LIBRARIES
UNIVERSITY OF WISCONSIN–MADISON

Wisconsin Academy review. Volume 32, Number 1 December 1985

Madison, Wisconsin: Wisconsin Academy of Sciences, Arts and Letters, December 1985

https://digital.library.wisc.edu/1711.dl/M7VWMQPYN447R8P

http://rightsstatements.org/vocab/InC/1.0/

The libraries provide public access to a wide range of material, including online exhibits, digitized collections, archival finding aids, our catalog, online articles, and a growing range of materials in many media.

When possible, we provide rights information in catalog records, finding aids, and other metadata that accompanies collections or items. However, it is always the user's obligation to evaluate copyright and rights issues in light of their own use.

728 State Street | Madison, Wisconsin 53706 | library.wisc.edu

WISCONSIN ACADEMY REVIEW

Published Quarterly by the Wisconsin
Academy of Sciences, Arts, and Letters.

December 1985
Volume 32, Number 1

The Wisconsin Academy of Sciences, Arts and Letters would like to thank these Wisconsin corporations for their generous support in 1985

Evjue Foundation, Inc.
Exxon Corporation
Gelatt Foundation
Highsmith Company
Janesville Foundation, Inc.
Marshall Erdman and Associates
Norman Bassett Foundation
Wausau Insurance Companies
Webcrafters-Frautschi Foundation
Wisconsin Electric Power
Wisconsin Power & Light Company

MEMBERSHIP INFORMATION

ACTIVE .... $25 annual dues
ASSOCIATE .... $10 annual dues (students only)
LIFE .... $300-500 in one lifetime payment
LIBRARY .... $20 annual dues

Your membership will encourage research, discussion, and publication in the sciences, arts, and letters of Wisconsin. Please send dues payment along with name and address to: Wisconsin Academy of Sciences, Arts and Letters, 1922 University Avenue, Madison, WI 53705. Academy members receive the annual TRANSACTIONS, the quarterly REVIEW, and occasional monographs or special reports.

The Wisconsin Academy of Sciences, Arts, and Letters is affiliated with the American Association for the Advancement of Science, the Association of Academies of Science, and the Educational Association Press of America.

Typeset by Impressions, Inc., Madison

Printed by American Printing, Madison
Second class postage paid at Madison

SUBSCRIPTION INFORMATION

The REVIEW is published quarterly by the Wisconsin Academy of Sciences, Arts, and Letters, 1922 University Avenue, Madison, WI 53705. Distributed to members as part of their dues. Available by subscription at $15 per year. Additional copies $4.00 postpaid.

Statements made by contributors to the WISCONSIN ACADEMY REVIEW do not necessarily reflect the views or official policy of the Wisconsin Academy of Sciences, Arts, and Letters.

Letters to the editor, poetry, fiction, line art, photographs, and article proposals are welcome. All correspondence related to the REVIEW or other Academy publications (change of address, single copy orders, undelivered copies, Academy membership) should be sent to the Wisconsin Academy of Sciences, Arts and Letters office.

Copyright © 1985 by the Wisconsin Academy of Sciences, Arts, and Letters.

ISSN 0512-1175

On the cover: *Icy Weather: Canvasbacks* by Owen Gromme, oil, 40″ x 28″, 1971. Plate from *The World of Owen Gromme*, published by Stanton & Lee, 1983 and printed through the generosity of Stanton & Lee. This color cover is made possible by the Walter and Trudi Scott Review Fund.

THE WISCONSIN ACADEMY OF SCIENCES, ARTS, AND LETTERS

The Wisconsin Academy of Sciences, Arts, and Letters was charterd by the state legislature on March 16, 1870 as an incorporated society serving the people of the state of Wisconsin by encouraging investigation and dissemination of knowledge in the sciences, arts, and letters.

COUNCIL

PRESIDENT
Joyce Erdman, Madison

PRESIDENT-ELECT
Gerald Viste, Wausau

IMMEDIATE PAST PRESIDENT
Kenneth Dowling, Madison

VICE PRESIDENTS
Brock Spencer (Sciences), Beloit
Warrington Colescott (Arts), Hollandale
Menahem Mansoor (Letters), Madison

SECRETARY-TREASURER
Jerry Apps, Madison

COUNCILORS-AT-LARGE
TERM EXPIRES 1989
Nancy Noeske, Milwaukee
William Halloran, Milwaukee

TERM EXPIRES 1988
James Crow, Madison
John Wilde, Evansville

TERM EXPIRES 1987
James R. Johnson, River Falls
Daniel O. Trainer, Stevens Point

TERM EXPIRES 1986
Margaret Fish Rahill, Milwaukee
Jon Harkness, Wausau

COUNCILOR-AT-LARGE EMERITUS
John Thomson, Madison

COUNCIL-APPOINTED POSITIONS

EXECUTIVE DIRECTOR
LeRoy R. Lee

LIBRARIAN
Jack A. Clarke, Madison

EDITORS
Kay and Philip Whitford, Transactions
Patricia Powell, Review

REVIEW STAFF

PUBLISHER
LeRoy Lee

EDITOR
Patricia Powell

CIRCULATION MANAGER
Sue Davis

EDITORIAL BOARD
Sally Behr, Madison
Warren Moon, Madison
Peter Muto, River Falls
Ray Peuchner, Milwaukee

POETRY CONSULTANTS
Arthur Hove, Madison
John Rosenwald, Beloit

WISCONSIN ACADEMY REVIEW

Published Quarterly by the Wisconsin
Academy of Sciences, Arts, and Letters.

December 1985
Volume 32, Number 1

CONTENTS

Editorial

Risky Business

Every day we receive more bad news about compounds which may adversely affect our health: coffee, eggs, bacon, burnt toast, too deep a suntan, too much fat for our hearts, too little fat to protect our fragile aging bones, too little calcium, too much vitamin B. More and more the response is "Let's do nothing and wait until another medical bulletin reverses the verdict." This issue of the *Review* adds one more category to our list of worries: our drinking water is contaminated. What we don't yet know is how risky is this contamination? What does it matter if 500 organic compounds have been detected in our drinking water unless we know the acceptable level and the toxic level of these compounds. Is the risk factor increasing or is the technology for detecting chemicals merely improving? We have read about hazardous waste dumps which are leaking, which are or may be contaminating the groundwater. In the papers presented here, we read about some of the problems of testing for the contaminants, from the prohibitive expense to the lack of research on the toxic level for humans. We can add water as one more issue about which we are uneasy but have too little information to form an intelligent opinion.

The cover story in the October issue of *Science 85* analyses the public's perceptions of environmental risks, which differ markedly from risk analysis experts' assessment of these risks. In fact, the articles point out, the general public's actions/reactions differ from any sensible assessment: The general public smokes billions of cigarettes a year while banning an artificial sweetener because of a one-in-a-million chance that it might cause cancer. The public refuses to wear seat belts although 45,000 people died last year in traffic collisions and half these deaths could have been prevented by using seat belts. The public brought the nuclear power industry to a standstill, with 80 percent of the polled public believing coal-generated power to be safer; yet nuclear power plants have caused the death of three persons in thirty years, while coal-generated power causes 10,000 deaths a year through mining, transportation, and pollution. What a capricious lot we, the general public, are. We don't know much about science/technology, but we do know what we like.

Working on articles for this issue has heightened my awareness of the relatively fragile physical world around me. I find all my social conversations eventually come round to something I've just read about bioassays of toxic substances or water diversion from the Great Lakes or contaminated fish or phosphates or aldicarb in the groundwater. This always leads back to media obsession with our health and the daily bulletins which announce that one more thing we've "always done" shortens our life or risks our health. Then the frightening word cancer is spoken. The environmental hazards are there; we do not at present know how to eliminate carcinogens from the world. Life on this planet has always been risky business; no one has ever been able to eliminate the risks. But we will continue to try, at the same time we smoke, don't use seat belts, buy handguns, ride bicycles in heavy traffic. . . . Capricious.

Patricia Powell

Groundwater Quality in Wisconsin

By Byron H. Shaw
College of Natural Resources, UW-Stevens Point

Groundwater is the source of drinking water for over 70 percent of Wisconsin citizens. Agriculture and many other industries depend on groundwater supplies. An excellent well code developed in 1936 and domestic waste water treatment program led to a very low incidence of water-borne diseases in the state. As a result, people developed false security about the safety of their drinking water. As long as it was clear and tasted good, and tested safe for bacteria, most people felt their water was *safe* and *pure.*

Several popular misconceptions about the origin of groundwater reaffirmed this false security. Statements about water coming all the way from Canada, from Lake Superior, from pure artesian springs or from the glaciers when no one inhabited the area encouraged people to believe that their own actions would have little or no effect on the quality of their drinking water. In reality most groundwater originates within a few miles of the wells where it is pumped back to the surface and has been in the ground less than fifty years. Water supplying many shallow private wells originates within several hundred feet of the well and has often been in the ground for several days to less than five years.

Chemical contamination of groundwater is not new. Nitrate levels have exceeded the 10 mg/l drinking water standard in many wells for over thirty years. However, the pin that burst the bubble of trust was the discovery of pesticides in 1980 and volatile organic chemicals from gasoline and various cleaning and degreasing agents in 1982 in our groundwater. The list of chemicals found in groundwater has grown rapidly, and new names are regularly added to the chemical-of-the-month club.

These disclosures caused the public to demand better protection of their groundwater supplies and resulted in Wisconsin groundwater legislation (Wisconsin Act 410) in 1984 which addresses many of the groundwater issues. Several counties in the state are developing groundwater management programs and plans. Research and monitoring activities have increased at universities and within state agencies in an attempt to understand better groundwater contaminations and develop strategies to prevent such problems.

Research is increasing the knowledge about groundwater but as yet has solved few problems. The following is a brief summary of major groundwater quality concerns.

Nitrate and nitrite

Nitrate is one of the oldest contaminants known to exist in Wisconsin groundwater. It causes methemoglobenemia (blue baby disease) in infants up to six months of age and problems with livestock. A drinking water standard of 10mg/l has been in effect for many years. Nitrate is water soluble and moves easily through soil. It does not naturally occur in soil minerals or groundwater; any elevated levels are due to human activities. Sources of nitrate in groundwater include fertilizers, animal waste, septic systems, and land disposal of nitrogen-containing waste in amounts that exceed the ability of plants to use it quickly. The standard was exceeded in 2.7 percent of small public water supplies in a 1980 DNR survey. However, as high as 25 percent of private wells in some parts of the state exceed the standard. Even when as much as ten inches of rainfall per year recharge the groundwater, it takes only 25 lbs. of nitrogen to raise groundwater concentrations to the 10 mg/l standard. Agricultural fertilization rates often exceed 200 lbs/acre for corn or potatoes. Most of the nitrogen not used by the plants leaches to the groundwater.

Pesticides

The classic example of a pesticide in groundwater is aldicarb. It is a highly toxic, water-soluble, systemic insecticide that has been found in groundwater in several states besides Wisconsin. Thirteen other pesticides have been found in Wisconsin's groundwater since the aldicarb discovery in 1980; none has been found in as many wells or at as high a concentration as aldicarb residues, except where spills have occurred. Over 500 pesticides are used in the state, with many having breakdown products that are as toxic as the parent compounds. Drinking water standards exist for only a few of these chemicals. Analytical methods for most are complex, making analysis costly. For some, sufficiently sensitive methods do not exist. Many efforts are underway to evaluate the extent of groundwater problems caused by pesticides and to develop means to minimize their movement to groundwater.

Gasoline in water

The buried gas tanks in Wisconsin cause concern, since many were installed in the 1950s or 60s and have exceeded the twenty-to-thirty year life expectancy. The increasing rate of leaks is resulting in many cases of groundwater contamination. Tolulene, zylenes, and especially benzene are public health concerns associated with this problem. Other gasoline additives may also pose significant health risks. The groundwater standard for benzene is 0.67 parts per billion (ppb). Therefore, one gallon of gasoline containing 1 percent benzene can contaminate 15 million gallons of groundwater to the groundwater standard. Tanks buried for over fifteen years should be removed and replaced. Disposing of waste gas by dumping in the septic system or on the driveway should be discouraged.

Volatile chemicals

Organic solvents, especially the chlorinated and bromated chemicals such as tetrachlorethylene, tri chlorethylene, and chloroform used for drycleaning, degreasing, and other industrial, domestic, and farm applications have contaminated groundwater. In over sixty-five cases these chemicals have been detected in municipal wells in the last several years. Ninety-six of the 620 private wells tested contained at least one volatile organic chemical (VOC). Improper disposal of these chemicals is obviously one source of the problem. Drinking water standards for many VOCs are only a few parts per billion, meaning small amounts of the products can contaminate large volumes of groundwater. Disposal of such persistent chemicals into septic systems or landfills also threatens groundwater.

Household chemicals

Little has been done to identify groundwater problems caused by the wide range of toxic chemicals used in homes. One potential problem is home use of fertilizers and pesticides where large volumes of roof runoff can cause increased leaching rates and groundwater contamination. The other major concern is disposal of chemicals into septic systems which are merely short-term sediment traps with all the waste water going to groundwater recharge. Projects to collect and properly dispose of toxic chemicals from homes and farms are needed, as are educational programs and product labeling to encourage safe use and disposal of all household chemicals, fertilizers, and pesticides.

Leaking landfills

Most landfills used in the state before the 1980s had little or no protection against leachate percolating to groundwater. Only 67 of the state's 3,791 active or abandoned waste disposal sites meet current environmental requirements. DNR has identified 198 abandoned waste disposal sites as high priority candidates for follow-up study for groundwater contamination. Cleanup of old sites is expensive and largely depends on the federal superfund for financial support. Newly engineered sites are much less likely to cause problems, but require extensive monitoring to be sure the installation is operating properly. Chemicals reaching groundwater from landfills are as varied as the multitude of chemicals disposed of in them. It is nearly impossible to inspect all refuse entering a landfill to be sure toxic chemicals are not being discarded at sites not approved to receive hazardous waste. Recycling efforts and education are key components along with well-engineered sites to prevent groundwater contamination. All existing and known abandoned landfills and dumps have recently been inventoried by DNR and are being rated for their potential to cause groundwater problems.

Bacteria and viruses in water

Even with all the chemicals appearing in groundwater, bacteria in drinking water is still the most common problem. About 13 percent of samples submitted to the State Hygiene Lab and 9 percent at the UW-Stevens Point Environmental Task Force Lab are positive for coliform bacteria. The incidence varies widely for different areas of the state. The coliform group of bacteria, used as the index of bacteriological safety, are not disease-causing bacteria, but indicate whether soil runoff or animal or human waste is reaching the water supply. Little is known about the possible occurrence of viruses in drinking water; however, the absence of coliform bacteria also probably indicates absence of viruses. Actual contamination of groundwater with bacteria is only likely to occur in areas of shallow, fractured bedrock or limestone or where very coarse sands and gravels occur. Sand and any fine-textured soils are generally a good filter for bacteria, preventing their movement to groundwater in most cases. The occurrence of bacteria in home water supplies is more often a result of poor well or plumbing maintenance than due to groundwater contamination.

Naturally occurring problems

Not all home or municipal water quality problems are caused by humans. In many parts of the state natural minerals in the ground are the problems. Hard water, due to calcium and magnesium, is a common problem in much of southern and eastern Wisconsin. While beneficial to health, hardness results in excessive detergent use and decreases efficiency of hot water heaters and plumbing due to scale formation. An opposite problem occurs in many central and northern Wisconsin areas, where very soft water results in slightly acid condition that dissolves iron and manganese, causing red or black staining, respectively. Acid water has also been linked to problems with high levels of lead and copper as a result of corrosion of household plumbing. Several municipalities have been forced to raise chemically the pH of water to prevent this problem. High iron and hydrogen sulfide (rotten egg odor) and other odors occur in some areas where water has passed through wet organic soils or passed through lake bottoms stripping out any oxygen and allowing these chemicals to dissolve in the water.

Other more localized problems exist ranging from naturally occurring levels of radium to high chlorides from road salt to a number of chemical spills that occur at plant sites or on highways or railroads.

While contaminants have been identified in Wisconsin groundwater, we still have an abundant supply of groundwater in good condition. However, we can no longer take for granted the quality of our drinking water; all citizens must take a more active interest in protecting this invaluable resource to prevent further contamination. Since most of our drinking water originates within a few miles of home, our own actions to preserve the quality of water are even more vital. The state legislature can be complimented for its current legislation to help manage this resource, but we need more regulations, better public education, and more research/monitoring to understand better our groundwater resource and to develop the best possible strategies to protect it.

Byron H. Shaw is professor of soil and water science at UW-Stevens Point. He received a Ph.D. in soil and water chemistry from UW-Madison.

Inland Lakes: Wisconsin's Neglected Water

By Lowell L. Klessig
College of Natural Resources, UW-Stevens Point

Lakes, often called the jewels of the landscape, were distributed by the glaciers that left Wisconsin 10,000 years ago. As the glaciers retreated north, they left chunks of ice buried in the moraines. When the ice melted, a depression (kettle) was left in the landscape. If the depression was deep enough to reach the underground water table, a lake was created. In other situations, the soil under the depression was impenetrable to water and a perched lake was created.

Some lakes (e.g., Devils Lake) were created when glacial debris dammed up rivers. Oxbow lakes were created by the reverse process: the river abandoned a section of its bed by cutting across a meander. Other lakes were created by dams built for hydropower, flood control, or recreation.

Lakes receive water from *direct precipitation, stream inlets, shoreland runoff,* or *ground water (springs).* Management options differ greatly depending on the source of a lake's water. For instance, lakes which depend on direct precipitation for most of their water are most susceptible to acid rain. The rain water does not have prior contact with the neutralizing chemicals in the soil. In another example, malfunctioning septic systems are of more concern in a lake fed by groundwater than in another lake fed primarily by streams.

Water leaves a lake through *evaporation, an outlet stream,* or *the groundwater flow (seepage lake).* A lake's water budget defines the relative importance of each source and each type of exit. Lakes that have little exchange of water with either streams or the groundwater are often naturally acidic and have floating bog vegetation around them.

Tour allure

Wisconsin has a well-deserved reputation as a vacation land. While tourists are attracted by many attributes of the state, lakes probably account for more decisions to visit Wisconsin than any other natural or cultural resource. Over 500,000 nonresidents were licensed to fish in Wisconsin in 1984—tops in the nation. In 1984, 1,286,000 Wisconsin residents bought an angler's license or were entitled to fish without one because of age. About 440,000 boats are registered by Wisconsin families. Add swimmers to anglers and boaters, and the number of active lake users grows. The attraction of Wisconsin lakes, however, goes beyond specific outdoor recreation activities of fishing, swimming, boating, and water skiing. A 1970 study showed that 62 percent of the people who purchased lakeshore property did so for "solitude and beauty." Twenty-two percent indicated that access to outdoor recreation was their primary motivation. Two out of three Wisconsin adults reported using lakes in a 1979 study by the Wisconsin Survey Research Laboratory. Altogether, about three million Wisconsinites and one million visitors enjoy Wisconsin lakes each year.

More water-oriented recreation and aesthetic appreciation can be attributed to Wisconsin's 970,000 acres of inland lakes than to its 170,000 acres of streams. Lakes get the lion's share of usage for swimming, boating, residential development, picnicking, visual enjoyment, and warm water fishing (pike, panfish).

The proportion of cold water fishing (mostly streams) to warm water fishing (mostly lakes) can be estimated by subtracting the sales of trout stamps (182,000 inland, 275,000 Great Lakes or daily) from the total fishing license sales (1,494,000). This leaves 1,007,000 people who only fished in warm water. Therefore, the ratio of warm water anglers to cold water anglers is at least two to one. However, many—probably most—purchasers of trout stamps also engage in some warm water fishing. If all trout anglers engaged in some warm water fishing, the ratio of warm water anglers to cold water anglers would be over three to one.

Precarious quality

The quality of a specific lake is a function of original morphology and land use in the watershed of the lake. Lakes are sinks. Thus, they accumulate sediment and nutrients. Unlike streams, which can flush themselves, lakes retain much of the material that washes into them. Thus a lake that was created with a large surface area and large volume (deep) and a relatively small and flat watershed around it is most likely to maintain high water quality. The small watershed will contribute less soil and nutrients and the flat topography will minimize erosion. Infertile, sandy soils also contribute less nutrients than richer soils. These conditions are most common in northern Wisconsin.

In other parts of the state, watersheds tend to be larger, soil richer, and topography tends to be steeper, resulting in more rapid sedimentation and faster aging of the lake (eutrophication). Impoundments tend to have especially large watersheds and thus fill in most rapidly.

The natural aging of a lake can be dramatically accelerated by human use of the shoreline and watershed. Forestry, agriculture, and residential development have all had major impacts on water quality. Severe erosion followed initial logging and forest fires. Agricultural fertilizers and manure have washed into lakes. These nutrients can support algae growth year after year, even without new additions, as the nutrients are recycled from the lake sediments. Soil erosion has been reduced where marginal farmland has reverted to forest. In other parts of the state, soil erosion (by water and wind) is accelerating with intensified agriculture. Lakeshore property owners have built homes too close to the lake, cleared too much of the shoreline buffer area, used too much lawn fertilizer, and failed to maintain properly their private septic systems. Municipalities have dumped their storm sewers and sometimes their nutrient-rich sewage treatment plant effluent into the community lake.

The result of all these natural and cultural factors is the degradation of our lakes. The process is very slow on lakes protected by their depth and watershed, but distressingly fast on lakes with high levels of human activity on the shoreline and in the watershed. While no panacea exists to cure all problems of all lakes, management strategies are available to prolong the useful life of these ephemeral resources.

Management efforts

The most effective strategy for managing a lake is protection of the lake through watershed management. However, watershed management is difficult when the watershed is large, privately owned, and intensively used. Shoreline zoning has helped, but the shorelines of many lakes were subdivided before 1968, when the counties developed such ordinances. Of course, streams often flow through lakes, thus improvement of stream water quality also improves lake water quality. Beyond those lakes in priority watersheds funded by the Wisconsin Fund, most voluntary watershed efforts are piecemeal and often reversed by subsequent owners of the property.

The most common management activity on lakes is weed harvesting. About half of the state's 150 lake districts, some voluntary property owners associations, and a scattering of local municipalities harvest excess aquatic vegetation from several hundred lakes.

Aeration can be used to prevent fish kills. Fish kills result when rotting plant material uses up all the oxygen from the atmosphere.

Several years ago, dredging to remove muck and deepen the lake was popular with the lake districts—special purpose units of government organized under chapter 33 of the statutes. Federal and state cost-sharing made this option attractive. However, the legislature and its audit bureau were critical of the funds required to dredge even a small lake. In 1982, all funds for lake districts were eliminated from the state budget.

Public investment

Local communities through several hundred property owners associations, 150 lake districts, select sportsmen's clubs, and other civic organizations have invested time and money to enhance their local lakes.

However, beyond some general law enforcement by the Department of Natural Resources and the county zoning administrator, the water quality of most lakes receives no attention. Only a small fraction of lakes have any management plan and fewer still are actively implemented. Beyond a 1959 mandate to classify surface waters by use and a more recent satellite study of lake trophic status (enrichment), no management classification of lakes exists.

In contrast, trout streams were classified years ago, and an aggressive program was established to protect class I trout streams by fencing out cattle on private farms, or by direct state purchase of the land around the better streams. Beyond public purchase, state management efforts include brush clearing to permit easier access by anglers, mechanical channelization, installation of wing dams, brush bundles and bank structures to improve habitat, beaver control, and research. Spring holes at the headwaters of trout streams are cleaned out with hydraulic dredges at state expense. With the passage of the clean water act amendments of 1972, other streams were classified on their ability to support various forms of aquatic life.

Another measure of public investment is the attention paid to point-source pollution (industries and municipal waste), which tends to affect streams, compared to the attention paid to nonprofit pollution (agricultural runoff, failing septic systems), which tends to affect lakes. Figure 1 illustrates how little investment there has been in inland lakes.

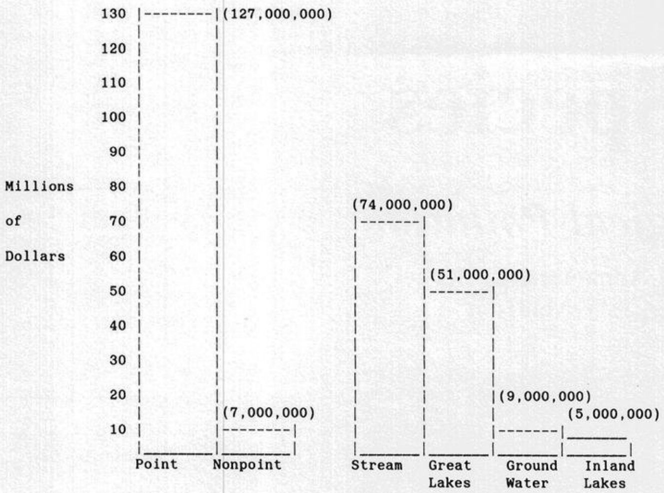


Figure 1. Relative expenditures of state/federal funds for grants/staff in Wisconsin in 1982. Development Document for a Post–1983 Water Quality Management Strategy (1982, Water Quality Planning Sections, Department of Natural Resources).

The discrepancy between lakes and streams increased in 1983–84 when the $2,300,000 of grants for lake districts was cut out of the governor's budget. After years of neglect, investment in groundwater management began to climb dramatically in 1984.

A prognosis

Fifteen times as much money is spent on 170,000 acres of streams than is spent on 970,000 acres of inland lakes. To put it another way, in 1982, state and federal investment in streams was $435 per acre, while investment in inland lakes was $5 per acre. While stream and lake water quality are related, the priority is clearly on streams.

In order to predict what is likely to happen in the future, it is necessary to assess why streams in general, and trout streams in particular, have received so much management attention and lakes have received so little. Several contributing, and often synergistic, factors are suggested below. It is impossible to assign relative weight to each factor.

Feasibility of management

- Point resources of pollution are easier to identify, monitor, and correct than nonprofit sources.
- Point source management requires interaction with a relatively small number of industries and municipalities while nonprofit sources require interaction with many private landowners.
- Streams flush themselves, and thus past sins of pollution can be washed away, making the impact of current management more evident.
- Private land along trout streams is typically undeveloped and thus easier and cheaper to purchase for public purposes than is lakeshore.

Sociology

- Resource managers consider protection of high-quality cold water a higher professional calling than management of eutrophic (rapidly aging) warm water.
- Resource managers, consciously or subconsciously, identify with the young to middle-age professional who fish trout and often have a negative perception of lake users: the "filthy rich" people who own lake homes and the "reckless and unappreciative" boaters who use the public access sites and litter the area with their beer cans.
- Trout anglers are represented by Trout Unlimited—an effective national organization. Their representatives are articulate and willing to travel both to fish and to testify before decision-making bodies. Home owners on several hundred lakes are represented by the Wisconsin Federation of Lakes and the Wisconsin Association of Lake Districts. However, most lake users are not represented at either the local or state level. The North American Lake Management Society is beginning this process at the federal level.

Funding

Municipalities are the best organized of all the groups involved. Given a legal mandate to improve sewage treatment, they have been effective at convincing state and federal legislators to share the cost of these improvements. By far, the greatest portion of funds spent to improve stream water quality has been directed to municipal sewage treatment.

Although purchase of trout stream corridors began long before the inland trout stamp program was initiated, the program now provides about $400,000 specifically for trout management.

Eventually, the importance of lakes to the hospitality industry and to the quality of life of Wisconsin citizens will receive greater recognition; just as the state recently discovered that most Wisconsin citizens and industries use groundwater and that its management was essential. However, the commitment to lakes will not be as dramatic for two general reasons. First, most of the factors outlined above will continue to influence allocation of staff time and grant funds. Second, the administrative frustrations with the lake district grant program (1974–84) still haunt the Department of Natural Resources in the legislature.

The 1985 legislature took a modest step toward recognizing the state's responsibility to manage publicly owned lakes. The Department of Natural Resources was granted $340,000 annually from funds generated by state taxes on gasoline used in boat motors. The four elements of the new program are:

- Self-help monitoring by local volunteers with instruction and data storage by the state.
- Diagnostic studies of short-term special conditions and long-term ambient water quality trends.
- Demonstration projects using new technologies.
- Education and information assistance (with UW-Extension).
- Other steps will be taken. The toughest problems are always left to the last.

Lowell L. Klessig is professor of environmental sciences at UW-Stevens Point. He received a Ph.D. in environmental management and research planning from UW-Madison.

Exotic Species

A Case Of Biological Pollution

By John J. Magnuson and Annamarie L. Beckel
Center for Limnology, UW-Madison

When we think of water pollution, we usually think in terms of chemical contaminants. Rarely do we consider biological pollution or the potential that introductions of nonnative species have to degrade our lakes. Yet the ecological disruption brought about by exotic species can be just as bad or even worse than that caused by the introduction of pesticides, chemical wastes, and other chemical contaminants to lakes.

There are many examples of the ecological havoc wreaked by exotic species, yet the public and even a few natural resource managers remain largely unaware or unconcerned about the problem. Species are purposely stocked in new waters, are released from bait buckets at the end of the day, and escape from rearing facilities of aquaculturists and fish hobbyists. Pets are released into nearby waters when families move or go on vacation.

Lake ecosystems are particularly vulnerable to disruption by exotic species because, in many ways, lakes are like islands (Fig. 1). Lakes are isolated from each other. They are surrounded by land that separates them in part from other lake habitats. Seepage lakes without an inlet or outlet have the greatest similarity to oceanic islands. Drainage lakes, on the other hand, are less isolated because streams provide transportation corridors to other lakes. Lakes, like islands, are small. The largest lake, neglecting the Caspian and Black seas, is Lake Superior, similar in area to Ireland or Iceland. And compared to continents and ocean basins, lakes, like islands, are relatively young. Wisconsin lakes are only 10,000 or so years old.

Similarities between islands and lakes suggest that what we know about the ecology of islands also applies to lakes. We know that the smaller, the more isolated, and the younger the island or lake, the fewer species present and the less able the ecological community to withstand disruption by a newly arriving species. The small size of islands or lakes both limits the variety of habitats present and leads to populations of small size. And in lakes, the new species—the exotic—whether from another continent or an adjacent lake, often dramatically alters existing community structure through species interactions. A change in community structure constitutes a "rule change." The new community has new properties and may be controlled by a different set of biological interactions than the earlier combination of species.

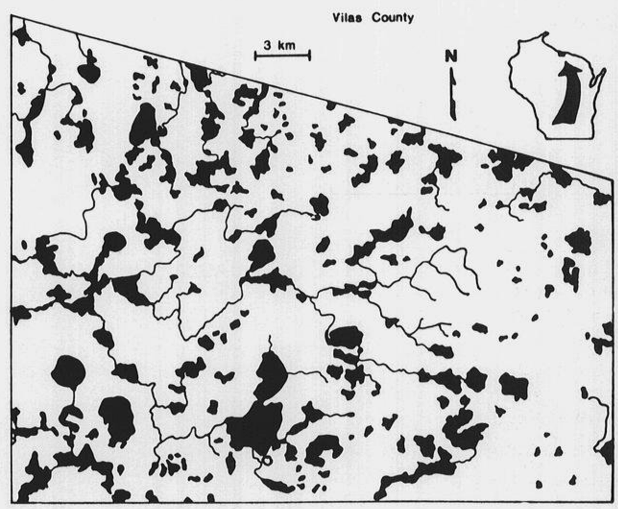


Fig. 1 A map of part of northern Wisconsin showing the "island" nature of lakes. They appear as an archipelago of lakes isolated in varying degrees by a sea of forested land.

The most dramatic and well-known example of the disruption caused by exotic species in Wisconsin waters is the series of changes initiated by the invasion of sea lamprey *Petromyzon marinus* (Fig. 2) into the upper Great Lakes. The invasion was made possible by the construction of the Welland Canal around Niagara Falls. The sea lamprey, a parasitic fish, was first sighted in Lake Huron in 1932, in Lake Michigan in 1936, and in Lake Superior in 1946. The expansion of lamprey populations led to the collapse of lake trout *Salvelinus namaycush* and burbot *Lota lota* stocks in all three lakes.

