaining their 1977 levels through the year 2000 and hydrocarbon emissions from off-highway motorcycles showing a 31 percent increase by the year 2000—from 556 tons in 1977 to 727 tons in the year 2000.

Area Source Emissions Forecast Summaries for 1982, 1985, and 2000

Tables 300 through 302 present the total regional area source emissions for each of the three forecast years disaggregated by county and by season. As may be seen in Table 302, particulate matter emissions are forecast to increase in the Region by approximately 300 tons between 1977 and the year 2000. Decreases from the 1977 emission levels are indicated for agricultural tilling operations, owing to a reduction in the amount of agricultural land in the Region which will be subject to tilling operations; small point sources, owing to the growth of a number of small point area sources and the shift of several sources to the point source inventory; forest wildfires, since the total acreage burned over

Table 300

COUNTY SUMMARY OF TOTAL FORECAST AREA SOURCE EMISSIONS BY SEASON: 1982

County	Season	Emissions (tons)				
		Particulate Matter	Sulfur Dioxide	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
Kenosha	Winter	108	483	572	498	552
	Spring	722	307	1,037	578	917
	Summer	86	69	3,140	279	1,436
	Fall	142	226	699	367	870
	Annual	1,058	1,085	5,448	1,722	3,775
Milwaukee	Winter	1,266	2,782	3,884	3,424	3,951
	Spring	1,263	1,671	4,759	2,539	6,460
	Summer	1,137	397	10,543	1,484	8,556
	Fall	1,184	1,297	3,878	2,208	6,101
	Annual	4,850	6,147	23,064	9,655	25,068
Ozaukee	Winter	59	273	340	269	322
	Spring	605	185	777	447	542
	Summer	77	47	2,222	212	789
	Fall	114	134	429	249	491
	Annual	855	639	3,768	1,177	2,144
Racine	Winter	277	673	802	676	734
	Spring	1,071	433	1,474	813	1,242
	Summer	254	106	4,514	376	1,994
	Fall	325	320	1,050	492	1,191
	Annual	1,927	1,532	7,840	2,357	5,161
Walworth	Winter	53	260	476	303	331
	Spring	1,513	192	1,352	671	637
	Summer	124	44	5,114	279	1,434
	Fall	216	127	918	307	619
	Annual	1,906	623	7,860	1,560	3,021
Washington	Winter	82	398	590	387	416
	Spring	1,021	279	1,442	744	725
	Summer	118	70	4,579	324	1,376
	Fall	183	197	948	383	689
	Annual	1,404	944	7,559	1,838	3,206
Waukesha	Winter	1,505	1,036	1,065	869	1,222
	Spring	2,115	632	2,127	944	2,070
	Summer	1,501	118	10,459	414	4,528
	Fall	1,549	463	2,130	595	2,166
	Annual	6,670	2,249	15,781	2,822	9,986
Region	Winter	3,350	5,905	7,729	6,426	7,528
	Spring	8,310	3,699	12,968	6,736	12,593
	Summer	3,297	851	40,571	3,368	20,113
	Fall	3,713	2,764	10,052	4,601	12,127
	Annual	18,670	13,219	71,320	21,131	52,361

Source: Wisconsin Department of Natural Resources and SEWRPC.

Table 301

COUNTY SUMMARY OF TOTAL FORECAST AREA SOURCE EMISSIONS BY SEASON: 1985

County	Season	Emissions (tons)				
		Particulate Matter	Sulfur Dioxide	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
Kenosha	Winter	111	520	577	515	568
	Spring	721	329	960	596	933
	Summer	86	73	3,131	281	1,458
	Fall	143	244	692	376	886
	Annual	1,061	1,166	5,360	1,768	3,845
Milwaukee	Winter	1,277	2,945	3,937	3,517	4,039
	Spring	1,274	1,789	4,804	2,639	6,556
	Summer	1,143	449	10,659	1,533	8,681
	Fall	1,192	1,393	3,923	2,283	6,190
	Annual	4,886	6,576	23,323	9,972	25,466
Ozaukee	Winter	62	299	358	283	338
	Spring	606	203	704	465	557
	Summer	79	51	2,231	216	815
	Fall	116	147	435	257	506
	Annual	863	700	3,728	1,221	2,216
Racine	Winter	280	713	823	696	754
	Spring	1,071	460	1,371	837	1,258
	Summer	256	114	4,510	383	2,017
	Fall	326	341	1,056	504	1,210
	Annual	1,933	1,628	7,760	2,420	5,239
Walworth	Winter	54	278	490	314	342
	Spring	1,515	207	1,194	695	643
	Summer	126	47	5,085	285	1,450
	Fall	218	136	913	315	630
	Annual	1,913	668	7,682	1,609	3,065
Washington	Winter	85	432	594	404	435
	Spring	1,020	303	1,275	771	740
	Summer	120	76	4,558	331	1,404
	Fall	184	214	933	394	708
	Annual	1,409	1,025	7,360	1,900	3,287
Waukesha	Winter	1,511	1,122	1,135	907	1,272
	Spring	2,113	684	2,072	978	2,120
	Summer	1,503	128	10,553	420	4,605
	Fall	1,551	502	2,180	614	2,215
	Annual	6,678	2,436	15,940	2,919	10,212
Region	Winter	3,380	6,309	7,914	6,636	7,748
	Spring	8,320	3,975	12,380	6,981	12,807
	Summer	3,313	938	40,727	3,449	20,430
	Fall	3,730	2,977	10,132	4,743	12,345
	Annual	18,743	14,199	71,153	21,809	53,330

Source: Wisconsin Department of Natural Resources and SEWRPC.

a six-year period (1970 through 1975) was used as a basis for the forecasts; and commercial vessels, because of the anticipated discontinuance of Milwaukee-based railroad-automobile ferry service on Lake Michigan.

For the 1982, 1985, and 2000 forecast years, industrial fugitive dust emissions and agricultural tilling operations ranked first and second, respectively, as major area source contributors of particulate matter emissions, together contributing over 70 percent of the total area source particulate matter emissions during each of the three forecast years. Total particulate matter emissions from area sources may be expected to increase slightly from a 1977 level of approximately 18,600 tons to about 18,700 tons in 1982, an increase of only 0.2 percent, and to 18,743 tons in 1985, an increase of 0.5 percent over the 1977 level. By the year 2000, emission levels are forecast to reach about 18,900 tons, an increase of only about 1.6 percent over 1977 levels. These low growth rates can be attributed in part to the 300-ton decrease between 1977 and 2000 in particulate matter emissions from agricultural tilling operations, a leading area source contributor, and only small increases in emissions from most other area source categories.

The combustion of fossil fuels for space heating, water heating, and industrial process heat was the primary contributor of sulfur dioxide emissions from area sources during the base year of 1977, and is forecast to be the primary contributor during 1982, 1985, and the year

Table 302

COUNTY SUMMARY OF TOTAL FORECAST AREA SOURCE EMISSIONS BY SEASON: 2000

County	Season	Emissions (tons)				
		Particulate Matter	Sulfur Dioxide	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
Kenosha	Winter	122	696	902	598	641
	Spring	711	434	1,130	655	1,003
	Summer	88	91	3,473	295	1,554
	Fall	147	322	989	415	959
	Annual	1,068	1,543	6,494	1,963	4,157
Milwaukee	Winter	1,348	3,849	5,452	4,125	4,600
	Spring	1,307	2,397	6,358	3,100	7,165
	Summer	1,182	719	12,642	1,845	9,505
	Fall	1,236	1,903	5,391	2,706	6,752
	Annual	5,073	8,868	29,843	11,776	28,022
Ozaukee	Winter	69	420	637	337	395
	Spring	592	279	813	505	615
	Summer	81	72	2,530	229	914
	Fall	118	205	688	285	562
	Annual	860	976	4,668	1,356	2,486
Racine	Winter	296	915	1,230	794	826
	Spring	1,068	590	1,538	916	1,324
	Summer	261	155	4,897	410	2,104
	Fall	333	443	1,429	557	1,281
	Annual	1,958	2,103	9,094	2,677	5,535
Walworth	Winter	62	373	629	362	386
	Spring	1,506	267	995	751	681
	Summer	129	64	5,157	301	1,519
	Fall	220	182	1,011	342	675
	Annual	1,917	886	7,792	1,756	3,261
Washington	Winter	98	616	1,004	488	506
	Spring	984	415	1,357	829	805
	Summer	123	104	4,943	346	1,516
	Fall	186	301	1,295	433	776
	Annual	1,391	1,436	8,599	2,096	3,603
Waukesha	Winter	1,539	1,561	1,342	1,104	1,404
	Spring	2,085	941	2,074	1,090	2,269
	Summer	1,511	176	10,965	441	4,884
	Fall	1,559	698	2,332	699	2,346
	Annual	6,694	3,376	16,713	3,334	10,903
Region	Winter	3,534	8,430	11,196	7,808	8,758
	Spring	8,253	5,323	14,265	7,846	13,862
	Summer	3,375	1,381	44,607	3,867	21,996
	Fall	3,799	4,054	13,135	5,437	13,351
	Annual	18,961	19,188	83,203	24,958	57,967

Source: Wisconsin Department of Natural Resources and SEWRPC.

2000. Of the 13 area source categories for which forecasts of sulfur dioxide emissions were made, commercial and institutional, industrial, and residential fuel uses produced almost 90 percent of the sulfur dioxide emissions for the base year 1977 and are projected to contribute over 90 percent during each of the three forecast years. Sulfur dioxide emissions from each of these fuel use categories are forecast to increase during each of the projection years. During 1982, these fuel use categories are forecast to contribute about 11,900 tons of sulfur dioxide emissions, or about 90 percent of the area source sulfur dioxide emissions in the Region. During 1985, the same categories are forecast to produce 12,900 tons of sulfur dioxide emissions, or about 91 percent of the 14,200 tons produced by area sources. By the year 2000, these categories are forecast to contribute 17,800 tons of sulfur dioxide emissions, or about 93 percent of the area source total of 19,200 tons—an increase of about 62 percent over the 1977 level.

This forecast increase may be attributed to two factors: an assumed change in fuel type for new users and a forecast increase in the number of fuel users. As discussed earlier in this chapter, it was assumed that the supply of natural gas will be restricted and that new users will be required to use fuel oil or electricity. Because distillate and residual fuel oils are generally higher in sulfur content than is commercial natural gas, the increased utilization of fuel oils may be expected to result in greater sulfur dioxide emissions from fuel combustion processes.

Much of the remaining 10 percent of sulfur dioxide emissions from area sources in the Region is expected to result from internal combustion engines. For the year 2000, railroad line and yard engines are forecast to contribute about 3 percent of the sulfur dioxide emissions, and agricultural equipment, about 2 percent. No other identified area source is expected to contribute more than 1 percent of the sulfur dioxide emissions during any of the three projection years. As indicated by Tables 300 through 302, Milwaukee County, the county in the Region with the largest number of heating units and industrial sources, is estimated to produce over 46 percent of the regional area source sulfur dioxide emissions.

Fourteen area source categories were identified as significant contributors of carbon monoxide emissions in the Region in the 1977 inventory, and are forecast to be 2000. All identified carbon monoxide emissions were produced by combustion processes, including forest wildfires, waste incineration, internal combustion engines, and fuel combustion for space heating, water heating, and industrial process heat. Four major categories were estimated to be responsible for approximately 90 percent of the 70,500 tons of carbon monoxide emissions from area sources in 1977. In decreasing magnitude, these were power boat operations, which accounted for about 20,500 tons, or 29 percent; agricultural equipment, which accounted for about 16,900 tons, or 24 percent; general utility engines, which accounted for about 16,800 tons, or 24 percent; and aircraft operations, which accounted for about 8,800 tons, or 12 percent.

Carbon monoxide emissions from agricultural equipment are projected to decrease in each of the forecast years to a total of about 9,700 tons in the year 2000, or approximately 12 percent of the total year 2000 area source carbon monoxide emissions, while power boat emissions are assumed not to change and to contribute approximately 25 percent of the area source total of 83,200 tons. Carbon monoxide emissions from general utility engines are forecast to show an increase of about 4,800 tons by the year 2000, a 29 percent increase, while carbon monoxide emissions from aircraft operations are forecast to experience the largest increase, both absolutely and relatively, by the year 2000—from about 8,800 tons in 1977 to about 23,800 tons in the year 2000, a 170 percent increase. Of the remaining 10 area source categories, only residential fuel use, commercial-

institutional fuel use, and railroad line and yard operations are forecast to make a significant contribution to total year 2000 area source carbon monoxide emissions, each accounting for less than 3 percent of the regional carbon monoxide emissions total.

Like carbon monoxide emissions, area source nitrogen oxide emissions are essentially the product of combustion processes. During each of the three forecast years, residential fuel use is forecast to be a major area source contributor of nitrogen oxide emissions (24 percent each year), followed by agricultural equipment, industrial fuel use, commercial-institutional fuel use, and railroad line engines, each expected to contribute more than 10 percent of the area source total.

Nitrogen oxide emissions from these five sources are anticipated to grow from a 1977 level of about 18,100 tons to about 21,600 tons in the year 2000, an increase of approximately 20 percent. Nitrogen oxide emissions from aircraft operations are anticipated to increase from a 1977 level of about 600 tons, or approximately 3 percent of the area source total, to a 2000 level of about 1,700 tons, or 7 percent of the area source total.

Hydrocarbon emissions forecasts for 1982, 1985, and 2000 were made for 23 area source categories. Five of these categories may each be expected to contribute over 10 percent each of the total area source hydrocarbon emissions in 1982 and 1985. These area source categories in descending order of magnitude for 1982 are cutback asphalt, expected to account for 20 percent of the area source hydrocarbon emissions; miscellaneous solvent use, expected to contribute 16 percent; power boats, expected to contribute 13 percent; general utility engines, expected to contribute 13 percent; and gasoline marketing, expected to contribute 10 percent. By the year 2000, cutback asphalt may be expected to contribute 18 percent of the approximately 58,000 tons of area source hydrocarbon emissions, followed in order by miscellaneous solvent use, general utility engines, and power boats. A reduction in gasoline use may be expected to result in lower emissions from gasoline marketing, both absolutely and relatively, in the year 2000 than those in 1982 and 1985. The three categories which show the largest absolute increase in hydrocarbon emissions between 1977 and 2000 are, in descending order: aircraft operations, about 2,300 tons; miscellaneous solvent use, about 2,000 tons; and general utility engines, about 1,600 tons.

Volatile Organic Compound Emissions

Table 303 provides a summary by source category of the estimated volatile organic compound (VOC) emissions for the Region in 1977, 1982, 1985, and 2000. This table is based on the hydrocarbon emissions forecasts made for point, area, and line sources for each forecast year and on the relative portion of reactive compounds in the total emissions forecast as depicted in Table 229 in Chapter VII. The coal-intensive versions of the point source hydrocarbon emissions forecasts for 1982, 1985, and 2000 and the line source hydrocarbon emissions forecasts for 1985 and 2000 under the "no build" alternative transportation plan were used as the basis for the volatile organic compound emissions forecasts.

Table 303

QUANTITY OF VOLATILE ORGANIC COMPOUND EMISSIONS IN THE REGION: 1977, 1982, 1985, AND 2000

Source	Emissions (tons)			
	1977	1982	1985[a]	2000[b]
Stationary Sources				
Storage, Transportation, and Marketing of Petroleum Products				
Gasoline and Crude Oil Storage	675	627	633	465
Bulk Gasoline Terminals	2,306	2,142	2,159	1,564
Gasoline Bulk Plants	769	712	733	670
Service Station Loading	3,054	2,243	2,273	1,558
Underground Service Station Tank Breathing	328	374	307	255
Service Station Unloading	3,186	2,742	2,983	2,469
Subtotal	10,318	8,840	9,088	6,981
Industrial Processes				
Paint Manufacturing	637	637	637	637
Industrial Surface Coating				
Automobiles	5,531	3,653	3,735	4,143
Cans	4,293	4,714	4,967	6,227
Metal Coils	26	29	30	36
Paper	2,005	2,005	2,005	2,005
Fabric	321	321	321	321
Wood Furniture	8	8	8	8
Miscellaneous Metal Products	4,067	4,286	4,418	5,082
Miscellaneous Surface Coating	360	377	387	435
Subtotal	16,611	15,393	15,871	18,257
Nonindustrial Surface Coating				
Architectural Coatings	3,911	4,059	4,168	4,732
Auto Refinishing	419	444	453	509
Subtotal	4,330	4,503	4,621	5,241
Solvent Use				
Degreasing	8,433	8,889	9,167	9,644
Dry Cleaning	2,416	2,576	2,619	2,996
Graphic Arts	202	219	229	280
Cutback Asphalt	10,552	10,552	10,552	10,552
Miscellaneous Solvent Use	7,993	8,304	8,533	9,986
Subtotal	29,596	30,540	31,100	33,458
Miscellaneous Stationary Sources				
Fuel Combustion	1,544	1,618	1,648	1,980
Solid Waste Disposal (incineration)	139	145	148	160
Forest Fires	92	26	26	26
Subtotal	1,775	1,789	1,822	2,166
Stationary Sources Subtotal	63,267	61,702	63,139	66,740
Mobile Sources				
Highway Vehicles				
Light-Duty Automobiles	30,522	16,004	11,465	12,705
Light-Duty Trucks	3,425	2,375	1,890	1,051
Heavy-Duty Gasoline Trucks	8,065	5,444	3,796	2,263
Heavy-Duty Diesel Trucks	541	501	401	386
Mass Transit Buses	112	118	112	75
Subtotal	42,665	24,442	17,664	16,480
Off-Highway Vehicles				
Agricultural Equipment	1,394	1,380	1,294	1,127
General Utility Engines	876	931	970	1,115
Snowmobiles	152	152	152	152
Construction Equipment	376	414	423	414
Industrial Equipment	1,148	1,202	1,234	1,193
Off-Highway Motorcycles	493	526	547	639
Subtotal	4,439	4,605	4,620	4,640
Railroad Lines	301	301	301	301
Railroad Yards	395	395	395	395
Aircraft	1,105	1,251	1,397	3,289
Commercial Vessels	23	18	18	18
Power Boats	6,135	6,135	6,135	6,135
Mobile Sources Subtotal	55,063	37,147	30,530	31,258
Total	118,330	98,849	93,669	97,998

[a] *1985 stage of the "no build" alternative transportation plan.*

[b] *2000 "no build" alternative transportation plan.*

Source: SEWRPC.

The 1982 estimate of about 98,800 tons of volatile organic compound emissions represents about 87 percent of the 114,800 tons of hydrocarbon emissions forecast for the Region. Some source categories display small absolute increases in emissions between 1977 and 1982, including nonindustrial surface coating operations, forecast to show an emissions increase of 173 tons; solvent use, forecast to show an increase of 944 tons; off-highway vehicles, forecast to show an increase of 166 tons; and aircraft operations, forecast to show an increase of 146 tons. The total 1982 emissions for the Region, however, show a net decrease of about 19,500 tons from the 1977 emissions level of about 118,300 tons. Mobile source volatile organic compound emissions account for the largest portion of this reduction, decreasing by about 17,900 tons from the 1977 level of about 55,100 tons, a decrease of approximately 33 percent. Most of this reduction is due to the 48 percent drop in emissions from light-duty automobiles expected to result from implementation of the federal motor vehicle emissions control program.

Volatile organic compound emission levels are forecast to decrease between 1982 and 1985 by about 5,200 tons, from about 98,800 tons in 1982 to about 93,700 tons in 1985. Like the reduction experienced between 1977 and 1982, this 5 percent reduction in three years primarily reflects the reduction in mobile source emissions. Emissions from highway vehicles are forecast to decrease from about 24,400 tons in 1982 to about 17,700 tons in 1985, a decrease of 6,700 tons, or approximately 27 percent. Stationary sources may be expected to increase over this same period by about 1,400 tons, with the largest increase being attributable to emissions resulting from solvent use.

Between 1985 and 2000, total regional volatile organic compound emissions are forecast to increase from about 93,700 tons to about 98,000 tons, a growth of approximately 5 percent. Volatile organic compound emissions from stationary sources are forecast to increase by 3,600 tons, or by about 6 percent, between 1985 and 2000. Emissions resulting from the storage, transportation, and marketing of petroleum products are forecast to decline between 1985 and 2000 as gasoline use declines. Mobile source emissions from highway vehicle use are forecast to decline by about 7 percent between 1985 and the year 2000, while emissions from aircraft activity are forecast to increase by 1,900 tons between 1985 and the year 2000. Emissions from industrial and nonindustrial surface coating operations are forecast to increase with industrial production. Emissions resulting from solvent use, such as dry cleaning and miscellaneous solvent use, are forecast to increase with concomitant increases in the regional population.

Total Forecast Air Pollutant Emissions in the Region: 1982, 1985, and 2000 Summary

The total air pollutant emissions forecasts for all point, line, and area sources in the Region during 1982, 1985, and 2000 are presented in Tables 304 through 306 by county and by season. The "worst case" forecasts occurred under the coal-intensive energy scenario for 1982, 1985, and 2000 for point source emission estimates and under the "no build" alternative transportation plan for all pollutant species except sulfur dioxide. Sulfur dioxide emissions were found to be highest under the adopted land use and transportation plans because of the anticipated increase in heavy-duty truck traffic attendant to the development of additional freeway facilities in the Region. Heavy-duty trucks emit sulfur dioxide emissions at a much higher rate than automobiles do.

As may be seen in Table 307, particulate matter emissions are forecast to decrease by about 700 tons, or by about 2 percent—from about 30,500 tons in 1977 to about 29,800 tons in 1982. As may be seen by comparing Figure 57 in Chapter VII and Figure 102, area sources may be expected to show a small increase of 28 tons and point sources an increase of about 580 tons in particulate matter emissions between 1977 and 1982. These increases are offset by a decrease of about 1,300 tons in particulate matter emissions from line sources, owing to the continued removal of lead compounds from gasoline. Between 1982 and 1985, total particulate matter emissions in the Region are expected to increase by 1,700 tons, with the greatest increase, about 1,500 tons, being attributable to increased coal use by point sources. Particulate matter emissions from point, area, and line sources are expected to increase between 1985 and 2000 by 3,300 tons, or 10 percent, with the largest increases being attributable to an increased use of coal by point sources and industrial growth in such sources. Increases in particulate matter emissions from line sources reflect the effects of an increase in vehicle miles of travel to a level that offsets the benefits of reduced lead compounds in gasoline. Particulate matter emissions are forecast to increase in the Region between 1977 and 2000 by about 4,300 tons, or 14 percent.

Total sulfur dioxide emissions in the Region are forecast to increase by about 21,900 tons, or about 10 percent—from approximately 210,900 tons in 1977 to about 232,800 tons in 1982. Although sulfur dioxide emissions from point, area, and line sources are forecast to increase, over 95 percent of the increase may be ascribed to growth in point sources and an increased use of coal by such sources. As indicated in Figure 103, almost 94 percent of the 1985 sulfur dioxide emissions is forecast to originate from point sources, with about 178,400 tons of the regional total of about 239,900 tons being attributable to sources in Milwaukee County. Sulfur dioxide emissions in the Region are forecast to increase by 3 percent between 1982 and 1985, but to decrease by 5 percent between 1985 and 2000. This net reduction in regional sulfur dioxide emissions is attributable to the projected closing of the Port Washington coal-burning electric power generating plant, off-setting growth in area, line, and other point sources during that period.

As indicated in Table 307, total regional carbon monoxide emissions are forecast to decrease from the 1977 base-year level of about 598,800 tons to about 435,800 tons in 1982, a decrease of 163,000 tons, or about 27 percent, between 1977 and 1982. Further reductions of about

96,300 tons between 1982 and 1985 and of about 67,800 tons between 1985 and the year 2000 are forecast. Although small increases in carbon monoxide emissions are expected during each of the three forecast years from point and area sources, these increases may be expected to be more than offset by major reductions in emissions from line sources, expected to result from the implementation of the federal motor vehicle emissions control program.

Figure 57 in Chapter VII and Figures 102 through Figure 104 indicate that nitrogen oxide emissions from point sources are forecast to increase in both relative and absolute terms during each of the three forecast years. Nitrogen oxide emissions from point sources may be expected to increase from about 40 percent of the regional total of 114,300 tons from all sources in 1977 to about 62 percent of the 146,600 tons forecast for the year 2000. Nitrogen oxide emissions from point sources, principally from electric power generating plants, are forecast to constitute a major share of the regional increase in nitrogen oxide emissions from all sources. Area sources are forecast to contribute approximately 17 to 18 percent of the nitrogen oxide emissions in the Region during each of the three forecast years, with absolute emission increases evident for each period owing principally to increases in emissions from commercial-institutional uses, residential uses, and industrial fuel use.

Table 304

SUMMARY OF TOTAL EMISSIONS FORECAST FOR THE SOUTHEASTERN WISCONSIN REGION BY COUNTY BY SEASON: 1982

County	Season	Emissions (tons)				
		Particulate Matter	Sulfur Dioxide	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
Kenosha	Winter	308	3,309	8,086	3,324	2,163
	Spring	922	3,133	7,430	3,363	2,469
	Summer	286	2,895	9,102	3,004	2,959
	Fall	342	3,052	6,780	3,131	2,403
	Annual	1,858	12,389	31,398	12,822	9,994
Milwaukee	Winter	3,120	44,622	58,425	18,011	13,940
	Spring	3,116	43,511	52,025	16,900	16,063
	Summer	2,991	42,237	55,090	15,520	17,998
	Fall	3,037	43,136	49,121	16,452	15,592
	Annual	12,264	173,506	214,661	66,883	63,593
Ozaukee	Winter	235	9,803	4,483	2,438	882
	Spring	782	9,716	4,322	2,592	1,070
	Summer	253	9,578	5,534	2,321	1,302
	Fall	290	9,665	3,808	2,381	1,009
	Annual	1,560	38,762	18,147	9,732	4,263
Racine	Winter	438	872	9,922	1,784	1,903
	Spring	1,231	632	9,257	1,872	2,340
	Summer	415	306	11,785	1,366	3,061
	Fall	485	520	8,461	1,526	2,268
	Annual	2,569	2,330	39,425	6,548	9,572
Walworth	Winter	143	366	5,763	1,025	868
	Spring	1,603	298	5,941	1,365	1,138
	Summer	214	149	9,432	932	1,918
	Fall	306	233	5,313	986	1,109
	Annual	2,266	1,046	26,449	4,308	5,033
Washington	Winter	162	676	5,940	1,597	1,086
	Spring	1,101	557	6,042	1,925	1,356
	Summer	199	348	8,886	1,462	1,989
	Fall	263	475	5,340	1,547	1,308
	Annual	1,725	2,056	26,208	6,531	5,739
Waukesha	Winter	1,738	1,148	19,221	2,869	2,990
	Spring	2,349	744	17,857	2,848	3,710
	Summer	1,735	230	25,246	2,179	6,110
	Fall	1,782	574	17,186	2,448	3,768
	Annual	7,604	2,696	79,510	10,344	16,578
Region	Winter	6,144	60,796	111,840	31,048	23,832
	Spring	11,104	58,591	102,874	30,865	28,146
	Summer	6,093	55,743	125,075	26,784	35,337
	Fall	6,505	57,655	96,009	28,471	27,457
	Annual	29,846	232,785	435,798	117,168	114,772

Source: Wisconsin Department of Natural Resources and SEWRPC.

Table 305

SUMMARY OF TOTAL EMISSIONS FORECAST FOR THE SOUTHEASTERN WISCONSIN REGION BY COUNTY BY SEASON: 1985

County	Season	Emissions (tons)				
		Particulate Matter	Sulfur Dioxide	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
Kenosha	Winter	319	3,392	6,107	3,285	2,064
	Spring	930	3,202	5,743	3,339	2,378
	Summer	294	2,946	7,655	2,961	2,880
	Fall	351	3,116	5,267	3,090	2,316
	Annual	1,894	12,656	24,772	12,675	9,638
Milwaukee	Winter	3,464	45,910	42,474	18,010	13,134
	Spring	3,460	44,754	38,856	16,946	15,345
	Summer	3,330	43,414	43,194	15,572	17,334
	Fall	3,379	44,359	36,723	16,480	14,890
	Annual	13,633	178,437	161,247	67,008	60,703
Ozaukee	Winter	242	9,834	3,420	2,406	851
	Spring	785	9,738	3,372	2,565	1,043
	Summer	259	9,586	4,761	2,286	1,288
	Fall	295	9,682	2,994	2,346	984
	Annual	1,581	38,840	14,547	9,603	4,166
Racine	Winter	475	1,164	7,403	1,818	1,759
	Spring	1,267	911	7,080	1,917	2,203
	Summer	451	565	9,916	1,403	2,936
	Fall	522	791	6,522	1,562	2,138
	Annual	2,715	3,431	30,921	6,700	9,036
Walworth	Winter	155	431	4,551	1,011	787
	Spring	1,615	360	4,774	1,366	1,056
	Summer	227	200	8,495	920	1,848
	Fall	318	289	4,360	973	1,033
	Annual	2,315	1,280	22,180	4,270	4,724
Washington	Winter	170	731	4,561	1,565	1,019
	Spring	1,105	601	4,745	1,906	1,292
	Summer	205	374	7,852	1,429	1,940
	Fall	269	513	4,264	1,516	1,249
	Annual	1,749	2,219	21,422	6,416	5,500
Waukesha	Winter	1,757	1,267	14,721	2,730	2,697
	Spring	2,360	829	14,039	2,712	3,437
	Summer	1,750	273	21,949	2,031	5,872
	Fall	1,798	646	13,696	2,303	3,500
	Annual	7,665	3,015	64,405	9,776	15,506
Region	Winter	6,582	62,729	83,237	30,825	22,311
	Spring	11,522	60,395	78,609	30,751	26,754
	Summer	6,516	57,358	103,822	26,602	34,098
	Fall	6,932	59,396	73,826	28,270	26,110
	Annual	31,552	239,878	339,494	116,448	109,273

Source: Wisconsin Department of Natural Resources and SEWRPC.

As with carbon monoxide emissions from line sources, nitrogen oxide emissions from line sources are forecast to decrease between each forecast year as a result of the implementation of the federal motor vehicle emissions control program.

Hydrocarbon emissions from point, area, and line sources are forecast to decrease from about 132,400 tons in 1977 to about 114,800 tons in 1982. Although hydrocarbon emissions from point sources are forecast to increase by about 2,900 tons between 1977 and 1982, area source hydrocarbon emissions are forecast to decrease by 31 tons, while line source hydrocarbon emissions are forecast to decrease from about 47,900 tons to 27,400 tons, or by about 43 percent over the five-year period as the impact of the federal motor vehicle emissions control program becomes significant. Line source hydrocarbon emissions are forecast to decrease by approximately 7,600 tons between 1982 and 1985, more than offsetting the anticipated increase of about 2,100 tons from area and point sources, and producing a net reduction between 1982 and 1985 of about 5,500 tons. Total regional hydrocarbon emissions for the year 2000 are forecast to increase by about 10,700 tons over the 1985 total of about 109,300 tons, an increase of about 10 percent. This net increase is the result of a forecast increase of about 7,300 tons in hydrocarbon emissions from point sources, and about 4,600 tons from area sources, while line source hydrocarbon emissions are forecast to decrease by about 1,200 tons.

Volatile organic compound emissions are forecast to decrease by about 5,200 tons between 1982 and 1985, thus representing about 86 percent of the approximately 109,300 tons of total hydrocarbon emissions in 1985. Volatile organic compound emissions are forecast to total about 98,000 tons in the year 2000, an increase of about 4,300 tons over the 1985 level but about 20,300 tons less than the 1977 base-year emissions, for a net reduction of about 17 percent over the forecast period.

FORECAST PARTICULATE MATTER CONCENTRATIONS: 1982, 1985, AND 2000

Point Sources

As was done for the inventory years, 1973 and 1977,

Table 306

SUMMARY OF TOTAL EMISSIONS FORECAST FOR THE SOUTHEASTERN WISCONSIN REGION BY COUNTY BY SEASON: 2000

County	Season	Emissions (tons)				
		Particulate Matter	Sulfur Dioxide	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
Kenosha	Winter	466	6,061	5,119	5,159	2,325
	Spring	1,055	5,799	4,933	5,170	2,633
	Summer	432	5,456	7,161	4,745	3,158
	Fall	491	5,687	4,667	4,907	2,573
	Annual	2,444	23,003	21,880	19,981	10,689
Milwaukee	Winter	3,876	48,257	30,373	21,042	14,679
	Spring	3,835	46,806	29,164	19,825	16,960
	Summer	3,710	45,127	34,891	18,293	19,170
	Fall	3,764	46,311	27,552	19,331	16,464
	Annual	15,185	186,501	121,980	78,491	67,273
Ozaukee	Winter	351	1,184	3,138	5,007	1,054
	Spring	874	1,042	3,109	5,150	1,247
	Summer	363	835	4,767	4,838	1,533
	Fall	399	969	2,920	4,917	1,186
	Annual	1,987	4,030	13,934	19,912	5,020
Racine	Winter	560	1,692	5,667	2,007	1,901
	Spring	1,331	1,366	5,562	2,082	2,339
	Summer	525	932	8,767	1,507	3,092
	Fall	597	1,219	5,257	1,698	2,279
	Annual	3,013	5,209	25,253	7,294	9,611
Walworth	Winter	195	589	3,567	1,036	857
	Spring	1,638	484	3,670	1,396	1,119
	Summer	262	280	7,756	903	1,942
	Fall	353	399	3,608	971	1,104
	Annual	2,448	1,752	18,601	4,306	5,022
Washington	Winter	203	978	3,748	1,609	1,126
	Spring	1,090	778	3,836	1,921	1,392
	Summer	228	466	7,346	1,397	2,087
	Fall	292	663	3,696	1,509	1,354
	Annual	1,813	2,885	18,626	6,436	5,959
Waukesha	Winter	1,848	1,778	10,792	2,932	2,879
	Spring	2,393	1,159	10,668	2,822	3,632
	Summer	1,820	393	19,316	2,034	6,194
	Fall	1,868	915	10,668	2,381	3,676
	Annual	7,929	4,245	51,444	10,169	16,381
Region	Winter	7,499	60,539	62,404	38,792	24,821
	Spring	12,216	57,434	60,942	38,366	29,322
	Summer	7,340	53,489	90,004	33,717	37,176
	Fall	7,764	56,163	58,368	35,714	28,636
	Annual	34,819	227,625	271,718	146,589	119,955

Source: Wisconsin Department of Natural Resources and SEWRPC.

Table 307

SUMMARY OF TOTAL EXISTING AND FORECAST AIR POLLUTANT EMISSIONS FOR THE SOUTHEASTERN WISCONSIN REGION BY COUNTY: 1977, 1982, 1985, AND 2000

County	Emissions (tons)											
	Particulate Matter				Sulfur Dioxide				Carbon Monoxide			
	1977	1982	1985[a]	2000[b]	1977	1982	1985[c]	2000[d]	1977	1982	1985[a]	2000[b]
Kenosha	1,494	1,858	1,894	2,444	1,628	12,389	12,656	23,003	43,291	31,398	24,772	21,880
Milwaukee	12,920	12,264	13,633	15,185	164,399	173,506	178,437	186,501	303,260	214,661	161,247	121,980
Ozaukee	1,608	1,560	1,581	1,987	38,688	38,762	38,840	4,030	24,591	18,147	14,547	13,934
Racine	2,644	2,569	2,715	3,013	1,996	2,330	3,431	5,209	54,342	39,425	30,921	25,253
Walworth	2,338	2,266	2,315	2,448	747	1,046	1,280	1,752	33,506	26,449	22,180	18,601
Washington	1,691	1,725	1,749	1,813	987	2,056	2,219	2,885	34,571	26,208	21,422	18,626
Waukesha	7,807	7,604	7,665	7,929	2,457	2,696	3,015	4,245	105,256	79,510	64,405	51,444
Region	30,502	29,846	31,552	34,819	210,902	232,785	239,878	227,625	598,817	435,798	339,494	271,718

Source: SEWRPC.

ambient air particulate matter concentrations due to emissions from point sources were simulated for the forecast years, 1982, 1985, and 2000, using the Wisconsin Atmospheric Diffusion Model. The model simulations were performed under the natural gas-intensive, fuel oil-intensive, and coal-intensive energy scenarios, for which emissions forecasts are summarized in Table 280, and under meteorological conditions defined by the average five-year—1964 through 1968—wind and atmospheric stability data as summarized in Table 308.

The results of the annual arithmetic average point source forecast modeling effort for the year 1982 are presented on Map 103 for the natural gas-intensive energy scenario, on Map 104 for the fuel oil-intensive energy scenario, and on Map 105 for the coal-intensive energy scenario. A comparison of Map 103 with Map 104 indicates that the annual arithmetic average particulate matter concentrations due to point sources in the Region in 1982 may be expected to be essentially of the same magnitude and spatial distribution under both the natural gas-intensive and fuel oil-intensive energy scenarios. On both maps the highest isopleth value is two micrograms per cubic meter ($\mu g/m^3$) and is located over the central portion of Milwaukee County. This finding is consistent with the results of the particulate matter emissions forecast for 1982, which indicated that under the fuel oil-intensive energy scenario point sources will emit about 7,135 tons of this pollutant species throughout the Region, or only about 50 tons more than the 7,087 tons anticipated under the natural gas-intensive energy scenario in the same year.

Under the coal-intensive energy scenario, the forecast for annual arithmetic average particulate matter levels in the Region in 1982, as shown on Map 105, also indicates a maximum isopleth value of two $\mu g/m^3$, but this isopleth extends over a considerably larger geographic area in Milwaukee County than is anticipated under either the natural gas-intensive or fuel oil-intensive scenario. Considering only the land area encompassed by the maximum isopleth value in Milwaukee County, approximately 24 square miles may be expected to lie within this isopleth under both the natural gas-intensive and fuel oil-intensive energy scenarios, while approximately 51 square miles may be expected to lie within this isopleth under the coal-intensive energy scenario. This finding is consistent with the results of the particulate matter emissions forecast for 1982, which indicated that point sources under the coal-intensive energy scenario may be expected to emit approximately 8,000 tons of this pollutant species as compared with about 7,100 tons under both the natural gas-intensive energy scenario and the fuel oil-intensive energy scenario. The coal-intensive point source emissions forecast, therefore, represents the potentially "worst case" condition for air quality maintenance planning purposes.

As may be seen by comparing the forecast particulate matter concentrations due to point sources in the Region in 1982 under the coal-intensive energy scenario with the corresponding simulated concentrations under the existing fuel use conditions in 1977, as shown on Map 60 in Chapter XI, the impact of point sources on the ambient levels of this pollutant species may be expected to decrease over this five-year period. In 1977 the maximum isopleth value indicated was five $\mu g/m^3$ and was centered over the eastern portion of the heavily industrialized Menomonee River Valley. As a result of the forecast decrease in particulate matter emissions from point sources, principally due to the emission controls installed at the Milwaukee Solvay Coke Company as discussed earlier in this chapter, the size of this localized "hotspot" in central Milwaukee County is expected to be significantly reduced by 1982.

Table 307 (continued)

County	Emissions (tons)							
	Nitrogen Oxides				Hydrocarbons			
	1977	1982	1985[a]	2000[b]	1977	1982	1985[a]	2000[b]
Kenosha	6,046	12,822	12,675	19,981	11,122	9,994	9,638	10,689
Milwaukee . . .	69,651	66,883	67,008	78,491	72,802	63,593	60,703	67,273
Ozaukee	10,016	9,732	9,603	19,912	4,912	4,263	4,166	5,020
Racine	7,263	6,548	6,700	7,294	11,312	9,572	9,036	9,611
Walworth. . . .	4,588	4,308	4,270	4,306	6,016	5,033	4,724	5,022
Washington . .	4,798	6,531	6,416	6,436	6,659	5,739	5,500	5,959
Waukesha . . .	11,927	10,344	9,776	10,169	19,604	16,578	15,506	16,381
Region	114,289	117,168	116,448	146,589	132,427	114,772	109,273	119,955

[a] *Coal-intensive energy scenario and the 1985 stage of the "no build" alternative transportation plan.*

[b] *Coal-intensive energy scenario and the 2000 "no build" alternative transportation plan.*

[c] *Coal-intensive energy scenario and the 1985 stage of the adopted transportation plan.*

[d] *Coal-intensive energy scenario and the 2000 adopted transportation plan.*

Source: SEWRPC.

Figure 102

RELATIVE CONTRIBUTION FROM POINT, LINE, AND AREA SOURCES TO TOTAL POLLUTANT BURDEN: 1982



Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 103

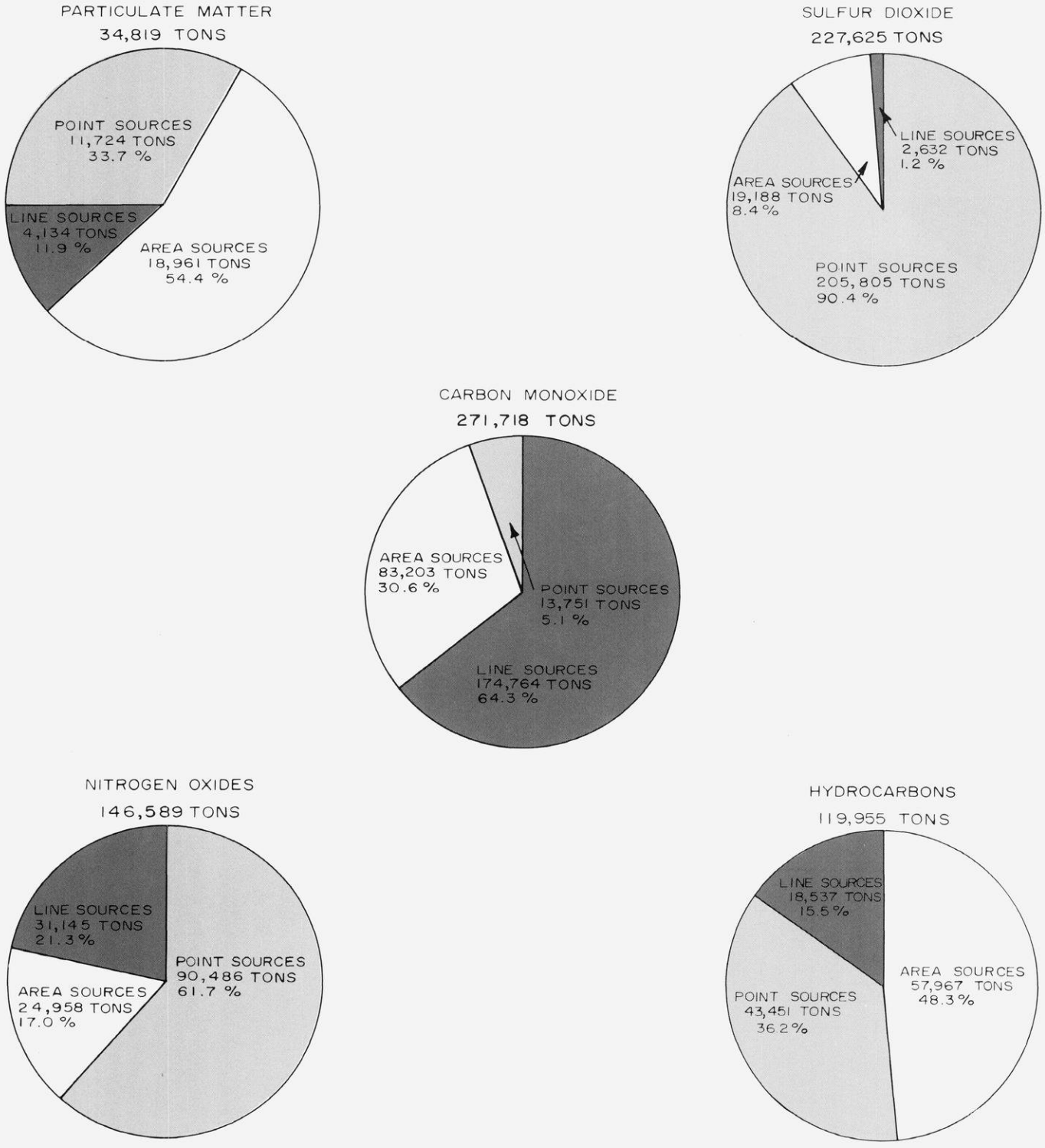
RELATIVE CONTRIBUTION FROM POINT, LINE, AND AREA SOURCES TO TOTAL POLLUTANT BURDEN: 1985



Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 104

RELATIVE CONTRIBUTION FROM POINT, LINE, AND AREA SOURCES TO TOTAL POLLUTANT BURDEN: 2000



Source: Wisconsin Department of Natural Resources and SEWRPC.

Table 308

FIVE-YEAR AVERAGE METEOROLOGICAL DATA USED IN FORECAST YEAR ANNUAL AVERAGE POINT SOURCE SIMULATION MODELING EFFORT: 1982, 1985, AND 2000

Data Group	Parameter	Variable Group	Frequency of Occurrence (percent)	Mixing Heights Associated with Atmospheric Stability Classes
Wind	Speed (knots)	0 - 3	8.9	- -
		4 - 6	26.4	
		7 - 10	34.3	
		11 - 16	24.8	
		17 - 21	5.0	
		>21	0.6	
		Total	100.0	
	Direction	North	6.87	- -
		North-Northeast	5.21	
		Northeast	6.23	
		East-Northeast	3.65	
		East	4.07	
		East-Southeast	3.39	
		Southeast	3.59	
		South-Southeast	4.37	
		South	8.96	
		South-Southwest	7.62	
		Southwest	9.14	
		West-Southwest	6.64	
		West	11.78	
		West-Northwest	8.12	
		Northwest	5.44	
		North-Northwest	4.92	
		Total	100.00	
Atmospheric Stability	Pasquill Stability Class	A—Extremely Unstable	0.34	1,500
		B—Unstable	3.35	1,500
		C—Slightly Unstable	9.74	1,170
		D—Neutral	60.23	1,000
		E—Slightly Stable	12.23	- -
		F—Stable	14.11	- -
		Total	100.00	- -

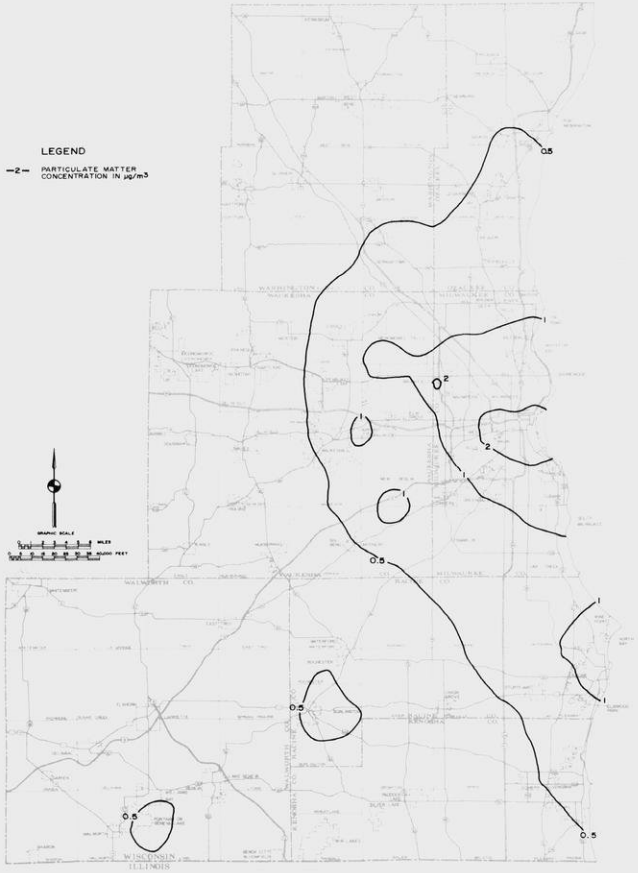
Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 106 indicates that under the coal-intensive energy scenario, the central portion of Milwaukee County will experience a particulate matter concentration of about five $\mu g/m^3$ on an annual arithmetic average basis in 1985 as a result of point source emissions. Reflecting the increase in particulate matter emissions from point sources as a result of anticipated industrial growth in the Region, the land area encompassed by the maximum isopleth in 1985 is approximately six square miles, an increase of about one square mile, or about 20 percent, over the five square miles of land area lying within this isopleth in 1977.

The impact of continued industrial growth in the Region is evident on Map 107, which illustrates the forecast particulate matter concentrations due to emissions from point sources in the year 2000 under the coal-intensive energy scenario. Although the maximum isopleth value remains at five $\mu g/m^3$, the land area encompassed by this isopleth comprises approximately 22 square miles in central Milwaukee County, an increase of about 17 square miles, or nearly 340 percent, over the land area encompassed by this isopleth in the year 1977. Therefore, a temporary reduction in the annual arithmetic average ambient air particulate matter concen-

Map 103

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE PARTICULATE MATTER CONCENTRATIONS IN THE REGION FROM FORECAST POINT SOURCE EMISSIONS: 1982 NATURAL GAS-INTENSIVE ENERGY SCENARIO

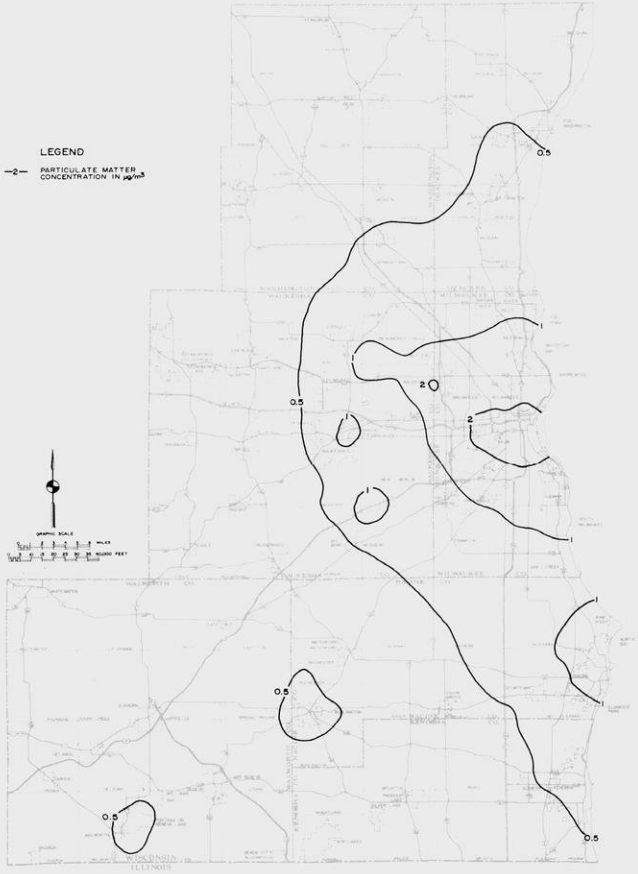


This map illustrates the impact of particulate matter emissions from point sources on ambient air quality in the Region in 1982 under the natural gas-intensive energy scenario, which assumes that natural gas supplies will be available to meet industrial energy demand. The highest isopleth value indicated on this map is two micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and is located over central Milwaukee County. Ambient air particulate matter concentrations due to point source emissions in other counties of the Region are generally below two $\mu g/m^3$. A comparison of regional ambient air particulate matter concentrations in 1977 and 1982, as indicated on Map 60 in Chapter XI and on this map, indicates that particulate matter concentrations due to point source emissions are expected to decrease over this five-year period. This finding is consistent with the results of the particulate matter emissions forecast for 1982, which indicate that point sources under this energy scenario will emit about 7,100 tons of particulate matter in the Region, a decrease of about 300 tons, or 4 percent, from the 1977 point source emissions level of 7,400 tons.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 104

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE PARTICULATE MATTER CONCENTRATIONS IN THE REGION FROM FORECAST POINT SOURCE EMISSIONS: 1982 FUEL OIL-INTENSIVE ENERGY SCENARIO



This map illustrates the impact of particulate matter emissions from point sources on ambient air quality in the Region in 1982 under the fuel oil-intensive energy scenario, which assumes the increased use of fuel oil to meet total industrial energy demand. The highest isopleth value indicated on this map is two micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and is located over central Milwaukee County. As may be seen by comparing Map 103 and this map, ambient air particulate matter concentrations forecast under the fuel oil-intensive energy scenario in 1982 may be expected to be essentially of the same magnitude and spatial distribution as under the natural gas-intensive scenario. This finding is consistent with the results of the particulate matter emissions forecasts for 1982, which indicate that point sources under both the natural gas-intensive and fuel oil-intensive energy scenarios will emit about 7,100 tons of particulate matter in the Region.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

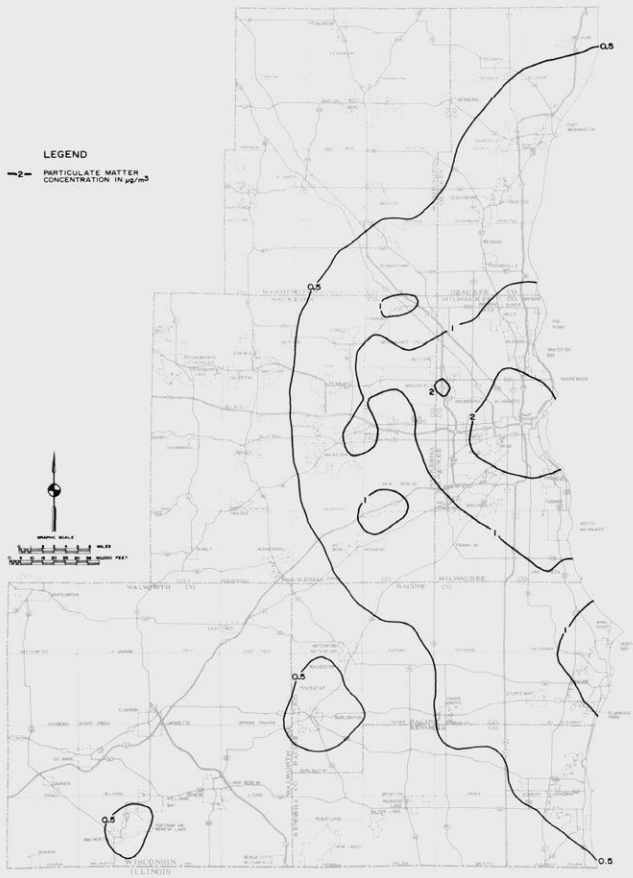
trations due to point source emissions in the Region may be expected by 1982. However, in the absence of further emission control measures, continued industrial growth and expansion will produce a more severe impact on ambient air quality, particularly in Milwaukee County, in the years between 1985 and 2000 than was experienced during 1977.

Line Sources

The forecast ambient air particulate matter concentrations in the Region due to emissions from line sources in the years 1982, 1985, and 2000 were simulated using the URBAN submodel of the Wisconsin Atmospheric Diffusion Model. The meteorological conditions under which the forecast line source simulations were per-

Map 105

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE PARTICULATE MATTER CONCENTRATIONS IN THE REGION FROM FORECAST POINT SOURCE EMISSIONS: 1982 COAL-INTENSIVE ENERGY SCENARIO

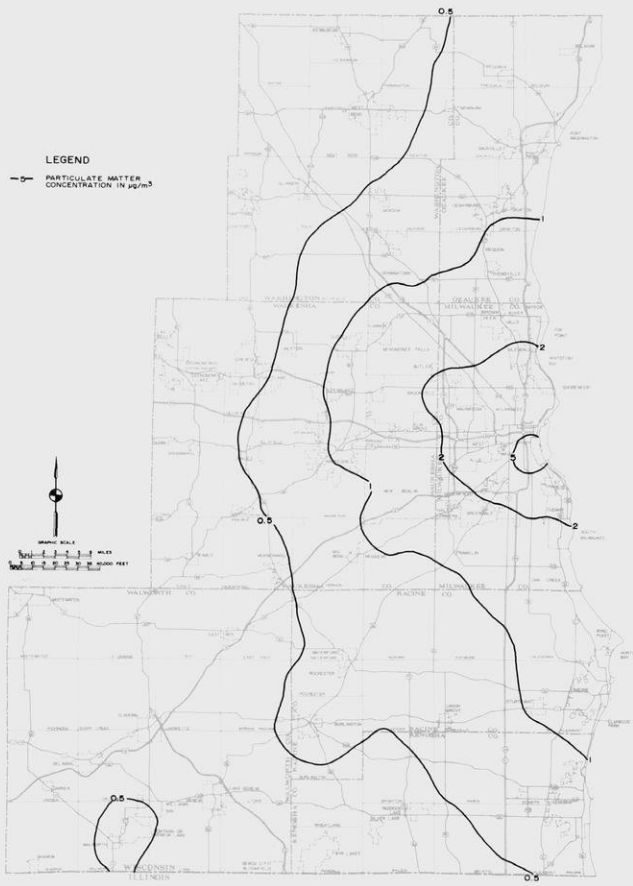


This map illustrates the impact of particulate matter emissions from point sources on ambient air quality in the Region in 1982 under the coal-intensive energy scenario, which assumes that natural gas supplies will not be available to meet total industrial energy demand. The highest isopleth value indicated on this map is two micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and extends over a considerably larger geographic area in Milwaukee County than it does under either the natural gas-intensive or fuel oil-intensive energy scenarios (see Maps 103 and 104). Considering only the land area encompassed by the maximum isopleth in Milwaukee County, approximately 51 square miles may be expected to lie within this isopleth under the coal-intensive energy scenario, an increase of approximately 27 square miles over the land area encompassed by this isopleth under both the natural gas-intensive and fuel oil-intensive energy scenarios. This finding is consistent with the results of the particulate matter emissions forecast for 1982, which indicate that point source emissions of particulate matter will increase to about 8,000 tons because of the conversion by large natural gas-burning facilities to coal use under the coal-intensive energy scenario and anticipated industrial growth in the Region.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 106

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE PARTICULATE MATTER CONCENTRATIONS IN THE REGION FROM FORECAST POINT SOURCE EMISSIONS: 1985 COAL-INTENSIVE ENERGY SCENARIO



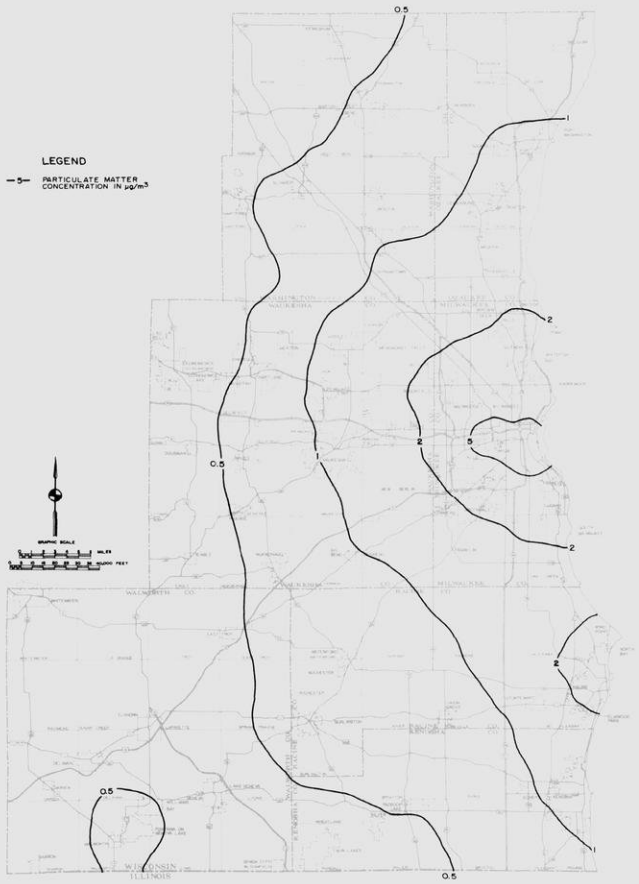
This map illustrates the impact of particulate matter emissions from point sources on ambient air quality in the Region in 1985 under the coal-intensive energy scenario, which assumes that natural gas supplies will not be available to meet total industrial energy demand. The highest isopleth value indicated on this map is five micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and is located over the central portion of Milwaukee County. As may be seen by comparing forecast ambient particulate matter concentrations from point source emissions in 1985 with corresponding concentrations in 1982, as shown on Map 105, point sources may be expected to have a greater impact on ambient levels of this pollutant species over this four-year period. This finding is consistent with the results of the particulate matter emissions forecast for 1985, which indicate that point source emissions of particulate matter will increase to about 9,500 tons because of the continuing conversion by natural gas facilities to coal use under this scenario and anticipated industrial growth in the Region.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

formed are summarized in Table 309, and represent the average meteorological conditions observed in the Region over the five-year period 1964 to 1968. The particulate matter emissions forecasts used in the line source simulations have been summarized in Table 281. The results of this simulation modeling effort are presented on Map 108 for the 1982 emissions forecast, on Maps 109 and 110 for the emissions forecast under the 1985 stage of the adopted transportation plan and "no build" alternative transportation plan, respectively, and on Maps 111 and

Map 107

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERGE PARTICULATE MATTER CONCENTRATIONS IN THE REGION FROM FORECAST POINT SOURCE EMISSIONS: 2000 COAL-INTENSIVE ENERGY SCENARIO

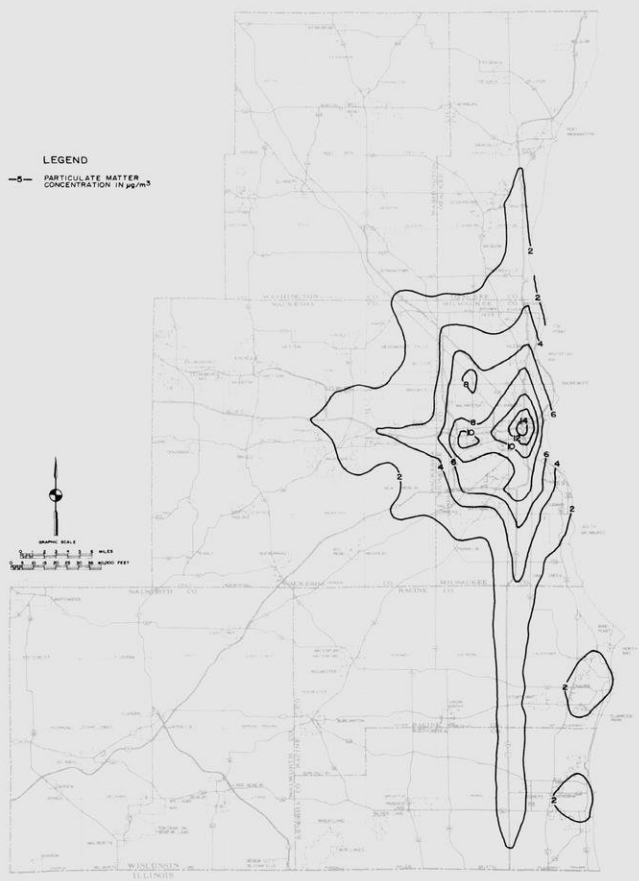


This map illustrates the impact of particulate matter emissions from point sources on ambient air quality in the Region in the year 2000 under the coal-intensive energy scenario, which assumes that natural gas supplies will not be available to meet total industrial energy demand. The highest isopleth value indicated on this map is five micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and is located over the central portion of Milwaukee County. As may be seen by comparing forecast ambient particulate matter concentrations from point source emissions in the year 2000 with corresponding levels in 1985, as shown on Map 106, point sources may be expected to have a greater impact on ambient levels of this pollutant species over this planning period. This finding is consistent with the results of the particulate matter emissions forecast for the year 2000, which indicate that point source emissions of particulate matter will increase to 11,700 tons because of anticipated industrial growth in the Region and the continued conversion by natural gas facilities to coal use under the coal-intensive energy scenario.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 108

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE PARTICULATE MATTER CONCENTRATIONS IN THE REGION FROM FORECAST LINE SOURCE EMISSIONS: 1982



This map illustrates the impact of particulate matter emissions from line sources on ambient air quality in the Region in 1982. The concentrations shown on this map indicate a decrease in the impact of line sources on ambient particulate matter levels in the Region between 1977 and 1982. As shown on Map 61 in Chapter XI, the maximum ambient air particulate matter concentration due to line sources in 1977 was 20 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and was centered over the Marquette Interchange. By 1982 the highest simulated ambient air particulate matter concentration due to line sources—again centered over the Marquette Interchange—is forecast to be reduced to 14 $\mu g/m^3$. This may be attributed in large part to the removal of lead compounds from gasoline, which substantially lowers the exhaust emission rate for particulate matter.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

112 for the emissions forecast under the adopted transportation plan and the "no build" alternative transportation plan for the year 2000, respectively.

In comparing the forecast annual arithmetic average particulate matter concentrations from line sources in the Region in the year 1982 with the corresponding concentrations in the year 1977, as shown on Map 61 in Chapter XI, it may be seen that the impact of line sources on the ambient air levels of this pollutant species may be expected to decline over this five-year period. The maximum isopleth value in the 1982 simulation, as indicated on Map 108, is 14 $\mu g/m^3$ and is centered over the Marquette Interchange in Milwaukee County.

In 1977 the maximum isopleth value—again centered over the Marquette Interchange—was indicated to be 20 $\mu g/m^3$. Although vehicle miles of travel in the Region for all vehicle types is expected to increase by about 3.5 percent between 1977 and 1982, particulate matter concentrations due to line source emissions are expected to decrease as a result of the removal of lead compounds from gasoline, which substantially lowers the exhaust emission rate for this pollutant species.

The increase in vehicle miles of travel in the Region between 1982 and 1985 under the "no build" alternative transportation plan may be expected to offset somewhat the large reduction in emissions gained by removing lead compounds from gasoline. As may be seen on Map 110, the maximum isopleth value indicated for the 1985 stage of the "no build" alternative transportation plan, 14 $\mu g/m^3$, is of the same magnitude but of a larger areal extent than that indicated for the 1982 line source simulation. Under the 1985 stage of the adopted transportation plan, however, the isopleth configuration, as shown on Map 109, closely parallels the 1982 distribution pattern. In fact, the areal extent of the isopleth values in 1985 is somewhat smaller than that of the equivalent values in 1982. This finding may be attributed to the fact that the vehicle miles of travel on the regional freeway system is lower under the 1985 stage of the adopted transportation plan than under the corresponding stage of the "no build" alternative transportation plan.

The impact of forecast continued growth in regional vehicle miles of travel on annual arithmetic average particulate matter levels in the year 2000 is indicated on Map 112 for the "no build" alternative transportation plan and on Map 111 for the adopted transportation plan. As may be seen by comparing Map 112 with Map 111, the "no build" alternative transportation plan may be expected to produce slightly higher average particulate matter levels than the adopted plan. The maximum isopleth value indicated under the "no build" alternative is 16 $\mu g/m^3$ and is centered over the Marquette Interchange. Under the adopted transportation plan for the year 2000, the maximum isopleth value indicated is 14 $\mu g/m^3$, again centered over the Marquette Interchange. Reflecting the anticipated increase in regional vehicle miles of travel between 1985 and 2000, both the "no build" alternative transportation plan and the adopted transportation plan are expected to have a greater impact on annual arithmetic average particulate matter levels in the year 2000 than in 1985. For the purpose of air quality attainment and maintenance planning, however, the "no build" alternative transportation plan provides the "worst case" particulate matter concentrations in both 1985 and 2000.

Area Sources

The forecast annual arithmetic average particulate matter concentrations due to emissions from area sources in the Region in the years 1982, 1985, and 2000 were simulated using the URBAN submodel of the Wisconsin Atmospheric Diffusion Model. The particulate matter emissions forecasts are summarized in Table 291, and the average meteorological data used for the simulation forecasts have been summarized in Table 309.

The results of the modeling effort for annual arithmetic average particulate matter concentrations from area source emissions in the year 1982 are presented on Map 113. As may be seen by comparing Map 113 with Map 62 in Chapter XI, only minor differences in the magnitude and spatial distribution of the depicted concentrations in 1977 and 1982 are evident. Similarly, Maps 114 and 115 indicate that the annual arithmetic average particulate matter concentrations in the Region in the years 1985 and 2000 resulting from area source emissions will deteriorate only slightly over the planning

Table 309

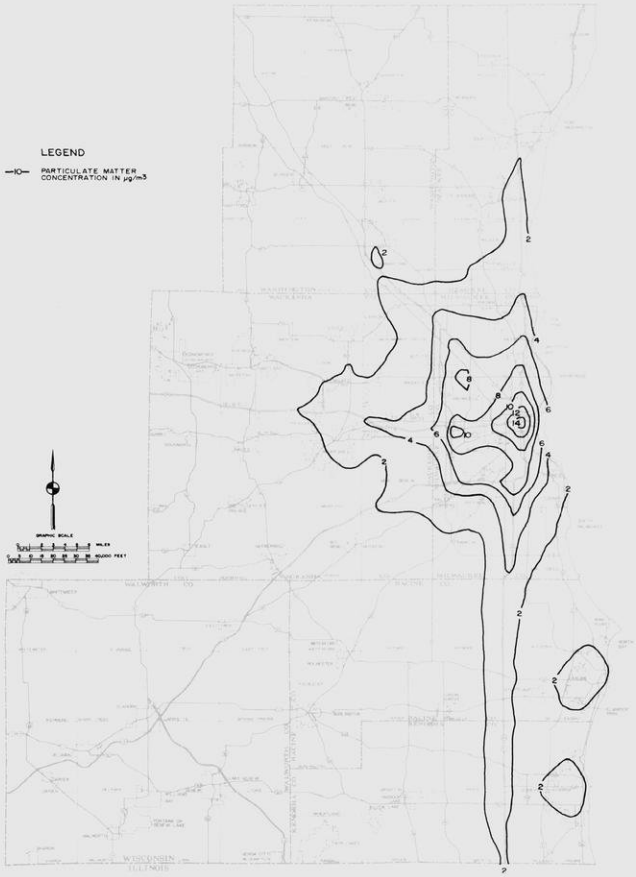
FIVE-YEAR AVERAGE METEOROLOGICAL DATA USED IN FORECAST YEAR ANNUAL AVERAGE LINE AND AREA SOURCE SIMULATION MODELING EFFORT: 1982, 1985, AND 2000

Stability Class	Heat Flux (langleys per minute)	Wind Speed (meters per second)	Percent Frequency by Wind Direction								
			North	Northeast	East	Southeast	South	Southwest	West	Northwest	All
Unstable	0.18	5	0.45	0.58	0.79	0.54	0.80	0.93	0.97	0.44	5.50
	0.18	10	0.73	0.96	0.64	0.66	1.06	1.45	1.70	0.83	8.03
Neutral	--	5	1.24	1.26	1.32	1.22	1.50	1.21	1.63	1.01	10.39
	--	10	2.80	2.65	1.83	2.01	3.36	2.61	3.32	2.16	20.74
	--	15	4.05	3.60	1.22	1.33	3.67	5.07	5.98	4.19	29.11
Stable	- 0.04	5	2.68	1.60	1.79	1.81	4.52	4.94	5.56	3.33	26.23
Total	--	--	11.95	10.65	7.59	7.57	14.91	16.21	19.16	11.96	100.00

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 109

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE PARTICULATE MATTER CONCENTRATIONS IN THE REGION FROM FORECAST LINE SOURCE EMISSIONS: 1985 STAGE OF THE ADOPTED TRANSPORTATION PLAN

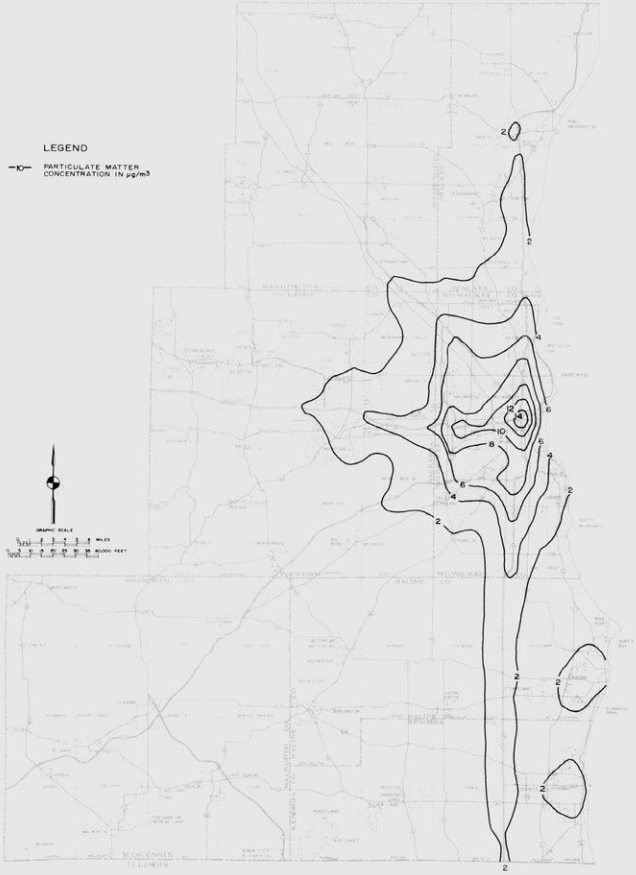


This map illustrates the impact of particulate matter emissions from line sources on ambient air quality in the Region as forecast under the 1985 stage of the adopted transportation plan. The concentrations shown on this map indicate a decrease in the impact of line sources on ambient particulate matter levels in the Region between 1977 and 1985. As shown on Map 61 in Chapter XI, the maximum ambient air particulate matter concentration due to line sources in 1977 was 20 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and was centered over the Marquette Interchange. In 1982 the highest ambient air particulate matter concentration due to line sources is expected to be 14 $\mu g/m^3$, again centered over the Marquette Interchange. Under the 1985 stage of the adopted transportation plan, the highest concentration is expected to be of the same magnitude as in 1982, but of a smaller areal extent. This reduction may be attributed largely to the removal of lead compounds from gasoline, which substantially lowers the exhaust emission rate for particulate matter.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 110

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE PARTICULATE MATTER CONCENTRATIONS IN THE REGION FROM FORECAST LINE SOURCE EMISSIONS: 1985 STAGE OF THE "NO BUILD" TRANSPORTATION PLAN

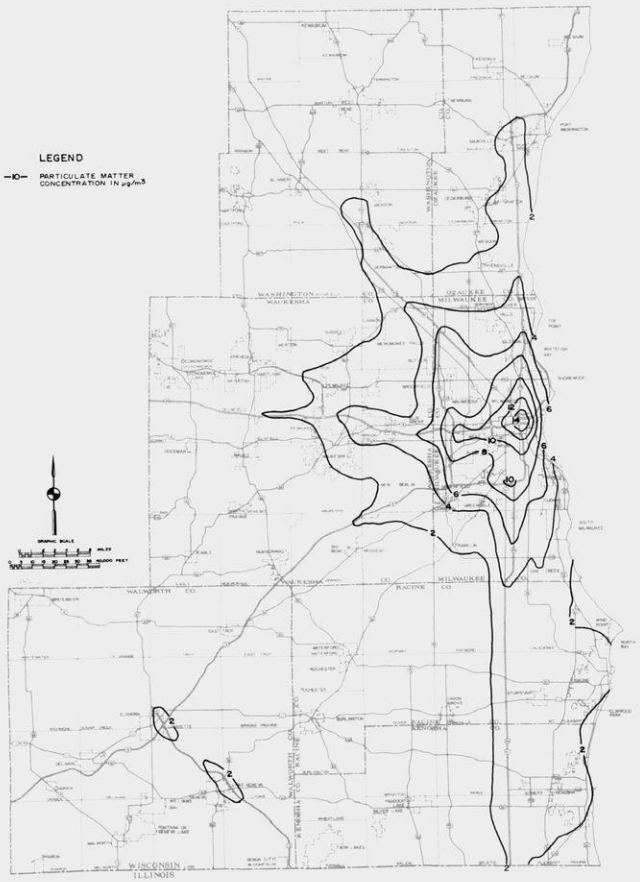


This map illustrates the impact of particulate matter emissions from line sources on ambient air quality in the Region as forecast under the 1985 stage of the "no build" alternative transportation plan. The concentrations shown on this map indicate a decrease in the impact of line sources on ambient particulate matter levels in the Region between 1977 and 1985. As shown on Map 61 in Chapter XI, the maximum ambient air particulate matter concentration due to line sources in 1977 was 20 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and was centered over the Marquette Interchange. As shown on Map 108, the highest ambient air particulate matter concentration due to line sources in 1982—again centered over the Marquette Interchange—is expected to be 14 $\mu g/m^3$. As shown on Map 109, under the 1985 stage of the adopted transportation plan, the highest concentration is expected to be of the same magnitude as in 1982 but of a smaller areal extent. As may be seen on this map, the maximum concentration indicated for the 1985 stage of the "no build" alternative transportation plan, 14 $\mu g/m^3$, is of the same magnitude but of a larger areal extent than that indicated for the 1985 stage of the adopted transportation plan. This finding may be attributed to the fact that the vehicle miles of travel on the regional freeway system is lower under the 1985 stage of the adopted transportation plan than under the corresponding stage of the "no build" alternative transportation plan.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 111

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE PARTICULATE MATTER CONCENTRATIONS IN THE REGION FROM FORECAST LINE SOURCE EMISSIONS: 2000 ADOPTED TRANSPORTATION PLAN

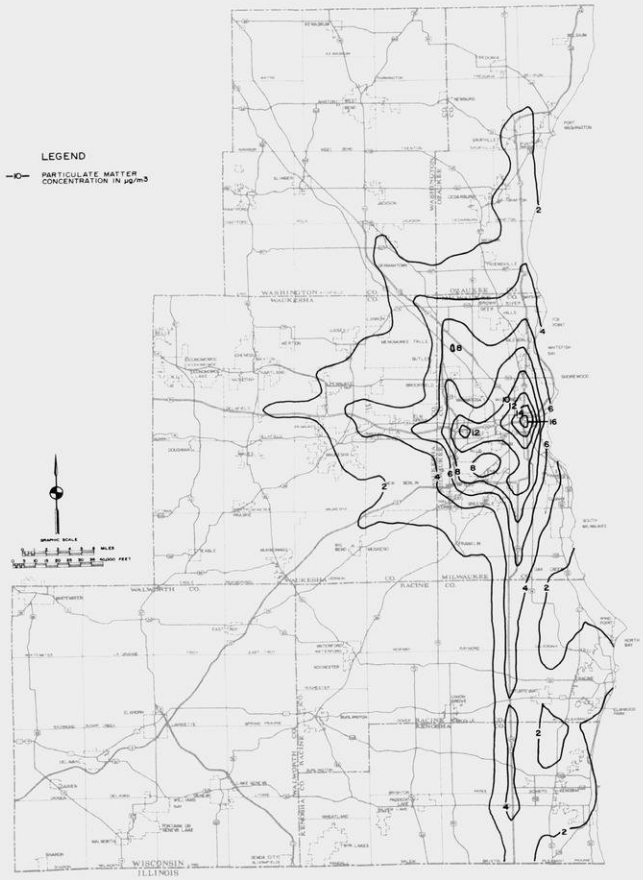


This map illustrates the impact of particulate matter emissions from line sources on ambient air quality in the Region as forecast under the adopted transportation plan for the year 2000. The concentrations shown on this map indicate little change in the impact of line sources on ambient particulate matter levels in the Region between 1985 and the year 2000. As shown on Map 109, the maximum ambient air particulate matter concentration due to line sources in 1985 is expected to be 14 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and will be centered over the Marquette Interchange. As may be seen on this map, the maximum concentration due to line sources in the year 2000 under the adopted transportation plan is anticipated to remain at 14 $\mu g/m^3$, and to again be centered over the Marquette Interchange. This finding may be attributed to the increase in vehicle miles of travel in the Region between 1985 and 2000, which may be expected to offset somewhat the emission reduction gained by removing lead compounds from gasoline.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 112

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE PARTICULATE MATTER CONCENTRATIONS IN THE REGION FROM FORECAST LINE SOURCE EMISSIONS: 2000 "NO BUILD" TRANSPORTATION PLAN



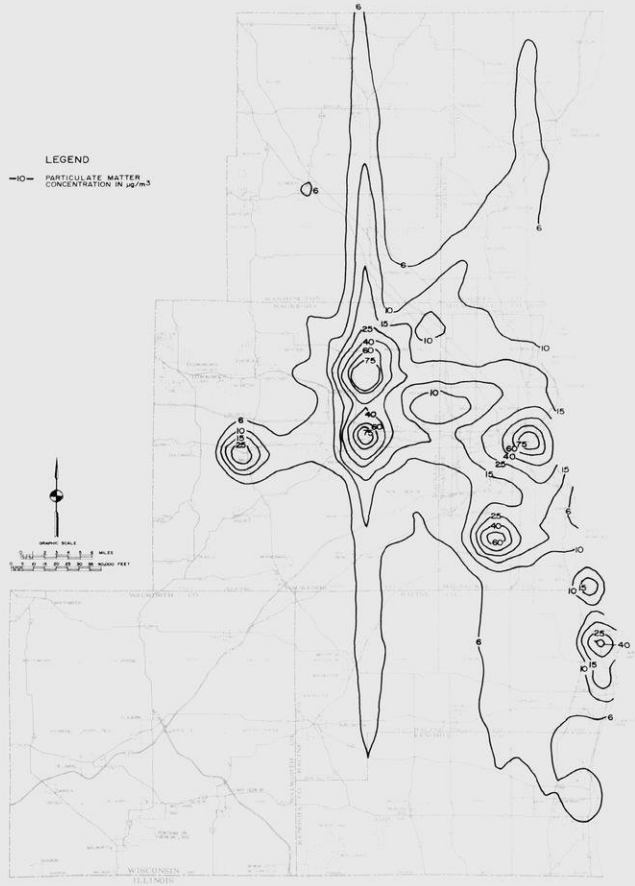
This map illustrates the impact of particulate matter emissions from line sources on ambient air quality in the Region as forecast under the "no build" alternative transportation plan for the year 2000. The concentrations shown on this map indicate an increase in the impact of line sources on ambient particulate matter levels in the Region between 1985 and the year 2000. As shown on Map 110, the maximum ambient air particulate matter concentration due to line sources in the year 1985 is expected to be 14 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and will be centered over the Marquette Interchange. As shown on Map 111, the maximum concentration indicated under the adopted transportation plan for the year 2000 is 16 $\mu g/m^3$, again centered over the Marquette Interchange. Reflecting the anticipated increase in regional vehicle miles of travel, the "no build" alternative transportation plan is expected to have a greater impact on annual arithmetic average particulate matter levels in the year 2000 than in 1985.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

period. This finding is consistent with the results of the particulate matter area source emissions forecasts, which indicated that the emissions of this pollutant species would increase by only about 300 tons, or less than 2 percent, over the planning period—from about 18,650 tons in 1977 to 18,950 tons in the year 2000. The highest particulate matter concentrations indicated in the forecast years are, as in 1977, principally attributable to emissions from quarries and other industrial fugitive dust sources in the Region.

Map 113

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE PARTICULATE MATTER CONCENTRATIONS IN THE REGION FROM FORECAST AREA SOURCE EMISSIONS: 1982



This map illustrates the impact of particulate matter emissions from area sources on ambient air quality in the Region in 1982. In 1982 particulate matter concentrations from area source emissions are anticipated to reach a maximum value of 75 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average. The maximum concentration may be expected to be located over two areas of Waukesha County—the vicinity of the City of Waukesha and the vicinity of the Village of Pewaukee—and over one area of Milwaukee County—the industrialized portion of the Menomonee River Valley. The principal area sources of emissions contributing to these concentrations are mining operations, unpaved roads, parking lots, truck terminal lots, and untreated aggregate storage piles in the Menomonee River Valley, all of which contribute fugitive dust emissions.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 114

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE PARTICULATE MATTER CONCENTRATIONS IN THE REGION FROM FORECAST AREA SOURCE EMISSIONS: 1985



This map illustrates the impact of particulate matter emissions from area sources on ambient air quality in the Region in 1985. In 1985 particulate matter concentrations from area source emissions are anticipated to reach a maximum value of 75 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average. The maximum concentration may be expected to be located over two areas of Waukesha County—the vicinity of the City of Waukesha and the vicinity of the Village of Pewaukee—and over two areas of Milwaukee County—the industrialized portion of the Menomonee River Valley and the City of Franklin. The principal area sources of emissions contributing to these concentrations are mining operations, unpaved roads, parking lots, truck terminal lots, and untreated aggregate storage piles in the Menomonee River Valley, all of which contribute fugitive dust emissions.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Composite Forecast of Particulate Matter Levels

The calibration equation derived from the validation procedure for the year 1977 (see Chapter XI) was used to convert the simulated annual arithmetic average particulate matter concentrations from combined point, line, and area sources in 1982, 1985, and 2000 to annual geometric averages. The composite forecasts of annual geometric average particulate matter concentrations in the Region thus calculated are presented on Map 116 for the year 1982 under the coal-intensive energy scenario, on Map 117 for the year 1985 under the coal-intensive energy scenario and the 1985 stage of the "no build"

alternative transportation plan, and on Map 118 for the year 2000 under the coal-intensive energy scenario and the "no build" alternative transportation plan.

Because the impact of point sources and line sources on particulate matter levels in the Region is expected to decline by 1982, the composite annual geometric average concentrations in Milwaukee County, as shown on Map 116, are forecast to encompass only a slightly larger area than they did in 1977. Approximately five square miles in the City of Milwaukee are forecast to exceed the primary annual standard of 75 $\mu g/m^3$ in 1982, about the same area indicated to exceed this standard in 1977. The land area exceeding the secondary annual standard of 60 $\mu g/m^3$ in the City of Milwaukee is forecast to increase slightly from about 24 square miles in 1977 to about 26 square miles in 1982. The area exceeding this secondary standard in the City of Franklin in 1977 is forecast to remain constant. The areas exceeding the primary and secondary annual standards in Waukesha County in 1977 and the small area exceeding the secondary annual standard in Racine County in 1977 are also expected to remain constant in 1982.

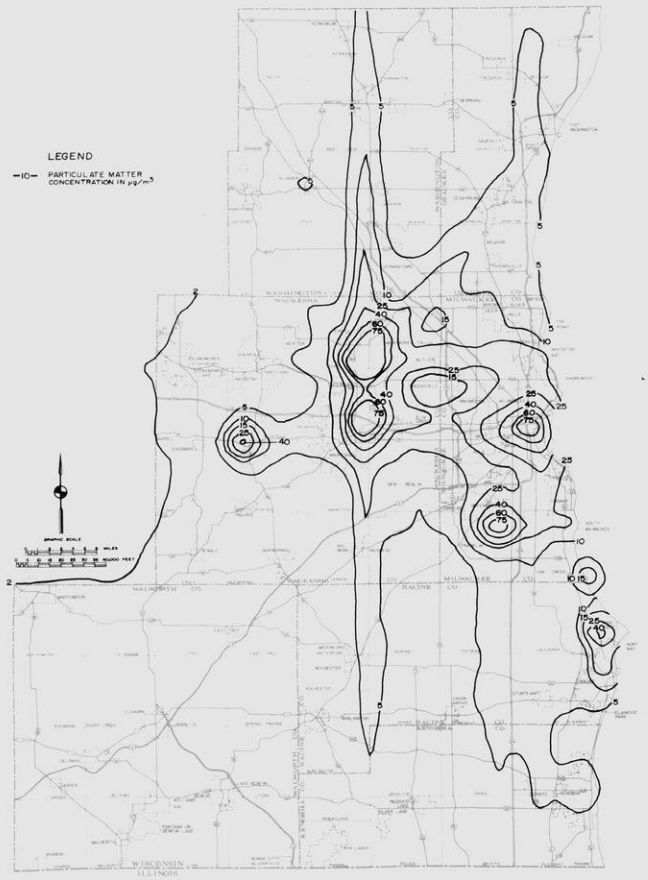
By the year 1985, the forecast growth in point, line, and area source particulate matter emissions is anticipated to result in an increase in the size of the area exceeding the primary annual standard in Milwaukee County, as shown on Map 117. Nearly eight square miles of land area in the City of Milwaukee are forecast to exceed this health-related standard. Moreover, the secondary standard is forecast to be exceeded over approximately 39 square miles in Milwaukee County in 1985, an increase of about 15 square miles, or about 63 percent, over the area exceeding that welfare-related standard in 1977. The area exceeding the secondary standard in Racine County is expected to remain constant at less than one square mile in 1985.

As shown on Map 118, by the area exceeding the primary annual standard in Milwaukee County will encompass approximately 11 square miles, an increase of six square miles, or 120 percent, over the area exceeding this standard in 1977. The secondary annual standard is expected to be exceeded over an additional 75 square miles in Milwaukee County in the year 2000, an increase of about 51 square miles, or about 213 percent, over the area exceeding this standard in 1977. The area exceeding the secondary standard in Racine County is expected to remain at the previous level of less than one square mile in 2000.

The particulate matter air pollution problem in Waukesha County is forecast to remain essentially unchanged over the planning period. Thus, parts of Waukesha County may be expected to continue to experience particulate matter concentrations at levels deleterious to human health and welfare. Similarly, parts of Milwaukee County may be expected to continue to exhibit harmful particulate matter levels. In Milwaukee County, however, the particulate matter air pollution problem is expected to increase in severity—both in magnitude and in areal extent—with time. The particulate matter problem in Racine County is expected to remain essentially unchanged with time. The annual average particulate matter air pollution problem in the Southeastern Wisconsin Region is such, therefore, that both a short-term attainment plan and a long-term maintenance plan will be required to alleviate the potential adverse effects of this pollutant species.

Map 115

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE PARTICULATE MATTER CONCENTRATIONS IN THE REGION FROM FORECAST AREA SOURCE EMISSIONS: 2000

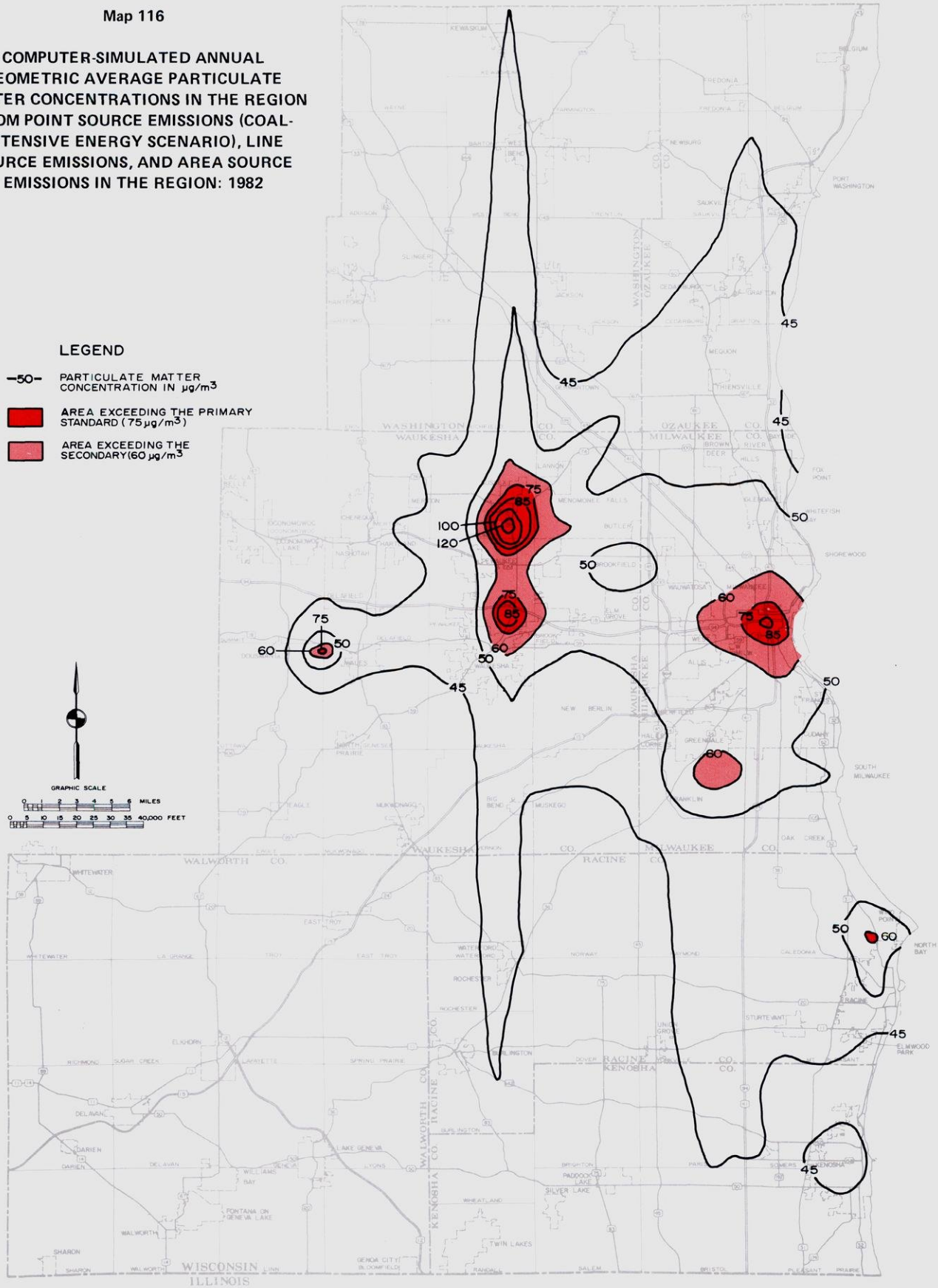


This map illustrates the impact of particulate matter emissions from area sources on ambient air quality in the Region in the year 2000. In the year 2000, particulate matter concentrations from area source emissions are anticipated to reach a maximum value of 75 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average. The maximum concentration may be expected to be located over two areas of Waukesha County—the vicinity of the City of Waukesha and the vicinity of the Village of Pewaukee—and over two areas of Milwaukee County—the industrialized portion of the Menomonee River Valley and the City of Franklin. The principal area sources of emissions contributing to this concentration are mining operations, unpaved roads, parking lots, truck terminal lots, and untreated aggregate storage piles in the Menomonee River Valley, all of which contribute fugitive dust emissions.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 116

COMPUTER-SIMULATED ANNUAL GEOMETRIC AVERAGE PARTICULATE MATTER CONCENTRATIONS IN THE REGION FROM POINT SOURCE EMISSIONS (COAL-INTENSIVE ENERGY SCENARIO), LINE SOURCE EMISSIONS, AND AREA SOURCE EMISSIONS IN THE REGION: 1982

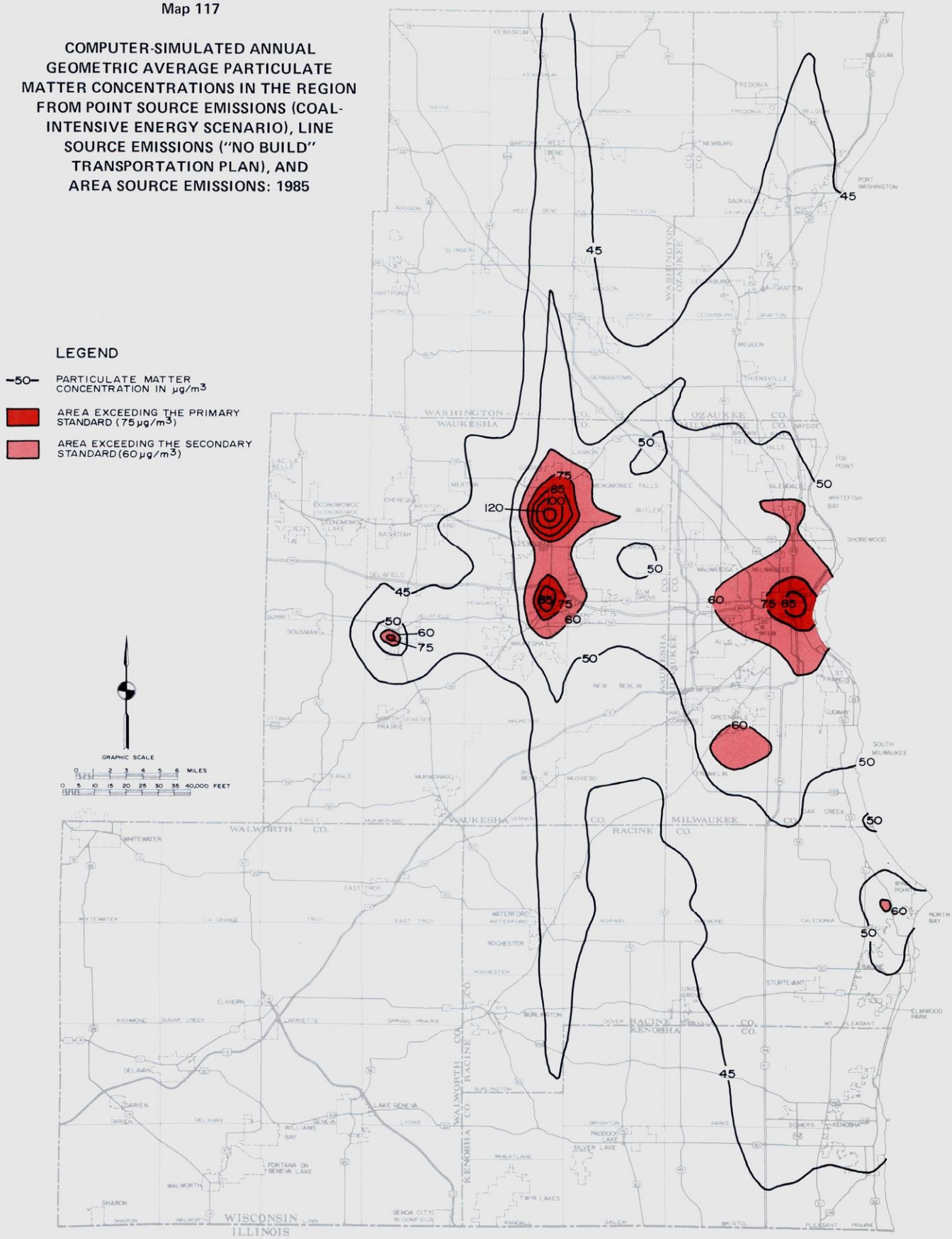


This map illustrates the composite impact of forecast point, line, and area source particulate matter emissions on ambient air quality in the Region in 1982. The concentrations shown on this map are derived from forecast emissions data as anticipated under the coal-intensive energy scenario, which assumes that natural gas supplies will not be available to meet total industrial energy demand. The air quality standard of 75 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual geometric average, is shown to be exceeded over a five-square-mile area in Milwaukee County and a 13-square-mile area in Waukesha County. The secondary annual geometric average standard of 60 $\mu g/m^3$ is shown to be exceeded over an additional 26-square-mile area in Milwaukee County, a 23-square-mile area in Waukesha County, and a 0.2-square-mile area in Racine County. An estimated 330,100 persons will reside in the areas impacted by particulate matter concentrations greater than the primary, or health-related, and secondary, or welfare-related, standards.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 117

COMPUTER-SIMULATED ANNUAL GEOMETRIC AVERAGE PARTICULATE MATTER CONCENTRATIONS IN THE REGION FROM POINT SOURCE EMISSIONS (COAL-INTENSIVE ENERGY SCENARIO), LINE SOURCE EMISSIONS ("NO BUILD" TRANSPORTATION PLAN), AND AREA SOURCE EMISSIONS: 1985

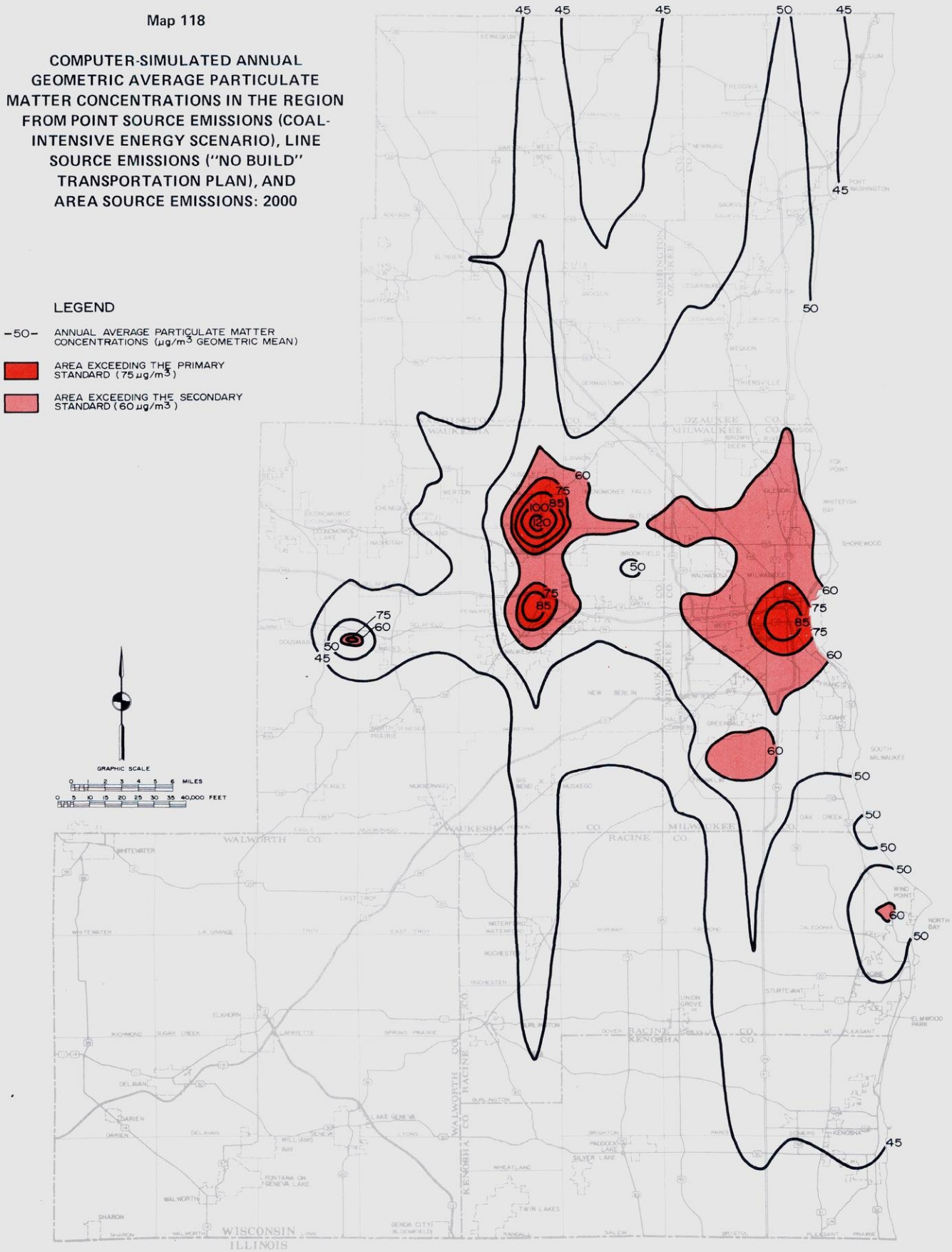


This map illustrates the composite impact of forecast point, line, and area source particulate matter emissions on ambient air quality in the Region in 1985. The concentrations shown on this map are derived from forecast emissions data as anticipated under the coal-intensive energy scenario, which assumes that natural gas supplies will not be available to meet total industrial energy demand, and the 1985 stage of the "no build" alternative transportation plan. The air quality standard of 75 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual geometric average, is shown to be exceeded over an eight-square-mile area in Milwaukee County and a 14-square-mile area in Waukesha County. The secondary annual geometric average standard of 60 $\mu g/m^3$ is shown to be exceeded over an additional 39-square-mile area in Milwaukee County, a 25-square-mile area in Waukesha County, and a 0.3-square-mile area in Racine County. An estimated 495,000 persons will reside in the areas impacted by particulate matter concentrations greater than the primary, or health-related, and secondary, or welfare-related, standards.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 118

COMPUTER-SIMULATED ANNUAL GEOMETRIC AVERAGE PARTICULATE MATTER CONCENTRATIONS IN THE REGION FROM POINT SOURCE EMISSIONS (COAL-INTENSIVE ENERGY SCENARIO), LINE SOURCE EMISSIONS ("NO BUILD" TRANSPORTATION PLAN), AND AREA SOURCE EMISSIONS: 2000



This map illustrates the composite impact of forecast point, line, and area source particulate matter emissions on ambient air quality in the Region in the year 2000. The concentrations shown on this map are derived from forecast emissions data as anticipated under the coal-intensive energy scenario, which assumes that natural gas supplies will not be available to meet total industrial energy demand, and the "no build" alternative transportation plan. The air quality standard of 75 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual geometric average, is shown to be exceeded over an 11-square-mile area in Milwaukee County and a 14-square-mile area in Waukesha County. The secondary annual geometric average standard of 60 $\mu g/m^3$ is shown to be exceeded over an additional 75-square-mile area in Milwaukee County, a 28-square-mile area in Waukesha County, and a 0.7-square-mile area in Racine County. An estimated 622,400 persons will reside in the areas impacted by particulate matter concentrations greater than the primary, or health-related, and secondary, or welfare-related, standards.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

24-Hour Concentrations: The Wisconsin Atmospheric Diffusion Model was also used to evaluate the effect of forecast particulate matter emissions in the years 1982, 1985, and 2000 on the attainment of the short-term, 24-hour, primary and secondary ambient air quality standards of 260 and 150 $\mu g/m^3$, respectively. This evaluation was conducted under the same "worst case" meteorological conditions used in the base year modeling effort, consisting of southerly winds at a ground level speed of about 5.6 miles per hour, slightly unstable atmospheric conditions for 12 hours of daylight, and slightly stable atmospheric conditions for 12 hours during the night.

The results of this 24-hour arithmetic average particulate matter modeling effort are presented on Map 119 for the 1982 emissions forecast, on Map 120 for the 1985 emissions forecast, and on Map 121 for the year 2000 emissions forecast. It should be noted that these short-term modeling results represent the uncalibrated particulate matter concentrations due to all forecast point, line, and area sources of emissions. Insofar as the modeling results are not calibrated, for reasons explained in Chapter XI, background pollutant concentrations as may be due to long-range transport, unidentified emission sources, chemical transformations, and naturally occurring particulate levels are not represented on Maps 119, 120, and 121. These modeling results should, therefore, be used either as a guide to indicate the direction of change in short-term particulate matter concentrations in the Region in future years, or as a general indication of expected ambient air quality levels.

In studying the maximum 24-hour average particulate matter levels in 1982, 1985, and 2000 and the corresponding 1977 levels, it is evident that the short-term average closely parallels the distribution and trends of the annual average. In the 1977 simulation results, and in all of the simulated forecast results, the primary and secondary 24-hour average standards are indicated to be exceeded in Waukesha County, and the secondary standard is indicated to be exceeded in Milwaukee County. As in the annual average modeling results, however, the only area which demonstrates further degradation throughout the forecast period is the heavily industralized portion of the Menomonee River Valley in Milwaukee County. Over the forecast period, the area exceeding the secondary 24-hour standard in the Menomonee River Valley increases from less than one square mile in 1977 to about three square miles in the year 2000. The area exceeding the secondary 24-hour average standard in the City of Franklin is expected to remain constant through the year 2000 at about one square mile. Therefore, it is anticipated that the secondary 24-hour average standard will be exceeded over a four-square-mile area in Milwaukee County in the year 2000 as a result of emissions from local sources. It is also anticipated that the primary 24-hour average standard will be exceeded over an 11-square-mile area in Waukesha County, and that the secondary standard will be exceeded over an additional 13-square-mile area in Waukesha County in the year 2000, again due to emissions from local sources. Considering that the primary 24-hour average standard is presently being exceeded in Milwaukee County, it is probable that violations of this standard will continue and intensify through the year 2000. On the basis of the short-term simulation modeling results, a short-term attainment plan and long-term maintenance plan will be required in order to alleviate the impact of deleterious particulate matter levels as forecast for the Southeastern Wisconsin Region through the year 2000.

FORECAST SULFUR DIOXIDE CONCENTRATIONS: 1982, 1985, AND 2000

Point Sources

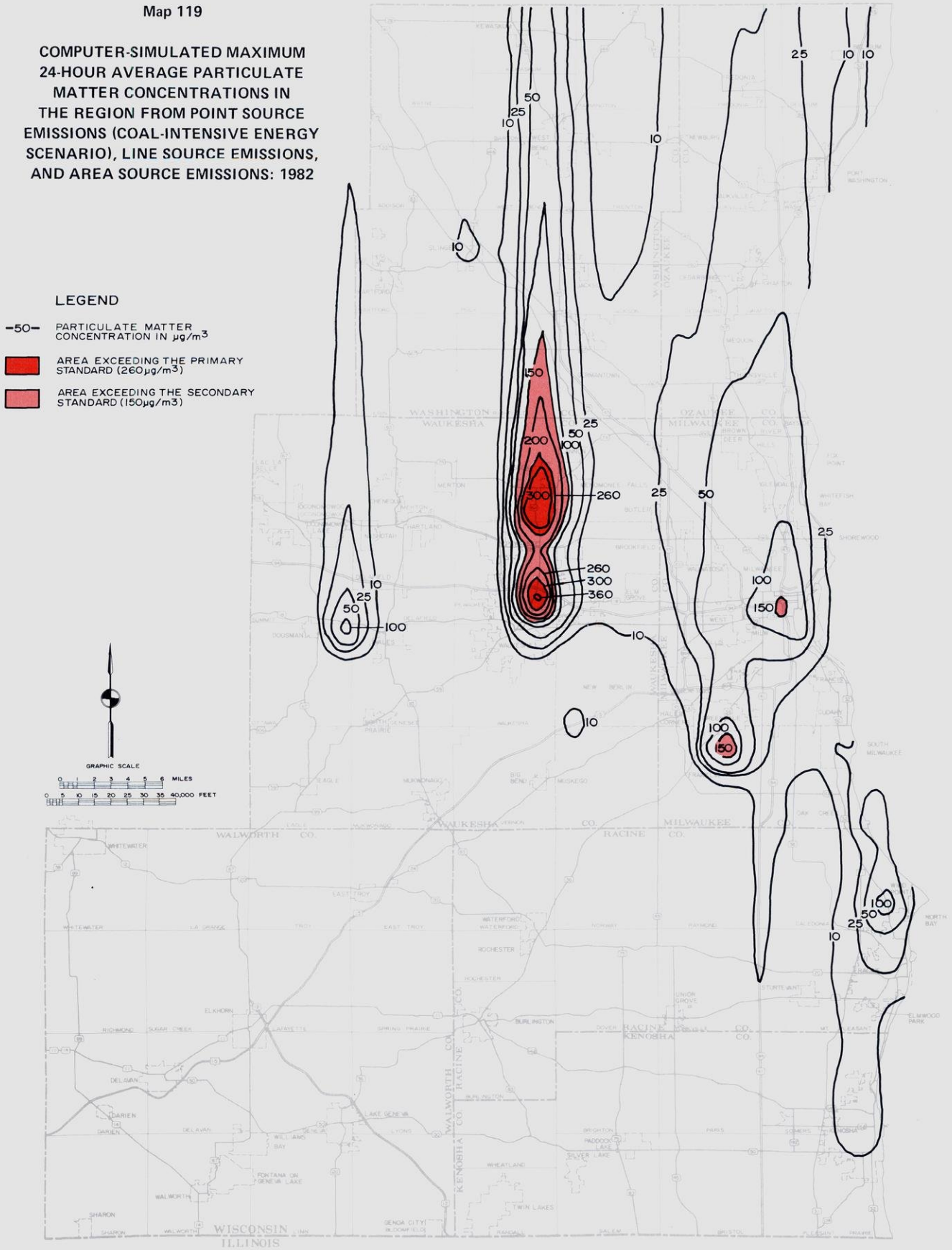
The forecast annual arithmetic average sulfur dioxide concentrations due to point source emissions were simulated for the years 1982, 1985, and 2000 using the multiple point sources (MLTPT) submodel of the Wisconsin Atmospheric Diffusion Model. The emissions data and the meteorological data used in these simulations are summarized in Table 280 and Table 308, respectively. The results of the simulation modeling effort for the year 1982 are presented on Map 122 for the natural gas-intensive energy scenario, on Map 123 for the fuel oil-intensive energy scenario, and on Map 124 for the coal-intensive energy scenario.

As may be seen on Map 122, the maximum isopleth value indicated under the natural gas-intensive energy scenario in 1982 is 20 micrograms per cubic meter ($\mu g/m^3$) and extends out over Lake Michigan from an area in central Milwaukee County. In comparing the annual arithmetic average sulfur dioxide concentrations due to point source emissions in the Region in 1982, as shown on Map 122, with those in 1976, as shown on Map 66 in Chapter XI, it may be seen that the maximum isopleth value of 20 $\mu g/m^3$ impacted Lake Michigan from a small area near the shoreline in 1976. In 1982, however, the 20 $\mu g/m^3$ isopleth impacts about two square miles of land area in Milwaukee County under the natural gas-intensive energy scenario. Under the fuel oil-intensive energy scenario in 1982, the 20 $\mu g/m^3$ isopleth encompasses approximately 11 square miles of land area in Milwaukee County, and the maximum isopleth value indicated on Map 123, 25 $\mu g/m^3$, is located over Lake Michigan. Under the coal-intensive energy scenario in 1982, as shown on Map 124, the 25 $\mu g/m^3$ isopleth impacts an area of about one square mile in Milwaukee County, while the 20 $\mu g/m^3$ isopleth impacts an additional 23 square miles of land area. Therefore, the coal-intensive energy scenario represents the potentially "worst case" condition for air quality maintenance planning purposes.

Under the coal-intensive energy scenario, the maximum isopleth value indicated for sulfur dioxide concentrations due to forecast point source emissions in the Region in 1985 is 30 $\mu g/m^3$, as shown on Map 125. This isopleth encompasses less than one square mile of land area in Milwaukee County. Reflecting the anticipated industrial growth in the Region, the area encompassed by the isopleth value of 30 $\mu g/m^3$ is forecast to expand to about 27 square miles in Milwaukee County by the year 2000, as shown on Map 126, including a small area

Map 119

COMPUTER-SIMULATED MAXIMUM 24-HOUR AVERAGE PARTICULATE MATTER CONCENTRATIONS IN THE REGION FROM POINT SOURCE EMISSIONS (COAL-INTENSIVE ENERGY SCENARIO), LINE SOURCE EMISSIONS, AND AREA SOURCE EMISSIONS: 1982

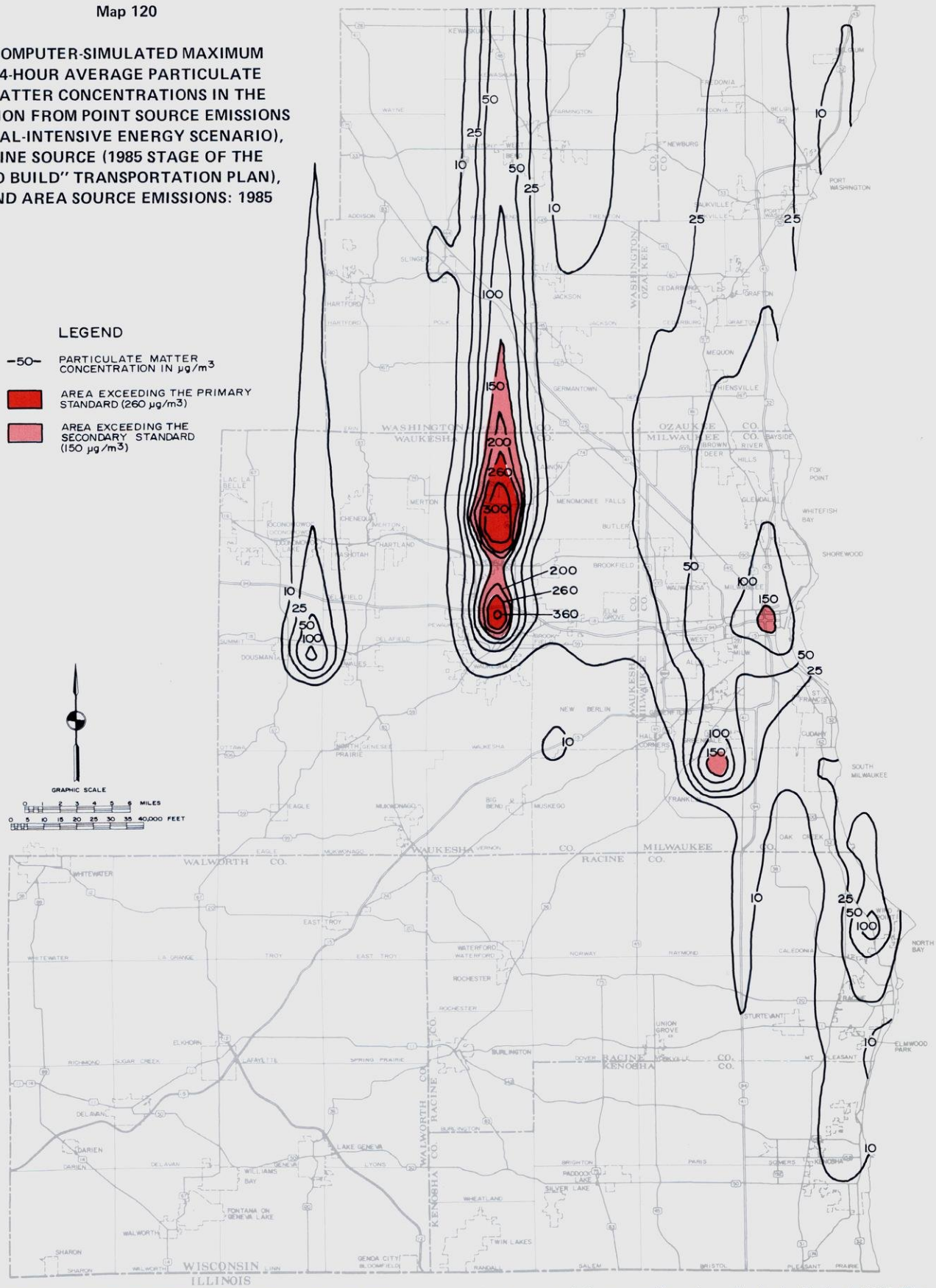


This map illustrates the composite impact of forecast point, line, and area source particulate matter emissions on ambient air quality in the Region in 1982. The concentrations shown on this map are derived from emissions data as anticipated under the coal-intensive energy scenario, which assumes that natural gas supplies will not be available to meet total industrial energy demand. This map indicates that the primary and secondary air quality standards, expressed as a 24-hour average, will be exceeded within the Region in 1982. The primary 24-hour standard of 260 micrograms per cubic meter ($\mu g/m^3$) is shown to be exceeded over an 11-square-mile area in Waukesha County. The secondary 24-hour standard of 150 $\mu g/m^3$ is shown to be exceeded over an additional 12-square-mile area in Waukesha County, a two-square-mile area in Milwaukee County, and a four-square-mile area in Washington County. An estimated 16,500 persons will reside in the areas impacted by particulate matter concentrations greater than the primary, or health-related, and secondary, or welfare-related, standards.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 120

COMPUTER-SIMULATED MAXIMUM 24-HOUR AVERAGE PARTICULATE MATTER CONCENTRATIONS IN THE REGION FROM POINT SOURCE EMISSIONS (COAL-INTENSIVE ENERGY SCENARIO), LINE SOURCE (1985 STAGE OF THE "NO BUILD" TRANSPORTATION PLAN), AND AREA SOURCE EMISSIONS: 1985

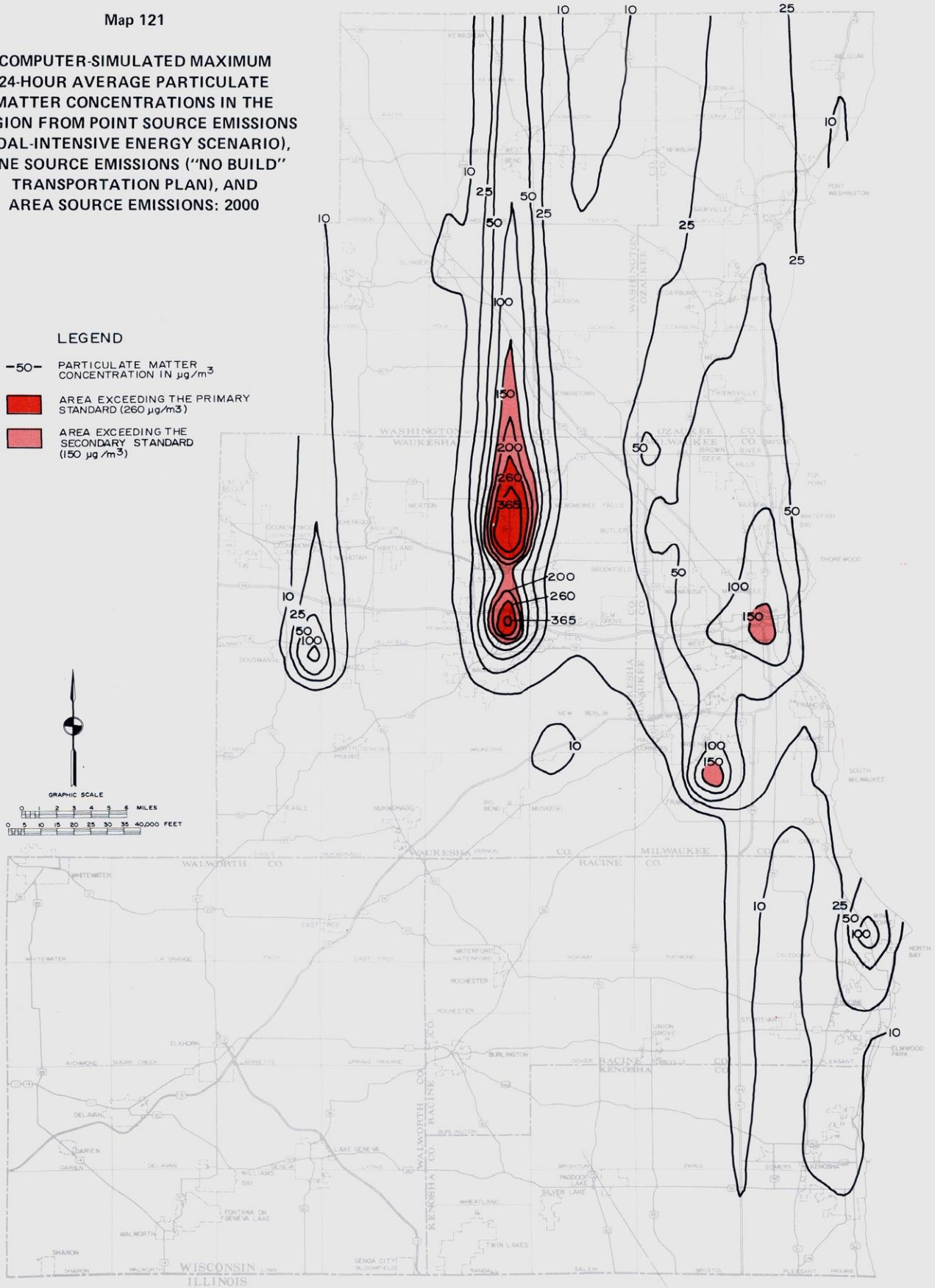


This map illustrates the composite impact of forecast point, line, and area source particulate matter emissions on ambient air quality in the Region in 1985. The concentrations shown on this map are derived from emissions data as anticipated under the coal-intensive energy scenario, which assumes that natural gas supplies will not be available to meet total industrial energy demand, and the 1985 stage of the "no build" alternative transportation plan. This map indicates that both the primary and secondary air quality standards for particulate matter, expressed as a 24-hour average, will be exceeded within the Region in 1985. The primary 24-hour standard of 260 micrograms per cubic meter ($\mu g/m^3$) is shown to be exceeded over an 11-square-mile area in Waukesha County. The secondary 24-hour standard of 150 $\mu g/m^3$ is shown to be exceeded over an additional 13-square-mile area in Waukesha County, a three-square-mile area in Milwaukee County, and a five-square-mile area in Washington County. An estimated 32,500 persons will reside in the areas impacted by particulate matter concentrations greater than the primary, or health-related, and secondary, or welfare-related, standards.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 121

COMPUTER-SIMULATED MAXIMUM 24-HOUR AVERAGE PARTICULATE MATTER CONCENTRATIONS IN THE REGION FROM POINT SOURCE EMISSIONS (COAL-INTENSIVE ENERGY SCENARIO), LINE SOURCE EMISSIONS ("NO BUILD" TRANSPORTATION PLAN), AND AREA SOURCE EMISSIONS: 2000

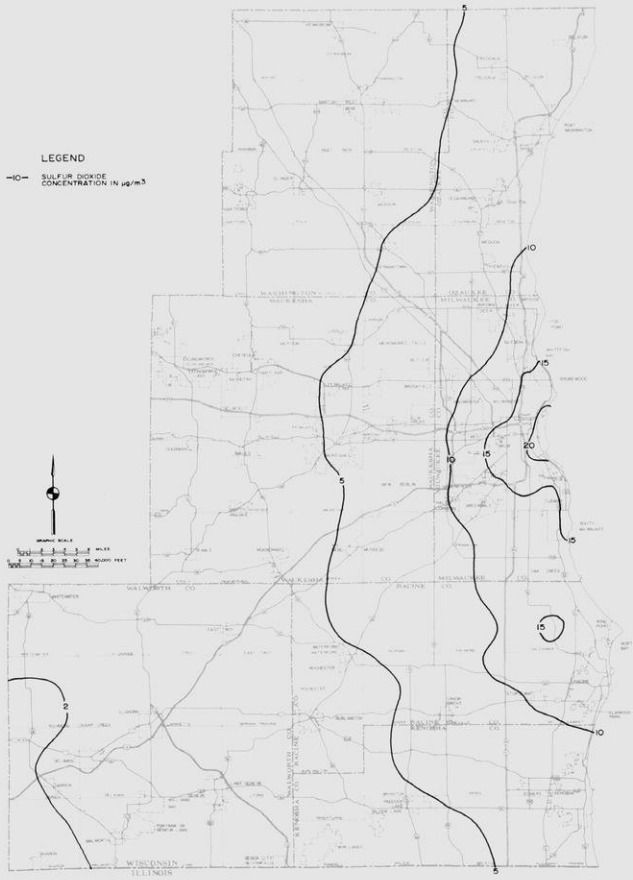


This map illustrates the composite impact of forecast point, line, and area source particulate matter emissions on ambient air quality in the Region in the year 2000. The concentrations shown on this map are derived from emissions data as anticipated under the coal-intensive energy scenario, which assumes that natural gas supplies will not be available to meet total industrial energy demand, and the "no build" alternative transportation plan. This map indicates that both the primary and secondary air quality standards for particulate matter, expressed as a 24-hour average, will be exceeded within the Region in the year 2000. The primary 24-hour standard of 260 micrograms per cubic meter ($\mu g/m^3$) is shown to be exceeded over an 11-square-mile area in Waukesha County. The secondary 24-hour standard of 150 $\mu g/m^3$ is shown to be exceeded over an additional 13-square-mile area in Waukesha County, a four-square-mile area in Milwaukee County, and a five-square-mile area in Washington County. An estimated 37,800 persons will reside in the area impacted by particulate matter concentrations greater than the primary, or health-related, and secondary, or welfare-related, standards.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 122

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE SULFUR DIOXIDE CONCENTRATIONS IN THE REGION FROM FORECAST POINT SOURCE EMISSIONS: 1982 NATURAL GAS-INTENSIVE ENERGY SCENARIO

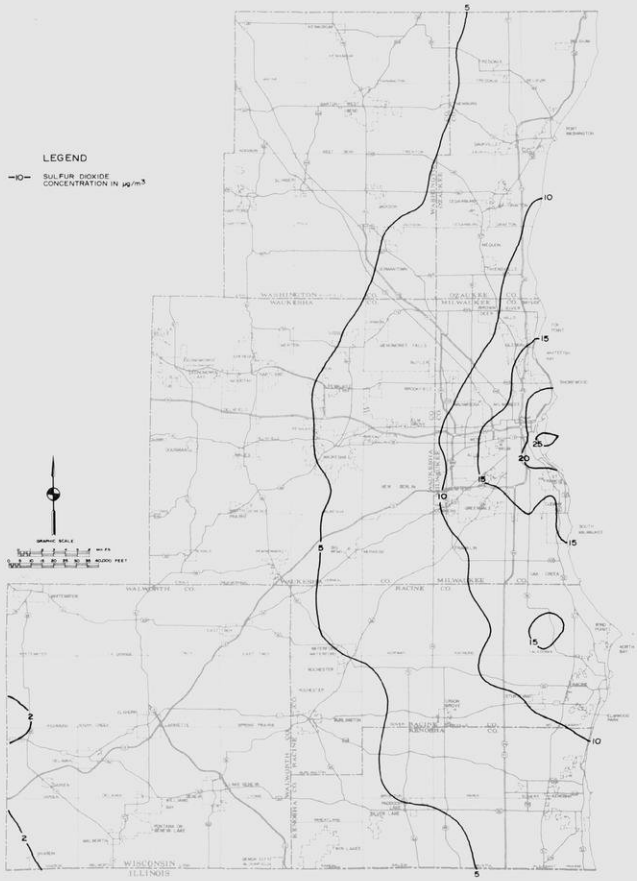


This map illustrates the impact of sulfur dioxide emissions from point sources on ambient air quality in the Region in 1982 under the natural gas-intensive energy scenario, which assumes that an adequate natural gas supply will be available to meet industrial energy demand. The maximum isopleth value shown on this map is 20 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and is located along the Lake Michigan shoreline in central Milwaukee County. As shown on Map 66 in Chapter XI, the maximum concentration of sulfur dioxide due to point source emissions in 1976 was 20 $\mu g/m^3$, and was also located along the Lake Michigan shoreline in central Milwaukee. In 1982 this 20 ug/m^3 isopleth is anticipated to impact about two square miles of land area in Milwaukee County.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 123

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE SULFUR DIOXIDE CONCENTRATIONS IN THE REGION FROM FORECAST POINT SOURCE EMISSIONS: 1982 FUEL OIL-INTENSIVE ENERGY SCENARIO



This map illustrates the impact of sulfur dioxide emissions from point sources on ambient air quality in the Region in 1982 under the fuel oil-intensive energy scenario, which assumes increased dependence on fuel oil to meet industrial energy demand. Under this energy scenario, the isopleth value of 20 micrograms per cubic meter ($\mu g/m^3$) is located over an 11-square-mile land area in Milwaukee County. The maximum isopleth value indicated on this map is 25 $\mu g/m^3$, expressed as an annual arithmetic average, and is located over Lake Michigan. The results of the sulfur dioxide emissions forecast for 1982 indicate that under the fuel oil-intensive energy scenerio, point sources will emit about 212,100 tons of sulfur dioxide in the Region, an increase of about 5,100 tons, or 2 percent, over the 207,000 tons expected to be emitted in 1982 under the natural gas-intensive energy scenario.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

around the Milwaukee County Institutions. It may be concluded, therefore, that the impact of continued industrial growth and development in the Region on annual average ambient air sulfur dioxide concentrations will grow progressively greater over the forecast period.

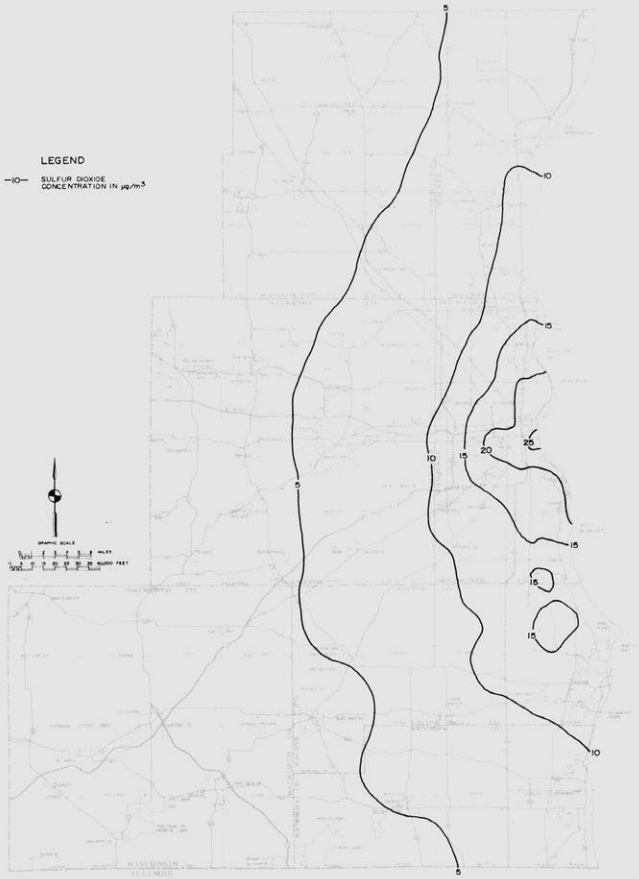
Line Sources

The annual arithmetic average sulfur dioxide concentrations in the Region due to forecast line source emissions in the years 1982, 1985, and 2000 were simulated using the URBAN submodel of the Wisconsin Atmospheric Diffusion Model. The forecast emissions data and the meteorological data used in the simulations are summarized in Table 281 and Table 309, respectively.

The results of the simulation effort for the year 1982 are presented on Map 127. As may be seen by comparing the 1982 line source sulfur dioxide concentrations with the

Map 124

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE SULFUR DIOXIDE CONCENTRATIONS IN THE REGION FROM FORECAST POINT SOURCE EMISSIONS: 1982 COAL-INTENSIVE ENERGY SCENARIO

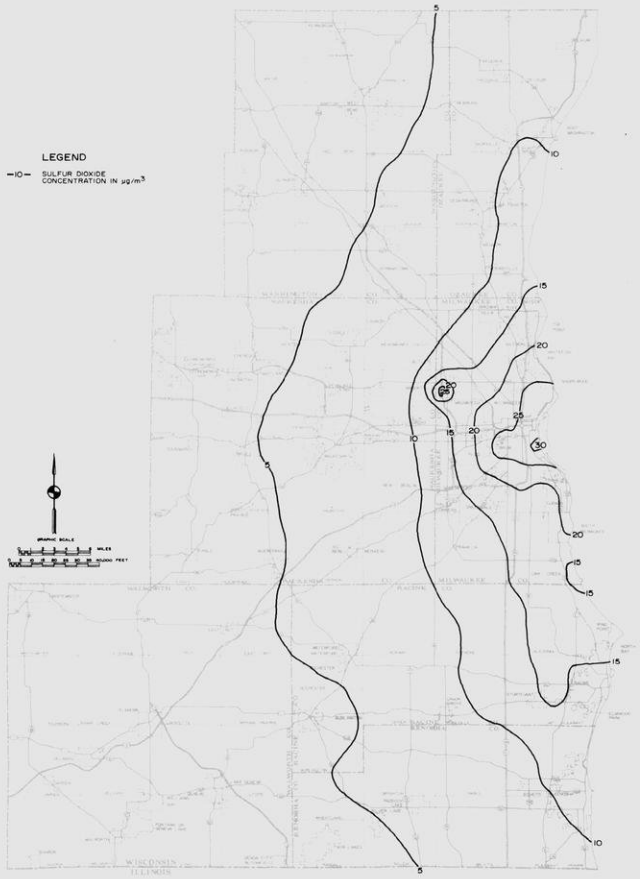


This map illustrates the impact of sulfur dioxide emissions from point sources on ambient air quality in the Region in 1982 under the coal-intensive energy scenario, which assumes that natural gas supplies will not be available to meet total industrial energy demand. The maximum isopleth value shown on this map is 25 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and is located over a land area of about 0.7 square mile in Milwaukee County. Furthermore, an isopleth value of 20 $\mu g/m^3$ is shown to be located over an additional 24 square miles of land area in Milwaukee County. The results of the sulfur dioxide emissions forecast for 1982 indicate that under the coal-intensive energy scenario, point sources will emit about 217,700 tons of sulfur dioxide in the Region, an increase of about 5,600 tons, or 3 percent, over the 212,000 tons expected to be emitted under the 1982 fuel oil-intensive energy scenario. The coal-intensive energy scenario, therefore, represents the potentially "worst case" condition for air quality maintenance planning.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 125

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE SULFUR DIOXIDE CONCENTRATIONS IN THE REGION FROM FORECAST POINT SOURCE EMISSIONS: 1985 COAL-INTENSIVE ENERGY SCENARIO



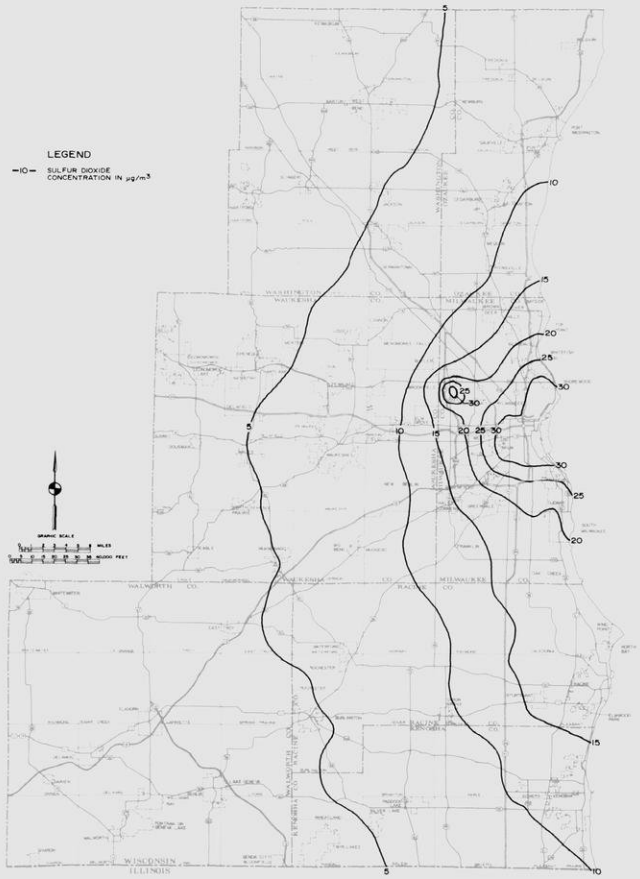
This map illustrates the impact of sulfur dioxide emissions from point sources on ambient air quality in the Region in 1985 under the coal-intensive energy scenario, which assumes that natural gas supplies will not be available to meet total industrial energy demand. The highest isopleth value shown on this map is 30 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and is located over a 0.4-square-mile area in central Milwaukee County. Reflecting the anticipated industrial growth and an assumed increased dependence on coal by industrial sources, the 20 $\mu g/m^3$ and 25 $\mu g/m^3$ isopleth values encompass a land area generally larger in extent than under previous forecasts, including a small area around Milwaukee County Institutions.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

corresponding concentrations in 1976, as shown on Map 67 in Chapter XI, only a slight increase in the area encompassed by the maximum isopleth value—8 $\mu g/m^3$ located over the Marquette Interchange in Milwaukee County—may be expected to occur over this six-year period. Similarly, only a slight increase in the area encompassed by the 8 $\mu g/m^3$ isopleth is evident under the 1985 stage of both the "no build" alternative transportation plan and the adopted transportation plan, as shown on Maps 128 and 129, respectively. Under the "no build" alternative transportation plan for the year 2000, a significant increase in the area encompassed by the 8 $\mu g/m^3$ isopleth may be expected, as shown on Map 130, as compared with the area encompassed by this isopleth in 1976—from less than one square mile in 1976 to more than three square miles in the year 2000.

Map 126

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE SULFUR DIOXIDE CONCENTRATIONS IN THE REGION FROM FORECAST POINT SOURCE EMISSIONS: 2000 COAL-INTENSIVE ENERGY SCENARIO

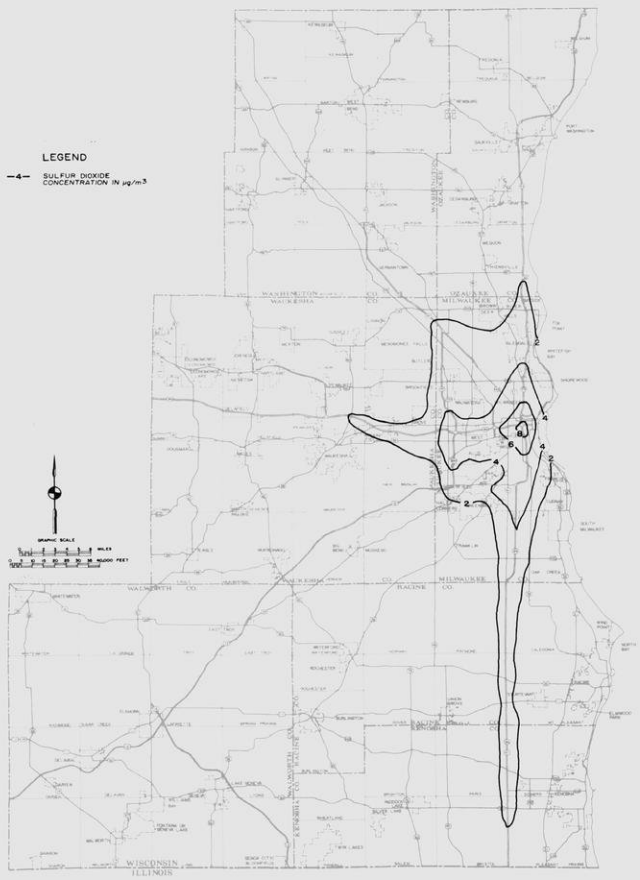


This map illustrates the impact of sulfur dioxide emissions from point sources on ambient air quality in the Region in the year 2000 under the coal-intensive energy scenario, which assumes that natural gas supplies will not be available to meet total industrial energy demand. The highest isopleth value indicated on this map is 30 micrograms per cubic meter ($\mu g/m^3$), expressed as annual arithmetic average, and is located over a land area of about 27 square miles in Milwaukee County. As shown on Map 125, the maximum ambient air sulfur dioxide concentration due to point sources in 1985 under this energy scenario is also expected to be 30 $\mu g/m^3$, but is expected to encompass a smaller land area of about 0.4 square mile. This finding is consistent with the results of the sulfur dioxide emissions forecast for the year 2000, which indicate that point sources under the coal-intensive energy scenario will emit about 205,800 tons of sulfur dioxide, reflecting the fact that the impact of the industrial growth and development anticipated in the Region under this energy scenario on sulfur dioxide concentrations will grow progressively greater between 1985 and the year 2000.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 127

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE SULFUR DIOXIDE CONCENTRATIONS IN THE REGION FROM FORECAST LINE SOURCE EMISSIONS: 1982



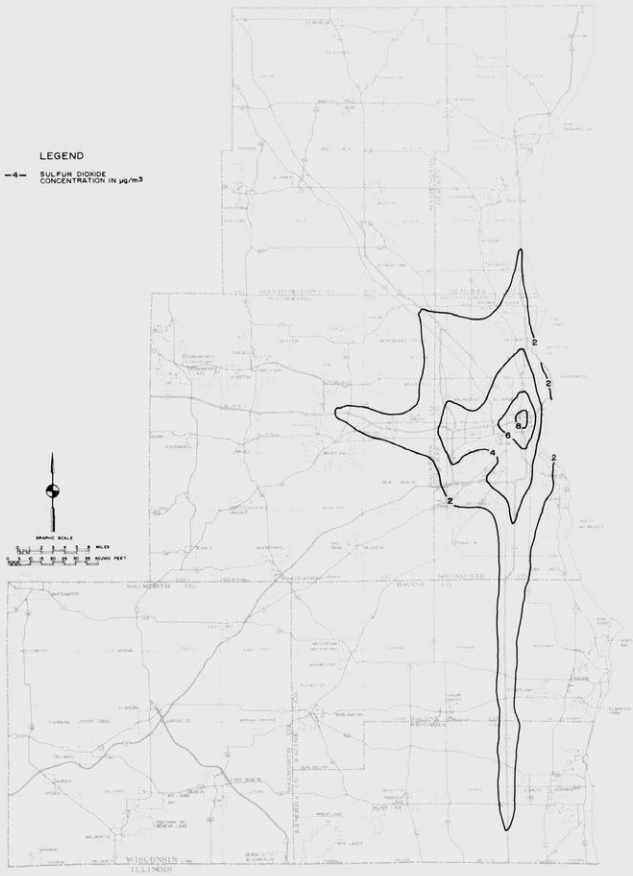
This map illustrates the impact of sulfur dioxide emissions from line sources on ambient air quality in the Region in 1982. As may be seen by comparing this map with Map 67 in Chapter XI, the area encompassed by the maximum isopleth value of eight micrograms per cubic meter ($\mu g/m^3$) is expected to increase slightly over the forecast period. This finding is consistent with the results of the sulfur dioxide emissions forecast for 1982, which indicate that line sources will emit about 1,900 tons of sulfur dioxide in the Region, an increase of about 50 tons, or 3 percent, over the 1977 line source emissions level of about 1,850 tons. As may be expected, the spatial distribution of sulfur dioxide concentrations due to forecast line source emissions in 1982 closely parallels the pattern of the regional freeway system.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Under the adopted transportation plan for the year 2000, essentially the same area is encompassed by the 8 $\mu g/m^3$ isopleth as is under the "no build" plan, but the maximum isopleth value indicated under the adopted plan, as shown on Map 131, is 10 $\mu g/m^3$, again centered over the Marquette Interchange. This finding is consistent with the sulfur dioxide emissions forecasts for the year 2000, which indicated that, although overall vehicle miles of travel for all vehicle types is lower under the adopted plan, the higher vehicle miles of travel for heavy-duty gasoline trucks and mass transit vehicles under the adopted plan as compared with the "no build" plan results in higher total sulfur dioxide emissions. It may be concluded, therefore, that the potentially "worst

Map 128

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE SULFUR DIOXIDE CONCENTRATIONS IN THE REGION FROM FORECAST LINE SOURCE EMISSIONS: 1985 STAGE OF THE "NO BUILD" TRANSPORTATION PLAN

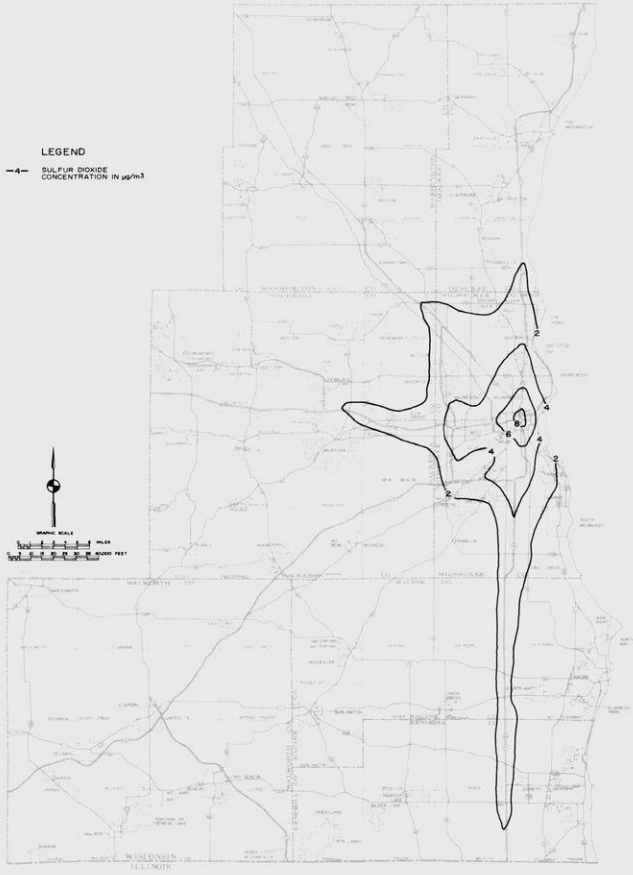


This map illustrates the impact of sulfur dioxide emissions from line sources on ambient air quality in the Region as forecast under the 1985 stage of the "no build" alternative transportation plan. As may be seen by comparing this map with Map 127, only a slight increase in the area encompassed by the maximum isopleth value of eight micrograms per cubic meter ($\mu g/m^3$) is anticipated to occur between 1982 and 1985. The results of the sulfur dioxide emissions forecast for 1985 indicate that line sources under the "no build" alternative transportation plan will emit about 2,000 tons of sulfur dioxide in the Region, an increase of about 100 tons, or 5 percent, over the 1982 line source emissions level of 1,900 tons. As may be expected, the spatial distribution of sulfur dioxide concentrations due to forecast line source emissions in 1985 closely parallels the pattern of the regional freeway system.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 129

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE SULFUR DIOXIDE CONCENTRATIONS IN THE REGION FROM FORECAST LINE SOURCE EMISSIONS: 1985 STAGE OF THE ADOPTED TRANSPORTATION PLAN

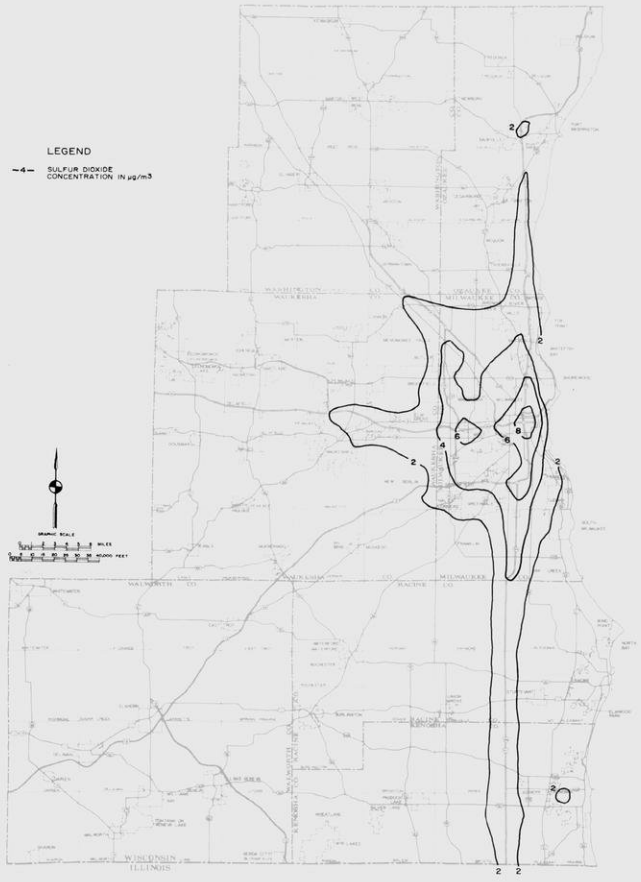


This map illustrates the impact of sulfur dioxide emissions from line sources an ambient air quality in the Region as forecast under the 1985 stage of the adopted transportation plan. The highest isopleth value shown on this map is eight micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and is located over the Marquette Interchange. As may be seen by comparing this map with Map 128, ambient air sulfur dioxide concentrations under the "no build" alternative plan and the adopted regional transportation plan for 1985 may be expected to be of about the same magnitude and spatial distribution. This finding is consistent with the results of the sulfur dioxide emission forecasts for the year 1985, which indicate that line sources under the "no build" alternative plan and adopted transportation plan will emit about 2,000 tons of sulfur dioxide in the Region. As may be expected, the spatial distribution of sulfur dioxide concentrations due to forecast line source emissions in 1985 closely parallels the pattern of the regional freeway system.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 130

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE SULFUR DIOXIDE CONCENTRATIONS IN THE REGION FROM FORECAST LINE SOURCE EMISSIONS: 2000 "NO BUILD" TRANSPORTATION PLAN

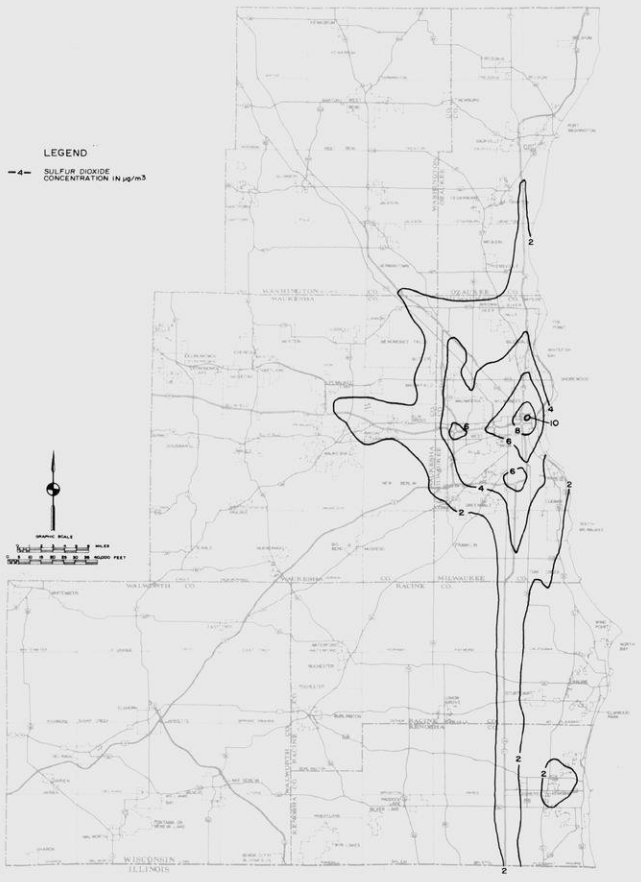


This map illustrates the impact of sulfur dioxide emissions from line sources on ambient air quality in the Region in the year 2000 under the 2000 "no build" transportation plan. The highest isopleth value shown on this map is eight micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and is located over the Marquette Interchange. As may be expected, the spatial distribution of sulfur dioxide concentrations due to forecast line source emissions in the year 2000 closely parallels the pattern of the regional freeway system.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 131

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE SULFUR DIOXIDE CONCENTRATIONS IN THE REGION FROM FORECAST LINE SOURCE EMISSIONS: 2000 ADOPTED TRANSPORTATION PLAN



This map illustrates the impact of sulfur dioxide emissions from line sources on ambient air quality in the Region in the year 2000 under the adopted transportation plan. The area encompassed by the eight micrograms per cubic meter ($\mu g/m^3$) isopleth value under this plan is essentially the same size as the corresponding area under the "no build" alternative transportation plan. However, the maximum isopleth value indicated under the adopted plan is 10 $\mu g/m^3$, again centered over the Marquette Interchange. This finding is consistent with the results of the sulfur dioxide emissions forecast for the year 2000, which indicate that the higher vehicle miles of travel for heavy-duty gasoline trucks and mass transit vehicles under the adopted plan as compared with the "no build" plan will result in higher total sulfur dioxide emissions. As may be expected, the spatial distribution of sulfur dioxide concentrations due to forecast line source emissions in the year 2000 closely parallels the pattern of the regional freeway system.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

case" conditions for sulfur dioxide concentrations resulting from line source emissions are defined by the adopted transportation plan.

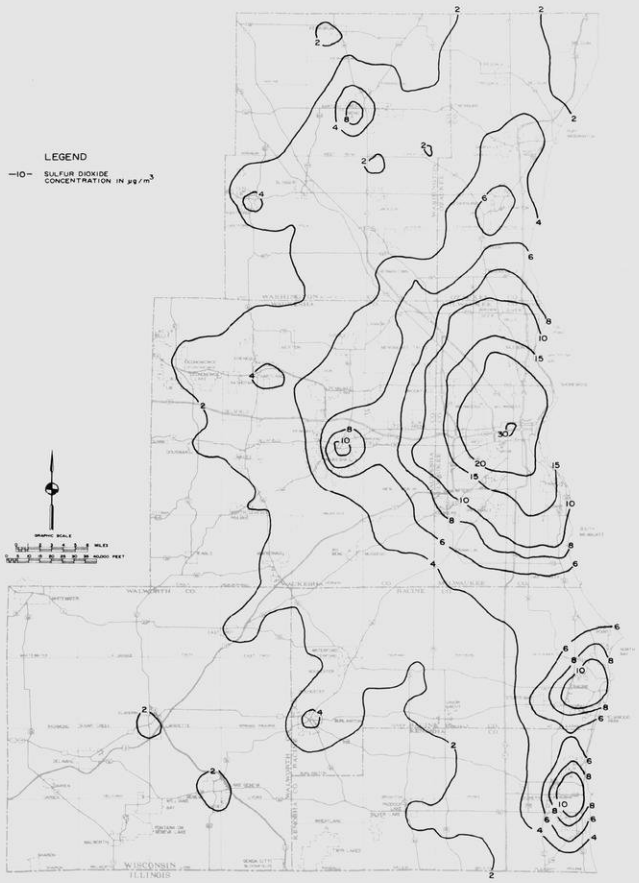
Area Sources

The annual arithmetic average sulfur dioxide concentrations due to forecast area source emissions in the Region in the years 1982, 1985, and 2000 were simulated using the URBAN submodel of the Wisconsin Atmospheric Diffusion Model. The emissions forecast data and the meteorological data used in these simulations are summarized in Table 291 and Table 309, respectively. The results of this simulation modeling effort are presented on Map 132 for the year 1982, on Map 133 for the year 1985, and on Map 134 for the year 2000.

The maximum isopleth value indicated for the year 1982, as shown on Map 132, is 30 $\mu g/m^3$ and is located

Map 132

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE SULFUR DIOXIDE CONCENTRATIONS IN THE REGION FROM FORECAST AREA SOURCE EMISSIONS: 1982

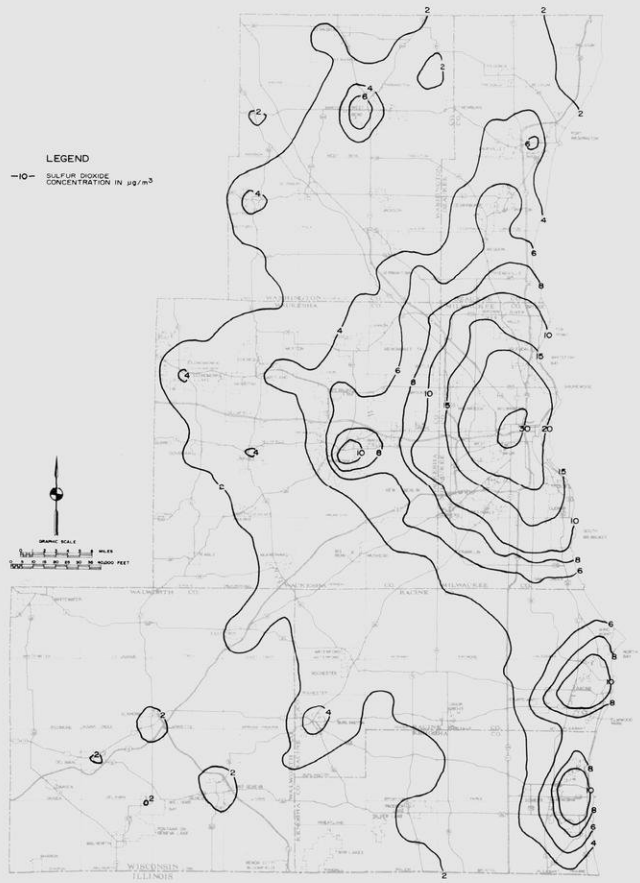


This map illustrates the impact of sulfur dioxide emissions from area sources on ambient air quality in the Region in 1982. As may be seen by comparing this map with Map 68 in Chapter XI, the impact of area source emissions on sulfur dioxide levels in the Region may be expected to increase between 1976 and 1982. The maximum isopleth value due to area source emissions in 1976 is 20 micrograms per cubic meter ($\mu g/m^3$). The highest isopleth value shown on this map is 30 $\mu g/m^3$, expressed as an annual arithmetic average, and is located over a 0.4-square-mile area in the City of Milwaukee. This increase in sulfur dioxide levels reflects the anticipated increase in fuel combustion over this six-year period.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 133

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE SULFUR DIOXIDE CONCENTRATIONS IN THE REGION FROM FORECAST AREA SOURCE EMISSIONS: 1985



This map illustrates the impact of sulfur dioxide emissions from area sources on ambient air quality in the Region in 1985. The highest isopleth value shown on this map is 30 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average. The continued growth anticipated in fuel combustion-related emission sources of sulfur dioxide is evidenced by the fact that the 30 $\mu g/m^3$ isopleth value encompasses an area of approximately six square miles in 1985, an increase of about 5.5 square miles, or about 1,100 percent, over the area encompassed by the same isopleth value in 1982.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

over a centralized area in the City of Milwaukee. As may be seen by comparing Map 132 with Map 68 in Chapter XI, which indicates a maximum isopleth value of 20 $\mu g/m^3$, ambient sulfur dioxide levels are forecast to increase as a result of area source emissions over this six-year period, reflecting the anticipated increase in fuel combustion. Continued growth in fuel combustion-related sources of sulfur dioxide emissions is evident on Map 133, which indicates that a six-square-mile area is encompassed by the 30 $\mu g/m^3$ isopleth, a significant increase over the less than one-square-mile area encompassed by the 30 $\mu g/m^3$ isopleth in 1982. As may be seen on Map 134, the 30 $\mu g/m^3$ isopleth in the year 2000 is expected to encompass approximately 37 square miles in Milwaukee County, an increase of about 31 square miles over the area expected to be encompassed by the same isopleth in 1985. It may be concluded, therefore, that the anticipated increase in fuel consumption by area sources will serve to increase the impact of area source sulfur dioxide emissions on annual arithmetic average ambient air sulfur dioxide levels in the Region over the planning period.

Composite Forecast of Sulfur Dioxide Levels

Annual Concentrations: The calibration equation, developed from the base year, 1976, linear regression analysis of the computer-simulated sulfur dioxide concentrations and the available monitoring data (see Chapter XI), was used to prepare composite forecasts of annual arithmetic average sulfur dioxide concentrations resulting from total point, line, and area sources of emissions in the Region in the years 1982, 1985, and 2000. These composite sulfur dioxide forecasts are presented on Map 135 for the year 1982 under the coal-intensive energy scenario, and on Map 136 for the year 1985 and Map 137 for the year 2000, both under the coal-intensive energy scenario and the adopted transportation plan.

As may be seen on Map 135, the maximum isopleth value indicated for the year 1982 is 60 $\mu g/m^3$ and encompasses an area of approximately 13 square miles in central Milwaukee County. Although this isopleth is equivalent to only 75 percent of the primary and secondary annual average sulfur dioxide air quality standard of 80 $\mu g/m^3$, it represents a significant deterioration from the maximum value of 50 $\mu g/m^3$ indicated through simulation modeling for the year 1976, as shown on Map 69 in Chapter XI. Further deterioration of the ambient air sulfur dioxide levels by the year 1985 is evidenced on Map 136. The maximum isopleth value shown for 1985 is 70 $\mu g/m^3$, or nearly 88 percent of the annual air quality standard, and encompasses an area of about two square miles in Milwaukee County.

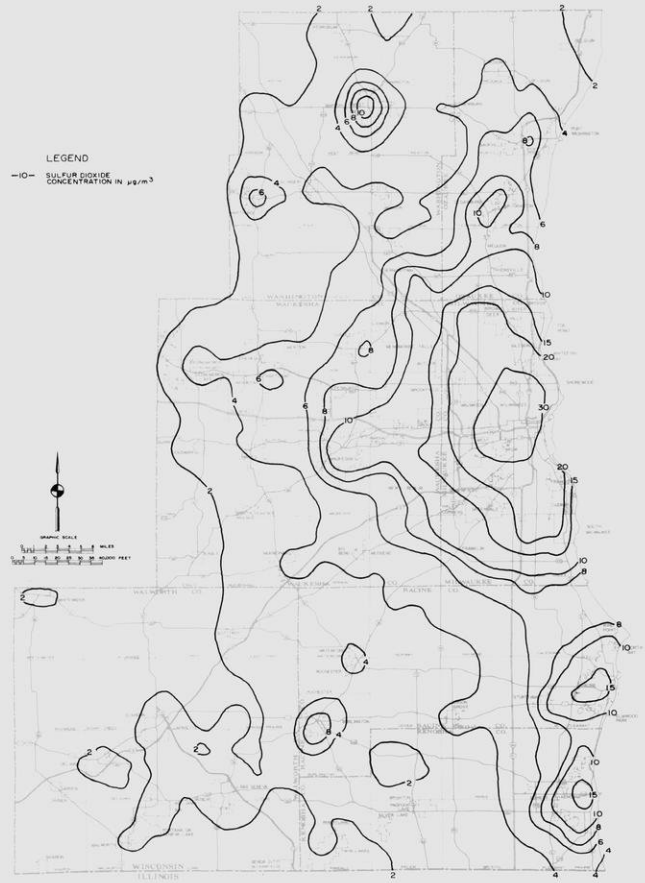
With the anticipated growth in industrial activity, and thus fuel consumption, by selected area sources and in vehicle miles of travel in the Region, the primary and secondary annual sulfur dioxide air quality standard may be expected to be exceeded over a 10-square-mile area in Milwaukee County by the year 2000, as shown on Map 137. It may be concluded, therefore, that a long-term maintenance plan will be required to reduce the sulfur dioxide concentrations anticipated in the Region by the year 2000 to levels which are not deleterious to the health and welfare of the future resident population of the Region.

24-Hour Concentrations: The Wisconsin Atmospheric Diffusion Model was used to evaluate the effect of forecast sulfur dioxide emissions in the years 1982, 1985, and 2000 on the attainment of the short-term, 24-hour, primary and secondary ambient air quality standard of 365 $\mu g/m^3$. Like the evaluation of short-term particulate matter forecasts, this evaluation was conducted under the "worst case" meteorological conditions as defined for the base year, 1976, simulation modeling effort. It should again be noted that the short-term modeling results represent the uncalibrated sulfur dioxide concentrations in the Region in the forecast years without consideration of the background levels of this pollutant species. Accordingly, the short-term simulation modeling results indicate the sulfur dioxide concentrations anticipated in the Region from identified local sources of emissions. The results of this modeling effort thus defined are presented on Map 138 for the year 1982 under the coal-intensive energy scenario, on Map 139 for the year 1985 under the coal-intensive energy scenario and the 1985 stage of the adopted transportation plan, and on Map 140 for the year 2000 under the coal-intensive energy scenario and the adopted transportation plan.

As may be seen on Map 138, the maximum isopleth value indicated for the year 1982 is 300 $\mu g/m^3$, or over 82 percent of the 365 $\mu g/m^3$ standard, and encompasses an area of less than one square mile in Milwaukee County. In comparing the 24-hour average sulfur dioxide concentrations anticipated in 1982 with the simulated concen-

Map 134

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE SULFUR DIOXIDE CONCENTRATIONS IN THE REGION FROM FORECAST AREA SOURCE EMISSIONS: 2000

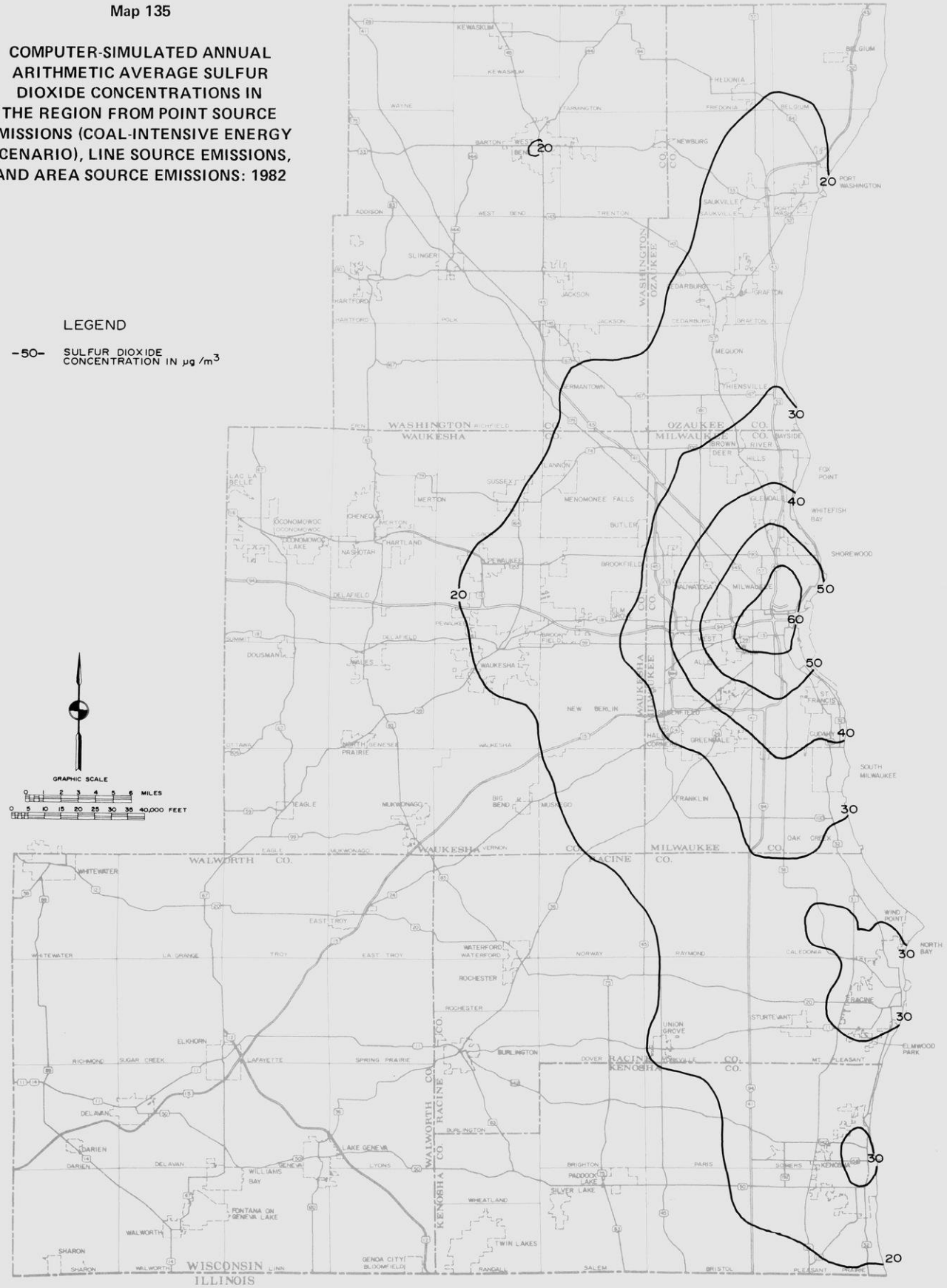


This map illustrates the impact of sulfur dioxide emissions from area sources on ambient air quality in the Region in the year 2000. The highest isopleth value indicated on this map is 30 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average. The effects of anticipated growth in fuel combustion and related sulfur dioxide emissions is evidenced by the fact that the 30 $\mu g/m^3$ isopleth value encompasses an area of approximately 36.5 square miles in Milwaukee County in the year 2000, an increase of about 30.5 square miles, or about 508 percent, over the area expected to be encompassed by the same isopleth value in 1985.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 135

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE SULFUR DIOXIDE CONCENTRATIONS IN THE REGION FROM POINT SOURCE EMISSIONS (COAL-INTENSIVE ENERGY SCENARIO), LINE SOURCE EMISSIONS, AND AREA SOURCE EMISSIONS: 1982

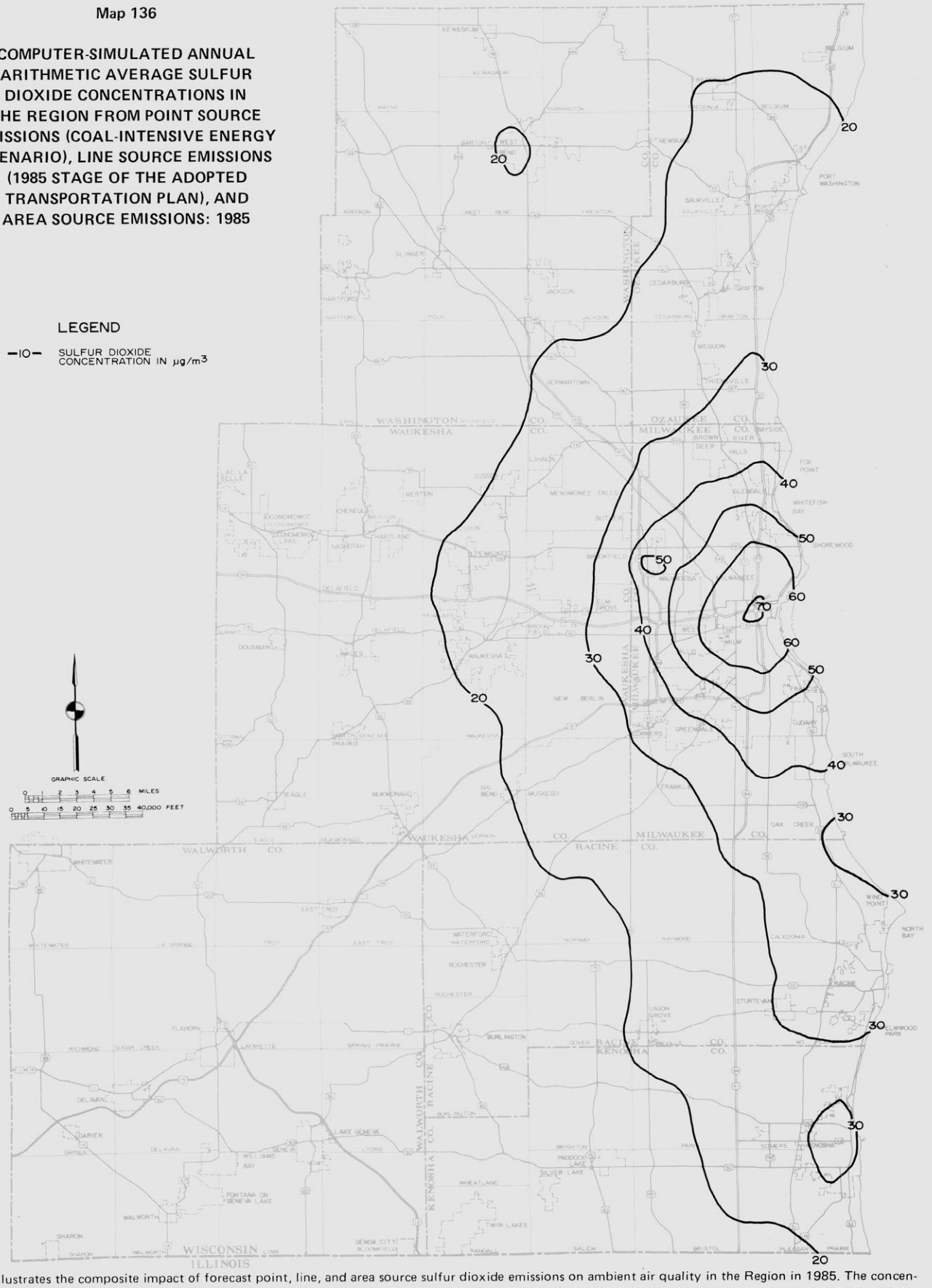


This map illustrates the composite impact of forecast point, line, and area source sulfur dioxide emissions on ambient air quality in the Region in 1982. The concentrations shown on this map are derived from emissions data as anticipated under the coal-intensive energy scenario, which assumes that natural gas supplies will not be available to meet total industrial energy demand. The highest isopleth value indicated on this map is 60 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and encompasses an area of approximately 13 square miles in central Milwaukee County. Although this isopleth is equivalent to only 75 percent of the primary and secondary annual sulfur dioxide air quality standard of 80 $\mu g/m^3$, it represents a significant deterioration from the ambient air concentration levels for 1976 as shown on Map 69 in Chapter XI, which indicated a maximum isopleth value of 50 $\mu g/m^3$. This increase is attributable to forecast increases in sulfur dioxide emissions from both line and area sources between 1976 and 1982.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 136

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE SULFUR DIOXIDE CONCENTRATIONS IN THE REGION FROM POINT SOURCE EMISSIONS (COAL-INTENSIVE ENERGY SCENARIO), LINE SOURCE EMISSIONS (1985 STAGE OF THE ADOPTED TRANSPORTATION PLAN), AND AREA SOURCE EMISSIONS: 1985

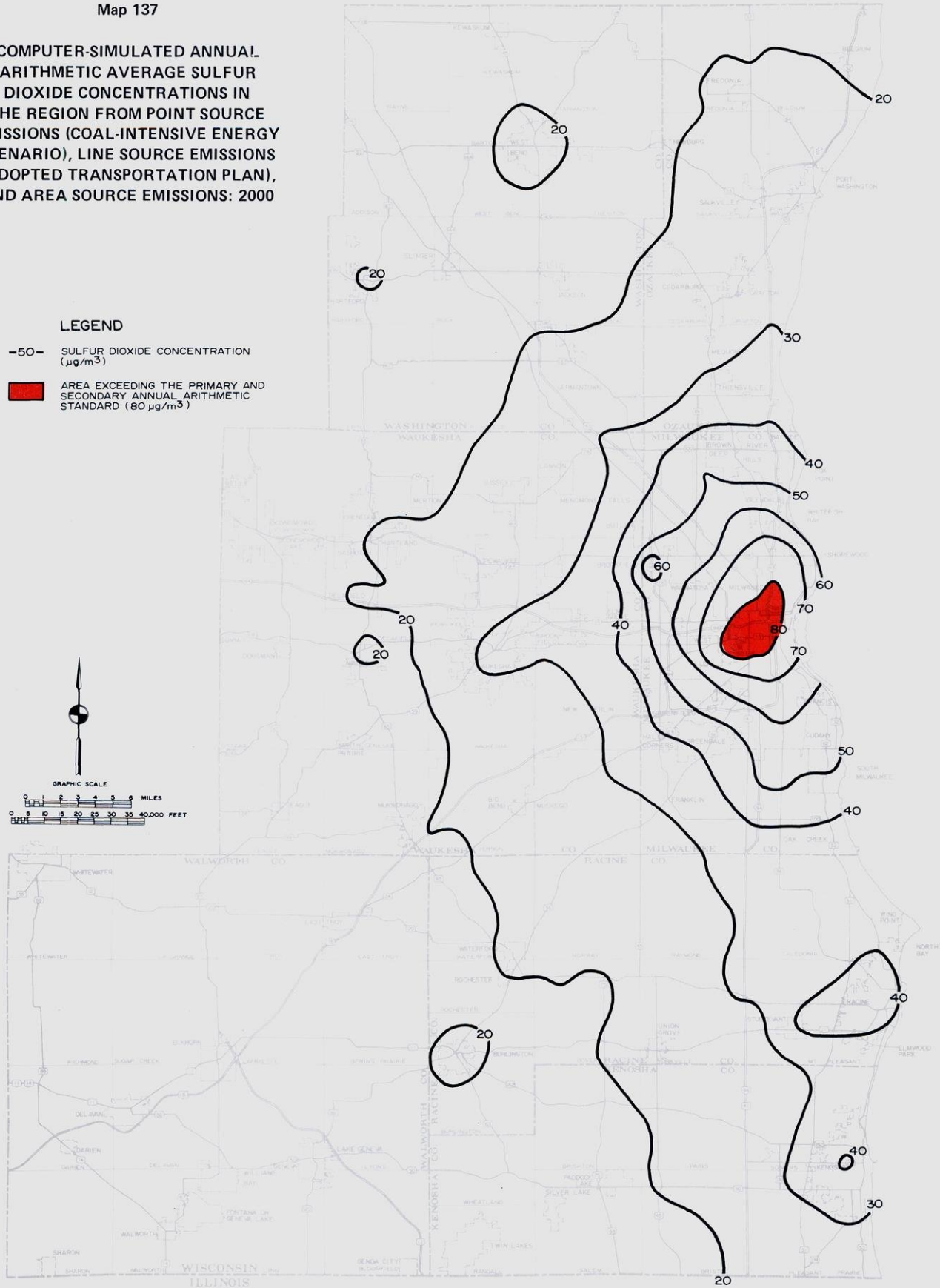


This map illustrates the composite impact of forecast point, line, and area source sulfur dioxide emissions on ambient air quality in the Region in 1985. The concentrations shown on this map are derived from emissions data as anticipated under the coal-intensive energy scenario, which assumes that natural gas supplies will not be available to meet total industrial energy demand, and the 1985 stage of the adopted transportation plan. The highest isopleth value indicated on this map is 70 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, or nearly 88 percent of the annual air quality standard. This value encompasses an area of about 1.4 square miles in Milwaukee County. By comparing Map 135 with this map, it may be seen that this concentration level represents a significant deterioration in sulfur dioxide levels between 1982 and 1985. This finding is consistent with the results of the sulfur dioxide emissions forecast for 1985, which indicate that point, line, and area sources together will emit about 239,900 tons of sulfur dioxide in the Region, an increase of about 7,100 tons, or 3 percent, over the 1982 emission level of 232,800 tons.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 137

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE SULFUR DIOXIDE CONCENTRATIONS IN THE REGION FROM POINT SOURCE EMISSIONS (COAL-INTENSIVE ENERGY SCENARIO), LINE SOURCE EMISSIONS (ADOPTED TRANSPORTATION PLAN), AND AREA SOURCE EMISSIONS: 2000

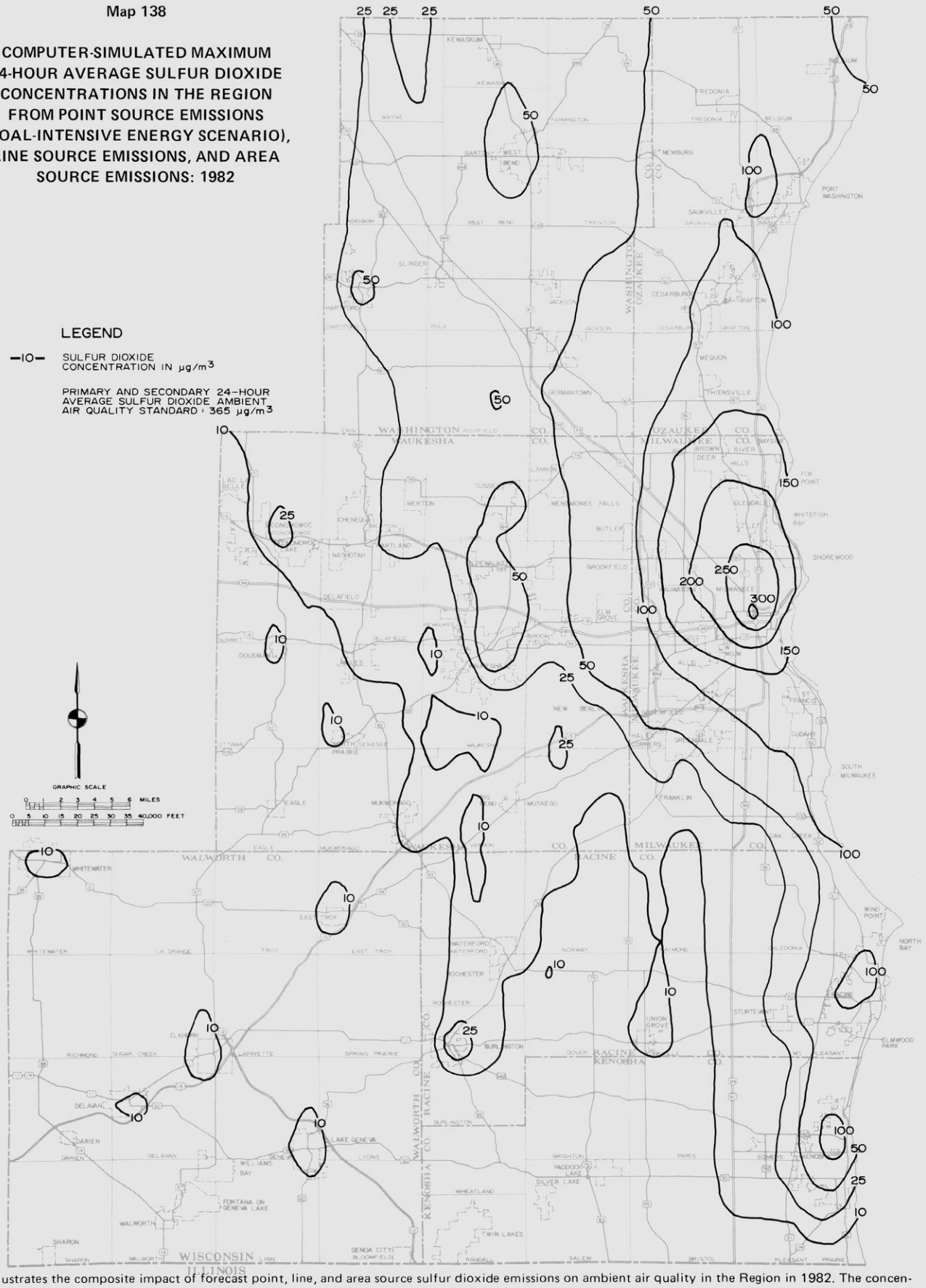


This map illustrates the composite impact of forecast point, line, and area source sulfur dioxide emissions on ambient air quality in the Region in the year 2000. The concentrations shown on this map are derived from emissions data as anticipated under the coal-intensive energy scenario, which assumes that natural gas supplies will not be available to meet total industrial energy demand, and the adopted transportation plan. This map indicates that the primary and secondary annual air quality standard of 80 micrograms per cubic meter (µg/m3) will be exceeded over a 10-square-mile area in Milwaukee County in the year 2000. This finding may be attributed to the anticipated growth in industrial activity, an anticipated conversion of industrial sources from natural gas to coal use, and an increase in vehicle miles of travel in the Region.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 138

COMPUTER-SIMULATED MAXIMUM 24-HOUR AVERAGE SULFUR DIOXIDE CONCENTRATIONS IN THE REGION FROM POINT SOURCE EMISSIONS (COAL-INTENSIVE ENERGY SCENARIO), LINE SOURCE EMISSIONS, AND AREA SOURCE EMISSIONS: 1982

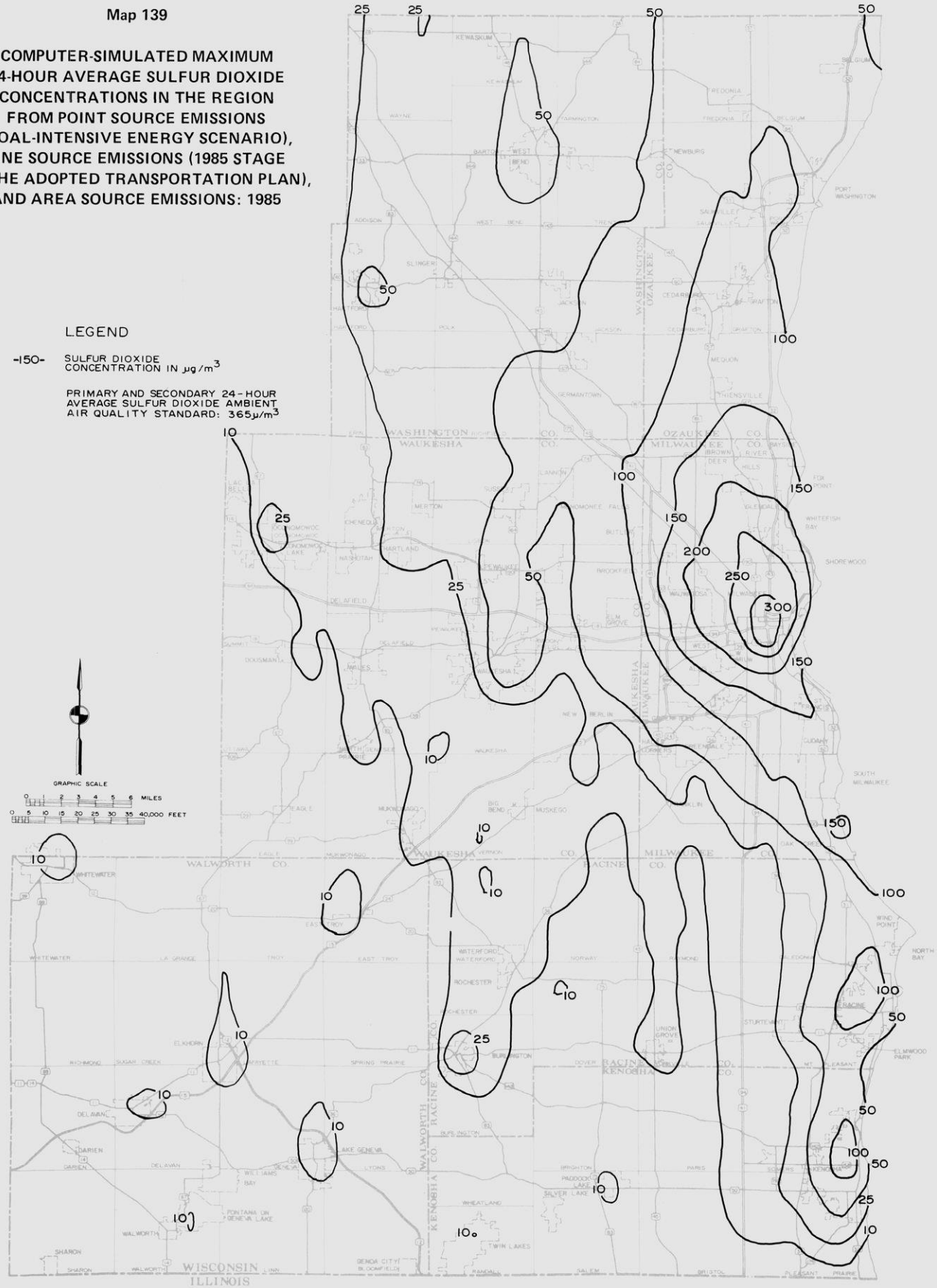


This map illustrates the composite impact of forecast point, line, and area source sulfur dioxide emissions on ambient air quality in the Region in 1982. The concentrations shown on this map are derived from emissions data as anticipated under the coal-intensive energy scenario, which assumes that natural gas supplies will not be available to meet total industrial energy demand. The highest isopleth value indicated on this map is 300 micrograms per cubic meter ($\mu g/m^3$), expressed as a 24-hour arithmetic average, representing over 82 percent of the 24-hour air quality standard. This value encompasses an area of about 0.3 square mile in Milwaukee County. In comparing the anticipated sulfur dioxide concentrations in 1982 with the simulated concentrations for the year 1976, as shown on Map 70 in Chapter XI, it is evident that the regional levels of this pollutant species may be expected to increase over this six-year planning period. The maximum isopleth value in 1982 is 200 percent higher than the maximum isopleth value of 100 $\mu g/m^3$ indicated for 1976.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 139

COMPUTER-SIMULATED MAXIMUM 24-HOUR AVERAGE SULFUR DIOXIDE CONCENTRATIONS IN THE REGION FROM POINT SOURCE EMISSIONS (COAL-INTENSIVE ENERGY SCENARIO), LINE SOURCE EMISSIONS (1985 STAGE OF THE ADOPTED TRANSPORTATION PLAN), AND AREA SOURCE EMISSIONS: 1985

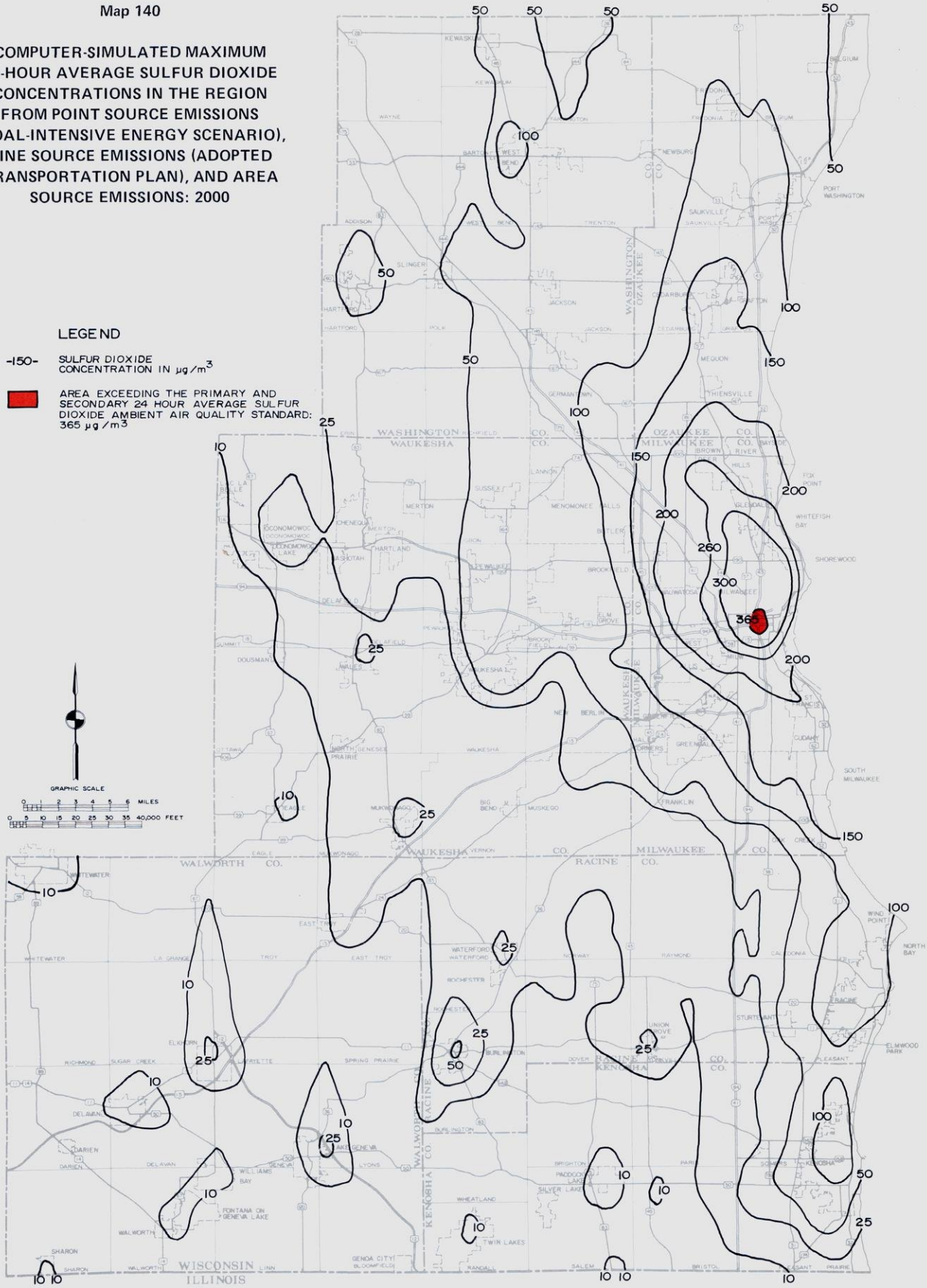


This map illustrates the composite impact of forecast point, line, and area source sulfur dioxide emissions on ambient air quality in the Region in 1985. The concentrations shown on this map are derived from emissions data as anticipated under the coal-intensive energy scenario, which assumes that natural gas supplies will not be available to meet total industrial energy demand, and the 1985 stage of the adopted transportation plan. The highest isopleth value indicated on this map is 300 micrograms per cubic meter ($\mu g/m^3$), expressed as a 24-hour arithmetic average, and may be expected to encompass a land area of about 4.3 square miles in Milwaukee County, which represents an increase of four square miles over the area encompassed by this isopleth in 1982. This increase may be attributed to the continued conversion by industrial sources from natural gas to coal use and to the increased vehicle miles of travel anticipated under the adopted transportation plan.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 140

COMPUTER-SIMULATED MAXIMUM 24-HOUR AVERAGE SULFUR DIOXIDE CONCENTRATIONS IN THE REGION FROM POINT SOURCE EMISSIONS (COAL-INTENSIVE ENERGY SCENARIO), LINE SOURCE EMISSIONS (ADOPTED TRANSPORTATION PLAN), AND AREA SOURCE EMISSIONS: 2000



This map illustrates the composite impact of forecast point, line, and area source sulfur dioxide emissions on ambient air quality in the Region in the year 2000. The concentrations shown on this map are derived from emissions data as anticipated under the coal-intensive energy scenario, which assumes that natural gas supplies will not be available to meet total industrial energy demand, and the adopted transportation plan. As may be seen on this map, the primary air quality standard of 365 micrograms per cubic meter ($\mu g/m^3$), expressed as a 24-hour arithmetic average, is estimated to be exceeded over a one-square-mile area in Milwaukee County in the year 2000.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

trations for the year 1976, as shown on Map 70 in Chapter XI, it is evident that the regional levels of this pollutant species may be expected to increase significantly over this six-year period—the maximum isopleth value in 1982 is 50 percent higher than the maximum isopleth value of 200 $\mu g/m^3$ indicated for 1976. Moreover, considering that the 24-hour air quality standard for sulfur dioxides was exceeded once during 1976 and was violated during 1977 and 1978, more severe and more frequent violations of these standards may be expected to occur by the year 1982 as the level of sulfur dioxide concentrations increases in general throughout the Region.

The area encompassed by the 300 $\mu g/m^3$ isopleth in the year 1985, as shown on Map 139, is expected to approximate four square miles. Moreover, significant increases in the areal extent of all isopleth values are indicated for 1985. Again, the severity and frequency of violations of the 24-hour sulfur dioxide air quality standards may be expected to increase by 1985.

The simulation modeling results indicate that the 24-hour sulfur dioxide air quality standards will be exceeded over an area of slightly more than one square mile in Milwaukee County in the year 2000, as shown on Map 140. As in 1982 and 1985, however, this standard may be expected to be exceeded over a far greater area of the Region if the background concentration of sulfur dioxide is not reduced from its present level. The background level of sulfur dioxide in the Region is estimated to be about 10 $\mu g/m^3$ on an annual average as determined through air quality simulation modeling. For shorter averaging periods, this background level may be much higher than the annual average. Because the one violation of the 24-hour sulfur dioxide standard was monitored in the Region during 1976, when the maximum simulated concentration was indicated to be 200 $\mu g/m^3$, there is a potential for this standard to be exceeded in parts of every county in the Region, with the exception of Walworth County, by the year 2000. Based on this premise, any area encompassed by an isopleth value of 200 $\mu g/m^3$ or greater in the design or intermediate years has the potential to experience excessive 24-hour average sulfur dioxide concentrations.

Three-Hour Concentrations: It was noted in Chapter XI that the violations of the three-hour sulfur dioxide secondary air quality standard of 1,300 $\mu g/m^3$ monitored during 1975 and 1977 were attributable principally to the impaction of a single point source on a sampling station, and that such sustained impaction was associated with certain meteorological conditions which have a relatively low frequency of occurrence. Such adverse meteorological conditions were said to include an extremely unstable atmosphere which quickly forces a stack plume to the ground, moderate wind speeds—on the order of 10 to 12 miles per hour—and a high degree of wind persistence which acts to prevent the plume impaction point from drifting at ground level. Since the emissions data base developed under the regional air quality attainment and maintenance planning program could not address the operating characteristics of all major point sources of sulfur dioxide emissions in order to determine the temporal distribution of such emissions with any specificity, the air quality simulation modeling effort could not reliably evaluate the three-hour standard. It was concluded, however, that given the probability of joint occurrence of the required meteorological conditions necessary for sustained plume impaction on a monitoring site—less than 1 percent of the time on an annual basis—it was unlikely that more than one violation of the three-hour standard would occur at the level of sulfur dioxide emissions experienced in 1976.

Although adverse meteorological conditions are not expected to occur more frequently in future years, the forecast increase in sulfur dioxide emissions, and the progressively deteriorating ambient air sulfur dioxide concentrations attendant to such emission increases, is expected to provide more opportunity for violations of the three-hour standard over the planning period. With higher sulfur dioxide levels persisting in the ambient air in future years, the three-hour standard may be expected to be exceeded with increasing frequency.

FORECAST CARBON MONOXIDE CONCENTRATIONS: 1982, 1985, AND 2000

As was noted in Chapter XI, the base year air quality simulation modeling effort for carbon monoxide was directed toward the determination of the maximum concentrations of this pollutant species on a regional basis under "worst case" meteorological conditions. This approach was preferred over attempting to calibrate the simulation model separately for each monitoring site, an approach which would have otherwise been required because the emission sources in the immediate vicinity of the sampling site have a predominant influence on the monitored carbon monoxide levels. The results of the simulation modeling for the forecast carbon monoxide levels in the Region in the years 1982, 1985, and 2000, therefore, are based on this same "worst case" approach, which is defined by the meteorological conditions summarized in Table 256 in Chapter XI.

As was also noted in Chapter XI, carbon monoxide emissions from point sources were found to have a negligible effect on ambient air quality at ground level. Since it was determined that carbon monoxide emissions from point sources would continue to constitute only a minor portion of the total regional emissions through the planning period—constituting at the most about 5 percent of the regional emissions—the impact of point source emissions on carbon monoxide concentrations in southeastern Wisconsin may be expected to be negligible through the year 2000. Only carbon monoxide emissions from forecast line and area source emissions, therefore, are considered in the simulation modeling results presented herein.

Line Sources

One-Hour Concentrations: The maximum one-hour average carbon monoxide concentrations in the Region resulting from forecast line source emissions in the year 1982

are presented on Map 141. The highest isopleth value indicated on Map 141 is 25 milligrams per cubic meter (mg/m^3) and is centered over the Marquette Interchange in Milwaukee County. This 25 mg/m^3 isopleth is approximately 63 percent of the primary and secondary one-hour average carbon monoxide air quality standard of 40 mg/m^3.

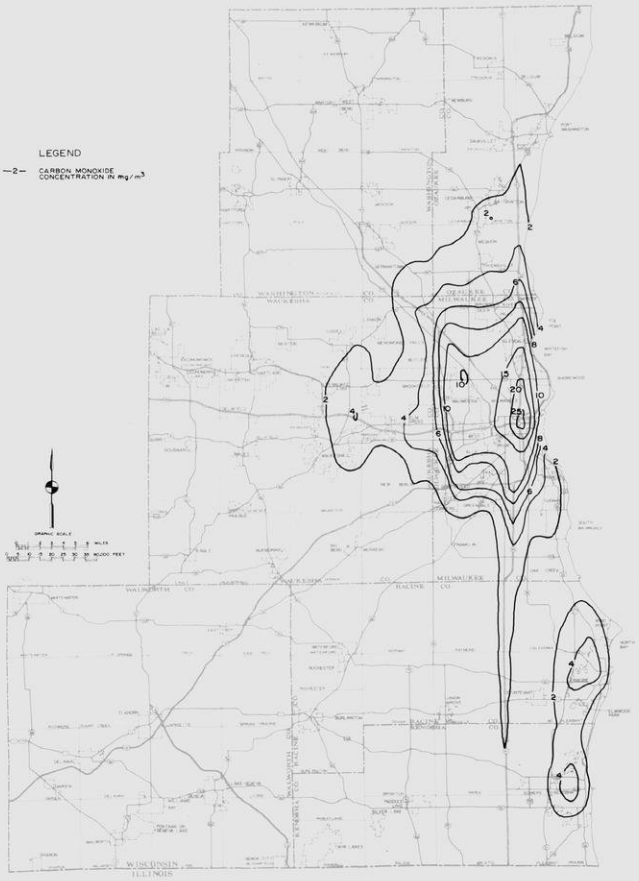
The maximum one-hour average carbon monoxide concentrations in the Region due to forecast line source emissions in the year 1985 are presented on Map 142 for the 1985 stage of the "no build" alternative transportation plan and on Map 143 for the 1985 stage of the adopted transportation plan. Comparison of Map 142 with Map 143 indicates that the "no build" plan has a slightly greater impact on ambient air carbon monoxide levels in 1985, as indicated by the fact that the maximum isopleth value under both plans—15 mg/m^3—encompasses an area of approximately four square miles in Milwaukee County under the "no build" plan and of only about two square miles under the adopted transportation plan. The maximum isopleth value of 15 mg/m^3 is only about 38 percent of the 40 mg/m^3 standard, and indicates a significant reduction from the maximum value of 25 mg/m^3 expected in the year 1982.

A continued reduction in the one-hour average carbon monoxide concentrations due to forecast line source emissions is expected through the year 2000 under both the "no build" alternative transportation plan and the adopted transportation plan, as shown on Maps 144 and 145, respectively. Although both cases yield average one-hour carbon monoxide concentrations well below the 40 mg/m^3 standard, the "no build" case indicates a maximum isopleth value of 10 mg/m^3 over the Marquette Interchange in the year 2000, as compared with a maximum isopleth value of 8 mg/m^3 under the adopted transportation plan. It may be concluded, therefore, that the "no build" alternative represents the potentially "worst case" condition for one-hour average carbon monoxide concentrations for air quality attainment and maintenance planning purposes.

Eight-Hour Concentrations: The maximum eight-hour average carbon monoxide concentrations in the Region resulting from forecast line source emissions in the year 1982 are presented on Map 146. Map 146 indicates that an area of approximately two square miles in Milwaukee County will exceed the eight-hour average carbon monoxide standard of 10 mg/m^3 in 1982 due solely to line source emissions. By 1985, however, the forecast reduction in line source emissions is expected to yield maximum ambient air carbon monoxide concentrations on the order of 60 percent of the eight-hour average standard. As may be seen on Maps 147 and 148, the maximum isopleth value indicated under the 1985 stage of both the "no build" alternative transportation plan and the adopted transportation plan is 6 mg/m^3. Under the 1985 stage of the "no build" alternative, however, the area encompassed by the 6 mg/m^3 isopleth comprises approximately five square miles, as compared with three square miles under the 1985 stage of the adopted transportation plan.

Map 141

COMPUTER-SIMULATED MAXIMUM ONE-HOUR AVERAGE CARBON MONOXIDE CONCENTRATIONS IN THE REGION FROM FORECAST LINE SOURCE EMISSIONS: 1982



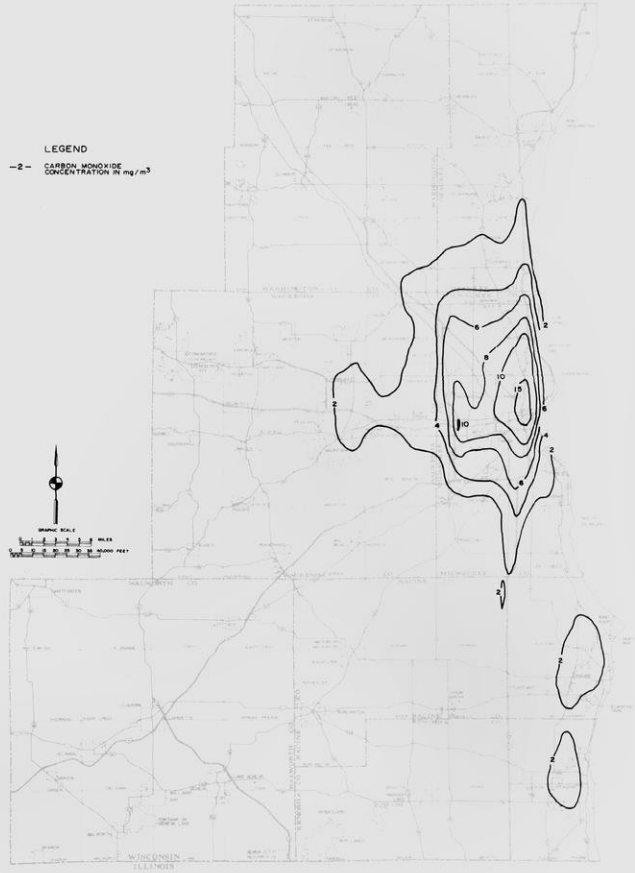
This map illustrates the impact of carbon monoxide emissions from line sources on one-hour average carbon monoxide concentrations in the Region in 1982. The concentrations shown on this map are representative of emission conditions during the peak morning travel hour, 7:00 a.m. to 8:00 a.m., and of meteorological conditions least favorable to pollutant dispersion. Under these "worst case" conditions, the maximum carbon monoxide concentration isopleth has a value of 25 milligrams per cubic meter (mg/m^3), expressed as a one-hour arithmetic average, and is located in the area of the Marquette Interchange. Thus, the one-hour average carbon monoxide air quality standard of 40 mg/m^3 is not expected to be exceeded in the Region in 1982.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

A continued reduction in the eight-hour average carbon monoxide concentrations due to forecast line source emissions is expected through the year 2000 under both the "no build" alternative and the adopted transportation plan, as shown on Maps 149 and Map 150, respectively. The maximum isopleth value indicated under the "no build" alternative is 4 mg/m^3, or 40 percent of the 10 mg/m^3 standard, and encompasses an area of about two square miles in Milwaukee County. Under the adopted transportation plan, the maximum isopleth value

Map 142

COMPUTER-SIMULATED MAXIMUM ONE-HOUR AVERAGE CARBON MONOXIDE CONCENTRATIONS IN THE REGION FROM FORECAST LINE SOURCE EMISSIONS: 1985 STAGE OF THE "NO BUILD" TRANSPORTATION PLAN

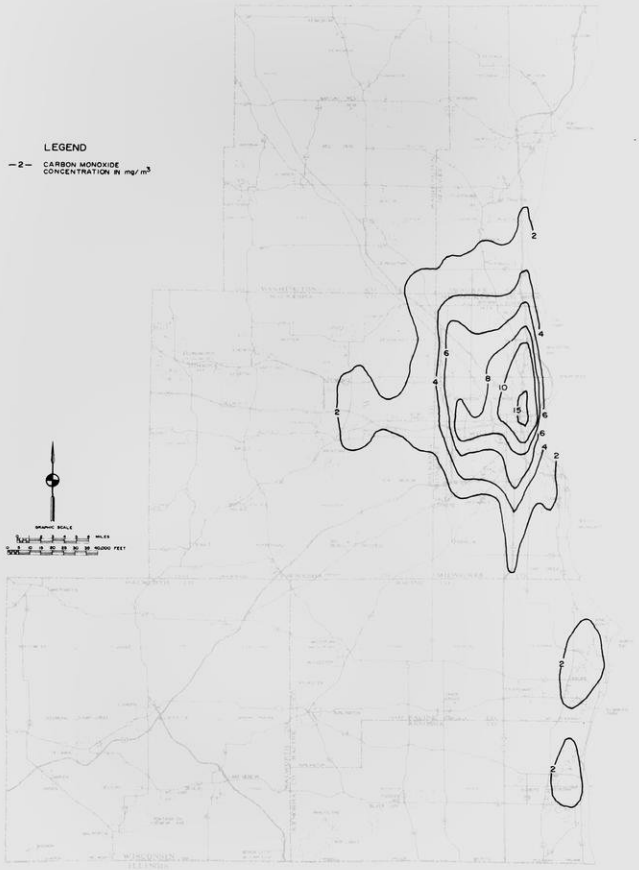


This map illustrates the impact of carbon monoxide emissions from line sources on one-hour average carbon monoxide concentrations in the Region under the 1985 stage of the "no build" alternative transportation plan. The concentrations shown on this map are representative of emission conditions during the peak morning travel hour, 7:00 a.m. to 8:00 a.m., and of meteorological conditions least favorable to pollutant dispersion. Under these "worst case" conditions, the maximum carbon monoxide concentration isopleth has a value of 15 milligrams per cubic meter (mg/m^3), expressed as a one-hour arithmetic average, and is centered over the area of the Marquette Interchange. A comparison of regional carbon monoxide concentrations in 1982 and 1985, as shown on Map 141 and this map, indicates that concentrations due to line source emissions are expected to decrease. This finding is consistent with the results of the carbon monoxide emissions forecast for 1985, which indicate that line sources under the "no build" transportation plan will emit about 258,600 tons of carbon monoxide in the Region, a decrease of about 96,400 tons, or 27 percent, from the 1982 line source emission level of 355,000 tons.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 143

COMPUTER-SIMULATED MAXIMUM ONE-HOUR AVERAGE CARBON MONOXIDE CONCENTRATIONS IN THE REGION FROM FORECAST LINE SOURCE EMISSIONS: 1985 STAGE OF THE ADOPTED TRANSPORTATION PLAN

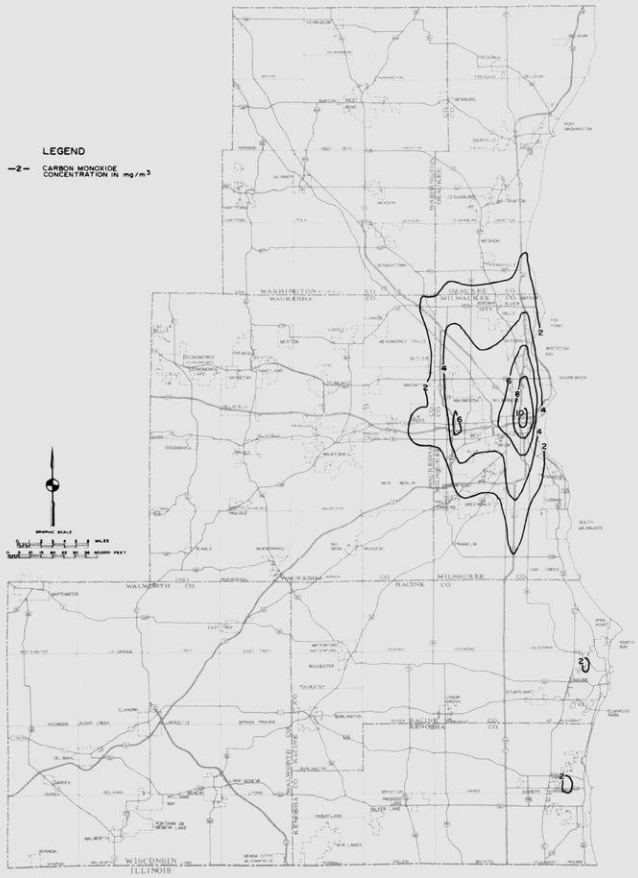


This map illustrates the impact of carbon monoxide emissions from line sources on one-hour average carbon monoxide concentrations in the Region in the year 1985 under the adopted transportation plan. The concentrations shown on this map are representative of emission conditions during the peak morning travel hour, 7:00 a.m. to 8:00 a.m., and of meteorological conditions least favorable to pollutant dispersion. Under these "worst case" conditions, the maximum carbon monoxide concentration isopleth has a value of 15 milligrams per cubic meter (mg/m^3), expressed as a one-hour arithmetic average, and is centered over the area of the Marquette Interchange in Milwaukee County. A comparison of regional carbon monoxide concentrations in 1985 under both transportation plans, as shown on Map 142 and this map, indicates that the "no build" plan has a somewhat greater impact than the adopted plan. The maximum isopleth value—15 mg/m^3 under both plans—encompasses an area of approximately four square miles in Milwaukee County under the "no build" plan and of about two square miles under the adopted transportation plan.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 144

COMPUTER-SIMULATED MAXIMUM ONE-HOUR AVERAGE CARBON MONOXIDE CONCENTRATIONS IN THE REGION FROM FORECAST LINE SOURCE EMISSIONS 2000 "NO BUILD" TRANSPORTATION PLAN

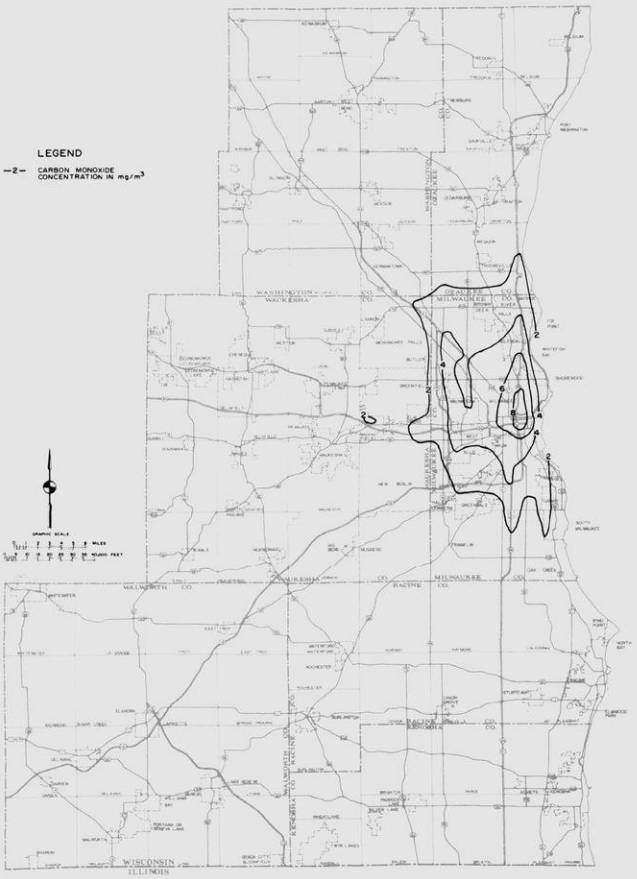


This map illustrates the impact of carbon monoxide emissions from line sources on one-hour average carbon monoxide concentrations in the Region in the year 2000 under the "no build" alternative transportation plan. The concentrations shown on this map are representative of emission conditions during the peak morning travel hour, 7:00 a.m. to 8:00 a.m., and of meteorological conditions least favorable to pollutant dispersion. Under these "worst case" conditions, the maximum carbon monoxide concentration isopleth has a value of 10 milligrams per cubic meter (mg/m^3), expressed as a one-hour arithmetic average, and is located in the area of the Marquette Interchange. As may be seen by comparing concentrations in 1985 and 2000, as shown on Map 142 and this map, continuing reductions in regional carbon monoxide concentrations may be expected. This finding is consistent with the results of the carbon monoxide emissions forecast for the year 2000, which indicate that line sources under the "no build" transportation plan will emit about 174,800 tons of carbon monoxide in the Region, a decrease of about 83,800 tons, or 32 percent, from the 1985 line source emission level of 258,600 tons.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 145

COMPUTER-SIMULATED MAXIMUM ONE-HOUR AVERAGE CARBON MONOXIDE CONCENTRATIONS IN THE REGION FROM FORECAST LINE SOURCE EMISSIONS 2000 ADOPTED TRANSPORTATION PLAN

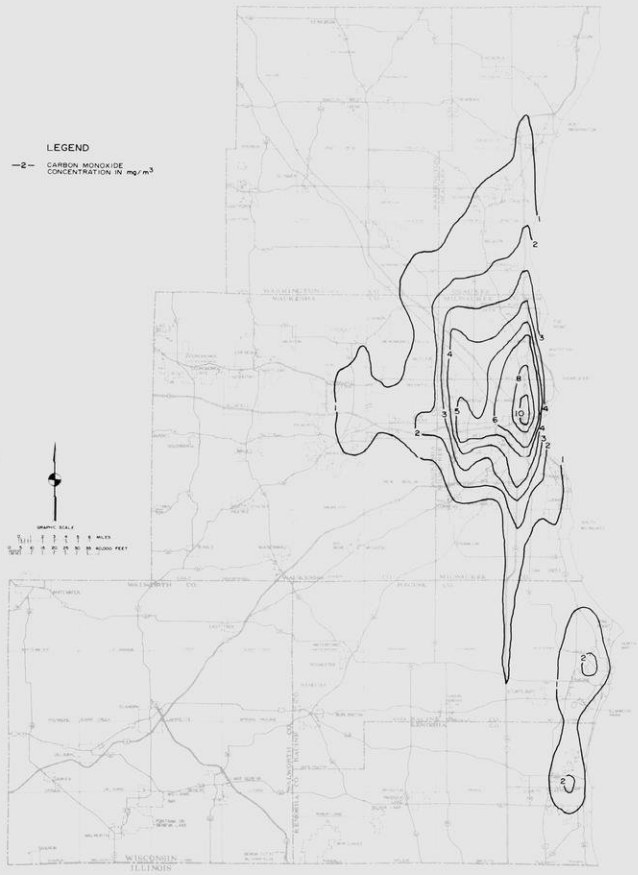


This map illustrates the impact of carbon monoxide emissions from line sources on one-hour average carbon monoxide concentrations in the Region in the year 2000 under the adopted transportation plan. The concentrations shown on this map are representative of emission conditions during the peak morning travel hour, 7:00 a.m. to 8:00 a.m., and of meterological conditions least favorable to pollutant dispersion. Under these "worst case" conditions, the maximum carbon monoxide concentration isopleth has a value of eight milligrams per cubic meter (mg/m^3), expressed as a one-hour arithmetic average, and is located in the area of the Marquette Interchange. As shown on Map 144, the maximum ambient air carbon monoxide concentration due to line sources under the "no build" transportation plan for the year 2000 is expected to be 10 mg/m^3. This finding is consistent with the results of the carbon monoxide emissions forecast for the year 2000, which indicate that line sources under the "no build" transportation plan will emit about 174,800 tons of carbon monoxide, an increase of about 600 tons, or 0.3 percent, over the emission level of 174,200 tons anticipated under the adopted transportation plan.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 146

COMPUTER-SIMULATED MAXIMUM EIGHT-HOUR AVERAGE CARBON MONOXIDE CONCENTRATIONS IN THE REGION FROM FORECAST LINE SOURCE EMISSIONS: 1982

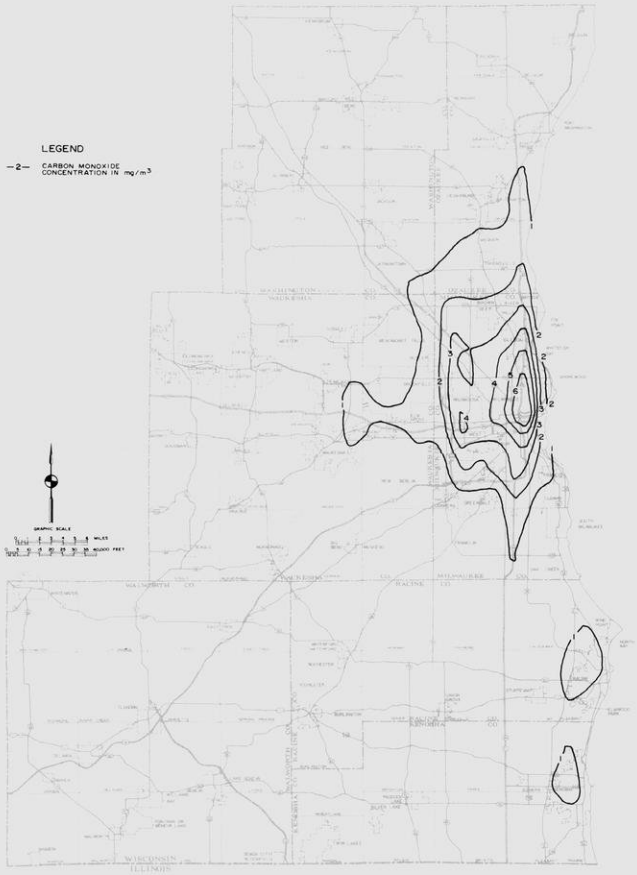


This map illustrates the impact of carbon monoxide emissions from line sources on maximum eight-hour average carbon monoxide concentrations in the Region in 1982. The highest isopleth value shown on this map is 10 milligrams per cubic meter (mg/m^3), expressed as an eight-hour arithmetic average, and encompasses an area of approximately two square miles in Milwaukee County which may be expected to exceed the eight-hour average carbon monoxide standard of 10 milligrams per cubic meter (mg/m^3).

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 147

COMPUTER-SIMULATED MAXIMUM EIGHT-HOUR AVERAGE CARBON MONOXIDE CONCENTRATIONS IN THE REGION FROM LINE SOURCE EMISSIONS: 1985 STAGE OF THE "NO BUILD" TRANSPORTATION PLAN



This map illustrates the impact of carbon monoxide emissions from line sources on maximum eight-hour average carbon monoxide concentrations in the Region in 1985 under the "no build" alternative transportation plan. The highest isopleth value shown on this map is six milligrams per cubic meter (mg/m^3), expressed as an eight-hour arithmetic average, and is located over the Marquette Interchange. The remaining portions of Milwaukee County and the Region have an ambient air carbon monoxide concentration of five mg/m^3 or less. The results of the carbon monoxide emissions forecast for 1985 indicate that line sources will emit about 258,600 tons of carbon monoxide in the Region under the "no build" alternative transportation plan, a decrease of about 96,400 tons, or 27.1 percent, from the 1982 line source emission level of about 355,000 tons. This decrease can be attributed to the more stringent motor vehicle emission standards established under the federal motor vehicle emissions control program.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

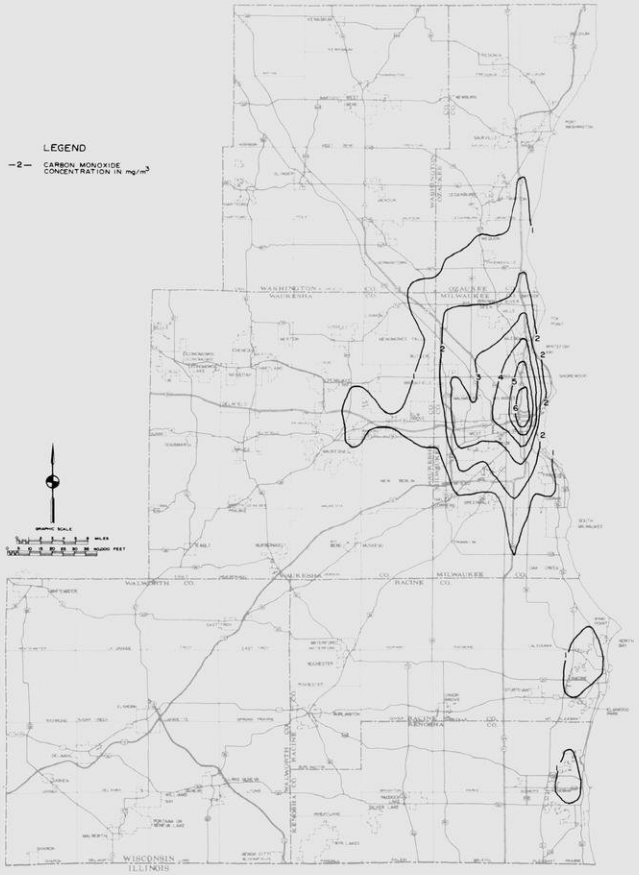
indicated is 3 mg/m^3, or 30 percent of the 10 mg/m^3 standard, and encompasses an area of approximately seven square miles in Milwaukee County. It may be concluded, therefore, that, as with the one-hour average carbon monoxide levels, the "no build" alternative represents the potentially "worst case" condition for eight-hour average carbon monoxide concentrations in the Region over the planning period.

Area Sources

One-Hour Concentrations: As carbon monoxide emissions from line sources decrease over the planning period, the relative contribution of emissions from area sources may be expected to increase. In 1973 area source carbon monoxide emissions accounted for only about 11 percent of the total carbon monoxide emissions inventory. By the year 2000, area source carbon monoxide emissions may

Map 148

COMPUTER-SIMULATED MAXIMUM EIGHT-HOUR AVERAGE CARBON MONOXIDE CONCENTRATIONS IN THE REGION FROM FORECAST LINE SOURCE EMISSIONS: 1985 STAGE OF THE ADOPTED TRANSPORTATION PLAN

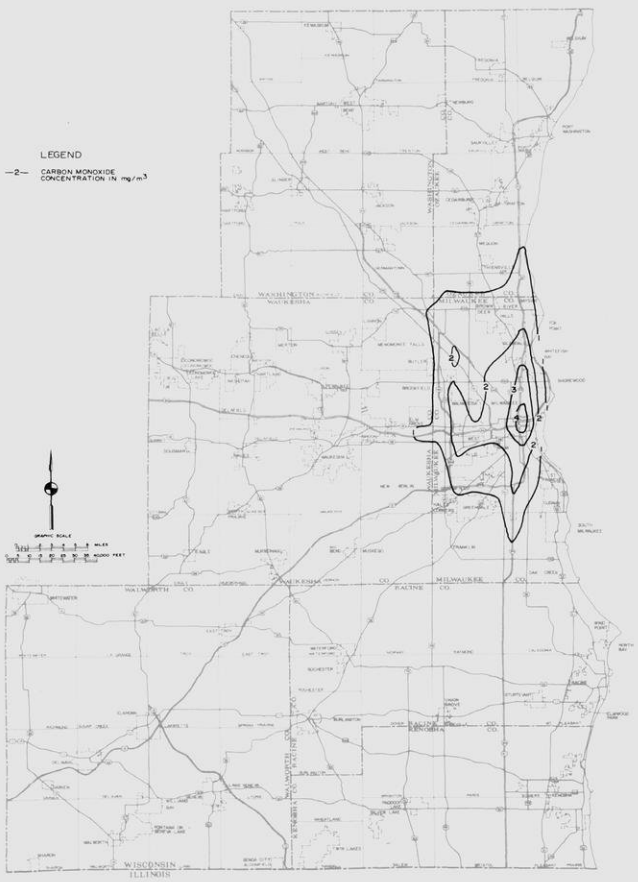


This map illustrates the impact of carbon monoxide emissions from line sources on maximum eight-hour average carbon monoxide concentrations in the Region in 1985 under the adopted transportation plan. The highest isopleth value shown on this map is six milligrams per cubic meter (mg/m^3), expressed as an eight-hour arithmetic average, and is located over the Marquette Interchange. The remaining portions of Milwaukee County and the Region have an ambient air carbon monoxide concentration generally at or below five mg/m^3. The results of the carbon monoxide emissions forecast for 1985 indicate that line sources will emit about 251,600 tons of carbon monoxide in the Region under the adopted transportation plan—about 7,000 tons, or about 2.7 percent, less than emission level of about 258,600 tons under the "no build" alternative transportation plan.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 149

COMPUTER-SIMULATED MAXIMUM EIGHT-HOUR AVERAGE CARBON MONOXIDE CONCENTRATIONS IN THE REGION FROM FORECAST LINE SOURCE EMISSIONS 2000 "NO BUILD" TRANSPORTATION PLAN



This map illustrates the impact of carbon monoxide emissions from line sources on maximum eight-hour average carbon monoxide concentrations in the Region in the year 2000 under the "no build" alternative transportation plan. The highest isopleth value shown on this map is four milligrams per cubic meter (mg/m^3), expressed as an eight-hour arithmetic average, and is located over the Marquette Interchange. The remaining portions of Milwaukee County and the Region have an isopleth value of three mg/m^3 or less. The results of the carbon monoxide emissions forecast for the year 2000 indicate that line sources will emit about 174,800 tons of carbon monoxide in the Region under the "no build" alternative transportation plan, a decrease of about 76,800 tons, or about 30 percent, from the emission level of about 251,600 tons under the 1985 stage of the adopted transportation plan. This reduction in carbon monoxide emissions is attributable to the more stringent motor vehicle exhaust standards of the federal motor vehicle emissions control program.

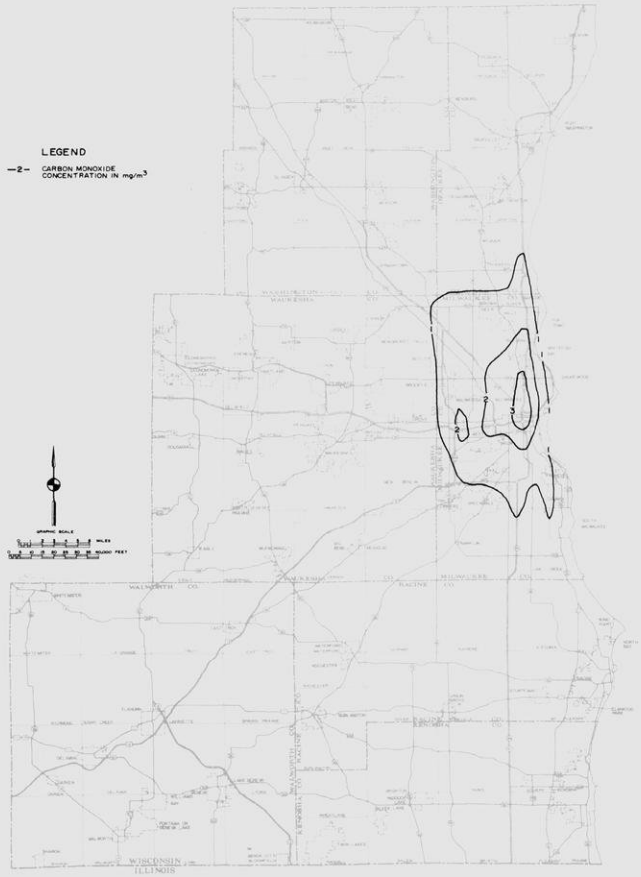
Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

be expected to account for about 31 percent of the total emissions. Area source emissions of carbon monoxide, however, are by definition areally diffuse, and generally would not be expected to significantly impact ambient air quality in the Region. In the case of one carbon monoxide area source category, however, aircraft operations, most of the inventory and forecast emissions emanate from a relatively small, well-defined location—General Mitchell Field in Milwaukee County. The growth in carbon monoxide emissions as a result of the forecast increase in commercial jet-powered aircraft operations at General Mitchell Field may be expected to have a measurable impact on ambient air quality.

The results of the air quality simulation modeling effort for the maximum one-hour average carbon monoxide

Map 150

COMPUTER-SIMULATED MAXIMUM EIGHT-HOUR AVERAGE CARBON MONOXIDE CONCENTRATIONS IN THE REGION FROM FORECAST LINE SOURCE EMISSIONS 2000 ADOPTED TRANSPORTATION PLAN

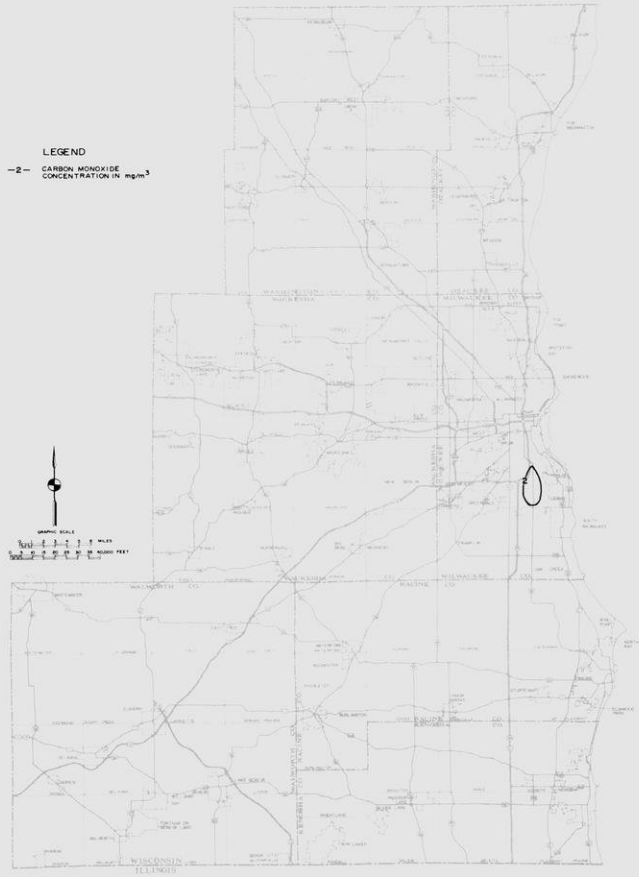


This map illustrates the impact of carbon monoxide emissions from line sources on maximum eight-hour average carbon monoxide concentrations in the Region in the year 2000 under the adopted transportation plan. The highest isopleth value shown on this map is three milligrams per cubic meter (mg/m^3), expressed as an eight-hour arithmetic average, and is located over the Marquette Interchange. The remaining portions of Milwaukee County and the Region have an isopleth value of two mg/m^3 or less. The results of the carbon monoxide emissions forecast for the year 2000 indicate that line sources will emit about 174,200 tons of carbon monoxide in the Region under the adopted transportation plan, about 550 tons, or about 0.3 percent, less than the emission level of about 174,800 tons under the "no build" alternative transportation plan. It may accordingly be concluded that the "no build" alternative represents the potentially "worst case" condition for eight-hour average carbon monoxide concentrations for air quality maintenance planning purposes.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 151

COMPUTER-SIMULATED MAXIMUM ONE-HOUR AVERAGE CARBON MONOXIDE CONCENTRATIONS IN THE REGION FROM FORECAST AREA SOURCE EMISSIONS: 1982



This map illustrates the impact of carbon monoxide emissions from area sources on maximum one-hour average carbon monoxide concentrations in the Region in 1982. The highest isopleth value shown on this map is two milligrams per cubic meter (mg/m^3), expressed as a one-hour arithmetic average, and is centered over General Mitchell Field. This concentration can be primarily attributed to carbon monoxide emissions from commercial jet aircraft operations at General Mitchell Field.

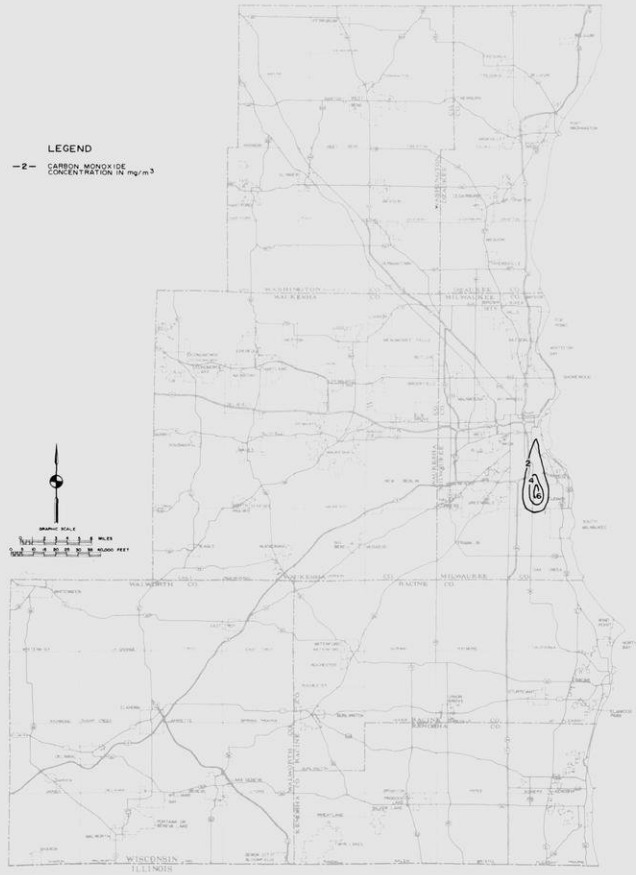
Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

concentrations in the Region due to forecast area source emissions in the year 1982 are presented on Map 151. The only one-hour average carbon monoxide isopleth shown on Map 151 has a value of 2 mg/m^3 and encompasses an area of about four square miles centered over General Mitchell Field. Although not reproduced in this report, the simulation modeling results indicated a nearly identical maximum one-hour average carbon monoxide concentration distribution in the year 1985.

The results of the simulation modeling for the maximum one-hour average carbon monoxide concentrations due to forecast area source emissions in the year 2000 are presented on Map 152. The highest isopleth value indi-

Map 152

COMPUTER-SIMULATED MAXIMUM ONE-HOUR AVERAGE CARBON MONOXIDE CONCENTRATIONS IN THE REGION FROM FORECAST AREA SOURCE EMISSIONS: 2000

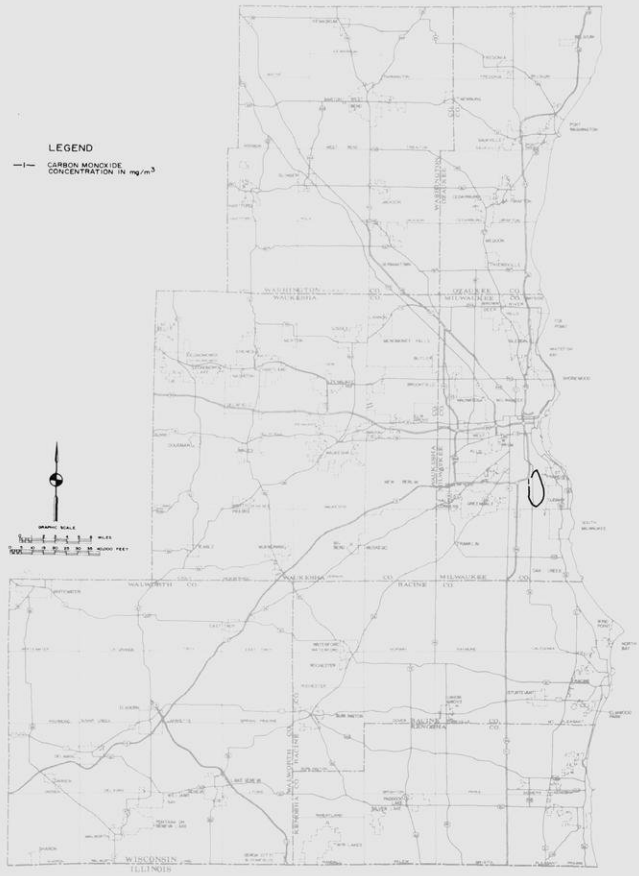


This map illustrates the impact of carbon monoxide emissions from area sources on maximum one-hour average carbon monoxide concentrations in the Region in the year 2000. The highest isopleth value shown on this map is six milligrams per cubic meter (mg/m^3), expressed as a one-hour arithmetic average, and is centered over General Mitchell Field. The forecast increase in carbon monoxide emissions from area sources between 1985 and the year 2000 can be primarily attributed to the continued growth in commercial jet aircraft operations expected at General Mitchell Field.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 153

COMPUTER-SIMULATED MAXIMUM EIGHT-HOUR AVERAGE CARBON MONOXIDE CONCENTRATIONS IN THE REGION FROM FORECAST AREA SOURCE EMISSIONS: 1982



This map illustrates the impact of carbon monoxide emissions from area sources on maximum eight-hour average carbon monoxide concentrations in the Region in 1982. The highest isopleth value shown on this map is one milligram per cubic meter (mg/m^3), expressed as an eight-hour arithmetic average, and is centered over General Mitchell Field. This concentration can be primarily attributed to carbon monoxide emissions from commercial jet aircraft operations at General Mitchell Field.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

cated on Map 152 is 6 mg/m^3, reflecting the increase in commercial jet operations at General Mitchell Field forecast to occur by the year 2000.

Eight-Hour Concentrations: The results of the simulation modeling for the maximum eight-hour average carbon monoxide concentrations in the Region due to forecast area source emissions in the year 1982 are presented on Map 153. The maximum isopleth value indicated on Map 153 is 1 mg/m^3 and is centered over General Mitchell Field in Milwaukee County. The corresponding simulation modeling results for the year 2000 are presented on Map 154, which indicates a maximum isopleth value of 3 mg/m^3 again centered over General Mitchell Field.

Composite Forecast of Carbon Monoxide Levels

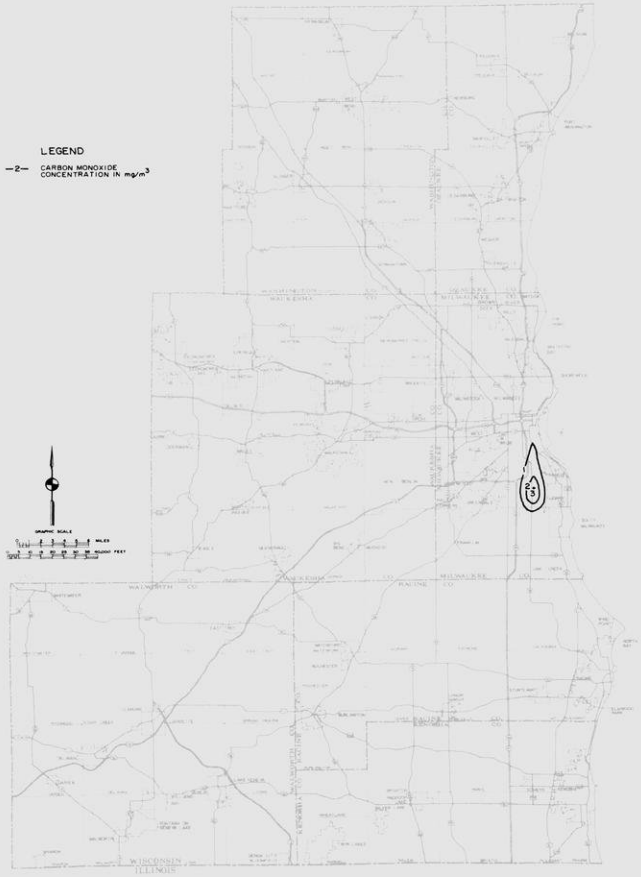
One-Hour Concentrations: The computer-simulated maximum one-hour average carbon monoxide concentrations resulting from forecast line and area source emissions in the Region in the year 1982 are presented on Map 155. The maximum isopleth value indicated on Map 155 is 25 mg/m^3, or about 63 percent of the ambient air quality standard of 40 mg/m^3. The maximum one-hour

average carbon monoxide concentrations in 1982 may be compared with the corresponding concentrations for the year 1977, as shown on Map 75 in Chapter XI. The maximum isopleth value indicated on Map 75 is 35 mg/m^3, or nearly 88 percent of the one-hour average carbon monoxide standard. It is evident, therefore, that the reduction in carbon monoxide emissions from line sources over the five-year period 1977-1982, anticipated to result principally from the federal motor vehicle emissions control program as discussed earlier in this chapter, may be expected to result in significant improvements in ambient air carbon monoxide concentrations by 1982. Moreover, the reduction in emissions expected to result from the federal motor vehicle emissions control program will in turn result in an improvement in the one-hour average carbon monoxide levels in southeastern Wisconsin through the year 2000, as evidenced on Maps 156 and 157. As may be seen on Map 156, even under the "worst case" emission conditions—the 1985 stage of the "no build" alternative—the maximum isopleth value is 15 mg/m^3, or only about 38 percent of the air quality standard. By the year 2000, as shown on Map 157, the maximum isopleth value is indicated to be 10 mg/m^3, or 25 percent of the standard, under the "no build" alternative. It may be concluded, therefore, that neither a short-term attainment plan nor a long-term maintenance plan—other than the continued implementation of the federal motor vehicle emissions control program—will be required to alleviate excess carbon monoxide levels in southeastern Wisconsin through the year 2000.

Eight-Hour Concentrations: The computer-simulated maximum eight-hour average carbon monoxide concentrations resulting from forecast line and area source emissions in the Region in the year 1982 are presented on Map 158. As may be seen on Map 158, an area of approximately three square miles centered over the Marquette Interchange in Milwaukee County is expected to exceed the eight-hour average carbon monoxide ambient air quality standard of 10 mg/m^3 in 1982. Comparison of Map 158 with Map 74 in Chapter XI, which presents the corresponding computer-simulated values for the year 1977, indicates that the area exceeding the eight-hour average carbon monoxide standard in 1982—an area three square miles in size—is about 18 square miles less than the 21-square-mile area exceeding this standard in 1977. Moreover, the maximum isopleth value is 10 mg/m^3 in 1982, as compared with a maximum value of 14 mg/m^3 in 1977. The carbon monoxide emissions reductions achieved through the implementation of the federal motor vehicle emissions control program between 1983 and 1985 should serve to eliminate violations of the eight-hour average standard by 1985. This expectation is based on the computer simulation results for the year 1985, as shown on Map 159, which indicate a maximum isopleth value of 8 mg/m^3 under the 1985 stage of the "no build" alternative transportation plan. Even further reductions in eight-hour average carbon monoxide concentrations in the Region may be anticipated by the year 2000. The computer simulation results for the year 2000, as shown on Map 160, indicate a maximum eight-hour average concentration of about 4 mg/m^3 under the "no build" alternative. It may be concluded, therefore, that a short-term attainment plan will be required to achieve the eight-hour average carbon monoxide standard in the Region prior to 1982, but that the full implementation of the federal motor vehicle emissions control program will obviate the need for a long-term maintenance plan.

Map 154

COMPUTER-SIMULATED MAXIMUM EIGHT-HOUR AVERAGE CARBON MONOXIDE CONCENTRATIONS IN THE REGION FROM FORECAST AREA SOURCE EMISSIONS: 2000



This map illustrates the impact of carbon monoxide emissions from area sources on maximum eight-hour average carbon monoxide concentrations in the Region in the year 2000. The highest isopleth value shown on this map is three milligrams per cubic meter (mg/m^3), expressed as an eight-hour arithmetic average, and is centered over General Mitchell Field. The forecast increase in carbon monoxide emissions between 1982 and the year 2000 can be primarily attributed to the growth in commercial jet aircraft operations expected at General Mitchell Field.

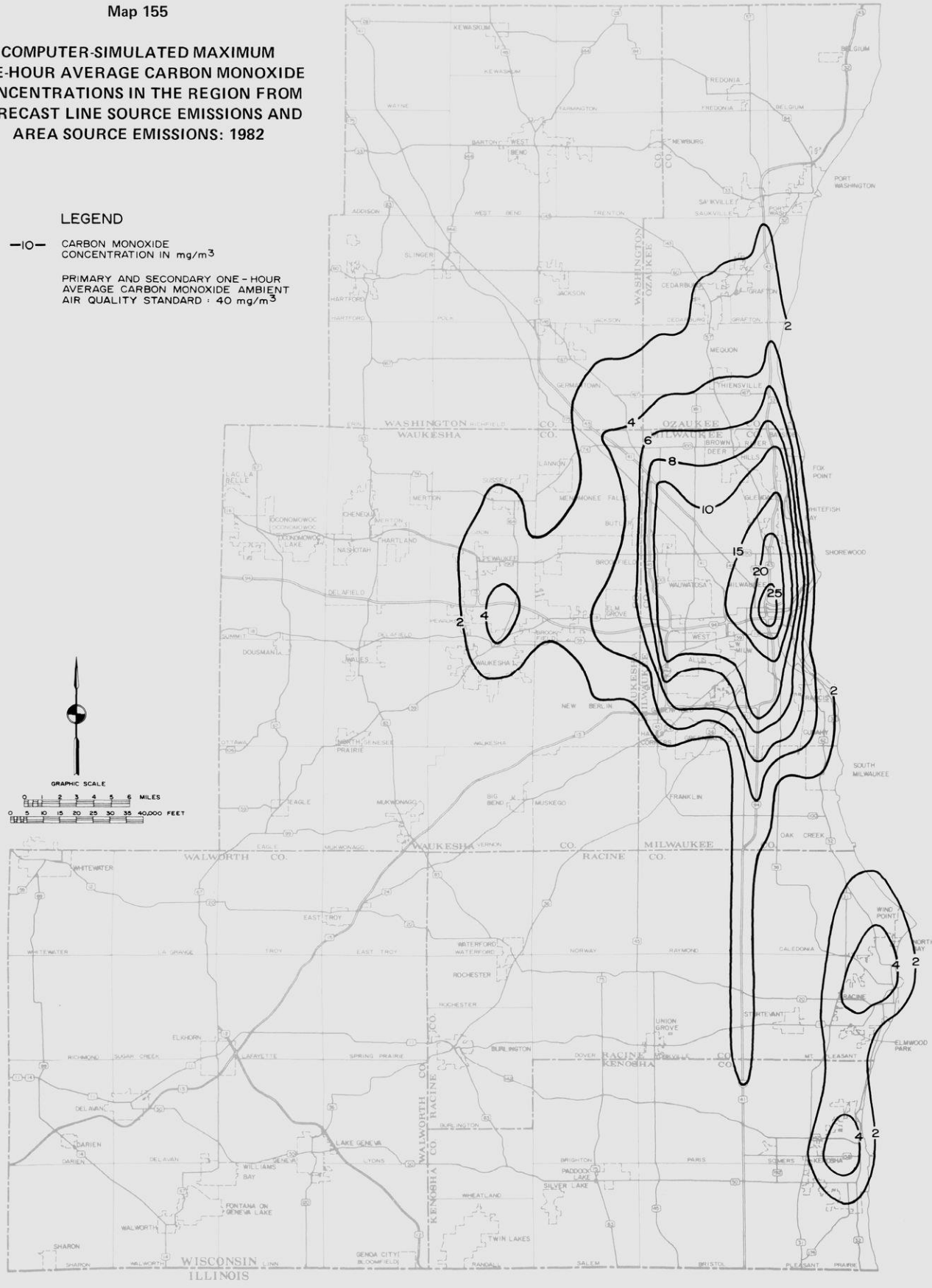
Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

FORECAST NITROGEN OXIDE CONCENTRATIONS: 1982, 1985, AND 2000

As was noted in Chapter XI of this report, there are several major limitations to the computer simulation of

Map 155

COMPUTER-SIMULATED MAXIMUM ONE-HOUR AVERAGE CARBON MONOXIDE CONCENTRATIONS IN THE REGION FROM FORECAST LINE SOURCE EMISSIONS AND AREA SOURCE EMISSIONS: 1982

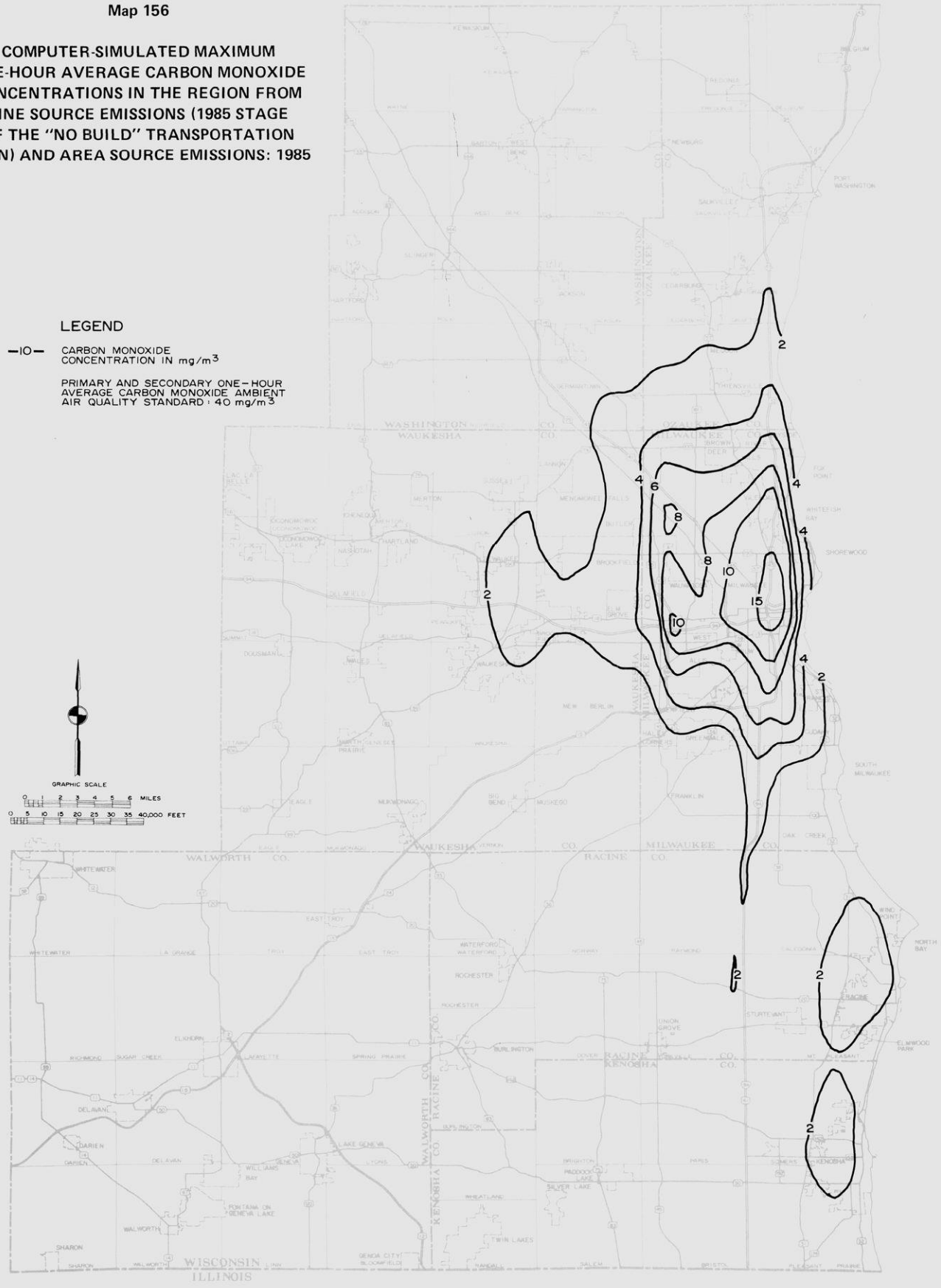


This map illustrates the impact of carbon monoxide emissions from both line and area sources on the maximum one-hour average carbon monoxide concentrations in the Region in 1982. The highest isopleth shown on this map is 25 milligrams per cubic meter (mg/m^3), expressed as a one-hour arithmetic average, and is located over the Marquette Interchange. A comparison of this map with Map 75 in Chapter XI indicates a decrease in the maximum carbon monoxide concentration—from 35 mg/m^3 to 25 mg/m^3—between 1977 and 1982. This reduction can be attributed to a decrease in line source emissions resulting from implementation of the federal motor vehicle emissions control program.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 156

COMPUTER-SIMULATED MAXIMUM ONE-HOUR AVERAGE CARBON MONOXIDE CONCENTRATIONS IN THE REGION FROM LINE SOURCE EMISSIONS (1985 STAGE OF THE "NO BUILD" TRANSPORTATION PLAN) AND AREA SOURCE EMISSIONS: 1985

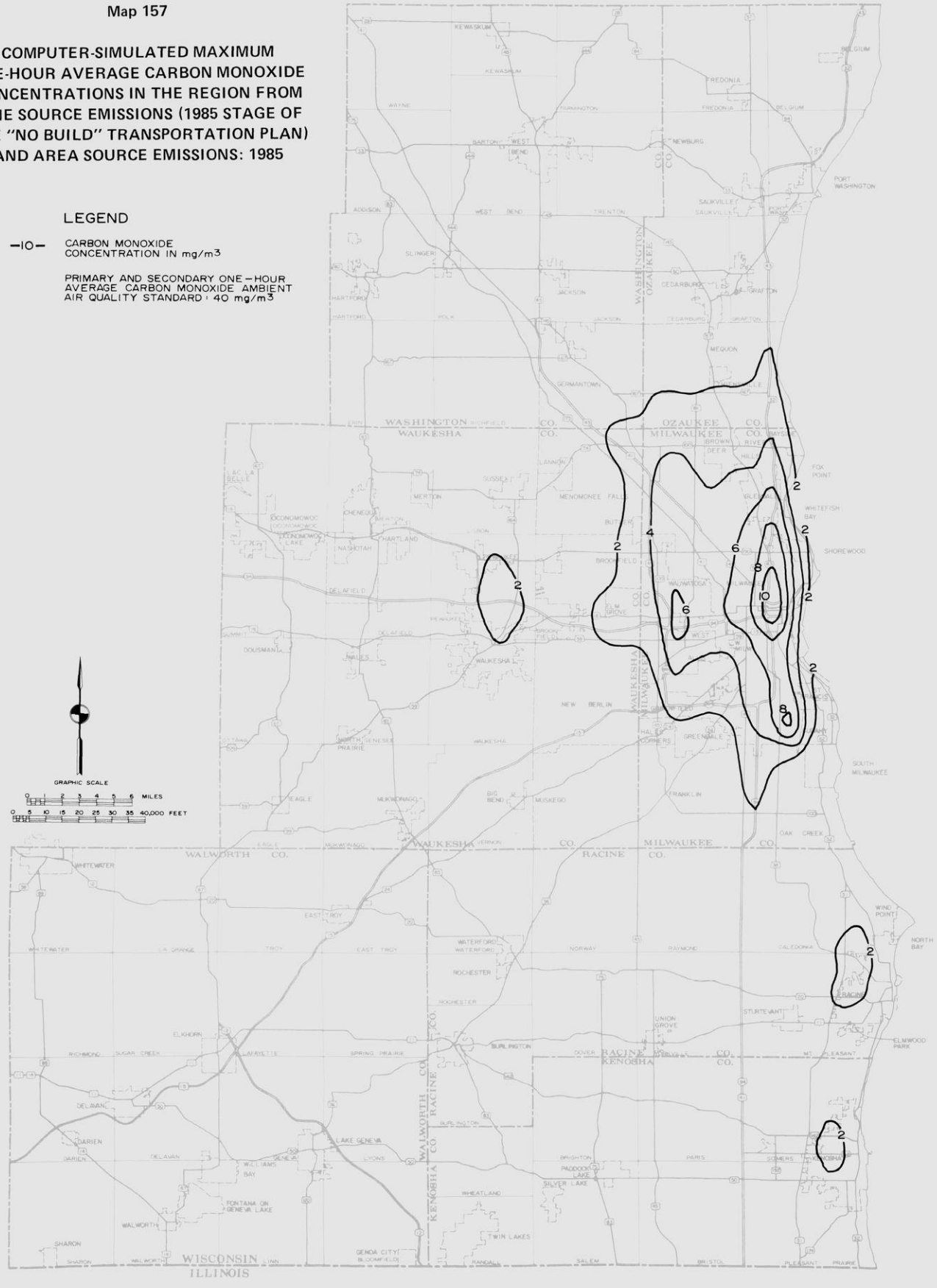


This map illustrates the impact of carbon monoxide emissions from both line and area sources on maximum one-hour average carbon monoxide concentrations in the Region in 1985 under the "no build" alternative transportation plan. The highest isopleth value shown on this map is 15 milligrams per cubic meter (mg/m^3), expressed as a one-hour arithmetic average, and is located over the Marquette Interchange. A comparison of Map 155 with this map shows a reduction in maximum carbon monoxide concentrations between 1982 and 1985 under the "no build" plan of from 25 mg/m^3 to 15 mg/m^3. This reduction can be attributed to the exhaust emission limitations placed on line sources under the federal motor vehicle emissions control program.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 157

COMPUTER-SIMULATED MAXIMUM ONE-HOUR AVERAGE CARBON MONOXIDE CONCENTRATIONS IN THE REGION FROM LINE SOURCE EMISSIONS (1985 STAGE OF THE "NO BUILD" TRANSPORTATION PLAN) AND AREA SOURCE EMISSIONS: 1985

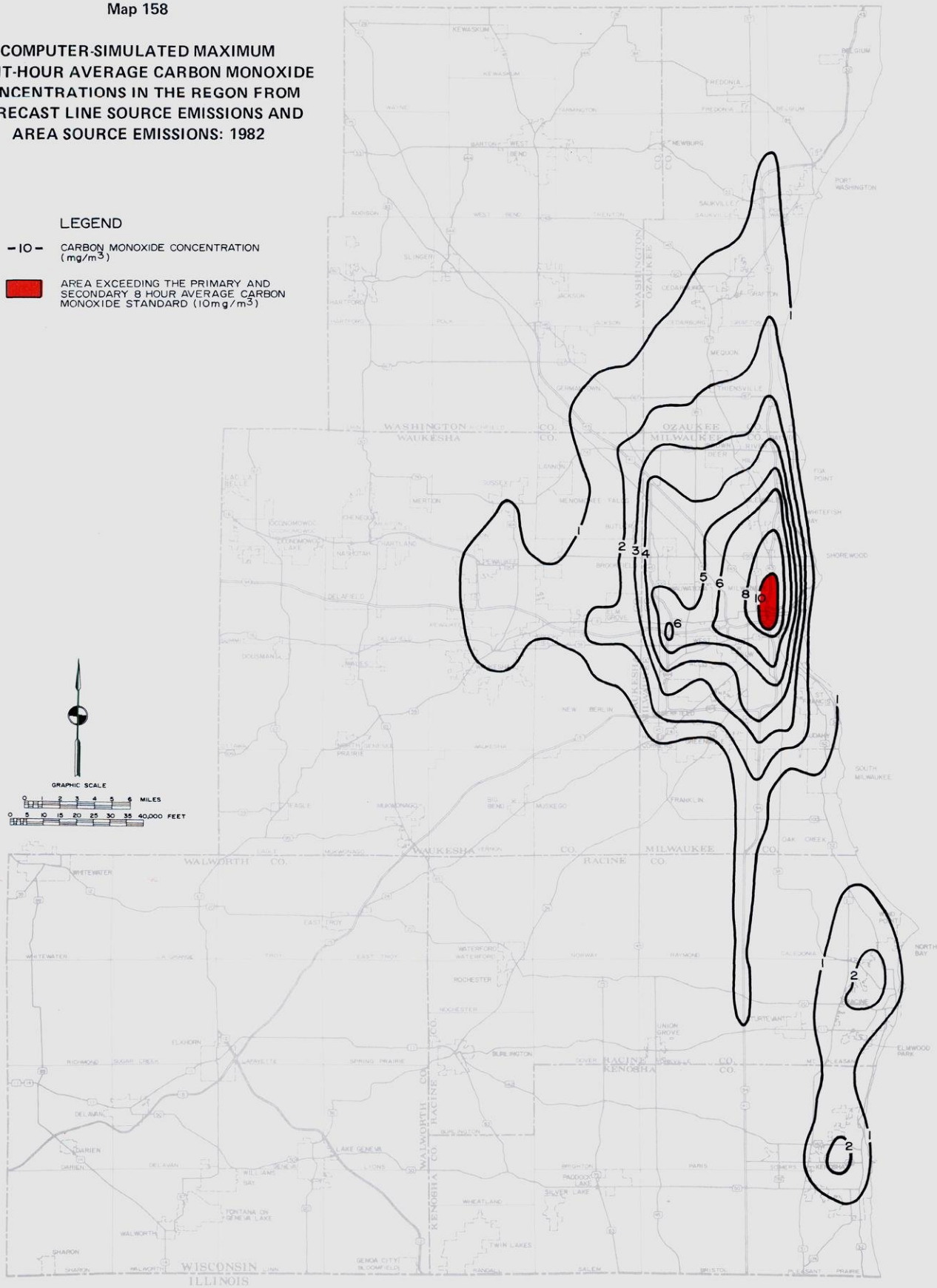


This map illustrates the impact of carbon monoxide emissions from both line and area sources on maximum one-hour average carbon monoxide concentrations in the Region in the year 2000 under the "no build" alternative transportation plan. The highest isopleth value shown on this map is 10 milligrams per cubic meter (mg/m^3), expressed as a one-hour arithmetic average, and is located over the Marquette Interchange. This maximum concentration is considerably lower than the maximum carbon monoxide concentration in 1985 of 15 mg/m^3. This reduction can be attributed to the exhaust emission limitations placed on line sources under the federal motor vehicle emissions control program.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 158

COMPUTER-SIMULATED MAXIMUM EIGHT-HOUR AVERAGE CARBON MONOXIDE CONCENTRATIONS IN THE REGON FROM FORECAST LINE SOURCE EMISSIONS AND AREA SOURCE EMISSIONS: 1982

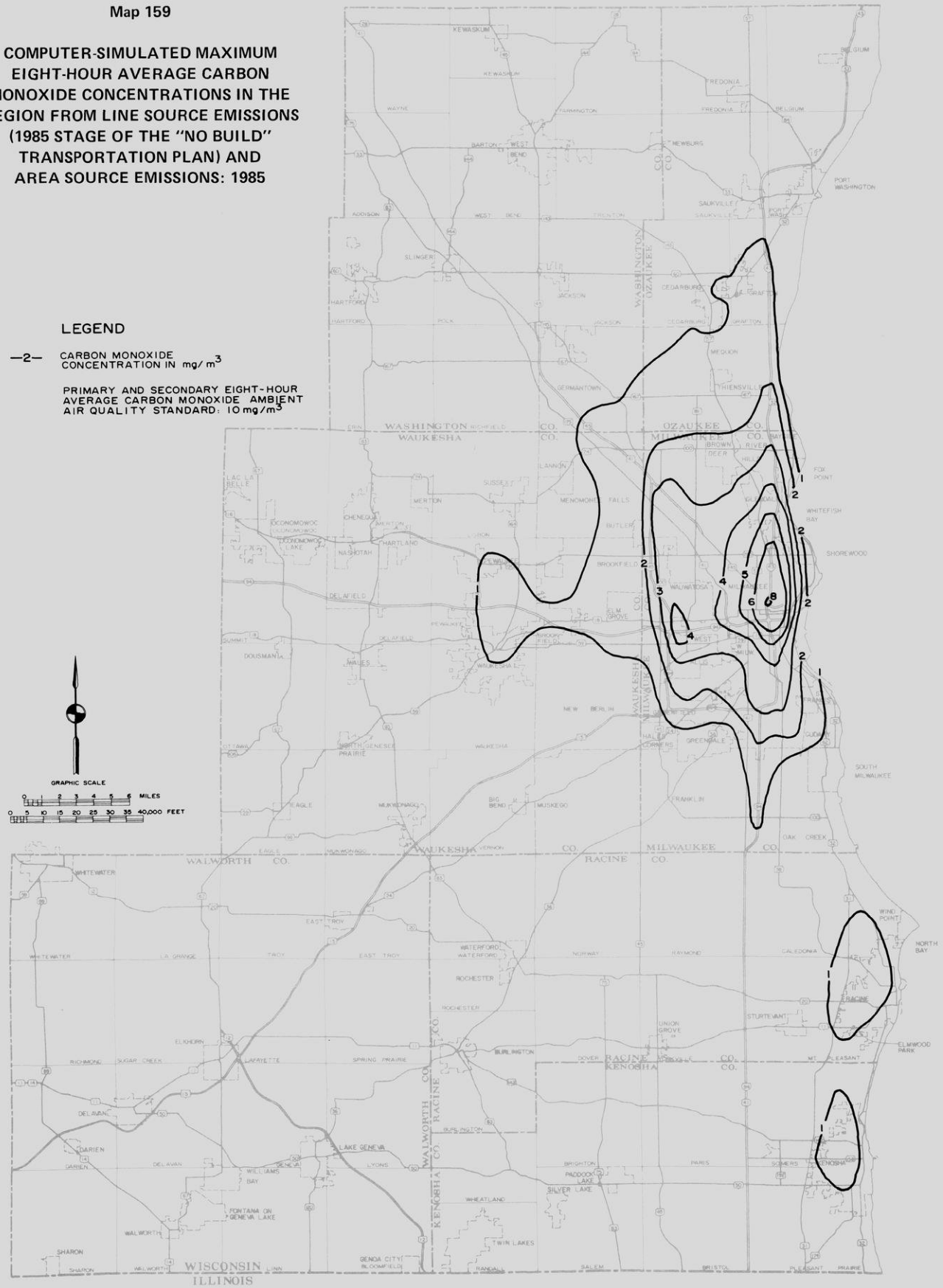


This map illustrates the impact of carbon monoxide emissions from both line and area sources on maximum eight-hour average carbon monoxide concentrations in the Region in 1982. The highest isopleth value shown on this map is 10 milligrams per cubic meter (mg/m^3), expressed as an eight-hour arithmetic average, and is located over the Marquette Interchange. Therefore, the eight-hour ambient air quality standard for carbon monoxide of 10 mg/m^3 will be exceeded over an area of approximately three square miles in central Milwaukee County in 1982.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 159

COMPUTER-SIMULATED MAXIMUM EIGHT-HOUR AVERAGE CARBON MONOXIDE CONCENTRATIONS IN THE REGION FROM LINE SOURCE EMISSIONS (1985 STAGE OF THE "NO BUILD" TRANSPORTATION PLAN) AND AREA SOURCE EMISSIONS: 1985

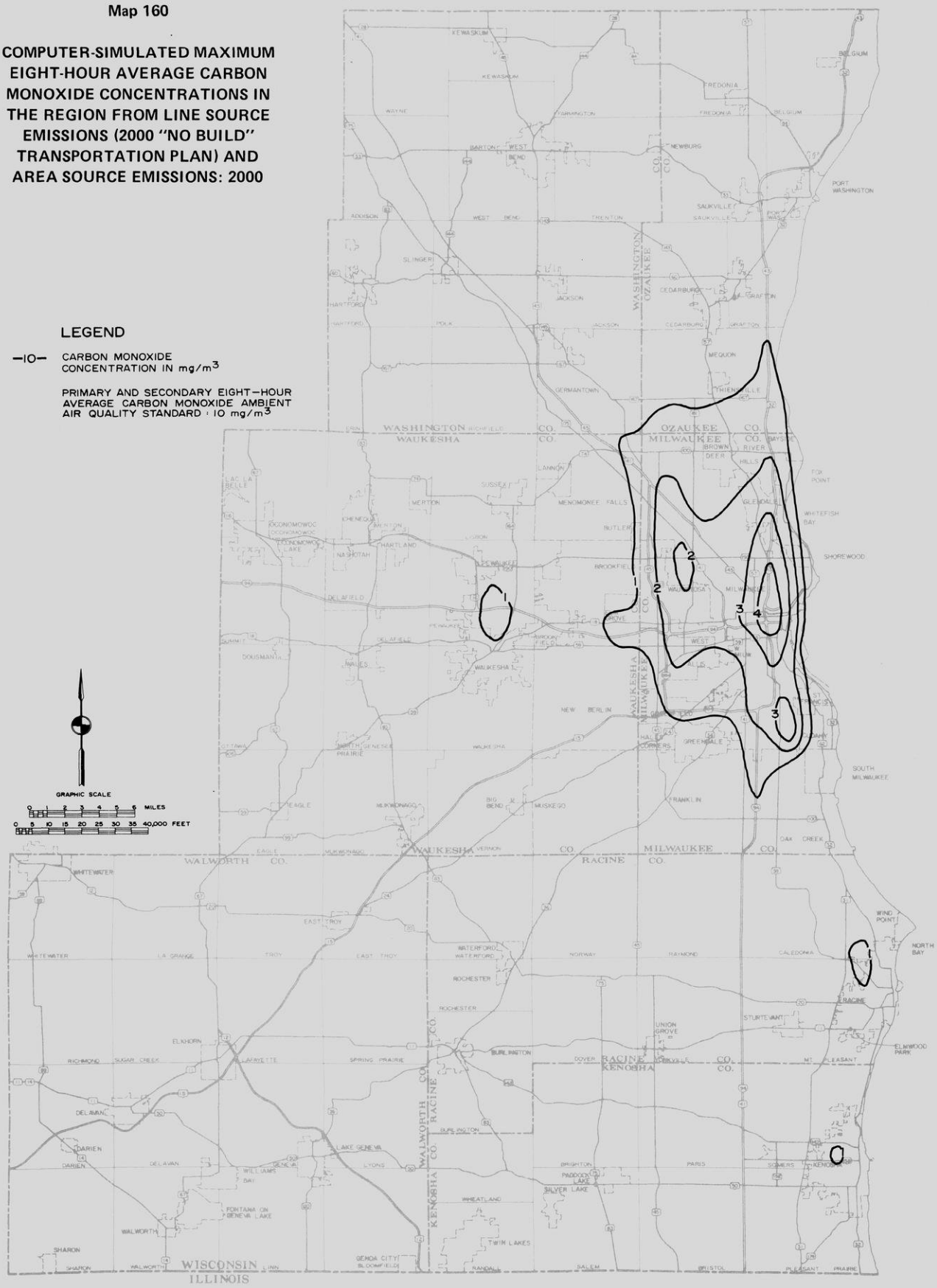


This map illustrates the impact of carbon monoxide emissions from both line and area sources on maximum eight-hour average carbon monoxide concentrations in the Region in 1985 under the "no build" alternative transportation plan. The highest isopleth value shown on this map is eight milligrams per cubic meter (mg/m^3), expressed as an eight-hour arithmetic average, and is located over the Marquette Interchange. Ambient air carbon monoxide concentrations due to area and line source emissions in other areas of Milwaukee County and the Region are generally at or below six milligrams per cubic meter (mg/m^3). By comparing this map with Map 158, it may be seen that the maximum eight-hour average carbon monoxide concentrations are generally expected to decrease between 1982 and 1985. These reductions can be attributed to the exhaust emission limitations placed on line sources under the federal motor vehicle emissions control program.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 160

COMPUTER-SIMULATED MAXIMUM EIGHT-HOUR AVERAGE CARBON MONOXIDE CONCENTRATIONS IN THE REGION FROM LINE SOURCE EMISSIONS (2000 "NO BUILD" TRANSPORTATION PLAN) AND AREA SOURCE EMISSIONS: 2000



This map illustrates the impact of carbon monoxide emissions from both line and area sources on maximum eight-hour average carbon monoxide concentrations in the Region in the year 2000 under the "no build" alternative transportation plan. The highest isopleth value shown on this map is four milligrams per cubic meter (mg/m^3), expressed as an eight-hour arithmetic average, and is located over the Marquette Interchange. The remaining portions of Milwaukee County and the Region have a carbon monoxide concentration of three mg/m^3 or less. By comparing this map with Map 159, it may be seen that the maximum eight-hour average carbon monoxide concentrations are generally expected to decrease between 1985 and the year 2000. This reduction can be attributed to the exhaust emission limitations placed on line sources under the federal motor vehicle emissions control program.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

annual average nitrogen dioxide concentrations in the Region. The foremost limitation is the fact that nitrogen dioxide is a photochemically reactive pollutant, a factor which cannot be accounted for in the Wisconsin Atmospheric Diffusion Model. Second, most nitrogen oxide emissions are in the form of nitric oxide, which is converted in the atmosphere to nitrogen dioxide. The rate of conversion of nitric oxide to nitrogen dioxide is variable and depends on atmospheric conditions, again a factor which cannot be accounted for in the Wisconsin Atmospheric Diffusion Model. Finally, since the prevailing ratio of nitric oxide to nitrogen dioxide in the atmosphere over southeastern Wisconsin has not been monitored, it is not possible to calibrate the nitrogen oxide modeling results against nitrogen dioxide monitoring data, nor, consequently, to estimate the background level of this pollutant species due to long-range transport. Notwithstanding these rather severe limitations, it is still possible to simulate the forecast nitrogen oxide concentrations in the Region in the assumed absence of photochemical reactions and, with cautious interpretation, to make certain judgments concerning future annual average levels of nitrogen dioxide concentrations in southeastern Wisconsin.

Point Sources

Map 161 presents the computer-simulated annual average nitrogen oxide concentrations in the Region from forecast point source emissions in the year 1982 under the coal-intensive energy scenario. As may be seen by comparing this simulation with the corresponding simulation for 1977, as shown on Map 76 in Chapter XI, the land area impacted by the maximum indicated isopleth value—5 micrograms per cubic meter ($\mu g/m^3$) in both 1977 and 1982—is considerably larger in 1982. It is expected that in 1982 this 5 $\mu g/m^3$ isopleth value will encompass a land area of approximately 123 square miles, an increase of 61 square miles, or about 98 percent, over the 62 square miles encompassed by the 5 $\mu g/m^3$ isopleth value in 1977.

The impact of forecast point source emissions on annual average nitrogen oxide concentrations is expected to increase over the planning period, as evidenced on Maps 162 and 163. The maximum isopleth value indicated for 1985 under the coal-intensive energy scenario is 10 $\mu g/m^3$, as shown on Map 162. This value increases to 15 $\mu g/m^3$ in the year 2000, as shown on Map 163. Although point sources are forecast to impact more severely on annual average nitrogen oxide levels in the Region over the planning period than in the past, the actual impact of the nitrogen oxide emissions from these sources on the ambient air quality standard of 100 $\mu g/m^3$ will be relatively small in the year 2000, since it is assumed that these concentrations are entirely nitrogen dioxide.

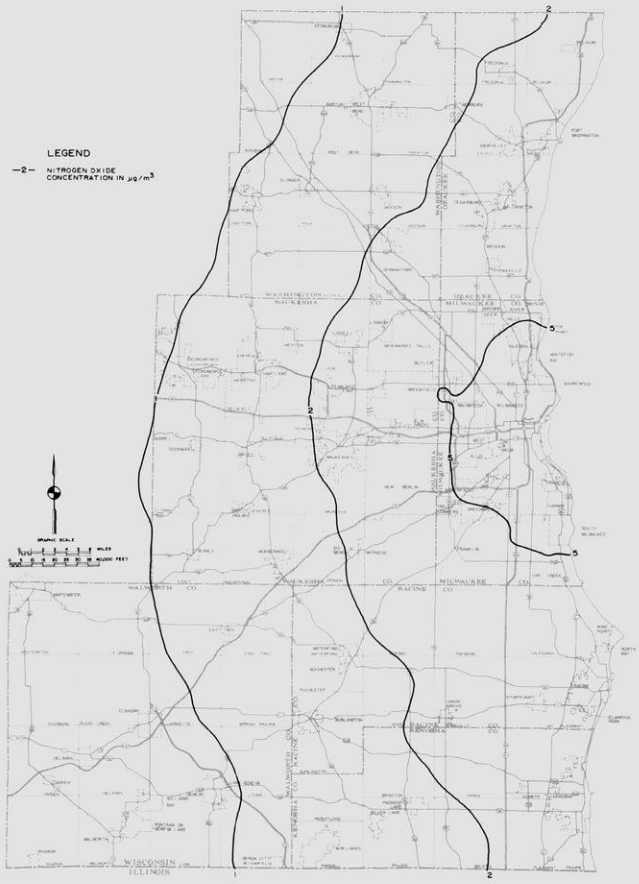
Line Sources

The computer-simulated annual average nitrogen oxide concentrations in the Region due to forecast line source emissions in 1982 are presented on Map 164. As may be seen by comparing this simulation with the corresponding simulation for 1977, as shown on Map 77 in Chapter XI, a significant improvement in annual average nitrogen oxide concentrations is expected over this five-year period. The maximum isopleth value expected in 1982 is 150 $\mu g/m^3$, as compared with 200 $\mu g/m^3$ in 1977. This value is located over the Marquette Interchange.

Annual average nitrogen oxide concentrations due to line source emissions in the Region are expected to

Map 161

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE NITROGEN OXIDE CONCENTRATIONS IN THE REGION FROM FORECAST POINT SOURCE EMISSIONS 1982 COAL-INTENSIVE ENERGY SCENARIO

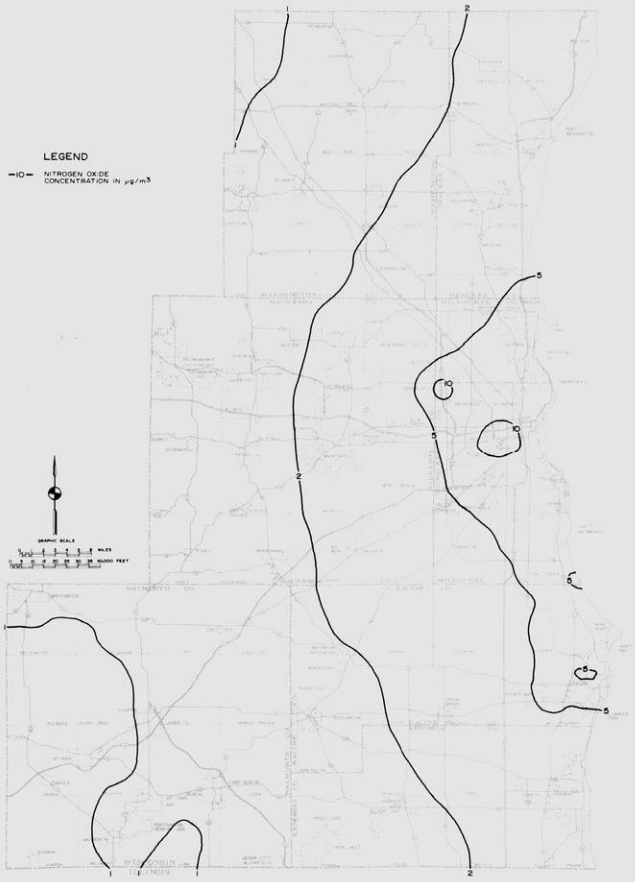


This map illustrates the impact of nitrogen oxide emissions from point sources on ambient air quality in the Region in 1982 under the coal-intensive energy scenario, which assumes that natural gas supplies will not be available to meet total industrial energy demand. The highest isopleth value shown on this map is five micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and encompasses most of Milwaukee County. Ambient air nitrogen oxide concentrations due to point sources in other counties of the Region are generally at or below two $\mu g/m^3$. The results of the nitrogen oxide emissions forecast for 1982 indicate that point sources under the coal-intensive energy scenario will emit about 58,000 tons of nitrogen oxides in the Region, an increase of about 11,700 tons, or 25 percent, over the 1977 point source emission level of 46,300 tons. This increase can be principally attributed to the assumed conversion by natural gas-burning facilities to coal use under the coal-intensive energy scenario.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 162

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE NITROGEN OXIDE CONCENTRATIONS IN THE REGION FROM FORECAST POINT SOURCE EMISSIONS 1985 COAL-INTENSIVE ENERGY SCENARIO

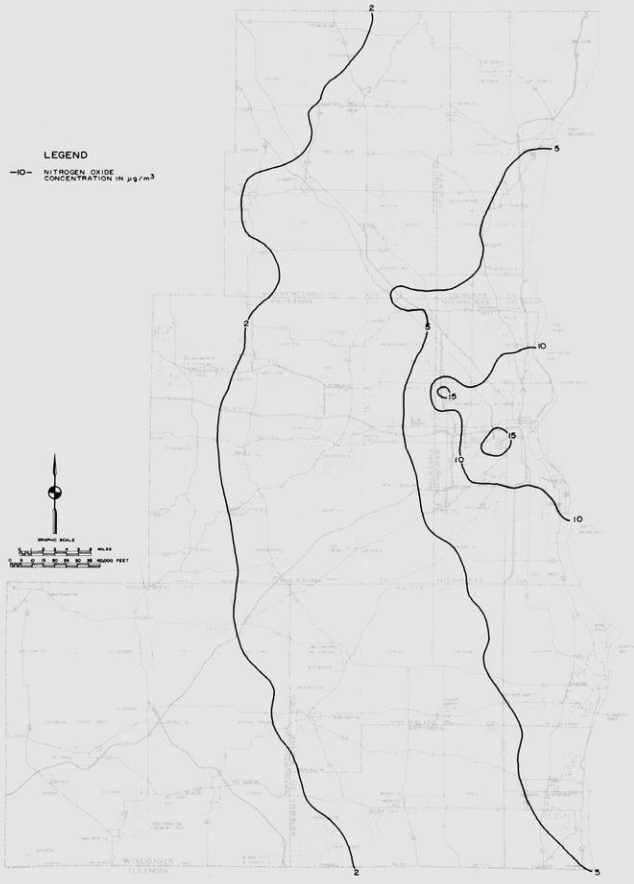


This map illustrates the impact of nitrogen oxide emissions from point sources on ambient air quality in the Region in 1985 under the coal-intensive energy scenario, which assumes that natural gas supplies will not be available to meet total industrial energy demand. The highest isopleth values shown on this map are 10 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and are located in central and northwestern Milwaukee County. Nitrogen oxide concentrations in the remaining areas of the Region are at or below five $\mu g/m^3$. The results of the nitrogen oxide emissions forecast for 1985 indicate that point sources under the coal-intensive energy scenario will emit about 60,700 tons of nitrogen oxides in the Region, an increase of about 2,700 tons, or about 5 percent, over the 58,000 tons expected to be emitted in 1982 under the coal-intensive energy scenario. This increase can be attributed to growth in activity at major industrial facilities and fuel-burning installations.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 163

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE NITROGEN OXIDE CONCENTRATIONS IN THE REGION FROM FORECAST POINT SOURCE EMISSIONS 2000 COAL-INTENSIVE ENERGY SCENARIO



This map illustrates the impact of nitrogen oxide emissions from point sources on ambient air quality in the Region in the year 2000 under the coal-intensive energy scenario. The highest isopleth values shown on this map are 15 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and are located in central and northwestern Milwaukee County. Most of the remaining area in central Milwaukee County has a nitrogen oxide concentration of 10 $\mu g/m^3$ or less. Nitrogen oxide concentrations in the remainder of Milwaukee County and the other counties in the Region total five $\mu g/m^3$ or less. The results of the nitrogen oxide emissions forecast for the year 2000 indicate that point sources under the coal-intensive energy scenario will emit about 90,500 tons of nitrogen oxides in the Region, an increase of about 29,700 tons, or about 49 percent, over the 60,700 tons expected to be emitted in 1985 under the coal-intensive energy scenario. This increase can be attributed to growth in activity at the major industrial facilities and fuel-burning installations.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

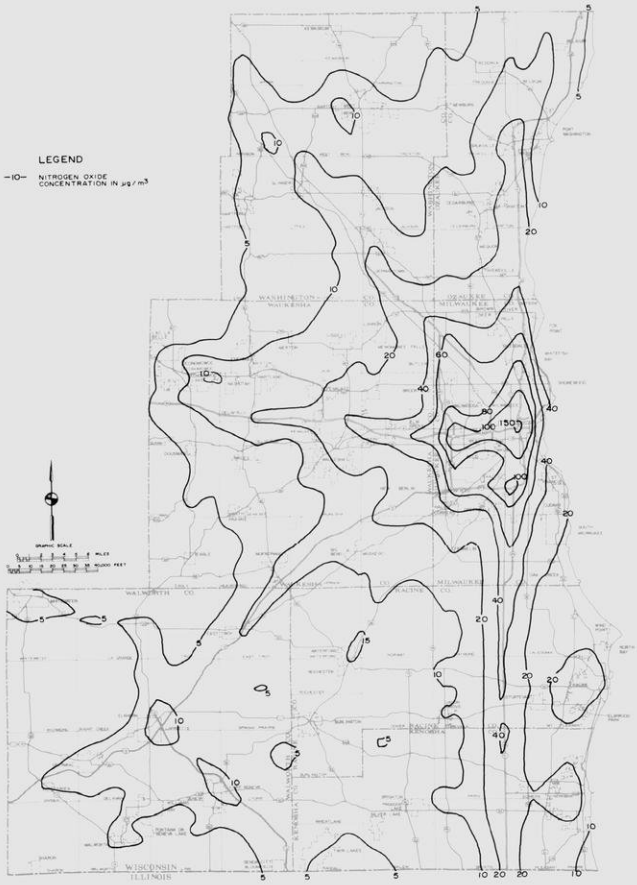
show further improvement between 1985 and 2000, as indicated on Maps 165 and 166, respectively. Under the 1985 stage of the "no build" alternative transportation plan the maximum isopleth value is expected to be 100 $\mu g/m^3$, as shown on Map 165, and will be located over both the Marquette and Zoo Interchanges. The maximum isopleth value under the "no build" alternative in the year 2000 remains at 100 $\mu g/m^3$, as shown on Map 166. However, the size of the areas encompassed by isopleths of equivalent value generally decrease throughout the Region between 1985 and 2000.

Area Sources

In general, the results of the simulation modeling for annual average nitrogen oxide concentrations from area source emissions indicate that very little change may be

Map 164

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE NITROGEN OXIDE CONCENTRATIONS IN THE REGION FROM FORECAST LINE SOURCE EMISSIONS: 1982

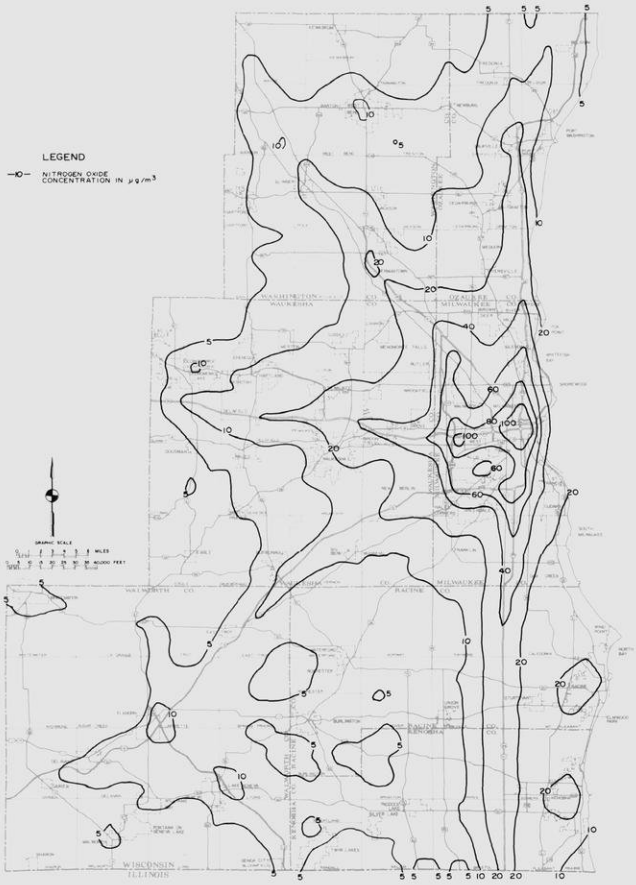


This map illustrates the impact of nitrogen oxide emissions from line sources on ambient air quality in the Region in 1982. The highest isopleth value shown on this map is 150 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and is located over the Marquette Interchange. The spatial distribution of the nitrogen oxide concentrations, which have been computer simulated in the assumed absence of photochemical reactions, generally conforms to the pattern of the regional freeway system.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 165

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE NITROGEN OXIDE CONCENTRATIONS IN THE REGION FROM FORECAST LINE SOURCE EMISSIONS: 1985 STAGE OF THE "NO BUILD" TRANSPORTATION PLAN



This map illustrates the impact of nitrogen oxide emissions from line sources on ambient air quality in the Region in 1985 under the 1985 stage of the "no build" transportation plan. The highest isopleth values shown on this map are 100 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and are located over the Marquette and Zoo Interchanges in Milwaukee County. The results of the nitrogen oxide emissions forecast for 1985 indicate that line sources under the 1985 stage of the "no build" transportation plan will emit about 33,900 tons of nitrogen oxides in the Region, a decrease of about 13,800 tons, or about 30 percent, from the 1977 line source emission level of 47,700 tons. These reductions can be primarily attributed to the federal motor vehicle emissions control program.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

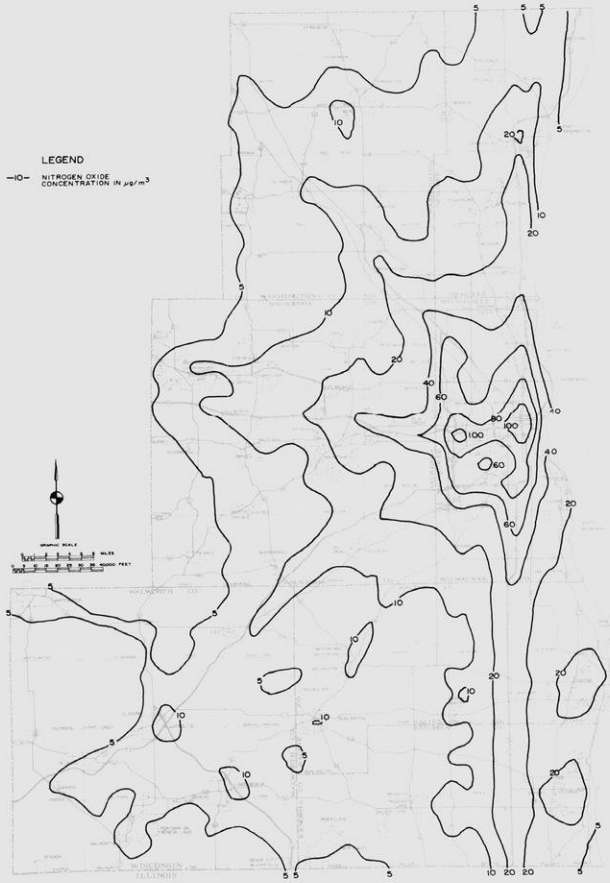
expected between 1977 and the year 2000. Comparison of the annual average nitrogen oxide concentrations due to forecast area source emissions in 1982, 1985, and 2000, as shown on Maps 167, 168, and 169, respectively, with the corresponding concentrations for 1977, as shown on Map 78 in Chapter XI, indicates that the only significant growth in nitrogen oxide concentrations in the Region over the planning period may be expected in the vicinity of General Mitchell Field in Milwaukee County. In 1977 the maximum isopleth value over General Mitchell Field was 60 $\mu g/m^3$. By the year 2000, the maximum isopleth value is expected to increase to 150 $\mu g/m^3$. This significant increase may be attributed to the growth in commercial jet operations anticipated at General Mitchell Field by the year 2000.

Composite Forecast of Nitrogen Oxide Levels

Map 170 presents the computer-simulated annual average

Map 166

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE NITROGEN OXIDE CONCENTRATIONS IN THE REGION FROM FORECAST LINE SOURCE EMISSIONS: 2000 "NO BUILD" TRANSPORTATION PLAN

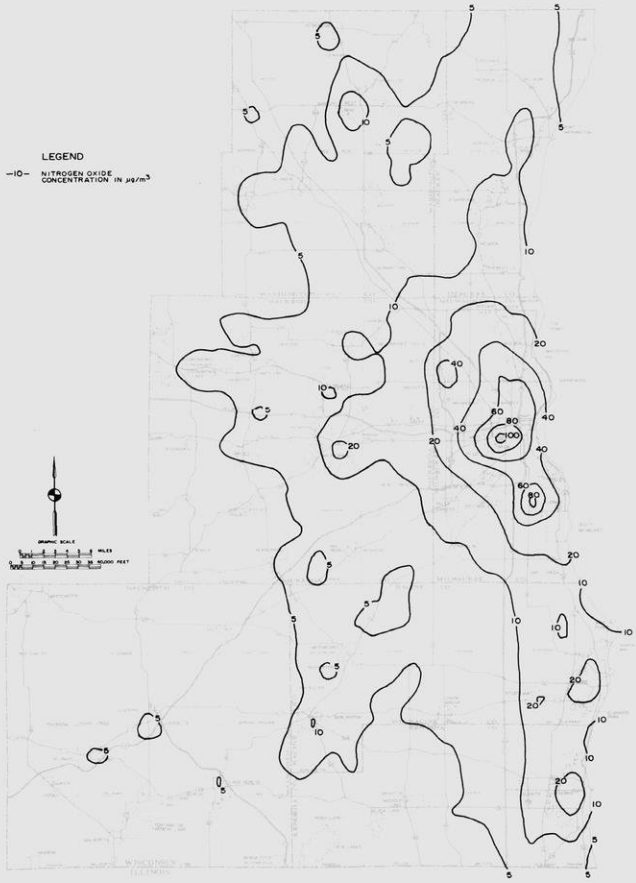


This map illustrates the impact of nitrogen oxide emissions from line sources on ambient air quality in the Region in the year 2000 under the "no build" transportation plan. The highest isopleth values shown on this map are 100 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and are located over the Marquette and Zoo Interchanges in Milwaukee County. A comparison of this map with Map 165 indicates that similar areas are encompassed by the maximum isopleth value in 1985 and the year 2000 under the "no build" transportation plan. However, the extent of the areas encompassed by other isopleths of equivalent value generally decreases between 1985 and 2000.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 167

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE NITROGEN OXIDE CONCENTRATIONS IN THE REGION FROM FORECAST AREA SOURCE EMISSIONS: 1982



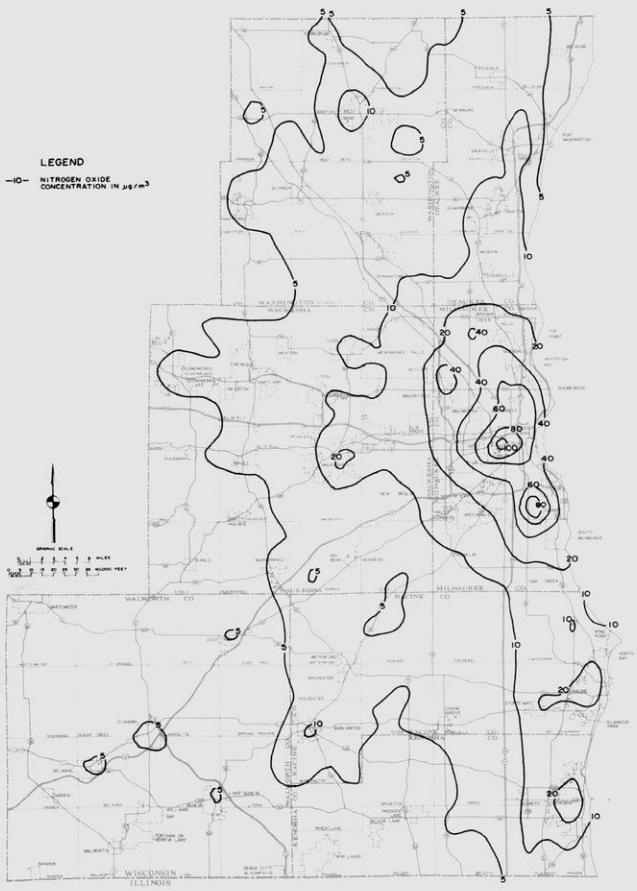
This map illustrates the impact of nitrogen oxide emissions from area sources on ambient air quality in the Region in 1982. The highest isopleth value shown on this map is 100 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and is located in central Milwaukee County. The principal area source of nitrogen oxide emissions in 1982 is expected to be residential fuel use.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

nitrogen oxide concentrations for 1982 resulting from total point, line, and area source emissions. The maximum isopleth value indicated for 1982 is 200 $\mu g/m^3$ and is located over central Milwaukee County. Comparison of the nitrogen oxide levels in 1982 with those in 1977, as shown on Map 79 in Chapter XI, indicates that a significant improvement in the ambient air concentrations of this pollutant species may be expected over this five-year period. In 1977 the maximum isopleth value was 300 $\mu g/m^3$ and was located over the Marquette Interchange. By 1982 the maximum isopleth value may be expected to be reduced to 200 $\mu g/m^3$, and to extend over an eight-square-mile area in central Milwaukee County, a decrease of about 20 square miles, or about 71 percent, from the 28 square miles encompassed by this isopleth value in 1977. This reduction may be

Map 168

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE NITROGEN OXIDE CONCENTRATIONS IN THE REGION FROM FORECAST AREA SOURCE EMISSIONS: 1985

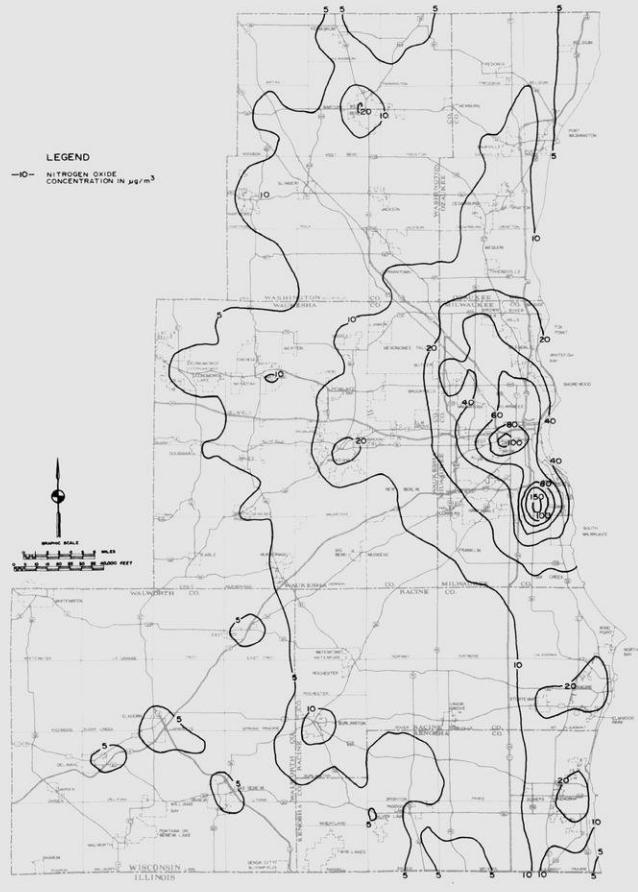


This map illustrates the impact of nitrogen oxide emissions from area sources on ambient air quality in the Region in 1985. The highest isopleth value shown on this map is 100 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and is located in central Milwaukee County. The principal area source of nitrogen oxide emissions in 1985 is expected to be residential fuel use. Nitrogen oxide emission from area sources are expected to increase by about 680 tons, or about 3 percent, between 1982 and 1985.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 169

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE NITROGEN OXIDE CONCENTRATIONS IN THE REGION FROM FORECAST AREA SOURCE EMISSIONS: 2000



This map illustrates the impact of nitrogen oxide emissions from area sources on ambient air quality in the Region in the year 2000. The highest isopleth value shown on this map is 150 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and is located near General Mitchell Field. In addition, two areas are shown to have a nitrogen oxide concentration of 100 $\mu g/m^3$, one located around General Mitchell Field and the other in central Milwaukee County. The principal area sources of nitrogen oxide emissions in the year 2000 are expected to be commercial jet aircraft operations and residential fuel use.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

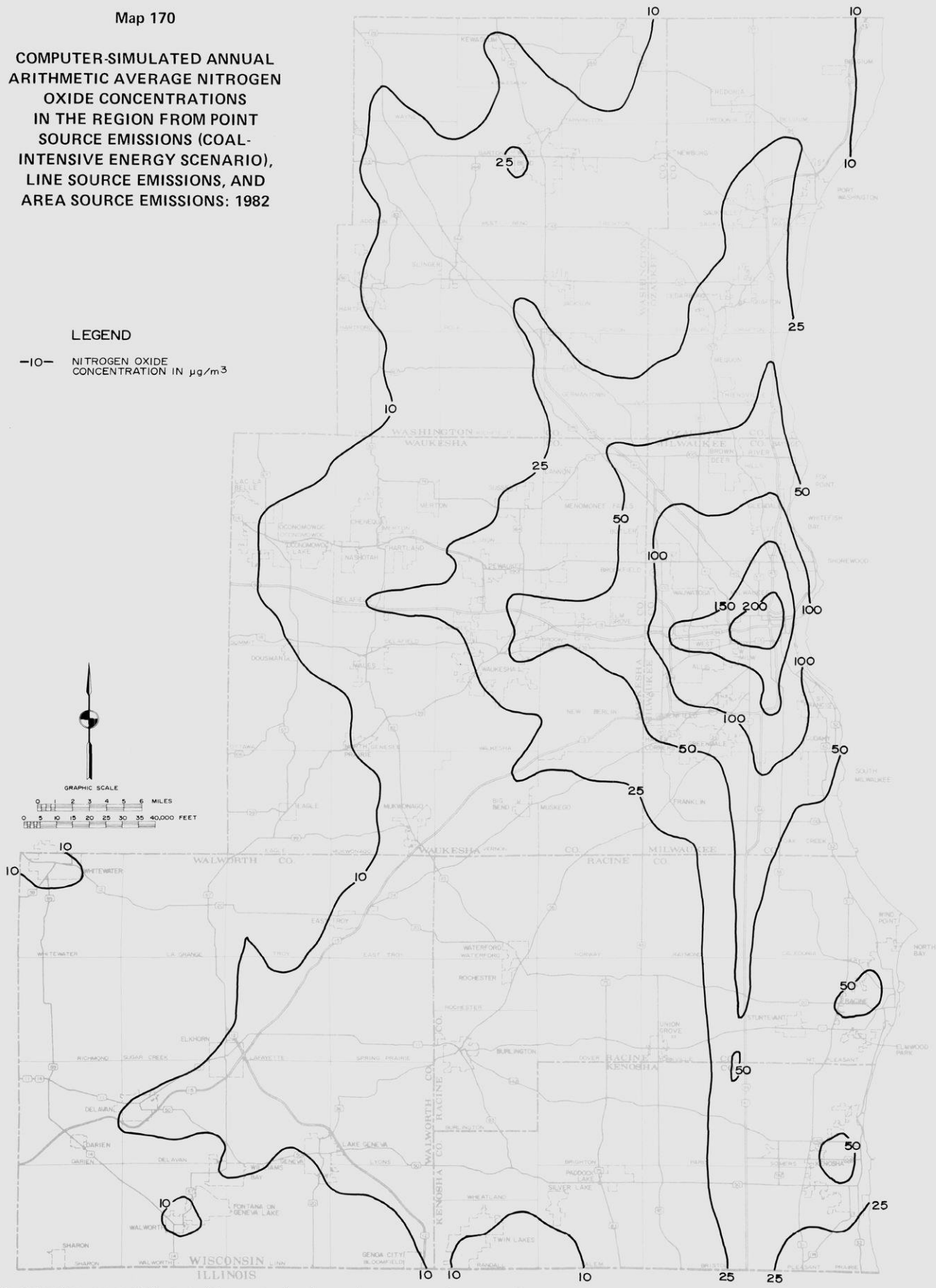
attributed principally to the decrease in line source emissions expected to result from implementation of the federal motor vehicle emissions control program.

A slight further improvement in annual average nitrogen oxide concentrations is expected to occur in the Region by 1985, as evidenced on Map 171. The area encompassed by the maximum isopleth value of 200 $\mu g/m^3$ in 1985 is approximately four square miles in size, a decrease of four square miles, or 50 percent, from the size of the area encompassed by this isopleth value in 1982. The simulation modeling results for the year 2000, as shown on Map 172, indicate a small increase in the size of the area encompassed by the 200 $\mu g/m^3$ maximum isopleth value—about two square miles larger than the corresponding 1985 area. This increase may be attributed to the forecast increase in vehicle miles of travel in the Region by the year 2000, which will somewhat offset the reduction in emissions expected to result from implementation of the federal motor vehicle emissions control program.