The drastic reduction in the predation pressure from lake trout and burbot allowed alewives *Alosa pseudoharengus* (Fig. 2), another exotic, to flourish. The origin of alewives in the Great Lakes is uncertain, but clearly, populations of the fish did not become predominant until after the decline of lake trout and burbot stocks. The nuisance effects of alewives, whose mortalities caused windrows of dead fish along the shores and whose spawning runs at peak density clogged municipal and other water intakes, were most pronounced in Lake Michigan.

The rainbow smelt *Osmerus mordax* (Fig. 2), another exotic, had been introduced into Crystal Lake, Michigan, and escaped via the outlet to Lake Michigan. It first appeared in Lake Michigan in 1923, in Lake Huron in 1925, and in Lake Superior in 1930. Smelt populations burgeoned. Concurrently lake herring or cisco *Coregonus artedii* populations collapsed, perhaps as a consequence of smelt (Fig. 3).

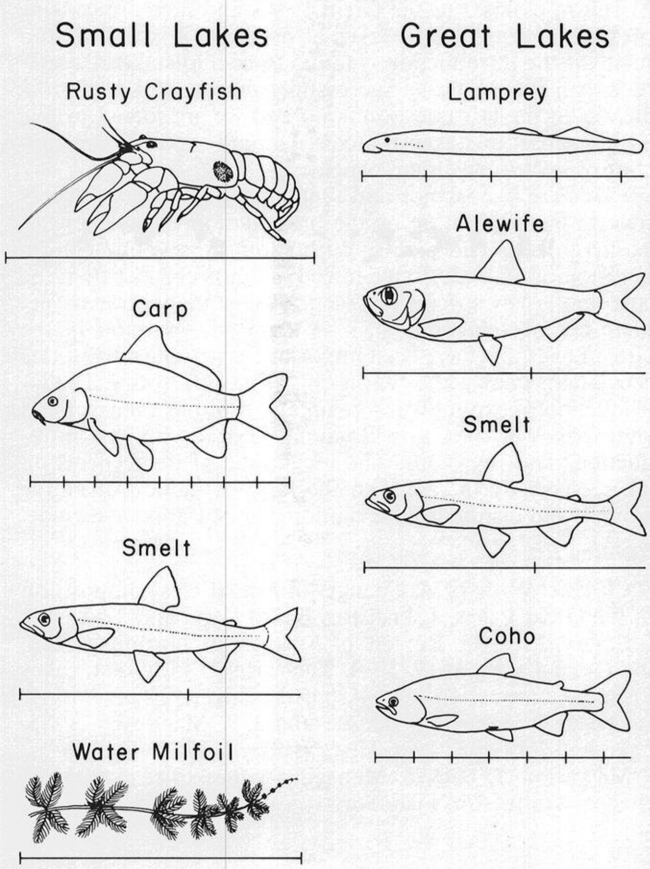


Fig. 2 Some common exotic organisms in the lakes of Wisconsin. A total of 34 species of exotic fish have been introduced into the Great Lakes of which 17 have self-sustaining populations, according to Emery. (See reading list.)

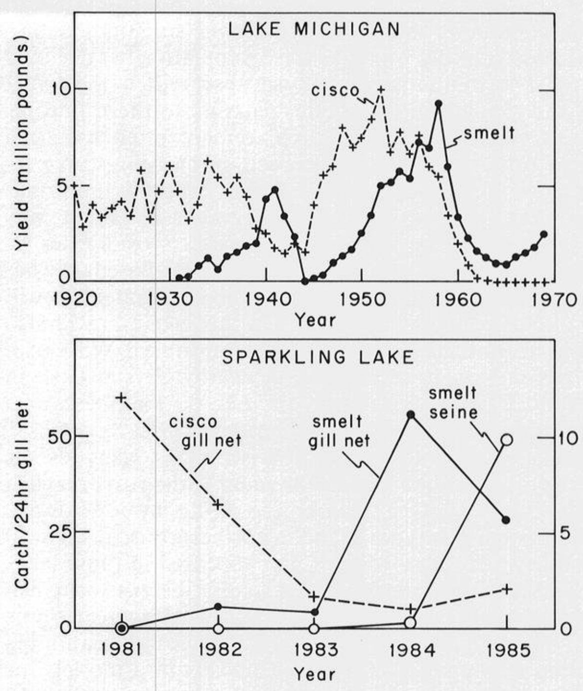


Fig. 3 Changes in the abundance of cisco and rainbow smelt in Lake Michigan (modified from Wells and McLain 1973, Technical Report 20, Great Lakes Fishery Commission, Ann Arbor, Michigan) and Sparkling Lake in Vilas Co. (from Magnuson LTER FISH DATA BASE).

The invaders—the sea lamprey, smelt, and alewife—generally showed long time lags between their first appearance and their proliferation, a pattern typical of exotic species. Certainly the initial invasion and population explosion of lampreys made the subsequent proliferation of alewives possible. Fish populations are still in a state of flux in the Great Lakes and the only recognizable defense against "pest" outbreaks is to maintain a relatively stable predator-prey balance. The Wisconsin Department of Natural Resources along with other states and federal and national agencies has attempted planting of coho salmon *Oncorhynchus kisutch* (Fig. 2) and chinook salmon *O. tshawytscha*, along with lake trout and several other salmonids. Center for Limnology researchers supported by the University of Wisconsin's Sea Grant Institute are helping unravel the complex interactions among exotic and native fishes in Lake Michigan and are using prey-predator models to help develop scientifically based protocals for stocking the salmonid predators.

Although invasions of exotics into smaller Wisconsin lakes are less well known and have received less notoriety, the results have been just as dramatic as those in the Great Lakes. Rainbow smelt, for example, are causing problems in some northern Wisconsin lakes. Researchers funded by the National Science Foundation (LTER) at the Center for Limnology's Trout Lake Station have found that introduced smelt are replacing native cisco at a rapid rate in Sparkling Lake. The project began in 1981, and smelt were first detected in the lake in 1982. The source of smelt in Sparkling

Lake is unknown, but the exotic must have been introduced accidentally or illegally because the lake is not connected to another containing smelt. Since 1982, the smelt population has increased rapidly while the cisco population has declined (Fig. 3). The trends parallel those observed in the Great Lakes and among similar species pairs in northern Europe.

The mechanism of species replacement often has been assumed to be competition between species for scarce resources, but in lakes, predation seems to be the important process. Even in the case of smelt and cisco, smelt may actually be eating the very young pelagic ciscos. Center researchers are currently testing this hypothesis. Based on what has happened in the Great Lakes, we predict that smelt will cause the local extinction of cisco in this lake and will also continue to find their way into other northern Wisconsin lakes. Several smelt were found in nearby Crystal Lake in 1984 and 1985. Other lakes in the Lac du Flambeau area have contained exotic smelt since at least 1972.

Another invader to northern Wisconsin's lakes also is wreaking ecological havoc. The invader is the rusty crayfish *Orconectes rusticus* (Fig. 2), a native of the lower Midwest. The rusty crayfish was not found in northern Wisconsin until about thirty years ago, when it first appeared in those lakes most accessible to humans. Most likely, the rusty crayfish eventually would have made it to northern Wisconsin on its own. It must have received a helping hand from vacationing fishermen who emptied their bait buckets into the lake or well-intended but poorly advised persons attempting to improve the lake's value.

A decade of research conducted by staff and students at the Center for Limnology has shown that the rusty crayfish is bigger and more aggressive than the blue *O. propinquus* and the fantail crayfish *O. virilis*, the other two predominant crayfish species found in northern Wisconsin. Consequently, rusty crayfish can outcompete the others for food and shelter. And unlike the fantail and blue crayfish, which appear to be relatively benign members of the ecological community, rusty crayfish are altering drastically the ecological communities of which they are a part.

Although all three crayfish species seek out high protein animal food, such as fish eggs, carrion, and insect larvae, much of their diet consists of the generally more abundant, but less nutritious plant food. Because rusty crayfish can reach much higher population densities than fantails and blues, they can have a devastating effect on aquatic plants. Rusties can eliminate entire weed beds, and in the process also consume the snails and insects living there. Through the consumption of those invertebrates and of fish eggs, as well as the destruction of habitat, rusty crayfish are replacing small fish, and ultimately bass and walleye, as top predators.

Other exotics also have reached nuisance levels in Wisconsin lakes. The carp *Cyrpinus carpio* (Fig. 2) was introduced early and is now a costly management problem. Although unpopular now, a different story was heard at the time of introduction. In the 1875–76 issue of the *Transactions* of the Wisconsin Academy of Sciences, Arts and Letters, P. R. Hoy wrote, "When you can go with hook and line and bag ten pound specimans of that most desirable fish, the carp, then you will feel like thanking the men who have so persistently persevered in investigating every condition that can secure benefits so great." Similar comments are made now about the popular Pacific salmon stocked in Lake Michigan and Lake Superior. Only the test of time will provide final judgment about success of present introduction of exotics.

Eurasian watermilfoil *Myriophyllum spicatum* (Fig. 2) was accidentally introduced into the United States and swept across the country to grow to nuisance levels along the shorelines of many southern Wisconsin lakes such as Lake Mendota in our Capital City. Many measures have been suggested to control Eurasian watermilfoil—water level fluctuations, toxic chemicals, weed cutters, and even other exotics that would eat the watermilfoil.

Exotics often are introduced for purposes such as food, recreation, or nuisance control. Each introduction should be carefully evaluated because new species do not come without environmental costs. As with biocides we must ask each other whether the exotic will have unwanted side effects on the lake ecosystem. For example, will the exotic cause the extinction of a native species (a common consequence of an introduced exotic) or will the new species compete with the game or food species? Will the exotic modify the habitat unacceptably as rusty crayfish have in some northern Wisconsin lakes? Also will the new species spread or "leak" from the site of introduction to other lakes and become a problem there? For example, smelt introduced into Crystal Lake, Michigan escaped to the Great Lakes and now are causing problems even in small lakes of northern Wisconsin. And finally if the introduction is found to be a mistake at a later date, can the exotic be successfully removed? Usually the answer to the last question is no and we are forced to live with our past mistakes at a cost. Lamprey control and carp control in Wisconsin are expensive.

Lakes are like islands and their communities are susceptible to transformation by the introduction or invasions of exotic animals and plants. With exotics, prevention of an invasion or an undesirable introduction is cheaper than the cost that a new species can incur in lake management. Yet there are introductions such as the Pacific salmon in the Great Lakes that have been important in helping rehabilitate ecosystems damaged by earlier invasions of exotics. The introduction of exotics will remain a part of our management alternatives in lakes as will having to deal with past introductions and invasions. The magnitude of their effects on lakes especially in regard to the local extinction of native animals and plants suggests caution and education as a guide.

Reading list

Christie, W. J. 1974. Changes in fish species composition of the Great Lakes. J. Fish Res Board Can. 31: 827–854.

Emery, L. 1985. Review of fish species introduced into the Great Lakes, 1819–1974. Tech. Rept. 45. Great Lakes Fishery Commission, Ann Arbor, Michigan. 31 p.

Lodge, D. M., A. L. Beckel, and J. J. Magnuson. 1985. Lake-bottom tyrant. Nat. Hist. 94(8): 32–37.

Magnuson, J. J. 1976. Managing with exotics: a game of chance. Trans. Am. Fish. Soc. 105: 1–9.

John J. Magnuson is professor of zoology and director of the Center for Limnology at UW-Madison.

Annamarie L. Beckel Ph.D. is a technical writer and researcher with the Center for Limnology, which plans, facilitates, and conducts research on Wisconsin waters and operates two laboratories in the state.

Water Quality and Land Development In a Karst Area: Door County, Wisconsin

By Ronald D. Stieglitz, UW-Green Bay
and William E. Schuster, Door County Soil & Water Conservation Department

A few years ago people in Winter Park, Florida were astonished to discover that an area of seemingly solid ground was collapsing and forming a deep, steep-sided impression, called a sinkhole. National news services noted the rapidly expanding collapse engulfed structures including streets, buildings, and a new car lot complete with some vehicles. In other parts of the country, visitors wander in awe through the underground rooms and passages of caves such as Carlsbad Caverns in New Mexico and Mammoth Cave in Kentucky where magnificent cave features are displayed and accessible to the public.

These two seemingly unrelated types of features have in fact the same basic origin. They are both products of water percolating through and dissolving part of the bedrock. Areas exhibiting such surface and subsurface features are known as karsts or karstic areas, and they present unique problems of land use. The term karst is German in origin and was first applied to the land forms of northwestern Italy and adjoining parts of Yugoslavia. Although Wisconsin has no such spectacular features, bedrock solution and karst features are widespread and troublesome.

People living in karst regions often find it difficult to obtain adequate supplies of good quality groundwater or to dispose effectively of waste materials. Openings in the rock directly join surface and subsurface flow systems, short-circuit the normally slow infiltration pathways of water through soil, and provide routes for the movement of contaminants into aquifers. Water flows easily both vertically and horizontally through rock, moving great distances in short periods of time. Large channelways provide little or no filtering of water, and as a result dissolved and suspended substances can be quickly and widely dispersed. The complexity of the pathways of flow is perhaps hard to imagine; however, a fair analogy for this dairy state is that karst areas are somewhat like Swiss cheese in that the rock is laced with open pockets and passages.

Overview of karst features and processes

Southwestern Wisconsin has the best known and most impressive solution features, such as Cave of the Mounds in Dane County and Lost River Cave in Iowa County. Eastern Wisconsin was thought to have relatively few caves or karst features because of the supposed destructive action of the Pleistocene ice sheets, but extensive solution features do exist in eastern Wisconsin, particularly in Door County. In fact the longest cave known in the state, Horseshoe Bay Cave, with over 1740 feet of mapped passages is located in Door County. Sinkholes, open joints or crevasses, and other small to medium-sized features formed by solutions and collectively known as karren, occur throughout eastern Wisconsin.

Karstic regions have fewer surface streams and more dry channels and intermittent streams than other areas because much of the drainage occurs beneath the surface. Sinkholes and open cracks in bedrock intercept a significant proportion of runoff and throughflow and divert it into the subsurface. Stream channels that do carry water may leak part or all of their flow into underground openings known as swallets. True underground streams may exist where the water flow is concentrated in the larger subsurface openings. Following intense rainfall or during the spring snow melt, groundwater is also forced back to the surface at temporary springs or resurgence points carrying with it substances that have entered the aquifer at distant points. Springs that flow most or all of the year in karst areas are seldom the sources of pure water that they are imagined to be.

The most common rocks sufficiently soluble to support karst landforms are the sedimentary carbonate rocks, limestone, primarily calcium carbonate $CaCo_3$, and dolomite or dolostone, primarily calcium magnesium carbonate $CaMg(CO_3)_2$. In Wisconsin most solution features are developed in rocks deposited as limestone in ancient seas and later altered to dolomite by complex chemical processes.

The rate at which carbonate rocks are dissolved depends on factors such as composition, texture, and impurities, but a principal control is the amount of the gas carbon dioxide (CO_2) in the infiltrating water. The CO_2 content is important because it dissociates or ionizes in water to produce carbonic acid, a weak acid, that increases the ability of groundwater to dissolve carbonate rocks.

Dolomite solution is a complicated process involving a series of chemical reactions that produce CO_2 , result in its ionization in soil and groundwater, and ultimately in rock solution. Although the details are complex and a series of reactions involved, the process can be summarized by the following equation:

$$2\ Ca\ Mg(CO_3)_2 + 4\ H_2O + 4\ CO_2 \rightleftharpoons 2\ Ca^{++} + 2\ Mg^{++} + 8\ H\ CO_3^-$$

This equation describes an equilibrium reaction because, as indicated by the arrows, it may proceed in either direction depending on conditions. Changes in carbonate availability, temperatures, or CO_2 content of the water can shift the direction of the reaction. Rock solution which produces calcium and magnesium ions that contribute to the hardness of groundwater occurs when conditions drive the reaction to the right. Cave decorations such as stalactites or draperies form under conditions which drive the reactions to the left resulting in calcium carbonate deposition.

Door County's physical environment

Door County is a pleasant mix of orchards, small towns, wooded hillsides, farm fields, and craggy bluffs overlooking expanses of blue water. These ingredients not only attract tourists and seasonal residents, but also combine to produce a rather fragile environment. In addition the area's continental climate is modified by the waters of Lake Michigan and Green Bay resulting in cool, comfortable summers. A significant proportion of the annual precipitation is stored on the surface as snow and released during a short spring melt period. The pulse of water produced saturates surface materials, recharges the bedrock aquifer, and fills surface streams and ponds. The spring runoff is an important element of the water budget in the county, and some streams or segments of streams flow only during that period.

Soils are, for the most part, thin and developed on glacial tills and outwash. The USDA Soil Conservation Service's Soil Survey of Door County indicates that 22 percent of Door County has soils less than 18 inches to bedrock. An additional 17 percent of the soils are mapped as being between 18 inches and 38 inches to bedrock. That means that less than three feet separate the surface from the upper part of an important bedrock aquifer. Thick overburden occurs in low lands and where the glaciers formed deposits along their margins known as moraines. Postglacial sand deposits are found along present beaches and associated with abandoned shorelines at higher elevations, particularly on the east side of the peninsula. Generally the unconsolidated materials are directly connected with the bedrock, and the two function as one aquifer, although perched water tables exist in some places.

Cream and buff-colored Silurian dolomite forms the bedrock of most of the peninsula. These rocks are inclined gently to the east and southeast where they disappear under Lake Michigan. The western edge of the layers forms a prominent set of cliffs along the shores of Green Bay known as the Niagaran Escarpment. The rocks are cut by innumerable fractures or joints which developed as the Earth's crust was stressed by internal and external forces. Joints serve as pathways for water to infiltrate into the aquifer. The escarpment and prominent northwest-southeast trending bedrock valleys provide ample topographic relief for horizontal water flow through the dolomite.

Geologic mapping is underway to locate sinkholes, widened joints, and other solution features and to identify areas most susceptible to groundwater pollution. The work, although not completed, has demonstrated that solution openings abound in parts of the county and that they are important access points for surface water inflow to the bedrock aquifer. Many rather large solution features exist but most are small ephemeral features that open and close in farm fields depending on the season, conditions, or tillage practices. In some areas the solution features appeared masked by or plugged by the glacial materials whereas in other places exposed bedrock displays few sinkholes or solution widened joints. As yet the relative significance of masking, topography, and lithologic differences to feature formation and density has not been totally determined.

In places solution channels and widened joints in the upper part of the bedrock form a porous and permeable zone that stores and transmits water. Numerous closed topographic depressions exist in the county that collect water from surface runoff and lateral flow through the bedrock. Some of these depressions are bedrock floored and contain prominent sinkholes, but all of them must act as sites of infiltration of water to the bedrock aquifer.

Impacts and stresses on water resources

The thin soils and bedrock features found in Door County provide an effective connection between the surface activities of man and the underlying drinking water supply aquifer. The vast majority of Door County residents rely on the dolomite and overlying glacial deposits for their household drinking water. Aquifer contamination has been a historical problem. Common sources of contaminants include, but are not limited to, gasoline tank sites, failing conventional septic systems or holding tanks and the improperly conducted land surface disposal of pumped septic or holding tanks.

The visual evidence of contaminated private wells includes the presence of odors, discoloration, foam, and an undesirable taste. Well testing by rural landowners has shown cases of unsafe drinking water due to bacterial contamination and high nitrate levels. Reports of contamination are most common during the early spring rains and snow melt runoff and following other heavy precipitation events.

The city of Sturgeon Bay's municipal water supply wells have also had several unsafe well tests requiring the abandonment of a number of wells. Preliminary studies have been conducted to consider utilizing Lake Michigan water, or cluster wells located on the outskirts of the city, to provide a long-term source of clean water. The use of filters on existing municipal supply wells has also been considered.

Perception and understanding

The city resident, farmer, rural landowner, village resident, and seasonal resident are all faced with the same problem of obtaining safe, clean drinking water. However, their perception and understanding of the problems and how they should react depends on many factors. The financial and regulatory impacts of their actions also appear to determine how they react to groundwater contamination; decisions are often determined by economics.

Residents of the city of Sturgeon Bay do not have to rely on a contaminated well for drinking water because a contaminated municipal supply is not used and the other remaining safe wells supply the required water. Thus, city residents are somewhat removed from the problem except for what they read in the newspaper and their increased water supply costs. New wells are drilled to replace the abandoned well, and the water supply continues to flow as long as a safe well can be obtained. Contingency plans have been established to reduce industrial water usage if the remaining number of safe wells cannot supply the required volume of water.

The farmer is affected much differently than the city resident. There is no second well to switch to in the event of contamination. The contaminated well is also the source of water for their livelihood. The farmer's options are somewhat limited. A new well can be drilled; however, this is an expensive project. Unlike the city resident the farmer must decide to drill and pay for the well on his own. However, in some areas the situation is accepted as an unavoidable yearly event to be tolerated, and drinking water may be obtained from a neighbor's unaffected well until the problem clears up.

The farmer's own operation may be the source of the pollution. Farmers are often aware that they, or their neighbors, may be polluting their well, and, thus, are very reluctant to report the bad well and draw attention to the situation in fear of regulatory action. The farmer may not believe that his operation is the pollutant source but is aware that others will, and that he may be forced to make expensive changes. The average farmer's operation has evolved over many years and the fact that traditional farming methods, associated with chemicals or animal waste, may cause groundwater pollution is not readily accepted.

The nonfarmer rural landowner whose well becomes contaminated by agricultural pollutants is typically not so accommodating and may seek action by regulatory agencies. As the number of nonfarmer landowners increases, it is expected that the number of complaints will also increase. However, due to the complex geology, it will be very difficult to establish one proven source of the pollution, although many possible sources may be located.

The landowner, full time or seasonal, who has a well with high bacterial count and a failing septic system, may also be reluctant to draw attention to the situation in fear of regulatory action. The landowner's reluctance is caused in part by the high cost of replacing the failing septic system. The landowner is aware that in many cases, soil depth is not sufficient for a conventional septic system and a more expensive mound system may be required. In very shallow soils, a holding tank may be necessary creating a monthly pumping cost. There is also a general misunderstanding by landowners of how surface landuses affect underlying aquifers.

Recent governmental response

In 1984, two projects were begun to address groundwater quality concerns in Door County. They are the upper Door priority watershed and the ad hoc water quality study committee. Both were initiated by committees of the county board.

The upper Door priority watershed, over 1500 acres, includes approximately one-half of the county north of Sturgeon Bay. The project was proposed by the county for inclusion in the Wisconsin Department of Natural Resource's Wisconsin Fund Priority Watershed Program in 1981 and was selected for funding in 1984. The Upper Door was the first priority watershed which had as its primary concern groundwater quality.

In the priority watershed program, areas are selected by the counties and the state for increased management of landuse practices to reduce nonpoint water pollution. Large amounts of state cost-share funds are made available to landowners in the watershed to construct and install practices to abate water pollution. The program has typically been oriented toward surface water quality and agricultural sources of water pollution because the majority of nonpoint water pollution sources are agriculturally related. Because of the primary concern with groundwater quality, the upper Door is reviewing nonagricultural sources in addition to agricultural sources.

Priority watersheds are divided into two phases: a phase of inventory and assessment and a phase of implementation. The upper Door priority watershed project is in the first phase. Maps are being completed of physical features such as permeable soils, shallow soils, high watertable soils, surface water drainage networks with an emphasis on closed depressions, karstic solution features, exposed bedrock and fracture traces. Information from the maps is being combined to produce a final composite map identifying areas of high potential for groundwater pollution. An overlay of livestock operations, along with a site visit analysis, will be used to rank the pollution potential from individual operations. An overlay of five years of crop rotations will be used to identify fields where continued row crops may result in excessive chemical application in areas of high potential for groundwater pollution.

To review nonagricultural sources, maps using USDA Soil Survey information were generated showing areas of suspected failing septic systems and areas unsuited for holding tank spreading sites. All dwellings are being located on the failing septic systems map; this information could be used for sanitary survey investigations. Holding tank spreading sites were located and onsite investigations are underway to determine soil depth, watertable location, spreading methods, and compliance with regulations.

The implementation plan to be written during the early months of 1986 will begin during the summer of 1986. The plan will include a cost-share budget for applicable practices and proposed management strategies for noncost-shareable practices.

The second governmental response is the ad hoc water quality study committee. In late 1984, three committees of the county board, the resource planning committee, the health commission and the land conservation committee, met to discuss water quality in Door County. The committees jointly requested the county board chairman to appoint a special ad hoc committee, made up of members of the original committees, to study and make recommendations regarding county management of water quality issues.

The ad hoc water study quality committee, along with a citizens advisory and technical advisory committee, spent late 1984 and the first eight months of 1985 studying septage disposal, failing private sewage systems, animal waste, abandoned wells, underground storage systems, abandoned landfills, applied chemicals, and lead arsenate. Once again the primary concern was groundwater pollution. The final ad hoc report and recommendations are to be presented prior to the 1986 budget preparation process to allow for the three committees to develop budgets and programs that will determine future county water resources management.

Ronald D. Stieglitz is associate professor of earth science at UW-Green Bay. He received a B.S. from UW-Milwaukee and M.S. and Ph.D. in geology from University of Illinois. He is presently engaged in research on the groundwater resources and paleozoic stratigraphy in eastern Wisconsin.

William E. Schuster received a B.S. in geology from UW-Oshkosh and is working on M.S. in environmental sciences at UW-Green Bay. He is head of the Door County Soil and Water Conservation Department.

Wisconsin's Groundwater Law and Regulations 1848 to 1985

By Harvey E. Wirth
Water Resources Center, UW-Madison

In Wisconsin water is regarded as an unlimited resource. Precipitation replenishing groundwater exceeds most foreseeable consumption needs. This renewable resource is valuable only if the right to use it satisfies each need and assures sufficient water of high quality. This right to use is in the Common Law of England and affirmed in Wisconsin's constitution. Increasing competition for groundwater expanded court, legislative, and regulatory actions in the interest of quality protection as well as rights to use. It should be regulated to maximize public and private good. This history delineates the law and regulatory actions promulgated to achieve that good.

Water is a universal commodity available to everyone, but competition for its use creates friction. Conflicts over groundwater rights result in water law and regulatory adjustments for domestic, industrial, and irrigation uses. Population growth, the improved standard of living, development of groundwater-using industries, and intensive agricultural use of land have had important consequences for Wisconsin's groundwater resource, necessitating legislative, court, and regulatory decisions.

Historically, development, conservation, and wise use of groundwater was the purpose of legislative and regulatory actions. Some failed, some predominated. This history shows the actions taken since statehood and discusses their significance to groundwater use. Development of groundwater law is highlighted to demonstrate the importance of land disposal of wastes on groundwater quality.

History of groundwater law

The Constitution of Wisconsin adopted in 1848 provided that the common law enforced in the Northwest Territory was the law of the state until altered or suspended by the legislature. The common law in force for groundwater—absolute property rights doctrine—was affirmed by the Wisconsin Supreme Court in *Huber v. Merkel*, 1903, permitting the person owning land to dig and apply what is found for his own purposes at his free will and pleasure. This absolute right continued as the basic groundwater law until modified in 1945 to protect public utility wells. In 1974 the Wisconsin Supreme Court set aside the Huber case when in *State v. Michels Pipeline Construction, Inc.* the court established the modified American rule of reasonable use. This action did not alter protection given public utility wells nor did the Michels case change the state's high capacity well statutes.

The first state agency charged with supervising water supply and excreta disposal was the Board of Health in 1876. In 1897 the Geological and Natural History Survey (GNHS) was created and began supplementary services in groundwater science. Bacteriological and chemical analyses on water started in 1903 with the creation of the Laboratory of Hygiene in conjunction with the university and Board of Health. The Railroad Commission—later the Public Service Commission—was given powers in 1907 to regulate public water utilities, initiating one of the most complete groundwater pumpage records existing.

Waste disposal statutes and regulations appeared in 1913 and 1914, when the board was empowered to license plumbers and regulate plumbing installations. Although a 1905 act required the board to review plans for public water systems, it was 1919 before additional legislation created the Bureau of Sanitary Engineering to review plans and control the waters of the state. In 1924 the public water supply code was initiated. Revised rules followed in 1929 and were enhanced in the 1950s by standards recommended by the Great Lakes-

Upper Mississippi River Board of State Sanitary Engineers and ultimately the U.S. drinking water standards in 1974.

A pioneering action began in Wisconsin with a well drillers' registration law in 1935, and a private well construction code in 1936. This pure drinking water law (PDWL) was amended in 1953 to include registration of pump installers. An attempt in 1951 to outlaw well pit construction, except for residential units serving three residences or less, backfired when the Wisconsin Farm Bureau prevailed on the 1953 legislature to include standards for well pit construction for private water supplies governed by the PDWL. As experience was obtained in enforcing the PDWL, legislative attempts were made to strengthen it, including requiring licensing rather than registration, requiring new well drillers and pump installers to pass a license examination, and setting minimum experience requirements for pump installers and increased experience for well drillers. All failed.

World War II substantially increased groundwater pumpage by industry. Lowering of pumping levels in aquifers along the eastern shore of Lake Michigan alarmed public water utilities. In 1945 they received priority protection through the high capacity well law. The law prohibits installation of wells on one property that will pump more than 100,000 gallons per day without receiving a permit. The permitting agency must determine if proposed well(s) will significantly interfere with a public utility well.

Companion legislation in 1945 appropriated funds to GNHS to investigate groundwater availability. This nonlapsing appropriation established a partnership with the U.S. Geological Survey (USGS).

In 1951, the legislature created a committee (later a council) of state agencies (NRCSA) to promote the welfare of the state by collecting, analyzing, and interpreting natural resources information. Functioning through subcommittees (one was water), NRCSA responded until its termination in 1977. (The error of that action was partially corrected seven years later by creation of a Groundwater Coordinating Council.) With respect to groundwater occurrence, source, quality, movement, and use, the committee functioned so that problems were understood and issues needing coordinated action were dealt with. The NRCSA prevailed on the 1965 legislature to establish an accelerated water research and monitoring program. The program became known as the 6S program. Funds appropriated were not committed unless approved by the director of the Water Resources Center, University of Wisconsin-Madison.

Declining water levels in municipal wells caused a flurry of activity in Fond du Lac in the 1950s. The city went outside its corporate limits in search of groundwater. Townships and private citizens began court actions to prevent the city from drilling in their vicinities. Eventually the Wisconsin Supreme Court decided in favor of Fond du Lac on the basis of *Huber v. Merkel*. Afterwards, the court urged the legislature to establish a water doctrine. The legislature did not act, and it was eighteen years later that the Wisconsin Supreme Court set aside the absolute property right rule for the modified reasonable use rule.

Supplemental irrigation of Wisconsin farm crops began in the 1950s. Competing demands by irrigators and municipalities caused conflicts over the state's riparian rights. The legislative council studied the problem for two years—including proposals to change surface and groundwater doctrines—but nothing was materially changed. The problem seemed to disappear as citizens and organizations had their say in public hearings.

Between 1936 and 1980 amendments were added to the private well code. Efforts were made to assure that private well and pump installations serving Grade A milk producers and processors were made in accordance with the new amendments. Instructional seminars were held to help drillers, pump installers, property owners, agriculture department sanitarians, and field men employed by dairies understand the code. The well drilling section staff reviewed 10,000 well logs annually, made special investigations of large areas (e.g., refuse disposal sites in abandoned quarries), maintained an active enforcement program suspending registrants who violated statutes or rules, and evaluated the code for clarity.

Even though Wisconsin was in the forefront in groundwater practices, it was forty-two years after registration (1936) that codification of rules pertaining to high capacity wells was accomplished. A court action involving two drilling firms who constructed high capacity wells without approval resulted in the attorney general's office advising codification of rules. Included were rules on school and sewage treatment plant water supplies. The fourth edition of the code was amended in 1978 to allow application of fertilizers by adding them to the discharge side of the pump and in 1980, to permit injection of pesticides into well pump discharge. These rights, however, are restricted to nonpotable water supplies, and strict controls to prevent backflow are stressed. Additional amendments, in 1981, provided for wells and reservoirs located in the vicinity of animal waste handling facilities. The 1981 amendments provided for use of pipe other than prime well-casing pipe including thermoplastic casing material. The pipe must be subject to testing procedures, and spot checking may be conducted by the state.