The highest annual average nitrogen dioxide concentration measured in the Region in 1977 was 70 $\mu g/m^3$, moni-

Map 170

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE NITROGEN OXIDE CONCENTRATIONS IN THE REGION FROM POINT SOURCE EMISSIONS (COAL-INTENSIVE ENERGY SCENARIO), LINE SOURCE EMISSIONS, AND AREA SOURCE EMISSIONS: 1982

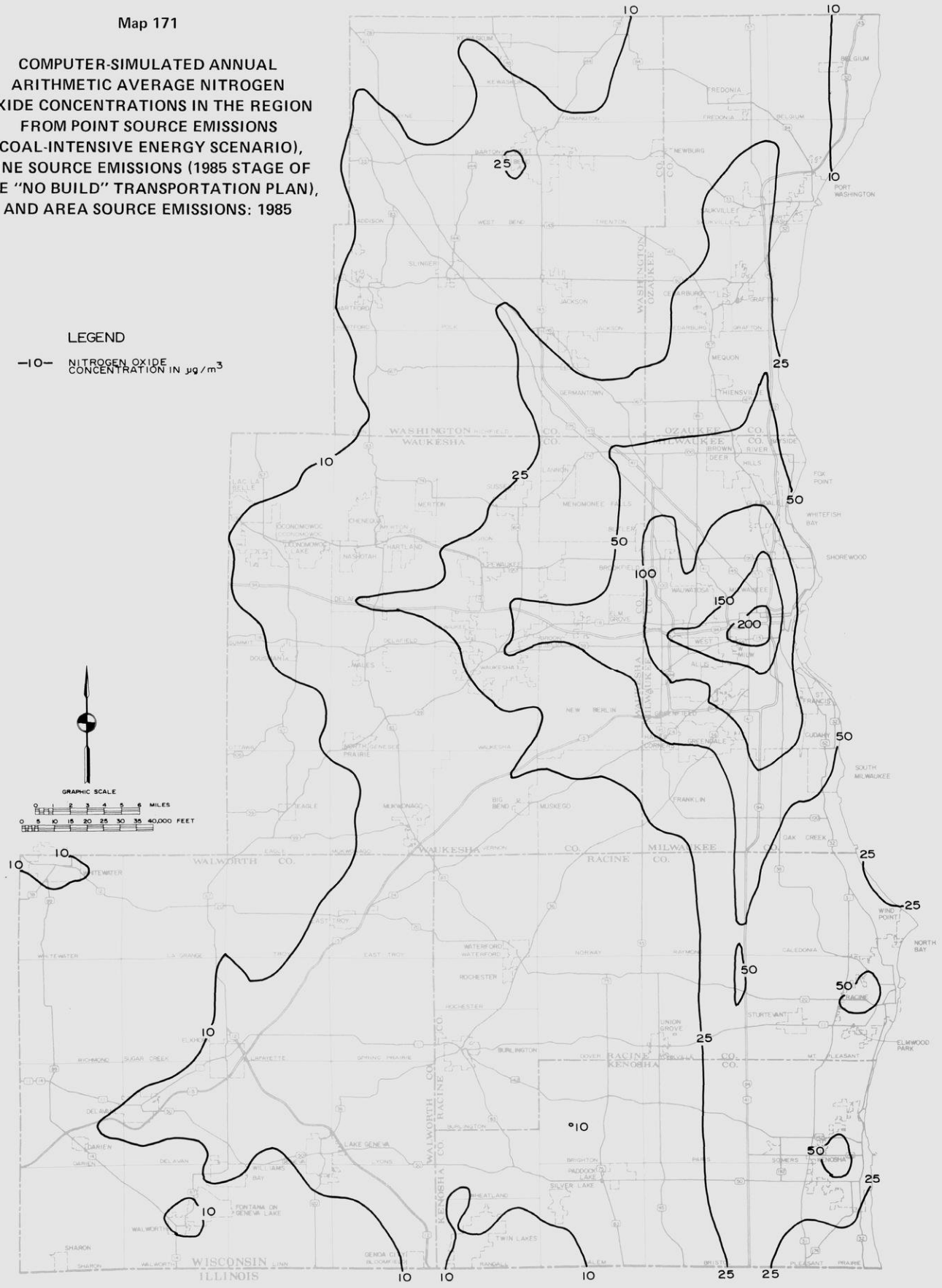


This map illustrates the composite impact of forecast point, line, and area source nitrogen oxide emissions on ambient air quality in the Region in 1982. The concentrations shown on this map are derived from forecast emissions data as anticipated under the coal-intensive energy scenario, which assumes that natural gas supplies will not be available to meet total industrial energy demand. The highest isopleth value shown on this map is 200 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and is located over central Milwaukee County. As may be seen by comparing this map with Map 79 in Chapter XI, an approximate 20-square-mile, or 72 percent, reduction in the extent of the area encompassed by the maximum isopleth value is expected between 1977 and 1982. This reduction may be attributed primarily to the continued implementation of the federal motor vehicle emissions control program.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 171

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE NITROGEN OXIDE CONCENTRATIONS IN THE REGION FROM POINT SOURCE EMISSIONS (COAL-INTENSIVE ENERGY SCENARIO), LINE SOURCE EMISSIONS (1985 STAGE OF THE "NO BUILD" TRANSPORTATION PLAN), AND AREA SOURCE EMISSIONS: 1985

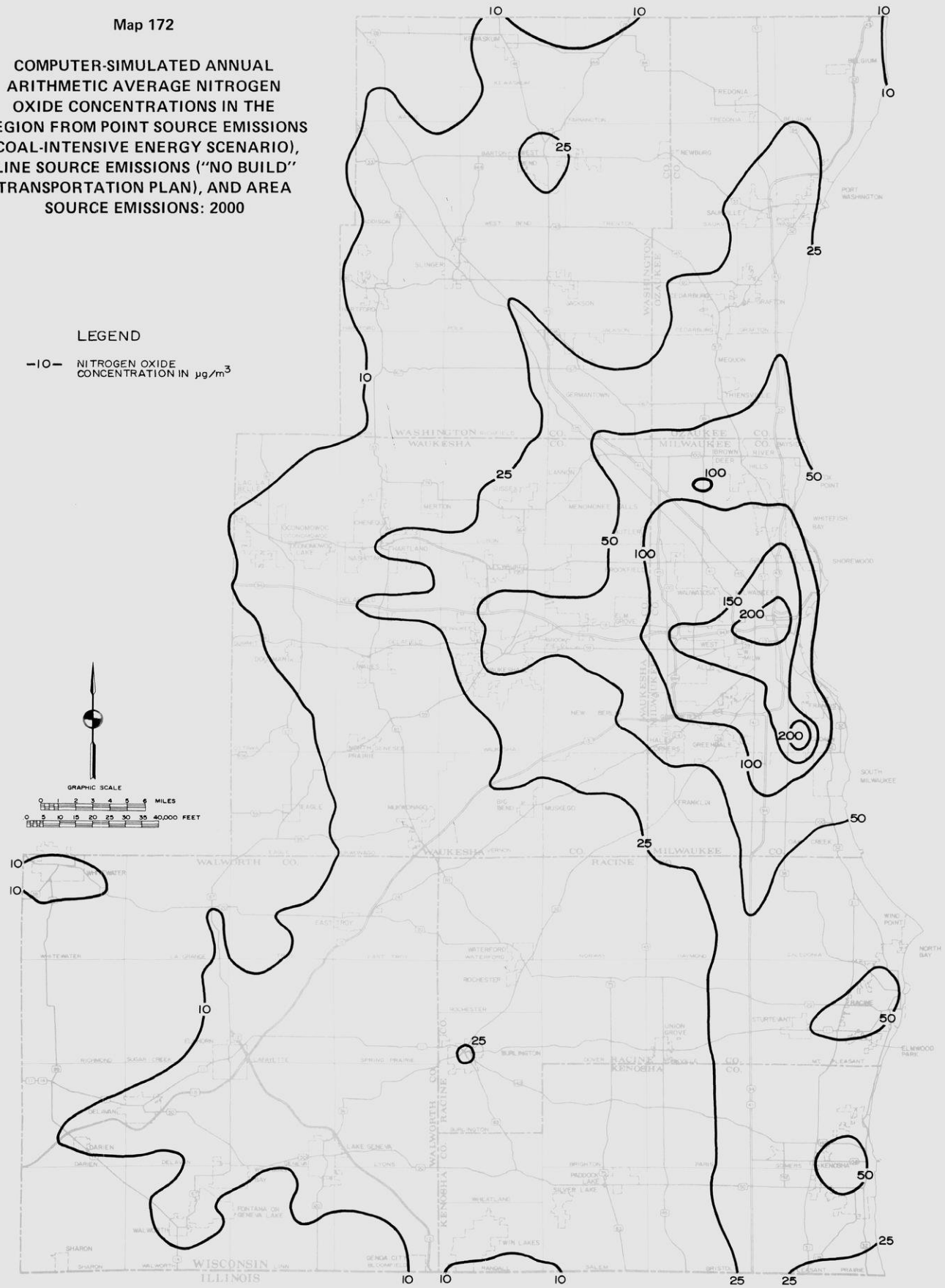


This map illustrates the composite impact of forecast point, line, and area source nitrogen oxide emissions on ambient air quality in the Region in 1985. The concentrations shown on this map are derived from forecast emissions data as anticipated under the coal-intensive energy scenario, which assumes that natural gas supplies will not be available to meet total industrial energy demand, and the 1985 stage of the "no build" transportation plan. The highest isopleth value shown on this map is 200 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and is located over central Milwaukee County. As may be seen by comparing this map with Map 170, an approximate 3.5-square-mile, or 55 percent, decrease in the extent of the area encompassed by the maximum isopleth value may be expected between 1982 and 1985.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 172

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE NITROGEN OXIDE CONCENTRATIONS IN THE REGION FROM POINT SOURCE EMISSIONS (COAL-INTENSIVE ENERGY SCENARIO), LINE SOURCE EMISSIONS ("NO BUILD" TRANSPORTATION PLAN), AND AREA SOURCE EMISSIONS: 2000



This map illustrates the composite impact of forecast point, line, and area source nitrogen oxide emissions on ambient air quality in the Region in the year 2000. The concentrations shown on this map are derived from emissions data as anticipated under the coal-intensive energy scenario, which assumes that natural gas supplies will not be available to meet total industrial energy demand, and the "no build" transportation plan. The highest isopleth values shown on this map are 200 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and are located in central Milwaukee County and around General Mitchell Field. As may be seen by comparing this map with Map 171, the area encompassed by the maximum isopleth of 200 $\mu g/m^3$ in the year 2000 is approximately 2.3 square miles larger than the corresponding area in 1985. This increase may be attributed to forecast increases in vehicle miles of travel, which are expected to offset the reductions in emissions anticipated under the federal motor vehicle emissions control program, and to forecast increases in commercial jet aircraft operations at General Mitchell Field.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

tored at 711 W. Wells Street in the City of Milwaukee. This concentration is well below the air quality nitrogen dioxide standard of 100 $\mu g/m^3$. For the same year, computer modeling results indicated a maximum annual average nitrogen oxide concentration of 300 $\mu g/m^3$. This concentration was indicated to be located over the Marquette Interchange, which is near the Wells Street monitoring site. Assuming that there is a direct relationship between monitored nitrogen dioxide levels and computer-simulated nitrogen oxide concentrations, maximum annual average nitrogen dioxide concentrations in the Region should not exceed the air quality standard of 100 $\mu g/m^3$ over the planning period, and should in fact decline by 1982 to about two-thirds of the 70 $\mu g/m^3$ maximum level monitored during 1977. It may be concluded, therefore, that neither a short-term attainment plan nor a long-term maintenance plan will be required to ensure safe levels of nitrogen dioxide in the Region over the planning period.

FORECAST HYDROCARBON CONCENTRATIONS: 1982, 1985, AND 2000

Like nitrogen oxides, hydrocarbons are photochemically reactive in the ambient air. Thus, the simulation modeling effort for forecast levels of this pollutant species represents only a generalized depiction of the dispersion characteristics of hydrocarbons in the atmosphere over the Region. The results of this forecast modeling effort are shown on Map 173 for 1982, on Map 174 for 1985, and on Map 175 for the year 2000.

As may be seen by comparing Map 173, which depicts the maximum three-hour (6:00 a.m. to 9:00 a.m.) hydrocarbon concentrations in the Region as forecast for the year 1982, with Map 81 in Chapter XI, which depicts the corresponding concentrations during 1977, a significant decrease in hydrocarbon levels in the Region may be expected over this five-year period. Whereas in 1977 a 90-square-mile area in Milwaukee County was anticipated to exceed the three-hour average ambient air quality standard for hydrocarbons—160 micrograms per cubic meter ($\mu g/m^3$)—only about 59 square miles are forecast to exceed this standard during 1982. Moreover, by the year 1985 only about 33 square miles are forecast to exceed the hydrocarbon standard in Milwaukee County, as shown on Map 174.

Although hydrocarbon concentrations may be expected to continue to decline in the central portion of Milwaukee County between 1985 and the year 2000, the increase in the emissions of this pollutant species expected to result from increases in commercial aircraft activity at General Mitchell Field will have an increasingly significant impact on ambient air quality in the Region, as may be seen on Map 175. This finding is consistent with the results of the regional hydrocarbon emissions forecasts, which indicate that automobiles and trucks, which significantly influence hydrocarbon concentrations in the early morning hours, may be expected to contribute less to the regional emissions burden of this pollutant species over the planning period, and that aircraft operations at General Mitchell Field may at the same time be expected to contribute more to the regional hydrocarbon emissions burden. Hydrocarbon emissions from automobiles and trucks are expected to decrease from about 47,900 tons in 1977 to about 17,700 tons in the year 2000, while hydrocarbon emissions from aircraft operations in the Region are expected to increase nearly three-fold—from about 1,200 tons in 1977 to about 3,500 tons in the year 2000—principally as a result of increased operations at General Mitchell Field. Although the increase in hydrocarbon emissions expected to result from aircraft operations is much smaller, in absolute terms, than the decrease in such emissions from line sources, the emissions from aircraft operations occur over a very localized area and will have a pronounced impact on ambient air quality in the immediate vicinity of the airport.

FORECAST OZONE CONCENTRATIONS: 1982, 1987, AND 2000

The attainment and maintenance of the ambient air quality standard for ozone—0.12 part per million (ppm) for a maximum one-hour average[11]—is achieved through the control of hydrocarbon emissions, specifically through the control of that class of reactive hydrocarbons known as volatile organic compounds. As detailed in Chapter XI of this report, the results of the Empirical Kinetics Modeling Approach (EKMA) have indicated that a 62 to 74 percent reduction in the 1977 level of those volatile organic compound emissions contributing to the ozone problem in the Region must be achieved in order to attain and maintain this standard in southeastern Wisconsin. In numerical terms, it will be necessary to reduce the approximately 102,200 tons of volatile organic compound emissions contributing to the ozone problem in the Region during 1977 to a maximum level of about 38,800 tons on an annual basis or, at an optimum level, to no more than 26,600 tons on an annual basis if the ozone standard is to be attained and maintained.

Table 310 presents a summary of the forecast volatile organic compound emissions which may be expected to contribute to the ozone problem in the Region in the year 1982—the year for which all primary, or health-related, standards are to be attained—the year 1987—the year to which an extension may be granted for attaining the primary ozone standard—and the year 2000—the plan design year. As may be seen in this table, volatile organic compound emissions are forecast to decrease by about 19,800 tons, or about 19 percent—from about 102,200 tons in 1977 to about 82,400 tons in the year 1982. This

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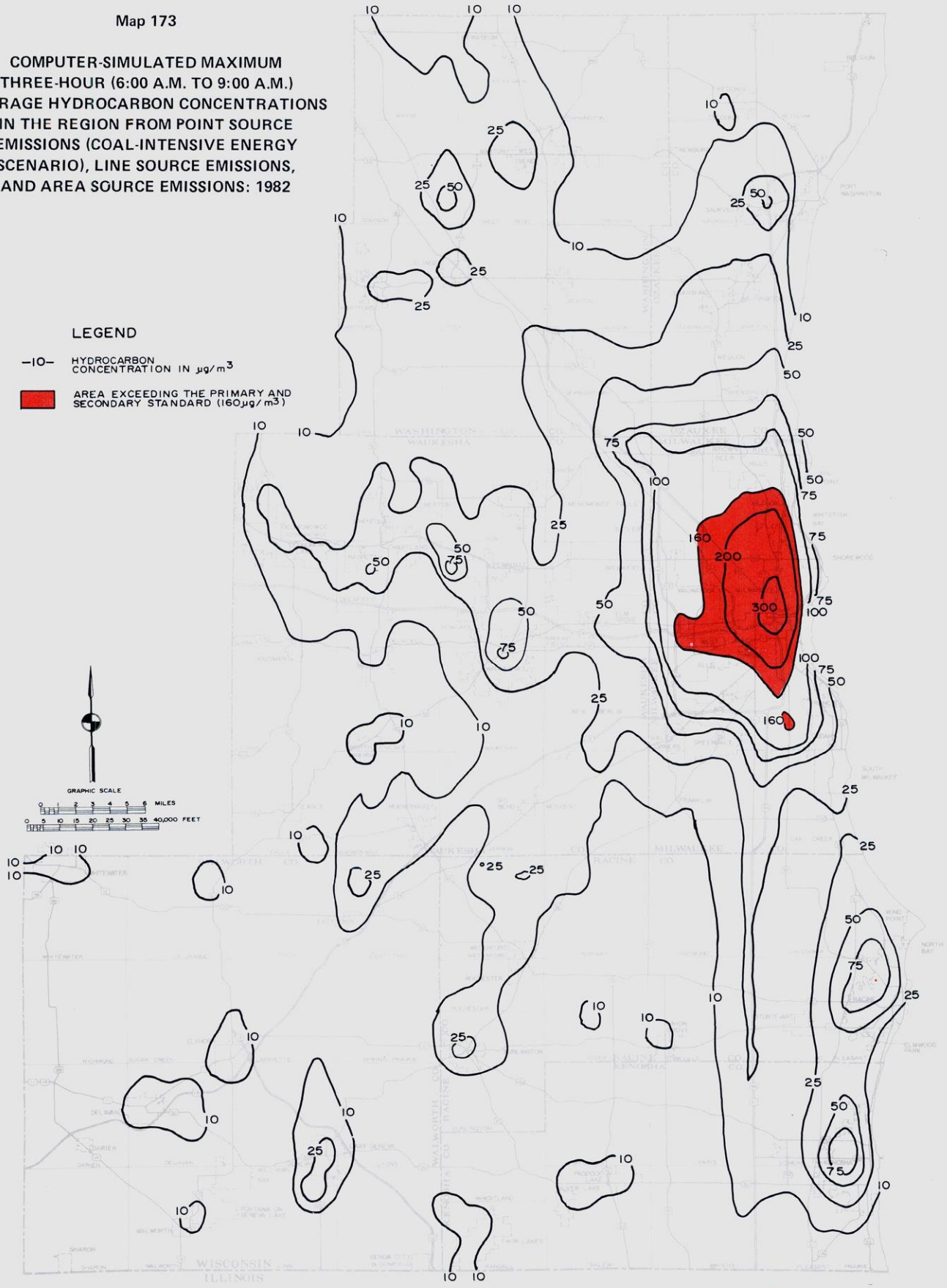
[11] *As noted in Chapter VI, the State of Wisconsin has not yet adopted the federally revised ozone standard of 0.12 ppm, and still defines the ozone standard as 0.08 ppm. It is envisioned, however, that the state ozone standard will be changed to bring it into accordance with the revised federal standard.*

Map 173

COMPUTER-SIMULATED MAXIMUM THREE-HOUR (6:00 A.M. TO 9:00 A.M.) AVERAGE HYDROCARBON CONCENTRATIONS IN THE REGION FROM POINT SOURCE EMISSIONS (COAL-INTENSIVE ENERGY SCENARIO), LINE SOURCE EMISSIONS, AND AREA SOURCE EMISSIONS: 1982

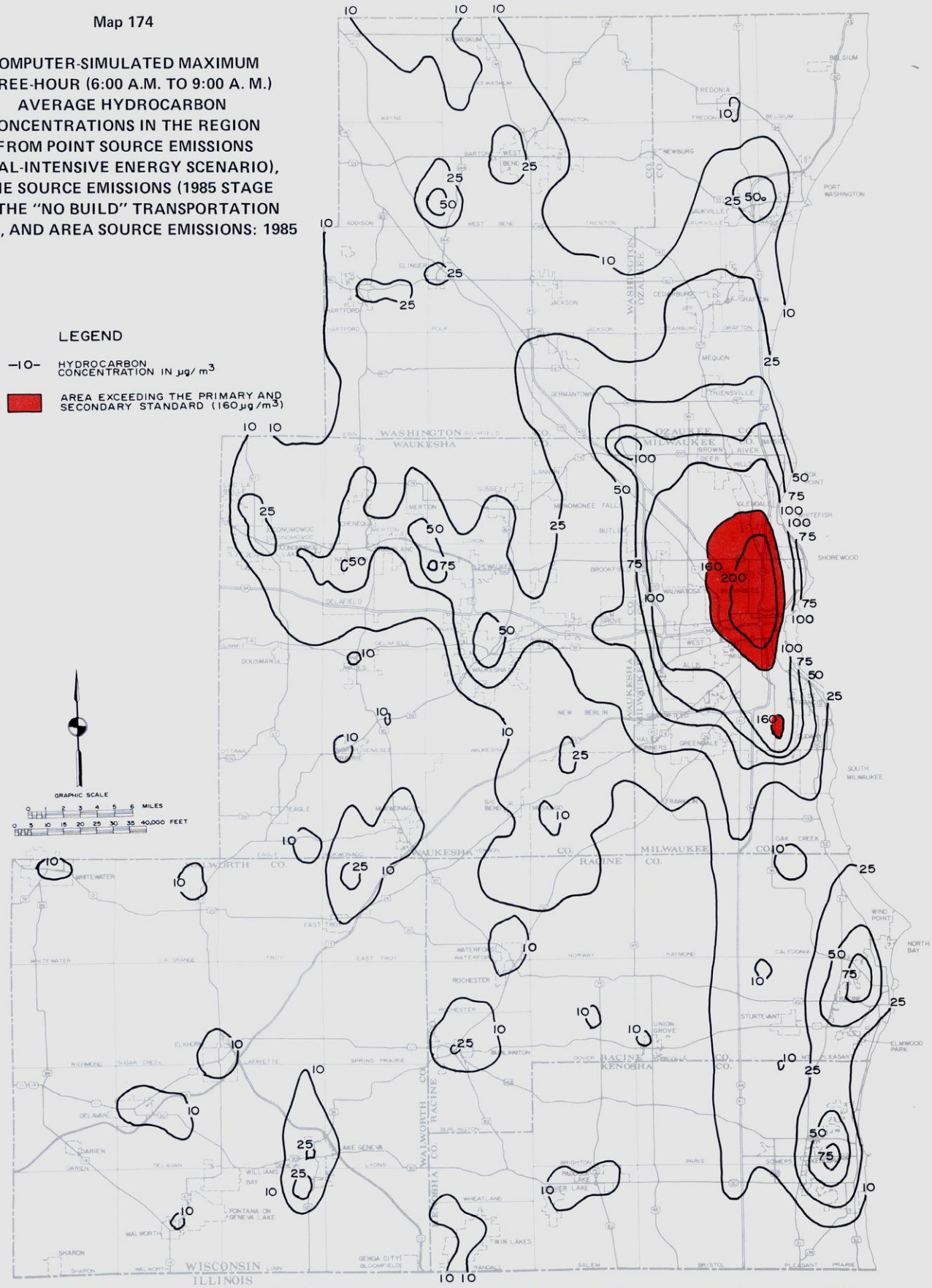


This map illustrates the composite impact of forecast point, line, and area source hydrocarbon emissions on ambient air quality in the Region in 1982 under conditions representative of peak morning travel hours, 6:00 a.m. to 9:00 a.m., and in the assumed absence of photochemical reactions. The concentrations shown on this map are derived from emissions data as anticipated under the coal-intensive energy scenario, which assumes that natural gas supplies will not be available to meet total industrial energy demand. The hydrocarbon ambient air quality standard of 160 micrograms per cubic meter ($\mu g/m^3$), expressed as a three-hour (6:00 a.m. to 9:00 a.m.) average, is shown on this map to be exceeded in two areas, both in Milwaukee County. The largest of the two is a 58-square-mile area in central Milwaukee County. The other area encompasses about one square mile in and around General Mitchell Field. The size of the total area indicated to exceed the standard is about 59 square miles—about 30 square miles less than the area exceeding the standard in 1977. This reduction can be attributed primarily to the continued implementation of the federal motor vehicle emissions control program.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 174

COMPUTER-SIMULATED MAXIMUM THREE-HOUR (6:00 A.M. TO 9:00 A. M.) AVERAGE HYDROCARBON CONCENTRATIONS IN THE REGION FROM POINT SOURCE EMISSIONS (COAL-INTENSIVE ENERGY SCENARIO), LINE SOURCE EMISSIONS (1985 STAGE OF THE "NO BUILD" TRANSPORTATION PLAN), AND AREA SOURCE EMISSIONS: 1985

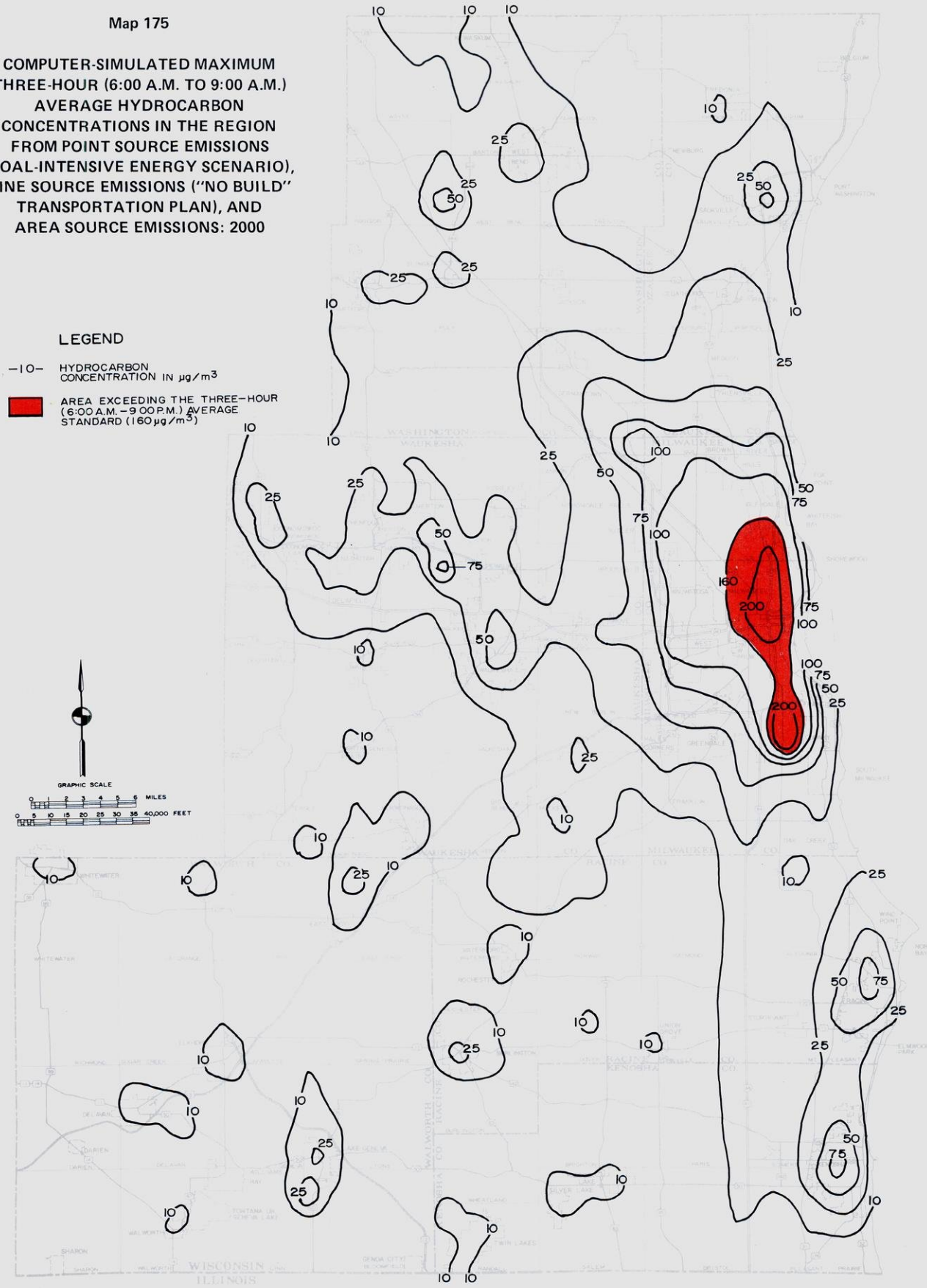


This map illustrates the composite impact of forecast point, line, and area source hydrocarbon emissions on ambient air quality in the Region in 1985 under conditions representative of peak morning travel hours, 6:00 a.m. to 9:00 a.m., and in the assumed absence of photochemical reactions. The concentrations shown on this map are derived from emissions data as anticipated under the coal-intensive energy scenario, which assumes that natural gas supplies will not be available to meet total industrial energy demand, and the 1985 stage of the "no build" transportation plan. The hydrocarbon ambient air quality standard of 160 micrograms per cubic meter ($\mu g/m^3$), expressed as a three-hour (6:00 a.m. to 9:00 a.m.) average, is shown on this map to be exceeded in two areas, both in Milwaukee County. As in 1982 (see Map 173), these two areas encompass portions of central Milwaukee County—about 31 square miles—and General Mitchell Field—about two square miles. This total area of about 33 square miles represents a decrease of about 26 square miles, or about 44 percent, from the 59 square miles indicated as exceeding the standard in 1982. This decrease can be attributed primarily to the continued implementation of the federal motor vehicle emissions control program.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 175

COMPUTER-SIMULATED MAXIMUM THREE-HOUR (6:00 A.M. TO 9:00 A.M.) AVERAGE HYDROCARBON CONCENTRATIONS IN THE REGION FROM POINT SOURCE EMISSIONS (COAL-INTENSIVE ENERGY SCENARIO), LINE SOURCE EMISSIONS ("NO BUILD" TRANSPORTATION PLAN), AND AREA SOURCE EMISSIONS: 2000



This map illustrates the composite impact of forecast point, line, and area source hydrocarbon emissions on ambient air quality in the Region in the year 2000 under conditions representative of peak morning travel hours, 6:00 a.m. to 9:00 a.m., and in the assumed absence of photochemical reactions. The concentrations shown on this map are derived from emissions data as anticipated under the coal-intensive energy scenario, which assumes that natural gas supplies will not be available to meet total industrial energy demand, and the "no build" alternative transportation plan. The hydrocarbon ambient air quality standard of 160 micrograms per cubic meter (mg/m^3), expressed as a three-hour (6:00 a.m. to 9:00 a.m.) average, is shown on this map to be exceeded over a 32-square-mile area in Milwaukee County. This area is about one square mile less in extent than the area exceeding the hydrocarbon standard in 1985, indicating that the hydrocarbon emission reductions anticipated to result from the continued implementation of the federal motor vehicle emissions control program may be offset somewhat by the emissions expected to result from an increase in aircraft operations at General Mitchell Field over the planning period.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

emission rate is approximately 43,600 tons, or about 112 percent, higher than the maximum allowable emission rate of about 38,800 tons per year. Table 310 also indicates that volatile organic compound emissions in the Region will total about 74,500 tons in 1987 and about 82,800 tons in the year 2000. These emission rates are, respectively, about 35,700 tons, or 92 percent, and 44,000 tons, or 113 percent, higher than the maximum allowable emission rate of 38,800 tons per year. It may be concluded, therefore, that a near-term attainment plan and a long-term maintenance plan will be required to control volatile organic compound emissions and in turn achieve the ozone standard in southeastern Wisconsin.

FORECAST POPULATION EXPOSURE TO EXCESSIVE POLLUTANT LEVELS

Based upon the foregoing estimate of air pollutant concentrations in the Region over the planning period, it may be concluded that certain segments of the regional population will be exposed to levels of air pollution deleterious to their health. Specifically, ambient air concentrations of particulate matter and ozone presently occur, and are expected to continue to occur, over the planning period at levels harmful to human health. Moreover, carbon monoxide concentrations on an eight-hour average basis have been monitored in parts of the Region at levels in excess of the health-related standard, and may be expected to continue to be excessive at least through the year 1982. In addition, based upon the forecast increase in sulfur dioxide emissions in the Region over the planning period, it is estimated that the annual average standard for this pollutant species will be exceeded in portions of southeastern Wisconsin by the year 2000. Under the assumption that the distribution of population in the Region will be in accordance with the Commission's adopted land use plan, an estimate was made of the regional population which may be exposed to excessive air pollutant concentrations.

The air quality simulation modeling results indicated that about 17 square miles in the Region—about five square miles in Milwaukee County and about 12 square miles in Waukesha County—exceeded the primary annual average ambient air quality standard for particulate matter in 1977. About 65,600 persons—about 54,800 persons in Milwaukee County and 10,800 persons in Waukesha County—resided within the 17-square-mile area in the Region exceeding this health-related standard during 1977. In the absence of further particulate matter emission controls, the primary particulate matter problem area in the Region is expected to increase to about 25 square miles—about 11 square miles in Milwaukee County and about 14 square miles in Waukesha County—by the year 2000. It is forecast that about 152,100 persons—about 129,700 persons in Milwaukee County and about 22,400 persons in Waukesha County—will reside within this 25-square-mile area in the year 2000. Other segments of the regional population are experiencing particulate matter concentrations in excess of the primary 24-hour average ambient air quality standard. Since the location, magnitude, and areal extent of particulate matter concentrations vary significantly from day to day, however, it is not possible to estimate with any precision the population exposed to excessive short-term particulate matter levels.

As noted in Chapter XI, the simulation modeling effort indicated that the eight-hour average carbon monoxide standard was exceeded over a 21-square-mile area in Milwaukee County during 1977. This area has an estimated resident population of 267,800 persons. It was noted earlier in this chapter that the area in Milwaukee County exceeding the eight-hour average carbon monoxide standard is forecast to decrease in size to about three square miles by 1982. It was also noted that the eight-hour average carbon monoxide standard is expected to be completely attained by 1985. Thus, it is estimated that about 43,800 persons will be exposed to excessive carbon monoxide concentrations in the Region in 1982. Thus, by 1985, no segment of the regional population is expected to be exposed to harmful carbon monoxide levels.

Five counties in the Southeastern Wisconsin Region—Kenosha, Milwaukee, Ozaukee, Racine, and Waukesha—have together been formally designated by the U. S. Environmental Protection Agency as a nonattainment area for ozone. Walworth and Washington Counties are presently designated as "unclassifiable" because of the lack of ozone monitoring data for these two counties. Because of the many violations of the ozone standard monitored in surrounding counties, however, it is likely that Walworth and Washington Counties also exceed the ambient air quality ozone standard on occasion. It may, therefore, be concluded that the entire regional population—about 1,777,900 persons in 1977—is exposed to harmful levels of ozone during portions of the summer months. If, as expected, ozone standard violations persist in all counties in the Region over the planning period, the year 2000 population of about 2,219,300 persons will be exposed to excessive ozone levels.

Annual average levels of sulfur dioxide in excess of the established primary ambient air quality standard do not presently occur in the Region. By the year 2000, however, the primary annual average standard is forecast to be exceeded over a 10-square-mile area in Milwaukee County. This area is forecast to have a resident popula-

Table 310

SUMMARY OF EXISTING AND FORECAST VOLATILE ORGANIC COMPOUND EMISSIONS IN THE REGION: 1977, 1982, 1987, AND 2000

Source Category	Emissions (tons)			
	1977	1982	1987	2000
Stationary	53,499	51,615	52,711	56,656
Mobile	42,665	24,436	15,275	16,481
Miscellaneous	5,999	6,301	6,491	9,612
Total	102,163	82,352	74,477	82,749

Source: SEWRPC.

tion of about 130,300 persons. Although violations of the primary 24-hour average sulfur dioxide standard were monitored in parts of Milwaukee County during 1977 and 1978, the areal extent of such violations, and thus the population at risk, cannot be determined.

In summary, certain segments of the regional population are presently exposed to harmful levels of particulate matter, carbon monoxide, ozone, and short-term average levels of sulfur dioxide. In the absence of further air pollution controls, portions of the regional population may be expected to continue to experience exposure to harmful levels of particulate matter, sulfur dioxide, and ozone. Only carbon monoxide is anticipated to be lowered to safe levels because of existing controls—principally, the federal motor vehicle emissions control program.

SUMMARY

A fundamental step in the air quality attainment and maintenance planning process is the identification of the extent and magnitude of the existing as well as probable future air pollution problems within the planning area. In order to determine the nature of future ambient air quality, it is necessary to first prepare forecasts of those factors which have a direct influence on the generation of air pollutant emissions. Those factors which have been identified as having a direct influence on the discharge rate from, or the location of, air pollutant emission sources, and for which forecasts have been prepared to the year 2000, include population, economic activity, land use development, transportation facilities and utilization, and energy availability and demand. Forecasts of these factors provide a basis upon which forecasts of air pollutant emissions from point, line, and area sources in the design and intermediate years can be prepared and ultimately, through the use of air quality simulation modeling techniques, upon which future air quality problems in the Region can be spatially and temporally defined.

It is important to note that several air pollutant emissions forecasts, representing a range of alternative futures, were prepared. Specifically, alternative emissions forecasts were prepared under alternative assumptions concerning the use of natural gas, fuel oil, and coal as primary energy sources for industrial purposes. Also, emissions forecasts were prepared under both the adopted regional transportation plan and the "no build" alternative to that plan. In terms of both total air pollutant emissions and ambient air quality, the "worst case" conditions were generally found to occur under the coal-intensive energy scenario for emissions from point sources and under the "no build" transportation alternative for emissions from line sources. The "worst case" conditions for emissions from area sources, for which only one set of forecasts was prepared because of the diverse nature characteristic of such individually small sources, were based on an assumption that natural gas supplies would be insufficient to meet residential and commercial-institutional demand after the year 1980.

Below is a summary of the growth and development expected in the Region to the year 2000, and of the impact that such growth and development is expected to have on future ambient air quality in southeastern Wisconsin.

1. The population of the Region may be expected to increase by up to 460,000 persons, or to about 2.22 million persons, by the year 2000—an increase of about 26 percent over the 1970 enumerated regional population of about 1.76 million persons.

2. Employment in the Region, a measure of economic activity, may be expected to reach 1,016,000 jobs by the year 2000—an increase of about 274,000 jobs, or about 37 percent, over the 1970 employment level of about 742,000 jobs.

3. About 113 square miles of land in the Region may be expected to be converted from rural to urban use by the year 2000. Thus, 23 percent of the Region would be devoted to urban uses in the year 2000 as compared with 19 percent in 1970.

4. Under the adopted regional transportation plan, the arterial street and highway system mileage would total about 3,526 miles in the year 2000—an increase of about 516 miles, or about 17 percent, over the 3,010 miles existing in 1972.

5. Average weekday vehicle miles of travel in the Region for all vehicle types may be expected to total 32.8 million miles by the year 2000 under the adopted regional land use and transportation plans—an increase of about 7.6 million miles, or about 30 percent, over the estimated 25.2 million vehicle miles of travel per average weekday in 1977.

6. Average weekday vehicle miles of travel for urban mass transit vehicles in the Region may be expected to total about 198,600 miles by the year 2000 under the adopted regional land use and transportation plans—an increase of about 129,900 miles, or 189 percent, over the estimated 68,700 vehicle miles of travel in 1977.

7. In the year 2000, natural gas supplies may not be available in sufficient quantities to meet the demand of industrial users. In order to define the "worst case" conditions for air quality attainment and maintenance planning purposes, primary energy requirements for major industrial uses were assumed to be met through the combustion of coal.

8. Total particulate matter emissions from all sources in the Region in the year 2000 may be expected to reach about 34,800 tons under the "worst case" conditions—an increase of about 4,300 tons, or 14 percent, over the 30,500 tons emitted during 1977.

9. Total sulfur dioxide emissions from all sources in the Region in the year 2000 may be expected to reach about 227,600 tons under the "worst case" conditions—an increase of about 16,700 tons, or about 8 percent, over the 210,900 tons emitted during 1977.

10. Total carbon monoxide emissions from all sources in the Region in the year 2000 may be expected to reach about 271,700 tons under the "worst case" conditions—a decrease of about 327,100 tons, or nearly 55 percent, from the 598,800 tons emitted during 1977.

11. Total nitrogen oxide emissions from all sources in the Region in the year 2000 may be expected to reach about 146,600 tons—an increase of about 32,300 tons, or about 28 percent, over the 114,300 tons emitted during 1977.

12. Total hydrocarbon emissions from all sources in the Region in the year 2000 may be expected to reach about 120,000 tons under the "worst case" conditions—a decrease of about 12,400 tons, or 9 percent, from the 132,400 tons emitted during 1977.

13. The primary annual geometric average standard for particulate matter of 75 micrograms per cubic meter may be expected to be exceeded over an 11-square-mile area in Milwaukee County and a 14-square-mile area in Waukesha County in the year 2000. In addition, the secondary annual average particulate matter standard of 60 micrograms per cubic meter may be expected to be exceeded over a 75-square-mile area in Milwaukee County, a 28.5-square-mile area in Waukesha County, and a less than one-square-mile area in Racine County in the year 2000.

14. Both the primary and secondary 24-hour average particulate matter standards—260 and 150 micrograms per cubic meter, respectively—may be expected to be exceeded in parts of Milwaukee County and Waukesha County in the year 2000.

15. The primary annual average sulfur dioxide standard of 80 micrograms per cubic meter may be expected to be exceeded over a 10-square-mile area in Milwaukee County in the year 2000. In addition, it is anticipated that violations of both the 24-hour average and three-hour average sulfur dioxide standards—365 and 1,300 micrograms per cubic meter, respectively—will continue to occur within the Region throughout the forecast period.

16. The primary one-hour average carbon monoxide standard of 40 milligrams per cubic meter is not expected to be exceeded anywhere in the Region in the year 2000. However, the primary eight-hour average carbon monoxide standard of 10 milligrams per cubic meter will probably be exceeded in Milwaukee County until 1985. In 1985 and thereafter, the reductions in emissions resulting from implementation of the federal motor vehicle emissions control program may be expected to lead to full attainment and maintenance of this standard.

17. The primary annual average nitrogen dioxide standard of 100 micrograms per cubic meter is not expected to be exceeded anywhere in the Region in the year 2000.

18. The primary and secondary three-hour average hydrocarbon standard of 160 micrograms per cubic meter is expected to be exceeded over a 32-square-mile area in central Milwaukee County in the year 2000—a decrease of about 58 square miles, or about 64 percent, from the 90-square-mile area exceeding this standard in 1977.

19. The primary one-hour average ozone standard of 0.12 part per million may be expected to be exceeded on occasion throughout the entire Region in the year 2000 at the present level of control. This conclusion is based on the 19 percent reduction in volatile organic compound emissions forecast to occur between 1977 and the year 2000—far less than the approximately 62 to 74 percent reduction needed to attain and maintain the ozone standard as determined through use of the Empirical Kinetics Modeling Approach.

20. An estimated 152,100 persons will reside in the 25-square-mile area of the Region expected to experience harmful annual average particulate matter concentrations in the year 2000. In addition, an estimated 130,300 persons will reside in the 10-square-mile area of the Region expected to experience harmful annual average sulfur dioxide concentrations in the year 2000. Finally, any person residing in southeastern Wisconsin in the year 2000 may be occasionally exposed to excessive ozone levels during the summer months.

In order to resolve the air pollution problems that are anticipated within the Region over the next two decades, it will be necessary to design, test, and evaluate control strategies for the attainment and maintenance of those pollutant species forecast to occur at harmful levels over the planning period. Table 311 presents the attainment plan and the maintenance plan requirements for each pollutant species by the averaging time corresponding to the ambient air quality standards.

As indicated in Table 311, nitrogen dioxide is the only pollutant species for which neither an attainment plan nor a maintenance plan is required to meet the ambient air quality standard in southeastern Wisconsin. Carbon monoxide is the only other pollutant species for which a long-term maintenance plan is not required, assuming, of course, that the eight-hour average standard presently violated has been attained. Sulfur dioxide is the only pollutant species for which a long-term plan is required to maintain the annual average standard, but not to attain that standard. Both an attainment and a maintenance plan are required to meet the short-term average sulfur dioxide ambient air quality standards, as well as to meet

Table 311

SUMMARY OF ATTAINMENT AND MAINTENANCE PLAN REQUIREMENTS BY POLLUTANT AND AVERAGING PERIOD

Pollutant	Averaging Period	Attainment Plan Required	Maintenance Plan Required
Particulate Matter. . .	Annual 24 hour	Yes Yes	Yes Yes
Sulfur Dioxide.	Annual 24 hour 3 hour	No Yes Yes	Yes Yes Yes
Carbon Monoxide. . .	8 hour 1 hour	Yes No	No No
Nitrogen Dioxide . . .	Annual	No	No
Hydrocarbons[a]	3 hour	Yes	Yes
Ozone[a].	1 hour	Yes	Yes

[a] *Since attainment and maintenance of the ozone standard are addressed through controls on hydrocarbon emissions, specifically volatile organic compounds, plan requirements for ozone and hydrocarbons are essentially the same, and attainment and maintenance plans for these two pollutants may be prepared jointly.*

Source: SEWRPC.

the short-term and long-term ambient air quality standards for particulate matter, hydrocarbons, and ozone. Chapter XIII discusses the design, testing, and evaluation of the required attainment and maintenance plans, and provides a description of the recommended attainment and maintenance plan for each pollutant species.

Chapter XIII

ALTERNATIVE AND RECOMMENDED PLANS

INTRODUCTION

Previous chapters in this report have identified existing and potential air pollution problems in the Southeastern Wisconsin Region. Specifically, a need has been established to prepare pollution abatement plans which will ensure either the short-term attainment or long-term maintenance—or both—of the federally prescribed particulate matter, sulfur dioxide, carbon monoxide, and ozone ambient air quality standards. The purpose of this chapter is to evaluate the alternative methods through which air pollutant emissions in the Region may be reduced to the levels that will result in ambient air pollutant concentrations at or below the health-related and welfare-related standards, and to recommend the most cost-effective means of providing clean air in southeastern Wisconsin through the year 2000.

The Wisconsin Atmospheric Diffusion Model was used as the principal analytical tool in evaluating alternative control strategies for nonreactive pollutant species. The alternative and recommended attainment and maintenance plans for particulate matter and for sulfur dioxide are thus based in large part on the use of this model. The carbon monoxide attainment plan is based on emission reductions anticipated to be achieved through the implementation of selected transportation control measures rather than on simulation modeling, since only localized areas in the Region are adversely affected by excessive levels of this pollutant species. The ozone attainment and maintenance plan is based on the control of hydrocarbon emissions—specifically, volatile organic compounds—and is evaluated by comparing the emission reductions to be achieved through proposed pollution abatement actions with the emission reductions determined to be required using the Empirical Kinetics Modeling Approach (EKMA). The recommended plans for each of these pollutant species are presented in the following sections of this chapter.

AIR POLLUTION CONTROL: AN OVERVIEW

The present approach to air pollution control in the United States is based on the promulgation of ambient air quality standards which are enforced through legally prescribed limitations on emissions from identified pollutant source categories. Conceptually, the emission limitation may be assumed to be one of two types: pervasive and restrictive. Within each of these two types of emission limitations, several further distinctions can be made.

The pervasive emission limitations, as the term implies, extend throughout broad geographic areas such as the entire United States, or throughout entire states of the United States, without spatial or temporal constraints of any kind. Five forms of pervasive emission limitations can be identified. The first and most prevalent form of pervasive emission limitation is the quantitative limitation, which specifies the allowable amount of a pollutant species that may be released into the atmosphere in terms of a process weight rate, heat input, or any similar unit of activity related to the source being controlled. For example, a new 1978 model year automobile may not emit more than 1.5 grams of hydrocarbons per vehicle mile of travel as determined under the Federal Test Procedure (FTP). Similarly, state regulations limit the amount of particulate matter emissions from fuel-burning installations with a heat input of more than 250 million British thermal units (BTU's) per hour in the Southeastern Wisconsin Region to 0.15 pound per million BTU heat input.

A second form of pervasive emission limitation places constraints on the pollutant content in primary fuels prior to combustion. Requiring the removal of lead compounds from gasoline—a measure which reduces the exhaust rate of particulate matter emissions from gasoline-powered motor vehicles—is an example of this type of emission limitation, as is prescribing limits on the sulfur content in the coal or fuel oil which is to be used by fuel-burning installations.

A third form of pervasive emission limitation is the visible emission limitation, which indirectly limits an emission rate by limiting the opacity of the effluent being discharged from a source. During the late nineteenth century, the Ringelmann Chart was accepted as the standard measure of smoke density for power plant testing by the American Society of Mechanical Engineers. The Ringelmann system is a scheme whereby smoke being emitted from a stack is compared with five shades varying between black and white on a graduated chart, the shades being accurately reproduced by means of a rectangular grid of black lines of definite width and spacing on a white background. The system is empirical in nature and has drawbacks. The apparent opacity of a stack plume is dependent upon not only the concentration of the particulate matter in the effluent, but also the size of the particles, the depth of the smoke plume under investigation, the color of the particles, and natural lighting conditions such as the direction of the sun relative to the observer. Despite such limitations, the Ringelmann Chart is still widely used today. In Wisconsin, visible emission limitations stipulate that emission sources are not to have a shade or density greater than number one on the Ringelmann Chart, which corresponds to a 20 percent opacity level.[1]

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[1] *Wisconsin Administrative Code, Chapter NR 154, Section NR 154.11(6)(a)1.*

A fourth type of pervasive emission limitation is the prohibitive limitation. An example of this type of limitation is the prohibition of open burning of leaves, agricultural wastes, and other combustible solid waste products. This type of prohibition is considered an emission limitation since it forces the use of other technology—such as landfill or closed incineration—to dispose of such wastes. With certain exceptions, the State of Wisconsin prohibits the open burning of solid wastes.[2]

The fifth form of pervasive emission limitation is commonly called the "best technology" limitation. This type of limitation simply requires all sources of a particular classification to use a prescribed process or method for controlling emissions. Generally, the required process or method is that which provides for the lowest emission rate as demonstrated through application and observed operating performance on existing facilities of a similar classification. For example, the State of Wisconsin presently requires that gasoline stored in quantities of 40,000 gallons or more be contained in a floating-roof tank. Although it is difficult to directly measure the emissions released from a floating-roof tank, it has been determined from engineering studies that, when well maintained, such a tank releases fewer emissions than a fixed-roof tank. This type of emission limitation, therefore, mandates the best technology available without actually specifying an emission limitation.

The underlying premise in defining a pervasive emission limitation is that there exists a level of control which can and should be met by all pollutant emission sources of a particular classification. With the possible exception of the prohibitive type of emission limitation, however, pervasive emission limitations are subject to several drawbacks which act to preclude full assurance that the ambient air quality standards will indeed be attained and maintained if this type of limitation is enforced. There is the potential, for example, for the ambient air quality standards to be exceeded if many pollutant sources—each emitting at the rate prescribed by the applicable pervasive limitations—are concentrated in a given area. Also, during periods of stagnating meteorological conditions the buildup of nondispersed air pollutants may be such that the ambient air quality standards will be exceeded, even with all sources contributing at the controlled pervasive emission rate. Certain additional emission limitations may, therefore, be necessary to serve as an adjunct to the pervasive emission limitations. These additional limitations may be termed restrictive emission limitations, since they may be spatially or temporally restricted as to application. An example of a temporally restrictive emission limitation is the State of Wisconsin requirement that all air pollution sources which emit 0.25 ton per day or more of any pollutant species for which air quality standards have been promulgated prepare emission control action programs for reducing the amount of contaminants released to the atmosphere during periods of an air pollution alert, air pollution warning, or air pollution emergency.[3] During these periods a source may release pollutants only during specific hours—such as between 12:00 noon and 4:00 p.m. during an air pollution alert—and the source may be required to cease operating entirely during an air pollution emergency. A restrictive emission limitation of this type is not directly related to an established pervasive emission limitation.

One form of restrictive emission limitation is emission density zoning. Under emission density zoning, a maximum rate of emission of an air pollutant is established with relation to geographic location, land use zoning, and existing ambient air quality levels. Under the emission density zoning approach, a region would be subdivided into areas of varying emission density limits. These emission density limits would be specified in terms of a maximum emission rate allowed per unit of time per unit of land area—for example, grams of particulate matter per second per acre. Any land use permitted by the existing land use zoning ordinance would continue to be allowed, but a source would not be allowed to emit more pollutants than the limit established for the parcel of land on which it is located. Emission density limits should be established on the basis of careful consideration of local population concentrations, prevailing meteorological conditions, the distribution of existing air pollutant emission sources, and existing ambient air quality levels. The underlying premise of emission density zoning is that the atmosphere has a certain assimilative capacity, or ability, to cleanse itself, which is dependent on local meteorology, and on the types and concentrations of pollutants in the air. The principal disadvantage of the emission density zoning approach is that it may place a constraint on desired economic growth in a geographic area. If, for example, a single major air pollution source in an identified zone were emitting up to the established emission density limit for that zone, no other source could be constructed within the defined area, despite the fact that necessary municipal services were provided and growth was desired in that zone. Moreover, a major industry could presumably purchase a substantially greater amount of land area in a zone than actually required for operation in order to be able to emit pollutants at a higher rate and still be within the allowable emission density limit per unit of land area in the zone. This first come-first served approach has certain negative implications for long-range economic planning and, consequently, has not been adopted anywhere in the United States at the present time.

A second form of restrictive emission limitation is an emission offset policy. An emission offset policy—which was described in Chapters II and III of this report—may

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[2] *Wisconsin Administrative Code, Chapter NR 154, Section NR 154.10.*

[3] *Wisconsin Administrative Code, Chapter NR 154, Section NR 154.20(2)(a). The criteria for the designation of an air pollution alert, air pollution warning, and air pollution emergency are set forth in Chapter VI of this report.*

be defined as a regulation requiring any new or modified source in an area not meeting the ambient air quality standards to provide for a reduction in emissions in the area greater than the emissions that the proposed source would produce at its Lowest Achievable Emission Rate. Under an emission offset policy, new growth and development can occur in any area not attaining the air quality standards, unless such development is precluded by land use zoning.

A third form of restrictive emission limitation is the Prevention of Significant Deterioration regulation. This type of regulation limits the impact that a new or modified source can have on ambient air quality by defining a maximum allowable ambient air concentration of a particular pollutant species which may be produced by a source. A new or modified source, for example, would not be permitted to singly contribute more than five micrograms per cubic meter of particulate matter to the ambient air on an annual geometric average basis in an area where moderate, well-controlled growth could be tolerated. Significant deterioration regulations—which were described in Chapters II and III of this report—act to allow growth and development while still maintaining the integrity of the ambient air.

A fourth form of restrictive emission limitation involves the promulgation and enforcement of differential emission standards between areas which are in attainment with the ambient air quality standards and those which exceed the standards. Under this limitation, air pollution sources in nonattainment areas are required to apply a more stringent level of control to meet emission standards than are sources in attainment areas. An air pollution source in a nonattainment area, for example, may be required to meet an emission limitation defined by the level of pollution released after the application of Reasonably Available Control Technology (RACT). The RACT emission limitation is generally determined on a source-by-source basis, and takes into account the technological and economic feasibility of implementing applicable control devices. A new or modified source to be built in a nonattainment area may be required to meet an emission limitation defined on a source-by-source basis as the Lowest Achievable Emission Rate (LAER). LAER, unlike RACT, does not take economic considerations into account. A new or modified source to be built in a clean air area may be required to meet an emission limitation defined by the level of pollution released after the application of Best Available Control Technology (BACT). The BACT level of control does take economic considerations into account. The underlying concept in differentiating between attainment and nonattainment areas when specifying emission limitation requirements is that it is neither necessary nor beneficial to unduly impose rigorous controls on sources which do not have a deleterious impact on the environment.

In summary, there are five basic types of pervasive emission limitations: the quantitative limitation, the pollutant content limitation, the visible emission limitation, the prohibitive limitation, and the "best technology" limitation. Pervasive emission limitations are based on the assumption that a certain level of control can be met by all pollutant emission sources of a particular classification. Application of such pervasive emission limitations by themselves, however, may not necessarily ensure the attainment and maintenance of ambient air quality standards because of such factors as local meteorological conditions and the density of emission sources. Supplementing the pervasive emissions limitations with restrictive emission limitations may, therefore, be necessary to preclude excessive air pollutant levels. Such restrictive emission limitations include air pollution episode control plans, emission density zoning, emission offset policies, prevention of significant deterioration regulations, and differential emission limitations for sources in nonattainment areas. The alternative and recommended air pollution control strategies described in the following sections constitute combinations of pervasive and restrictive emission limitations required to meet the federally prescribed ambient air quality standards within southeastern Wisconsin.

PARTICULATE MATTER PLAN

The previous two chapters of this report have identified the magnitude and areal extent of the existing particulate matter problem in the Region, based on air quality simulation modeling. The results of this modeling indicate that the primary and secondary annual average and 24-hour average particulate matter ambient air quality standards will continue to be exceeded in the Region through the year 2000 in the absence of further abatement measures. It was therefore deemed necessary to design, test, and evaluate strategies for the short-term attainment and long-term maintenance of the particulate matter standards in southeastern Wisconsin.

Three principal sources of particulate matter pollution have been identified in the Region: industrial processes, fuel-burning installations, and fugitive dust. Accordingly, alternative strategies for the control of particulate matter emissions from these three types of sources were formulated and evaluated, and a recommended particulate matter abatement plan proposed.

Committed Particulate Matter Control Actions

The Clean Air Act Amendments of 1977 require that the State of Wisconsin prepare an implementation plan by July 1, 1979, which provides for the achievement of the primary particulate matter ambient air quality standards by December 31, 1982. In the Southeastern Wisconsin Region, such an implementation plan must be prepared for the 5-square-mile area in Milwaukee County and the 12-square-mile area in Waukesha County, shown on Map 63 in Chapter XI, which have been demonstrated through available air quality monitoring data and the simulation modeling effort to exceed the primary annual average particulate matter standard. The Clean Air Act Amendments of 1977 also require that this State Implementation Plan (SIP) provide for the attainment of the secondary particulate matter ambient air quality standard as expeditiously as possible—generally taken to

mean within three years—after the primary standard has been attained.[4] As shown on Map 63 in Chapter XI, the secondary annual average particulate matter standard is estimated to be exceeded over a 24-square-mile area in Milwaukee County, a 23-square-mile area in Waukesha County, and a less than one-square-mile area in Racine County.

The Clean Air Act Amendments of 1977 mandate that certain control elements be included as an integral part of each SIP to achieve the ambient air quality standards. Specifically, the State must demonstrate the reduction in emissions, and attendant air quality benefits, which may be obtained through the application, at a minimum, of Reasonably Available Control Technology (RACT) on existing sources which lie within, or impact upon, areas exceeding the established standards. The prescribed RACT emission limitations on industrial processes, fuel-burning installations, and fugitive dust sources in attaining the ambient air quality standards, therefore, represent an initial set of strategies for the abatement of particulate matter levels in the Region. The conclusions of the evaluation of these committed actions are presented in the following sections. It should be noted that the federal act requires further actions beyond those contained in the SIP as submitted in July 1979 if such actions are found to be necessary to meet the standards. The committed actions discussed in the following sections do not include any additional actions beyond those contained in the July 1979 SIP.

In addition to the application of RACT emission limitations on existing sources, the Clean Air Act as amended in 1977 requires that limitations be applied on new or modified sources of emissions which desire to locate or expand in either clean air areas or nonattainment areas. In general, major emission sources seeking to locate or expand in clean air areas must ensure the Prevention of Significant Deterioration of ambient air quality in the clean air area.[5] Such sources must install and operate the Best Available Control Technology (BACT) and demonstrate that the allowable increments of pollution—set forth in Table 1 in Chapter II—are not exceeded. New major sources of air pollutant emissions seeking to locate or expand in nonattainment areas are required to install and operate pollution control technology providing for the Lowest Achievable Emission Rate (LAER), and to obtain emission offsets from other sources in the area such that a net air quality improvement can be demonstrated as a result of constructing the new or modified source.

The pollution control requirements which a new or modified source must meet are determined as a part of the New Source Review (NSR) process necessary to obtain a permit to construct from the Wisconsin Department of Natural Resources. Since the NSR process is intended to improve air quality in nonattainment areas and prevent the deterioration of air quality in clean air areas, it is essential to the implementation of the regional air quality attainment and maintenance plan that such a process be effectively implemented and administered. Thus, the NSR process, with its associated BACT emission limitations and Prevention of Significant Deterioration regulations for major sources in clean air areas and LAER emission limitations and emission offset requirements for major sources in nonattainment areas, is considered herein as a committed action. The impact of the NSR process on ambient air quality in the Region over the planning period cannot be directly determined, however, since it affects only new or modified facilities, the development or location of which are generally not known. Notwithstanding this limitation, the NSR process is envisioned to provide an effective implementation mechanism for attaining and maintaining the ambient air quality standards in southeastern Wisconsin.

Determination of RACT Emission Limitations for Point Sources: There are three basic methods for prescribing the allowable emission level under RACT: the efficiency limitation method, the control equipment specification method, and quantitative emission limits method. Under the efficiency limitation method, the allowable RACT emission level is defined by an overall collection efficiency that must be met by each source. Each source is assigned an allowable emission rate based on the amount of particulate matter generated by the source and the collection efficiency applicable to that source. This method is generally not considered viable for defining RACT emission limitations because of the difficulties involved in measuring collection efficiency and because of the large technical support staff required to witness and review stack test results.

Under the control equipment specification method, the allowable RACT emission level is defined by specifying the type of collector that must be installed, operated, and maintained to capture particulate matter in the effluent from each source. This method, accordingly, places constraints on the options available for controlling particulate matter emissions from a source, and is generally considered too inflexible to allow improvement as control technology evolves.

Under the quantitative emission limits method, only the allowable emission rate is specified for each source irrespective of the control efficiency of the equipment selected by the source operator to meet the RACT emission level. Of the three methods for defining RACT

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[4] *The U. S. Environmental Protection Agency has granted the State of Wisconsin an extension, allowing it to prepare and submit a plan by March 1, 1980, for the attainment of the secondary particulate matter ambient air quality standards.*

[5] *A major source is defined as one of the 28 industrial source categories listed in Chapter II which have the potential to emit more than 100 tons of a pollutant species after the application of pollution controls, or any other source which has the potential to emit more than 250 tons of a pollutant species after the application of pollution controls.*

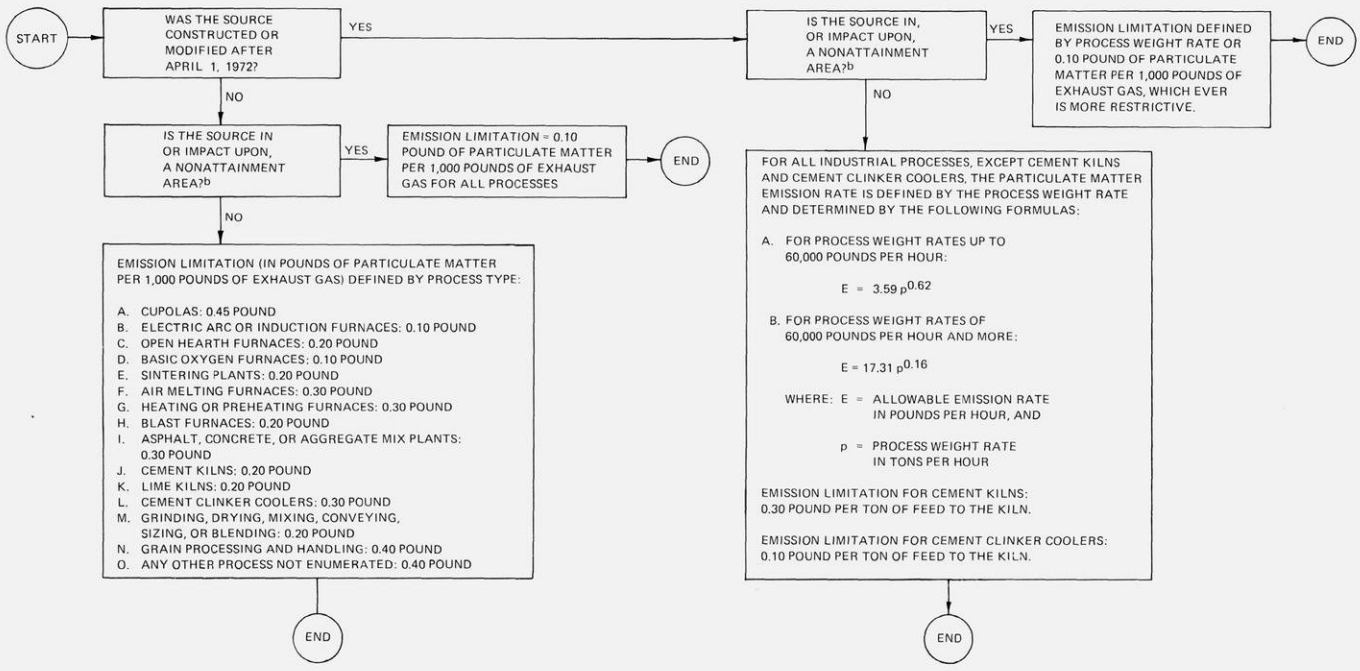
emission limitations, the quantitative emission limits method allows the source owner the greatest flexibility in controlling the particulate effluent, and presents the most effective approach to enforcement since only a stack test on the outlet side of the collector is necessary to determine compliance with the established emission rate.

In defining an RACT emission limitation under the quantitative emission limits method, a specific emission rate standard must be promulgated that can be attained by each industrial process type and each category of fuel-burning installation in a nonattainment area. The first step in the determination of this RACT emission rate standard is to identify the level of control being achieved by existing sources using specific types of air pollution control equipment. The level of control exhibited by existing sources may then be used to define the RACT emission standard. Based on a study of existing industrial facilities in the State of Wisconsin, the Department of Natural Resources has determined that the RACT maximum allowable particulate matter emission rate for industrial process sources should be 0.10 pound of particulate per 1,000 pounds of exhaust gas. The Department has also determined that the RACT maximum emission rate for fuel-burning installations in a nonattainment area should be established at 0.10 pound of particulate matter per million British thermal units (BTU's) for boilers with a heat input of greater than 100 million or more BTU's per hour, and 0.24 pound of particulate matter per million BTU's for boilers with a heat input of less than 100 million BUT's per hour. The implications of these RACT emission limitations as they apply to industrial process sources and fuel-burning installations in the Southeastern Wisconsin Region were evaluated through simulation model analyses.

RACT Emission Limitations for Industrial Process Sources in Southeastern Wisconsin: Figure 105 presents a schematic representation of the proposed RACT emission limitations for industrial process sources in the Region. As may be seen in the figure, the first criterion in determining the applicable emission rate from an industrial process is the date on which the source was constructed or modified. If the source was constructed or modified before April 1, 1972—a date which corresponds to the effective date of the initial Wisconsin SIP—and if the source is not located in a designated nonattainment area, the emission limitation is defined by the process type. For sources that meet this criterion, the allowable particulate matter emission rate may vary between 0.10 pound per 1,000 pounds of exhaust gas for electric arc and induction furnaces, or basic oxygen furnaces, to 0.45 pound per 1,000 pounds of exhaust gas for cupolas. If, however, a source which was con-

Figure 105

SCHEMATIC REPRESENTATION OF PROPOSED PARTICULATE MATTER EMISSION LIMITATIONS FOR INDUSTRIAL PROCESS SOURCES IN SOUTHEASTERN WISCONSIN[a]



[a] *Not including asphalt concrete plants, petroleum refineries, secondary lead smelters, secondary brass and bronze ingot production plants, and iron and steel plants that commenced construction or modification on or after February 1, 1975.*

[b] *A source is considered to impact a nonattainment area if its particulate matter emissions produce an ambient air concentration equal to or greater than one microgram per cubic meter on an annual average basis or equal to or greater than five micrograms per cubic meter on a maximum 24-hour average basis.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

structed or modified before April 1, 1972, lies within, or impacts upon, a designated nonattainment area, as shown on Map 82 in Chapter XI, the RACT emission limitation of 0.10 pound per 1,000 pounds of exhaust gas must be met irrespective of the process type.

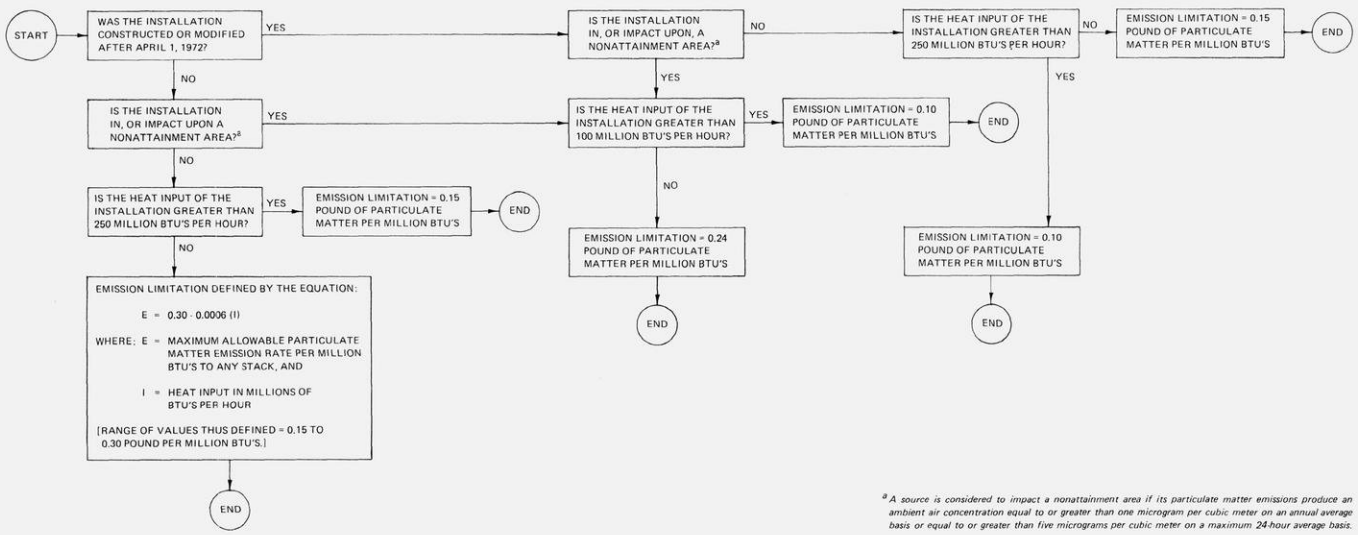
A new source—that is, a source constructed or modified after April 1, 1972—which is not located in, or does not impact upon, a designated nonattainment area must meet a particulate matter emission rate defined by the process weight rate. The relationship between the emission rate and the process weight rate is defined by the equation set forth in Figure 105. Based on this equation, an industrial process having a throughput weight of 50 pounds per hour of raw material has a maximum allowable particulate matter emission rate of 0.36 pound per hour. Similarly, an industrial process with a throughput of 60,000 pounds per hour has a maximum allowable particulate matter emission rate of 29.57 pounds per hour. If, however, the newly constructed or modified source lies within, or impacts upon, a designated nonattainment area, either the RACT particulate matter emission rate of 0.10 pound per 1,000 pounds of exhaust gas or the emission rate defined by the process weight rate—whichever is more stringent—applies to the source irrespective of the process type.

RACT Emission Limitations for Fuel-Burning Installations in Southeastern Wisconsin: Figure 106 presents a schematic representation of the proposed particulate matter emission limitations for fuel-burning installations in the Region. As with the proposed emission limitations for industrial processes, the first criterion in determining the applicable emission rate is the date on which the fuel-burning installation was constructed or modified. If the installation was constructed or modified prior to April 1, 1972, and if it does not lie within or impact upon the boundaries of a designated nonattainment area, the applicable emission rate is determined as a function of the heat input of the facility. If, for example, the fuel-burning installation has a heat input of at least 250 million BTU's per hour, the applicable emission rate would be 0.15 pound of particulate matter per million BTU's. Conversely, if the fuel-burning installation has a heat input value of less than 250 million BTU's per hour, the applicable emission rate would vary between 0.15 pound and 0.30 pound of particulate matter per million BTU's, depending on the facility's actual heat input value. The relationship between the allowable emission rate and the heat input of a fuel-burning installation constructed prior to April 1, 1972, and which does not lie within, or impact upon, a nonattainment area, is given by the equation set forth in Figure 106. An emission rate of 0.10 pound of particulate matter per million BTU's is applicable to fuel-burning installations constructed or modified after April 1, 1972, which do not lie within, or impact upon, a designated nonattainment area, and which have a heat input of more than 250 million BTU's per hour. An emission rate of 0.15 pound of particulate matter per million BTU's is applicable to sources with a heat input value of less than 250 million BTU's per hour.

Irrespective of the construction or modification date of a fuel-burning installation, if one lies within, or impacts upon, a designated nonattainment area, more stringent emission limitations are required. As may be seen in Figure 106, a fuel-burning installation located in, or impacting upon, a designated nonattainment area is required to meet an emission limit of 0.10 pound of

Figure 106

SCHEMATIC REPRESENTATION OF PROPOSED PARTICULATE MATTER EMISSION LIMITATIONS FOR FUEL-BURNING INSTALLATIONS IN SOUTHEASTERN WISCONSIN



[a] A source is considered to impact a nonattainment area if its particulate matter emissions produce an ambient air concentration equal to or greater than one microgram per cubic meter on an annual average basis or equal to or greater than five micrograms per cubic meter on a maximum 24-hour average basis.

Source: Wisconsin Department of Natural Resources and SEWRPC.

particulate matter per million BTU's if the source has a heat input value of 100 million or more BTU's per hour, or to meet an emission limit of 0.24 pound of particulate matter per million BTU's if the source has a heat input value of less than 100 million BTU's per hour.

The Impact of RACT Emission Limitations on Particulate Matter Concentrations Due to Point Sources: Table 312 presents a summary of the particulate matter emissions from point sources in the Region in 1982 as forecast under the RACT emission limitations for industrial process sources and fuel-burning installations by the Wisconsin Department of Natural Resources. For comparative purposes, the point source emissions for 1977 and the forecast emissions for 1982 as anticipated under both the natural gas-intensive and coal-intensive energy scenarios have also been included in Table 312. It should be noted that the particulate matter emissions forecast under the RACT limitations as shown in Table 312 do not reflect any significant growth in industrial activity in nonattainment areas over the 1977 level since the Department of Natural Resources is considering a regulation to require emission offsets to accommodate such growth. The concepts underlying an emission offset policy have been discussed in detail in Chapters II and III of this report. As applied in practice to the Southeastern Wisconsin Region, the proposed emission offset policy would require that any new facility, or an existing facility that is to be substantially modified, which lies within, or impacts upon, a primary or secondary particulate matter nonattainment area—as determined through simulation modeling techniques— obtain a greater emission reduction from sources within the nonattainment area than the new or modified source would itself produce under the most stringent control technology. Such greater than one-for-one emission reductions may be achieved, for example, by paving unpaved roads within or near the proposed new or modified facility, thereby reducing fugitive dust emissions, or through the purchase and installation of control equipment on a previously uncontrolled or less-controlled source in the affected nonattainment area, providing, of course, that the benefiting source was already in compliance with any applicable emission regulations. The exact mechanisms for obtaining the required offset emission reductions, however, would be left to the discretion of the owners or operators of the affected facility, subject to the approval of the Wisconsin Department of Natural Resources. If growth were allowed to occur in nonattainment areas without such an offset provision, the forecast particulate matter emissions in 1982 under the RACT limitations for industrial process and fuel-burning installations would be higher than the 6,754 tons shown in Table 312 under the RACT/offset conditions but below the 7,087 tons as shown for the natural gas-intensive energy scenario.

As presently forecast, approximately 6,754 tons of particulate matter emissions would be released from point sources in the Region in 1982 under the RACT emission limitations. This represents a decrease of about 333 tons, or nearly 5 percent, from the estimated 7,087 tons of particulate matter emissions forecast for 1982 under the natural gas-intensive energy scenario and without RACT controls. The RACT emission forecast represents an even greater decrease from the total emissions forecast under the coal-intensive energy scenario, again without RACT controls or an offset policy. About 1,263 tons, or nearly 16 percent, fewer emissions would be released under the RACT emission limitations than under the coal-intensive energy scenario. Finally, the 1982 forecast of particulate matter emissions under RACT controls represents a decrease of about 678 tons, or about 9 percent, from the 1977 emission level of about 7,432 tons. However, part of this decrease is due to the addition of control measures designed to bring several point sources into compliance with existing regulations, and to the planned cessation of operations at the Lakeside electric power generation plant.

The Wisconsin Atmospheric Diffusion Model was used to simulate the impact of the particulate matter emissions from point sources on ambient air quality in the Region in 1982 under the RACT emission limitations. The results of this modeling effort are shown on Map 176. The maximum isopleth value indicated on Map 176 has a value of two micrograms per cubic meter ($\mu g/m^3$) and encompasses a land area of approximately nine square miles. Under the natural gas-intensive energy scenario, as shown on Map 103 in Chapter XII, and the coal-intensive energy scenario, as shown on Map 105 in Chapter XII, the land area encompassed by the two $\mu g/m^3$ isopleth—again, the maximum isopleth value indicated—is 23 square miles and 51 square miles, respectively. In areal extent, therefore, the ambient air particulate matter concentrations due to forecast point source emissions in 1982 under the

Table 312

FORECAST PARTICULATE MATTER EMISSIONS FROM POINT SOURCES IN THE REGION UNDER PROPOSED RACT EMISSION LIMITATIONS: 1982

County	Emissions (tons)			
	1977	Natural Gas-Intensive Energy Scenario[a]	Coal-Intensive Energy Scenario[b]	RACT/Offset[c]
Kenosha	49	411	527	407
Milwaukee	6,095	5,221	5,990	4,920
Ozaukee	536	538	538	538
Racine	293	316	339	300
Walworth	127	134	156	134
Washington	10	125	125	125
Waukesha	322	342	342	330
Region	7,432	7,087	8,017	6,754

[a] *This forecast is based on existing energy use by major industrial facilities in the year 1977 and does not reflect the impact of Reasonably Available Control Technology, or of an emissions offset policy.*

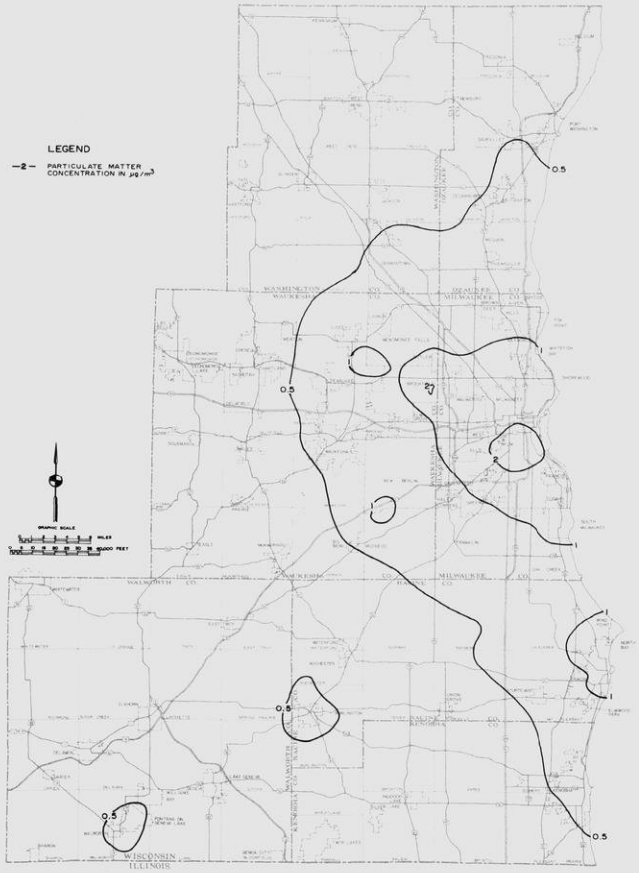
[b] *This forecast is based on the assumption that large industrial users of natural gas will switch to coal as a primary energy source. This forecast does not reflect the impact of Reasonably Available Control Technology, or of an emissions offset policy.*

[c] *This forecast is based on the assumed implementation and enforcement of Reasonably Available Control Technology, and, irrespective of fuel conversions or other modifications, an emissions offset policy.*

Source: Wisconsin Department of Natural Resources.

Map 176

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE PARTICULATE MATTER CONCENTRATIONS IN THE REGION FROM FORECAST POINT SOURCE EMISSIONS UNDER RACT/OFFSET LIMITATIONS: 1982



This map illustrates the impact of particulate matter emissions from point sources on ambient air quality in the Region in 1982 assuming implementation and enforcement of Reasonably Available Control Technology (RACT) emission limitations for industrial process sources and fuel-burning installations in the Region. The maximum isopleth value shown on this map is two micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and encompasses an area of about nine square miles in Milwaukee County. Under the natural gas-intensive energy scenario (see Map 103 in Chapter XII) and the coal-intensive energy scenario (see Map 105 in Chapter XII), the two $\mu g/m^3$ isopleth value—again the maximum particulate matter concentration indicated—encompasses areas of about 23 square miles and about 51 square miles, respectively, in 1982. Thus, the implementation of RACT emission limitations for industrial processes and fuel-burning installations may be expected to result in a significant reduction in the areal extent of maximum particulate matter concentrations in the Region due to forecast point source emissions in 1982.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

RACT limitations represent an improvement over the concentrations forecast under either the natural gas- or coal-intensive energy scenarios.

Because the emission limitations presently in effect for the Region as defined in the existing SIP are quite similar to the proposed RACT regulations, most point sources in the seven-county area will not need to install additional control equipment in order to reduce their emission rates. Estimates prepared by the Wisconsin Department of Natural Resources indicate that only eight industrial facilities will need to install additional particulate matter control equipment in order to achieve compliance with the RACT emission limitations. Under the proposed RACT rules, therefore, point sources will release 5 percent fewer particulate matter emissions than they would under the natural gas-intensive energy scenario. In addition, the proposed RACT rules will serve to reduce the land area affected by the two $\mu g/m^3$ maximum annual isopleth value by about 14 square miles, or about 61 percent.

Determination of RACT Emission Limitations for Fugitive Dust Sources: There are two types of fugitive dust emission sources: common sources and process sources. Common sources are those sources that give rise to fugitive emissions on plant property, but which are not directly related to process operations. Such sources include paved and unpaved roadways, storage piles, and areas subject to vehicular traffic such as automobile and truck parking lots. Common sources also include the handling of raw, intermediate, finished, and waste materials which takes place during the loading, unloading, conveying, screening, grinding, and drying of such materials. Process sources of fugitive dust emissions consist of well-defined process stream flows. Fugitive dust emissions from process sources are released to the atmosphere from leakage, materials charging and handling, and inadequate operational control.

Only within the last few years has fugitive dust been recognized as having a significant impact on ambient air particulate matter concentrations. Consequently, most potential fugitive dust sources have not been quantified by good emission estimation techniques, much less by actual measurement. As a result, fugitive dust emission control techniques have not been advanced to that stage of application wherein a resulting control efficiency may be anticipated with a high degree of confidence. There are, however, certain fugitive dust abatement measures which may be deemed to be Reasonably Available Control Technology. These abatement measures include suppression techniques, general "good housekeeping" practices, enclosure, equipment changes or modifications, and process improvements.

Suppression of fugitive dust emissions can be accomplished through the agglomeration of particles on a surface or through the coating of a surface to prevent erosion. Water sprays, oils, chemicals, and foam may all serve as the agglomeration agent for surface particles so that they resist becoming airborne by wind forces or mechanical disturbances. Suppression, which has an overall efficiency rate of 70 percent, is a good control method for temporary treatment, and works well to control materials which are being moved or processed. For roadways subject to mechanical disturbance, suppression is best achieved by paving. For particles that may emanate from long-term storage piles, suppression can be accomplished through the use of certain resins as a palliative treatment.

The use of "good housekeeping" practices may reduce fugitive dust emissions by removing loose particles from surfaces subject to either windblown effects or mechanical disturbances. Street sweeping is one example of a "good housekeeping" practice for cleaning roadways. In certain cases, the use of "good housekeeping" practices can greatly reduce or eliminate the need for other fugitive dust emission controls.

Enclosure of fugitive dust emission sources prevents particles from escaping to the ambient air. This method of control may be applicable to conveyor systems or to unloading areas. Where complete enclosure is not possible, partial enclosure may prove helpful. Enclosure may also include the addition of chutes or sleeves to material transfer systems so that the release of particulate matter to the ambient air is minimized.

Equipment change for the control of fugitive dust emissions entails the substitution of one process for another such that the equipment used in the new process is not a source of fugitive emissions. The replacement of an open conveyor with a closed pneumatic transfer system vented through a collector is an example of a process change which eliminates fugitive emissions. Similar to equipment changes, process changes, where possible, may also act to reduce fugitive dust emissions.

Based on the availability of control technology as stated above, the Wisconsin Department of Natural Resources has promulgated in the Wisconsin Administrative Code six general rules for the control of fugitive dust emissions throughout the State. These six rules, however, are not specific enough to enable ready interpretation and consistent implementation by all affected fugitive dust sources. Enforcement of these rules, therefore, may not often be practicable. These rules are:

1. Where possible, water or chemicals must be used to control dust in the demolition of existing buildings or structures, and in construction operations.

2. Dirt roads, material stockpiles, and other surfaces which have the potential to create airborne dust must be covered with an application of asphalt, oil (tar), water, suitable chemicals, or plastic, provided such application does not create a hydrocarbon, odor, or water pollution problem.

3. Hoods, fans, and air-cleaning devices must be installed to enclose and vent the areas where dusty materials are handled.

4. Materials which are likely to become airborne while being moved on public roads, railroads, or navigable waters must be covered or secured.

5. Agricultural practices such as the tilling of land or application of fertilizers must be carried out in such a manner as not to cause air pollution.

6. Paving and maintenance of roadways or parking lots must be accomplished so as not to create air pollution.

In addition to these six general rules for the prevention of fugitive dust emissions, the Department of Natural Resources is proposing that potential fugitive dust sources in primary and associated secondary particulate matter nonattainment areas be required to meet a specific emission limitation—expressed either as a quantitative emission limitation, as a visible emission limitation, or a "best technology" emission limitation. These specific emission limitations include:

1. Industrial and commercial private roadways, and areas subject to traffic of more than 10 vehicles in any hour, shall be paved with bituminous or portland cement concrete or other surface approved by the Department of Natural Resources, and should periodically be cleaned in order to be kept free of loose material. Where paving is shown to be unreasonable or where the roadway or area is to be used for less than one year, dust shall be controlled by other methods approved by the Department such as watering, chemical suppression, or the use of stabilizers.

2. Storage piles having a volume of material transfer greater than 100 tons in any year and materials having a silt content of 5 percent to 20 percent shall be treated with water, surfactants, stabilizers, and chemicals and shall be draped or enclosed on a minimum of three sides. Access areas surrounding such storage piles shall be watered, cleaned, or treated with stabilizers as needed to prevent fugitive dust from vehicular traffic.

3. Storage piles involving a volume of material transfer greater than 100 tons in any year and materials having a silt content of 20 percent or more shall be completely enclosed or draped except for that portion of the pile being worked, loaded, or unloaded. Access areas surrounding such storage piles shall be watered, cleaned, or treated with stabilizers as needed to prevent fugitive dust from vehicular traffic.

4. Materials-handling operations, including but not limited to crushing, grinding, mixing, screening, compacting, conveying, and waste handling of material with more than 5 percent silt, and loading and unloading of railcars, trucks, ships, or barges, shall be controlled such that visible dust emissions shall not exceed 10 percent opacity when wind speeds are less than 25 miles per hour except for three minutes in any hour, when such visible emissions may equal 50 percent opacity.

5. Any device used to control fugitive emissions from materials-handling operations which has a discharge to the ambient air shall be controlled to provide an emission rate equal to or less than 0.10 pound of particulate matter per 1,000 pounds of exhaust gas.

6. Fugitive particulate emissions originating from processes shall be controlled to an exhaust gas concentration rate equal to or less than 0.10 pound

of particulate matter per 1,000 pounds exhaust gas at any point of emission to the ambient air.

7. Emissions from any building or structure opening other than a stack shall be controlled such that visible emissions shall not exceed 10 percent opacity except for three minutes in any hour, when such visible emissions may equal 50 percent opacity.

8. Coking operations shall be controlled so that:

   a. There are no visible emissions beyond one meter from the charging ports while coal is being charged to the oven except for a total of 125 seconds during five consecutive oven charges.

   b. Fugitive emissions from pushing operations are captured by a traveling hood and controlled to not more than 0.08 pound of particulate matter per 1,000 pounds of exhaust gas. Any visible emissions escaping capture shall not exceed 20 percent opacity for each pushing operation.

   c. There are no visible emissions from 90 percent of the doors of all coke ovens in use; 95 percent of all coke oven charging port lids; and 90 percent of all offtake piping except that open for charging, pushing, cleaning, and maintenance as determined by a one-pass observation.

In addition, quench towers for the application of water on hot coke shall be equipped with grit arrestors or equivalent equipment approved by the Department. Water used in quenching shall not include coke by-product plant effluent.

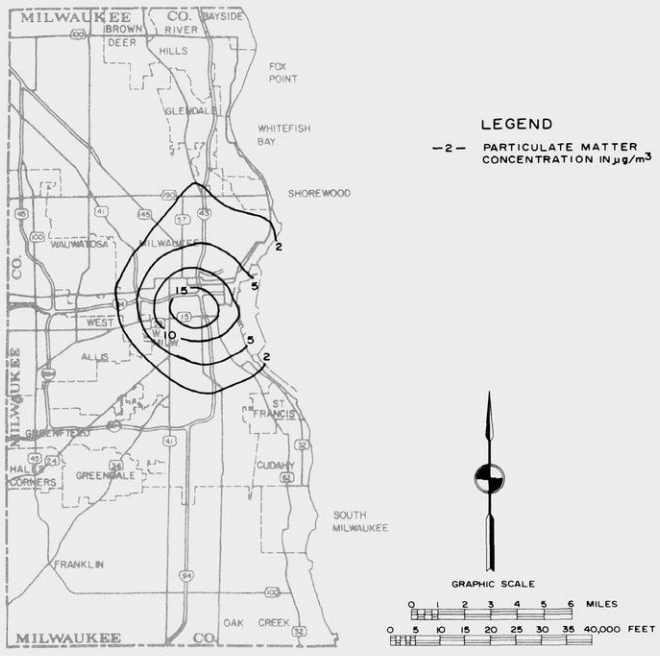
The Impact of RACT Emission Limitations on the Menomonee River Valley Fugitive Dust Emissions: In order to estimate the impact of the Menomonee River Valley fugitive dust emissions on monitored particulate matter levels in the Region, the 1977 inventory data compiled by the City of Milwaukee, Department of City Development, were simulated using the Wisconsin Atmospheric Diffusion Model. The results of this modeling effort are presented on Map 177. The maximum isopleth value indicated on Map 177 is 15 $\mu g/m^3$, expressed as an annual arithmetic average at the average mixing height of particulate matter monitors in the Region, and is centered over the eastern portion of the heavily industrialized Menomonee River Valley. These simulated concentrations reflect the impact of the estimated 719 tons of uncontrolled fugitive dust emissions resulting from vehicular traffic on unpaved roads, unpaved automobile parking lots, and unpaved truck parking lots, and from uncovered aggregate storage piles.

For unpaved roads and unpaved automobile and truck parking lots, the most effective RACT emission reduction strategy would be, of course, to pave the exposed surfaces. The U. S. Environmental Protection Agency (EPA) has estimated that covering such exposed surfaces with bituminous or Portland cement concrete would yield an approximate 85 percent reduction in fugitive dust emissions from these types of sources. For uncovered storage piles, the most effective RACT emission reduction strategy would be to treat the piles with a suppressant or surfactant—a measure which the EPA has indicated should reduce fugitive dust emissions from this source category by about 80 percent. Under the assumption of full implementation of these RACT controls, the fugitive dust emissions from the sources identified in the City of Milwaukee inventory for 1977 would have been reduced by about 594 tons, or nearly 83 percent—from the uncontrolled emission level of 719 tons to the RACT emission level of 125 tons—as shown in Table 313.

The computer-simulated annual arithmetic average particulate matter concentrations resulting from the RACT-controlled fugitive dust emissions in the Menomonee

Map 177

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE PARTICULATE MATTER CONCENTRATIONS DUE TO UNCONTROLLED FUGITIVE DUST EMISSIONS IN THE MENOMONEE RIVER VALLEY: 1977



This map illustrates the impact of uncontrolled fugitive dust emissions in the Menomonee River Valley in Milwaukee County on ambient air quality in the Region in 1977. The highest isopleth value shown on this map is 15 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average at the average height of the particulate matter monitors in the Region. This concentration reflects the impact of the estimated 719 tons of fugitive dust emissions identified in a special study by the City of Milwaukee, Department of City Development, as resulting from vehicle travel on unpaved roads and unpaved automobile and truck parking lots, and from uncovered aggregate storage piles in the heavily industrialized portion of the Menomonee River Valley.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Table 313

UNCONTROLLED AND RACT EMISSION LEVELS FOR FUGITIVE DUST SOURCES IN THE MENOMONEE RIVER VALLEY: 1977

Fugitive Dust Source	Uncontrolled Emissions (tons)	RACT Emissions (tons)
Unpaved Automobile Parking Lots	36	5
Unpaved Truck Parking Lots	61	9
Unpaved Roads	262	39
Uncovered Aggregate Storage Piles	360	72
Total	719	125

Source: Wisconsin Department of Natural Resources and City of Milwaukee, Department of City Development.

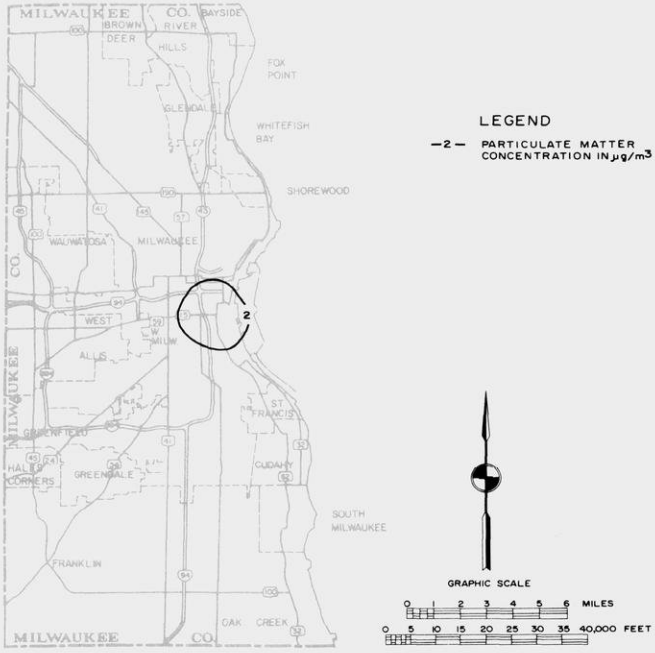
River Valley are presented on Map 178. The maximum, and only, isopleth value shown on this map is about 2 $\mu g/m^3$, expressed as an annual arithmetic average at the average mixing height of particulate matter monitors in the Region, as compared with 15 $\mu g/m^3$ as shown on Map 177 for uncontrolled fugitive dust emissions. It may be concluded, therefore, that a significant improvement in ambient air particulate matter levels could be effected through the application of RACT controls on fugitive dust sources in the Menomonee River Valley.

The Impact of RACT Emission Limitations on Industrial Fugitive Dust Sources in Southeastern Wisconsin: In order to estimate the impact of industrial fugitive dust emissions on monitored particulate matter levels in the Region, the 1977 inventory data as prepared by the Wisconsin Department of Natural Resources were individually computer simulated. The results of this modeling effort are presented on Map 179. As may be seen on Map 179, several distinct areas in the Region have high particulate matter concentrations resulting from industrial fugitive dust emissions. Those areas are located in the Town of Lisbon south of the Village of Sussex, in the Town of Pewaukee north of the City of Waukesha, and in the Town of Ottawa east of the Village of Dousman in Waukesha County; in the City of Franklin and in the Menomonee River Valley in the City of Milwaukee in Milwaukee County; and in the Town of Caledonia north of the City of Racine in Racine County. With the exception of the localized concentration of particulate matter in the Menomonee River Valley, all the major concentrations on Map 179 may be attributed primarily to the fugitive dust emissions emanating from quarrying operations.

Quarrying operations are a major source of fugitive dust emissions because of the numerous opportunities for the release of particulates to the ambient air during the crushing, grinding, conveying, storage, and transfer processes involved in the extraction and beneficiation of materials. Of the approximate 8,050 tons of fugitive dust emissions

Map 178

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE PARTICULATE MATTER CONCENTRATIONS DUE TO CONTROLLED FUGITIVE DUST EMISSIONS IN THE MENOMONEE RIVER VALLEY: 1977



This map illustrates the impact of fugitive dust emissions in the Menomonee River Valley in Milwaukee County on ambient air quality in the Region after the implementation of Reasonably Available Control Technology (RACT). The application of RACT measures would have yielded an 80 percent to 85 percent reduction in fugitive dust emissions in the Menomonee River Valley. Applicable RACT measures include paving unpaved roads and automobile and truck parking lots with bituminous or Portland cement concrete, and treating uncovered storage piles with a suppressant or surfactant. Under the assumption of full implementation of these RACT measures, the maximum particulate matter concentration due to fugitive dust emissions in the Menomonee River Valley would have been reduced to two micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average—a decrease of about 13 $\mu g/m^3$, or about 87 percent, from the maximum concentration resulting from uncontrolled fugitive dust emissions (see Map 177).

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

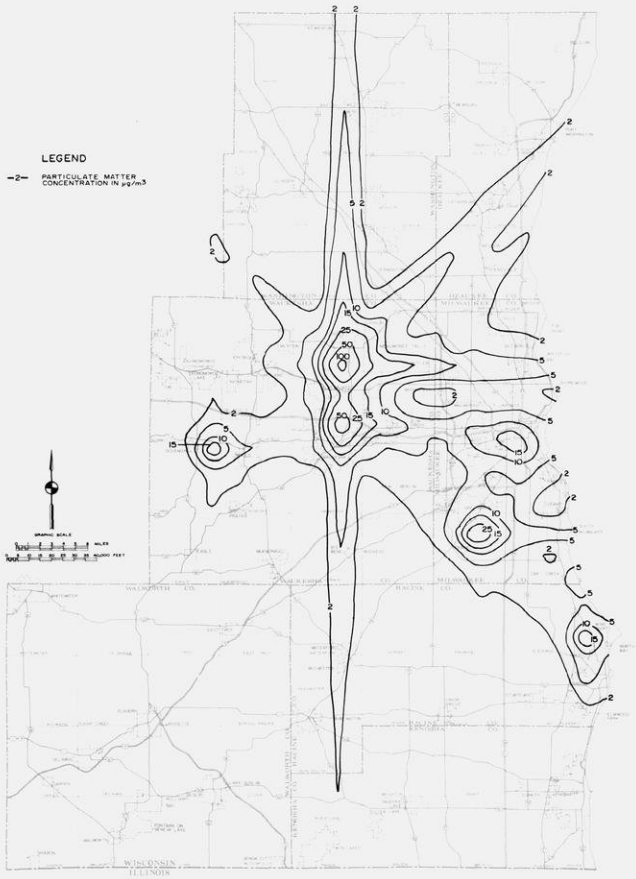
identified in the 1977 inventory, about 6,480 tons, or more than 80 percent, are attributable to only nine quarrying operations in the Region. The total fugitive dust emissions estimated to be released from these quarrying operations are presented in Table 314 by source category. As may be seen in Table 314, three processes—primary crushing, secondary crushing, and transfer and conveying operations—account for about 4,600 tons of fugitive dust emissions, or more than 71 percent of the total emissions from the nine identified quarries.

The Wisconsin Department of Natural Resources has estimated that uncontrolled industrial fugitive dust emissions would have been reduced by about 5,090 tons,

or by more than 63 percent—from the 8,050 tons identified in the 1977 inventory to about 2,960 tons—with the full implementation of the Department's proposed RACT emission limitations. The uncontrolled fugitive dust emissions and those released after application of the DNR-proposed RACT emission levels in southeastern Wisconsin are detailed by county in Table 315. At the DNR-proposed RACT emission level indicated in Table 315, the fugitive dust emission sources identified in the Region may be anticipated to influence ambient air particulate matter concentrations to the extent shown on Map 180. As may be seen by comparing Map 180 with Map 179, a substantial improvement in ambient air quality may be expected to be gained through the application of RACT controls on industrial fugitive dust emission sources in southeastern Wisconsin.

Map 179

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE PARTICULATE MATTER CONCENTRATIONS DUE TO UNCONTROLLED INDUSTRIAL FUGITIVE DUST EMISSIONS IN THE REGION : 1977



This map illustrates the impact of uncontrolled industrial fugitive dust emissions on ambient air quality in the Region in 1977. The highest isopleth value shown on this map is 100 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average at the average height of particulate matter monitors in the Region. The highest concentrations are located in the Town of Lisbon south of the Village of Sussex, in the Town of Pewaukee north of the City of Waukesha, and in the Town of Ottawa east of the Village of Dousman in Waukesha County; in the City of Franklin and in the City of Milwaukee in and around the Menomonee River Valley in Milwaukee County; and in the Town of Caledonia in Racine County. These concentrations reflect the impact of the approximately 8,100 tons of industrial fugitive dust emissions identified in 1977 by the Wisconsin Department of Natural Resources. With the exception of the particulate matter concentrations in the heavily industrialized portion of the Menomonee River Valley, all of the peak particulate matter levels indicated on this map may be attributed principally to fugitive dust emissions resulting from quarrying operations.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Table 314

ESTIMATED UNCONTROLLED FUGITIVE DUST EMISSIONS FROM QUARRYING OPERATIONS IN THE REGION: 1977

Source	Emissions (tons)
Loading Operations	284
Storage Piles	183
Primary Crushing	1,003
Secondary Crushing	2,071
Transfer and Conveying	1,542
Vehicular Traffic	340
Wind Erosion	1,026
Miscellaneous[a]	34
Total	6,483

[a] *Miscellaneous sources include overburden removal, drilling and blasting, lime crushing and pulverizing, and packaging.*

Source: Wisconsin Department of Natural Resources

Table 315

UNCONTROLLED AND RACT EMISSION LEVELS FOR INDUSTRIAL FUGITIVE DUST SOURCES IN THE REGION: 1977

County	Uncontrolled Emissions (tons)	RACT Emissions (tons)
Kenosha	14	3
Milwaukee	2,233	1,103
Ozaukee	14	14
Racine	542	214
Walworth	--[a]	--[a]
Washington	21	21
Waukesha	5,227	1,604
Region	8,051	2,959

[a] *The Department of Natural Resources did not include Walworth County in its industrial fugitive dust inventory.*

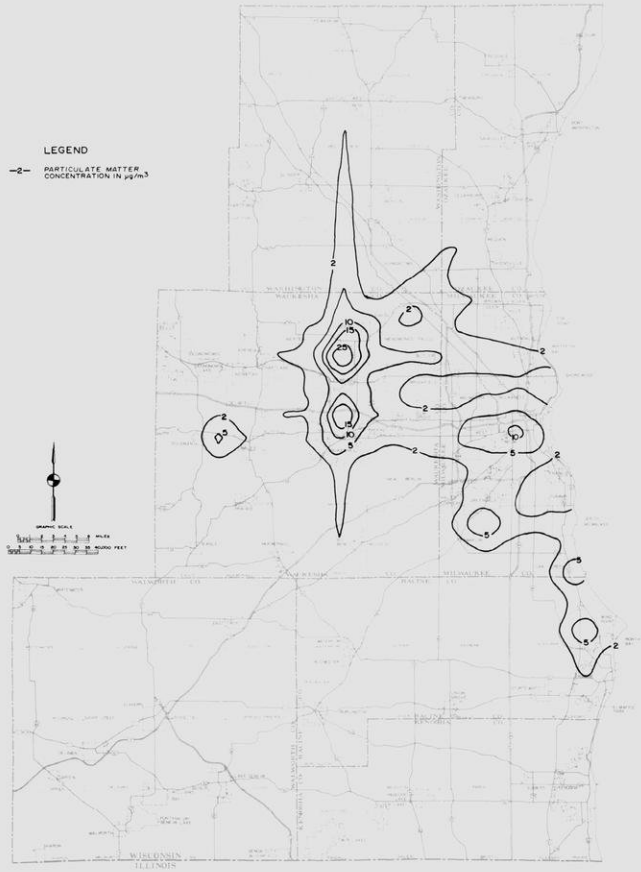
Source: Wisconsin Department of Natural Resources.

Evaluation of Committed Particulate Matter Control Strategies: As stated earlier in this chapter, the Federal Clean Air Act Amendments of 1977 require the State to adopt and enforce, at a minimum, Reasonably Available Control Technology (RACT) for existing sources which lie within, or impact upon, designated nonattainment areas. For the Southeastern Wisconsin Region, the adoption and enforcement of proposed RACT limitations for particulate matter emissions from industrial process sources, fuel-burning installations, and fugitive dust sources may be expected to yield an overall annual reduction of about 6,400 tons, or nearly 21 percent of the 1977 annual average emission level of about 30,500 tons, as shown in Table 316. As may be seen in this table, the relative difference between the forecast and the RACT particulate matter emissions may be expected to gradually decrease over the forecast period. This finding may be attributed to the anticipated growth in particulate matter emissions from most source categories in the Region between 1977 and the year 2000. In fact, by the year 2000 total particulate matter emissions in the Region under the proposed RACT limitations may be expected to approximate 96 percent of the 1977 emissions level.

The air quality benefits derived from the application of RACT emission limitations on point sources lying within, or impacting upon, designated nonattainment areas in the Region, and from the application of RACT controls on identified fugitive dust emission sources in the Region, have been estimated through the use of the Wisconsin Atmospheric Diffusion Model. Map 181 presents the forecast annual geometric average particulate matter concentrations from all sources in the Region in 1982 under the proposed RACT limitations for both point source

Map 180

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE PARTICULATE MATTER CONCENTRATIONS DUE TO CONTROLLED INDUSTRIAL FUGITIVE DUST EMISSIONS IN THE REGION: 1977



This map illustrates the impact of industrial fugitive dust emissions on ambient air quality in the Region in 1977 after the implementation of Reasonably Available Control Technology (RACT). Under full implementation of the RACT emission limitation measures, industrial fugitive dust emissions would have been reduced by more than 63 percent—from about 8,100 tons under uncontrolled operations to about 3,000 tons under controlled operations. As may be seen by comparing this map with Map 179, concentration levels of this pollutant species are anticipated to decrease significantly under controlled conditions, with the maximum concentration decreasing from 100 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, to 25 $\mu g/m^3$. This 75 percent reduction is most evident near major quarrying operations in Waukesha County.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Table 316

COMPARISON OF EXISTING, FORECAST, AND RACT TOTAL PARTICULATE MATTER EMISSIONS IN THE REGION ON AN ANNUAL AVERAGE BASIS 1977, 1982, 1985, AND 2000

Year	Emissions (tons)	Difference	Percent Difference
1977			
Existing . . .	30,502	6,377	20.9
RACT	24,125		
1982			
Forecast. . .	29,846	5,696	19.1
RACT	24,150		
1985			
Forecast[a] . .	31,552	5,742	18.2
RACT	25,810		
2000			
Forecast[b] . .	34,819	5,644	16.2
RACT	29,175		

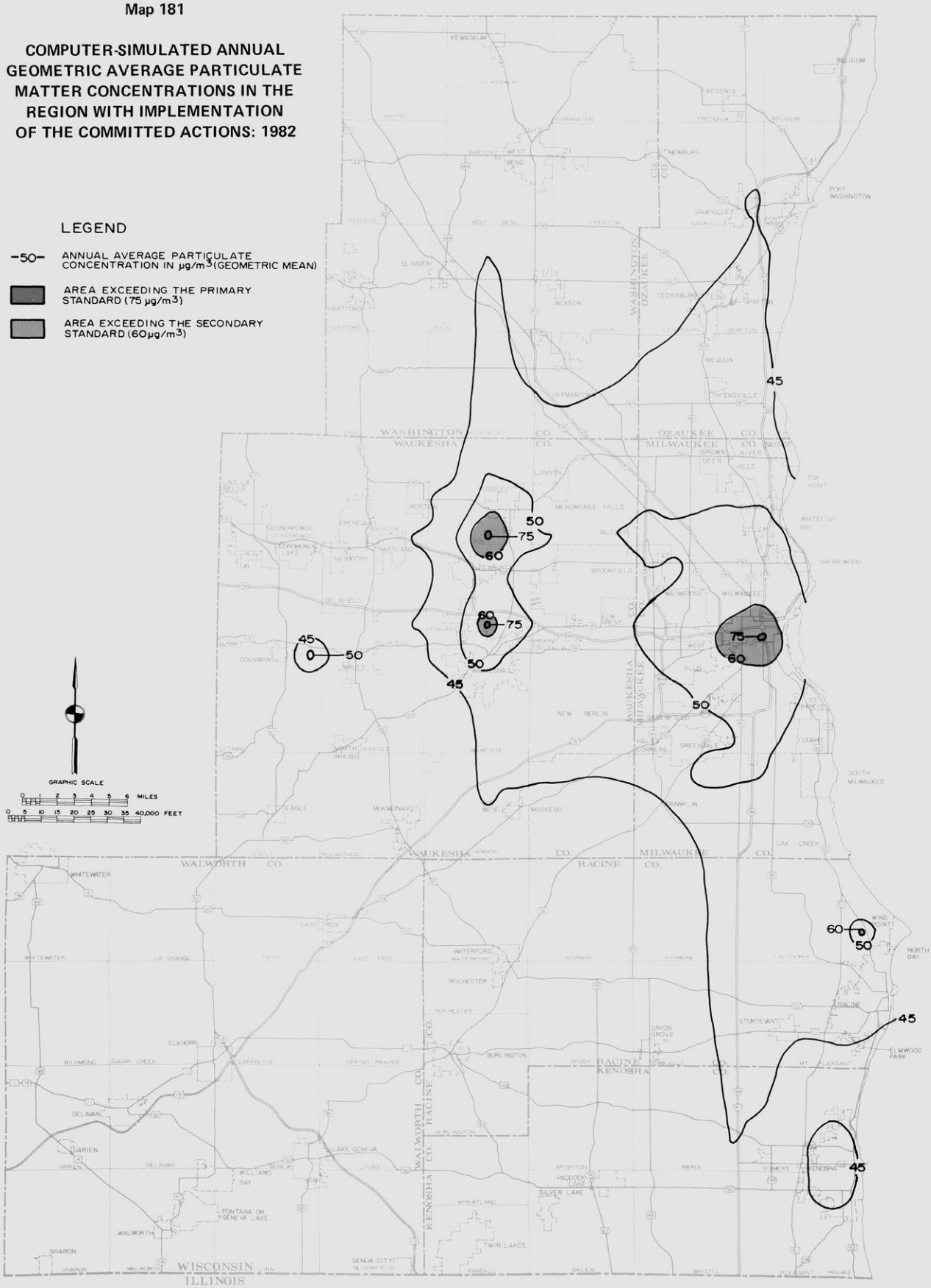
[a] *Coal-intensive energy scenario and the 1985 stage of the "no build" transportation plan.*

[b] *Coal-intensive energy scenario and the 2000 "no build" transportation plan.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Map 181

COMPUTER-SIMULATED ANNUAL GEOMETRIC AVERAGE PARTICULATE MATTER CONCENTRATIONS IN THE REGION WITH IMPLEMENTATION OF THE COMMITTED ACTIONS: 1982



This map illustrates the composite impact of forecast point, line, and area source particulate matter emissions on ambient air quality in the Region in 1982 as forecast under the proposed Reasonably Available Control Technology (RACT) emission limitations for industrial process sources, fuel-burning installations, and fugitive dust sources. As may be seen on this map, the primary annual geometric average ambient air quality standard of 75 micrograms per cubic meter ($\mu g/m^3$) may be expected to be exceeded over a less than one-square-mile area in Milwaukee County—in the heavily industrialized portion of the Menomonee River Valley—and over two less than one-square-mile areas in the Towns of Pewaukee and Lisbon in Waukesha County. The secondary annual geometric average standard of 60 $\mu g/m^3$ is estimated to be exceeded over an additional 10-square-mile area in the City of Milwaukee, an additional one-square-mile area in the Town of Pewaukee, an additional four-square-mile area in the Town of Lisbon, and a less than one-square-mile area in the Town of Caledonia. Thus, the simulation modeling results indicate that, although significant improvement in air quality may be expected, neither the primary, or health-related, nor secondary, or welfare-related, ambient air quality standards for particulate matter will be fully attained throughout the Region in 1982 under the proposed RACT emission limitations for point and fugitive dust sources. It should be noted, however, that if the long-range transport of particulate matter into the Region is reduced as a result of controls on extraregional sources, the particulate matter concentrations indicated on this map may also be significantly reduced, and the standards perhaps met.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

and fugitive dust emissions. The primary annual particulate matter standard of 75 $\mu g/m^3$ is indicated on Map 181 to be exceeded over a 0.7-square-mile area in the heavily industrialized portion of the Menomonee River Valley in the City of Milwaukee, over a 0.1-square-mile area in the Town of Pewaukee, and over a 0.3-square-mile area in the Town of Lisbon. Map 181 also indicates that the secondary annual particulate matter standard of 60 $\mu g/m^3$ will be exceeded over an additional 9.6 square miles in the City of Milwaukee, an additional one square mile around the primary standard violation area in the Town of Pewaukee, an additional 4.0 square miles around the primary standard violation area in the Town of Lisbon, and 0.1 square mile in the Town of Caledonia in Racine County. The areas in which the standards will be exceeded in 1982 under the committed actions in Milwaukee, Racine, and Waukesha Counties have been delineated on Map 182. The simulation modeling results, therefore, indicate that neither the primary, or health-related, nor the secondary, or welfare-related, annual average ambient air quality standards for particulate matter will be fully attained throughout the Region by 1982 under the proposed RACT emission limitations for point and fugitive dust sources.

A statistical test, termed the Larsen technique, was used to evaluate the effectiveness of the RACT emission limitations in attaining the primary and secondary 24-hour average particulate matter ambient air quality standards—260 $\mu g/m^3$ and 150 $\mu g/m^3$, respectively—in 1982. The Larsen technique, which was developed by Ralph I. Larsen of the U. S. EPA's National Environmental Research Center is described in detail in Appendix H, uses the annual geometric mean either observed at a monitoring site or calculated at a model receptor point, the corresponding standard geometric deviation, and the number of observations to predict the highest and second-highest 24-hour particulate matter concentrations. For this evaluation the annual geometric mean was determined from the 1982 RACT simulation modeling results, which were considered representative of an average of 365 days of observations. Because the standard geometric deviation—a value which may only be determined from recorded monitoring data—is required for the Larsen technique, the forecast of 24-hour average particulate matter levels in the Region in 1982 was calculated only for those areas in which a monitoring site was located during 1977.

The results of the application of the Larsen technique to the particulate matter concentrations simulated for 1982 assuming application of RACT emission limitations at 28 receptor areas are shown on Map 183.[6] As may be seen on Map 183, the primary 24-hour average particulate matter standard of 260 $\mu g/m^3$ is estimated to be exceeded only in the City of Waukesha. Twenty-four other areas are indicated to exceed the secondary 24-hour average standard of 150 $\mu g/m^3$, while only three of the calculated values shown are below this level. It should be noted that, although the primary and secondary 24-hour average particulate matter standards are estimated to be exceeded in the Region during 1982 under RACT controls, the Larsen technique does not permit an evaluation of the areal extent of such violations. Violations of the primary and secondary 24-hour average standards may, therefore, occur in other areas of the Region where estimates could not be provided for 1982.

Although the RACT particulate matter control strategies do not provide for the attainment of either the annual average or 24-hour average ambient air quality standards by 1982, implementation of RACT measures would represent significant progress toward this end, as may be seen by comparing Map 181 with Map 116 in Chapter XII. Map 116 indicates that without RACT controls approximately 5.3 square miles in Milwaukee County and 12.4 square miles in Waukesha County will exceed the primary annual particulate matter standard. With full implementation of the RACT controls, the area exceeding this standard may be expected to be reduced to 0.7 square mile in Milwaukee County and 0.4 square mile in Waukesha County, a decrease of about 4.6 square miles and 12 square miles, respectively (see Map 181).

The economic and physical growth and development anticipated to occur in the Region over the next two decades may be expected to diminish the initial effectiveness of the RACT limitations in achieving the particulate matter air quality standards. Even with the enforcement of an emission offset requirement—which, as discussed earlier, would mandate that all new or modified industrial facilities which lie within, or impact upon, a nonattainment area obtain a greater than one-for-one particulate matter emission reduction prior to commencing operation—the primary annual ambient air quality standard may be expected to be exceeded over a 1.1-square-mile area in Milwaukee County and a 0.4-square-mile area in Waukesha County in the year 2000, as indicated on Map 184. Although this represents only a slight increase over the extent of the area exceeding the primary annual standard in 1982, Map 184 indicates that RACT particulate matter emission controls are not expected to provide for either the attainment or maintenance of the annual average particulate matter standards throughout the Region over the planning period. The Larsen technique indicates that the primary and secondary 24-hour average standards will also be exceeded in parts of the Region through the year 2000. It may be concluded, therefore, that since the committed actions—RACT emission limitations on industrial process sources, fuel-burning installations, and fugitive dust sources—and the proposed emission offset policy are not expected to provide for either the attainment or maintenance of the annual average and 24-hour average particulate matter ambient air quality standards throughout the Region, additional control measures may be required to meet these objectives.

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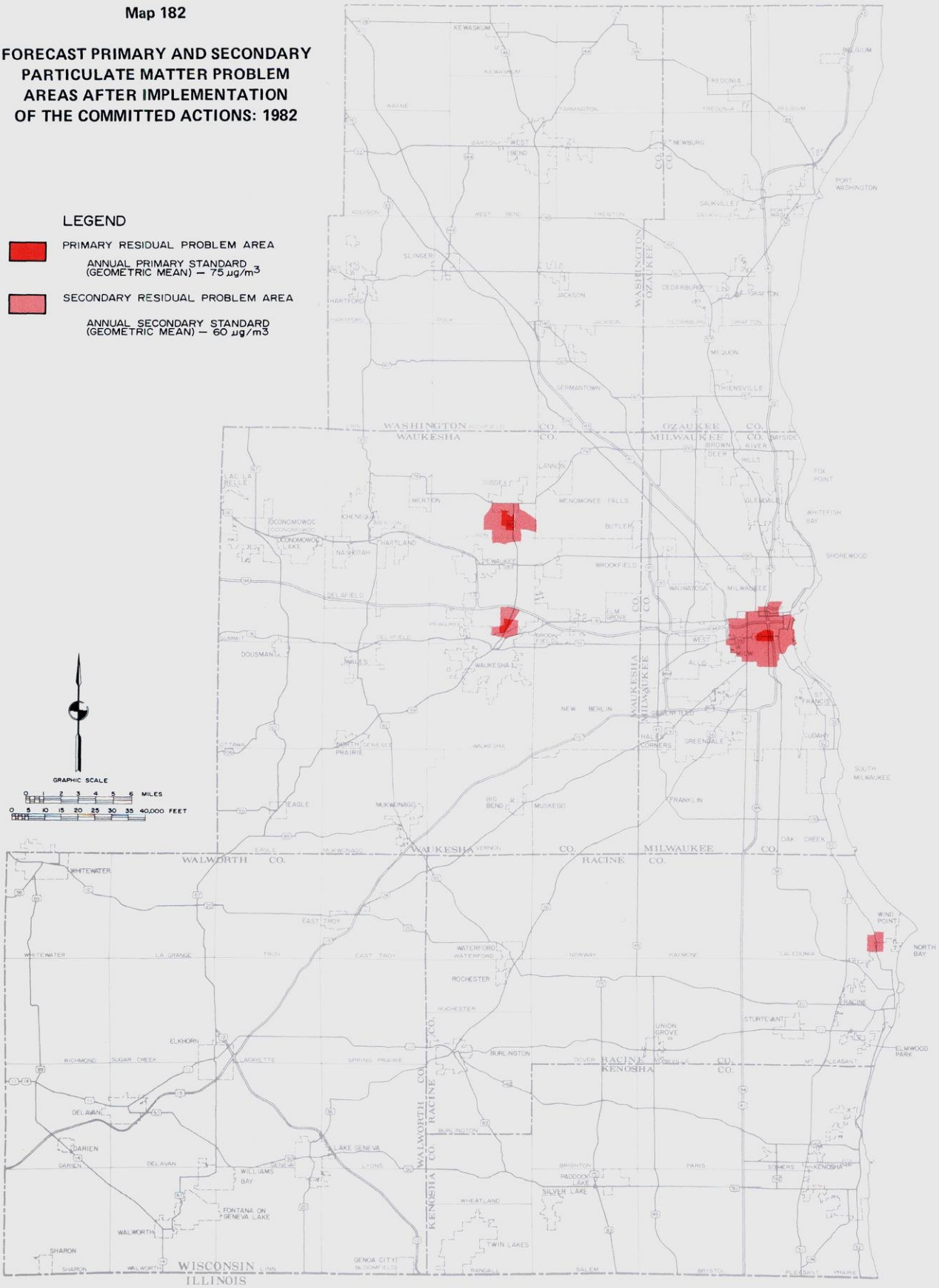
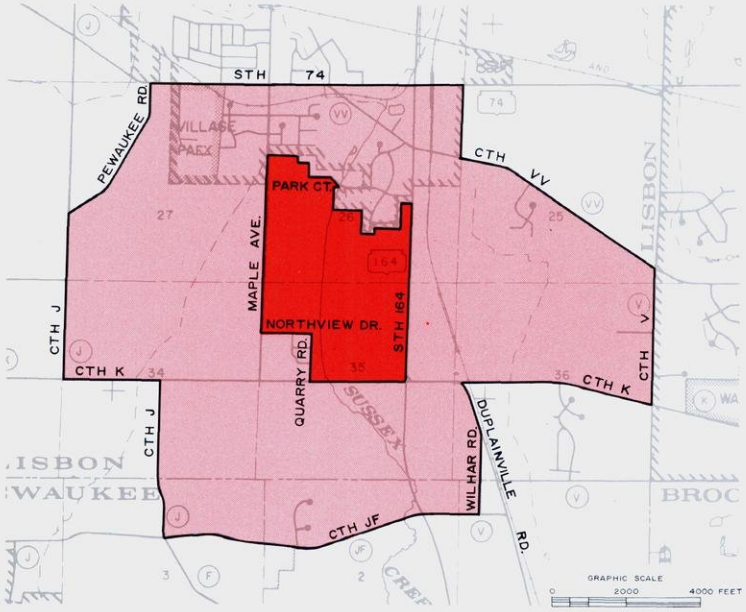
[6] *The values shown on Map 183 represent the second highest 24-hour average particulate matter concentrations forecast for 1982, since the standard may be exceeded once per year before a violation is recorded.*

Map 182

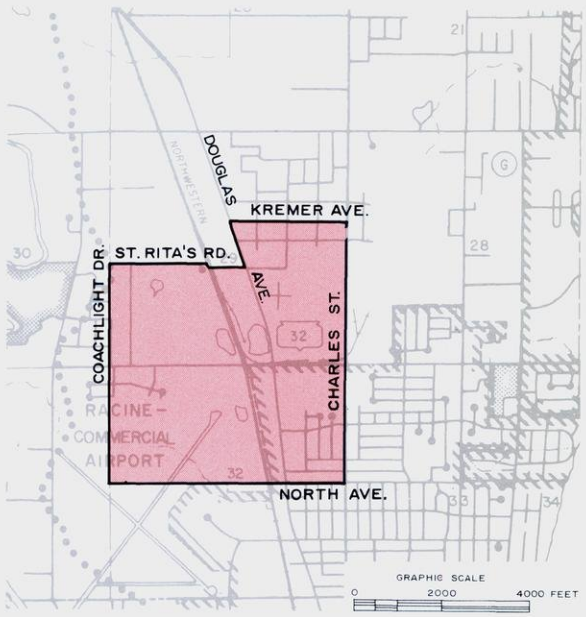
FORECAST PRIMARY AND SECONDARY PARTICULATE MATTER PROBLEM AREAS AFTER IMPLEMENTATION OF THE COMMITTED ACTIONS: 1982



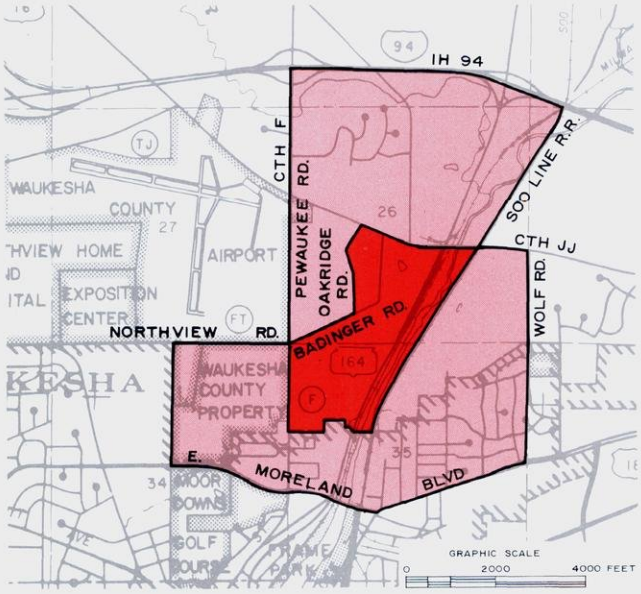
RESIDUAL PROBLEM AREA IN SUSSEX: 1982



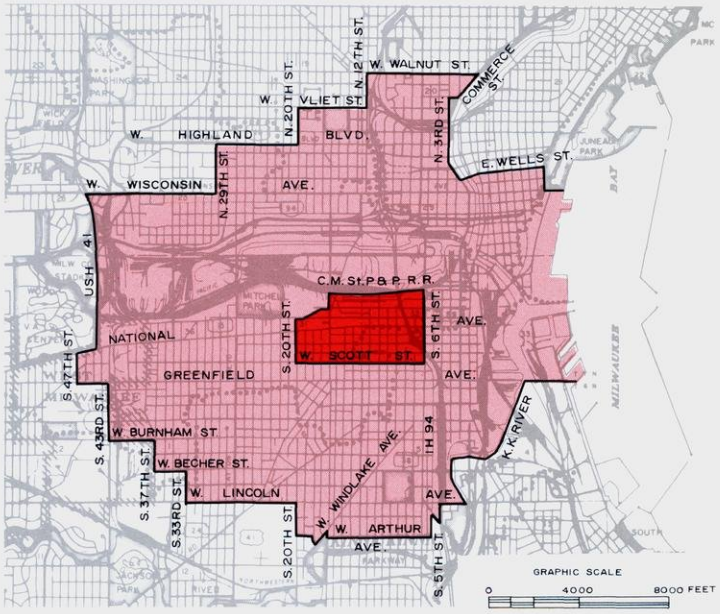
RESIDUAL PROBLEM AREA IN RACINE: 1982



RESIDUAL PROBLEM AREA IN WAUKESHA: 1982



RESIDUAL PROBLEM AREA IN MILWAUKEE: 1982

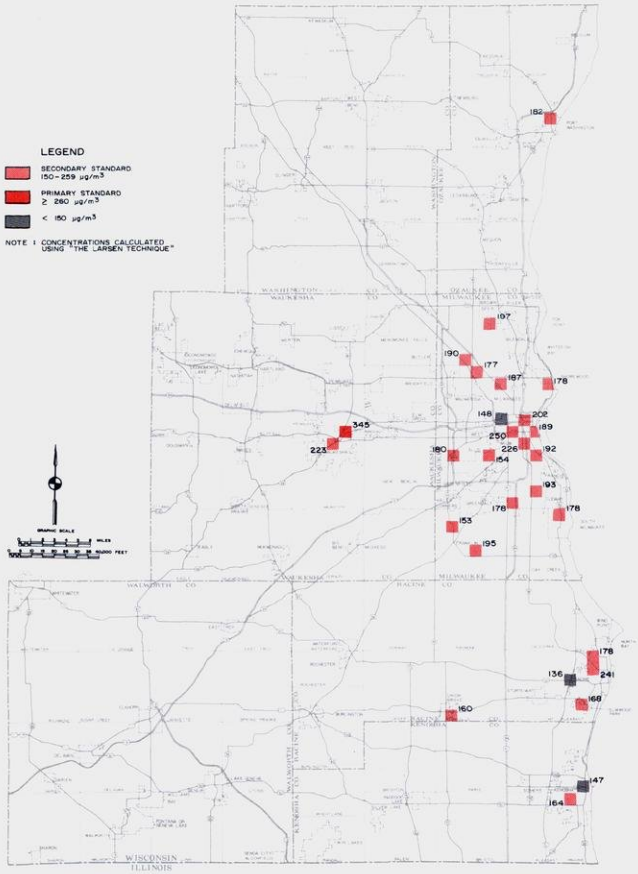


The above map illustrates the anticipated residual particulate matter problem areas in the Region in 1982 after the implementation of the committed actions. As may be seen on this map, attainment of the primary, or health-related, annual average particulate matter ambient air quality standard is not expected in parts of the City of Milwaukee, the City of Waukesha, and near the Village of Sussex. Furthermore, attainment of the secondary, or welfare-related, annual average particulate matter ambient air quality standard is not expected in parts of the City of Milwaukee, the City of Waukesha, the Village of Sussex, and Racine County.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 183

FORECAST SECOND HIGHEST 24-HOUR AVERAGE PARTICULATE MATTER CONCENTRATIONS IN SELECTED AREAS OF THE REGION AS PREPARED USING THE LARSEN TECHNIQUE AFTER IMPLEMENTATION OF THE COMMITTED ACTIONS: 1982



This map illustrates the second highest 24-hour average particulate matter concentrations due to point, line, and area source emissions in the Region as forecast for 1982 using the Larsen statistical technique and assuming implementation of the committed actions at 28 monitoring sites in 1977. As may be seen on this map, the primary 24-hour average standard is estimated to be exceeded only in the City of Waukesha. It can be seen by comparing this map with Map 65 in Chapter XI that, although RACT particulate matter control strategies do not provide for the attainment of the 24-hour average ambient air quality standards by 1982, implementation of these measures would provide for a significant reduction in concentrations.

Source: SEWRPC.

Potential Actions for the Control of Residual Particulate Matter Emissions

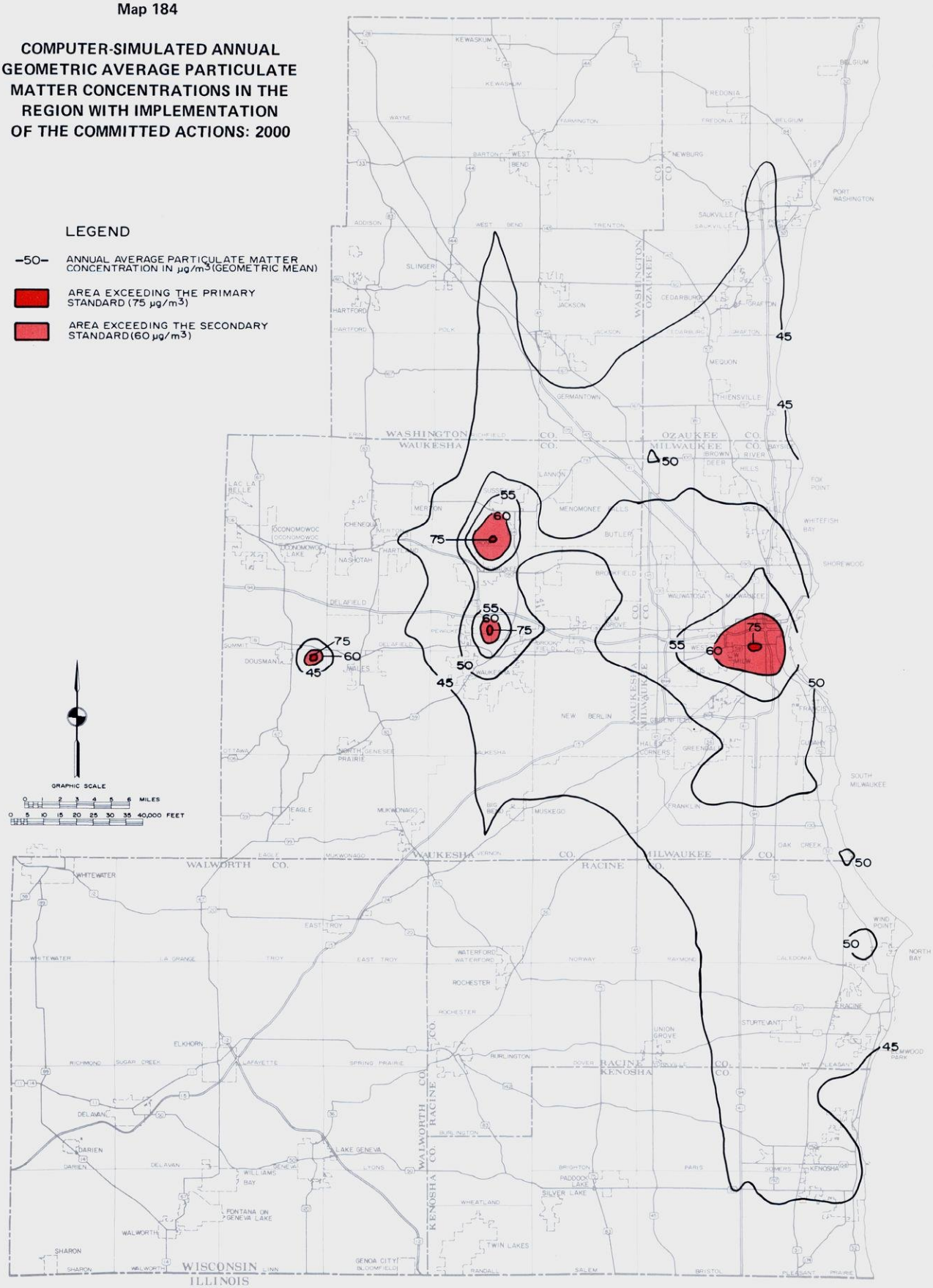
As noted in the previous section, a residual particulate matter problem may be expected to exist in parts of Milwaukee, Racine, and Waukesha Counties even assuming the full implementation of the committed control actions identified in the State Implementation Plan and required by the Federal Clean Air Act Amendments of 1977. Having identified this residual problem, there are two alternatives which may be pursued. The first is essentially a "no further action" alternative in which no controls beyond the committed actions would be implemented or enforced. The second alternative would seek to attain and maintain the standards by either identifying and controlling other sources contributing to the particulate matter levels in the defined problem areas or by establishing more stringent controls than those required by the committed actions for sources within the nonattainment areas. These two alternative approaches are examined in the following sections.

The "No Further Action" Alternative: The principal argument in support of the "no further action" alternative is that the results of the simulation modeling effort for the forecast years 1982 and 2000 under the RACT emission limitations include a constant background adjustment factor of approximately 38 $\mu g/m^3$ on an annual geometric average basis, which is equivalent to about 44 $\mu g/m^3$ on an annual arithmetic average basis. As explained in Chapter XI, this background adjustment factor was determined from the 1977 base year simulation model calibration effort and represents an estimate of the particulate matter levels in the atmosphere over the Region due to unidentified local emission sources, long-range transport, chemical transformations, and naturally occurring particles in the ambient air. The inclusion of the background adjustment factor in the forecast simulation modeling effort is equivalent to assuming that there will be no reduction in the impact of these four potential contributing sources on ambient air particulate matter concentrations in the Region over the planning period. Moreover, of necessity the background adjustment factor was added uniformly to each calculated particulate matter concentration in the Region. This is equivalent to assuming that the levels of unidentified emission sources, long-range transport, natural sources, and chemical transformations are the same throughout the Region. It is probable, however, that the background particulate matter levels vary substantially throughout the Region—being higher in some areas and lower in others—and that such background levels will decrease as controls are mandated, implemented, and enforced on sources upwind of the Region. With the increased recognition of fugitive dust as a major contributor to the particulate matter problem in the Region, it is also probable that additional sources of this nature will be identified and subjected to control under the committed RACT limitations. The particulate matter levels in 1982 and 2000 under the RACT emission limitations may, therefore, be somewhat less than indicated on Map 181 and Map 184.

The background adjustment factor of 38 $\mu g/m^3$ on an annual geometric average basis is particularly significant because it represents more than one-half of the primary particulate matter standard of 75 $\mu g/m^3$ and more than three-fifths of the secondary standard of 60 $\mu g/m^3$. In aggregate, those local emission sources which have been identified, quantified, and analyzed through air quality simulation modeling techniques may, therefore, be unduly constrained in the effort to attain and maintain the standards as a result of present deficiencies in defin-

Map 184

COMPUTER-SIMULATED ANNUAL GEOMETRIC AVERAGE PARTICULATE MATTER CONCENTRATIONS IN THE REGION WITH IMPLEMENTATION OF THE COMMITTED ACTIONS: 2000



This map illustrates the composite impact of forecast point, line, and area sources of particulate matter emissions on ambient air quality in the Region in the year 2000 as forecast assuming implementation of Reasonably Available Control Technology (RACT) emission limitations for industrial processes, fuel-burning installations, and fugitive dust sources. As may be seen on this map, the primary annual geometric average ambient air quality standard of 75 micrograms per cubic meter ($\mu g/m^3$) may be expected to be exceeded over a one-square-mile area in Milwaukee County and a less than one-square-mile area in Waukesha County in the year 2000. Although this represents only a slight increase in the area exceeding the primary annual standard in 1982 (see Map 181), it indicates that the RACT emission limitations alone will not provide for either the attainment or maintenance of the primary standard throughout the Region over the planning period. It should be noted, however, that if the long-range transport of particulate matter into the Region is reduced as a result of controls on extraregional sources, the particulate matter concentrations indicated on this map may also be significantly reduced, and the standards perhaps met.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

ing all sources—both local and extraregional—contributing to the particulate matter problem in southeastern Wisconsin. The "no further action" alternative avoids placing more stringent controls than those required by the committed actions on presently identified pollution sources. Acceptance of this approach would be based on the assumption that more stringent controls may not be necessary nor equitable given the limitations of the simulation modeling analyses, and the uncertainties associated with background particulate matter levels, particularly the levels contributed by long-range transport.

Because of the uncertainties regarding background particulate matter levels, the "no further action" alternative must be accompanied by certain stipulations. First, all committed actions, including RACT emission limitations on industrial processes, fuel-burning installations, and fugitive dust sources, must be implemented and enforced. Second, an extensive air quality monitoring program must be designed and operated in those areas of the Region where the simulation modeling effort has indicated violations of the particulate matter ambient air quality standards in the forecast years under the RACT emission limitations. Monitors should also be strategically placed to provide a quantitative estimate of the amount of pollution transported into southeastern Wisconsin from extraregional sources. The total monitoring effort should be supplemented with laboratory analyses of selected filter pads in order to compile data on the composition and probable source of the deposited material. Finally, industrial growth and development should be permitted in those areas of the Region indicated as exceeding either the primary or secondary particulate matter ambient air quality standards in 1982 (see Maps 181 and 182) if it can be demonstrated that such growth or development would not cause or contribute to a violation of the standards. Generally, this would require that any new or modified source in a nonattainment area obtain emission offsets.[7] Also, if a source proposed for construction or modification lies outside the nonattainment area boundaries but is of sufficient size to significantly impact such areas as determined through air quality simulation modeling techniques, that source should be required to obtain a greater than one-for-one emission reduction within the identified nonattainment area. This restriction on industrial growth and development is necessary to prevent the exacerbation of suspected violations of the standard. This restriction would be lifted either when the standards are attained as a result of background level reductions achieved through controls on extraregional sources, or when local controls have been implemented to attain the standards.

The "no further action" alternative, with the accompanying extensive air quality monitoring program and industrial growth and development restrictions, offers no definitive assurance that the particulate matter ambient air quality standards will be attained. However, this alternative provides an equitable and flexible plan, until such time as further monitoring results yield more definitive information concerning the probable sources, whether intra- or extraregional, contributing to the forecast particulate matter problem. At that time, a revised plan would have to be prepared.

The "Increased Control" Alternative: Under the "increased control" alternative, specific actions are recommended to attain and maintain the particulate matter ambient air quality standards in the Region. Such actions are intended to reduce either the background particulate matter levels—through the identification, quantification, and control of previously unidentified local emission sources—or to place more stringent controls than federally mandated on known particulate matter emission sources within the forecast nonattainment areas in the Region.

Based on the simulation modeling analysis and evaluation of RACT emission limitations, the residual particulate matter problem in the Region may be characterized as anticipated primary and secondary standard violations in parts of Waukesha County, secondary standard violations in a portion of Racine County, principally due to quarrying operations, and primary and secondary standard violations in parts of Milwaukee County which may be attributed to unidentified emission sources, most probably local fugitive dust sources. Since the residual particulate matter problem is expected to stem primarily from two distinct emission source categories, it is necessary to design and evaluate two separate courses of action under the "increased control" alternative. These two potential courses of action—the control of re-entrained road dust in Milwaukee County and the control of emissions from quarrying operations in Racine and Waukesha Counties—are discussed below.

Evaluation of Controls on Re-Entrained Road Dust: A local emission source which may contribute significantly to the background particulate matter concentrations in the Region is road dust re-entrained into the ambient air by motor vehicles. Re-entrained road

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[7] *In promulgating the final ruling on the federal emissions offset policy (Federal Register, Vol. 44, No. 11, January 16, 1979), the U. S. Environmental Protection Agency (EPA) exempted new or modified sources having uncontrolled emissions of less than 50 tons per year from the requirement of obtaining a greater than one-for-one emission reduction if it can be demonstrated that such a source would not cause or contribute to a violation of the ambient air quality standards. As a result of a later court ruling (Alabama Power Company v. Costle, 13 ERC 1225), however, the EPA proposed deleting this "50 ton" exemption (Federal Register, Vol. 44, No. 173, September 5, 1979). At the same time, the EPA proposed establishing "de minimis" emission levels below which such requirements would be necessary. Thus, at the present time a new or modified source emitting less than 10 tons per year each of particulate matter, sulfur dioxide, nitrogen dioxide, or volatile organic compounds, or less than 100 tons per year of carbon monoxide, is considered to be "de minimis" and as having no significant impact on ambient air quality, and therefore is not required to obtain emission offsets.*

dust includes particles which have been deposited on roadways due to atmospheric fallout of suspended particulate matter, which have dropped from vehicles upon the road surface, or which have been loosened from the road surface itself through the abrasive action of vehicle tires, and which are subsequently resuspended into the ambient air as a result of the turbulent wind flow and mechanical force established by vehicular movements. Since re-entrained road dust has only recently been identified as a potentially significant source of particulate matter emissions, it was not directly included in the base year nor the forecast year simulation modeling effort. Thus, by its omission from the inventory, it must be considered as a part of the 38 $\mu g/m^3$ background concentration.

As indicated on Map 181, the most extensive area forecast to experience violations of the primary and secondary ambient air quality standards for particulate matter in 1982 under the RACT emission controls is located in central Milwaukee County. This area contains the arterial streets and highways experiencing the highest traffic volumes within both the Region and the State of Wisconsin. Consequently, the impact of re-entrained road dust on air quality in the Region would be expected to be the most pronounced in this area. It also follows that the control of re-entrained road dust in this area of Milwaukee County may be expected to produce the greatest air quality benefit. Accordingly, an estimate was made of the re-entrained road dust generated by vehicular movements in and around the area forecast to exceed the primary and secondary annual average particulate matter air quality standards in Milwaukee County in 1982. This study area, as shown on Map 185, is bounded by North Avenue on the north, Howard Avenue on the south, IH 894 and USH 45 on the west, and IH 94 and IH 43 on the east. Within the area delineated on Map 185, there are 200.1 miles of arterial street and highway facilities—62.6 miles of divided facilities and 137.5 miles of undivided facilities.

The quantity of road dust re-entrained into the ambient air depends on the volume of traffic, the vehicle mix, the amount and silt content of the material deposited on the roadway, and the surface moisture content. During 1977 the City of Milwaukee, Department of City Development, conducted a study to estimate the amount of road dust re-entrained into the atmosphere in and around the heavily industrialized portion of the Menomonee River Valley.[8] Based upon the findings of the study, the City determined that approximately 0.0187 pound of particles of less than 30 microns in diameter were re-entrained into the ambient air for each vehicle mile of travel. This emission factor was applied to the estimated annual vehicle miles of travel within each of the U. S. Public Land Survey quarter sections in the study area during 1977 in order to determine the total potential particulate matter emissions burden due to re-entrained road dust. This total potential burden was then adjusted to reflect the number of days during 1977 for which precipitation events of 0.01 inch or more had been recorded. This adjustment was made in order to account for the suppression of dust emissions as a result of moisture binding. Based on this procedure, it was estimated that 5,535 tons of particulate matter were re-entrained into the atmosphere over the study area delineated on Map 185 as a result of vehicular traffic during 1977.

The impact of the estimated 5,535 tons of re-entrained road dust emissions on ambient air quality in the Region in 1977 was determined using the Wisconsin Atmospheric Diffusion Model. The results of this modeling effort are shown on Map 186. The maximum isopleth value indicated on Map 186 is 60 $\mu g/m^3$ on an annual arithmetic average basis, and is centered over the Marquette Interchange in the City of Milwaukee.[9] This finding is not surprising given that the highest traffic volumes in the study area occur at the Marquette Interchange. It may be concluded, therefore, that re-entrained road dust resulting from vehicular movements is a significant contributor to ambient air particulate matter levels in Milwaukee.

There are five basic control measures which can be used to reduce the quantity of road dust re-entrained into the atmosphere as a result of vehicular movements: improved street cleaning, including broom sweeping, vacuum sweeping, and flushing; modified snow and ice control procedures, including the substitution of salt for sand, plowing as a substitute for the application of anti-skid materials, and the application of less anti-skid materials; control of dirt and mud carryout from such sources as construction sites and truck terminals; surfacing of unpaved parking lots, road shoulders, and driveways; and the reduction of traffic volumes. Of these five measures, improved street cleaning practices may be expected to have the most significant positive impact on the control of road dust.

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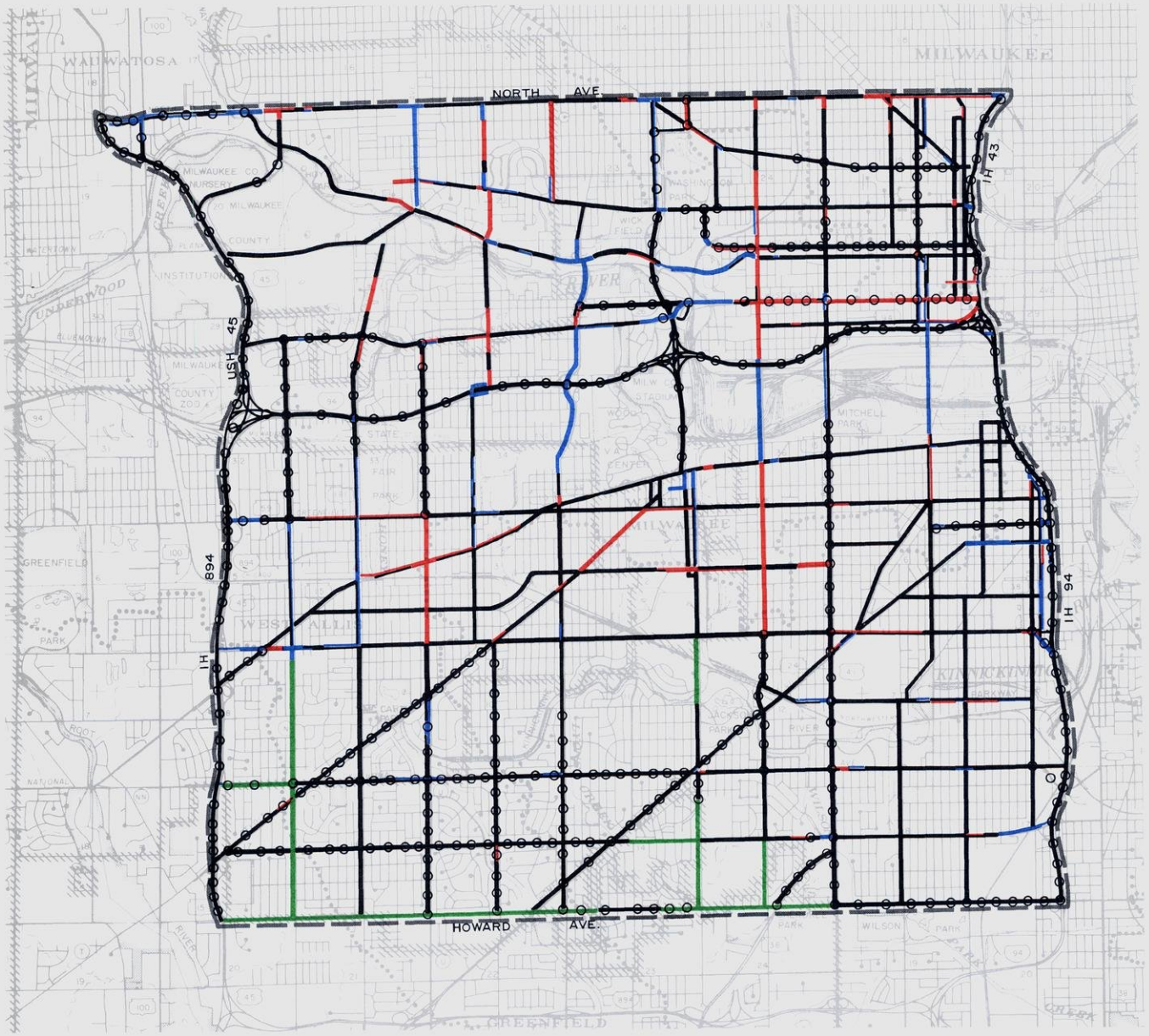
[8] *City of Milwaukee, Department of City Development, Program Research and Development, Estimating Dust Entrainment From Vehicular Traffic on Expressway Segments and Selected Paved Roads in the Menomonee River Valley, July 31, 1978.*

[9] *It is important to note that the highest annual arithmetic average isopleth value of 60 $\mu g/m^3$ due to re-entrained road dust exceeds the regional average background level of 44 $\mu g/m^3$ on an annual arithmetic average basis (38 $\mu g/m^3$ on an annual geometric average basis). As noted earlier in this chapter, the use of a single background adjustment factor throughout the Region may underestimate the actual level in certain areas and overestimate the actual level elsewhere. The forecast road dust concentrations indicate that the average regional background level of particulate matter may indeed represent an underestimate in and around the Marquette Interchange.*

Map 185

RE-ENTRAINED ROAD DUST STUDY AREA



LEGEND

- PROPOSED PARTICULATE MATTER CONTROL STUDY AREA BOUNDARY
- 24-HOUR ARTERIAL RESTRICTED PARKING
- NO PARKING ON ARTERIAL DURING PEAK HOURS
- ARTERIAL FACILITIES WITHOUT CURB AND GUTTER
- UNDIVIDED ARTERIAL FACILITIES
- DIVIDED ARTERIAL FACILITIES

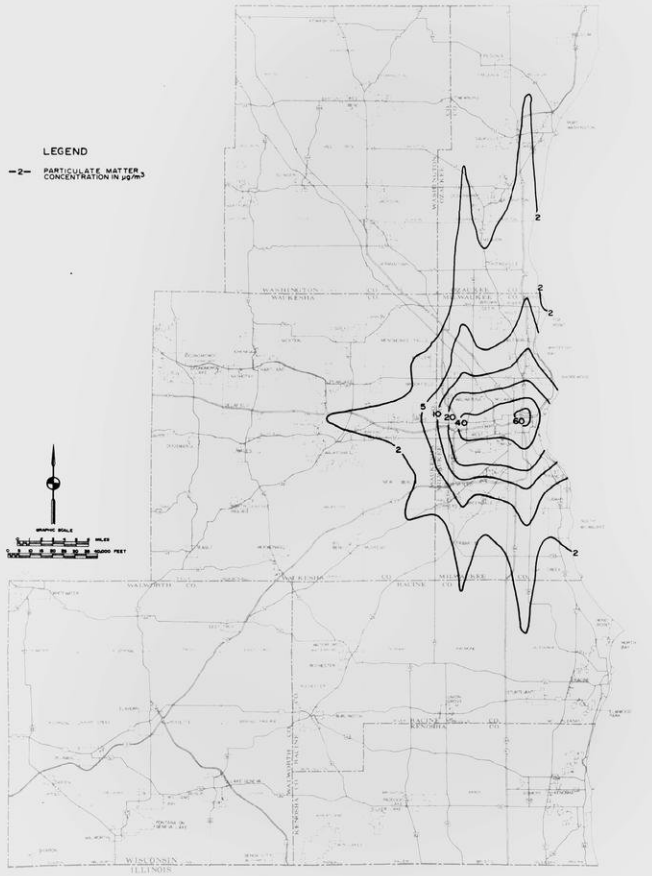
GRAPHIC SCALE
0 1/2 1 MILE
0 2000 4000 6000 8000 FEET

This map indicates the portion of Milwaukee County anticipated to exceed the primary and secondary air quality standards for particulate matter in 1982 under RACT emission controls. The approximately 36.8-square-mile area is bounded by North Avenue on the north, IH 894 and USH 45 on the west, Howard Avenue on the south, and IH 94 and IH 43 on the east. The delineated area contains 200.1 miles of arterial street and highway facilities—62.6 miles of divided facilities and 137.5 miles of undivided facilities—and it is estimated that about 5,500 tons of particulate matter per year are re-entrained into the atmosphere over this area as a result of vehicular traffic. It is proposed that a special study be conducted of the effectiveness of improved street cleaning techniques in this area in reducing particulate matter emissions and meeting the established air quality standards.

Source: SEWRPC.