Groundwater supervision underwent a massive change in 1965. Following a one-year study by a governor's committee on Wisconsin's water resources management, the Board of Health was stripped of most of its water resources responsibilities. Programs were transferred to a reconstituted Department of Resource Development and later to the Department of Natural Resources (DNR), formed in 1967. Thereafter the legislature enacted statutes designed to protect groundwater, i.e., statutes governing land disposal of wastes (1967), pollutant discharge elimination system (1973), hazardous waste management program (1977), point source pollution program (1977), revised metallic mining reclamation act (1977), recognition of trial programs such as the alternative mound systems (1979), change in private sewage system management (1979).

In 1971 a pioneering act established a research program at the University of Wisconsin-Madison to study problem soils incapable of supporting conventional sewage systems.

From 1976 to 1979, the DNR responded to the U.S. Safe Drinking Water Act by evaluating about 2,000 noncommunity and 200 community-other-than-municipal water systems. It hoped to determine the work load and cost to effect water supply corrections if DNR were to assume primacy. The study showed favorable results and enabled the DNR Board to seek primacy. It did so with the provision that the U.S. Environmental Protection Agency (EPA) make an effort to change the safe drinking water act as it pertained to noncommunity public water systems or to accept the state's private water supply program. The EPA granted a special dispensation allowing sanitary surveys to be scheduled as staff time permitted and reducing the extent of sampling. This reduced the cost of managing these systems under a primacy proviso. The board sought full primacy, which was granted by EPA. The legislature in 1979 gave DNR authority to accept primacy. Because a relationship exists between wetlands and groundwater this history highlights Wisconsin's diffused water law and policies. The landmark decision of the Wisconsin Supreme Court in *Just v. Marinette County* is important. This decision established case law in mid-1972, stating that the changing of wetlands and swamps to the detriment of the public by upsetting the natural environment is an unreasonable use of that land. However, still no statutes control wetlands. Legislation beginning with 1971 has failed to pass because environmentalists and farmers could not resolve their differences.

The increase in hazardous waste disposal on land and the realization of its dire consequences led to reevaluation of disposal rules. The objections of mining and others to the groundwater nondegradation provision in the newly drafted mining rules led DNR to propose a groundwater protection strategy and general rules for groundwater quality (1980). The strategy and rules are contained in a framework covering land disposal of solid, liquid, toxic, and hazardous substances.

DNR's proposal became the catalyst which ultimately resulted in the emergence of a massive groundwater management initiative as enacted by the 1983 Wisconsin Act 410. This legislation created a host of new developments and implementations all intended for the preservation of the state's groundwater. It established Chapter 160 of the statutes creating new responsibilities to state and local agencies and particularly the requirement there be standards inclusively for all facilities, practices, and activities that could affect groundwater quality. Chapter 160 required DNR to establish by rule where the standards apply, procedures for determining whether a standard has been exceeded, and the range of response if a standard is exceeded. It decrees two standards of water quality evaluation: (1) substances of public health concern and (2) substances of public welfare concern and requires that creation by rule of "preventive action limits" specified to protect public health or welfare. In essence, the statutes recognize that groundwater degradation has and may continue to occur. These standards, found in NR140 of the administrative code, became effective April 1985. Act 410 additionally included new goals and objectives for the state's new groundwater management policy, such as requiring DATCP, DOT, and DILHR to manage the bulk storage of fertilizers and pesticides, salt mixtures intended for highways, and flammable and combustible liquids; requiring a total laboratory certification and registration requirement for all engaged in sanitary analytical work; establishing a groundwater coordinating council; more forceably recognizing the role of the University of Wisconsin-Extension in public information, education, and groundwater research; establishing a groundwater fund and continuing the waste management fund as an environmental repair fund; requiring the Pesticide Review Board to conform its pesticide rules with Chapter 160; authorizing counties to manage private well construction and pump installation, the disposal of septage, and requiring municipal sewage systems to accept septage throughout the winter months; including excess nitrates found in livestock or residential wells as contaminants and eligible for repair compensation; and generally strengthening many provisions relating to land disposal of solid and liquid wastes, nonhazardous as well as hazardous.

Overall, Wisconsin's history in groundwater law and regulation shows that the state has not taken this valued resource for granted. Wisconsin's laws and regulations for groundwater have been extensive in the twentieth century. The future will judge the effectiveness of the state's actions.

Conclusions and recommendations

Water rights, protection of public trust, availability of high quality groundwater continue as concerns of legislators, courts, regulators, and citizens. From statehood to the 1980s, laws and regulations were created to oversee the state's groundwater. Some actions are supportive, e.g., laws and regulations controlling disposal of hazardous substances. Uncontrolled, these substances could make groundwater unusable and endanger public health. Some actions might be termed regressive, such as abandonment of NRCSA which for twenty-five years coordinated information among state agencies, the legislature, and governor. Other actions, like the repeated refusal to strengthen the pure drinking water law, allowed interwoven political ideology to prevail. As a result, the law was never assessed in scientific terms, and fundamental reasons for the change were ignored. Another, such as DNR's proposed strategy regulation stating that groundwater may not be degraded beyond certain limits, represents a backward step to prevent degradation of groundwater. This proposed strategy departs from Wisconsin's traditional role of not allowing a law or rule permitting degradation.

The compilation of this history disclosed actions which could be expanded or deleted. The following recommendations, not prioritized, are presented to ensure that groundwater shall remain safe and available.

Advancements have occurred in the well drilling and pump installation industries since the 1953 amendment to the pure drinking water law of 1936. Experience in enforcing the law and the increase in use of land for disposal of wastes warrants strengthening the PDWL. The legislature should consider Senate Bill 521 of the 1973 session, or something similar.

The program authorized by Chapter 502, Laws of 1965, relating to accelerated water resources research and data collection—the 6S program—should be reestablished in DNR in accordance with the intent and purpose of the original appropriation established by the legislature.

Conservation of water use should be emphasized.

The high capacity well law should be amended to require a permit rather than approval, and that permit should be renewed annually or biennially.

Laws, regulations, policies, and decision making should be based on science and reason, not politics.

The explosion of solid and hazardous waste increasingly disposed of on land is endangering the groundwater resource presently and will to a greater extent in the future, preventive action limits notwithstanding. New directions for minimizing the use of the land as the receptacle for solid, liquid, toxic, and hazardous substances should be explored including mandatory recycling, mandatory reuse, incineration of burnable materials and chemical or biological treatment of liquids.

This summary is taken from a detailed discussion of Wisconsin groundwater law which will be completed during 1985.

Harvey E. Wirth P.E. holds a B.S. and M.S. in civil engineering-sanitary option from UW-Madison. He is the retired director of the Bureau of Environmental Health, Division of Health, Wisconsin Department of Health and Social Services.

Land Use and Water Quality

By G. V. Simsiman and G. Chesters
Water Resources Center, UW-Madison
J. G. Konrad and R. T. Bannerman
Wisconsin Department of Natural Resources

Concern for Great Lakes water quality prompted the governments of the United States and Canada, under the Great Lakes water quality agreement of April 15, 1972, to direct the International Joint Commission (IJC) to conduct studies of the impact of land use activities on the water quality of the Great Lakes Basin and to recommend remedial measures for maintaining or improving Great Lakes water quality. Pilot watershed studies were conducted in both countries covering a full range of urban and rural land uses found in the Great Lakes Basin. Of the six major watersheds chosen for intensive study, the Menomonee River watershed served as the focus of investigations on the impact of urban land uses on water quality. Specifically, the objectives of the study were to identify critical urban nonpoint sources of pollution and determine quantities of major pollutants likely to affect Lake Michigan water quality.

The 35,200 hectare (ha) Menomonee River watershed is located in the southeastern corner of Wisconsin and discharges to Lake Michigan at Milwaukee. This highly urbanized watershed encompasses all or parts of four counties and seventeen cities, villages, and towns and a population of about 400,000 persons (12 persons/ha). Existing urban land uses range from an intensely developed commercial/industrial complex in the lower quarter of the watershed to low to medium density residential areas in the center half of the watershed, while the upper quarter is being converted from rural to urban land use, as reflected by scattered urban development.

Procedure

Surface water quality was monitored at nine stations from 1976 to 1977 and six stations from 1978 to 1979 during baseflow and runoff events. These stations (Fig. 1) were located at the headwaters of small streams or storm sewer systems draining to the Menomonee River. The subwatersheds monitored ranged from 49 to 2,150 ha each containing a predominantly single land use: residential, commercial, industrial, freeway, and agricultural (Table I). All stations had automated flow and sampling equipment.

Water loadings were estimated by integrating flows over the hydrographs for all recorded events. Concentration and flow data were used to estimate pollutant loadings using a stratified random sampling model enhanced by a ratio estimator.

Discussion will focus primarily on loadings of suspended sediment and total phosphorus (P) to illustrate the factors influencing the quantity of pollutants arising from urban nonpoint sources. Values for chloride and trace elements are also given to show the magnitude of these contaminants in an urban setting.

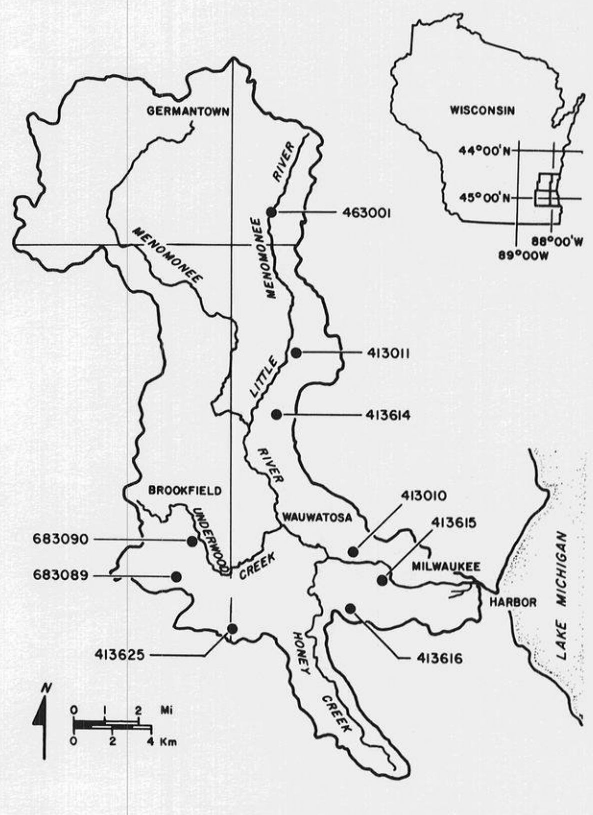


Figure 1. Location of monitoring stations.

Table I. Some Characteristics of the Drainage Areas of the Monitoring Stations

STORET number	Location	Predominant land use	Drainage system	Area, ha	Connected imperviousness, %
413616	Allis Chalmers Corp., City of West Allis	Heavy industry	Storm sewered	49	90
683089	Brookfield Square Shopping Center	Commercial	Storm sewered	61	45
413615	Stadium interchange, I-94, manhole #120	Freeway	Storm sewered	64	43
413010	Schoonmaker Creek at Vliet St.	Medium density residential	Storm sewered	179	33
413011	Noyes Creek at 91st St.	Medium density residential	Storm sewered	552	28
463614	Timmerman Airport, manhole #6	Commercial	Storm sewered	140	7
463001	Donges Bay Road, Mequon	Agriculture	Natural ditches	2144	1
413625	City of New Berlin at 124th St. and Greenfield Ave.	Low density residential	Natural ditches	224	0.3
683090	Village of Elm Grove, ditch at Underwood Parkway	Low density residential	Natural ditches	166	0

Table II. Average Seasonal Event Loadings of Water, Suspended Solids and Total Phosphorus—1976–1979[1]

STORET number	Water, m^3/ha			Suspended solids, kg/ha			Total, P, kg/ha		
	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall
413616	510	2,000	130	81	920	3.5	0.45	2.4	0.081
683089	880	950	170	290	170	21	0.28	0.19	0.026
413615	1,400	980	140	590	290	23	0.57	0.35	0.034
413010	430	490	47	230	160	6.5	0.38	0.25	0.020
413011	1,400	930	130	510	260	15	0.48	0.26	0.026
413614	140	300	130	16	68	4.2	0.030	0.090	0.030
463001	870	140	20	150	75	4.7	0.36	0.14	0.009
413625	440	100	16	410	40	2.0	0.24	0.080	0.004
683090	39	19	15	0.9	0.5	0.5	0.008	0.009	0.004

[1]See Table I for land uses and extent of connected imperviousness.

Table III. Annual Event Loadings of Water, Suspended Solids and Total Phosphorus[1]

STORET number	Water, m^3/ha				Suspended solids, kg/ha				Total P, kg/ha			
	1976	1977	1978	1979	1976	1977	1978	1979	1976	1977	1978	1979
413616[2,4]	790	4,000			210	1,700			1.1	4.3		
683089[2]	450	2,000	2,800	1,800	84	540	670	350	0.42	0.49	0.77	0.32
413615[2]	230	2,400	3,500	2,800	50	990	1,400	630	0.11	0.95	1.6	0.71
413010	800	940	1,300	780	230	440	540	290	0.42	0.62	0.98	0.42
413011	3,600	1,500	2,600	1,800	1,500	830	520	440	1.4	0.69	0.71	0.42
413614[2,4]	180	840			66	95			0.12	0.16		
413001[3]	1,800	200	600	700	280	130	300	77	0.65	0.20	0.75	0.29
413625[2]	4	140	450	1,200	0.3	19	230	1,200	0.001	0.050	0.21	0.86
683090[2,4]	0	110			0.0	3			0.000	0.030		

[1]See Table I for land uses and extent of connected imperviousness.
[2]Summer and fall loadings only in 1976.
[3]Summer and fall loadings only in 1977.
[4]Stations were not monitored in 1978 and 1979.

Table IV. Event Loadings of Chloride and Trace Elements—1977[1]

STORET number	Chloride	Arsenic	Cadmium	Chromium	Copper	Lead	Nickel	Zinc
413616	160	0.048	0.088	0.31	1.3	7.0	0.21	13
683089	46	0.012	0.013	0.032	0.13	1.2	0.032	0.58
413615	160	0.014	0.018	0.094	0.42	5.2	0.051	1.9
413010	24	0.002	0.007	0.046	0.15	0.80	0.018	0.41
413011	100	0.007	0.002	0.046	0.11	0.22	0.027	0.28
413614	19	0.004	0.006	0.009	0.034	0.15	0.007	0.29
463001	3	0.001	0.000	0.005	0.012	0.012	0.001	0.024
413625	9	0.000	0.002	0.001	0.005	0.014	0.001	0.014
683090	4	0.000	0.000	0.000	0.003	0.006	0.001	0.015

[1]See Table I for land uses and extent of connected imperviousness.

Seasonal and annual loadings

Data presented in Tables II, III, and IV include only loadings during runoff events and thus provide estimates of nonpoint source pollution from land uses within the watershed. Water and pollutant loadings varied considerably among land uses from season to season and year to year (Tables II and III). On a unit area basis, urban areas generated greater nonpoint pollution loads including chloride and trace elements (Table IV) than the rural areas. Seasonal and annual variation in pollutant loadings is influenced largely by differences in runoff amounts. Most of the annual runoff occurred during spring and summer, as did pollutant loadings.

Examination of pollutant loadings reveal that differences between land uses within a season or year are due to the variation in the amount of runoff and/or pollutant concentration. High pollutant loadings observed at stations 413616, 413615, 683089, 413011, and 413010 were related to high water loads and usually to high concentrations of suspended solids and such associated pollutants as phosphorus and lead. Stations with low pollutant loads in certain years (413625 and 683090) showed low water loads and low pollutant concentrations. In general, runoff yield has a greater effect than pollutant concentration on the magnitude of pollutant loads.

Factors affecting loadings

In analyzing pollutant loadings from predominantly homogeneous areas, we must consider the amount of runoff and pollutant concentrations. This dual analysis of stormwater pollution provides a two-sided relative hazard-ranking system. One aspect involves those hydraulic factors which determine relative amounts of runoff, which in urban areas are the nature of the drainage system and the extent of impervious areas connected to the subwatershed outfalls by a drainage network. The connectedness of impervious surfaces to drainage systems determines the rapidity with which water is transported from the land to receiving streams. Of lesser importance in determining runoff in urban as compared to rural watersheds are soil permeability, slope, ground cover and depression storage. Storm-sewered areas with relatively high connected imperviousness (413616, 413615 and 683089) generate high amounts of runoff and also export high pollutant loads without much dilution, Thus, those stations with high runoff often have high concentrations of pollutants. This is likely caused by the easy washoff and efficient transport of pollutants in curb and gutter storm sewer systems from impervious surfaces, and the intensive scour and transport capacities of large volumes of water. Stations with natural drainage systems and low connected imperviousness (413625 and 683090) have relatively low runoff and generate much lower pollutant loads. Natural drainage promotes infiltration, reduces runoff, and traps some pollutants.

The other aspect of the relative hazard-ranking system pertains to those land use activities and land covers that affect the concentrations of pollutants. Some of these are long-term factors which result in persistently high concentrations, such as lead values from heavy traffic (413615) or heavy industrial (413616) areas. Inversely, some factors are conducive to low pollutant concentrations such as the increased trapping efficiency for suspended solids and associated pollutants as P and metals at stations 413625 and 683090. Other activities affecting pollutant concentration are of short term duration, i.e., either temporary or seasonal. Most visible are the effects of winter salting activities on chloride values at station 413615 during spring and on suspended solids concentrations at station 683089 in the spring of 1977. Some short-term activities may mask longer term differences, as at stations 413011 and 413625 where the impacts of ongoing construction throughout the study period could not be separated from pollutant loads not related to construction.

A blanket remedial policy based solely on type of land use is not advisable. Rather, remedial measures should be oriented towards curtailing those short-term activities or phenomena which result in high pollutant concentrations, and towards those areas, which because of their hydraulic and/or other indigenous characteristics, generate long-term heavy pollutant loads. Undoubtedly, minimization of connected imperviousness in any future development or urbanization schemes could effectively and inexpensively prevent high pollutant loads; methods might include porous pavement, vegetated swales, and detention ponds.

Conclusions

Seasonal and annual pollutant loadings varied considerably for all land uses. Seasonal, annual, and site differences were accounted for mostly by variations in the amount of runoff and, to some extent, by variations in pollutant concentrations. On a unit area basis, urban areas generated much greater nonpoint pollution loads than rural or less urbanized areas as exemplified by suspended solids, total phosphorus, and lead. In order to devise a hazard-ranking system for homogeneous land use areas, factors responsible for accelerated pollutant loadings must be identified. The principal factor affecting runoff generation from a land use area is the extent of connected impervious areas. In this regard, urban areas drained by curb and gutter storm sewer systems generated much larger runoff and pollutant loads than areas drained by adequately maintained, natural drainage swales. Vegetated drainage swales appear to trap effectively particulate pollutants. Because some pollutants are closely associated with suspended solids, control of suspended solids will effectively reduce phosphorus, lead, and other metal loadings. Some land uses cause persistently high concentrations of pollutants in runoff, such as high lead values in heavy traffic and heavy industrial sectors. Other factors affecting pollutant concentrations are very temporary or seasonal, such as at construction sites and during road salting.

Remedial measures attempt to curtail those short-term land use activities which result in high pollutant concentrations, and should focus on those areas, which because of their hydraulic characteristics generate high pollutant loadings. Minimizing the extent of connected impervious areas in any future development or urbanization schemes could effectively and inexpensively prevent high pollutant loads.

Geronimo V. Simsiman received a B.S. in agriculture and M.S. in soil science from the University of Philippines. He pursued a Ph.D. in soil science at UW-Madison and joined the Water Resources Center, UW-Madison. He has engaged primarily in research on the effects of pollutants, nonpoint source pollution and water quality, and groundwater contamination.

Roger T. Bannerman earned a B.S. in chemistry from Humboldt University and M.S. in water chemistry from UW-Madison. Roger works for the Wisconsin Department of Natural Resources as an environmental water chemist. For the past decade he has been heavily involved in nonpoint source pollution projects and more recently assists in the administration of the Wisconsin Nonpoint Source Water Pollution Abatement Program.

John G. Konrad is chief of the nonpoint source and land management section of the Wisconsin Department of Natural Resources and is responsible for administering the Wisconsin Nonpoint Source Water Pollution Abatement Program, which provides technical and financial assistance to landowners for installation of nonpoint source control practices in selected project areas. He holds a Ph.D. in soil science from UW-Madison.

Pollution Indicator

Induction of Liver Enzyme Activity in Fish

By Mark J. Melancon
Medical College of Wisconsin, Milwaukee

A wide variety of chemical pollutants have been found in the aquatic environment. Some of the major catagories of such chemical pollutants are hydrocarbons from coal and petroleum benzene, toluene, polycyclic aromatic hydrocarbons (PAHs); pesticides (toxaphene, DDT, aldrin); and other chlorinated hydrocarbons (polychlorinated biphenyls (PCBs); polybrominated biphenyls (PBBs), polychlorinated dibenzodioxins (PCDDs), polychlorinated dibenzofurans (PCDFs). All of these have been or are presently of environmental concern. Many of them have been found in bodies of water in or adjacent to the state of Wisconsin such as Lake Michigan, Green Bay, the Mississippi River, the Lower Fox River and the Sheboygan River.

Routine chemical analysis of fish, water, and/or sediment samples from every body of water for these chemicals would be prohibitively expensive. Such analysis involves extracting the chemicals from the samples, concentrating and partially purifying the extracted chemicals, and finally identifying and quantifying the chemicals present by gas chromatography and mass spectroscopy.

One way of limiting the number of chemical analyses which must be performed is to use the keys or indicators or determine which areas should be tested and for which chemicals. One indicator might be the past or present use patterns of chemicals in a certain watershed. Another possibility is the response of indicator species in a particular location. We sometimes hear of cases of large fish kills which lead to investigations of the nature and source of the causative agents. It would be useful to have more sensitive indicators, responses of fish or other aquatic species less catastrophic than death, to reflect exposure to certain chemicals. The activity of certain liver enzymes might be useful for this purpose.

In most species of animals, including fish, the liver is the major site of metabolism of foreign chemicals. Generally this metabolism makes the chemicals more water-soluble and facilitates their excretion, but in some cases may make the chemicals more toxic. Exposure to certain chemicals can increase this type of metabolism. A number of the aquatic pollutants mentioned above, including some of the PAHs, PCBs, PCDDs and PCDFs, have this capability. When liver is homogenized and separated into fractions by differential centrifugation, this metabolism is found to reside in the microsome fraction. This enzyme system is called hepatic microsomal monooxygenase activity and is capable of metabolizing a wide variety of chemicals including some endogenous chemicals. Because of this, a variety of assays may be used to quantify hepatic microsomal monooxygenase activity. We thus have the possibility of assaying for elevations of hepatic microsomal monooxygenase activity as a more subtle method for detecting the exposure of fish to certain pollutants.

Some of the earliest studies of this type were done using fish captured from different locations in the ocean. Generally fish were obtained from bays which were thought to be polluted (containing commercial harbors, refineries, with polluted rivers entering) and from bays which were thought not to be polluted. In every case the hepatic microsomal monooxygenase activity was greater in fish from the polluted bays than in fish from the nonpolluted bays. In a similar study I found that hepatic microsomal monooxygenase activity was greater in fish from the polluted bays than in fish from the nonpolluted bays. In a similar study I found that hepatic microsomal monooxygenase activity in carp captured in the lower Menomonee River basin in Milwaukee was over twenty times greater than that in carp which had been obtained from a U.S. Department of the Interior hatchery and maintained in the laboratory for two years. Interpreting results from this type of study can be a problem because some difference other than pollutant exposure might be responsible for the differences in enzyme activity. Differences between the locations in the water temperature or food, or genetic differences between the fish in different locations might affect enzyme activity. To avoid this possibility other approaches to the study of environmental induction of hepatic microsomal monooxygenase activity have evolved.

Two such studies have been done in Wisconsin. I performed one of these studies together with John Lech and Steven Yeo in the department of pharmacology and toxicology at the Medical College of Wisconsin, and the other was done by Dr. Robert Binder together with Dr. Lech.

Induction of hepatic microsomal monooxygenase activity in carp and bullheads by Kinnickinnic River water.

The purpose of this study was to determine whether water from the Kinnikinnic River Basin was capable of inducing hepatic microsomal monooxygenase activity in fish. This required constructing a procedure to make clear that any differences observed could be attributed to differences in the chemical content of the exposure waters. The exposures of the fish were done at the University of Wisconsin–Great Lakes Research Facility and the preparation of microsomes and enzyme assays were done in the department of pharmacology and toxicology at the Medical College of Wisconsin. Circular fish tanks were set up to receive either dechlorinated Milwaukee municipal water or Kinnikinnic River water which was pumped into the laboratory. Cooling units kept water from both sources at the same temperature; all tanks received light during the same period each day; and all fish were fed the same commercial pelleted fish diet. To begin the experiment, carp which had been obtained from a U.S. Department of the Interior hatchery and maintained in the laboratory for at least one year were placed in the

Table 1. Hepatic Microsomal Monooxygenase Activity in Carp Exposed to Dechlorinated Municipal Water or to River Water

Days	Dechlorinated Municipal Water	Kinnickinnic River Water	(Transferred to Dechlorinated Municipal Water)
	Hepatic Microsomal Monooxygenase Activitya[a]		
3	0.39 ± 0.06[b]	1.68 ± 0.19[c]	
6	0.52 ± 0.07	2.32 ± 0.40[c]	
11	0.65 ± 0.09	4.43 ± 0.78[c]	
20	0.27 ± 0.05	3.73 ± 0.35[c]	
24	0.29 ± 0.08	2.24 ± 0.62[c]	1.40 ± 0.28c
31	0.25 ± 0.04	2.28 ± 0.26[c]	0.66 ± 0.10[cd]
46	0.26 ± 0.08	2.07 ± 0.33[c]	0.38 ± 0.04[d]

[a]The hepatic microsomal monooxygenase activity was assayed as the deethylation of ethoxyresorufin and the results are presented as nanomoles of product formed per minute per mg of microsomal protein.

[b]Values are given as the mean ± the standard error.

[c]Values are significantly different than those for carp maintained continuously in dechlorinated municipal water ($p<0.05$).

[d]For carp exposed to river water and then transferred at day 20 to municipal water indicates significant difference from values for carp continuously exposed to river water ($p<0.05$).

Table 2. Hepatic Microsomal Monooxygenase Activity in Bullheads Exposed to Dechlorinated Municipal Water or to River Water

Days	Dechlorinated Municipal Water	Kinnickinnic River Water
	Hepatic Microsomal Monooxygenase Activity[a]	
5	0.036 ± 0.012[b]	0.177 ± 0.075[c]
13	0.051 ± 0.013	0.213 ± 0.043[c]
20	0.100 ± 0.027	0.244 ± 0.052[c]
31	0.175 ± 0.044	0.624 ± 0.087[c]

[a]The hepatic microsomal monooxygenase activity was assayed as the deethylation of ethoxyresorufin and the results are presented as nanomoles of product formed per minute per mg of microsomal protein.

[b]Values are given as the mean ± the standard error.

[c]Values are significantly different than those for bullheads maintained continuously in dechlorinated municipal water ($p<0.05$).

Table 3. Hepatic Microsomal Monooxygenase Activity in Laboratory-Cultured Lake Trout

Fish Age	Hatchery	Lake Michigan	Green Bay
	Hepatic Microsomal Monooxygenase Activity[a]		
Embryos	16 ± 3[b]	99,107	66
45 days post-hatch	44 ± 3	156 ± 15	195 ± 8
55 Days post-hatch	108 ± 2 (670 ± 26)	929 ± 67	657 ± 49
210 days post-hatch	131 ± 15 (641 ± 91)	131 ± 13 (608 ± 105)	

[a]The hepatic microsomal monooxygenase activity was assayed as the hydroxylation of benzo(a)pyrene and the results are presented as units per mg of microsomal protein.

[b]Values are given as the mean ± the standard error. Data in parentheses are values from PCB treated trout.

Table 4. PCB Content of Laboratory-Cultured Lake Trout

Group	47 Days Post-Hatch	210 Days Post-Hatch
	Total PCB Content (ug/g)	
Hatchery	0.18 ± 0.02a	0.22 ± 0.02
Lake Michigan	4.30 ± 0.30	0.40 ± 0.02
Green Bay	2.19 ± 0.08	

a Values are given as the means of determinations on two samples ± range.

tanks receiving water from the sources described above. At intervals, groups of carp were removed from each tank, liver microsomes were prepared, and assays for hepatic microsomal monooxygenase activity were performed. The data in Table 1 show the large increase in enzyme activity which occurred in the carp exposed to the river water. When some of the carp which had been exposed to the river water were placed in fresh water, the enzyme activity dropped rapidly to the levels found in the carp which had not been exposed to river water. Two such experiments done on consecutive years gave similar results.

An additional experiment was done using bullheads. From the data in Table 2 we can see that enzyme activity was also increased in the bullheads by river water, but that the increase was not as great as that observed in carp.

It is clear that something in the Kinnikinnic River water elevated hepatic microsomal monooxygenase activity in these carp and bullhead. Although we have not done chemical analysis on the river water to determine the causative agent(s), PCBs are present in the sediments in the river where the water intake pipe was located.

Induction of hepatic microsomal monooxygenase activity in lake trout embryos and fry from eggs collected from fish in Lake Michigan and Green Bay.

For years no lake trout have been naturally reproducing in Lake Michigan. One possible factor for this reproductive failure is the presence of PCBs in the mature lake trout, the transfer of these PCBs to the gametes, and possible harmful effects on the developing young. In previous studies, Richard Peterson and Patrick Guiney of the University of Wisconsin–Madison, Dr. Lech, and I showed that a PCB which was taken up by rainbow trout in the fall of one year was transferred in part to the developing gametes during spawning season the next fall. In the female trout this represented a transfer of about 10 percent of their total content of this PCB to the eggs at spawning time. A study was therefore done to determine whether microsomal monooxygenase activity was induced in embryos and fry from eggs gathered from Lake Michigan and Green Bay lake trout.

For this study lake trout eggs and milt were collected from hatchery stock, from Lake Michigan fish, and from Green Bay fish. The fertilized eggs were cultured at the University of Wisconsin–Great Lakes Research facility. At various times embryos and fry were used for the preparation of microsomes and determination of microsomal monooxygenase activity. Table 3 contains data on monooxygenase activity of young lake trout of various ages. It can be seen that activity in young trout derived from the wild is greater than that in hatchery-derived young at the embryo state and at 45 and 55 days posthatch. There was no difference between the wild hatchery-derived young when the fish were much older. The values in parentheses are the values for young trout given PCBs experimentally. These results show that these groups of fish were capable of being induced and that the activity could be raised to environmental levels by treatment with PCBs. The tissue levels of PCBs for these young fish is shown in Table 4. It can be seen that the young fish derived from the wild had high levels of PCBs at a time when their enzyme activity was high and had much lower levels of PCBs when their enzyme activity was the same as that of hatchery-derived young. The decrease in PCB concentration with age in the juvenile lake trout derived from Lake Michigan trout was expected because of the dilution of the initial body burden of the PCBs by growth.

It is clear that embryonic and young lake trout which might be developing in Lake Michigan or Green Bay have elevated microsomal monooxygenase activity. At this point, however, it has not been demonstrated that such induction is necessarily harmful to these young fish.

Conclusions

It has been demonstrated that hepatic microsomal monooxygenase activity can be elevated in fish by exposure to certain pollutants in the aquatic environment. The presence of elevated microsomal monooxygenase activity in fish in a particular location might be used as indicator for subsequent chemical analysis to determine the pollutants present.

Research is continuing to determine whether such environmental induction is harmful to the fish.

The two research studies described which related to Wisconsin waters were each funded in part by the Wisconsin Sea Grant College Program and in part by the National Institute of Environmental Health Sciences.