Map 186

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE PARTICULATE MATTER CONCENTRATIONS DUE TO UNCONTROLLED RE-ENTRAINED ROAD DUST IN PARTS OF MILWAUKEE COUNTY: 1977



This map illustrates the impact of the estimated 5,500 tons of re-entrained road dust emissions during 1977 on ambient air quality in the Region. The highest isopleth value shown on this map is 60 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and is centered over the Marquette Interchange. This finding is not surprising given the fact that the highest traffic volumes in the study area occur at this interchange.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Due to the severity of winter conditions in southeastern Wisconsin, it is not always practicable to reduce the use of anti-skid materials on the regional street and highway system. Moreover, the substitution of salt for sand may contribute to the degradation of water quality in the Region. It should also be noted that the application of anti-skid materials in the winter season—when particulate matter concentrations are generally at their lowest level during the year—will not significantly affect the higher particulate matter concentrations in the summer season if the streets and highways are properly cleaned in the spring.

The control of dirt and mud carryout from construction sites and truck terminals may reduce the quantity of particulate matter re-entrained from road surfaces near the source, but since this material is most often deposited after only a short distance of travel, it does not offer an areawide solution to the problem. Furthermore, as unpaved parking areas, shoulders, and driveways are paved—an RACT fugitive dust control measure mentioned earlier in this chapter—the amount of dirt and mud carryout is expected to be significantly reduced.

Reducing traffic volumes on the regional arterial street and highway system is a measure which can serve to decrease not only particulate matter emissions due to re-entrained dust, but carbon monoxide and hydrocarbon emissions as well. Transportation control measures which would result in reduced traffic volumes are reviewed later in this chapter. It is not probable, however, that the travel demand by residents in the Region will decline enough to preclude further actions to reduce re-entrained road dust.

Improved street cleaning is a control measure which can reduce the amount of material on the road surface irrespective of the source of the deposited material. Street cleaning may be accomplished using mainly one of three types of equipment: mechanical or broom sweepers, vacuum sweepers, and flushers. The mechanical or broom sweeper has a rotating bristle gutter broom which sweeps road debris away from the curb into the path of a main broom and subsequently into a storage hopper. Vacuum sweepers also use a gutter broom to move debris away from the curb and into the path of the sweeper. Unlike mechanical sweepers, however, vacuum sweepers use a suction force for depositing materials into a storage hopper. Street flushers use water streams to move debris from the road surface to the gutter, where the material may be collected in a catch basin or picked up by a sweeper. Flushers, however, may contribute to water quality problems by depositing the contaminants carried in the surface runoff.

In removing the smaller, resuspendable-sized particles, mechanical or broom sweepers are not as effective as vacuum sweepers. In fact, the broom sweeper may actually generate dust in the ambient air through the abrasive action of the broom against the road surface and through the imperfect capture of debris displaced from the gutter. Also, broom sweepers have a lower capture rate for smaller particles since the bristles allow such particles to pass through the broom. Increasing the water flow and decreasing the rotational speed of the brooms, however, may reduce the dust generated by mechanical sweepers.

Vacuum sweepers have a greater air quality benefit than broom sweepers since they are capable of removing small particles as well as the heavier debris from the roadway. In one series of tests of vacuum sweepers encompassing 93 runs with operating speeds between one and six miles per hour, the removal of small particles—in this case defined as less than 43 microns in diameter—was consis-

tently higher than 75 percent.[10] Since road dust is continuously being regenerated and redeposited on the road surface, however, the overall efficiency of vacuum sweepers in reducing re-entrained dust is a function of the frequency of the sweeping operations. A study prepared for the U. S. Environmental Protection Agency by PEDCo-Environmental, Inc., estimated that weekly vacuum sweeping of roadways would yield about a 50 percent removal of fine particles.[11] Bi-weekly vacuum sweeping, accordingly, would yield an overall removal efficiency of about 25 percent of the road dust available for re-entrainment.

The effectiveness of using vacuum sweepers to sweep the approximately 200 miles of arterial street and highway facilities in and around the areas expected to exceed the primary and secondary particulate matter standards in Milwaukee County during 1982 was evaluated using the Wisconsin Atmospheric Diffusion Model. This evaluation was conducted under the premise of weekly vacuum sweeping, with an anticipated 50 percent removal efficiency, and under the premise of bi-weekly vacuum sweeping, with an anticipated 25 percent removal efficiency. The evaluation under both premises assumed implementation of the point source and fugitive dust source RACT emission limitations defined earlier in this chapter. The results of this simulation modeling effort are presented on Map 187 for a bi-weekly vacuum sweeping program and on Map 188 for a weekly vacuum sweeping program. As may be seen on Map 187, a bi-weekly vacuum sweeping program may be expected to provide for the attainment of the primary annual average particulate matter ambient air quality standard of 75 $\mu g/m^3$ throughout Milwaukee County by 1982. A 0.4-square-mile area located near the Marquette Interchange, however, may still be expected to experience violations of the secondary annual average standard of 60 $\mu g/m^3$. The particulate matter concentrations shown on Map 188 indicate that under a weekly vacuum sweeping program both the primary and secondary annual average ambient air quality standards will be attained throughout Milwaukee County in 1982.

A comparison of Map 187 with Map 188 indicates that significant air quality benefits will be achieved by increasing the street cleaning effort along major travel corridors. However, since a bi-weekly street cleaning schedule may be expected to result in attainment of the annual standards over all but a 0.4-square-mile area in Milwaukee County, it may not be economically justifiable to clean the arterial streets and highways more frequently, with the exception of the freeway segments comprising the Marquette Interchange. Because of the excessive particulate matter concentrations expected near the Marquette Interchange in 1982, a weekly vacuum sweeping effort would be justified on the adjacent freeway segments, and would be expected to provide for complete attainment of the standards throughout Milwaukee County.

Evaluation of Controls on Emissions From Quarries: It was noted earlier in this chapter that quarrying operations accounted for about 6,483 tons of particulate matter emissions, or more than 80 percent of the 8,051 tons of fugitive dust emissions identified in the Wisconsin Department of Natural Resources' (DNR) 1977 inventory. Under the DNR-proposed RACT emission limitations for fugitive dust sources, fugitive dust emissions from quarrying operations are expected to be reduced by about 4,466 tons, or about 69 percent, to 2,017 tons per year. Included among the DNR-proposed RACT emission limitations to reduce fugitive dust emissions from quarrying operations are the paving of unpaved quarry roads, water suppression on paved quarry roads, and chemical-water suppression on crushing, handling, and storage processes. As has been demonstrated by the simulation modeling effort for alternative control strategies, however, the DNR-proposed RACT emission limitations for fugitive dust sources are not expected to provide for the attainment of the particulate matter ambient air quality standards in and around major quarries in the Region. Accordingly, more stringent control measures may be required for quarrying operations if these standards are to be attained and maintained.

Primary and secondary crushing and the transfer and conveying of materials account for about 4,615 tons, or more than 71 percent, of the 6,483 tons of fugitive dust emissions generated each year by the nine major quarries included in the DNR inventory. Under the DNR-proposed RACT limitations, the fugitive dust emissions from these processes would be reduced by about 3,100 tons, or about 67 percent, to about 1,500 tons per year through the use of chemical-water spray suppression on primary and secondary crushing operations and through the partial enclosure of transfer and conveying operations. With chemical-water spray suppression and total enclosure with exhaust ventilation to a fabric filter baghouse, possibly preceded by a cyclone precleaner, the control efficiency of fugitive dust emissions from these sources could be increased to between 90 and 95 percent. Assuming a minimum of 90 percent control on primary and secondary crushing and transfer and conveying operations, the overall fugitive dust emissions from quarries may be expected to be reduced by about 5,500 tons, or more than 85 percent—from about 6,500 tons of uncontrolled emissions to about 1,000 tons of emissions under this control alternative. A comparison of the existing fugitive dust emissions from quarrying operations with the DNR-proposed RACT level of control—alternative 1—and the more stringent level of control specified herein—alternative 2—is shown in Table 317 by source.

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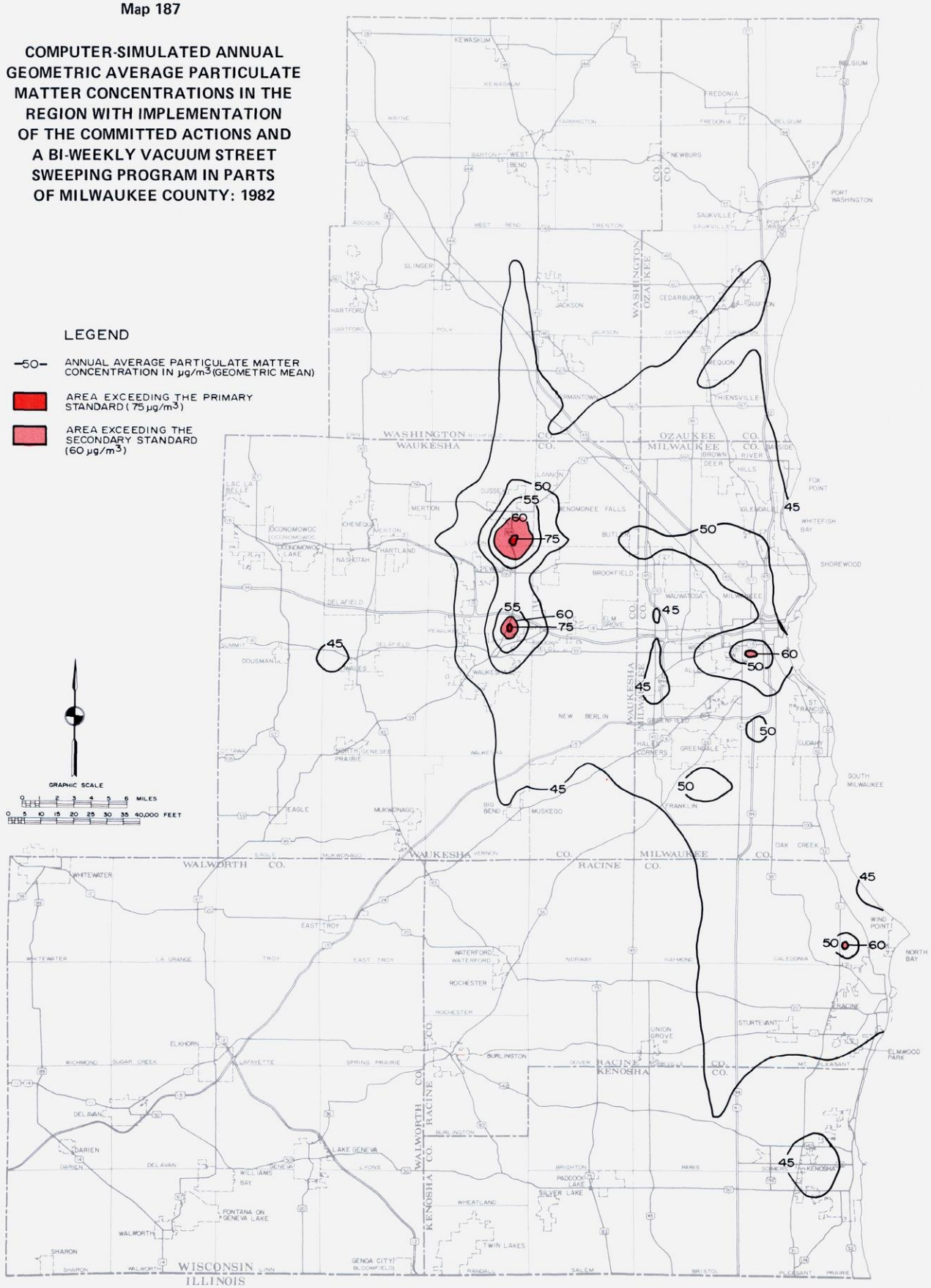
[10] *J. P. Horton, "Street Cleaning Effectiveness: Vacuum Sweepers," American Public Works Association Reporter, April 1976.*

[11] *K. Axtell and J. Zell, Control of Re-entrained Dust From Paved Streets, PEDco-Environmental, Inc., EPA Contract No. 68-02-1375, July 1977.*

Map 187

COMPUTER-SIMULATED ANNUAL GEOMETRIC AVERAGE PARTICULATE MATTER CONCENTRATIONS IN THE REGION WITH IMPLEMENTATION OF THE COMMITTED ACTIONS AND A BI-WEEKLY VACUUM STREET SWEEPING PROGRAM IN PARTS OF MILWAUKEE COUNTY: 1982

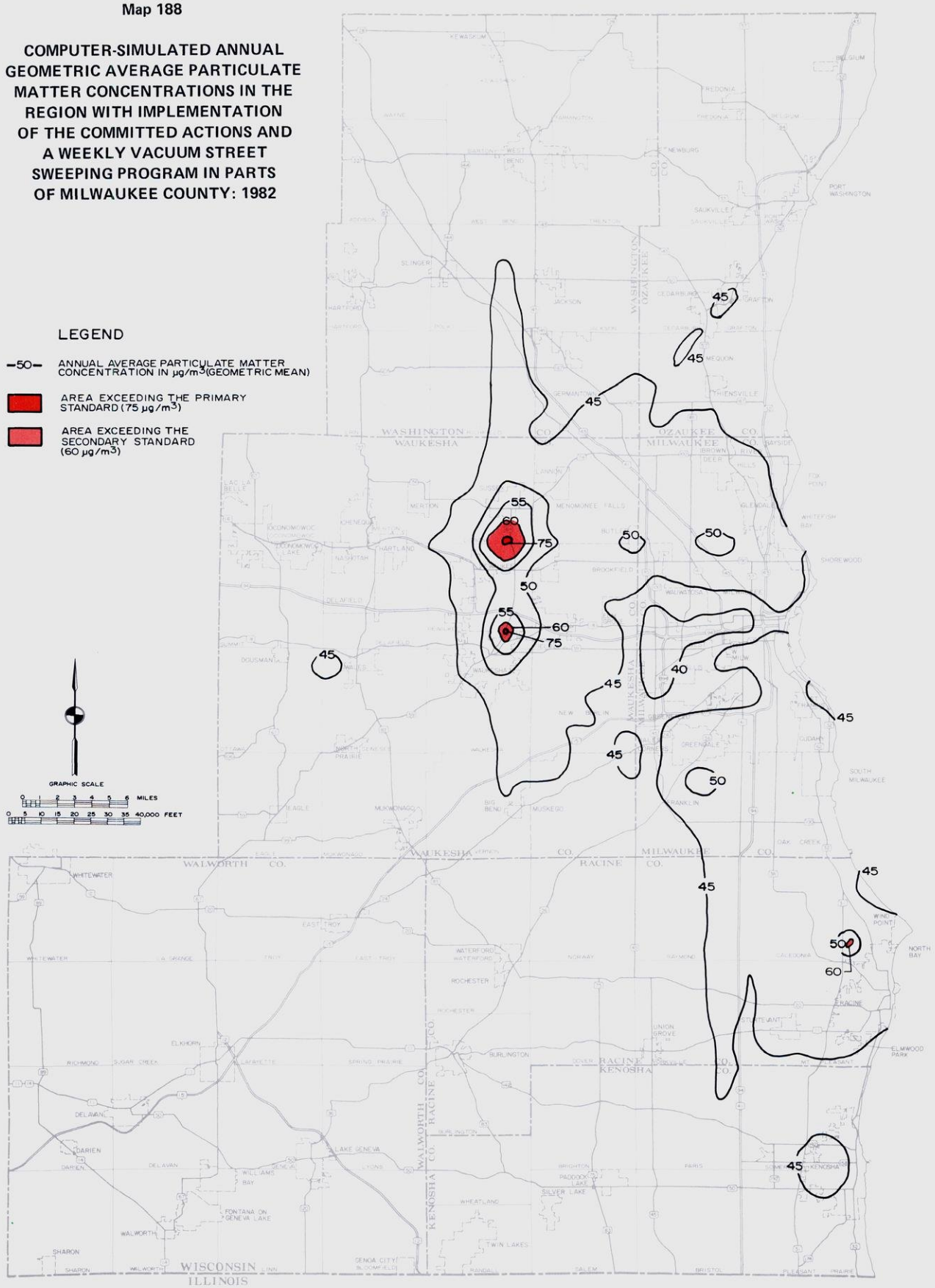


This map illustrates the composite impact of forecast point, line, and area source and re-entrained road dust emissions on ambient air quality in the Region in 1982, assuming full implementation of the industrial and fugitive dust RACT emission limitations and a bi-weekly vacuum sweeping schedule with a 25 percent fine particle removal efficiency. The bi-weekly vacuum sweeping effort was restricted to those major arterial street and highway facilities in Milwaukee County bounded by North Avenue on the north, IH 894 and USH 45 on the west, Howard Avenue on the south, and IH 94 and IH 43 on the east. As may be seen on this map, a bi-weekly vacuum sweeping program together with RACT emission limitations may be expected to provide for the attainment of the primary annual average particulate matter standard of 75 micrograms per cubic meter (ug/m^3) in Milwaukee County by 1982. However, a 0.4-square-mile area near the Marquette Interchange may still be expected to exceed the secondary annual average standard of 60 ug/m^3.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 188

COMPUTER-SIMULATED ANNUAL GEOMETRIC AVERAGE PARTICULATE MATTER CONCENTRATIONS IN THE REGION WITH IMPLEMENTATION OF THE COMMITTED ACTIONS AND A WEEKLY VACUUM STREET SWEEPING PROGRAM IN PARTS OF MILWAUKEE COUNTY: 1982



This map illustrates the composite impact of forecast point, line, and area source and re-entrained road dust emissions on ambient air quality in the Region in 1982, assuming full implementation of the industrial and fugitive dust RACT emission limitations and a weekly vacuum sweeping program with a 50 percent fine particle removal efficiency. The weekly vacuum sweeping effort was restricted to those major arterial street and highway facilities in Milwaukee County bounded by North Avenue on the north, IH 894 and USH 45 on the west, Howard Avenue on the south, and IH 94 and IH 43 on the east. As may be seen on this map, a weekly vacuum sweeping program together with RACT emission limitations may be expected to provide for attainment of the primary annual average particulate matter standard of 75 micrograms per cubic meter ($\mu g/m^3$) in Milwaukee County in 1982. A comparison of this map with Map 187 indicates that significant air quality benefits may be achieved by increasing the frequency of the street sweeping effort. However, since a bi-weekly street cleaning schedule may be expected to result in attainment of the annual standard over all but a 0.4-square-mile area in the City of Milwaukee, a weekly street cleaning schedule of the entire study area may not be economically justifiable, and such weekly cleaning should be limited to the freeway segments comprising the Marquette Interchange.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Table 317

COMPARISON OF ALTERNATIVE CONTROLS ON PARTICULATE MATTER EMISSIONS FROM QUARRYING OPERATIONS

Source	Estimated Emissions 1977	Control Alternative 1[a]	Control Alternative 2[b]
Loading Operations	284	75	75
Storage Piles	183	37	37
Primary Crushing	1,003	315	100
Secondary Crushing	2,071	636	207
Transfer and Conveying	1,542	557	154
Vehicular Traffic	340	168	168
Wind Erosion	1,026	205	205
Miscellaneous	34	24	24
Total	6,483	2,017	970

[a] *Control alternative 1 includes the paving of unpaved roads, the use of water suppression on paved roads, and the control of emissions from crushing, handling, and storage operations through chemical-water spray suppression.*

[b] *Control alternative 2 includes all measures set forth under control alternative 1, but requires the full enclosure of primary and secondary crushing operations with ventilation to a fabric filter baghouse and the full enclosure of all transfer and conveying operations.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

The Wisconsin Atmospheric Diffusion Model was used to evaluate the effectiveness of applying more stringent controls on primary and secondary crushing operations and transfer and conveying operations, applying the RACT emission limitations on industrial processes, fuel-burning installations, and fugitive dust sources, and implementing the proposed bi-weekly vacuum sweeping program in portions of Milwaukee County. The results of this simulation modeling effort are shown on Map 189 for 1982. As indicated on Map 189, the composite effect of applying these more stringent controls on quarry emissions along with other RACT control measures is to provide for the attainment of the primary annual average particulate matter standard of 75 $\mu g/m^3$ throughout the Region by 1982. However, Map 189 also indicates that three areas—a 0.4-square-mile area in the City of Milwaukee, a 0.1-square-mile area in the Town of Lisbon, and a 0.2-square-mile area in the Town of Pewaukee—may be expected to experience violations of the secondary annual average particulate matter standard of 60 ug/m^3. As already noted, a weekly vacuum street sweeping program in the secondary standard nonattainment area in the City of Milwaukee—instead of the bi-weekly program otherwise indicated—would provide for attainment in this area.

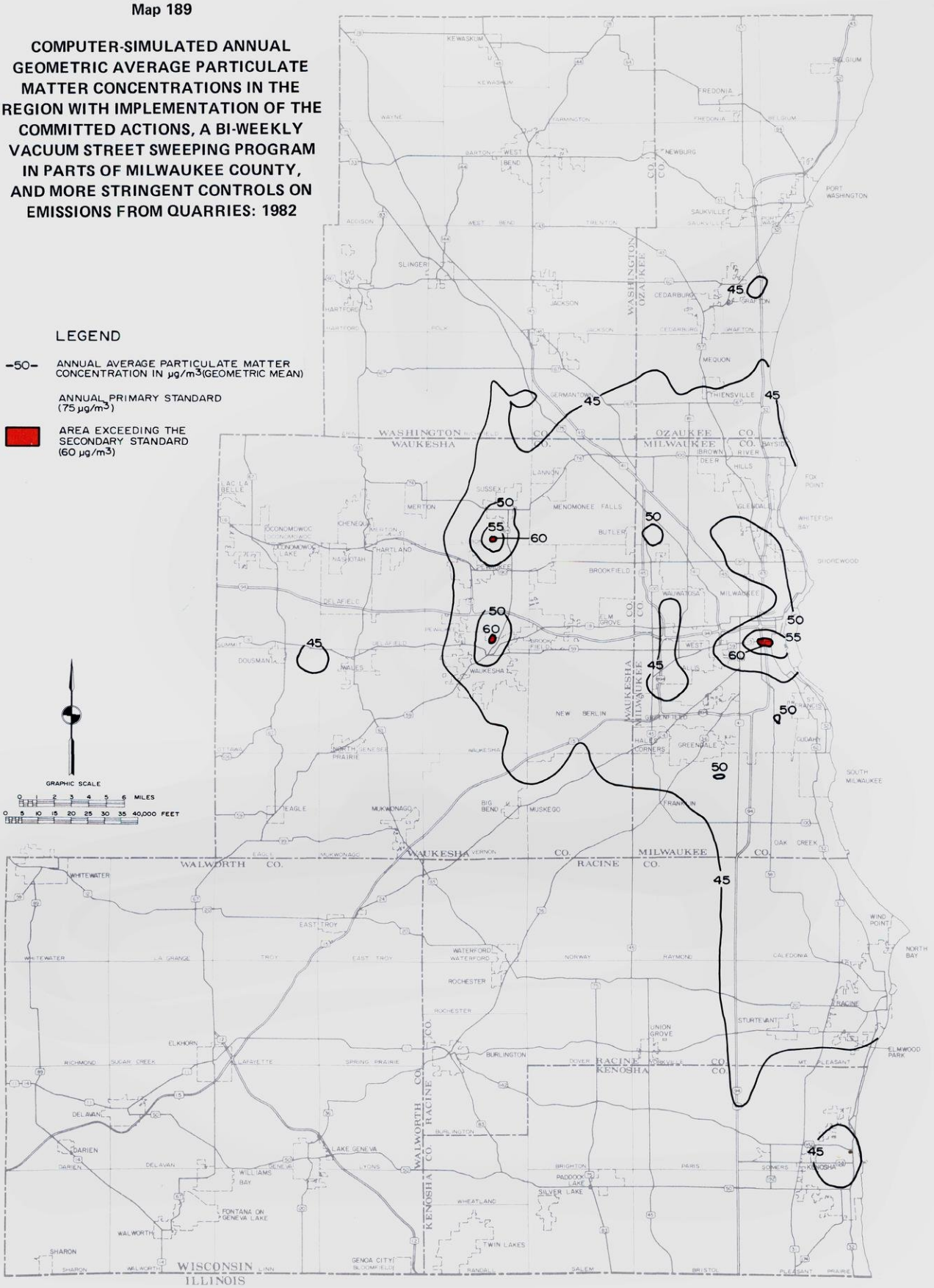
For those small areas indicated to experience violations of the secondary annual average particulate matter standard in the Towns of Lisbon and Pewaukee, a more rigorous monitoring program rather than further controls on quarrying operations should be implemented since, as was discussed under the "no further control" alternative, it is probable that the background level of particulate matter will decrease in future years as controls are placed on sources upwind of the Region. It should also be noted that the areas expected to experience violations of the secondary annual standard in the Towns of Lisbon and Pewaukee do not encompass any residential structures, nor do they impinge upon prime agricultural lands or environmental corridors. The welfare of the regional population, therefore, would not be adversely affected by these anticipated violations.

Evaluation of Alternatives: Two alternative actions for the resolution of the residual particulate matter problem in the Region forecast to persist after the implementation and enforcement of committed actions have been presented in this section: a "no further action" alternative and an "increased control" alternative. Under the "no further action" alternative, only those committed actions mandated by federal law—including RACT emission limitations on industrial processes, fuel-burning installations, and fugitive dust sources—would be implemented and enforced. The attainment and maintenance of the particulate matter ambient air quality standards under this alternative would depend extensively on the effectiveness of controls placed on sources upwind of the Region and on the identification and control of local fugitive dust sources. The "no further action" alternative is both viable and flexible since the local background levels of particulate matter will probably be reduced over the forecast period, although to an as yet undetermined extent, as controls on upwind sources serve to decrease the quantity of material subject to long-range transport, and as local fugitive dust emission sources are identified and controlled. Also, if the reductions gained under this alternative are not sufficient to attain and maintain the standards, additional or more stringent controls on local sources may be implemented and enforced as deemed necessary.

Because it is not possible at this time to estimate the reduction in local particulate matter concentrations that would result from controls on upwind sources or on unidentified local fugitive dust sources, it is not possible to demonstrate whether the particulate matter air quality standards could be attained and maintained under the "no further action" alternative. However, under the "worst case" conditions for this alternative, particulate matter concentrations in the Region would be unaffected by upwind controls and additional local controls, and ambient air levels of particulate matter would remain the same as shown on Map 181 for 1982 and on Map 184 for the year 2000. Both Map 181 and Map 184 indicate that violations of the primary annual average particulate matter standards may be expected in parts of Milwaukee County and Waukesha County and that violations of the secondary annual average standard may be expected in parts of Milwaukee, Racine, and Waukesha Counties through the year 2000. Also, application of the Larsen technique indicates that the primary 24-hour average particulate matter standard will be exceeded in parts of Waukesha County and that the secondary 24-hour standard will be exceeded in parts of Kenosha, Milwaukee, Racine, and Waukesha Counties in both 1982 and 2000 after implementation of only the committed actions. Under the "worst case" conditions for the "no further action" alternative, therefore, approximately 11,700 persons in the Region would be exposed

Map 189

COMPUTER-SIMULATED ANNUAL GEOMETRIC AVERAGE PARTICULATE MATTER CONCENTRATIONS IN THE REGION WITH IMPLEMENTATION OF THE COMMITTED ACTIONS, A BI-WEEKLY VACUUM STREET SWEEPING PROGRAM IN PARTS OF MILWAUKEE COUNTY, AND MORE STRINGENT CONTROLS ON EMISSIONS FROM QUARRIES: 1982



This map illustrates the composite impact of forecast point, line, and area source and re-entrained road dust emissions on ambient air quality in the Region in 1982, assuming full implementation of the industrial and fugitive dust RACT emission limitations, a bi-weekly vacuum street sweeping schedule, and more stringent controls on quarrying operations. Included in the more stringent control measures for quarrying operations were chemical-water spray suppression on primary and secondary crushing operations and total enclosure on transfer and conveying operations, with exhaust ventilation to a fabric filter baghouse. These control measures together may be expected to reduce overall fugitive dust emissions from quarries to about 970 tons—a decrease of about 5,500, or 85 percent, from the uncontrolled emissions level of about 6,500 tons. As may be seen by comparing this map with Map 188, implementing these more stringent controls on quarry emissions along with RACT control measures will serve to provide for the attainment of the primary annual average particulate matter standard of 75 micrograms per cubic meter ($\mu g/m^3$) throughout the Region by 1982. However, a 0.4-square-mile area in the City of Milwaukee, a 0.1-square-mile area in the Town of Lisbon, and a 0.2-square-mile area in the Town of Pewaukee may still be expected to exceed the secondary annual average air quality standard of 60 $\mu g/m^3$.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

to harmful particulate matter levels on an annual average in 1982, and 15,400 persons would be exposed to harmful levels in the year 2000. Thus, two stipulations—a continuous and extensive monitoring program in and around the anticipated nonattainment areas and an emission offset policy governing industrial growth and development—would need to accompany this alternative to protect the public health.

Under the "increased control" alternative, specific actions would be implemented to reduce fugitive dust emissions resulting from re-entrained road dust in parts of Milwaukee County, and to further reduce the level of emissions from quarrying operations in parts of Racine and Waukesha Counties. It has been estimated that a bi-weekly vacuum street sweeping program could yield an approximate 25 percent reduction in the number of fine particles on roadway surfaces available for resuspension, and that a weekly program could yield an approximate 50 percent reduction. Not all of the 200 miles of arterial street and highway facilities in the study area, however, may be amenable to street sweeping since not all roadways have a curb and gutter. Material deposited on such roadways would tend to be displaced onto the shoulder adjacent to the road surface, where re-entrainment from normal traffic flow would be unlikely. Similarly, roadways having a curb and gutter but with unrestricted parking in the curb lane would not be expected to yield large quantities of re-entrained dust since most of the fine particles lie close to the gutter away from the traffic flow. One study found that approximately 88 percent of the material deposited by weight on road surfaces was within one foot of the curb.[12]

Of the 200 miles of arterial street and highway facilities in the study area in Milwaukee County, about 8.7 miles, or 4.4 percent, do not have a curb and gutter, as indicated on Map 185. Virtually all arterial street facilities in the study area have some form of parking restriction. Those facilities which have all day or peak travel-period parking restrictions, however, allow the curb lane to be used for traffic flow and thus contribute more significantly to the re-entrained dust emissions burden. Arterial facilities with all day or peak travel-period parking restrictions are also indicated on Map 185, and account for approximately 62.5 miles, or 31.3 percent, of the 200 miles of arterial street and highway facilities in the study area. For cleaning purposes, however, all streets with a curb and gutter may be subject to the imposition of temporary parking restrictions. If the nearly 190 miles of arterial street and highway facilities in the study area having curbs and gutters, including the 62.5 miles with all day or peak travel-period parking restrictions, were vacuum swept at least on a bi-weekly schedule, the re-entrained road dust emissions burden would be substantially reduced.

Since re-entrained road dust increases directly with an increase in vehicle miles of travel, and since the highway facilities in and around the Marquette Interchange exhibit the greatest traffic volumes in the Region, a weekly vacuum sweeping effort—which is expected to reduce the road dust available for re-entrainment by about 50 percent—may prove effective in attaining the particulate matter standards in this localized area. The specific freeway segments requiring a weekly vacuum sweeping effort would include IH 94 to 35th Street on the west, Greenfield Avenue on the south, IH 794 to 7th Street on the east, and IH 43 to North Avenue on the north.

The "increased control" alternative also calls for the application of more stringent controls on certain quarrying operations, specifically on primary and secondary crushing operations and transfer and conveying operations. Under the committed RACT emission limitations these operations would be controlled through wet suppression, which, as mentioned earlier, has an overall removal efficiency of about 70 percent. The emissions from these quarrying operations would be reduced by a minimum of 90 percent under the "increased control" alternative, which calls for total enclosure of the operations, with ventilation to a fabric filter baghouse supplementing the wet suppression system. As shown on Map 189, the simulation modeling results indicate that a 90 percent control efficiency on these quarrying operations will provide for the attainment of the primary and secondary annual average particulate matter standards by 1982 in and around all of the major quarries in the Region except the Halquist Stone and Vulcan Materials facilities in the Towns of Lisbon and Pewaukee in Waukesha County. A decrease in the background particulate matter level in the Region would serve to bring these two areas into attainment.

The ability of the vacuum street sweeping effort in parts of Milwaukee County, along with 90 percent control on certain quarrying operations in Racine and Waukesha Counties and the implementation of the committed actions, to provide for the maintenance of the annual average particulate matter standards over the planning period was assessed using the Wisconsin Atmospheric Diffusion Model. The results of this modeling effort for the year 2000 are shown on Map 190. Map 190 indicates that maintenance of the annual average standards will be achieved through the year 2000 under the "increased control" alternative in all but the small areas near quarrying operations in the Town of Lisbon and the Town of Pewaukee. These areas, however, are essentially limited to the air space directly over the quarries, and thus the emissions contained therein are not expected to adversely affect the health and welfare of the regional population. Occupational exposure, though, may occur at adverse levels within the quarry boundaries.

The Larsen statistical technique was used to estimate the level of the second highest 24-hour average particulate matter concentrations in the year 2000 under the "increased control" alternative. The results of this effort are shown on Map 191. As indicated on Map 191, under the "increased control" alternative one section in the

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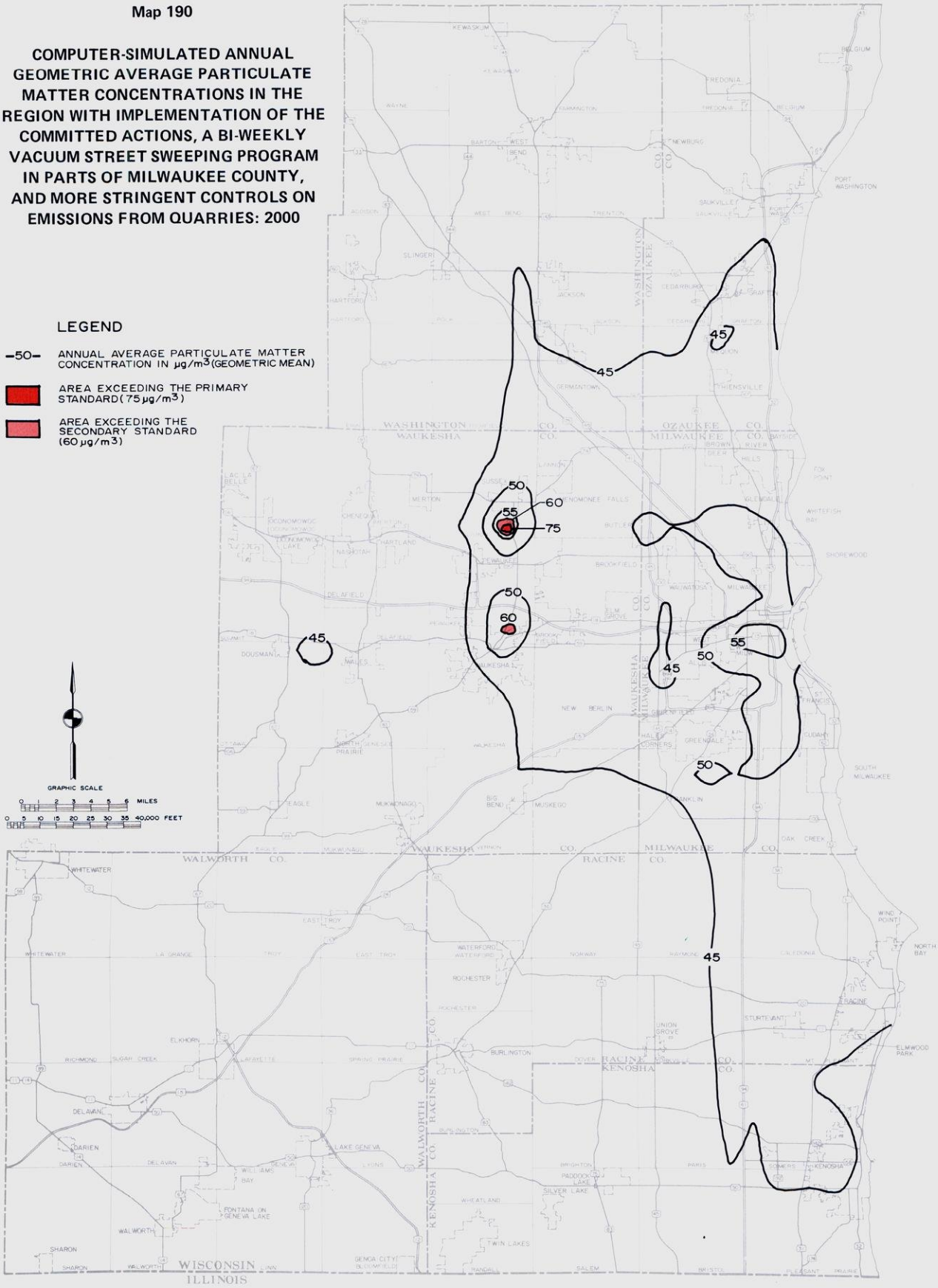
[12] *J. D. Sartor and G. B. Boyd, Water Pollution Aspects of Street Surface Contaminants, U. S. Environmental Protection Agency, EPA-R2-72-081, November 1972.*

Map 190

COMPUTER-SIMULATED ANNUAL GEOMETRIC AVERAGE PARTICULATE MATTER CONCENTRATIONS IN THE REGION WITH IMPLEMENTATION OF THE COMMITTED ACTIONS, A BI-WEEKLY VACUUM STREET SWEEPING PROGRAM IN PARTS OF MILWAUKEE COUNTY, AND MORE STRINGENT CONTROLS ON EMISSIONS FROM QUARRIES: 2000

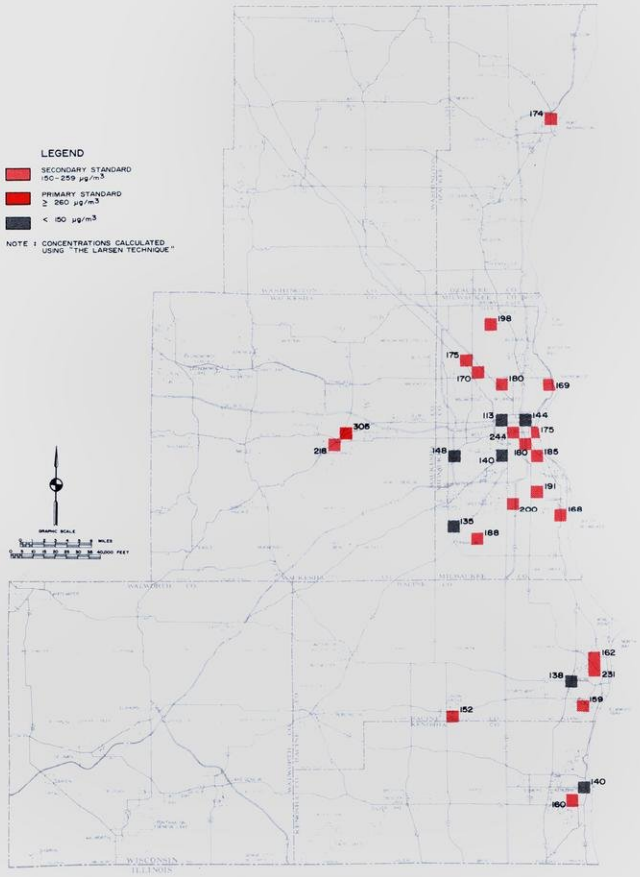


This map illustrates the composite impact of forecast point, line, and area source and re-entrained road dust emissions on ambient air quality in the Region in the year 2000, assuming full implementation of the industrial and fugitive dust RACT emission limitations, a bi-weekly vacuum street sweeping schedule, and more stringent controls on quarrying operations. It may be seen on this map that maintenance of the annual average particulate matter standards is expected to be achieved by the year 2000 under these assumptions in all but small areas near quarrying operations in the Towns of Lisbon and Pewaukee in Waukesha County. These areas are essentially limited to the atmosphere directly above the quarries, and emissions in these areas are not expected to adversely affect the health and welfare of the regional population.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 191

FORECAST OF THE SECOND HIGHEST 24-HOUR AVERAGE PARTICULATE MATTER CONCENTRATIONS IN SELECTED AREAS OF THE REGION AS PREPARED USING THE LARSEN TECHNIQUE AFTER IMPLEMENTATION OF THE COMMITTED ACTIONS, A BI-WEEKLY VACUUM STREET SWEEPING PROGRAM IN PARTS OF MILWAUKEE COUNTY, AND MORE STRINGENT CONTROLS ON EMISSION FROM QUARRIES: 2000



This map illustrates the second highest 24-hour average particulate matter concentrations due to point, line, and area source and re-entrained road dust emissions in the Region as forecast for the year 2000 using the Larsen statistical technique and assuming full implementation of the industrial and fugitive dust RACT emission limitations, a bi-weekly vacuum street sweeping schedule, and more stringent controls on quarrying operations. As shown on this map, the highest 24-hour average concentration which may be expected is about 305 micrograms per cubic meter ($\mu g/m^3$) in the Town of Pewaukee, substantially exceeding the primary air quality standard. Areas of Kenosha, Milwaukee, Racine, and Waukesha Counties may also be expected to exceed the secondary standard. It should be noted that these results are based on the assumption of a constant background particulate matter concentration, and that the control of upwind sources and presently unidentified local fugitive dust emission sources may substantially reduce or eliminate the forecast 24-hour standard violations.

Source: SEWRPC.

Town of Pewaukee may be expected to exceed the primary 24-hour particulate matter standard in the year 2000, while sections of Kenosha, Milwaukee, Racine, and Waukesha Counties may be expected to exceed the secondary standard. It must be noted, however, that these results are again based on the assumption of a constant background particulate matter concentration. The control of upwind sources and of presently unidentified local fugitive dust emission sources may serve to reduce or eliminate these forecast 24-hour standard violations. A continuing monitoring program will be required to measure the effectiveness of such controls. Due to the limitations of available simulation modeling techniques, the anticipated development of new, fine particulate matter ambient air quality standards, and the inherent inadequacies of present ambient air quality monitoring equipment, it would be necessary that an emission offset policy be put in effect for new industrial growth and development under the "increased control" alternative until it is clearly established that attainment of the standards has been achieved.

In summary, there are two potential alternatives which may be pursued to resolve the residual particulate matter problem in the Region after the implementation of the committed actions: a "no further action" alternative and an "increased control" alternative. Both alternatives offer a viable approach to resolving the residual particulate matter problem in the Region, and sound arguments may be made for the selection of either option to supplement the committed actions.

Recommended Particulate Matter Plan

Major Plan Components: Based upon the foregoing evaluation of alternative control measures, the "no further control" alternative plan is recommended for adoption as the particulate matter control element of the regional air quality attainment and maintenance plan. This element is comprised basically of the committed actions, including the application of Reasonably Available Control Technology (RACT) on industrial process sources, fuel-burning installations, and fugitive dust emission sources. In addition, the committed actions include pollution controls on major new or modified sources of emissions. For major new sources proposed for construction or modification in nonattainment areas, or which may lie outside such an area but cause or contribute to a violation of the ambient air quality standards in that area, the committed actions would require the application of control technology providing the Lowest Achievable Emission Rate (LAER), and would further require that emission offsets be obtained from other sources in the nonattainment area such that a net improvement in ambient air quality is realized. For major new sources proposed for construction or modification in clean air areas, and which will not significantly impact upon a nonattainment area, the committed actions would require the application of the Best Available Control Technology (BACT), and would further require, in order to prevent the significant deterioration of ambient air quality in the clean air area, that the allowable increments of particulate matter concentration increases are not exceeded. In addition, the recommended element calls for the development of a pilot vacuum street sweeping program in Milwaukee County in order to definitively measure the effectiveness of road surface cleaning as a means to control fugitive dust emissions. In a separate but related element, an expanded ambient air quality

monitoring program is also recommended in order to determine more definitively the effects of long-range transport on background concentrations of particulate matter. The expanded air quality monitoring program should address the previously identified areas of potential high-volume sampling errors associated with high-volume sampling rates, orientation of samples, passive dust deposition, and chemical activity or growth of the suspended particulates.

The committed actions component of the particulate matter control plan is in accordance with, and meets the July 1979 requirements of, the federal Clean Air Act Amendments of 1977, and implementation of these actions is recommended on the basis of the significant air quality improvements which, as demonstrated through air quality simulation modeling, are anticipated to result from these actions. The simulation modeling results for the forecast year 1982, as shown on Map 116 in Chapter XII, indicate that without the implementation of the committed actions approximately 5.3 square miles in Milwaukee County and 12.4 square miles in Waukesha County will exceed the primary annual average particulate matter ambient air quality standard. The simulation modeling results indicate that with the implementation of the committed actions, 0.7 square mile in Milwaukee County and 0.4 square mile in Waukesha County, as shown on Map 181, will exceed the annual primary standard of 75 $\mu g/m^3$ in 1982. Moreover, whereas Map 118 in Chapter XII indicates that 11.0 square miles in Milwaukee County and 14.2 square miles in Waukesha County will exceed the primary annual standard in the year 2000 without further controls, Map 184 indicates that the primary annual standard will be exceeded over 1.1 square miles in Milwaukee County and 0.4 square mile in Waukesha County in the design year if the committed actions are fully implemented and supplemented with an emission offset policy. In terms of population exposure, about 84,500 persons will reside in the areas that will not meet the primary standard on an annual average basis in the year 1982 without implementation of further control measures, as compared with 11,700 persons under full implementation of the committed actions. Similarly, 152,100 persons may be expected to reside in the areas in the Region that will not meet the primary standard on an annual average basis in the year 2000 without further controls, as compared with 15,400 persons with full implementation of the committed actions.

The extent of the areas over which the secondary annual average particulate matter ambient air quality standard is forecast to be exceeded in 1982 and 2000 is also forecast to decrease with implementation of the committed actions, as may be seen by comparing Maps 116 and 118 in Chapter XII, which present the particulate matter concentrations forecast in the Region without further controls in the years 1982 and 2000, respectively, with Maps 181 and 184, which present such concentrations with implementation of the committed actions. In 1982, as shown on Map 116, a 25.7-square-mile area in Milwaukee County, a 0.2-square-mile area in Racine County, and a 22.3-square-mile area in Waukesha County may be expected to exceed the secondary annual average standard of 60 $\mu g/m^3$ without further controls. Under implementation of the committed actions, however, as shown on Map 181, a 9.6-square-mile area in Milwaukee County, a 0.1-square-mile area in Racine County, and a 5.0-square-mile area in Waukesha County may be expected to exceed the secondary annual standard. Similarly, in the year 2000 the committed actions will serve to reduce the extent of the areas exceeding the secondary annual standard from 75.3 square miles in Milwaukee County and 28.4 square miles in Waukesha County, as shown on Map 118, to 11.3 square miles in Milwaukee County and 6.9 square miles in Waukesha County, as shown on Map 184.

Improvement in the 24-hour average particulate matter ambient air concentrations over the forecast period is also expected to result from implementation of the committed actions. Application of the Larsen statistical technique, which was used to estimate the second highest maximum 24-hour average particulate matter concentrations, indicates that both the primary standard of 260 $\mu g/m^3$ and the secondary standard of 150 $\mu g/m^3$ could be exceeded in parts of the Region over the planning period even with full implementation of the committed actions. The Larsen technique, however, cannot estimate the areal extent over which such violations will occur and, therefore, continuous monitoring will be required to measure future short-term particulate matter levels. This monitoring program should be augmented by an appropriate meteorological monitoring program to identify the impact of the long-range transport of particles on 24-hour standard violations.

The "no further action" alternative is recommended for three reasons. First, background particulate matter levels are not homogeneously distributed throughout the Region. The spatial variability of the background particulate matter levels—which may not be accounted for in the simulation modeling effort—may yield an overestimate of future pollutant concentrations in some areas in the Region and an underestimate in others. Additional ambient air quality monitoring will assist in overcoming this modeling limitation.

Second, as fugitive dust sources in the Region are better identified, quantified, and controlled, it is probable that the committed actions in themselves will be considered sufficient to lead to the attainment and maintenance of the standards by such sources. Because the overall effectiveness of the committed actions for fugitive dust sources cannot be fully ascertained, the application of more stringent controls on local sources may not be warranted—nor equitable—if imposed at the present time.

Third, as controls are placed on upwind particulate matter sources, the quantity of this pollutant species subject to long-range transport is anticipated to decrease, with a resulting improvement in ambient air quality in the Region. As with controls for fugitive dust sources, the total impact of such upwind controls on ambient air quality in the Region cannot be precisely ascertained. Until such time as a determination of the local impact

of upwind controls can be made, therefore, more stringent controls on local sources may not be warranted, nor equitable.

Insofar as the "no further action" alternative is recommended in part because of uncertainties regarding the effectiveness of the committed actions in controlling local fugitive dust sources, every effort should be made to comprehensively identify and quantify this category of potential particulate matter emissions. To this end, it is recommended that a pilot vacuum street sweeping study be conducted in Milwaukee County to determine the air quality benefits to be gained from the control of road dust. Based on the air quality simulation modeling analysis of particulate matter emissions from fugitive dust sources, road dust may contribute significantly to the particulate matter problem in areas with high traffic volumes in the Region. However, prior to the large capital expenditure of public funds for street sweeping equipment, with attendant operating and maintenance costs, additional study will be required of such factors as the area to be swept and the frequency of cleaning in order to provide the most cost-effective program for controlling road dust emissions.

The foregoing discussion has outlined the three major components of the recommended particulate matter plan: implementation of the committed actions; establishment of an expanded air quality monitoring program; and development of a pilot street sweeping program in Milwaukee County. The specific elements of these three components are presented in the following sections.

Committed Actions: The committed actions for existing sources of particulate matter emissions include the implementation and enforcement of Reasonably Available Control Technology (RACT), and, for major new sources of particulate matter emissions, the implementation and enforcement of more stringent air pollution controls. The federally mandated RACT limitations include controls on particulate matter emissions from industrial processes, fuel-burning installations, and fugitive dust sources. The emission limitations and control measures prescribed under the RACT rules are as follows for each of these three source categories:

1. Industrial Process Sources

   a. For all industrial processes established or modified after April 1, 1972 but before July 1, 1979, and which lie within, or impact upon, a primary or secondary particulate matter nonattainment area, the particulate matter emissions should be limited to 0.10 pound per 1,000 pounds of exhaust gas.

   b. For all industrial processes established or modified after April 1, 1972 but before July 1, 1979, and which do not lie within, or impact upon, a primary or secondary particulate matter nonattainment area, the particulate matter emission limitation should be determined by the process weight rate and calculated by the formulas set forth in Figure 105.

   c. For all industrial processes established or modified prior to April 1, 1972 but before July 1, 1979, and which lie within, or impact upon, a primary or secondary particulate matter nonattainment area, the particulate matter emissions should be limited to 0.10 pound per 1,000 pounds of exhaust gas.

   d. For all industrial processes established or modified prior to April 1, 1972 but before July 1, 1979, and which do not lie within, or impact upon, a primary or secondary particulate matter nonattainment area, the particulate matter emission limitation should be determined by source category as defined in Figure 105.

2. Fuel-Burning Installations

   a. For all fuel-burning installations constructed prior to July 1, 1979, with a heat input greater than 100 million British Thermal Units (BTU's) per hour, and which lie within, or impact upon, a primary or secondary particulate matter nonattainment area, the particulate matter emissions should be limited to 0.10 pound per million BTU's.

   b. For all fuel-burning installations constructed or modified after April 1, 1972 but before July 1, 1979 with a heat input greater than 250 million BTU's per hour, and which do not lie within, or impact upon, a primary or secondary particulate matter nonattainment area, the particulate matter emissions should be limited to 0.10 pound per million BTU's.

   c. For all fuel-burning installations constructed or modified prior to April 1, 1972 with a heat input greater than 250 million BTU's per hour, and which do not lie within, or impact upon, a primary or secondary particulate matter nonattainment area, the particulate matter emissions should be limited to 0.15 pound per million BTU's.

   d. For all fuel-burning installations constructed or modified after April 1, 1972 but before July 1, 1979 with a heat input less than 100 million BTU's per hour, and which do not lie within, or impact upon, a primary or secondary particulate matter nonattainment area, the particulate matter emissions should be limited to 0.15 pound per million BTU's.

   e. For all fuel-burning installations constructed prior to July 1, 1979 with a heat input of less than 100 million BTU's per hour, and which lie within, or impact upon, a primary or secondary particulate matter nonattainment area, the

particulate matter emissions should be limited to 0.24 pound per million BTU's.

f. For all fuel-burning installations constructed or modified prior to April 1, 1972 with a heat input of less than 250 million BTU's per hour, and which do not lie within, or impact upon, a primary or secondary particulate matter nonattainment area, the particulate matter emissions should be limited to the rate defined by the equation set forth in Figure 106.[13]

3. Fugitive Dust Sources

a. Industrial and commercial private roadways, and areas subject to traffic of more than 10 vehicles in any hour, should be paved, and should be periodically cleaned to remove loose material.

b. Storage piles of material having a silt content of 5 to 20 percent should be treated with water, surfactants, stabilizers, or chemicals, and be draped or enclosed on a minimum of three sides. Access areas around such storage piles should be watered, cleaned, or treated with stabilizers to prevent fugitive dust.

c. Storage piles of materials having a silt content of 20 percent or more should be completely enclosed or draped when materials are not being worked, loaded, or unloaded. Access areas should be watered, cleaned, or treated with stabilizers.

d. For all materials-handling operations, visible fugitive dust emissions should be controlled to 10 percent opacity when wind speeds are less than 25 miles per hour except for three minutes in any hour, when visible emissions may equal 50 percent opacity.

e. Any device used to control fugitive emissions from materials-handling operations, and which has a discharge to the ambient air, should not exceed an emission limitation of 0.10 pound of particulate matter per 1,000 pounds of exhaust gas.

f. Particulate matter emissions from industrial processes should be limited to 0.10 pound per 1,000 pounds of exhaust gas.

g. Visible fugitive emissions from any building or structure egress should be controlled to 10 percent opacity except for three minutes in any hour, when the emissions may equal 50 percent opacity.

h. Visible fugitive emissions should be controlled during coking operations at the charging ports, doors, and quench towers, and during pushing operations.

i. In general, all sources which have the potential to generate airborne dust should be covered, paved, or treated in such a manner so as to reduce the fugitive emissions which may be released to the ambient air.

As noted, the committed actions also call for controls on major new or modified sources of particulate matter emissions constructed after July 1, 1979. The control measures prescribed under the committed actions for major new or modified sources of particulate matter emissions are as follows:

1. Major New or Modified Sources Proposed for Construction in Nonattainment Areas

a. Any major new source, or any major modification to an existing source, which is to be located within or which will have a significant impact upon a particulate matter nonattainment area, must apply control technology providing for the Lowest Achievable Emission Rate (LAER). The definition of LAER control technology is determined on a facility-by-facility basis and does not consider economic impact.

b. Any major new or modified source which is to be located within or which will have a significant impact upon a nonattainment area must obtain a greater than one-for-one emission reduction in the nonattainment area such that a net improvement in ambient air quality is realized. This emission offset is an integral component of the committed actions since it ensures the long-term effectiveness of such actions while providing flexibility for continued industrial growth and development in the Region.

2. Major New or Modified Sources Proposed for Construction in Clean Air Areas

a. Any major new source, or any major modification to an existing source, which is not to be located within a nonattainment area and which will not have a significant impact upon such an area must apply the Best Available Control Technology (BACT). The definition of BACT is determined on a facility-by-facility basis and does consider economic impact. In general, the BACT level of control is more stringent than the RACT but less stringent than LAER levels of control.

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[13] *An exemption to the RACT emission limitations for fuel-burning installations of this capacity may be granted if the facility was constructed prior to April 1, 1972, and if the originally allowable emission rate for that facility has been maintained with no appreciable degradation. (See Wisconsin Administrative Code, Chapter NR 154, Section 154.11(4)(e), (f).)*

b. Any major new or modified source which is not to be located within a nonattainment area and which will not have a significant impact upon such an area must demonstrate that the particulate matter concentrations added to the ambient air as a result of the operation of the source will not exceed the allowable increments established to prevent the significant deterioration of air quality in clean air areas. These allowable increments are set forth in Table 1 in Chapter II of this report.

Air Quality Monitoring Program: The existing particulate matter ambient air quality monitoring network in the Region should be supplemented with additional hi-vol samplers sited in such a manner so as to fulfill the following objectives:

1. To ascertain the ambient particulate matter concentrations in the Region due to long-range transport from extraregional sources,

2. To verify the results of the air quality simulation modeling effort and to monitor the effectiveness of proposed controls on local sources in suspected nonattainment areas presently defined only through air quality simulation modeling, and

3. To minimize the inherent sampler monitoring errors associated with various sampling volume rates, sampler orientation, passive filter loadings, and chemically reactive growth of the sampled particles.

A monitoring network designed to meet the first objective—quantifying long-range transport—should consider the spatial variability of transported pollutants. Recognizing that background particulate matter levels are not constant in all areas of the Region, several hi-vol sampling sites should be established along regional boundaries, particularly on the southern periphery near the Chicago urbanized area. These peripheral sites should be augmented by other hi-vol samplers located in such a manner so as to establish a traverse of the Region in order to measure the change in transported pollutant concentrations with distance away from the boundary area.[14] Such a hi-vol particulate matter monitoring network would also provide a measure of the effectiveness of controls on upwind emission sources and a means for more precisely determining differential background levels throughout the Region.

Hi-vol particulate matter monitors designed to meet the second objective—verifying the air quality simulation modeling results and measuring the effectiveness of local controls in and around suspected nonattainment areas—will provide the basis for future determinations of the necessity, or lack thereof, for more stringent controls on local sources. This monitoring effort would support the first objective in that the effectiveness of controls on upwind sources could be evaluated against the need for further local controls. In particular, such monitoring should be conducted in the proximity of the major quarrying operations located in Racine and Waukesha Counties. The proposed monitoring network for particulate matter is described in more detail in the last section of this chapter.

The third objective can be accomplished by establishing a standardized sampling volume rate that will capture the respirable suspended particulates but not be unduly biased by high-velocity capture of larger, setteable particulates. In addition, careful attention must be given to sampler orientation with respect to local or nearby point sources which can unduly bias the ambient loadings. It will also be necessary that the particulate filters be exposed to the atmosphere in the sampler unit for an absolute minimum time both before and after the active 24-hour sampling period.

Street Sweeping Program: Re-entrained road dust may be a significant source of fugitive particulate matter emissions. Such road dust emissions may be controlled through an effective street sweeping program. It is therefore recommended that a pilot street sweeping program be designed and conducted jointly by the municipalities in the re-entrained road dust study area—the Cities of Greenfield, Milwaukee, Wauwatosa, West Allis, and West Milwaukee in Milwaukee County (see Map 185)—to firmly establish the ambient air quality benefits to be gained from a regularly scheduled road cleaning effort. If the results of this pilot program demonstrate direct reductions in ambient air particulate matter levels, a vacuum street sweeping program should be implemented throughout the study area as expeditiously as possible thereafter.

It should be noted that street sweeping in parts of Milwaukee County has been recommended as an important way to control urban nonpoint source water pollution and reduce urban storm water contamination.[15] Street sweeping was identified as one of a set of urban land management practices. The Commission and the Wisconsin Department of Natural Resources have jointly

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[14] *The origin of particles captured by the hi-vol monitors may be determined in most cases through laboratory techniques involving mass spectroscopy. Such laboratory analyses of exposed filters may be of substantial value in determining the relative contribution of particules transported into the Region from external sources to local ambient air quality.*

[15] *See SEWRPC Planning Report No. 30, A Regional Water Quality Management Plan for Southeastern Wisconsin: 2000, Volume Three, Recommended Plan, June 1979; and SEWRPC Technical Report No. 18, State of the Art of Water Pollution Control in Southeastern Wisconsin, Volume Three, Urban Storm Water Runoff, December 1976.*

undertaken a study to determine the effectiveness of two potential practices for the control of nonpoint source pollution in urban storm water: street sweeping and storm water detention.[16] As a part of this work program, the amount of particulate matter deposited on street surfaces as a result of atmospheric fallout and the effectiveness of various street sweeping practices—in terms of frequency and interval between sweeping—in reducing water pollution are to be evaluated over the three-year period beginning July 1, 1979. The pilot vacuum street sweeping program recommended as a part of the particulate matter attainment and maintenance plan should, wherever feasible, incorporate the findings of this urban storm water control program.

Estimation of Compliance Costs of Particulate Matter Control Measures: Estimated compliance costs for the control of particulate matter emissions from industrial point sources and industrial fugitive dust sources—including quarrying operations—in the Region were prepared by ETA Engineering, Inc., with the assistance of the Wisconsin Department of Natural Resources. The cost analyses as prepared by ETA Engineering were based on a "standard source" concept designed to represent typical installations based on parameters such as annual throughput, physical size, and exhaust air requirements.[17] Components of the capital costs include basic equipment, auxiliary equipment, and installation. The basic equipment cost includes the delivered cost of the equipment. Auxiliary equipment costs encompass those items essential to the operation of the control system, including hooding, ductwork, fans and motors, and pumps. Costs for foundations and supports, electrical insulation, painting work, construction fees and field expenses, startup, and performance testing are included in the capital installation costs. Net annualized costs were calculated using direct expenses based on contractor studies prepared for the U. S. Environmental Protection Agency on the cost of labor and materials, operation and maintenance, replacement parts, utilities, and waste disposal. Indirect costs included overhead, taxes, insurance, interest, and depreciation.

As was discussed in Chapter IX of this report, the properties and characteristics of a particulate point source gas stream will generally dictate the appropriate particulate matter control system, with electrostatic precipitators, venturi wet scrubbers, and baghouses being capable of meeting the definition of Reasonably Available Control Technology (RACT). In some cases more than one control technique may meet RACT criteria and economic conditions. The costs presented herein represent the judgment of ETA Engineering, Inc., as to the most appropriate control device for an affected facility.

Table 318 presents a summary of compliance cost estimates for the committed actions as prepared by ETA Engineering, Inc., and identifies the number of affected facilities subject to control. These affected facilities are also identified by name in Appendix I and by location on Map 192. As may be seen in Table 318, the Wisconsin Department of Natural Resources has identified eight facilities as not being in compliance with the RACT emission limitations for industrial sources as proposed under the committed actions. Of these eight facilities, two asphalt plants and one cement manufacturing plant were assessed as being capable of achieving emission compliance by upgrading the efficiency of current control equipment without incurring significant costs. Four foundries and one electric power generation plant are the principal sources affected, with the capital costs for one electric utility estimated at $2,164,000, or more than 85 percent of the total industrial point source capital cost of $2,531,000. Since these cost estimates are based on a "standard source" model, however, the actual costs incurred by such facilities may be subject to revision after detailed engineering studies have been conducted and economic impacts considered.

Estimates of compliance costs for the control of fugitive particulate matter emissions were made by ETA Engineering, Inc., for 54 industrial sources and nine major quarrying and stone-crushing operations in the Region. The industrial fugitive particulate matter cost analyses are based on the assumption that all emissions within one plant could be ducted to a single collector. The concept of a "standard plant" was used to determine compliance costs for industrial fugitive emissions sources, with the data extrapolated to each specific affected source in the Region. The sources were categorized into eight groups: asphalt batch plants, cement grinding and batch plants, grain elevators and terminals, secondary smelters, bulk storage and terminals, foundries and machine manufacture, power plants, and quarrying operations. Control techniques included paving and cleaning of access roads and parking areas, covering and wet suppression of outside storage piles, the use of wet scrubbers, and ventilation to fabric filter baghouses. As may be seen in Table 318, the total capital cost of compliance with the proposed RACT emission limitations on fugitive dust sources is estimated at $28,741,000 in 1978 dollars. The net annualized cost for these facilities is about $12,569,000 in 1978 dollars. Most of the capital costs—about $24 million—and most of the net annualized costs—about $9,479,000—would be incurred by foundries and machine manufacturing facilities in the Region.

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[16] *See Work Plan Evaluation of Urban Nonpoint Source Pollution Management in Milwaukee County, Wisconsin prepared jointly by the Southeastern Wisconsin Regional Planning Commission and the Wisconsin Department of Natural Resources for the nationwide urban runoff program, of the U. S. Environmental Protection Agency in February 1979.*

[17] *It is important to note that the cost analyses prepared by ETA Engineering, Inc., are preliminary estimates and are not based on detailed engineering studies of each affected facility. The final cost for required air pollution control equipment which will be incurred by an existing facility to meet the RACT emission limitations may be accurately and precisely determined only through detailed studies which consider the unique operating characteristics and requirements of each facility.*

Table 318

SUMMARY OF COMPLIANCE COST ESTIMATES FOR PARTICULATE MATTER FROM INDUSTRIAL POINT SOURCES, INDUSTRIAL FUGITIVE DUST SOURCES, AND QUARRYING OPERATIONS IN THE REGION

Source	Number of Facilities Affected	Capital Cost	Annualized Costs (in thousands of dollars)[a]			Net Annualized Costs (in thousands of dollars)	Reduction in Emissions (tons per year)	Cost Effectiveness of Control (thousands of dollars per ton)
			Capital Charges	Operation and Maintenance	Materials			
Industrial Point Sources	8	2,531	413	111	N/A	524	119.9	4.40
Industrial Fugitive Dust Sources								
Asphalt Batch Plants	3	497	100	140	10	250	16.1	15.50
Cement Grinding and Batch Plants	6	1,718	351	50	12	413	11.1	37.20
Grain Elevators and Terminals	5	871	177	27	16	220	145.7	1.50
Secondary Smelters	6	103	22	29	--	51	81.2	0.60
Bulk Storage and Terminals	5	226	49	30	88	167	34.1	4.90
Foundries and Machine Manufacture	27	24,011	4,872	4,583	24	9,479	309.0	30.70
Power Plants	2	324	66	37	1,630	1,733	271.95	6.40
Quarrying Operations	9	991	200	56	--[b]	256	4,466.4	0.06
Total	64[c]	31,272	6,250	5,063	1,780	13,093	5,455.45	2.40 (average)

NOTE: N/A indicates data not available.

[a] *Expressed in 1978 dollars.*

[b] *Included under operation and maintenance costs.*

[c] *Seven of the eight industrial point sources are also industrial fugitive dust sources. Thus 64, not 71, facilities are affected.*

Source: Wisconsin Department of Natural Resources and ETA Engineering, Inc.

All cost estimates for the recommended particulate matter plan as set forth in Table 318 represent expenditures incurred by the private sector, and do not include any allocation of government funds. However, public monies will be required to fund a pilot vacuum street sweeping program in parts of Milwaukee County. The cost of the recommended pilot program will of course be related to the scope of work undertaken in this initial program. In the event that a bi-weekly vacuum street sweeping schedule is deemed feasible in parts of Milwaukee County, and that a weekly sweeping effort in and around the Marquette Interchange is found to have air quality benefits, the Commission staff has prepared an estimate of the public funds necessary to operate such a program. Based on an estimate of 190 miles of arterial street and highway facilities with curbs and gutters in the study area which would be swept once every two weeks, and about 14 miles of highway facilities which would be swept weekly, four vacuum street sweepers will be required to meet the proposed schedule. Capital costs for four vacuum sweepers at about $40,000 each would total about $160,000. Also, based on average operating and maintenance costs presently incurred by the County and City of Milwaukee for the existing street sweeping program, net annualized costs are estimated at $338,000. If such funds were to be spent on a vacuum street sweeping program, they would represent approximately one-half of 1 percent of the total capital costs, and about 2.6 percent of the net annualized costs, of implementing the recommended particulate matter plan in southeastern Wisconsin. The cost of the recommended ambient air quality monitoring program for particulate matter, which would also be financed with public monies, is discussed later in this chapter.

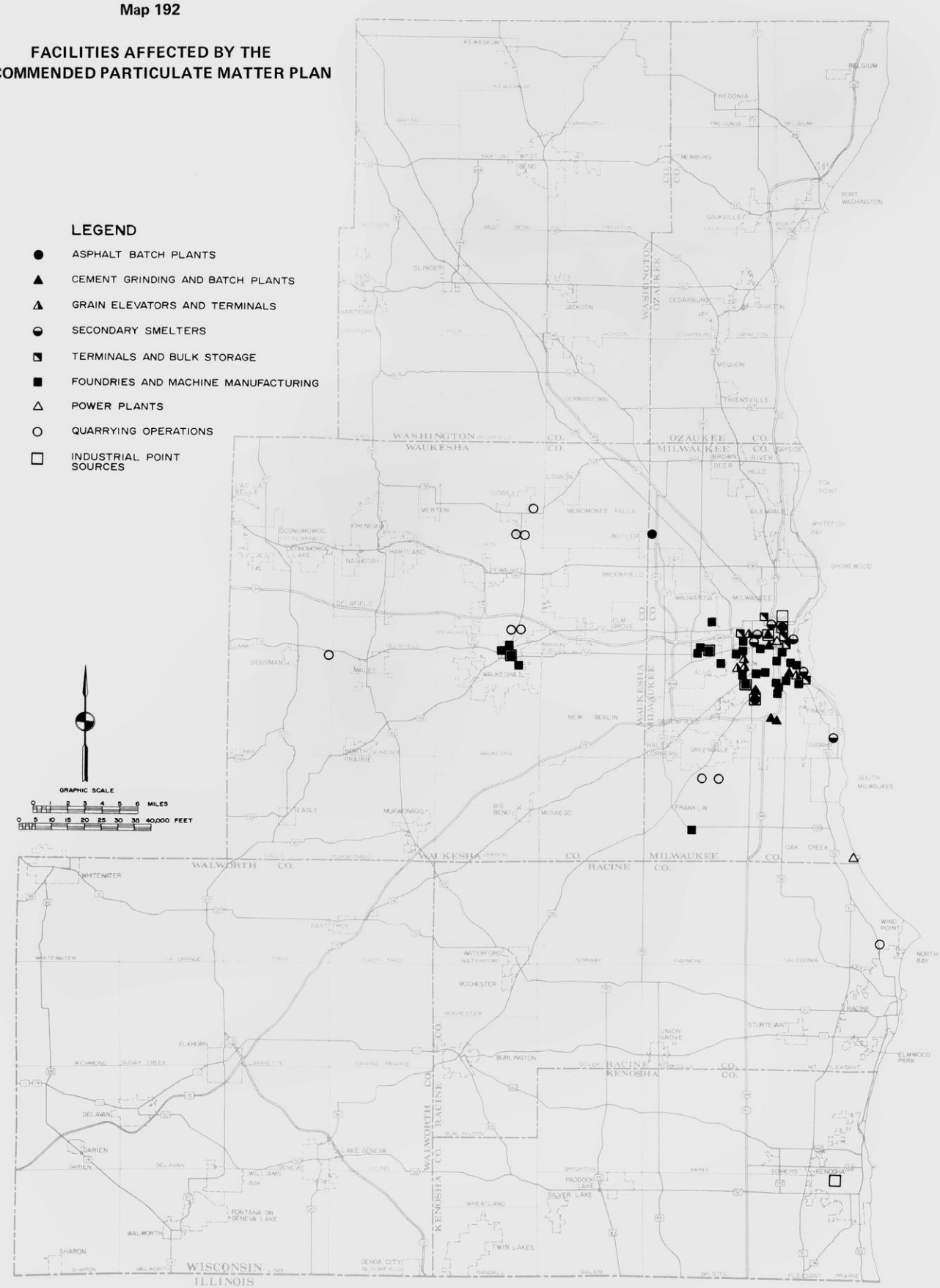
SULFUR DIOXIDE PLAN

As indicated in the previous two chapters of this report, ambient air quality monitoring data and air quality simulation modeling results indicate that the 24-hour primary standard for sulfur dioxide is being exceeded within the Region, and may be expected to continue to be exceeded in the future in the absence of short-term abatement and long-term maintenance actions. In addition, the simulation modeling effort indicates that in the absence of abatement measures, violations of the three-hour and annual sulfur dioxide standards may be expected by the year 2000. Thus, strategies for the attainment and long-term maintenance of these sulfur dioxide standards in southeastern Wisconsin must be developed.

Combustion processes are the principal source of sulfur dioxide air pollutant emissions, with the burning of sulfur-bearing fossil fuels, particularly in coal-burning steam electric generating plants, being the major con-

Map 192

FACILITIES AFFECTED BY THE RECOMMENDED PARTICULATE MATTER PLAN



This map shows the location of those facilities identified by the Wisconsin Department of Natural Resources (DNR) as being located within or impacting upon the designated particulate matter nonattainment area. Of these 71 facilities, the DNR has identified eight industrial point sources and 63 industrial fugitive dust sources as not being in compliance with the RACT emission limitations for industrial sources as proposed under the committed actions. Included in the eight point sources are two asphalt plants, one cement manufacturing plant, four foundries, and one electric power generating plant. The sources of industrial fugitive dust emissions are categorized as asphalt batch plants, cement grinding and batch plants, grain elevators and terminals, secondary smelters, bulk storage and terminals, foundries and machine manufacture, power plants, and quarrying operations.

Source: Wisconsin Department of Natural Resources and SEWRPC.

tributor to the sulfur dioxide air pollution burden in the Region. Although sulfur dioxide emissions are generally attributable to a relatively few large point sources, air pollutant emissions inventories for southeastern Wisconsin indicate that the area source categories of residential fuel use, commercial-institutional fuel use, and industrial fuel use are all important contributors to sulfur dioxide levels in the ambient air.

Committed Sulfur Dioxide Control Actions

As with the particulate matter plan, the initial component of the sulfur dioxide plan is comprised of committed actions—that is, actions which are presently mandated by either state or federal requirements. The committed actions as they pertain to the control of sulfur dioxide air pollution include controls on both existing and new or modified major sources of sulfur dioxide emissions. The formal designation by the U. S. Environmental Protection Agency of the sulfur dioxide nonattainment area in Milwaukee County (see Map 85 in Chapter XI), as proposed by the Wisconsin Department of Natural Resources, is also considered herein as a committed action. The designation of the sulfur dioxide nonattainment area in Milwaukee County will require that the Wisconsin Department of Natural Resources establish a control level defined as Reasonably Available Control Technology (RACT) for existing major sources in that area.

Major new or modified sources of sulfur dioxide emissions locating within, or significantly impacting upon, the nonattainment area in Milwaukee County would be required to apply control technology producing the Lowest Achievable Emission Rate (LAER), determined on a facility-by-facility basis, and would further be required to obtain a greater than one-for-one sulfur dioxide emission reduction from other sources in the area such that a net improvement in ambient air quality is realized. Major new or modified sources of sulfur dioxide emissions locating outside, and not impacting upon, the nonattainment area in Milwaukee County would be required to apply the Best Available Control Technology (BACT), determined on a facility-by-facility basis, and would further be required to demonstrate that the sulfur dioxide concentrations added to the ambient air as a result of the operation of the new or modified source do not exceed the allowable increments (see Table 1, Chapter II).

Although the RACT emission limitations have not presently been determined by the Wisconsin Department of Natural Resources for sulfur dioxide sources in and around the proposed nonattainment area in Milwaukee County, there are emission regulations in effect which such sources are presently required to meet. These regulations are summarized in the following section.

Existing Limitations on Sulfur Dioxide Emissions: Existing sulfur dioxide emission limitations for fuel-burning sources apply primarily to new or modified fossil fuel-fired steam generators rated at over 250 million British Thermal Units (BTU's) per hour. For units firing oil, the emission limit is 0.80 pound of sulfur dioxide per million BTU heat input capacity. A higher emission limit of 1.2 pounds of sulfur dioxide per million BTU input is allowed for units firing coal. In the Southeastern Wisconsin Region, installations of 250 million BTU's per hour or less are not permitted to burn coal with a sulfur content exceeding 1.11 pounds per million BTU's in the coal. In addition to these limitations on basic fuel use, sulfur content restrictions have been placed on the use of standby fuels. These state regulations prohibit the use of standby fuels with a sulfur content greater than 1.5 percent by weight as fired for coal, 1 percent for residual oil, and 0.70 percent for distillate oil.

Revised federal New Source Performance Standards are now in effect for sulfur dioxide emissions from new, modified, and reconstructed electric utility steam generation units of more than 73 megawatts heat input maximum capacity per hour (250 million BTU's per hour) of fossil fuel which were constructed after September 18, 1978. For solid and solid-derived fuels—except solid solvent-refined coal—these New Source Performance Standards prescribe that sulfur dioxide emissions to the atmosphere shall not exceed 1.20 pounds per million BTU heat input. A 90 percent reduction in potential sulfur dioxide emissions is also required except when emissions to the atmosphere are less than 0.60 pound per million BTU heat input, for which a 70 percent reduction in potential emissions is permitted. For gaseous and liquid fuels not derived from solid fuels, the sulfur dioxide emissions into the atmosphere are limited to 0.80 pound per million BTU heat input, and a 90 percent reduction in potential sulfur dioxide emissions is required. The percent reduction requirement does not apply if the sulfur dioxide emissions into the atmosphere are less than 0.20 pound per million BTU heat input. Compliance with the emission limit and percent reduction requirements is determined by using continuous monitors to obtain a 30-day "moving" average. The percent reduction is computed on the basis of overall sulfur dioxide removed by all types of sulfur compound removal technology, including both flue gas desulfurization systems, and fuel pretreatment systems, such as coal cleaning, coal gasification, and coal liquefaction.

Evaluation of Committed Sulfur Dioxide Control Actions: A coal-intensive energy scenario was developed under which it was assumed that new or modified fossil fuel-fired steam generators rated at more than 250 million BTU heat input per hour would not exceed the existing sulfur dioxide emission limitation of 1.2 pounds of sulfur dioxide per million BTU heat input capacity. For installations of less than 250 million BTU heat input per hour, the sulfur dioxide emissions forecasts were based upon the existing limitation of 1.11 pounds of sulfur content per million BTU's in the coal. The simulation modeling effort for year 2000 sulfur dioxide emissions performed under the coal-intensive energy scenario and assuming implementation of these committed limitations indicated that violations of the three-hour, 24-hour, and annual sulfur dioxide standards may be expected to occur in a portion of Milwaukee County. It may be concluded,

therefore, that strategies beyond the committed actions will be required to attain and maintain the ambient air quality sulfur dioxide standards.

Potential Actions for the Control of Residual Sulfur Dioxide Emissions

As noted in the previous section, the three-hour, 24-hour, and annual sulfur dioxide standards are forecast to be exceeded in a part of Milwaukee County, even with the implementation of the committed sulfur dioxide emission limitations. Unless sulfur dioxide background levels are significantly reduced, which is not anticipated because of the forecast increased use of coal, both regionally and nationally, additional control measures for sulfur dioxide sources will be necessary. A number of alternatives are available for consideration, including the banning of the use of coal by small area combustion sources, sulfur content limitations on the sulfur dioxide emissions from major fuel-burning installations, and limitations on the sulfur content in fuels burned by major fuel-burning installations. These three alternative approaches are examined below.

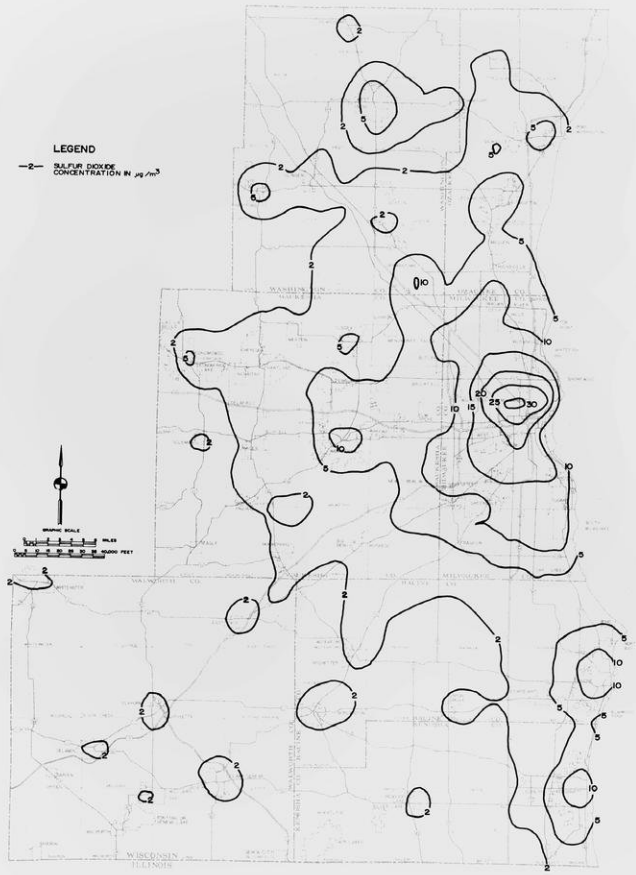
Coal Ban Alternative on Small Combustion Sources: Although sulfur dioxide emissions are contributed by point, line, and area sources, the simulation modeling results indicate that point and area sources are the largest contributors in those areas of Milwaukee County expected to exceed the standards. The total sulfur dioxide emissions from area sources, specifically those from the combustion of fossil fuels for residential and commercial-institutional use, are not extremely large in quantity, but their impact on ambient air concentration levels is significant because of the generally low chimney and stack heights. Although coal is not the primary fuel used by small combustion sources, it is a significant contributor of sulfur dioxide emissions because of its high sulfur content . A restriction on the use of coal by residential and commercial-institutional area sources is therefore examined as a means of reducing ambient air sulfur dioxide concentrations in the Region.

The area source emissions forecast for the year 2000 indicates that two area source categories—residential fuel use and small commercial-institutional fuel use—will contribute 15,200 tons, or about 79 percent, of the estimated 19,200 tons of total area source sulfur dioxide emissions in the Region. In order to appraise the impact that these two area source categories will have on sulfur dioxide levels in the Region, the year 2000 forecasts of sulfur dioxide emissions from residential and small commercial-institutional fuel use were individually simulated. The computer-simulated concentrations for sulfur dioxide emissions from residential fuel use in the year 2000 are presented on Map 193. The maximum sulfur dioxide concentration indicated on Map 193 is 30 micrograms per cubic meter ($\mu g/m^3$) and is located in central Milwaukee County. A comparison of Map 193 with Map 137 in Chapter XII, which presents the forecast annual arithmetic average sulfur dioxide concentrations resulting from all emission sources in the year 2000, indicates that residential fuel use may be expected to contribute approximately one-third of the total sulfur dioxide levels forecast for the most highly polluted area of Milwaukee County by the design year.

Because coal-fired residential space and water heating is a significant contributor to sulfur dioxide emissions in the Region, year 2000 conditions were modeled using emissions calculated on the assumption of a total restriction on coal use for residential space and water heating. The spatial distribution of the housing units using coal for space and water heating in 1977 is shown on Map 194.

Map 193

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE SULFUR DIOXIDE CONCENTRATIONS FROM RESIDENTIAL FUEL USE IN THE REGION: 2000

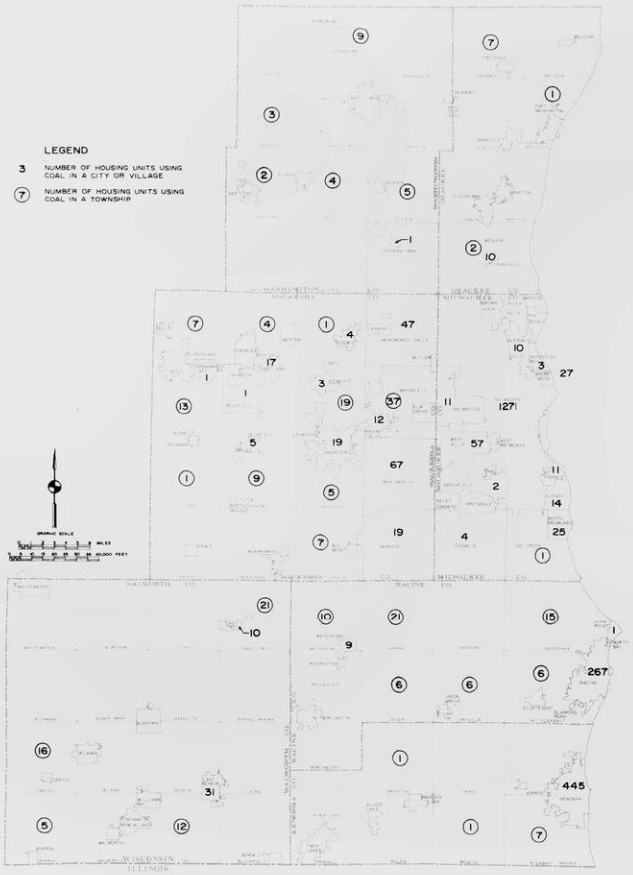


This map illustrates the impact of forecast sulfur dioxide emissions from residential fuel use on ambient air quality in the Region in the year 2000. As may be seen on this map, the maximum sulfur dioxide concentration resulting from residential fuel use in the year 2000 is expected to be about 30 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and will be located in central Milwaukee County. Thus, residential fuel use may be expected to contribute significantly to future sulfur dioxide concentrations in the Region—about 38 percent of the annual arithmetic average standard of 80 $\mu g/m^3$ by the year 2000.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 194

HOUSING UNITS USING COAL FOR SPACE AND WATER HEATING BY CIVIL DIVISION: 1977

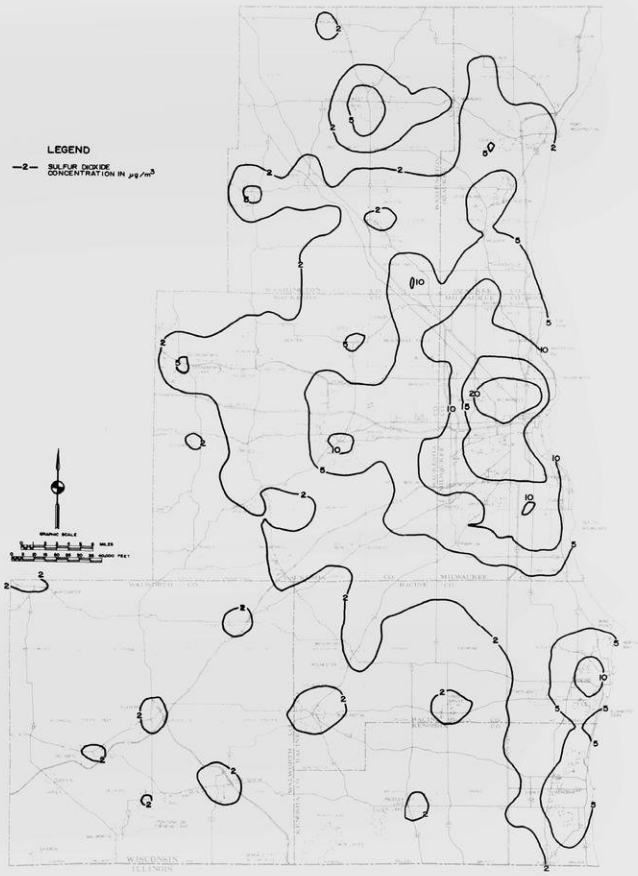


The number of housing units in the Region estimated to use coal as a fuel for space or water heating is displayed on the above map by civil division. The number of coal-burning housing units was estimated based on statistical data provided by the U. S. Bureau of the Census and local coal suppliers. From these data it was determined that approximately 2,900 housing units used coal as a primary fuel during 1977, of which about 1,440 such units, or nearly 50 percent, were located within Milwaukee County.

Source: U. S. Bureau of the Census and SEWRPC.

Map 195

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE SULFUR DIOXIDE CONCENTRATIONS FROM RESIDENTIAL FUEL USE IN THE REGION UNDER A COAL BAN ALTERNATIVE: 2000



This map illustrates the impact of forecast sulfur dioxide emissions from residential fuel use on ambient air quality in the Region in the year 2000 under the assumption that coal will not be used for space and water heating. As may be seen on this map, the maximum sulfur dioxide concentration due to residential fuel use under this assumption is expected to be 20 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and will be located in central Milwaukee County. A comparison of this map with Map 193 indicates that restricting the use of coal for residential space and water heating will reduce the maximum sulfur dioxide concentration from about 30 $\mu g/m^3$ to about 20 $\mu g/m^3$.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Those housing units in the Region forecast to burn coal in the year 2000 were assigned new fuel sources, with 20 percent of the units assigned electrical power and 80 percent assigned fuel oil.[18] As shown in Table 319, this assumed fuel conversion produced a net reduction of approximately 400 tons per year in sulfur dioxide emissions from residential fuel use in the Region, about 50 percent of which was in Milwaukee County. The results of the simulation modeling under these assumed fuel conditions are shown on Map 195. In comparison to the conditions indicated on Map 193, the area encompassed by the 15 $\mu g/m^3$ isopleth shows little change under a coal ban alternative, but the 30 $\mu g/m^3$ isopleth over Milwaukee County has been eliminated. The maxi-

[18] *Although future fuel conversions may be made to alternate, lower polluting energy sources, including solar energy, this energy scenario represents an alternate "worst case" situation.*

mum sulfur dioxide concentration resulting from residential fuel use is reduced from 30 $\mu g/m^3$ to 20 $\mu g/m^3$, a difference of 10 $\mu g/m^3$, or about 33 percent, on an average annual basis. Based on these modeling results, a ban on the use of coal for residential space and water heating may be expected to yield an average reduction in ambient air sulfur dioxide levels of about 10 $\mu g/m^3$ in that portion of Milwaukee County which, without such a restriction, is forecast to experience sulfur dioxide levels in excess of 30 $\mu g/m^3$.

The second major area source of sulfur dioxide emissions in the Region in the year 2000 is small commercial and institutional space and water heating. The results of the simulation of the impact of forecast sulfur dioxide emissions on ambient air quality from this source category are presented on Map 196. Map 196 indicates that there are two areas in Milwaukee County where sulfur dioxide concentrations exceed 15 $\mu g/m^3$. This maximum isopleth level occurs in two areas in and around the area of peak annual average sulfur dioxide concentrations as forecast for the year 2000. Because coal produces the greatest sulfur dioxide emissions on a heat content basis, the emissions for the year 2000 were recalculated under the assumption of alternative fuel use. For this analysis, sulfur dioxide emissions were recomputed on the assumption that all users of coal would convert to distillate fuel oil. The sulfur dioxide emissions produced by this fuel conversion are presented in Table 320. Map 197 depicts the anticipated distribution of annual average

Table 319

FORECAST SULFUR DIOXIDE EMISSIONS FROM RESIDENTIAL FUEL USE WITH AND WITHOUT COAL USE: 2000

County	Emissions (tons)	
	With Coal	Without Coal[a]
Kenosha	674	603
Milwaukee	3,452	3,236
Ozaukee	524	501
Racine.	832	782
Walworth.	441	427
Washington . . .	708	702
Waukesha.	1,833	1,789
Region	8,464	8,040

[a] *This forecast is based on the conversion of all coal-burning residential heating units to new fuel sources, with 80 percent converting to distillate oil and 20 percent to electricity.*

Source: SEWRPC.

Table 320

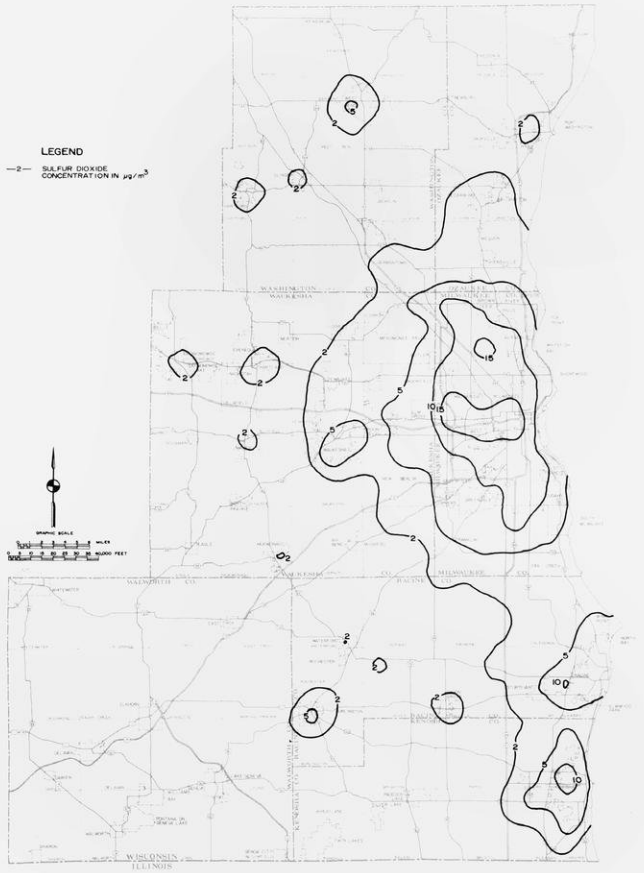
FORECAST SULFUR DIOXIDE EMISSIONS FROM COMMERCIAL-INSTITUTIONAL FUEL USE WITH AND WITHOUT COAL USE: 2000

County	Emissions (tons)	
	With Coal	Without Coal
Kenosha	661	483
Milwaukee	3,260	2,953
Ozaukee	196	139
Racine.	839	624
Walworth.	232	172
Washington . . .	378	264
Waukesha.	1,133	834
Region	6,699	5,469

Source: SEWRPC.

Map 196

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE SULFUR DIOXIDE CONCENTRATIONS FROM COMMERCIAL AND INSTITUTIONAL FUEL USE IN THE REGION: 2000



This map illustrates the impact of forecast sulfur dioxide emissions from small commercial-institutional fuel use on ambient air quality in the Region in the year 2000. As may be seen on this map, the maximum sulfur dioxide concentration resulting from small commercial-institutional fuel use in the year 2000 is expected to be about 15 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and will be located in central and north-central portions of Milwaukee County. This maximum 15 $\mu g/m^3$ sulfur dioxide concentration is about 20 percent of the annual arithmetic average standard of 80 $\mu g/m^3$.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

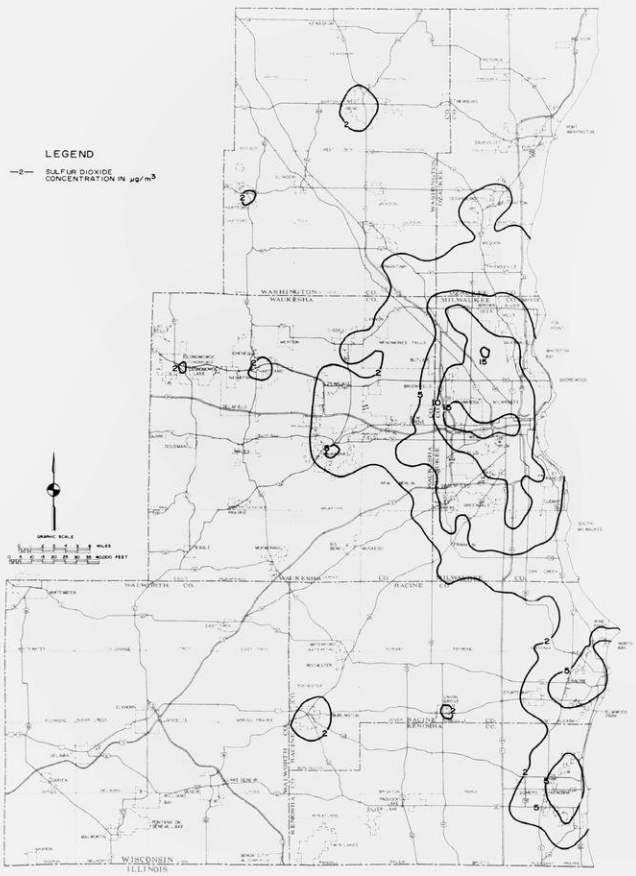
sulfur dioxide concentrations from small commercial-institutional fuel use without coal. As may be seen by comparing Map 197 with Map 196, the two areas with a maximum sulfur dioxide concentration of 15 $\mu g/m^3$ in Milwaukee County are of smaller areal extent under a coal ban alternative. Furthermore, the 10 $\mu g/m^3$ isopleth in Racine and Kenosha Counties with the use of coal is reduced to 5 $\mu g/m^3$ under the assumed fuel substitution.

Evaluation of the Coal Ban Alternative on Small Combustion Sources: Although coal use for residential and small commercial-institutional space and water heating represents a relatively small amount of the total forecast coal use in the Region in the year 2000—less than 75,000 tons out of a total of more than 5 million tons—a coal use ban would have a significant impact on the forecast sulfur dioxide concentrations in the Region. Accordingly, a restriction on the burning of coal by the relatively few remaining area sources still using it appears to be an effective way to reduce ambient air concentrations of sulfur dioxide.

Map 198 presents the forecast annual arithmetic average sulfur dioxide concentrations due to area source emissions in the Region in the year 2000 under the assump-

Map 197

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE SULFUR DIOXIDE CONCENTRATIONS FROM COMMERCIAL-INSTITUTIONAL FUEL USE IN THE REGION UNDER A COAL BAN ALTERNATIVE: 2000

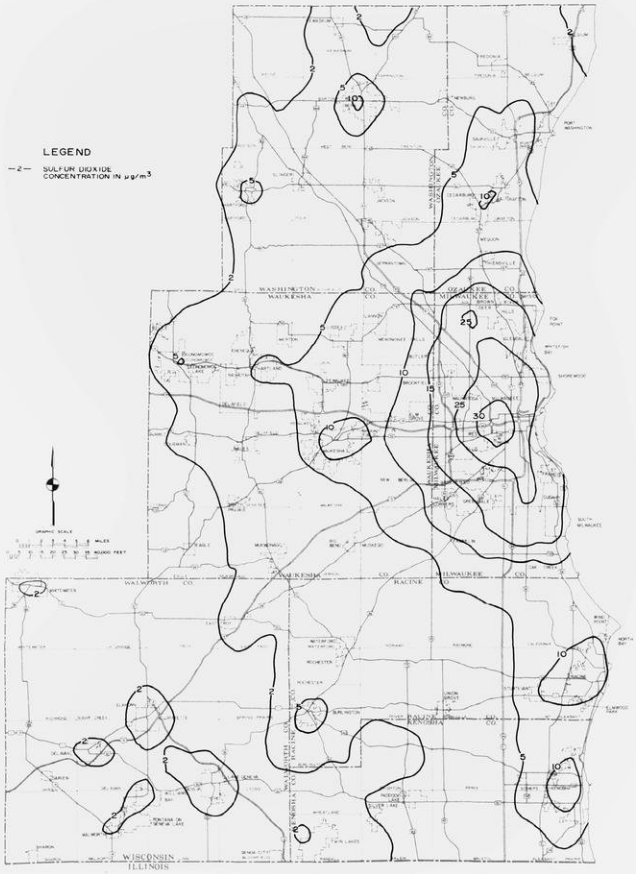


This map illustrates the impact of forecast sulfur dioxide emissions from small commercial-institutional fuel use on ambient air quality in the Region in the year 2000 under the assumption that coal will not be used for space and water heating. Under this assumption, the maximum sulfur dioxide concentration isopleth resulting from small commercial-institutional fuel use is expected to be 15 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and will be located in two areas in central Milwaukee County. Although the maximum sulfur dioxide concentration of 15 $\mu g/m^3$ as shown on this map is of the same magnitude as the maximum sulfur dioxide concentration shown on Map 196, which depicts the sulfur dioxide concentrations in the year 2000 without a restriction on coal use for small commercial-institutional purposes, the areal extent of this maximum concentration is significantly reduced by eliminating coal use.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 198

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE SULFUR DIOXIDE CONCENTRATIONS FROM RESIDENTIAL AND COMMERCIAL-INSTITUTIONAL FUEL USE IN THE REGION UNDER A COAL BAN ALTERNATIVE: 2000



This map illustrates the impact of forecast sulfur dioxide emissions from area sources on ambient air quality in the Region in the year 2000 under the assumption that coal will not be used for residential and small commercial-institutional space and water heating. Under this assumption, the maximum forecast sulfur dioxide concentration is 30 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and occurs in central Milwaukee County. As may be seen by comparing this map with Map 134 in Chapter XII, which depicts the forecast sulfur dioxide concentrations due to area sources without a restriction on coal use, a prohibition on the use of coal for residential and small commercial-institutional uses may be expected to result in a reduction in the extent of the area encompassed by the 30 $\mu g/m^3$ isopleth of from about 36 square miles to about 9 square miles in the year 2000.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

tion of a ban on coal for residential and small commercial-institutional space and water heating uses. The results of this modeling effort may be compared with the results of the modeling effort conducted in the same year under an assumption of coal use, as presented on Map 134.

The most noticeable difference between these two maps is the significant reduction in the area encompassed by the 30 ug/m^3 isopleth, which is located in that area of Milwaukee County where concentrations are forecast to exceed the annual standard by the year 2000. The size of area which is forecast to reach or exceed 30 ug/m^3 in the year 2000 as a result of emissions from all area sources is approximately 36 square miles. With the coal ban alternative, this area is forecast to be reduced to approximately 9 square miles.

Map 199 illustrates the composite impact of sulfur dioxide emissions from point sources under the coal-intensive energy scenario, line sources under the adopted transportation plan, and area sources under the coal ban alternative on regional air quality in the year 2000. Map 199 indicates that two portions of Milwaukee County, encompassing a total area of about 1.1 square miles, will exceed the annual sulfur dioxide standard of 80 ug/m^3 in the plan design year.

Emission Limitations on Major Point Sources: The evaluation of a ban on coal use for residential and small commercial-institutional space and water heating indicated that elimination of the residual sulfur dioxide problem in the Region by the year 2000 would require additional control strategies, principally in Milwaukee County. It is important to note, however, that this evaluation was conducted under the premise of a "worst-case," coal-intensive energy scenario. This analysis indicated that if such an extensive conversion from natural gas to coal by industries in the Region is realized in future years due to the unavailability of alternative fuels, more stringent emission limitations will be required on those industrial facilities converting to coal.

From a planning standpoint there are two fundamental approaches which may be pursued to provide for the attainment and maintenance of the sulfur dioxide ambient air quality standards in southeastern Wisconsin: controlling emissions from the stack, irrespective of the fuel type used for combustion, or controlling the allocation of certain fuel types. The sets of actions associated with each approach are discussed below.

Controls on Stack Emissions: If an industrial source with a heat input of 250 million or less BTU's per hour converts to coal because of economic or fuel availability considerations, present regulations would require that source to meet an emission limitation of 2.22 pounds of sulfur dioxide per million BTU heat input. As indicated on Map 137 in Chapter XII, however, widespread conversion to coal use by such facilities—even at the 2.22-pound sulfur dioxide emission limitation—may be expected to produce ambient air sulfur dioxide concentrations in excess of the annual arithmetic average standard of 80 ug/m^3 in parts of Milwaukee County by the year 2000. It may be concluded, therefore, that a sulfur dioxide emission limitation more stringent than 2.22 pounds per million BTU heat input may be necessary by the year 2000 to maintain the sulfur dioxide ambient air quality standards in the eventuality of extensive conversions to coal use. Also, as is indicated on Map 199, banning the use of coal for residential and small commercial-institutional purposes is not anticipated to provide for the maintenance of the annual sulfur dioxide standard in the Region if extensive conversions to coal are permitted at the existing 2.22-pound emission limitation.

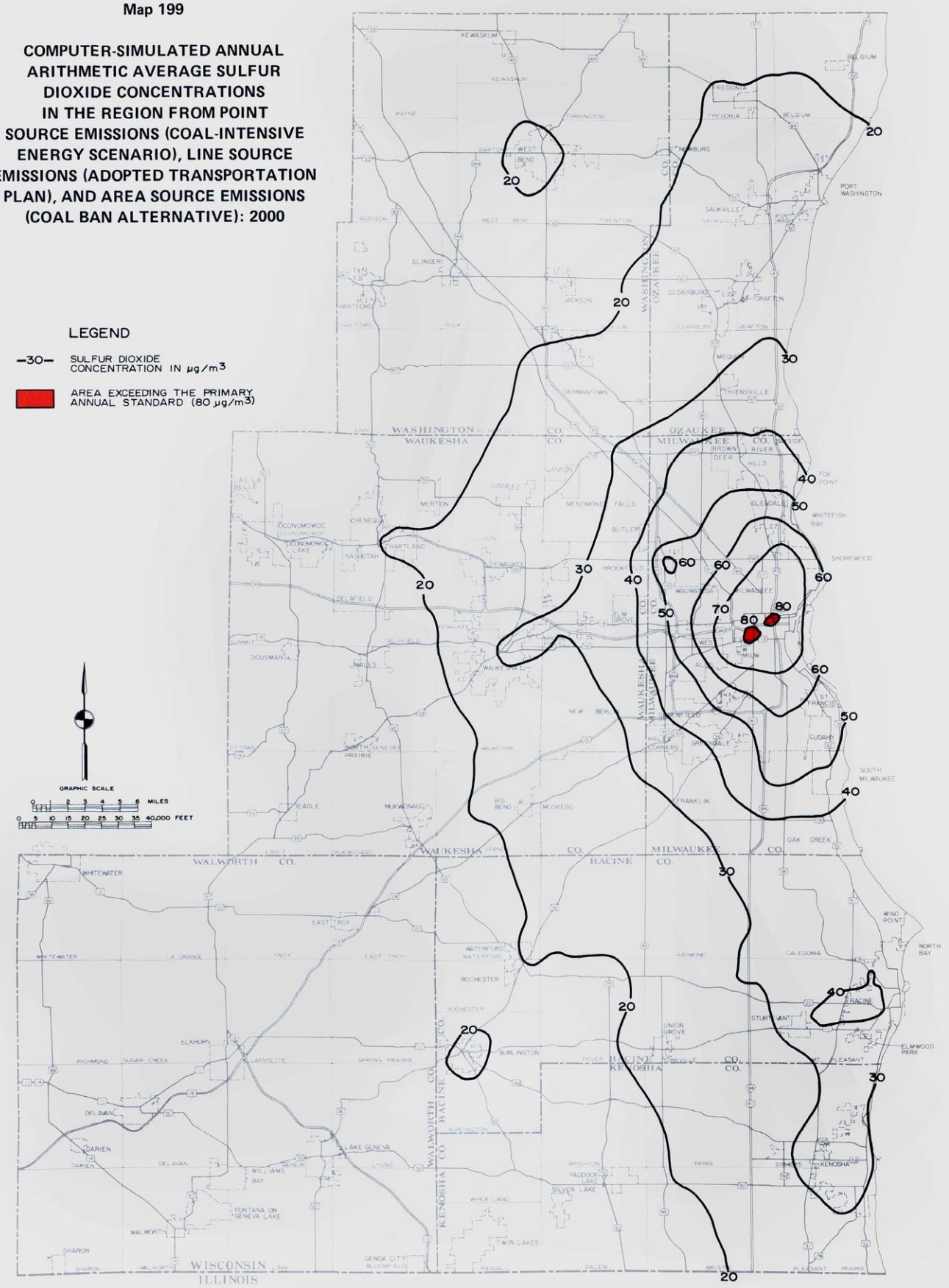
The conversion from natural gas to coal as a primary fuel would have considerable economic impacts. A facility which undertakes such a conversion may be expected to incur both the capital costs of new or modified boiler units and the costs of providing air pollution control equipment. The actual expense of conversion is also significantly affected by the proposed size and intended operational characteristics of the new unit and the type of control device selected to abate potential air pollutant emissions. Consideration must also be given to the compatability of a device or technique used to control sulfur dioxide emissions with the device or technique used to control particulate matter emissions. A fixed sulfur dioxide emission limitation more stringent than the existing 2.22 pounds per million BTU heat input standard, therefore, may not be economically feasible if required of all sources converting to coal.

One way to resolve potential conflicts between the need to achieve an emission rate less than 2.22 pounds of sulfur dioxide per million BTU heat input—if the conversion to coal use is undertaken by many industrial sources—and the need to establish emission standards which are both technologically and economically feasible is to require a facility-by-facility review of the level of control to be achieved by particular sources which propose to, or are required to, convert to coal. Such an action would, of course, require that the existing sulfur dioxide emission limitation of 2.22 pounds per million BTU heat input be revised by the year 2000. This revision would enable a variable, but no less stringent, standard to be developed specifically related to the size and operational characteristics of each facility to be converted, and in consideration of prevailing levels of sulfur dioxide in the ambient air.

Similarly, a variable emission standard may be deemed necessary by the year 2000 for new or modified facilities with a heat input capacity of more than 250 million BTU's per hour. This revised standard would be no less stringent than the existing limitation of 1.2 pounds per million BTU heat input. As with smaller sources, the exact sulfur dioxide emission standard for boilers with a heat input capacity of 250 million or more BTU's per hour should be based on technological and economic considerations and determined on a facility-by-facility basis.

Map 199

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE SULFUR DIOXIDE CONCENTRATIONS IN THE REGION FROM POINT SOURCE EMISSIONS (COAL-INTENSIVE ENERGY SCENARIO), LINE SOURCE EMISSIONS (ADOPTED TRANSPORTATION PLAN), AND AREA SOURCE EMISSIONS (COAL BAN ALTERNATIVE): 2000



This map illustrates the impact of forecast sulfur dioxide emissions on ambient air quality in the Region in the year 2000 under the assumptions of intensive coal use by industry, full implementation of the adopted transportation plan, and a restriction on the use of coal for residential and small commercial-institutional purposes. As may be seen on this map, two portions of Milwaukee County encompassing a total area of about one square mile may be expected to exceed the primary annual average sulfur dioxide ambient air quality standard of 80 micrograms per cubic meter ($\mu g/m^3$) in the year 2000 under these assumed conditions. The area indicated on this map as exceeding the annual average standard in the year 2000 is about 9 square miles less in extent than the area indicated to exceed the same standard without a restriction on the use of coal for residential and small commercial-institutional space and water heating (see Map 137 in Chapter XII).

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

It is significant to note that there are no sulfur dioxide emission limitations in effect for existing coal-burning sources having a heat input capacity greater than 250 million BTU's per hour. Thus, sources of this size presently operating in southeastern Wisconsin are not required to burn coal of a specified sulfur content or to restrict the amount of sulfur dioxide released into the ambient air. There are two large electric power generating plants in Milwaukee County which can be placed into this category of sulfur dioxide emission sources: the Oak Creek Plant and the Valley Plant of the Wisconsin Electric Power Company. The Valley Plant is the largest point source of sulfur dioxide emissions in the DNR-proposed nonattainment area. In the absence of regulatory controls on such large sources, sulfur dioxide emission levels may increase or decrease at the discretion of the facility operator. Between 1977 and 1978, for example, the weighted average sulfur content of the coal burned at the Valley Plant increased from about 3.34 percent to about 3.68 percent. Moreover, whereas the coal with the highest sulfur content burned at the Valley Plant during 1977 was, on the average of 4.22 percent sulfur, coal with a maximum average sulfur content of 4.40 percent was burned at this facility during 1978.

Controls on Fuel Allocation: The determination that more stringent sulfur dioxide emission limitations will be required for major fuel-burning installations by the year 2000 is based, in part, on the assumption that natural gas will not be available for industrial purposes throughout the planning period and that coal will be used as the substitute fuel. It is anticipated, however, that if natural gas supplies are made available in quantities adequate to meet the forecast industrial demand in the Region, the ambient air sulfur dioxide concentrations forecast under the coal-intensive energy scenario will be substantially reduced.

In order to determine annual arithmetic average sulfur dioxide levels in the Region under the assumption that natural gas supplies will be adequate to meet industrial demand, a point source emissions forecast was prepared for the year 2000 under the assumption that all facilities presently using natural gas would continue to do so. Also, facilities presently using coal or fuel oil as a primary energy source were assumed to continue to do so through the year 2000. This point source emissions forecast was computer simulated using the Wisconsin Atmospheric Diffusion Model and subsequently combined with the line source emissions forecast under the adopted transportation plan and area source emissions under the coal ban alternative. The results of this simulation modeling effort are presented on Map 200. The maximum annual isopleth value shown on Map 200 is 70 $\mu g/m^3$—10 $\mu g/m^3$ less than the ambient air quality standard of 80 $\mu g/m^3$. It may be concluded, therefore, that the availability of natural gas for industrial use is of major importance in determining whether or not the maintenance of the annual average sulfur dioxide ambient air quality standard will be achieved through the year 2000.

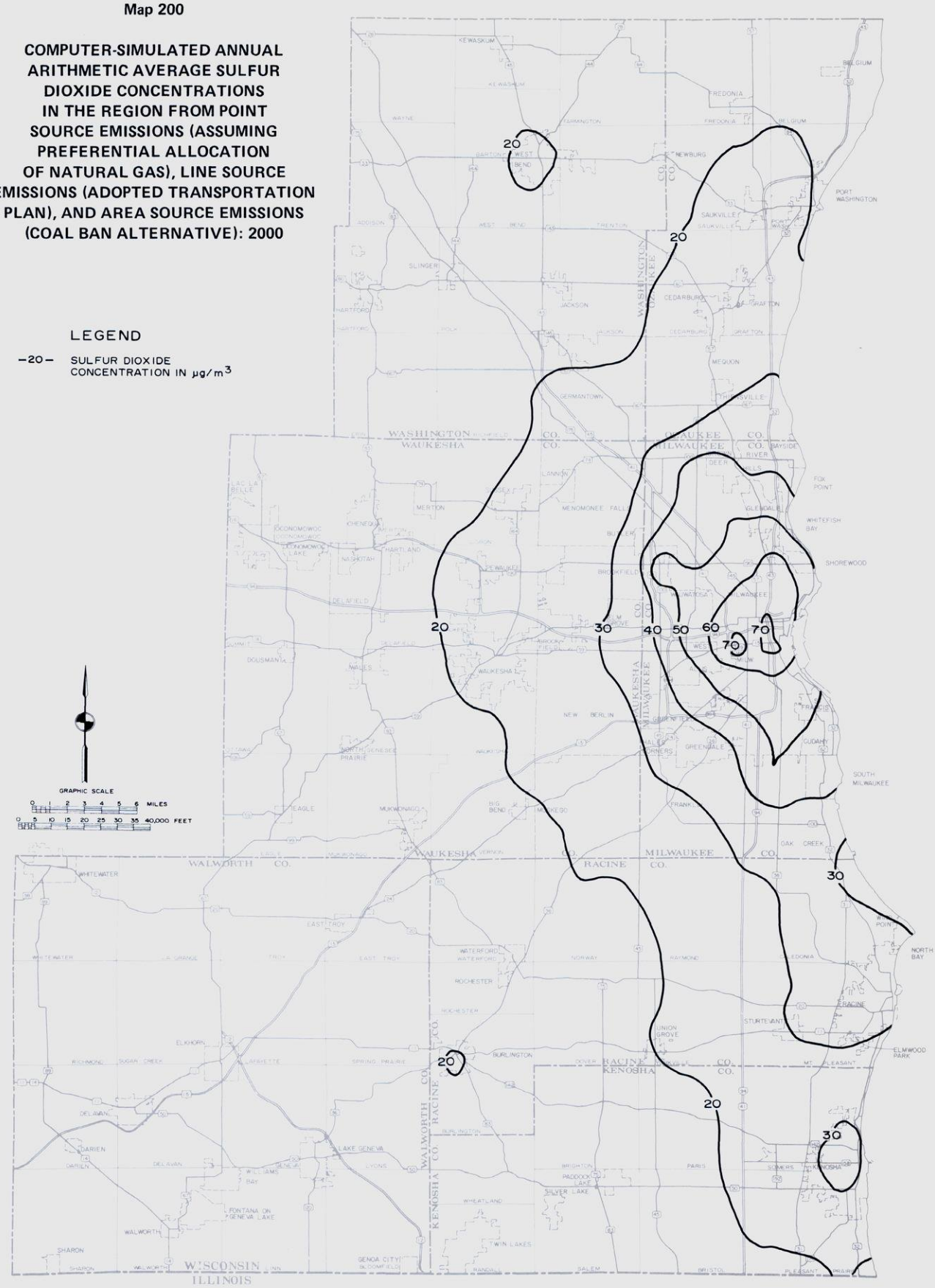
Under the assumptions of a ban on coal use for residential and small commercial-institutional space and water heating and the continued availability of natural gas for industrial purposes, a decline in the 24-hour average sulfur dioxide concentrations in the Region in the year 2000, as compared with the corresponding sulfur dioxide levels under the coal-intensive energy scenario, may be expected. As may be seen by comparing Map 201 with Map 140 in Chapter XII, the maximum 24-hour average sulfur dioxide isopleth value is 365 $\mu g/m^3$ in Milwaukee County under the coal-intensive energy scenario, but 300 $\mu g/m^3$ under the assumed availability of natural gas for industry. Moreover, the area shown on both maps to be encompassed by the 300 $\mu g/m^3$ isopleth decreases by about 9 square miles, or 36 percent—from 25 square miles under the coal-intensive energy scenario to 16 square miles under the natural gas scenario. Also, as may be seen on Map 202, the second highest three-hour average sulfur dioxide concentration which is expected to occur in the year 2000—as determined through use of the Larsen technique—is 940 $\mu g/m^3$, or approximately 72 percent of the three-hour average secondary standard of 1,300 $\mu g/m^3$. Thus, the determination of whether the sulfur dioxide ambient air quality standards may be maintained in the Region through the year 2000 is principally dependent on the extent to which coal is substituted for natural gas by major fuel-burning installations.

Evaluation of Potential Actions: The evaluation of actions with the potential to abate sulfur dioxide concentrations in the Region is focused principally on the prohibition of the replacement or installation of coal-fired heating units—sources which are individually too small to be effectively or economically controlled—in Milwaukee County for residential and commercial-institutional space heating and water heating purposes, and on controlling the emissions of sulfur dioxide from major fuel-burning installations. The intent of the ban on the replacement or installation of coal-fired heating units in Milwaukee County for residential and commercial-institutional purposes is to replace such coal-burning units with alternative fuel-burning units at the time of normal retirement, rather than strictly prohibiting their use in the short-term. Even with a gradual replacement of small coal-burning units, it is anticipated that coal use by these sources will be effectively eliminated by the year 2000.

It is difficult to evaluate future levels of sulfur dioxide concentrations in the Region and the effectiveness of alternative controls since ambient air concentrations of this pollutant species are highly dependent upon the type of fuel used for combustion by industrial sources. Accordingly, the need for and stringency of additional controls on sulfur dioxide emissions from point sources are directly related to the extent to which natural gas is replaced by coal as a primary energy source. Because of these uncertainties, it would not be justifiable at the present time to establish a fixed sulfur dioxide emission limitation for new or modified sources with emissions lower than the existing emission standards. A continual assessment of sulfur dioxide levels in the Region will be required to enable the Wisconsin Department of Natural Resources to determine emission limitations on a facility-by-facility basis, considering technological feasiblity, economic impacts, and the actual rate of fuel conver-

Map 200

COMPUTER-SIMULATED ANNUAL ARITHMETIC AVERAGE SULFUR DIOXIDE CONCENTRATIONS IN THE REGION FROM POINT SOURCE EMISSIONS (ASSUMING PREFERENTIAL ALLOCATION OF NATURAL GAS), LINE SOURCE EMISSIONS (ADOPTED TRANSPORTATION PLAN), AND AREA SOURCE EMISSIONS (COAL BAN ALTERNATIVE): 2000

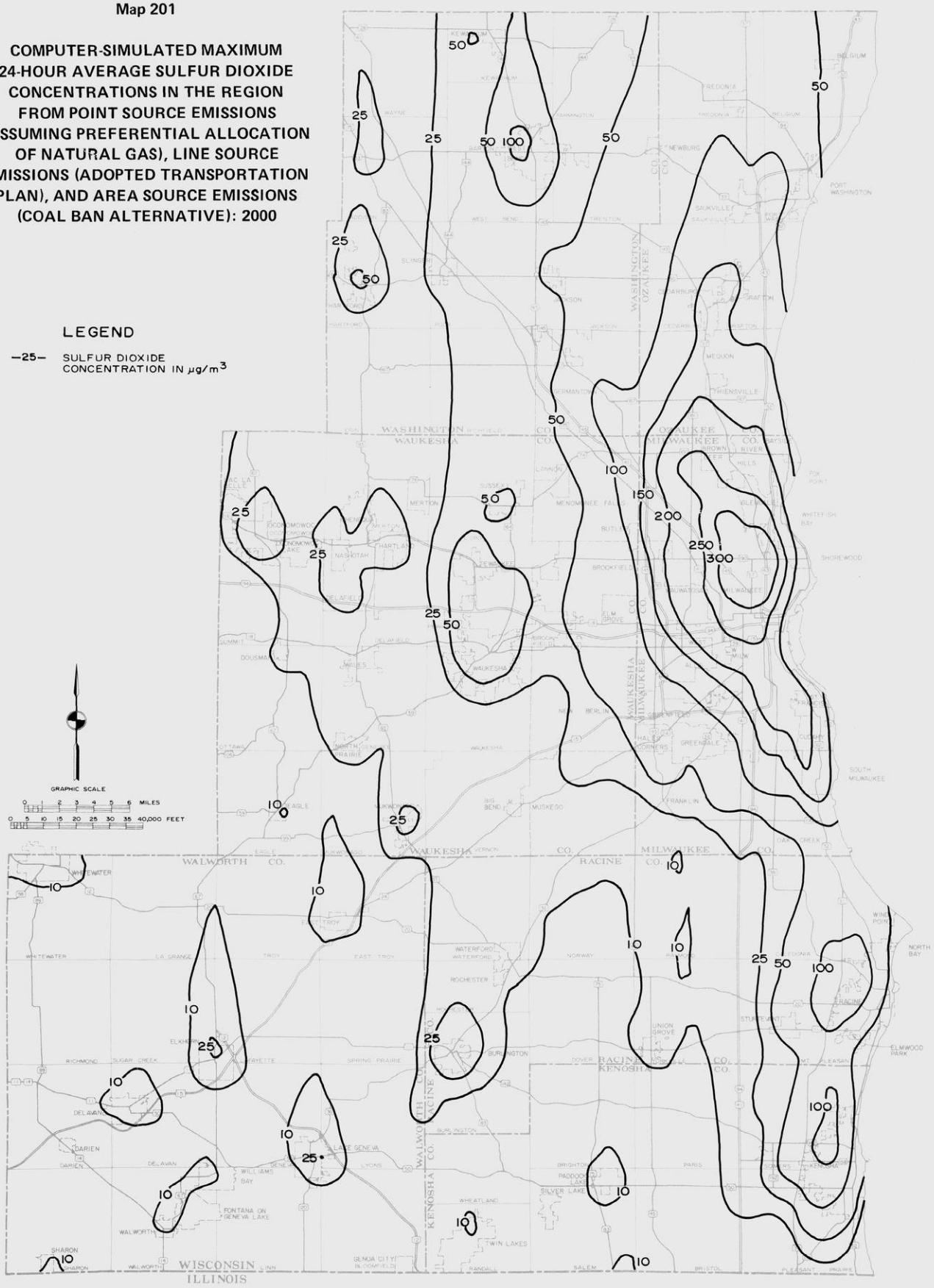


This map illustrates the impact of forecast sulfur dioxide emissions on ambient air quality in the Region in the year 2000 under the assumptions of full implementation of the adopted transportation plan, a restriction on the use of coal for residential and small commercial-institutional purposes, and preferential allocation of natural gas supplies to meet industrial energy demand. The maximum sulfur dioxide concentration shown on this map is 70 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, and encompasses two areas in central Milwaukee County. Since this maximum annual average sulfur dioxide concentration is 10 $\mu g/m^3$ less than the ambient air quality standard of 80 $\mu g/m^3$, it may be concluded that averting the extensive use of coal by industries in the Region, and restricting the use of coal by other, smaller sources, will provide for the continued maintenance of this standard throughout southeastern Wisconsin over the planning period.

Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

Map 201

COMPUTER-SIMULATED MAXIMUM 24-HOUR AVERAGE SULFUR DIOXIDE CONCENTRATIONS IN THE REGION FROM POINT SOURCE EMISSIONS (ASSUMING PREFERENTIAL ALLOCATION OF NATURAL GAS), LINE SOURCE EMISSIONS (ADOPTED TRANSPORTATION PLAN), AND AREA SOURCE EMISSIONS (COAL BAN ALTERNATIVE): 2000



This map illustrates the anticipated 24-hour average sulfur dioxide concentrations in the Region in the year 2000 assuming full implementation of the adopted transportation plan, a restriction on the use of coal for residential and small commercial-institutional purposes, and the preferential allocation of natural gas supplies to meet industrial energy demand. The maximum 24-hour average sulfur dioxide concentration shown on this map is 300 micrograms per cubic meter ($\mu g/m^3$) and occurs in central Milwaukee County. This maximum concentration is 65 $\mu g/m^3$, or about 18 percent, less than the 24-hour average sulfur dioxide ambient air quality standard of 365 $\mu g/m^3$.

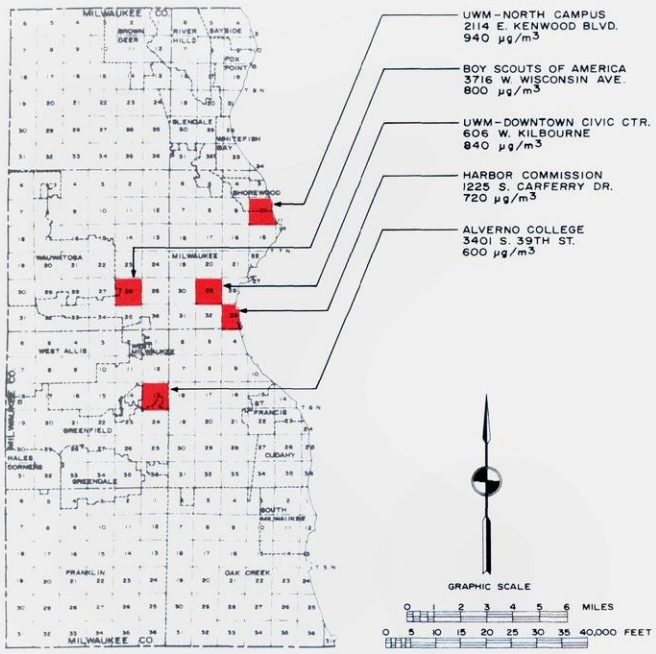
Source: Air Quality Modeling Group, University of Wisconsin-Madison; and SEWRPC.

sions. To enable the Department to respond effectively to such changing conditions, however, sulfur dioxide emission limitations that are flexible with respect to technological, economic, and environmental considerations must be promulgated. In this way, the long-term maintenance of the sulfur dioxide ambient air quality standards in the Region can be ensured without imposing unnecessary costs.

At the present time, there are no sulfur dioxide emission limitations applicable to large sources—that is, fuel-burning installations with a heat input capacity of 250 million or more BTU's per hour. The need to establish limitations for such sources which are presently in operation is evident from the short-term sulfur dioxide concentrations observed in the Region in 1977 and 1978. (Although there were violations of the short-term standard observed during 1977 and 1978, there were no observed violations of the sulfur dioxide standards during 1979.) It is significant to note that just two sources of this size in Milwaukee County—the Oak Creek Plant and the Valley Plant of the Wisconsin Electric Power Company—contributed about 151,900 tons, or 72 percent, of the total 210,900 tons of sulfur dioxide emissions from all known sources in the Region during 1977. Controlling sulfur dioxide emissions from the large fuel-burning installations shown to cause or contribute to violations may be expected to have a beneficial impact on ambient air quality.

Map 202

FORECAST SECOND HIGHEST THREE-HOUR AVERAGE SULFUR DIOXIDE CONCENTRATIONS IN SELECTED U. S. PUBLIC LAND SURVEY SECTIONS IN THE REGION AS PREPARED USING THE LARSEN TECHNIQUE AFTER IMPLEMENTATION OF COMMITTED AND PROPOSED ACTIONS: 2000



This map illustrates the second highest three-hour average sulfur dioxide concentrations in the year 2000 as forecast for five locations in Milwaukee County using the Larsen statistical technique, and assuming full implementation of the regional transportation plan, a restriction on the use of coal for residential and small commercial-institutional purposes, and the preferential allocation of natural gas supplies to meet industrial energy demand. The five areas for which future sulfur dioxide concentrations were forecast for this averaging period correspond to the existing sulfur dioxide monitoring sites in Milwaukee County. As may be seen on this map, under the above-mentioned assumptions the area around the University of Wisconsin-Milwaukee North Campus may be expected to experience the second highest three-hour average sulfur dioxide concentration of 940 micrograms per cubic meter ($\mu g/m^3$). This level, although the largest of the values calculated for the year 2000, is about 360 $\mu g/m^3$, or about 28 percent, less than the secondary three-hour average sulfur dioxide ambient air quality standard of 1,300 $\mu g/m^3$.

Source: SEWRPC.

As with new or modified fuel-burning installations, a level of control for large existing sources that is technologically feasible and economically practicable must be determined by the Wisconsin Department of Natural Resources in consultation with the source owner or operator. Significant environmental, economic, and energy-related problems could result from imposing regulatory sulfur dioxide emission limitations without prior determination of the source's ability to comply with mandated standards. Thus, the extent to which sulfur dioxide emission controls on large sources may be practically implemented should be explored by the Wisconsin Department of Natural Resources as a means for abating excessive short-term average sulfur dioxide concentrations in the Region.

Since the potential conversion of industrial sources from natural gas use to coal use, with its attendant potentially adverse health effects on the residents of the Region, has been identified as an impediment to attaining and maintaining the ambient air quality standards for sulfur dioxide in the Region, the extent to which the postulated conversions to coal may be averted will determine the stringency of the sulfur dioxide emission limitations required for fuel-burning installations. One way to reduce the number of conversions to coal, should natural gas supplies in Wisconsin be curtailed over the planning period as forecast, is to preferentially allocate the statewide apportionment of available natural gas supplies to those areas—such as southeastern Wisconsin—having ambient air quality problems. Under this approach, the Wisconsin Public Service Commission (PSC), as the agency responsible for monitoring the activities of public utilities, is envisioned to divert the natural gas allocation from industries in clean air areas of the State to industries in nonattainment areas. Sources in clean air areas would thus be required to convert to alternative fuels such as coal or fuel oil. Although the preferential allocation of available natural gas supplies to industries in southeastern Wisconsin may necessitate expenditures for air pollution control in other parts of the State that might not otherwise be required, the lower level of control generally required in clean air areas where Best Available Control Technology would be applied is less costly than the level of control required in nonattainment areas, where the Lowest Achievable Emission Rate would be applied. Accordingly, the recommended action should be cost-effective for the State as a whole as well as for the Region.

It may be concluded from the evaluation of alternative actions for the control of sulfur dioxide concentrations in the Region that the volatility of future energy supplies is such that specific revisions to sulfur dioxide emission limitations for existing and new or modified fuel-burning installations may not and, in fact, should not be promulgated at the present time. Rather, the approach to providing safe levels of sulfur dioxide in the Region.lies in developing a flexible framework for regulatory actions which may be implemented in response to the changing demand and availability of various fuel types.

Recommended Sulfur Dioxide Plan

Major Plan Components: The attainment and maintenance strategies evaluated herein for meeting the established sulfur dioxide standards are centered on efforts to reduce emissions from coal-burning sources. Based on the evaluation of the alternative control measures presented, the recommended sulfur dioxide control plan consists of four major components: a ban on the use of coal for residential and small commercial-institutional space and water heating in Milwaukee County; more stringent controls on sulfur dioxide emissions from new and existing small point sources if extensive conversion from natural gas to coal occurs; a study of the effect on ambient air quality of establishing more than controls for existing point sources with a heat input capacity of more than 250 million BTU's per hour that cause or significantly contribute to ambient air quality standard violations; and, in the event that a shortage of natural gas threatens a curtailment or cutoff of natural gas supplies to industries in the Region, the preferential allocation of natural gas by the Wisconsin Public Service Commission to industries in southeastern Wisconsin, with special consideration given to the industrial users of natural gas in Milwaukee County. The plan also recognizes as committed actions the formal designation of the proposed sulfur dioxide nonattainment area in Milwaukee County; the requirements calling for major new or modified sources within or impacting upon this nonattainment area to obtain the Lowest Achievable Emission Rate and greater than one-for-one emission offsets in the area; and the requirements calling for major new or modified sources in clean air areas in the Region to apply the Best Available Control Technology and demonstrate that the quality of the ambient air will not be significantly deteriorated.

In Milwaukee County, the adoption and enforcement of the recommended ban on coal as a fuel for residential and commercial-institutional space and water heating may be expected to result in a net reduction of over 500 tons of sulfur dioxide emissions, for a 3 percent reduction in the total emissions forecast from area sources of 19,200 tons by the year 2000. It is recommended that the conversion from coal to alternative fuels not be required to be accomplished by a specific date, but that a ban on these small coal-burning area sources follow a normal retirement schedule. That is, the ban on coal use would apply to individual furnaces and boilers only at the time of normal replacement or retirement of the heating unit. Fuel use inventories conducted by the Commission indicate a trend toward lower coal use for residential purposes. A replacement ban on coal-fired units would further encourage this trend.

Simulation modeling results indicate that if a major conversion from natural gas to coal becomes necessary for industrial sources in southeastern Wisconsin, the existing emission limitations of 2.22 pounds of sulfur dioxide per million BTU's for boilers with a heat input of 250 million or less BTU's per hour, and 1.20 pounds of sulfur dioxide per million BTU's for boilers with a heat input greater than 250 million BTU's per hour, may not be stringent enough to prevent violations of the annual primary sulfur dioxide standard in parts of Milwaukee County. It is therefore recommended, in the event of significant fuel conversions to coal, that a facility-by-facility review of the air quality impact of such fuel conversions on sulfur dioxide concentrations be made. It is recommended that emission limitations and potential control technology be determined on a facility-by-facility basis by the Wisconsin Department of Natural Resources in consultation with the source owner/operator.

During the planning period, fuel-burning installations with heat input capacities greater than 250 million BTU's per hour are forecast to be the major contributors of sulfur dioxide emissions in the Region. Because of the present lack of emission limitations for sources of this size, it is recommended that the impact of these sources on the annual, 24-hour, and three-hour average sulfur dioxide ambient air concentrations in or near designated nonattainment areas be analyzed. If a source is found to significantly contribute to violations of the sulfur dioxide standards, an emission limitation should be established on the source by the Wisconsin Department of Natural Resources in consideration of the technological and economic feasibility and environmental effects of implementation.

Based on the forecast growth in point, line, and area source sulfur dioxide emissions between the 1976 base year and the year 2000, the principal determinant as to whether the annual average sulfur dioxide standard will be met through the year 2000 is the degree to which major fuel-burning installations in the Region may substitute alternative fuels, particularly coal, for natural gas. This coal-intensive energy scenario, which represents a "worst case" air pollution situation, was developed for major point sources using natural gas because of the uncertainty regarding the availability and price of future natural gas supplies. In the event that it becomes necessary to curtail or terminate natural gas supplies to major industrial users in southeastern Wisconsin, it is recommended that the Wisconsin Public Service Commission preferentially allocate natural gas to those industries where violations of the sulfur dioxide ambient air quality standards are forecast to occur, with special consideration given to the major industrial natural gas users in Milwaukee County.

Estimation of Compliance Costs of Sulfur Dioxide Control Measures: Because the sulfur dioxide plan does not recommend that specific actions be implemented by

identified facilities, it is not possible at this time to estimate the costs of attaining and maintaining the ambient air quality standards for this pollutant species. Moreover, conversions to coal use by industrial facilities—considered herein as a "worst case" condition—were assumed to result from the lack of natural gas supplies relative to the forecast demand. Such conversions as may occur, and the attendant air pollution control costs, are therefore assumed to result from the economic considerations of the source owner or operator and not from a specific action recommended in the sulfur dioxide plan. Ultimately, the cost of attaining and maintaining sulfur dioxide concentrations in the Region at levels below the established ambient air quality standards will depend upon the degree to which conversions to coal use are effected, and the level of control deemed necessary on individual sources by the Wisconsin Department of Natural Resources.

CARBON MONOXIDE AND HYDROCARBON/OZONE PLANS

Ambient air quality simulation modeling results, as described in the previous two chapters, indicate that the eight-hour average ambient air quality standard for carbon monoxide—10 milligrams per cubic meter (mg/m^3)—may be expected to continue to be exceeded in the Region, particularly in and around the Marquette Interchange, until at least 1983. It was accordingly necessary to develop an attainment plan for carbon monoxide which would achieve this standard in a more timely manner. Modeling results also indicate that the attainment and maintenance of the ambient air quality standard for ozone—0.12 part per million (ppm) on a maximum one-hour average basis—will require that the 1977 level of regional hydrocarbon emissions, specifically those hydrocarbons classified as volatile organic compounds, be reduced by 62 to 74 percent. Thus, the ozone concentrations in the Region may be expected to meet the standards if the 102,200 tons of volatile organic compounds emitted during 1977 are reduced to a maximum annual emission rate of about 38,800 tons or, at an optimum level, no more than 26,600 tons per year.

The alternative and recommended attainment and maintenance plans for carbon monoxide and hydrocarbon/ozone are presented in the following sections. Such plans are discussed jointly because of the commonality of emission sources and since many control actions—particularly transportation-related control actions—have a corresponding influence on carbon monoxide and hydrocarbon emissions. The effectiveness of implementing committed actions in attaining and maintaining the ambient air quality standards was evaluated to determine the need for alternative control measures; this evaluation is presented herein.

Committed Carbon Monoxide and Hydrocarbon/Ozone Actions

As with the attainment and maintenance plans for particulate matter and sulfur dioxide, the established regulatory scheme serves as the foundation for the attainment and maintenance plans for carbon monoxide, hydrocarbons, and ozone in the Region. This existing regulatory scheme includes both the emission limitations presently adopted and enforced by the State of Wisconsin or the federal government and the control requirements mandated by the Clean Air Act Amendments of 1977. These existing emission limitations and control requirements represent the components of the committed actions.

There are two principal areas of control addressed by the committed actions: controls on stationary sources through the application of Reasonably Available Control Technology (RACT), and the control of mobile sources through the enforcement of the federal motor vehicle emissions control program (FMVECP). Since hydrocarbons are released from both stationary and mobile sources, both the RACT emissions limitations and the FMVECP will affect the emission level of this pollutant species. Carbon monoxide, however, is principally a product of combustion present in motor vehicle exhaust. Such exhaust accounted for about 87 percent of the total emissions of this pollutant species in the Region during 1977. Accordingly, the abatement of carbon monoxide concentrations in the Region is addressed only through controls on mobile sources.

RACT Emission Limitations on Stationary Sources: The U. S. Environmental Protection Agency has classified stationary sources of volatile organic compound emissions into 34 categories for which RACT regulations have been, or will soon be, promulgated. These 34 volatile organic compound RACT emission categories are presented in Table 321. As may be seen in Table 321, the 34 RACT categories are divided into three groups. The first group is comprised of 15 source categories for which the EPA has issued control technique guidelines, which have been formally adopted by the State of Wisconsin, and for which compliance is to be achieved by 1982.[19] The second group is comprised of 10 source categories which have not presently been adopted by the State of Wisconsin, but which must be implemented by 1982 in accordance with federal mandates. The third group is comprised of nine source categories for which EPA control technique guidelines are expected by 1980 and for which implementation is expected between

[19] *Regulations for these 15 source categories were incorporated into the Wisconsin Administrative Code, Section NR 154.13, in July 1979. The U. S. Environmental Protection Agency, however, has asked the Wisconsin Department of Natural Resources to provide additional information and explanation of these RACT rules in order to clarify implementation and enforcement procedures. In particular, since some RACT rules, such as those on the use of cutback asphalt, are applicable only during the ozone season, the definition of the ozone season is a significant factor in determining the dates on which the rules are applicable. The ozone season in the State of Wisconsin is presently defined as April 1st through October 31st of each year.*

Table 321

LIST OF VOLATILE ORGANIC COMPOUND RACT SOURCE CATEGORIES

Group Number	Source Category
I	Sources for which Control Guidance Has Been Issued and for which Implementation Is Expected by 1982
	Surface Coating of Automobiles and Light-Duty Trucks Surface Coating of Cans Surface Coating of Metal Coils Surface Coating of Paper Surface Coating of Fabric Products Surface Coating of Metal Furniture Surface Coating of Large Applicances Surface Coating for Insulation of Magnet Wire Petroleum Liquids in Fixed-Roof Tanks Bulk Gasoline Plants Gasoline Loading Terminals Service Stations, Stage I Miscellaneous Refinery Sources Solvent Metal Cleaning Cutback Asphalt
II	Sources for which Control Guidance Has Not Yet Been Issued But for which Implementation is Expected by 1982
	Petroleum Refinery Fugitive Emissions (leaks) Surface Coating of Miscellaneous Metal Parts and Products Vegetable Oil Processing Factory Surface Coating of Flatwood Paneling Pharmaceutical Manufacture Rubber Tire Manufacture Graphic Arts (printing) Petroleum Liquid Storage, Floating Roof Tanks Dry Cleaning, Perchloroethylene Gasoline Tank Trucks, Leak Prevention
III	Sources for which Control Guidance Has Not Yet Been Issued and for which Implementation Is Expected between 1982 and 1987
	Architectural and Miscellaneous Coatings Synthetic-Based Rubber Manufacture Organic Chemical Manufacture Process Streams Fugitive (leaks) Waste Disposal Storage and Handling Ship and Barge Transport of Gasoline and Crude Oil Wood Furniture Manufacture Service Stations, Stage II

Source: U. S. Environmental Protection Agency and Wisconsin Department of Natural Resources.

1982 and 1987. The impact of the RACT emission limitations on these three groups is discussed in the following sections.

Group I RACT Controls: Of the 15 volatile organic compound emission source categories for which RACT regulations have been adopted by the State of Wisconsin, eight are surface coating operations, five are petroleum processing or storage operations, one involves the use of equipment for metal cleaning or degreasing, and one involves the use of cutback asphalt as a paving material. Only 11 of the 15 RACT categories are relevant to ambient air quality in the Region since there are no petroleum refineries or large appliance, magnet wire, or metal furniture surface coating operations presently in operation in southeastern Wisconsin. As may be seen in Table 230 in Chapter VII, these 11 sources emitted about 37,700 tons of volatile organic compounds in the Region during 1977—nearly 37 percent of the estimated total of 102,200 tons.[20] Under the growth assumptions detailed in Chapter XII, the volatile organic compound emissions from these 11 source categories may be expected to decrease to about 35,700 tons in 1982, and to increase to about 37,000 tons by the year 2000, as shown in Table 303 in Chapter XII, without additional control measures.

Of the estimated 37,700 tons of volatile organic compound emissions released from the Group I RACT categories during 1977, approximately 12,200 tons were associated with the surface coating of automobiles, cans, metal coils, paper, and fabric. Surface coating operations may meet RACT emission limitations through the incineration or catalytic oxidation of evaporative losses, the capture of evaporative losses by vapor recovery systems, or the substitution of low-solvent content coatings for high-solvent content coatings. Table 322 provides a summary of the types of controls applicable to each of the surface coating categories existing in the Region and of the reduction in emissions achievable with the implementation of each control technique or device. Which of the alternative RACT control methods is to be selected is left to the discretion of the source owner or operator, subject, of course, to the approval of the DNR. Such selection is generally based on the operational characteristics of a source. Based on a "standard source" model, the DNR has estimated that the volatile organic compound emissions from these five surface coating categories in southeastern Wisconsin may be reduced by about 8,800 tons, or more than 72 percent—from about 12,200 tons in 1977 to about 3,400 tons in 1982—under forecast industrial growth conditions. By 1987 the DNR estimates that approximately 3,600 tons of volatile organic compound emissions will be released from surface coating operations in the Region after the application of RACT controls—an increase of about 200 tons, or about 6 percent, over the 1982 emission level. This increase is anticipated to result from the general growth expected in these five categories.

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[20] *As mentioned in Chapter XI of this report, not all of the total 118,300 tons of volatile organic compounds released in the Region during 1977 contributed to the high ozone concentrations observed during the summer season. Accordingly, the volatile organic compound emissions from agricultural equipment, snowmobiles, power boats, off-highway motorcycles, and miscellaneous solvent use—which jointly accounted for 16,200 tons of volatile organic compound emissions during 1977—were not included in the modeling effort for volatile organic compound emissions.*

Table 322

RACT CONTROLS FOR SURFACE COATING OPERATIONS

Operation	Alternative RACT Control Methods	Estimated Emission Reduction (percent)
Automobile Coating	1. Waterborne and high solid coating	65-93
	2. Incineration	90 +
	3. Carbon adsorption	85 +
Can Coating	1. Incineration: catalytic,	90 +
	noncatalytic	90-98
	2. Waterborne and high solid coating	60-90
	Power coating (interior two-piece can)	100
	3. Carbon adsorption (interior two-piece can)	90
	4. Ultraviolet curing (for exterior coatings)	Up to 100
Metal Coil Coating	1. Incineration: thermal,	90-98
	catalytic	90
	2. Waterborne and high solid coating	70-95
Paper Coating	1. Incineration	95
	2. Carbon adsorption	90 +
	3. Low-solvent coating	80-100
Fabric Coating	1. Incineration	95
	2. Carbon adsorption	90 +
	3. Low-solvent coating	80-100

Source: U. S. Environmental Protection Agency and Wisconsin Department of Natural Resources.

There are four petroleum storage and transfer-related Group I RACT categories: storage of petroleum in fixed-roof tanks, bulk gasoline terminals, bulk gasoline plants, and service station loading. Fixed-roof petroleum storage tanks are designed to operate with only slight internal pressure or at a vacuum and, consequently, the volatile organic compound emissions resulting from tank breathing, filling, and emptying may be substantial. The RACT method of control for fixed-roof tanks is to require all such tanks with a storage capacity of 40,000 gallons or more to have a floating roof to reduce the emissions. RACT emission controls on fixed-roof tanks were implemented in southeastern Wisconsin prior to 1977 and the resulting emissions were estimated at about 91 tons during that year. This emission level is forecast to remain constant over the forecast period.

Bulk gasoline terminals are storage facilities which receive gasoline from refineries by pipeline, ship, or barge, and subsequently deliver the gasoline to bulk gasoline plants or to commercial or retail distributors. The average throughput of bulk gasoline terminals is generally greater than 20,000 gallons of gasoline per day. Volatile organic compounds may be emitted from the storage tanks, the tank trucks, points along the tank truck vapor gathering system, and the vapor control unit. Three types of vapor control systems meet the definition of RACT for bulk gasoline terminals: refrigeration, compression-refrigeration-absorption, and thermal oxidation. Refrigeration, in which captured vapors are cooled to a temperature of about - 100°F and condensed, yields an approximate emission reduction of between 80 and 93 percent. Compression-refrigeration-absorption, which is based on the absorption of gasoline vapors under pressure with chilled gasoline from storage, yields an approximate emission reduction of between 71 and 92 percent. Thermal oxidation, in which the captured vapors are oxidized through incineration, yields an emission reduction greater than 99 percent. In 1977, as may be seen in Table 230 in Chapter VII, bulk gasoline terminals produced about 2,300 tons of volatile organic compound emissions in the Region. With the application of RACT controls, the volatile organic compound emissions from this source category are anticipated to be reduced by about 2,000 tons, or more than 86 percent, to about 287 tons in 1982. A slight increase to 291 tons of emissions from this source category is forecast for 1987.

Bulk gasoline plants are secondary distribution facilities which receive gasoline from bulk terminals by trailer transport, store the gasoline in above-ground storage tanks, and subsequently distribute the gasoline to farms, businesses, and service stations. The average throughput of bulk gasoline plants is generally less than 20,000 gallons of gasoline per day. Volatile organic compounds may be emitted from bulk gasoline plants during the filling of tank trucks and storage tanks. RACT controls for bulk gasoline plants prescribe the use of the submerged filling method for loading tank trucks rather than the top-splash method—a procedural change which may reduce emissions by 58 percent—and the use of a vapor balance system during the loading and unloading of tank trucks and storage tanks. Vapor balance is a technique wherein displaced vapors from tank trucks are transferred to storage tanks, and subsequently to the trucks that deliver gasoline to the bulk plant. These collected vapors may then be recovered or oxidized. As indicated in Table 303 in Chapter XII, volatile organic compound emissions from bulk gasoline plants in the Region were estimated at 769 tons in 1977, and forecast at 712 tons in 1982 and 733 tons in 1985. With the implementation of the above-mentioned RACT controls, the emissions from bulk gasoline plants in the Region are forecast to decrease by about 441 tons, or more than 57 percent—from the 1977 emission level of 769 tons to 328 tons by the year 1982.

Volatile organic compound emissions are released as a result of vapor displacement during the filling of underground gasoline storage tanks at gasoline service stations. As discussed in Chapter VII, there are two methods for loading gasoline into storage tanks: the splash fill method, which emits hydrocarbons at a rate of about 11.5 pounds per 1,000 gallons of gasoline; and the submerged fill method, which emits hydrocarbons at a rate of about 7.3 pounds per 1,000 gallons of gasoline. Based on the assumption that 50 percent of the service stations in the Region used the splash fill method and 50 percent the submerged fill method, it was estimated that 3,100 tons of volatile organic compound emissions were released during the loading of gasoline at service stations in the Region during 1977.

Emissions from underground tank filling operations at service stations can be reduced through the use of the vapor balance system. The vapor balance system employs a vapor return hose which returns gasoline vapors dis-

placed from the underground tank to the tank truck storage compartments being emptied. The control efficiency of the vapor balance system ranges from 93 percent to 100 percent. Volatile organic compound emissions from underground tank filling operations at service stations using both the submerged fill method and a vapor balance system are, therefore, not expected to exceed 0.3 pound per 1,000 gallons of gasoline. At this level of control, volatile organic compound emissions from underground tank filling are forecast to total about 92 tons in 1982 and 93 tons in 1987.

Solvent metal cleaning is a term used to refer to use of nonaqueous solvents to clean and remove soils from metal surfaces by cold cleaning, open top vapor degreasing, or conveyorized degreasing. Such solvents include petroleum distillates, chlorinated hydrocarbons, ketones, and alcohols. It has been estimated that 8,400 tons of volatile organic compound emissions were released into the atmosphere over the Region during 1977 as a result of these metal cleaning and degreasing operations.

Because degreasers have such diversity in design and application, RACT limitations cannot readily be expressed in terms of an emission standard. Rather, RACT limitations on this source category must be defined as requirements for the implementation of operating procedures which minimize solvent loss or which necessitate the retrofit of applicable control devices. Required control equipment may be as simple as a manual cover or as complex as a carbon adsorption system, depending on the size and design of the degreaser. Required operating procedures include covering degreasing equipment whenever possible, properly using solvent sprays, promptly repairing leaking equipment, and properly disposing of the waste solvents. The Wisconsin Department of Natural Resources has estimated that implementation of these procedures and control devices would yield a 50 percent reduction in volatile organic compound emissions from degreasing operations. Under this assumption, the solvent emissions from this source category are forecast to total about 4,400 tons in 1982 and 4,700 tons in 1987.

Cutback asphalt is so termed because the asphalt oils are thinned, or "cut," to facilitate the application of the bituminous aggregate mixture. Cutback asphalt is applied in a spray directly to the road surface or in a cold mix. As the cutback asphalt cures, the solvent evaporates into the atmosphere at a rate which is dependent on the cure type. The average emission rate for three cure types are: 25 percent for slow cure (SC), 70 percent for medium cure (MC), and 80 percent for rapid cure (RC). In 1977 the use of cutback asphalt in southeastern Wisconsin was estimated in the Pacific Environmental Services inventory to have resulted in the release of 10,600 tons of volatile organic compound emissions.

The definition of RACT for this source category consists of the substitution of emulsified asphalt for cutback asphalt. Emulsified asphalt consists of a maximum of 35 percent water and 60 to 70 percent of an asphaltic emulsifier which is composed of nonvolatile organic compounds. During the curing process, the water evaporates and the emulsifier is retained in the asphalt. To encourage the use of asphalt emulsions, the Wisconsin Department of Natural Resources has restricted the use of cutback asphalt except in certain limited cases—such as for the control of road dust—and has banned altogether the use of rapid-curing cutback asphalt. The Department estimates that these regulations will reduce the volatile organic compound emissions from the use of cutback asphalt by about 64 percent. The forecast emissions under this level of RACT control are, therefore, estimated to average about 3,800 tons per year over the forecasting period.

Table 323 presents the existing and forecast volatile organic compound emissions for the Group I RACT source categories. As may be seen in this table, the above-mentioned RACT emission limitations for the 11 source categories operational in the Region provide for a volatile organic compound emission reduction of about 24,900 tons, or more than 66 percent, between 1977 and 1982—from about 37,700 tons in 1977 to about 12,800 tons in 1982. This significant reduction is based on the assumption of full implementation of the Group I RACT limitations by 1982. After 1982, the forecast growth in emissions from can coating operations and degreasing operations—offset somewhat by a moderate decline in petroleum storage and transfer operation emissions—provides for a slight increase in the overall emissions from this source group of about 900 tons, or about 7 percent, by the year 2000. The 13,700 tons of volatile organic compound emissions forecast for the year 2000, however, represents a decrease of about 24,000 tons, or about 64 percent, from the existing 1977 emission level.

Table 323

EXISTING AND FORECAST VOLATILE ORGANIC COMPOUND EMISSIONS FROM GROUP I RACT SOURCE CATEGORIES IN THE REGION

Source Category	Emissions (tons)				
	1977	1982	1985	1987	2000
Surface Coating					
Automobiles	5,531	648	662	672	733
Cans	4,293	2,122	2,237	2,313	2,802
Metal Coils	26	29	30	31	36
Paper	2,005	251	251	251	251
Fabric	321	321	321	321	321
Subtotal	12,176	3,371	3,501	3,588	4,143
Petroleum Transfer and Storage					
Fixed-Roof Tanks	91	91	91	91	91
Bulk Gasoline Plants	769	328	336	345	288
Bulk Gasoline Terminals	2,306	287	289	291	243
Service Station Loading					
Loading	3,054	92	93	91	76
Tank Breathing	328	374	307	300	255
Subtotal	6,548	1,172	1,116	1,118	953
Solvent Metal Cleaning	8,433	4,447	4,583	4,674	4,822
Cutback Asphalt	10,552	3,799	3,799	3,799	3,799
Total	37,709	12,789	12,999	13,179	13,717

Source: Wisconsin Department of Natural Resources and SEWRPC.

Group II RACT Controls: Of the 10 volatile organic compound emission source categories shown in the Group II RACT category in Table 321, only five—surface coating of miscellaneous metal parts and products, graphic arts (printing), petroleum storage in floating-roof tanks, dry cleaning, and gasoline tank truck leaks—contribute emissions in the Region. The emissions from leaks in gasoline trucks have not been considered separately, but rather were considered collectively with emissions from stage I service station loading operations in Group I. The remaining four sources in the Group II RACT category released an estimated 7,300 tons of volatile organic compound emissions in the Region during 1977.