Mark Melancon is a member of the Department of Pharmacology and Toxicology at Medical College of UW-Milwaukee.

Why Research is Essential to Maintain Water Quality
Using Hazardous Waste Disposal as an Example

By Gordon Chesters
Water Resources Center, UW-Madison

This article responds to a misunderstanding about the role of research in providing long- and short-term solutions to water quality and other natural resource problems of Wisconsin. I am prompted to write it because of the long process the state went through in developing groundwater legislation, which initially omits research as a state need. Groundwater management and its even-handed enforcement throughout the state and amongst all users is an extremely difficult policy to achieve. Prior to the new legislation, the state did not attempt to develop a long-term plan for groundwater preservation but tried to provide convenient solutions to real or imagined "brush-fire" problems. However, the long-term solution and plan is still beyond our grasp because of gaps in the information base which can only be closed by research.

Structuring research

All natural resources are inexorably intertwined. Thus, an impact in one part of the ecological system is reflected—either rapidly or very slowly—in another part. For example, rapid depletion in dissolved oxygen in a lake caused by negligent action may cause an immediate fishkill. On the other hand, the slow incursion of a toxicant into a large water body may not constitute a threat for several decades. Because our actions have an impact throughout the system, we must examine the environment as an interconnected group of many different media and compartments. An air pollutant falling on a parking lot in Milwaukee is eventually washed off by rain and carried to a channel, perhaps eventually to a river, where it undergoes reactions with dissolved or suspended materials, with the river bed or with river biota. If this pollutant does not quickly decompose, it is likely to reach a lake where it may stay in solution or suspension or become part of the sediment; it may be taken up by microfauna, microflora, or aquatic plants; or it may by some route be taken up by fish. If the fish are consumed by humans, a serious public health problem may ensue. The regulatory apparatus required to control this chain of events is staggering. Implementating research in the form of control strategies to protect water quality depends on having effective institutions which can act wisely and rapidly. The difficulties can be shown with the above example. To prevent that pollutant reaching a lake and becoming a public health nuisance, a management technique should be implemented on the land to protect the water resource. Many local and state governments are involved in the land portion of the decision; however, decisions on the water resource are made almost entirely by federal agencies. How do we bring these diverging authorities together to examine effectively land use impacts on water resources? Superimpose on this the fact that the original air pollutant may enter the atmosphere hundreds of miles from its point of deposition thereby involving other institutional relationships.

Many problems in the environmental, agricultural, and social sciences require a multidisciplinary, often interinstitutional, approach. University administrations, federal agencies, and congressional committees agree that this approach is essential. Notwithstanding, the multidisciplinary, inter-institutional research programs successfully concluded are limited, in part, because of inadequate formulation of project objectives and program design. Research has too often pursued uncoordinated, narrow objectives, with results inadequate for problem solution or delineating alternative courses of action which decision makers can evaluate.

In dealing with many contemporary water quality problems, university faculties (singled out because the University of Wisconsin System is the major research unit of the state) must coordinate their activities with those of the responsible local, state, and federal agencies. These interdisciplinary programs must incorporate the needs of the involved agencies who utilize the findings, the decision makers who evaluate alternative plans for problem solution, and the general public who fund the research and must live with the consequences of the decisions. If these needs are not taken into account, a research program will probably not provide meaningful solutions to practical problems.

Planning is essential to achieve a sound multiagency, problem-oriented research and action program, but the funds necessary for adequate program design are seldom available. Fiscal support guarantees are required to lure successful researchers, extension specialists, and administrators away from busy schedules. It is not reasonable to expect them to spend time designing projects which may never be undertaken. The lack of financial guarantees often leads to development of ill-conceived programs with a long lag phase during the early years of the program.

Cooperative ventures are more likely to be undertaken in Wisconsin than in many states because of the favorable philosophical climate which exists and the effective extension service which translates research findings into action-oriented education programs.

What steps are required to develop a successful multiagency research-demonstration program on water quality protection?

The most important step is to encourage leaders who earn the trust and respect of the investigators and those charged with implementing the findings. A principal investigator must elicit cooperation from participants, show sound judgement in combining research personnel into effective teams, have the technical knowledge and ability to guide the program in the proper direction and to bring to account participants who shirk their responsibilities, seek and utilize the pertinent advice of individuals outside the program, and have the energy to see the program through to its conclusion.

A closely knit team of researchers, extension specialists, and government personnel is needed to prepare and implement the program. In Wisconsin there are many dedicated people whose potential skills and capabilities are not being fully utilized in these efforts, perhaps because the know-how for developing a coordinated research-demonstration-education program is not present, perhaps because of lack of encouragement, perhaps because they have not been introduced to the multidisciplinary approach.

Another ingredient is active program outreach to inform the interested public, government officials, and other decision makers of the goals and consequences of the program. Furthermore, throughout the planning phase the team should keep its administrators and potential funding agencies fully apprised of project development. Granting agency personnel should be involved directly in planning to coordinate the program with the mission of the agency and increase funding probability. However, this involvement requires tact to retain program independence and avoid political pressures from mission-oriented agencies.

The roles played by local, state, and federal agencies are diverse. Because of their daily encounters with "real world" situations they can focus attention on problems of greatest concern. They may participate directly and provide monitoring assistance, analytical capability, and—in the case of regulatory agencies—define the legal constraints which apply. Ultimately, the agencies must apply research to the practical problems. Therefore, problem-oriented research-demonstration programs must deliver findings in a format which meets agency needs. Information/technology transfer must be a significant component of mission-oriented research programs.

Last, administrators and legislators should be sympathetic to groups developing and participating in multidisciplinary programs. The participants must be assured that the reward system is as fair to them as it is to personnel who confine themselves to individual projects. For example, publications in scientific journals are not the only measure of research contributions. In fact, the nature of interdisciplinary programs dictates that the output of the team takes precedence over individual efforts.

Hazardous waste pollution

Hazardous materials in the environment is one of the foremost problems facing Wisconsin and the nation. Improper use and disposal of the materials is widespread, creating serious ecological, economic, and health concerns. Despite concerted attempts to control the introduction, cleanup, and disposal of these materials, the problem persists. Regulations dealing with this matter are complex, overlapping, and difficult to understand and administer. In many cases, adequate means for control and disposal do not exist; where they do, problems of cost, scale or lack of knowledge at the local level sometimes preclude their application. This problem illustrates the multifaceted research needed to achieve implementable solutions.

The hazardous materials require both immediate responses and a long-term view. The danger of contaminating groundwater supplies, the reluctance of citizens to have disposal facilities sited near their homes, the lack of technology for disposing of some hazardous materials are a few of the specific problems associated with this issue. Solving these problems requires the cooperation of government agencies and the public. The resources of a large, public university can be a significant factor in achieving adequate solutions.

Initial emphasis should be on two issues of current major concern in Wisconsin: a) hazardous waste disposal including siting of disposal facilities; improved landfill design and wastewater treatment processes; alternative means of waste disposal, such as recycling, recovery, or detoxification; dredging and dredge-material disposal; and social, economic, and legal issues; b) groundwater contamination including better understanding of groundwater systems; extent and long-term potential for contamination; impacts on groundwater of various agricultural, industrial, and waste-disposal practices; and potential health effects due to contamination. Of particular importance is the tracking of contaminants through an aquifer. This is a difficult and long-term research goal particularly for pollutants which undergo transformations during transport through the groundwater system.

In recent years, the public has become increasingly alarmed over hazardous materials in the environment. Public concern stems primarily from incidents like the crisis of New York's Love Canal, contamination of the Sheboygan River fish by PCBs, the recent fears of pesticide infiltration into groundwater in central Wisconsin and many others. Public concern is justified. Questions exist about the true extent of the dangers, ways to control or alleviate the introduction of wastes into the environment, and the general issue of law to protect society from potential dangers without disrupting the nation's economic and social fabric.

In Wisconsin, 500,000 tons of hazardous wastes are produced annually, some are highly toxic, others are troublesome due to their bulk. The three disposal sites—all in southeastern Wisconsin—which can handle hazardous wastes are rapidly filling up. None of them handles such toxic substances as arsenic, cadmium, PCBs, and cyanide. In addition, mining activities have been delayed in part due to fears that acid leachate from waste disposal sites will enter lakes, rivers, and groundwater. The potential for groundwater contamination by hazardous substances, either from inadequate disposal practices or from direct application of pesticides to agricultural lands, is a critical concern. Several areas of the state are particularly vulnerable to the impact of agricultural chemicals or industrial wastes applied to or dumped on the soil surface. The sand plains in the center of the state and some areas in the far northwest have high groundwater tables overlaid with highly permeable sands, which have little or no ability to absorb or retain pollutants dissolved in percolating waters. Large areas of the northwest and southeast have deeper aquifers, but they are overlaid with fractured dolomitic limestone whose fissures form a natural piping system. This can short-circuit contaminated seepage, shunting it directly into groundwater. Recent federal and state legislation directed at protecting or enhancing surface water quality may, in fact, be endangering groundwater resources by encouraging new practices for land disposal of industrial wastes, mine tailings, municipal sewage sludges, and the like. The use of agricultural chemicals, especially insecticides, nematicides, and herbicides, has aroused public concern about their possible intrusion into drinking water sources.

Dredge spoil disposal is another example of a current Wisconsin problem with hazardous waste ramifications. Currently all materials dredged from harbors and rivers is automatically considered contaminated and must be deposited in special diked facilities. Dredging has been discontinued in several Wisconsin harbors because of lack of adequate and approved disposal sites. The economic and social ramifications of this situation are severe for coastal and river communities and the recreational and shipping industries. Governor Dreyfus asked the Wisconsin Coastal Zone Management Program to examine the dredging problem, emphasizing the most polluted materials, and to recommend courses of action for the state. In order to define and maintain a future state policy more information is needed on the effects of various policies, for on-land and in-lake disposal.

To deal with these and other problems, research is needed on several major problems associated with waste disposal and groundwater contamination.

Since most disposal will continue to be through traditional sanitary landfill and wastewater treatment facilities, these systems must be improved. Landfills need to prevent escape of hazardous materials into groundwater. Industrial and municipal sewage treatment processes must ensure the removal of toxic materials. Nevertheless, certain materials are so volatile or the danger of their persistence in the environment if they escape is so great, that other means of disposal need to be examined, namely detoxifying the substances. Such methods as laser pyrolysis, chemical and biological decomposition, reverse osmosis, composting, and high temperature incineration need to be investigated.

A second need is for a general analysis of waste disposal systems. This involves, in part, an assessment of the adequacy of various methods of handling different toxic materials. For example, current disposal sites are often so far from the people disposing of waste material that disposal costs are prohibitive and the wastes are placed in "temporary" storage or "dumped." Current disposal control strategies are targeted at the biggest users of toxic substances (as in the case of PCBs), but much of the potential waste is in small, widely dispersed units (e.g., PCBs in fluorescent light capacitors) which, cumulatively, may pose an equally large problem. Strategies for dealing with these situations need to be investigated.

A third set of issues deals with the siting of hazardous waste disposal facilities. Among the questions to be addressed are: What kinds of information are needed to make site selection decisions? How adequate is existing information? What standards of care are needed for handling different kinds of hazardous materials, and how can risks be minimized? What kinds of trade-offs are involved, particularly when the most desirable sites are on valuable agricultural or recreational land? How serious is the current situation and the long-range problem? Who pays for disposal, and how much? How do we insure that state and local governments and the public have adequate input in the decision-making process? An alternative to standard disposal methods is the option of recycling and recovering materials. The expense of disposal and the scarcity of many resources suggest the need for this approach. Working with "hazardous" substances requires care, but there is a potential for converting or recycling some of the less toxic materials and for removing toxic residues in order to utilize the remaining waste materials. Pilot projects have indicated that recycling is possible for certain mining wastes that would otherwise have to be dumped. Other studies have shown the potential for greater recovery of metals from industrial wastes. There is considerable interest in uses for fly ash which is not particularly hazardous but is troublesome due to its high volume.

Finally, there are questions related to groundwater contamination. At present, strategies and methodologies do not exist to address the problems of groundwater contamination and the resultant health effects that Wisconsin residents could face. To address this issue, it seems most appropriate to concentrate first on what is probably the simplest and most prominent case, pesticide contamination of groundwater underlying the central sand plains. If the current problem with the central sands is solved and the results are transferrable to other areas, the need for expensive, detailed monitoring programs in the future may be circumvented.

Interwoven with these problems of hazardous waste disposal and potential groundwater contamination are many social, economic, and legal questions. The answers will provide the framework within which technical decisions can be made. We need a better method of assessing risks so a coherent strategy for handling toxic materials can be developed. What are high risks? What are "acceptable" risks? What materials should be banned or destroyed; what materials should be disposed of routinely? When are the risks of not doing something greater than the risks of taking a particular line of action?

We also need a better understanding of social impacts such as those involved in siting issues, where residents of an area may be adversely affected by a larger society's need for a disposal site. There are other societal trade-offs involved too, such as the use of valuable land for disposal sites. We need to look more closely at the costs involved: costs to posterity; the cost-effectiveness of various measures; costs of treating material as waste, rather than as a renewable resource; allocation of cleanup and disposal costs among various elements of society; the need to provide incentives in certain situations. In sum, the whole set of issues is permeated not only by technical and management problems but also by a series of social, health, and equity problems.

A critical need for better public information on this issue also exists. The public must be informed of current practices and options for the future, and technical assistance must be given to those communities now faced with the problem of what to do with hazardous waste—especially those who work on small scale local landfills, small waste treatment facilities, and small businesses. The benefits of the total effort depend on close working relations with state and local governments, business and industry, and concerned and affected members of the public. Technical assistance and public education, though inherent to the research effort, are critical and deserve special attention in their own right.

Extensive details are not warranted in this article, but the university system should initiate specific research programs which would address the questions raised. Of particular concern are the health implications associated with disposal of hazardous materials in the environment and how these materials are degraded and/or dispersed through surface and groundwater resources.

Gordon Chesters is director of the Water Resource Center, professor of soil science and chairman of the water chemistry program at UW-Madison. He also works with the Institute for Environmental Studies and the Environmental Toxicology Center. He holds a B.Sc. degree in chemistry and biochemistry from the University of Wales, U.K., and M.S. and Ph.D. degrees from UW-Madison in bacteriology and soil science. He is on the board of directors of the recently formed National Nonpoint Source Institute.

The Zero-Discharge Debate

Wisconsin's Wasteload Allocation Program:

By Michael T. Llewellyn
Wisconsin Department of Natural Resources

The Federal Water Pollution Control Act (33 U.S.C. 466 E. S.), also known as the clean water act, was passed in 1972. With this passage, congress established an aggressive public works program to "restore and maintain the chemical, physical, and biological integrity of the nation's water (s. 101(a))." Through a comprehensive program of construction grants and the establishment of water quality standards and various levels of treatment requirements for both public and private wastewater discharges, states were to achieve "fishable and swimmable" waters by July 1, 1983. However, congress also stated that it is a national goal to achieve "zero discharge" of pollutants into the nation's navigable waters by 1985.

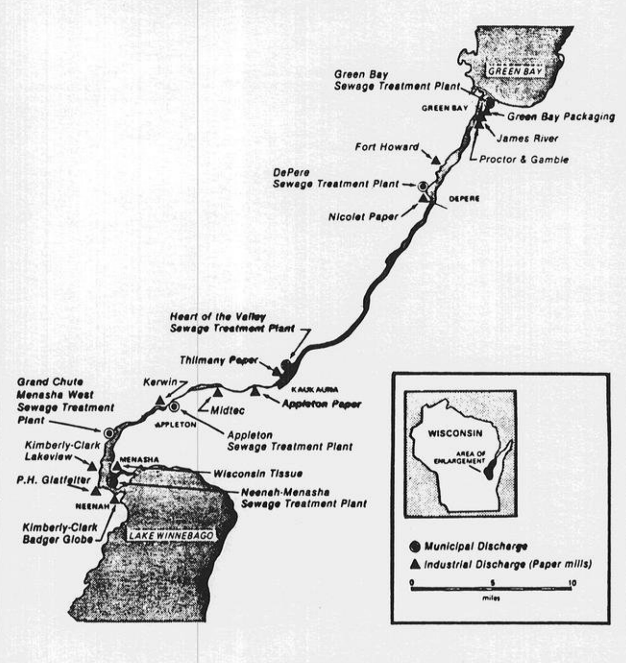
The clean water act and Wisconsin water pollution statutes require a series of procedures to attain desired water quality. Each state is responsible for classifying its navigable waters and subsequently establishing water quality standards on a parameter-by-parameter basis. In Wisconsin all streams classified as "full warm water fish and aquatic life" must obtain a minimum dissolved oxygen concentration of 5 mg/1. Concurrently, each discharger must, at a minimum, meet nationally uniform or "categorical" effluent discharge limits. These limits apply to specific "classes" for discharges, for example sulfite-based paper mills or municipal treatment plants. All similar classes of dischargers must meet these technology-based limits regardless of the stream to which the effluent is discharged. If this level of discharge fails to meet the respective water quality standards, the state is responsible for issuing "water quality-related effluent limitations" which are specifically calculated to attain water quality standards.

Development of water quality effluent limits on the Lower Fox River began in the mid 1970s. The Lower Fox River was highly degraded due to excessive organic pollution loads from both industrial and municipal discharges. Even with the imposition of categorical effluent limitations beginning in 1972, the water quality standard for dissolved oxygen (5 mg/1) imposed was not attained. Therefore, the Department of Natural Resources (DNR) utilized a mathematical water quality model to determine the amount of a pollutant known as BOD (biochemical oxygen demanding material) which could be discharged at levels which would attain the 5 mg/1 dissolved oxygen standard.

Due to the number of discharges on the Lower Fox River, a process known as a "wasteload allocation" was followed to ration the allowable load of BOD among the industrial and municipal dischargers. In 1976, the governor designated the Fox Valley Water Quality Planning Agency to provide a local forum to develop policy recommendations to the department regarding the method of allocation for the allowable wasteloads. The department would provide the technical expertise to define the allowable loading of BOD. However, since the "rationing" of the load concerned the regulated community and interest groups consensus was sought. Other important policy recommendations for the Fox Valley Water Quality Planning Agency included establishing a "reserve capacity" and identifying a margin of safety. These latter two concepts would require a portion of the determined total maximum daily load to be "withheld" either for future dischargers or expansion of current dischargers or in the case of margin of safety, permanently withholding a portion of the total maximum daily load for use related to the potential for water quality violations due to uncertainty in the modeling results.

After several years of intensive discussion among the department, the Fox Valley Water Quality Planning Agency, and the regulated community, a wasteload allocation process was codified (NR 212, Wisconsin Administrative Code). The code adopted by the Natural Resources Board became effective through individual discharge permits on July 1, 1983. On the Lower Fox River, two distinct wasteload allocations were determined. Cluster I and Cluster II are river segments where the accumulative impact for a cluster of dischargers is evident (see figure). Each cluster's total maximum daily load was determined in individual allocations through the use of an agreed-upon rationing formula. The wasteload allocation for each cluster was determined by calculating the total amount of biological oxygen demand allowable as a function of river flow and temperature.

Location of Municipal and Major Industrial Waste Dischargers to the LOWER FOX RIVER.



As river flow decreases and water temperature increases, the allocation becomes more stringent due to the river's inability to assimilate this waste. However, as river conditions improve, the dischargers are allowed to increase their discharge, since the ability of the river to assimilate the waste increases with higher flow and lower water temperature. The "flow/temperature" permits were one innovative option developed in the NR 212 process. Thus, the department allows the "full use" of the river's cleansing ability while still attaining the desired water quality standard. If all dischargers use their full allowable daily loads, theoretically the river would continuously be at the minimum allowable dissolved oxygen concentration. However, since most dischargers fluctuate their discharge levels day to day, a considerable "cushion" usually exists.

The Consolidated Paper Company reallocation

In late 1982, Consolidated Paper Company - Appleton Division (CPI) ceased discharging into the Cluster II region of the Lower Fox River. Since Consolidated Paper Company was one of seven dischargers in this segment, "surplus" assimilative capacity became available. The department approved the concept of allowing the full use of the assimilative capacity as long as the appropriate water quality standard was attained; therefore, the remaining Cluster II dischargers requested that the "abandoned" CPI wasteload allocation be "reallocated" to them. However, there was not a consensus from these dischargers as to the amount of the CPI wasteload allocation to be rationed to each discharger. In fact, two industries immediately applied for more than was made available from CPI.

Following the department's philosophy of seeking local input, the department asked the Fox Valley Water Quality Planning Agency to recommend resolution of CPI's wasteload allocation. Many available options were presented to the public over a two-year period. One option included withholding CPI's load in "permanent reserve" for the benefit of improved water quality. Other options included allocating CPI's load to dischargers who demonstrated a need due to increased production since the original allocation, or to withhold CPI's wasteload allocation in reserve for future new industries or municipal growth. Since the Lower Fox River had not been assigned a reserve capacity in the original allocation, new industries or municipalities were effectively precluded from discharging during the wasteload allocation season. After a lengthy public participation process, the Fox Valley Water Quality Planning Agency recommended that the CPI wasteload allocation be reallocated to all existing Cluster II dischargers based on a consensus formula. A public hearing was held on the proposal in February 1985, and no public appearances were made. However, upon notification by the department of its intent to modify the individual permits for the remaining Cluster II dischargers, the department received comments from several environmental groups objecting to permit modifications. These objections have since raised major questions regarding the issue of zero discharge as legitimate operative policy rather than a goal of the clean water act and the issue of anti-degradation.

Zero discharge and anti-degradation

Environmental interest groups argued that the existing dischargers on the Cluster II region had been assigned effluent limitations based on the original allocation and had been meeting those limits since July 1983. By reallocating the CPI wasteload allocation, the "new modified" permits would reflect more lenient limitations, thereby resulting in "backsliding." The backsliding argument is made in light of the zero discharge philosophy which, as argued by the environmental groups, calls for continual but incremental steps towards eliminating the discharge of all pollutants into the state's waters.

Secondly, the environmental groups contended that since CPI had not discharged for over two years, the ambient water quality in Cluster II of the Lower Fox River was theoretically higher than the minimal standards of 5 parts per million. Since the 5 parts per million minimum was premised on 7 entities discharging (including CPI) the elimination of one discharger would result in higher water quality. By reallocating the CPI wasteload allocation and essentially allowing full use of the assimilative capacity by the remaining six dischargers, the ambient water quality would be lower, albeit within the allowable standard. Thus the reallocation also was seen as being contrary to the anti-degradation policy of the state. The department contended that the environmental groups' interpretation of the anti-degradation policy was incorrect in that the lowering of ambient water quality was allowed by a new discharge as long as the water quality standard was attained.

Essential to resolving Cluster II controversy is a necessity to address the zero discharge goal. One interpretation of the clean water act holds that although congress established zero discharge as a goal, the operative mechanisms within the law only allow permits to be issued which reflect categorical limits or where further required, water quality-related effluent limitations. States must establish water quality standards which are based on criteria necessary to attain the desired water use. Effluent limitations are then "back-calculated" from the criteria. Zero discharge as a policy would require a continued reduction in pollution—accomplished by gradually redefining the limitations of categorical treatment technology. The department has maintained that permits must reflect the allowable discharge to attain a specific water quality standard. Thus, there is no legal mechanism to limit a discharger to effluent limitations more restrictive than what the specific water quality standard allows. However, under this interpretation the department could either "upgrade" the specific water quality standard on Cluster II to reflect the higher ambient dissolved oxygen or establish an anti-degradation policy which is in essence to adopt the zero discharge goal by precluding a lowering of ambient water quality, although the standard would allow for lower concentrations. In effect, this approach would reflect a policy of keeping water quality at current levels regardless of additional assimilative capacity becoming available in the future.

In countering zero discharge, the dischargers on Cluster II argued that requiring them to discharge at levels more restrictive than necessary to attain the specific standard places them at a competitive disadvantage; their competitors discharge into rivers where categorical limits are sufficient to maintain water quality standards or into rivers where the full assimilative capacity is still allocated to all dischargers. The Cluster II dischargers further contend that when river conditions dictate severe restrictions in discharge levels, many firms face decisions to curtail production. Thus, a public policy arises as to the economic benefit of allowing dischargers to use all assimilative capacity available while maintaining the water quality standard (albeit at the absolute minimum concentration) or requiring even more restrictive levels which may result in "negligible" water quality benefits for a short duration.

From a public policy perspective, decisionmakers must utilize both scientific information regarding the necessary water quality "benchmarks" and social issues regarding equitability across the state. The zero discharge goal assumes that "all pollution is bad" and that water quality standards are simply minimal criteria to provide for interim benchmarks of water quality improvements. The dilemma of "how clean is clean" must be addressed in terms of specific instream water quality concentrations. If in fact the state adopts an anti-degradation policy whereby all waterbodies are not allowed to degrade beyond current levels, significant economic impacts may occur as well as increases in either solid waste or air emissions as dischargers adjust treatment technologies.

The Cluster II issue, therefore, has resulted in reconsideration of many fundamental philosophies and policy issues required to implement state and federal water quality legislation. Despite dramatic improvements in water in Wisconsin and Wisconsin's national reputation as leader in aggressive, innovative water pollution control programs, there is a continued public concern to reduce gradually all pollutant discharges to waterbodies. However, current statutes do not adequately address procedures for going beyond water quality related effluent limitations, since the "benchmark" of permanent limits is the numerical criteria of a particular water quality standard. If indeed zero discharge is the ultimate direction that water pollution control agencies must go, federal and state laws must be uniform to provide a national program to alleviate inequitable requirements to particular regions or waterways.

Michael Llewellyn is currently chief of the water resources planning and policy section of the Bureau of Water Resources Management for the Wisconsin Department of Natural Resources. He received a B.S. in political science and M.S. in water resources management.

Fish and Dissolved Oxygen in *The Wisconsin River*

By Daniel W. Coble
Wisconsin Cooperative Fishery Research Unit
UW-Stevens Point

Fish, like other animals, require oxygen for respiration, which they obtain from oxygen dissolved in water (DO). Oxygen is dissolved in water mainly from two sources: the atmosphere, a process aided by wind on lakes and riffles in streams, and from oxygen produced in the daytime by green plants, both algae and rooted plants. Biological consumption of DO includes respiration by fish, invertebrate animals, green plants at night, and bacteria. Bacterial decomposition of organic matter can be a large consumer of DO. Therefore, rivers that receive large amounts of organic wastes, from sewage or paper mills for example, often have lower concentrations of DO than they would otherwise. Reduced DO levels can affect fish populations.

The many species of freshwater fish differ in their tolerance to low DO. For example, trout are intolerant whereas common carp and some of the bullhead catfishes are tolerant of low DO. Most, if not all, of Wisconsin's 157 species of fish will tolerate some depletion of DO. The amount that can be tolerated depends on a complex of interacting factors, including species of fish, the DO concentration, time of exposure to lowered DO, temperature, season, densities of competitors and predators, and stresses from disease-causing organisms and chemicals.

Most surface waters contain a variety of fish species of which some, sport fish, are valued by anglers while others are not. In general sport fishes tend to be less tolerant of low DO—and other forms of environmental degradation—than nonsport fishes. Since waters that receive large amounts of organic wastes frequently experience oxygen depletion, these waters can be expected to have fewer sport fish than they would otherwise.

This sport fish-DO relationship was brought out in a study I published of the Wisconsin River fish populations in relation to dissolved oxygen in the Wisconsin River *Transactions of the American Fisheries Society.* Results of that study are summarized here. Although fish populations can be affected by other forms of pollution, for example toxic wastes, this study examined effects of low DO resulting from large amounts of organic waste discharges into the Wisconsin River.

The Wisconsin River, the longest within the state, over 600 kilometers long (1 km = 0.62 mi.), has a history of problems related to low DO caused by large quantities of organic waste effluents. The section of river I studied extended from Petenwell Flowage, river km 280, upstream to river km 589, just below Rainbow Dam (fig. 1). Scattered along this reach of the upper Wisconsin River were nineteen industries, including sixteen pulp and paper mills, and fourteen municipal sewage treatment plants, all discharging waste in the river.

Fish populations were sampled at up to twenty-four locations for a total of forty-five samples in summer and fall in 1976 and 1977 and also at two pairs of impoundments in summer 1978. One pair of impoundments was in the upper and one was in the lower part of the section of river studied, and one member of each pair had a history of lower DO levels than the other. These impoundments were Lake Alice and Hat Rapids, and Biron and Mosinee. Eight samples were obtained at each of the upper pair and ten at each of the lower.

For each sample, fish were caught in a small-mesh seine in afternoon, by electroshocker at night, and in stationary nets set overnight. The fish were identified, counted, measured, weighed, and released.

Dissolved-oxygen data were obtained in three ways: (1) from measurements at the time and place of fish sampling, (2) from synoptic surveys of sections of the river by personnel of the Wisconsin Department of Natural Resources (DNR), and (3) from automatic monitors installed at six dams between Wausau and Petenwell, inclusive. In the synoptic surveys department personnel traversed 145 to 296 km sections of the river over a period of one to several days measuring DO at intervals of 0.16 km or more. Synoptic and automatic monitor data from July and August 1973–76 were used. The DO measurements were averaged at each location, and a profile was constructed (fig. 2) representing average summer DO concentrations in 1973–1977.

In all 19,531 fish of 42 species and comprising 3,804 kg (1,729 lb) were caught. The sport fish were muskellunge, northern pike, walleye, yellow perch, bluegill, pumpkinseed, black crappie, white crappie, white bass, largemouth bass, smallmouth bass, rock bass, and warmouth. Nonsport fishes important in terms of numbers of individuals or total weight

Figure 1. The Wisconsin River. The section studied lies between the broken lines across the river.

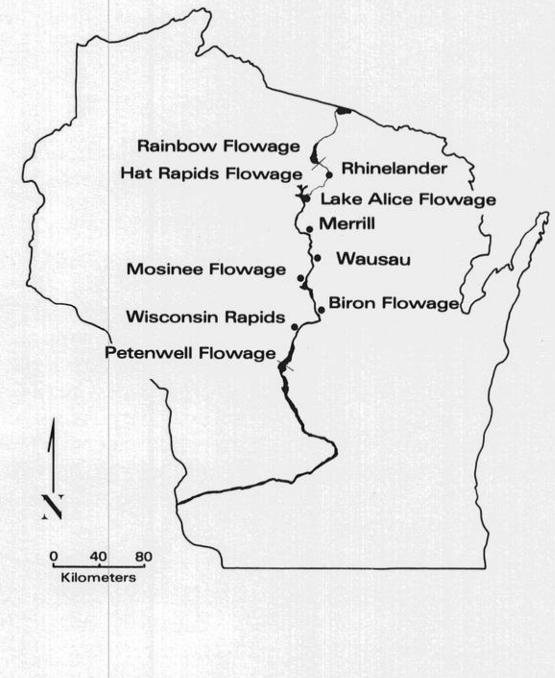
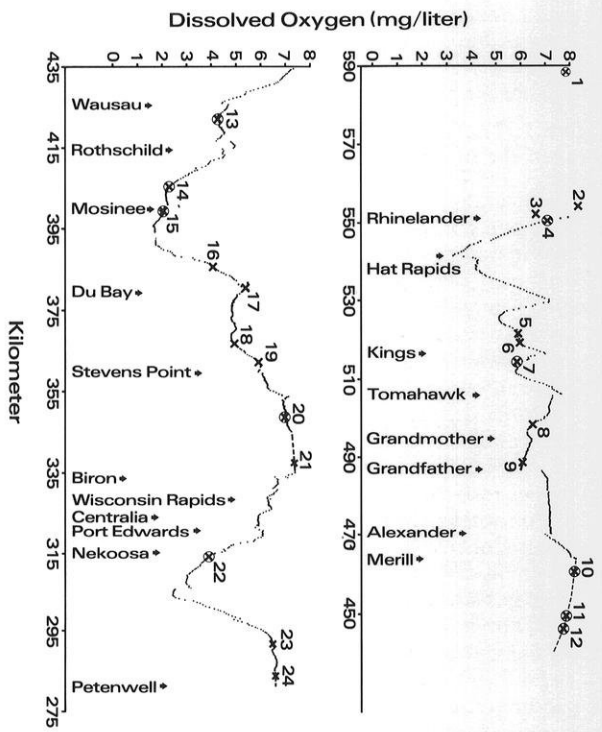


Figure 2. Average summer dissolved oxygen concentrations 1973–1977, in the Wisconsin River between river kilometers 590 and 275. Dots indicate portions of the profile where dissolved oxygen was measured; dashed portions of the profile are interpolated. Fish sampling sites in 1976–1977 are numbered on the profile from 1 to 24; crosses indicate impoundments and circled crosses indicate flowing water. Names of dams are given along the abscissa.



included black and yellow bullheads, common carp, five species of suckers, and bowfin. The fish data were analyzed on the basis of numbers, rather than weight, of fish that were 100 mm long (3.9 in.) or longer. On this basis the sampling indicated that the six most abundant species in decreasing order were black bullhead, black crappie, common carp, yellow bullhead, yellow perch, and bluegill.