As noted earlier, Group II source categories are those for which guidance on applicable RACT techniques has not yet been issued by the U. S. Environmental Protection Agency. The Wisconsin Department of Natural Resources has, however, gathered enough information on and conducted sufficient investigation of the control of such sources to enable a generalized RACT emission limitation to be defined. Because of the uncertainties regarding the final EPA-mandated RACT emission limitations, the reductions in volatile organic compound emissions from Group II source categories as estimated by the Department may be subject to revision as more information becomes available.

Table 324 presents the existing and forecast volatile organic compound emissions from the Group II RACT source categories as estimated by the Wisconsin Department of Natural Resources. As may be seen by comparing this table with Table 303 in Chapter XII, which details the forecast emissions from these source categories at the present level of control, the Department estimates that volatile organic compound emissions from graphic arts operations may be reduced by at least 40 percent by limiting the solvent content of the printing ink to no more than 2.9 pounds per gallon. The Department also estimates that dry-cleaning emissions may be reduced by at least 55 percent through either the substitution of low-solvent cleaning fluids for high-solvent fluids or the use of carbon adsorption methods. The use of low-solvent coatings for miscellaneous metal parts may be expected to yield about a 50 percent reduction in volatile organic compound emissions from this source category. By sealing the numerous points of leaks in floating-roof tanks used for gasoline storage, the Department estimates that fugitive volatile organic compound emissions from such tanks may be reduced by about 85 percent, assuming maximum storage capacity.

Table 324

EXISTING AND FORECAST VOLATILE ORGANIC COMPOUND EMISSIONS FROM GROUP II RACT SOURCE CATEGORIES IN THE REGION

Source Category	Emissions (tons)				
	1977	1982	1985	1987	2000
Graphic Arts	202	132	137	143	168
Dry Cleaning	2,416	1,159	1,190	1,210	1,348
Gasoline Storage in Floating-Roof Tanks	584	97	97	97	97
Miscellaneous Metal Coating	4,067	2,145	2,209	2,255	2,541
Total	7,269	3,533	3,633	3,705	4,154

Source: Wisconsin Department of Natural Resources and SEWRPC.

With full implementation of the Group II RACT controls, volatile organic compound emissions from Group II source categories may be expected to be reduced by 3,800 tons, or more than 52 percent—from about 7,300 tons in 1977 to about 3,500 tons in 1982. Due to anticipated growth in certain of the Group II RACT source categories, a slight increase of about 200 tons in emissions is expected to occur between 1982 and 1987. Between 1982 and the year 2000, volatile organic compound emissions are forecast to increase by about 700 tons, or more than 20 percent, to about 4,200 tons.

Group III RACT Controls: Of the nine Group III source categories shown in Table 321, only three are applicable to southeastern Wisconsin—architectural and miscellaneous coatings, wood furniture manufacture, and service station unloading. In 1977 these Group III RACT categores released an estimated 8,500 tons of volatile organic compound emissions.

As with the Group II RACT source categories, the EPA has not yet issued final determinations on the degree of control to which the Group III RACT sources are to be subject. However, the Wisconsin Department of Natural Resources has determined certain minimum levels of control which may reasonably be achieved by sources in the Group III category. For architectural coatings, the Department has estimated that the increased use of water-based paints could produce an approximate 30 percent reduction in volatile organic compound emissions. Included in this category are automobile refinishing operations—for which the Department has estimated a minimum 25 percent control efficiency—and miscellaneous coating operations—for which control would be achieved through the use of low-solvent content paints and coatings. Similarly, the Department has estimated that a 50 percent reduction in volatile organic compound emissions from wood furniture manufacture would result from the use of low-solvent content materials. For gasoline service station unloading—that is, the transfer of gasoline from underground storage tanks to vehicle fuel tanks—the use of a vapor balance system between the pump and the fuel tank may be expected to yield at least a 50 percent control of emissions.

As shown in Table 325, with partial implementation of the Group III RACT controls by 1982, and full implementation by 1987, volatile organic compound emissions from Group III source categories are anticipated to decrease from about 8,500 tons in 1977 to about 7,000 tons in 1982, or by more than 17 percent, and to about 4,400 tons in 1987, or by nearly 48 percent. Between 1987 and the year 2000, volatile organic compound emissions from these sources are forecast to increase by about 400 tons, or about 8 percent, to about 4,800 tons.

Mobile Source Controls: Line sources contribute significantly to the total regional emissions burden, accounting for about 87 percent of the total carbon monoxide emissions and 36 percent of the total hydrocarbon emissions in the Region during 1977. The approach to reducing line source emissions is embodied in the federal motor vehicle emissions control program, under which the automobile manufacturers are required to apply on-board emission control devices to motor vehicles. As was evidenced in the comparison of motor vehicle emission rates in 1977 with those in 1973, as discussed in Chapter VII of this report, the federal motor vehicle emissions control program has already resulted in significant reductions in carbon monoxide and hydrocarbon emission levels. As newer, more controlled, vehicles enter the fleet, the impact of this control program is expected to increase substantially. New vehicle emission rate limitations, however, have been postponed or made less stringent, on several occasions since 1970. The forecasts of ambient air quality in the Region have been based on the latest emission rates—and intended year of implementation—mandated by the U. S. Environmental Protection Agency. Any deviation from the emission rates thus defined—and presented in Chapter XII of this report—would alter the carbon monoxide and hydrocarbon emissions forecasts on which the determination of the need for either attainment or maintenance plans for these two pollutant species has been based. The extent to which the federal motor vehicle emissions control program affects the forecast line source emissions in the Region is described in the following section.

The U. S. Environmental Protection Agency's revisions to aircraft emission standards are another type of mobile source control. Therefore, aircraft emission limitations are also considered part of the committed mobile source controls, and are discussed herein.

The Federal Motor Vehicle Emissions Control Program: Although efforts to control air pollutant emissions from motor vehicles were initiated in 1968, it was not until the enactment of the Clean Air Act Amendments of 1970 that specific mobile source emission rates were mandated by the federal government. These standards, which were originally envisioned for full attainment by 1975, required that new vehicle emissions ultimately achieve a 90 to 95 percent reduction from the uncontrolled emission level. The federal motor vehicle emissions control program, however, experienced several delays in attaining this goal, principally because major automobile manufacturers were unable to develop the necessary emission control devices in accordance with the mandated schedule.

A summary of the changes in automobile exhaust emission standards since 1976 is provided in Table 326. As may be seen in this table, under the Clean Air Act Amendments of 1970 a hydrocarbon exhaust emission rate of 0.41 gram per vehicle mile of travel and a carbon monoxide emission rate of 3.4 grams per vehicle mile of travel was required to be met by model year 1977 vehicles. Compliance schedule revisions granted to the automobile manufacturers in 1973 and 1975 postponed the attainment of these emission limitations until 1978. With the passage of the Clean Air Act Amendments of 1977, a further extension—until 1980 for the 0.41 gram hydrocarbon standard and until 1981 for the 3.4 gram carbon monoxide standard—was granted. Moreover, the 1977 amendments not only postponed the attainment of the most stringent nitrogen oxide emission standard until 1981, but also relaxed the standard from 0.4 gram per vehicle mile of travel standard to 1.0 gram per vehicle mile of travel. The motor vehicle emission rates established under the Clean Air Act Amendments of 1977 are the basis for the line source emissions forecasts for the Region as presented in Chapter XII of this report.

The forecast effect of the federal motor vehicle emissions control program on line source emissions is presented graphically in Figure 107 for carbon monoxide and in

Table 325

EXISTING AND FORECAST VOLATILE ORGANIC COMPOUND EMISSIONS FROM GROUP III RACT SOURCE CATEGORIES IN THE REGION

Source Category	Emissions (tons)				
	1977	1982	1985	1987	2000
Architectural and Miscellaneous Coatings . .	5,327	4,299	4,099	4,147	4,549
Wood Furniture Manufacture	8	8	4	4	4
Service Station Unloading.	3,186	2,742	298	291	247
Total	8,521	7,049	4,401	4,442	4,800

Source: Wisconsin Department of Natural Resources and SEWRPC.

Table 326

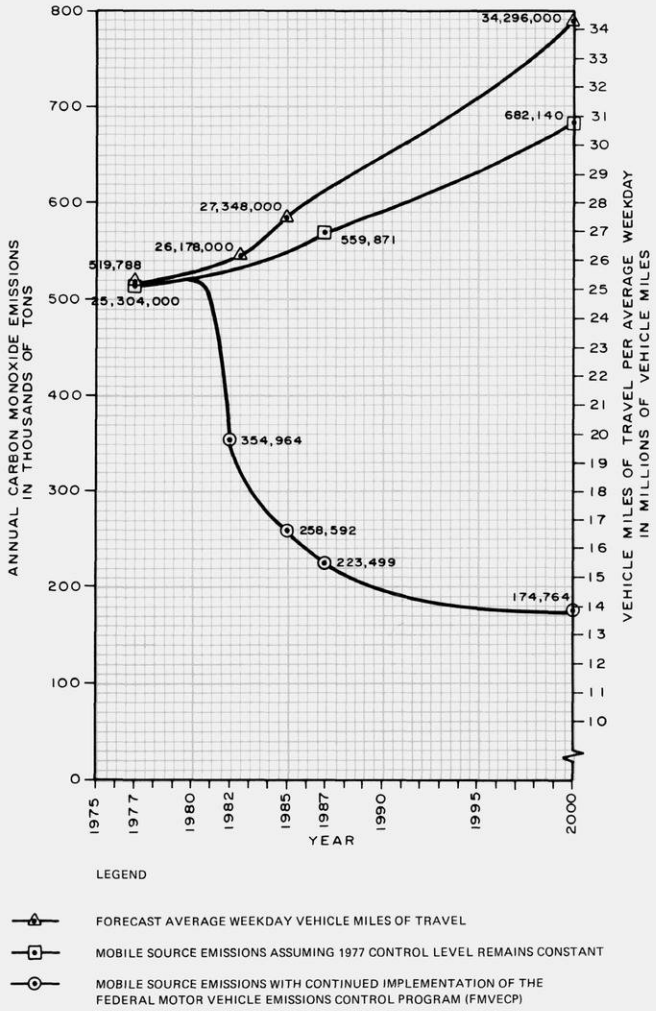
AUTOMOBILE EXHAUST EMISSION CONTROL SCHEDULES: 1976-1982

Schedule Determinant	Emission Rate (grams per vehicle mile of travel)						
	1976	1977	1978	1979	1980	1981	1982
1970 Clean Air Act							
Hydrocarbons	1.5	0.41	----	----	----	----	----→
Carbon Monoxide . .	15.0	3.4	----	----	----	----	----→
Nitrogen Oxides . . .	3.1	2.0	0.4	----	----	----	----→
As of July 1, 1977							
Hydrocarbons	1.5	----	0.41	----	----	----	----→
Carbon Monoxide . .	15.0	----	3.4	----	----	----	----→
Nitrogen Oxides . . .	3.1	2.0	0.4	----	----	----	----→
1977 Amendments							
Hydrocarbons	1.5	----	----	----	0.41	----	----→
Carbon Monoxide . .	15.0	----	----	----	7.0	3.4	----→
Nitrogen Oxides . . .	3.1	2.0	----	----	----	1.0	----→

Source: National Council on Environmental Quality.

Figure 107

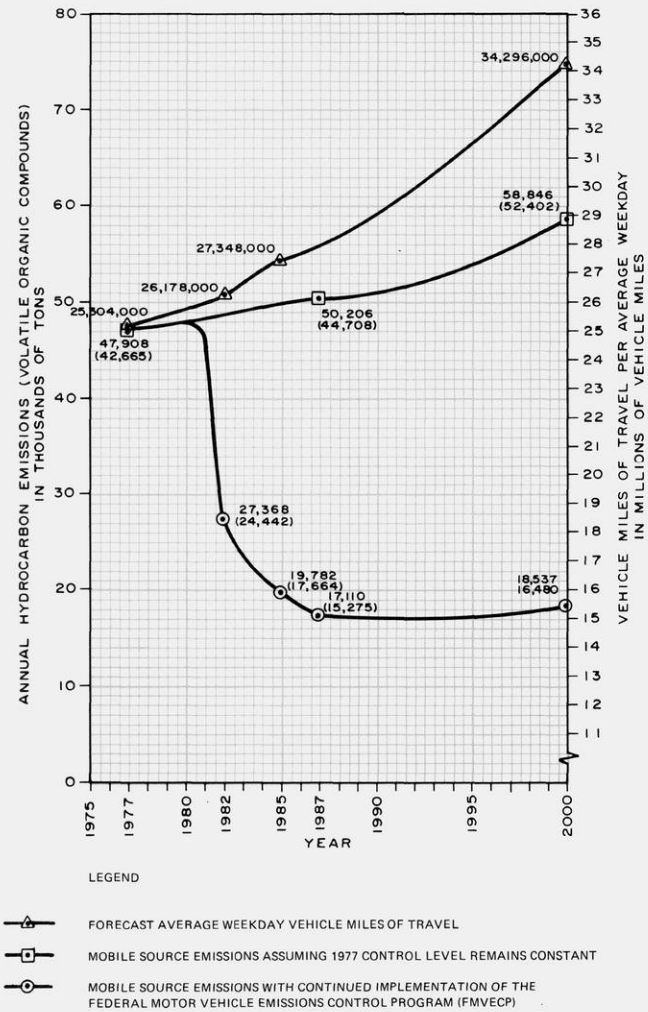
FORECAST EFFECT OF THE FEDERAL MOTOR VEHICLE EMISSIONS CONTROL PROGRAM ON LINE SOURCE CARBON MONOXIDE EMISSIONS UNDER THE "NO BUILD" TRANSPORTATION PLAN: 1977-2000



Source: SEWRPC.

Figure 108

FORECAST EFFECT OF THE FEDERAL MOTOR VEHICLE EMISSIONS CONTROL PROGRAM ON LINE SOURCE HYDROCARBON (VOLATILE ORGANIC COMPOUND) EMISSIONS UNDER THE "NO BUILD" TRANSPORTATION PLAN: 1977-2000



Source: SEWRPC.

Figure 108 for hydrocarbons. [21] As may be seen in Figure 107, carbon monoxide emissions from all mobile sources are forecast to decrease rapidly between 1977 and 1987—from about 519,800 tons in 1977 to 223,500 tons in 1987, or by 57 percent—even though vehicle miles of travel is forecast to increase from about 25.2 million on an average weekday in 1977 to about 28.1 million on an average weekday in 1987—an increase of 2.9 million vehicle miles of travel, or about 12 percent. Considering both the forecast growth in travel and the forecast reduction in carbon monoxide emissions, it may be concluded that the federal motor vehicle emissions control program will provide for an approximate 66 percent reduction in carbon monoxide emissions from line sources over the 11-year, 1977 through 1987, period. The line source carbon monoxide emissions forecast for 1987 under the assumption that all automobiles will meet the same emission standards met by the 1977 vehicle fleet are indicated

[21] *Emissions forecast under the "no build" transportation plan are presented in these figures in order to eliminate the influence of facility improvements on improving traffic flow and subsequently air pollutant emissions. The "no build" alternative does not provide for any new transportation facilities other than those facilities committed to construction as of 1978. Thus, the reduction in emissions indicated in the figures can be primarily attributed to implementation of the federal motor vehicle emissions control program.*

in Figure 107 to total 559,900 tons—about 336,400 tons, or 60 percent, more than the 223,500 tons forecast under the federal motor vehicle emissions control program. As new vehicles enter the fleet, the impact of the federal motor vehicle emissions control program is expected to become more significant. This is illustrated in Figure 107, which indicates that in the year 2000, carbon monoxide emissions from motor vehicles at the 1977 level of control will approximate 682,100 tons, or about 507,300 tons more than the 174,800 tons forecast under the emissions limitations prescribed by the Clean Air Act Amendments of 1977.

Figure 108 indicates that hydrocarbon emissions from line sources will decrease by about 30,800 tons, or more than 64 percent, between 1977 and 1987—from 47,900 tons in 1977 to about 17,100 tons in 1987. Under the assumption that the 1977 emission standards will remain in effect, the hydrocarbon emissions from line sources are forecast to increase by about 2,300 tons, or nearly 5 percent, to about 50,200 tons over this 10-year period. Under the same assumption, hydrocarbon emissions from line sources in the Region in the year 2000 are estimated at 58,800 tons, or about 40,300 tons more than the 18,500 tons forecast under the latest federal motor vehicle emissions control program limitations.

It is significant to note in Figure 108 that the downward trend in hydrocarbon emissions from line sources is forecast to reverse in the early to mid-1990's. This observation may be explained by noting that the vehicle fleet in the early 1990's is comprised almost entirely of vehicles meeting the most stringent emission rates presently mandated. Subsequent to that time, the forecast increase in vehicle miles of travel in the Region becomes the dominant factor in determining the emission burden contributed by line sources. The diminishing impact of the federal motor vehicle emissions control program in the decade preceding the year 2000 is significant from the standpoint of the long-term maintenance of the ozone ambient air quality standard.

Aircraft Emission Limitations: In July 1973, the U. S. Environmental Protection Agency promulgated gaseous emission regulations for several classes of newly manufactured and newly certified aircraft engines. In March 1978, the EPA proposed modifying the emission standards and changing the scope of the standards such that they only apply to commercial aircraft engines rated at 6,000 or more pounds of thrust.[22] At the same time, the EPA determined that the control technology available to meet the carbon monoxide and hydrocarbon emission standards for such newly manufactured aircraft engines could readily be adapted to in-use commercial aircraft engines. On this basis, all newly certified commercial aircraft engines with a thrust of 6,000 or more pounds must meet the carbon monoxide and hydrocarbon standards by January 1, 1984, while all existing aircraft engines of this class and use must be retrofit to meet the same standards by January 1, 1986.

These carbon monoxide and hydrocarbon emission limitations will serve to reduce the carbon monoxide and hydrocarbon emission factors for common air carrier aircraft, shown in Table 134 in Chapter VII, by a maximum of 50 percent by 1985 and by 90 percent by the year 2000. Since, in the Region, common air carriers of this size operate only at General Mitchell Field in Milwaukee County, only this regional airport is affected by the regulations. Based on the assumption that all commercial jet aircraft operating at Mitchell Field will attain this 50 percent level of control by 1985, total carbon monoxide emissions from aircraft in the Region may be expected to be reduced by 600 tons, or slightly less than 6 percent—from the 11,500 tons forecast under the existing level of control to about 10,900 tons.[23] By the year 2000, the new standards may be expected to reduce the carbon monoxide emissions from aircraft operations in the Region by about 3,100 tons, or by about 13 percent—from 23,800 tons to about 20,700 tons.

Similarly, the new standards may be expected to produce a 360-ton, or 22 percent, reduction in hydrocarbon emissions from aircraft in the Region in 1985—from 1,600 tons at the present level of control to about 1,240 tons. By the year 2000, hydrocarbon emissions from regional aircraft may be expected to be reduced by about 1,600 tons, or more than 46 percent—from about 3,500 tons to 1,900 tons.

Evaluation of Committed Actions: It was noted in Chapter XI of this report that, at a minimum, a 62 percent reduction in volatile organic compound emissions from the 1977 level would be required in order to attain and maintain the ambient air quality standard for ozone. It was also noted that, to ensure safe levels of ozone in the ambient air, an optimum reduction of 74 percent would be required. Thus, the attainment and maintenance of the maximum hourly average ozone standard of 0.12 ppm necessitates reducing the 102,200 tons of volatile organic compounds emissions in the Region in 1977 to between 26,600 tons at the 74 percent reduction level and 38,800 tons at the 62 percent reduction level on an annual average basis.

Table 327 and Figure 109 illustrate the progress made toward meeting the required emission reductions stemming from implementation of RACT limitations on stationary sources and the continued enforcement of the federal motor vehicle emissions control program. As indicated in this table and figure, the committed actions

[22] *The final commercial aircraft engine emission limitations are to be promulgated by the U. S. Environmental Protection Agency during the fourth quarter of 1979 and the first quarter of 1980.*

[23] *Forecast emissions from aircraft operations in the Region in the years 1985 and 2000 are presented in Table 291 in Chapter XII of this report.*

Table 327

EXISTING AND FORECAST VOLATILE ORGANIC COMPOUND EMISSIONS IN THE REGION UNDER IMPLEMENTATION OF THE COMMITTED ACTIONS

Source Category	Emissions (tons)				
	1977	1982	1985	1987	2000
Stationary Source RACT					
Group I	37,709	12,789	12,999	13,179	13,717
Group II	7,269	3,533	3,633	3,705	4,154
Group III	8,521	7,049	4,401	4,442	4,800
Subtotal	53,499	23,371	21,033	21,326	22,671
Federal Motor Vehicle Emissions Control Program[a]	42,665	24,442	17,664	15,275	16,480
Miscellaneous Sources[b]	5,999	6,301	6,297	6,491	9,612
Total	102,163	54,114	44,994	43,092	48,763

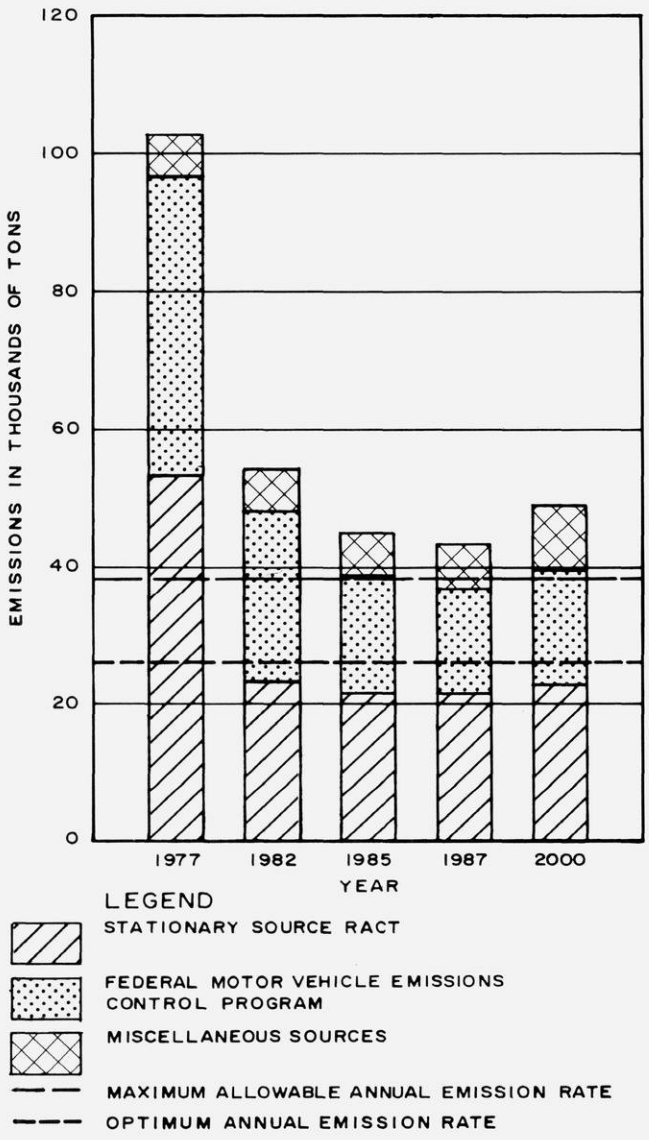
[a] *Forecast emissions based on the "no build" transportation plan.*

[b] *Includes aircraft, general utility engines, industrial and construction equipment, railroad line and yards, fuel combustion, incineration, forest wildfires, and commercial vessels. Not included in this category are agricultural equipment, power boats, off-highway motorcycles, snowmobiles, and miscellaneous solvent use. These categories were omitted from the modeling effort for volatile organic compound emissions since they were deemed to have little or no effect on ozone formation within and upwind of major urban areas.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 109

IMPACT OF THE IMPLEMENTATION OF RACT LIMITATIONS ON STATIONARY SOURCES AND CONTINUED ENFORCEMENT OF THE FEDERAL MOTOR VEHICLE EMISSIONS CONTROL PROGRAM ON VOLATILE ORGANIC COMPOUND EMISSIONS IN THE REGION: 1977-2000



Source: SEWRPC.

provide for a significant reduction in volatile organic compound emissions in the Region between 1977 and 1982. RACT limitations on stationary sources, for example, are expected to yield an overall emission reduction of about 30,100 tons, or more than 56 percent—from about 53,500 tons in 1977 to 23,400 tons in 1982. The federal motor vehicle emissions control program is also expected to produce a significant reduction in volatile organic compound emissions in the Region—from 42,700 tons in 1977 to about 24,400 tons in 1982, for a 43 percent reduction. The total reduction expected in volatile organic compound emissions between 1977 and 1982 will be offset somewhat by the slight increase in emissions anticipated from miscellaneous sources. Nonetheless, RACT controls on stationary sources and the federal motor vehicle emissions control program are expected to reduce total volatile organic compound emissions from about 102,200 tons in 1977 to about 54,100 tons in 1982—a 48,100-ton, or more than 47 percent, reduction. This forecast 1982 level is, however, about 15,300 tons, or about 39 percent, higher than the maximum level of 38,800 tons permissible per year if attainment and maintenance of the ozone ambient air quality standard is to be achieved. Although further progress in reducing volatile organic compound emissions in the Region between 1982 and 1987 may be expected—from 54,100 tons to 43,100 tons—the continued growth of regional sources is forecast to produce a 5,700-ton, or 13 percent, increase in volatile organic compound emissions by the year 2000—from 43,100 tons in 1987 to 48,800 tons in the year 2000. It may be concluded, therefore, that the committed actions—specifically, the RACT limitations on stationary sources and the federal motor vehicle emissions control program—are not adequate in themselves to provide for the attainment and maintenance of the ambient air quality standard for ozone continuously throughout the planning period.

Attendant to the finding that the committed actions are not expected to lead to the attainment of the ozone standard by 1982 is the conclusion that additional controls, including a federally mandated vehicle inspection program, must be implemented. Further, since it has been demonstrated in Chapter XII that the ambient air quality standards for carbon monoxide are not expected to be attained throughout the Region prior to 1983, and since carbon monoxide emission controls do not presently extend beyond the limits set by the federal motor vehicle emissions control program, additional control measures will also be required to ensure the prompt attainment of the eight-hour average standard for this pollutant species in the Region. Alternative measures for the control of volatile organic compound and carbon monoxide emissions are presented below.

Potential Actions for the Control of Residual Carbon Monoxide and Hydrocarbon/Ozone Emissions

As noted in the previous section, a residual problem with respect to the attainment and maintenance of the carbon monoxide, hydrocarbon, and ozone ambient air quality standards in the Region may be expected even assuming full implementation of the present RACT emission limitations for stationary sources, and the benefits expected to result from implementation of the federal motor vehicle emissions control program (FMVECP). Additional and potentially more stringent, emission controls will be required in order to attain and maintain these ambient air quality standards. In the case of carbon monoxide, implementation of the FMVECP will provide for the attainment of the eight-hour average standard—10 milligrams per cubic meter (mg/m^3)—prior to 1985. Additional control measures on mobile sources, if implemented in a timely manner, could accelerate the attainment date to the year 1982. In the case of hydrocarbons—specifically, volatile organic compounds—both controls on mobile sources and more stringent emission limitations on stationary sources could provide for the short-term attainment and long-term maintenance of the one-hour average ambient air quality standard for ozone of 0.12 part per million (ppm). The following section of this chapter examines alternative control measures which could serve to reduce carbon monoxide and hydrocarbon emissions from stationary and mobile sources. These alternative control measures are then examined as components of grouped plan alternatives.

Alternative Stationary Source Controls: There are several stationary sources of hydrocarbons which, through either process or design changes or solvent substitution, may achieve more substantial reductions in volatile organic compound emissions than otherwise prescribed by RACT limitations. The economic impact of implementing more stringent control measures on certain stationary sources may, however, preclude their ready adoption. Moreover, the present lack of widespread availability of certain substitute solvents may, as a practical matter, negate any proposed emission limitation based on the implementation of more stringent measures. Such factors must be taken into account in devising alternative control strategies for stationary sources.

As indicated in Table 323, the surface coating operations within the Region associated with cans, automobiles, and paper are those principally affected by the committed RACT emission limitations.[24] An examination of the emission reductions to be achieved through implementation of the RACT measures prescribed for these three sources indicates that, aside from the fact that the prescribed limits may be achieved by 1982—primarily through the use of low-solvent waterborne coatings—more stringent emission limitations on the surface coating of cans, automobiles, and paper products are not technologically feasible at this time, mainly because of the lack of substitute solvents. In certain instances, particularly for can coating operations, the use of substitute solvents must be approved by the U. S. Food and Drug Administration, as well as the product purchaser. Also, as in the case of substitute solvents for paper coating operations, many of the alternative materials do not meet necessary product quality standards. It may therefore be concluded that it is not technologically feasible at the present time to require additional emission reductions from coating operations regulated under the Group I RACT controls.

Since the emission reductions to be achieved through the implementation of the RACT limitations prescribed for petroleum storage and transfer operations, as shown in Table 323, represent an overall control efficiency of about 90 percent, more stringent controls on such sources may not be expected to yield further emission reductions of any consequence. Additional controls on solvent metal cleaning and cutback asphalt, however, may result in further emission reductions.

The principal way to achieve the RACT emission limitations prescribed for solvent metal cleaning, or degreasing, operations is to retrofit solvent-capture equipment onto existing cleaning units, and to render the captured solvents inert through either carbon adsorption, refrigeration, or distillation. An overall emission reduction efficiency of 50 percent can thus be achieved, although in certain cases a control efficiency of 75 percent may be achieved depending on the size and operational characteristics of the degreaser. Equipment availability may be a problem since only a few companies now supply the equipment necessary to make RACT-prescribed control modifications, but full compliance may nonetheless be expected by 1982. Based upon a review of the operating characteristics of degreasers and of available control devices, however, an overall reduction efficiency greater than 50 percent is not expected.

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[24] *The facilities affected by the RACT emission limitations on the surface coating of metal coils and the surface coating of fabrics are presently in compliance with the regulations.*

The final source in the Group I RACT category from which further emission reductions may potentially be achieved is the use of cutback asphalt. In the 1920's and the 1930's, cutback asphalt emerged as a low-cost adequate binder for paving materials that provided weather resistance and a dust-free surface to respond to the growing demand for roadways brought about by the increasing number of automobiles. After World War II, the sale of cutback asphalt remained at an almost constant level while the sale of asphalt cement more than quadrupled between 1954 and 1974. Since 1973 the use of cutback asphalt has steadily decreased, being replaced by either a bituminous plant mix—asphalt cement—for maintenance, construction, and reconstruction projects, or asphalt emulsion for light surface applications. Asphalt emulsions can be substituted for cutback asphalt in all but cold weather applications, for which bituminous plant mix may be used. To effect a total conversion from cutback asphalt to asphalt emulsion it is necessary to replace the spray nozzles on the trucks applying the asphalt, provide preheaters, make adjustments to the pumps to apply the emulsion, and train employees on the use of asphalt emulsions. In 1982 and annually thereafter, a net reduction of 3,800 tons in volatile organic compound emissions may be expected in the Region with the substitution of asphalt emulsions for cutback asphalt. This 3,800-ton reduction represents a nearly 30 percent decrease from the 12,800 tons of volatile organic compound emissions forecast from Group I RACT categories for 1982 without this substitution, as shown in Table 323.

A review of the available emission control techniques and devices for Group II RACT categories—graphic arts, dry cleaning, gasoline storage in floating-roof tanks, and miscellaneous metal coating—and Group III RACT categories—architectural and miscellaneous coatings, wood furniture manufacture, and service station unloading—indicates that process changes and solvent substitution as additional measures to control emissions in excess of the levels shown in Tables 324 and 325 are not technologically feasible at the present time. A principal limiting factor in obtaining further emission reductions from these sources is the lack of substitutes for currently used solvents—particularly in the graphic arts, dry-cleaning, and architectural coating categories—which render a finished product of comparable quality. Although future manufacturing of acceptable solvents may follow in response to the demand, it would not be practicable to propose additional reductions in emissions from the Group II and Group III RACT categories at this time.

As noted in Chapter XI of this report, certain sources of hydrocarbon emissions in the Region were considered to be predominantly rural in nature or otherwise not a contributing influence to ambient air concentrations of ozone within or downwind of urban areas. These sources are agricultural equipment, power boats, snowmobiles, miscellaneous solvent use, and off-highway motorcycles. In total, these five sources are estimated to have released 16,200 tons of volatile organic compound into the atmosphere of the Region during 1977. Although these sources have been deemed to have little or no direct influence on ozone formation in the Region, technological changes, effected on a national rather than a regional level, may yield substantial emission reductions. In particular, many of the power units for off-highway motorcycles and outboard power boats are two-cycle engines. As noted in Chapter VII, two-cycle engines produce substantially more hydrocarbon emissions—about five times more on an overall average— than do four-cycle engines. A national program to reduce the number of powered devices utilizing two-cycle engines, therefore, may be attended by a reduction in hydrocarbon emissions. In southeastern Wisconsin, for example, replacing all two-cycle engines on off-highway motorcycles and powered boats with four-cycle engines would serve to reduce the 6,600 tons of volatile organic compound released by these two sources during 1977 by more than 77 percent—from 6,600 tons to about 1,500 tons.

Similarly, a national effort to reduce the solvent content of such miscellaneous sources as shoe polish, hair spray, household cleaners, and other sundry applications could yield significant emission reductions. As mentioned in Chapter VII, miscellaneous solvent use was responsible for the release of about 8,000 tons of volatile organic compound emissions in the Region during 1977. Although such emissions from miscellaneous solvent use may be scavenged or otherwise removed from the ambient air within the environs of the household, substituting other materials for the reactive solvents may eliminate the potential for such emissions to impact ozone formation in the exterior atmosphere.

Programs directed at replacing two-cycle engines with the less-polluting four-cycle engines, and at substituting alternative materials for the reactive solvents used in miscellaneous household products, must be conducted on a national, rather than a local or regional, level since such engines and solvents are manufactured and distributed throughout the country. Implementation of a local ban on the use of such products would be difficult, if not impossible, to enforce. A national effort, however, could reasonably effect such conversion without producing an undue economic constraint on manufacturers in localized areas and without imposing regulations that would be impossible to enforce on a local or even regional scale.

Alternative Mobile Source Controls: In addition to the federal motor vehicle emissions control program, there are two principal alternative control strategies for reducing carbon monoxide and hydrocarbon emissions from mobile sources: the establishment of a vehicle inspection and maintenance (I/M) program to ensure that motor vehicles operate within the prescribed emission limitations set forth by the FMVECP; and a transportation systems management program, which would seek to ensure that efficient use is made of existing transportation facilities. A vehicle inspection and maintenance program is required by the Clean Air Act Amendments of 1977 to be established in areas which cannot demonstrate attainment of the carbon monoxide or ozone ambient air quality standards by the year 1982. Such a program is considered herein, however, as an alternative

control measure since, although the carbon monoxide and ozone standards are not expected to be attained in the year 1982 with full implementation of the committed actions, it may be possible to achieve these standards by 1982 if more stringent controls are placed on stationary sources or if the vehicle miles of travel in the Region is sufficiently reduced through transportation systems management actions. Moreover, the configuration of an I/M program may itself take several alternative forms, each designed to yield a different emission reduction. It is also envisioned that the plan selected for implementation in southeastern Wisconsin will be comprised of the best combination of mobile source and stationary source controls, and to that end an I/M program may be used to alleviate the extent to which less cost-effective controls on stationary sources are used to obtain the required emission reductions.

Vehicle Inspection and Maintenance (I/M): Because tailpipe emissions from highway motor vehicles have been demonstrated to be major sources of hydrocarbon, nitrogen oxide, and carbon monoxide air pollutants, Federal Statutes have been enacted to require reductions in pollutant emissions from new vehicles. Under the federal motor vehicle emissions control program, automobiles and light-duty gasoline trucks must be designed and manufactured so as to meet, with proper maintenance, applicable air pollution emission standards for their useful lives. In order to ensure that most new motor vehicles meet the federal emission standards, the U. S. Environmental Protection Agency, through the federal motor vehicle emissions control program, certifies new vehicle prototypes, tests assembly-line production vehicles, and requires manufacturers to recall in-use vehicles which fail to meet emission standards because of design defects. Assuming that each new motor vehicle does meet the federal emission standards at the time it is placed in service, the vehicle is not designed and cannot be expected to meet the standards throughout its life without further attention to engine components and adjustments to the emission control systems. In reality, slightly over 90 percent of sampled new assembly-line vehicles have been found by the U. S. Environmental Protection Agency to meet federal new vehicle emission standards.

In addition to certifying new vehicle prototypes, testing selected production vehicles, and mandating manufacturer recall of in-use vehicles that fail to meet emission standards because of design defects, the U. S. Environmental Protection Agency has proposed the establishment of a warranty program which would require vehicle manufacturers to pay for emission control repairs on 1981 and later model year vehicles that are found to violate emission standards. The warranty program would cover light-duty vehicles for five years or 50,000 miles, whichever occurs first, provided that the vehicle owner had followed prescribed manufacturer's maintenance instructions. Through the first 24 months, or 24,000 miles, whichever occurs first, the vehicle manufacturer would be required to make any repair necessary in order to bring the vehicle into emission compliance. After this 24-month or 24,000-mile period, the manufacturer would be required to repair only those emission control components such as the catalytic converter or thermal reactor, or other components that were installed in or on a vehicle for the sole or primary purpose of reducing vehicle emissions and which were not in general use prior to the 1968 model year. This warranty program would apply only in those areas which have a U. S. Environmental Protection Agency-approved inspection and maintenance program. This proposed program is contingent upon the establishment of a "short" emissions test for EPA-approved I/M programs which will correlate with the 14-hour federal test procedure but require only a few minutes to complete. Under the proposed warranty regulations, the manufacturer would be responsible for demonstrating that the vehicle owner had not properly maintained the vehicle, and dealers of light-duty vehicles would be required to certify that each vehicle met emission standards when sold. It should be noted that many causes of an I/M emission test failure, such as maladjustment of the air-fuel ratio, would not be covered by the federal warranty provisions.

Research has shown that the effectiveness of vehicle emission control systems commonly diminishes with age and accumulated mileage. In tests conducted by the EPA on vehicles which have been in use for two or three years, two-thirds of cars tested did not meet at least one of the emission standards for hydrocarbons or carbon monoxide. Thus, a vehicle which has a properly designed and manufactured emission control system when placed in service cannot be expected to meet air pollutant emission standards throughout its in-use life without periodic maintenance and adjustment of emission control systems.

This diminution in emission control effectiveness has been shown to be caused not only by normal wear of the engine and emission control components, but to a major degree by poor or improper engine and emission control device maintenance, or by deliberate tampering and/or maladjustment of emission control system settings. Periodic vehicle inspection and maintenance has proven to be an effective way to reduce vehicle emission control diminution. Basically, an I/M program is designed to periodically check the pollutant emission levels of motor vehicles to determine whether they meet certain specified tailpipe emission standards and to adjust those levels to, or below, those standards in the event the vehicle fails the inspection. An I/M program serves as a logical extension and integral part of a comprehensive motor vehicle emissions control program by increasing the frequency and quality of vehicle maintenance, thereby reducing the average emissions produced per vehicle mile of travel.

Because of the contribution made by mobile sources, particularly light-duty vehicles, to the total urban anthropogenic carbon monoxide, hydrocarbon, and nitrogen oxide emissions burden, I/M programs are now required by Federal Statute to be implemented by December 31, 1982, in those areas which cannot demonstrate attainment of the ozone or carbon monoxide standards. The U. S. Environmental Protection Agency has interpreted this statute to be restricted in its application to urbanized

areas with populations greater than 200,000. Those states which contain areas so characterized must include, as part of their revision to their State Implementation Plan (SIP), provisions for the implementation of an inspection and maintenance program.

Basically, an I/M program requires vehicle owners to bring their vehicles to an approved vehicle testing facility at a stated time interval, usually once each year. At this testing station a tailpipe exhaust emissions test is performed, the results of which are compared to established emission standards for that particular vehicle species by model year and equipment configuration. If the vehicle fails to meet the emission standards, the owner is required to have the vehicle adjusted and/or repaired to bring it into emission compliance.

If the vehicle is not brought into emission compliance, with certain specific exceptions, it will not be allowed to legally operate on the roadways. This restriction may be accomplished by not allowing re-registration of the vehicle or by requiring the display of a special decal indicating emission compliance. Such vehicles as farm trucks, research vehicles, and vehicles older than a specific age may be exempted from the I/M program. In addition, if a vehicle fails to meet the emission standards during the testing and cannot economically be brought into emission compliance—that is, repair costs would exceed a specified upper cost limit—the vehicle can be exempted from emission compliance. This exemption, based on estimated repair costs, is fundamentally a safeguard to lessen the economic impact on those driving older vehicles.

The inspection phase of an I/M program should, at a minimum, meet the following requirements: 1) it should be of short duration; 2) it should be applicable to warmed-up vehicles; and 3) it should be able to identify high-emitting vehicles. Two distinct types of emissions tests, idle mode and loaded mode tests, meet these criteria for tailpipe emissions tests. These two test modes are commonly administered in a total of five different inspection configurations, with tampering, safety, and noise inspections added if desired. The idle mode test for hydrocarbon and carbon monoxide emissions consists of analyzing a sample of the test vehicle's tailpipe exhaust with the vehicle in a neutral gear. This simple emission test is made by inserting a remote probe into the exhaust tailpipe. The pollutant concentration is then determined by exhaust gas analyzers. The exhaust emission levels may be recorded at both the manufacturer's recommended idle speed and at an extremely high idle speed of approximately 2,250 revolutions per minute.

The loaded mode test involves a test of the vehicle exhaust with the vehicle's drive wheels mounted on a chassis dynamometer, in a forward drive gear, and under load to simulate actual driving conditions. This emissions test may be made at one or more steady loaded states and at idle speed, or a transient loaded test may be conducted which consists of a schedule of driving phases including a defined sequence of idle, acceleration, cruise, and deceleration modes. If the transient test is conducted, the composite exhaust sample from the test run is collected and analyzed to determine the pollutant concentrations.

The loaded mode test is more complex, slightly more time consuming, and slightly more costly—requiring the use of a dynamometer to produce drag on the engine—than the idle mode test, but provides a better indication of actual emissions since it represents a closer approximation of actual driving conditions. The loaded mode test also provides better diagnostic information in the event that repair and adjustments are necessary. In addition, the loaded mode emissions test has the potential to measure the nitrogen oxide levels in a tailpipe exhaust stream, and may thus be useful in those areas with a defined nitrogen oxide problem. The advantages of the idle mode test are that little technical training of test personnel is required, inspection facilities have greater inspection capacity, and the emissions tests can be administered at service stations and private garages.

The generally recognized administrative, owner-operator, alternatives to emission testing and inspection facilities are inspection facilities operated by the government (state, county, or local); contractor-operated facilities, operated by a private corporation under contract to a government; or privately operated facilities at garages or service stations under license or certification by the government. The idle mode test may be administered under any of the three owner-operator alternatives, but the loaded mode test is generally restricted to government- or contractor-operated facilities because of the added capital costs involved—in particular, the cost of the chassis dynamometer.

The spatial distribution of inspection facilities depends on the owner-operator plan. Government- and contractor-operated inspection facilities are limited in their number, but may have several lanes, and are established at centralized locations to serve a large number of vehicles per inspection site. The centralized inspection facility may require more vehicle waiting time for emission testing and involve greater travel distances to the test site. Approved test garages and service stations may be more numerous and can individually inspect fewer vehicles with less waiting time. Such facilities are generally spatially decentralized, thus requiring less travel distance to the test facility.

A study conducted by the U. S. Environmental Protection Agency between 1976 and 1978 of vehicles that exceeded the federal emission standards indicated that 47 percent of the excess vehicle emissions were attributable to equipment maladjustment; 25 percent to deterioration due to improper vehicle use, use of improper fuel, and premature parts failure; 18 percent to tampering; 7 percent to insufficient maintenance; and 3 percent to inadequate basic design and poor production practices. As noted, equipment maladjustment and improper maintenance are major causes of excessive carbon monoxide and hydrocarbon tailpipe exhaust emissions. For example,

increases in carbon monoxide and hydrocarbon emissions may be caused by a decrease in the air-fuel ratio and/or engine idle speed, a restricted positive crankcase ventilation valve or air filter, or choke and carburetor malfunctions. Increases in carbon monoxide emissions may also be caused by a malfunctioning heat riser valve, intake manifold leaks, emission control device malfunction, or catalytic converter breakdown. Increases in hydrocarbon emissions may also be caused by ignition system malfunctions, advanced spark timing, exhaust valve and intake manifold leaks, emission control device malfunction, and catalytic converter breakdown. The major causes of excessive hydrocarbon and carbon monoxide tailpipe exhaust emissions are summarized in Table 328. The maintenance phase of an operational I/M program in Portland, Oregon indicated that carburetor adjustment accounted for 78 percent, and engine tune-up 14 percent, of the repairs required to bring failed vehicles into emission compliance.

Table 328

MAJOR CAUSES OF EXCESSIVE EXHAUST EMISSIONS

Pollutant	Major Causes of Excessive Emissions
Carbon Monoxide	Carburetor out of adjustment Air-fuel mixture imbalances Malfunction of emission control devices
Hydrocarbons	Improper timing Ignition system malfunctions Malfunction of emission control devices

Source: U. S. Environmental Protection Agency.

A critical factor affecting the impact of an I/M program on vehicle exhaust emissions is the I/M standards or "cut points." The selected cut point is that pollutant emission level which separates the vehicles which pass the emission test from those which fail the test. The cut point is, in effect, a stringency factor which defines the proportion of the total vehicles tested in the program that will fail the inspection and be required to undergo repairs and/or adjustments in order to achieve compliance with the established emission standard. Cut points for each of the controlled pollutants, usually carbon monoxide and hydrocarbons, are set that will achieve a desired emission reduction within a practical limit while being acceptable to both the general public and the repair industry. The establishment of cut points requires considerable time and effort and may be based on demonstration programs conducted prior to the mandatory phase of the program, or on an evaluation of the standards developed in other I/M programs.

The maintenance phase of an I/M program involves the adjustment and/or repair of those vehicles which have been identified during the inspection phase as high emitters. The level of vehicle preventive maintenance required is primarily the responsibility of the automotive service industry. In this context, specific mechanic training is essential to ensure that those doing repair work understand the functioning and maintenance of emission control devices, in addition to knowing which engine parameters affect emissions and the correct procedures for tuning the engine in order to minimize emissions. To give the consumer some guarantee of credibility and competence on the part of a particular facility doing emission control work, such work can be certified. In order to retain its emission repair certification, a repair facility should be required to perform quality work.

There are two principal factors which must be considered in the design and evaluation of an I/M program for the Southeastern Wisconsin Region. The first is the counties within the Region which should be included in the testing program, and the second is the standard at which the emission testing should be conducted. These two factors have a significant impact on the degree to which a reduction in emissions may be achieved through implementation of an I/M program in southeastern Wisconsin. The reductions in emissions that may be achieved under alternative I/M program configurations based on variations in these two integral factors are examined in the following sections.

Counties Affected by a Vehicle Inspection and Maintenance Program: It has been noted that the Clean Air Act Amendments of 1977 as interpreted by the U. S. Environmental Protection Agency require the establishment of an I/M program in those urbanized areas with populations of 200,000 or more which cannot demonstrate attainment of the carbon monoxide or ozone ambient air quality standards by December 31, 1982. In the Southeastern Wisconsin Region, Kenosha, Milwaukee, Ozaukee, Racine, and Waukesha Counties together have been designated as a nonattainment area for ozone based on available ambient air quality monitoring data (see Chapter XI). Moreover, it has been demonstrated, as discussed earlier in this chapter, that implementation of the committed actions above will not be sufficient to achieve the reductions in volatile organic compound emissions necessary to provide for the attainment of the ozone standard by 1982. A vehicle inspection and maintenance program in the above-mentioned five counties would, therefore, be required in accordance with federal regulations.

Two counties in the Region—Walworth and Washington—lack the ozone monitoring data necessary to determine whether the standards for this pollutant species are being attained and maintained. Thus, Walworth and Washington Counties are presently designated as unclassifiable areas with respect to ozone pollution. Accordingly, the inclusion of these two counties in a regional I/M program is not specifically mandated by the Clean Air Act Amendments of 1977. The Southeastern Wisconsin Region, however, represents an integrated unit with respect to transportation movements and facilities, and the level of intercounty travel may warrant the establishment of an I/M program throughout the seven-county area.

Table 329 presents a summary of the distribution of the average weekday vehicle miles of travel within each county by the county of residence of the tripmaker. The table indicates that almost 77 percent of the vehicle miles of travel within Kenosha County is made by tripmakers residing in that county, while 6 percent of the vehicle miles of travel in Kenosha County is made by residents of Milwaukee County. Residents of Walworth and Washington Counties account for about 1 percent and 2 percent, respectively, of the total average weekday vehicle miles of travel within the five counties of the Region requiring an I/M program. Although this represents a relatively small fraction of the total travel within the five counties requiring the program, it is equivalent to approximately 700,000 vehicle miles per average weekday.

A second measure of intercounty travel is the distribution of vehicle miles traveled by a resident of one county within each of the seven counties in the Region. This distribution of travel is presented in Table 330. Whereas Table 329 indicated that almost 77 percent of all travel in Kenosha County is made by residents of that county, Table 330 indicates that over 82 percent of the total travel by Kenosha County residents is made in Kenosha County. Table 330 also indicates that nearly 22 percent of all travel by Walworth County residents is made in those counties requiring an I/M program, and that more than 38 percent of the total travel made by Washington County residents is made in those counties requiring an I/M program. It may therefore be concluded that a significant proportion of the travel generated by Walworth County and Washington County residents occurs in the designated ozone nonattainment areas within the Region.

Vehicle Inspection Stringency Factor: As indicated earlier, the establishment of a practical range within which exhaust emissions may occur and still pass the inspection test is a critical factor in the design of an I/M program. If the range is too broad, the effectiveness of the I/M program will be diminished. If the range is too narrow, an excessive number of vehicles may be required to be retested one or more times. This range dictates the stringency factor, which is stated as the probable percentage of vehicles which may be expected to fail the emissions test based on program specific data. Stringency factors of 20, 30, or 40 percent are considered practicable and are evaluated herein.

Table 331 indicates by vehicle type the total hydrocarbon and volatile organic compound emissions which may be expected from line sources under alternative stringency factors for the year 1987 if all seven counties in the Region are included in a vehicle inspection and maintenance program that will begin on January 1, 1982, and Table 332 indicates the same for the year 2000. As may be seen in Table 331, with a 20 percent stringency factor an I/M program may be expected to reduce hydrocarbon emissions from line sources in 1987 by about 4,800 tons, or nearly 29 percent—from about 16,700 tons to about 11,900 tons. With a 30 percent stringency factor these hydrocarbon emissions may be expected to be reduced by about 5,200 tons, or more than 31 percent, to about 11,500 tons; and with a 40 percent stringency factor the hydrocarbon emissions may be expected to be reduced by about 5,500 tons, or nearly 33 percent, to about 11,200 tons. As shown in Table 332, by the year 2000, an I/M program with a 20 percent stringency factor may be expected to yield a hydrocarbon emission reduction of about 7,000 tons, or nearly 40 percent—from about 17,700 tons to about 10,700 tons. With a 30 percent stringency factor, the hydrocarbon emissions from mobile sources in the year 2000 may be expected to decrease by about 7,300 tons, or more than 41 percent, to about 10,400 tons; and with a 40 percent stringency factor the hydrocarbon emissions may be expected to be reduced by about 7,900 tons, or nearly 45 percent, to about 9,800 tons. As indicated in both Table 331 and Table 332, although the reduction in emissions increases with an increase in the stringency factor under an I/M program, the increase is not directly proportional to the increase in the stringency factor. A 10 percent increase in the stringency factor in 1987, for example, provides only about a 2 percent additional reduction in hydrocarbon emissions from mobile sources.

Figure 110 presents a graphic depiction of the reduction in hydrocarbon emissions from line sources that may be expected under the adopted transportation plan with implementation of the federal motor vehicle emissions control program and an I/M program with either a 20, 30, or 40 percent stringency factor. As may be seen in this figure, only slight additional reductions in total hydrocarbon emissions from mobile sources are gained by increasing the stringency factor to above 20 percent. It is important to note that at a 40 percent stringency level, twice as many vehicles would fail the inspection and require retesting as would at a 20 percent stringency level. Establishment of an I/M program with a 20 percent stringency factor, therefore, may provide for the most substantial reductions in hydrocarbon emissions with the least inconvenience and expense to vehicle owners and operators. The percent reduction in total volatile organic compound emissions with a 20 percent stringency factor I/M program is estimated at 28 percent in 1987, or about 4,200 tons of the 14,912 tons of total volatile organic compounds forecast to be emitted from mobile sources in the Region in 1987, and at 39 percent in the year 2000.

It should also be noted that an I/M program may be expected to yield a substantial reduction in carbon monoxide emissions from mobile sources. Figure 111 depicts the decrease in carbon monoxide emissions which may be expected to result from the implementation of the federal motor vehicle emissions control program and an I/M program with a 20 percent stringency factor. As may be seen in this figure, an I/M program with a 20 percent stringency factor may be expected to reduce carbon monoxide emissions from line sources in 1987 by about 77,000 tons, or more than 35 percent—from about 218,500 tons to 141,500 tons. By the year 2000, carbon monoxide emissions from line sources may be expected to be reduced by about 68,700 tons, or more than 39 percent—from about 174,200 tons to about 105,500 tons—as a result of an I/M program. It is important to

Table 329

DISTRIBUTION OF VEHICLE MILES OF TRAVEL BY LIGHT-DUTY VEHICLES WITHIN EACH COUNTY IN THE REGION BY COUNTY OF TRIPMAKER RESIDENCE [a]

County	County of Residence of Tripmaker							Total
	Kenosha (percent)	Milwaukee (percent)	Ozaukee (percent)	Racine (percent)	Walworth (percent)	Washington (percent)	Waukesha (percent)	
Kenosha	76.8	6.2	0.1	13.6	2.2	0.2	0.9	100.0
Milwaukee	0.4	78.8	3.5	2.6	0.3	1.6	12.8	100.0
Ozaukee	0.2	17.2	70.6	0.2	--	8.2	3.6	100.0
Racine	6.8	11.2	0.2	76.7	2.1	0.4	2.6	100.0
Walworth	5.0	6.8	0.1	6.7	78.1	--	3.3	100.0
Washington	0.4	12.8	7.1	0.6	0.1	67.9	11.1	100.0
Waukesha	0.2	5.3	0.7	0.5	2.5	3.5	87.3	100.0
Travel in Areas Designated for I/M Program	6.2	53.4	5.4	9.9	0.9	2.0	22.2	100.0

[a] *Light-duty vehicles include both light-duty automobiles and light-duty trucks.*

Source: SEWRPC.

Table 330

DISTRIBUTION OF VEHICLE MILES OF TRAVEL BY LIGHT-DUTY VEHICLES IN THE REGION BY COUNTY OF TRIPMAKER RESIDENCE AND BY COUNTY OF TRAVEL [a]

County	County of Travel							Total
	Kenosha (percent)	Milwaukee (percent)	Ozaukee (percent)	Racine (percent)	Walworth (percent)	Washington (percent)	Waukesha (percent)	
Kenosha	82.1	3.6	0.2	10.0	3.3	0.3	0.5	100.0
Milwaukee	0.8	92.7	1.4	2.0	0.5	1.1	1.5	100.0
Ozaukee	0.1	38.3	53.3	0.3	0.1	5.9	2.0	100.0
Racine	9.1	16.2	0.1	70.8	2.8	0.3	0.7	100.0
Walworth	3.5	4.5	--	4.7	78.1	0.1	9.1	100.0
Washington	0.3	19.8	6.8	0.7	--	61.9	10.5	100.0
Waukesha	0.3	35.8	0.7	1.0	0.6	2.3	59.3	100.0
Travel in Areas Designated for I/M Program	96.4	98.4	94.0	96.9	21.8	38.1	97.1	100.0

[a] *Light-duty vehicles include both light-duty automobiles and light-duty trucks.*

Source: SEWRPC.

note, however, that the federal motor vehicle emissions control program may be expected to provide for the attainment of the ambient air quality standards for carbon monoxide prior to 1985, before any significant reductions in emissions will be realized as a result of implementation of an I/M program in the Region. An I/M program, although not a contributing factor to the attainment or maintenance of the carbon monoxide standards, will provide for even lower carbon monoxide concentrations in the ambient air over the Region than would be achieved under the federal motor vehicle emissions control program alone.

Transportation Systems Management Program: There are three principal ways to reduce carbon monoxide and hydrocarbon emissions from motor vehicles: directly install emission control devices; reduce vehicle miles of travel by either eliminating vehicle trips, increasing automobile occupancy rates, or introducing a shift in the modal split toward increased transit use; and improve traffic flow and thus provide for higher vehicle operating speeds and/or reduced vehicle idling time. The impact of installing emission control devices on motor vehicles has been quantified under the discussion of the federal motor vehicle emissions control program. The other two ways

Table 331

ANNUAL TOTAL HYDROCARBON (VOLATILE ORGANIC COMPOUND) EMISSIONS BY ALTERNATIVE VEHICLE INSPECTION/MAINTENANCE STRINGENCY FACTORS 1987 STAGE OF THE ADOPTED TRANSPORTATION PLAN

Vehicle Type[a]	Tons of Emissions per Stringency Standard[b]			
	No Program	20 Percent	30 Percent	40 Percent
Light-Duty Gasoline Automobiles	10,870 (9,566)	6,722 (5,915)	6,418 (5,648)	6,125 (5,390)
Light-Duty Gasoline Trucks	1,752 (1,544)	1,084 (954)	1,035 (911)	983 (865)
Heavy-Duty Gasoline Trucks	3,515 (3,269)	3,515 (3,269)	3,515 (3,269)	3,515 (3,269)
Heavy-Duty Diesel Trucks	371 (364)	371 (364)	371 (364)	371 (364)
Mass Transit	172 (169)	172 (169)	172 (169)	172 (169)
Total	16,680 (14,912)	11,864 (10,671)	11,511 (10,361)	11,166 (10,057)

[a] *An I/M program is assumed to be initiated on a mandatory inspection/voluntary maintenance basis in 1982 and applied to all light-duty vehicles 15 years old and newer with full benefits to be taken, assuming that mechanics are trained. A mandatory inspection and mandatory maintenance program is assumed to begin in 1983.*

[b] *Figures in parentheses represent volatile organic compound emissions.*

Source: SEWRPC.

Table 332

ANNUAL TOTAL HYDROCARBON (VOLATILE ORGANIC COMPOUND) EMISSIONS BY ALTERNATIVE VEHICLE INSPECTION/MAINTENANCE STRINGENCY FACTORS 2000 ADOPTED TRANSPORTATION PLAN

Vehicle Type[a]	Tons of Emissions per Stringency Standard[b]			
	No Program	20 Percent	30 Percent	40 Percent
Light-Duty Gasoline Automobiles	13,451 (11,837)	6,942 (6,109)	6,708 (5,903)	6,116 (5,381)
Light-Duty Gasoline Trucks	1,054 (928)	544 (479)	526 (463)	479 (422)
Heavy-Duty Gasoline Trucks	2,624 (2,440)	2,624 (2,440)	2,624 (2,440)	2,624 (2,440)
Heavy-Duty Diesel Trucks	386 (378)	386 (378)	386 (378)	386 (378)
Mass Transit	204 (200)	204 (200)	204 (200)	204 (200)
Total	17,719 (15,783)	10,700 (9,606)	10,448 (9,384)	9,809 (8,821)

[a] *An I/M program is assumed to be initiated on a mandatory inspection/voluntary maintenance basis in 1982 and applied to all light-duty vehicles 15 years old and newer with full benefits to be taken, assuming that mechanics are trained. A mandatory inspection and mandatory maintenance program is assumed to begin in 1983.*

[b] *Figures in parentheses represent volatile organic compound emissions.*

Source: SEWRPC.

to reduce hydrocarbon and carbon monoxide emissions from motor vehicles represent indirect approaches in that a reduction is sought through induced changes in travel habits and patterns and in traffic flow. Such changes as may be required to minimize exhaust emissions in the short term are best achieved through a program of transportation systems management actions.

Table 333 provides a summary of potential transportation systems management actions which may serve to either reduce vehicle miles of travel in the Region or improve traffic flow. As may be seen in this table, certain control actions may serve to achieve both purposes. Parking controls, for example, may provide a preferential allocation of available spaces to carpool vehicles—thereby encouraging the use of high-occupancy vehicles which, in turn, reduces the number of vehicle trips—or may restrict parking on major arterials during peak hours—thereby allowing the curb lane to be used for travel, thus improving traffic flow. Many of the transportation systems management actions listed in Table 333 have been recommended for implementation as a part of the adopted transportation plan for southeastern Wisconsin for the year 2000.[26] Specifically, the adopted transportation plan for the Region calls for such actions as encouraging carpooling and vanpooling, freeway operational control, curb parking restrictions and central business district parking rate structure modifications to encourage transit use, the construction of additional park-ride/park-and-pool lots, and both short-term and long-term transit improvements.

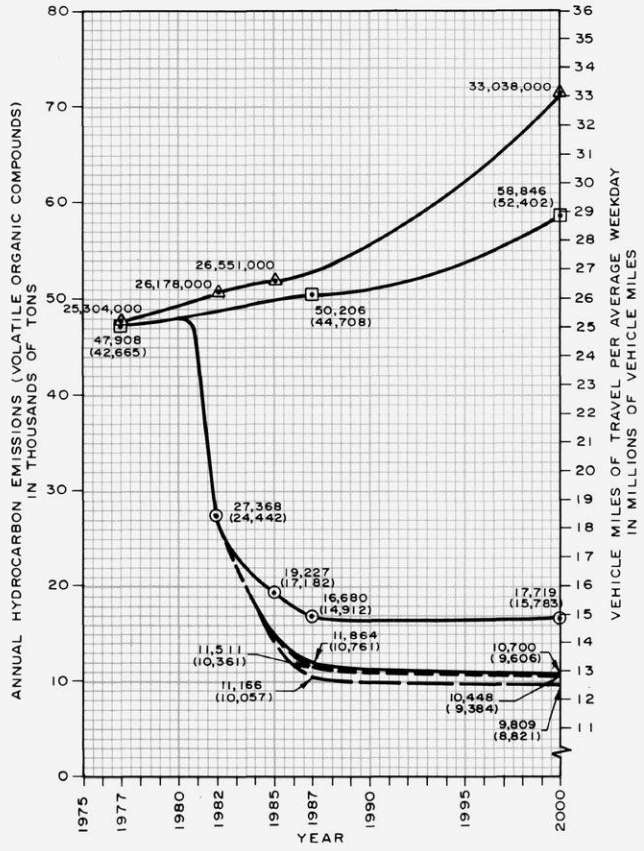
The collective impact of the transportation systems management actions contained in the adopted transportation plan on forecast carbon monoxide and volatile organic compound emissions from line sources is illustrated in Figure 112, which compares forecast emissions under the "no build" transportation alternative with such emissions under the adopted plan. The principal differences between the "no build" and the adopted plan are the provisions in the adopted plan for substantially more transit service use and for such major transportation systems management actions as freeway operational control.[27] As indicated in Figure 112, about 251,600 tons

[26] *See Chapter VII of SEWRPC Planning Report No. 25, A Regional Land Use Plan and a Regional Transportation Plan for Southeastern Wisconsin: 2000, Volume Two, Alternative and Recommended Plans, May 1978.*

[27] *It should also be noted, however, that because of increased travel by heavy-duty gasoline trucks in the Region as forecast under the adopted transportation plan for the year 2000, carbon monoxide emissions from this source category increase significantly to about 50,470 tons, or about 7,655 tons more than forecast under the "no build" alternative.*

Figure 110

ANNUAL TOTAL HYDROCARBON (VOLATILE ORGANIC COMPOUND) EMISSIONS FROM MOBILE SOURCES UNDER THE ADOPTED TRANSPORTATION PLAN WITH AND WITHOUT A VEHICLE INSPECTION/ MAINTENANCE PROGRAM: 1977-2000



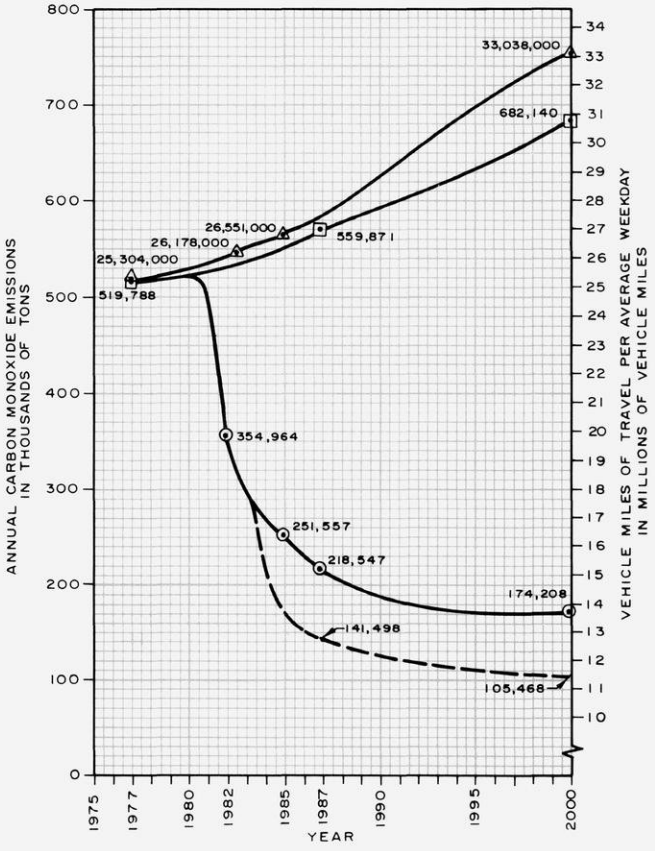
LEGEND

- FORECAST AVERAGE WEEKDAY VEHICLE MILES OF TRAVEL
- MOBILE SOURCE EMISSIONS ASSUMING 1977 CONTROL LEVEL REMAINS CONSTANT
- MOBILE SOURCE EMISSIONS WITH CONTINUED IMPLEMENTATION OF THE FEDERAL MOTOR VEHICLE EMISSIONS CONTROL PROGRAM (FMVECP)
- MOBILE SOURCE EMISSIONS WITH FMVECP AND VEHICLE INSPECTION AND MAINTENANCE PROGRAM WITH A 20 PERCENT STRINGENCY FACTOR
- MOBILE SOURCE EMISSIONS WITH FMVECP AND VEHICLE INSPECTION AND MAINTENANCE PROGRAM WITH A 30 PERCENT STRINGENCY FACTOR
- MOBILE SOURCE EMISSIONS WITH FMVECP AND VEHICLE INSPECTION AND MAINTENANCE PROGRAM WITH A 40 PERCENT STRINGENCY FACTOR

Source: SEWRPC.

Figure 111

ANNUAL TOTAL CARBON MONOXIDE EMISSIONS FROM MOBILE SOURCES UNDER THE ADOPTED TRANSPORTATION PLAN WITH AND WITHOUT A VEHICLE INSPECTION/MAINTENANCE PROGRAM: 1977-2000



LEGEND

- FORECAST AVERAGE WEEKDAY VEHICLE MILES OF TRAVEL
- MOBILE SOURCE EMISSIONS ASSUMING 1977 CONTROL LEVEL REMAINS CONSTANT
- MOBILE SOURCE EMISSIONS WITH CONTINUED IMPLEMENTATION OF THE FEDERAL MOTOR VEHICLE EMISSIONS CONTROL PROGRAM (FMVECP)
- MOBILE SOURCE EMISSIONS WITH FMVECP AND VEHICLE INSPECTION AND MAINTENANCE PROGRAM WITH A 20 PERCENT STRINGENCY FACTOR

Source: SEWRPC.

of carbon monoxide emissions are forecast under the adopted transportation plan for 1985—about 7,000 tons, or about 3 percent, fewer emissions than forecast under the "no build" alternative. Similarly, about 218,500 tons of carbon monoxide emissions are forecast to be emitted by line sources in the Region in 1987 under the adopted transportation plan—about 5,000 tons, or about 2 percent, lower than the approximately 223,500 tons forecast to be emitted under the "no build" alternative. By the year 2000, this difference narrows to about 600 tons, or less than one-half of 1 percent—from about 174,800 tons under the "no build" alternative to about 174,200 tons under the adopted transportation plan.

Figure 112 indicates that there is a difference of about 555 tons, or about 3 percent (482 tons, or about 3 percent, of which are volatile organic compound emissions) between the total hydrocarbon emissions forecast from

Table 333

SUMMARY OF TRANSPORTATION SYSTEMS MANAGEMENT ACTIONS WITH A POTENTIAL TO IMPROVE AMBIENT AIR QUALITY

Purpose	Method	Actions
Reduce Vehicle Miles of Travel	Reduce vehicle trips	● Auto-free zones ● Combined vehicle trips ● Road user fees ● Work time rescheduling ● Bicycle lanes ● Pedestrian walkways
	Increase automobile occupancy rate	● Parking controls ● Ride-sharing including carpooling and vanpooling ● Park-ride/park and pool lots and fringe parking
	Introduce a shift in modal split	● Short-term transit improvements ● Long-term transit improvements ● Parking controls ● Park-ride lots
Improve Traffic Flow	Increase vehicle operating speeds	● Freeway management ● Parking controls ● Work time rescheduling ● Traffic engineering
	Reduce vehicle idling time	● Traffic engineering improvements

Source: SEWRPC.

line sources for 1985 under the "no build" transportation plan and those forecast under the adopted transportation plan. A total of 19,782 tons of hydrocarbon emissions, 17,664 tons of which are volatile organic compound emissions, are forecast under the "no build" alternative, and 19,227 tons of hydrocarbon emissions, 17,182 tons of which are volatile organic compound emissions, are forecast under the adopted transportation plan. In 1987, a difference of 430 tons, 363 tons of which are volatile organic compound emissions, is forecast—from 17,110 tons (15,275 tons of volatile organic compound emissions) under the "no build" alternative, to 16,680 tons (14,912 tons of volatile organic compound emissions) under the adopted transportation plan. In the year 2000, 17,719 tons of total hydrocarbon emissions (15,783 tons of volatile organic compound emissions) are forecast under the adopted transportation plan, 818 tons (697 tons of volatile organic compound emissions) lower than the 18,537 tons (16,480 tons of volatile organic compound emissions) forecast under the "no build" alternative.

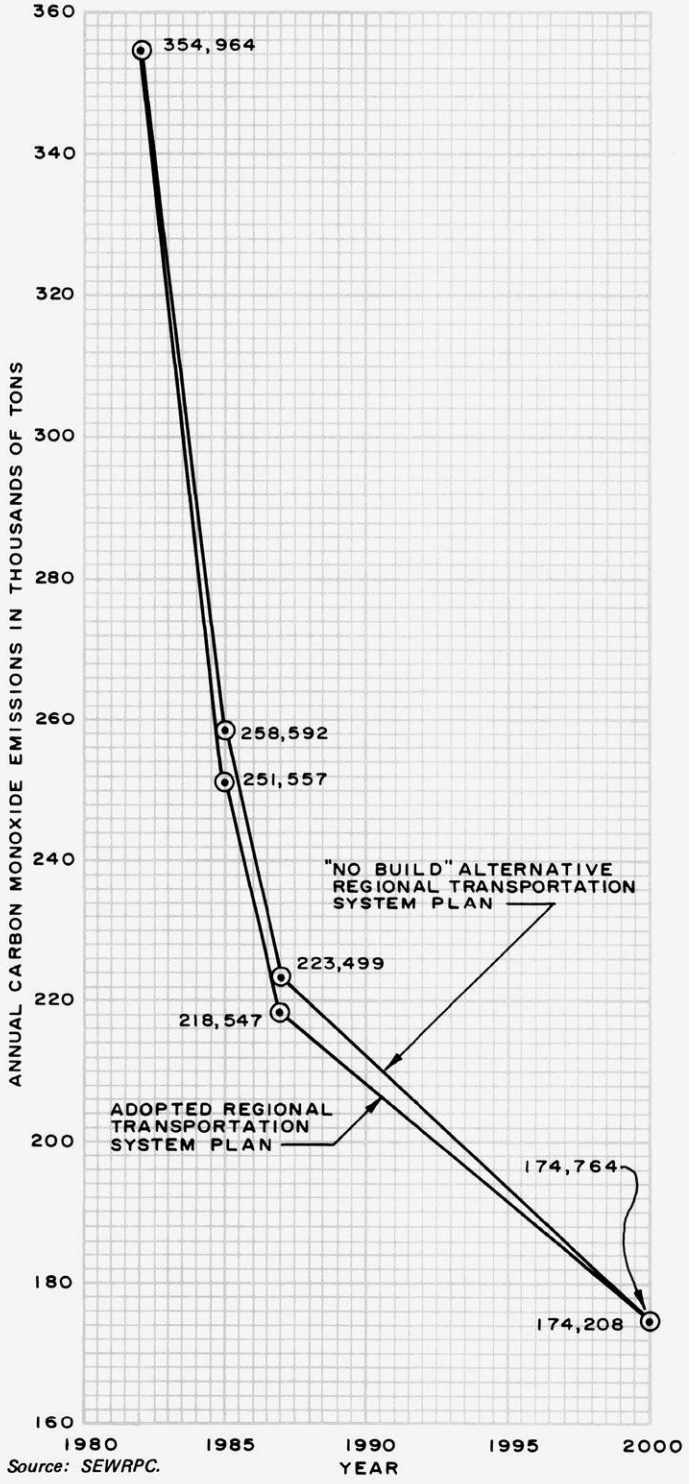
In terms of attainment and maintenance of the ambient air quality standard for ozone, a reduction in total volatile organic compound emissions of about 480 tons in 1985, 360 tons in 1987, and 700 tons in the year 2000, or of about 0.8 percent, 0.6 percent, and 1.1 percent, respectively, is forecast under the adopted regional transportation plan as compared with the "no build" alternative. Thus, although implementation of the adopted transportation plan, with its associated transportation systems management actions, represents further progress toward attainment of the ozone ambient air quality standard by 1987, the forecast volatile organic compound emissions in both 1987 and 2000 remain in excess of the maximum allowable emission rate of 38,800 tons per year from all sources—point, area, and line. A total of 42,700 tons of volatile organic compound emissions is forecast from all sources in the Region in 1987 with full implementation of the adopted transportation plan—about 3,900 tons, or about 10 percent, more than the maximum allowable emission rate of 38,800 tons per year, and about 16,100 tons, or about 61 percent, more than the optimal emission rate of 26,600 tons per year. By the year 2000, volatile organic compound emissions under this forecast may be expected to increase to about 48,100 tons—about 9,300 tons, or about 24 percent, more than the maximum allowable emission rate of 38,800 tons per year. Additional transportation system management actions, however, may serve to further reduce the volatile organic compound emission levels in the Region by the year 2000.

One goal of a transportation systems management program is to reduce traffic volumes on facilities operating over design capacity. As discussed in Chapter XII of this report, simulation model studies indicate that approximately 39 miles, or about 1 percent, of the 3,526 miles of arterial street and highway facilities in the Region may be expected to operate over design capacity by the year 2000 under the adopted transportation plan. Those facilities forecast to operate over design capacity in the year 2000 are indicated on Map 98 in Chapter XII. As may be seen on Map 98, Kenosha, Milwaukee, and Waukesha Counties are all expected to have transportation facilities operating over capacity in the year 2000. The forecast average weekday vehicle miles of travel on the facilities operating over design capacity in these three counties in the year 2000 is presented in Table 334. Transportation systems management actions designed to abate travel on these congested facilities may provide for further reductions in air pollutant emissions from motor vehicles.

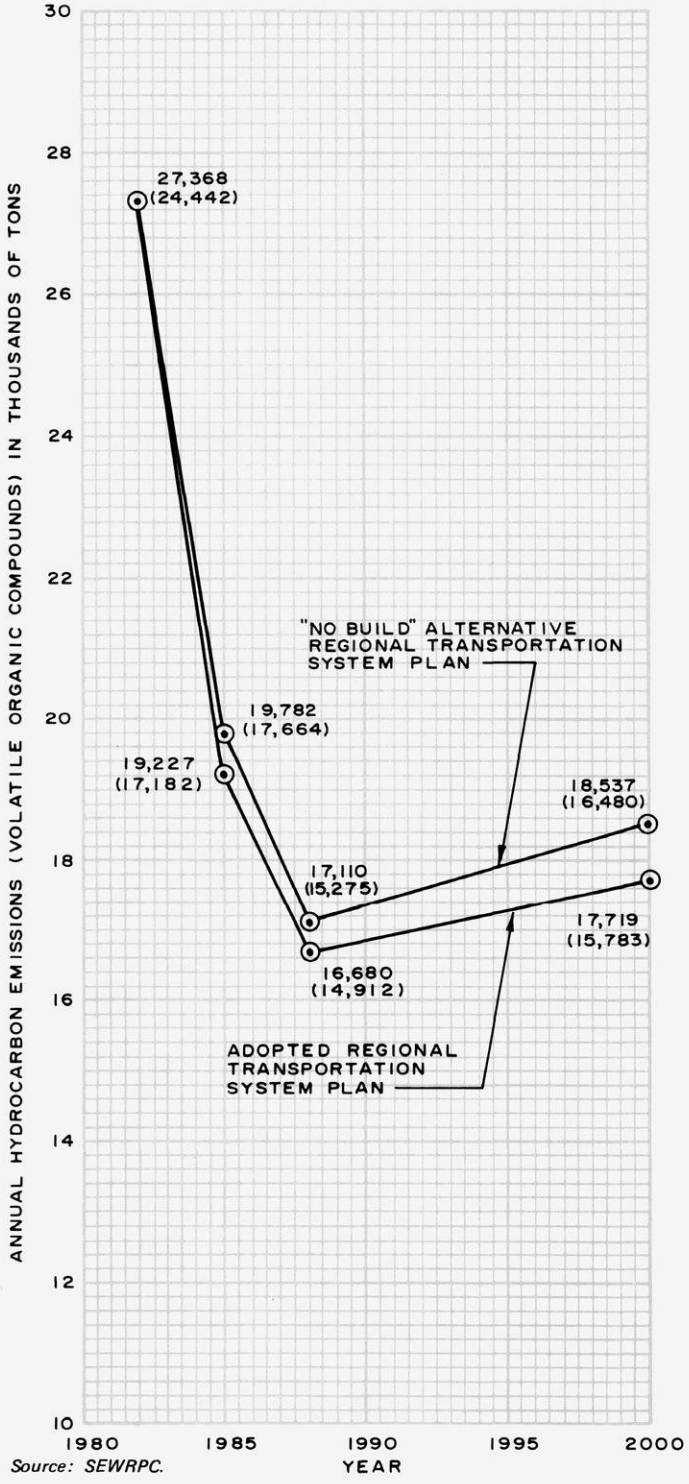
The average operating speed for vehicles on facilities operating over capacity is about 15 miles per hour on arterial streets and about 35 miles per hour on freeways. At design capacity, average vehicle operating speeds are about 25 miles per hour on arterial streets and 40 miles per hour on freeway facilities. Vehicles traveling at lower speeds on facilities operating over design capacity—which account for about 1.17 million vehicle miles of travel per average weekday—may be expected to produce 10,840 tons of carbon monoxide emissions and 1,320 tons of hydrocarbon emissions, 1,175 tons of which are volatile organic compound, emissions in the year 2000. If the same vehicles were traveling on uncongested facilities—that is, facilities operating at or below design capacity—they would produce approximately 7,825 tons of carbon monoxide emissions and 830 tons of hydrocarbon emissions, 735 tons of which would be volatile organic compound emissions, in the year 2000. Thus, carbon

Figure 112

COLLECTIVE IMPACT OF THE TRANSPORTATION SYSTEMS MANAGEMENT ACTIONS IN THE ADOPTED TRANSPORTATION PLAN AND OF THE "NO BUILD" TRANSPORTATION PLAN ON FORECAST CARBON MONOXIDE AND VOLATILE ORGANIC COMPOUND EMISSIONS FROM LINE SOURCES



Source: SEWRPC.



Source: SEWRPC.

Table 334

FORECAST TRAVEL ON FACILITIES OPERATING OVER CAPACITY: 2000

County	Average Weekday Vehicle Miles of Travel on Facilities Operating Over Capacity
Kenosha	70,400
Milwaukee	866,000[a]
Waukesha.	237,000
Region	1,173,400

[a] *Includes 198,000 average weekday vehicle miles of travel on freeways in Milwaukee County.*

Source: SEWRPC.

monoxide emissions would be reduced by about 3,000 tons, or 28 percent, and hydrocarbon emissions by 500 tons, or 37 percent, if travel demand in the Region were accommodated on facilities operated at or under design capacity in the year 2000. This carbon monoxide emission reduction represents a decrease of about 1.7 percent from the 174,200 tons of line source emissions forecast under the adopted transportation plan for the year 2000; while the hydrocarbon emission reduction represents a decrease of about 2.8 percent from the 17,700 tons of line source emissions forecast under the adopted transportation plan for the year 2000. Furthermore, a 440-ton reduction in volatile organic compound emissions from line sources would be achieved in the year 2000 if travel were accommodated on uncongested facilities—a 2.8 percent decrease from the 15,800 tons forecast for the year 2000 under the adopted transportation plan.

Assuming that implementation of the transportation systems management actions could provide a proportionate emission reduction in the years 1982 and 1987, carbon monoxide emissions from line sources may be expected to total about 348,900 tons in 1982 and about 214,800 tons in 1987, while hydrocarbon emissions from line sources may be expected to total about 26,600 tons in 1982 and about 16,200 tons in 1987. In terms of the attainment of the ambient air quality standard for ozone, alleviating traffic congestion in the Region could serve to reduce the forecast volatile organic compound emissions by about 700 tons in 1982 and about 400 tons in 1987, thus lowering the total regional burden of this pollutant species to about 53,200 tons in 1982 and about 42,300 tons in 1987. These emission levels both remain well in excess of the maximum allowable emission rate of 38,800 tons per year.

The emission reductions projected herein to result from implementation of the transportation systems management program have not specifically been related to individual control actions. In many cases, it is not possible to establish such relationships since transportation systems management actions often have only an indirect impact on the level of air pollutant emissions from mobile sources. For example, freeway operational control, particularly with regard to preferential access for high-occupancy vehicles, may encourage carpool and vanpool formation and thus reduce air pollutant emissions by reducing vehicle miles of travel, but it will also increase the idling time of vehicles in the queue on the low-occupancy entrance ramp, thereby increasing the emissions from these vehicles. The air quality improvement, if any, can therefore be attributed to the net effect of implementation of a transportation systems management action. For the purposes of regional air quality management planning, grouping mutually supportive and complementary transportation systems management actions into "packages" recommended for implementation provides an effective approach to achieving emission reduction goals. In the following sections, therefore, each transportation systems management action which may yield a reduction in emissions from mobile sources operating on the arterial street and highway system in the Region is discussed and, where possible, such reductions are quantified. These individual actions are summarily grouped into transportation systems management "packages" and evaluated as complementary actions.

Road User Fees: Imposing road user fees means assessing a variable or fixed cost to the owner or operator of a motor vehicle for the use of that vehicle on common roadways. Insofar as the owner or operator incurs such costs, this action represents a disincentive to the use of motor vehicles and may provide for a reduction in vehicle miles of travel. Road user fees may be assessed in several ways: as a toll collected at access points to certain controlled roadways; as an increase in the annual vehicle registration fees; as a parking tax; or as an increase in the motor fuel tax. In the case of tolls and parking taxes, the per vehicle assessment may be reduced or eliminated for high-occupancy vehicles.

The underlying principle of imposing road user fees is that the temporal and spatial demand for travel may be modified through the application of cost penalties. This action, however, may discriminate against low-income groups and commuters making essential work trips. Road user fees may also discourage the use of particular routes which may result in economic losses through employee turnover and decreased business activity in certain areas. The impact may be of sufficient magnitude to necessitate the relocation of businesses or residences. These formidable disadvantages must be considered in judging the air quality benefits to be derived from road pricing techniques.

It should be noted that if road user fees are to be effective in reducing vehicle miles of travel, alternatives to the use of the personal automobile must be made available.

The capacity of the transit system must be increased and ride-sharing programs promoted in order to offer substitute modes of travel. Without such alternatives, road user fees will do little to reduce vehicle miles of travel or air pollutant emissions from mobile sources. Since it may be expected that carpool and vanpool formation, and mass transit use, would increase as a result of imposing road user fees, a reduction in air pollutant emissions would be achieved by this action.

Parking Controls: In the previous section it was noted that special parking taxes or surcharges, as a form of road user fee, may be effective in reducing vehicle miles of travel in the Region. Temporal parking restrictions such as two-hour metered limits may also contribute to a shift to mass transit or high-occupancy vehicles by discouraging the use of personal automobiles for work trips in congested areas. Parking controls, in the form of parking restrictions on certain major arterial facilities during peak travel-demand hours, may also improve traffic flow, and thus reduce emissions, by allowing the curb lane to be used to accommodate the demand.

As with the road user fee action, parking controls require the provision of increased transit capacity and a carpool/vanpool promotion program if they are to be effective in reducing air pollutant emissions from mobile sources. Without such support activities, parking controls would serve only as disincentives to automobile use without providing an alternative means of transportation. Moreover, measures to improve traffic flow must be considered to be effective only in the short term since this action in itself encourages the use of the personal automobile by increasing its convenience.

Auto-Free Zones: Auto-free zones may be viewed as parking controls extended over a broad, contiguous geographic area. Auto-free zones prohibit the entry of private vehicles into certain restricted areas. Within these designated areas facilities are provided to encourage walking, supplemented with public transit where desirable. There are three basic types of auto-free zones which may be useful in reducing air pollutant emissions: occasional pedestrian streets, in which temporary barriers close off streets normally used by vehicles during certain days of the week or during special seasons of the year; regularly scheduled traffic bans, which prohibit the vehicular use of streets during certain hours of the day, usually during the time stores are open for business; and permanent pedestrian areas, which prohibit vehicular traffic, with the possible exception of mass transit vehicles, at all times.

The placement and areal extent of auto-free zones are significant factors in determining the air pollutant emission reductions that may be gained through implementing this action. Because of their potential attractiveness for retail establishments, auto-free zones may constitute a major traffic generator. However, without adequate parking facilities adjacent to, or mass transit service to and within, auto-free zones, congestion and deteriorating traffic flow may result at the periphery of such areas. Moreover, vehicles which otherwise would have used facilities in and through the auto-free zone may use alternative facilities in the proximity of the auto-free zone in order to complete a trip. If a reduction in emissions is to be gained from the establishment of auto-free zones, care must be taken to ensure that congestion is not inadvertently caused or shifted from the controlled area to peripheral facilities.

Short-Term and Long-Term Transit Improvements: Increased mass transit capacity has been identified as an integral support measure for the effective implementation of road user fees, parking controls, and auto-free zones. If such transportation systems management actions are to yield air pollutant reductions in the short term, they must be accompanied by sufficient transit capacity to accommodate the anticipated increase in ridership. Moreover, mass transit facilities must in themselves offer an attractive alternative to the use of private vehicles. Improving access to the mass transit system through the provision of park-ride lots in fringe areas with extended bus service and providing shelters along major bus routes in urban areas are examples of measures which may increase the attractiveness of public transportation.

In the long-term, the adopted transportation plan envisions that transit ridership will account for about 335,000 person trips on an average weekday in the year 2000. Under the "no build" alternative, only 160,900 transit person trips may be expected on an average weekday in the year 2000. The adopted transportation plan, therefore, provides for 174,100, or 108 percent, more transit person trips on an average weekday than does the "no build" alternative. Under the assumption that the number of transit person trips will increase linearly each year between 1972—the base year for the transportation plan—and the year 2000, transit ridership in 1982 may be expected to account for about 238,100 person trips on an average weekday under the adopted transportation plan—about 62,200 person trips, or 35 percent, more than are expected under the "no build" alternative. Under the same assumption, about 265,100 transit person trips per average weekday may be expected in 1987 with implementation of the adopted transportation plan—about 93,500, or 54 percent, more than are expected under the "no build" alternative.

Table 335 indicates the impact of transit ridership on vehicle miles of travel in the Region in the years 1982, 1987, and 2000 as forecast under the adopted transportation plan, and Table 336 indicates the corresponding impact under the "no build" alternative. In Tables 335 and 336, the average weekday vehicle miles of travel which would have been made in personal automobiles in the absence of the forecast transit ridership is presented by trip purpose, as are equivalent average auto-occupancy rates and average trip lengths. As shown in Table 335, transit ridership in the year 2000 as forecast under the adopted transportation plan will be equivalent to a reduction of about 1,463,000 vehicle miles of travel by personal automobiles on an average weekday. In 1982 and 1987, the equivalent reduction is estimated at 1,013,600 and 1,139,200 vehicle miles of travel per average weekday, respectively.

Table 335

REDUCTION IN VEHICLE MILES OF TRAVEL AS A RESULT OF MASS TRANSIT USE UNDER THE ADOPTED TRANSPORTATION PLAN: 1982, 1987, AND 2000

Trip Purpose	1972 Existing Transit Person Trips	Forecast Transit Person Trips			Auto Occupancy (persons per auto)	Equivalent Auto Driver Trips			Average Trip Length (miles)	Equivalent Average Weekday Vehicle Miles Traveled by Personal Automobile		
		1982	1987	2000		1982	1987	2000		1982	1987	2000
Home-Based Work	70,900	93,900	105,400	135,300	1.12	83,800	94,100	120,800	7.47	626,000	703,000	902,400
Home-Based Shopping . .	18,800	27,000	31,100	41,700	1.41	19,100	22,100	29,600	3.96	75,600	87,500	117,200
Home-Based Other	28,300	50,900	62,200	91,500	1.48	34,400	42,000	61,800	4.89	168,200	205,400	302,200
Nonhome-Based.	13,100	12,300	11,900	10,800	1.32	9,300	9,000	8,200	4.92	45,800	44,300	40,300
School	53,100	54,000	54,500	55,700	2.70	20,000	20,200	20,600	4.90	98,000	99,000	100,900
Total	184,200	238,100	265,100	335,000	--	166,600	187,400	241,000	--	1,013,600	1,139,200	1,463,000

Source: SEWRPC.

Table 336

REDUCTION IN VEHICLE MILES OF TRAVEL AS A RESULT OF MASS TRANSIT USE UNDER THE "NO BUILD" TRANSPORTATION PLAN: 1982, 1987, AND 2000

Trip Purpose	1972 Existing Transit Person Trips	Forecast Transit Person Trips			Auto Occupancy (persons per auto)	Equivalent Auto Driver Trips			Average Trip Length (miles)	Equivalent Average Weekday Vehicle Miles Traveled by Personal Automobile		
		1982	1987	2000		1982	1987	2000		1982	1987	2000
Home-Based Work	70,900	66,300	64,000	58,100	1.12	59,200	57,100	51,900	7.47	442,200	426,500	387,700
Home-Based Shopping . .	18,800	17,800	17,200	15,900	1.41	12,600	12,200	11,300	3.96	49,900	48,300	44,700
Home-Based Other	28,300	28,000	27,800	27,400	1.48	18,900	18,800	18,500	4.89	92,400	91,900	90,500
Nonhome-Based.	13,100	9,800	8,100	3,800	1.32	7,400	6,100	2,900	4.92	36,400	30,200	14,300
School	53,100	54,000	54,500	55,700	2.70	20,000	20,200	20,600	4.90	98,000	99,000	100,900
Total	184,200	175,900	171,600	160,900	--	118,100	114,400	105,200	--	718,900	695,900	638,100

Source: SEWRPC.

The reduction in carbon monoxide and hydrocarbon emissions expected to result from increased transit ridership under the adopted transportation plan as compared with under the "no build" alternative is presented in Table 337. As may be seen in Table 337, transit ridership under the adopted transportation plan may be expected to yield a carbon monoxide emission reduction of about 3,700 tons in the year 2000, 2,600 tons in 1987, and 3,500 tons in 1982. Similarly, hydrocarbon emissions may be expected to be about 400 tons lower in the year 2000 under the adopted transportation plan than under the "no build" alternative, and 250 tons and 255 tons lower in 1982 and 1987, respectively. As noted in the discussion of the comparative emission levels between the adopted transportation plan and the "no build" alternative, the complete package of transportation systems management actions contained in the adopted plan is expected to yield a carbon monoxide emissions reduction of about 5,000 tons in 1987 and about 600 tons in the year 2000.[28] Similarly, transportation systems management actions are expected to yield hydrocarbon emissions reduction of about 400 tons in 1987 and 800 tons in the year 2000 under the adopted transportation plan as compared with under the "no build" alternative. Although other mitigating factors—

[28] *It should be noted that the relatively small difference in carbon monoxide emissions between the adopted transportation plan and the "no build" alternative is due in part to the increase in travel by heavy-duty gasoline trucks in the year 2000 forecast under the adopted plan. The impact of transportation systems management actions on carbon monoxide emissions from line sources in the year 2000, therefore, is somewhat obscured by this forecast increase in heavy-duty gasoline truck travel.*

Table 337

REDUCTIONS IN EMISSIONS EXPECTED WITH INCREASED TRANSIT RIDERSHIP UNDER THE ADOPTED TRANSPORTATION PLAN: 1982, 1987, AND 2000

Year	Equivalent Average Weekday Vehicle Miles of Travel: Adopted Transportation Plan	Equivalent Average Weekday Vehicle Miles of Travel "No Build" Alternative	Net Difference in Equivalent Average Weekday Vehicle Miles of Travel	Average Emission Rates[a] (grams per 1,000 vehicle miles of travel)		Reduction Benefits of Adopted Transportation Plan (tons per year)	
				Carbon Monoxide	Hydrocarbons	Carbon Monoxide	Hydrocarbons (volatile organic compounds)
1982	1,013,600	718,900	294,700	35,056	2,532	3,530	255 (224)
1987	1,139,200	695,900	443,300	17,328	1,648	2,625	250 (220)
2000	1,463,000	638,100	824,900	13,273	1,532	3,741	432 (380)

[a] *Assumes an average operating speed of 25 miles per hour and an average annual temperature of 45° F.*

Source: SEWRPC.

such as changes in regional vehicle miles of travel, modal split, and transportation facilities—will influence the relative emissions from line sources in the forecast years, the differences in emissions between the adopted transportation plan and the "no build" alternative may be primarily attributed to the increase in transit ridership expected under the adopted plan.

It should be noted that the emission reductions expected to result from increased transit ridership in 1982 have not been identified because only one transportation forecast—based on the "no build" alternative—was prepared for this intermediate year. Thus, an emission reduction may be postulated for 1982 based on the assumed implementation of the adopted transportation plan. Under this assumption, carbon monoxide emissions from line sources in 1982 would be reduced by about 3,500 tons, or about 1 percent—from 355,000 tons to 351,500 tons. Hydrocarbon emissions from line sources in 1982 would be reduced by about 300 tons, or nearly 1 percent—from about 27,400 tons to 27,100 tons; and volatile organic compound emissions would be reduced by about 200 tons, or nearly 1 percent—from 24,400 tons to 24,200 tons.

It must be noted that actual transit ridership in the Region was below the forecast levels in 1977 and 1978, as shown in Figure 101 in Chapter XII. Under the forecast growth in mass transit utilization, transit ridership should have been approximately 61,056,000 persons in 1977 and 62,613,000 persons in 1978. As shown in Table 338, however, actual transit ridership was only 50,899,400 persons in 1977 and 48,449,200 persons in 1978. The 1977 transit ridership level was, therefore, about 10,156,600 persons, or about 17 percent, below the forecast level, while 1978 transit ridership was approximately 14,163,800 persons, or nearly 23 percent, below the forecast level. The decline in transit ridership between 1977 and 1978 may be attributed largely to a 39-day transit operators' strike which shut down the entire Milwaukee County Transit System for parts of the months of May and June. A cessation in June of the commuter-oriented transit service provided by Ozaukee County also contributed to the decline in transit ridership. Mass transit ridership in 1979 is expected to increase substantially over the 1977 and 1978 ridership levels. Preliminary estimates indicate that mass transit ridership in the Region will total about 61,138,000 revenue passengers in 1979, an increase of about 12.7 million revenue passengers, or about 26 percent, over the 1978 ridership level. It is evident, however, that a greater effort will have to be expended to make mass transit more attractive to potential users if the forecast ridership levels are to be achieved or surpassed in the near future.

Carpool and Vanpool Programs: A carpool or vanpool may be defined as two or more persons over the age of 18 riding to work or school on a regular basis in the same automobile, van, or light truck. "Regular basis" means use of the carpool or vanpool in conformity with an established, regular pattern. This definition excludes anomalous ride-sharing on the trip to work or school while including ride-sharing customarily utilized for only a portion of the total number of work or school trips made by the participants. The definition of carpool and vanpool as used in this report also excludes ride-sharing for purposes other than work or school, such as shopping, social-recreational, or personal business trips.

Table 338

MASS TRANSIT RIDERSHIP IN THE REGION: 1977 AND 1978

Urbanized Area	1977	1978	Percent Change
Kenosha	1,064,400	1,152,300	8
Milwaukee			
Milwaukee County	47,873,100	45,417,000[a]	- 5
Ozaukee County	46,400	20,600[b]	- 56
Waukesha County	182,700	182,400	--
Wisconsin Coach Lines, Inc.	241,000	134,600	- 44
Subtotal	48,343,200	45,754,600	- 5
Racine	1,491,800	1,542,300	3
Total	50,899,400	48,449,200	- 5

[a] *For state funding purposes, Milwaukee County reported a total ridership during 1978 of 52,544,700 passengers. The difference between the two ridership figures can be attributed to the inclusion in the higher figure as separate rides of transfers by patrons using passes. The lower figure represents total trips made by transit.*

[b] *Ozaukee County terminated mass transit service on June 10, 1978.*

Source: SEWRPC.

The primary carpooling promotional effort which has been undertaken to date in southeastern Wisconsin has been the Metropolitan Milwaukee Area Carpooling Program (MMACP) for Milwaukee, Ozaukee, Washington, and Waukesha Counties. This promotional effort—administered by Milwaukee County in cooperation with the Federal Highway Administration, the Wisconsin Department of Transportation, and the Commission—was initiated in April 1975 and was designed to encourage higher vehicle occupancy and, thereby, to effect reductions in motor fuel consumption and to reduce traffic congestion and automobile parking requirements. The initial phase of the program consisted of the design and conduct of a multimedia carpooling promotional campaign which was carried out over a 12-month period. During this phase, an attempt was made to stimulate interest in carpooling among major employers in the area, representatives of community service and employer organizations, labor unions, governmental agencies, and members of the news media. Direct personal contacts were made with major employers, while radio, television, newspaper, and billboard advertisements were used to inform employees of small companies, self-employed persons, students, and the public in general about the advantages of carpooling. The MMACP also lent assistance to firms and agencies in initiating and maintaining company carpool programs, and provided a matching service for persons in search of a carpool partner. In the second phase of the program, begun in April 1976, an evaluation of the carpooling campaign was conducted in order to assess the overall effectiveness of the multimedia promotional effort. The results and findings of this evaluation have been set forth in SEWRPC Technical Report No. 20, Carpooling in the Metropolitan Milwaukee Area, March 1977.

Table 339 presents a summary of selected characteristics of carpoolers and carpools in the four-county metropolitan Milwaukee area as determined through surveys conducted during the evaluation phase of the MMACP. As may be seen in this table, more than 92,000 persons traveled to work or school in about 38,900 carpools in the study area between 1975 and 1976. This level of carpooling is estimated to have removed about 25,900 vehicles from the road which, prior to carpooling, accounted for about 1.086 million vehicles miles of travel per day. With carpool vehicles traveling an estimated 595,000 miles per day, the net reduction in vehicle miles of travel within the four-county study area due to carpooling is about 491,000 miles per day. Under the assumption that all carpooling is accomplished in personal automobiles and that the level of carpooling remained essentially constant through 1977, it may be inferred that 491,000 more vehicle miles of travel would have been made within the Region in 1977 in the absence of the carpooling effort in the four metropolitan Milwaukee counties. In the absence of carpooling, therefore, average weekday vehicle miles of travel for light-duty gasoline vehicles in 1977 would have totaled about 22,157,900 miles, rather than the 21,667,100 miles indicated in Table 202 in Chapter VII, a 2.3 percent difference.

Correspondingly, 2.3 percent more carbon monoxide and volatile organic compound emissions would have been released from light-duty gasoline vehicles in the four-county study area during 1977 in the absence of the carpooling effort. The overall impact of carpooling in the metropolitan Milwaukee area on carbon monoxide and volatile organic compound emissions from automobiles in the Region during 1977 is indicated in Table 340. Without the benefit of carpooling, carbon monoxide emissions from light-duty gasoline vehicles in the Region would have totaled about 402,000 tons in 1977—about 7,100 tons, or slightly less than 2 percent, more than the 394,900 tons emitted under a carpooling program. Volatile organic compound emissions from this vehicle type would have totaled about 31,100 tons in the absence of carpooling—about 500 tons, or slightly less than 2 percent, more than the 30,500 tons emitted with carpooling.

In the second phase of the MMACP, an attempt was made to determine the extent to which carpooling activities were influenced by the multimedia promotional campaign and to estimate the latent demand for carpooling. The MMACP survey indicated that approximately 8,100 persons formed about 3,400 carpools, with an auto occupancy rate of 2.38 persons per vehicle, as a result of the promotional campaign. Since the total expenditures of the metropolitan Milwaukee program were approximately $200,000, it cost about $58.82 to establish each carpool.

Approximately 92,000 persons expressed a latent demand for carpooling in the MMACP survey, including about 35,000 persons who indicated that they intended to join carpools in the future and an additional 57,000

Table 339

SELECTED CHARACTERISTICS OF CARPOOLERS AND CARPOOLS IN THE METROPOLITAN MILWAUKEE AREA: 1975-1976

Characteristics	Milwaukee County	Ozaukee County	Washington County	Waukesha County	Total
Estimated number of carpoolers	69,068	4,848	6,100	12,027	92,043
Number of carpools	28,899	1,987	2,574	5,393	38,853
Auto occupancy rate	2.39	2.44	2.37	2.23	2.37
Median one-way trip length	7	14	19	15	8
Percent previous auto drivers	61.67	65.80	68.76	66.67	62.96
Vehicle miles traveled per day before carpooling	596,319	89,320	159,385	240,552	1,085,576
Number of autos used by carpoolers prior to carpooling	42,594	3,190	4,194	8,018	57,996
Percent of carpoolers that always carpooled	17.50	18.44	18.75	15.87	17.42
Number of carpool vehicles adjusted for always carpooled vehicles	23,841	1,620	2,091	4,537	32,089
Number of vehicles removed from the road as a result of carpooling	18,753	1,570	2,103	3,481	25,907
Daily carpool vehicle miles traveled excluding always carpooled vehicle miles traveled	333,780	45,374	79,467	136,121	594,742
Vehicle miles of travel saved per day by carpooling	262,539	43,946	79,918	104,431	490,834

Source: University of Wisconsin-Milwaukee and SEWRPC.

persons who indicated they would carpool if they could find a carpool partner. It is unlikely, however, that all of this latent demand for carpooling will be realized, or that all of the current carpoolers will continue carpooling. Nevertheless, there remains a significant pool of persons potentially interested in and available for carpooling and, thus, the potential for reducing regional vehicle miles of travel through further promotion of the carpool program.

Due to the initial success of the MMACP, the carpooling promotional campaign, which ceased operation in the spring of 1976, was reactivated during the fall of 1979. This new campaign is scheduled to operate over a three-year period and is to end in the fall of 1982, at which time a second evaluation will be conducted. A total of $225,000 has been budgeted for the carpooling program over this three-year period, of which approximately $18,000 is to be allocated for the post program evaluation. The remaining $207,000 is to be apportioned into approximately equal expenditures of $69,000 annually. Assuming that the cost of forming each carpool remains at about $60, approximately 1,150 new carpools will be established each year.[29] If the occupancy rate of carpool vehicles remains at 2.38 persons, these 1,150 new carpools formed annually will carry 2,737 carpoolers each year. This estimate represents the minimum increase in carpool activity which may be expected to occur in the four-county metropolitan Milwaukee area by 1982. The approximately 8,200 persons in the 3,450 carpools expected to be formed as a result of the direct promotional campaign between 1979 and 1982 represent less than 10 percent of the 92,000 persons expressing identified latent demand.

The 3,450 carpools expected to be formed as a result of the promotional campaign represent 9 percent of the 38,850 carpools existing in 1977. In estimating the reduction in emissions that will be achieved at this increased level of carpooling, it was assumed that the new carpools would produce a corresponding 9 percent savings in regional vehicle miles of travel by light-duty gasoline vehicles. Thus, if about 38,850 carpools in 1977 yielded a savings of 490,834 vehicle miles of travel per day in the Region, the 42,300 carpools in 1982 would yield a savings of about 534,400 vehicle miles of travel per day. Carpools formed between 1979 and 1982, therefore, would account for a savings of about 43,600 vehicle miles of travel per day. As may be seen in Table 282 in Chapter XII, light-duty gasoline vehicles are forecast to account for 22,398,200 vehicle miles of travel per day in 1982. At this rate of travel, about 235,900 tons of carbon monoxide emissions and 16,000 tons of volatile organic compound emissions would be produced by light-duty gasoline vehicles, as may be seen in Table 281 and in Table 303 in Chapter XII, respec-

[29] *Although inflation would have eroded the $58.82 cost (in 1975 dollars) per carpool formed to about $84.24 (in 1979 dollars), the second MMACP compaign will not require the same initial start-up costs required in the first campaign. More actual dollars may, therefore, be expended for promoting carpools through various media in the 1979-1982 campaign.*

Table 340

ESTIMATED CARBON MONOXIDE AND VOLATILE ORGANIC COMPOUND EMISSIONS FROM LIGHT-DUTY GASOLINE VEHICLES WITH AND WITHOUT CARPOOLING IN THE METROPOLITAN MILWAUKEE AREA: 1977

County	Emissions (tons)			
	Carbon Monoxide		Volatile Organic Compounds	
	With Carpooling	Without Carpooling	With Carpooling	Without Carpooling
Kenosha[a]	30,280	30,280	2,362	2,362
Milwaukee	211,241	216,036	16,064	16,429
Ozaukee	16,320	16,690	1,294	1,323
Racine[a]	36,535	36,535	2,843	2,843
Walworth[a]	17,309	17,309	1,372	1,372
Washington	19,424	19,865	1,542	1,577
Waukesha	63,800	65,248	5,045	5,160
Region	394,909	401,963	30,522	31,066

[a] *The degree to which carpooling and vanpooling occur in Kenosha, Racine, and Walworth Counties has not presently been quantified, and thus emission estimates for these three counties in 1977 are shown to be the same with and without carpooling.*

Source: SEWRPC.

Table 341

FORECAST CARBON MONOXIDE AND VOLATILE ORGANIC COMPOUND EMISSIONS FROM LIGHT-DUTY GASOLINE VEHICLES WITH AND WITHOUT INCREASED CARPOOLING IN THE METROPOLITAN MILWAUKEE AREA: 1982

County	Emissions (tons)			
	Carbon Monoxide		Volatile Organic Compounds	
	Existing Carpooling Effort	Increased Carpooling Effort	Existing Carpooling Effort	Increased Carpooling Effort
Kenosha[a]	18,341	18,341	1,250	1,250
Milwaukee	125,272	125,021	8,450	8,433
Ozaukee	9,849	9,829	674	673
Racine[a]	22,029	22,029	1,500	1,500
Walworth[a]	10,704	10,704	732	732
Washington	11,337	11,314	776	774
Waukesha	38,328	38,251	2,622	2,617
Region	235,860	235,489	16,004	15,979

[a] *The degree to which carpooling and vanpooling occur in Kenosha, Racine, and Walworth Counties has not presently been quantified, and thus emission estimates for these three counties in 1982 are shown to be the same with and without carpooling.*

Source: SEWRPC.

tively. The 43,600 vehicle miles of travel expected to be saved by new carpools in 1982 represents a decrease of about two-tenths of 1 percent from the 22,398,200 vehicle miles of travel forecast for that year. An emission reduction of corresponding magnitude may thus be expected as a result of this increased carpooling effort. Table 341 indicates the carbon monoxide and volatile organic compound emissions expected to be released from light-duty gasoline vehicles in the Region in 1982 at the existing level of carpooling and with the anticipated increase in carpooling in the metropolitan Milwaukee area. As may be seen in Table 341, carbon monoxide emissions from this vehicle type are expected to decrease by about 370 tons, and volatile organic compound emissions by about 25 tons, with the increased carpooling effort.

It is important to note that the emission estimates shown under the increased carpooling effort in Table 341 are representative of the minimum level of increased carpooling which may be expected with the MMACP promotional campaign between 1979 and 1982. The maximum level of carpooling would completely satisfy the latent demand by the year 1982. Since the latent demand for carpooling, as determined in the evaluation of the first MMACP campaign, is 92,000 persons—nearly twice the level of the existing carpooling effort at the time of the first campaign—it may be postulated that twice as many carpools may be formed, resulting in twice the savings in vehicle miles of travel per day. Under this scenario, there would be about 184,000 persons in about 77,700 carpools achieving a savings of about 1,068,800 vehicle miles of travel per day in 1982, half of which would be attributable to new carpools. New carpools would, therefore, reduce the forecast 22,398,200 vehicle miles of travel by light-duty gasoline vehicles in 1982 by about 534,400 miles per day, or about 2.4 percent, to about 21,863,800 miles per day. In this extreme case, carbon monoxide emissions from light-duty gasoline vehicles in 1982 would be reduced by about 4,100 tons, or about 1.7 percent—from about 235,900 tons at the existing level of carpooling to 231,800 tons; and volatile organic compound emissions would be reduced by 300 tons—from 16,000 tons, as forecast under existing conditions, to 15,700 tons.

Based on the foregoing analysis, by 1982 carbon monoxide emissions may be expected to be reduced by 370 tons at a minimum and 4,100 tons at a maximum under the increased carpooling effort in the four-county metropolitan Milwaukee area. Similarly, by 1982 volatile organic compound emissions may be expected to be reduced by about 25 tons at a minimum and about 300 tons at a maximum. The extent to which these emission reduction benefits are actually achieved, however, will depend in part on the degree to which incentives are provided to encourage increased vehicle occupancy rates and upon how much the vehicle left at home is used.

Many persons perceive carpooling to be inconvenient in that the freedom to travel at will is relinquished. In order to overcome this perceived loss of convenience, certain alternative benefits must be made available to induce the potential carpooler. Such benefits could include preferential access to freeways at metered entrance ramps and preferential parking treatment at work place destinations.

Park-Ride and Park and Pool Lots: It has been noted in the previous two sections that incentives must be provided to encourage the use of mass transit facilities and promote carpool and vanpool formation. One such incentive to increase the attractiveness of using high-occupancy vehicles may be the provision of park-ride lots for mass transit users and park and pool lots for vanpoolers and carpoolers.

As shown on Map 203, there were six carpool parking lots at key freeway interchanges in the Region during 1978. These six lots were located at the following intersections: IH 43 and STH 57 in Ozaukee County; IH 94 and STH 164 in Waukesha County; IH 94 and STH 67 in Waukesha County; STH 15 and CTH Y in Waukesha County; STH 15 and CTH F in Waukesha County; and STH 15 and STH 83 in Waukesha County. In addition to these six carpool parking lots, the adopted transportation plan for southeastern Wisconsin calls for the establishment of seven specific new carpool lots. As shown on Map 203, these lots are to be located at the following interchanges: USH 41-45 and Lannon Road, USH 41 and STH 60, USH 45 and STH 60, and USH 45 and Paradise Road, all in Washington County; USH 16 and CTH C and IH 94 and STH 83, both in Waukesha County; and STH 15 and STH 20 in Walworth County. The enumeration of the above 13 existing and proposed carpool parking lots is not meant to preclude the establishment of such lots at other locations. In this respect, the adopted transportation plan envisions that these lots would be developed wherever needed, preferably on available excess highway right-of-way.

The use of available parking supply at the six carpool parking lots in the Region during 1978 is indicated in Table 342. Of the 286 available parking spaces at the existing carpool lots, 135 spaces were used on an average weekday during 1978, representing a utilization rate of 47 percent.

Map 203 also indicates the location of the 29 existing and proposed public transit stations in the Region that will provide parking facilities under the adopted transportation plan for the year 2000. During 1978 off-street parking was provided at six public transit/park-ride stations and at an additional eight shopping center lots. The use of the available parking at these 14 facilities during 1978 is indicated in Table 343. Of the 1,340 parking spaces available at the six public transit stations, 603 spaces, or 45 percent, were occupied on an average weekday in 1978. Also, about 668 parking spaces, or 69 percent, of the total 965 parking spaces available at shopping center lots were occupied on an average weekday during 1978. In total, therefore, 1,271 parking spaces, or 55 percent of the available 2,305 parking spaces at transit/park-ride stations and shopping center lots, were used on an average during 1978.

In addition to the six existing transit stations, 32 other transit stations—23 of which are to have off-street parking facilities—are proposed for development by the year 2000. Selected characteristics of these 38 transit stations are presented in Table 344. With total transit station development as proposed under the adopted transportation plan, 7,175 parking spaces will be made available to transit users by the year 2000.

Freeway Traffic Management: In addition to encouraging a modal shift from personal, low-occupancy, vehicles to either mass transit or high-occupancy vehicles, it is important to find other means to reduce the low operating speeds, or even extended idling times, experienced on major freeway segments during peak travel periods. Currently, during certain periods of the day the traffic flow on the freeway system "breaks down" and stop and go conditions are experienced. When that occurs both traffic volumes and average vehicle speeds are substantially reduced, while carbon monoxide and hydrocarbon emissions are significantly increased. In the Milwaukee urbanized area, the adopted transportation plan recommends that a freeway operational control system be expanded to constrain access to the freeway system during peak hours, and thereby to ensure high rates of traffic flow at reasonable operating speeds.

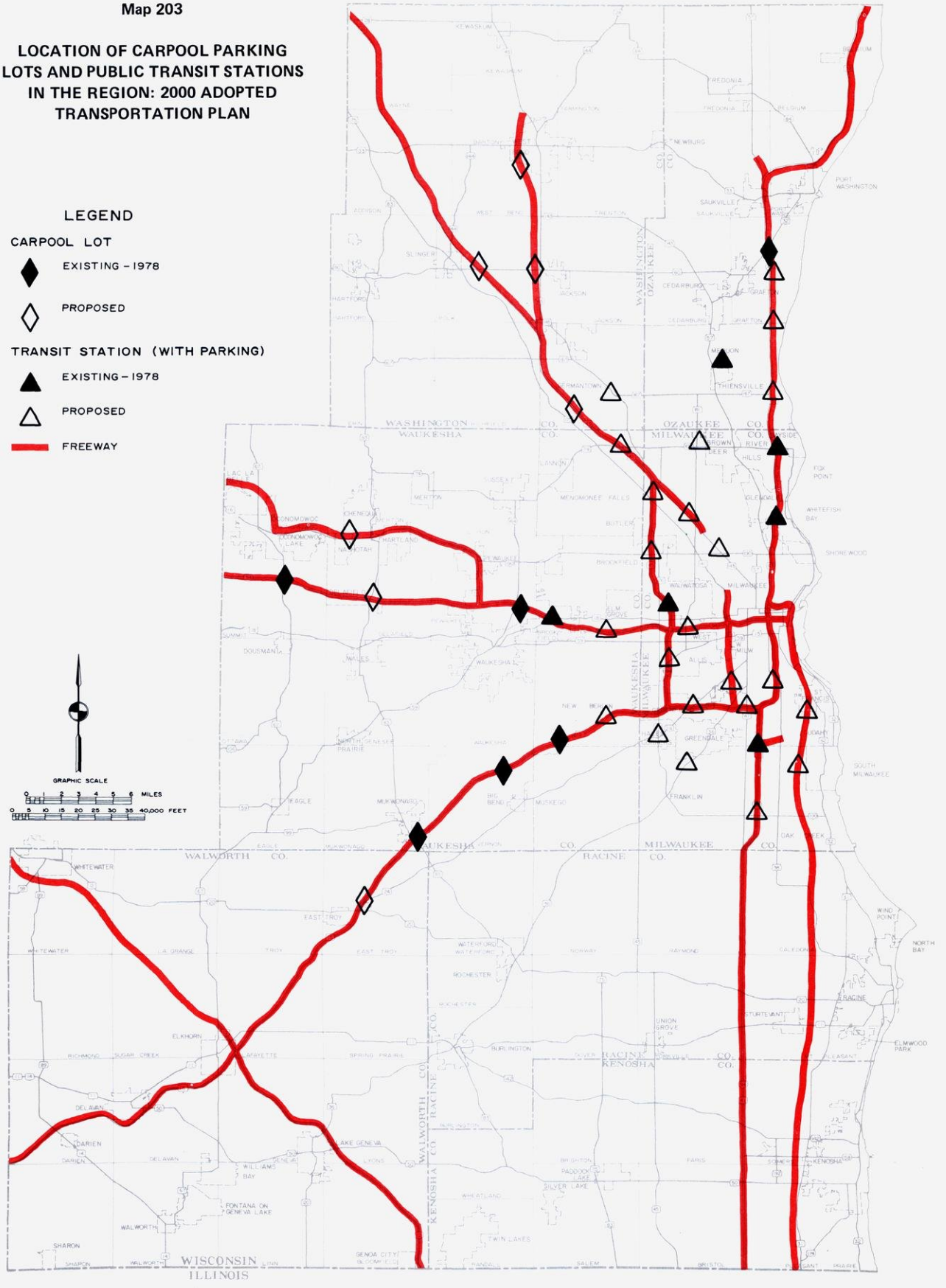
As presently envisioned, the freeway traffic management control system would continuously measure traffic volumes on the freeway system through a series of interconnected traffic sensing devices. As traffic volumes approach the level beyond which travel is constrained, fewer low-occupancy automobiles and trucks would be permitted on the system. At times, some entrance ramps would be closed entirely.

To ensure the proper functioning of the freeway traffic management control system, ramp meters would be provided throughout the metropolitan Milwaukee area. A ramp meter and a corresponding freeway traffic detector are presently in operation on 20 freeway entrance ramps, as shown on Map 204. Each of these ramp meters is controlled independently from the other ramp meters. The controller for each ramp meter can select from one of three metering rates, one vehicle every 6, 9, or 12 seconds, depending upon the level of freeway congestion measured by its corresponding freeway detector.

In addition to providing better driving conditions for the freeway user during peak periods of travel, the freeway management control system may also be used as an inducement for travel in high-occupancy vehicles—buses, carpools, and vanpools—by ensuring priority access to the freeway system by such vehicles. One priority treatment consists of an exclusive bus entrance ramp in the

Map 203

LOCATION OF CARPOOL PARKING LOTS AND PUBLIC TRANSIT STATIONS IN THE REGION: 2000 ADOPTED TRANSPORTATION PLAN



The adopted transportation system plan calls for the continued promotion of carpooling to reduce vehicular travel demand, thereby saving valuable motor fuel resources and reducing the demand for capital investment in arterial facility improvements. To this end, the plan recommends the provision of off-street parking facilities at 13 key freeway interchanges, an increase of seven facilities over the six provided in 1978, in addition to the parking facilities provided at the 29 transit stations located throughout the Milwaukee urbanized area.

Source: SEWRPC.

Table 342

USE OF PARKING SUPPLY AT CARPOOL PARKING LOTS: 1978

Location	Available Parking Spaces	Autos Parked on an Average Weekday: 1978	Percent of Spaces Used
Oconomowoc			
STH 67 and IH 94	50	21	42
Pewaukee			
STH 164 and IH 94	40	20	50
Mukwonago			
STH 83 and STH 15	60	35	58
Big Bend			
CTH F and STH 15	50	28	56
New Berlin			
CTH Y and STH 15	36	25	69
Grafton			
STH 57 and IH 43	50	6	12
Total	286	135	47

Source: SEWRPC.

Table 343

USE OF PARKING SUPPLY AT FREEWAY FLYER TERMINALS: 1978

Terminal	Available Parking Spaces	Autos Parked on an Average Weekday: 1978	Percent of Spaces Used
Public Transit Stations			
W. College Avenue (Milwaukee)	300	203	68
W. Watertown Plank Road (Wauwatosa)	200	105	53
North Shore (Glendale)	190	118	62
Brown Deer (River Hills)	250	68	27
Goerkes Corners (Brookfield)	250	107	43
Milwaukee Area Technical College (Mequon)[a]	150	2	1
Subtotal	1,340	603	45
Shopping Center Lots			
Northland (Milwaukee)	100	14	14
K-Mart (Hales Corners)	100	96	96
Treasure Island (West Allis)	100	103	103
Treasure Island (Brookfield)	140	160	114
Spring Mall (Greenfield)	200	153	77
S. 27th Street Target (Milwaukee)	100	74	74
Northridge (Milwaukee)	100	41	41
Treasure Island (Brown Deer)	125	27	22
Subtotal	965	668	69
Total	2,305	1,271	55

[a] *Public transit service to this station was terminated by the Ozaukee County Board of Supervisors on June 10, 1978.*

Source: SEWRPC.

Milwaukee central business district. Another treatment involves the striping of an existing freeway ramp to two lanes, and the exclusive designation of one lane for high-occupancy vehicles.

The Wisconsin Department of Transportation is presently upgrading the existing Milwaukee County freeway traffic management system, working toward the provision of a central control and surveillance system in the next few years. The central control and surveillance system would extend the locally responsive freeway traffic management system by providing the capability for interconnected surveillance of the metered parts of the Milwaukee area freeway system, and the potential to provide control that is responsive to varying freeway operational conditions, i.e., accidents, disabled vehicles, and other incidents. Work is now underway to upgrade 11 existing ramp meters on the East-West Freeway (IH 94), making their technology compatible with provision of a central control and surveillance system.

The reduction in air pollutant emissions associated with the existing freeway traffic management program cannot be quantified at the present time since the impacts of, for example, improving traffic or inducing travel in high-occupancy vehicles have not been directly measured. Similarly, the extent to which additional ramp metering may prove beneficial in freeway traffic management has not been determined as yet. In order to evaluate such questions, the Commission is proposing that a freeway traffic management system study be conducted in the Milwaukee area.[30] This proposed study, if funded and conducted in a timely manner, will provide, among other data, a more definitive answer as to the air quality benefits which may be derived from a comprehensive freeway traffic management program.

Work Time Rescheduling: As with a freeway management program, work time rescheduling may serve to maximize utilization of the existing transportation system by reducing peak-hour travel, thus providing for an improvement in traffic flow and consequently a reduction in air pollutant emissions from motor vehicles. Work time rescheduling may take one of three basic forms: flexible work hour programs, staggered work hour programs, or shortened work weeks. Each affect the employer, the employee, and peak travel demand in different ways. Flexible work hour programs allow workers to determine their daily work hours according to personal preference, as long as their work hours total a specified number on either a daily or weekly basis. In staggered work hour programs, worker starting and quitting times are scheduled at short intervals, such as 15 minutes, over selected morning starting and evening quitting periods, rather than at a single starting and quitting time. The reduced work

[30] *See Milwaukee Area Freeway Traffic Management System Study Prospectus, SEWRPC, June 1979.*

Table 344

SELECTED CHARACTERISTICS OF PRIMARY TRANSIT STATIONS IN THE MILWAUKEE URBANIZED AREA: 2000 ADOPTED TRANSPORTATION PLAN

Transit Station Identification					Type of Service				Passenger Facilities		
Primary Service Corridor	Number	Name	Civil Division	Status	Primary	Secondary	Tertiary	Collection-Distribution	Shelter	Number of Parking Spaces	Buses per Peak Hour in Peak Direction
East Side	1	W. North Avenue	City of Milwaukee	Proposed	X	X	X		X	--	24
	2	W. Locust Street	City of Milwaukee	Proposed	X	X	X		X	--	14
	3	Northshore	City of Glendale	Existing	X	X	X	X	X	200	6
	4	W. Brown Deer Road	Village of River Hills	Existing	X		X	X	X	325	8
	5	Northridge	City of Milwaukee	Proposed	X	X	X		X	150	4
	6	STH 167—Mequon	City of Mequon	Proposed	X		X	X	X	300	6
	7	MATC—Mequon	City of Mequon	Existing	X		X		X	100	6
	8	CTH C—Grafton	Town of Grafton	Proposed	X				X	100	4
	9	CTH Q—Grafton	Town of Grafton	Proposed	X		X	X	X	325	4
Northwest	10	N. Sherman Boulevard	City of Milwaukee	Proposed	X	X	X		X	--	9
	11	Capitol Court	City of Milwaukee	Proposed	X	X	X		X	200	9
	12	W. Silver Spring Drive	City of Milwaukee	Proposed	X	X	X		X	150	5
East-West	13	Downtown Milwaukee	City of Milwaukee	Proposed	X	X	X	X	X	--	159
	14	VA Center	City of Milwaukee	Proposed	X				X	--	7
	15	State Fair Park	City of Milwaukee	Proposed	X	X	X		X	300	14
	16	Brookfield Square	City of Brookfield	Proposed	X		X	X	X	100	5
	17	Goerke's Corners	Town of Brookfield	Existing	X		X	X	X	300	10
	18	Waukesha	City of Waukesha	Proposed	X		X	X	X	--	10
Zoo Freeway-North	19	Watertown Plank Road	City of Wauwatosa	Existing	X	X	X	X	X	250	12
	20	W. Capitol Drive	City of Wauwatosa	Proposed	X	X	X	X	X	300	8
	21	W. Good Hope Road	City of Milwaukee	Proposed	X		X	X	X	300	3
	22	STH 74—Menomonee Falls	Village of Menomonee Falls	Proposed	X		X	X	X	300	4
	23	Mequon Road—Germantown	Town of Germantown	Proposed	X		X		X	150	2
Zoo Freeway-South	24	W. National Avenue	City of West Allis	Proposed	X		X	X	X	350	14
Stadium Freeway-South	25	W. National Avenue	Village of West Milwaukee	Proposed	X	X	X		X	--	6
	26	W. Morgan Avenue	City of Milwaukee	Proposed	X		X	X	X	100	6
IH 94-South	27	W. Morgan Avenue	City of Milwaukee	Proposed	X	X	X	X	X	200	14
	28	W. College Avenue	City of Milwaukee	Existing	X		X	X	X	375	9
	29	W. Ryan Road	City of Oak Creek	Proposed	X		X		X	375	3
Airport Freeway	30	S. 27th Street	City of Milwaukee	Proposed	X	X	X	X	X	375	8
	31	S. 76th Street	City of Greenfield	Proposed	X	X	X	X	X	300	11
	32	W. Grange Avenue	Village of Greendale	Proposed	X		X		X	--	3
	33	W. Rawson Avenue	City of Franklin	Proposed	X		X		X	200	3
	34	Hales Corners	Village of Hales Corners	Proposed	X		X	X	X	325	6
	35	Moorland Road—New Berlin	City of New Berlin	Proposed	X		X		X	100	2
Lake Freeway	36	E. Oklahoma Avenue	City of Milwaukee	Proposed	X	X	X		X	--	17
	37	E. Layton Avenue	City of Cudahy	Proposed	X		X	X	X	200	8
	38	E. Rawson Avenue	City of Oak Creek	Proposed	X		X	X	X	425	9

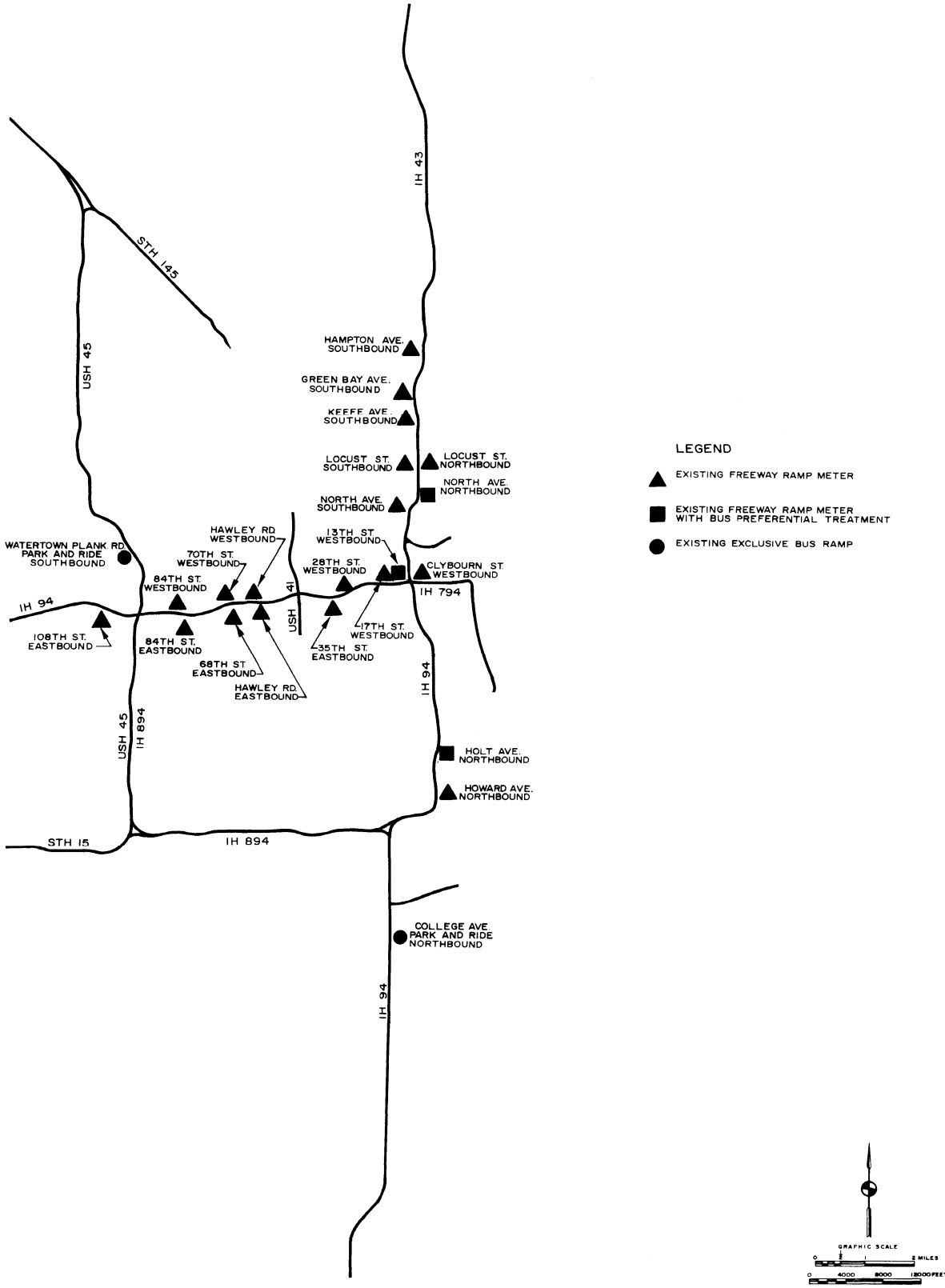
Source: SEWRPC.

week most commonly requires employees to work a total of 40 hours each week, while reducing the number of days worked each week from five to four.

The application of work time rescheduling is not new to southeastern Wisconsin. The staggering of work, school, and store hours in the Milwaukee area was identified during World War II as the best way to reduce traffic congestion and assure provision of adequate mass transit equipment to serve peak travel demands during that wartime period. Some of the staggered work hours implemented during World War II still remain in effect in the Milwaukee area, the principal example being the staggered starting and quitting times of the city, county, and state employees headquartered in the downtown Milwaukee area.

Map 204

EXISTING MILWAUKEE COUNTY FREEWAY TRAFFIC MANAGEMENT SYSTEM



A limited freeway traffic management system has been implemented to date in Milwaukee County by the Wisconsin Department of Transportation. A freeway ramp meter and a corresponding freeway traffic detector are in operation on 20 freeway ramps, as shown on this map. Each ramp meter is controlled independently of the other ramp meters. The controller for each ramp meter can select one of three metering rates, one vehicle every 6, 9, or 12 seconds, depending on the level of freeway congestion measured by the corresponding freeway detector. At some of these 20 controlled ramps in Milwaukee County, preferential access has been provided to motor buses, operating in what is commonly referred to as "Freeway Flyer" service, which enter the freeway system to provide modified rapid transit service between the Milwaukee central business district and outlying park-ride lots. This preferential access allows the buses to bypass automobile traffic waiting at the controlled ramp. Also, at two existing park-ride lots in Milwaukee County, exclusive ramps have been provided for buses, although ramp meters have not yet been installed at these locations.

Source: Wisconsin Department of Transportation.

Even though applications of work time rescheduling exist in southeastern Wisconsin, little information has been gathered or analyzed on the effectiveness of such programs in reducing systemwide peak-hour traffic congestion, and no information is available on the impact of such programs on air pollutant emissions from motor vehicles. As a consequence, the reduction in emissions which may be associated with work time rescheduling programs cannot be quantified at this time.

It should also be noted that work time rescheduling, in certain forms, may prove counterproductive to the objective of improving ambient air quality. Reducing the work week from five to four days, for example, may result in a loss of worker productivity which would necessitate an increase in the labor force and, consequently, an increase in work tripmaking. In order to avoid implementing work time rescheduling programs which may prove counterproductive to other transportation and environmental goals, and to determine the impact of such programs on peak-period congestion on the transportation system, the Commission has proposed that a study be conducted on work time rescheduling in the Milwaukee area.[31] If, during the course of the proposed study, work time rescheduling programs are deemed effective in reducing transportation system congestion, and are determined feasible for the Milwaukee area, an evaluation of the reduction in air pollutant emissions which may be achieved through such programs will be made as an integral part of the study.

Bicycle Lanes: The extent to which bicycles are used for trip purposes other than recreation in the Region is not presently known. The Federal Highway Administration (FHWA), however, has compiled certain national statistics concerning bicycle use. For example, as determined by the FHWA, the average trip length of bicycle trips for work purposes is 2.5 miles. Based on the findings of the 1972 travel surveys, approximately 22.7 percent of all home-based work trips in the Region were 2.5 miles or less in length. As was indicated in Table 275 in Chapter XII, approximately 1,098,400 person trips are forecast to be made by automobile drivers for home-based work purposes on an average weekday in the year 2000. Assuming that 22.7 percent of these 1,098,400 trips were under 2.5 miles in length, then about 249,340 home-based work trips could potentially be made by bicycle travel. If the average trip length is two miles, the average weekday travel by automobiles could be reduced by about 498,680 vehicle miles of travel with maximum bicycle use.

The use of bicycles as a mode of travel, however, is limited to days in warmer months without significant precipitation events. Over an annual period with normal climatic conditions, therefore, bicycles may represent a feasible alternative to the personal automobile for home-based work trips on as few as 50 days during the year. At this rate, bicycles could serve to reduce vehicle miles of travel in the Region by about 24.9 million miles per year in 2000. This reduction in vehicle miles of travel by automobiles would yield a reduction of about 42 tons in hydrocarbon emissions—37 tons of which would be volatile organic compound emissions—and of 365 tons in carbon monoxide emissions in the year 2000. Under the assumption of maximum bicycle substitution for automobile driver home-based work trips, a reduction of about 60 tons in hydrocarbons—53 tons in volatile organic compound emissions—could be achieved in 1982, and a reduction of about 40 tons in hydrocarbons—35 tons in volatile organic compound emissions—could be achieved in 1987. Similarly, carbon monoxide emissions could be reduced by about 820 tons in 1982 and 425 tons in 1987. Although the emission reduction benefits are relatively small—at a maximum less than one-half of 1 percent of the total line source emissions forecast in the design and intermediate years—the use of bicycles as an alternative to the personal automobile may be expected to reduce emissions, particularly volatile organic compound emissions, during the summer months when ozone concentrations are at their highest levels.

Reduced Vehicle Idling Time: In comparison to a moving vehicle, a motor vehicle in the idle mode of operation produces carbon monoxide and hydrocarbons at a relatively high emission rate. In addition to the high incidence of vehicle idling during peak travel periods, vehicle idling is prevalent at stop signs and signalized intersections. Just as a freeway traffic management control system may reduce idling time on regional highway facilities, traffic engineering improvements may yield benefits on major arterial streets. Such traffic engineering improvements may include progressive signalization along a heavily traveled arterial facility—whereby a vehicle traveling at a fixed speed would be able to reach each signalized intersection in the "green" cycle—and the provision of special right-hand or left-hand turn lanes. It should be noted, however, that as with any measure which improves traffic flow, traffic engineering improvements may actually lead to an increase in automobile travel rather than to a decrease. Measures such as progressive signalization and special turn lanes must, therefore, be viewed as short-term remedial actions for alleviating congestion in certain areas.

Combined Vehicle Trips: Combining two or more vehicle trips such as multiple shopping trips into a single trip may result in the elimination of unnecessary vehicle trips and generally provide for an overall reduction in the average trip length. This measure, therefore, may yield both a reduction in vehicle miles of travel and an improvement in traffic flow. Moreover, by combining vehicle trips the number of cold starts—that is, the first 505 seconds of operating time after an engine has been off for at least four hours—may be substantially reduced. Carbon monoxide and hydrocarbons are emitted at a significantly greater rate during the cold operating period than during the stabilized mode of operation. A program to increase the public awareness of the benefits—both in terms of air pollution control and potential energy savings—of combining vehicle trips should, therefore, be considered for implementation.

[31] *See Milwaukee Area Work Time Rescheduling Study Prospectus, SEWRPC, December 1978.*

Transportation Systems Management "Packages": As noted previously in this chapter, not all transportation systems management actions are mutually supportive and, in certain cases, a given action may in fact be in direct conflict with the objectives of another action. The 12 actions included in the foregoing discussion have therefore been evaluated to determine the compatibility of joint implementation with the other actions. The results of this evaluation are presented in Table 345, wherein each action has been deemed supportive, nonsupportive, or as having no impact on the air quality benefits achievable through implementation of the remaining actions.

It may be seen in Table 345 that certain actions, when considered as primary techniques, are supported by many secondary actions, but when considered as a secondary technique have either no impact or a nonsupportive effect on other actions. For example, the air quality benefits achievable through the primary technique of reducing vehicle idling time is supported by secondary techniques such as parking controls, carpooling, short-term and long-term transit improvements, and freeway traffic management—all actions which result in improved traffic flow. Reducing vehicle idling time as a secondary technique, however, is nonsupportive of most primary techniques, since this action would make the use of the personal vehicle more attractive and discourage carpooling or mass transit use.

Those actions which are mutually supportive as both primary and secondary techniques are indicated by the shaded areas in Table 345. As may be seen in this table, two primary techniques—road user fees and park-ride/park and pool lots—are each supported by seven secondary actions. Parking controls as a primary technique has six supporting actions, and auto-free zones as a primary technique has five supporting actions. The remaining eight primary techniques all have four or less supporting actions. The four primary techniques having five or more supporting actions may be considered to be "packages" of transportation-related measures which may be expected to yield air pollutant emission reductions. These four packages may be described as follows:

1. The Road User Fee Package—consisting of the imposition of a tax on a motor vehicle collected at the time of registration, a toll collected at access points to certain controlled roadways, a parking surcharge, or a motor fuel tax, supplemented by a carpool promotion program, park-ride/park-and-pool lots, a freeway traffic management control program, bicycle lanes and storage facilities, a promotional campaign to encourage combining vehicle trips, and both long-term and short-term improvements in the transit system.

2. The Park-Ride/Park-and-Pool Lot Package—consisting of the development of special parking facilities for potential transit users in both urban and extended service areas and for potential carpoolers at key freeway interchanges, supplemented by a carpool promotion campaign, road user fees, auto-free zones, parking controls in congested urban areas, a freeway traffic management program, and both long-term and short-term improvements in the transit system.

3. The Parking Control Package—consisting of parking restrictions on certain facilities during periods of peak travel demand or metered limits on the duration of parking in certain congested areas to discourage the use of private vehicles for work trips, supplemented by auto-free zones, bicycle lanes, a carpool promotional campaign, park-ride/park-and-pool lots, and both long-term and short-term improvements in the transit system.

4. The Auto-Free Zone Package—consisting of the development of occasional pedestrian streets, regularly scheduled traffic bans, and permanent pedestrian malls in urban areas in such a manner so as not to contribute to or cause congestion in an adjacent area, supplemented by bicycle lanes, parking controls, park-ride/park-and-pool lots, and both long-term and short-term improvements in the transit system.

These four packages have the following actions in common: the imposition of road user fees, the development of park-ride/park-and-pool lots, a carpool promotional campaign, and both long-term and short-term improvements in the transit system. Of these actions, the imposition of road user fees is the least feasible for implementation from a legal and public acceptance standpoint. For example, the collection of tolls at access points along major highway facilities in the Region is not compatible with existing federal laws. Moreover, economic forces in the motor vehicle fuel market are in themselves acting as a road pricing technique to discourage the consumption of gasoline. It is not anticipated that further pricing disincentives levied through new taxes or surcharges would meet with widespread public acceptance at the present time.

If the road user fee is eliminated from further consideration as a viable means for controlling air pollution from motor vehicles, the basic transportation-related control package consists of encouraging the use of high-occupancy vehicles supplemented by a freeway traffic management program. Although it is not possible to precisely define the reduction in air pollutant emissions that would result from a rigorous program to encourage the use of high-occupancy vehicles, a general estimate can be made of the maximum reduction in regional vehicle miles of travel which may be expected under full implementation of this basic control package. Table 346 indicates the daily reduction in vehicle miles of travel by light-duty gasoline vehicles that would result from mass transit use and carpool formation in the years 1982, 1987, and 2000. As may be seen in this table, a maximum reduction of 829,100 vehicle miles of travel on an average weekday may be expected as a result of carpooling and mass transit use in 1982, representing about 3.5 percent of the total forecast travel by light-duty gasoline vehicles. By the year 2000, average week-

Table 345

INTERRELATIONSHIP OF SELECTED TRANSPORTATION SYSTEMS MANAGEMENT ACTIONS

Primary Technique	Secondary Technique: Auto-Free Zones	Combined Vehicle Trips	Road User Fees	Work Time Rescheduling	Bicycle Lanes	Parking Controls	Carpool and Vanpool Programs	Park-Ride/Park-and-Pool Lots	Short-Term Transit Improvements	Long-Term Transit Improvements	Freeway Traffic Management	Reduced Vehicle Idling Time
Auto-Free Zones	X	--	--	--	S	S	--	S	S	S	--	--
Combined Vehicle Trips	--	X	S	--	--	--	--	--	--	--	--	N
Road User Fees	--	S	X	--	S	S	S	S	S	S	S	--
Work Time Rescheduling	--	--	--	X	--	--	N	--	N	N	S	S
Bicycle Lanes	S	--	S	--	X	S	N	--	N	N	--	N
Parking Controls	S	--	--	--	S	X	S	S	S	S	--	N
Carpool and Vanpool Programs	--	N	S	--	N	S	X	S	N	N	S	N
Park-Ride/Park-and-Pool Lots	S	N	S	--	--	S	S	X	S	S	S	N
Short-Term Transit Improvements	S	N	S	N	N	S	N	S	X	S	N	N
Long-Term Transit Improvements	S	N	S	N	N	S	N	S	--	X	N	N
Freeway Traffic Management	--	--	S	S	--	--	S	S	S	S	X	N
Reduced Vehicle Idling Time	--	S	--	S	S	S	S	S	S	S	S	X

NOTE: S = Supporting Action; N = Nonsupporting Action; -- = No Impact.

Mutually Supportive and Reinforcing Action.

Source: SEWRPC.

Table 346

FORECAST REDUCTIONS IN VEHICLE MILES OF TRAVEL IN THE REGION DUE TO FULL IMPLEMENTATION OF THE HIGH-OCCUPANCY VEHICLE TRANSPORTATION CONTROL PACKAGE: 1982, 1987, AND 2000

Year	Average Weekday Vehicle Miles of Travel Saved by:		Total	Total Forecast Travel by Light-Duty Gasoline Vehicles on an Average Weekday	Percent of Travel Saved by the Use of High-Occupancy Vehicles	Reduction Benefits of Use of High-Occupancy Vehicles (tons)	
	Mass Transit Use	Carpooling				Carbon Monoxide	Hydrocarbons (volatile organic compounds)
1982	294,700	534,400	829,100	22,398,200	3.5	8,255	635 (560)
1987	443,300	557,800	1,001,100	23,196,200	4.0	5,190	435 (385)
2000	824,900	618,500	1,443,400	28,115,000	5.0	5,405	671 (590)

Source: SEWRPC.

day vehicle miles of travel may be expected to be reduced by 1,443,400 miles as a result of carpooling and mass transit use, representing about 5 percent of the total forecast travel by light-duty gasoline vehicles. In terms of total emissions from line sources, the high-occupancy vehicle package may be expected to reduce carbon monoxide emissions by about 8,300 tons, or 2.3 percent, in 1982—from about 355,000 tons to about 346,700 tons. In the year 2000, carbon monoxide emissions may be expected to decrease by about 5,400 tons, or 3.1 percent—from about 174,200 tons to 168,800 tons. Similarly, total hydrocarbon emissions from line sources in 1982 may be expected to decrease by about 600 tons, or 3.3 percent—from about 18,200 tons to about 17,600 tons. In the year 2000, hydrocarbon emissions may be expected to decrease by about 700 tons, or 4.0 percent—from about 17,700 tons to 17,000 tons.

It is important to note that the above-mentioned emission reductions are based solely on the reduction in travel by personal vehicles expected to result from the promotion of the use of high-occupancy vehicles. The reductions in emissions to be achieved through carpooling and mass transit use should not be construed as the only emission reductions to be achieved through the implementation of transportation systems management actions. Nor should the implementation of other transportation-related actions be precluded where such actions may prove locally beneficial. The preceding analysis does indicate, however, that the promotion of carpooling and mass transit use, together with a freeway traffic management program, offers the greatest potential emission reduction benefits of all the alternative transportation control measures considered.

Evaluation of Alternative Controls: Alternative controls on both stationary and mobile sources of carbon monoxide and hydrocarbon emissions have been examined in the previous sections of this chapter as potential measures for attaining and maintaining the established ambient air quality standard for ozone, and for accelerating the attainment of the established ambient air quality standards for carbon monoxide. Based on the foregoing examination of individual control measures, alternative plans were formulated to meet these attainment and maintenance objectives.

The first alternative considered was full implementation of the adopted regional transportation plan. A principal element of this alternative is the implementation of a set of coordinated, mutually reinforcing, transportation systems management actions. The volatile organic compound emissions which may be expected under this alternative supplement to the committed actions are presented in Table 347.

As may be seen by comparing Table 347 with Table 327, fully implementing the adopted transportation plan would serve to reduce forecast volatile organic compound emissions in the Region in 1982 by about 200 tons, or less than 1 percent—from about 54,100 tons to about 53,900 tons[32]; reduce such emissions in 1987 by about 400 tons, or about 1 percent—from about 43,100 tons

[32] *The emission reductions forecast for 1982 under the adopted transportation plan include a benefit of 3,530 tons of carbon monoxide emissions and 224 tons of volatile organic compound emissions due to increased transit use, and 370 tons of carbon monoxide emissions and 25 tons of volatile organic compound emissions due to an increase in carpooling, in comparison to the levels anticipated under a "no build" transportation alternative for that year.*

Table 347

EXISTING AND FORECAST VOLATILE ORGANIC COMPOUND EMISSIONS IN THE REGION UNDER IMPLEMENTATION OF THE COMMITTED ACTIONS AND THE ADOPTED TRANSPORTATION PLAN

Source Category	Emissions (tons)			
	1977	1982	1987	2000
Stationary Source RACT				
Group I	37,709	12,789	13,179	13,717
Group II	7,269	3,533	3,705	4,154
Group III	8,521	7,049	4,442	4,800
Subtotal	53,499	23,371	21,326	22,671
Mobile Sources	42,665	24,193	14,912	15,783
Miscellaneous Sources[a]	5,999	6,301	6,491	9,612
Total	102,163	53,865	42,729	48,066

[a] *Includes aircraft, general utility engines, industrial and construction equipment, railroad line and yards, fuel combustion, incineration, forest wildfires, and commercial vessels. Not included in this category are agricultural equipment, power boats, off-highway motorcycles, snowmobiles, and miscellaneous solvent use. These categories were omitted from the modeling effort for volatile organic compound emissions since they were deemed to have little or no effect on ozone formation within and upwind of major urban areas.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

to about 42,700 tons; and reduce such emissions in the year 2000 by about 700 tons, or slightly more than 1 percent—from about 48,800 tons to about 48,100 tons. In all years, however, the forecast volatile organic compound emissions under this alternative would remain in excess of the maximum allowable emission rate of 38,800 tons per year. Therefore, additional control measures will be required in order to attain and maintain the ambient air quality standard for ozone in the Southeastern Wisconsin Region.

Since attainment of the ambient air quality standard for ozone may not be demonstrated for 1982, a vehicle inspection and maintenance (I/M) program must be established in the Region. As noted earlier, such a program may take several configurations. The two most critical factors in the design and implementation of such a program are the counties to be included and the stringency of the inspection test. In southeastern Wisconsin, five counties—Kenosha, Milwaukee, Ozaukee, Racine, and Waukesha—have together been designated as a nonattainment area for ozone based upon available monitoring data. Walworth and Washington Counties are presently designated as unclassifiable with regard to attainment because of the lack of ozone monitoring data in these two counties. Because ozone is characteristically transported over long distances, and because violations of the ozone ambient air quality standard have been measured throughout the Midwest wherever such monitoring has been conducted, it is probable that the ozone standard is exceeded on occasion during the summer months in Walworth and Washington Counties. Moreover, the level of daily travel made by residents of Walworth and Washington Counties within the five counties in the Region presently designated as a nonattainment area for ozone indicates that all counties in southeastern Wisconsin should be included in an I/M program. Accordingly, the second alternative to be evaluated calls for the implementation of the committed actions, the adopted regional transportation plan, and an I/M program with a 20 percent stringency standard that is inclusive of all seven counties in the Region.

The volatile organic compound emissions in the Region forecast under this second alternative are presented in Table 348. As may be seen by comparing Table 348 with Table 321, this second alternative would serve to reduce volatile organic compound emissions in the Region in 1987 by about 4,600 tons, or nearly 11 percent—from about 43,100 tons to about 38,500 tons—and to reduce the emissions in the year 2000 by about 6,900 tons, or about 14 percent—from about 48,800 tons to about 41,900 tons. Since an I/M program could not be implemented prior to 1982 because of the time necessary to enact required enabling legislation and, subsequently, to establish test facilities, the volatile organic compound emissions in the year 1982 under the second alternative are forecast to remain the same as under the first alternative—about 53,900 tons.

It is significant to note that under full implementation of the second alternative, attainment of the ambient air quality standard for ozone is indicated in the year 1987, when the volatile organic compound emissions are forecast to total about 38,500 tons—about 300 tons, or 1 percent, less than the maximum allowable emission rate of 38,800 tons per year. Although continued conduct of an I/M program with a 20 percent test stringency factor may be expected to provide for a further reduction in volatile organic compound emissions from mobile sources between 1987 and 2000—from about 10,700 tons to about 9,600 tons—this reduction may be expected to be more than offset by an increase in emissions from stationary and miscellaneous sources over the same period. The forecast level of 41,900 tons of volatile organic compound emissions in the Region in the year 2000 under this alternative is about 3,100 tons, or about 8 percent, higher than the maximum allowable emission rate of 38,800 tons per year. Therefore, although attainment of the ambient air quality standard for ozone may be demonstrated for the year 1987, this alternative does not provide for the continued maintenance of the standard in the Region through the year 2000.

A third alternative to be considered calls for the implementation of all the components in the second alternative—the committed actions, the adopted transportation plan, and an I/M program—but with an I/M test stringency factor of 30 percent. The volatile organic compound emissions forecast in the Region under this third alternative are presented in Table 349. As may be seen in this table, total volatile organic compound emissions

Table 348

EXISTING AND FORECAST VOLATILE ORGANIC COMPOUND EMISSIONS IN THE REGION UNDER IMPLEMENTATION OF THE COMMITTED ACTIONS, THE ADOPTED TRANSPORTATION PLAN, AND A VEHICLE INSPECTION AND MAINTENANCE PROGRAM WITH A 20 PERCENT STRINGENCY STANDARD

Source Category	Emissions (tons)			
	1977	1982	1987	2000
Stationary Source RACT				
Group I	37,709	12,789	13,179	13,717
Group II	7,269	3,533	3,705	4,154
Group III	8,521	7,049	4,442	4,800
Subtotal	53,499	23,371	21,326	22,671
Mobile Sources	42,665	24,193	10,671	9,606
Miscellaneous Sources[a]	5,999	6,301	6,491	9,612
Total	102,163	53,865	38,488	41,889

[a] *Includes aircraft, general utility engines, industrial and construction equipment, railroad line and yards, fuel combustion, incineration, forest wildfires, and commercial vessels. Not included in this category are agricultural equipment, power boats, off-highway motorcycles, snowmobiles, and miscellaneous solvent use. These categories were omitted from the modeling effort for volatile organic compound emissions since they were deemed to have little or no effect on ozone formation within and upwind of major urban areas.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Table 349

EXISTING AND FORECAST VOLATILE ORGANIC COMPOUND EMISSIONS IN THE REGION UNDER IMPLEMENTATION OF THE COMMITTED ACTIONS, THE ADOPTED TRANSPORTATION PLAN, AND A VEHICLE INSPECTION AND MAINTENANCE PROGRAM WITH A 30 PERCENT STRINGENCY STANDARD

Source Category	Emissions (tons)			
	1977	1982	1987	2000
Stationary Source RACT				
Group I	37,709	12,789	13,179	13,717
Group II	7,269	3,533	3,705	4,154
Group III	8,521	7,049	4,442	4,800
Subtotal	53,499	23,371	21,326	22,671
Mobile Sources	42,665	24,193	10,361	9,384
Miscellaneous Sources[a]	5,999	6,301	6,491	9,612
Total	102,163	53,865	38,178	41,667

[a] *Includes aircraft, general utility engines, industrial and construction equipment, railroad line and yards, fuel combustion, incineration, forest wildfires, and commercial vessels. Not included in this category are agricultural equipment, power boats, off-highway motorcycles, snowmobiles, and miscellaneous solvent use. These categories were omitted from the modeling effort for volatile organic compound emissions since they were deemed to have little or no effect on ozone formation within and upwind of major urban areas.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

in the Region in 1987 are forecast to approximate 38,200 tons—about 600 tons, or 2 percent, less than the maximum allowable emission rate of 38,800 tons per year. As under the second alternative, maintenance of the ozone standard cannot be demonstrated through the year 2000, at which time the volatile organic compound emissions are forecast to total about 41,700 tons—about 2,900 tons, or 7 percent, more than the maximum allowable emission rate of 38,800 tons.