Effects of low DO concentrations on fish have been studied extensively in laboratories. Numerous studies have shown that for many species, DO concentrations below 5 parts per million (ppm) have deleterious effects on embryonic development and survival, fecundity, growth, food conversion, swimming ability, respiration, circulatory dynamics, metabolism, behavior, and sensitivity to toxic stress.

These results form the basis of regulatory agencies', minimum standard for DO in surface waters of 5 ppm. That is, agencies have proposed or enforced regulations that require dischargers to limit their effluents to levels that do not reduce DO in receiving waters to less than 5 ppm.

Average summer DO concentrations in the upper Wisconsin River in the mid 1970s ranged from 2 to 8 ppm (fig. 2). At six locations (sites 13-16, 18, 22) average DO was chronically less than 5 ppm. The fish populations at these locations in 1976 and 1977 were different than at the sites where DO exceeded 5 ppm. A smaller proportion of the fish community was composed of sport fish in areas where DO was below 5 ppm; an average of 24 percent of the fish community was comprised of sport fishes in these areas compared with 45 percent in areas where DO was higher. Moreover, these areas also had fewer total species of fish (23 vs. 37) and fewer species of sport fish (8 vs. 12) than the areas of the river with higher DO levels.

Fishes of the perch family and the sunfish family were largely responsible for the difference in proportions of sport fishes. Percentages of yellow perch, walleyes, bluegills, pumpkinseeds, crappies, and large- and smallmouth bass were greater in areas where DO exceeded 5 ppm than where it was lower.

Results of sampling the pairs of flowages in 1978 were the same. Sport fish comprised a greater percentage of the fish community than nonsport fishes in Lake Alice and Biron Flowage, the impoundments of each pair that traditionally averaged more than 5 ppm DO in summer. Here too, fishes of the perch and sunfish families were largely responsible for the difference.

Results of this study of the Wisconsin River support laboratory investigations on effects of low DO on fish and also the minimum DO criterion of 5 ppm of regulatory agencies. Waste discharges should be limited to levels that do not reduce DO to less than 5 ppm in our warmwater streams if the United States is to achieve its goal of restoring and maintaining fishable-swimmable water quality.

Daniel W. Coble is leader of the Wisconsin Cooperative Fishery Research Unit and professor of fisheries at UW-Stevens Point. Cooperators of the research unit are the U.S. Fish and Wildlife Service, the Wisconsin Department of Natural Resources, and UW-Stevens Point. Coble obtained a B.S. degree from Purdue University, an M.S. from Oregon State University, and Ph.D. from the University of Toronto. He accepted his present position in 1971.

Bioassay of Toxic Substances in Water

By George A. Blondin, Lynda Knobeloch, and John M. Harkin
Water Resources Center, UW-Madison

In recent years it has been recognized that many surface and groundwater samples contain substances of natural or man-made origin which in minute amounts can exert toxic effects on humans, domesticated animals, fish, and wildlife. Toxicants present in trace amounts in aquatic samples can produce acute, chronic, mutagenic, teratogenic, or carcinogenic effects in humans or animals exposed to or ingesting them. For example, surface or groundwater used for drinking water is frequently contaminated by trace quantities of such substances as heavy metals, pesticides, and volatile organic or industrial chemicals which elude easy detection yet may exert pernicious effects on humans or domesticated animals consuming the water. Similarly, aquatic life forms in lakes and streams are exposed to inorganic and organic chemicals emanating from municipal and industrial effluents and agricultural and urban run-off. Singly or in combination, these substances may exert toxic effects on aquatic biota and consequently on organisms higher on the food web. For example, organochlorine pesticides, polychlorinated biphenyls, organomercurial compounds, and dioxins are bioconcentrated from water and cause harmful effects on such higher life forms as water fowl, carnivores, and humans consuming fish or mollusks from polluted waters.

Public concern about the quality and safety of surface and groundwater has forced environmental scientists to focus on appropriate methodologies to assess the risk to humans and other species posed by pollutants in water. Conventionally, to assess such risk, two types of measurements must be made: determination by chemical analysis of the identity and amounts of toxic materials present in given environmental samples and correlation of analytical with toxicity data for these compounds. These procedures are too costly and time-consuming for routine monitoring practices. Many analytical tests are required to ensure detectability and accurate quantitation of a bewildering number of chemical contaminants. Often, appropriate analytical methodology and/or toxicological information is not available for the mounting list of new chemical compounds reaching our water resources. Moreover, when several toxicants are present, combined analytical/toxicological information may be inadequate because aggregate risk from mixtures is unknown. Effects on organisms of additive, synergistic, or antagonistic interactions of chemical mixtures in environmental samples are difficult to predict.

Whole organism bioassays

To provide short-cuts in risk assessment and to attempt to cope with the problems of assessing the aggregate toxicity of combined pollutants, scientists and regulatory officials have sought bioassays suitable for use in examining environmental samples. From 1965 to 1978, several hundred toxic chemicals were evaluated in the United States by acute and chronic toxicity tests utilizing various species of fish such as rainbow trout and fathead minnow and aquatic invertebrates such as the *Daphnia magna* water flea. The results were usually expressed as LC_{50}-values, i.e., the concentration of toxic chemical lethal to 50 percent of the test organisms during a specified exposure period. These tests provided a convenient starting point for rapid evaluation of relative toxicity of a variety of chemicals, and they represented a preliminary means for relatively rapid assessment of aggregate toxicity in surface and groundwaters. Although the tests can provide aggregate toxicological information for aquatic samples, they do not identify or quantify the chemicals responsible for the response. Analytical/toxicological testing could then be applied to positively responding samples to afford a more comprehensive assessment of the identity and toxicology of offending compounds.

Whole organism tests have been criticized in recent years for technical and practical reasons beyond the scope of this discussion. Mainly, these tests were still too costly ($700 to $14,000 per test) and time consuming (48 hours to 35 days) for biomonitoring. For example, in 1979, the U.S. Toxic Substances Control Act called for the toxicological testing of all new chemicals. For logistical reasons, whole organism tests have been applied to only a small fraction of the thousands of potentially toxic chemicals. Clearly, the U.S. technical and scientific community does not have the time, laboratory facilities, trained personnel, and financial resources to implement the directives of the Toxic Substances Control Act by utilizing whole organisms for biomonitoring.

Bacterial and biochemical biomonitors

The urgent need for affordable, rapid screening procedures for chemical toxicity has led to the recent development of a wide range of biomonitoring assays that can be carried out *in vitro* in minutes. The spectrum of bioassays extends from tests with simple enzymes such as dehydrogenases, adenosine triphosphatases, acid and alkaline phosphatases, ureases, lipases, proteases, cholinesterases, or mixed function oxidases through tests utilizing bacterial suspensions such as *Photobacterium phosphoreum, Spirillum volutans, Pseudomonas fluorescens,* and *Aeromonas hydrophila.* Simple *in vitro* enzyme tests are too specific and too far removed from whole organisms to qualify as good surrogates. The bacterial tests are extremely selective because membrane transport systems prevent many toxicants from entering the cell. The complexity of the bacterial cell wall and its associated enveloping slime layer provides a protective coating that may often prevent absorption of toxicants into the cell. Even if a toxicant is shown to have an adverse effect on a bacterial population, the environmental significance or health risk to humans, mammals, birds, or fish of such an effect is still difficult to assess. The problem of reproducibility of results also must be addressed. Experience has shown that even rigorous strain maintenance programs cannot guarantee genetic stability of bacteria. Without this assurance, batch-to-batch variations are likely to affect reproducibility of EC_{50} values.

Despite these shortcomings, one bacterial test has achieved status as a useful biomonitor. Scientists at Beckman Instruments, Inc. (Carlsbad, Calif.) have developed a test—the Microtox™Assay—based on bacterial bioluminescence. The assay consists of measuring the light output of luminescent bacteria (*P. phosphoreum*) in the presence and absence of toxicants. Chemical toxicity is expressed as EC_{50} values which in this case is the toxicant concentration causing a 50 percent reduction of bacterial light output for five minutes at 15°C. The assay is rapid, simple, and inexpensive ($30 per test), including biologicals, reagents, labor, and equipment. Assay of sixty toxic chemicals suggested that the Microtox test was as sensitive and correlated well with the 96-hour LC_{50} for fathead minnows.

Although reported to be sensitive, the Microtox assay sometimes lacks reproducibility and appears to offer poor sensitivity to some recently attempted toxic challenges. For example, Microtox EC_{50} values for cadmium, zinc, and lead have varied by a factor of 50 for lead, 20 for zinc, and 10 for cadmium. Furthermore, where good correlation has been observed among the results of several investigators, the sensitivity of the Microtox test to certain toxic challenges falls short of that of whole organism tests. For example, the average of four different determinations of EC_{50} for cyanide was 10.6 ± 2.1 ppm. The 96 hour LC_{50} for cyanide using fathead minnow gave a range of values between 0.12 to 0.16 ppm. Hence, the sensitivity of the Microtox test to cyanide is only 1 percent that of a whole organism test. Other toxic materials for which little correlation exists between inhibition of bacterial light output and whole organism tests include the pesticides DDT, malathion, and diazinon, and the heavy metals copper, cadmium, and silver. It appears that the utility of bioluminescent bacteria as environmental biomonitors is somewhat diminished by these limitations. Bacteria, including *P. phosphoreum*, are probably insulated from the action of certain toxic chemicals by the absence of specific transport mechanisms for uptake of these agents. This renders them insensitive to many toxic challenges. Variations in luminescent bacterial cell suspensions due to genetic instability may account for the lack of reproducibility in determining EC_{50} values for some toxic chemicals.

Mitochondrial biomonitors

We have recently initiated use of mammalian mitochondrial preparations as biomonitors of environmental toxicants. All eukaryotic cells contain mitochondria in their cytoplasm. These subcellular organelles constitute the biochemical power plants of such cells.

Mitochondria contain the enzymes required to oxidize organic nutrients in cells to produce carbon dioxide and water, with formation of adenosine triphosphate (ATP), the major energy-storing compound in cells. Mitochondria also perform other functions requiring an organized system of enzymes and membrane structures and processes. The array of delicately balanced metabolic and transport functions makes mitochondria susceptible to most toxic substances, because interference with a single enzyme or membrane activity can disorganize the entire system making mitochondria sensitive to extremely low concentrations of toxicants.

The literature is replete with studies of effects of toxic chemicals on mitochondrial functions. These studies have been directed toward the goal of clarifying the properties of basic metabolic processes in mitochondria. No effort has been made to apply this knowledge to the practical objective of monitoring environmental quality.

The isolation of mitochondria from mammalian tissue is a routine exercise. Of the many preparations described, mitochondria isolated from rat livers and beef hearts are the best characterized preparations. Our studies are being performed with mitochondria isolated from beef hearts. An electron micrograph of this preparation is shown in figure 1. In this picture, it is easy to discern the outer boundary membrane of some mitochondria, and the highly convoluted inner membrane system is clearly visible throughout the field. These organelles are about the same size as bacteria.

A variety of responses of mitochondrial suspensions can be used as an end-point in biomonitoring assays, but for speed and simplicity in quantitative testing, two spectrophotometric methods offer the most appropriate measurements. In one test, reduction in light transmission caused by light scattering is used as a measure of toxin-induced mitochondrial swelling. A second test is based on a phenomenon called *Reverse Electron Transfer*, i.e., the effect of toxic chemicals on the production of reduced nicotinamide adenine dinucleotide (NADH) is monitored by observing light absorption in the far ultraviolet range. Both tests take five minutes to perform.

Test protocols are under development, but dose-response curves for several toxic chemicals have been extremely encouraging. Typical compounds examined include pentachlorophenol, which shows a high correlation between the Microtox test and fish assays and three different toxins (lead, zinc, and cyanide) which show poor correlation between these two tests. From table 1 it can be seen that mitochondria show high correlation with acute fish toxicity tests and on the average are three times more sensitive than the latter. The data show low correlation between Microtox and fish tests for cyanide, lead, and zinc.

Mitochondria also respond with significantly greater sensitivity than the Microtox assay in the detection of 2,4-dinitrophenol and cadmium. Tests with ethanol were conducted as controls to document relative mitochondrial insensitivity to this reagent, which can be used as a solvent to dissolve water-insoluble toxicants when conducting mi-

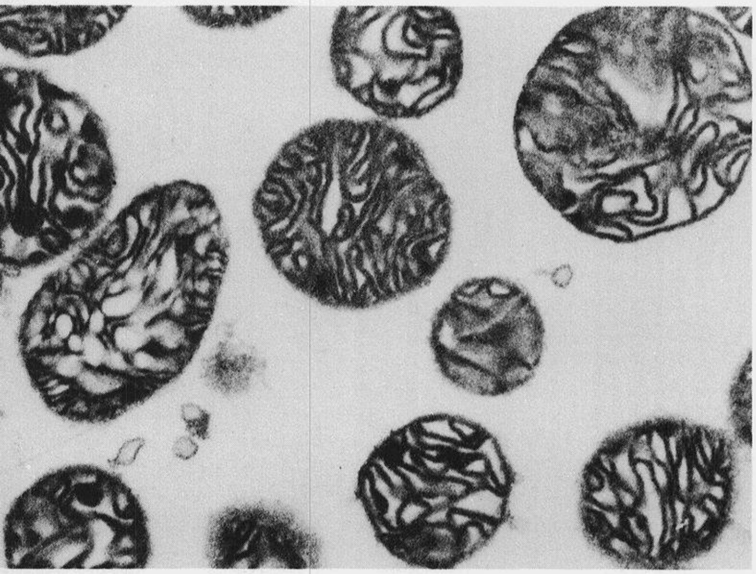


Fig. 1. Transmission electron micrograph of isolated beef heart mitochondria magnified 37,800 times. (courtesy of E. Valdivia and C. Gabel, Enzyme Institute, UW-Madison.)

Table I. Comparative Acute Toxicity Values

Toxin	EC$_{50}$ or LC$_{50}$ (mg/liter) Mitochondria	Microtox	Fish
Pentachlorophenol	0.079	0.74	0.40
Cyanide	0.066	11	0.27
Lead	0.28	15	0.33
Zinc	1.6	20	3.1
2,4-Dinitrophenol	2.5	16	—
Cadmium	0.87	60	—
Ethanol	27,000	44,000	—
Silver	0.12	—	—

tochondrial tests. We have not found comparative toxicity data for this group of chemicals.

The mitochondrial assay is likely to be more cost effective than the Microtox test. Estimates show that the expected cost, including biologicals, reagents, labor, and equipment amortization, could be as low as $2 per assay, well below the $30 established for the Microtox test.

Conclusions

Tests with luminescent bacteria and mammalian mitochondria are fast, simple, and cost effective. It is too early to make definitive statements about overall sensitivity and reproducibility of the mitochondrial bioassays; however, to date the tests are encouraging. Batch-to-batch variation in mitochondrial preparations have produced EC$_{50}$ values for zinc and pentachlorophenol that differ from the mean by no more than 7 percent and the sensitivity of the mitochondrial assay is better than for whole organism tests.

It is interesting to speculate why mitochondrial tests are more sensitive and reproducible than the Microtox test. According to the endosymbiont theory of mitochondrial origin, the modern eukaryotic cell is thought to have arisen by two evolutionary events: first, the appearance of a mitochondrial-free nucleated cell which depended entirely on glycolysis for energy, and second, the emergence of oxidative phosphorylation as a means of energy conservation in prokaryotic cells, the forerunners of modern bacteria. At some early time the nucleated cell (eukaryote) was invaded by the prokaryote. The invasion resulted in establishment of a symbiotic relationship which gave the host cell a more efficient means of energy conservation. Isolated prokaryotes continued to evolve separately giving rise to modern bacteria. Bacteria have learned to survive in hostile environments by two major tactics: viz., high mutagenic frequency and evolution of extremely selective membrane transport systems. These characteristics diminish the utility of bacteria as test organisms in biomonitoring practices because they give rise to poor overall sensitivity and reproducibility in response to chemical toxicants.

Mitochondria, on the other hand, evolved within the protective, more constant environment of cellular cytoplasm. In the course of this evolution much of the genetic machinery for mitochondrial protein synthesis was relinquished to the cell nucleus where replication is characterized by a higher order of fidelity. Thus, mitochondria are less prone to mutational variations than bacteria. Furthermore, mitochondria evolved without a requirement for the complex, impermeable cell wall of bacteria. The mitochondrial outer membrane is a porous structure that allows free access of small molecules (<1000 Daltons) to the interior space. Hence, when mitochondria are removed from their natural protective environment by isolation, they are far more accessible to diverse chemical toxins than bacteria because they are devoid of protective devices. This, coupled with the complex variety of functions housed in mitochondria which are subject to disruption by toxins, makes mitochondria an ideal substrate for toxicity screening.

All indications are that mitochondrial bioassays are ideal for routine analysis for toxicants in water or extracts of other environmental samples, such as soil, food, landfill leachate, and municipal and industrial effluents.

George A. Blondin obtained a Ph.D. in biochemistry from Clark University. From 1965 until 1980 he was a research associate at UW-Madison's Institute for Enzyme Research where he engaged in fundamental research on mammalian mitochondria. Since 1980 he has been associated with the Department of Soil Science and the Water Resources Center on the UW-Madison campus; his current interests are environmental monitoring and waste water purification by membrane technology.

Lynda M. Knobeloch obtained a B.S. degree in medical technology and is presently pursuing a Ph.D. in the UW-Madison environmental toxicology program.

Nitrate in Wisconsin Groundwater

By Rebecca W. Fox and John M. Harkin
Environmental Toxicology Center, UW-Madison

Many private wells in Wisconsin have nitrate-nitrogen above the maximum safety level of 10 mg/liter established by both the U.S. Public Health Service and U.S. Environmental Protection Agency (EPA). Nitrate reaches groundwater by leaching from soil. Sources of nitrogen (N) compounds that give rise to nitrate nitrogen in the soil are fertilizers, decomposing soil organic matter, human and animal wastes, rainfall, and fixation of atmospheric nitrogen by soil microorganisms.

In soil, nitrogen is involved in a complex system of gains, losses, and interactions. Nitrogen gas is fixed from the air by some microorganisms or industrial synthesis of ammonia, used mainly for the production of fertilizer. Plants and microorganisms assimilate fixed nitrogen and convert it to organic forms such as amino acids, proteins, purines, pyrimidines, and nucleic acids, the forms present in human and animal wastes and soil organic matter. Decomposition of organic matter by soil microorganisms produces ammonium-nitrogen, which can be assimilated by plants or oxidized to nitrite and nitrate by aerobic bacteria which use it for energy. Nitrogen can be lost from the soil to the air by ammonia volatilization or denitrification of nitrite and nitrate by microorganisms. In the absence of molecular oxygen, denitrifying bacteria use nitrate while digesting soil organic matter, releasing nitrogen to the atmosphere in the forms of nitrogen gas and nitrous oxide.

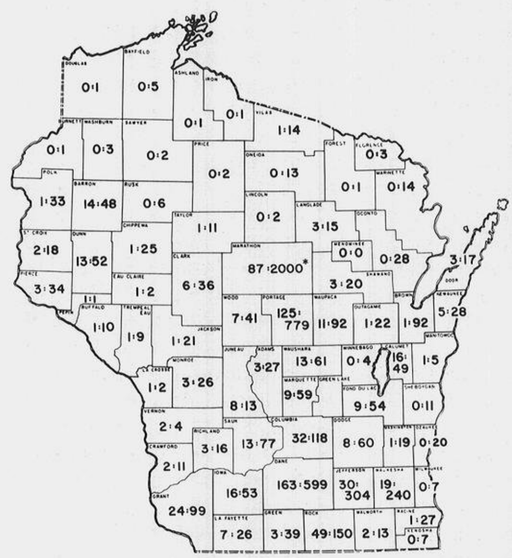
Nitrate leaching

Both nitrate and ammonium-nitrogen ions are highly water-soluble, but ammonium-nitrogen is positively charged and adheres to the soil while the negatively charged nitrate is not bound and moves freely with percolating water. Most fixed nitrogen entering surface and groundwater is from nonpoint sources, with agriculture being a major contributor. Extensive fertilizer use greatly increases the potential for groundwater contamination. Little direct surface water contamination occurs with fertilizer, since nitrogen fertilizer salts enter the soil rapidly, reducing losses in runoff. Surface water nitrogen increases usually result from industrial and sewage treatment plant effluent or livestock wastes.

Groundwater contamination by nitrate is often high in areas where coarse-textured soils are farmed intensively. Crop irrigation practices and shallow water tables increase the likelihood of nitrate contamination. Once nitrate has leached below the rooting zone, the area of high microbial activity in the soil, there is little chance for it to be incorporated into organic forms. If soil nitrate is not used by crops or denitrified by microorganisms it is probably leached.

Irrigated potato fields in the central sands of Wisconsin are prone to leaching of nitrate and other water-soluble chemicals. Sandy soils drain rapidly and contain little organic matter, making it necessary for most of the nitrogen required by crops to be added as fertilizer. Potato plants have a high nitrogen demand, but shallow roots; applied fertilizer and water move rapidly below the root zone. The sandy soils are well aerated and lack organic matter, providing little opportunity for denitrification. As a result, much of the fertilizer unused by plants leaches as nitrate to the groundwater.

Figure 1. Proportion of private wells tested in 1984 with NO_3-N levels exceeding 10 mg/liter. Counties with more than 20% of the wells tested exceeding 10 mg/liter were: Waushara (21%), Grant (24%), Dunn (25%), Columbia (27%), Lafayette (27%), Green Lake (28%), Barron (29%), Iowa (30%), Rock (33%), Calumet (33%), Juneau (62%). Total for Marathon County includes private and noncommunity public wells.



Leachates from septic system drainfields are high in fixed nitrogen and enter the soil below the rooting zone. Most of this nitrogen becomes nitrate, which causes very high nitrate levels in the vicinity of each septic system. Many rural homeowners have elevated nitrate in their well water because of their own or neighbors' septic systems. Researchers have developed design modifications to reduce or eliminate nitrate from septic systems, but none has been adopted into common practice.

Numerous private and noncommunity public wells in Wisconsin have elevated levels of nitrate. Data from the state Laboratory of Hygiene and the Portage and Marathon county health departments on private wells tested for nitrate in 1984 are summarized in figure 1. This map shows the number of private wells with nitrate above the safety level among those tested in each county. Only a few private wells in most counties are tested annually; 1984 was a typical year. Testing rates are high in counties with histories of high groundwater nitrate (e.g. Portage) or high awareness of nitrate problems (Dane). Despite the incompleteness of the data base, it is evident that the groundwater in many areas of the state is contaminated with nitrate.

Public health concerns

Human health concerns arising from exposure to nitrate are infant methemoglobinemia and possible formation of carcinogenic compounds in the digestive tract. Livestock are also susceptible to similar effects.

The most notable acute effect of nitrate ingestion is infant methemoglobinemia. The causative agent of this condition is not nitrate, but nitrite formed from it by bacterial reduction either before ingestion or in the intestine. Hemoglobin, the oxygen carrier in blood, consists of four globin protein chains and four heme subunits. Each heme has a complexed atom of iron at the center of a porphyrin ring. In the oxygenated form of hemoglobin the iron is in its reduced ferrous state. Methemoglobin is formed when nitrite oxidizes this ferrous iron to its ferric state. Methemoglobin is unable to bind oxygen reversibly because the sixth coordinate position of iron in the heme complex, which is normally the carrier for oxygen, has lost its unpaired electron and is occupied by water. The conversion of hemoglobin to methemoglobin occurs constantly in the body, but is kept low (1–2 percent) by the enzyme methemoglobin reductase, which reduces methemoglobin back to hemoglobin.

The first symptoms of methemoglobinemia are a brownish blue discoloration of the skin, first noticeable around the lips, which spreads to the fingers, toes, the face, and eventually the entire body. These signs, called cyanosis, first appear with methemoglobin levels around 10 percent. Anoxia develops at 30 to 40 percent levels. As the level increases, nausea and vomiting develop. Death occurs with levels of 50 to 75 percent. Treatment of methemoglobinemia is simple: injection or infusion of a reducing agent such as methylene blue or ascorbic acid (vitamin C). Vitamin C is considered useful for prophylaxis of nitrate toxicity.

Methemoglobin formation can be caused by many materials other than nitrate, e.g. aniline dyes absorbed through the skin or drugs such as phenacetin, sulfonamides, and nitroglycerin (used by cardiac patients for angina pectoris). However, infants are seldom exposed to these compounds. Cyanosis in newborn babies usually is an indication of congenital heart disease, rather than nitrate poisoning.

Most cases of infant methemoglobinemia occur below the age of one year, the majority at less than two months. Many factors make infants more susceptible to methemoglobinemia than adults. Most important is the pH of the intestinal tract during the early months of life. The gastric pH in babies is relatively high, usually near neutrality. This allows the growth of reducing bacteria in the upper gastrointestinal tract. Adult gastric juices are acidic and consequently sterile.

A source of nitrate in the diet more important than water is vegetables, e.g. spinach or beets. Depending upon how the crop was fertilized and when harvested, many vegetables, including those processed to baby food, have high nitrate contents. However, by the time babies start eating such solid food, the pH in their stomachs is sufficiently acidic to avoid nitrate-reducing bacteria.

Over 80 percent of the hemoglobin in infants is fetal hemoglobin, which differs from adult hemoglobin in its amino acid composition and is more susceptible to oxidation. Being deficient in methemoglobin reductase, infants are also less able to reduce methemoglobin back to hemoglobin. All bacteria in the family *Enterobacteriaceae* which normally inhabit the lowest sections of the intestinal tract can reduce nitrate to nitrite. Gastrointestinal disturbances in infants cause these enteric bacteria to invade the stomach or upper intestinal tract. Cases of infant methemoglobinemia observed in a third world country recently were invariably associated with diarrhea stemming from gastrointestinal infections. Without nitrate-reducing bacteria in the stomach or upper intestinal tract, most ingested nitrate is absorbed unchanged before reaching the reducing bacteria in the colon. It is mostly excreted in the urine. Another factor predisposing infants to methemoglobinemia is their relatively higher fluid intake (per body weight) compared with adults. If water is contaminated with nitrate, the dietary intake of babies fed by formula is relatively magnified. Bacterial contamination of high nitrate wells appears to play a significant role in most cases of infant methemoglobinemia.

If private wells are improperly constructed—too shallow and/or too close to septic systems—the drinking water from them is likely to be contaminated with nitrate and enteric bacteria and viruses. Many private wells in Wisconsin are improperly constructed, even though codes established as early as 1951 prescribed installation guidelines designed to avoid bacterial contamination. A recent nationwide study of rural drinking water quality established that the commonest contaminant among those for which drinking water is regularly tested was bacterial indicator organisms—a sign of fecal contaminants and an indicator of possible pathogens; nitrate was the second most frequent contaminant.

Infant methemoglobinemia was first recognized clinically in 1945. From 1945 to 1975, several thousand cases, including many fatalities, have been reported throughout the world and ascribed to ingesting nitrate in water. Most cases were in the period 1945 to 1950. Many surveys indicate that incidences of infant methemoglobinemia are rare at concentrations below 10 mg/liter nitrate-nitrogen in the drinking water. The risk of methemoglobinemia increases progressively as the concentration rises above 10 with most cases occurring at concentrations above 22 mg/liter. The EPA has established 10 mg/liter nitratenitrogen as the maximum allowable for all public water systems serving at least fifteen connections or twenty-five people for at least sixty days a year. The EPA regulations do not apply to private wells. These standards were established empirically and leave many questions unanswered.

Not all countries, including developed countries, observe the EPA standard, which is the same as the World Health Organization recommendation. Most countries have established standards ranging from 4.5 to 22 mg/liter. Despite the higher standards in some countries, there is little evidence of infant methemoglobinemia in recent times. For instance, no cases were observed in a German town whose municipal water supply contained up to 60 mg/liter nitrate-nitrogen. Babies in rural communities in Israel receiving water with 20 mg/liter nitrate-nitrogen were just as healthy as those in Jerusalem, receiving nitrate-free water. The methemoglobin-hemoglobin levels in both groups were identical. Feeding orange juice—a good source of vitamin C—to rural babies was considered as an explanation.

Methemoglobinemia survey

We sent questionnaires to all pediatricians and general practitioners listed with the State Medical Society: 744 questionnaires were distributed and 569 (76 percent) replies were received. Only twelve physicians had seen or heard of a case of infant methemoglobinemia; with some referring to the same cases, there were only eight distinct cases. None involved nitrate in well water in the last five years. Most incidents occurred over twenty years ago. In two cases nitrate was not the cause: one was aniline dye in newly stamped linens, the other involved a complication of streptococcal sepsis.

Clearly nitrate-induced methemoglobinemia is rare even though many wells in Wisconsin have over 10 mg/liter nitrate-nitrogen. While there could be many explanations, the most probable is awareness by pediatricians and parents of potential problems in areas where nitrate contamination exists. The resurgence of breast feeding helps to avoid the problem. Administration of vitamin supplements or feeding of fruit juices to infants provides ascorbic acid which suppresses nitrate toxicity. Infant feeding formulas made from cows' milk must be acidified because cows' milk is too rich to be digested easily by babies. Consideration should be given to acidification of baby formula with ascorbic acid rather than citric acid.

Livestock

Ruminants (cattle, sheep, goats) are more susceptible to high levels of nitrate in food and water than monogastric animals, because nitrate is reduced to nitrite in the rumen of these animals as an intermediate step in the formation of ammonia for protein synthesis. If an animal rapidly consumes food or water high in nitrate, nitrite poisoning can develop, with methemoglobinemia symptoms showing as cyanosis, rapid breathing, and nervousness. Symptoms of chronic poisoning in livestock are higher incidence of abortion, irritability, and decreased milk production. Avoidance of feeds high in nitrate and provision of fresh forage high in vitamin C avoids problems in areas where water is high in nitrate.

Nitrosamines

N-nitroso compounds, especially *N*-nitrosamines, are chemical carcinogens in every species of laboratory animal tested. In acidic solution, nitrite reacts with secondary or tertiary amines to form *N*-nitroso compounds. Nitrosation reactions can occur in air, soil, or water and in humans and animals. Mixing nitrite and amines from ingested food and water with the acidic gastric juices in the stomach provides favorable conditions for nitrosamine formation. Simultaneous feeding of nitrite and amines leads to nitrosamine formation and gastric tumors in laboratory animals.

This finding aroused concern that chronic exposure to nitrate in food and water might cause cancer in humans. For nitrosamine formation to occur, nitrate must be reduced to nitrite. When nitrate is absorbed by the gastrointestinal tract, although most is excreted in the urine, some travels through the circulatory system and is secreted in the saliva. About 20 percent of the salivary nitrate is reduced by bacteria in the mouth to nitrite. When both are swallowed, nitrite may react with amines in the stomach and the unexcreted fraction of nitrate is recirculated. High nitrate intake can lead to large increases in the salivary nitrite. Nitrosation has been demonstrated in laboratory animals at normal dietary levels of nitrate, nitrite, and amines, but the extent to which this occurs in humans is unknown. Vitamins C and E in the diet can inhibit nitrosamine formation. Cancer risk from dietary intake of nitrate cannot be accurately assessed. A National Academy of Sciences panel on nitrates placed the boundaries for increased lifetime risk of liver cancer from all sources of nitrosamines at 60 cases in 100,000 and 1 case in 100 million.

Several epidemiological studies have shown a positive correlation between elevated nitrate in drinking water and an increased incidence of stomach cancer. However these studies provide no firm causal link, and statistical analysis cannot provide proof nor predict the magnitude of the role of nitrate and nitrite in carcinogenesis.

Nitrogen control

Of the many sources through which nitrogen enters the environment, the most troublesome to regulate are diffuse (nonpoint) sources. Nitrogen loss from croplands presents a challenging problem, with many control strategies available. Appropriate techniques include the use of agricultural best management practices, improved management of plant nutrient systems, limitations on rates of fertilizer application and fundamental changes in agriculture.

Management practices in agriculture that prevent soil erosion and runoff decrease nitrogen losses. Best management practices include soil and water conservation, crop rotation, and use of cover crops. Use of these practices is often limited by economics and soil conditions.

When nitrogen fertilizer is applied in excess of crop needs, nitrate accumulates in the soil, and often in the plant as well. Soil and plant tissue testing helps to evaluate nitrogen needs. Slow-release fertilizers that regulate the nitrogen available during the growing season reduce the nitrate available for leaching. Probably the most important aspect of increased fertilizer efficiency is timing of application so that nitrogen is applied as needed. Addition of organic supplements to soils increases nitrogen immobilization. Use of urease and nitrification inhibitors, which retard urea hydrolysis or the nitrification of ammonium-nitrogen decreases the nitrogen present as nitrate.

Another control strategy restricts the amount of nitrogen fertilizer applied. This involves a sacrifice in crop yield, as a cost of improving environmental quality. Other changes which would reduce nitrate pollution are the development of more efficient crop varieties, genetic engineering, or plant breeding to produce new symbionts which fix nitrogen, and increased use of manure as fertilizer.

Finally, homeowners can control nitrate in their drinking water by use of an anion exchanger, a water treatment analogous to water softening. However, this option is likely to be more expensive and inconvenient than installation of a good well that yields nitrate-free water.

Rebecca W. Fox received a B.S. in medical technology from the University of Kentucky. She is completing a master's degree in environmental toxicology at UW-Madison.

Health Implications of Aldicarb Residues in Wisconsin Groundwater

By J. M. Harkin and G. Chesters
Environmental Toxicology Center, UW-Madison
F.A. Jones
Wisconsin Department of Agriculture, Trade, and Consumer Protection

In August, 1979 small amounts of unchanged or chemically modified derivatives of Union Carbide Agricultural Chemical Company's systemic insecticide aldicarb were identified in Long Island groundwater. Since then numerous attempts have been made to forecast whether similar contamination could occur elsewhere and how long residues in groundwater might remain at levels of concern for the health of humans or domesticated animals drinking tainted water.

Initially, the manufacturer developed a numerical rating system, based on knowledge of aldicarb use, weather patterns, and soil types to predict which areas of the country might be prone to problems with residues in groundwater. The central sands area of Wisconsin was ranked a distant second to Long Island in this scheme; other states followed far behind Wisconsin. Potatoes are grown in irrigated sands over shallow groundwater in the central sands and Long Island, but Wisconsin was considered at less risk for four reasons: 1) application rates were lower (two to three versus five to seven lbs of active ingredient per acre); 2) the Long Island aquifer is confined by sea water and does not discharge readily to the land surface, where aldicarb residues decompose almost immediately; 3) the Long Island water is slightly acidic, causing aldicarb residues to persist, whereas Wisconsin groundwater is hard or alkaline, tending to decompose aldicarb residues by chemical hydrolysis; 4) the average annual precipitation on Long Island is much higher (40 to 50 versus 30 inches/year) increasing chances of residue leaching.

Subsequent testing confirmed widespread contamination of Wisconsin groundwater with aldicarb residue at levels lower than those on Long Island, but some were still above those considered safe by government health advisories. As predicted, contamination levels in other states were lower still and incidences less frequent.

The large-scale rating system cannot predict whether a particular well near a pesticide-treated field will be polluted nor how long excessive levels in the locality might last. Such predictions require evaluation of all the factors which contribute to intrusion of aldicarb residues into groundwater, the rates and directions in which they spread once they are in the groundwater, and the mechanisms that lead to their dispersal and decomposition in and removal from groundwater. Each contributing factor must be weighted mathematically. Estimates of the magnitude of each factor should be derived from experimental measurements, but often, for lack of data, assumptions of reasonable average numbers must be made.

This process, called mathematical modeling, is so complicated that high-speed computers are needed to solve the equations involved. The accuracy of the method can be tested by comparing predictions with field measurements, or by varying values or estimates for each contributing factor, it can be determined which can best be manipulated by management practices to reduce pollutant inputs or persistence.

In hydrogeology, modeling was initially applied—with much success—to questions of water supply. It gave accurate predictions to practical questions such as the likely yield from wells placed at selected positions in aquifers and the rates of depletion and recharge during operation of these wells. Only recently, with the detection of greater numbers and amounts of contaminants in groundwater, have modeling efforts been applied to predict the spread of contaminants in aquifers and when contaminant concentrations are expected to fall to predetermined safe levels at selected locations.

To perform such calculations, measurements must be made of the aquifer's characteristics and the properties of the contaminant. Important parameters include the velocity and direction of groundwater flow, which in turn are determined by the hydraulic gradient (or pressure head) on the water and the porosity and uniformity of the medium through which it flows. Depending on the topography of the overburden and the resulting hydraulic heads, plus the presence or absence of confining rock or clay layers or fractured rock or gravel seams, groundwater may tend to flow laterally or downward at various angles and at varying velocities. Well established field-hydrogeological methods can be used to trace groundwater movement, however. The situation becomes more complicated when trying to analyze how contaminants behave as they move with the water.

Factors which influence how a stable, highly water-soluble substance moves in groundwater are **diffusion**, the natural spreading of a solute in stationary water due to molecular movement; **dispersion**, the spreading of the solute while moving with the water through the tortuous pathways between sand/gravel particles or along rock crevices in aquifers; **sorption**, interactions between the solute and the surfaces of the porous solid matrix through which it passes in solution. Sorption tends to retard movement of contaminants. Substances which are good sorbents are clay particles, because of their large surface area, and coatings of soil organic matter on soil particles. Soil organics have a strong affinity for most organic compounds and cations. Sorption plays a critical role in preventing the spread of many toxic

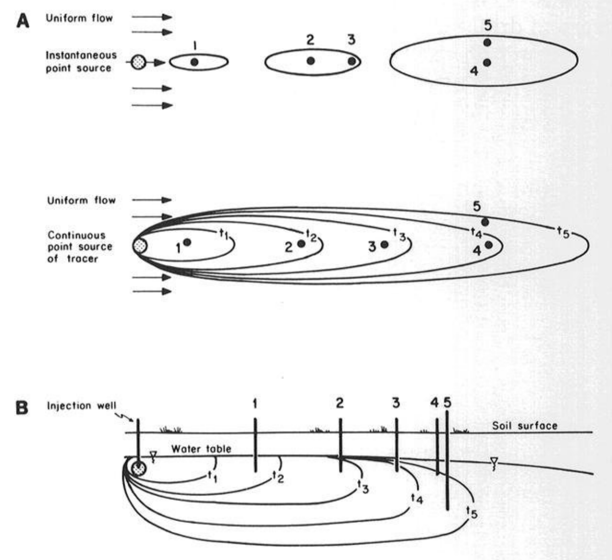


Figure 1. a. Detectable contaminant limits in two horizontal dimensions of the groundwater plume from a single-slug or continuous input. The spreading pattern assumes uniform lateral groundwater flow through an isotropic sand. b. Detectable contaminant limits with depth under similar circumstances. The concentrations decrease in water samples taken from interceptor wells in the sequence 1 > 2 > 3 > 4 due to longitudinal dispersion, and 4 > 5 due to transverse dispersion (Fig. 1a), and 1 > 2 > 3 > 4 due to longitudinal dispersion and 4 > 5 due to vertical dispersion (Fig. 1b).

environmental contaminants, particularly heavy metals and lipophilic persistent organics such as DDT, toxaphene, PCBs, dioxins, etc.

Figure 1a shows how a contaminant injected at a single point into groundwater is expected to spread as the groundwater moves downgradient from the point of injection. Two cases are illustrated, one for a single, one-time injection or "slug load," the other for a continuous steady injection of materials. In both cases, the dispersion of the contaminant increases with distance from the source. Monitoring wells installed downgradient from the point of injection can be used to withdraw samples for chemical analysis to determine contaminant concentrations. The concentrations encountered are not uniform across the oval areas designated, but are highest in the middle and decrease gradually toward the edges, which designate the limits of detection of the analytical methods.

The manner in which concentrations fall off from the center of the plume is difficult to predict: the concentration gradient may be linear or curvilinear, depending on the interplay of the physical parameters mentioned above. Prediction of concentrations becomes even more complicated when a third dimension is added to the picture, as in Figure 1b. The contaminant concentrations also decrease by spreading out with depth in the groundwater. To account for this phenomenon, interceptor wells are usually installed in clusters at various depths downgradient from contaminant sources, or multilevel samplers are used to trace the spread of the three-dimensional contaminant "plume" which expands like a gradually inflated balloon away from the input source.

Bromide is a stable chemical species not often found in or readily absorbed by soil and therefore often used as a tracer for contaminant plumes. Even for the simplest case possible, the movement of a single-slug injection of bromide into a homogeneous sandy aquifer through which movement of water was mainly lateral, expert hydrogeologists were unable to match predicted bromide concentrations with those measured in samples withdrawn from a field of numerous downgradient test wells.

The picture becomes more complex when chloride is used as a tracer even though it too is chemically stable and not absorbed. Chloride already present in the water and inputs other than an intentional single slug injection, e.g. from diffuse sources such as potassium fertilizers applied to fields or road salt, creates greater variability in measured concentrations. With groundwater pollutants of health concern, such as nitrate, the situation is further complicated by the multiplicity of its input sources, the transformations among different chemical forms of nitrogen, and the retention of one form (NH_4 cations) by soil particles. Removal mechanisms involving uptake by plants or incorporation by bacteria into soil organic matter or bacterial denitrification reduce nitrate flux from the surface to groundwater, and complicate prediction of nitrate leaching to and movement in groundwater.

Predictability is more difficult with complicated organic compounds such as aldicarb, which is incorporated into gypsum granules coated with carbon when applied to soil. Soil moisture gradually leaches some material out of these granules, and this rapidly changes in the soil. Oxidation at a sulfur atom it contains, thought to be catalyzed mainly by soil microorganisms, converts aldicarb (A) into two toxic derivatives—aldicarb sulfoxide (ASO) and aldicarb sulfone (ASO_2)—containing one or two oxygen atoms on the sulfur. These forms all have different water solubilities and tendencies to stick to soil particles or soil organic matter, factors which determine how fast they may be taken up by plants, leach to groundwater, or disperse in groundwater. Another complication is that each of these forms can be broken down to harmless fragments by chemical and microbial reactions in the soil. Rates of breakdown increase with temperature. Aldicarb residues are less of a problem in southern states for this reason.

The rates for each of the oxidation and breakdown processes differ. The interplay among rates of oxidation of A to ASO and ASO_2, the breakdown to nontoxic fragments, the uptake of each toxic form by plants, the retention of each by soil constituents, and the leaching by percolating rain and irrigation water determine how large a fraction of toxic residues may reach groundwater. Pesticide application rates and placement times, e.g., at potato seedpiece planting or above preformed roots at seedling emergence later in the season, irrigation schedules, rainfall patterns, and the variability of the soil help determine the amounts and concentrations of residues reaching groundwater.

Modeling aldicarb residue movement to and in groundwater is much more complicated than the textbook examples of tracer movement, because it does not involve a one-time slug or continuous injection directly into the water at a single point. Instead a complicated random pattern of intrusion occurs over a large area (about 130 acres in the irrigated circle of each 160-acre potato field). Experiments with field lysimeters, which collect all drainage water seeping through aldicarb-treated soil, show that residues do not percolate into groundwater in a uniform flow, but in waves of different concentrations. The pattern of aldicarb use from year to year also affects leaching patterns.

Once in the groundwater, aldicarb residues do not become distributed according to the simple rules for bromide or chloride in a uniform flow field. Although under normal circumstances groundwater oozes through the central sands sand-and-gravel aquifer at a rate of about one foot per day, mainly laterally in the direction of discharge points, high-capacity irrigation pumps perturb this flow pattern. Irrigation pumping draws water from the surrounding aquifer in a cone of depression, retarding the movement of downgradient water away from the fields and accelerating the flow of upgradient water towards the well. Pumping may also result in some vertical mixing of the water.

Soil percolation normally seeps into groundwater so slowly that it comes to rest gently at the top of the aquifer. Contaminants such as aldicarb residue it contained in groundwater therefore reside in a layer near the water table. Highest concentrations of aldicarb residues are found near the surface of groundwater six to twelve months after aldicarb use. If aldicarb is not used again, clean percolate can settle on top of the contaminated layer, causing it to sink in the aquifer. This and the effects of pumping cause some vertical distribution of aldicarb residues.

If aldicarb were stable, it might be relatively easy to predict its vertical distribution based on physical effects, but this situation is confounded by chemical and microbial breakdown. The water pH and alkalinity increase with depth in the aquifer, conditions which enhance the alkali-catalyzed hydrolysis of aldicarb residues to nontoxic products. The groundwater also contains substantial numbers of bacteria capable of slowly detoxifying and degrading aldicarb residues. These are not pathogenic or fecal bacteria but small species apparently adapted to living in the nutrient-poor conditions of groundwater.

The temperature near the groundwater surface fluctuates from about 4°C in March to about 20°C in August. The temperature fifteen feet below the water table is more uniform at 10 to 11°C. These temperature fluctuations may also promote vertical mixing of surface layers and affect the rates of chemical and microbial destruction of toxic aldicarb residues.

This complicated scenario makes aldicarb concentrations in groundwater extremely difficult to predict. A combination of mathematical models must be used: one for the leaching process, a second for the lateral and downward dispersion. Efforts to calculate concentrations deemed likely to be encountered in interceptor wells involve many assumptions concerning the appropriate values to use for aldicarb loadings, plant uptake, breakdown in surface soils, etc. as well as for rates of A and ASO oxidation and A, ASO and ASO_2 degradation in the plant rooting zone, the vadose (or unsaturated) zone between the rooting zone and the water table, and in the groundwater . In calculations performed so far, predicted values do not match those measured: the residues dissipate faster than predicted in some spots but persist longer than expected in others. Plots of concentration distribution cannot be made, because too many samples from monitoring wells contain no detectable residues. In contrast, the distribution of nitrate and chloride is easy to describe with a reasonable number of monitoring wells, because real values are found for each sample. Thus, we are still far from being able to predict how much aldicarb residues reach groundwater from farm use, and what happens to them once in the groundwater.

Health implications

Various advisories have been issued concerning levels of aldicarb in drinking water considered to be safe, which have reflected the toxicological information available when the guidelines were issued. This is also a complicated assessment.

The first value was produced by a National Research Council Committee on Drinking Water and Health, convened by the U.S. National Academy of Science. Their value of seven micrograms per liter or parts per billion (ppb) was for aldicarb itself, and was issued long before it was suspected that aldicarb residues would be found in groundwater. The value was derived to cover the eventuality of aldicarb occurrence in surface water. In fact, aldicarb is decomposed extremely rapidly and is never found in surface water. Aldicarb as such is never found in groundwater either, only a mixture of ASO and ASO_2. Most toxicological testing has been done with aldicarb, rather than ASO or ASO_2, but some data are available for all three forms. The acute toxicity (LD_{50}) of aldicarb is about 1 mg/kg in rodents; ASO is slightly more toxic ($LD_{50} = 0.9$ mg/kg); ASO_2 is about twenty-five times less toxic. Breakdown products have negligible acute toxicity. In plants and animals, aldicarb is also converted to ASO and ASO_2. Aldicarb, ASO and ASO_2 are not phytotoxic, or carcinogenic, mutagenic, or teratogenic. Thus, unlike many pesticides, aldicarb residues exhibit no known chronic toxic effects.

Because of its high acute toxicity, the level considered safe in drinking water is still low, but subject to much debate. The U.S. Environmental Protection Agency's (EPA) Office of Drinking Water recommends a level of 10, the EPA Office of Pesticide Programs 30, and the World Health Organization 50 ppb; this variability reflects the lack of agreement on what is considered to be an acceptable daily dietary intake and what magnitude of safety factor should be applied to derive the critical figure. Safety factors are predicated upon the amount of toxicological information available for the compound under consideration. A hundred-fold factor is used to derive the 10 ppb figure for aldicarb, ignoring the fact that experiments with human volunteers have been conducted. All of these values assume that an adult consumes about two quarts of untreated water daily.

In studies with rats, no physiological or clinical effects were observed with residue levels of 1,200 ppb in their drinking water. However, from ongoing studies with mice, UW-Madison researchers have suggested that 1 ppb of aldicarb in drinking water causes suspicious signs in a screening test for immune suppression. Surprisingly, this effect was less pronounced at higher aldicarb concentrations (10, 100, 1000 ppb)—an anomaly in toxicological science. Confirmation of this observation is still being sought. ASO and ASO_2 or their degradation products were not tested.

On Long Island, granular activated charcoal filters were used to purify the water. Since these are not 100 percent efficient, they could leave minor traces (in the ppb range) in water with initially high residue levels.

Most Wisconsin groundwater is hard, even in the central sands area of the state. The term "sand" describes the particle size of soil grains, not their chemical composition. While the glacial outwash sands do comprise mainly silica (quartz), they also contain dolomitic limestone grit, which contributes calcium and magnesium alkalinity to the groundwater. Values in central Wisconsin average over 100 mg/liter as calcium hardness or 1000 times the concentration of the highest contamination of aldicarb residues ever found in a Wisconsin household well. Boiling Wisconsin groundwater with 100 ppb of aldicarb residues to make tea or coffee completely destroys all the toxins by chemical hydrolysis. Deepening of contaminated wells led to aldicarb-free, but harder water.

Thus, prediction of aldicarb residue movement to and in groundwater is beyond our predictive capability, and the toxicological significance of aldicarb residues is still subject to scientific dispute.

Anyone with a well concerned about the possibility of its yielding water tainted with aldicarb residues should examine the history of aldicarb use in the area, the direction of groundwater flow, the depth of the well below the water table, and, if grounds for suspicion still exist, have an analysis for aldicarb residues performed. The safest and simplest ploy to avoid intake of aldicarb residues is to boil any water consumed, adding a minuscular pinch of baking soda if the water's natural alkalinity is low.

John M. Harkin obtained a B.Sc. (honors) degree in chemistry/biochemistry from the University of Glasgow, Scotland and a doctorate in chemistry, physics, and botany from the University of Heidelberg, Germany. After eleven years in the Research Institute for the Chemistry of Wood and Polysaccarides at the University of Heidelberg, he immigrated to the United States and worked at the USDA-FS Forest Products Laboratory. He is professor of soil science at UW-Madison with a joint appointment in the Water Resources Center and is associate director of the Environmental Toxicology Center at UW-Madison.

Frank A. Jones is a soil scientist in the Wisconsin Department of Agriculture, Trade and Consumer Protection. He holds a B.S. (cum laude) in biology from Loyola University of Chicago and is completing a Ph.D. in the environmental toxicology program at UW-Madison. His research deals with modeling the transport of pesticides—particularly aldicarb—in soils (roots and vadose zones) and groundwater.

Bacterial Breakdown of Aldicarb Residues in Groundwater

By E. Kudjo Dzantor and J. M. Harkin
Environmental Toxicology Center, UW-Madison

Advances in chemical technology have improved our standard of living but increased the hazards to man and the environment. The manufacture and use of chemicals result in generation of wastes that threaten the environment when improperly managed. Knowledge of the environmental impact and mechanisms and rates of breakdown of chemicals is inadequate. The past few years have seen a spate of chemical accidents that have degraded natural resources, especially water supplies.

Biodegradation is critical for removal of organic chemicals from the environment. Until recently, the question of whether it is significant in groundwater has received only minor attention. Two factors have impeded study of biodegradation in groundwater: the conceptualization of the occurrence of significant numbers or activities of microorganisms in an environment traditionally considered sterile because of its harsh nutritional, temperature, and aeration regimen; and the physical difficulty of sampling the subsurface aseptically. Groundwater contamination has led to a reexamination of the role of microorganisms in cleansing polluted aquifers. New methods have been devised which facilitate aseptic sampling of groundwater, characterization of its microbial population, and potential for degradation of organic contaminants. Microbial degradation in groundwater has been demonstrated for naturally occurring compounds; such synthetics as toluene, chlorobenzene, and styrene; the phenolic compounds in creosote; and bituminous hydrocarbons in oil sand deposits.

The compound attracting most attention as a groundwater contaminant in Wisconsin is aldicarb, a soil-incorporated pesticide which systemically controls insects, mites, and nematodes in crops. It is used in the central sands region of Wisconsin primarily to control Colorado beetle, leaf hoppers, green peach aphids, flea beetles, and nematodes on potatoes. Its effectiveness depends on its ease of uptake from soil. The high water solubilities of aldicarb and its two insecticidal metabolites (aldicarb sulfoxide and aldicarb sulfone) enhance their pesticidal efficacy, but facilitate groundwater contamination especially when aldicarb is used on permeable sandy soils with relatively high water tables under irrigation. Aldicarb and its oxides have been shown to be broken down by microbiota in the topsoil. It is important to determine whether microorganisms also transform aldicarb residues which have entered groundwater.

Sampling

To study this question, groundwater samples were taken aseptically using autoclave-sterilized equipment. To avoid extraneous contamination, sampling wells were voided several times to ensure collection of aquifer water rather than water that had been standing in each well.

An aseptic drilling technique was used to sample groundwater sediments. A split-spoon sampler lined with a sterilized plastic liner was pounded into the sediment at depths below the water table. Portions of the core were separated under sterile conditions ensuring that only the center portions of the samples were used, minimizing chances of contamination by ambient bacteria.

Testing

Bacterial counts were made using traditional pour-plate techniques with a yeast extract (0.05 percent) and glucose (0.05 percent) agar medium made with groundwater. Samples were examined for the presence of fungi on pour-plates of Rose Bengal-streptomycin agar.

Bacterial colonies isolated were characterized by routine identification protocols; mixed populations and individual isolates were tested for ability to form colonies on plates with mineral salts plus purified agar containing only aldicarb or one of its oxides as carbon and energy source.

Bacterial decomposition of radiolabeled aldicarb, aldicarb sulfoxide, and aldicarb sulfone was measured by $^{14}CO_2$ evolution from pesticide-amended groundwater samples incubated in the dark for nine to ten weeks.

Groundwater organisms

Bacterial counts for groundwater and sediment samples are shown in Tables I and II. The counts were fairly uniform in the range of 10^3 colony forming units (cfu) per milliliter of groundwater and 10^4 cfu/g of dry sediments; no changes in overall composition were observed over a two-year period. Fungi were never isolated from groundwater sediments.

Results are consistent with the mounting evidence supporting occurrence of substantial bacterial populations in groundwater. To obtain samples representative of *in situ* conditions, wet sediment collection by drilling is far superior to well water collection; however, the latter method still enjoys popularity because of its simplicity and low cost.

As with any live count method, our bacterial counts are limited to organisms that grow on the selected media. Our aerobic techniques preclude isolation and enumeration of obligate anaerobes, which may constitute a major portion of groundwater microflora. Consequently, the bacterial counts observed may be far below the total numbers of bacteria in groundwater or aquifer sediments. Higher direct counts of subsurface bacteria have been reported elsewhere. Despite our inadequate knowledge of the cultural preferences of groundwater bacteria, the composition of the population observed was quite diverse, and the counts were relatively high.

Table I. Enumeration of Groundwater Bacteria

Sampling date	Site/ Field	Wall depth, ft	Depth to water table, ft	Mean bacterial counts, cfu/ml $\times 10^{-3}$
11/82	4D/5	29	6.5[1]	2.7
1/83	1A/6	2.9	4.9	7.4
	1B/6	7.2	5.2	6.0
	5A/6	12	4.5	8.4
	5B/6	7.2	4.9	8.0
2/83	1A/6	2.9	5.6	4.6
	1B/6	7.2	5.9	5.3
	5A/6	12	5.6	3.0
	5B/6	7.2	5.6	4.9
3/83	1A/6	2.9	3.9	4.8
	1B/6	7.2	3.9	3.5
	5A/6	12	3.6	5.1
	5B/6	7.2	3.6	4.8
8/83	5A/7	10	5.2	3.7
9/83	5A/7	10	4.5	0.6
12/83	5A/7	10	nd	0.9
	5B/7	7.5	nd	0.6
5/85	5A/7	10	3.9	5.2
12/84	5A/7	10	nd	4.5

[1] Measurements from 12/83.
nd Not determined.

Table II. Enumeration of Bacteria in Two Aquifier Sediments Collected in December, 1984

Sample No.	Sampling depth, ft.	Mean bacterial counts, cfu/g dry sediment $\times 10^{-4}$
1a	7.5	9.0
1b	10	8.5
1c	15	4.7
2a	7.0	6.2
2b	10	4.7

Eighteen isolates showed obvious differences in gross colony morphology, cell size and shape and cultural peculiarities. Ten were Gram positive, eight Gram negative. Their sizes ranged from relatively large spore-forming *Bacillus* spp. to small rods or ovoid cells. Rod-cocci dimorphism was frequently observed.

Most isolates were facultative anaerobes, with some preferring low oxygen levels. These organisms grew better inside rather than on the surface of the agar. Nine isolates tentatively have been identified: three *Bacillus*, two *Corynebacteria*, three *Flavobacterium*, and one *Cytophaga*. Their nutritional requirements ranged widely: the *Bacillus* spp. were generally indiscriminate with regard to culture substrate composition and concentration, the *Flavobacterium* spp. grew well on dilute yeast extract-glucose agar but only slowly or not at all on nutrient agar. Some bacteria grew on agar plates only in association with other colonies and could not be isolated.

The size and properties of the isolates strongly suggest that they are indigenous to the subsurface. However, it is uncertain whether some species might be indigenous to groundwater while others are recent arrivals with percolating water. It might be argued that the *Bacillus* spp.—well-known soil inhabitants—exist in the aquifer as endospores leached into the groundwater and do not constitute actively metabolizing groundwater bacteria. Some of the genera are typically found in the vadose (unsaturated) zone between the root zone and water table. Many of our isolates were pigmented, an observation which has been reported elsewhere, but some investigators argue that groundwater bacteria should have lost such a trait since it is a characteristic useful only at the surface. The question of whether groundwater microorganisms are indigenous or transients is irrelevant if the transients adapt to subsurface conditions and remain metabolically active. *Pseudomonas stutzeri* is strictly aerobic and generally inhabits the vadose-zone, but was found in a creosote-contaminated aquifer. This organism metabolizes such groundwater contaminants as phenol, and may be important in removing phenols from polluted aquifers.

Table III. Mineralization of Aldicarb and Its Oxides in Groundwater Samples[1]

Compound	Duration of incubation, days	% of added ratioactivity, evolved as $^{14}CO_2$ at 10°C	20°C
Aldicarb	70	0.9	0.3
Aldicarb sulfoxide	63	3.6	5.9
Aldicarb sulfone	63	1.3	12.6

[1]Means of at least 2 replicates.

Aldicarb residues biodegradation

Table III shows the microbial breakdown with time of radiolabeled aldicarb, aldicarb sulfoxide, and aldicarb sulfone to $^{14}CO_2$ in groundwater samples. Incubation temperatures of 10°C and 20°C were chosen to represent the mean and highest annual groundwater temperatures in central Wisconsin.

About 6 percent of the ^{14}C in aldicarb sulfoxide and 12 percent in the sulfone were converted to $^{14}CO_2$ after nine weeks. These rates converted to 0.10 and 0.19 percent/day for the sulfoxide and sulfone. Aldicarb breakdown was ten times slower. This was confirmed by autoradiographic studies using sediments. However, since some experiments have shown that only aldicarb sulfoxide and sulfone, not aldicarb itself, are the pesticide residues in Wisconsin groundwater, the slower rate of aldicarb breakdown may be relatively unimportant.

Evolution of $^{14}CO_2$ from aldicarb sulfoxide showed a typical degradation pattern: a lag (acclimation) phase of two to four weeks followed by a period of rapid mineralization. Evolution of $^{14}CO_2$ from aldicarb sulfone showed no lag phase but reflected the degradation pattern of an acclimated population. With the sulfone system at 20°C, some radioactivity was incorporated into the bacterial cells, as measured by radioactivity trapped on membrane filters.

Some isolates formed pinpoint colonies on aldicarb or its oxides used as sole carbon source. Ability of a bacterium and five soil fungi to utilize aldicarb as a sole carbon source or degrade it as a cometabolite has been reported previously.

Significance of findings

The relative newness of groundwater microbiology makes such work difficult. Pour-plate methods do not accurately predict *in situ* numbers of environmental mixed bacterial populations because of their varied cultural preferences. This problem is worse for groundwater bacteria whose nutritional and cultural preferences are even less well defined. Use of groundwater rather than aquifer sediments gives poorer estimates of true *in situ* rates of biodegradation. Finally our measurement of $^{14}CO_2$ does not provide an accurate picture of the rate of detoxification of aldicarb residues by microbial degradation in groundwater. The aldicarb used was labeled in such a position that $^{14}CO_2$ evolution could only come from complete mineralization. Aldicarb and its oxides, however contain amide and ester bonds hydrolyzable by enzymes which occur in a free state in soils and groundwater. In bacteria these enzymes can transform pesticide residues into nontoxic fragments long before they are converted to $^{14}CO_2$.

Conclusion

Substantial numbers of bacteria exist in the saturated regions of soil. Under certain conditions these microbial populations degrade pollutants in groundwater. Our results show that the oxides of aldicarb—aldicarb sulfoxide and aldicarb sulfone—can be mineralized by bacteria inhabiting groundwater. Observations about biodegradation potential made under laboratory conditions are still difficult to relate to field conditions.

Interest in deploying microorganisms to clean up polluted aquifers has been gaining momentum with advances in biotechnology. Of equal importance is the need to understand the biology of groundwater and the mechanisms by which groundwater bacteria transform chemical pollutants. The need for a sustained research effort in these areas cannot be overemphasized.

E. Kudjo Dzantor received his B.S. (honors) degree in agriculture from the University of Science and Technology, Komasi, Ghana. He earned M.S. and Ph.D. from UW-Madison in soil microbiology and biochemistry. From 1982 to 1984 he was a postdoctoral trainee in the Environmental Toxicology Center at UW-Madison and has recently been involved with various environmental science research projects.

The Great Phosphate Debate:

Does Detergent Formula Affect Groundwater Contamination?

By B. J. Alhajjar and J. M. Harkin
Water Chemistry Program, UW-Madison

Protection of groundwater is important to Wisconsin for two reasons: *people depend heavily on groundwater for drinking water and polluted water may cause public health hazards* and *nutrient-bearing groundwater discharging to surface water can contribute to eutrophication of recreational lakes and streams that are important to the tourism economy.* This document summarizes a doctoral thesis by B. J. Alhajjar (1985) at the University of Wisconsin-Madison.

Trends favor establishing permanent residential development around highly desirable lakeshores in rural areas. Present policies on public sewer extensions favor relying on septic systems as a permanent means of wastewater disposal in outlying areas. Wisconsin has more than 600,000 septic systems, with many in sandy soils where the biochemical and physical purification processes of household wastewater may be insufficient. Septic tank effluent not sufficiently purified during soil percolation may pollute groundwater with phosphorus (P), nitrogen (N), bacteria, and viruses.