The volatile organic compound emissions forecast under a fourth alternative—which deviates from the second and third alternatives only in that the stringency factor applied in the I/M program is established at 40 percent—are presented in Table 350. As may be seen in this table, attainment of the ambient air quality standard for ozone is indicated in 1987, at which time the volatile organic compound emissions are forecast to total about 37,900 tons—about 900 tons, or 2 percent, less than the maximum allowable emission rate of 38,800 tons per year—but the standard is still not maintained through the year 2000. Under this fourth alternative, the volatile organic compound emissions in the Region in the year 2000 are forecast to total about 41,100 tons—about 2,300 tons, or 6 percent, more than the maximum allowable emission rate of 38,800 tons per year.

As may be seen by comparing Table 350 with Table 327, this fourth alternative would serve to reduce volatile organic compound emissions by about 7,700 tons, or about 47 percent, from the level achieved in the year 2000 under implementation of the committed actions alone—from about 16,500 tons under the committed actions to about 8,800 tons. However, even with this substantial reduction in emissions from mobile sources, maintenance of the ambient air quality standard for ozone in the Region will require the implementation of additional control measures on stationary sources.

As noted earlier, the only stationary source for which additional control measures—measures more stringent than those required by RACT emission limitations—have been deemed feasible is the use of cutback asphalt. Cutback asphalt, the use of which has been steadily declining since 1974, may be readily replaced with either bituminous plant mix or asphalt emulsion. A fifth alternative considered to achieve attainment and the maintenance of the ozone ambient air quality standard is a prohibition on the use of cutback asphalt in southeastern Wisconsin. The forecast of volatile organic compound emissions in the Region under implementation of the committed actions and a prohibition on the use of cutback asphalt is presented in Table 351. As may be

Table 350

EXISTING AND FORECAST VOLATILE ORGANIC COMPOUND EMISSIONS IN THE REGION UNDER IMPLEMENTATION OF THE COMMITTED ACTIONS, THE ADOPTED TRANSPORTATION PLAN, AND A VEHICLE INSPECTION AND MAINTENANCE PROGRAM WITH A 40 PERCENT STRINGENCY STANDARD

Source Category	Emissions (tons)			
	1977	1982	1987	2000
Stationary Source RACT				
Group I	37,709	12,789	13,179	13,717
Group II	7,269	3,533	3,705	4,154
Group III	8,521	7,049	4,442	4,800
Subtotal	53,499	23,371	21,326	22,671
Mobile Sources	42,665	24,193	10,057	8,821
Miscellaneous Sources[a]	5,999	6,301	6,491	9,612
Total	102,163	53,865	37,874	41,104

[a] *Includes aircraft, general utility engines, industrial and construction equipment, railroad line and yards, fuel combustion, incineration, forest wildfires, and commercial vessels. Not included in this category are agricultural equipment, power boats, off-highway motorcycles, snowmobiles, and miscellaneous solvent use. These categories were omitted from the modeling effort for volatile organic compound emissions since they were deemed to have little or no effect on ozone formation within and upwind of major urban areas.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Table 351

EXISTING AND FORECAST VOLATILE ORGANIC COMPOUND EMISSIONS IN THE REGION UNDER IMPLEMENTATION OF THE COMMITTED ACTIONS AND A PROHIBITION ON THE USE OF CUTBACK ASPHALT AS A PAVING MATERIAL

Source Category	Emissions (tons)			
	1977	1982	1987	2000
Stationary Source RACT				
Group I	37,709	8,990	9,380	9,918
Group II	7,269	3,533	3,705	4,154
Group III	8,521	7,049	4,442	4,800
Subtotal	53,499	19,572	17,527	18,872
Mobile Sources	42,665	24,442	15,275	16,480
Miscellaneous Sources[a]	5,999	6,301	6,491	9,612
Total	102,163	50,315	39,293	44,964

[a] *Includes aircraft, general utility engines, industrial and construction equipment, railroad line and yards, fuel combustion, incineration, forest wildfires, and commercial vessels. Not included in this category are agricultural equipment, power boats, off-highway motorcycles, snowmobiles, and miscellaneous solvent use. These categories were omitted from the modeling effort for volatile organic compound emissions since they were deemed to have little or no effect on ozone formation within and upwind of major urban areas.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

seen in this table, prohibiting the use of cutback asphalt, as a supplement to the committed actions, would not provide for either the attainment or maintenance of the ambient air quality standard for ozone in the Region over the planning period. Under this alternative, the minimum level of volatile organic compound emissions is forecast to occur in 1987, at which time the emissions may be expected to total about 39,300 tons—about 500 tons, or more than 1 percent, higher than the maximum allowable emission rate of 38,800 tons per year.

Since it is evident from the foregoing evaluation of the fifth alternative that attainment of the ambient air quality standard for ozone will not likely be achieved in the Region by 1982 with the application of stationary controls alone, an I/M program will be required. Thus, a sixth alternative for consideration would include the implementation of the committed actions, a prohibition on the use of cutback asphalt, the implementation of the adopted transportation plan, and the establishment of an I/M program with a 20 percent stringency factor. The volatile organic compound emissions in the Region forecast under this sixth alternative are presented in Table 352. As may be seen in this table, under this alternative, volatile organic compound emissions in 1982 may be expected to total about 50,100 tons—about 11,300 tons, or 29 percent, more than the maximum allowable emission rate of 38,800 tons per year. This forecast emission level for 1982, however, is the lowest of the levels forecast under all of the alternatives for 1982, and represents a decrease of about 52,100 tons, or about 51 percent, from the 1977 emission level of about 102,200 tons.

Although attainment of the ambient air quality standard for ozone is not indicated in 1982 under the sixth alternative, attainment is indicated in 1987. In 1987 an emission level of about 34,700 tons is forecast—about 4,100 tons, or nearly 11 percent, less than the maximum allowable emission rate of 38,800 tons per year. Furthermore, the 34,700 tons of emissions forecast for 1987 represent a decrease of about 67,500 tons, or nearly 66 percent, from the 1977 emissions level of 102,200 tons. This emission level, however, is about 8,100 tons, or about 30 percent, higher than the optimum emission level of about 26,600 tons per year. Nonetheless, the forecast reduction of 67,500 tons in volatile organic compound emissions in the Region by 1987 is, based on the state-of-the-art in the analytical procedures used, expected to provide for the attainment of the ambient air quality standard for ozone by this year.

Table 352

EXISTING AND FORECAST VOLATILE ORGANIC COMPOUND EMISSIONS IN THE REGION UNDER IMPLEMENTATION OF THE COMMITTED ACTIONS, THE ADOPTED TRANSPORTATION PLAN, A VEHICLE INSPECTION AND MAINTENANCE PROGRAM WITH A 20 PERCENT STRINGENCY STANDARD, AND A PROHIBITION ON THE USE OF CUTBACK ASPHALT AS A PAVING MATERIAL

Source Category	Emissions (tons)			
	1977	1982	1987	2000
Stationary Source RACT				
Group I	37,709	8,990	9,380	9,918
Group II	7,269	3,533	3,705	4,154
Group III	8,521	7,049	4,442	4,800
Subtotal	53,499	19,572	17,527	18,872
Mobile Sources	42,665	24,193	10,671	9,606
Miscellaneous Sources[a]	5,999	6,301	6,491	9,612
Total	102,163	50,066	34,689	38,090

[a] *Includes aircraft, general utility engines, industrial and construction equipment, railroad line and yards, fuel combustion, incineration, forest wildfires, and commercial vessels. Not included in this category are agricultural equipment, power boats, off-highway motorcycles, snowmobiles, and miscellaneous solvent use. These categories were omitted from the modeling effort for volatile organic compound emissions since they were deemed to have little or no effect on ozone formation within and upwind of major urban areas.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Table 352 indicates that, in addition to providing for the attainment of the ambient air quality standard for ozone by 1987, implementation of all components of the sixth alternative will provide for the maintenance of this standard through the year 2000. As shown in this table, volatile organic compound emissions in the Region in the year 2000 are forecast to total about 38,100 tons—about 700 tons, or 2 percent, less than the maximum allowable emission rate of 38,800 tons per year. Again, of all alternatives evaluated, only the sixth alternative may be expected to provide for both the attainment, by 1987, and the maintenance, through the year 2000, of the ambient air quality standard for ozone in southeastern Wisconsin.

It should be noted that increasing the test stringency factor in the I/M program would provide for additional reductions in emissions—about 300 tons with a 30 percent stringency factor and about 600 tons with a 40 percent stringency factor—in 1987. The impact of such additional control would not, however, be appreciably greater than the impact of a 20 percent stringency level. It should also be noted that the emission reductions required in the Region were determined, in part, by assuming that controls would be placed on upwind, extraregional sources. For the purpose of the Empirical Kinetics Modeling Approach simulation modeling effort, for example, it was assumed that ozone concentrations in the air transported into the Region in future years would be reduced by about 50 percent from existing levels. This assumption was based on the fact that other urbanized areas, particularly northeastern Illinois, which may impact on ambient air quality in southeastern Wisconsin are required by the EPA to reduce precursor emissions by 50 percent or more. Continuous monitoring will be required to measure the effectiveness of controls on upwind sources in order to ensure that the ambient air quality standard for ozone will not be exceeded on account of the long-range transport of excessive concentrations of ozone and its precursor compounds.

Since stationary sources contribute only a small percentage of the total carbon monoxide emissions burden in the Region, and since an I/M program may not be expected to influence motor vehicle emissions until after 1982, efforts to accelerate the attainment date for the eight-hour average carbon monoxide ambient air quality standard—presently envisioned prior to 1985 under the federal motor vehicle emissions control program—must be based on the short-term implementation of transportation systems management actions. From the evaluation of alternative controls, it has been estimated that carbon monoxide emissions may be reduced by 8,300 tons by 1982 through the implementation of the adopted transportation plan and its associated transportation systems management actions, particularly as they relate to the use of high-occupancy vehicles. Assuming that this reduction was achieved by 1982, the forecast carbon monoxide emission level would be reduced by about 2 percent—from about 355,000 tons to 346,700 tons, as shown in Table 353. Although this emission reduction represents only a small portion of the total regional carbon monoxide emission burden, the transportation systems management actions may be expected to have the most significant impact in urbanized areas experiencing heavy travel demand. Thus, this 8,300-ton, or 2 percent, reduction may be expected to have a disproportionately large impact on carbon monoxide concentrations in localized "hotspots." Achieving this emission reduction goal may be effected through short-term transportation planning such as the transportation improvement program (TIP) and the transportation systems management (TSM) planning effort. Moreover, these transportation programs may serve to identify specific carbon monoxide problem areas and recommend solutions particular to the travel characteristics of the problem areas so identified.

Table 353 also presents the forecast carbon monoxide emissions from mobile sources under the implementation of additional transportation systems management actions and an I/M program with a 20 percent stringency factor for the years 1987 and 2000. As indicated in this table, with full implementation of all actions carbon monoxide emissions may be expected to total about 105,500 tons in the year 2000—a decrease of about 69,300 tons, or nearly 40 percent, from the emission level forecast under the "no build" alternative. Over the planning period,

Table 353

EXISTING AND FORECAST CARBON MONOXIDE EMISSIONS FROM MOBILE SOURCES UNDER ALTERNATIVE CONTROL MEASURES

Alternative Control	Existing 1977	Forecast 1982	Forecast 1987	Forecast 2000
--	519,788	--	--	--
"No Build" Transportation Alternative	--	354,964	223,499	174,764
Adopted Transportation Plan	--	346,709	218,547	174,208
Inspection and Maintenance Program (20 percent stringency standard)	--	--	141,498	105,468

Source: SEWRPC.

carbon monoxide emissions from mobile sources are forecast to decrease by about 414,300 tons, or nearly 80 percent, assuming full implementation of the adopted transportation plan and the I/M program.

Recommended Carbon Monoxide and Hydrocarbon/Ozone Plan

Major Plan Components: Based upon the foregoing evaluation of alternative control measures, the set of alternative control measures comprised of implementation of the committed air pollution emission control actions, the adopted regional transportation plan, a vehicle inspection and maintenance (I/M) program with a stringency factor of 20 percent, and a prohibition on the use of cutback asphalt as a paving material is recommended for adoption as the carbon monoxide and hydrocarbon/ozone control element of the regional air quality attainment and maintenance plan. The primary objective of this plan element is the attainment and maintenance of the ambient air quality standard for ozone in the Region. This objective can be achieved by reducing hydrocarbon emissions, specifically those reactive hydrocarbons known as volatile organic compounds, to a level not exceeding 38,800 tons per year, and by accelerating the attainment of the eight-hour average carbon monoxide standard—presently envisioned to be achieved prior to 1985—to the earliest date practicable.

The implementation of the committed actions component of the recommended hydrocarbon/ozone control element is in accordance with, and meets the July 1, 1979 requirements of, the federal Clean Air Act Amendments of 1977, and is recommended on the basis of the significant volatile organic compound emission reductions from stationary sources which would result from these actions in future years. In addition, the federal motor vehicle emissions control program, which has been considered herein to be a committed action, is anticipated to yield significant reductions in volatile organic compound emissions from mobile sources operating in the Region based on its assumed enforcement on a national level. As with all other pollutant species, the committed actions for carbon monoxide and hydrocarbons include requirements for major new sources of emissions, including the application of control technology which obtains the Lowest Achievable Emission Rate (LAER) in designated nonattainment areas, and the application of the Best Available Control Technology (BACT) in clean air areas within the Region.

As indicated in Table 327, the application of Reasonably Available Control Technology (RACT) to stationary sources and the continued enforcement of the federal motor vehicle emissions control program with regard to mobile sources is expected to reduce volatile organic compound emissions in the Region by about 53,400 tons, or 52 percent, between 1977 and the year 2000. Nevertheless, the implementation of the committed actions will not serve to reduce the volatile organic compound emissions in the Region to a level below the prescribed maximum emission rate of 38,800 tons per year—a rate which must be achieved in order to attain and maintain the ambient air quality standard for ozone over the planning period. Thus, additional control measures have been deemed necessary as a supplement to the committed actions to meet this objective.

The recommended plan for the attainment and maintenance of the carbon monoxide and hydrocarbon/ozone ambient air quality standards includes additional controls for both mobile and stationary sources. The additional mobile source controls consist of implementing the adopted regional transportation plan, with its associated transportation systems management actions. There are two objectives to be achieved through the implementation of transportation systems management actions as envisioned in the adopted regional transportation plan, both of which have associated emission reduction benefits: improving traffic flow and reducing vehicle miles of travel. The set of coordinated, mutually reinforcing, transportation systems management actions which has been identified as having the greatest potential to reduce carbon monoxide and volatile organic compound emissions from motor vehicles is comprised of measures to increase the use of high-occupancy vehicles. Such measures consist of a carpool/vanpool formation promotional campaign, additional park-ride and park-and-pool lots, freeway traffic management, and both short-term and long-term improvements in mass transit service. The identification of such transportation systems management actions, however, does not preclude the implementation of other actions which may be deemed desirable to either improve traffic flow, and thereby reduce congestion, or reduce vehicle miles of travel.

It is estimated that with full implementation of the adopted regional transportation plan as a supplement to the committed actions, volatile organic compound emissions in the Region will be reduced to 42,700 tons by 1987 and to 48,100 tons by the year 2000. These forecast emission levels, however, remain in excess of the maximum allowable emission rate of 38,800 tons per year, a rate which must be achieved if the ambient air quality standard for ozone is to be attained and maintained in the Region.

It is estimated that 8,300 tons of carbon monoxide emissions from mobile sources could be eliminated if the adopted transportation plan were fully implemented. Although this 8,300-ton reduction in carbon monoxide emissions represents only about 2 percent of the total of 355,000 tons of carbon monoxide emitted from mobile sources in the Region in 1982, the impact of such a reduction would be quite significant in the most intensely urbanized areas of the Region, particularly in areas of high travel demand near localized carbon monoxide "hotspots." The areawide transportation improvement program (TIP) and the regional transportation systems management (TSM) plan may be used as mechanisms to achieve these short-term reductions in carbon monoxide emissions and thereby accelerate attainment of the eight-hour average carbon monoxide ambient air quality standard.

Because attainment of the carbon monoxide and hydrocarbon/ozone standards is not expected before 1982, a vehicle inspection and maintenance program is included as a component of the recommended carbon monoxide and hydrocarbon/ozone control element in accordance with the federal Clean Air Act Amendments of 1977. The recommended I/M program would have a 20 percent stringency standard and would consist of an annual inspection, beginning in the year 1982, of all automobiles and light-duty trucks registered in the seven-county Southeastern Wisconsin Region, with mandatory repair of vehicles failing the emissions test. As a supplement to the committed actions and the implementation of the adopted transportation plan, a seven-county I/M program with a 20 percent stringency factor may be expected to provide for the attainment of the ambient air quality standard for ozone in the Region by 1987. With the inclusion of the I/M component, volatile organic compound emissions in the Region are forecast to total about 38,500 tons in 1987, a level that is 300 tons, or about 1 percent, lower than the maximum allowable emission rate of 38,800 tons per year. However, even with the inclusion of an I/M component in the recommended plan element, the ozone ambient air quality standard is not expected to be maintained through the year 2000 after attainment in 1987 because of the growth and development anticipated in the Region.

In order to ensure maintenance of the ambient air quality standard for ozone through the year 2000, the recommended plan element also calls for a prohibition on the use of cutback asphalt as a paving material. Cutback asphalt can be replaced by bituminous plant mix or asphalt emulsions. Prohibiting the use of cutback asphalt is expected to yield an annual reduction in volatile organic compound emissions in the Region of about 3,800 tons and to provide for both the attainment and maintenance of the ambient air quality standard for ozone.

The recommended plan may be expected not only to provide for the attainment and maintenance of the ambient air quality standard for ozone in the Region, but also to accelerate the attainment of the ambient air quality standard for carbon monoxide. Although attainment of the eight-hour average carbon monoxide standard is presently envisioned prior to 1985—principally through enforcement of the federal motor vehicle emissions control program—implementation of the adopted transportation plan component of the recommended air quality maintenance plan, with its associated transportation systems management actions, may be expected to result in a significant reduction in carbon monoxide emissions from mobile sources in urbanized areas, particularly where high travel demand has been a factor in monitored violations of the carbon monoxide standard.

The carbon monoxide and volatile organic compound emissions in the Region as forecast under the control regulations prescribed by the committed actions, and as forecast under implementation of all supplemental components of the recommended air quality attainment and maintenance plan, are presented in Table 354 and are illustrated graphically in Figures 113 and 114, respectively. As may be seen in this table, implementation of the recommended air quality attainment and maintenance plan may be expected to result in a reduction of about 8,300 tons in carbon monoxide emissions and of about 4,000 tons in volatile organic compound emissions in 1982 as compared with the corresponding emission levels forecast under only the committed actions. In relative terms, the recommended plan provides for a carbon monoxide emission reduction of about 2 percent and a volatile organic compound emission reduction of about 8 percent from the corresponding emission levels forecast under the committed actions for 1982. In 1987, the recommended regional air quality attainment and maintenance plan provides for an 82,000-ton, or about 27 percent, reduction in carbon monoxide emissions, and an 8,400-ton, or about 20 percent, reduction in volatile organic compound emissions, as compared with the emission levels forecast under the committed actions. The recommended plan also provides for a 69,300-ton, or 26 percent, reduction in carbon monoxide emissions and a 10,700-ton, or 22 percent, reduction in volatile organic compound emissions in the Region in the year 2000 as compared with the emission levels anticipated under the committed actions alone. The carbon monoxide and volatile organic compound emissions thus forecast under the recommended regional air quality attainment and maintenance plan may be expected to lead to the attainment and maintenance of the ambient air quality standards for carbon monoxide and ozone in the Region through the year 2000.

Estimation of Compliance Costs of Carbon Monoxide and Hydrocarbon/Ozone Control Measures: Compliance cost estimates for implementing RACT guidelines for the control of volatile organic compound emissions in the Region, as shown in Table 355, are based on an economic impact analysis of RACT guidelines in the State of Wisconsin prepared by Booz, Allen and Hamilton, Inc., cost estimates of RACT guidelines prepared by the U. S. Environmental Protection Agency, and the number and type of affected facilities identified by the Wisconsin Department of Natural Resources.[33] Emission totals are based on 1977 inventories and engineering cost estimates, and costs are expressed in 1977 dollars.

[33] *See Booz, Allen and Hamilton, Inc., Economic Impact of Implementing RACT Guidelines in the State of Wisconsin EPA-905/5-78-004, March 1979.*

Table 354

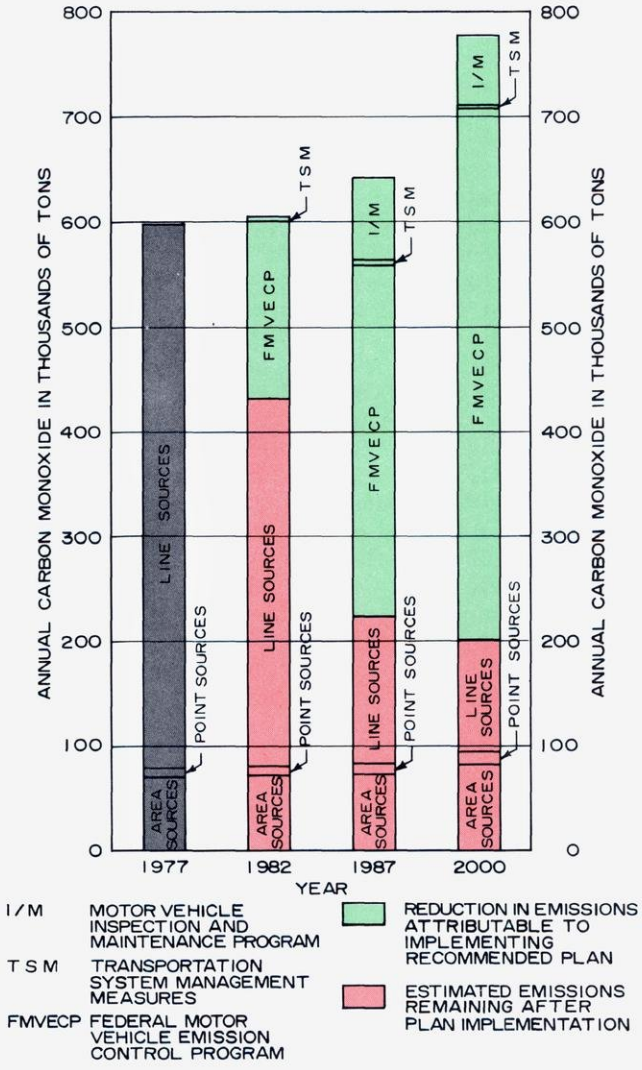
FORECAST CARBON MONOXIDE AND VOLATILE ORGANIC COMPOUND EMISSIONS IN THE REGION UNDER THE COMMITTED ACTIONS AND THE RECOMMENDED AIR QUALITY ATTAINMENT AND MAINTENANCE PLAN: 1982, 1987, AND 2000

Pollutant	Forecast (tons of emission)											
	1982		Difference		1987		Difference		2000		Difference	
	Committed Actions	Recommended Plan	Absolute	Percent	Committed Actions	Recommended Plan	Absolute	Percent	Committed Actions	Recommended Plan	Absolute	Percent
Carbon Monoxide	435,862	427,562	- 8,300	- 1.9	306,337	224,336	- 82,001	- 26.8	271,781	202,485	- 69,296	- 25.5
Volatile Organic Compounds	54,114	50,066	- 4,048	- 7.5	43,092	34,689	- 8,403	- 19.5	48,763	38,090	- 10,673	- 21.9

Source: SEWRPC.

Figure 113

IMPACT OF THE RECOMMENDED PLAN ON FORECAST CARBON MONOXIDE EMISSIONS IN THE REGION



Source: SEWRPC.

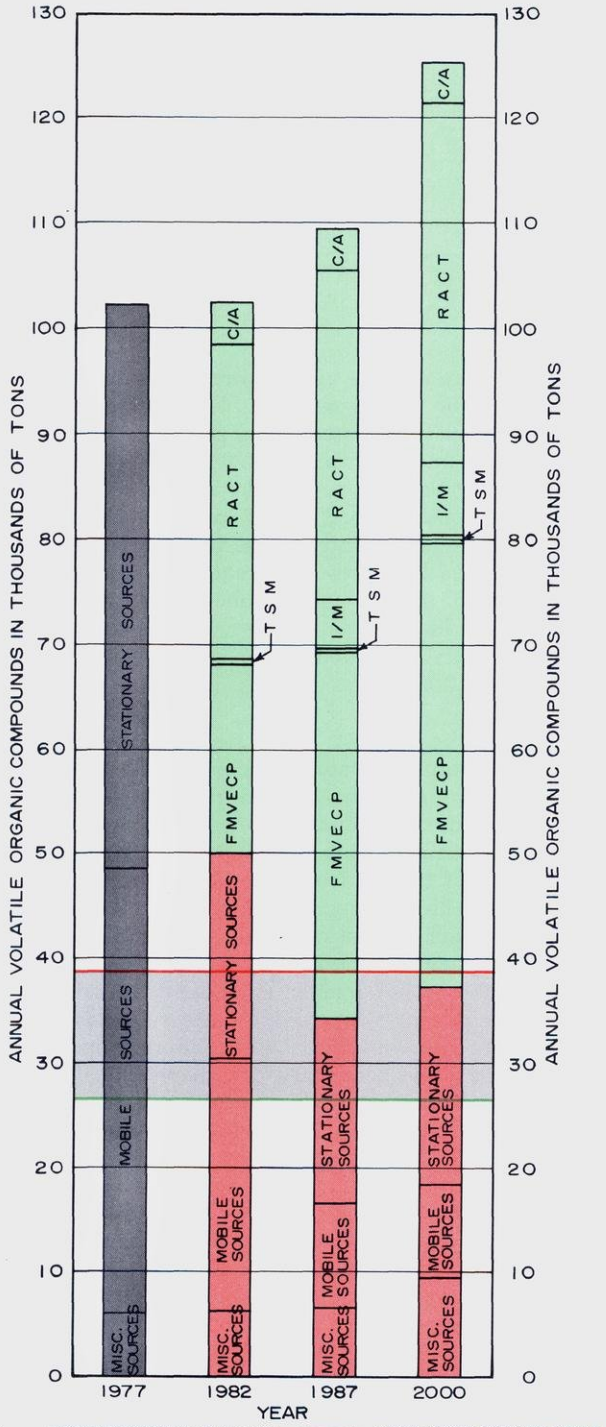
RACT for the control volatile organic compound emissions from the five types of surface coating operations in the Region is expected to be applied to 13 facilities. The cost of implementing RACT at the seven facilities in the Region associated with the surface coating of cans is based on the assumed use of low-solvent, waterborne coatings. The application of RACT controls to these seven facilities is expected to require a capital expenditure of $1.8 million and produce a net reduction of 2,200 tons in volatile organic compound emissions annually at an estimated annualized cost of $277 per ton, or $582,000.

RACT for the control of volatile organic compound emissions from the surface coating of automobiles includes the use of cathodic electro-deposition for the prime coat, urethane enamels or powder coating for the top coat, and high solids enamel for the final repair. The capital cost of this control technology, which affects two facilities in the Region, is estimated at $10.3 million, with an annualized cost of $530 per ton of reduction in volatile organic compound emissions. RACT for the control of volatile organic compound emissions from paper coating operations, which affect two facilities in the Region, consists of the use of thermal incineration with primary and secondary heat recovery. The use of this type of control may be expected to yield an annual emission reduction of 1,754 tons at an annualized cost of $375 per ton.

The compliance costs for the Group I RACT category of petroleum transfer and storage emissions are expected to affect 1,300 facilities in the Region, predominantly gasoline service stations. The compliance costs presented in Table 355 are based on the use of the submerged filling method and vapor recovery systems at bulk gasoline terminals and the use of the submerged filling method and a vapor balance system at bulk gasoline plants. Total capital costs for the two categories are estimated at $2.3 million. The estimated costs of implementing RACT on gasoline service station loading are based upon the assumption that 75 percent of the service stations within the Region will install coaxial or concentric vapor balance systems, while the other 25 percent will use the two-point vapor balance system. The vapor balance system returns displaced vapors from the underground gasoline

Figure 114

IMPACT OF THE RECOMMENDED PLAN ON FORECAST VOLATILE ORGANIC COMPOUND EMISSIONS IN THE REGION



Source: SEWRPC.

storage tank to the tank truck during loading of the storage tank. In a two-point vapor recovery system the storage tank has two risers, one riser for fuel delivery and the other for returning vapors to the tank truck. The coaxial or concentric system uses a concentric liquid vapor return line whereby a coaxial adaptor fits on the storage tank riser and allows the vapors to exit from the same opening through which the fuel is delivered. The capital cost of the application of this control technology to the approximately 1,200 gasoline service stations in the Region is estimated at $2.7 million, with a net annualized cost of about $637,000, or about $520 per station.[34]

The cost estimate for RACT measures to reduce volatile organic compound emissions from metal degreasing operations is based on the use of equipment modifications, including manual covers, carbon adsorption, and refrigerated chillers. Based on the annualized cost estimate prepared by Booz, Allen and Hamilton, Inc., of $58 per ton of reduction in emissions from metal degreasing in the State, the annualized control cost for the approximately 4,500 affected facilities in the Region has been estimated at $231,000, or $51 per facility.

RACT to reduce emissions from cutback asphalt consists of the substitution of emulsified asphalt for cutback asphalt. Cutback asphalt and asphalt emulsion prices are similar; therefore, no additional material costs are anticipated. However, a one-time capital investment of $6.00 per ton of emission reduction achieved will be required to teach personnel how to apply asphalt emulsions and to modify spray nozzles on distributor trucks. The one-time conversion from cutback asphalt to emulsified asphalt in the Region, based on an anticipated emission reduction of 10,522 tons, will cost approximately $63,200.

Compliance costs for the control of volatile organic compound emissions from Group II RACT categories affect approximately 320 facilities in the Region. RACT to reduce emissions from floating-roof tanks for gasoline storage consists of the addition of a secondary roof seal in addition to the primary seal. The capital cost of this type of control is based on an estimated capital expenditure of $17,000 per rim-mounted secondary seal per gasoline storage tank. Capital costs for the application of carbon adsorption control to dry-cleaning plants using perchloroethylene are estimated at $1.4 million, with an annualized cost-effectiveness of about $154 per ton of volatile organic compound emissions reduced. Emissions from miscellaneous metal coating operations are controlled under proposed RACT limitations for the use of low-solvent coating products, which affect an estimated 54 facilities in the Region. As shown in Table 355, the capital cost of RACT to control emissions from miscellaneous metal coating operations is estimated at $2.5 million, with a control effectiveness of $663 per ton of emissions reduced on an annualized basis.

[34] *The cost estimates made by Booz, Allen and Hamilton, Inc., for gasoline service station controls were based on a generalized two-island, four-pump station having a monthly throughput of 44,000 gallons of gasoline.*

Table 355

SUMMARY OF COMPLIANCE COST ESTIMATES FOR VOLATILE ORGANIC COMPOUNDS IN THE REGION

RACT Category	Number of Facilities Affected	Capital Costs (in thousands)	Net Annualized Costs (in thousands)	Reduction in Emissions (tons per year)	Annual Cost-Effectiveness of Control (dollars per ton)
Group I RACT					
Surface Coating					
Automobiles	2	$10,256	$1,513	2,854	530
Cans	7	1,820	582	2,171	277
Metal Coils	1[a]	--	--	--	--
Paper	2	2,395	658	1,754	375
Fabric	1[a]	--	--	--	--
Petroleum Transfer and Storage					
Fixed-Roof Tanks	5[a]	$ --	$ --	--	--
Bulk Gasoline Plants	82	987	271	441	615
Bulk Gasoline Terminals	12	1,331	123	2,019	61
Service Station Loading	1,220	2,674	637	2,962	215
Solvent Metal Cleaning	4,500[b]	1,102	231	3,986	58
Cutback Asphalt	--[c]	63[c]	--	10,552	--
Group II RACT					
Graphic Arts (printing)	4[d]	$ --	$ --	70	--
Dry Cleaning	255	1,379	194	1,257	154
Gasoline Storage in Floating-Roof Tanks	8	440	86	487	177
Miscellaneous Metal Coating	54	2,464	1,274	1,922	663
Group III RACT					
Architectural and Miscellaneous Coatings	--[d]	$ --	$ --	1,028	--
Wood Furniture Manufacture	2[d]	--	--	--	--
Service Station Unloading	1,220[e]	7,300	1,980	444	4,459
Total[f]	6,155	$32,211	$7,549	31,947	236

[a] *Existing facilities are currently meeting RACT requirements.*

[b] *Number of potential affected facilities.*

[c] *Assumes a one-time conversion cost based on training six employees per county and modifying three trucks per county.*

[d] *No change in cost is expected assuming that low-solvent coating products are used.*

[e] *Service stations are listed under both "loading" and "unloading" categories. Some service stations may also be included under "solvent metal cleaning."*

[f] *In addition to the RACT control costs, the compliance costs for volatile organic compounds include the cost of implementation of a vehicle inspection and maintenance program in the seven-county Southeastern Wisconsin Region, which is estimated at $11.5 million per year. Of that total, about $6.8 million, or 59 percent, is expected to be expended by the State of Wisconsin for individual vehicle tests, and about $4.7 million, or 41 percent, is expected to be expended by the public sector to repair vehicles which fail the emissions test. Since the I/M program is expected to reduce volatile organic compound emissions by about 4,200 tons in 1987, the cost of $11.5 million represents a cost of about $2,740 per ton emission reduction.*

Source: Booz, Allen and Hamilton, Inc., Wisconsin Department of Natural Resources, and SEWRPC.

Compliance costs for the control of emissions from the three Group III RACT categories of architectural and miscellaneous coating, wood furniture manufacture, and service station unloading are presented in Table 355. No increase in cost is assumed for the control of the first two emission categories assuming that low-solvent coating and paint products are used. Based on an EPA-estimated mean capital cost of $6,000 per gasoline station for a vapor recovery system to capture the gasoline vapors produced during vehicle fueling operations, a total capital cost of $7.3 million is estimated. Assuming that the implementation of these controls will act to reduce emissions by 444 tons per year, a cost-effectiveness of $4,459 per ton is estimated on an annualized basis, or about $18 per gallon of gasoline recovered.

The estimated cost of applying RACT controls to reduce volatile organic compound emissions from RACT Groups I, II, and III in the Region is $32.2 million. The expenditure of this sum will result in an estimated 32,000-ton

reduction in volatile organic compound emissions from these sources at an annualized cost of $7.6 million, or about $237 per ton.

The only cost associated with the implementation of the transportation-related component of the recommended regional air quality attainment and maintenance plan is that of developing a vehicle inspection and maintenance program in southeastern Wisconsin. The cost of implementing the adopted regional transportation plan is not included in the cost of the regional air quality plan since the transportation plan was prepared in response to a broad range of socioeconomic considerations in addition to air quality concerns.

As presently envisioned in the draft enabling legislation for establishing a vehicle inspection and maintenance program in southeastern Wisconsin, such a program would be operated by a state-licensed contractor, who would incur all capital and operating costs. All fees for inspection tests would be paid by the State. The U. S. Environmental Protection Agency estimates that each vehicle inspection will cost between $4.00 and $10.00, with the higher fee including both emissions and safety inspections.[35] A representative fee of $6.00 per vehicle inspection is a reasonable estimate for an emissions test only. The final fee, however, will be established on the basis of contractor bids submitted to, and selected by, the State of Wisconsin.

Based on the Commission's forecast of automobile availability, it is estimated that 945,000 automobiles will be registered in the Region in 1982. Since the recommended test stringency standard is 20 percent, it may be expected that about one-fifth of the vehicles tested will fail the initial test and require retesting. Thus, about 1,134,000 inspection tests are anticipated to be administered during 1982. Assuming a cost of $6.00 per test in 1977 dollars, total state expenditures for the inspection and maintenance program are forecast at $6.8 million in 1982, including administrative costs.

For those vehicles failing the initial emissions tests, repair costs will be incurred by the vehicle owner. Based on data available from the ongoing I/M programs in the States of Arizona and Oregon, the average repair cost for vehicles failing the inspection test is under $25. Assuming that an average repair cost of $25 is applicable to southeastern Wisconsin, and assuming that 20 percent, or about 189,000, of the vehicles inspected during 1982 will fail the test, a cost of approximately $4.7 million may be expected to be incurred in 1982 by the private sector to bring vehicles into compliance with emission standards.

In total, therefore, a vehicle inspection and maintenance program in the Southeastern Wisconsin Region will cost about $11.5 million per year. Of that $11.5 million, about $6.8 million, or about 59 percent, is forecast to be expended by the State for individual vehicle tests, and about $4.7 million, or about 41 percent, is forecast to be expended by the public sector to repair vehicles that fail the emissions test. The I/M program is expected to effect a reduction in volatile organic compound emissions of about 4,200 tons in 1987, which, assuming a total program cost of about $11.5 million, represents a cost of about $2,740 per ton of emission reduction.

THE RECOMMENDED AMBIENT AIR QUALITY MONITORING NETWORK

As noted in both Chapter XI and in this chapter, additional ambient air quality monitoring data will be required to more precisely define nonattainment areas in the Region; to measure progress toward the attainment of the ambient air quality standards; and, subsequent to attainment, to ensure that regional growth and development patterns do not interrupt the continued maintenance of the ambient air quality standards in southeastern Wisconsin through the year 2000. An ambient air quality monitoring network which has been designed to meet these objectives, and which is recommended for implementation as an integral part of the air quality attainment and maintenance plan for the Southeastern Wisconsin Region, is presented herein by pollutant species.

The Recommended Particulate Matter Monitoring Network

As indicated on Map 205 and in Table 356, there were 29 particulate matter ambient air quality monitoring stations in the Region operated by the Wisconsin Department of Natural Resources (DNR) and eight operated by the Racine County Department of Air Pollution Control during 1978, the latest year for which verified data are available. In addition, three particulate matter ambient air quality monitoring stations, all in Ozaukee County, were operated by the Wisconsin Electric Power Company during 1978. Data obtained at these three stations, however, have not been certified by the DNR since the DNR was not able to conduct an audit of that data, and the data collection operations were terminated in February 1979.[36] All 40 of the particulate matter ambient air quality monitors used the U. S. Environmental Protection Agency (EPA)-approved high-volume gravimetric reference method of sampling.

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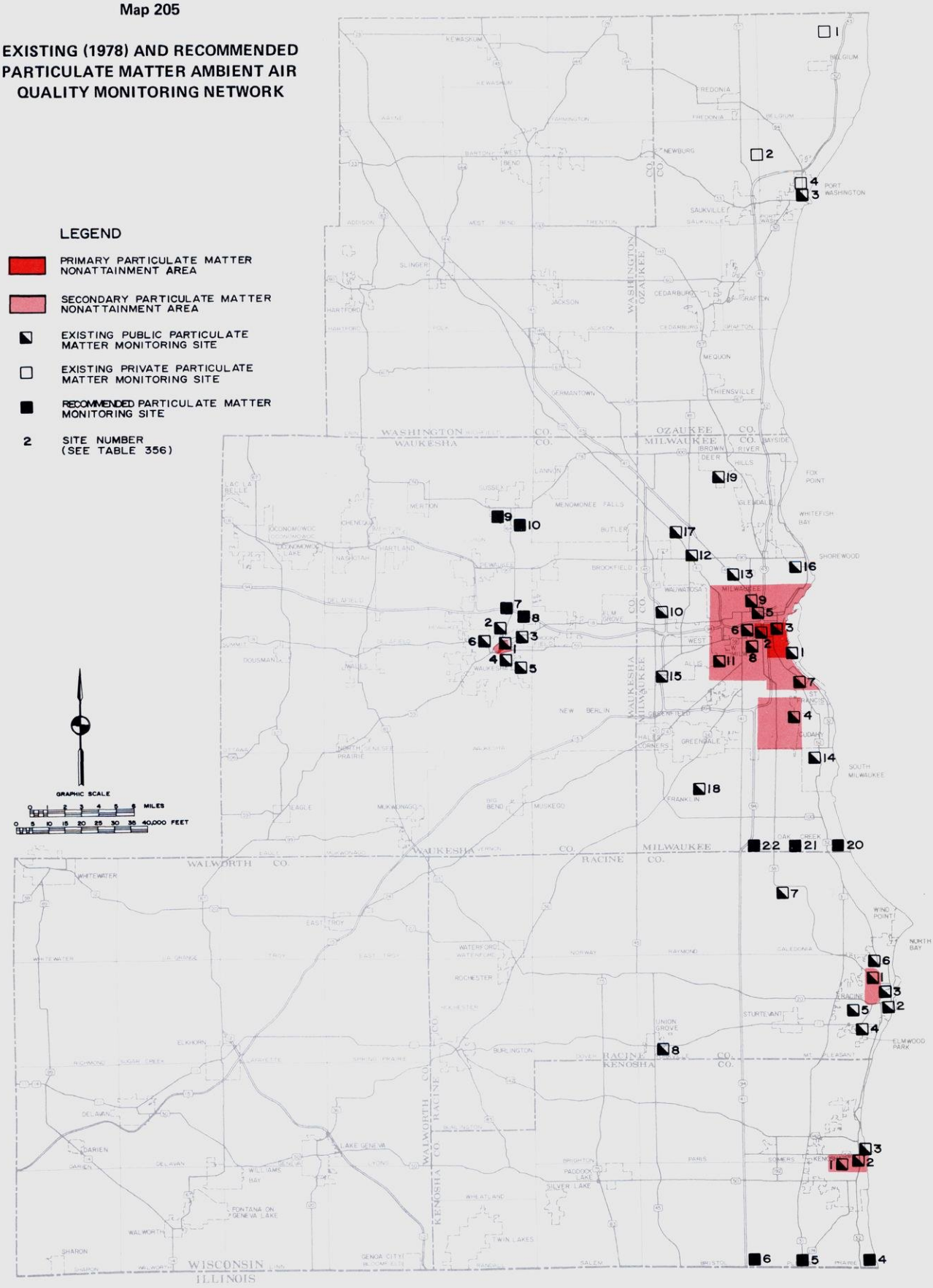
[35] *U. S. Environmental Protection Agency, Information Document on Automobile Emissions Inspection and Maintenance Programs, EPA-400/2-78-001, January 1978.*

[36] *As of December 1979, the Wisconsin Electric Power Company has established three particulate matter monitoring stations within a radius of approximately five miles of the Pleasant Prairie electric generating plant under construction near the Wisconsin/Illinois border in Kenosha County.*

Map 205

EXISTING (1978) AND RECOMMENDED PARTICULATE MATTER AMBIENT AIR QUALITY MONITORING NETWORK



This map identifies the location of the 40 particulate matter ambient air quality monitors operating in the Region during 1978. Of these 40 particulate matter monitors, 29 were operated by the Wisconsin Department of Natural Resources, eight were operated by the Racine County Department of Air Pollution Control, and three were operated by the Wisconsin Electric Power Company. This map also identifies the general location of 10 additional particulate matter monitors recommended under the plan. The plan recommends that four of the additional monitors be located in the area of major quarrying operations in order to verify the results of the air quality simulation modeling results, and that three of the additional monitors be located near the Milwaukee County/ Racine County line and three near the Wisconsin/Illinois state line to measure the long-range transport of particulate matter.

Source: SEWRPC.

Table 356

EXISTING (1978) AND RECOMMENDED PARTICULATE MATTER AMBIENT AIR QUALITY MONITORING NETWORK

Code Number on Map 205	Existing Monitoring Sites			Particulate Matter Concentration (ug/m^3)		
	Address	Civil Division	Operator	Maximum 24-Hour Average	Second Highest 24-Hour Average	Annual Geometric Average
	Kenosha County					
1	6415 35th Avenue	Kenosha	Department of Natural Resources	185	149	60.2
2	720 59th Place	Kenosha	Department of Natural Resources	157	153	58.2
3	625 52nd Street	Kenosha	Department of Natural Resources	158	135	55.8
	Milwaukee County					
1	1750 S. Kinnickinnic Avenue	Milwaukee	Department of Natural Resources	354	230	98.4
2	230 S. Muskego Avenue	Milwaukee	Department of Natural Resources	325	209	88.3
3	600 E. Greenfield Avenue	Milwaukee	Department of Natural Resources	270	266	80.2
4	5300 S. Howell Avenue	Milwaukee	Department of Natural Resources	216	204	68.9
5	711 W. Wells Street	Milwaukee	Department of Natural Resources	217	154	67.5
6	3419 W. Wisconsin Avenue	Milwaukee	Department of Natural Resources	198	139	62.3
7	2969 S. Howell Avenue	Milwaukee	Department of Natural Resources	149	120	57.8
8	1640 S. 24th Street	Milwaukee	Department of Natural Resources	134	91	56.3
9	1313 W. Reservoir Street	Milwaukee	Department of Natural Resources	192	129	53.9
10	9722 W. Watertown Plank Road	Wauwatosa	Department of Natural Resources	171	115	51.6
11	2300 S. 51st Street	Milwaukee	Department of Natural Resources	155	122	50.4
12	7528 W. Appleton Avenue	Milwaukee	Department of Natural Resources	159	119	49.2
13	3281 N. 41st Street	Milwaukee	Department of Natural Resources	166	124	44.3
14	1001 15th Avenue	South Milwaukee	Department of Natural Resources	183	121	44.2
15	9501 W. Cleveland Avenue	West Allis	Department of Natural Resources	142	101	44.2
16	3201 N. Downer Avenue	Milwaukee	Department of Natural Resources	139	103	42.1
17	5100 N. 91st Street	Milwaukee	Department of Natural Resources	151	87	40.4
18	8885 S. 68th Street	Franklin	Department of Natural Resources	109	99	39.2
19	7841 N. 47th Street	Brown Deer	Department of Natural Resources	149	98	35.1
	Ozaukee County					
1	Jay Road and Alder Road[a]	Town of Belgium	Environmental Research & Technology, Inc.[b]	161	147	29.7
2	Willow Road and CTH KK[a]	Town of Port Washington	Environmental Research & Technology, Inc.[b]	143	140	28.7
3	408 N. Lake Street	Port Washington	Department of Natural Resources	148	138	37.0
4	Norport Drive and STH 32[a]	Town of Port Washington	Environmental Research & Technology, Inc.[b]	140	139	34.6
	Racine County					
1	1501 Albert Street	Racine	Racine County Department of Air Pollution Control	374	210	67.2
2	1519 Washington Avenue	Racine	Racine County Department of Air Pollution Control	210	152	64.0
3	730 Washington Avenue	Racine	Racine County Department of Air Pollution Control	163	154	51.0
4	3701 Durand Avenue	Racine	Racine County Department of Air Pollution Control	138	115	48.5
5	4901 Washington Avenue	Racine	Racine County Department of Air Pollution Control	149	117	46.1
6	2210 Rapids Drive	Racine	Racine County Department of Air Pollution Control	130	120	44.8
7	6922 Nicholson Road	Husher	Racine County Department of Air Pollution Control	181	123	43.2
8	925 15th Avenue	Union Grove	Racine County Department of Air Pollution Control	161	104	42.7
	Waukesha County					
1	1230 The Strand	Waukesha	Department of Natural Resources	416	339	120.5
2	1344 White Rock Avenue	Waukesha	Department of Natural Resources	324	311	77.4
3	612 E. Main Street	Waukesha	Department of Natural Resources	283	235	75.0
4	1335 Cleveland Court	Waukesha	Department of Natural Resources	275	187	74.1
5	1116 Adams Court	Waukesha	Department of Natural Resources	223	146	71.2
6	130 W. St. Paul Avenue	Waukesha	Department of Natural Resources	147	129	56.6

Code Number on Map 205	Recommended Monitoring Sites		
	Location	Number of Additional Monitors	Proposed Operator
4-6	Kenosha County Wisconsin/Illinois State Line	3	Department of Natural Resources
20-22	Milwaukee County Milwaukee County/Racine County Line	3	Department of Natural Resources
7-8	Waukesha County Town of Pewaukee	2	Department of Natural Resources
9-10	Town of Sussex	2	Department of Natural Resources

[a] *Data were collected by an industrial source have not been certified by the Department of Natural Resources. Data collection terminated in February 1979.*

[b] *Environmental Research & Technology, Inc., operated this site for the Wisconsin Electric Power Company.*

Source: SEWRPC.

In addition to the 37 particulate matter monitors presently operated by the DNR and Racine County, the recommended ambient air quality monitoring network calls for the placement of high-volume gravimetric samplers in such a manner so as to both verify the results of the air quality simulation modeling effort and quantify the amount of particulate matter transported into the Region from sources in the heavily industrialized northeastern Illinois-northwestern Indiana area. The results of the simulation modeling indicated existing and future violations of the primary and/or secondary particulate matter ambient air quality standards in areas near quarrying operations in parts of the City of Franklin in Milwaukee County; in part of the Town of Caledonia in Racine County; and in parts of the City of Menomonee Falls, the Villages of Pewaukee, Sussex, and Wales, and the Towns of Lisbon and Pewaukee in Waukesha County. Thus, the placement of special-purpose, short-term, high-volume gravimetric monitors around major quarrying operations has been deemed necessary under the recommended particulate matter plan in order to measure progress toward attaining the ambient air quality standards for this pollutant species.

Map 205 indicates four areas in the Region within which the location of additional particulate matter ambient air quality monitors should be considered to verify the air quality simulation modeling results, and to measure progress toward attainment of the standards as controls on quarrying operations are implemented. Within at least two of these four areas a minimum of two high-volume gravimetric monitors should be sited in such a manner so as to sample ambient air particulate matter concentrations both upwind and downwind of the suspected source of emissions. Concurrently, data on such characteristics of the quarry operations concerned as material throughput, meteorology, and vehicle traffic should be compiled in order to permit determination of emission factors, as well as of ambient air quality conditions. Specific site selection within these four areas will depend on such factors as access, availability of electrical power, and security from vandalism.

Map 205 also indicates the recommended location of six particulate matter ambient air quality monitors—three in Kenosha County near the Wisconsin/Illinois state line and three along the Milwaukee County/Racine County line—that would serve to measure particulate matter transported into the Region from extraregional sources. Of these six monitors, one should be located within one mile of Lake Michigan, one about two to three miles inland, and one about four to five miles inland. A regular program of laboratory analysis of filters obtained from these six recommended monitors should be established in order to determine the source of the particulate matter loadings—whether local or extraregional.

In total, therefore, the recommended ambient air quality monitoring network calls for the operation of 10 additional special-purpose, short-term, high-volume gravimetric monitoring stations within the Region to supplement the data provided by the 37 particulate matter monitoring stations presently operated by the DNR and the Racine County Department of Air Pollution Control. Four of the recommended stations are to be established for the purpose of more precisely defining particulate matter pollution near major quarrying operations in the Region, and six are to be established to measure the amount of particulate matter being transported into the Region from extraregional sources.

It is further recommended that all existing and recommended particulate matter monitoring be reviewed as to conformance with the siting requirements set by the EPA and be categorized as being either population- or source-oriented. Further, samples to determine the long-range transport of particular matter should be taken and recorded so as to minimize undue influence from local sources. It is also recommended that all filters be placed and retrieved so as to allow no more than a total of one day of passive loading on the filters, and that flow rates be established at a level meeting the minimum EPA-approved sampling rate in order to minimize the impact of settleable solids. Finally, the frequency of monitoring should be approximately every other day.

The Recommended Sulfur Dioxide Monitoring Network

As indicated on Map 206 and in Table 357, in 1978 there were 10 sulfur dioxide ambient air quality monitoring stations in the Region. Six of these were in Milwaukee County and were operated by the Wisconsin Department of Natural Resources (DNR), and one was in the City of Racine and was operated by the Racine County Department of Air Pollution Control. In addition, three other sulfur dioxide ambient air quality monitoring stations—all in Ozaukee County—were operated by the Wisconsin Electric Power Company. However, data collected at these three sites have not been certified by the DNR since the DNR was not able to conduct an audit of the data.[37] All 10 of the sulfur dioxide sampling stations in the Region used U. S. Environmental Protection Agency-approved continuous monitoring instruments.

No additional sulfur dioxide monitors to supplement the existing network are recommended at this time. This determination is based on the findings of the air quality simulation modeling effort, which indicated that the maximum sulfur dioxide concentrations in southeastern Wisconsin may be expected to occur in and around the heavily industrialized portion of the Menomonee River Valley and the central business district of the City of Milwaukee. Of the six sulfur dioxide monitors in the City of Milwaukee, two—the one located at 2114 E. Kenwood Boulevard and the one located at 1225 S. Carferry Drive—lie within the proposed sulfur dioxide nonattainment area. Moreover, the monitoring station located at 600 W. Kilbourn Avenue lies within the area of maximum

[37] *Three additional sulfur dioxide monitors have been operated by the Wisconsin Electric Power Company near the Pleasant Prairie electric power generating plant just north of the Wisconsin/Illinois border since December 1979.*

annual average sulfur dioxide concentrations as forecast by the air quality simulation model. Since the existing sulfur dioxide ambient air quality monitors may be expected to measure progress toward both the attainment of the sulfur dioxide ambient air quality standards and the future maintenance of the standards, no additional monitoring stations are deemed necessary for this pollutant species. Future growth and development in the Region at variance with the adopted regional land use plan may necessitate additional sulfur dioxide monitoring, as may the increased concern over the problem of acid rain.

The Recommended Carbon Monoxide Monitoring Network

As indicated on Map 207 and in Table 358, in 1978 there were five carbon monoxide ambient air quality monitors in Milwaukee County and one carbon monoxide monitor in Waukesha County[38] operated by the Wisconsin Department of Natural Resources (DNR), and one carbon monoxide monitor in the City of Racine operated by the Racine County Department of Air Pollution Control. In addition, there was one carbon monoxide monitoring site in Ozaukee County operated by the Wisconsin Electric Power Company. However, data collected at this site have not been certified by the DNR, since the DNR was not able to conduct an audit of the data. All eight carbon monoxide sampling sites in the Region used U. S. Environmental Protection Agency-approved continuous monitoring instruments.

Under the air quality simulation modeling effort, an area encompassing the Marquette Interchange in Milwaukee County was identified as experiencing the highest one-hour average and eight-hour average carbon monoxide concentrations in the Region. Because of a lack of available monitoring data, this computer-predicted result cannot be verified by direct observation at the present time. Accordingly, the recommended monitoring network calls for the placement of a carbon monoxide monitor in the area of the Marquette Interchange. Since the directional roadways comprising the Marquette Interchange accommodate the highest traffic volumes of any arterial highway facilities in the Region and the State, it may be expected that the highest carbon monoxide concentrations will be measured at this location. Special-purpose carbon monoxide monitoring in the Marquette Interchange area is needed not only to assess the simulation modeling results, but also to measure further progress toward attainment of the ambient air quality standards as the recommended transportation-related controls are implemented. In addition to the placement of a special-purpose carbon monoxide monitor at the Marquette Interchange, it is recommended that traffic volume and composition, vehicle speeds, and meteorological conditions be measured in support of the carbon monoxide monitoring effort.

[38] *The carbon monoxide monitor in the City of Waukesha was relocated from 726 N. Grand Avenue to 225 N. Grand Avenue in July 1978.*

The Recommended Photochemical Oxidant Monitoring Network

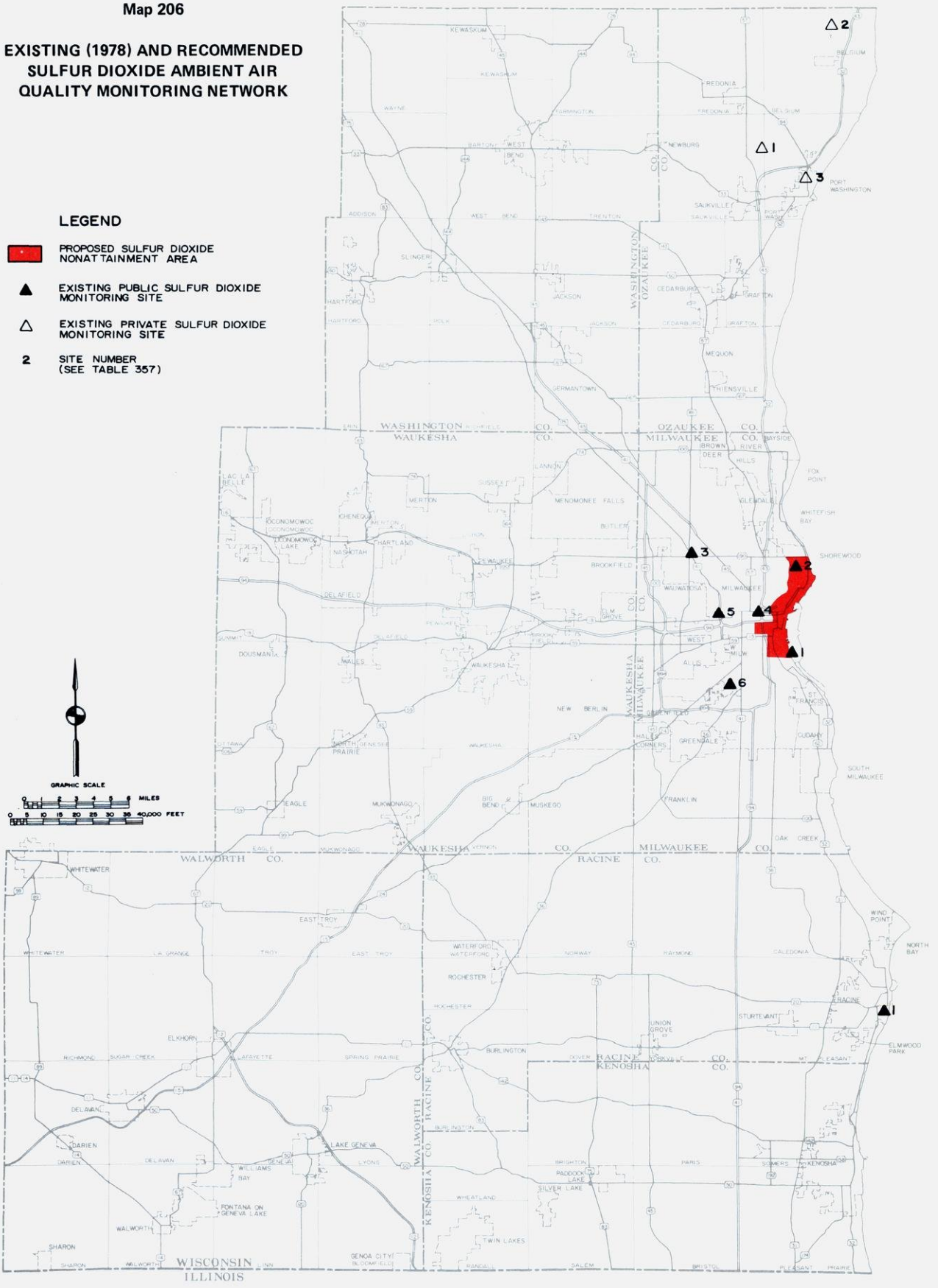
The recommended photochemical oxidant monitoring network encompasses the siting of ambient air quality monitors for nitrogen oxides, nitrogen dioxide, nonmethane hydrocarbons, and ozone. These four atmospheric contaminants are considered jointly because of their mutual involvement in the photochemical oxidant formation cycle and because monitoring data for all four species are required as input to the city-specific version of the Empirical Kinetics Modeling Approach (EKMA). The photochemical oxidant monitoring network need be operated only during the ozone season, defined for southeastern Wisconsin by the U. S. Environmental Protection Agency as April 1 to November 1.

The ratio of nonmethane hydrocarbons to nitrogen oxides in the ambient air over an urban area is particularly important in determining the maximum ozone concentration observed downwind of that urban area. As may be seen on Map 208 and in Table 359, however, there were only seven monitoring stations for nitrogen dioxide, three monitoring stations for nitrogen oxides, and two monitoring stations for nonmethane hydrocarbons in operation in the Region during 1978. The data from the eight monitors—three for nitrogen dioxide, three for nitrogen oxides, and two for nonmethane hydrocarbons—operated by the Wisconsin Electric Power Company (WEPCO), have not been certified by the Wisconsin Department of Natural Resources (DNR) since the DNR was not able to conduct an audit of the data. It should also be noted that these WEPCO monitoring sites are located north of the heavily industrialized areas in Milwaukee County and thus may not be representative of the urban environment. Moreover, the city-specific version of the EKMA requires as input concentrations of nitrogen oxides and nonmethane hydrocarbons attributable to local emission sources in the urbanized area and also to long-range transport. Thus, the EKMA will be able to be better applied to the Southeastern Wisconsin Region when the nitrogen oxide and nonmethane hydrocarbon concentrations are defined at or near the Illinois-Wisconsin border—for the purpose of measuring the transport of precursor compounds—and in or near the central business district of the City of Milwaukee—for the purpose of measuring the local contribution to the concentrations of precursor compounds.

The recommended monitoring network calls for the placement of a nitrogen oxide monitor and a nonmethane hydrocarbon monitor in both southern Kenosha County and the City of Milwaukee. This recommendation is in addition to the two nitrogen oxide monitors operated by and located near the Wisconsin Electric Power Company's Pleasant Prairie electric power generating plant in Kenosha County. Also, since the maximum ozone concentrations recorded downwind of the City of Milwaukee have been recorded at the monitoring station in the Village of Grafton in Ozaukee County, it is recommended that a nitrogen oxide monitor and a nonmethane hydrocarbon monitor be placed at this site in order to improve on the ability to estimate the rate of chemical activity involved in ozone formation. The addition of

Map 206

EXISTING (1978) AND RECOMMENDED SULFUR DIOXIDE AMBIENT AIR QUALITY MONITORING NETWORK



As indicated on this map, there were 10 sulfur dioxide monitoring stations operating in the Region during 1978. Six of these stations were operated by the Wisconsin Department of Natural Resources, one by the Racine County Department of Air Pollution Control, and three by the Wisconsin Electric Power Company. A need for additional sulfur dioxide monitoring in the Region has not been identified at the present time.

Source: SEWRPC.

Table 357

EXISTING (1978) AND RECOMMENDED SULFUR DIOXIDE AMBIENT AIR QUALITY MONITORING NETWORK

Code Number on Map 206	Existing Monitoring Sites			Sulfur Dioxide Concentration ($\mu g/m^3$)				
	Address	Civil Division	Operator	Maximum Three-Hour Sample	Second Highest Three-Hour Sample	Maximum 24-Hour Sample	Second Highest 24-Hour Sample	Annual Sample
	Milwaukee							
1	1225 S. Carferry Drive	Milwaukee	Department of Natural Resources	1,206.0	1,187.7	779.0	481.8	70.2
2	2114 E. Kenwood Boulevard[a]	Milwaukee	Department of Natural Resources	1,277.3	1,028.0	594.8	400.6	55.3
3	7528 W. Appleton Avenue	Milwaukee	Department of Natural Resources	332.3	329.7	115.3	114.6	48.0
4	600 W. Kilbourn Avenue	Milwaukee	Department of Natural Resources	526.0	518.3	201.4	178.1	47.4
5	3716 W. Wisconsin Avenue[a]	Milwaukee	Department of Natural Resources	1,025.3	724.0	195.0	179.4	46.6
6	3401 S. 39th Street	Milwaukee	Department of Natural Resources	1,003.3	777.7	303.0	297.3	44.3
	Ozaukee County							
1	Willow Road and CTH KK[b]	Town of Port Washington	Environmental Research & Technology, Inc.[c]	820.0	680.7	208.3	121.0	10.2
2	Jay Road and Alder Road[b]	Town of Belgium	Environmental Research & Technology, Inc.[c]	253.0	161.3	115.0	51.6	8.1
3	Norport Drive and STH 32[b]	Town of Port Washington	Environmental Research & Technology, Inc.[c]	259.0	103.7	147.0	44.2	8.3
	Racine County							
1	1521 Washington Avenue	Racine	Racine County Department of Air Pollution Control	330.0	287.0	197.7	146.0	49.9

[a] *Stations to be relocated in 1980.*

[b] *Data were collected by an industrial source and have not been certified by the Department of Natural Resources. Data collection terminated in February 1979.*

[c] *Environmental Research & Technology, Inc., operated this site for the Wisconsin Electric Power Company.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Table 358

EXISTING (1978) AND RECOMMENDED CARBON MONOXIDE AMBIENT AIR QUALITY MONITORING NETWORK

Code Number on Map 207	Existing Monitoring Sites			Carbon Monoxide Concentrations (mg/m^3)			
	Address	Civil Division	Operator	Maximum One-Hour Average	Second Highest One-Hour Average	Maximum Eight-Hour Average	Second Highest Eight-Hour Average
	Milwaukee County						
1	1225 S. Carferry Drive	Milwaukee	Department of Natural Resources	18.0	12.4	8.4	6.09
2	3401 S. 39th Street	Milwaukee	Department of Natural Resources	10.5	9.7	5.27	5.07
3	7528 W. Appleton Avenue	Milwaukee	Department of Natural Resources	15.1	13.9	10.15	9.07
4	3716 W. Wisconsin Avenue	Milwaukee	Department of Natural Resources	16.3	15.6	9.65	9.08
5	600 W. Kilbourn Avenue	Milwaukee	Department of Natural Resources	17.1	13.6	9.54	6.92
	Ozaukee County						
1	Norport Drive and STH 32[a]	Town of Port Washington	Environmental Research & Technology, Inc.	4.6	3.4	2.86	2.42
	Racine County						
1	1521 Washington Avenue	Racine	Racine County Department of Air Pollution Control	8.8	8.8	5.12	4.85
	Waukesha County						
1	225 N. Grand Avenue	Waukesha	Department of Natural Resources and Carroll College	17.0	13.6	9.59	6.66

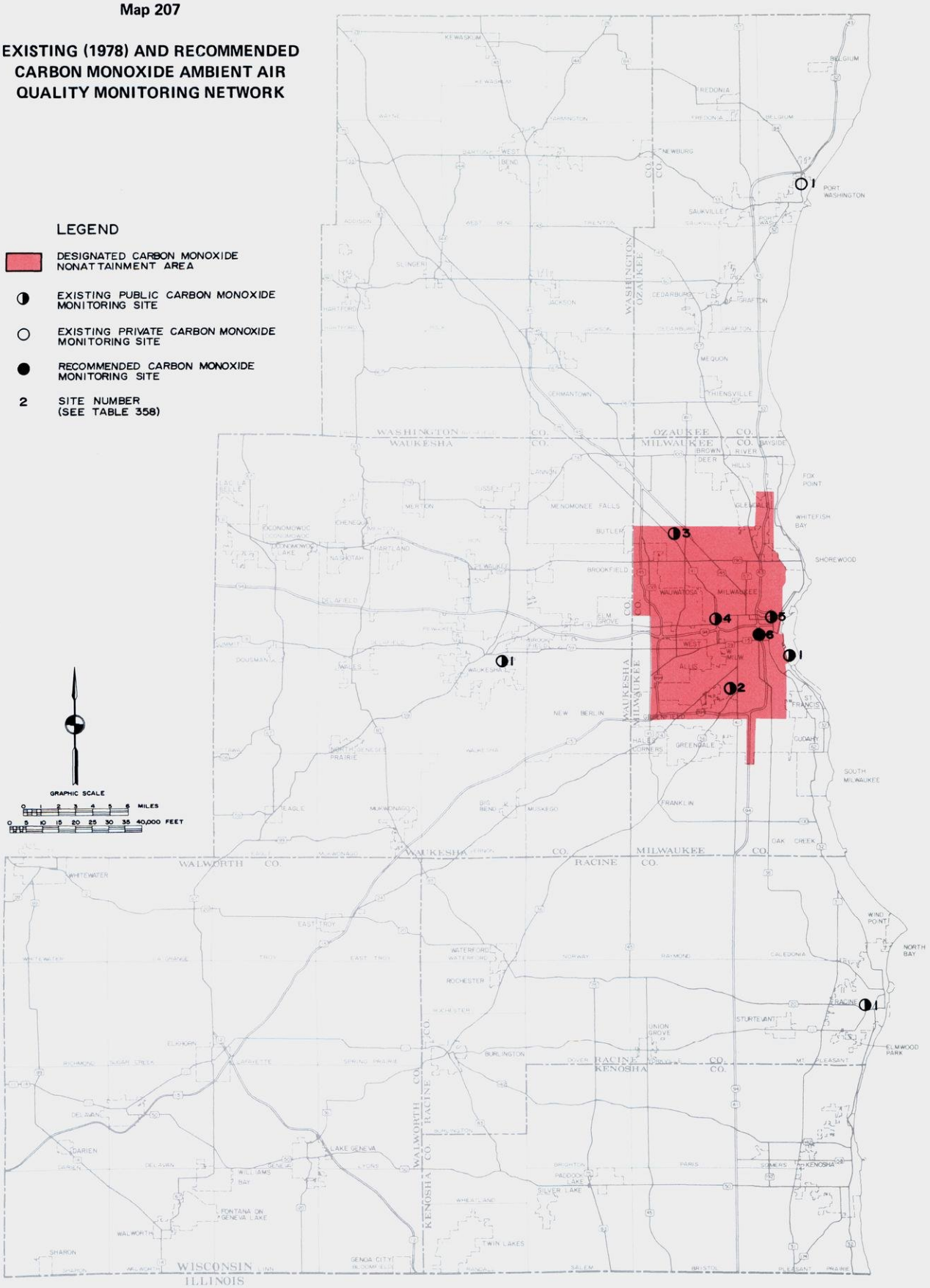
	Recommended Monitoring Sites		
	Milwaukee County		
6	Marquette Interchange	Milwaukee	Department of Natural Resources

[a] *Data were collected by an industrial source and have not been certified by the Department of Natural Resources. Data collection terminated in February 1979.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Map 207

EXISTING (1978) AND RECOMMENDED CARBON MONOXIDE AMBIENT AIR QUALITY MONITORING NETWORK

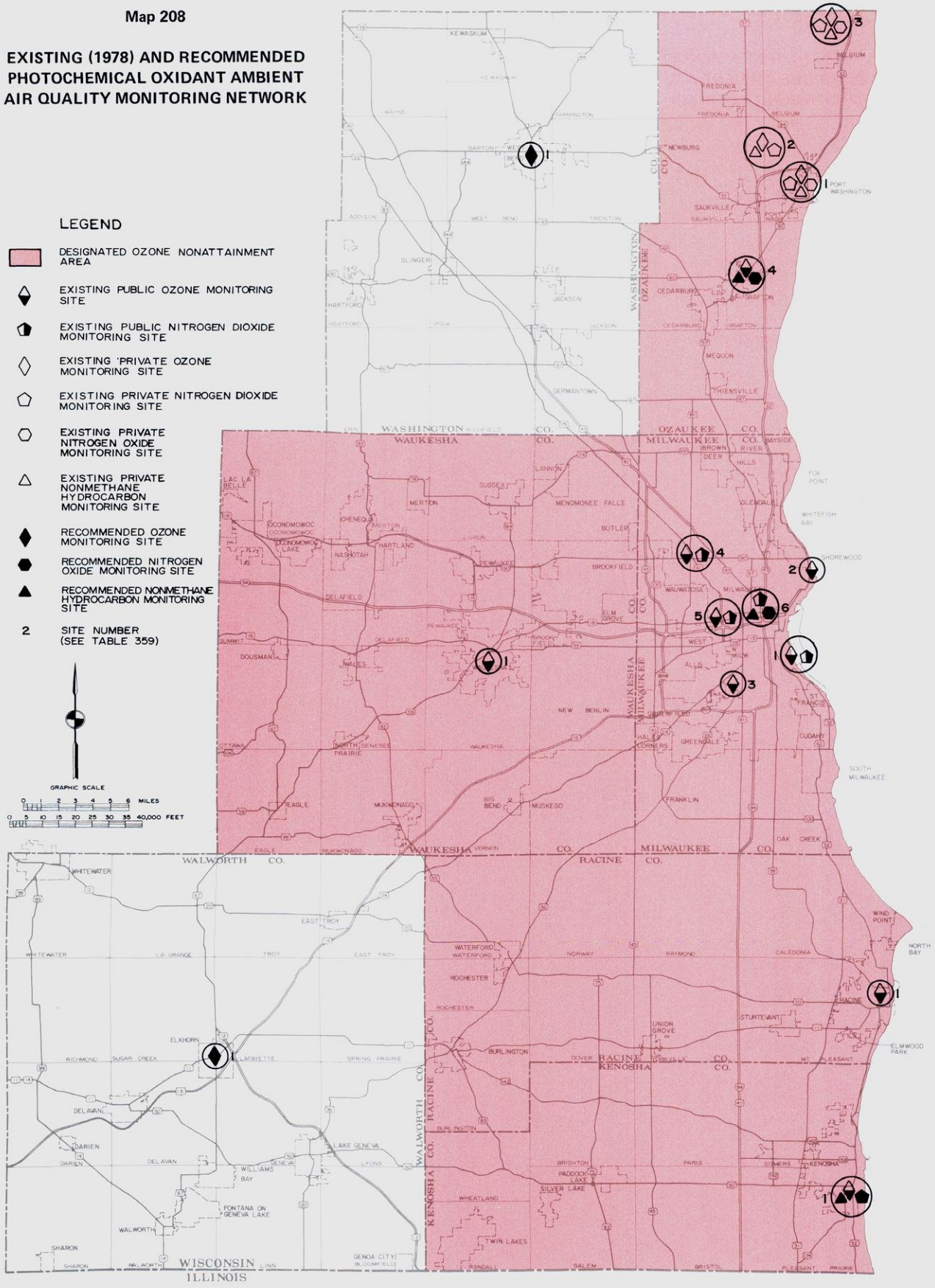


This map illustrates the existing and recommended carbon monoxide monitoring networks in the Region. As may be seen on this map, there were eight carbon monoxide monitoring stations in the Region during 1978. Six of these eight stations were operated by the Wisconsin Department of Natural Resources, one by the Racine County Department of Air Pollution Control, and one by the Wisconsin Electric Power Company. Because the air quality simulation modeling results have indicated that the highest one-hour average and eight-hour average carbon monoxide concentrations in the Region are centered over the Marquette Interchange in Milwaukee County, the plan calls for one additional carbon monoxide monitoring station to be located adjacent to this interchange in order to verify the results of the air quality simulation modeling effort and to measure progress toward attaining the carbon monoxide ambient air quality standards.

Source: SEWRPC.

Map 208

EXISTING (1978) AND RECOMMENDED PHOTOCHEMICAL OXIDANT AMBIENT AIR QUALITY MONITORING NETWORK



This map illustrates the existing and recommended ambient air quality monitoring networks for photochemical oxidants in the Region. There are three existing nitrogen oxide monitoring stations, all operated by the Wisconsin Electric Power Company; seven existing nitrogen dioxide monitoring stations, four operated by the Wisconsin Department of Natural Resources and three by the Wisconsin Electric Power Company; two existing nonmethane hydrocarbon monitoring stations, both operated by the Wisconsin Electric Power Company; and 11 existing ozone monitoring stations, eight operated by the Wisconsin Department of Natural Resources, two by the Wisconsin Electric Power Company, and one by the Racine County Department of Air Pollution Control. The recommended monitoring network calls for the addition of three nitrogen oxide monitors, three nonmethane hydrocarbon monitors, and two ozone monitors. All of the recommended new monitors are proposed to be operated by the Wisconsin Department of Natural Resources. Placement of the nitrogen oxide monitoring stations and nonmethane hydrocarbon monitoring stations in Kenosha, Milwaukee, and Ozaukee Counties would serve to define more precisely the local and long-range transport of emissions and their contribution to the formation of ozone. Ozone monitors should be placed in Walworth County and Washington County in order to determine whether the ozone ambient air quality standards are being attained in these two counties.

Source: SEWRPC.

Table 359

EXISTING (1978) AND RECOMMENDED PHOTOCHEMICAL OXIDANT AMBIENT AIR QUALITY MONITORING NETWORK

Code Number on Map 208	Existing Monitoring Sites			Nitrogen Oxide Concentration ($\mu g/m^3$) Annual Arithmetic Mean	Nitrogen Dioxide Concentration ($\mu g/m^3$) Annual Arithmetic Mean	Nonmethane Hydrocarbon Concentration ($\mu g/m^3$) Maximum Three-Hour Average (6:00 a.m. to 9:00 a.m.)	Second Highest Nonmethane Hydrocarbon Concentration ($\mu g/m^3$) Three-Hour Average	Ozone Concentration ($\mu g/m^3$) Maximum One-Hour Average	Second Highest Ozone Concentration ($\mu g/m^3$) One-Hour Average
	Address	Civil Division	Operator						
	Kenosha County								
1	8518 22nd Avenue	Kenosha	Department of Natural Resources	--	--	--	--	373	365
	Milwaukee County								
1	1225 S. Carferry Drive	Milwaukee	Department of Natural Resources	--	52.3	--	--	320	306
2	2114 E. Kenwood Boulevard. .	Milwaukee	Department of Natural Resources	--	--	--	--	359	337
3	3401 S. 39th Street	Milwaukee	Department of Natural Resources	--	--	--	--	365	345
4	7528 W. Appleton Avenue . . .	Milwaukee	Department of Natural Resources	--	51.4	--	--	300	282
5	3716 W. Wisconsin Avenue. . .	Milwaukee	Department of Natural Resources	--	66.8	--	--	322	275
6	711 W. Wells Street	Milwaukee	Department of Natural Resources	--	80.3	--	--	--	--
	Ozaukee County								
1	Norport Drive and STH 32[a] . .	Town of Port Washington	Environmental Research & Technology, Inc.[b]	29.8	22.1	348.9	317.8	425	404
2	Willow Road and CTH KK[a] . .	Town of Port Washington	Environmental Research & Technology, Inc.[b]	27.4	17.5	--	--	--	--
3	Jay Road and Alder Road[a]. . .	Town of Belgium	Environmental Research & Technology, Inc.[b]	23.9	18.9	133.3	133.3	412	367
4	1950 Washington Street	Grafton	Department of Natural Resources	--	--	--	--	382	353
	Racine County								
1	1521 Washington Avenue. . . .	Racine	Racine County Department of Air Pollution Control	--	--	--	--	490	394
	Waukesha County								
1	225 N. Grand Avenue.	Waukesha	Department of Natural Resources	--	--	--	--	386	308

Code Number on Map 208	Recommended Monitoring Sites			Pollutant for Which Additional Monitor is Recommended			
	Location	Civil Division	Proposed Operator	Nitrogen Oxides	Nitrogen Dioxide	Nonmethane Hydrocarbons	Ozone
	Kenosha County						
1	Southern Kenosha County . . .	Kenosha	Department of Natural Resources	X		X	
	Milwaukee County						
1	711 W. Wells Street	Milwaukee	Department of Natural Resources	X		X	
	Ozaukee County						
4	1950 Washington Street	Grafton	Department of Natural Resources	X		X	
	Walworth County						
1	Center City	Elkhorn	Department of Natural Resources				X
	Washington County						
1	West Bend	West Bend	Department of Natural Resources				X

[a] *Data were collected by an industrial source and have not been certified by the Department of Natural Resources. Data collection terminated in February 1979.*

[b] *Environmental Research & Technology, Inc., operated this site for the Wisconsin Electric Power Company.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

these monitors in Kenosha, Milwaukee, and Ozaukee Counties will provide for a network forming a longitudinal traverse of the Region that will more precisely define the extent to which local emission sources contribute to ozone formation in southeastern Wisconsin as compared with the ozone and precursor compounds contributed by extraregional sources.

As also indicated on Map 208 and in Table 359, it is recommended that additional ozone monitors be located in Walworth County and in Washington County. Since inspection and maintenance and transportation controls are being suggested for these counties, and since no ozone monitoring has been conducted in these two counties, such monitoring will be necessary to verify the areawide nature of the ozone problem. The placement of ozone monitors near the geographic centers of Walworth and Washington Counties will enable a determination of whether violations of the ozone standard are occurring in these two presently unclassifiable areas.

Cost of the Recommended Monitoring Network

The recommended ambient air quality monitoring network calls for the addition of 10 particulate matter monitoring stations, 1 carbon monoxide monitoring station, 2 ozone monitoring stations, 3 nitrogen oxide monitoring stations, and 3 nonmethane hydrocarbon monitoring stations as a supplement to the existing ambient air quality monitoring network. The estimated capital and net annualized costs of the purchase and operation of these 19 additional ambient air quality monitors are presented in Table 360.

As may be seen in Table 360, the total capital cost of purchasing 10 additional high-volume particulate matter gravimetric samplers is estimated at $6,300. Since each of these 10 particulate matter monitors will require individual siting, the monthly operating and maintenance costs assume the leasing of secured space on private facilities at approximately $100 per month and the use of electrical power at $8.00 per month. The cost of filter pads and of travel time to replace the filters has not been included in the estimation of monthly operating and maintenance costs because of the variability of sampling frequency. Based on the foregoing assumptions, therefore, the monthly operating and maintenance costs for the recommended 10 additional particulate matter monitors are estimated to be $1,100.

The estimated costs of establishing a carbon monoxide monitoring station near the Marquette Interchange include a capital expenditure of about $7,400 for a nondispersive infrared monitor and a monthly operating and maintenance cost of about $280. The monthly operating and maintenance costs include approximately $100 per month in rent for the secured space, approximately $147 for cylinder gas, assuming a usage of 1.5 tanks per month at $98 per tank, about $8.00 per month for electrical power, and about $340 per year for the installation and operation of leased telephone line for remote data acquisition.

The capital cost of the recommended addition of three nitrogen oxide monitors is estimated at $21,000. The monthly operating and maintenance cost is estimated at $540, and includes the cost of secured space, gas cylinders, electrical power, and telephone line for remote data acquisition. Similarly, the capital cost of the recommended three additional nonmethane hydrocarbon monitors and two additional ozone monitors is estimated to be $40,800 and $8,200, respectively, with monthly operating and maintenance costs estimated at $735 and $360, respectively.

In total, the additional monitoring units called for in the recommended ambient air quality monitoring network are estimated to require a capital expenditure of $83,700, and—assuming that the nitrogen oxide, nonmethane hydrocarbon, and ozone monitors operate only during the months of April through October—an annual operation and maintenance expenditure of $27,800. It should be noted, however, that the costs of adding new personnel as may be required to operate the monitors and reduce the observed data have not been included in the cost estimates above.

SUMMARY

This chapter has set forth a recommended plan for attaining and maintaining the established federal and state ambient air quality standards in the seven-county Southeastern Wisconsin Region. This chapter has also summarized the results of the process by which this plan was prepared, including the formulation and evaluation of alternative plans and the selection of a recommended

Table 360

ESTIMATED COST OF THE RECOMMENDED ADDITIONS TO THE AMBIENT AIR QUALITY MONITORING NETWORK

Pollutant	EPA-Approved Monitoring Method	Representative Equipment Manufacturer	Estimated Unit Costs		Number of Recommended Additional Units	Total Costs	
			Capital	Monthly Operation and Maintenance		Capital	Monthly Operation and Maintenance
Particulate Matter	High-Volume Gravimetric Sampler	General Metal Works, Inc.	$ 625	$108[a]	10	$ 6,250	$1,080
Carbon Monoxide	Nondispersive Infrared	Bendix Corporation	7,400	280	1	7,400	280
Nitrogen Oxides	Chemiluminescence	Columbia Scientific Industries Corporation	7,000	180	3	21,000	540[c]
Nonmethane Hydrocarbons	Gas Chromatograph	Byron Instruments, Inc.	13,600[b]	245	3	40,800	735[c]
Ozone	Chemiluminescence	Meloy Laboratories, Inc.	4,100	180	2	8,200	360[c]
Total	--	--	--	--	19	$83,650	$2,995

[a] *Does not include the cost of filter pads or of travel time to replace filters.*

[b] *Includes the cost of hydrogen generator and zero air generator.*

[c] *To be operated only during the ozone season, April 1 to November 1.*

Source: Wisconsin Department of Natural Resources.

plan from among those plans by the Regional Planning Commission's Technical Coordinating and Advisory Committee on Regional Air Quality Planning.

The recommended attainment and maintenance plan is comprised of four distinct elements: 1) a particulate matter control plan, 2) a sulfur dioxide control plan, 3) a carbon monoxide and hydrocarbon/ozone control plan, and 4) an ambient air quality monitoring plan.[39] Each of these plan elements prescribes a set of actions designed to attain and maintain ambient air quality standards within the Region. The prescribed actions are comprised of coordinated combinations of 1) committed measures—that is, those controls that have been mandated by federal or state regulations—and 2) additional control measures indicated by the analyses conducted under the planning program to be necessary to abate the residual air pollution problems anticipated to occur even with full implementation of the committed measures. A summary of the recommended measures for each of the four plan elements is presented in the following sections.

Particulate Matter Pollution Control Plan

Based upon analyses of available ambient air quality monitoring data and ambient air quality simulation modeling results, it was determined that action is required to provide for the attainment and maintenance of the particulate matter ambient air quality standards. The areas of the Region within which the ambient air quality standards for particulate matter are not presently being met—areas designated as particulate matter nonattainment areas—are shown on Map 209.[40] The analyses indicated that, if the actions described below are fully implemented, significant progress toward the attainment and maintenance of the federal and state ambient air quality standards for particulate matter may be expected, with the possibility that the standards will be met and maintained as controls are applied to fugitive dust sources in the Region and to upwind extraregional air pollution sources. The particulate matter control plan consists of 1) control measures relating to existing sources of emissions, including industrial processes, fuel-burning installations, and fugitive dust emission sources; 2) control measures relating to new sources of emissions; 3) an intensive ambient air quality monitoring effort; and 4) a pilot vacuum street sweeping program in Milwaukee County.

Control of Existing Sources of Particulate Matter Emissions: The Wisconsin Natural Resources Board has established emission limitations for all sources of particulate matter, including industrial processes, fuel-burning installations, and fugitive dust sources. These limitations are set forth in Chapter NR 154 of the Wisconsin Administrative Code. In addition, the Wisconsin Department of Natural Resources has adopted amendments to Chapter NR 154 that impose more stringent emission limitations on certain existing sources of particulate matter impacting upon nonattainment areas. These more stringent emission limitations have been based upon what has been termed Reasonably Available Control Technology (RACT). The application of the RACT limitations to existing sources is also considered herein to be a committed action.

The RACT emission limitations for industrial processes are prescribed either as a control measure for the specific process type or as a function of the process weight rate. Formulas for determining the emission rate allowable for specific industrial process facilities are set forth in Figure 105. The RACT particulate matter emission limitations for fuel-burning installations are a function of the heat input capacity of the boiler. For example, as shown in Figure 106, the maximum allowable emission rate for boilers with a heat input capacity greater than 100 million British Thermal Units (BTU's) per hour and which lie within or impact upon a designated particulate matter nonattainment area is 0.10 pound of particulate matter per million BTU's. For boilers with a heat input capacity of 100 million or less BTU's per hour and which lie within or impact upon a designated nonattainment area, the maximum allowable emission rate is 0.24 pound of particulate matter per million BTU's.

For fugitive dust emission sources, RACT-defined emission limitations are expressed either as a function of the exhaust gas production rate or as a specified control operation. Private industrial and commercial roadways and areas subject to a traffic volume of more than 10 vehicles in any hour should be paved, and should be periodically cleaned to remove loose material. Storage piles of material with annual transfer rates of at least 100 tons and having a silt content of 5 percent to 20 percent should be treated with water, surfactants, stabilizers, or chemicals, and should be draped or enclosed on a minimum of three sides. Access areas around such storage piles should be cleaned and either watered or treated with stabilizers to prevent fugitive dust. Storage piles having an annual transfer rate of at least 100 tons and a silt content of 20 percent or greater should be completely enclosed or draped when materials are not being worked, loaded, or unloaded. Access areas to these storage piles should also be cleaned and either watered or treated with stabilizers. For all materials-handling operations dealing with materials of more than

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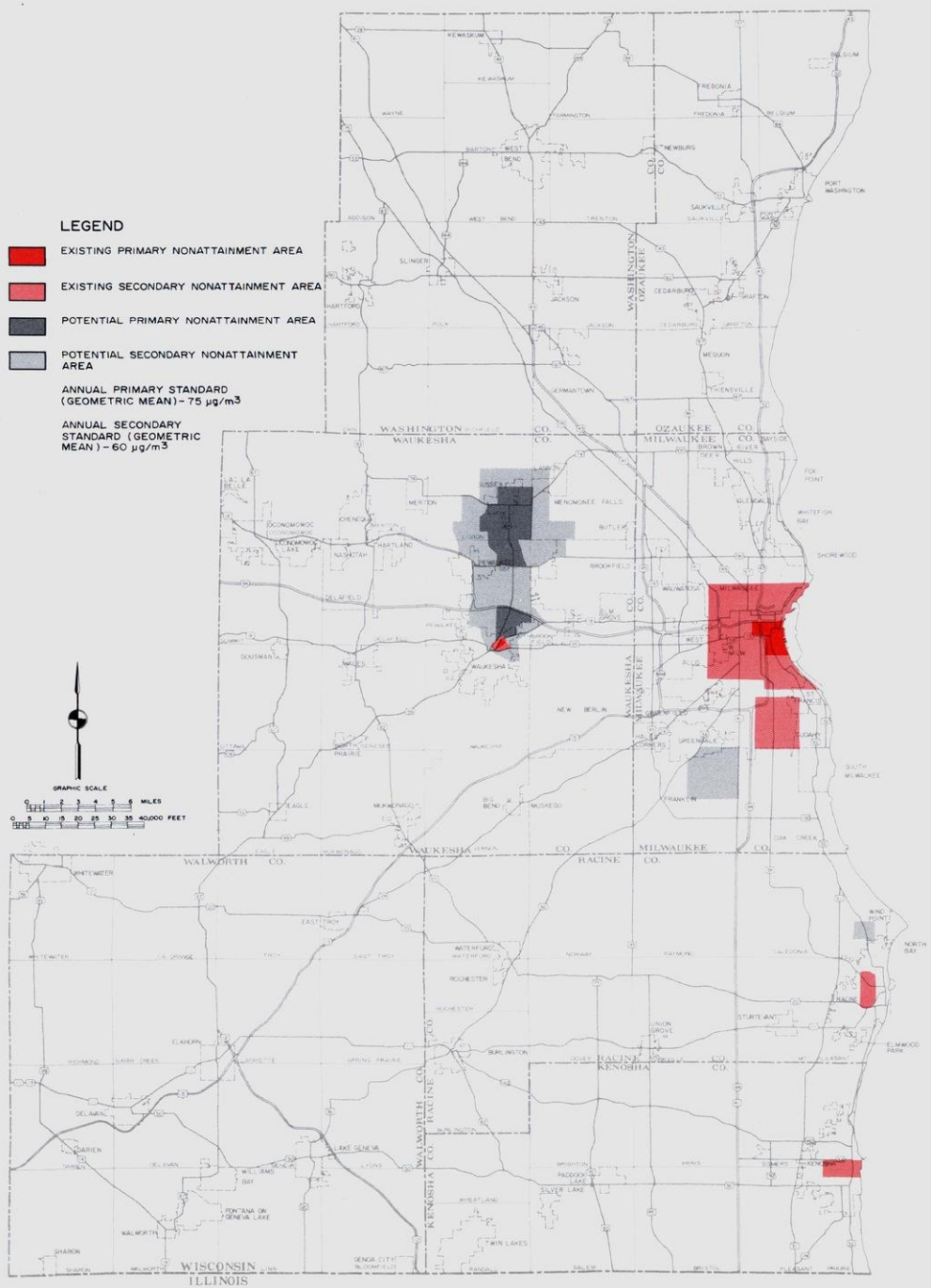
[39] *An attainment plan for nitrogen dioxide was not deemed necessary since available monitoring data for this pollutant species indicate that the ambient air quality standard has not been exceeded within the Region. Moreover, since the ambient air concentrations of total nitrogen oxides are forecast to decrease over the planning period, a maintenance plan for nitrogen dioxide was also not deemed necessary.*

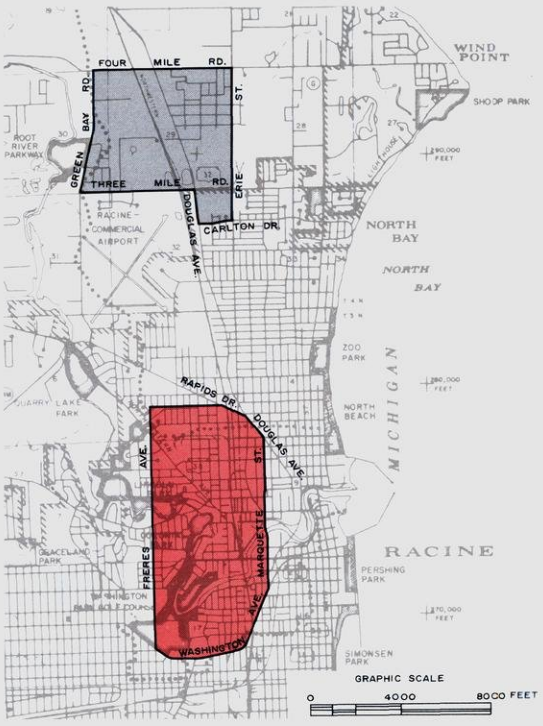
[40] *The Wisconsin Electric Power Company and Milwaukee County have questioned the designation of the Mitchell Field area as a secondary nonattainment area for particulate matter, contending that the monitored ambient air quality violations were the direct result of local construction activities.*

Map 209

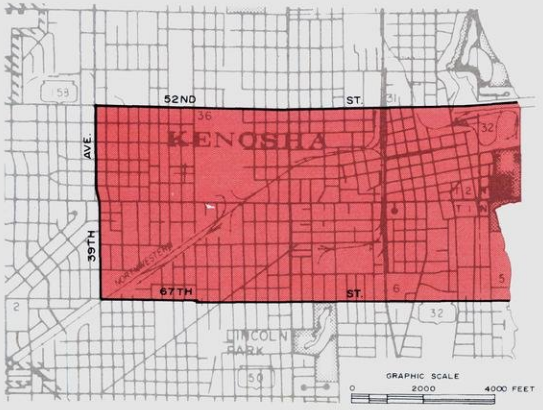
EXISTING AND POTENTIAL PARTICULATE MATTER PROBLEM AREAS IN THE REGION: 1977



RACINE PROBLEM AREA



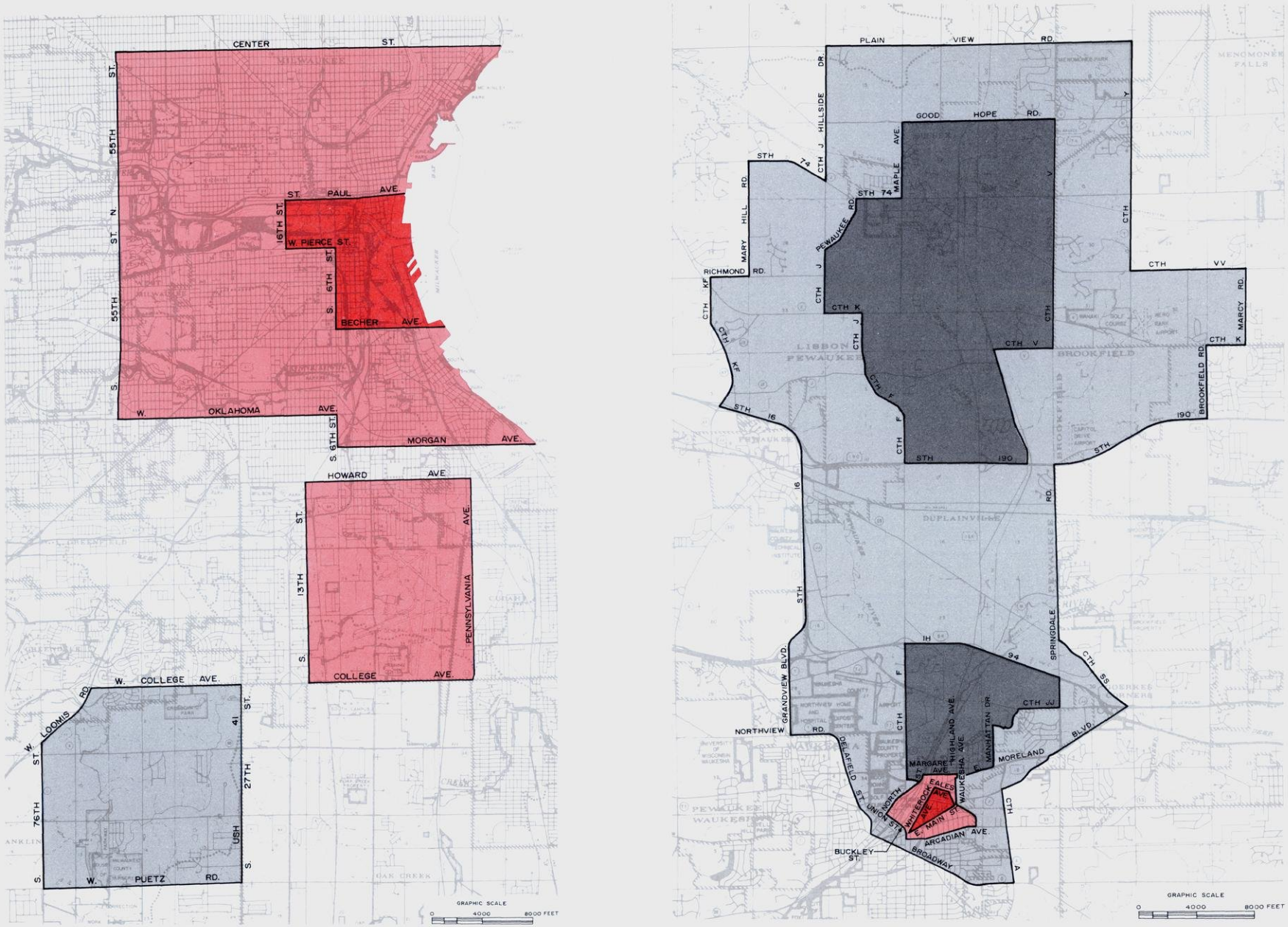
KENOSHA PROBLEM AREA



MILWAUKEE PROBLEM AREA

Map 209 (continued)

SUSSEX-WAUKESHA PROBLEM AREA



This map illustrates the location of two existing primary and five secondary particulate matter nonattainment areas in the Region as designated by the Wisconsin Department of Natural Resources. These nonattainment areas were designated on the basis of available ambient air quality monitoring data. In addition to these formally designated nonattainment areas, the simulation modeling effort of the 1977 point, area, and line source emission inventories indicates the potential for two areas in Waukesha County, encompassing a total of approximately 12 square miles, to exceed the primary annual average particulate matter ambient air quality standard of 75 micrograms per cubic meter ($\mu g/m^3$). In addition, an associated area of approximately 23 square miles is indicated as exceeding the secondary annual standard of 60 $\mu g/m^3$. The modeling effort also indicated two additional areas, one in Milwaukee County and one in Racine County—both associated with quarrying activities—that have the potential to exceed the secondary annual average particulate matter standard.

Source: SEWRPC.

5 percent silt content, visible fugitive dust emissions should be controlled to 10 percent opacity when wind speeds are less than 25 miles per hour except for three minutes in any hour, when visible fugitive emissions may equal 50 percent opacity. Any device used to control fugitive emissions from materials-handling operations that has a discharge to the ambient air should not exceed an emission limitation of 0.10 pound of particulate matter per 1,000 pounds of exhaust gas. Any device used to control fugitive emissions from industrial processes should be limited to 0.10 pound of particulate matter per 1,000 pounds of exhaust gas. Visible fugitive emissions from any building or structure opening should be controlled to 10 percent opacity except for three minutes in any hour, when fugitive emissions may equal 50 percent opacity. Visible fugitive emissions should be controlled during coking operations at the charging ports, doors, and quench towers, and during pushing operations. In general, all sources with the potential to generate airborne dust should be covered, paved, or treated in such a manner so as to reduce the fugitive emissions which may be released to the ambient air.

The plan proposes that the RACT emission limitations be applied to all existing sources of particulate matter inside the designated nonattainment areas shown on Map 209. In addition, it is recognized that there may be existing sources of particulate matter emissions lying outside the designated nonattainment areas that have an impact on air quality in the nonattainment areas. Accordingly, the RACT emission limitations should sometimes also be applied to existing sources outside the nonattainment areas. The determination of significant impact can only be made on a case-by-case basis by the implementing regulatory agency utilizing mathematical modeling techniques.[41] This determination has been completed for the Region by the Wisconsin Department of Natural Resources. The list of facilities designated in the 1979 State Implementation Plan to which the RACT emissions would apply, including all fugitive dust-emitting facilities within the nonattainment areas and all other facilities inside and outside those areas which significantly impact on those areas, is set forth in Appendix I. For all other existing sources, the plan recommends that the emissions be limited as prescribed in Chapter NR 154 of the Wisconsin Administrative Code.

Control of New or Modified Sources of Particulate Matter Emissions: New or modified sources of particulate matter emissions are defined as any new industrial process facility, fuel-burning installation, or fugitive dust source proposed after July 1, 1979. For such sources, more stringent emission limitations are proposed than those currently set forth in Chapter NR 154 of the Wisconsin Administrative Code, and in the RACT revision to that code. For those major[42] new or modified sources that are proposed to be located outside the particulate matter nonattainment areas identified on Map 209, and which have been determined on a case-by-case basis not to impact those areas significantly, the plan recommends that the federally prescribed New Source Performance Standards (NSPS) be applied. For all other categories of new or modified sources, the plan recommends that the allowable emission limitations be based upon the federally prescribed Best Available Control Technology (BACT). In addition, it should be recognized that under committed federal actions, decisions as to whether to allow new sources of particulate matter emissions are subject to the overriding considerations inherent in the regulations designed to prevent the significant deterioration of air quality in areas where the air quality standards are being met. The increments of air pollutant concentrations allowed in such "clean air" areas are set forth in Chapter II of this report.

The recommended plan proposes that new or modified sources proposed within the designated particulate matter nonattainment areas shown on Map 209, or which are proposed outside those nonattainment areas but have been determined to significantly impact on the ambient air quality in those areas, achieve the federally prescribed Lowest Achievable Emission Rate (LAER) emission limitations, which, in general, are more stringent than either RACT or BACT. In addition, the plan proposes that such sources which have a potential to exceed the "de minimis" of 10 tons of particulate matter per year after the application of LAER control technology be required to obtain at least a one-for-one emission offset from existing sources in or near the nonattainment area so that the net impact on ambient air quality in the nonattainment area is beneficial. The actual amount of such emission offsets would be determined through a negotiated agreement between the owner or operator of the proposed new or modified source and the Wisconsin Department of Natural Resources.

Intensive Ambient Air Quality Monitoring Actions: The foregoing described actions for the control of particulate matter emissions from existing and new or modified

[41] *In the analysis of a particular emission facility, a single source simulation model, rather than a multiple source model such as the Wisconsin Atmospheric Diffusion Model, is generally used to determine the air quality impact of the source. Such single source models use the Gaussian technique to predict the maximum and intermediate pollutant concentrations downwind of the facility along a predetermined centerline. A regional model, such as the Wisconsin Atmospheric Diffusion Model, uses the mass conservation technique to predict within fixed areal units, pollutant concentrations resulting from emissions from many distinct sources.*

[42] *A major source is defined as one of the 28 industrial source categories listed in Chapter II which have the potential to emit more than 100 tons of a pollutant species after the application of pollution controls, or any other source which has the potential to emit more than 250 tons of a pollutant species after the application of pollution controls.*

sources of particulate matter are considered to be fully committed. Implementation of these committed actions may be expected to yield significant reductions in particulate matter levels in the nonattainment areas of the Region. In the absence of further abatement measures, it is possible that a residual particulate matter problem will exist in parts of Milwaukee, Racine, and Waukesha Counties, as shown on Map 182. This conclusion is based on the results of the ambient air quality simulation modeling carried out under the study.

Because of the 1) significant reduction in ambient air particulate matter concentrations expected to result from implementation of the committed actions, 2) uncertainties inherent in the air quality simulation modeling, 3) uncertainties concerning the levels of long-range transport of particulate matter into the Region, and 4) uncertainties related to the actual amount of emissions released from mineral extraction operations in the Region, it was not deemed sound to place more stringent emission limitations on particulate matter sources—particularly mineral extraction operations—than prescribed under the committed actions noted above. The analyses of the simulation modeling results indicated that it was possible, in this respect, that the particulate matter ambient air quality standards will be achieved in the Region as the amounts of this pollutant species in the ambient air due to long-range transport are reduced through controls placed on upwind extraregional sources.

In light of these uncertainties, and in order to avoid unnecessarily placing further economically burdensome restrictions on particulate matter sources in the Region, the plan recommends instead that the following two ambient air quality monitoring actions be implemented:

1. A local, short-term ambient air quality monitoring effort should be undertaken to determine the level of emissions released from mineral extraction operations in the Region. Such a program should be designed to collect ambient air quality and related source-operating characteristics and weather data that will permit verification of the ambient air quality simulation efforts carried out under this study. The subareas of the Region indicated by such modeling to have a particulate matter problem are shown on Map 209. It is to these subareas of the Region that the intensive short-term monitoring efforts should be directed. Pending the results of that monitoring effort, the plan calls for no additional control actions to be taken by mineral extraction operators other than those prescribed in the committed actions.

2. An areawide special-purpose air quality monitoring effort should be undertaken to measure the particulate matter levels in the Region resulting from the long-range transport of particulate matter into the Region.

Pilot Vacuum Street Sweeping Program: One of the alternative measures considered in the study to further reduce particulate matter concentrations in the ambient air was more frequent and timely street sweeping in the heavily urbanized areas of the Region. Re-entrained road dust has been identified as a significant local source of particulate matter. Given the uncertainties noted above, however, the plan does not recommend widespread changes in municipal street sweeping programs. Rather, the plan calls for the development of a pilot vacuum street sweeping program in those portions of Milwaukee County shown on Map 187. This recommendation, possibly combined with a special ambient air quality monitoring program, is intended to permit a quantitative evaluation of the impact of such an improved street sweeping program on ambient air quality.

Cost of Particulate Matter Control Plan: It is estimated that a particulate matter emission reduction of 5,500 tons per year, or 18 percent of the 30,500 tons of total particulate matter emissions estimated to have been released into the atmosphere over the Region in 1977, can be achieved with implementation of the recommended actions. The plan recommendations would affect 64 existing facilities in the Region, eight of which are industrial point sources, and 63—including seven of the eight industrial point sources—of which are fugitive dust sources. The cost of carrying out the plan recommendations at these 64 facilities would include a one-time capital expenditure of about $31.3 million, and attendant operating costs of about $13.1 million per year. The annual cost-effectiveness of control would thus approximate $2,400 per ton of reduction in 1978 dollars. These costs do not include costs attendant to the development of the pilot vacuum street sweeping program, since the exact scope of work for such a program has not yet been defined. The costs attendant to both the local, short-term, and the areawide, long-term, particulate matter monitoring efforts are included in the cost of the recommended ambient air quality monitoring program.

Sulfur Dioxide Pollution Control Plan

Based upon analyses of available ambient air quality monitoring data and ambient air quality simulation modeling results, it was determined that action is required to provide for the attainment of the 24-hour average sulfur dioxide ambient air quality standards and for the maintenance of the three-hour average and annual average sulfur dioxide ambient air quality standards in a portion of Milwaukee County. According to the simulation modeling results, the determination of whether sulfur dioxide standards can be maintained within the Region through the year 2000 is principally dependent upon the extent of industrial source fuel conversion from natural gas to coal.

At the present time, there is not an officially designated nonattainment area for sulfur dioxide in the Region. The Wisconsin Department of Natural Resources has proposed that the U. S. Environmental Protection Agency designate a 7.4-square-mile area in Milwaukee County as a nonattainment area for sulfur dioxide, as shown on Map 85 in Chapter XI. The analyses indicated that if the actions described below for the control of sulfur dioxide emissions in the Region are fully implemented, the federal and state ambient air quality standards for sulfur dioxide will be met throughout the Region over the

planning period, given current trends in the use of natural gas and fuel oil by major industrial sources. If, however, extensive conversions from oil and natural gas to coal are made by major industrial sources, particularly in Milwaukee County, additional control actions beyond those presently foreseen may be necessary in order to maintain the sulfur dioxide ambient air quality standards. Because of the many uncertainties underlying any fuel demand and availability forecasts, the extent to which such conversions will actually occur is not presently known and cannot be reliably predicted.

The sulfur dioxide plan consists of the following committed actions: 1) designation of a nonattainment area for sulfur dioxide, and 2) application of emission control limitations to existing sources and to new sources. The plan further recommends the establishment of a regulatory framework to ultimately ban the use of coal for residential and small commercial-institutional space and water heating, and the establishment of a preferential allocation of natural gas supplies to industrial users in the Region.

Designation of Sulfur Dioxide Nonattainment Area: The plan includes as a committed action the formal designation of the sulfur dioxide nonattainment area shown on Map 85 in Chapter XI. The designation of such an area provides the basis for the establishment of Reasonably Available Control Technology (RACT) emission limitations for those existing sources of sulfur dioxide significantly impacting upon this area, and thus helps to ensure the attainment and long-term maintenance of the sulfur dioxide ambient air quality standards.

Control of Existing Sources of Sulfur Dioxide Emissions: The Wisconsin Natural Resources Board has established emission limitations for certain stationary sources of sulfur dioxide. These standards are set forth in Chapter NR 154 of the Wisconsin Administrative Code. It is important to note, however, that there are no sulfur dioxide emission limitations applicable to existing large coal-fired fuel-burning installations in the Region. There is a restriction on the sulfur content of the coal burned by installations with a heat input capacity of 250 million British Thermal Units (BTU's) per hour or less—a maximum sulfur content of 1.11 pounds per million BTU's in the coal is specified—but such a restriction does not apply to the coal burned at installations having a heat input capacity greater than 250 million BTU's per hour.

The plan assumes as a committed action that, upon designation of the sulfur dioxide nonattainment area shown on Map 85 in Chapter XI, RACT emission limitations for sulfur dioxide will be developed and applied to any existing sources inside the nonattainment area, and to any additional existing sources that may lie outside the nonattainment area but which are individually determined to have a significant impact upon air quality in the nonattainment area. In particular, such RACT emission limitations should be established for fuel-burning installations with heat input capacities greater than 250 million BTU's per hour shown to cause or contribute to violations of the ambient air standards—installations which are presently not regulated by the emission limitations or prescribed maximums for sulfur content in coal set forth in Chapter NR 154 of the Wisconsin Administrative Code.

Control of New or Modified Sources of Sulfur Dioxide Emissions: New sources of sulfur dioxide emissions would be defined as any new or modified fuel-burning installation proposed after July 1, 1979. A sulfur dioxide emission limitation of 0.80 pound per million BTU heat input is presently in effect for new or modified liquid fossil fuel-fired steam generators which have a heat input capacity greater than 250 million BTU's per hour. For those major new or modified sources that are proposed to be located outside the proposed sulfur dioxide nonattainment area identified on Map 85 in Chapter XI, and which have been determined on a case-by-case basis not to impact significantly on the nonattainment area, the plan recommends that, at a minimum, the federally prescribed New Source Performance Standards (NSPS) be applied.[43] For all other categories of new or modified sources, the plan recommends that, at a minimum, the allowable emission limitations be based upon the federally prescribed Best Available Control Technology (BACT).

The Wisconsin Department of Natural Resources should be granted the authority to require, on a case-by-case basis, emission limitations more stringent than otherwise prescribed for new or modified sources under the committed actions if extensive conversions by industry to coal use are found to cause or contribute to violations of the ambient air quality standards for sulfur dioxide. In addition, it should be recognized that under committed federal actions, decisions as to whether to allow new or modified sources of sulfur dioxide emissions are subject to the overriding considerations inherent in the regulations designed to prevent significant deterioration of air quality in areas where the air quality standards are being met. The allowable limits of air quality impact in such "clean air" areas are set forth in Table 1 in Chapter II of the report.

The recommended plan assumes as a committed action that any new or modified sources that will be built within the proposed sulfur dioxide nonattainment area shown on Map 85 in Chapter XI, or that will be built outside that area but will significantly impact upon it, will achieve the federally prescribed Lowest Achievable Emission Rate (LAER) emission limitations. Such emission limitations are more stringent than either the RACT or BACT emission limitations.

Elimination of the Use of Coal for Space and Water Heating: The analyses indicated that the use of coal as a primary fuel for residential and small commercial-institutional space and water heating, while no longer predominant throughout the Region, remains as a significant contributor to sulfur dioxide concentrations in the ambient air in the Region, particularly in Milwaukee County. Individuals and operators of small businesses

[43] *Ibid.*

have been voluntarily eliminating the use of coal for such purposes over a long period of time in favor of the use of fuel oil, natural gas, and electricity. The plan proposes that a formal ban be placed on the use of coal in Milwaukee County for new and replacement space and water heating purposes by residential and small commercial-institutional facilities; that is, residential and commercial-institutional facilities with less than one million BTU per hour heat input. It is not envisioned in the plan that steps will have to be taken to mandatorily phase out the remaining sources in Milwaukee County; however, the plan does envision an educational program which would encourage voluntary conversion from coal to an alternate fuel.

Preferential Allocation of Natural Gas: Given the energy cost and availability problem facing the nation, it is recognized that there may be increased pressures on industrial fuel-burning installations in southeastern Wisconsin in future years to convert from natural gas to coal. In order to minimize such conversions and the detrimental effect that they would have on ambient air quality and on the economy, public health, and environmental quality in the Region through the addition of new sources of sulfur dioxide emissions, the recommended plan calls for a preferential allocation of natural gas supplies by the Wisconsin Public Service Commission to industrial sources in the Region in the event that supplies are curtailed. Such a preferential allocation would assist in reducing the number of conversions to coal-burning installations and thereby contribute toward meeting the ambient air quality standards for sulfur dioxide. In addition, such allocation would serve to reduce particulate matter emissions.

Cost of the Sulfur Dioxide Control Plan: Because the sulfur dioxide plan does not recommend that specific actions be implemented by identified facilities, it is not possible at this time to estimate the cost of attaining and maintaining the ambient air quality standards for this pollutant species. For example, while the plan proposes that RACT emission limitations be applied to existing sources of sulfur dioxide emissions which lie within or significantly impact upon the proposed nonattainment area, cost estimates of compliance with such limitations cannot be made until the RACT regulations are developed and their impact upon each source known. Conversions to coal use by industrial facilities may be assumed to result from a future lack of natural gas supplies relative to the forecast demand. Such conversions as may occur, and the attendant air pollution control costs, are, therefore, assumed to result from the economic considerations of the source owner or operator and not from a specific action recommended in the sulfur dioxide plan.

Carbon Monoxide and Hydrocarbon/
Ozone Pollution Control Plan

Based upon analyses of available ambient air quality monitoring data and ambient air quality simulation modeling results, it was determined that action is required to accelerate attainment of the eight-hour average carbon monoxide ambient air quality standard for that part of Milwaukee County designated as a nonattainment area, shown on Map 83 in Chapter XI, and to provide for the attainment and maintenance of the one-hour average ozone ambient air quality standard throughout the entire seven-county Region. The carbon monoxide and ozone pollution control plans are discussed jointly because of the commonality of emission sources, and because many of the control actions recommended—particularly transportation-related control actions—have an impact on both carbon monoxide and hydrocarbon emissions. Given the current state-of-the-art, the air quality plan approaches the attainment and maintenance of the ozone standards through the control of hydrocarbon emissions, particularly those reactive hydrocarbons known as volatile organic compounds. The currently designated ozone nonattainment area in the Region is shown on Map 84 in Chapter XI. This area encompasses all of the counties in the Region except Walworth and Washington Counties. No ozone monitors have to date been located in those two counties. However, analyses conducted in the study indicate that violations of the ozone ambient air quality standard probably occur in these counties as well. Accordingly, the plan recommends that monitors be placed in these counties to confirm the study analyses. If the monitoring data reveal violations of the ozone standard, then it is recommended that the nonattainment area be extended over the entire seven-county Region.

The goal of the recommended plan for carbon monoxide is to reduce the emissions of this pollutant species from mobile sources in the near-term in order to provide for the attainment of the eight-hour average standard throughout the Region by 1982. The analyses conducted indicated that under existing control regulations, this standard will be attained and maintained subsequent to 1982 but prior to 1985.

The goal of the recommended hydrocarbon/ozone plan is to reduce the 1977 level of volatile organic compound emissions—about 102,200 tons—by 62 to 74 percent by 1987. This reduction would result in a maximum annual emission rate of between 26,600 tons and 38,800 tons. The results of the Empirical Kinetics Modeling Approach (EKMA) have indicated that such a reduction is necessary if the ozone ambient air quality standard is to be attained and maintained in the Region.

In order to meet the carbon monoxide and hydrocarbon/ozone ambient air quality standards, the recommended plan calls for: 1) control measures to reduce volatile organic compound and carbon monoxide emissions from existing stationary sources; 2) control measures to reduce volatile organic compound and carbon monoxide emissions from new stationary sources; 3) continuation of the federal motor vehicle emissions control program; 4) continued efforts toward implementation of the regional transportation plan, most importantly including the recommended transportation systems management actions; 5) establishment of an automobile inspection and maintenance program for the purpose of testing vehicle emission rates; and 6) a prohibition on the use of cutback asphalt as a paving material in the Region.

Control Measures for Existing Stationary Sources of Volatile Organic Compound and Carbon Monoxide Emissions: The Wisconsin Natural Resources Board has established emission limitations for specific classes of stationary sources of volatile organic compound and carbon monoxide emissions. These limitations are set forth in Chapter NR 154 of the Wisconsin Administrative Code. For example, the carbon monoxide emissions in the exhaust from new cupolas and basic oxygen furnaces, both of which are found in the Region, must be incinerated at 1,300° for 0.3 second. In addition, the Board has recently adopted revisions to Chapter NR 154 that provide for the imposition of more stringent emission limitations on certain existing sources of volatile organic compound emissions and has scheduled the development of such rules for additional sources. These more stringent emission limitations are based upon Reasonably Available Control Technology (RACT). The application of the RACT limitations to existing sources of volatile organic compound emissions is considered to be a committed action.

The plan proposes that the RACT emission limitations pertaining to volatile organic compounds be applied to all existing sources inside the designated five-county nonattainment area shown on Map 84 in Chapter XI. In addition, it is recognized that there may be existing sources of volatile organic compound emissions located in Walworth and Washington Counties which impact air quality in the presently designated nonattainment area. Under the rules adopted by the Natural Resources Board to date, the RACT emission limitations are to be applied to existing sources not only in the presently designated nonattainment area but also in Walworth and Washington Counties, as well as in the entire State.

Control Measures for New Stationary Sources of Volatile Organic Compound and Carbon Monoxide Emissions: New sources of volatile organic compound and carbon monoxide emissions are defined as those proposed after July 1, 1979. If the entire seven-county Region is ultimately designated as a nonattainment area for ozone, pending the results of ambient air quality monitoring in Walworth and Washington Counties, then all new or modified sources of volatile organic compound emissions should achieve the federally prescribed Lowest Achievable Emission Rate (LAER) limitations. Such emission limitations may be more stringent than the RACT emission limitations noted above. The plan recommends that the current emission limitations prescribed in Chapter NR 154 be applied to new stationary sources of carbon monoxide whether they lie within or outside the nonattainment area shown on Map 83 in Chapter XI.

Federal Motor Vehicle Emissions Control Program: The plan recognizes as a fully committed action, continued enforcement of the federal motor vehicle emissions control program for mobile sources. This program applies to all newly manufactured automobiles and trucks marketed within the United States.

Implementation of Regional Transportation Plan: The foregoing actions are all considered to be committed under existing federal and state law. The implementation of these committed actions is expected to reduce annual volatile organic compound emissions in the Region by about 59,100 tons, or nearly 58 percent—from about 102,200 tons in 1977 to about 43,100 tons in 1987. The 43,100-ton emission rate forecast for 1987, however, is about 4,300 tons, or about 11 percent, higher than the maximum allowable emission rate of about 38,800 tons per year—the rate required to attain the ozone standard. Accordingly, additional actions are recommended in the plan to address this residual problem.

One important action that can be taken to attain and maintain the carbon monoxide and hydrocarbon/ozone ambient air quality standards is implementation of the adopted regional transportation plan, particularly including those elements of the plan dealing with transportation systems management. Such transportation systems management actions consist of those measures that are designed to both improve traffic flow and reduce vehicle miles of travel. The regional transportation system plan, which is documented in SEWRPC Planning Report No. 25, A Regional Land Use Plan and a Regional Transportation Plan for Southeastern Wisconsin: 2000, and SEWRPC Community Assistance Planning Report No. 26, A Transportation Systems Management Plan for the Kenosha, Milwaukee, and Racine Urbanized Areas in Southeastern Wisconsin: 1979, includes a set of coordinated, mutually reinforcing, transportation systems management actions which have been identified as having the greatest potential for reducing carbon monoxide and volatile organic compound emissions from motor vehicles. These were carefully reviewed by the Technical Coordinating and Advisory Committee and recommended for inclusion in the plan. Of particular importance are the following measures as identified in the transportation plan: 1) implementation of a freeway traffic management system; 2) conduct of an extensive and ongoing carpool/vanpool formation promotional campaign; 3) development of additional park-ride and park-and-pool lots; and, most importantly, 4) extensive short-term and long-term improvements in public transit service. Analyses conducted under the air quality program indicate that full implementation of the adopted transportation plan, when considered as a supplement to the committed actions noted above, will reduce volatile organic compound emissions in the Region to about 42,700 tons by 1987 and to about 48,100 tons by the year 2000, reductions of about 58 and 53 percent, respectively, from the 1977 level of 102,200 tons. These forecast emission levels, however, remain in excess of the maximum allowable emission rate of 38,800 tons per year.

Given full implementation of the adopted transportation plan, carbon monoxide emissions in 1982 would be reduced by about 8,300 tons, or about 2 percent—from the 355,000 tons forecast from mobile sources in the Region in 1982 to 346,700 tons. Although this reduction is relatively small, its impact would be most significant in the most intensely urbanized areas of the Region, particularly in areas of high travel demand within the carbon monoxide nonattainment area, shown on Map 83 in

Chapter XI. Implementation of the adopted transportation plan would, therefore, accelerate attainment of the eight-hour average carbon monoxide ambient air quality standard in the Region to the year 1982. Given the impact of the federal motor vehicle emissions control program and of continued regional transportation plan implementation, maintenance of the ambient air quality standard through the year 2000 should be readily achievable.

Vehicle Inspection and Maintenance Program: In order to ensure that the emission control equipment now being required on automobiles and light-duty trucks under the federally mandated pollution control program is properly maintained, the plan recommends that a vehicle inspection and maintenance (I/M) program be established. Under this program, all automobiles and light-duty trucks registered in the seven-county Southeastern Wisconsin Region that are less than 15 years of age at the time of inspection—that is, all automobiles and light-duty trucks on which federally mandated pollution control equipment has been installed—would be tested annually to ensure that their vehicle emission rate does not significantly exceed federally mandated exhaust emission standards. It is recommended that the I/M program be conducted at a number of strategically located testing stations, and that the exhaust emissions test be established with a 20 percent stringency standard. The stringency standard is a measure of the percent of vehicles which may be expected to fail the initial test.

Implementation of the I/M program as specified, when considered as a supplement to the committed actions and implementation of the adopted transportation plan, is expected to reduce the volatile organic compound emissions in the Region to about 38,500 tons by 1987, and to about 41,900 tons by the year 2000. Accordingly, attainment of the ozone ambient air quality standard may be expected to be achieved by 1987.

Prohibition on the Use of Cutback Asphalt: While the analyses indicated that the above-noted actions would likely result in the achievement of the ozone ambient air quality standard by 1987, the continued maintenance of this standard is not expected because of anticipated regional growth and development. Accordingly, the recommended plan calls further for a prohibition on the use of cutback asphalt as a paving material in southeastern Wisconsin. Cutback asphalt can be replaced by bituminous plant mix or asphalt emulsions. Prohibiting the use of cutback asphalt is expected to yield an annual reduction in volatile organic compound emissions in the Region of about 3,800 tons. As a supplement to the aforementioned committed and recommended actions, implementation of a ban on the use of cutback asphalt is expected to reduce volatile organic compound emissions in the Region to about 34,700 tons and 38,100 tons in the years 1987 and 2000, respectively. Thus, the attainment and maintenance of the ozone ambient air quality standard may be anticipated over the entire planning period if all of the committed and recommended actions are fully implemented.

Cost of the Carbon Monoxide and Hydrocarbon/Ozone Plan: Most of the costs of the recommended carbon monoxide and hydrocarbon plan element are attributable to the recommended RACT controls on stationary sources for the control of volatile organic compound emissions, and to the establishment and operation of the vehicle I/M program. The cost of continued implementation of the federal vehicle emissions control program is borne as part of the cost of purchasing new vehicles and is not considered a "new" cost for the purposes of this plan. Similarly, the cost of implementation of the regional transportation plan is not considered a new cost since the plan was prepared primarily to improve transportation service, and not air quality. The cost of the transportation plan has been documented in other Commission reports and is not included here.

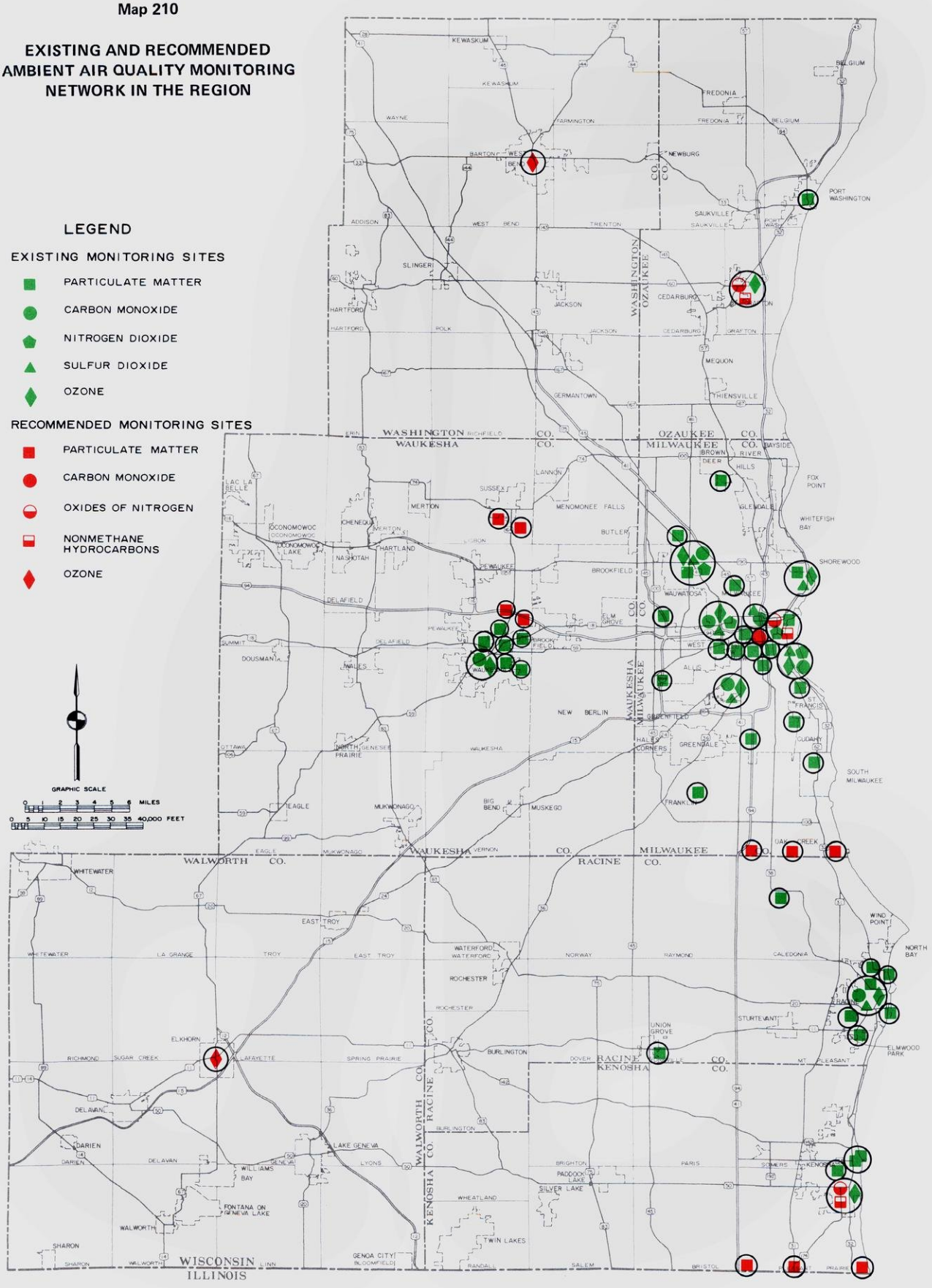
In total, about 6,200 facilities would be affected by implementation of the proposed RACT emission limitations. Of this total, about 4,500 facilities are solvent metal cleaning operations and about 1,200 are gasoline service stations. The cost of carrying out the plan recommendations at these 6,200 facilities includes a one-time capital expenditure of about $32.2 million and attendant operating costs of about $7.6 million per year in 1978 dollars. The capital cost of this reduction would approximate $1,000 per ton, and the annual cost-effectiveness of control would approximate $237 per ton of reduction.

The total cost of implementing the vehicle I/M program would approximate $11.5 million annually. This cost consists of an estimated $6.8 million annually to cover the cost of building, operating, and maintaining the necessary testing stations, and $4.7 million annually to be incurred by vehicle owners to repair vehicles which fail the test. Thus, the estimated cost of the proposed reduction is $2,740 per ton.

Recommended Ambient Air Quality Monitoring Network The regional air quality attainment and maintenance plan recommends the continued operation of the existing ambient air quality monitoring network in the Region, and proposes that such operation be expanded and adjusted in the manner described below. The existing and proposed network is summarized on Map 210. In 1978 there were 37 ambient air quality monitors in operation within the Region certified by the Wisconsin Department of Natural Resources (DNR) that gathered data on particulate matter: three monitors in Kenosha County, 19 monitors in Milwaukee County, one monitor in Ozaukee County, eight monitors in Racine County, and six monitors in Waukesha County. There were seven DNR-certified monitors gathering data on sulfur dioxide: six in Milwaukee County and one in Racine County. There were also seven DNR-certified monitors gathering data on carbon monoxide: five in Milwaukee County, one in Racine County, and one in Waukesha County. There were four DNR-certified monitors gathering data on nitrogen dioxide, all in Milwaukee County. And finally, there were nine DNR-certified monitors gathering data on ozone: one in Kenosha County, five in Milwaukee County, one in Ozaukee County, one in Racine County, and one in Waukesha County. The plan recommends that

Map 210

EXISTING AND RECOMMENDED AMBIENT AIR QUALITY MONITORING NETWORK IN THE REGION



This map illustrates the ambient air quality monitoring network in the Region in 1978 and the recommended monitoring network. In 1978 there were 37 particulate matter, seven sulfur dioxide, seven carbon monoxide, four nitrogen dioxide, and nine ozone monitors in operation in the Region. The recommended monitoring network consists of 10 additional particulate matter monitors to measure the long-range transport of particulate matter into the Region and to verify the results of the air quality simulation modeling efforts associated with quarrying operations in the Region. The placement of one additional carbon monoxide ambient air quality monitor in the area of the Marquette Interchange in Milwaukee County is recommended in order to verify the simulation modeling results which indicate high carbon monoxide concentrations in that area. Three additional nitrogen oxide monitors and three additional nonmethane hydrocarbon monitors are recommended in order to access the concentrations of these compounds in terms of both transport from extraregional sources and local contributions. The placement of an ozone monitor in both Walworth and Washington Counties is recommended in order to verify air quality simulation modeling results that indicate the existence of an ozone problem in these two counties and to provide a basis for implementation of the recommended vehicle inspection and maintenance program throughout the Region.

Source: SEWRPC.

operation of all of these monitors be continued, recognizing that it may be desirable from time to time to change the precise location and orientation of the monitoring equipment.

The plan also recommends that the following special ambient air quality monitoring efforts be undertaken:

1. The placement of six high-volume particulate gravimetric samplers, as shown on Map 210, along east-west areas near the Lake Michigan shoreline in Kenosha and Milwaukee Counties for the purpose of measuring the long-range transport of particulate matter.

2. The placement of from two to four high-volume particulate gravimetric samplers around at least one major quarrying operation in the Region for the purpose of verifying the air quality simulation modeling results. This effort is intended to be of short-term duration.

3. The placement of such additional particulate matter monitors as may be found to be necessary to adequately assess the impacts of the proposed pilot vacuum street sweeping program in Milwaukee County.

4. The placement of an additional carbon monoxide ambient air quality monitor in the area of the Marquette Interchange in Milwaukee County in order to assess the simulation modeling results which indicate that this area presently experiences, and may be expected to continue to experience, the highest carbon monoxide concentrations in the Region, and to measure further progress toward attainment of the eight-hour average carbon monoxide ambient air quality standard.

5. The placement of air quality monitors for nitrogen oxides and nonmethane hydrocarbons near the Illinois/Wisconsin state line in Kenosha County, in or near the central business district of the City of Milwaukee, and downwind of the Milwaukee urbanized area in Grafton in Ozaukee County, as shown on Map 210, so that additional data can be gathered during the ozone season on the concentrations of these compounds, in terms of both the transport of such compounds from extra-regional sources and the local contributions. Such data are required as input to the Empirical Kinetics Modeling Approach.

6. The placement of monitors for ozone in Walworth County and in Washington County, as shown on Map 210, in order to confirm air quality simulation data that indicate the existence of an ozone problem in such counties, and to provide a basis for the implementation of the recommended vehicle inspection and maintenance program throughout the Region.

It is recommended that all existing monitoring sites be reviewed so as to ensure conformance with the U. S. Environmental Protection Agency (EPA)-prescribed siting requirements. In addition, care should be taken to minimize sampling error as may result from passive filter loading, excessive volume sampling rates, and source-oriented sampler exposure, particularly with regard to the existing and recommended high-volume particulate gravimetric monitors. It is, therefore, recommended that the exposed filters used in monitoring particulate matter be removed for analysis within one day of the sampling period; that such monitors operate at the minimum EPA-approved volume sampling rate; that the orientation of such monitors in relation to local emission sources be duly recorded; and that the new monitors established to assess long-range transport be operated on an every-other-day basis during the ozone season.

The cost of operating the ambient air quality monitoring network in the Region during 1979—the latest year for which data are available—was approximately $350,000, excluding the capital costs for monitoring instruments. It is estimated that a one-time capital cost of $83,700 will be required for the special ambient air quality monitoring efforts recommended under the plan. In addition, there will be an average annual operation and maintenance cost for such efforts over a probable five-year period of $27,800. These costs would be in addition to those already being incurred for the establishment and maintenance of the existing ambient air quality monitoring network described above.

CONCLUSION

The recommended air quality attainment and maintenance plan set forth in this chapter represents the results and findings of extensive analyses of existing and probable future air pollution levels in the Southeastern Wisconsin Region. The recommended plan as described herein presents a course of action for abating air pollution problems utilizing the latest state-of-the-art in analytical tools. The committed and recommended measures that should be taken to achieve the attainment and maintenance of the ambient air quality standards in the Region are presented in Table 361. Because of the dynamic nature of the air quality planning process, modifications to the plan should be expected as the state-of-the-art of air quality planning advances and as additional ambient air quality monitoring data are obtained. The mechanisms to be used in implementing the recommended plan are presented in the following chapter.

Table 361

SUMMARY OF ACTIONS CONTAINED IN THE RECOMMENDED AIR QUALITY ATTAINMENT AND MAINTENANCE PLAN

Type of Action	Particulate Matter Plan	Sulfur Dioxide Plan	Carbon Monoxide and Hydrocarbon/Ozone Plan	Ambient Air Quality Monitoring Network Plan
Committed	● Apply emission limitations to existing and new sources - Fuel-burning installations - Industrial processes - Industrial fugitive dust sources ● Apply Reasonably Available Control Technology to existing sources - Fuel-burning installations - Industrial processes - Industrial fugitive dust sources	● Apply emission limitations to small existing point sources and to new sources, and place sulfur limits on standby fuel ● Designate part of Milwaukee County as a nonattainment area ● Establish Reasonably Available Control Technology emission limitations for existing sources of sulfur dioxide emissions which lie within or impact upon the nonattainment area ● Require new or modified sources of emissions which lie within, or impact upon, the nonattainment area to obtain an emissions offset from other sources of sulfur dioxide emissions in the area	● Apply emission limitations or solvent substitutions to specified existing and new process sources ● Apply Reasonably Available Control Technology to specified existing stationary sources of volatile organic compound emissions ● Implement the federal motor vehicle emissions control program	● Maintain existing ambient air quality monitoring network
Proposed Additions to the State Implementation Plan	● Adopt and enforce New Source Performance Standards and Prevention of Significant Deterioration Regulations for new or modified sources ● Establish and enforce an emission offset policy for new or modified stationary sources after the application of Lowest Achievable Emission Rate control technology ● Conduct special-purpose ambient air quality monitoring programs related to mineral extraction operations and to long-range transport of particulate matter	● Adopt and enforce New Source Performance Standards and Prevention of Significant Deterioration Regulations for new or modified stationary sources ● Ban the use of coal for residential and small commercial-institutional space and water heating in Milwaukee County, allowing for voluntary phase-out of such existing uses	● Adopt and enforce Lowest Achievable Emission Rate technology for new or modified stationary sources of volatile organic compound emissions and continue to abide by carbon monoxide regulations in Chapter NR 154 of the Wisconsin Administrative Code ● Implement adopted regional transportation plan with its associated transportation systems management actions ● Establish a vehicle inspection and maintenance program in southeastern Wisconsin ● Prohibit the use of cutback asphalt as a paving material in southeastern Wisconsin	● Locate and operate six special-purpose particulate matter samplers for the purpose of monitoring long-range transport ● Locate and operate two to four special-purpose particulate matter samplers around at least one major quarrying operation for the purpose of verifying computer simulation modeling results ● Locate and operate special-purpose particulate matter samplers as necessary to adequately assess the impact of the proposed pilot vacuum street sweeping program in southeastern Wisconsin ● Locate and operate a special-purpose carbon monoxide sampler in the area of the Marquette Interchange in Milwaukee County to verify computer simulation modeling results and to measure progress toward attainment of the ambient air quality standards ● Locate and operate special-purpose monitors for nitrogen oxides and nonmethane hydrocarbons near the Illinois/Wisconsin border in Kenosha County, in or near the central business district of the City of Milwaukee, and downwind of the Milwaukee urbanized area in Ozaukee County ● Locate and operate special-purpose ozone monitors in Walworth and Washington Counties for the purpose of establishing attainment or nonattainment of the ambient air quality standards
Other Recommended Actions	● Establish a pilot vacuum street sweeping program in parts of Milwaukee County	● Preferentially allocate natural gas supplies to industries in or significantly impacting upon a nonattainment area in southeastern Wisconsin in the event of statewide shortages in order to minimize coversions to coal	--	--
Costs (millions of dollars)	Private Sector Capital—$31.3 Operation and Maintenance—$13.1 Public Sector Capital—[a] Operation and Maintenance—[a]	Private Sector[b] Public Sector[b]	Private Sector Capital—$32.2 Operation and Maintenance—$12.2[c] Public Sector Capital - - Operation and Maintenance—$11.5	Private Sector - - Public Sector Capital—$0.0837 Operation and Maintenance—$0.0278

[a] *Cost to the public sector will be incurred as a result of the recommended pilot vacuum street sweeping program. The exact costs will depend on the scope of work undertaken in this study.*

[b] *Costs associated with the sulfur dioxide plan will depend on the level of control defined by the Wisconsin Department of Natural Resources as being RACT.*

[c] *Includes $7.5 million for operating and maintaining control equipment on stationary sources, and an estimated $4.7 million to be incurred by vehicle owners for the repair of vehicles failing the emissions inspection test.*

Source: SEWRPC.

Chapter XIV

PLAN IMPLEMENTATION

INTRODUCTION

The recommended regional air quality attainment and maintenance plan for the seven-county Southeastern Wisconsin Region as described in the preceding chapter of this report provides a design for the near-term attainment and the long-term maintenance of the established federal and state ambient air quality standards. These standards are set forth in Table 57 of Chapter VI of this report. The recommended plan is comprised of four major elements: a particulate matter pollution control plan, a sulfur dioxide pollution control plan, a carbon monoxide and hydrocarbon/ozone pollution control plan, and recommendations for a continuing and expanded ambient air quality monitoring effort. For the first three of these major plan elements, recommendations are set forth concerning the appropriate actions to be followed to ensure, to the extent practicable given the state-of-the-art of air quality planning and the available ambient air quality monitoring data, the attainment and maintenance of the ambient air quality standards applicable to the identified pollutant species. For the fourth major element, the recommendations concern the development of an ambient air quality monitoring network that would help verify the analyses conducted under the study, provide the basis for future air quality simulation modeling and analyses, and provide bench mark data necessary to measure progress toward achieving and maintaining the ambient air quality standards. While the recommended plan is designed to attain and maintain the ambient air quality standards, the plan is not complete in a practical sense until the steps required to implement the plan—that is, to convert the plan into action policies and programs—are specified.

Accordingly, this chapter is intended as a guide for use in implementing the recommended regional air quality attainment and maintenance plan. The chapter outlines the activities which must be taken by the various levels and agencies of government concerned if the objectives of the recommended plan are to be realized. Those units and agencies of government which have plan adoption and plan implementation powers applicable to the recommended regional air quality attainment and maintenance plan are identified; desirable formal plan adoption actions are specified; and specific implementation actions for each of the units and agencies of government concerned are recommended.

To the maximum extent possible, the plan implementation recommendations are based upon, and related to, existing governmental programs and are predicated upon existing enabling legislation. However, because of the ever-present possibility of unforeseen changes in economic conditions, energy demand and availability, state and federal legislation, case law decisions, governmental organization, and fiscal policies, it is not possible to declare the precise manner in which the regional air quality attainment and maintenance plan implementation process should be administered throughout the full planning period. Consequently, changes over time in the means of plan implementation may be expected.

While the recommendations set forth in this chapter are addressed exclusively to the public sector, it is recognized that concerned citizens—both individual and corporate—and environmental interest groups have important functions in the effort to achieve and maintain clean ambient air in the Region. The principal and underlying reason for a public participation program is to provide a mechanism for ensuring that the goals of the air quality planning program are actively supported and endorsed. It is envisioned that the active support and continuing participation of these concerned citizens and interest groups will facilitate the implementation of the recommended plan elements, and thereby aid in achieving the goal of clean, safe, and healthful air in the Southeastern Wisconsin Region.

PLAN IMPLEMENTATION ORGANIZATIONS

Although the Regional Planning Commission can promote and encourage plan implementation in various ways, the advisory role of the Commission makes actual implementation of the recommended regional air quality attainment and maintenance plan entirely dependent upon actions by certain local, state, and federal agencies of government. Except for implementation of those recommendations contained in the adopted regional land use and transportation plans as those plan recommendations may affect ambient air quality, relatively few units and agencies of government are directly involved in implementation of the regional air quality attainment and maintenance plan. All of the agencies needed for implementation of the plan are already in existence. Consequently, the creation of new agencies for plan implementation is not presently envisioned.

Technical Coordinating and Advisory Committee on Regional Air Quality Planning

Since planning at its best is a continuing function, a public body should remain on the scene to coordinate and advise on the execution of the regional air quality attainment and maintenance plan, and should undertake plan updating and modifications as may be necessitated by changing events. Although the Regional Planning Commission is charged with and will perform this continuing areawide air quality planning function in cooperation with the Wisconsin Departments of Natural Resources and Transportation and the U. S. Environmental Protection Agency, it cannot do so properly without the active participation and support of citizens and governmental

officials through an appropriate advisory committee structure. Accordingly, it is recommended that the Technical Coordinating and Advisory Committee on Regional Air Quality Maintenance Planning be reconstituted as the Technical Coordinating and Advisory Committee on Regional Air Quality Planning to provide a focus for the coordination of the execution of the regional air quality attainment and maintenance plan. This Committee would remain as an advisory committee to the Southeastern Wisconsin Regional Planning Commission, pursuant to Section 66.945(7) of the Wisconsin Statutes, and would report directly to the Commission. It is recommended that all agency representatives and individuals currently serving on the Committee remain as members of the continuing Committee, and that the question of Committee membership be left open so that additional members may be added as appropriate. Among other duties, it is envisioned that the reconstituted Committee would meet as necessary, desirably at least once each year, to review progress toward implementation of the recommended plan, as well as the need for amendatory action dictated by future events.

Local Level Agencies

Local level agencies consist of county, city, village, and town governments. Except for the implementation responsibilities specified in the adopted regional land use and transportation plans, such local level agencies have few direct responsibilities with regard to implementation of the regional air quality attainment and maintenance plan. Responsibility for the implementation of the latter plan rests largely with state and federal agencies.

However, implementation of that portion of the air quality plan that relies upon implementation of the regional transportation plan to meet ambient air quality standards for carbon monoxide and hydrocarbon/ozone is largely the responsibility of local agencies and units of government. For example, those recommendations of the regional transportation plan relating to improving levels of public transit service to reduce reliance on private vehicles are the direct responsibility of the public transit operators in the Region—namely, at the current time, the Cities of Kenosha and Racine and the Counties of Milwaukee and Waukesha. Those local units and agencies of government involved in implementing the regional transportation plan are identified in companion Commission documents, and will not be specified here.[1]

[1] *For a complete listing of the agencies and units of government involved in the implementation of the regional land use and transportation plans, see Chapter IX of SEWRPC Planning Report No. 25, A Regional Land Use Plan and a Regional Transportation Plan for Southeastern Wisconsin: 2000, Volume Two, Alternative and Recommended Plans, and Chapter IX of SEWRPC Community Assistance Planning Report No. 21, A Transportation System Management Plan for the Kenosha, Milwaukee, and Racine Urbanized Areas in Southeastern Wisconsin: 1979.*

It should be noted that to date, only one local unit of government in the Region—Racine County—currently has an air quality management program. The major emphasis of this program, which is reviewed and approved annually by the Wisconsin Department of Natural Resources and the U. S. Environmental Protection Agency, is on ambient air quality monitoring through data collection and analysis, and on air quality program enforcement, including compliance and prosecution activities. The program also includes a public information and awareness component. The program is funded primarily by monies appropriated by Racine County, supplemented by federal grants.

State Level Agencies

At the state level, the following agencies perform functions that are important to adoption and implementation of the regional air quality attainment and maintenance plan.

Wisconsin Department of Natural Resources: As described in some detail in Chapter III of this report, primary responsibility for air quality monitoring and air pollution control in Wisconsin rests with the Wisconsin Department of Natural Resources which is governed by a seven-member Natural Resources Board. The basic authority and accompanying responsibilities of the Department relating to pollution control are set forth in Section 144.31(1) and (2) of the Wisconsin Statutes as effected by Chapter 34, Laws of 1979. Under this section, the Department is given broad authority to prepare, revise, and implement comprehensive plans for the prevention, abatement, and control of air pollution; conduct studies, investigations, and research relating to air pollution; adopt, amend, and repeal rules and regulations pertaining to air pollution control; and enforce air quality-related statutes, rules, and regulations by appropriate administrative and judicial proceedings. The Department has been designated as the agency responsible for preparing the federally required State Implementation Plan for Air Quality, which is the primary vehicle by which the U. S. Environmental Protection Agency ensures that appropriate steps are being taken to attain and maintain the ambient air quality standards.

Wisconsin Department of Transportation: The Wisconsin Department of Transportation is authorized to provide the State with an integrated transportation system and to assist in the preservation and improvement of public transit systems within the State. As such, the Department has important responsibilities in implementation of the adopted regional transportation plan.

Wisconsin Public Service Commission: The Wisconsin Public Service Commission is responsible for the regulation of public utilities. As such, the Commission is responsible for emergency resource management with regard to natural gas and electric power. Because of the importance of such resource management, in particular the management of scarce fuels, the Commission could potentially have an important function in achieving and maintaining the ambient air quality standards. Accordingly, it is appropriate that certain plan recommendations be addressed to this Commission.

Federal Level Agencies

At the federal level, the following agencies perform functions that are important to adoption and implementation of the regional air quality attainment and maintenance plan.

U. S. Environmental Protection Agency: Responsibility for air quality matters at the federal governmental level is concentrated in the U. S. Environmental Protection Agency (EPA). The EPA is authorized to establish ambient air quality standards; establish emission standards for attainment of the ambient air quality standards; conduct research pertaining to the prevention and control of air pollution; monitor the actions of states toward the attainment and maintenance of ambient air quality standards through the review and approval of state implementation plans; promulgate air quality-related policies, such as emission offset policies for areas not attaining ambient air quality standards and prevention of significant deterioration policies for areas currently meeting such standards; and regulate the air quality monitoring system throughout the United States. As such, the EPA is the central federal agency for all air quality planning and regulatory efforts.

U. S. Department of Transportation: The role of the U. S. Department of Transportation in air quality planning is a supporting one, focused largely on providing the financial resources needed by local units of government to implement those transportation system improvement and management actions recommended in transportation plans that have significant, beneficial air quality impacts. Of particular importance in this regard are the various federal aid programs administered by the Federal Highway Administration and the Urban Mass Transportation Administration, aid programs that have become essential for carrying out the transportation system management actions contained in the transportation plans for metropolitan areas.

Regional Planning Commission

The Southeastern Wisconsin Regional Planning Commission has no statutory plan implementation powers. However, in its role as a coordinating agency for planning and development activities within southeastern Wisconsin, and in particular in its role as the metropolitan transportation planning organization for the Region, the Commission helps to implement the regional air quality attainment and maintenance plan. In addition, the Commission provides a basis for the continued existence and support of the Technical Coordinating and Advisory Committee on Regional Air Quality Planning. Importantly, the Commission should continue to conduct, in cooperation with the various local, state, and federal agencies concerned, the continuing regional land use-transportation-air quality planning programs. This program should provide for the periodic reassessment of the regional land use, transportation, and air quality plans, focusing on the need to adjust and modify such plans as may be necessary in light of actual progress toward attaining and maintaining the ambient air quality standards.

PLAN ADOPTION AND INTEGRATION

Upon adoption of the regional air quality attainment and maintenance plan by formal resolution of the Southeastern Wisconsin Regional Planning Commission, in accordance with Section 66.945(10) of the Wisconsin Statutes, the Commission will transmit a certified copy of the resolution adopting the plan, together with a copy of the plan itself, to all local legislative bodies within the Southeastern Wisconsin Region and to all of the state and federal agencies that have been identified herein as having plan implementation functions. Adoption, endorsement, or formal acknowledgment of the regional air quality attainment and maintenance plan by the local legislative bodies and by the state and federal agencies concerned is highly desirable, if not essential, if a common understanding is to be reached among the several governmental levels, and if their staffs are to program the necessary plan implementation work. As a part of the adopting or endorsing action, the policy-making body or individual of the designated unit or agency should direct its staff to fully integrate the regional air quality attainment and maintenance plan elements into the plans and programs of that unit or agency of government. Adoption of the regional air quality attainment and maintenance plan by any unit or agency of government can pertain only to the statutory duties and functions of the adopting agencies, and such adoption does not and cannot preempt or commit any action by another unit or agency of government acting within its own area of functional and geographic jurisdiction.

Local Level Agencies

1. It is recommended that the seven County Boards of Supervisors in the Region formally adopt the regional air quality attainment and maintenance plan by resolution, pursuant to Section 66.945(12) of the Wisconsin Statutes, after a report and recommendation by appropriate committees and commissions. A model resolution for plan adoption is set forth in Appendix J.

2. It is recommended that the Common Councils of the Cities of Kenosha and Racine, and the governing bodies of any other cities, villages, or towns which may in the future undertake the provision of public mass transit services, formally adopt the regional air quality attainment and maintenance plan by resolution, pursuant to Section 66.945(12) of the Wisconsin Statutes, after a report and recommendation by appropriate committees and commissions. In addition, it is recommended that the Common Council of the City of Milwaukee formally adopt the plan because of the particularly important transportation systems management responsibilities of the City relating to air quality management in the central area of Milwaukee County.

State Level Agencies

1. It is recommended that the Wisconsin Natural Resources Board endorse the regional air quality

attainment and maintenance plan and direct its staff in the Wisconsin Department of Natural Resources to integrate the plan recommendations into future and continuing revisions of the State Implementation Plan for Air Quality required under federal legislation. The State Implementation Plan should be one of the primary mechanisms through which the regional air quality attainment and maintenance plan is implemented.

2. It is recommended that the Wisconsin Department of Transportation endorse the regional air quality attainment and maintenance plan and utilize the plan recommendations as a frame of reference for the initiation of a vehicle inspection and maintenance program and for the review and funding of transportation system improvement and management actions which are found to have significant air quality benefits.[2]

3. It is recommended that the Wisconsin Public Service Commission formally acknowledge the regional air quality attainment and maintenance plan and utilize the plan recommendations in making decisions in future years concerning the allocation of scarce natural gas resources.

Federal Level Agencies

1. It is recommended that the U. S. Environmental Protection Agency formally acknowledge the regional air quality attainment and maintenance plan and utilize the plan recommendations in the performance of its broad range of responsibilities in air quality management.

2. It is recommended that the U. S. Department of Transportation, Federal Highway Administration and Urban Mass Transportation Administration, formally acknowledge the regional air quality attainment and maintenance plan and utilize the plan recommendations in its administration of highway and transit aid programs, giving particular attention to those transportation improvement and management measures which are found to have significant air quality benefits.