A ban on P in detergents in Wisconsin (Chapter 375 W.S., 1977) provoked concern for the effects that P-free, carbonate (CO_3)-built detergent might have on the performance of septic systems. Such concerns justified initiating an investigation of the effects which P-built and P-free detergent formulations have on the performance and treatment efficiency of septic systems and on the quality of groundwater under coarse-textured soils close to discharge areas. A particular focus was on the potential movement of N, P, bacteria, and viruses into the groundwater from septic systems. Two groups of septic systems were studied. The first comprised eight systems receiving wastes from households using P-built laundry detergent. Nine systems in the second group received wastes from households using P-free, CO_3-built detergent. All were new or replacement systems of approximately the same age, located in sandy soils over shallow aquifers close to groundwater discharge areas in south-central Wisconsin (Fig. 1). Each homeowner was given a supply of P-built or P-free detergent for the study and requested to keep records of the load size and frequency of laundry, and the nature and frequency of use of laundry additives (bleaches, fabric softeners, etc.).

The direction of local groundwater flow at each site was determined using a "Dowser" model 10 groundwater flow meter (K-V Associates, Falmouth, Mass.). Three wells were placed in the effluent plume downflow from the drainfields of individual septic systems. Groundwater monitoring wells labeled No. 1 were 30 cm from the edge of the drainfield and Nos. 2 and 3 were downflow at intervals of 3 m. Background (control) monitoring wells labeled No. 4 were more than 10 m from the edge of the drainfields upflow in the hydrologic gradient at each site. Additionally, wells labeled No. 5 were installed immediately adjacent at the drainfield at sites 8 (a P system) and 10 (a CO_3 system).

All wells extended to a depth of 1 m below the water table and were sealed to prevent intrusion of surface water. The soil removed from drill holes was placed in sequence on a clean sheet of plastic and the soil profile was described. Water meters were installed at each household and water loads to individual septic systems were determined.

Depth to the water table from the land surface was measured for each well just before pumping to determine the seasonal fluctuation of water table in the vicinity of the systems.

Each month for two years, samples of effluent from each septic tank and water from wells in the vicinity of each system were collected in clean plastic bottles and kept on ice

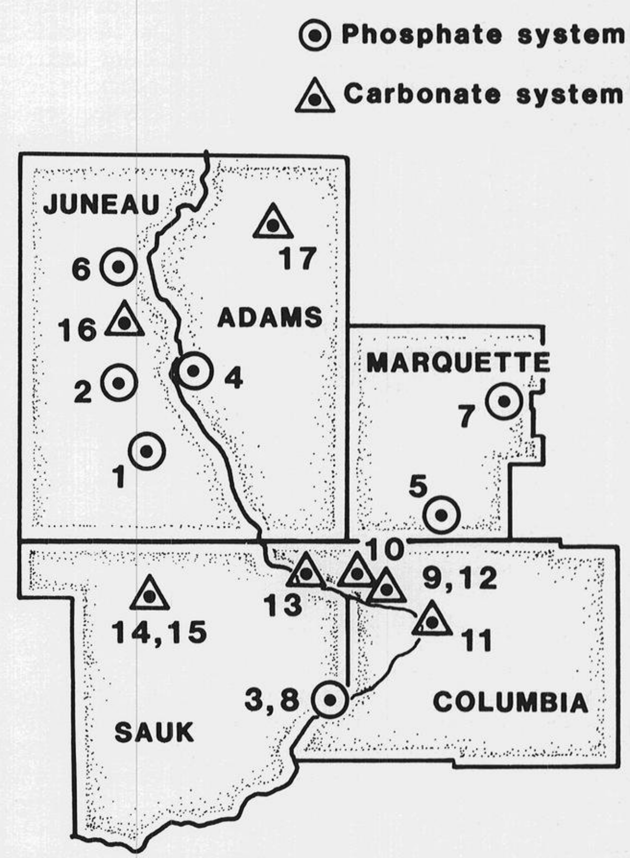


Figure 1. Locations of septic systems.

during transport to the laboratory where they were refrigerated at 4°C. Samples for bacterial and viral analyses were collected in sterilized bottles. Temperature and pH were measured on effluent and water samples *in situ*.

The septic system at site 8 was inoculated with a total poliovirus dose of 3.3 x 10^{10} count/100 ml by flushing down the toilet. The inoculum was obtained from stools containing various combinations of the three polio virus serotypes in diapers of infants who received the Sabin trivalent oral poliovirus vaccine. Over a period of six months, effluent and groundwater samples were collected for virus analysis from the septic tank and the monitoring wells. Data for the virus study were collected by Stramer (1984).

At the end of the study, soil samples at the gravel-soil interface (the site at which a clogging mat forms naturally in septic systems) were collected at each system and a total carbon analysis was made. A followup was conducted by a last round of sampling at all sites after approximately five years of system operation.

Laboratory analysis

Total coliforms (TC), fecal coliforms (FC), and fecal streptococci (FS)—used as indicators for the presence of pathogenic bacteria—and poliovirus (PV) were assayed at the Food Research Institute, UW-Madison; assays were begun within twelve hours of sampling. Chemical analyses were conducted at the Soil Science Department, UW-Madison. Chloride (Cl), electrical conductivity (EC), sodium (Na), nitrate (NO_3), ammonium (NH_4), total N, ortho-P (soluble), and total P were determined on effluent and groundwater samples. Potassium (K), calcium (Ca), magnesium (Mg), biochemical oxygen demand (BOD), solids (total, total volatile, total suspended, and volatile suspended), alkalinity, and indicator bacteria were determined on effluent samples. Indicator bacteria were counted regularly in water samples from the wells near septic system Site 8 and occasionally in others. Fluorescence was determined on water samples; turbidity interfered with measurements in septic tank effluent.

Data were examined thoroughly, statistically evaluated, and modeled at individual sites by applying techniques that are either discriminatory or not to outliers. The data were pooled at individual effluent and groundwater sampling locations based on detergent type for sites 1 to 8, 9 to 17, and all sites. The resulting pooled populations were statistically evaluated. The Cl concentrations were used as tracers to estimate amount of undiluted effluent in the plume of pollution at wells 1, 2, 3 and 5. Monte Carlo (stochastic) simulations were used to account for various sources of uncertainties on estimates of contaminant transport to groundwater or contaminant removal in the soil. Association of a simple contaminant transport model with stochastic simulation properly described the transport of effluent P, N, TC, FC, and FS but not PV groundwater. The combined model provided applicability to a large area, accountability for variations in data and greater power of prediction. Simulations were sound by statistical evaluation and the conclusions that resulted from other statistical techniques were comparable to the simulated results.

Linear multiple regression models were used to investigate which effluent characteristics were important in predicting quality of effluent from septic systems as a function of detergent type.

Statistical analysis and stochastic transport modeling of the large two-year data base from the two groups of septic systems receiving detergents of two types led to the following conclusions:

1. Drawing general conclusions from a single constituent could yield misleading information about the nature and distribution of other groundwater contaminants. In particular, conclusions drawn on the nature of P and N from Cl, EC, or fluorescence are usually misleading.
2. Based on median values, all septic systems under investigation were seeping NO_3 to the local groundwater and 12 of 17 systems in excess of the drinking water standard of 10 mg/liter as NO_3-N.
3. Significant local groundwater contamination by NH_4 (median of greater than 1 mg/liter as N) was detected in 5 of 17 systems in the immediate vicinity of the absorption fields. However, only one system remained high in NH_4 at a distance of 6 m from the drainfield.
4. Soils at individual septic systems were extremely efficient in removing P from effluents regardless of their coarse texture. Even after receiving septic tank effluent leachate, groundwater at all sites contained a median of <0.1 mg/liter of total P, the level EPA recommended to control eutrophication at points where waters are not discharging directly to lakes and streams.
5. Results from the simulation transport of effluent—inferred from Cl concentrations—for N and P are found in Table I.

Table I. Summary Percentages from the Monte Carlo simulation of the amount of effluent, total nitrogen transported (NT), and total phosphorus transported (PT) to the intercepted groundwater plume from septic systems receiving laundry wastes of P-Built and CO_3-built detergents, and all systems combined

	No. of samples	mean	90% confidence interval
	P-Built Detergents		
Amount of effluent (%)[1]	595	39	38–40
% NT	595	54	51–57
% PT	595	0.52	0.35–0.70
	CO_3-Built Detergents		
Amount of effluent (%)	444	45	35–54
%NT	444	94	92–96
%PT	444	0.05	0.02–0.08
	All Systems		
Amount of effluent (%)	1,039	42	36–47
%NT	1,039	71	69–72
%PT	1,039	0.32	0.26–0.39

[1]Inferred from C1 concentrations.

Table II. Summary Percentages from the Monte Carlo simulation of the amount of effluent, total coliform transported (TCT), fecal coliforms transported (FCT), and fecal streptococci transported (FST) to the groundwater plume intercepted at site 8

	No. of Samples	Mean	90% confidence interval
Amount of Effluent (%)[1]	600	19	16–21
% TCT	600	1.0	0.8–2.0
% FCT	600	0.2	0.12–0.23
% FST	600	0.2	0.17–0.21

[1]Inferred from C1 concentrations.

The P transported (percent PT) to the monitoring wells did not exceed a mean of 1 percent (a mean of <0.1 mg/liter) for both groups of sites. **Therefore, neither detergent type contributes to groundwater contamination by P, and properly functioning septic systems are not a source of P to groundwater, are not a biological nuisance, and do not contribute to lake eutrophication.** Conversely, the mean level of N transported to groundwater (percent NT) is 54 and 94 percent respectively from septic systems receiving laundry wastewater of P- and CO_3-built detergents. This corresponds to 39 and 69 mg/liter of N reaching groundwater from septic systems processing P- and CO_3-built detergents. This means that the systems leached an average of four and seven times more N to local groundwater than the recommended standard of 10 mg/liter with P- and CO_3-built detergent use. The use of P-built detergents reduces N transport to groundwater by approximately 57 percent.

6. Although banning of P from laundry detergents reduces the P load reaching sewage treatment plants in sewered areas, thereby reducing the cost for tertiary treatment for P removal and for sludge disposal on land, it is not recommended in unsewered areas where septic systems are in use and groundwater contamination by N is more critical. Unsewered areas should not be included and affected by the P ban in laundry detergents, as recommended by the Wisconsin Center for Public Policy (1984). A P detergent ban does not have to be statewide: regional and/or municipal bans could be implemented. The current P ban on laundry detergents in Wisconsin, however, does have some environmental benefits. Only 55 of Wisconsin's 600 sewage treatment plants have P removal capacity sufficient to reach the purification standard of 1 mg/liter P. Until the rest of the treatment plants are upgraded, the P ban serves as an interim measure for improving water quality of the state's lakes and waterways and the Great Lakes. On the other hand, the ban places some economic burdens on the consumer due to higher detergent use for P-free formulations. Our results showed that households receiving CO_3-built detergent laundered slightly more frequently and used considerably more detergent than households using P-built detergent (average of 76 and 66 loads/year/capita, and 20 and 12 g detergent/day/capita).

7. Results of simulated transport analysis of effluent—from chloride data—for TC, FC, FS, and PV are presented in Table II. Indicator bacteria were not transported to local groundwater but were completely removed by the soil under the seepage bed. The means of numbers of TC, FC, and FS transported were >1 count/100 ml of groundwater, in keeping with the U.S. Public Health Service drinking water standard. On the other hand, the inoculated PV managed to escape from the system in the effluent entering the soil under the seepage bed. Of the 3.3 x 100^{10} counts/100 ml of poliovirus inoculated into the septic tank, a mean of 70 counts/100 ml escaped from the tank with the effluent and an overall mean of 62 counts/100 ml was transported to groundwater (88 percent transport).

8. An extremely important observation was the greater likelihood that viruses are encountered in water from wells at a greater distance from the septic tank system than those close to it. This corresponded with the higher ionic strength closer to the septic systems. Viruses appear to be adsorbed to the sediments of the unconfined aquifer closer to the septic system due to high ionic strength, and to desorb farther away from the drainfield as a result of reduction in ionic strength. Ionic strength of groundwater from well 5 was four times higher than that of water from other wells.

9. Indicator bacteria (TC, FC, and FS) cannot be used as indicators for the presence of viruses; the soil retained the indicator bacteria but not the much smaller virus. Virus contamination of groundwater through septic tank leachate resulted from what was otherwise a well-functioning conventional system. The system was new and had no clogging layer when the tests were conducted. An older system with a mature clogging mat might not leak as many viruses.

10. Results of multiple regression analyses also indicated improved retention of NH_4 with the use of P-built detergent. This may be due to precipitation in the septic tank of $MgNH_4PO_4$ and/or nitrification followed by denitrification in the soil. However, effluent quality was better with the CO_3-built detergent and groundwater pollution by other chemical species based on Cl data was higher with P-built detergent. This must be because Na tripolyphosphate in the P-built detergent is a complexing agent for cations, whereas Na_2CO_3 in the P-free detergent is a precipitating agent for Ca and Mg. These cations attract such anions as Cl, and Na, K, Mg, and Ca as well as Cl concentrations were significantly higher in effluents from systems receiving P-built detergents. For the same reason, EC, alkalinity, filtered and unfiltered total solids, total volatile solids, total suspended solids, volatile suspended solids, temperature, Na adsorption ratio, and BOD were higher in systems receiving P-based detergents. With its higher nutrient and energy content this effluent may stimulate growth of denitrifying bacteria, thus enhancing N loss to the atmosphere and significantly reducing groundwater contamination by N. The amount of carbon—an energy source for bacteria—in the clogging mat was on average four times higher with P-built than CO_3-built detergent.

11. Multiple regression analyses showed the effect of CO_3-built detergent was to increase buffer capacity of effluents thereby preventing the drastic pH increase expected. No significant differences in pH were found in the two types of effluents resulting from detergent use.

12. Total counts of indicator bacteria in effluents obtained from households using P-built detergent were approximately 10 percent higher than for those using CO_3-built detergent. This increase in bacterial growth as a result of the excess P from the P-built detergent caused slightly improved treatment and degradation of organic matter.

13. Fluorescence was not a good tracer for detecting plumes of contamination emanating from septic systems. The fluorescence in the water resulted from materials, such as humic or fulvic acids, other than optical brighteners derived from laundry products; optical brighteners generally did not pass undecomposed through the septic system.

14. Shallow groundwater quality in the Wisconsin, Lemonweir, Yellow, and Baraboo river basins of south-central Wisconsin is relatively better than the Fox and Mecan river basins; this may be due to greater human activities in the latter basins.

Bashar J. Alhajjar received his B.S. degree in agriculture and soil science from the University of Baghdad, Iraq. He completed the M.S. degree in soil science and is working on a Ph.D. in water chemistry at UW-Madison.

Nutrient Loads to the Madison Lakes

By William Sonzogni
State Laboratory of Hygiene and UW-Madison

The Madison lakes, Mendota, Monona, Waubesa, Kegonsa, and Wingra, are among the most studied lake chains in the world. These lakes are highly eutrophic, i.e., they receive large additions of nutrients. Nuisance blooms of algae and lush growths of aquatic weeds are common manifestations of eutrophication in each of the lakes.

Pioneering work on the relationship between nutrient loads and in-lake nutrient concentrations was done on the Madison lakes, particularly Lake Mendota. Much of the nutrient data collected over the years have been on phosphorus (P), which is believed to be the limiting nutrient over most or all of the year in the Madison lakes. Over twenty investigators have collected in-lake P data on Lake Mendota since 1925.

Since the early 1940s, no particular trend in P concentrations in Lake Mendota is apparent. The pre-1940 data are lower than the post-1940 data, but it is not clear that there was an actual historical increase in the P concentration of the lake. One explanation for the increase about 1940 is a change in the analytical method for P. Other data such as nutrient loading or zooplankton data do not suggest a change in the P concentration.

Nutrient load estimates

Several studies have estimated the nutrient loads to the Madison lakes. The first study, in the 1940s under the direction of C. N. Sawyer, was probably the first of its kind worldwide. Not until the 1960s was the importance of determining the rate of nutrient inputs generally recognized.

The most recent estimates of the nutrient loads to the Madison lakes were made during the 1970s. Table 1 shows update of P loads to Lake Mendota. Data are presented for soluble P (SRP) and total phosphorus (TP). These loads were developed from detailed sampling during 1976 and 1977, and the data were adjusted to represent typical conditions based on long-term flow records. Loads can vary greatly from year to year, primarily as a result of annual variations in runoff. Our study estimated (based on unit area load data) that rural runoff TP inputs to Lake Mendota could range from 5400 to 52200 kg. Extreme events could widen this range.

Nitrogen loads for Lake Mendota given in Table 2 are rough at best, as nitrogen inputs are not as easily quantified as P. Runoff inputs can vary as widely as rural runoff as estimated from unit area loading coefficients. Rural runoff loads of total nitrogen (TN) were 160000 kg in 1976 but only 48000 kg in the low flow year of 1977. TN urban runoff inputs were estimated to be 20000 kg for 1976 and 26000 kg for 1977. High base flow (stream flow during periods of no runoff) loads represent the high nitrate levels typically found in groundwater in the Madison area. Because this source of nitrogen is uncontrollable, as well as sources such as groundwater seepage and nitrogen fixation, control of nitrogen inputs to the Madison lakes does not appear to be a viable management option.

Table 1. Estimated Typical Annual Phosphorus Load to Lake Mendota

	kg SRP	kg TP
Wastewater discharge	0	0
Urban runoff	2,500	5,000
Rural runoff	12,000	25,000
Precipitation on lake surface	800	1,000
Dry fallout on lake surface	1,000	2,400
Groundwater seepage	150	150
Base flow	2,500	4,100
TOTAL	18,950	37,650

a From Lathrop (1979)

Table 2. Estimated Typical Annual Nitrogen Load to Lake Mendota[a]

	kg Inorg. N		kg Total N	
Wastewater Discharge	0		0	
Urban Runoff	7,700		33,100	
Rural Runoff	145,200	(26,300-313,000)[b]	235,900	(52,200-521,600)[b]
Precipitation on Lake Surface	23,600		31,300	
Dry Fallout on Lake Surface	29,500		61,200	
Groundwater Seepage	77,600		77,600	
Base Flow	61,200	(135,000)[c]	61,200	(160,000)[c]
Nitrogen Fixation	0		39,900	
TOTAL	344,800		540,200	

[a] From Sonzogni and Lee (1974)
[b] Range estimated in Sonzogni and Lee (1974)
[c] Baseflow load based on the average of 1976 and 1977 measurements given in Lathrop (1979)

Less attention has been given to the lower lakes in the Yahara chain than to Lake Mendota. Table 3 presents a summary of P loadings for lakes Monona, Waubesa, and Kegonsa. The largest source for each of the lakes is the Yahara River, the input from the upstream lake. Runoff appears to be the other significant contributor.

The smallest of the Madison lakes, Wingra, does not receive input from the Yahara River but is spring fed. Estimated loadings to the lake are given in Table 4. Urban runoff is the principal source of P to the lake. Sedimentation ponds in the Lake Wingra basin installed since these 1972 estimates may have reduced loadings. Groundwater input (spring flow) is the principal source of inorganic nitrogen. Because of this natural source of nitrogen, it would be virtually impossible to control nitrogen input to the lake.

Table 3. Estimated Typical Annual Phosphorus Load to the Lower Madison Lakes*

	Monona		Kg Waubesa		Kegonsa	
	SRP	TP	SRP	TP	SRP	TP
Wastewater Discharge	0	0	0	0	900	1,000
Urban Runoff	3,000	6,000	2,000	3,000	300	400
Rural Runoff	1,000	2,000	2,000	5,000	4,000	7,000
Precipitation on Lake Surface	200	300	100	200	200	300
Dry Fallout on Lake Surface	200	1,000	100	700	200	1,000
Yahara River	11,000	15,000	9,000	13,000	10,000	14,000
Lake Wingra via Murphy Creek	50	2,000	—	—	—	—
TOTAL	15,400	26,500	13,200	21,900	15,600	23,700

*from Sonzogni and Lee (1975)

Table 4. Estimated Typical Annual Phosphorus Load to Lake Wingra*

	kg SRP	TP
Urban Runoff	570	980
Precipitation on Lake Surface	50	140
Springflow	30	80
TOTAL	650	1,200

*From Kluesener 1972.

Fertilizer Spill

During April of 1984 a major fertilizer spill occurred in the Lake Mendota watershed. A liquid fertilizer tank in the western portion of the watershed was inadvertently drained. Because this occurred during a rain storm, the ammonium phosphate was transported to Pheasant Branch Creek, which drains into the northwestern end of Lake Mendota. Department of Natural Resources officials estimated that about 5000 gal (18925 L) of the fertilizer reached Lake Mendota. The State Laboratory of Hygiene estimated that over 4000 kg of SRP entered Lake Mendota from this spill. This amounts to more than 20 percent of the estimated annual input of SRP.

Although an input of this magnitude is important, variations in the P load of that size occur naturally as random runoff. In fact, later in the spring of 1984, several large runoffs occurred, and following this the Madison lakes were at record or near record water levels. Because rain came before a plant cover was established, the amount of sediment and associated nutrients from rural runoff during this period was large. The fertilizer spill and runoff inputs caused nutrient input to Lake Mendota during 1984 to be unusually high, an impact likely to be observed over the next several years. Any conclusions about current weed growth and algal growth in Lake Mendota should consider this information.

Bioavailability of P

Although land runoff is a major source of TP for the Madison lakes, much P that enters the lakes is particulate P, not all of which can be utilized in the growth of algae and macrophytes. For example, in Great Lakes tributaries potentially bioavailable particulate P amounted to less than 40 percent of the total particulate P. Since in many streams (including those draining into the Madison lakes) the particulate P makes up about 50 percent or more of the annual input of the TP, a large part of the P entering streams appears to be biologically unavailable. By contrast, sewage treatment plants discharge P in a form that is highly bioavailable.

Internal cycling of nutrients

In addition to external sources of nutrients, nutrients are cycled internally among the different lake compartments, such as sediments, zooplankton, water column, and fish. The interactions are complex. However, changes in the biological makeup of the lakes could influence their nutrient concentration. For example, a poor-year class of planktivorous fish could conceivably result in decreased grazing of zooplankton. Large crops of zooplankton could, in turn, reduce phytoplankton concentrations. Thus, in-lake P concentrations could decrease due to reduced uptake of P by phytoplankton. Alternately, the excess P might be available for uptake by a different source, for instance, macrophytes.

Probably the most studied aspect of P cycling has been the exchange of P between lake water columns and sediments. While it is clear that lake sediments are a sink for P over the long term, the overall importance of sediments in maintaining high P levels over the near term is still much debated. For example, if external P inputs to a lake were eliminated, it is not clear how long release of P from bottom sediment would maintain high P levels, that is, eutrophic conditions.

There is no question that P builds up in the bottom of waters of the Madison lakes during stratified conditions (surface and bottom waters do not mix). As the depth of mixed layer is progressively lowered during the summer-fall season (as the result of wind induced mixing often associated with the passage of cold fronts), soluble reactive P is entrained in the P deficient surface layer. This P pulse is often followed by a bloom of algae.

Options for reducing inputs

To control excessive production in lakes, one must control the sources of nutrients to the lakes. However, the steps already taken to control or eliminate nutrient sources in the Madison lakes limited the remaining options.

Rural runoff and urban runoff offer the best possibilities for further control. No point sources of importance—sewage treatment plants and industrial sources—discharge to the Madison lakes. Considerable effort has been made to divert sewage effluent around the Madison lakes, a move which probably improved lakes Kegonsa and Waubesa and prevented increased degradation of lakes Mendota and Monona. Other sources such as groundwater seepage, base flow, and atmospheric inputs are essentially uncontrollable. The size of the Madison lakes also precludes any practical measures to control internal sediment nutrient regeneration from sediments. This leaves rural and urban runoff to control.

Of the rural sources to the Madison lakes, agricultural runoff is the prime contributor of nutrients; woodland runoff and wetlands do not contribute significant amounts of nutrients.

Over the last ten years strategies to reduce runoff from agricultural land have been developed, but the most practical measure appears to be some form of conservation tillage, which maintains cover on the land to retard soil erosion. These practices are gaining wide acceptance since they can offer increased earnings from the farmer. Reducing erosion from farm fields reduces the nutrient input from rural runoff. Even so, the amount of the reduction may not have a major effect on the lakes. In the Lake Erie basin, the maximum possible reduction in P was estimated to be about 30 percent. Such a reduction would be unlikely for the Madison lakes. Given the great variations in the runoff loading from year to year, the effectiveness of control measures will also vary greatly.

A point to consider is that a large percentage of the TP entering the lake from rural runoff is likely unavailable to plants. Thus, controlling agricultural runoff may have a limited effect on the bioavailable P input. In determining the cost-effectiveness of the P control programs, the reduction of bioavailable as well as TP should be considered.

Urban runoff controls have also been extensively studied. Methods for controlling P that might be applied to the Madison lakes include runoff retention basins, in-line storage and in-line screens, and the use of the natural or artificial wetlands. All of these reduce peak flows and allow water to infiltrate into the ground as well as to remove solids. Other methods include street sweeping, proper home lawn fertilizer application, and land use planning. Controlling the runoff from construction sites offers the greatest return for the dollar invested.

Due to the relatively small urban input to the Madison lakes, implementing these controls will not have much effect on the lakes. Some controls are already in place, such as land use planning and a runoff retention basin for the Lake Wingra watershed. Further controls would need to be demonstrably cost-effective.

Although estimates of annual nutrient loads to the Madison lakes have been refined, large natural variations in annual inputs can occur. The lakes' large agricultural watersheds make them particularly susceptible to runoff inputs, which can vary greatly from year to year. Other random events have been noted, such as an accidental liquid fertilizer spill in 1984 which resulted in an input of about 4,000 kg of soluble reactive phosphorus to Lake Mendota (or about one-fifth the annual input estimated for the lake). The most promising option for reducing nutrient inputs to the lakes appears to be land conservation measures that reduce rural runoff. However, even with widespread adoption of these measures, the nutrient load probably would not be lowered to the extent that major changes in the quality of the lakes would occur.

William C. Sonzogni is associate professor of civil and environmental engineering at UW-Madison and the State Laboratory of Hygiene.

Modeling Great Lakes Diversion Impacts

By Eric D. Loucks and Erhard F. Joeres
Environmental Engineering, UW-Madison

The North American Great Lakes System plays an essential role in the lives of many people in the United States and Canada. The lakes serve as a domestic water supply for more than 30 million inhabitants of the basin. Commercial navigation on the lakes is responsible for the transport of large quantities of grain, stone, and coal between industrial and distribution centers. Significant amounts of hyroelectric power are generated on the connecting channels between the lakes, especially the Niagara and St. Lawrence rivers. Despite the enormous volume of water contained in the system, its hydrology is sensitive, and sound decision-making about additional water withdrawals will be necessary to maintain the well-being of the region and its people. It may seem ironic to address such an issue at this time when current water levels are at or near their all time highs, making additional withdrawal from the lakes seem little reason for concern. The current high water event can, however, be expected to last only a short time in comparison to the lifetime of hydropower facility or a navigation vessel. The long term well-being of the system is at issue, and although it may appear that no problem exists, the Great Lakes system can change rather rapidly. Between 1964 and 1972, for example, the Lake Michigan-Huron water level rose from an elevation below the 10th percentile to an elevation above the 90th percentile of all recorded water levels. It could be the reverse as easily in the future.

Two classes of water withdrawals threaten the overall viability of the system. These are interbasin diversions and consumptive use. Diversion entails the construction of a pipeline or canal to transport water to users outside the Great Lakes watershed, while consumptive use refers to the portion of water withdrawal that is not returned to the lakes.

Consumptive use occurs largely because in the course of any water use activity, a certain amount of evaporation is unavoidable. The percentage of a given withdrawal which becomes consumptive use depends on the purpose of the withdrawal. A relatively small percentage of a domestic supply withdrawal is consumed. For older systems this may approach 12 percent. Usually it is less. Consumptive use of withdrawals for industry and manufacturing are quite variable but generally higher than for domestic supplies. The range of consumptive use levels in the manufacturing sector is 5 to 50 percent of the withdrawal rate, with papermaking, sugar refining, and food processing the most water-consuming manufacturing activities. Some industries have made great strides in the recycling of process water in recent years, and additional progress should occur in this sector in the future.

Many nuclear and coal-fired power facilities are located on the shores of the Great Lakes to take advantage of the ready source of cooling water. These plants consume large volumes of water in the cooling process, particularly those designed to reduce thermal pollution through the use of closed cycle cooling systems. Although the current rate of consumption with today's mix of coal and nuclear power plants is a deceptive 1.5 percent, these facilities account for more than half of all Great Lakes water withdrawals and thus constitute a major component of consumptive use.

In contrast to consumptive use, the rate at which water is diverted out of the basin is well defined. There is one such diversion from Lake Michigan into the watershed of the Illinois River, a tributary of the Mississippi. The diversion has two purposes: one is the improvement of the summertime navigation on the Illinois waterway, and second is the rather dubious function of diluting the effluent of the Chicago sanitary and sewerage district's waste treatment facility. There is also a diversion into the Great Lakes from the Albany River watershed to the north but since it does not represent a loss of the Great Lakes water resource it is outside the present discussion. Perhaps the issue which has commanded the greatest amount of political attention is not any present diversion, but rather the possibility of establishing one or more new diversions in the future.

Several diversion proposals have been discussed in recent years. Among these were proposed coal slurry pipelines which would carry coal and water, in a 50 percent mixture, from mining areas in the west to users in the midwest. The water for such a system would have to come from the demand region in the first place, since none was available in the western coal fields. In another, the Corps of Engineers was actively studying the possibility of diverting additional water from Lake Michigan into the Mississippi River watershed and had in fact requested permission to test the existing diversion at higher flows. A backdrop to these comparatively minor schemes is the twenty-year-old proposal to create the North American Water and Power Alliance (NAWAPA), an idea that receives recurring attention. The NAWAPA project basically calls for cross-connecting every watershed on the continent, largely to allow regions undergoing dry periods or experiencing growing water demands to share water with areas receiving sufficient rainfall. NAWAPA also envisions a number of diversions both into and out of the Great Lakes. Although the entire scheme will probably never be realized, subprojects have been built. One such subproject is the Garrison diversion from the Missouri River watershed into the watershed of the Souris River.

Competent planning and decision-making strategies will be needed to address any diversion proposals which might be put forth in the future and also to deal with consumptive use rates which are expected to rise steadily throughout the next several decades. A research project recently completed at the University of Wisconsin at Madison focused on the development of appropriate methods for evaluating the effects of diversion on the Great Lakes System and the industries which depend most on the maintenance of historical water levels and flows, namely hydropower and commercial navigation. Since consumptive use and diversion similarly affect the hydrology of the lakes the methodologies developed in the study are equally applicable to detailed investigation of either kind of loss.

The study employed a two-phase approach consisting of a hydrologic simulation followed by an economic evaluation. In the hydrologic portion, a computer simulation model is employed to determine the effect of a specific diversion on the anticipated Great Lakes water levels and connecting channel flowrates. The series of computed levels and flows are then analyzed using economic evaluation models to obtain estimates of the costs which might be incurred were the proposed diversion actually constructed.

The hydrologic evaluations were performed using a specially modified version of the Great Lakes regulation model. This model was originally developed by the Great Lakes Hydraulics and Hydrology Branch of the U.S. Army Corps of Engineers. It was designed to test alternative potential regulation plans for Lake Superior and has been the model of choice in several other studies of the Great Lakes water levels. In particular, it has been the standard hydrologic evaluation model in studies falling under the direction of the International Joint Commission (IJC), the official U. S. and Canadian research and advisory body for the Great Lakes.

The purpose of the model is to determine the monthly mean water level and outflow for each of the five lakes in the system. The computations are based on the historical series of water supplies to each individual lake, the rate of diversion into and out of the lakes and the regulation policies imposed on the two controlled lakes in the system: Lake Superior and Lake Ontario. The Great Lakes Regulation Model has three distinct components. One simulates the regulation policy used to determine the number of gate openings in the St. Mary's River compensating works at the outlet of Lake Superior. A second model does the same for the Lake Ontario regulation plan. The third model computes the resulting levels and flows of the three unregulated lakes located in between. The third model, known as the middle lakes routing model, solves a system of equations based on the hydraulic relationships among the lakes to derive the resulting levels and flows. In contrast to the hydraulic laws governing the middle lakes routing model, the two regulation models are conditioned on the water management provisions governing the releases from Lakes Ontario and Superior. Regulation of Lake Superior, as the largest and furthest upstream of the Great Lakes, is especially critical to the system. The control policy is fixed by international agreement (through the IJC) and has been altered several times since regulation was made possible by the construction of the St. Mary's River compensating works in 1921. The current plan, called Plan 1977, is comprised of a conditional set of decisions based in part on water guarantees for power and navigation, water levels of both lakes Superior and Michigan-Huron and the time of the year.