SUBSEQUENT ADJUSTMENT OF THE PLAN

No plan can be permanent in all of its aspects or precise in all of its elements. The very definition and characteristics of areawide planning suggest that an areawide plan, to be viable and of use to local, state, and federal units and agencies of government, must be periodically adjusted through formal amendments, extensions, additions, deletions, and refinements to reflect changing conditions. This is particularly true in the field of air quality planning, where the state-of-the-art is imprecise and in its relative infancy and where improvements in the planning process and in ambient air quality monitoring can be expected in future years. Amendments, extensions, and additions and deletions to the plan can be expected to be forthcoming, not only from the Commission under the continuing regional land use-transportation-air quality planning program, but also from state agencies as they adjust and refine statewide plans and programs and from federal agencies as national policies are established or modified, as new programs are created, or as existing programs are expanded or curtailed. Adjustments must also come from local planning programs that of necessity must be prepared in greater detail and may be expected to result in refinements to the plan. This is particularly true of the transportation system management elements of the plan.

All of these adjustments and refinements will require the cooperation of the local, state, and federal units and agencies of government concerned, as well as coordination by the Southeastern Wisconsin Regional Planning Commission, which has been empowered under Section 66.945(8) of the Wisconsin Statutes to act as a coordinating agency for planning programs and activities of the local units of government. To achieve this coordination among local, state, and federal programs most effectively and efficiently and, therefore, to ensure the timely adjustment of the regional air quality attainment and maintenance plan, it is recommended that all of the local, state, and federal agencies having various planning and plan implementation powers transmit all relevant subsequent planning studies, plan proposals, and proposed regulations to the Southeastern Wisconsin Regional Planning Commission. The Commission shall consider all such studies, proposals, and regulations for integration into and, as may be needed, adjustment of the regional air quality attainment and maintenance plan. Of particular importance in this respect will be the continuing role of the Technical Coordinating and Advisory Committee on Regional Air Quality Planning, which will be responsible for reviewing all proposed plan modifications and amendments.

PARTICULATE MATTER POLLUTION CONTROL PLAN IMPLEMENTATION

As outlined in the preceding chapter of this report, the particulate matter control plan consists of measures to control emissions from existing sources and new or modified sources of particulate matter, a particulate matter air quality monitoring effort, and a pilot vacuum street sweeping program in portions of Milwaukee County.

Control of Particulate Matter Emissions from Existing Sources

The Wisconsin Department of Natural Resources has adopted amendments to Chapter NR 154 of the Wisconsin Administrative Code that define Reasonably Available Control Technology (RACT) and require such technology to be applied to certain existing sources of particulate matter. It is recommended that the Depart-

[2] *Recently proposed legislation would place the responsibility for carrying out the necessary automobile inspection and maintenance program with the Wisconsin Department of Transportation as herein recommended. See 1979 Assembly Bill No. 500.*

ment establish compliance schedules for affected facilities in the Region. In addition, it is recommended that the Department continue to enforce the particulate matter emission limitations and related regulations set forth in Chapter NR 154 that would apply to all remaining sources of particulate matter emissions in the Region and not affected by the RACT limitations.

Control of Particulate Matter Emissions from New or Modified Sources

At the present time, the Wisconsin Department of Natural Resources has regulatory authority over new or modified sources of particulate matter which are located in, or significantly impact upon, nonattainment areas in the Region. This authority requires that the Wisconsin Department of Natural Resources establish regulations to provide for the attainment and maintenance of particulate matter ambient air quality standards within designated particulate matter nonattainment areas in the Region. These regulations would include a determination of the Lowest Achievable Emission Rate (LAER) on a facility-by-facility basis as major sources are proposed for construction or modification. In addition, this authority requires that rules pertaining to an emission offset policy be established, and that any other major sources in the area owned or controlled by an applicant meet or be scheduled to meet the emission limitations specified by the Wisconsin Department of Natural Resources.

Although the Wisconsin Department of Natural Resources presently has review authority for new or modified sources in clean air areas in the Region, the U. S. Environmental Protection Agency retains separate authority to issue new source or modification permits in clean air areas under Prevention of Significant Deterioration (PSD) regulations. Therefore, it is recommended that the U. S. Environmental Protection Agency delegate to the Wisconsin Department of Natural Resources the authority to issue PSD permits in clean air areas in the Region. This would require that the Wisconsin Administrative Code be modified to reflect the recently revised federal New Source Performance Standards (NSPS), and that the Best Available Control Technology (BACT) be installed on a facility-by-facility basis on those sources not subject to NSPS as well as on any new or modified sources subject to PSD requirements. Revisions to the code would also have to account for the protection of increments of pollution allowable under the federally prescribed rules pertaining to the prevention of significant deterioration of clean air. In addition, the Department should establish rules which require the applicant to analyze the air quality impacts of the proposed new source construction or modification and demonstrate preservation of the air quality increments. The rules should also require the applicant to do pre- and post-construction air quality monitoring.

Particulate Matter Air Quality Monitoring Actions

The plan recommends that two intensive particulate matter ambient air quality monitoring efforts be undertaken one to measure particulate matter emissions from mineral extraction operations in the Region and the other to measure particulate matter emissions resulting from the long-range transport of particulate matter into the Region. It is recommended that these two special air quality monitoring efforts, together with additional air quality monitoring actions described below, be carried out by the Wisconsin Department of Natural Resources, and that such efforts conform with the procedural recommendations set forth in Chapter XIII, as well as with the standard specifications and requirements for air quality monitoring promulgated by the U. S. Environmental Protection Agency.

Pilot Vacuum Street Sweeping Program

The recommended plan calls for the conduct of a pilot vacuum street sweeping program within the central portion of Milwaukee County. Because of the various jurisdictions involved in the maintenance of the arterial highway system, several units and agencies of government will be involved in the conduct of this effort. It is recommended that the Wisconsin Department of Transportation act as the lead public agency in undertaking this pilot effort. It is recommended that this Department prepare a study design outlining the scope of the pilot effort, including a determination of a precise study area, and setting forth a recommended time schedule and budget for the effort. The preparation of this study design should be guided by a special technical advisory committee created by the Department for this purpose. This technical advisory committee should include appropriate representation from Milwaukee County; the municipalities of Milwaukee, Wauwatosa, Greenfield, West Milwaukee, and West Allis; the Wisconsin Department of Transportation; the Wisconsin Department of Natural Resources; the U. S. Environmental Protection Agency; and the Regional Planning Commission. It is envisioned that demonstration funding to help defray the cost of the street sweeping program would be provided by and through the Wisconsin Departments of Natural Resources and Transportation and the U. S. Environmental Protection Agency. If the air quality impact of the pilot vacuum street sweeping program is found to be beneficial, a determination will then be made as to which agency or agencies will be responsible for the continued cost.

SULFUR DIOXIDE POLLUTION CONTROL PLAN IMPLEMENTATION

The sulfur dioxide pollution control plan consists of the following committed actions: designation of a nonattainment area for sulfur dioxide, application of emission control limitations to existing sources, and application of emission control limitations to new and modified sources. In addition, the plan consists of the following recommended actions: a prohibition on the replacement of existing and installation of new coal-fired facilities for small-scale space and water heating purposes, and the establishment of a preferential allocation of natural gas supplies to industrial users in the Region.

Designation of Sulfur Dioxide Nonattainment Area

The Wisconsin Department of Natural Resources has proposed the designation of a sulfur dioxide nonattainment area in the Region. Upon approval of that designation by

the U. S. Environmental Protection Agency, it becomes, for the purposes of this plan, a committed action. Such designation is essential to provide the basis for the establishment of more stringent and broadly applicable rules and regulations for the control of sulfur dioxide emissions from existing sources.

Control of Sulfur Dioxide Emissions from Existing Sources

It is recommended that, upon formal designation of the sulfur dioxide nonattainment area by the U. S. Environmental Protection Agency, the Wisconsin Department of Natural Resources take steps to prepare and adopt administrative rules defining the Reasonably Available Control Technology (RACT) limitations to be applied to existing sources of sulfur dioxide emissions that significantly impact upon air quality in the nonattainment area. In conjunction with this effort, the Department should identify those existing sources to which the sulfur dioxide RACT emission limitations would apply. In addition, it is recommended that the Department continue to enforce the sulfur dioxide emission limitations and related regulations currently set forth in Chapter NR 154 of the Wisconsin Administrative Code and that would apply to those existing sources of sulfur dioxide emissions in the Region not affected by the proposed RACT limitations.

Control of Sulfur Dioxide Emissions from New or Modified Sources

As with particulate matter, the Wisconsin Department of Natural Resources has review authority for new or modified sources of sulfur dioxide emissions. If the proposed sulfur dioxide nonattainment area is eventually designated by the U. S. Environmental Protection Agency, the Wisconsin Department of Natural Resources will have the authority to establish regulations providing for the attainment and maintenance of the sulfur dioxide ambient air quality standards in that area of the Region.

Again as with particulate matter, the U. S. Environmental Protection Agency currently retains separate authority to issue new source or modification permits in clean air areas under Prevention of Significant Deterioration regulations. Thus, it is recommended that the U. S. Environmental Protection Agency delegate to the Wisconsin Department of Natural Resources the authority to issue Prevention of Significant Deterioration permits in clean air areas in the Region, and that the Wisconsin Administrative Code be appropriately modified to reflect this authority.

Prohibition on the Replacement of Existing and Installation of New Coal-Fired Facilities for Small-Scale Space and Water Heating Purposes

The plan recommends that the replacement of existing and installation of new coal-fired facilities for residential and small commercial-institutional space and water heating purposes be prohibited in Milwaukee County. Such small sources are defined as having a heat input capacity of less than one million BTU's per hour. Such existing coal-fired facilities could remain in use until the end of their useful lives. The ban would serve to eliminate the use of coal for small-scale space and water heating purposes in Milwaukee County. It is recommended that the Wisconsin Department of Natural Resources appropriately amend Chapter NR 154 of the Wisconsin Administrative Code to place such a prohibition on the replacement of those remaining facilities and to prohibit the installation of such new facilities in Milwaukee County. In cooperation with Milwaukee County, the Department should also undertake an educational program that would encourage the owners of the buildings where coal is still used for such purposes to convert voluntarily to an alternate fuel.

Preferential Allocation of Natural Gas

The plan recommends that, should natural gas supplies be curtailed in Wisconsin in future years to the point where industrial firms in the Region contemplate conversion to the use of coal, such conversions be forestalled through the preferential allocation of natural gas supplies to industrial sources in the Region. It should be noted that preferential allocation of natural gas may be expected to serve to lower not only sulfur dioxide emissions below what they would be under intensive coal use, but emissions of other pollutant species as well. Accordingly, it is recommended that the Wisconsin Public Service Commission prepare and promulgate rules that would provide for such a preferential allocation in the event that this contingency would occur. It is intended that such a preferential allocation system would be used only if natural gas supplies were severely curtailed and the conversion to coal by industrial firms in the Region appears to be imminent.

CARBON MONOXIDE AND HYDROCARBON/OZONE POLLUTION CONTROL PLAN IMPLEMENTATION

The carbon monoxide and hydrocarbon/ozone pollution control plan consists of the following recommended actions: application of emission control limitations to existing stationary sources of carbon monoxide and volatile organic compound emissions; application of emission control limitations to new or modified sources of carbon monoxide and volatile organic compound emissions; continued implementation of the federal motor vehicle emissions control program; continued efforts toward implementation of the regional transportation plan; establishment of a vehicle inspection and maintenance program for pollution control equipment; and establishment of a prohibition on the use of cutback asphalt as a paving material in the Region.

Control of Carbon Monoxide and Volatile Organic Compound Emissions from Existing Sources

It is recommended that the Wisconsin Department of Natural Resources continue to enforce the regulations currently set forth in Chapter NR 154 of the Wisconsin Administrative Code that apply to specified existing stationary sources of carbon monoxide and volatile organic compound emissions constructed between 1972 and 1979. In addition, it is recommended that the Department continue its effort to develop and promulgate Reasonably Available Control Technology (RACT) emission limitations for specified existing sources of volatile organic compounds. The Department should

identify all existing sources that would be affected by the existing and proposed RACT rules for volatile organic compounds and establish compliance schedules for all affected facilities within the Region.

It is further recommended that the Department of Natural Resources undertake a special short-term air quality monitoring effort in Walworth and Washington Counties to determine whether the ambient air in these two counties currently exceeds the ambient air quality standard for ozone. If it is determined that the ozone standards are being violated, then it is recommended that the Department take steps to propose the expansion of the current nonattainment area for ozone to include the entire seven-county Southeastern Wisconsin Region, and that the U. S. Environmental Protection Agency formally make such a designation.

Control of Carbon Monoxide and Volatile Organic Compound Emissions from New or Modified Sources

It is recommended that the Wisconsin Department of Natural Resources continue to enforce and administer the regulations set forth in Chapter NR 154 of the Wisconsin Administrative Code pertaining to stationary sources of carbon monoxide emissions. Such regulations are identical to those specified for existing stationary sources.

At the present time the Wisconsin Department of Natural Resources is administering regulations pertaining to volatile organic compound emissions from new or modified stationary sources throughout the seven-county Southeastern Wisconsin Region. Any such new or modified source in the Region must presently meet the Lowest Achievable Emission Rate (LAER) as determined by the Department on a facility-by-facility basis.

Federal Motor Vehicle Emissions Control Program

It is recommended that the U. S. Environmental Protection Agency continue to enforce the federal motor vehicle emissions control program for mobile sources. The agency should ensure that all newly manufactured automobiles and trucks marketed within the Region fully comply with the rules pertaining to allowable emission limitations.

Regional Transportation Plan Implementation

As previously noted, many local, state, and federal units and agencies of government are involved in implementation of the regional transportation plan. Such units and agencies of government are designated, and their various plan implementation responsibilities enumerated, in companion Commission planning documents previously noted, and are incorporated by direct reference herein. However, it is useful to reiterate some of the transportation system improvement and management actions proposed in the adopted transportation plan which are pertinent to air quality management. These actions and their implementing agency designations are as follows:

Transportation System Management Action	Designated Implementing Agencies
1. Expand and improve public transit service and encourage the use of such service	City of Kenosha, City of Milwaukee, City of Racine, Milwaukee County, Ozaukee County, Washington County, Waukesha County
2. Expand system of park-ride transit lots and park-and-pool ride-sharing lots	Wisconsin Department of Transportation, Milwaukee County, Waukesha County, Ozaukee County, Washington County
3. Conduct carpooling and vanpooling promotional efforts	Wisconsin Department of Transportation, Milwaukee County
4. Establish Milwaukee area freeway traffic management system	Wisconsin Department of Transportation

The implementation of the foregoing and related transportation systems improvement and management measures is expected to aid in achieving ambient air quality standards for ozone and carbon monoxide. It is envisioned that as the air quality-transportation planning process proceeds, additional transportation-related actions having beneficial air quality impacts will be identified and implemented.

Vehicle Inspection and Maintenance Program

It is recommended that the Wisconsin Departments of Transportation and Natural Resources jointly seek legislative approval of the institution of a vehicle inspection and maintenance program pertaining to the emission control systems on automobiles and light-duty trucks. It is proposed that primary responsibility for the inspection and maintenance program be assumed by the Wisconsin

Department of Transportation. The Wisconsin Department of Natural Resources would be responsible for ensuring that the program serves to achieve the results that have been estimated in the planning studies. Given the extensive daily travel between all seven counties within the Region, it is proposed that this vehicle inspection and maintenance program be carried out over the entire Region, and that the Wisconsin Department of Transportation establish one or more vehicle inspection and emission testing stations in each county.

Prohibition on the Use of Cutback Asphalt

It is recommended that the Wisconsin Department of Natural Resources take appropriate actions to amend Chapter NR 154 of the Wisconsin Administrative Code to prohibit the use of cutback asphalt as a paving material in southeastern Wisconsin. Cutback asphalt can be replaced as a paving material by bituminous plant mix or asphalt emulsions.

AIR QUALITY MONITORING NETWORK IMPLEMENTATION

It is recommended that the Wisconsin Department of Natural Resources implement all of the recommended actions relating to the collection of ambient air quality data as set forth in the plan. In addition to continuing the operation of its existing network of air quality monitors, it is recommended that the Department undertake special monitoring programs to measure the long-range transport of particulate matter; to measure the level of particulate matter emissions emanating from quarrying operations in the Region; to measure the level of carbon monoxide in the ambient air in the area of the Marquette Interchange in Milwaukee County; to measure the level of oxides of nitrogen, nonmethane hydrocarbons, and ozone in the ambient air near the Wisconsin-Illinois state line, in the central business district of the City of Milwaukee, and in the Grafton area of Ozaukee County; and to measure the existing ozone levels in Walworth and Washington Counties and the long-range transport of ozone and its precursors from extraregional areas. In addition, it is recommended that the Department of Natural Resources conduct any special air quality monitoring that may be required in the conduct of the recommended pilot vacuum street sweeping program in portions of Milwaukee County.

SUMMARY

This chapter has recommended specific actions for implementation of the regional air quality attainment and maintenance plan. The most important recommended plan implementation actions are summarized in the following paragraphs by level of government and by responsible agency or unit of government.

Local Level

County Boards of Supervisors: It is recommended that each county board of the seven counties comprising the Region upon recommendation of appropriate agencies and commissions:

1. Adopt the regional air quality attainment and maintenance plan as that plan affects that county.

2. If it has not already done so, adopt the regional land use plan, the regional transportation system plan, and the regional transportation systems management plan as those plans affect that county.

3. Cooperate with the Wisconsin Department of Natural Resources in continuing air quality monitoring and enforcement efforts (Racine County only).

4. Cooperate with the Wisconsin Department of Transportation in conducting a pilot vacuum street sweeping program in the central portion of Milwaukee County.

5. Cooperate with the Wisconsin Department of Natural Resources in encouraging owners of buildings where coal is still used for space and water heating purposes to convert to an alternate fuel (Milwaukee County only).

6. Take appropriate actions to implement those transportation system improvement and management actions which are identified as having significant air quality benefits.

Common Councils, Village Boards, and Town Boards: It is recommended that each Common Council, Village Board, and Town Board within the Region upon recommendation of appropriate agencies and commissions:

1. Adopt the recommended regional air quality attainment and maintenance plan (Cities of Kenosha, Milwaukee, and Racine only).

2. Take appropriate actions to implement those transportation system improvement and management actions which are identified as having significant air quality benefits.

3. Cooperate with the Wisconsin Department of Transportation in the conduct of a pilot vacuum street sweeping program (Municipalities of Greenfield, Milwaukee, West Allis, West Milwaukee, and Wauwatosa).

State Level

Wisconsin Department of Natural Resources: It is recommended that the Wisconsin Department of Natural Resources Board and the Department of Natural Resources:

1. Adopt the regional air quality attainment and maintenance plan and integrate the plan recommendations into the State Implementation Plan for Air Quality required under federal legislation.

2. Complete the development and application of Reasonably Available Control Technology (RACT)

emission limitations through administrative rule with respect to existing sources of particulate matter, sulfur dioxide, and volatile organic compound emissions.

3. Assume complete responsibility for regulating new or modified sources of particulate matter, sulfur dioxide, and volatile organic compound emissions in clean air areas through the delegation of authority to administer Prevention of Significant Deterioration regulations.

4. Establish a regulatory program that would provide for an emission offset procedure for criteria pollutants associated with nonattainment areas.

5. Cooperate with the Wisconsin Department of Transportation in the conduct of a pilot vacuum street sweeping program in portions of Milwaukee County.

6. Enact appropriate rules to prohibit in Milwaukee County the replacement of existing and the installation of new coal-fired facilities for residential and small commercial-institutional space and water heating purposes.

7. In cooperation with the Wisconsin Department of Transportation, seek legislative approval for the institution of a vehicle inspection and maintenance program pertaining to emission control systems on automobiles and light-duty trucks.

8. Enact appropriate rules to prohibit the use of cutback asphalt as a paving material in the seven-county Southeastern Wisconsin Region.

9. Continue the existing network of air quality monitors, expand the network as recommended, and undertake special monitoring programs as recommended in the plan.

Wisconsin Department of Transportation: It is recommended that the Wisconsin Department of Transportation:

1. Endorse the regional air quality attainment and maintenance plan.

2. In cooperation with the Wisconsin Department of Natural Resources, seek legislative authority to initiate a vehicle inspection and maintenance program.

3. Direct available state and federal transportation system funding toward those transportation system improvement and management actions identified as having significant air quality benefits.

4. Take the lead in conducting a pilot vacuum street sweeping program in the central portion of Milwaukee County.

Wisconsin Public Service Commission: It is recommended that the Wisconsin Public Service Commission:

1. Formally acknowledge the regional air quality attainment and maintenance plan.

2. Prepare and promulgate a contingency plan that would provide for the preferential allocation of natural gas supplies to industrial sources in the seven-county Southeastern Wisconsin Region in the event that such supplies become severely curtailed or the cost becomes noncompetitive, and the conversion to coal by industrial sources in the nonattainment areas or impacting on such areas becomes imminent.

Federal Level

U. S. Environmental Protection Agency: It is recommended that the U. S. Environmental Protection Agency:

1. Formally acknowledge the recommended regional air quality attainment and maintenance plan.

2. Through the vehicle of the State Implementation Plan for Air Quality, approve actions to be proposed by the Wisconsin Department of Natural Resources concerning the development of Reasonably Available Control Technology (RACT) emission limitations for particulate matter, sulfur dioxide, and volatile organic compound emissions; and transfer Prevention of Significant Deterioration authority for regulating new and modified sources of such emissions to the Wisconsin Department of Natural Resources.

3. Continue implementation of the federal motor vehicle emissions control program for mobile sources.

U. S. Department of Transportation: It is recommended that the U. S. Department of Transportation, Federal Highway Administration and Urban Mass Transportation Administration:

1. Formally acknowledge the recommended regional air quality attainment and maintenance plan.

2. Utilize the plan recommendations in its administration of highway and transit aid programs, giving particular attention to the funding of those transportation improvement and management measures found to have significant air quality benefits.

Chapter XV

SUMMARY AND CONCLUSIONS

INTRODUCTION

The Commission, since its inception, has placed great emphasis on the importance of the development of a comprehensive plan for the physical development of the Region. One of the important elements of such a plan is a regional air quality attainment and maintenance plan. Clean ambient air protects and enhances the natural resource base of the Region and the overall quality of the environment, and is vital to the health and well being of all kinds of life within southeastern Wisconsin, and to the continued sound social and economic development of the Region.

The primary purpose of the regional air quality attainment and maintenance plan was to identify those areas within the Southeastern Wisconsin Region which are presently experiencing, or which could be expected to experience, excessive air pollution levels, and to evaluate alternative pollution abatement measures designed to achieve and maintain clean air throughout the seven-county area. Specifically, the regional air quality attainment and maintenance plan was to identify and quantify the principal sources of air pollution in the Region, both existing and forecast to the year 2000; to provide an evaluation of alternative control measures which are technologically and economically feasible for application by the identified air pollution sources; and to recommend the implementation of specific control actions to ensure the prompt attainment of clean ambient air in the Region and its continued maintenance through the year 2000. The plan was also intended to provide assistance to the Wisconsin Department of Natural Resources in the development of additions to, and revisions of, the State Implementation Plan. The major findings and recommendations of the regional air quality attainment and maintenance planning effort are documented in this report.

BASIC PRINCIPLES AND CONCEPTS

The history of the air pollution problem parallels the history of the use of fossil fuels for combustion. As far back as ancient Rome, air pollution has been associated with the onset of physical ailments. The advent of the Industrial Revolution during the 18th Century, with its attendant demand for carbonaceous fuels, vastly accelerated the rate at which pollutant emissions were deposited into the ambient air. Eventually, unplanned and unchecked industrial growth, combined with the virtual lack of controls on air pollutant emissions, led to a series of air pollution episodes during which local mortality and morbidity rates were dramatically increased. One such episode at Donora, Pennsylvania, in October 1948, prompted action by both government officials and private citizens to investigate the relationships between the various components of air pollution, still not identified at the time, and its affects on human health and welfare.

The first federal air pollution legislation enacted in the United States was the Air Pollution Control-Research and Technical Assistance Act of 1955. Although this act provided authorization for the Surgeon General of the United States to collect and publish information on air pollution, it envisioned a narrow role for the federal government, assuming instead that the primary responsibility for air pollution control was to lie with state and local governments. The federal government, however, assumed a greater responsibility for air pollution control with the passage of the Clean Air Act of 1963. This act authorized the U. S. Department of Health, Education and Welfare to directly intervene when air pollution was found to endanger the public health and welfare. Amendments to the Clean Air Act passed in 1965 further increased federal involvement in the control of air pollution. Moreover, the passage of the Air Quality Act of 1967 empowered the U. S. Department of Health, Education and Welfare to issue federal air quality criteria, establish ambient air quality standards, and designate air quality control regions.

The U. S. Environmental Protection Agency was created in 1970, and assumed the responsibilities formally vested in the U. S. Department of Health, Education and Welfare. Concurrently, Congress further amended the Clean Air Act in 1970 to strengthen the effectiveness of various programmatic, regulatory, and enforcement activities as contained in former air quality legislation. The Clean Air Act Amendments of 1970 mandated ambient air quality standards and established emission standards for certain new stationary sources and nonstationary sources, including new model automobiles. In addition, these amendments required states to identify air pollution problem areas within their jurisdiction and to prepare an implementation plan to provide for the attainment of the ambient air quality standards in those problem areas.

The Wisconsin State Implementation Plan to achieve the ambient air quality standards was prepared by the Wisconsin Department of Natural Resources and submitted to the U. S. Environmental Protection Agency in January 1972. On May 31, 1972, the EPA approved the Wisconsin State Implementation Plan, but rescinded that approval on March 3, 1973. Approval of the Wisconsin State Implementation Plan, as well as approvals of other state plans, was rescinded as a result of court challenges by environmental groups that contended that such plans did not contain adequate provisions for ensuring that the ambient air quality standards would be maintained once they were initially met. Thus, in June 1973, the

U. S. Environmental Protection Agency required states to identify areas which, because of anticipated growth and development, had the potential to exceed any ambient air quality standard by 1985.

In response to that U. S. Environmental Protection Agency requirement, the Wisconsin Department of Natural Resources in June 1974 proposed that two subareas of the State—the seven-county Southeastern Wisconsin Region and a three-county area consisting of Brown, Outagamie, and Winnebago Counties—be designated as air quality maintenance areas. On June 2, 1975, the U. S. Environmental Protection Agency rejected the designation of the seven-county Southeastern Wisconsin Region as such an area, substituting instead a tristate air quality maintenance area consisting of the seven southeastern Wisconsin counties, six counties in northeastern Illinois, and two counties in northwestern Indiana. This total area was designated as the Illinois-Indiana-Wisconsin Interstate Air Quality Maintenance Area. The area was divided into three portions, with each portion corresponding to that part of the area included within each of the respective states. Thus, although the seven-county Southeastern Wisconsin Region constitutes an intrastate, rather than an interstate, air quality control region, for air quality planning purposes the Region constitutes only a portion of a much larger tristate air quality maintenance area. The air quality attainment and maintenance plan presented herein, however, represents a recommended course of action to achieve and preserve clean air only in the southeastern Wisconsin portion of that tristate area (see Map 4 in Chapter II). The mechanism to be used in incorporating the attainment and maintenance plans for each portion of the Illinois-Indiana-Wisconsin tristate maintenance area must be addressed by the U. S. Environmental Protection Agency.

Because the State was required to revise the State Implementation Plan to provide for the long-term maintenance of the ambient air quality standards, and since the nature of such a long-term plan is directly related to the anticipated growth and development within the designated maintenance areas, the Commission, on November 12, 1973, was asked by the Wisconsin Department of Natural Resources and Department of Transportation to cooperate in the preparation of a comprehensive air quality maintenance plan for the Southeastern Wisconsin Region. Accordingly, the Commission in February 1974 created a Technical Coordinating and Advisory Committee on Regional Air Quality Maintenance Planning to assist the Commission and its staff in the design and conduct of a regional air quality maintenance planning program. The Committee membership included public officials responsible for environmental management, representatives of the local industrial community, and interested citizens. A prospectus which documented the need for the program and outlined the desirable scope and content of the program was completed by the Committee in July 1974. Work on the regional air quality maintenance plan, as outlined in the prospectus, began in September 1974.

As originally intended, the regional air quality maintenance plan was to supplement the State Implementation Plan—which was to provide for the near-term attainment of the ambient air quality standards—by seeking to ensure the long-term maintenance of the standards. During the conduct of the work effort, however, it became apparent that the State Implementation Plan was not adequate to ensure the attainment of the ambient air quality standards. Responding in part to this deficiency in the Wisconsin State Implementation Plan, as well as in the implementation plans of other states, the Congress passed the Clean Air Act Amendments of 1977, which placed particular emphasis on the prompt attainment of the ambient air quality standards. These amendments required states to revise their implementation plans to demonstrate attainment and to document the regulations to be enforced and procedures to be followed in achieving this goal. Accordingly, the Commission expanded the original scope of work, as outlined in the prospectus, to incorporate the preparation of an attainment plan to achieve the ambient air quality standards. Thus, the regional air quality attainment and maintenance plan detailed herein recommends actions to ensure both the near-term attainment and long-term maintenance of the ambient air quality standards. The specific ambient air quality standards to be met in the Region, and the analytical tools used to evaluate the effectiveness of the alternative and recommended actions in attaining and maintaining those standards, are summarized in the following sections.

Air Quality Criteria and Standards

Over the past several decades, the scientific, medical, and engineering communities, with the technical and financial assistance of federal, state, and local governmental agencies, have sought to identify the toxic agents present in the atmosphere and their sources, quantify their presence in the ambient air, and define the threshold concentrations at which these agents exhibit deleterious effects on human, plant, and animal life, and on artifacts. The body of laboratory, epidemiological, and toxicological data concerning air pollution and its observed effects may be collectively referred to as air quality criteria. Air quality criteria are the foundation upon which ambient air quality standards are based.

Based upon the air quality criteria collected and collated to date, six air pollutants have been identified for which ambient standards have been set: particulate matter, sulfur oxides (measured as sulfur dioxide), carbon monoxide, nitrogen dioxide, hydrocarbons, and ozone. [1]

[1] *Ambient air quality standards for a seventh pollutant, lead, were promulgated by the Administrator of the U. S. Environmental Protection Agency on October 5, 1978. More detailed ambient air quality monitoring will be needed to determine whether the standard for this pollutant species is being exceeded in the Region and whether, in fact, a plan need be prepared to ensure the attainment and maintenance of the ambient air quality standard for lead.*

Ambient air quality standards have been promulgated for these pollutants by the U. S. Environmental Protection Agency, and these standards are incorporated into the plan presented in this report. The ambient air quality standard for hydrocarbons has been promulgated as a guideline standard for achieving salubrious ozone levels, since hydrocarbon compounds in themselves have not been found to have adverse effects on humans or on plant and animal life.

The established federal and state ambient air quality standards for these six pollutant species are presented in Table 57 in Chapter VI. As may be seen in this table, for each of the six pollutant species there is a primary, or health-related, standard, and a secondary, or welfare-related, standard. Both the primary and secondary standards were established at levels which were believed to provide an adequate margin of safety—that is, at levels below those observed to be associated with adverse health effects or damage. In those instances where the level at which a pollutant adversely affects human health has been found to be lower than the level at which it causes harm to plant and animal life or artifacts, the secondary standard has been established at the same level as the primary standard. Also, ambient air quality standards have been established for more than one averaging time for particulate matter, sulfur dioxide, and carbon monoxide in order to prevent excessive short-term exposures to deleterious pollutant levels, as well as to prevent the harmful effects which have been found to be associated with long-term exposures to pollutant concentrations at generally lower average levels.

The principal goal of the air quality planning effort is the attainment and maintenance of the ambient air quality standards presented in Table 57 in Chapter VI. Concomitant with the achievement of these established ambient air quality standards is the acceptance of the air quality criteria upon which the standards are based. The collation of air quality criteria, however, is a dynamic process, with new laboratory, epidemiological, and toxicological data on the effects of air pollutants being continually gathered, reviewed, and assimilated into the existing body of knowledge. As the air quality criteria become more comprehensive, it may be deemed justifiable and in the public interest for the Administrator of the U. S. Environmental Protection Agency to modify the existing ambient air quality standards. Such was the case for ozone when, in February 1979, the ambient air quality standard was changed from 0.08 part per million (ppm) for a maximum one-hour average to 0.12 ppm for a maximum one-hour average. Any further revisions to the existing ambient air quality standards in future years, therefore, may require that the recommended regional air quality attainment and maintenance plan be amended accordingly.

Analytical Procedures Applied in the Study

The existing ambient air quality in the Region may be characterized both through ambient air quality monitoring—that is, by direct measurement—and through air quality simulation modeling.[2] In order to satisfactorily characterize the nature of the air pollution problem, an ambient air quality monitoring network must be based upon the development of standardized monitoring procedures and the use and maintenance of reliable instrumentation, as well as the efficient placement of monitors to maximize the representativeness of collected air samples. For each pollutant species, the U. S. Environmental Protection Agency has defined a standard reference monitoring method, has designated equivalent monitoring methods, and has established certain minimum requirements concerning the number, location, and operational characteristics of ambient air quality monitoring sites. Thus, available data from the existing ambient air quality monitoring network serve as the initial analytical tool for characterizing air pollutant levels in southeastern Wisconsin.

Ambient air quality monitors, however, measure pollutant concentrations at discrete points and, unless the network of monitors is impractically dense, may not adequately depict the areal extent of the air pollution problem. Moreover, whereas available monitoring data may provide an historical perspective and indicate trends in air pollution levels, monitors cannot provide prior knowledge of future pollutant concentrations resulting from anticipated growth and change. In addition, data obtained from the existing ambient air quality monitoring network may be biased to some nonuniform degree by such factors as prevailing meteorological conditions, passive loading, sampler orientation, and volume flow rates. Such inherent limitations to ambient air quality monitoring define a need for a supplemental analytical device in order to properly represent the nature and extent of air pollution problems in the Region. Air quality simulation modeling, when used as an extension of, and adjunct to, ambient air quality monitoring, provides this necessary supplemental device.

Monitoring and modeling thus have complementary roles in the air quality attainment and maintenance planning process. Ambient air quality monitoring is best suited for determining the absolute values of pollutant concentrations at any given location, but has limited capability for addressing the variability of pollutant levels due to changes in emissions and meteorological conditions. Alternatively, air quality simulation modeling has a limited capability for accurately determining absolute levels of pollutants in the ambient air, but is well suited for evaluating spatial and temporal patterns of pollutant concentrations and for evaluating the

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[2] *Existing ambient air quality levels presumably could also be indirectly characterized by long-term epidemiological studies. No such studies have been carried out within the Region to date. Moreover, since the measure of air quality would be indirect, quantification of pollutant levels with sufficient accuracy and precision to utilize directly in air quality management planning would be difficult if not impossible.*

impacts of specified emissions and meteorological conditions. Air quality simulation modeling, like ambient air quality monitoring, however, does have certain inherent limitations. These limitations are principally related to the requirement that, for modeling purposes, the complex physical and chemical processes ongoing in the atmosphere be translated into a set of predictive mathematical equations. The algorithms used to describe these complex atmospheric processes only approximate, rather than precisely replicate, the dispersion and reactivity of pollutants in the ambient air. Thus, neither air quality simulation modeling nor ambient air quality monitoring used individually is capable of adequately characterizing the air pollution problem in southeastern Wisconsin. When used in conjunction, however, modeling and monitoring are mutually supportive and act to overcome the deficiencies to which each technique is subject.

No single air quality simulation model was found to be capable of meeting all the requirements of the regional air quality attainment and maintenance planning program. Since it was necessary to simulate the transport and diffusion of both chemically reactive and nonreactive pollutant species, and to simulate dispersion over both long-term and short-term averaging periods, two different air quality simulation models were used. The Emperical Kinetics Modeling Approach (EKMA), developed by the U. S. Environmental Protection Agency, was the model selected for evaluating the ozone problem in the Region. The Wisconsin Atmospheric Diffusion Model (WIS*ATMDIF), developed by the Air Quality Modeling Group of the University of Wisconsin-Madison, was used to simulate the diffusion of nonreactive pollutant species: total suspended particulates, sulfur dioxide, and carbon monoxide. In addition, this model was used to approximate the transport and dispersion of nitrogen oxides and hydrocarbons while not accounting for the reactivity of these pollutant species.

The EKMA model uses a chemical mechanism—considered to be representative of a detailed sequence of chemical reactions occurring in hydrocarbon compounds commonly found in an urban environment—to simulate ozone concentrations downwind of a large urban area. The EKMA is best suited to determining the sensitivity of maximum hourly ozone concentrations to changes in ambient levels of nonmethane hydrocarbons and nitrogen oxide precursor emissions. The results of the EKMA simulation are stated as the percent reduction in reactive hydrocarbon emissions from within the urban area required to reduce the maximum upwind ozone concentrations to a level below the established standard.

The WIS*ATMDIF model consists of three submodels which are used to simulate the diffusion of nonreactive air pollutants in the atmosphere over both long-term and short-term averaging periods. The submodel used depends on the characteristics of the emission source to be simulated and the required averaging period. The WIS*ATMDIF model is particularly adept at simulating pollutant concentrations resulting from numerous emission sources over broad geographic areas.

Underlying the use of the aforementioned air quality simulation models is the need to collate an extensive data base on air pollution sources and dispersion mechanisms. Conceptually, simulation models require information on the total quantity and rate of release of air contaminants from each emissions source, the location of sensitive receptors in relation to the emission sources, and the mechanisms acting to diffuse the emissions as they travel between the source and receptor. The preparation of a comprehensive air pollutant emissions inventory for the Southeastern Wisconsin Region was therefore an integral part of the development of the recommended regional air quality attainment and maintenance plan.

Emissions Inventory

All sources of air pollution emissions may be grouped into one of three general categories: point sources, line sources, or area sources. For the purpose of the regional air quality attainment and maintenance planning program, point sources are defined as large discrete sources, such as tall stacks associated with industrial operations; line sources are defined as transportation-related emission sources, predominantly motor vehicles operating over arterial streets and highways; and area sources are defined as the aggregation of many small, highly diffused sources of pollutant emissions which may not individually be major contributors of pollution, but which collectively may have a significant impact on ambient air quality. Under the procedures used in the collation of this regional air pollutant emissions inventory, all major industrial facilities, four classes of motor vehicles, and 30 categories of area sources were identified and the pollutant emission rates for each were quantified and distributed temporally by season and spatially by U. S. Public Land Survey quarter section.

In simulating the transport and diffusion of pollutant emissions over long-term averaging periods, such as a year, meteorological conditions observed at the National Weather Service Office at General Mitchell Field in Milwaukee County were considered representative of the atmospheric variables affecting dispersion. The meteorological data obtained from this station included primary elements, such as temperature and wind speed and wind direction, and derived elements, such as atmospheric stability and mixing heights.

But with one exception, the meteorological patterns experienced in the Region pose no unique problems for the simulation modeling effort. The topography of the Region is fairly uniform and does not induce circulatory wind fields on a broad geographic scale, such wind fields being difficult to simulate. The presence of Lake Michigan on the eastern boundary of the Region, however, with its moderating influence on weather conditions, does contribute to unique wind field patterns at certain times during the year. In particular, the differential heating of the land surface and the adjacent water surface establishes a helical wind circulation commonly referred to as the "lake breeze" effect. Although the lake breeze effect may be expected to influence the diffusion of air pollutants along the shoreline, this type of wind circula-

tion occurs primarily during the warmer months of the year, and does not penetrate across the entire Region. The lake breeze phenomenon, coupled with gradient winds, is strongly suspected of being an important factor in the long-range transport and recirculation of air pollutants along and within a corridor paralleling the shoreline of Lake Michigan. Thus, for annual averaging periods, the influence of Lake Michigan on the dispersion of air contaminants may be considered to be negligible for a regional scale modeling effort. However, for short-term averaging periods, and for emission sources at or near the shoreline, the lake breeze effect may be a significant factor in determining air pollutant concentrations in a localized area.

For all air quality simulations performed in the air quality attainment and maintenance planning program, the meteorological data used were derived from the same temporal period for which the emission inventories were prepared in order to more accurately calibrate the modeling results with the observed monitoring data. Calibration of the modeling results was performed to reduce the influence of systematic errors which may be inherent in the simulation technique, and to account for unidentified local emission sources, chemical transformations in the atmosphere, the long-range transport of air pollutants, and naturally occurring background pollutant levels. The calibrated model was subsequently used to forecast ambient air quality conditions in future years under the growth and development patterns expected to occur in the Region, and to evaluate the effectiveness of alternative air pollution abatement measures in reducing excessive pollutant concentrations. The existing and forecast conditions in the Region relating to the socioeconomic base, air pollution emissions, and ambient air quality are summarized in the following section.

INVENTORY AND FORECAST FINDINGS

Natural Resource Base

Elements of the natural resource base having particular significance to the regional air quality attainment and maintenance planning program include climate, land forms, lakes and streams, woodlands, water and wetlands, fish and wildlife habitat areas, and agricultural lands. The importance of properly considering these elements of the natural resource base in the regional air quality attainment and maintenance planning effort cannot be overemphasized. Without a proper understanding and recognition of these natural resource base elements and of their interrelationship with the air resource itself, alteration of the natural environment proceeds at a risk of excessive costs in terms of monetary expenditures and destruction of nonrenewable or slowly renewable resources. Pertinent information on these elements is presented in the following paragraphs.

The Region has a continental-type climate characterized by a continuous progression of markedly different seasons and a large range in annual temperature, onto which are superimposed frequent distinct changes in weather conditions which, particularly in the winter and spring, normally occur once every two or three days. In addition to marked temporal weather changes, the Region exhibits spatial weather differences, the most significant of which are the moderating effect on temperature and the lake breeze wind circulation pattern attributable to Lake Michigan.

The annual temperature range, which is based on monthly means for eight geographically representative observation stations, extends from an average monthly low of 19°F in January to an average monthly high of 73°F in July. The total annual precipitation in the Region, based on eight geographically representative observation stations, is 31.26 inches expressed as water equivalent, with monthly averages ranging from a February low of 1.19 inches to a high of 3.77 inches in June. Relative to total annual precipitation, annual snowfall quantities are extremely variable as demonstrated by historical records in Milwaukee, which indicate that snowfall ranged from a low of 11.0 inches during the winter of 1884-1885 to a high of 109.8 inches during the winter of 1885-1886. Precipitation events are particularly significant to air quality since they tend to cleanse the atmosphere by removing pollutants through the process of washout.

Prevailing winds, which determine the direction pollutants will travel from their source and which aid in the removal and dispersion of pollutants from the atmosphere, follow a clockwise pattern in terms of the prevailing direction over the seasons of the year, being northwesterly in the late fall and in the winter, northeasterly in the spring, and southwesterly in the summer and early fall. Wind velocities may be expected to be less than 5 miles per hour about 15 percent of the time, between 5 and 15 miles per hour about 60 percent of the time, and in excess of 15 miles per hour about 25 percent of the time.

Variations in the time of sunrise and sunset and the daily hours of sunlight are of importance to air quality attainment and maintenance planning because of the role sunlight plays in the formation of ozone. Daylight hours range from a minimum of about 9.0 on the winter solstice to a maximum of 15.4 on the summer solstice. The smallest amount of sky cover occurs during the July through October period, when the mean monthly daytime sky cover is approximately 0.5, whereas a sky cover of about 0.7 may be expected between November and April. Correspondingly, the frequency and intensity of photochemical formation reaches a maximum in the months with the greatest number of daylight hours and the lowest percentage of cloud cover.

Southeastern Wisconsin is marked by an interesting, varied, and attractive landscape. The regional topography resulting from glaciation influences the dispersion of air pollutants by disturbing the laminar flow of winds found in areas with little or no relief. On a regional level, however, the topography of southeastern Wisconsin does not vary sufficiently to establish persistent perturbations in the mean wind flow, which would significantly affect the dispersive capabilities of the atmosphere.

As a result of its glacial history the Region has an abundant supply of sand and gravel deposits, the most productive of which are concentrated in the Kettle Moraine area. These deposits are important sources of concrete aggregate and of gravel for construction purposes. Niagara dolomite is mined in open quarries, most of which are located in Waukesha County, and is used as a high-quality dimensional building stone and, when crushed, concrete aggregate and gravel for construction purposes. The mining, processing, and transporting of the sand, gravel, and dolomite are sources of particulate matter in the atmosphere.

Soils are a source of particulate matter in the atmosphere through both natural causes, such as wind erosion, and man-made causes, such as tilling operations. Soils are also of importance to regional air quality attainment and maintenance planning in that certain types of soils place a constraint on the location and character of urban development. Soil survey data and interpretations reveal that approximately 716 square miles, or about 27 percent of the Region, are covered by soils that are poorly suited for residential development with public sanitary sewer service; approximately 1,637 square miles, or about 61 percent of the Region, are poorly suited for residential development without public sanitary sewer service on lots smaller than one acre in size; and about 1,181 square miles, or approximately 44 percent of the Region, are poorly suited for residential development without public sanitary sewer service on lots one acre or larger in size.

The water quality of the lakes and streams in the Region is affected to some extent by the level of pollutants in the atmosphere. The precipitation-related process of washout, as well as the gravitational settling of contaminants onto the surface of water bodies, adds to the pollutant loading of lakes and streams in the Region. The Region contains 1,148 lineal miles of major streams and 100 major lakes, the latter having a total surface area of 57 square miles, or about 2 percent of the area of the Region, and a total shoreline length of 448 miles. In general, the surface waters of the Region may be characterized as highly polluted. Surface water degradation is partially attributable to air pollutants entering the hydrologic system by precipitation, settling, or impaction.

The most important elements of the natural resource base, including the best remaining woodlands, wetlands, wildlife habitat areas, major bodies of surface water and related undeveloped floodlands and shorelands, ground water recharge and discharge areas, and sites having historic, scenic, and recreational value, occur within the Region in lineal areas termed by the Commission environmental corridors. There are about 542 square miles of primary environmental corridor within the Region, comprising about 20 percent of the total area of the Region.

Prime agricultural lands cover about 25 percent, or over 630 square miles, of the total area of the Region. Primary environmental corridors and prime agricultural lands are the two types of land use most affected by air pollution. The attainment and maintenance of clean air seeks to protect these areas, which contribute significantly to the overall quality of the environment as well as to the economy of the Region, from the deleterious and damaging effects of excessive pollutant levels.

Socioeconomic Base

Existing concentrations of air pollutants in the Region are significantly related to the present level of ongoing human activities and movements. Specifically, the size and distribution of the regional population, the level of economic activity, the land use, the location, capacity, and utilization of the regional transportation system, and the supply of and demand for various energy sources all contribute to or influence the existing and future air pollution levels in the Region.

Population: Population both affects, and is affected by, air pollution. The size and distribution of the resident population determines both the number of persons exposed to air pollution with attendant hazards to health, and the level and distribution of air pollutant emissions. The population of the Region in 1975 was estimated to be 1,789,871 persons. The population of the Region increased at the rate of about 6,800 persons per year between 1970 and 1975, considerably lower than the 18,000 persons per year growth rate between 1960 and 1970, or the 33,000 persons per year growth rate between 1950 and 1960. Population growth within the Region has been occurring primarily in the outlying suburban and rural-fringe areas, while the populations of the older central cities and suburbs of the Region have remained relatively stable or have actually declined. Between 1970 and 1975, the resident population of Milwaukee County decreased by about 41,700 persons, or about 4 percent. Milwaukee County's share of the total regional population has also continued to decline—from a maximum concentration of about 72 percent of the total residents of the Region in 1930 to about 57 percent in 1975. Waukesha County experienced the largest growth in population between 1970 and 1975, gaining about 31,400 persons.

The population of the Region may be expected to reach about 2.22 million persons in the year 2000—an increase of about 460,000 persons, or about 26 percent, over the 1970 enumerated regional population of about 1.76 million persons. In general, county population forecasts indicate relatively rapid population growth in Ozaukee, Washington, and Waukesha Counties, with slower rates of population growth in Kenosha, Racine, and Walworth Counties. Only Milwaukee County is forecast to experience a net population decline in the year 2000 from the 1970 population level.

Economic Activity: Economic activity levels, and changes in such levels, may be used as an indicator of the levels of industrial process throughput and of changes in such throughput, and, consequently, of the level of air pollutant emissions from major industrial facilities. Thus, employment patterns in the Region, as a measure of economic activity, have particularly important implications for long-range air quality planning. Employment opportunities within the Region increased at a rate of

approximately 8,740 jobs per year between 1960 and 1975, to a level of about 779,000 jobs in 1975. The economic factors which promote population growth and urbanization in the Region are largely centered in and around the major urban centers of Milwaukee, Racine, and Kenosha, although a diffusion of economic activity into the outlying areas of the Region is occurring. There were 37,400 new jobs created in the Region between 1970 and 1975. Of this total, approximately 12,300, or 33 percent, were located in Waukesha County—an 18 percent increase over the number of jobs in that county in 1970. Over the same time period, Milwaukee County experienced an increase of about 4,800 jobs, or about 13 percent of the regional total—a 1 percent increase over the number of jobs in 1970.

Employment in the Region is expected to increase to a level of about 1,016,000 jobs by the year 2000—an increase of about 274,400 jobs, or 37 percent, over the 1970 employment level of 741,600 jobs. This indicates an annual average rate of increase of about 9,200 jobs, or about 1.2 percent, over the 30-year period. Milwaukee and Waukesha Counties are expected to experience the largest absolute increases in employment—82,700 and 90,200 jobs, respectively—while Kenosha and Washington Counties are expected to experience the smallest absolute increases—15,100 and 15,700 jobs, respectively. The largest relative rates of employment growth are expected in Ozaukee and Waukesha Counties—112 percent and 134 percent, respectively—while the smallest relative rate of employment growth, 16 percent, is expected in Milwaukee County.

Between 1970 and 2000, employment in the trade, government, and education services and private services groups may be expected to increase faster than total regional employment. Employment in manufacturing, while increasing at a slower rate than total regional employment, may be expected to continue to constitute the largest sector with 320,300 jobs, or about 32 percent of the total regional employment, in the year 2000. Only one industry group—agriculture—is expected to experience a decline in employment between 1970 to 2000—from 10,600 jobs in 1970 to 7,500 jobs in the year 2000. This expected decline reflects a continuation of an established trend and is due, in part, to the mechanization of farming processes, but more importantly to the loss of farmland in the Region through the conversion of land from agricultural to urban use.

Land Use Development: A fundamental consideration in air quality planning is the existing and future land use pattern of the planning area. The density and distribution of the various urban and rural land uses determine to a large degree the character, magnitude, and distribution of air pollutant emissions.

Land within the Region has been undergoing a particularly rapid conversion from rural to urban use. Recent urban development within the Region has been discontinuous and highly diffused, consisting primarily of many scattered, low-density, isolated enclaves of residential development located away from established urban centers. The 20-year period from 1950 to 1970 showed the most dramatic increase in urban land use development in the history of the Region. While the urban population of the Region increased by 47 percent over this period, the amount of land devoted to urban use increased by 188 percent. The population density of the developed urban area of the Region peaked in 1920 at a level of about 11,400 persons per square mile, and has steadily declined since then to a level of about 4,400 persons per square mile in 1970. The highly diffused nature of recent urban development and the sharp decline in urban population density have intensified many long-standing environmental problems in the Region and have created new environmental problems of an unprecedented scale and complexity, including air pollution problems.

The Southeastern Wisconsin Region is the most highly urbanized area within the State, yet less than 20 percent of its total area is presently devoted to urban-type land uses. The largest single land use category within the Region is still agriculture, which presently occupies about 60 percent of the total area. The next largest land use categories are the water and wetland group and the open lands group, both of which occupy about 10 percent of the total area of the Region. The urban-type land use occupying the greatest area is residential use, which presently accounts for about 9 percent of the total area of the Region.

The adopted land use plan for the Region is designed to accommodate the forecast year 2000 resident population of about 2.22 million persons and regional employment level of about 1.02 million jobs. These levels of population and employment are proposed to be accommodated by the infilling of existing urban areas and by the conversion of about 113 square miles of land from rural to urban use by the year 2000. The residential category of urban land use is expected to demonstrate the highest absolute and relative gains under the Commission's normative land use plan, increasing by about 38,600 acres, or nearly 25 percent—from about 156,300 acres in 1970 to about 194,900 acres in the year 2000. The regional land use plan seeks to encourage urban development only in those areas of the Region covered by soils suitable for such development, not subject to special hazards such as flooding, and readily serviceable by such essential public facilities and services as sanitary sewerage, public water supply, and, importantly, mass transit. The plan seeks to maintain all of the remaining environmental corridors in essentially natural open uses, and to maintain all of the remaining prime agricultural lands in agricultural use.

Transportation Facilities: The development and utilization of transportation facilities within the Region are significant factors in the determination of the magnitude and spatial distribution of air pollutant emissions from mobile sources and, as such, are important considerations in the air quality attainment and maintenance planning process. Moreover, the transportation planning process itself may serve as a tool for achieving the attainment of certain ambient air quality standards in the short-term and their maintenance in the long-term.

Surface transportation facilities are of three basic types: arterial streets and highways, collector and land access streets, and mass transit facilities. There were 9,819 miles of streets and highways open to traffic in the Region in 1972. Collector and land access streets accounted for 6,700 miles, or more than 68 percent of this total, while arterial streets and highways accounted for 3,119 miles, or about 32 percent of this total. Under the adopted regional transportation plan, 407 miles would be added to the arterial street and highway system in the Region, a 13 percent increase over the 1972 system to about 3,526 miles by the year 2000. The collector and land access streets required to support the adopted land use plan would total about 8,550 miles in the year 2000, an increase of 1,850 miles, or 28 percent, over the 1972 system.

Approximately 20.1 million vehicle miles of travel occurred on the arterial street and highway system of the Region on an average weekday in 1972. Most of this arterial utilization occurred within the intensely urbanized areas of the Region, with Milwaukee County accounting for more than 54 percent of the total vehicle miles of travel and exhibiting by far the most intensive use of the arterial system—more than 13,400 vehicle miles of travel per mile of arterial street and highway on an average weekday. Under the adopted regional transportation plan, the vehicle miles of travel on the arterial street and highway system in the Region is expected to increase to about 30.1 million per average weekday by the year 2000, an increase of nearly 50 percent over this 28-year period. Travel on the collector and land access street system could be expected to account for about 2.7 million vehicle miles of travel on an average weekday in the year 2000. In total, therefore, about 32.8 million vehicle miles of travel will be made in the Region on an average weekday in the year 2000.

In 1972 approximately 166 miles of arterial street and highway facilities, or about 5 percent of the total arterial street and highway mileage, operated over design capacity. By the year 2000, only 39 miles of arterial street and highway facilities, or about 1 percent of the total 3,526 miles, may be expected to operate over design capacity if the adopted regional transportation plan is fully implemented. The number of miles of arterial street and highway facilities operating at design capacity, however, is expected to increase from about 155 miles, or about 5 percent of the total system in 1972, to about 344 miles, or about 10 percent of the total system in the year 2000.

Mass transit service within the Region was provided only in the Kenosha, Milwaukee, and Racine urbanized areas in 1972. The Milwaukee mass transit operation was by far the dominant operation, accounting for more than 98 percent of the seat miles and passenger miles of service provided, and for more than 98 percent of the revenue passengers carried within the Region. Approximately 1,060 round-trip route miles of primary, secondary, and tertiary mass transit service were provided in Milwaukee County in 1972. Under the adopted regional transportation plan, the level of service in Milwaukee County would increase by about 2,010 round-trip route miles, or about 190 percent, to 3,070 round-trip route miles of primary, secondary, and tertiary service by the year 2000.

Mass transit service in the Kenosha and Racine urbanized areas was provided over 59 and 81 round-trip route miles, respectively, in 1972. Under the adopted transportation plan, the level of service in the Kenosha urbanized area would increase by about 88 round-trip route miles, or about 150 percent, to 147 round-trip route miles by the year 2000. In the Racine urbanized area, the adopted transportation plan calls for the addition of 72 round-trip route miles, for a nearly 89 percent increase over the 1972 level of service.

Under the adopted transportation plan, transit utilization in the Milwaukee urbanized area may be expected to increase from 52.3 million revenue passengers in 1972 to 85.4 million revenue passengers in the year 2000, an increase of 33.1 million revenue passengers, or 63 percent, over this 28-year period. Correspondingly, transit passenger miles of travel in the Milwaukee urbanized area may be expected to increase from 1.2 million passenger miles per average weekday in 1972 to 1.6 million passenger miles per average weekday in the year 2000, an increase of 33 percent over this 28-year period. Transit utilization may also be expected to increase in the Kenosha and Racine urbanized areas under the adopted transportation plan. In the Kenosha area, transit travel may be expected to increase from about 0.5 million revenue passengers per year, or about 9,600 passenger miles per average weekday, in 1972, to about 5.4 million revenue passengers per year, or about 42,000 passenger miles per average weekday, in the year 2000—an increase of 980 percent in revenue passenger miles per year and of about 338 percent in passenger miles per average weekday. In the Racine area, transit travel may be expected to increase from about 0.5 million revenue passengers per year, or about 10,900 passenger miles per average weekday, in 1972, to about 6.0 million passengers per year, or about 46,300 passenger miles per average weekday, in the year 2000—an increase of about 1,100 percent in revenue passenger miles per year and of about 325 percent in passenger miles per average weekday. It should be noted that the expected increases in transit utilization are predicated upon, among other factors, implementation of not only the adopted regional transportation plan, but also of the adopted regional land use plan with its emphasis on centralized, higher-density urban development—development most readily served by public transit.

Energy Supply and Demand: The natural resource base of the State of Wisconsin does not have any known primary fuel deposits, reserves, or supplies. Consequently, the State and the Region must rely exclusively on the importation of primary fuels to meet their energy needs.

Industries in southeastern Wisconsin have historically relied extensively on natural gas as a primary fuel for combustion. Natural gas production from domestic

sources in the continental United States, however, has been steadily decreasing since 1967. Demand for natural gas, conversely, has risen each year, primarily because it is a "clean" fuel and the costs have been well below other types of primary fuels. This deficit between domestic supply and demand has been made up through increasing imports.

As with natural gas, the domestic supply of petroleum is inadequate to meet the demand within the United States and imports are required to make up the deficit. Most estimates place the known petroleum reserves in the world at between 600 and 700 billion barrels, with 694 billion barrels representing a "best" estimate. At the present rate of consumption, this estimated reserve of 694 billion barrels of petroleum may be expected to last from 35 to 40 years. Although 90 percent of the world's producing wells are in North America, this area has only 7 percent of the world's proven oil resources. The United States, Wisconsin, and the Region, consequently, may be expected to become more dependent on foreign petroleum imports.

Since the domestic supplies of natural gas and petroleum are not adequate to meet demand, and since the world's proven reserves of such fuels are being depleted, the Commission considered alternative energy scenarios in preparing the forecast of air pollutant emissions for the Region. Of the alternative fuel sources considered, only coal was determined to be able to serve readily as a substitute for other primary fuels used in industrial applications within the next two decades. The assumed use of coal in future years also represents a "worst case" scenario since this fuel type has the potential to emit air pollutants in substantially greater quantities than are emitted by other primary fuel types. Thus, the regional air quality attainment and maintenance plan was developed in consideration of the possibility that the Region will become more dependent on the use of coal as a primary energy source, and that ambient air quality in future years will be impacted more severely than if natural gas supplies were able to meet the expected demand.

Ambient Air Quality

Particulate Matter: Particulate matter is a general term for a large variety of solid and liquid substances which have the ability to remain suspended in the ambient air for indefinite periods of time. This category of air pollution includes particles placed into the atmosphere from both natural and man-made sources. Natural sources of particulate matter include particles such as bacteria, viruses, fungi, molds, yeasts, pollen, and spores from live and decaying plant and animal life, and particles caused by wind erosion, volcanic activity, and forest fires. In addition, human activities and movements place substantial quantities of soot, dust, and fly ash into the atmosphere as a by-product of combustion, industrial processes, agricultural activities, and transportation movements.

Particulate matter may be injurious to human health in one or more of the following ways: a particle may be chemically or physically toxic—that is, poisonous in the human system if it is absorbed or inhaled; a particle may act as a carrier of another toxic substance; or a particle may interfere with the cleansing mechanisms in the human respiratory tract. It is principally through the respiratory system that particulate matter enters the human body.

Particulate matter air pollution has also been found to have an adverse effect on animals, vegetation, and artifacts. Many of the effects of high particulate matter levels observed in humans, for example, have also been observed in animals. Also, vegetation damage may occur as particles are deposited on plant leaves which, in the presence of moisture, develop into a hard, adherent crust. Such incrustations can damage plant tissue and inhibit growth by reducing the light necessary for photosynthesis and starch formation. In addition, particulate matter acts to soil and corrode materials. Corrosion of materials may be induced by either the acidic nature of the particles themselves or by corrosive chemicals carried by the particles.

Based upon the physical and chemical nature of particulate matter, and upon the observed biological and material response to its presence in the atmosphere, a primary ambient air quality standard—that is, the maximum level permissible to protect human health—and a secondary ambient air quality standard—that is, the maximum level permissible to protect plant and animal life from injury and materials from damage—have been promulgated by the federal government. Also, since both long-term and short-term exposures to particulate matter have been observed to produce adverse effects, an annual and a 24-hour average ambient air quality standard have been established for both the primary and secondary levels. On an annual basis, the primary ambient air quality standard for particulate matter has been established at 75 micrograms per cubic meter ($\mu g/m^3$, geometric mean) in order to protect human health, and the secondary standard has been established at 60 $\mu g/m^3$ (geometric mean) to prevent damage to plants, animals, and materials. In order to protect the public health from excessive short-term exposures, the primary 24-hour standard has been established at 260 $\mu g/m^3$ (arithmetic average), and to prevent other adverse effects, the secondary 24-hour standard has been established at 150 $\mu g/m^3$ (arithmetic average). The existing and forecast particulate matter levels in the Region as they relate to the above-mentioned ambient air quality standards, and the major sources of particulate matter emissions, are summarized in the following sections.

Existing Particulate Matter Levels: In 1977, the base year selected for the analysis of existing particulate matter levels in the Region, there were 38 high-volume gravimetric samplers operating as a part of the regional ambient air quality monitoring network: 19 sites in Milwaukee County, 7 sites in Racine County, 6 sites in Waukesha County, 4 sites in Kenosha County, and 1 site each in Ozaukee and Walworth Counties. During this year, 4 monitoring stations in Milwaukee County measured ambient air quality levels exceeding the primary annual standard for particulate matter—75 $\mu g/m^3$—and

10 stations, 5 in Milwaukee County, 2 in Kenosha County, 2 in Racine County, and the station in Walworth County, measured ambient air quality levels exceeding the secondary annual standard of 60 $\mu g/m^3$. In addition, of the 6 monitoring stations in Waukesha County—operated in the City of Waukesha under a special monitoring program—2 sites measured ambient air quality levels exceeding the primary annual standard, and 3 sites measured levels exceeding the secondary annual standard. Based upon these monitoring findings, supplemented by monitoring data from 1976 and 1978, the Wisconsin Department of Natural Resources proposed that certain areas within the Region be designated as nonattainment areas for either the primary or secondary ambient air quality standard for particulate matter. The primary and secondary particulate matter nonattainment areas, as formally designated by the U. S. Environmental Protection Agency on October 5, 1978, are shown on Map 82 in Chapter XI.

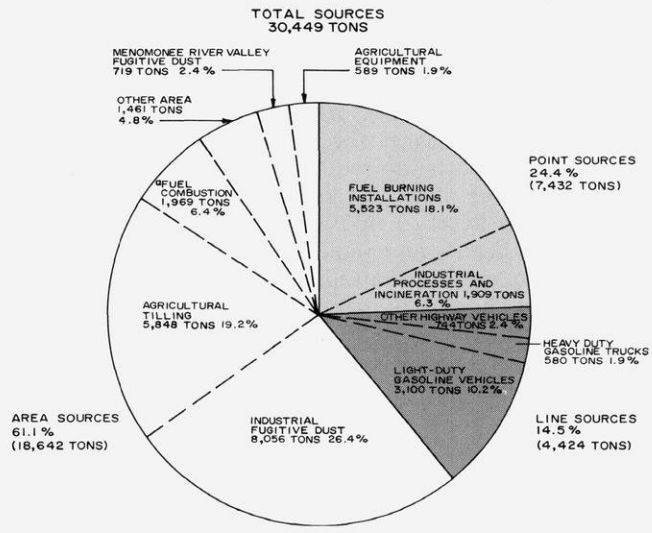
As is shown on Map 82, there are two designated primary particulate matter nonattainment areas in the Region—one in and around the heavily industrialized portion of the Menomonee River Valley in the City of Milwaukee, and one in the northeast portion of the City of Waukesha—and five designated secondary nonattainment areas—one each surrounding the primary nonattainment areas in the Cities of Milwaukee and Waukesha, one centered in and around General Mitchell Field in Milwaukee County, and one each in the Cities of Kenosha and Racine. In total, approximately 3 square miles in the Region, or about one-tenth of 1 percent of the total area of the Region, have been formally designated as primary particulate matter nonattainment areas, and approximately 38 square miles, or about 1.4 percent of the total area, have been formally designated as secondary particulate matter nonattainment areas. About 20,200 persons reside in the designated primary nonattainment areas and about 335,300 persons reside in the designated secondary nonattainment areas.

In order to determine the underlying causes of the monitored violations of the primary and secondary ambient air quality standards within the designated particulate matter nonattainment areas in the Region, a comprehensive regional particulate matter emissions inventory was conducted for the year 1977. The impact of the emissions inventoried on the ambient air quality was subsequently analyzed by using the Wisconsin Atmospheric Diffusion Model to simulate the impact of point, line, and area sources of emissions. The results and findings of this emissions inventory and modeling effort are summarized in the following section.

Particulate Matter Emissions Inventory and Air Quality Simulation Modeling Results and Findings: The particulate matter emissions inventory conducted for the Region for 1977 included the identification, quantification, and determination of the spatial and temporal distribution of all known point, line, and area sources of this pollutant species. The inventory found that, in total, approximately 30,500 tons of particulate matter were released into the atmosphere over the Region from all known sources during 1977. As may be seen in Figure 115 and

Figure 115

SUMMARY OF PARTICULATE MATTER EMISSIONS IN THE REGION BY MAJOR SOURCE CATEGORY: 1977



[a]INCLUDES AREA SOURCE EMISSIONS FROM FUEL USED FOR RESIDENTIAL, SMALL COMMERCIAL-INSTITUTIONAL, AND SMALL INDUSTRIAL SPACE AND WATER HEATING PURPOSES.

Source: SEWRPC.

in Table 362, about 18,600 tons of particulate matter, or about 61 percent of the total particulate matter emitted in the Region in 1977, were attributable to area source categories of emissions. About 13,900 tons of these area source emissions, or about 74 percent of the total 18,600 tons, were attributable to only two of the 20 area source categories—industrial fugitive dust, which contributed about 8,050 tons, or 43 percent, and agricultural tilling operations, which contributed about 5,850 tons, or 31 percent. Of the remaining 18 area source categories of particulate matter emissions, none accounted for more than 5 percent of the total emissions for this pollutant species. It is significant to note that Waukesha County, which has undergone substantial industrial development while maintaining an overall mixed rural-urban character, exhibits the largest total particulate matter emissions from area sources, accounting for about 6,660 tons, or nearly 36 percent, of the total of 18,600 tons of particulate matter emitted within the Region in 1977. For all other pollutant species, Milwaukee County has been found to be the greatest contributor of area source emissions. It should be noted that the 1977 particulate matter emission inventory did not include such nontraditional emission sources as re-entrained road dust because of the uncertainties concerning the rate at which such emissions are released into the atmosphere.

As also indicated in Table 362 and Figure 115, point sources—that is, major industrial facilities and fuel-burning installations—generated about 7,400 tons of particulate matter emissions in the Region during 1977,

Table 362

SUMMARY OF SUSPENDED PARTICULATE MATTER EMISSIONS IN THE REGION BY COUNTY AND BY MAJOR SOURCE CATEGORY: 1977

County	Point Sources			Line Sources			Area Sources			Total	
	Emissions (tons)	Percent of Source Total	Percent of County Total	Emissions (tons)	Percent of Source Total	Percent of County Total	Emissions (tons)	Percent of Source Total	Percent of County Total	Emissions (tons)	Percent of Region
Kenosha	49	0.7	3.3	368	8.3	24.6	1,078	5.8	72.1	1,495	4.9
Milwaukee . . .	6,095	82.0	47.2	2,056	46.5	15.9	4,768	25.6	36.9	12,919	42.4
Ozaukee	536	7.2	33.3	224	5.1	13.9	848	4.5	52.7	1,608	5.3
Racine	293	4.0	11.1	420	9.5	15.8	1,932	10.4	73.0	2,645	8.7
Walworth. . . .	127	1.7	5.4	264	6.0	11.3	1,946	10.4	83.3	2,337	7.6
Washington . .	10	0.1	0.6	272	6.1	16.1	1,407	7.6	83.3	1,689	5.5
Waukesha . . .	322	4.3	4.1	820	18.5	10.5	6,663	35.7	85.4	7,805	25.6
Region	7,432	100.0	24.4	4,424	100.0	14.5	18,642	100.0	61.1	30,498	100.0

Source: SEWRPC.

or more than 24 percent of the total of 30,500 tons. Of the 7,400 tons of particulate matter emitted from point sources during 1977, about 5,500 tons, or more than 74 percent, were attributable to large fuel-burning installations, principally in Milwaukee County. Line sources—that is, motor vehicles—contributed the least to the regional emissions burden of particulate matter, accounting for only 4,400 tons, or 15 percent, of the total particulate matter emitted in the Region during 1977.

As previously mentioned, the impact on ambient air quality of the level and distribution of particulate matter emissions as described above was simulated using the Wisconsin Atmospheric Diffusion Model under prevailing meteorological conditions for 1977. The ambient air particulate matter concentrations as calculated through this modeling effort were mathematically calibrated to existing monitoring data in order to provide an adjustment factor that would reduce systematic errors in the modeling technique and account for the impact of long-range transport, chemical transformations in the atmosphere, unidentified local emission sources, and naturally occurring levels of particulate matter in the ambient air. The calibrated results of the air quality simulation modeling effort are shown on Map 63 in Chapter XI.

As is shown on Map 63, the results of the air quality simulation modeling effort indicated that a 5-square-mile area in Milwaukee County and a 12-square-mile area in Waukesha County exceeded the primary annual average ambient air quality standard for particulate matter, 75 $\mu g/m^3$, during 1977. The air quality simulation modeling effort also indicated that an additional 24-square-mile area in Milwaukee County, a 0.1-square-mile area in Racine County, and a 23-square-mile area in Waukesha County exceeded the secondary annual average ambient air quality standard for particulate matter, 60 $\mu g/m^3$, during 1977. These results were in agreement with the monitoring data and, in fact, the correlation between the observed monitoring data and the modeling results was 0.93, a mathematically significant value.

As may be seen by comparing the air quality simulation modeling results shown on Map 63 with the designated particulate matter nonattainment areas shown on Map 82, a large area in Waukesha County exceeding the primary particulate matter standard and areas in Milwaukee, Racine, and Waukesha Counties exceeding the secondary standard lie outside the presently designated nonattainment areas. These areas, which correspond to locations of major quarrying activity in the Region in 1977, are not presently subject to ambient air quality monitoring. Accordingly, although the air quality simulation modeling results indicate that violations of the particulate matter ambient air quality standards may be occurring in areas around major quarrying operations, these conclusions cannot presently be supported with ambient air quality monitoring data. Conversely, the air quality simulation modeling results for 1977 do support the designation of the existing primary and secondary particulate matter nonattainment areas in Milwaukee and Waukesha Counties.

An estimated 65,600 persons, or 3.7 percent of the total regional population, resided in those areas of the Region indicated through air quality simulation modeling to exceed the primary, or health-related, annual average particulate matter standards in 1977. It was therefore deemed necessary to prepare a plan to ensure the near-term attainment of the particulate matter ambient air quality standards throughout the Region.

Forecast Particulate Matter Levels: In order to evaluate the probable impact of future regional growth and development on particulate matter levels in the Region, forecasts of particulate matter emissions in southeastern Wisconsin were prepared for the year 1982—the year mandated by Congress for achieving the primary standards—the year 1985—corresponding to the intermediate stage year of the adopted regional land use and transportation plans—and the design year 2000—the year to which the plan is to ensure the maintenance of the ambient air quality standards. The particulate matter emissions were

Table 363

SUMMARY OF EXISTING AND FORECAST PARTICULATE MATTER EMISSIONS IN THE REGION BY COUNTY: 1977, 1982, 1985, AND 2000

County	Existing 1977 Emissions (tons)	Forecast 1982 Emissions (tons)			Forecast 1985 Emissions (tons)			Forecast 2000 Emissions (tons)		
			Difference 1977-1982			Difference 1977-1985			Difference 1977-2000	
		Emissions	Absolute	Percent Change	Emissions	Absolute	Percent Change	Emissions	Absolute	Percent Change
Kenosha	1,495	1,858	363	24.3	1,894	399	26.7	2,444	949	63.5
Milwaukee . . .	12,919	12,264	- 655	- 5.1	13,633	714	5.5	15,185	2,266	17.5
Ozaukee	1,608	1,560	- 48	- 3.0	1,581	- 27	- 1.7	1,987	379	23.6
Racine	2,645	2,569	- 76	- 2.9	2,715	70	2.6	3,013	368	13.9
Walworth. . . .	2,337	2,266	- 71	- 3.0	2,315	- 22	- 0.9	2,448	111	4.7
Washington . .	1,689	1,725	36	2.1	1,749	60	3.6	1,813	124	7.3
Waukesha . . .	7,805	7,604	- 201	- 2.6	7,665	- 140	- 1.8	7,929	124	1.6
Region	30,498	29,846	- 652	- 2.14	31,552	1,054	3.5	34,819	4,321	14.2

Source: SEWRPC.

forecast under the coal-intensive, or "worst case," energy scenario for point sources; under the "no build" alternative to the adopted transportation plan for line sources; and under the assumption that natural gas supplies would be inadequate to meet residential, small industrial, and commercial-institutional space heating and water heating demands after 1980 for area sources. The total particulate matter emissions in the Region as forecast for the years 1982, 1985, and 2000 on the basis of the above premises are summarized by county in Table 363. The relative contributions of point, line, and area sources to the total particulate matter emissions burden in the Region as forecast for the years 1982, 1985, and 2000 are shown in Figure 116.

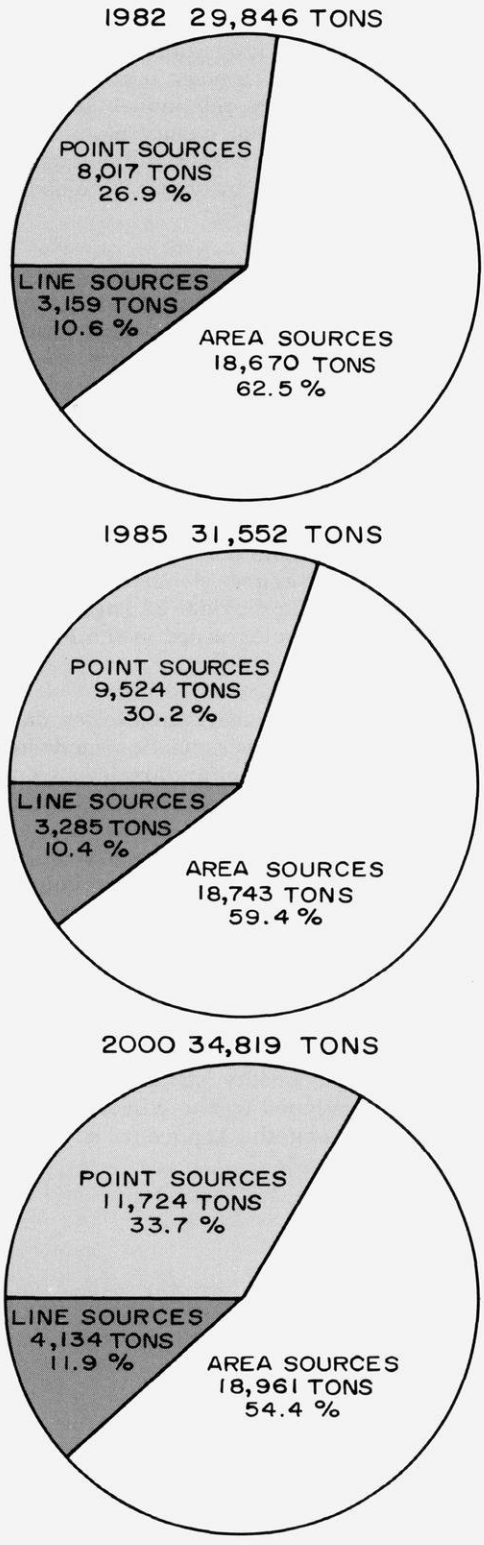
As may be seen in Table 363, total particulate matter emissions in the Region from all sources may be expected to increase by about 4,300 tons, or about 14 percent, between 1977 and the year 2000—from 30,500 tons to 34,800 tons. This forecast increase may be attributed almost entirely to particulate matter emissions from point sources—expected to increase from about 7,400 tons in 1977 to about 11,700 tons in the year 2000 as a result of the anticipated increase in coal use for industrial purposes, as well as the general growth and development of the Region. The small, 300-ton, increase in particulate matter emissions from area sources expected between 1977 and the year 2000 is expected to be offset by an equivalent reduction in particulate matter emissions from line sources. As a result, point sources are expected to contribute approximately 34 percent of the total regional particulate matter emissions burden in the year 2000—as compared with 24 percent in the year 1977; and area sources are expected to contribute about 54 percent of the total particulate matter emissions burden in the year 2000—as compared with 61 percent in 1977.

Particulate matter emissions from point, line, and area sources in the Region were forecast using the calibrated Wisconsin Atmospheric Diffusion Model to simulate future ambient air quality with regard to this pollutant species. For forecasting purposes, the average meteorological conditions observed in the Region over a five-year period, 1964 through 1968, were used in the simulation modeling effort. The results of this air quality simulation modeling effort for the year 2000 are shown on Map 118 in Chapter XII. As is shown on Map 118, an 11-square-mile area is forecast to exceed the primary annual standard of 75 $\mu g/m^3$ in Milwaukee County in the year 2000—an increase of six square miles, or 120 percent, over the area exceeding this standard in 1977. The secondary annual standard of 60 $\mu g/m^3$ is expected to be exceeded over an additional 75-square-mile area in Milwaukee County in the year 2000, an increase of about 51 square miles, or 213 percent, over the area exceeding this standard in 1977. Finally, the areas exceeding the secondary annual standard around major quarrying operations in Milwaukee, Racine, and Waukesha Counties in 1977 are forecast to also exceed this standard in the year 2000.

Based on the results of the air quality simulation modeling effort for the year 2000, it may be concluded that the particulate matter air pollution problem in the Region will increase in severity—both in magnitude and in areal extent—over the design period under the coal-intensive scenario. An estimated 152,100 persons, or 6.9 percent of the total forecast regional population in the year 2000, will reside in areas not meeting the primary, or health-related, annual average ambient air quality standard for particulate matter. In other words, approximately 86,500, or about 132 percent, more people will be exposed to harmful particulate matter levels in the year 2000 than

Figure 116

RELATIVE CONTRIBUTION OF POINT, LINE, AND AREA SOURCES TO THE TOTAL FORECAST PARTICULATE MATTER EMISSIONS IN THE REGION 1982, 1985, AND 2000



Source: SEWRPC.

were in 1977. A plan for the long-term maintenance of particulate matter ambient air quality standards was thus deemed necessary as a supplement to the attainment plan.

Sulfur Dioxide: Sulfur dioxide is the most predominant of all sulfur compounds in the atmosphere and therefore may be used as an index of the total sulfur oxide pollution problem. Sulfur dioxide is a nonflammable, nonexplosive, colorless gas that is highly soluble in water. It can act as either a reducing agent or an oxidizing agent. Even in low concentrations it has a pungent, irritating odor. The principal source of sulfur dioxide in the atmosphere is the combustion of fossil fuels containing elemental sulfur or sulfur-bearing compounds.

Inhalation of sulfur dioxide has been found to produce a constriction in human bronchial tubes. Sulfur dioxide has also been found to accentuate symptoms in persons with chronic respiratory disease, and has been associated with increased morbidity of elderly persons having cardiovascular disease. Sulfur dioxide in the ambient air thus represents a threat to human health.

Some animals have been found to be able to tolerate higher sulfur dioxide concentrations than can be accepted by humans. Vegetation and materials have also been found to be more tolerant of sulfur dioxide concentrations. Humans have thus been determined to be the most susceptible to the effects of sulfur dioxide.

Because both long-term and short-term exposures to sulfur dioxide have been associated with increased respiratory illness in humans, a primary annual average standard and a primary 24-hour average standard for sulfur dioxide have been established by the federal government to protect the public health. The primary annual average standard was established at 80 micrograms per cubic meter ($\mu g/m^3$), and the primary 24-hour average standard was established at 365 $\mu g/m^3$, based on available laboratory, toxicological, and epidemiological data. Since concentrations below these levels have not been found to have an adverse effect on plants, animals, and materials, no annual average or 24-hour average secondary standards are deemed necessary. In order to prevent a short-term exposure to extremely high doses of sulfur dioxide, however, a three-hour average secondary standard was established at 1,300 $\mu g/m^3$. The existing and forecast sulfur dioxide levels in the Region as they relate to the above-mentioned ambient air quality standards, and the major sources of sulfur dioxide emissions, are summarized in the following sections.

Existing Sulfur Dioxide Levels: In 1976, the base year selected for the analysis of existing sulfur dioxide levels in the Region, there were five sulfur dioxide ambient air quality monitors operating as a part of the regional ambient air quality monitoring network: four sites in Milwaukee County and one site in Racine County. During this year, none of these five monitoring sites recorded a violation of the annual, 24-hour, or three-hour average sulfur dioxide ambient air quality standards. However, violations of the 24-hour average sulfur dioxide standard were recorded during 1978 at two monitoring sites in the City of Milwaukee—1225 S. Carferry Drive and 2114 E. Kenwood Boulevard. Based upon these monitored viola-

tions of the 24-hour standard, the Wisconsin Department of Natural Resources has proposed that the 7.4-square-mile area in Milwaukee County shown on Map 85 in Chapter XI be designated as a nonattainment area for sulfur dioxide.[3]

As with particulate matter, a comprehensive sulfur dioxide emissions inventory was conducted for the Region for the year 1976 in order to determine the magnitude and spatial distribution of sulfur dioxide emission sources and to identify other potential problem areas. The impact of the inventoried emissions on ambient air quality within the Region was evaluated using the Wisconsin Atmospheric Diffusion Model. The results and findings of this emissions inventory and modeling effort are summarized below.

Sulfur Dioxide Emissions Inventory and Air Quality Simulation Modeling Results and Findings: The sulfur dioxide emissions inventory conducted for the Region for the year 1976 is summarized by county and by major source category in Table 364. The relative contribution of point, line, and area sources to the total sulfur dioxide emissions burden in the Region in 1976 is indicated in Figure 117. As may be seen in Table 364 and in Figure 117, point sources were the principal contributor to the sulfur dioxide emissions burden in the Region in 1976, accounting for about 236,600 tons, or nearly 95 percent, of the total 249,900 tons of emissions of this pollutant species. As is also indicated in Table 364, about 184,800 tons of the point source emissions, or more than 78 percent of the sulfur dioxide emissions from point sources in the Region in 1976, were attributable to facilities located within Milwaukee County—primarily fuel-burning installations having a heat input capacity of 100 million British Thermal Units (BTU's) per hour and greater.

Area sources accounted for about 11,400 tons of sulfur dioxide emissions during 1976, or less than 5 percent of the total sulfur dioxide emissions in the Region during that year. About 10,200 tons of these sulfur dioxide emissions, or about 90 percent of the total sulfur dioxide emissions from all area sources in 1976, were attributable to the combustion of fossil fuels in residential, small industrial, and commercial-institutional boilers or furnaces. Line sources of sulfur dioxide emissions did not contribute significantly to the regional emissions burden, accounting for only about 1,800 tons, or less than 1 percent, of the total estimated emissions of this pollutant species during 1976.

As previously mentioned, the impact on air quality of the level and distribution of sulfur dioxide emissions in the Region as described above was simulated using the Wisconsin Atmospheric Diffusion Model under prevailing meteorological conditions for 1976. Although there were too few sulfur dioxide monitoring stations operating in the Region during 1976 to permit the calibration of the modeling results with mathematical significance, agreement was observed on an annual average basis between the concentrations calculated by the model and the available sulfur dioxide ambient air quality monitoring data.[4] The results of the annual average sulfur dioxide modeling effort for the year 1976 are shown on Map 69 in Chapter XI.

Consistent with the results and findings of the available ambient air quality monitoring data for sulfur dioxide levels in 1976, the air quality simulation modeling results indicated that the primary annual average ambient air quality standard of 80 $\mu g/m^3$ was not exceeded anywhere in the Region during 1976. The simulation modeling results shown on Map 69 indicate a maximum isopleth value of 50 $\mu g/m^3$, centered in and around the central business district in the City of Milwaukee—a value which is only about 63 percent of the primary annual average standard. Furthermore, simulation modeling results indicated that neither the 24-hour average standard nor three-hour average standard for sulfur dioxide—365 $\mu g/m^3$ and 1,300 $\mu g/m^3$, respectively—were exceeded in the Region during 1976.

Both the available ambient air quality monitoring data and the results of the air quality simulation modeling effort indicated attainment of the sulfur dioxide ambient air quality standards in 1976. Although the monitoring data and modeling results proved mutually supportive, violations of the 24-hour average sulfur dioxide standard were recorded at two locations in Milwaukee County during 1978, indicating a need for a sulfur dioxide attainment plan for parts of the Region.

It should again be noted that the proposed designation of a sulfur dioxide nonattainment area in Milwaukee County based on the violations of the 24-hour average sulfur dioxide ambient air quality standard observed during 1978 has been questioned by the Wisconsin Electric Power Company. Among the arguments advanced

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[3] *The designation of a sulfur dioxide nonattainment area in Milwaukee County has been challenged by the Wisconsin Electric Power Company based upon the marginal nature of the violations and questions concerning the accuracy of the monitoring data, as well as the fact that no such violations were monitored during 1979. The issues raised by WEPCO have not yet been formally resolved by the U. S. Environmental Protection Agency.*

[4] *The mathematical significance of the correlation between the monitored and calculated pollutant concentrations is a statistical measure of the probability that the predicted relationship is not due to random chance. Although the relationship between the predicted sulfur dioxide concentrations and the monitored sulfur dioxide concentrations could not be demonstrated to be significant in a mathematical sense—essentially because there were too few sulfur dioxide monitoring sites on which to make comparisons—the correlation was nonetheless significant in a practical sense.*

Table 364

SUMMARY OF SULFUR DIOXIDE EMISSIONS IN THE REGION BY COUNTY AND BY MAJOR SOURCE CATEGORY: 1976

County	Point Sources			Line Sources			Area Sources			Total	
	Emissions (tons)	Percent of Source Total	Percent of County Total	Emissions (tons)	Percent of Source Total	Percent of County Total	Emissions (tons)	Percent of Source Total	Percent of County Total	Emissions (tons)	Percent of Region
Kenosha	392	0.17	26.2	180	10.0	12.0	925	8.1	61.8	1,497	0.6
Milwaukee . . .	184,788	78.09	96.8	768	42.9	0.4	5,444	47.6	2.9	191,000	76.4
Ozaukee	51,136	21.60	98.8	112	6.3	0.2	502	4.4	0.9	51,750	20.7
Racine	208	0.09	11.6	180	10.0	10.0	1,400	12.3	78.3	1,788	0.7
Walworth. . . .	32	0.01	4.7	124	6.9	18.3	522	4.6	77.0	678	0.3
Washington . .	8	--[a]	0.9	120	6.7	13.3	775	6.8	85.8	903	0.4
Waukesha . . .	84	0.04	3.7	308	17.2	13.7	1,857	16.2	82.6	2,249	0.9
Region	236,648	100.00	94.7	1,792	100.0	0.7	11,425	100.0	4.6	249,865	100.0

[a] *Less than 0.01 percent.*

Source: SEWRPC.

by the company against the proposed designation is the fact that no such violation of the 24-hour average standard, or of the standard for any other sulfur dioxide averaging period, was monitored during 1979, and thus, presumably, the violations observed during 1978 were due to unique circumstances not related to the normal operation of existing sulfur dioxide emission sources. Formal resolution of this issue rests within the administrative authority of the U. S. Environmental Protection Agency.

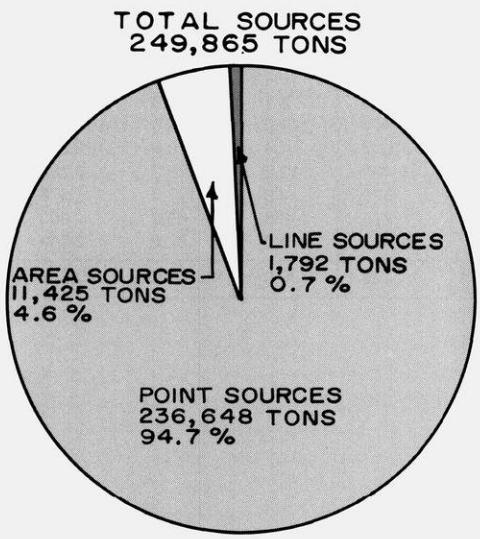
Forecast Sulfur Dioxide Levels: In order to evaluate the impact of future regional growth and development on sulfur dioxide levels in the Region, forecasts of sulfur dioxide emissions in southeastern Wisconsin were prepared for the years 1982, 1985, and 2000. The sulfur dioxide emissions were forecast under the coal-intensive, or "worst-case," energy scenario for point sources; under the adopted regional transportation plan for line sources; and under the assumption that natural gas supplies would be inadequate to meet residential, small industrial, and commercial-institutional space and water heating demands after 1980 for area sources. The total sulfur dioxide emissions in the Region as forecast for the years 1982, 1985, and 2000 on the basis of the above premises are summarized by county in Table 365. The relative contributions of point, line, and area sources to the total sulfur dioxide emissions burden in the Region as forecast for the years 1982, 1985, and 2000 are shown in Figure 118.

As may be seen in Table 365, total sulfur dioxide emissions in the Region from all sources may be expected to decrease by about 22,300 tons, or about 9 percent, between 1976 and the year 2000—from about 249,900 tons to about 227,600 tons. This anticipated decrease is attributable to a reduction in point source emissions, since such emissions are expected to decline by about 30,800 tons, or 13 percent—from about 236,600 tons in 1976 to about 205,800 tons in the year 2000. This reduction will be offset somewhat by an increase in sulfur dioxide emissions from area and line sources. Area source sulfur dioxide emissions are forecast to increase by about 7,800 tons, or 68 percent, between 1976 and 2000—from about 11,400 tons to about 19,200 tons. Line source sulfur dioxide emissions are forecast to increase by about 800 tons, or 44 percent—from about 1,800 tons in 1976 to about 2,600 tons in the year 2000. The reduction in sulfur dioxide emissions from point sources between 1976 and 2000 is anticipated to result primarily from the assumed retirement of the Wisconsin Electric Power Company's Port Washington Plant after 1985. Sulfur dioxide emissions from point sources in Ozaukee County, therefore, are forecast to decrease by about 48,200 tons, or more than 94 percent, between 1976 and the year 2000—from about 51,100 tons to about 2,900 tons. Thus, although a general shift to more extensive use of coal by industrial facilities in the Region has been forecast, point source emissions of sulfur dioxide are anticipated to decrease on a regional basis because of the large reduction in emissions expected to result from the retirement of the electric power generation plant at Port Washington in Ozaukee County.[5]

[5] *The proposed retirement schedule for generating units at the Port Washington electric power generating plant is: Unit 1 by January 1, 1991; Unit 2 by January 1, 1994; Unit 3 by January 1, 1999; Unit 4 by January 1, 2000; and Unit 5 by January 1, 2001. The 1978 WEPCO Advance Plan does not contain proposals for the construction of a new electric power generating plant at the North Harbor site in downtown Milwaukee.*

Figure 117

SUMMARY OF SULFUR DIOXIDE EMISSIONS IN THE REGION BY MAJOR SOURCE CATEGORY: 1976



Source: SEWRPC.

The impact on ambient air quality of the forecast sulfur dioxide emissions from point, line, and area sources in the Region was simulated using the Wisconsin Atmospheric Diffusion Model. The results of this simulation modeling effort for annual average sulfur dioxide levels in the Region in the year 2000 are shown on Map 137 in Chapter XII. As shown on Map 137, the annual average sulfur dioxide ambient air quality standard of 80 $\mu g/m^3$ is indicated to be exceeded over a 9.6-square-mile area in the year 2000. However, the simulation modeling effort indicated that the annual average sulfur dioxide standard would not be exceeded in 1985. Thus, sulfur dioxide levels may be anticipated to exceed the annual average standard in parts of Milwaukee County after 1985 but prior to the year 2000.

The underlying reason for the increase in ambient air sulfur dioxide concentrations by the year 2000 is that, although regional point source emissions are forecast to decrease over the planning period, the near ground-level sulfur dioxide emissions from line sources and, in particular, from area sources are forecast to increase. Line and area source emissions have a greater impact on ambient air quality since they are released near the surface. Point source emissions, which are generally released from substantially elevated stacks, must travel through a greater volume of air, and therefore become more dilute before impacting upon the surface. Thus, the relatively significant increase in sulfur dioxide emissions from line and area sources anticipated between 1976 and 2000—about 68 and 44 percent, respectively—may be expected to result in violations of the annual average sulfur dioxide ambient air quality standard, assuming the "worst case" coal-intensive and transportation system scenario. Moreover, as the annual average sulfur dioxide levels increase, the potential for violations of the short-term sulfur dioxide standards may also be expected to increase.

An estimated 130,300 persons will reside in that portion of Milwaukee County forecast to exceed the annual average sulfur dioxide ambient air quality standard of 80 $\mu g/m^3$ in the year 2000. It has been concluded, therefore, that an attainment plan and a maintenance plan are required to ensure salubrious levels of sulfur dioxide in the Southeastern Wisconsin Region.

Carbon Monoxide: Carbon monoxide is a colorless, odorless, tasteless gas which is slightly lighter than air. It is the most widely distributed and most commonly occurring of the air pollutants, accounting by weight for more total atmospheric pollution than all the other pollutants combined. Carbon monoxide is formed primarily by the incomplete combustion of carbonaceous material used as fuels for motor vehicles, space heating, and industrial processes, or burned as refuse. Among the natural sources of carbon monoxide are such physical sources as volcanoes, lightning-caused forest fires, and the photodissociation of carbon dioxide in the upper atmosphere, as well as oceans through as yet undetermined mechanisms.

Carbon monoxide is the agent responsible for most of the poisoning deaths occurring in the United States each year. Carbon monoxide is readily absorbed into the lungs and reacts with proteins in the blood, most notably hemoglobin, to reduce the oxygen-carrying and -exchange mechanism in the circulatory system. Normally, oxygen is attached to hemoglobin compounds, termed oxyhemoglobin, and carried to tissues in the body where the oxygen is exchanged for waste gas. Hemoglobin, however, has an affinity for carbon monoxide over 200 times greater than for oxygen. When carbon monoxide is inhaled, therefore, carboxyhemoglobin is preferentially formed. Carboxyhemoglobin is a much more stable compound than oxyhemoglobin and, consequently, does not permit the necessary exchange of gases in the body's tissues to occur. The result, if sufficient concentrations of carbon monoxide are inhaled, is mortality by suffocation.

Carboxyhemoglobin may build up in the blood, depending on such factors as the ambient air concentration of carbon monoxide, length of exposure, and breathing rate. This buildup is rapid at early exposures to carbon monoxide and gradually proceeds at a slower rate. If the concentration of carbon monoxide remains constant, an equilibrium will be reached—that is, the pressure of carbon monoxide in the blood will be equal to the opposing pressure of the carbon monoxide in the alveolar sacs and the ambient air—after about eight hours of exposure.

Deleterious health effects are exhibited in humans when carboxyhemoglobin levels reach about 2.5 percent in the blood. Thus, the air quality standards for carbon

Table 365

SUMMARY OF EXISTING AND FORECAST SULFUR DIOXIDE EMISSIONS IN THE REGION BY COUNTY: 1976, 1982, AND 2000

County	Existing 1976 Emissions (tons)	Forecast 1982 Emissions (tons)			Forecast 1985 Emissions (tons)			Forecast 2000 Emissions (tons)		
			Difference 1976-1982			Difference 1976-1985			Difference 1976-2000	
		Emissions	Absolute	Percent Change	Emissions	Absolute	Percent Change	Emissions	Absolute	Percent Change
Kenosha	1,497	12,389	10,892	727.6	12,656	11,159	745.4	23,003	21,506	1,436.6
Milwaukee . . .	191,000	173,506	- 17,494	- 9.2	178,437	- 12,563	- 6.6	186,501	- 4,499	- 2.4
Ozaukee	51,750	38,762	- 12,988	- 25.1	38,840	- 12,910	- 24.9	4,030	- 47,720	- 92.2
Racine	1,788	2,330	542	30.3	3,431	1,643	91.9	5,209	3,421	191.3
Walworth. . . .	678	1,046	368	54.3	1,280	602	88.8	1,752	1,074	158.4
Washington . .	903	2,056	1,153	127.7	2,219	1,316	145.7	2,885	1,982	219.5
Waukesha . . .	2,249	2,696	447	19.9	3,015	766	34.1	4,245	1,996	88.8
Region	249,865	232,785	- 17,080	- 6.8	239,878	- 9,987	- 3.9	227,625	- 22,240	- 8.9

Source: SEWRPC.

monoxide are intended to limit the formation of carboxyhemoglobin in the bloodstream to levels below 2 percent. Since carboxyhemoglobin builds up rapidly during early exposures to carbon monoxide, and since it reaches an equilibrium after about eight hours, a one-hour average and an eight-hour average primary ambient air quality standard have been established by the federal government. These primary standards, 40 milligrams per cubic meter (mg/m^3) and 10 mg/m^3 for the one-hour average and the eight-hour average periods, respectively, are thought to be sufficient to protect the public health with an adequate margin of safety.

Although carbon monoxide has been shown to be harmful to human health and to the health of animals with similar respiratory systems, it has not been shown to have a detrimental effect on vegetation or materials at levels presently found in the ambient air. Moreover, certain plants and soil microorganisms may actually remove carbon monoxide from the air. The secondary ambient air quality standards for carbon monoxide have, therefore, been establishcd at the same level as the primary standards. The existing and forecast carbon monoxide levels in the Region as they relate to the above-mentioned ambient air quality standards, and the major sources of carbon monoxide emissions, are summarized in the following sections.

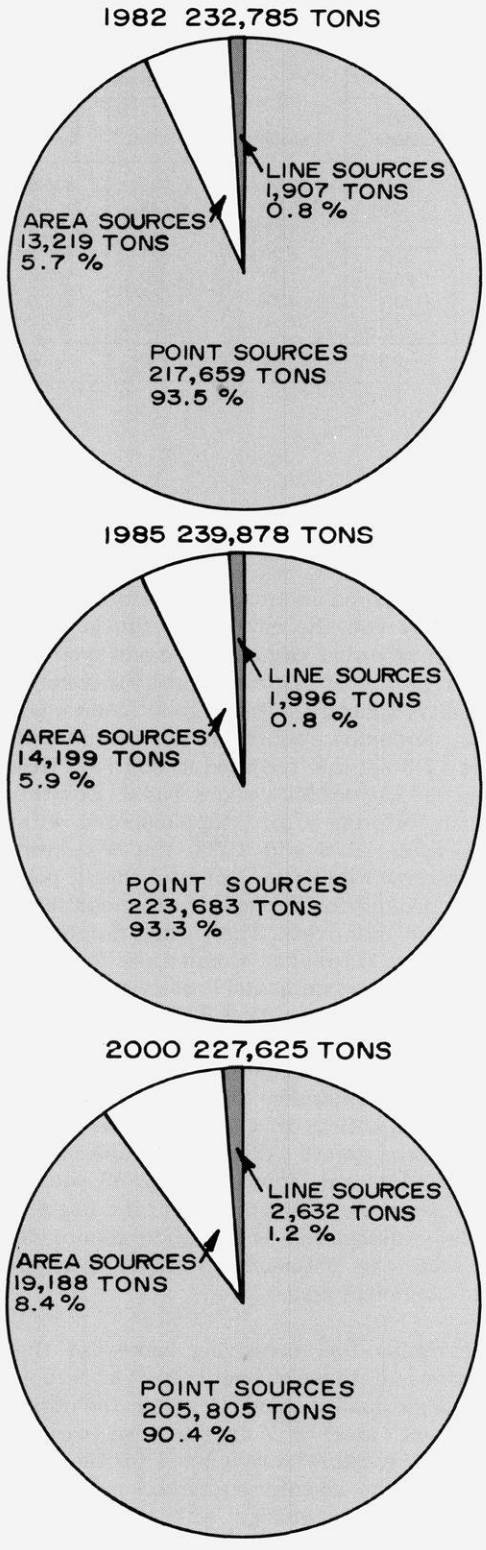
Existing Carbon Monoxide Levels: In 1977, the base year selected for the analysis of existing carbon monoxide levels in the Region, there were seven monitoring stations measuring carbon monoxide levels in the ambient air over southeastern Wisconsin: five in Milwaukee County, one in Racine County, and one in Waukesha County. The highest one-hour average carbon monoxide concentration recorded during 1977 was 25.8 mg/m^3—or about 65 percent of the 40 mg/m^3 ambient air quality standard—measured at 606 W. Kilbourn Avenue in the City of Milwaukee. The five carbon monoxide monitoring sites in Milwaukee County and the monitoring site in Waukesha County each recorded carbon monoxide concentrations in excess of the 10 mg/m^3 eight-hour average ambient air quality standard. The highest eight-hour average carbon monoxide concentration monitored during 1977 was 17.3 mg/m^3, recorded at 3716 W. Wisconsin Avenue in the City of Milwaukee. Based upon the findings of this monitoring effort, supplemented with monitoring data from 1976 and 1978, the Wisconsin Department of Natural Resources proposed that a portion of Milwaukee County be designated as a nonattainment area for carbon monoxide. The carbon monoxide nonattainment area in Milwaukee County, as formally designated by the U. S. Environmental Protection Agency on March 3, 1978, is shown on Map 83 in Chapter XI.

As shown on Map 83, the designated carbon monoxide nonattainment area in Milwaukee County encompasses parts of the municipalities of Glendale, Greenfield, Milwaukee, Wauwatosa, West Allis, West Milwaukee, and Whitefish Bay. In total, approximately 85 square miles, or about 3 percent of the total area of the Region, have been formally designated as a carbon monoxide nonattainment area. An estimated 730,600 persons reside in this nonattainment area.

In order to determine the underlying causes of the monitored violations of the eight-hour average carbon monoxide ambient air quality standard within the designated nonattainment area, a comprehensive carbon monoxide emissions inventory was collated for the year 1977. The impact of the inventoried carbon monoxide emissions on ambient air quality was subsequently analyzed through use of the Wisconsin Atmospheric Diffusion Model. The results and findings of this emissions inventory and modeling effort are summarized in the following section.

Figure 118

RELATIVE CONTRIBUTION OF POINT, LINE, AND AREA SOURCES TO THE TOTAL FORECAST SULFUR DIOXIDE EMISSIONS IN THE REGION: 1982, 1985, AND 2000



Source: SEWRPC.

Carbon Monoxide Emissions Inventory and Air Quality Simulation Modeling Results and Findings: The carbon monoxide emissions inventory conducted for the Region for the year 1977 is summarized by county and by major source category in Table 366. The relative contributions of point, line, and area sources to the total carbon monoxide emissions burden in the Region in 1977 are indicated in Figure 119. As may be seen in Table 366 and Figure 119, line sources were the principal contributor to the carbon monoxide emissions burden in the Region, accounting for about 519,800 tons, or nearly 87 percent, of the total 598,800 tons of emissions of this pollutant species. As also indicated in Table 366, about 273,900 tons, or about 53 percent of the total line source emissions in the Region during 1977, were attributable to motor vehicles operating within Milwaukee County.

The 1977 level and distribution of carbon monoxide emissions in the Region as described above were simulated for their impact on ambient air quality under "worst case" conditions. These "worst case" conditions include a winter weekday from 4:00 a.m. to 1:00 p.m., low wind speeds from a southerly direction, clear skies, and atmospheric stability conditions not conducive to pollutant dispersion. The use of "worst case" meteorological conditions was intended to predict the maximum levels of carbon monoxide which may reasonably be expected, rather than to replicate the dispersion of this pollutant species on any one day. Because a complete set of monitoring data was not available for the "worst case" conditions, five winter days with more complete monitoring data were selected for use in model calibration. The results of this simulation modeling effort are presented on Map 75 in Chapter XI for the maximum one-hour average carbon monoxide concentrations and on Map 74 in Chaper XI for the maximum eight-hour average concentrations in the Region under the 1977 emission levels.

As indicated on Map 75, the maximum one-hour average carbon monoxide concentration in the Region in 1977 was 35 mg/m^3 and occurred in the vicinity of the Marquette Interchange in Milwaukee County. This level is approximately 12 percent below the 40 mg/m^3 standard. This finding is consistent with the available carbon monoxide ambient air quality monitoring data which indicate that the one-hour average carbon monoxide ambient air quality standard was not exceeded during 1977.

As shown on Map 74, the eight-hour average carbon monoxide standard of 10 mg/m^3 is estimated by the simulation model to have been exceeded over a 21-square-mile area in Milwaukee County under "worst case" meteorological conditions. An estimated 267,800 persons, or 15.1 percent of the total regional population, resided in this area in 1977. The air quality simulation modeling results thus support the findings of the ambient air quality monitoring effort that an attainment plan is required to ensure safe levels of carbon monoxide throughout the Region.

Table 366

SUMMARY OF CARBON MONOXIDE EMISSIONS IN THE REGION BY COUNTY AND BY MAJOR SOURCE CATEGORY: 1977

County	Point Sources			Line Sources			Area Sources			Total	
	Emissions (tons)	Percent of Source Total	Percent of County Total	Emissions (tons)	Percent of Source Total	Percent of County Total	Emissions (tons)	Percent of Source Total	Percent of County Total	Emissions (tons)	Percent of Region
Kenosha	32	0.4	0.08	37,694	7.2	87.1	5,565	7.9	12.9	43,291	7.2
Milwaukee . . .	6,840	79.8	2.30	273,936	52.7	90.3	22,484	31.9	7.4	303,260	50.6
Ozaukee	380	4.4	1.50	20,659	4.0	84.0	3,552	5.1	14.4	24,591	4.1
Racine	33	0.4	0.06	46,639	9.0	85.8	7,670	10.9	14.1	54,342	9.1
Walworth. . . .	506	5.9	1.50	24,947	4.8	74.5	8,053	11.4	24.0	33,506	5.6
Washington . .	292	3.4	0.84	26,584	5.1	76.9	7,695	10.9	22.3	34,571	5.8
Waukesha . . .	490	5.7	0.47	89,329	17.2	84.9	15,437	21.9	14.7	105,256	17.6
Region	8,573	100.0	1.40	519,788	100.0	86.8	70,456	100.0	11.8	598,817	100.0

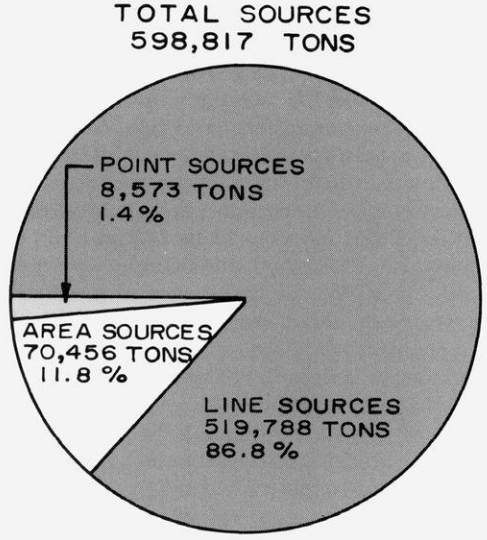
Source: SEWRPC.

Forecast Carbon Monoxide Levels: In order to evaluate the impact of future growth and development on carbon monoxide levels in the Region, forecasts of carbon monoxide emissions were prepared for the years 1982, 1985, and 2000. The carbon monoxide emissions were forecast under the coal-intensive, or "worst case," energy scenario for point sources; under the "no build" alternative to the adopted regional transportation plan for line sources; and under the assumption that natural gas supplies would be inadequate to meet residential, small industrial, and commercial-institutional space and water heating demands after 1980 for area sources. The total carbon monoxide emissions in the Region as forecast for the years 1982, 1985, and 2000 on the basis of the above premises are summarized by county in Table 367. The relative contributions of point, line, and area sources to the total carbon monoxide emissions burden in the Region for the years 1982, 1985, and 2000 are shown in Figure 120.

As may be seen in Table 367, total carbon monoxide emissions from all sources in the Region may be expected to decrease by about 327,100 tons, or about 55 percent, between 1977 and the year 2000—from about 598,800 tons to about 271,700 tons. This anticipated decrease is attributable to a reduction in line source carbon monoxide emissions, which are forecast to decline by about 345,000 tons, or more than 66 percent, between 1977 and the year 2000—from about 519,800 tons to about 174,800 tons—as a result of the implementation of the federal motor vehicle emissions control program. This reduction is expected to be offset somewhat by increases in carbon monoxide emissions from point and area sources. Area source carbon monoxide emissions are forecast to increase by about 12,700 tons, or 18 percent—from about 70,500 tons in 1977 to about 83,200 tons in the year 2000. Point source carbon monoxide emissions are forecast to increase by 5,200 tons, or more than 60 percent—from about 8,600 tons in 1977 to about 13,800 tons in the year 2000. It is important to note that the 66 percent reduction in carbon monoxide emissions from line sources between 1977 and 2000 takes into account an increase of nearly 50 percent in total vehicle miles of travel in the Region over the same period.

Figure 119

SUMMARY OF CARBON MONOXIDE EMISSIONS IN THE REGION BY MAJOR SOURCE CATEGORY: 1977



Source: Wisconsin Department of Natural Resources and SEWRPC.

In order to evaluate future ambient air concentrations of carbon monoxide with regard to the attainment of the eight-hour average standard, carbon monoxide emissions from point, line, and area sources in the Region were forecast for the years 1982, 1985, and 2000 using the Wisconsin Atmospheric Diffusion Model under the same

Table 367

SUMMARY OF EXISTING AND FORECAST CARBON MONOXIDE EMISSIONS IN THE REGION BY COUNTY: 1977, 1982, 1985, AND 2000

County	Existing 1977 Emissions (tons)	Forecast 1982 Emissions (tons)			Forecast 1985 Emissions (tons)			Forecast 2000 Emissions (tons)		
			Difference 1977-1982			Difference 1977-1985			Difference 1977-2000	
		Emissions	Absolute	Percent Change	Emissions	Absolute	Percent Change	Emissions	Absolute	Percent Change
Kenosha	43,291	31,398	- 11,893	- 27.5	24,772	- 18,519	- 42.8	21,880	- 21,411	- 49.5
Milwaukee . . .	303,260	214,661	- 88,599	- 29.2	161,247	- 142,013	- 46.8	121,980	- 181,280	- 59.8
Ozaukee	24,591	18,147	- 6,444	- 26.2	14,547	- 10,044	- 40.8	13,934	- 10,657	- 43.3
Racine	54,342	39,425	- 14,917	- 27.5	30,921	- 23,421	- 43.1	25,253	- 29,089	- 53.5
Walworth. . . .	33,506	26,449	- 7,057	- 21.1	22,180	- 11,326	- 33.8	18,601	- 14,905	- 44.5
Washington . .	34,571	26,208	- 8,363	- 24.2	21,422	- 13,149	- 38.0	18,626	- 15,945	- 46.1
Waukesha . . .	105,256	79,510	- 25,746	- 24.5	64,405	- 40,851	- 38.8	51,444	- 53,812	- 51.1
Region	598,817	435,798	- 163,019	- 27.2	339,494	- 259,323	- 43.3	271,718	- 327,099	- 54.6

Source: SEWRPC.

"worst case" meteorological conditions used in the base year modeling effort. The results of this simulation modeling effort are presented on Maps 158 and 159 in Chapter XII for the years 1982 and 1985, and on Map 160 in Chapter XII for the year 2000. As shown on Map 158, the simulation modeling results indicate that a 2.7-square-mile area around the Marquette Interchange in Milwaukee County may be expected to exceed the eight-hour average carbon monoxide standard of 10 mg/m^3 in 1982. However, Maps 159 and 160 indicate that this eight-hour average standard may be expected to be attained by 1985 and maintained through the year 2000. It was concluded, therefore, that although an attainment plan is required to achieve the eight-hour carbon monoxide ambient air quality standard in the Region, a maintenance plan to ensure the long-term maintenance of this standard is not. The attainment plan, however, is to accelerate the attainment of the carbon monoxide standard to the year 1982.

Nitrogen Dioxide: Nitrogen dioxide, a reddish-brown gas with a characteristic pungent odor, is one member of a family of nitrogen oxide compounds found in the atmosphere. From the standpoint of air pollution, however, nitric oxide (NO) and nitrogen dioxide (NO_2) are the most important of the various oxides of nitrogen. Under the high temperature conditions accompanying the burning of fossil fuels, nitric oxide and, to a much lesser extent, nitrogen dioxide are formed when air is used as the oxidizing agent. Two molecules of nitric oxide—a colorless, odorless gas—are formed when atmospheric oxygen and nitrogen react through the absorption of heat energy. Nitrogen dioxide may then be formed when two molecules of nitric oxide react with atmospheric oxygen in the ambient air.

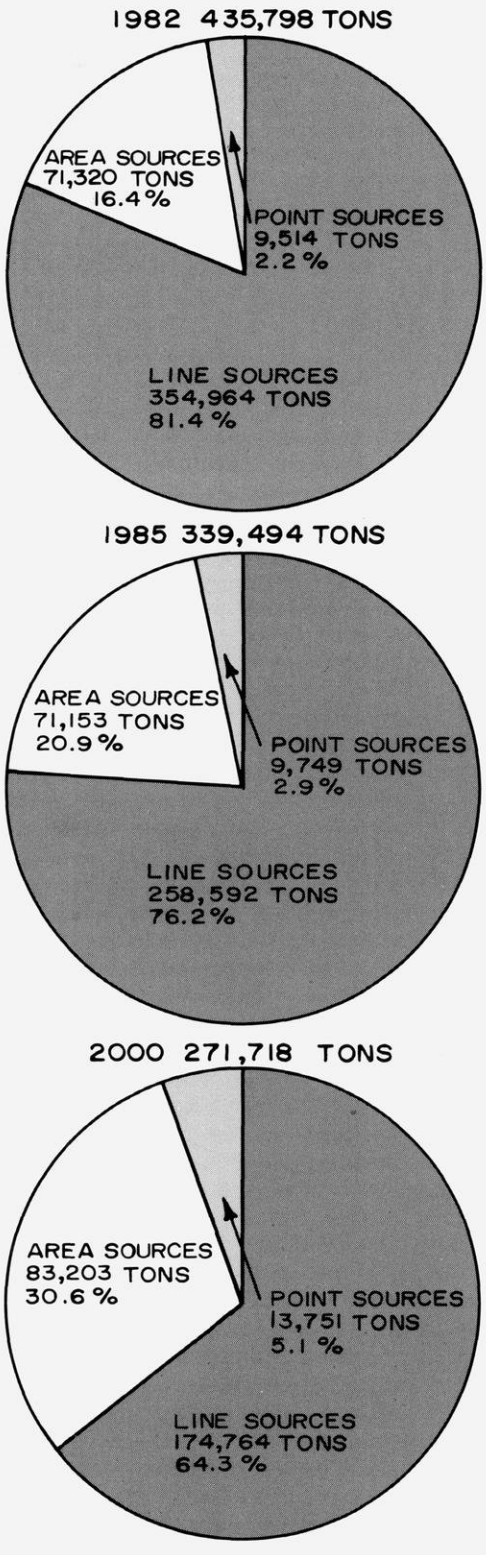
Both nitric oxide and nitrogen dioxide have been demonstrated to produce adverse health effects. The concentrations at which such effects are observed, however, are many times the level at which nitric oxide is found to occur in the ambient air. Nitric oxide, therefore, is not in itself considered to be harmful; rather, its toxic potential stems from its rapid oxidation to nitrogen dioxide and from its role in the photochemical formation of oxidant products.

Long-term exposures to concentrations of nitrogen dioxide at levels commonly found in the ambient air have been associated with impaired respiratory functioning in elementary school-age children and an increase in the frequency of acute respiratory illness in family groups. Similarly, long-term exposure of laboratory animals has shown that nitrogen dioxide inhalation increases susceptibility to bacterial pneumonia and influenza infections and may lead to pulmonary emphysema. Nitrogen dioxide has also been found to react chemically with the water in plant tissues to form a mixture of nitrous and nitric acids which may severely damage the vegetation.

Nitrogen dioxide is the most damaging of the oxides of nitrogen, particularly with long-term periods of exposure. Based upon available laboratory, toxicological, and epidemiological data, therefore, a primary annual average nitrogen dioxide ambient air quality standard has been established by the federal government at 100 micrograms per cubic meter ($\mu g/m^3$). Since adverse effects on animal and plant life, and damage to materials, have been found to occur at concentrations in excess of that level harmful to humans, the secondary annual average nitrogen dioxide standard has been established at the same level as the primary standard. The existing and forecast nitrogen

Figure 120

RELATIVE CONTRIBUTION OF POINT, LINE, AND AREA SOURCES TO THE TOTAL FORECAST CARBON MONOXIDE EMISSIONS IN THE REGION: 1982, 1985, AND 2000



Source: SEWRPC.

dioxide levels in the Region as they relate to the above-mentioned ambient air quality standards, and the major sources of nitrogen oxide emissions, are summarized in the following sections.

Existing Nitrogen Dioxide Levels: In 1977, the base year selected for the analysis of existing nitrogen dioxide levels in the Region, there were four monitoring sites, all in the City of Milwaukee, which sampled for ambient air concentrations of nitrogen dioxide. The highest annual average value reported during 1977—70 $\mu g/m^3$ at 711 W. Wells Street—was well below the standard of 100 $\mu g/m^3$. Thus, based upon the available monitoring data, existing nitrogen dioxide levels in the Region do not pose a threat to the health of the regional population.

Although the monitoring data indicated attainment of the annual average nitrogen dioxide ambient air quality standard, an investigation of the magnitude and distribution of the sources of nitrogen oxide emissions in the Region was conducted, and the results of the investigation were evaluated using the Wisconsin Atmospheric Diffusion Model in order to determine whether this standard was attained throughout the Region during 1977. It should be noted that the emissions inventory was expressed in terms of total nitrogen oxides because, although most of the emissions are in the form of nitric oxide, the rate of conversion of nitric oxide to nitrogen dioxide in the atmosphere of the Region is unknown. The results and findings of this emissions inventory and modeling effort are summarized below.

Nitrogen Oxide Emissions Inventory and Air Quality Simulation Modeling Results and Findings: The nitrogen oxide emissions inventory conducted for the Region for the year 1977 is summarized in Table 368 by county and by major source category. The relative contributions of point, line, and area sources to the total nitrogen oxide emissions burden in the Region in 1977 are indicated in Figure 121. As may be seen in Figure 121, line sources and point sources contributed about equally—about 47,700 tons and 46,300 tons, or 42 and 41 percent, respectively—to the total nitrogen oxide emissions burden in the Region during 1977 of about 114,300 tons. The major point source facilities contributing to the nitrogen oxide emissions in the Region during 1977 were fuel-burning installations—in particular, those installations having a heat input capacity of 100 million or more British Thermal Units (BTU's) per hour—which accounted for about 44,100 tons, or more than 95 percent, of the total 46,3000 tons of this pollutant species emitted by point sources. Milwaukee County accounted for about 38,900 tons, or about 84 percent, of the nitrogen oxide emissions from point sources during 1977. Milwaukee County also accounted for about 21,500 tons, or 45 percent, of the total nitrogen oxide emissions from line sources during 1977.

The level and distribution of nitrogen oxide emissions in the Region as described above were simulated using the Wisconsin Atmospheric Diffusion Model under prevailing meteorological conditions for 1977. Because nitrogen oxides are photochemically reactive, their atmospheric chemistry was not accounted for in the modeling effort.

Table 368

SUMMARY OF NITROGEN OXIDE EMISSIONS IN THE REGION BY COUNTY AND BY MAJOR SOURCE CATEGORY: 1977

County	Point Sources			Line Sources			Area Sources			Total	
	Emissions (tons)	Percent of Source Total	Percent of County Total	Emissions (tons)	Percent of Source Total	Percent of County Total	Emissions (tons)	Percent of Source Total	Percent of County Total	Emissions (tons)	Percent of Region
Kenosha	267	0.58	4.4	4,116	8.6	68.1	1,663	8.2	27.5	6,046	5.3
Milwaukee . . .	38,884	83.99	55.8	21,459	45.0	30.8	9,308	45.8	13.4	69,651	60.9
Ozaukee	6,355	13.73	63.4	2,569	5.4	25.6	1,092	5.4	10.9	10,016	8.8
Racine	342	0.74	4.7	4,646	9.8	64.0	2,275	11.2	31.3	7,263	6.4
Walworth. . . .	192	0.41	4.2	2,893	6.1	63.1	1,503	7.4	32.8	4,588	4.0
Washington . .	23	0.05	0.5	2,975	6.2	62.0	1,800	8.8	37.5	4,798	4.2
Waukesha . . .	233	0.50	2.0	9,010	18.9	75.5	2,684	13.2	22.5	11,927	10.4
Region	46,296	100.00	40.5	47,668	100.0	41.7	20,325	100.0	17.8	114,289	100.0

Source: SEWRPC.

Moreover, the applicable ambient air quality standard is based on annual average concentrations of nitrogen dioxide rather than nitrogen oxides. This simulation modeling effort, therefore, was not intended to define the levels of nitrogen dioxide in the ambient air, but rather to evaluate the spatial distribution of nitrogen oxides within the Region in order to identify potential problem areas not otherwise identified through ambient air quality monitoring. The results of this air quality simulation modeling effort are shown on Map 79 in Chapter XI.

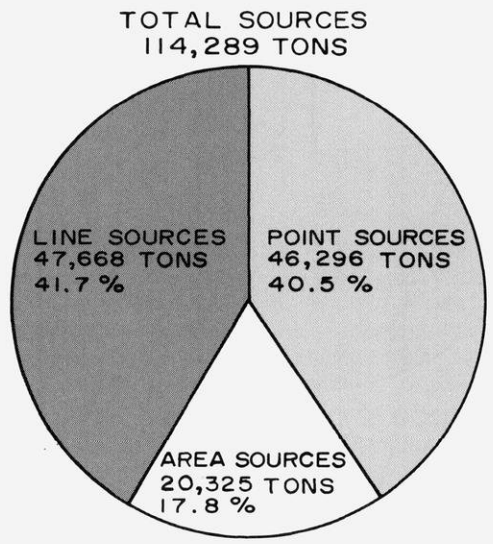
As shown on Map 79, the maximum nitrogen oxide concentration in 1977 was 300 $\mu g/m^3$ and was centered over the Marquette Interchange in Milwaukee County. Since the maximum annual average nitrogen dioxide concentration monitored during 1977 was 70 $\mu g/m^3$, and since the maximum nitrogen oxide concentration of 300 $\mu g/m^3$ predicted by the simulation model occurs in the vicinity of this monitor, it may be inferred that the ratio of nitrogen dioxide to total nitrogen oxides in the area of the Marquette Interchange is approximately 1:4.25. Thus, only if the simulation modeling results had indicated nitrogen oxide levels in excess of 425 $\mu g/m^3$ would it have been assumed that the annual average nitrogen dioxide standard of 100 $\mu g/m^3$ had been exceeded.

The distribution of the nitrogen oxide isopleths shown on Map 79 generally follows the pattern defined by the regional freeway system. Since no other nitrogen oxide isopleths exceed the value of 300 $\mu g/m^3$ calculated for the area of the Marquette Interchange—an area encompassed by existing nitrogen dioxide monitoring sites—it may be concluded by inference that no area in the Region presently exceeds the annual average ambient air quality standard for nitrogen dioxide.

Since the ambient air quality standard for nitrogen dioxide is not presently exceeded in the Region, an attainment plan for this pollutant species was not deemed necessary. In order to evaluate the impact of the anticipated growth and development in the Region on the continued maintenance of the nitrogen dioxide standard, forecasts of future emissions of this pollutant species were prepared and analyzed. These forecasts and analyses are summarized below.

Figure 121

SUMMARY OF NITROGEN OXIDE EMISSIONS IN THE REGION BY MAJOR SOURCE CATEGORY: 1977



Source: SEWRPC.

Forecast Nitrogen Dioxide Levels: Nitrogen oxide emissions were forecast under the coal-intensive, or "worst case," energy scenario for point sources; under the "no build" alternative to the adopted regional transportation plan for line sources; and under the assumption that

Table 369

SUMMARY OF EXISTING AND FORECAST NITROGEN OXIDE EMISSIONS IN THE REGION BY COUNTY: 1977, 1982, 1985, AND 2000

County	Existing 1977 Emissions (tons)	Forecast 1982 Emissions (tons)			Forecast 1985 Emissions (tons)			Forecast 2000 Emissions (tons)		
		Emissions	Difference 1977-1982		Emissions	Difference 1977-1985		Emissions	Difference 1977-2000	
			Absolute	Percent Change		Absolute	Percent Change		Absolute	Percent Change
Kenosha	6,046	12,822	6,776	112.1	12,675	6,629	109.6	19,981	13,935	230.5
Milwaukee . . .	69,651	66,883	- 2,768	- 4.0	67,008	- 2,643	- 3.8	78,491	8,840	12.7
Ozaukee	10,016	9,732	- 284	- 2.8	9,603	- 413	- 4.1	19,912	9,896	98.8
Racine	7,263	6,548	- 715	- 9.8	6,700	- 563	- 7.8	7,294	31	0.4
Walworth. . . .	4,588	4,308	- 280	- 6.1	4,270	- 318	- 6.9	4,306	- 282	- 6.1
Washington . .	4,798	6,531	1,733	36.1	6,416	1,618	33.7	6,436	1,638	34.1
Waukesha . . .	11,927	10,344	- 1,583	- 13.3	9,776	- 2,151	- 18.0	10,169	- 1,758	14.7
Region	114,289	117,168	2,879	2.5	116,448	2,159	1.9	146,589	32,300	28.3

Source: SEWRPC.

natural gas supplies would be inadequate to meet residential, small industrial, and commercial-institutional space and water heating demands after 1980 for area sources. The total nitrogen oxide emissions in the Region as forecast on the basis of the above premises for the years 1982, 1985, and 2000 are summarized by county in Table 369. The relative contributions of point, line, and area sources to the total nitrogen oxide emissions burden in the Region as forecast for the years 1982, 1985, and 2000 are shown in Figure 122.

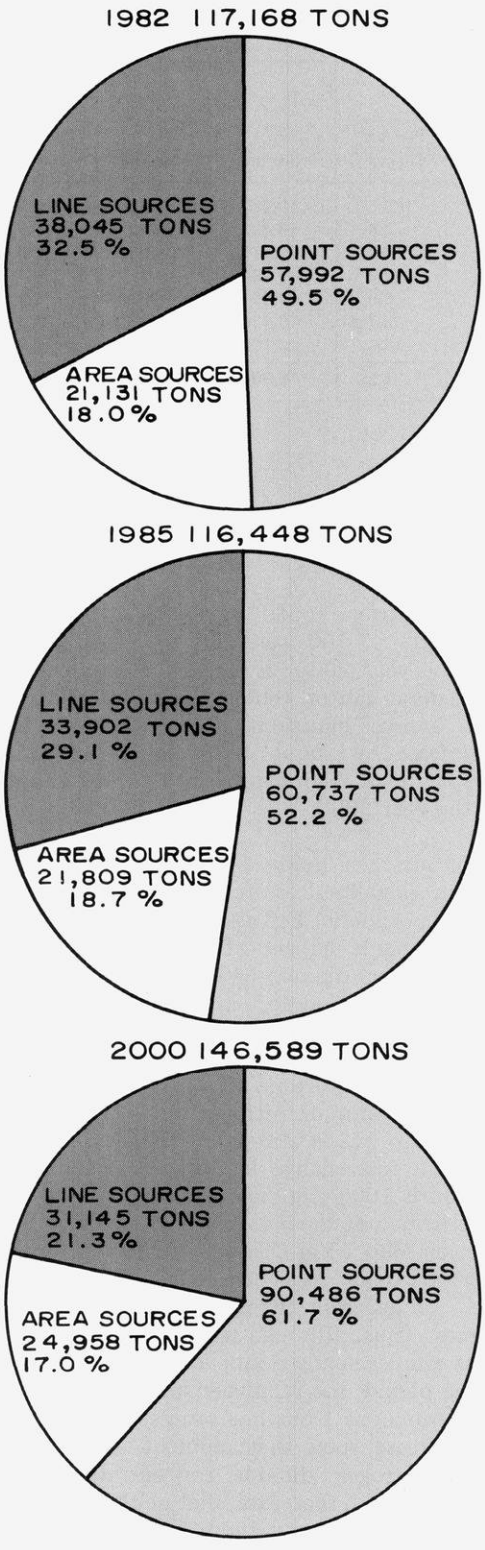
As may be seen in Table 369, total nitrogen oxide emissions in the Region from all sources may be expected to increase by about 32,300 tons, or more than 28 percent, between 1977 and the year 2000—from about 114,300 tons to about 146,600 tons. As may be seen by comparing Figure 121 with Figure 122, point source nitrogen oxide emissions demonstrate the greatest increase in both an absolute and relative sense, increasing by about 44,200 tons, or more than 95 percent—from 46,300 tons in 1977 to 90,500 tons in the year 2000. This significant increase in nitrogen oxide emissions from point sources is due principally to the assumed addition of electric power generation plants in Kenosha, Milwaukee, and Ozaukee Counties.[6] Offsetting this increase somewhat is a decrease of about 16,600 tons, or about 35 percent, in nitrogen oxide emissions from line sources—from about 47,700 tons in 1977 to about 31,100 tons in the year 2000—as a result of implementation of the federal motor vehicle emissions control program. Area source emissions, however, may be expected to increase by about 4,700 tons, or about 23 percent—from about 20,300 tons in 1977 to about 25,000 tons in the year 2000.

The forecasts of nitrogen oxide emissions from point, line, and area sources in the Region were simulated using the Wisconsin Atmospheric Diffusion Model in order to evaluate the probable impact of future growth and development on nitrogen dioxide levels. As noted earlier, no representative prediction of nitrogen dioxide in the ambient air could be made because of the photochemical nature of this pollutant species. The results of this simulation modeling effort are presented on Map 172 in Chapter XII. The maximum nitrogen oxide concentration indicated on Map 172 is 200 $\mu g/m^3$ and is centered over the Marquette Interchange in Milwaukee County. This concentration is 100 $\mu g/m^3$ less than the 300 $\mu g/m^3$ concentration indicated at the Marquette Interchange for 1977, as shown on Map 79 in Chapter XI. This forecast decrease in nitrogen oxide concentrations is attributable to the expected reduction in nitrogen dioxide emissions from line sources. Thus, although nitrogen oxide emissions from point sources nearly double on a regional basis over the planning period, the relatively small decrease in the near-surface emissions from line sources is expected to offset this increase such that ambient air quality improvements in nitrogen dioxide concentrations are realized. It was concluded, therefore, that neither a short-term attainment plan nor a long-term maintenance plan is required to ensure salubrious levels of nitrogen dioxide in the Region.

[6] *The 1978 Advance Plan of the Wisconsin Electric Power Company does not include proposals for the construction of an additional electric power generating plant in Milwaukee County.*

Figure 122

RELATIVE CONTRIBUTION OF POINT, LINE, AND AREA SOURCES TO THE TOTAL FORECAST NITROGEN OXIDE EMISSIONS IN THE REGION: 1982, 1985, AND 2000



Source: SEWRPC.

Hydrocarbons and Ozone: Hydrocarbons are compounds whose molecules consist solely of hydrogen and carbon atoms. Hydrocarbons have no direct effect on human health at levels currently found in the atmosphere. Hydrocarbons, however, enter into and promote the formation of photochemical oxidants—the most significant of which is ozone—and other compounds that have been shown to have a deleterious effect on public health. Hydrocarbons react with oxygen atoms, ozone molecules, and certain other oxidation products generated by the action of sunlight on other components in the atmosphere, particularly nitrogen dioxide. Sunlight alone has no appreciable effect on hydrocarbons in the ambient air, and without such reactive products as ozone, hydrocarbons would not be involved in photochemical air pollution.

Photochemical oxidants enter the body through the respiratory tract. Being chemically active, oxidants may react with the mucus and tissue layers in all compartments of the respiratory tract, causing a deterioration of the cellular lining and, consequently, a restriction of normal pulmonary functions. Ozone in particular appears to cause substantial damage to the respiratory tract. In laboratory experiments in which animals were exposed to a mixture of photochemical oxidants, ozone was found to be the principal damage-producing pollutant.

Of all the oxidant products, only ozone is known to deteriorate materials. Rubber is probably the most important material sensitive to ozone. Ozone has also been found to deteriorate the cellulose in textile fibers. Ozone acts in the presence of light and humidity to alter appreciably the breaking strength and fluidity of fibers. The susceptibility of different fibers is related to their chemical structure. In increasing order, the most susceptible fibers appear to be cotton, acetate, nylon, and polyester.

In order to protect the public health and welfare from the deleterious effects of photochemical oxidants, the federal government initially established an ambient air quality standard for this mixture of reactive pollutants, measured as ozone, at 160 micrograms per cubic meter ($\mu g/m^3$) or 0.08 part per million (ppm) for a one-hour maximum average. The one-hour averaging period was promulgated since adverse health effects were observed to occur rapidly during short-term exposures, and since a tolerance to the effects of this pollutant species was suspected with longer-term exposures. In addition, since photochemical oxidants are not emitted into the atmosphere, but rather are formed in the ambient air through the reaction of sunlight with precursor compounds, a hydrocarbon ambient air quality standard was promulgated as a guideline for achieving the photochemical oxidant standard. The hydrocarbon standard was established by the federal government at 160 $\mu g/m^3$ (0.24 ppm) for a three-hour, 6 a.m. to 9 a.m., averaging period since a strong correlation was observed between early morning hydrocarbon concentrations and maximum ozone concentrations during the afternoon.

Recognizing that ozone was the principal photochemical oxidant product, the federal government redesignated the photochemical oxidant ambient air quality standard

to an ozone ambient air quality standard on February 8, 1979. Moreover, the revised standard was established at 235 $\mu g/m^3$ (0.12 ppm) for a maximum one-hour average. This increase was promulgated on the basis of more recent health data, which indicated that toxic ozone effects do not occur below a level of about 300 $\mu g/m^3$ (0.15 ppm) for a one-hour period of exposure. An ambient air quality standard for ozone of 235 $\mu g/m^3$ (0.12 ppm) was therefore deemed sufficient to protect the public health and welfare with an adequate margin of safety.

Existing Hydrocarbon and Ozone Levels: Only a limited amount of ambient air quality monitoring data on regional hydrocarbon levels is available to date. Under a special contract with the Wisconsin Department of Natural Resources, Washington State University did monitor for hydrocarbon concentrations at the Kenosha Airport between August 4 and September 30, 1976. Of the 58 monitoring days, 43 recorded violations of the three-hour average ambient air quality standard for hydrocarbons. The highest three-hour (6 a.m. to 9 a.m.) average recorded was about 553 $\mu g/m^3$ (0.83 ppm) total nonmethane hydrocarbons, measured on September 19, 1976, and the second highest was 420 $\mu g/m^3$ (0.63 ppm), measured on August 21, 1976. These levels are, respectively, approximately 250 and 150 percent above the established standard. Additional hydrocarbon monitoring was conducted on 13 days in August 1975 in the City of Milwaukee, and in the City of Kenosha at intermittent times from March through May 1977. Although limited in quantity and spatial distribution, the available hydrocarbon monitoring data indicated that numerous violations of the standard for this pollutant species are occurring in the Region.

There were nine ambient air quality monitoring sites in the Region during the summer of 1977 which were recording ozone levels in the ambient air: five in Milwaukee County, one in Racine County, and one each in Kenosha, Ozaukee, and Waukesha Counties. With the exception of the station in Racine County, all of these monitoring sites recorded maximum hourly average ozone concentrations in excess of the ambient air quality standard of 0.12 ppm. The highest maximum hourly average ozone concentration measured during 1977 was 0.204 ppm, recorded at 2114 E. Kenwood Boulevard in the City of Milwaukee—a level approximately 70 percent above the established standard.

On the basis of ozone monitoring data recorded between 1973 and 1977, the U. S. Environmental Protection Agency designated Kenosha, Milwaukee, Ozaukee, Racine, and Waukesha Counties as an ozone nonattainment area. Because ambient air quality monitoring for ozone levels in Walworth and Washington Counties has not been conducted to date, the U. S. Environmental Protection Agency designated these two counties as unclassified with regard to the attainment or nonattainment of the ozone standards. In total, therefore, approximately 1,675 square miles, or more than 62 percent of the total area of the Region, are included within the designated ozone nonattainment area. Approximately 1,629,000 persons, or 92 percent of the total regional population, reside within the five counties designated as a nonattainment area for ozone, as shown on Map 84 in Chapter XI.

Hydrocarbon Emissions Inventory and Ozone Simulation Modeling Results and Findings: Because ozone is a photochemically reactive pollutant species which forms in the atmosphere, the numerical simulation modeling techniques which have been used to evaluate nonreactive pollutant species are not applicable. One of the techniques recommended by the U. S. Environmental Protection Agency for evaluating ozone levels in the ambient air, and the effectiveness of alternative controls, is the Empirical Kinetics Modeling Approach (EKMA). The EKMA model uses a chemical mechanism to determine maximum ozone concentrations upwind of an urban area. This mechanism is based upon initially defined conditions of local and transported concentrations of ozone and its precursor compounds. The results of the EKMA model are stated as the reduction in hydrocarbon emissions required from local sources in order to reduce the maximum ozone concentrations to a level below the established standard. A comprehensive regional hydrocarbon emissions inventory was therefore conducted for the year 1977 to serve as the basis against which the necessary reduction in emissions, as defined by the EKMA modeling results, would be determined.

Not all hydrocarbon compounds are equally reactive in the atmosphere during the photochemical oxidation process. Those very reactive hydrocarbons, termed volatile organic compounds, contribute much more significantly to the formation of ozone than the less-reactive hydrocarbon compounds, and consequently are the focus of alternative emission control measures. The ratio of volatile organic compounds to total hydrocarbons varies depending upon the nature of the source category. For example, hydrocarbon emissions from solvent use are 100 percent volatile organic compounds, whereas only about 88 percent of the hydrocarbon emissions in automobile exhaust are volatile organic compounds. Accordingly, a separate volatile organic compound emissions inventory was derived from the 1977 total hydrocarbon emissions inventory for the Region. In addition, a private consulting firm, Pacific Environmental Services, Inc., inventoried seven categories of volatile organic compound emissions, which were included in the 1977 inventory at the request of the Wisconsin Department of Natural Resources. The procedures used to inventory these seven source categories cannot be endorsed by either the Committee or the Commission; nonetheless, the results of the inventory were included as an approximation of the potential volatile organic compound emissions from these source categories on a regionwide basis.

The estimated distribution of total hydrocarbon emissions in 1977 is summarized by county and by major source category in Table 370. The relative contributions of point, line, and area sources to the total hydrocarbon emissions burden in the Region during 1977 are indicated in Figure 123. As may be seen in Table 370 and

Table 370

SUMMARY OF HYDROCARBON EMISSIONS IN THE REGION BY COUNTY AND BY MAJOR SOURCE CATEGORY: 1977

County	Point Sources			Line Sources			Area Sources			Total	
	Emissions (tons)	Percent of Source Total	Percent of County Total	Emissions (tons)	Percent of Source Total	Percent of County Total	Emissions (tons)	Percent of Source Total	Percent of County Total	Emissions (tons)	Percent of Region
Kenosha	3,857	12.0	34.7	3,527	7.4	31.7	3,738	7.1	33.6	11,122	8.4
Milwaukee . . .	22,200	69.1	30.5	24,922	52.0	34.2	25,680	49.0	35.3	72,802	55.0
Ozaukee	938	2.9	19.1	1,935	4.0	39.4	2,039	3.9	41.5	4,912	3.7
Racine	1,801	5.6	15.9	4,325	9.0	38.2	5,186	9.9	45.8	11,312	8.6
Walworth. . . .	654	2.0	10.9	2,339	4.9	38.9	3,023	5.8	50.2	6,016	4.5
Washington . .	1,054	3.3	15.8	2,520	5.3	37.8	3,085	5.9	46.3	6,659	5.0
Waukesha . . .	1,623	5.1	8.3	8,340	17.4	42.5	9,641	18.4	49.2	19,604	14.8
Region	32,127	100.0	24.3	47,908	100.0	36.2	52,392	100.0	39.5	132,427	100.0

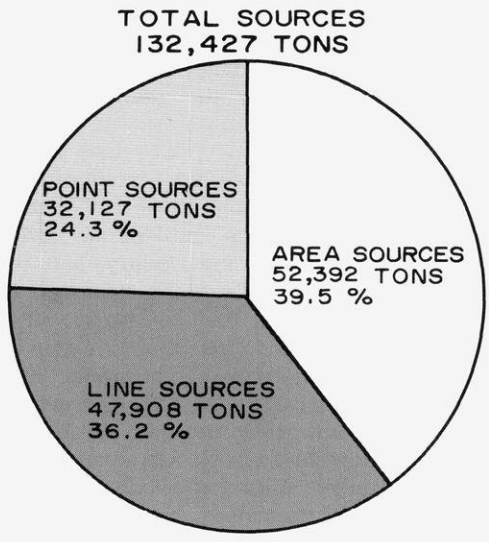
Source: SEWRPC.

Figure 123, area sources contributed about 40 percent of the total 132,400 tons of hydrocarbons emitted in the Region during 1977, while line sources and point sources contributed approximately 36 and 24 percent, respectively. Milwaukee County accounted for about 72,800 tons, or about 55 percent, of the total 132,400 tons of hydrocarbon emissions in the Region during 1977.

The 1977 volatile organic compound emissions inventory, which, as noted, was derived from the 1977 total hydrocarbon emissions inventory, accounted for only those hydrocarbon compounds in each source category which are photochemically active, plus the inventory of seven source categories conducted by a private consulting firm. A summary of the 1977 volatile organic compound emissions inventory for the Region is presented by county in Table 371. Not all of the volatile organic compound emissions identified in Table 371, however, contribute to the maximum ozone concentrations observed downwind of the major urban areas in the Region. Ozone is a seasonal pollutant, occurring in high concentrations only when sunlight is sufficient in intensity to cause the photodissociation of precursor compounds. The ozone season in southeastern Wisconsin thus extends only from about April through October. The regional volatile organic compound emissions inventory summarized in Table 371, however, includes emissions over an annual period from both rural and urban sources. In order to more meaningfully relate the regional volatile organic compound emissions inventory to the results of the EKMA modeling effort, therefore, those emissions source categories which were deemed to have little or no effect on ozone formation within or upwind of major urban areas were not included in the effort. These source categories, which include agricultural equipment, power boats, off-highway motorcycles, snowmobiles, and miscellaneous solvent use, accounted for about 16,200 tons, or less than 14 percent, of the total 118,300 tons

Figure 123

SUMMARY OF HYDROCARBON EMISSIONS IN THE REGION BY MAJOR SOURCE CATEGORY: 1977



Source: SEWRPC.

of volatile organic compounds emitted in the Region during 1977. The 1977 volatile organic compound emissions inventory as deemed relative to the EKMA modeling effort is summarized by county in Table 372.

The EKMA modeling effort focused on the simulation of the maximum ozone concentrations recorded downwind of the City of Milwaukee on June 12, 1976—the date on which the second highest ozone concentration,

Table 371

SUMMARY OF VOLATILE ORGANIC COMPOUND EMISSIONS IN THE REGION BY COUNTY: 1977

County	Volatile Organic Compounds (tons)	Percent of Region Total
Kenosha	10,269	8.7
Milwaukee	64,804	54.8
Ozaukee	4,421	3.7
Racine.	10,099	8.5
Walworth.	5,436	4.6
Washington . . .	5,904	5.0
Waukesha.	17,397	14.7
Total	118,330	100.0

Source: SEWRPC.

Table 372

SUMMARY OF VOLATILE ORGANIC COMPOUND EMISSIONS IN THE REGION RELATIVE TO THE EKMA MODELING EFFORT: 1977

County	Volatile Organic Compounds (tons)	Percent of Region Total
Kenosha	9,038	8.9
Milwaukee	59,388	58.1
Ozaukee	3,733	3.7
Racine.	8,316	8.1
Walworth.	3,913	3.8
Washington . . .	4,475	4.4
Waukesha.	13,300	13.0
Total	102,163	100.0

Source: SEWRPC.

or first violation of the ozone standard, was recorded at the monitoring site in Ozaukee County. The meteorological data, emission data, and data pertaining to the local and transported concentrations of ozone and its precursor compounds recorded on this date were used as input to the EKMA model in order to calculate the maximum hourly ozone level expected under existing conditions. A second EKMA modeling effort, which assumed that future levels of transported ozone concentrations from extraregional sources would be lower than the ambient air quality standard, was then undertaken in order to determine the degree to which it would be necessary to control emissions from local sources. The results of this EKMA simulation modeling effort indicated that the 102,200 tons of volatile organic compound emissions in the Region during 1977 would have to be reduced by 62 percent, at a minimum, to 74 percent, at an optimum, in order to achieve the ambient air quality standard for ozone. The volatile organic compound emission rate in the Region, therefore, should not exceed 38,800 tons in any year, and ideally should not exceed 26,600 tons in any year. The attainment and maintenance of the ambient air quality standard for ozone, therefore, may be evaluated against the achievement of the maximum permissible volatile organic compound emission rate.

Forecast Hydrocarbon and Ozone Levels: The Clean Air Act Amendments of 1977 require that all primary, or health-related, ambient air quality standards be attained by December 31, 1982. However, in certain cases an extension until December 31, 1987, may be granted for the attainment of the ozone standard. In order to evaluate the attainment and maintenance of the ambient air quality standard for ozone in the Region, forecasts of volatile organic compound emissions were prepared for the years 1982, 1987, and 2000. A summary of the emissions forecasts for these years is presented in Table 373. It should be noted that only those control regulations, including the federal motor vehicle emissions control program, in effect prior to July 1, 1979, were accounted for in the forecast of volatile organic compound emissions.

As may be seen in Table 373, volatile organic compound emissions in the Region are forecast to decrease by about 19,800 tons, or 20 percent, from the 1977 emission level by the year 1982. This emission rate is approximately 43,600 tons, or 112 percent, higher than the maximum allowable emission rate of about 38,800 tons per year. Attainment of the ozone standard is therefore not indicated by the year 1982 under the present level of emission control.

Table 373 also indicates that volatile organic compound emissions in the Region will total about 74,500 tons in 1987 and 82,800 tons in the year 2000. These emission rates are about 35,700 tons and 44,000 tons, or about 92 percent and 113 percent, respectively, higher than the maximum allowable emission rate of 38,800 tons of volatile organic compound emissions per year. It has therefore been concluded that a regional attainment plan and a maintenance plan will be required for ozone over the planning period.

RECOMMENDED REGIONAL AIR QUALITY ATTAINMENT AND MAINTENANCE PLAN

The recommended regional air quality attainment and maintenance plan is comprised of four distinct elements: a particulate matter control plan, a sulfur dioxide control plan, a carbon monoxide and hydrocarbon/ozone control

Table 373

SUMMARY OF EXISTING AND FORECAST VOLATILE ORGANIC COMPOUND EMISSIONS IN THE REGION 1977, 1982, 1987, AND 2000

Source Category	Existing 1977 Emissions (tons)	Forecast Emissions (tons)		
		1982	1987	2000
Stationary	53,499	51,615	52,711	56,656
Mobile.	42,665	24,436	15,275	16,481
Miscellaneous . . .	5,999	6,301	6,491	9,612
Total	102,163	82,352	74,477	82,749

Source: SEWRPC.

plan, and an ambient air quality monitoring plan. Each of these plan elements prescribes a set of actions designed to attain and maintain clean air in the Region. The prescribed actions are comprised of coordinated combinations of committed measures—that is, those controls that have been mandated through federal or state regulations—and additional control measures indicated by the analyses conducted under the planning program to be necessary to abate the residual air pollution problems anticipated to occur even with full implementation of the committed measures.

Particulate Matter Pollution Control Plan

Based upon analyses of available ambient air quality monitoring data and ambient air quality simulation modeling results, it was determined that action is required to provide for the attainment and maintenance of the particulate matter ambient air quality standards. The areas of the Region within which the ambient air quality standards for particulate matter are not presently being met—areas designated as particulate matter nonattainment areas—are shown on Map 82 in Chapter XI. The analyses indicated that, if the actions described below are fully implemented, significant progress toward the attainment and maintenance of the federal and state ambient air quality standards for particulate matter may be expected, with the possibility that the standards will be met and maintained as controls are applied to fugitive dust sources in the Region and to upwind extraregional air pollution sources. The particulate matter control plan consists of 1) control measures relating to existing sources of emissions, including industrial processes, fuel-burning installations, and fugitive dust emission sources; 2) control measures relating to new sources of emissions; 3) an intensive ambient air quality monitoring effort; and 4) a pilot vacuum street sweeping program in portions of Milwaukee County.

Control of Existing Sources of Particulate Matter Emissions: The Wisconsin Natural Resources Board has established emission limitations for all sources of particulate matter, including industrial processes, fuel-burning installations, and fugitive dust sources. These limitations are set forth in Chapter NR 154 of the Wisconsin Administrative Code. In addition, the Wisconsin Department of Natural Resources has adopted amendments to Chapter NR 154 that impose more stringent emission limitations on certain existing sources of particulate matter impacting upon nonattainment areas. These more stringent emission limitations have been based upon what has been termed Reasonably Available Control Technology (RACT). The application of the RACT limitations to existing sources is also considered herein to be a committed action.

The RACT emission limitations for industrial processes are prescribed either as a control measure for the specific process type or as a function of the process weight rate. The RACT particulate matter emission limitations for fuel-burning installations are a function of the heat input capacity of the boiler.

For fugitive dust emission sources, RACT-defined emission limitations are expressed either as a function of the exhaust gas production rate or as a specified control operation.

The plan proposes that the RACT emission limitations be applied to all existing fugitive dust sources in the designated nonattainment areas shown on Map 82, as well as to those sources whose stack emissions significantly impact these areas. In addition, it is recognized that there may be existing sources of particulate matter emissions lying outside the designated nonattainment areas which can significantly impact air quality in the nonattainment areas. Accordingly, the RACT emission limitations should sometimes also be applied to existing sources outside the nonattainment areas. This determination of significant impact can only be made on a case-by-case basis by the implementing regulatory agency utilizing mathematical modeling techniques. This determination has been completed for the Region by the Wisconsin Department of Natural Resources. The list of facilities designated in the 1979 State Implementation Plan to which the RACT emissions would apply is set forth in Appendix I. For all other existing sources lying outside the nonattainment areas, the plan recommends that the emissions be limited as prescribed in Chapter NR 154 of the Wisconsin Administrative Code.

Control of New or Modified Sources of Particulate Matter Emissions: New or modified sources of particulate matter emissions are defined as any new industrial process facility, fuel-burning installation, or fugitive dust source proposed after July 1, 1979. For such sources, more stringent emission limitations are proposed than those currently set forth in Chapter NR 154 of the Wisconsin Administrative Code, and in the RACT revision to that code. For those major[7] new or modified sources that

[7] *A major source is defined as one of the 28 industrial source categories listed in Chapter II which have the potential to emit more than 100 tons of a pollutant species after the application of pollution controls, or any other source which has the potential to emit more than 250 tons of a pollutant species after the application of pollution controls.*

are proposed to be located outside the particulate matter nonattainment areas identified on Map 82 in Chapter XI, and which have been determined on a case-by-case basis not to impact those areas significantly, the plan recommends that the federally prescribed New Source Performance Standards (NSPS) be applied. For all other categories of new or modified sources, the plan recommends that the allowable emission limitations be based upon the federally prescribed Best Available Control Technology (BACT). In addition, it should be recognized that under committed federal actions, decisions as to whether to allow new sources of particulate matter emissions are subject to the overriding considerations inherent in the regulations designed to prevent the significant deterioration of air quality in areas where the air quality standards are being met. The increments of air pollutant concentrations allowed in such "clean air" areas are set forth in Chapter II of this report.

The recommended plan proposes that new or modified sources proposed within the designated particulate matter nonattainment areas shown on Map 82 in Chapter XI, or which are proposed outside those nonattainment areas but have been determined to significantly impact on the ambient air quality in those areas, achieve the federally prescribed Lowest Achievable Emission Rate (LAER) emission limitations, which, in general, are more stringent than either RACT or BACT. In addition, the plan proposes that such sources which have the potential to exceed the U. S. Environmental Protection Agency-defined "de minimis" level of particulate matter emissions per year after the application of LAER control technology be required to obtain at least a one-for-one emission offset from existing sources in or near the nonattainment area. The actual amount and location of such emission offsets would be determined through a negotiated agreement between the owner or operator of the proposed new or modified source and the Wisconsin Department of Natural Resources.

Intensive Ambient Air Quality Monitoring Actions: The foregoing described actions for the control of particulate matter emissions from existing and new or modified sources of particulate matter are considered to be fully committed. Implementation of these committed actions may be expected to yield significant reductions in particulate matter levels in the nonattainment areas of the Region. In the absence of further abatement measures, it is possible that a residual particulate matter problem will exist in parts of Milwaukee, Racine, and Waukesha Counties, as shown on Map 182 in Chapter XIII. This conclusion is based on the results of the ambient air quality simulation modeling carried out under the study.

Because of the 1) significant reduction in ambient air particulate matter concentrations expected to result from implementation of the committed actions, 2) uncertainties inherent in the air quality simulation modeling, 3) uncertainties concerning the amount of fugitive dust emitted from regional sources and the levels of long-range transport of particulate matter into the Region, and 4) uncertainties related to the actual amount of emissions released from mineral extraction operations in the Region, it was not deemed sound to place more stringent emission limitations on particulate matter sources—particularly mineral extraction operations—than are otherwise prescribed under the committed actions noted above. The analyses of the simulation modeling results indicated that it is possible, in this respect, that the particulate matter ambient air quality standards will be achieved in the Region as the amounts of this pollutant species in the ambient air due to regional fugitive dust sources and to long-range transport are reduced through appropriate controls.

In light of these uncertainties, and in order to avoid unnecessarily placing further economically burdensome restrictions on particulate matter sources in the Region, the plan recommends instead that the following two ambient air quality monitoring actions be implemented:

1. A local, short-term ambient air quality monitoring effort should be undertaken to determine the level of emissions released from mineral extraction operations in the Region. Such a program should be designed to collect ambient air quality and related source-operating characteristics and weather data that will permit verification of the ambient air quality simulation efforts carried out under this study. The subareas of the Region indicated by such modeling to have a particulate matter problem are shown on Map 209 in Chapter XIII. It is to these subareas of the Region that the intensive short-term monitoring efforts should be directed. Pending the results of that monitoring effort, the plan calls for no additional control actions to be taken by mineral extraction operators other than those already prescribed in the committed actions.

2. An areawide, long-term, special-purpose air quality monitoring effort should be undertaken to measure the particulate matter levels in the Region resulting from the long-range transport of particulate matter into the Region.

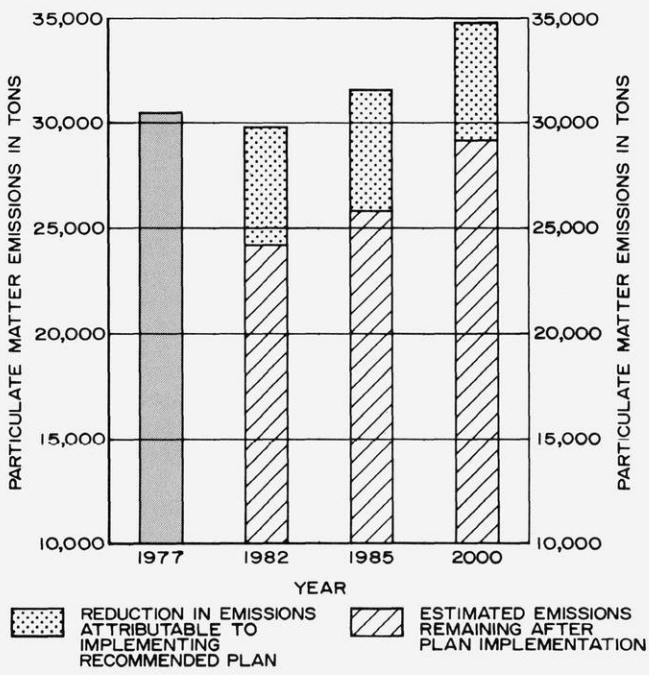
Pilot Vacuum Street Sweeping Program: One of the alternative measures considered in the study to further reduce particulate matter concentrations in the ambient air was more frequent and timely street sweeping in the heavily urbanized areas of the Region. Re-entrained road dust has been identified as a significant local source of particulate matter. Given the uncertainties noted above, however, the plan does not recommend widespread changes in municipal street sweeping programs. Rather, the plan calls for the development of a pilot vacuum street sweeping program in those portions of Milwaukee County shown on Map 187 in Chapter XIII. This recommendation, combined with a special ambient air quality monitoring program, is intended to permit a quantitative evaluation of the impact of such an improved street sweeping program on ambient air quality.

Cost of Particulate Matter Control Plan: It is estimated that a particulate matter emission reduction of 5,500 tons per year, or 18 percent of the 30,500 tons of total particulate matter emissions estimated to have been released into the atmosphere over the Region in 1977,

can be achieved with implementation of the recommended actions. Figure 124 presents a graphic summary of the particulate matter emission reductions expected to be achieved under the recommended plan in the years 1982, 1985, and 2000. The plan recommendations would affect 64 existing facilities in the Region, eight of which are industrial point sources, and 63—including seven of the eight industrial point sources—of which are fugitive dust sources. The cost of carrying out the plan recommendations at these 64 facilities would include a one-time capital expenditure of about $31.3 million, and attendant operating costs of about $13.1 million per year. The annual cost-effectiveness of control would thus approximate $2,400 per ton of reduction in 1978 dollars. These costs do not include costs attendant to the development of the pilot vacuum street sweeping program, since the exact scope of work for such a program has not yet been defined. The costs attendant to both the local, short-term, and the areawide, long-term, particulate matter monitoring efforts, with the exception of monitoring in conjunction with the recommended pilot vacuum street sweeping program, are included in the cost of the recommended ambient air quality monitoring program.

Figure 124

EXISTING AND FORECAST PARTICULATE MATTER EMISSIONS WITHOUT ADDITIONAL CONTROLS AND UNDER THE RECOMMENDED PLAN



Source: SEWRPC.

Sulfur Dioxide Pollution Control Plan

Based upon analyses of available ambient air quality monitoring data and ambient air quality simulation modeling results, it was determined that action is required to provide for the attainment of the 24-hour average sulfur dioxide ambient air quality standards and for the maintenance of the three-hour average and annual average sulfur dioxide ambient air quality standards in a portion of Milwaukee County. At the present time, there is no officially designated nonattainment area for sulfur dioxide in the Region. The Wisconsin Department of Natural Resources has proposed that the U. S. Environmental Protection Agency designate a 7.4-square-mile area in Milwaukee County as a nonattainment area for sulfur dioxide, as shown on Map 85 in Chapter XI, although the underlying basis for such a designation has been questioned by the Wisconsin Electric Power Company. The analyses indicated that if the actions described below for the control of sulfur dioxide are fully implemented, the federal and state ambient air quality standards for sulfur dioxide will be met throughout the Region over the planning period, given current trends in the use of natural gas and fuel oil by major industrial sources. If, however, extensive conversions from oil and natural gas to coal are made by major industrial sources, particularly in Milwaukee County, additional control actions beyond those presently foreseen may be necessary in order to maintain the sulfur dioxide ambient air quality standards. Because of the many uncertainties underlying any fuel demand and availability forecasts, the extent to which such conversions will actually occur is not presently known and cannot be reliably predicted.

The sulfur dioxide plan consists of the following committed actions: 1) designation of a nonattainment area for sulfur dioxide in Milwaukee County, and 2) application of emission control limitations to existing sources and to new sources of sulfur dioxide emissions lying within or significantly impacting upon the nonattainment area. The plan further recommends the establishment of a regulatory framework to ultimately ban the use of coal for residential and small commercial-institutional space and water heating, and the establishment of a preferential allocation of natural gas supplies to industrial users in the Region.[8]

Designation of Sulfur Dioxide Nonattainment Area: The plan incorporates as a committed action the formal designation by the U. S. Environmental Protection Agency of the sulfur dioxide nonattainment area shown on Map 85 in Chapter XI. The designation of such an area will provide the basis for the establishment of Reasonably Available Control Technology (RACT) emission

[8] *The preferential allocation of natural gas supplies may be expected to improve ambient air quality not only in terms of sulfur dioxide concentrations but also in terms of concentrations of all other pollutant species. Natural gas, being a "cleaner" fuel than coal, releases a lower quantity of each pollutant species for a given heat output.*

limitations for existing sources of sulfur dioxide significantly impacting upon this area, and will thus help to ensure the attainment and maintenance of the sulfur dioxide ambient air quality standards.

Control of Existing Sources of Sulfur Dioxide Emissions: The Wisconsin Natural Resources Board has established emission limitations for certain stationary sources of sulfur dioxide. These standards are set forth in Chapter NR 154 of the Wisconsin Administrative Code.

The plan assumes as a committed action that, upon designation of the sulfur dioxide nonattainment area shown on Map 85 in Chapter XI, RACT emission limitations for sulfur dioxide will be developed and applied to any existing sources inside the nonattainment area, and to any additional existing sources lying outside the nonattainment area that are determined on a case-by-case basis to have a significant impact on air quality in the nonattainment area. In particular, such RACT emission limitations should be established for fuel-burning installations with heat input capacities greater than 250 million BTU's per hour shown to cause or contribute to violations of the ambient air standards—installations which are presently not regulated by the emission limitations or prescribed maximums for sulfur content in coal set forth in Chapter NR 154 of the Wisconsin Administrative Code.

Control of New or Modified Sources of Sulfur Dioxide Emissions: New sources of sulfur dioxide emissions would be defined as any new or modified fuel-burning installation proposed after July 1, 1979. For those major new or modified sources that are proposed to be located outside the proposed sulfur dioxide nonattainment area identified on Map 85 in Chapter XI, and which have been determined on a case-by-case basis not to impact significantly on the nonattainment area, the plan recommends that, at a minimum, the federally prescribed New Source Performance Standards (NSPS) be applied.[9] For all other categories of new or modified sources, the plan recommends that, at a minimum, the allowable emission limitations be based upon the federally prescribed Best Available Control Technology (BACT).

The Wisconsin Department of Natural Resources should be granted the authority to mandate emission limitations more stringent than otherwise prescribed for new or modified sources under the committed actions if extensive conversions by industry to coal use are found to cause or contribute to violations of the ambient air quality standards for sulfur dioxide. In addition, it should be recognized that under committed federal actions, decisions as to whether to allow new or modified sources of sulfur dioxide emissions are subject to the overriding considerations inherent in the regulations designed to prevent the significant deterioration of air quality in areas where the air quality standards are being met. The allowable limits of air quality impact in such "clean air" areas are set forth in Table 1 in Chapter II of this report.

The recommended plan assumes as a committed action that any new or modified sources that will be built within the proposed sulfur dioxide nonattainment area shown on Map 85 in Chapter XI, or that will be built outside that area but will significantly impact upon it, will achieve the federally prescribed Lowest Achievable Emission Rate (LAER) emission limitations and obtain a greater than one-for-one emission reduction from existing sources in the nonattainment area such that a net improvement in ambient air quality is realized. Such LAER emission limitations are more stringent than either the RACT or BACT emission limitations.

Elimination of the Use of Coal for Space and Water Heating: The analyses indicated that the use of coal as a primary fuel for residential and small commercial-institutional space and water heating, while no longer predominant throughout the Region, remains as a significant contributor to sulfur dioxide concentrations in the ambient air in the Region, particularly in Milwaukee County. Individuals and operators of small businesses have been voluntarily eliminating the use of coal for such purposes over a long period of time in favor of the use of fuel oil, natural gas, and electricity. The plan proposes that a formal ban be placed on the use of coal in Milwaukee County for residential and small commercial-institutional space and water heating. It is not envisioned in the plan that steps will have to be taken to mandatorily phase out the remaining sources in Milwaukee County; however, the plan does envision an educational program which would encourage the voluntary conversion to an alternative fuel.

Preferential Allocation of Natural Gas: Given the energy cost and availability problem facing the nation, it is recognized that there may be increased pressures on industrial fuel-burning installations in southeastern Wisconsin in future years to convert from natural gas to coal. In order to minimize such conversions and the detrimental effect that they would have on ambient air quality in the Region through the addition of new sources of sulfur dioxide emissions, the recommended plan calls for a preferential allocation of natural gas supplies by the Wisconsin Public Service Commission to industrial sources located in nonattainment areas or significantly impacting on such areas in the Region in the event that supplies are curtailed. Such a preferential allocation would serve to minimize the number of conversions to coal use by industry, and thereby would contribute significantly toward the attainment of the ambient air quality standards.

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[9] *A major source is defined as one of the 28 industrial source categories listed in Chapter II which have the potential to emit more than 100 tons of a pollutant species after the application of pollution controls, or any other source which has the potential to emit more than 250 tons of a pollutant species after the application of pollution controls.*

Cost of the Sulfur Dioxide Control Plan: Because the sulfur dioxide plan does not recommend that specific actions be implemented by identified facilities, it is not possible at this time to estimate the cost of attaining and maintaining the ambient air quality standards for this pollutant species. For example, while the plan proposes that RACT emission limitations be applied to existing sources of sulfur dioxide emissions which lie within or significantly impact upon the proposed nonattainment area, if, in fact, such an area is designated by the U. S. Environmental Protection Agency, cost estimates of compliance with such limitations cannot be made until the RACT regulations are developed and their impact upon each source known. Conversions to coal use by industrial facilities may be assumed to result from a future lack of natural gas supplies relative to the forecast demand. Such conversions as may occur, and the attendant air pollution control costs, are, therefore, assumed to result from the economic considerations of the source owner or operator and not from a specific action recommended in the sulfur dioxide plan.

Carbon Monoxide and Hydrocarbon/ Ozone Pollution Control Plan

Based upon analyses of available ambient air quality monitoring data and ambient air quality simulation modeling results, it was determined that action is required to accelerate attainment of the eight-hour average carbon monoxide ambient air quality standard that part of Milwaukee County designated as a nonattainment area, shown on Map 83 in Chapter XI, and to provide for the attainment and maintenance of the one-hour average ozone ambient air quality standard throughout the entire seven-county Region. The carbon monoxide and ozone pollution control plans are considered jointly because of the commonality of emission sources, and because many of the control actions recommended—particularly transportation-related control actions—have an impact on both carbon monoxide and hydrocarbon emissions. Given the current state-of-the-art, the air quality plan approaches the attainment and maintenance of the ozone standards through the control of hydrocarbon emissions, particularly those reactive hydrocarbons known as volatile organic compounds. The designated ozone nonattainment area in the Region is shown on Map 84 in Chapter XI. This area encompasses all of the counties in the Region except Walworth and Washington Counties. No ozone monitors have to date been located in these two counties. However, analyses conducted in the study indicate that violations of the ozone ambient air quality standard probably occur in these counties as well. Accordingly, the plan recommends that monitors be placed in these counties to verify the results of the simulation modeling effort. If the monitoring data reveal violations of the ozone standard, then it is recommended that the nonattainment area be extended over the entire seven-county Region.

The goal of the recommended carbon monoxide plan is to reduce the emissions of this pollutant species from mobile sources in the near term in order to provide for the attainment of the eight-hour average standard throughout the Region by 1982. The analyses conducted indicated that under existing control regulations, this standard will be attained and maintained subsequent to 1982 but prior to 1985.

The goal of the recommended hydrocarbon/ozone plan is to reduce the 1977 level of volatile organic compound emissions contributiong to the regional ozone problem—which totaled about 102,200 tons—by 62 to 74 percent by 1987. This reduction would result in a maximum annual emission rate of between 26,600 tons and 38,800 tons. The results of the Empirical Kinetics Modeling Approach (EKMA) have indicated that such a reduction is necessary if the ozone ambient air quality standard is to be attained and maintained in the Region.

In order to meet the carbon monoxide and hydrocarbon/ozone ambient air quality standards, the recommended plan calls for: 1) control measures to reduce volatile organic compound and carbon monoxide emissions from existing stationary sources; 2) control measures to reduce volatile organic compound and carbon monoxide emissions from new stationary sources; 3) continuation of the federal motor vehicle emissions control program; 4) continued efforts toward implementation of the regional transportation plan, most importantly including the recommended transportation systems management actions; 5) establishment of an automobile inspection and maintenance program; and 6) a prohibition on the use of cutback asphalt as a paving material in the Region.

Control Measures for Existing Stationary Sources of Volatile Organic Compound and Carbon Monoxide Emissions: The Wisconsin Natural Resources Board has established regulations for specific classes of stationary sources of volatile organic compound and carbon monoxide emissions. These limitations are set forth in Chapter NR 154 of the Wisconsin Administrative Code. The Wisconsin Natural Resources Board has also recently enacted amendments to Chapter NR 154 that provide for the imposition of more stringent emission limitations on certain existing sources of volatile organic compound emissions and has scheduled the development of such rules for additional sources. These more stringent emission limitations are based upon Reasonably Available Control Technology (RACT). The application of the RACT limitations to existing sources of volatile organic compound emissions is considered to be a committed action.

The plan proposes that the RACT emission limitations pertaining to volatile organic compounds be applied to specific categories of existing sources inside the designated five-county ozone nonattainment area shown on Map 84 in Chapter XI. In addition, it is recognized that there may be existing sources of volatile organic compound emissions located in Walworth and Washington Counties which impact air quality in the presently designated nonattainment area. Under the rules adopted by the Natural Resources Board to date, the RACT emission limitations are to be applied to existing sources not only in the presently designated nonattainment area but also in Walworth and Washington Counties, as well as in the entire State.

Control Measures for New Stationary Sources of Volatile Organic Compound and Carbon Monoxide Emissions: New sources of volatile organic compound and carbon monoxide emissions are defined as those proposed after July 1, 1979. If the entire seven-county Region is ultimately designated as a nonattainment area for ozone, pending the results of ambient air quality monitoring in Walworth and Washington Counties, then all new or modified sources of volatile organic compound emissions should achieve the federally prescribed Lowest Achievable Emission Rate (LAER) limitations. Such emission limitations may be more stringent than the RACT emission limitations noted above. The plan recommends that the current regulations prescribed in Chapter NR 154 be applied to new stationary sources of carbon monoxide whether they lie within or outside the nonattainment area shown on Map 83 in Chapter XI.

Federal Motor Vehicle Emissions Control Program: The plan recognizes as a fully committed action, continued enforcement of the federal motor vehicle emissions control program for mobile sources. This program applies to all newly manufactured automobiles and trucks marketed within the United States.

Implementation of Regional Transportation Plan: The foregoing actions are all considered to be committed under existing federal and state law. The implementation of these committed actions is expected to reduce annual volatile organic compound emissions in the Region by about 59,100 tons, or nearly 58 percent—from about 102,200 tons in 1977 to about 43,100 tons in 1987. The 43,100-ton emission rate for 1987, however, is about 4,300 tons, or about 11 percent, higher than the maximum allowable emission rate of about 38,800 tons per year—the rate required to attain the ozone standard. Accordingly, additional actions are recommended in the plan to address this residual problem.

One important action that can be taken to attain and maintain the carbon monoxide and hydrocarbon/ozone ambient air quality standards is implementation of the adopted regional transportation plan, particularly including those elements of the plan dealing with transportation systems management. Such transportation systems management actions consist of those measures that are designed to both improve traffic flow and reduce vehicle miles of travel. The regional transportation plan includes a set of coordinated, mutually reinforcing, transportation systems management actions which have been identified as having the greatest potential for reducing carbon monoxide and volatile organic compound emissions from motor vehicles. Of particular importance are the following measures as identified in the transportation plan: 1) implementation of a freeway traffic management system; 2) conduct of an extensive and ongoing carpool/vanpool formation promotional campaign; 3) development of additional park-ride and park-and-pool lots; and, most importantly, 4) extensive short-term and long-term improvements in public transit service. Analyses conducted under the air quality program indicate that full implementation of the adopted transportation plan, when considered as a supplement to the committed actions noted above, will reduce volatile organic compound emissions in the Region to about 42,700 tons by 1987 and to about 48,100 tons by the year 2000, reductions of about 58 and 53 percent, respectively, from the 1977 level of 102,200 tons. These forecast emission levels, however, remain in excess of the maximum allowable emission rate of 38,800 tons per year.

Given full implementation of the adopted regional transportation plan, carbon monoxide emissions in 1982 would be reduced by about 8,300 tons, or about 2 percent—from the 355,000 tons forecast to be emitted from mobile sources in the Region in 1982 to 346,700 tons. Although this reduction is relatively small, its impact would be most significant in the most intensely urbanized areas of the Region, particularly in areas of high travel demand within the carbon monoxide nonattainment area, shown on Map 83 in Chapter XI. Implementation of the adopted transportation plan would, therefore, accelerate attainment of the eight-hour average carbon monoxide ambient air quality standard in the Region to the year 1982. Given the impact of the federal motor vehicle emissions control program and of continued regional transportation plan implementation, maintenance of the ambient air quality standard through the year 2000 should be readily achievable.

Vehicle Inspection and Maintenance Program: In order to ensure that the emission control equipment now being required on automobiles and light-duty trucks under the federally mandated pollution control program is properly maintained, the plan recommends that a vehicle inspection and maintenance (I/M) program be established. It should be noted that the establishment of a vehicle inspection and maintenance program is specifically required by the Clean Air Act Amendments of 1977 in areas which are forecast not to attain either the carbon monoxide or ozone ambient air quality standards by December 31, 1982. If such a program is not established in these nonattainment areas, the U. S. Environmental Protection Agency is empowered to impose sanctions within the defaulting areas. Such sanctions may include prohibitions on industrial construction and the withholding of federal sewer and highway construction funds. Under an I/M program, all automobiles and light-duty trucks registered in the seven-county Southeastern Wisconsin Region that are less than 15 years of age at the time of inspection—that is, all automobiles and light-duty trucks on which federally mandated pollution control equipment has been installed—would be tested annually to ensure that their vehicle emission rate does not significantly exceed federally mandated exhaust emission standards. It is recommended that the I/M program be conducted at a number of strategically located testing stations, and that the exhaust emissions test be established with a 20 percent stringency standard. The stringency standard is a measure, based on nationwide averages, of the percent of vehicles which may be expected to fail the initial test.

Implementation of the I/M program as specified, when considered as a supplement to the committed actions and implementation of the adopted transportation plan, is

expected to reduce the volatile organic compound emissions in the Region to about 38,500 tons by 1987, and to about 41,900 tons by the year 2000. Accordingly, attainment of the ozone ambient air quality standard may be expected to be achieved by 1987.

Prohibition on the Use of Cutback Asphalt: While the analyses indicated that the above-noted actions would likely result in the achievement of the ozone ambient air quality standard by 1987, the continued maintenance of this standard is not expected because of anticipated regional growth and development. Accordingly, the recommended plan calls further for a prohibition on the use of cutback asphalt as a paving material in southeastern Wisconsin. Cutback asphalt can be replaced by bituminous plant mix or asphalt emulsions. Prohibiting the use of cutback asphalt is expected to yield an annual reduction in volatile organic compound emissions in the Region of about 3,800 tons. As a supplement to the aforementioned committed and recommended actions, implementation of a ban on the use of cutback asphalt is expected to reduce volatile organic compound emissions in the Region to about 34,700 tons and 38,100 tons in the years 1987 and 2000, respectively. Thus, the attainment and maintenance of the ozone ambient air quality standard may be anticipated over the entire planning period if all of the committed and recommended actions are fully implemented.

Cost of the Carbon Monoxide and Hydrocarbon/Ozone Plan: Most of the costs of the recommended carbon monoxide and hydrocarbon plan element are attributable to the recommended RACT controls on stationary sources for the control of volatile organic compound emissions, and to the establishment and operation of the vehicle I/M program. The cost of continued implementation of the federal motor vehicle emissions control program is borne as part of the cost of purchasing new vehicles and is not considered a "new" cost for the purposes of this plan. Similarly, the cost of implementation of the regional transportation plan is not considered a new cost since the plan was prepared primarily to improve transportation service, and not air quality. The cost of the transportation plan has been documented in other Commission reports and is not included here.

In total, about 6,200 facilities would be affected by implementation of the proposed RACT emission limitations. Of this total, about 4,500 facilities are solvent metal cleaning operations and about 1,200 are gasoline service stations. The cost of carrying out the plan recommendations at these 6,200 facilities includes a one-time capital expenditure of about $32.2 million and attendant operating costs of about $7.6 million per year in 1978 dollars. The capital cost of this reduction would approximate $1,000 per ton, and the annual cost-effectiveness of control would approximate $237 per ton of reduction.

The total cost of implementing the vehicle I/M program would approximate $11.5 million annually. This cost consists of an estimated $6.8 million annually to cover the cost of building, operating, and maintaining the necessary testing stations, and $4.7 million annually to be incurred by vehicle owners to repair vehicles which fail the test. Thus, the estimated cost of the proposed reduction is $2,740 per ton.

Recommended Ambient Air Quality Monitoring Network The regional air quality attainment and maintenance plan recommends the continued operation of the existing ambient air quality monitoring network in the Region, and proposes that such operation be expanded and adjusted in the manner described below. The existing and proposed network is summarized on Map 210 in Chapter XIII. In 1978 there were 37 ambient air quality monitors in operation within the Region certified by the Wisconsin Department of Natural Resources (DNR) that gathered data on particulate matter: three monitors in Kenosha County, 19 monitors in Milwaukee County, one monitor in Ozaukee County, eight monitors in Racine County, and six monitors in Waukesha County. There were seven DNR-certified monitors gathering data on sulfur dioxide: six in Milwaukee County and one in Racine County. There were also seven DNR-certified monitors gathering data on carbon monoxide: five in Milwaukee County, one in Racine County, and one in Waukesha County. There were four DNR-certified monitors gathering data on nitrogen dioxide, all in Milwaukee County. And finally, there were nine DNR-certified monitors gathering data on ozone: one in Kenosha County, five in Milwaukee County, one in Ozaukee County, one in Racine County, and one in Waukesha County. The plan recommends that operation of all of these monitors be continued, recognizing that it may be desirable from time to time to change the precise location and orientation of the monitoring equipment.

The plan also recommends that the following special ambient air quality monitoring efforts be undertaken:

1. The placement of six high-volume particulate matter gravimetric samplers, as shown on Map 210 in Chapter XIII, near the Lake Michigan shoreline in Kenosha and Milwaukee Counties for the purpose of measuring the long-range transport of particulate matter.

2. The placement of from two to four high-volume particulate matter gravimetric samplers around one or two major quarrying operations in the Region for the purpose of verifying the results of the air quality simulation modeling effort. This effort is intended to be of short-term duration.

3. The placement of such additional particulate matter monitors as may be found to be necessary to adequately assess the impacts of the proposed pilot vacuum street sweeping program in portions of Milwaukee County.

4. The placement of an additional carbon monoxide ambient air quality monitor in the area of the Marquette Interchange in Milwaukee County to collect ambient air quality and related emission produc-

tion and weather data in order to permit verification of the simulation modeling results which indicate that this area presently experiences, and may be expected to continue to experience, the highest carbon monoxide concentrations in the Region, and to measure further progress toward attainment of the eight-hour average carbon monoxide ambient air quality standard.

5. The placement of air quality monitors for nitrogen oxides and nonmethane hydrocarbons near the Illinois/Wisconsin state line in Kenosha County, in or near the central business district of the City of Milwaukee, and downwind of the Milwaukee urbanized area in Grafton in Ozaukee County, as shown on Map 210 in Chapter XIII, so that additional data can be gathered during the ozone season on the concentrations of these compounds, in terms of both the transport of such compounds from extraregional sources and the local contributions. Such data are required as input to the Empirical Kinetics Modeling Approach.

6. The placement of monitors for ozone in Walworth County and in Washington County, as shown on Map 210 in Chapter XIII, in order to verify the results of air quality simulation modeling efforts that indicate the existence of an ozone problem in such counties, and to provide a basis for the implementation of the recommended vehicle inspection and maintenance program throughout the Region.

It is recommended that all existing monitoring sites be reviewed so as to ensure conformance with the U. S. Environmental Protection Agency (EPA)-prescribed siting requirements. In addition, care should be taken to minimize sampling error as may result from passive filter loading, excessive volume sampling rates, and source-oriented sampler exposure, particularly with regard to the existing and recommended high-volume particulate gravimetric monitors. It is, therefore, recommended that the exposed filters used in monitoring particulate matter be removed for analysis within one day of the sampling period; that such monitors operate at the minimum EPA-approved volume sampling rate; that the orientation of such monitors in relation to local emission sources be duly recorded; and that the new monitors established to assess long-range transport be operated on an every-other-day basis during the ozone season.

The cost of operating the ambient air quality monitoring network in the Region during 1979—the latest year for which data are available—was approximately $350,000, excluding the capital costs for monitoring instruments. It is estimated that a one-time capital cost of about $83,700 in 1979 dollars will be required for the special ambient air quality monitoring efforts recommended under the plan. In addition, there will be an average annual operation and maintenance cost for such efforts over a probable five-year period of about $27,800. These costs would be in addition to those already being incurred for the maintenance of the existing ambient air quality monitoring network described above.

PUBLIC REACTION TO THE RECOMMENDED PLAN

The recommended regional air quality attainment and maintenance plan was the subject of a public informational meeting held by the Commission at 7:30 p.m. on May 7, 1980, at the Milwaukee Area Technical College (MATC) and of a public hearing held at MATC at 7:30 p.m. on May 14, 1980. Prior to the informational meeting and the public hearing, the Commission prepared and widely distributed a SEWRPC Newsletter (Vol. 20, No. 2), which presented in summary form the plan recommendations. The minutes of the public informational meeting and the public hearing were published by the Commission and are available at the Commission offices.[10]

Several important issues were raised during the public informational meeting and public hearing. These issues, and the response of the Commission staff and Advisory Committee to these issues, are summarized below.

Cost-Effectiveness of the Particulate Matter Plan

Testimony was presented at the public hearing to the effect that the particulate matter component of the recommended plan was not cost-effective. It was noted that foundries and machine manufacturing industries would be expected to spend approximately $24 million for particulate matter control equipment in order to achieve about a 1,300-ton emission reduction. This represents about 77 percent of the total capital expense identified in the particulate matter control plan component, but achieves only about 6 percent of the total anticipated emission reductions. It was further noted that fugitive dust controls on quarrying operations would have a capital cost of only about $990,000, or about 3 percent of the total, but could be expected to achieve a reduction of about 4,500 tons, or about 82 percent of the total required particulate matter emissions reduction.

In response to these comments, it should be noted that equivalent emission reductions may not produce equivalent impacts on ambient air quality. In fact, it has been projected that the control of industrial fugitive emissions, including emissions from foundry and machine industries, will result in a 13-microgram-per-cubic-meter ($\mu g/m^3$) reduction in the annual average particulate matter concentration in the Milwaukee nonattainmenta area. Other factors such as the spatial location and concentrations of the sources, climatologic factors, and the height and character of an emission point are also important. How the spatial location and concentration of sources are related to nonattainment areas and population concentrations are particularly important in this respect. Accordingly, the Commission studies included a determination not only of the contribution of each air pollution source category to the total emissions burden in the Region, but, equally importantly from the standpoint of impact on ambient air quality, of the distribution of the sources.

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[10] *See Minutes of Public Informational Meeting and Public Hearing, A Regional Air Quality Attainment and Maintenance Plan for Southeastern Wisconsin: 2000, May 1980.*

The air quality modeling effort consisted of individual computer simulations of the impact of point, line, and area sources of emissions on ambient air quality. For particulate matter, this modeling effort resulted in the determination that emissions released by industrial sources through stacks indeed had a minor impact on ambient air quality within the Region as compared with the impact of either line or area sources, both of which are associated with activities at or near ground level. Moreover, in comparing the results of the point source modeling effort for the years 1973 and 1977 (see Chapter XI), significant improvement was noted in the air quality impact of particulate matter emissions from industrial stacks. This improvement was attributed to the increased level of control being applied to such sources over this five-year period.

These findings are reflected in the cost estimates for achieving Reasonably Available Control Technology (RACT) on stack emissions from industrial process sources and fuel-burning installations. Only eight industrial point source facilities have been identified as requiring additional control equipment to meet the RACT-specified stack emission limitations.[11] The capital cost of applying RACT to these eight facilities is estimated at $2.5 million, of which approximately $2.2 million, or more than 85 percent, is attributable to controls at a single electric power generation station. The remaining $0.3 million—which represents less than 1 percent of the total capital cost of the particulate matter control plan component—is expected to be distributed principally between four foundry facilities. In addition, two asphalt plants and one cement manufacturing plant are expected to be able to meet RACT emission limitations by upgrading existing equipment without incurring significant capital costs.

Whereas the approach to air pollution control has historically been focused on reducing emissions from large industrial stacks, the fact that the ambient air quality standards continue to be exceeded in the Region indicates that other, nontraditional, sources of emissions indeed require identification and control. One of the most significant nontraditional sources of particulate matter emissions identified in the regional air quality attainment and maintenance plan is fugitive dust emanating from unpaved roads and parking lots, uncovered or untreated aggregate storage piles, and industrial process losses. Quarrying operations have been identified as the largest single fugitive dust source, since the extraction, processing, and transfer of mined material are generally conducted in unenclosed areas. Since quarrying operations and other fugitive dust sources release emissions near ground level, such sources may be expected to have a disproportionate impact on ambient air quality as compared with an equivalent quantity of emissions from industrial stacks. Simulation modeling results have supported this contention, and have led to the conclusion that the control of fugitive dust sources is essential to the attainment and maintenance of the particulate matter ambient air quality standards.

In addition to fugitive dust sources associated with industrial processes—predominantly in urbanized areas—and quarrying operations—predominantly isolated sources in more rural areas—other man-made sources, such as agricultural tilling, may release significant quantities of particulate matter emissions. Agricultural tilling operations were estimated to have released 5,850 tons, or about 19 percent, of the total particulate matter emissions in the Region during 1977. Emissions from agricultural tilling operations, however, are fairly uniformly dispersed over more than one million acres in southeastern Wisconsin. Such emissions are also quite seasonal, impacting air quality only during a few months of the year. Thus, Commission studies indicate that the emissions from agricultural tilling operations do not cause or significantly contribute to annual violations of the ambient air quality standards, especially in urban nonattainment areas. Levels in excess of short-term ambient air quality standards, however, can at times be directly attributed to agricultural activities, especially during dry weather conditions.

The density of industrial fugitive dust sources in urban areas, and the intensity of fugitive dust emissions from quarrying operations in more rural areas, are two separate problems; however, both contribute to violations of the ambient air quality standards, but in different parts of the Region. Insofar as the application of RACT emission controls to both quarrying operations and industrial fugitive dust sources may be expected to assist in the attainment and maintenance of the standards in the areas affected by each, an overall comparison of the cost per ton of emission reduction for each of these sources does not accurately represent the achieved air quality benefits. Controlling only quarrying operations, which is expected to have a capital cost of about $600 per ton of emission reduction, will not, unfortunately, contribute toward the attainment and maintenance of the standards in areas where industrial fugitive dust sources significantly impact ambient air quality. Controlling industrial fugitive dust emissions—at a cost of about $33,000 per ton of emission reduction, or 55 times the cost per ton of controlling quarrying operations—while costly, appears to be the only feasible way to achieve the clean air goals in those parts of the Region impacted by such sources.

Due to the fact that there are two separate particulate matter problems in the Region—the density of industrial fugitive dust emission sources in urbanized areas and the

[11] *These eight facilities—seven industrial process sources and one fuel-burning installation—are identified in Appendix I. Based on determinations by the Wisconsin Department of Natural Resources, other industrial stack emission sources located within the designated particulate matter nonattainment areas of the Region either do not significantly contribute to violations of the ambient air quality standards or are presently meeting the RACT emissions limitations.*

intensity of fugitive dust emissions from quarrying operations in essentially rural areas—the Commission staff concluded, and the Advisory Committee concurred, that separate control measures are necessary to adequately address both problems and that the overlapping of effects of these two sets of control measures are negligible. A possible exception to this observation may exist in the Waukesha area, where both industrial process fugitive dust emissions and quarrying operations may influence ambient air quality conditions. Also, because of the diverse nature of and spatial differences in the two particulate matter problems in the Region, one set of emission controls—such as may be effective for controlling fugitive dust from quarrying operations—may not be substituted for controls on industrial fugitive dust sources. Since the control of fugitive dust emissions from quarrying operations is envisioned to lead to the attainment and maintenance of the particulate matter standards in the areas in which such operations impact ambient air quality, and since the control of industrial fugitive dust is expected to have a similar effect in more urbanized areas, a comparison of the relative cost-effectiveness of each set of controls is not an appropriate criterion for selective implementation of one set of controls over another. Thus, the basic structure of the recommended plan was reaffirmed as being a cost-effective approach to attainment and maintenance of the ambient air quality standards.

Designation of a Sulfur Dioxide Nonattainment Area in the Region

Testimony was presented at the public hearing to the effect that the proposed sulfur dioxide nonattainment area should not be designated at this time because of the marginal violations of the short-term sulfur dioxide ambient air quality standards monitored in parts of the City of Milwaukee. It was proposed instead that the monitoring data be reviewed annually for any significant deterioration of sulfur dioxide ambient air quality.

In response, the Commission staff noted that the designation of a nonattainment area is specifically mandated by the U. S. Congress in the Clean Air Act as amended in August 1977 if violations of one or more of the established national ambient air quality standards are found to occur. Monitored violations of the short-term, 24-hour average sulfur dioxide ambient air quality standard were recorded by the Wisconsin Department of Natural Resources at two locations in the City of Milwaukee during 1977 and again in 1978. These monitoring data are presented in Table 374. The Department in fulfilling its duties, therefore, is required to propose a sulfur dioxide nonattainment area in parts of the City of Milwaukee.

There are two arguments which have been advanced against the designation of a sulfur dioxide nonattainment area in the City of Milwaukee. The first argument is that the monitored sulfur dioxide levels which prompted the proposed designation were only marginally above the established standard and, considering the accuracy of the monitoring instrument itself, may not reflect "real world" violations of the standard. Of the nine monitored

Table 374

MONITORED 24-HOUR AVERAGE SULFUR DIOXIDE LEVELS IN EXCESS OF THE ESTABLISHED AMBIENT AIR QUALITY STANDARDS: 1977 AND 1978

Monitoring Site	Date	24-Hour Average Sulfur Dioxide Concentration ($\mu g/m^3$)[a]
Milwaukee Harbor Commission 1225 S. Carferry Drive Milwaukee	January 8, 1978 January 9, 1978 January 25, 1978 January 28, 1978	379.0 603.3 371.3 365.5
University of Wisconsin- Milwaukee, North Campus 2114 E. Kenwood Boulevard Milwaukee	February 1, 1977 December 22, 1977 January 22, 1978 January 23, 1978 August 23, 1978	371.0 382.0 367.8 421.3 400.6

[a] *The primary and secondary 24-hour average sulfur dioxide ambient air quality standard is 365 micrograms per cubic meter ($\mu g/m^3$).*

Source: Wisconsin Department of Natural Resources.

24-hour average sulfur dioxide levels exceeding the ambient air quality standard, six were less than 5 percent above the standard, and only one was measured at a concentration more than 10 percent above the standard. Regardless of the degree to which a monitored violation exceeds the established standard, however, if such violations are measured, the designation of a sulfur dioxide nonattainment area must be made under the provisions of the applicable federal laws.

A second argument against the designation of a sulfur dioxide nonattainment area is that either the monitoring instrument itself, or the instrument used to calibrate the monitor, was improperly calibrated and thus provided inaccurate data. In response to this argument it is noted that the Wisconsin Department of Natural Resources has established a quality assurance program to verify the accuracy of the monitoring data. A description of the efforts to establish the validity of the monitoring data must be submitted to the U. S. Environmental Protection Agency in support of the Department's proposal to designate a nonattainment area. Final determination of the validity of the sulfur dioxide monitoring in the City of Milwaukee thus rests with the U. S. Environmental Protection Agency. Until such time as the U. S. Environmental Protection Agency deems the monitoring data submitted as a part of the proposed sulfur dioxide nonattainment area designation invalid, the Commission must accept the findings and results of the Wisconsin Department of Natural Resources' quality assurance program.

Based upon the foregoing, the Commission staff recommended, and the Advisory Committee concurred, that the plan continue to recognize as a committed action the designation of a sulfur dioxide nonattainment area

in the City of Milwaukee. Should the U. S. Environmental Protection Agency ultimately reject the proposed designation of the nonattainment area for whatever reason, then those plan recommendations which relate to the designation of a nonattainment area, e.g., the enactment of Reasonably Available Control Technology rules to be applied to existing sources of sulfur dioxide emissions within or impacting upon the nonattainment area, would be inapplicable.

The Commission staff also recommended, and the Advisory Committee concurred, that the ambient air quality monitoring data for any pollutant species for which one or more nonattainment areas have been designated in the Region be reviewed by the Wisconsin Department of Natural Resources on a semi-annual basis in order to determine progress toward attainment of the ambient air quality standards. Such a semi-annual review of the monitoring data should serve to relieve the imposition of the nonattainment area designation, with its attendant economic impacts, as expeditiously as practicable in areas which attain the standards.

Banking of Emission Reduction Credits

Testimony was presented at the public hearing to the effect that neither the regional air quality attainment and maintenance plan nor the State Implementation Plan contained recommendations for institutionalizing the "banking" of emission reduction credits in connection with the proposed emission offset policy applicable in both nonattainment and attainment areas. In an emission reduction credit banking system, the emission reductions achieved by the owner or operator of a source over and above the emission reductions required by the State Implementation Plan could be held in reserve, or "banked," for the future use, trade, or sale by the owner or operator of that source.

An institutionalized emission reduction credit banking system would both assist in the attainment and maintenance of the ambient air quality standards and promote a more favorable economic climate in the Southeastern Wisconsin Region. In an emission reduction credit banking system, an industrial firm seeking to construct or expand in a nonattainment area, or in a clean air area, is offered an incentive to apply and operate more stringent air pollution controls than are otherwise required by existing regulations, the incentive being the establishment of emission reduction credits that can be banked for future use by the firm or sold to another firm. Such a banking system would provide a means whereby industries could achieve emission reductions in excess of and in advance of their immediate needs in offset transactions, potentially at a lower cost than if the same reductions were required at a later date. Thus, new industrial growth could be accommodated less expensively than would be possible without an emission reduction credit banking system.

Although an emission reduction credit banking system may be expected to provide an incentive to industry to increase the level of air pollution control and thereby accelerate attainment of the air quality standards, there are many technical, administrative, and policy decisions which must be addressed in the design of such a system if both environmental and economic objectives are to be mutually and satisfactorily achieved. The basic process in an emission reduction credit banking system is to create an emission reduction credit; have the credit confirmed and certified by the responsible air pollution control agency; bank the credit for future use, trade, or sale; and, finally, withdraw and dispose of the credit for development, expansion, or profit. At each stage in the emission reduction credit banking system there are a number of alternative procedures which may be developed and administered. For example, the buying, selling, or trading of emission reduction credits may be accomplished by a public auction system, wherein a public authority collects and resells credits, determining base price, frequency of auctions, and size of credits to be offered; by a public monopsony-monopoly system, wherein a public authority acts as the sole purchaser and sole supplier of emission reduction credits; or by a private trading system, wherein all emission reduction credit transactions are accomplished through private brokerage or agreements with the approval of the air pollution control agency. Other factors, such as the duration over which a credit may be banked, the geographic area over which a credit for a certain pollutant species may be used as a future offset for new development, and the technical procedures to be followed in verifying that the use of a banked credit produces no adverse air quality impacts, must be firmly established in the regulatory scheme if the emission reduction credit banking system is to receive widespread acceptance by industry.

Based upon the foregoing, the Commission staff recommended, and the Advisory Committee concurred, that a prospectus be prepared setting forth a detailed program of study on alternative emission reduction credit systems for the Southeastern Wisconsin Region.[12] The preparation of this prospectus should be conducted under the auspices of the Technical Coordinating and Advisory Committee on Regional Air Quality Planning. For this purpose, the Committee membership may be expanded to include personnel from local economic development authorities and a broader range of major industrial concerns. Because of the significant environmental and economic advantages expected to be associated with a functioning emission reduction credit banking system, it is recommended that the preparation of the prospectus begin as soon as practicable.

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[12] *This prospectus should be cognizant of, and in conformance with, federal guidance relating to the administration at the state and local levels of the U. S. Environmental Protection Agency emission offset policy. Federal guidance on the emission offset policy has been set forth in the Code of Federal Regulations Title 40, Part 51, Appendix S), and most recently in the Federal Register, Vol. 45, No. 94, May 13, 1980. The prospectus should also recognize that the creation of an Air Resource Allocation Council has recently*

(Footnote continued on next page)

Economic and Locational Impacts of the Recommended Plan

Testimony was presented at the public hearing to the effect that the implementation and enforcement of Reasonably Available Control Technology (RACT) for existing industrial sources in southeastern Wisconsin may place the Region at a competitive disadvantage with other parts of the country in terms of economic growth and development. Three arguments were advanced in support of this contention. First, whereas many states have exempted from RACT controls the use of certain solvents which have been shown not to contribute to the formation of ozone in the atmosphere—specifically, 1,1,1 trichloroethane (Methyl Chloroform) and methylene chloride—the State of Wisconsin does not exempt such substances. Second, it was alleged that the State of Wisconsin has more stringent RACT emission limitations for particulate matter than do other states. Finally, it was suggested that the more stringent RACT rules enforced in nonattainment areas within southeastern Wisconsin may have adverse and undesirable intraregional and extraregional impacts on industrial development patterns.

In response to the first contention, it should be noted that approximately 40 states have exempted the use of 1,1,1 trichloroethane from RACT controls. About 25 states have also exempted methylene chloride from RACT controls. These exemptions have been granted on the basis of research which has indicated that these compounds are relatively nonreactive and do not contribute to the formation of ozone in the ambient air. There is evidence, however, that 1,1,1 trichloroethane and methylene chloride are carcinogenic substances and may thus represent a serious threat to human health.[13] Air pollution concerns per se, therefore, are not the only reason Wisconsin requires RACT controls on these compounds. If and when further scientific evidence indicates that these two compounds are not carcinogenic substances, then the Commission should indeed endorse the exemption of 1,1,1 trichloroethane and methylene chloride from RACT controls. Until such time, however, the Commission staff recommended, and the Advisory Committee concurred, that 1,1,1 trichloroethane and methylene chloride not be exempted from RACT emission limitations.

In response to the concern that the State of Wisconsin imposes more stringent RACT rules on particulate matter sources than do other states, the Commission staff undertook a comparison of RACT emission limitations in effect in Wisconsin with those of 13 other states which were deemed by the Commission to be representative. Such a comparison is difficult to make since the manner of expressing an emission limitation may take different forms. In certain states the allowable amount of particulate matter pollution may be expressed as a function of the process weight rate, while in other states—including Wisconsin—the emission limitation may be expressed as a function of either the volume, or the weight, of the exhaust gas. Moreover, many states, including Wisconsin, have special provisions for certain types of particulate matter emission sources which are not specifically addressed in the control regulations in other states. To overcome these difficulties, the analysis undertaken by the Commission staff consisted of a comparison of allowable emissions from existing industrial facilities in the Southeastern Wisconsin Region and allowable emissions from theoretical facilities with the same operational characteristics and located in major metropolitan areas in other areas of the country.

The industrial facilities selected for this comparative analysis were the eight facilities identified in Chapter XIII of this report as requiring the installation of control equipment to meet the State of Wisconsin RACT

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been authorized in the State of Wisconsin (Assembly Bill 1199). This council would advise the Department of Natural Resources on the use and protection of the available air resource in clean air areas. The council is to consist of 11 members and is to be comprised of seven citizen members appointed by the Governor—one to represent major sources of air pollution, one to represent minor sources of air pollution, one to represent local government, one to represent the tourism industry, one to represent the interests of labor, and two to represent environmental interests—and four members of the legislature—one from each of the two major parties in each house of the legislature. The council is charged with preparing recommendations for the allocation of the available air resources in attainment areas among various existing and possible future air pollution problem sources considering ambient air quality standards, ambient air increments of additional air pollution, and emission limitations. Among the issues to be considered by the council are methods to be used in establishing emission reduction options to apportion the available air resource, such as an emission reduction credit banking system. It is anticipated that a prospectus for an emission reduction credit banking and trading system in the Southeastern Wisconsin Region will assist the Air Resource Allocation Council in fulfilling its mandated tasks.

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[13] *The U. S. Environmental Protection Agency (EPA) has set forth a partial bibliography of sources presenting evidence that 1,1,1 trichloroethane and methylene chloride may be carcinogenic substances. This bibliography is contained in the Federal Register; Vol 44, No. 108, June 4, 1979. The EPA notes at this reference that both compounds may be carcinogenic and that 1,1,1 trichloroethane may also contribute to the depletion of the ozone layer in the stratosphere. Moreover, it is possible that one or both of these substances may be broken down in the environment to form hydrochloric acid, which may contribute to the acid rain phenomenon. Neither of these compounds, however, is presently on the EPA hazardous air pollutant list.*

emission limitations.[14] Since each of these eight facilities is located within a major urbanized area in the Region, the emission limitations applicable within metropolitan areas in other states were used for comparative purposes. In those cases where a facility had more than one process or boiler, each process or boiler was compared separately. Operational characteristics for each facility were obtained from the Wisconsin Department of Natural Resources point source emissions inventory for the year 1978. The eight particulate matter emission sources used in the comparison consist of four foundries, two asphalt production plants, one cement grinding facility, and one electric power generation plant. It is important to understand, in this respect, that of the 198 stack-vented industrial facilities in the Region which in 1977 emitted more than 10 tons per year of particulate matter, these eight may not be the only ones affected by the state regulations. As new air quality sampling and emission studies are completed, it is theoretically possible that the State would add to the list. Thus, the issue raised in the public hearing is potentially farther-reaching than the testimony might indicate.

In Table 375, the allowable particulate matter emissions from the industrial processes conducted at the Arneson Foundry in Kenosha under the present RACT emission limitations imposed by the State of Wisconsin are compared with the emission limitations of other selected states. As may be seen in this table, particulate matter emissions from the operation of the iron cupola would be reduced from the 1978 average level of 26.25 pounds per hour (lbs/hr) to 14.18 lbs/hr. under the RACT emission limitation, a decrease of about 12 lbs/hr., or nearly 46 percent. Only 5 of the 13 other states in this comparison have a more stringent emission limitation than does Wisconsin. All neighboring states except Minnesota have emission limitations less stringent than those imposed in Wisconsin. As indicated in this table, the highest emission rate for the iron cupola process is allowed by the State of Michigan, which would permit 28.36 lbs/hr. to be emitted, twice the level permitted by the State of Wisconsin.

Under the Wisconsin RACT rules, the steel electric arc furnace at the Arneson Foundry would be allowed to emit up to 10.62 lbs/hr. of particulate matter, a level far higher than the 0.36 lb/hr. this source was reportedly releasing during 1978. Only two other states—Iowa and Washington—have less stringent emission limitations for this process source.

[14] *This analysis compared only the emission limitations on fuel-burning installations and industrial process sources. A comparison of RACT limitations on fugitive dust sources in various states was not deemed practicable since such emission limitations are generally expressed in terms of control actions rather than specific emission standards. For example, many states require storage piles to be covered, sprayed, or enclosed, while other states require that visible emissions not extend beyond lot lines but do not specify control techniques. In such cases where specific emission reductions cannot be directly ascertained, the level of stringency embodied in the emission limitations cannot be defined.*

Table 375

A COMPARISON OF ALLOWABLE PARTICULATE MATTER EMISSIONS FROM THE ARNESON FOUNDRY IN KENOSHA, WISCONSIN, AND ALLOWABLE EMISSIONS FROM SIMILAR FACILITIES IN OTHER SELECTED STATES

State	Allowable Emission Rate (pounds per hour)	
	Iron Cupola[a]	Steel Electric Arc Furnace[b]
Illinois	18.88[c]	8.56[d]
Indiana	18.99[c]	8.56[d]
Iowa	18.99[c]	20.50[e]
Kentucky	13.92[d]	8.56[d]
Michigan	28.36[f]	10.62[g]
Minnesota	11.13[h]	7.09[h]
Missouri	15.81[i]	8.56[d]
New York	18.99[c]	8.16[j]
Ohio	13.92[d]	8.56[d]
Oklahoma	13.92[d]	8.56[d]
Tennessee	18.99[c]	8.56[d]
Texas	18.82[k]	9.21[k]
Washington	13.68[l]	20.50[l]
Wisconsin		
(With RACT)	14.18[m]	10.62[m]
(Present Emission Rate)	26.25[n]	0.36[n]
(With BACT)[o]	11.13[h]	7.09[h]

[a] *Process conditions assume a weight rate of 6.2 tons per hour, an exhaust gas temperature of 400° F, and an exhaust gas flow rate of 26,000 actual cubic feet per minute, which is equal to a flow rate of about 15,970 standard cubic feet per minute. Weight of the exhaust gas is equal to 70,910 pounds per hour.*

[b] *Process conditions assume a weight rate of 3.0 tons per hour, an exhaust gas temperature of 150° F, an exhaust gas flow rate of 27,500 actual cubic feet per minute (23,925 standard cubic feet per minute), and a weight of 106,227 pounds of dry exhaust gas per hour.*

[c] *Emission limitation established specifically for small foundry operations by process weight rate.*

[d] *Emission limitation (E) is related to the process weight rate (P) in tons per hour by the formula:* $E = 4.10\ P^{0.67}$

[e] *Emission limitation established specifically for electric furnaces: 0.10 grain per standard cubic foot of dry exhaust gas.*

[f] *Emission limitation established specifically for production cupolas having total plant melt rate of 0 to 10 tons per hour: 0.10 pound per 1,000 pounds of dry exhaust gas.*

[g] *Emission limitation established specifically for steel electric arc furnaces: 0.10 pound per 1,000 pounds of dry exhaust gas.*

[h] *Emission limitation (E) is related to the process weight rate (P) in tons per hour by the formula:* $E = 3.59\ P^{0.62}$

[i] *Emissions for existing iron cupolas in Missouri either may not exceed 0.4 grain of particulate matter per standard cubic foot of dry exhaust gas, or must be operated so as to remove not less than 85 percent of the emissions in the exhaust gas, whichever is more restrictive. The emissions indicated in the table are based on the 85 percent removal regulation since, for this facility, that level is more restrictive.*

[j] *Emission limitation (E) is related to the process weight rate (P) in tons per hour by the formula:* $E = 0.024\ P^{0.67}$

[k] *Emission limitation (E) is related to the process weight rate (P) in tons per hour by the formula:* $E = 3.12\ P^{0.985}$

From a review of Table 375, it may be concluded that the Wisconsin RACT emission limitations for iron cupolas having the operational characteristics exemplified by the Arneson Foundry are more stringent than those of 7 of the 13 states, and less stringent than those of 5 of the states considered in this comparison. The least stringent emission limitation for such iron cupolas is enforced in the State of Michigan, which permits twice the level of particulate matter which would be allowed under the Wisconsin RACT rules. There are only two states, however, which impose less stringent limitations than does the State of Wisconsin on particulate matter emissions from steel electric arc furnaces like that at the Arneson Foundry. For both the iron cupola and the steel electric arc furnace, the State of Minnesota has the most stringent limitations—11.13 lbs/hr. and 7.09 lbs/hr., respectively. The Minnesota emission limitations are thus equivalent to the Best Available Control Technology (BACT) limitations enforced by the State of Wisconsin in clean air areas.

A comparison of the allowable particulate matter emissions from two processes at the General Casting Corporation facility in the City of Waukesha with the probable limitations of equivalent facilities in other selected states is presented in Table 376. As may be seen in this table, the allowable emission rate for the induction furnace operation at this facility under the RACT rules—37.74 lbs/hr.—is significantly higher than the actual emission rate during 1978—5.48 lbs/hr. Moreover, only the States of Iowa, Texas, and Washington have an emission limitation for this process less stringent than that of the State of Wisconsin at the RACT level of control. The most stringent regulations, which are enforced in the State of Minnesota, permit only about 47 percent of the emissions allowed under the Wisconsin RACT rules. The relatively high absolute emission level permitted for this source under the Wisconsin RACT rules may be associated with the high volume of exhaust gas released—approximately 85,000 standard cubic feet per minute (SCFM). Conversely, a process with a relatively low exhaust gas volume has a lower level of allowable emissions.

A case in point is the borings dryer process at the General Casting Corporation, which has a relatively low exhaust gas volume of about 2,100 SCFM. As shown in Table 376, under this condition the allowable emission rate under

Table 375 (continued)

[l] *Emission limitation defined as 0.10 grain of particulate matter per standard cubic foot of dry exhaust gas.*

[m] *Emission limitation defined as 0.10 pound of particulate matter per 1,000 pounds of dry exhaust gas.*

[n] *Present emission rate determined from the Wisconsin Department of Natural Resources' 1978 Point Source Emissions Inventory.*

[o] *BACT emission limitations refer to the new source limitations presently defined in Chapter NR 154.11 of the Wisconsin Administrative Code.*

Source: SEWRPC.

Table 376

A COMPARISON OF ALLOWABLE PARTICULATE MATTER EMISSIONS FROM THE GENERAL CASTING CORPORATION IN WAUKESHA, WISCONSIN, AND ALLOWABLE EMISSIONS FROM SIMILAR FACILITIES IN OTHER SELECTED STATES

State	Allowable Emission Rate (pounds per hour)	
	Induction Furnace[a]	Borings Dryer[b]
Illinois	22.86[c]	6.52[c]
Indiana	22.86[c]	6.52[c]
Iowa	72.86[d]	6.52[c]
Kentucky	22.86[c]	6.52[c]
Michigan	37.74[e]	6.52[c]
Minnesota	17.61[f]	5.40[f]
Missouri	22.86[c]	6.52[c]
New York	21.79[g]	6.22[g]
Ohio	22.86[c]	6.52[c]
Oklahoma	22.86[c]	6.52[c]
Tennessee	22.86[c]	6.52[c]
Texas	39.03[h]	6.18[h]
Washington	72.86[d]	1.80[d]
Wisconsin		
(With RACT)	37.74[e]	0.93[e]
(Present Emission Rate)	5.48[i]	4.78[i]
(With BACT)[k]	17.61[f]	3.73[j]

[a] *Process conditions assume a maximum weight rate of 13.0 tons per hour, an exhaust gas temperature of 70°F, and an exhaust gas flow rate of 85,000 actual cubic feet per minute (approximately 85,000 standard cubic feet per minute). Weight of the exhaust gas is approximately 377,400 pounds per hour.*

[b] *Process conditions assume a maximum weight rate of 2.0 tons per hour, an exhaust gas temperature of 500°F, and an exhaust gas flow rate of 3,821 actual cubic feet per minute (ACFM), which is equivalent to a flow rate of about 2,102 standard cubic feet per minute (SCFM). Weight of the exhaust gas is approximately 9,331 pounds per hour.*

[c] *Emission limitation (E) is related to the process weight rate (P) in tons per hour by the formula: $E = 4.10\ P^{0.67}$*

[d] *Emission limitation defined as 0.10 grain of particulate matter per standard cubic foot of dry exhaust gas.*

[e] *Emission limitation defined as 0.10 pound of particulate matter per 1,000 pounds of dry exhaust gas.*

[f] *Emission limitation (E) is related to the process weight rate (P) in tons per hour by the formula: $E = 3.59\ P^{0.62}$*

[g] *Emission limitation (E) is related to the process weight rate (P) in pounds per hour by the formula: $E = 0.024\ P^{0.67}$*

[h] *Emission limitation (E) is related to the process weight rate (P) in tons per hour by the formula: $E = 3.12\ P^{0.985}$*

[i] *Present emission rate determined from the Wisconsin Department of Natural Resources' 1978 Point Source Emissions Inventory.*

[j] *Emission limitation defined as 0.4 pound of particulate matter per 1,000 pounds of dry exhaust gas.*

[k] *BACT emission limitations refer to the new source limitations presently defined in Chapter NR 154.11 of the Wisconsin Administrative Code.*

Source: SEWRPC.

the Wisconsin RACT rules is only about 0.93 lb/hr. This level is more stringent than that allowed by any of the other 13 states compared. It is also significant to note that the Wisconsin RACT emission limitation for this borings dryer is more stringent than the BACT emission limitation for a new source. The Wisconsin BACT emission limitation is expressed as a function of the process weight rate rather than as a set of exhaust gas characteristics. Although the reason for this discrepancy is related to the exhaust gas flow rate, it is counterintuitive and in direct conflict with the inherent regulatory structure of the extant air pollution control laws and regulations to impose an RACT emission limitation more stringent than the BACT limitation for the same process type.

Another case of the RACT emission limitation being more stringent than the BACT limitation for a similar new source can be demonstrated by the cupola operation at the Motor Castings Company, as shown in Table 377. In addition to being more stringent than the limitations imposed by every other state compared but Washington, the Wisconsin RACT limitation on this source—7.96 lbs/hr.—is more stringent than the BACT limitation of 15.88 lbs/hr. In addition, as shown in Table 377, the Wisconsin RACT limitation for particulate matter emissions from the cupola at the Milwaukee Malleable & Grey Iron Works is more stringent than the limitations imposed by all but two states—Minnesota and Washington.

Table 377

A COMPARISON OF ALLOWABLE PARTICULATE MATTER EMISSIONS FROM SELECTED FOUNDRIES IN NONATTAINMENT AREAS WITHIN THE REGION AND ALLOWABLE EMISSIONS FROM SIMILAR FACILITIES IN OTHER SELECTED STATES

State	Allowable Emission Rate (pounds per hour)		
	Milwaukee Malleable & Grey Iron Works		Motor Castings Company—Plant No. 1
	Cupola[a]	Air Melt Furnace[b]	Cupola[c]
Illinois	16.65[d]	8.56[e]	20.44[e]
Indiana	16.65[f]	8.56[e]	25.20[f]
Iowa	16.65[d]	8.56[e]	20.44[e]
Kentucky	12.05[e]	8.56[e]	20.44[e]
Michigan	20.78[g]	8.56[e]	9.95[h]
Minnesota	9.74[i]	7.09[i]	15.88[i]
Missouri	12.75[j]	8.56[e]	28.05[j]
New York	16.65[k]	8.16[l]	11.53[m]
Ohio	12.05[e]	8.56[e]	20.44[e]
Oklahoma	12.05[e]	8.56[e]	20.44[e]
Tennessee	16.65[d]	8.56[e]	20.44[e]
Texas	15.22[n]	9.21[n]	33.11[n]
Washington	10.03[o]	6.17[o]	7.68[o]
Wisconsin			
(With RACT)	10.39[p]	3.20[p]	7.96[p]
(Present Emission Rate)	10.64[q]	6.65[q]	18.11[q]
(With BACT)[r]	9.74[i]	7.09[i]	15.88[i]

Table 377 (continued)

[a] *Process conditions assume a maximum weight rate of 5.0 tons per hour, an exhaust gas temperature of 220° F, and an exhaust gas flow rate of 15,000 actual cubic feet per minute, which is equal to a flow rate of about 11,700 standard cubic feet per minute. Weight of the exhaust gas is approximately 51,950 pounds per hour.*

[b] *Process conditions assume a maximum weight rate of 3.0 tons per hour, an exhaust gas temperature of 279° F, and an exhaust gas flow rate of 10,000 actual cubic feet per minute (7,200 standard cubic feet per minute). Weight of the exhaust gas is approximately 31,968 pounds per hour.*

[c] *Process conditions assume a maximum weight rate of 11.0 tons per hour, an exhaust gas temperature of 160° F, and an exhaust gas flow rate of 10,546 actual cubic feet per minute, which is equal to a flow rate of about 8,965 standard cubic feet per minute. Weight of the exhaust gas is approximately 39,805 pounds per hour.*

[d] *Emission limitation established by schedule designed specifically for cupolas having a process weight rate of less than 20,000 pounds per hour.*

[e] *Emission limitation (E) is related to the process weight rate (P) in tons per hour by the formula: $E = 4.10\ P^{0.67}$*

[f] *Emission limitation established by schedule designed specifically for foundry cupolas having a process weight rate of less than 50 tons per hour.*

[g] *Emission limitation established specifically for cupolas having a total plant melt rate of between 0 to 10 tons per hour: 0.40 pound per 1,000 pounds of exhaust gas.*

[h] *Emission limitation established specifically for cupolas having a total plant melt rate of greater than 10 tons per hour but less than or equal to 20 tons per hour: 0.25 pound per 1,000 pounds of dry exhaust gas.*

[i] *Emission limitation (E) is related to the process weight rate (P) in tons per hour by the formula: $E = 3.59P^{0.62}$*

[j] *Emissions from existing cupolas in Missouri either may not exceed 0.4 grain of particulate matter per standard cubic foot of dry exhaust gas, or must be operated so as to remove not less than 85 percent of the emissions in the exhaust gas, whichever is more restrictive. The emissions indicated in this table are based on the 85 percent removal regulation since, for this facility, that level is more restrictive.*

[k] *Emission limitation established by schedule designed specifically for ferrous jobbing foundries having a process weight rate of 50,000 pounds per hour or less.*

[l] *Emission limitation (E) is related to the process weight rate (P) in pounds per hour by the formula: $E = 0.024\ P^{0.67}$*

[m] *In New York State this cupola would be considered to be a part of the production foundry since it operates more than four hours in a 24-hour period. The emission limitation is therefore defined as 0.15 grain of particulate matter per standard cubic foot per minute of exhaust gas.*

[n] *Emission limitation (E) is related to the process weight rate (P) in tons per hour by the formula: $E = 3.12\ P^{0.985}$*

[o] *Emission limitation defined as 0.10 grain of particulate matter per standard cubic foot of dry exhaust gas.*

[p] *Emission limitation defined as 0.20 pound of particulate matter per 1,000 pounds of dry exhaust gas and assumes that the control equipment has not been allowed to degrade more than 0.05 pound per 1,000 pounds of exhaust gas from original design conditions.*

[q] *Present emission rate determined from the Wisconsin Department of Natural Resources' 1978 Point Source Emissions Inventory.*

[r] *BACT emission limitations refer to other new source limitations presently defined in Chapter NR 154.11 of the Wisconsin Administrative Code.*

Source: SEWRPC.

The above examples have all dealt with comparative emissions from foundry operations. Table 378 presents a comparison of the emission limitations imposed on asphalt production plants under the Wisconsin RACT rules with the limitations imposed on such plants in other selected states. As indicated in this table, the Wisconsin limitations are more stringent—by a factor of about two—than the limitations of the other states compared. Under the Wisconsin RACT rules, the particulate matter emission limitations for the City of Milwaukee Asphalt Plant and the Sherwin Corporation asphalt production process—10.99 lbs/hr. and 11.66 lbs/hr., respectively—are about twice as stringent as those of the State of Washington—21.20 lbs/hr. and 22.50 lbs/hr., respectively—and nearly five times as stringent as those of the State of New York—50.25 lbs/hr. and 54.70 lbs/hr., respectively. For both the City of Milwaukee Asphalt Plant and the Sherwin Corporation, the Wisconsin BACT emission limitations are more stringent than the RACT emission limitations.

The Wisconsin RACT emission limitation for the cement grinding process at the Universal Atlas Cement Division of the U. S. Steel Corporation—5.07 lbs/hr. as shown in Table 379—is more stringent than the BACT emission limitation for new such sources by a factor of about two. Moreover, the 5.07 lbs/hr. RACT emission limitation is the most stringent control level of all the states compared. The State of Michigan, which has the next most stringent regulations, permits an emission level about 1.5 times the Wisconsin RACT level, while the State of Texas, which has the least stringent regulations, permits an emission level more than 12 times higher than that allowed under the Wisconsin RACT rules.

Of the eight facilities compared in this analysis, the Wisconsin Electric Power Company's Wells Street plant is the only fuel-burning installation subject to the RACT emission limitations. As shown in Table 380, there were two boilers in operation at the Wells Street plant during 1978. The Wisconsin RACT emission limitations applicable to these two boilers have been compared with the allowable emission rate for boilers of similar size in other selected states (see Table 380). As may be seen in Table 380, only boilers located in major metropolitan areas within the State of Illinois, Minnesota, and Ohio are subject to particulate matter emission limitations as stringent as the Wisconsin RACT controls. The least stringent controls on boilers of this size—0.60 pound per million BTU heat input capacity—are enforced in the State of Iowa. Also, the State of New York has a special provision for stoker-fed boilers which allows such boilers to emit particulate matter at the 0.60-pound-per-million BTU level. Thus, the Wisconsin RACT rules for fuel-burning installations are more stringent than the limitations imposed by 10 of the 13 states considered in this comparison.

There are two important conclusions which may be derived from the foregoing analyses. First, in many cases, the Wisconsin RACT emission limitations are more stringent than the emission limitations enforced for similar processes in other states. Second, the Wisconsin RACT rules for existing sources are, in certain cases, more stringent than the Wisconsin BACT emission limitations for new such sources. Both of these conclusions

Table 378

A COMPARISON OF ALLOWABLE PARTICULATE MATTER EMISSIONS FROM EXISTING ASPHALT PRODUCTION PLANTS IN NONATTAINMENT AREAS WITHIN THE REGION AND ALLOWABLE EMISSIONS FROM SIMILAR FACILITIES IN OTHER SELECTED STATES

State	Allowable Emission Rate (pounds per hour)	
	City of Milwaukee Asphalt Plant[a]	Sherwin Corporation[b]
Illinois	44.58[c]	49.66[c]
Indiana	44.58[c]	49.66[c]
Iowa	31.79[d]	33.75[d]
Kentucky	44.58[c]	49.66[c]
Michigan	32.94[e]	34.97[e]
Minnesota	32.37[f]	35.24[f]
Missouri	44.58[c]	49.66[c]
New York	50.25[g]	54.70[g]
Ohio	44.58[c]	49.66[c]
Oklahoma	44.58[c]	49.66[c]
Tennessee	44.58[c]	49.66[c]
Texas	31.15[h]	31.52[h]
Washington	21.20[i]	22.50[i]
Wisconsin		
(With RACT)	10.99[j]	11.66[j]
(Present Emission Rate)	48.40[k]	41.54[k]
(With BACT)[l]	8.48[m]	9.00[m]

[a] *Process conditions assume a maximum weight rate of 50 tons per hour, an exhaust gas temperature of 275°F, and an exhaust gas flow rate of 34,345 actual cubic feet per minute, which is equivalent to a flow rate of about 24,728 standard cubic feet per minute. Weight of the exhaust gas is equal to 109,792 pounds per hour.*

[b] *Process conditions assume a maximum weight rate of 85 tons per hour, an exhaust gas temperature of 250°F, and an exhaust gas flow rate of 35,000 actual cubic feet per minute (26,250 standard cubic feet per minute). Weight of the exhaust gas is equal to 116,550 pounds per hour.*

[c] *Emission limitation (E) is related to the process weight rate (P) in tons per hour by the formula:* $E = (55.0\ P^{0.11})\text{-}40$

[d] *Emission limitation defined as 0.15 grain of particulate matter per standard cubic foot of dry exhaust gas.*

[e] *Emission limitation defined as 0.30 pound of particulate matter per 1,000 pounds of dry exhaust gas.*

[f] *Emission limitation (E) is related to the process weight rate (P) in tons per hour by the formula:* $E = 17.31\ P^{0.16}$

[g] *Emission limitation (E) is related to the process weight rate (P) in pounds per hour by the formula:* $E = (39.0\ P^{0.082})\text{-}50$

[h] *Emission limitation (E) is related to the exhaust volume flow rate (Q) in actual cubic feet per minute by the formula:* $E = 0.048\ Q^{0.62}$

[i] *Emission limitation defined as 0.10 grain of particulate matter per standard cubic foot of dry exhaust gas.*

[j] *Emission limitation defined as 0.10 pound of particulate matter per 1,000 pounds of dry exhaust gas.*

[k] *Present emission rate determined from the Wisconsin Department of Natural Resources' 1978 Point Source Emissions Inventory.*

[l] *BACT emission limitations refer to the new source limitations presently defined in Chapter NR 154.11 of the Wisconsin Administrative Code.*

[m] *Emission limitation defined as 0.04 grain of particulate matter per standard cubic foot of dry exhaust gas.*

Source: SEWRPC.

Table 379

A COMPARISON OF ALLOWABLE PARTICULATE MATTER EMISSIONS FROM THE UNIVERSAL ATLAS CEMENT DIVISION OF U. S. STEEL CORPORATION IN MILWAUKEE, WISCONSIN, AND ALLOWABLE EMISSIONS FROM SIMILAR FACILITIES IN OTHER SELECTED STATES

State	Allowable Emission Rate (pounds per hour)[a]
Illinois	35.40[b]
Indiana	35.40[b]
Iowa	35.40[b]
Kentucky	35.40[b]
Michigan	7.60[c]
Minnesota	26.41[d]
Missouri	35.40[b]
New York	33.77[e]
Ohio	35.40[b]
Oklahoma	35.40[b]
Tennessee	35.40[b]
Texas	63.98[f]
Washington	9.78[g]
Wisconsin	
(With RACT)	5.07[h]
(Present Emission Rate)	10.23[i]
(With BACT)[k]	10.10[j]

[a] *Process conditions assume a cement grinding operation with a maximum throughput capacity of 25 tons per hour, an exhaust gas temperature of 180° F, and an exhaust gas flow rate of 13,750 actual cubic feet per minute, which is equivalent to a flow rate of about 11,413 standard cubic feet per minute. Weight of the exhaust gas is approximately 50,674 pounds per hour.*

[b] *Emission limitation (E) is related to the process weight rate (P) in tons per hour by the formula : $E = 4.10\ P^{0.67}$*

[c] *Emission limitation defined as 0.15 pound of particulate matter per 1,000 pounds of exhaust gas.*

[d] *Emission limitation (E) is related to the process weight rate (P) in tons per hour by the formula: $E = 3.59\ P^{0.62}$*

[e] *Emission limitation (E) is related to the process weight rate (P) in tons per hour by the formula: $E = 0.024\ P^{0.67}$*

[f] *Emission limitation (E) is related to the process weight rate (P) in tons per hour by the formula: $E = 25.4\ P^{0.287}$*

[g] *Emission limitation defined as 0.10 grain of particulate matter per standard cubic foot of dry exhaust gas.*

[h] *Emission limitation defined as 0.10 pound of particulate matter per 1,000 pounds of dry exhaust gas.*

[i] *Present emission rate determined from the Wisconsin Department of Natural Resources' 1978 Point Source Emissions Inventory.*

[j] *Emission limitation defined as 0.20 pound of particulate matter per 1,000 pounds of dry exhaust gas.*

[k] *BACT emission limitations refer to the new source limitations presently defined in Chapter NR 154.11 of the Wisconsin Administrative Code.*

Source: SEWRPC.

Table 380

A COMPARISON OF ALLOWABLE PARTICULATE MATTER EMISSIONS FROM THE WISCONSIN ELECTRIC POWER COMPANY'S WELLS STREET PLANT IN MILWAUKEE, WISCONSIN, AND ALLOWABLE EMISSIONS FROM SIMILAR FACILITIES IN OTHER SELECTED STATES

State	Allowable Emission Rate (pounds per million BTU's)[a]	
	254 Million BTU Rated Capacity[b]	304.2 Million BTU Rated Capacity[c]
Illinois	0.10	0.10
Indiana	0.36[d]	0.35[d]
Iowa	0.60	0.60
Kentucky	0.26[e]	0.25[e]
Michigan	0.26	0.25
Minnesota[j]	0.10	0.10
Missouri	0.26[f]	0.25[f]
New York	0.60[g]	0.28[h]
Ohio	0.10	0.10
Oklahoma	0.26	0.25
Tennessee	0.26	0.25
Texas	0.30	0.30
Washington	0.20	0.16
Wisconsin		
(With RACT)	0.10	0.10
(Present Emission Rate)	0.83[i]	1.23[i]
(With BACT)[k]	0.10	0.10

[a] *This analysis assumes that the boiler is located within the major metropolitan area in each state, that each boiler uses solid fuel, and that each boiler was constructed before 1968.*

[b] *Type of boiler: underfed stoker-rated capacity equal to 160,000 pounds of steam per hour.*

[c] *Type of boiler: pulverized dry bottom-rated capacity equal to 225,000 pounds of steam per hour.*

[d] *Emission limitation (E) is related to the heat input capacity (Q) in millions of BTU's per hour by the formula: $E = 0.87(Q)^{-0.16}$*

[e] *Emission limitation (E) is related to the heat input capacity (Q) in millions of BTU's per hour by the formula: $E = 0.9634\ Q^{-0.2356}$*

[f] *Emission limitation (E) is related to the heat input capacity (Q) in millions of BTU's per hour by the formula: $E = 1.09\ Q^{-0.259}$*

[g] *Emission limitation specific to stoker-fed boilers.*

[h] *Emission limitation (E) is related to the heat input capacity (Q) in millions of BTU's per hour by the formula: $E = 1/Q^{0.22}$*

[i] *Present emission rate determined from the Wisconsin Department of Natural Resources' 1978 Point Source Emissions Inventory.*

[j] *The State of Minnesota is presently considering a change in the RACT emission limitation for fuel-burning installations from the existing limit of 0.10 pound of particulate matter per million BTU's, to 0.40 pound per million BTU's.*

[k] *BACT emission limitations refer to the new source limitations presently defined in Chapter NR 154.11 of the Wisconsin Administrative Code.*

Source: SEWRPC.

have significant implications with respect to the location of interregional and intraregional industrial facilities.

Because the Wisconsin air pollution control regulations are generally more stringent than are those enforced in other states, the Southeastern Wisconsin Region may be at an economic disadvantage in competing with industries in other states. In particular, existing industries within the Region seeking to expand their operations may find the development climate more favorable outside Wisconsin. Also, because the BACT limitations for new sources in clean air areas of the Region are in certain cases less stringent than the RACT limitations on existing sources in nonattainment areas, the impetus may exist for an existing facility to relocate from the nonattainment area to a clean air area within the Region. Although air quality concerns are not the sole factor in determining the location or expansion of industrial development, such concerns may influence economic development patterns.

As was discussed in Chapter XI of this report, the point source modeling effort has indicated that forecast industrial growth in the Region without additional RACT controls on stack-vented particulate emissions is not expected to significantly impact particulate matter concentrations in southeastern Wisconsin on an annual average basis. This conclusion is based upon the finding that even with an extensive conversion by industry to coal use, particulate matter concentrations resulting from point source emissions would not exceed 5 micrograms per cubic meter ($\mu g/m^3$), expressed as an annual arithmetic average, in the year 2000 (see Map 107 in Chapter XII). In comparison, a maximum particulate matter concentration of 14 $\mu g/m^3$ is expected to result from line source emissions in the year 2000 (see Map 111 in Chapter XII), and a maximum particulate matter concentration of 75 $\mu g/m^3$ is expected to result from area source emissions in the year 2000 (see Map 115 in Chapter XII), both expressed as an annual arithmetic average. Thus, based upon the regional analysis, industrial stack emissions have the least impact on particulate matter ambient air quality in the Region under the "worst case" energy scenario and at the pre-RACT level of control. With the implementation and enforcement of RACT controls on industrial processes and fuel-burning installations, the maximum particulate matter concentration resulting from point source emissions is expected to be 2 $\mu g/m^3$ (see Map 176 in Chapter XIII), expressed as an annual arithmetic average. On a regional basis, therefore, RACT controls on industrial process and fuel-burning installations may be expected to provide for a net decrease of 3 $\mu g/m^3$ of particulate matter on a maximum annual average basis. It is important to note, however, that this finding is based upon the application of a simulation model having a spatial resolution of about one mile square. A finer resolution, microscale model may be necessary to assess the contribution of each individual stack's emissions to localized ambient air quality.

Based upon the preceding analysis, the Commission staff recommends, and the Advisory Committee concurs, that the following actions be undertaken by the Wisconsin Department of Natural Resources:

1. The RACT emission limitations should be reevaluated considering economic and technological factors and those costs associated with placing industrial sources at an economic disadvantage with similar sources in other states. This may require that a separate RACT emission limitation be defined or that a variance to the RACT rule be made for each affected facility which takes into consideration the unique economic and operating characteristics of each type of emission source.

2. The RACT emission limitations, as reevaluated, should be established at a level which is no more stringent, and ideally should be less stringent, than the BACT level for new sources with the same operational characteristics as the affected facility.

These recommended actions may be expected to alleviate undue constraints on economic development in the Region, while not significantly impairing the attainment and maintenance of the particulate matter ambient air quality standards on a regional level. Furthermore, if the RACT emission limitations are redefined using the state-of-the-art in microscale modeling techniques, it is envisioned that attainment and maintenance of the standards can be ensured in the proximity of all industrial sources of particulate matter emissions.

Concluding Remarks—Public Reaction

In summary, it may be concluded that the recommended regional air quality attainment and maintenance plan generally met with a favorable response at the public informational meeting and hearing. In reviewing all of the comments, opinions, and suggestions presented at the informational meeting and hearing, the Commission, upon the recommendation of the Technical Coordinating and Advisory Committee, added the following elements to the recommended plan:

1. It is recommended that the Southeastern Wisconsin Regional Planning Commission undertake the preparation of a prospectus detailing a course of study for establishing an emission reduction credit banking and trading system in the Region. It is envisioned that such an institutionalized system would provide an economic incentive for industries to control air pollution beyond the level required by existing regulations and thereby accelerate attainment of the ambient air quality standards in the Region.

2. It is recommended that the Wisconsin Department of Natural Resources undertake a review of the existing Reasonably Available Control Technology (RACT) emission limitations for particulate matter sources and that such limitations be reevaluated considering economic and technological factors and those costs associated with placing industrial sources at an economic disadvantage with similar sources in other states. The RACT emission limitations for existing sources as reevaluated should be no more stringent than the Best Available Control Technology (BACT) limitations for new such sources with the same operational characteristics.

3. It is recommended that the Department of Natural Resources review the available ambient air quality monitoring data from nonattainment areas in the Region on a semi-annual basis in order to determine whether rescission or redefinement of the nonattainment area designation is warranted.

IMPLEMENTATION

The legal and governmental framework existing within the Region is such that the existing state, county, and local units of government can implement the major recommendations contained in the regional air quality attainment and maintenance plan. These levels, agencies, and units of government include at the local level the governing bodies of the cities, villages, towns, and counties within the Region; at the state level the Wisconsin Department of Natural Resources, the Wisconsin Department of Transportation, and the Wisconsin Public Service Commission; and at the federal level the U. S. Environmental Protection Agency and the U. S. Department of Transportation. For a summary of the recommended, as well as committed, actions contained in the regional air quality attainment and maintenance plan, along with the recommended implementing agencies, see Table 381.

Primary responsibility for implementation of the regional air quality attainment and maintenance plan is placed

Table 381

SUMMARY OF ACTIONS CONTAINED IN THE RECOMMENDED REGIONAL AIR QUALITY ATTAINMENT AND MAINTENANCE PLAN

Type of Action	Basis for Enforcement	Particulate Matter Plan	Sulfur Dioxide Plan	Carbon Monoxide and Hydrocarbon/Ozone Plan	Ambient Air Quality Monitoring Network Plan
Committed	State Implementation Plan as of May 1972[a]	● Apply emission limitations to existing and new sources[a] - Fuel-burning installations - Industrial processes - Industrial fugitive dust sources	● Apply emission limitations to small existing point sources and to new sources, and place sulfur limits on standby fuel[a]	● Apply emission limitations or solvent substitutions to specified existing and new process sources[a]	● Maintain existing ambient air quality monitoring network[a]
	State Implementation Plan as of July 1979[a]	● Apply Reasonably Available Control Technology to existing sources[a] - Fuel-burning installations - Industrial processes - Industrial fugitive dust sources	● Designate part of Milwaukee County as a nonattainment area[a,g] ● Establish Reasonably Available Control Technology emission limitations for existing sources of sulfur dioxide emissions which lie within or impact upon the nonattainment area[a,g] ● Require new or modified sources of emissions which lie within, or impact upon, the nonattainment area to obtain an emissions offset from other sources of sulfur dioxide emissions in the area[a,g]	● Apply Reasonably Available Control Technology to specified existing stationary sources of volatile organic compound emissions[a]	
	Federal Law[f]			● Implement the federal motor vehicle emissions control program[f]	
Proposed Additions to the State Implementation Plan		● Adopt and enforce New Source Performance Standards and Prevention of Significant Deterioration Regulations for new or modified sources[a] ● Establish and enforce an emission offset policy for new or modified stationary sources after the application of Lowest Achievable Emission Rate control technology[a] ● Conduct special-purpose ambient air quality monitoring programs related to mineral extraction operations and to long-range transport of particulate matter[a]	● Adopt and enforce New Source Performance Standards and Prevention of Significant Deterioration Regulations for new or modified stationary sources[a] ● Ban the use of coal for residential and small commercial-institutional space and water heating in Milwaukee County, allowing for voluntary phase-out of such existing uses[a]	● Adopt and enforce Lowest Achievable Emission Rate technology for new or modified stationary sources of volatile organic compound emissions and continue to abide by carbon monoxide regulations in Chapter NR 154 of the Wisconsin Administrative Code[a] ● Implement adopted regional transportation plan with its associated transportation systems management actions[b] ● Establish a vehicle inspection and maintenance program in southeastern Wisconsin[c] ● Prohibit the use of cutback asphalt as a paving material in southeastern Wisconsin[a]	● Locate and operate six special-purpose particulate matter samplers for the purpose of monitoring long-range transport[a] ● Locate and operate two to four special-purpose particulate matter samplers around at least one major quarrying operation for the purpose of verifying computer simulation modeling results[a] ● Locate and operate special-purpose particulate matter samplers as necessary to adequately assess the impact of the proposed pilot vacuum street sweeping program in southeastern Wisconsin[a] ● Locate and operate a special-purpose carbon monoxide sampler in the area of the Marquette Interchange in Milwaukee County to verify computer simulation modeling results and to measure progress toward attainment of the ambient air quality standards[a]

with the Wisconsin Department of Natural Resources. It is recommended that the Wisconsin Department of Natural Resources integrate the plan recommendations into the State Implementation Plan for air quality required under federal regulations; complete the development and application of Reasonably Available Control Technology (RACT) emission limitations for existing sources of particulate matter, sulfur dioxide, and volatile organic compound emissions; assume delegation of prevention of significant deterioration authority for regulating new or modified sources of emissions in clean air areas; establish a regulatory program that would provide for an emissions offset procedure for new sources of emissions in, or impacting upon, nonattainment areas; cooperate in the conduct of a pilot vacuum street sweeping program; enact appropriate rules to prohibit the replacement of coal-fired facilities for residential and small commercial-institutional space and water heating purposes in Milwaukee County; seek legislative approval for the establishment of a vehicle inspection and maintenance program; enact appropriate rules prohibiting the use of cutback asphalt as a paving material in the Region; and continue to operate the existing network of air quality monitors, undertaking special and expanded programs as recommended.

It is recommended that the Wisconsin Department of Transportation, in cooperation with the Wisconsin Department of Natural Resources, seek legislative authority to initiate a vehicle inspection and maintenance program in the Region; direct available state and federal transportation system funding toward those identified transportation system improvement and management actions that have a significant air quality benefit; and be the lead agency in the conduct of a pilot vacuum street sweeping program in parts of Milwaukee County. It is also recommended that the Wisconsin Public Service Commission prepare and promulgate a contingency plan that would provide for the preferential allocation of natural gas supplies to industrial sources in the nonattainment areas

Table 381 (continued)

Type of Action	Basis for Enforcement	Particulate Matter Plan	Sulfur Dioxide Plan	Carbon Monoxide and Hydrocarbon/Ozone Plan	Ambient Air Quality Monitoring Network Plan
Proposed Additions to the State Implementation Plan (continued)					● Locate and operate special-purpose monitors for nitrogen oxides and nonmethane hydrocarbons near the Illinois/Wisconsin border in Kenosha County, in or near the central business district of the City of Milwaukee, and downwind of the Milwaukee urbanized area in Ozaukee County[a] ● Locate and operate special-purpose ozone monitors in Walworth and Washington Counties for the purpose of establishing attainment or nonattainment of the ambient air quality standards[a]
Other Recommended Actions		● Establish a pilot vacuum street sweeping program in parts of Milwaukee County[d] ● Reevaluate the Reasonably Available Cost Technology emission limitations considering economic and technological factors and those costs associated with placing industrial sources at an economic disadvantage with similar sources in other states[a]	● Preferentially allocate natural gas supplies to industries in or significantly impacting upon a nonattainment area in southeastern Wisconsin in the event of statewide shortages in order to minimize conversions to coal[e]		● Review available monitoring data from nonattainment areas on a semi-annual basis in order to determine whether rescission or redefinement of the nonattainment area designation is warranted[a]
		● Prepare a prospectus detailing a course of study for establishing an emission reduction credit banking and trading system in the Southeastern Wisconsin Region[h]			

[a] *Implementing agency: Wisconsin Department of Natural Resources.*

[b] *Implementing agency: Wisconsin Department of Transportation and local transportation facility implementing agencies.*

[c] *Implementing agency: Wisconsin Department of Natural Resources and Department of Transportation.*

[d] *Implementing agency: Wisconsin Department of Transportation.*

[e] *Implementing agency: Wisconsin Public Service Commission.*

[f] *Implementing agency: U. S. Environmental Protection Agency.*

[g] *These actions are considered committed contingent upon the formal designation of the sulfur dioxide nonattainment area.*

[h] *Preparation of the prospectus is to be the responsibility of the Southeastern Wisconsin Regional Planning Commission.*

Source: SEWRPC.

of the Region or significantly impacting such areas in the event that such supplies become severely curtailed and the conversion to coal by industrial sources in the Region becomes imminent.

It is recommended that all local units of government charged with the development and maintenance of transportation facilities take appropriate actions to implement those transportation system improvement and management actions which have been identified as having significant air quality benefits. Also, it is recommended that Milwaukee County and the municipalities of Greenfield, Milwaukee, West Allis, West Milwaukee, and Wauwatosa cooperate with the Wisconsin Department of Natural Resources and Department of Transportation in the conduct of a pilot vacuum street sweeping program.

It is recognized that the active participation by concerned citizens and environmental groups is important to the successful implementation of the recommended regional air quality attainment and maintenance plan. Accordingly, a program established to promote such public participation is deemed an essential part of the continuing air quality planning process. Such a public participation program would serve to both inform and educate concerned citizens as to current problems regarding and potential solutions to air pollution in the Region, as well as to elicit and evoke public response, advice, and constructive criticism of the air quality plan and planning process.

On the federal level, the plan recognizes as committed actions the formal designation by the U. S. Environmental Protection Agency (EPA) of the nonattainment area as proposed by the Wisconsin Department of Natural Resources in a portion of Milwaukee County for sulfur dioxide, and the continued implementation and enforcement of the federal motor vehicle emissions control program. In addition, the plan recommends that the EPA, through the vehicle of the State Implementation Plan for air quality, approve actions proposed by the Wisconsin Department of Natural Resources concerning the development of RACT emission limitations, and transfer the responsibility for regulating new and modified sources of such emissions in clean air areas of the Region with respect to prevention of significant deterioration authority to the Wisconsin Department of Natural Resources. It is also recommended that the U. S. Department of Transportation utilize the plan recommendations in its administration of highway and transit aid programs, giving particular attention to the funding of those transportation improvement and management measures found to have significant air quality benefits.

CONCLUSION

The regional air quality attainment and maintenance plan recommended herein provides another important element of the evolving comprehensive plan for the physical development of the seven-county Southeastern Wisconsin Region. The plan is based upon extensive inventories, forecasts, and analyses of the Region's natural and socioeconomic resource base; existing and forecast air pollutant emission sources and resultant ambient air quality; and existing air pollution control plans, laws, regulations, and studies. The plan has been prepared under the direction of a committee comprised of knowledgeable and experienced representatives of natural resource interest groups, local industries, and federal, state, and local governmental agencies charged with the protection of the air resource. The plan was also subject to public review at a public informational meeting and public hearing.

The recommended regional air quality attainment and maintenance plan has identified existing and potential ambient air quality problems, and has set forth a course of action to abate excessive air pollutant levels presently experienced in the Region and to prevent the further occurrence of such deleterious air pollutant levels. If the plan is fully implemented, it is expected that the residents of the seven-county Southeastern Wisconsin Region will not be exposed to ambient air which could be harmful to their health, which could adversely influence their welfare, or which could detract from the overall quality of their environment.

The recommended regional air quality attainment and maintenance plan has been developed within the confines of the existing federal and state regulatory scheme. Thus, such elements as the established ambient air quality standards, the emission limitations mandated by existing regulations, and the prescribed level of control defined as "reasonable" for various air pollution sources have been tacitly integrated into the regional air quality attainment and maintenance plan. The study of air pollution as a science, however, is new and relatively imprecise. This fact is borne out by the numerous and frequent changes in the assemblage of air quality-related laws and regulations which have evolved from the continually expanding body of knowledge concerning the sources, the effects, and the means of controlling air pollutants. There is every reason to believe that this dynamic process of revision, modification, and addition to the body of knowledge concerning air pollution will continue to foster corresponding amendments to the regulatory scheme. Thus, although the recommended regional air quality attainment and maintenance plan is based, in part, on the acceptance of the federal and state approach to the provision of clean air, the plan also recognizes the need to maintain a flexible approach to air pollution control.

It is recognized that there are several emerging air pollution concerns which may warrant consideration in future air quality management planning efforts. These concerns include the impact of acid rain on lakes and streams; the potential significant increases in particulate matter pollution which may result from the increased use of diesel-powered motor vehicles; the synergistic effects of the simultaneous exposure to excessive levels of multiple pollutant species; and the problem of sulfate formation associated with the use of catalytic converters on motor vehicles. These concerns are only representative of a wide range of potential air quality problems which could not be addressed within the scope of the present planning effort. Amendments to the plan may be necessitated as these emerging concerns are better defined.

Though implementation of the regional air quality attainment and maintenance plan may be difficult and sometimes controversial, the potential benefits are great. The importance of the implementation of this plan cannot be overemphasized. Although the Southeastern Wisconsin Region is the most heavily urbanized portion of the State, it is blessed with an abundance of high-quality resource amenities, including Lake Michigan, numerous inland lakes and streams, woodlands and wetlands, wildlife habitat, and scenic landscapes. Unfortunately, a high degree of urbanization is generally accompanied by air pollution problems which may seriously detract from, or even severely damage, other elements of the natural resource base. The recommended regional air quality attainment and maintenance plan sets forth a framework of action within which the desirable qualities of urbanization may be accommodated with the preservation of the air resource and, ultimately, which will improve the overall quality of the environment for the residents of the Southeastern Wisconsin Region.

APPENDICES

Appendix A

TECHNICAL COORDINATING AND ADVISORY COMMITTEE ON REGIONAL AIR QUALITY PLANNING

Richard A. Keyes Chairman	Environmental Engineer, Division of Environmental Services, Milwaukee County
Barbara J. Becker Vice-Chairman	Member, Southeastern Wisconsin Coalition for Clean Air
Richard F. Pierce Secretary	Principal Specialist, Environmental Planning Division, Southeastern Wisconsin Regional Planning Commission
Alice G. Altemeier	League of Women Voters, Ozaukee County
Kurt W. Bauer	Executive Director, Southeastern Wisconsin Regional Planning Commission
Wesley J. Beaton	Director of Environmental Health, City of Racine
Gerald D. Bevington	Coordinator of Air Programs, Southeast District, Wisconsin Department of Natural Resources
John W. Blakey	President, Quality Aluminum Casting Company, Waukesha
Edwin J. Hammer	Environmental Engineer, Bureau of Environmental Analysis and Review, Wisconsin Department of Transportation
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Appendix B

POINT SOURCES IN THE REGION THAT EMIT MORE THAN 10 TONS OF POLLUTANTS PER YEAR: 1973

Code Number on Map 41	Point Source	Address	Emissions	
			10 to 100 Tons per Year	More Than 100 Tons per Year
	Kenosha County			
1	American Motors Corporation—Lakefront Plant	57th Street and 4th Avenue Kenosha	X	
2	American Motors Corporation—Main Plant	5626 25th Avenue Kenosha		X
3	Anaconda Company—Brass Division	1420 63rd Street Kenosha		X
4	Arneson Foundry, Inc.	3303 66th Street Kenosha	X	
5	Kenosha Asphalt Paving	5817 46th Street Kenosha	X	
6	Ocean Spray Cranberries, Inc.	7800 S. 60th Avenue Kenosha	X	
	Milwaukee County			
1	Acme Galvanizing, Inc.	2730 S. 19th Street Milwaukee	X	
2	A. F. Gallun & Sons Corporation	1818 N. Water Street Milwaukee	X	
3	Allied Smelting Corporation	5116 W. Lincoln Avenue West Allis		X
4	Allis Chalmers Corporation—Foundry	1126 S. 70th Street West Allis		X
5	Allis Chalmers Corporation—Hawley Division	801 S. 60th Street West Allis	X	
6	Allis Chalmers Corporation—Power House	1126 S. 70th Street West Allis		X
7	Allis Chalmers Corporation—Tractor Division	1126 S. 70th Street West Allis	X	
8	Alton Box Board Company—Container Division	2800 W. Custer Avenue Milwaukee	X	
9	American Can Company	6000 N. Teutonia Avenue Milwaukee		X
10	American Motors Corporation—Milwaukee Body Plant	3880 N. Richards Street Milwaukee		X
11	Amoco Oil—Milwaukee Terminal	1200 S. Harbor Drive Milwaukee		X
12	Ampco Metal—Division of Ampco—Pittsburgh Corporation	1745 S. 38th Street Milwaukee	X	
13	A. O. Smith Corporation—Auto Rail Division	3533 N. 27th Street Milwaukee		X
14	Appleton Electric Company—Foundry Division	2105 5th Avenue South Milwaukee	X	
15	Atlantic Richfield Company	301 E. Washington Street Milwaukee		X
16	Babcock & Wilcox Company—Tubular Products Division	3839 W. Burnham Street West Milwaukee	X	
17	Barclay Foundry Industries, Inc.	4239 W. Lincoln Avenue Milwaukee		X
18	Briggs & Stratton Corporation	2711 N. 13th Street Milwaukee	X	
19	Briggs & Stratton Corporation	2560 N. 32nd Street Milwaukee	X	
20	Briggs & Stratton Corporation	3300 N. 124th Street Wauwatosa		X
21	Briggs & Stratton Corporation	1706 S. 68th Street West Allis		X

Code Number on Map 41	Point Source	Address	Emissions	
			10 to 100 Tons per Year	More Than 100 Tons per Year
	Milwaukee County (continued)			
22	Bucyrus-Erie Company	1100 Milwaukee Avenue South Milwaukee		X
23	Caterpillar Tractor Company, Inc.	150 West Holt Avenue Milwaukee	X	
24	Chicago, Milwaukee, St. Paul & Pacific Railroad Company—West Milwaukee Shops	3301 W. Canal Street Milwaukee	X	
25	City of Milwaukee Asphalt Plant	408 W. Traser Street Milwaukee	X	
26	City of Wauwatosa Incinerator	11140 W. Walnut Road Wauwatosa	X	
27	Clark Oil & Refining Corporation Granville Terminal	9451 N. 107th Street Milwaukee		X
28	Columbia Hospital	3321 N. Maryland Avenue Milwaukee	X	
29	Continental Can Company	4300 N. Port Washington Road Glendale		X
30	Cudahy Tanning Company	5043 S. Packard Avenue Cudahy	X	
31	Cutler-Hammer, Inc.—Specialty Products Division	315 N. 12th Street Milwaukee	X	
32	De Sales Preparatory Seminary, Inc.	3501 S. Lake Drive Milwaukee	X	
33	Energy Unlimited	4200 S. 76th Street Greenfield	X	
34	Evinrude Motors—Foundry & Assembly Plant	6161 N. 64th Street Milwaukee	X	
35	Falk Corporation	3001 W. Canal Street Milwaukee	X	
36	Federal Malleable Company	805 S. 72nd Street West Allis	X	
37	Froedtert Malt Corporation	3830 W. Grant Street Milwaukee	X	
38	General Electric Company—Medical Systems Division	4855 W. Electric Avenue Milwaukee	X	
39	General Split Corporation	748 W. Virginia Street Milwaukee	X	
40	Globe-Union, Inc.	3450 W. Hopkins Street Milwaukee	X	
41	Globe-Union, Inc.	900 E. Keefe Avenue Milwaukee	X	
42	GMC—Delco Electronics Division	7929 S. Howell Avenue Oak Creek	X	
43	Geuder Paeschke & Frey Company	St. Paul Avenue Milwaukee	X	
44	Grede Foundries, Inc.—Liberty Foundry	6432 W. State Street Wauwatosa	X	
45	Grey Iron Foundry, Inc.	1501 S. 83rd Street West Allis		X
46	Griffith-Hope Company	6607 W. Mitchell Street West Allis	X	
47	Harley-Davidson Motor Company, Inc.	11700 W. Capitol Drive Wauwatosa	X	
48	Harley-Davidson Motor Company, Inc.	3700 W. Juneau Avenue Milwaukee		X
49	Harley-Davidson Motor Company, Inc.	7475 S. 6th Street Oak Creek	X	

Code Number on Map 41	Point Source	Address	Emissions	
			10 to 100 Tons per Year	More Than 100 Tons per Year
	Milwaukee County (continued)			
50	Harnischfeger Corporation	4400 W. National Avenue Milwaukee	X	
51	Heil Company–Bulk Trailer and Dehydrator Division	445 W. Oklahoma Avenue Milwaukee	X	
52	Highway Pavers, Inc.– Asphalt Plant	12125 W. Silver Spring Road Milwaukee	X	
53	Howmet Corporation– Crucible Steel Casting Division	2850 S. 20th Street Milwaukee	X	
54	Hynite Corporation	4301 E. Depot Road Oak Creek	X	
55	INRYCO, Inc.	4101 W. Burnham Street West Milwaukee		X
56	Interstate Drop Forge Company	4051 N. 27th Street Milwaukee	X	
57	J. C. Penney Company Catalog Division	11800 W. Burleigh Street Wauwatosa	X	
58	Joseph Schlitz Brewing Company	235 W. Galena Street Milwaukee		X
59	Joseph Schlitz Brewing Company– Container Division	7620 S. 10th Street Oak Creek		X
60	Kearney & Trecker Corporation	11000 Theodore Trecker Way West Allis	X	
61	Kohl's Food Stores	11100 W. Burleigh Street Milwaukee	X	
62	Krause Milling Company	4222 W. Burnham Street West Milwaukee	X	
63	Kurth Malting Corporation	2100 S. 43rd Street West Milwaukee	X	
64	Ladish Company	5481 S. Packard Avenue Cudahy		X
65	Cutler-Hammer, Inc.– Industrial Systems Division	4265 N. 30th Street Milwaukee	X	
66	Lutheran Hospital of Milwaukee, Inc.	2200 W. Kilbourn Avenue Milwaukee	X	
67	Marquette Cement Manufacturing Company	745 W. Canal Street Milwaukee		X
68	Maynard Steel Casting Company	2856 S. 27th Street Milwaukee	X	
69	Miller Brewing Company	4000 W. State Street Milwaukee		X
70	Milprint, Inc.	4200 N. Holton Street Milwaukee		X
71	Milsco Manufacturing Company	9009 N. 51st Street Milwaukee	X	
72	Milwaukee County Institutions Power Plant	9050 Watertown Plank Road Wauwatosa		X
73	Milwaukee Forge	1532 E. Oklahoma Avenue Milwaukee	X	
74	Milwaukee Malleable & Grey Iron Works	2773 S. 29th Street Milwaukee	X	
75	Milwaukee Solvay Coke Company	311 E. Greenfield Avenue Milwaukee		X
76	Mobil Oil Corporation– Jones Island Terminal	1414 S. Harbor Drive Milwaukee	X	
77	Motor Castings Company Plant 1	1323 S. 65th Street West Allis		X

Code Number on Map 41	Point Source	Address	Emissions	
			10 to 100 Tons per Year	More Than 100 Tons per Year
	Milwaukee County (continued)			
78	Motor Castings Company Plant 2	657 S. 72nd Street Milwaukee		X
79	Pabst Brewing Company	917 W. Juneau Avenue Milwaukee		X
80	P & V Atlas Industrial Center	724 W. Oregon Street Milwaukee		X
81	Patrick Cudahy, Inc.	Corner of Barnard and Kingan Avenues Cudahy	X	
82	Pelton Casteel, Inc.	148 W. Dewey Place Milwaukee	X	
83	Pfister & Vogel Tanning Company	1531 N. Water Street Milwaukee		X
84	Phillips Petroleum Company—Milwaukee Terminal	2100 S. Harbor Drive Milwaukee		X
85	PPG Industries, Inc.	235 E. Pittsburgh Avenue Milwaukee		X
86	Pressed Steel Tank Company, Inc.	1445 S. 66th Street West Allis	X	
87	Pressed Steel Tank Company, Inc.	4601 W. Lincoln Avenue West Milwaukee	X	
88	Rexnord, Inc.—Construction Machinery Division	4701 W. Greenfield Avenue West Milwaukee		X
89	Rexnord, Inc.—Nordberg Machinery Group	3073 S. Chase Avenue Milwaukee		X
90	Rexnord, Inc.—Power House	4751 W. Greenfield Avenue Milwaukee	X	
91	St. Francis Major Seminary	3257 S. Lake Drive St. Francis	X	
92	St. Joseph's Convent	1501 S. Layton Boulevard Milwaukee	X	
93	St. Joseph's Hospital	5000 W. Chambers Street Milwaukee	X	
94	St. Regis Paper Company—Northern Paperboard Division	1514 E. Thomas Avenue Milwaukee		X
95	Shell Oil Company—Terminal and Bulk Depot	1626 S. Harbor Drive Milwaukee	X	
96	Sherwin Corporation	2129 W. Morgan Avenue Milwaukee	X	
97	Sisters of St. Francis of Assisi	3221 S. Lake Drive Milwaukee	X	
98	Sorgel Transformers—Division of Square D Company	838 W. National Avenue Milwaukee	X	
99	Spic & Span, Inc.	4301 N. Richards Street Milwaukee		X
100	Square D Company	4041 N. Richards Street Glendale	X	
101	Teledyne Wisconsin Motor	1910 S. 53rd Street West Allis		X
102	Treat All Metals, Inc.	5140 N. Port Washington Road Milwaukee	X	
103	Union Oil Company of California	9521 N. 107th Street Milwaukee		X
104	University Foods Corporation—Red Star Yeast Division	325 N. 27th Street Milwaukee	X	
105	University of Wisconsin-Milwaukee Heating Plant	3359 N. Downer Avenue Milwaukee		X

Code Number on Map 41	Point Source	Address	Emissions	
			10 to 100 Tons per Year	More Than 100 Tons per Year
	Milwaukee County (continued)			
106	Veterans Administration Center	5000 W. National Avenue Wood		X
107	Victory Steel	679 S. 76th Street Milwaukee	X	
108	Wauwatosa East High School	1732 Wauwatosa Avenue Wauwatosa	X	
109	Wehr Steel Company	2100 S. 54th Street West Allis	X	
110	Western Metal Specialty— Division Western Industries, Inc.	1211 N. 62nd Street Milwaukee	X	
111	West Shore Pipe Line Company— Granville Station	9401 N. 107th Street Milwaukee	X	
112	White Construction Company— Asphalt Plant	11340 W. Brown Deer Road Milwaukee	X	
113	Wisconsin Electric Power Company—Commerce Station	1338 W. Commerce Street Milwaukee		X
114	Wisconsin Electric Power Company—E. Wells Station	108 E. Wells Street Milwaukee		X
115	Wisconsin Electric Power Company—Lakeside Station	3744 S. Lake Drive Milwaukee		X
116	Wisconsin Electric Power Company—Oak Creek Station	Elm Road East of STH 32 Oak Creek		X
117	Wisconsin Electric Power Company—Valley Station	1035 W. Canal Street Milwaukee		X
118	Wisconsin Petroleum Terminal Corporation	198 S. Harbor Drive Milwaukee	X	
	Ozaukee County			
1	Cedarburg Power Plant	523 N. Mequon Street Cedarburg	X	
2	City of Port Washington Incinerator	306 N. Park Street Port Washington		X
3	Doerr Electric Corporation	1201 S. Doerr Way Cedarburg	X	
4	Gilson Brothers Company	440 Fredonia Avenue Fredonia		X
5	Murphy Oil Corporation	801 S. Park Street Port Washington		X
6	P C M Division of Koehring	369 W. Western Avenue Port Washington	X	
7	Pioneer Container Corporation	333 E. Pioneer Road Cedarburg	X	
8	Simplicity Manufacturing Company	500 N. Spring Street Port Washington		X
9	Tecumseh Products Company	900 North Street Grafton	X	
10	Village of Grafton Incinerator	909 Falls Street Grafton	X	
11	Wisconsin Electric Power Company—Washington Station	237 W. Grand Avenue Port Washington		X

Code Number on Map 41	Point Source	Address	Emissions	
			10 to 100 Tons per Year	More Than 100 Tons per Year
	Racine County			
1	A. W. Oakes & Sons, Inc.	Oakes Road Racine	X	
2	Beecham, Inc. (Horlicks)	1450 Summit Avenue Racine	X	
3	Continental Can Company—Plant No. 445	1901 Chickory Road Racine	X	
4	Foster Forbes Glass Company	S. McHenry Street Burlington	X	
5	Frank Pure Foods Company	10508 Kraut Road Franksville	X	
6	In-sink-erator Division—Emerson Electric Company	4700 21st Street Racine	X	
7	Jacobsen Manufacturing Company	1721 Packard Avenue Racine	X	
8	J. I. Case Company—Agricultural Equipment Division Foundry Plant	24th and Meade Street Racine		X
9	J. I. Case Company—Tractor Plant	25th and Meade Street Racine		X
10	Modine Manufacturing Company	1500 De Koven Avenue Racine	X	
11	The Nestle Company, Inc.	637 S. Pine Street Burlington	X	
12	Racine Steel Casting Company	1442 N. Memorial Drive Racine	X	
13	Rainfair, Inc.	1501 Albert Street Racine		X
14	S. C. Johnson & Sons, Inc.	1525 Howe Street Racine	X	
15	S. C. Johnson & Son, Inc.—Waxdale Plant	Willow Road Sturtevant		X
16	Webster Electric Company, Inc.	1900 Clark Street Racine	X	
17	Western Publishing Company—Main Plant	1220 Mound Avenue Racine	X	
18	Young Radiator Company	709 Marquette Street Racine		X
	Walworth County			
1	Alpha Cast, Inc.	520 N. Jefferson Street Whitewater		X
2	Colt Industries Trent Tube Division—Plant No. 2	498 S. Church Street East Troy	X	
3	Federal Chemical Company	STH 59 Whitewater	X	
4	Sharon Foundry, Inc.	141 Seymour Street Sharon		X
5	University of Wisconsin—Whitewater	800 W. Main Street Whitewater		X
6	U. S. Gypsum Company	208 Adeline Street Walworth	X	

Code Number on Map 41	Point Source	Address	Emissions	
			10 to 100 Tons per Year	More Than 100 Tons per Year
	Washington County			
1	Amity Leather Products Company—No. 5	735 S. Main Street West Bend	X	
2	Chrysler Outboard Corporation Hartford Plant No. 1	105 N. Michigan Avenue Hartford		X
3	Gehl Company	143 Water Street West Bend	X	
4	Kasten Manufacturing Corporation	536 Main Street Allenton	X	
5	Regal Ware, Inc.	1675 Reigle Drive Kewaskum	X	
6	West Bend Company	400 Washington Street West Bend		X
	Waukesha County			
1	Amron Corporation	525 Progress Avenue Waukesha	X	
2	Carnation Company—Can Division	N90 W14600 Commerce Drive Menomonee Falls		X
3	City of Waukesha Municipal Incinerator	900 Sentry Drive Waukesha		X
4	General Casting Corporation	706 E. Main Street Waukesha		X
5	International Harvester	1401 Perkins Avenue Waukesha	X	
6	RTE Corporation	1900 E. North Street Waukesha		X
7	Vulcan Materials Company—Midwest Division	N52 W23096 Lisbon Road Lisbon	X	
8	Vulcan Materials Company—Midwest Division	Box 1253 CTH CC Ottawa	X	
9	W. A. Krueger Company	12821 W. Bluemound Road Brookfield		X
10	Waukesha Motor Company	1000 W. St. Paul Avenue Waukesha	X	
11	Wisconsin Centrifugal, Inc.	905 E. St. Paul Avenue Waukesha		X
12	Zenith Sintered Products, Inc.	9305 Tipp Street Menomonee Falls	X	

Appendix C

PASQUILL ATMOSPHERIC STABILITY CLASSIFICATION

This appendix presents an explanation and step-by-step procedure for calculating the stability class using the Pasquill Stability Classification, a system of classifying atmospheric stability on an hourly basis for use in air pollution research. Atmospheric stability near the ground—that is, the tendency of an air parcel to move through the atmosphere in a vertical direction—is dependent primarily upon net radiation and wind speed. In the absence of clouds, incoming solar radiation (insolation) during the day is dependent upon solar altitude, measured as the angle of the sun above the horizon. At a given latitude, the solar altitude is a function of time of day and time of year. When clouds are present, their cover and thickness act to decrease both short-wave incoming solar radiation and outgoing long-wave terrestrial radiation. In determining stability using this classification scheme, insolation is estimated by solar altitude and is modified for existing conditions of total cloud cover and cloud ceiling height. At night, estimates of outgoing radiation are made by considering cloud cover.

There are seven stability classes defined by the Pasquill system: A) extremely unstable, B) unstable, C) slightly unstable, D) neutral, E) slightly stable, F) stable, and G) extremely stable. In Table C-1, the stability class as a function of wind speed expressed in knots and net radiation is presented. The net radiation index ranges from 4, the highest positive net radiation (directed toward the earth), to -2, the highest negative net radiation (directed away from the earth). As a rule, instability occurs with high levels of incoming solar radiation and low wind speed, stability with high net radiation loss and light winds, and neutral conditions with cloudy skies and high wind speeds.

The net radiation index to be used with wind speed to obtain the stability class is determined as follows:

1. If the cloud cover is 100 percent and the cloud ceiling is below 7,000 feet, the net radiation index is equal to zero, whether it is day or night.

2. For night conditions (night is defined as the period from one hour before sunset to one hour after sunrise):

   a. If total cloud cover is less than or equal to 40 percent, the net radiation index is equal to - 2.

   b. If total cloud cover is greater than 40 percent, the net radiation index is equal to - 1.

3. For daytime conditions:

   a. The insolation class number is determined as a function of solar altitude as presented in Table C-2.

   b. If total cloud cover is less than or equal to 50 percent, the net radiation index in Table C-1 corresponds to the insolation class number.

   c. If the cloud cover is greater than 50 percent, the insolation class number is modified as follows:

      1) If the cloud ceiling is below 7,000 feet, subtract 2.

      2) If the cloud ceiling is higher than or equal to 7,000 feet but below 16,000 feet, subtract 1.

      3) If the total cloud cover is equal to 100 percent, subtract 1. This applies only to ceilings of below or equal to 7,000 feet since cases with 100 percent cloud cover below 7,000 feet are considered in item 1 above.

      4) If the insolation class number has not been modified by steps 1), 2), or 3) above, assume a modified class number equal to the insolation class number.

      5) If the modified insolation class number is less than 1, it is assumed to equal 1.

      6) The net radiation index in Table C-1 then corresponds to the modified insolation class number.

Since urban areas do not become as stable in the lower layers as do nonurban areas, stability classes E, F, and G may be combined into a single class, E, or classes F and G may be combined and identified as class F.

Table C-1

STABILITY CLASS AS A FUNCTION OF NET RADIATION AND WIND SPEED

Wind Speed (knots)	Net Radiation Index						
	4	3	2	1	0	- 1	- 2
0, 1	1	1	2	3	4	6	7
2, 3	1	2	2	3	4	6	7
4, 5	1	2	3	4	4	5	6
6	2	2	3	4	4	5	6
7	2	2	3	4	4	4	5
8, 9	2	3	3	4	4	4	5
10	3	3	4	4	4	4	5
11	3	3	4	4	4	4	4
⩾12	3	4	4	4	4	4	4

Source: National Climatic Center.

Table C-2

ISOLATION AS A FUNCTION OF SOLAR ALTITUDE

Solar Altitude (a)	Insolation	Insolation Class Number
$60^{\circ} < a$	Strong	4
$35^{\circ} < a < 60^{\circ}$	Moderate	3
$15^{\circ} < a < 35^{\circ}$	Slight	2
$a < 15^{\circ}$	Weak	1

Source: National Climatic Center.

Appendix D

MULTIPLE POINT SOURCE SUBMODEL FOR ANNUAL AVERAGE AMBIENT AIR POLLUTANT CONCENTRATIONS

This appendix describes the computer program which calculates the annual average ambient air concentration for an array of point sources. This program, referred to as the multiple point sources (MLTPT) submodel, is part of the Wisconsin Atmospheric Diffusion Model (WIS*ATMDIF).

On a short-term basis, the concentration of pollutants in the plume exhibit a Gaussian distribution about the effective centerline of the plume. However, on a long-term basis, the concentration may be considered uniform laterally within a wedge-shaped sector due to the random fluctuation of the velocity vector. When the wind vector falls outside of the sector—assumed to be 22.5^{o}—the concentration is assumed to be zero. Vertical diffusion is determined by a Gaussian dispersion coefficient. When this coefficient is large compared to the mixing height, trapping occurs and the concentration is eventually uniform within the sector both laterally and vertically.

By integrating the standard Gaussian plume equation in the crosswind y- direction, the basic long-term dispersion equation is formed. This equation is valid up to the distance x_m, where x_m is defined by:

$$z_m = 2.15\,\sigma_z\,(x_m) \qquad (1)$$

where: z_m = the vertical cross-section height of the plume
σ_z = vertical dispersion coefficient

For interaction of the plume with the ground, but not the mixing height, the concentration for one set of meteorological conditions from one source to one receptor is:[1]

$$C_A = \frac{\sqrt{2/\pi}\,Q}{2\pi\,U_s\sigma_z x}\,\exp\,\left[-\frac{h^2}{2\sigma_z^2}\right] \quad \text{for } x \le x_m \qquad (2)$$

where: C_A = pollutant concentration (micrograms per cubic meter)
U_s = wind speed at stack height (meters)
σ_z = vertical dispersion coefficient (meters)
x = downwind distance (meters)
Q = pollutant emission rate (grams per second)
h = stack height

For the trapping due to the mixing height above the plume, an additional integration is carried out in the z-direction and the concentration is:

$$C_M = \frac{Q}{2\pi\,U_s z_m x} \quad \text{for } x \ge 2x_m \qquad (3)$$

where: C_M = maximum pollutant concentration

For the intermediate or transition case, a linear interpolation is assumed so that:

$$C_T = \frac{Q}{2\pi U_s x}\left[\frac{B}{\sigma_z} - \left(\frac{B}{\sigma_z} - \frac{1}{z_m}\right)\left(\frac{x}{x_m} - 1\right)\right] \qquad (4)$$

for $x_m < x < 2x_m$

where: C_T = pollutant concentration at any intermediate downwind

$$B = \sqrt{2/\pi}\,\exp\left[-\frac{h^2}{2\sigma_z^2}\right]$$

Equations 1 through 4 are similar to those used to determine the air pollutant concentrations resulting from point sources in the U. S. Environmental Protection Agency Climatological Dispersion Model.

The value for the vertical dispersion coefficient (σ_z) depends on the atmospheric stability and the surface roughness, as well as on the downwind distance, x. The empirical values of σ_z are obtained from the relationship,

$$\sigma_z = 1{,}000\,a\left(\frac{X}{1{,}000}\right)^{b} \qquad (5)$$

where a and b may have one of 12 values, as shown in Table D-1.

Table D-1

FACTORS USED IN THE DETERMINATION OF THE VERTICAL DISPERSION COEFFICIENTS IN THE MLTPT SUBMODEL

Atmospheric Stability	Rural Area		Urban Area	
	a	b	a	b
Very Unstable	0.450	2.10	0.63	1.40
Unstable	0.110	1.10	0.34	1.28
Slightly Unstable	0.061	0.92	0.169	1.043
Neutral	0.033	0.60	0.124	0.724
Stable	0.023	0.51	0.0485	0.581
Very Stable	0.015	0.45	0.0485	0.581

Source: SEWRPC.

[1] *exp = e (the base of natural logarithms) to the x power.*

For a given distance between the source and the receptor point, x, and a given atmospheric stability and a given mixing height, either equation 2, 3, or 4 is used to calculate the concentration at the receptor. The annual average concentration at the receptor point due to one point source is obtained by multiplying each individual concentration by appropriate frequency factors, as indicated mathematically in the following equation:

$$C = \sum_{s=1}^{S} \sum_{\ell=1}^{L} \sum_{z_m=1}^{Z_m} f_1(N,s,\ell) f_2(z_m,\ell) C_{A,M,T} \qquad (6)$$

The summation is done for six wind speeds (S = 6), six atmospheric stabilities (L = 6), and three mixing heights (Z_m = 3). Only that wind direction (N) which is oriented along the source receptor line is used in the summation.

This sequence of equations is repeated for each receptor point, and the entire process is then repeated for each source. The concentrations for each point source at a receptor point are then summed to yield the annual average concentration at that point.

Appendix E

PLUME RISE EQUATIONS USED IN MULTIPLE POINT SOURCES SUBMODEL

This appendix describes the equations used in the multiple point sources (MLTPT) program for computing the plume rise above a point source of pollutant emissions. The effective stack height (h) is the sum of the physical stack height (h_s) and the plume rise (Δh). The plume rise depends on the wind speed (U_s), atmospheric stability, stack diameter, stack gas volume flow rate, stack gas exit temperature, and ambient air temperature.

In formulating the plume rise equations, it is convenient to use the heat flux emitted from the stack and the stack gas exit velocity. The heat flux from a stack is calculated by the following formula:

$$Q_h = 84.88 Q_v \left(\frac{T_s - T_a}{T_s + 460} \right)$$

where: Q_h = stack gas exit heat flux (kilocalories)
Q_v = stack gas exit volume flow rate (cubic meters per second)
T_s = stack gas exit temperature (^oF)
T_a = ambient air temperature (^oF)
84.88 = constant, which includes specific heat of air
460 = conversion factor for degrees Farenheit to degrees Rankine

The stack gas exit velocity (V_s) is related to the stack gas exit volume flow rate (Q_v) and the diameter of the stack (D) according to the following equation:

$$V_s = \frac{4Q_v}{D^2}$$

From empirical studies, it has been determined that one set of plume rise equations is applicable to large sources—sources having a heat flux greater than 5,000 kilocalories per second—and one set of equations is applicable to smaller sources.

For large sources there are two plume rise equations, depending on the stability of the atmosphere. These equations, developed by G. A. Briggs, are as follows:[1]

1. For unstable and neutral atmospheres

$$\Delta h = 2.5 Q_h^{1/3} h_s^{2/3} / U_s$$

2. For stable atmospheres

$$\Delta h = 2.96 \left[\frac{Q_h}{0.0064(U_s)} \right]^{1/3}$$

For small sources there are three plume rise equations, again depending on atmospheric stability. The equations, which were developed by H. Moses and J. E. Carson, are as follows: [2]

1. For unstable atmospheres

$$\Delta h = (3.47 V_s D + 10.53 Q_h^{1/2}) / U_s$$

2. For neutral atmospheres

$$\Delta h = (0.35 V_s D + 5.41 Q_h^{1/2}) / U_s$$

3. For stable atmospheres

$$\Delta h = (-1.04 V_s D + 4.58 Q_h^{1/2}) / U_s$$

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[1] *G. A. Briggs, "Plume Rise," Atomic Energy Commission Critical Review Series, U. S. Atomic Energy Commission, Division of Technical Information, 1969.*

[2] *H. Moses and J. E. Carson, "Stack Design Parameters Influencing Plume Rise," Journal of the Air Pollution Control Association, Vol. 18, No. 454, 1968.*

Appendix F

URBAN SUBMODEL FOR AIR POLLUTANT CONCENTRATIONS DUE TO LINE AND AREA SOURCE EMISSIONS

This appendix describes the computer program which computes ambient air concentrations of air pollutants due to emissions from area and line sources in a city or an urbanized area. The model is based on a numerical solution of the species continuity equation for a turbulent atmospheric boundary layer. All of the area and line emission sources in the Region may be treated simultaneously using this model. The sources are specified on a three-dimensional grid as a function of position and height. Wind and eddy-diffusivity profiles are specified by inputting the height of the mixing layer, the upper wind speed, the net heat flux, and the surface roughness. A rotation transformation is performed on the source array in order to change the effective wind direction to one of eight positions.

The program may be used to simulate the dispersion of chemically nonreacting pollutants for one set of meteorological conditions. The steady-state solution or a time-dependent solution may be obtained. Also, the annual average concentration array may be obtained by iterating 48 or more sets of meteorological conditions. In this appendix, a brief theoretical description of the URBAN submodel and an explanation of the meteorological parameters are provided.

THE DIFFUSION EQUATION

The ambient air concentration of a nonreacting pollutant is calculated at some distance from the stack. Consider a fixed rectangular coordinate system with the x-axis oriented along the wind vector (u), the y-axis crosswind, and the z-axis oriented vertically upward. By considering advection of pollutants in the x-direction and diffusion in the y- and z-directions, conservation of mass for a steady turbulent flow of nonreacting species (with Fick's Law of diffusion assumed) may be written as:

$$u\frac{\partial C}{\partial x} - \frac{\partial}{\partial y}\left(K_y \frac{\partial C}{\partial y}\right) - \frac{\partial}{\partial z}\left(K_z \frac{\partial C}{\partial z}\right) = 0 \qquad (1)$$

where:
- u = the wind speed
- C = the ambient concentration of a pollutant species
- K_y = the turbulent eddy-diffusivity in the crosswind direction
- K_z = the turbulent eddy-diffusivity in the vertical direction

The boundary conditions are: 1) the pollutant concentration is zero upwind, 2) pollutants are emitted at rate Q, and 3) the net flux of pollutants is zero.

Since u, K_y, and K_z are functions of z, a numerical solution is dictated. A first-order, fully implicit scheme is used that has the desirable property of being stable for large step sizes. Consider a volume of fluid with sides x, y, and z located at a point i + 1, j, k. Properties at the point i, j, k are known, but in the i + 1 plane they are unknown. Conservation of mass for a particular species for an element of fluid not adjacent to a boundary may be written as:

$$\begin{aligned} &u_k C_{i+1,j,k}\Delta y\Delta z \\ &+ (K_y)_k \Delta x\Delta z(C_{i+1,j,k} - C_{i+1,j+1,k})/\Delta y \\ &+ (K_y)_k \Delta x\Delta z(C_{i+1,j,k} - C_{i+1,j-1,k})/\Delta y \\ &+ (K_z)_{k+1/2} \Delta x\Delta y(C_{i+1,j,k} - C_{i+1,j,k+1})/\Delta z \\ &+ (K_z)_{k-1/2} \Delta x\Delta y(C_{i+1,j,k} - C_{i+1,j,k-1})/\Delta z \\ &= u_k C_{i,j,k}\Delta y\Delta z \end{aligned} \qquad (2)$$

If a source were present at the position of the volume in question, the right-hand side of equation 2 would show an additional term for the source. At a boundary, one or more of the terms on the left-hand side is dropped. The right-hand side contains the known values of concentration, while the left-hand side contains the unknown concentrations. The values of wind speed and eddy diffusivity are presumed known. A similar equation must be written for each box of fluid in the i + 1 plane and for the set of equations solved simultaneously. Then the procedure is to step to the i + 2 plane and repeat the process with the i + 1 plane known.

As an example, consider an array four boxes wide and four boxes high. The set of 16 algebraic equations for the i + 1 plane may be written as:

$$[A]\,[C] = [D] \qquad (3)$$

where A is a 16 x 16 matrix defined below, C is a 1 x 16 matrix of the unknown concentrations, and D is a 1 x 16 matrix of the corresponding known concentration fluxes in the i plane plus any source terms. In equation 2 we let

$$\begin{aligned} u\Delta y\Delta z &= a \\ K_y\Delta x\Delta z/\Delta y &= e \\ K_z\Delta x\Delta y/\Delta z &= f \end{aligned} \qquad (4)$$

Then the A-matrix is as shown below. The solution is simply:

$$C = [A]^{-1}\,[D] \qquad (5)$$

Since the A-matrix is often large, as shown on the following page, there are more efficient means of solution than directly inverting A. We used a subroutine which factors A such that $A = LL^T$ where L is a lower triangular matrix

$$A=\begin{bmatrix}
(a_1+e_1+f_{3/2}) & -e_1 & 0 & 0 & -f_{3/2} & & & & & & & & & & & & & & & & \\
-e_1 & (a_1+2e_1+f_{3/2}) & -e_1 & 0 & 0 & -f_{3/2} & & & & & & & & & & & & & & & \\
0 & -e_1 & (a_1+2e_1+f_{3/2}) & -e_1 & 0 & 0 & -f_{3/2} & & & & & & & & & & & & & & \\
0 & 0 & -e_1 & (a_1+e_1+f_{3/2}) & 0 & 0 & 0 & -f_{3/2} & & & & & & & & & & & & & \\
-f_{3/2} & 0 & 0 & 0 & (a_2+e_2+f_{3/2}+f_{5/2}) & -e_2 & 0 & 0 & -f_{5/2} & & & & & & & & & & & & \\
 & -f_{3/2} & 0 & 0 & -e_2 & (a_2+2e_2+f_{3/2}+f_{5/2}) & -e_2 & 0 & 0 & -f_{5/2} & & & & & & & & & & & \\
 & & -f_{3/2} & 0 & 0 & -e_2 & (a_2+2e_2+f_{3/2}+f_{5/2}) & -e_2 & 0 & 0 & -f_{5/2} & & & & & & & & & & \\
 & & & -f_{3/2} & 0 & 0 & -e_2 & (a_2+e_2+f_{3/2}+f_{5/2}) & 0 & 0 & 0 & -f_{5/2} & & & & & & & & & \\
 & & & & -f_{5/2} & 0 & 0 & 0 & (a_3+e_3+f_{5/2}+f_{7/2}) & -e_3 & 0 & 0 & -f_{7/2} & & & & & & & & \\
 & & & & & -f_{5/2} & 0 & 0 & -e_3 & (a_3+2e_3+f_{5/2}+f_{7/2}) & -e_3 & 0 & 0 & -f_{7/2} & & & & & & & \\
 & & & & & & -f_{5/2} & 0 & 0 & -e_3 & (a_3+2e_3+f_{5/2}+f_{7/2}) & -e_3 & 0 & 0 & -f_{7/2} & & & & & & \\
 & & & & & & & -f_{5/2} & 0 & 0 & -e_3 & (a_3+e_3+f_{5/2}+f_{7/2}) & 0 & 0 & 0 & -f_{7/2} & & & & & \\
 & & & & & & & & -f_{7/2} & 0 & 0 & 0 & (a_4+e_4+f_{7/2}) & -e_4 & 0 & 0 & & & & & \\
 & & & & & & & & & -f_{7/2} & 0 & 0 & -e_4 & (a_4+2e_4+f_{7/2}) & -e_4 & 0 & & & & & \\
 & & & & & & & & & & -f_{7/2} & 0 & 0 & -e_4 & (a_4+2e_4+f_{7/2}) & -e_4 & & & & & \\
 & & & & & & & & & & & -f_{7/2} & 0 & 0 & -e_4 & (a_4+e_4+f_{7/2}) & & & & &
\end{bmatrix}$$

and L^T is the transpose of L. This may be readily done since A is a positive-definite, symmetric band matrix. The solution of the system of linear equations is determined by letting $Y = L^TC$ and computing Y by back substitution in the equation $LY = D$. When Y is known, C may be determined by back substitution in $L^TC = Y$.

METEOROLOGICAL PARAMETERS

The wind speed and the eddy diffusivity are specified as a function of vertical distance above the surface. Both of these parameters are dependent on the stability of the atmosphere. In terms of boundary-layer notation, atmospheric stability may be characterized by the following parameter L of A. S. Monin and A. M. Obukhov:[1]

$$L = \frac{u_*^3 \rho c_p T}{kgH} \tag{6}$$

where: L = the units of length.
u_* = the so-called friction velocity
H = the net heat flux to the ambient air density
c_p = the specific heat
T = temperature
k = Karman's constant = 0.4
g = the gravitational constant

It is convenient to introduce a drag coefficient (c_g) based on the geostrophic wind (u_g) such that:

$$u_* = c_g u_g \tag{7}$$

The geostrophic drag coefficient has been shown to be a function of the surface Rossby Number ($R_o = u_g/Z_o f$) and L, where f is the Coriolis parameter of the earth and Z_o is the surface roughness. For a neutral atmosphere, H. H. Lettau suggests the following empirical relationship:[2]

$$c_g = 0.16/[\log_{10}(R_o) - 1.8] \tag{8}$$

To account for the effects of stratification on the drag coefficient, the following values have been assigned:

Unstable flow	$c_g = 1.2\ c_g$ (neutral)
Slightly stable flow ...	$c_g = 0.8\ c_g$ (neutral)
Stable flow	$c_g = 0.6\ c_g$ (neutral)

The surface roughness (Z_o) may be calculated according to the following relationship developed by Lettau:

$$Z_o = \frac{\bar{H}a}{2\bar{A}} \tag{9}$$

where: $\bar{H}$ = the effective height of the roughness elements
a = the frontal or silhouette area seen by the wind
$\bar{A}$ = the low area (i.e., the total area of the Region divided by the number of roughness elements)

Typically, Z_o is 0.02 to 0.1 meter for open country, 0.1 to 1 meter for forested areas, and 0.5 to 10 meters for urban areas.

The selection of values for the net heat flux to the air (H) requires some judgment and experience. For a neutrally stratified atmosphere H = O. H = 0.24 and H = - 0.06 langleys per minute were chosen as representative of unstable flow and very stable flow, respectively.

The above information is sufficient to calculate the wind profile and the eddy-diffusivity profile within the surface layer of the atmosphere. The equations used are summarized in Table F-1. Above the surface layer the wind profile is calculated using a linear relationship and the eddy diffusivity is assumed constant with height, as shown in Table F-1.

The above scheme is based on starting with the upper, or geostrophic, wind. But typically the wind speed is known at 10 meters or perhaps two meters. A simple interactive method has been developed to compute the upper wind and, hence, the entire profile from one particular wind speed at a specified height.

[1] *A. S. Monin and A. M. Obukhov "Basic Laws of Turbulent Mixing in the Ground Layer of the Atmosphere," Doklady Ahad. Nauk SSSR, 151, 163-187, 1954.*

[2] *H. H. Lettau "Wind Profile, Surface Stress, and Geostrophic Drag Coefficients," Advances in Geophysics, Volume 6, Atmospheric Diffusion and Air Pollution, 241-256, Academic Press, New York, 1959.*

Table F-1

WIND PROFILE AND EDDY DIFFUSIVITY EQUATIONS FOR USE IN THE URBAN SUBMODEL

	Stability	z_{max}	Wind Speed, u	Eddy Diffusivity, K_z
Within Surface Layer	Neutral	$400u_*$	$\frac{u_*}{.4}\ln\left(\frac{z+z_o}{z_o}\right)$	$.4u_*z$
	Stable	L	$\frac{u_*}{.4}\left[\ln\left(\frac{z+z_o}{z_o}\right)+\frac{5.2z}{L}\right]$	$.4u_*z/\left(1+\frac{5.2}{L}z\right)$
		6L	$\frac{u_*}{.4}\left[\ln\left(\frac{z+z_o}{z_o}\right)+5.2\right]$	$.4u_*z/6.2$
	Unstable	2L	$\frac{u_*}{.4}\left[2(\tan^{-1}x-\tan^{-1}x_o)+\ln\left(\frac{x-1}{x_o-1}\right)-\ln\left(\frac{x+1}{x_o+1}\right)\right]$ $x = [1-15(z+z_o)/L]^{1/4};\ x_o = (1-15z_o/L)^{1/4}$	$.4u_*z\left(1-\frac{15z}{L}\right)^{.25}$
Above Surface Layer	Neutral	z_m	$(u_g-u_{SL})\left(\frac{z-400u_*}{z_m-400u_*}\right)^{.2}+u_{SL}$	$.4u_*(400u_*)$
	Stable	z_m	$(u_g-u_{SL})\left(\frac{z-6L}{z_m-6L}\right)^{.5}+u_{SL}$	$.4u_*(L)$
	Unstable	z_m	$(u_g-u_{SL})\left(\frac{z+2L}{z_m+2L}\right)^{.2}+u_{SL}$	$.4u_*(400u_*)\left(1-\frac{6000u_*}{L}\right)^{.25}$
Calm	Neutral	z_m	0	1
	Stable	z_m	0	.01
	Unstable	z_m	0	$.7\left(\frac{gH}{c_p\rho\bar{T}}\right)^{1/3}(z)^{4/3}$

Source: SEWRPC.

Appendix G

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION
QUESTIONNAIRE—AIR POLLUTION POINT SOURCE PROJECTIONS

Your reply to this questionnaire will be used by the Commission to update information extracted from the 1973 Wisconsin Department of Natural Resources (DNR) Point Source Emissions Inventory for Southeastern Wisconsin. If you do not have an answer readily available for any given question, please ignore that question. Incomplete entries will be further researched and completed by the Commission staff.

Facility _____

_____

Mailing Address

Wisconsin DNR Bureau of Air Pollution Control File Number _____

Standard Industrial Classification Code _____

Air Pollution Contract

_____

Phone _____

Title _____

EMISSIONS DATA—1973 As of Date: _____

Number of Stacks or Release Points _____

Number of Boilers _____

Reported Total Facility Emissions Average Tons/Year—1973

Particulate Matter	Sulfur Oxides	Nitrogen Oxides	Carbon Monoxide	Hydrocarbons
_____	_____	_____	_____	_____

Please answer all questions in this section of the questionnaire to the best of your ability. Since you are the most knowledgeable source of information about your facility, your response will be used as the best estimate available for projecting regional ambient air quality.

1. Indicate your plant production or output as a percentage of total plant capacity for: 1973 _____ 1975 _____

2. If your plant did not reach full production during 1975, estimate during what year your present facility may be expected to reach full production or be operating at maximum capacity. _____

3. Do you anticipate building or installing new production facilities on your present plant site? _____ Please indicate the nature of such facilities and estimated capacity as a multiple of your 1975 production.

   During 1980 _____

   During 1990 _____

   During 2000 _____

4. If additional production facilities are to be operated at other than the present plant site but within the seven-county Southeastern Wisconsin Region (Kenosha, Milwaukee, Ozaukee, Racine, Walworth, Washington, and Waukesha Counties), please indicate the type of facility, approximate location within county, and capacity.

_____

_____

_____

5. Do you anticipate changes in process methods or the use of materials which may significantly change emissions?

Prior to 1980 _____ Prior to 1990 _____ Prior to Year 2000 _____

Please indicate the nature of the change. _____

6. With regard to operating equipment wearing out or becoming obsolescent, is there for your facility an average rate established for replacement of process production or heating equipment? For example, an annual process equipment replacement rate of 5 percent would result in a complete turnover of equipment every 20 years.

_____

_____

7. Is it possible to make a similar statement concerning the rate at which plant process or heating equipment becomes obsolescent and is replaced?

_____

8. May future difficulties in obtaining energy for production or heating result in conversions to alternative energy uses? Please indicate alternatives under consideration.

Coal _____ Natural Gas _____ Oil Distillate (1,2) _____
Residual (5,8,6) _____

Propane _____ Butane _____ Electricity _____ Other _____

9. Do you anticipate any air pollution problems resulting from excess emissions between this date and 1980? _____

If so, what alternatives are being considered?

_____

_____

_____

_____ _____

Interviewee(s) Date

Appendix H

LARSEN STATISTICAL TECHNIQUE

This appendix describes the statistical technique used to evaluate the effectiveness of the RACT emission limitations for attaining the primary and secondary 24-hour average particulate matter ambient air quality standards. This statistical technique is based on the assumption that the frequency distribution of air pollutants in urban areas may be approximated by a lognormal distribution—that is, a "normal" or Gaussian distribution—applied to the logarithm of the variable rather than to the variable itself.[1] It has been shown that the median concentrations of air pollutants are approximately proportional to the averaging time raised to an exponent, and that the maximum concentrations are approximately inversely proportional to the averaging time raised to an exponent. Using the annual arithmetic mean and the standard geometric deviation for some other known averaging time, the geometric mean and standard geometric deviation for a designated averaging time may be determined.

Both the first and second highest concentrations which are expected to occur during a one-year period may be graphically calculated using a log-probability paper if the geometric mean, standard geometric deviation, and number of samples are known. For this report, annual (geometric mean) concentrations calculated by the Wisconsin Atmospheric Diffusion Model for 28 receptor sites were used as the values for the geometric mean for each forecast year. For each monitoring site the standard geometric deviation recorded in 1977 was used in the Larsen technique. A sampling period of 365 days was used for the calculations.

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[1] *R. I. Larsen, A Mathematical Model for Relating Air Quality Measurements to Air Quality Standards, U. S. Environmental Protection Agency, AP-89, November 1971.*

The geometric mean is plotted at the 50 percent point on the log-probability paper as depicted in Figure H-1. Using the geometric standard deviation, values are plotted at the 16 percent point and the 84 percent point. Once these two points have been plotted, a straight line is drawn through each point. If the measured frequency is lognormally distributed, the measured frequency distribution should lie along this line.

The measured frequency distribution is calculated using a correction term F:

$$F = \frac{r - 0.4}{n} \times 100\% \qquad (1)$$

where: F = plotting frequency (percent),
r = rank order (highest to lowest), and
n = number of samples

For a year of 24-hour samples, n = 365; thus, the highest expected concentration would occur at a frequency of:

$$F_{highest} = \frac{1 - 0.4}{365} \times 100\% = 0.16\% \qquad (2)$$

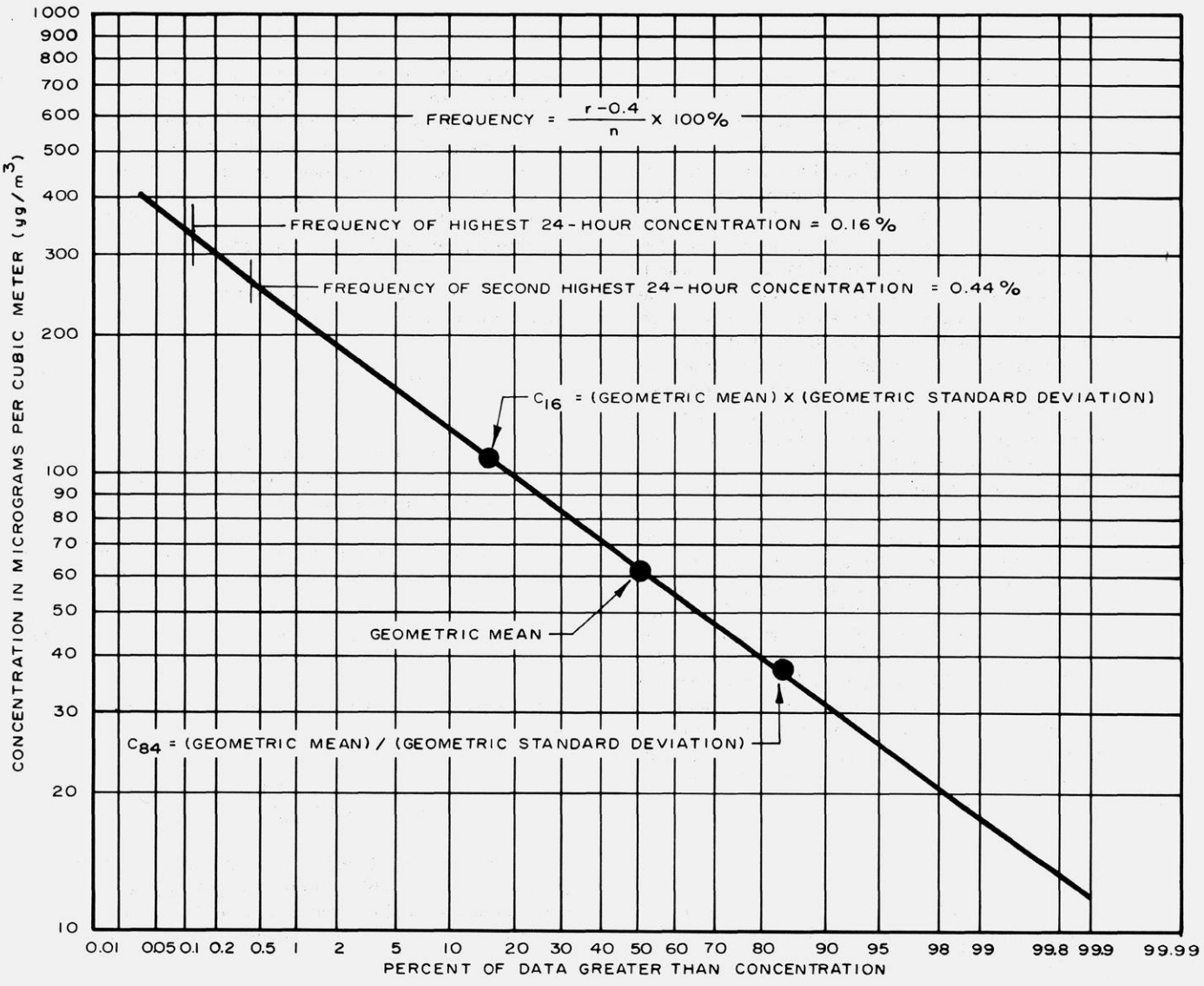
and the second highest value would occur at a frequency of:

$$F_{second\ highest} = \frac{2 - 0.4}{365} \times 100\% = 0.44\% \qquad (3)$$

Thus, the second highest expected concentrations in micrograms per cubic meter ($\mu g/m^3$) would occur at a frequency of 0.44 percent and be derived by drawing a straight line from this frequency value to the vertical (concentration) axis.

Figure H-1

EXAMPLE OF THE LARSEN TECHNIQUE FOR ESTIMATING THE HIGHEST AND SECOND HIGHEST 24-HOUR AVERAGE PARTICULATE MATTER CONCENTRATIONS



Source: U. S. Environmental Protection Agency.

Appendix I

FACILITIES AFFECTED BY RECOMMENDED PARTICULATE MATTER PLAN

Name[a]	Address
Industrial Point Sources	
Arneson Foundry, Inc.	3303 - 66th Street, Kenosha
City of Milwaukee Asphalt Plant	408 W. Traser Street, Milwaukee
General Casting Corporation	706 E. Main Street, Waukesha
Milwaukee Malleable & Grey Iron Works	2773 S. 29th Street, Milwaukee
Motor Castings Company, Plant No. 1	1323 S. 65th Street, West Allis
Sherwin Corporation	2129 W. Morgan Avenue, Milwaukee
Universal Atlas Cement Division of U. S. Steel Corporation	712 W. Canal Street, Milwaukee
Wisconsin Electric Power Company	108 E. Wells Street, Milwaukee
Industrial Fugitive Dust Sources	
Asphalt Batch Plants	
City of Milwaukee Asphalt Plant	408 W. Traser Street, Milwaukee
Highway Pavers, Inc.—Asphalt Plant	12101 W. Silver Spring Road, Milwaukee
Sherwin Corporation	2129 W. Morgan Avenue, Milwaukee
Cement Grinding and Batch Plants	
Best Block South, Inc.	4400 S. 13th Street, Milwaukee
Central Ready-Mixed Concrete Company	4350 S. 13th Street, Milwaukee
Huron Cements	470 S. 11th Street, Milwaukee
Medusa Cement Company	344 E. Stewart, Milwaukee
Tews Lime and Cement, Inc.	2020 W. Morgan, Milwaukee
Universal Atlas Cement Division of U. S. Steel Corporation	712 W. Canal Street, Milwaukee
Grain Elevators and Terminals	
Cargill, Inc.	335 S. Muskego, Milwaukee
Continental Grain Company	960 E. Bay Street, Milwaukee
Froedtert Malt Corporation	3830 W. Grant Street, West Milwaukee
Krause Milling Company	4222 W. Burnham, West Milwaukee
Kurth Malting Corporation	2100 S. 43rd Street, West Milwaukee
Secondary Smelters	
Afram Brothers Company	900 S. Water Street, Milwaukee
Framitized Steel Company of Milwaukee	260 N. 12th Street, Milwaukee
Ladish Company	5481 S. Packard Avenue, Cudahy
Miller Compressing Company—Greenwood Yard	900 W. Bruce Street, Milwaukee
Miller Compressing Company—Jones Island Yard	1000 E. Bay Street, Milwaukee
Miller Compressing Company—Muskego Yard	510 S. Muskego, Milwaukee
Terminals and Bulk Storage	
Chicago, Milwaukee, St. Paul & Pacific Railroad	3301 W. Canal Street, Milwaukee
Hometown, Inc.	1616 W. Canal Street, Milwaukee
International Salt Company	1835 S. Carferry Drive, Milwaukee
Lake Shore Sand & Stone—Division of Construction Aggregates Corporation	515 W. Canal Street, Milwaukee
Morton Salt—Division of Morton-Norwich	515 W. Canal Street, Milwaukee

Name[a]	Address
Industrial Fugitive Dust Sources (continued)	
Foundries and Machine Manufacture	
Aelco Foundries, Inc.	1980 S. 4th Street, Milwaukee
Allied Smelting Corporation	5116 W. Lincoln Avenue, West Allis
Allis-Chalmers	1126 S. 70th Street, West Allis
Aluminum Casting & Engineering Company	2039 S. Lenox Street, Milwaukee
Ampco Metal—Division of Ampco, Pittsburgh Corporation	1745 S. 38th Street, Milwaukee
Badger Die Casting Corporation	201 W. Oklahoma Avenue, Milwaukee
Barclay Foundry Industries, Inc.	4239 W. Lincoln Avenue, Milwaukee
Chromalloy American Corporation—Federal Casting Division	805 S. 72nd Street, West Allis
Falk Corporation	3001 W. Canal Street, Milwaukee
General Casting Corporation	706 E. Main Street, Waukesha
Grede Foundries, Inc.	1320 S. First Street, Milwaukee
Grede Foundries, Inc.	6432 W. State Street, Wauwatosa
Grey Iron Foundry, Inc.	1501 S. 83rd Street, West Allis
Howmet Turbine Components Corporation—Crucible Steel Casting Division	2850 S. 20th Street, Milwaukee
International Harvester	1401 Perkins Avenue, Waukesha
Maynard Steel Casting Company	2856 S. 27th Street, Milwaukee
Mid-City Foundry Company	1521 W. Bruce Street, Milwaukee
Milwaukee Malleable & Grey Iron Works	2773 S. 29th Street, Milwaukee
Milwaukee Solvay Coke Company	311 E. Greenfield Avenue, Milwaukee
Milwaukee Valve Company, Inc.	2375 S. Burrel Street, Milwaukee
Motor Castings Company, Plant No. 1	1323 S. 65th, Milwaukee
Pelton Casteel, Inc.	148 W. Dewey Place, Milwaukee
Quality Aluminum Casting Company, Plant No. 1.	1242 Lincoln Avenue, Waukesha
Rexnord-Nordberg	3073 S. Chase Avenue, Milwaukee
Vilter Manufacturing Corporation	2217 S. 1st Street, Milwaukee
Wehr Steel Company	2100 S. 54th Street, West Allis
Wisconsin Centrifugal, Inc.	905 E. St. Paul Avenue, Waukesha
Power Plants	
Wisconsin Electric Power Company—Oak Creek Plant	Elm Road, East of STH 32, Oak Creek
Wisconsin Electric Power Company—Valley Plant	1035 W. Canal Street, Milwaukee
Quarrying Operations	
Franklin Stone Products, Inc.	7220 S. 68th Street, Franklin
Halquist Stone Company, Inc.	W. Good Hope Road, Lannon
Halquist Stone Company, Inc.	N52 W23564 Lisbon Road, Sussex
Vulcan Materials Company—Midwest Division	Box 1253, CTH CC, Town of Ottawa
Vulcan Materials Company—Midwest Division, Quarry No. 306	5713 W. Rawson Road, Franklin
Vulcan Materials Company—Midwest Division, Quarry No. 326	N52 W23096 Lisbon Road, Sussex
Vulcan Materials Company—Midwest Division, Quarry No. 383	1501 Three Mile Road, Racine
Waukesha Lime & Stone Company	W223 N507, STH 164, Waukesha
Waukesha Lime & Stone Company	W233 N554 STH 164, Waukesha

[a] *List of affected facilities is under continuous review by the Wisconsin Department of Natural Resources, and is subject to change.*

Appendix J

MODEL RESOLUTION FOR ADOPTION OF THE REGIONAL AIR QUALITY ATTAINMENT AND MAINTENANCE PLAN FOR SOUTHEASTERN WISCONSIN

WHEREAS, the Southeastern Wisconsin Regional Planning Commission, which was duly created by the Governor of the State of Wisconsin in accordance with Section 66.945(2) of the Wisconsin Statutes on the 8th day of August 1960 upon petition of the Counties of Kenosha, Milwaukee, Ozaukee, Racine, Walworth, Washington, and Waukesha, has the function and duty of making and adopting a master plan for the physical development of the Region; and

WHEREAS, the U. S. Environmental Protection Agency has designated the seven-county Southeastern Wisconsin Region as the Wisconsin portion of the Illinois-Indiana-Wisconsin Interstate Air Quality Maintenance Area; and

WHEREAS, the U. S. Environmental Protection Agency and the Wisconsin Department of Natural Resources have designated portions of the seven-county Southeastern Wisconsin Region as nonattainment areas for one or more air pollutants for which federal and state standards have been established; and

WHEREAS, the Governor of the State of Wisconsin has designated the Southeastern Wisconsin Regional Planning Commission as the lead local agency for air quality/transportation planning; and

WHEREAS, the Southeastern Wisconsin Regional Planning Commission, pursuant to its function and duty as a regional planning agency and its designation as the lead local agency for air quality/transportation planning, has prepared and adopted at its meeting held on the 5th day of June 1980, a regional air quality attainment and maintenance plan set forth in a report entitled, SEWRPC Planning Report No. 28, A Regional Air Quality Attainment and Maintenance Plan for Southeastern Wisconsin: 2000; and

WHEREAS, the Commission has transmitted certified copies of its resolution adopting the regional air quality attainment and maintenance plan, together with the aforementioned SEWRPC Planning Report No. 28, to the local units of government concerned and to the appropriate state and federal agencies; and

WHEREAS, the (name of local governing body) has supported, participated in the financing of, and generally concurred in the regional planning programs undertaken by the Southeastern Wisconsin Regional Planning Commission, and believes that the regional air quality attainment and maintenance plan prepared by the Commission is a sound and valuable guide to air quality management in the development of not only the Region but also the local community, and that the adoption of such plan by the (name of local governing body) will assure a common understanding by the units and agencies of government concerned and enable these units and agencies of government to program the necessary plan implementation work.

NOW, THEREFORE, BE IT HEREBY RESOLVED that, pursuant to Section 66.945(12) of the Wisconsin Statutes, the (name of local governing body) on the _____ day of _____, 19__, hereby adopts the regional air quality attainment and maintenance plan previously adopted by the Southeastern Wisconsin Regional Planning Commission as set forth in SEWRPC Planning Report No. 28 as a guide for regional and community development.

BE IT FURTHER HEREBY RESOLVED that the _____ clerk transmit a certified copy of this resolution to the Southeastern Wisconsin Regional Planning Commission and to the Secretary of the Wisconsin Department of Natural Resources.

_____

(President, Mayor, or Chairman of the Local Governing Body)

ATTESTATION

_____

(Clerk of Local Governing Body)