The policy employed for the mangement of Lake Ontario water level is officially known as Plan 1958D. It is physically impossible for Lake Ontario to have any effect on the water levels of any of the other Great Lakes because Niagara Falls serves as a barrier to the propagation of such effects. Plan 1958D is therefore designed primarily for the efficient operation of the hydropower and navigation facilities along the St. Lawrence Seaway. Most of the seaway facilities were completed in 1958, hence the plan name. The current version was authorized in 1963.

In the study, comparisons are made among various diversion scenarios through the use of a so-called base case scenario. The base case is intended to represent current water use conditions. Since the historical series of recorded water conditions contains perturbations caused by alterations to lake regulation policies, it is necessary to derive a corrected series which uses a consistent set of management policies. As in other studies the hydrologic simulation model is used to develop the base case.

The base case assumes the consistent use of Plan 1977 and Plan 1958D for the control of lakes Superior and Ontario, respectively, over the entire period for which supply data are available (1900–78). The existing diversions are taken to be constant flows as follows: The Long Lake-Ogoki diversion at 5.0 thousand cubic feet per second (tcfs) into Lake Superior, the Chicago sanitary and ship canal diversion at 3.2 tcfs out of Lake Michigan-Huron, and the Welland Canal at 7.4 tcfs both out of Lake Erie and into Lake Ontario.

Several diversion possibilities were examined in the course of the UW investigation. The scenarios investigated called for diversion flows ranging from 5 to 30 tcfs. The source of the hypothetical diversions was taken as either Lake Superior or Lake Michigan-Huron. In every scenario it was necessary to make adjustments to the outflow control policies in order to account for the losses in basin supply that occur as a result of the diversion. Some adjustments to the regulation plans are needed to assure that the water levels will exhibit a pattern of variability which is (statistically) similar to that experienced under prediversion conditions. Plans must also be changed to assure hydraulic continuity is satisfied, that is, releases of water plus withdrawal does not exceed average supply in the long run.

Some general results of the simulations are given in the accompanying tables. Table 1 lists average changes in water level over the entire period of record relative to the corresponding Base Case water levels. The scenarios used to obtain these elevation changes were based on diversions of 5 and 10 tcfs out of Lake Superior and of 10 and 30 tcfs out of Lake Michigan-Huron. Lake level changes, which are expressed in feet, are given for lakes Superior, Michigan-Huron, and Erie. Results are not listed for Lake Ontario because it is possible to regulate this lake in a manner which would result in zero impact. At least this is possible over the assigned range of diversion flows.

Table 1. Mean Changes in Water Level Under Various Diversion Scenarios (in feet)

Lake	SU5	SU10	MH10	MH30
Superior	−0.22	−0.63	−0.24	−0.63
Michigan-Huron	−0.35	−0.69	−0.69	−2.07
Erie	−0.24	−0.48	−0.48	−1.45

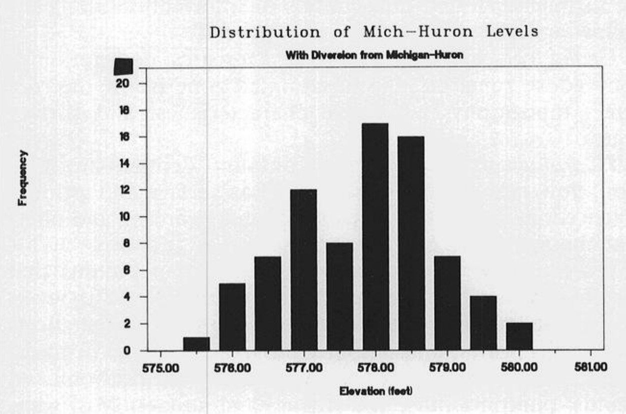
Although, the same objective (i.e. focusing on the behavior of one lake only) can be applied to Lake Superior, simulation results have shown that such action is myopic and clearly to the disadvantage of the system as a whole. For example, if the release policy is changed such that a lesser level of impact is maintained for Lake Superior under conditions of the SU10 scenario, the overall variability of Lake Michigan-Huron water levels increases by a factor of three. Interestingly, despite this higher level of variability, the mean impact to this lake remains at the given value of 0.69 feet. In fact, the uncontrolled middle lakes (Michigan-Huron and Erie) exhibit impacts which are insensitive to the location of the diversion and vary linearly with the diversion flow rate. The series of monthly water levels which result are not the same from case to case by any means; it just happens that the mean value is fixed.

The mean water level impacts illustrated here are intended merely to convey a sense of magnitude for technically feasible diversions or consumptive use losses. The results confirm the intuitive conclusion that water diversion will cause water levels to decrease by some small average amount, although intuition gives no guidance as to the distribution of the reductions. This water level decrease is costly to the commercial shipping industry and the loss of flow is costly to the hydropower industry. The changes in level are not large enough, however, to produce any degree of sustained and offsetting benefit to the lakeshore property owners. A brief summary of the computed economic consequences based on the simulated water levels and current economic conditions is given in Table 2.

Table 2. Computed Average Annual Costs to Hydropower and Shipping. (in millions of 1979 dollars)

	SU5	SU10	MH10	MH30
Mean	38.1	78.7	76.4	237.3
Maximum	57.4	89.6	86.0	295.3
Minimum	17.0	68.8	67.0	203.5

It must be recognized that the lake system is too complex to be characterized completely by its mean behavior shown in Table 1. Given that basin supply is not uniform in time and that operating policies are a complex set of conditional rules, it is clear that the response of lake levels to continuous withdrawal should also be nonlinear. The resulting series of water level changes are consequently not uniform in time. Overall behavior of the lakes can thus only appropriately be investigated by means of a simulation strategy which allows observation of lake levels through time. For some considerations it is the extreme, albeit rare, event that will be of primary interest. Figure 1 illustrates the empirical frequency distribution of water level changes for one of the scenarios investigated. Such representations enable a broader understanding of the comprehensive effects of water diversion.



The above discussion avoids any advocacy position, but instead illustrates the insights which can be gained from quantitative analysis of water management/regulation options for the Great Lakes. The illustration has focused on the politically divisive issue of withdrawals for the purpose of interbasin transfer. It also highlights the need for further study of the impacts caused by consumptive use. The modeling strategy presented is adequate for evaluation of consumptive use impacts; however, more research is necessary to determine both the actual present amounts and likely future consumption rates for each of the Great Lakes individual watersheds. Given this information, it would be possible to investigate the geographical distribution of adverse consumptive use effects and perhaps also to begin to develop management policies to reduce or more equitably distribute such impacts. The authors are currently pursuing new research initiatives to address these problem areas. A related matter is the possibility of using selective, short term diversions for the control of excessively high water levels as previously suggested. Although such limited diversions would have an immediate and evident flood mitigation objective, potential beneficial uses of the diverted water in other watersheds need to be investigated, along with the technical constraints inherent in the problem. Additional issues which deserve attention include questions relating to the effect which excessive withdrawal or consumption might have on water quality and the mechanisms by which industrialization and urbanization have affected the hydrologic cycle and thus changed natural water supply trends.

The Great Lakes represent a unique resource of immeasurable value. It is imperative, however, that their value be recognized as possessing a multitude of dimensions we may as yet not understand. All human interactions with and exploitation of this great resource ought to proceed from a perspective of respectful caution for its complexity and vulnerability.

Acknowledgement: This work was funded by the University of Wisconsin Sea Grant Institute under grants from the National Sea Grant College Program, National Oceanic and Atmospheric Administration, U. S. Department of Commerce, and from the State of Wisconsin.

For further information:

"Evaluation of Hydrologic Impacts Caused by Diversion of Great Lakes Water" by E. D. Loucks, E. F. Joeres, and K. W. Potter. Aug 1985. Available through the UW Sea Grant Institute.

"The Economic Impact of Withdrawing Water from the Great Lakes Basin" by Martin David and Stuart Rosenthal. May 1985. Available through the UW Sea Grant Institute.

Eric D. Loucks is research assistant while completing his Ph.D. in civil and environmental engineering.

Erhard F. Joeres is professor of civil and environmental engineering at UW-Madison.

Statewide Groundwater Quality Data Base and Monitoring Program: Needs and Management

By G. Chesters, G. V. Simsiman, and J. M. Harkin
Water Resources Center, UW-Madison
O. R. Ehart
Wisconsin Department of Agriculture, Trade, and Consumer Protection

This paper addresses the need to develop a statewide data base for groundwater quantity, quality, and management. The program should be developed and managed to accommodate both existing data and additional data necessary for a complete description of the state's groundwater resources. The data base should be well documented, and the data should be quality-assured since it must serve eventually as the foundation for developing, validating, and using mathematical models to delineate those areas of the state which are sensitive zones of potential groundwater contamination.

A detailed workbook should be prepared describing how the data base is to be assembled. The base format would permit easy access and be compatible with some existing data bases and with mathematical models being generated and mounted in the state and nationally. The data base would be more useful if the Wisconsin model were uniformly formatted with those of other midwestern states to permit region-wide information retrieval. The intercompatibility and format of the proposed data base should be examined by groundwater modeling groups.

In an early phase, a fully documented data book with abstracts should be prepared to inform potential users of data base capability. The data base would reveal information gaps. Consultations with state agencies and legislative councils would bring out potential applications of the data base. Evaluation of existing data would determine the completeness and accuracy with which these applications could be met. Initial data storage could begin with about twenty counties in which groundwater problems are most severe; phasing would ease the financial burden on the state. Later the data base could be completed for the remaining fifty counties. Easily retrievable data would be extremely valuable to many industries, which might provide financial support for the data base assembly.

Data collection should initially place special emphasis on parameters important to evaluation of pesticide and hazardous waste impacts on groundwater. Nonetheless, the data base should have capability and flexibility for addressing a diversity of problems and be applicable to different water and land resource uses and management.

Data storage. A data system must be sufficiently flexible to accommodate regionally variable information and multifactoral analysis and be compatible with other systems. This analytical capability is essential if the data are to be used for identifying policy options and delineating problem solutions. Data in the system would accommodate county-based data entries. The system should be developed with compatibility for information available through the Environmental Protection Agency (EPA) on demographic, climatological, and other pertinent information stored in Office of Pesticide Programs and Office of Toxic Substances data bases. The system should contain geological, hydrological, water quality, and water- and land-use data. The data should be further separated into subsets of information along the following lines:

Geological: Soils and their characteristics; description of the vadose zone, i.e., the unsaturated zone below the root zone; topography; watertable characteristics; and surface water.

Hydrological: Groundwater contours; depths; stratification; flow rate and direction as well as surface and groundwater connections (recharge and discharge areas); and physical characteristics of the water.

Water quality and use: Known levels of pollutants that affect water quality and standards established for them as they relate to intended use of the water and potential effects on human health, and amount and availability of drinking water; scheduling regimes for irrigation; well locations and depths; pumping rates; drawdown; and suitability of wells for intended uses.

Land uses and land practices: Agricultural uses and practices including pesticide and fertilizer use (as well as misuse, spills, and back siphoning into wells); crop rotational schemes; conventional or no-till cultivation; irrigation or dryland farming; tolerance of crops to water stress; methods of waste disposal; and soil and water conservation practices. Other rural uses and practices including forest lands, pesticide use, and timber management practices; and mining effects and restoration practices. Urban uses and practices including pesticide and fertilizer use; industrial development; septic systems; solid and hazardous waste disposal; density of residential arrays; light and heavy industry; parks and recreational areas including schools, hospitals, government buildings which often have large grounds; and roads.

Data entries could initially be limited to the twenty-one contiguous counties of La Crosse, Monroe, Juneau, Adams, Wood, Portage, Waupaca, Waushara, Marquette, Green Lake, Dodge, Washington, Ozaukee, Milwaukee, Racine, Kenosha, Waukesha, Jefferson, Dane, Sauk, and Columbia. These counties provide a diversity of land uses, soil characteristics, geological characteristics, and major aquifers and include glaciated and unglaciated parts of the state. Data needs and uses of the system could be delineated through a groundwater management committee of the legislative council to assure that its most important use would be determining mitigation factors for agency and legislative purposes. Further development of the data base would provide predictability on movement, transport, sources, dispersion, and rate of dissipation of materials. Attempts should be made to predict the implications of uninterrupted, modified or canceled use of particular compounds.

Data management. The data management activities should be designed to include:

Division into individual sets. For example, the section on hydrological data might have individual sets dealing with (a) groundwater contours, including maps; (b) groundwater depths, i.e., thickness of saturated formations; (c) stratification; (d) flow rates and directions; (e) surface to groundwater connections, i.e., recharge and discharge areas.

Thorough documentation of each data set should be undertaken and depending on the degree of replication of the available data a statistically-based quality assurance assessment should be made. The documentation should include at least: (a) who conducted the analyses; (b) when the analyses were conducted; (c) methods of sample collection; (d) techniques for sample storage; (e) methods of analysis; (f) changes in c, d, and e with time, and how these changes affect long-term comparability of the data; (g) extent of replication; (h) data reliability. *Arrangement* of data and coded information on computer tapes or disks.

Standardization of procedures for putting numeric information into computer-usable form.

Complete instructions for use of the stored data.

A system of checks for possible errors in the data as part of a quality assurance program.

These data base needs and management to provide a major assist to the state's decision-making process could be initiated quickly. Frequently, decisions must be made even with an incomplete data base and mechanisms should be devised to provide the most appropriate policy options under these circumstances. As new data are collected and analyzed, these policy options could be modified and made more realistic. In this way, the data base becomes a dynamic tool undergoing continuous modification and seeking new applications.

Monitoring protocol

During the past five to eight years, concerns over the deterioration of groundwater quality in Wisconsin have been expressed by the general public, decision makers, regulatory and health agencies, environmental activists, and scientists. There have been long-held concerns over the incursion of nitrate into groundwater, but it was the early findings of aldicarb (marketed as Temik) in the aquifer underlying the central sand plain of the state and the potential threat from groundwater contamination from metal mining which recently raised the specter of serious, widespread groundwater contamination.

Devising an even-handed groundwater policy which treats all users similarly and is applicable statewide is difficult but not insurmountable. Using available scientific knowledge and groundwater monitoring information, the state could select contaminant-sensitive areas for investigation and analyze five to eight compounds—likely groundwater contaminants—chosen because they display a diversity in use pattern and location; chemical properties; point, nonpoint, and multiple sources; transport in the environment; chemical and biological degradability; and potential health effects. Such a strategy is better than conducting multiple analyses on a grab bag of samples chosen with very little thought. Analysis is expensive and thousands of "no detect" values at $100/parameter do not do justice to our present state of knowledge nor to the use of tax funds. State testing for pesticides other than aldicarb in domestic wells has revealed only a few isolated instances of groundwater contamination due to agricultural use of pesticides. Detected levels are mostly so low that they have no toxicological significance. The expensive monitoring of a large number of pesticides other than aldicarb appears unjustified. Statewide and national programs of broad-spectrum pesticide analysis should be reevaluated.

Parameter selection. For Wisconsin, appropriate choices might be nitrate, aldicarb, the herbicide atrazine, a volatile synthetic organic chemical of high usage such as trichloroethylene, and a typical aromatic petroleum product such as benzene. Here are some reasons for selecting these particular compounds.

Nitrate is ubiquitous in the environment, originates from a diversity of natural and man-made nonpoint sources, is highly soluble in water and has been the subject of widespread investigations in many states.

Aldicarb is an extensively used insecticide, highly water-soluble, very mobile in the environment, not strongly adsorbed in coarse-textured soils, toxic in fairly low concentrations (LD_{50} = 0.8 mg/kg in female rats), and has been the subject of extensive scientific and public inquiry. The compound would be classified as a nonpoint source pollutant, but as a restricted-use pesticide produced by only one manufacturer its origin and the location of its uses are well known.

Atrazine is the most extensively used herbicide for corn. It has a fairly low water solubility and is relatively persistent, particularly during cold, wet falls and springs. Although it is not a major toxicological threat to humans and wildlife and is strongly adsorbed by soils, it may still be a valuable indicator pesticide for assaying potential for movement of a widely used lipophilic pesticide. It has been found in extremely low concentrations as a contaminant of groundwater in Wisconsin, the eastern shore region of Maryland, and southern Ontario.

Trichloroethylene is a typical representative of the volatile organic chemicals commonly encountered in drinking water and is the organochlorine compound most frequently detected in national surveys, e.g., the National Organics Monitoring Survey, the National Screening Program, and the Community Water Supply Survey. Although it is almost water insoluble, its volatility makes it mobile in the environment. Moreover, its persistence and tendency to sorb onto clay particles make it a long-term pollutant, and its liver carcinogenicity makes it a potential health hazard. Because of its widespread use in drycleaning, as a solvent for degreasing, and as a septic system "cleaner" it is a multiple-source pollutant. It is easy to analyze by the purge-and-trap method followed by gas chromatography with electron capture detection.

Benzene is the best representative of the most stable, aromatic fraction of petroleum. It is only slightly soluble in water, but enough dissolves to be easily detected during normal household water use wherever petroleum spills (e.g., from ruptured fuel oil or gasoline storage tanks) have occurred. It is the petroleum hydrocarbon most commonly encountered in national groundwater surveys. It is easily recoverable, together with trichloroethylene, by purge-and-trap extraction of water samples and determined by gas chromatography. It is important as a potential health hazard because of its known carcinogenicity and effects on blood cell formation in the bone marrow.

This list is by no means exhaustive, but it serves to illustrate the principle that a small number of compounds representing a wide diversity of contaminant types can be investigated without producing intolerable strain on the financial and analytical capability of the state. A mechanism is needed to allow continuous upgrading of parameter lists, but strong justification is needed to add or remove a selected parameter.

A statewide sampling and monitoring strategy. Recent experiences with pesticide monitoring of groundwater have shown that in qualitative and quantitative terms analyses from different laboratories are inconsistent and show poor replicability. Comparability and precision of quantitative analyses using different methodologies on the same sample leave much to be desired. Moreover, the need for extensive confirmatory (qualitative) analysis greatly expands the cost of monitoring programs; however, it is essential to confirm groundwater contamination findings before data are released to the public. For the sake of credibility, groundwater samplers and analysts must utilize reliable methods to assure the validity of data.

In developing a monitoring protocol, the researcher should be advised of the scope of the anticipated monitoring scheme. On a statewide basis existing problems of groundwater contamination must be evaluated and an assessment made of "what the traffic will bear" in terms of financial support and provision of skilled sampling and analytical personnel.

Dividing Wisconsin into ten groundwater sampling regions would permit one person to sample each region adequately. An average-sized region would be about 5,400 square miles, necessitating maximum travel of $>$ 50 miles to the most remote sampling site in the region. The sampling protocol should define:

Where. The sampling sites should be concentrated in areas judged to be most sensitive to groundwater contamination. Sensitivity is based on extent of usage or disposal of materials; shallowness to groundwater; and high soil permeability, i.e., conditions most conducive to materials transport.

How. Field sampling techniques must be defined but may differ depending on the characteristics of the compound of concern. Multilevel samples may be essential in some cases, particularly where research is designed to analyze dispersion of materials in an aquifer, with an eventual determination of when the contaminant will attain nontoxic concentrations.

Who. The sampling specialist should also be capable of conducting analyses, e.g., temperature, pH, dissolved oxygen, reduction potential and conductivity measurements *in situ.*

What. The sampler should be given a list of specifications to be recorded with the collection of each sample.

How much. A protocol is needed to decide whether to continue, discontinue, or expand sampling at a particular site depending on conditions such as obvious groundwater problem or no contamination. Continuing evaluation of problem sites is essential, but to continue sampling where no contamination has been detected is a luxury Wisconsin cannot afford. Site selection and sampling strategies must be reevaluated frequently, perhaps on a quarterly schedule, utilizing the expertise of user groups.

How many. The analytical capability of each state agency must be determined to optimize the number of samples. Conditions for sample transportation and storage should be described to avoid sample deterioration.

Analytical methods should be selected carefully and evaluated to set up routine procedures. The extent to which an analytical program can accommodate special analyses not subject to routinization should be defined.

If the methodology for a particular analysis is to be changed, comparability of the new data with previously obtained data must be estimated. Furthermore, for each data set a decision should be made as to whether the old data must be modified to make them compatible with new data.

The extent of replicate sampling and analysis must be clearly established and definitions of "replication" should be understood.

On a statewide basis the need for a centrally located quality assurance program is obvious. The qualifications of the persons in charge of quality assurance must be defined as well as the quality of available laboratory facilities. The methods selected to conduct the quality assurance program (quantitative and confirmatory analyses) and maintain records must be stipulated, and it is necessary to define what steps will be taken when a problem is uncovered.

To estimate the size of a groundwater monitoring program in the state we assumed that ten field sampling personnel and ten analysts would be needed. With support staff, purchase of new equipment, maintenance of equipment, travel for sample collection, computer costs, and participation in a quality assurance program, total program costs would approximate \$1.5 million in the first year and perhaps \$1 million in succeeding years.

Orlo R. ("Bob") Ehart holds a B.S. in biology and chemistry from the University of North Dakota and a M.S. degree in entomology and ecology from North Dakota State University. He is completing his Ph.D. in land resources at UW-Madison while serving as executive assistant to the secretary of Wisconsin Department of Agriculture, Trade and Consumer Protection. He was director of the groundwater pesticide control section and chief of the pesticide control program in DATCP.

Effective Information Dissemination

By G. Chesters, K. Sy, and S. Calcese
Water Resources Center, UW-Madison

Water quality information is being generated more rapidly than institutions can use it. Furthermore, much information gathering and compiling duplicates other efforts. An efficient system of information and technology transfer is desperately needed in the area of water resource management in Wisconsin. Such a program must collect and compile data, evaluate available information, and propose rational alternatives to Wisconsin's major water resource management questions. These must be communicated in a comprehensible format for Wisconsin citizens. Only in this way can an informed public influence the decision-making process and the decision maker obtain the best information from which to make rational judgments.

A cooperative scheme of information and technology transfer in water resources management with dissemination to interested publics is needed in Wisconsin. The scheme described here allows an advisory council to define and prioritize the state's water resources management problems while retaining sufficient flexibility to study site-specific problems. Specifically it is necessary to:

Establish a statewide advisory council to work with a core program staff to define water resource issues and set priorities;

Mount an information retrieval system on all facets of water resource management in Wisconsin, including technical, legal, social, economic, and political aspects;

Identify information gaps and research needs and conduct research necessary to develop rational water resource management alternatives;

Delineate alternative water resource management strategies, discuss the advantages and disadvantages of each, and prepare materials for information and technology transfer using existing mechanisms of dissemination;

Train students, technicians, and leaders for portions of the information and technology transfer program.

A water quality technology transfer program minimally involves retrieving available information on a given topic, evaluating that information, using the information to develop potential solutions, and disseminating those alternatives to decision makers, citizen groups, professional organizations, industry, and other publics. A research component permits filling important information gaps. A training component demonstrates the elements of the technology transfer process and instructs individuals in the technical details of final implementation. A statewide advisory council would provide the broad perspective essential to identify major water resource problems, select by a priority system those problems to be considered, and define the scope of each study. An effective council would outline the constraints on problem solution, specify the impact of a proposed solution on related problems, identify information gaps, and develop special strategies required for problem solution. The advisory council should have a chairperson, be of manageable size (seven to ten), have balance among the disciplines (engineering, biological, physical, social and political sciences, business, and law), and represent state government, industry, and citizen groups.

Beginning with the highest priority decided by the advisory council, the staff would retrieve available information by a comprehensive search of water-related bibliographic data bases—printed and computerized—and would include all applicable abstracting and indexing services and printed catalogs of major libraries. Examples include *Selected Water Resources Abstracts, National Technical Information Service,* and *Enviroline.* The searchers eliminate duplicate references and sort the remaining into primary and secondary references. They would follow clues to additional information: obtain current issues of a journal with numerous relevant articles; contact the institutions which have a strong research program about ongoing work; ask an author who has written prolifically on the subject to share insights on the overall problem which may not be published; and acquire pertinent documents.

When little or no documentation exists, the staff would seek unpublished data from state and local government or regional planning agencies which might affect the water quality problem. Such data might be contained in data bases such as STORET (U.S. Environmental Protection Agency) or WATSTORE (U.S. Geological Survey). A third source of initial information is unpublished research in progress or recently completed. Data bases which list ongoing projects by subject such as *Water Resources Research* (U.S. Department of the Interior) should also be searched and the principal investigator contacted directly for new information.

New research conclusions, changes in institutional structures, and other factors make what once was the best solution to a water quality problem unacceptable a few years later. In some instances no acceptable solution can be found until additional research is conducted. Thus a transfer scheme must allow for information to be updated when necessary.

As staff evaluate the initial information retrieved, they must determine whether the research methodology and data collection techniques are valid and reliable, and whether the interpretations and conclusions are supported by the data. If the answer to the first question is negative, the document should be discarded. In the second case a reevaluation might be possible.

As valid information is acquired, staff may discover water quality problems not addressed by available information. These gaps need to be carefully defined, research needs ordered, and research initiated to attempt to fill gaps. The advisory council should set research priorities, review proposals, and identify funding for research.

The process continues by taking the best information available, even if incomplete, and integrating it into a framework for developing alternatives, which must include information on all aspects of the problem. For example, technology might suggest solutions to a water pollution problem, which, for legal, social, or economic reasons may not be implemented. The staff should consider all potential solutions, evaluate the feasibility of each, and assess the likelihood of each actually being implemented. Even feasible solutions may not be recommended if the optimum solution to one problem intensifies another problem, e.g., a management system may preserve the quality of surface water to the detriment of groundwater.

The development of alternatives will require a variety of subject specialists working closely with experts from those areas most affected by the problem.

Table I. Summary of Components for Technology Transfer Scheme

Task or process	End product	Personnel required	Time, months
Advisory Council deliberation on pending information needs	Problem identification and prioritization	Legislative, state agency, university, industry, and environmental representatives	As needed
Information request initiated by individual client with specific request	Description of needed information and the purpose for which the information will be used	Initiators of request and program staff	As needed
Information retrieval	Initial information	Information scientists	2 to 6
Update initial information	Final information	Information scientists	2
Identify information gaps	Outline of research needs	Subject specialists	2 to 4
Conduct research where feasible	Research conclusions	Research personnel	6 to 36
Evaluate information and formulate alternative solutions, summarizing advantages and disadvantages of each	Initial alternative solutions	Subject specialists	3 to 6
	Final alternative solutions	Subject specialists	1 to 2
Package information and prepare educational materials by region	Initial dissemination material	Writers, artists, media specialists	2
Disseminate information utilizing existing mechanisms	Public awareness of alternatives and informed decision making	Trained disseminators in individual states	2 to 24
Demonstrate overall technology transfer program Train personnel in specific elements of technology transfer program	Trained information and technology transfer specialists and other technicians	Information scientists, technical specialists, research personnel, and communications specialists	Time frame dependent on individual needs of trainees
Conduct cooperative research	" "	" "	"
Teach methodologies for improving decision making processes	" "	" "	"

Table II. Sample Materials for Dissemination

Materials	Intended audience
Press releases including background of problem, reasons for current concern, summary of alternative solutions	General public, elementary and secondary educators
Brochures or leaflets with brief general summaries of problems and alternative solutions by region	General public, elementary and secondary educators
Slide sets or films portraying local area related to problem, significance of problem, etc.	General public, elementary and secondary educators
Semi-technical reports outlining problems and alternative solutions	Legislators, administrators, planners, researchers, university faculty
Graphs, charts, maps, etc., to display potential impact of alternative solutions	Legislators, administrators, planners, researchers, university faculty
Technical details of implementing a particular alternative	Disseminators, technicians

The alternative solutions need to be presented to two broad categories of people: information disseminators who serve as trainers and transfer agents, and information recipients who directly use the information to affect policy and planning. Information recipients include the general public, educators, legislators, administrators, planners, industry, and technical staffs in state agencies such as the DNR, DATCP, and DHSS. Each recipient has a different level of technical expertise and each has a different reason for needing the information. Materials for dissemination should reflect pertinent information for a given region and then specific constraints for the whole state. The materials prepared for dissemination will help convey the scope and significance of a water quality problem, the solutions which currently are feasible, and the solutions which might be possible with new legislation or new research. In some instances, disseminators will work with legislators, the governor's office, agency administrators, or UW system faculty. They must identify existing channels of communication to reach larger audiences. Citizens' interest groups such as Wisconsin's Environmental Decade, education coordinators in a field related to the particular problem, and professional societies such as the Wisconsin Section of the American Water Resources Association provide established channels from newsletters to workshops. Figure I shows in summary form who the disseminators might contact and in what way they might have an impact. The sample end products identified in the circles can be relied on if based on information gathered and intensely evaluated in the manner suggested.

Concomitant with the development of a technology transfer program, a training scheme should be instituted to use the expertise developed by the program. The training might

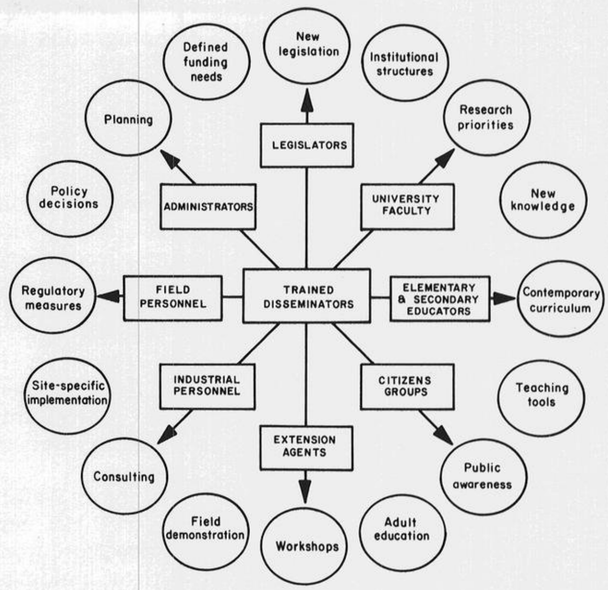


Figure 1. Information dissemination and technology transfer.

range from a week-long workshop designed to provide instruction on a particular element of the program to a one-year internship for people wishing to participate in all elements of the program, to graduate degree work in which the student contributes to a cooperative research effort. The participants will become important adjuncts to the program's eventual scope and success.

In addition to improving technology transfer and information dissemination mechanisms, development of innovative public school curricula supplements (kindergarten through 12th grade) are needed to deal with water quality values and concerns. The major input to the curriculum design and preparation of teaching materials should come from teachers themselves, and curricula supplements should be integrated into present curricula. Thus, the history of the environmental movement might be presented in a history course, water rights might be discussed in a current affairs course, mathematical modeling of water quality might be introduced in a mathematics course, while water quality could be discussed in a science or chemistry or biology course.

Educating students, the decision-makers of the future, should be an essential part of any information dissemination program since the goal is to achieve a well-informed citizenry.

Karen J. Sy is assistant professor of library and information science at the University of Washington in Seattle. She holds a M.S. in library science and a Ph.D. in land resources from UW-Madison.

Sarah Calcese is librarian for the Water Resources Reference Services, Water Resources Center, UW-Madison, where she serves a diverse clientele ranging from high shcool students to state agency staff to university students and faculty in Wisconsin and neighboring states.

Galleria: Frances Myers

By Warrington Colescott
photographs by Marylu Raushenbush

It is one of Philadelphia's most important artistic events, the opening night of the Print Club's juried exhibition. The suite of small, paneled galleries is crowded with collectors, artists and students, business leaders and cultural gurus, the socially prominent and the socially naive; silk gowns brush against ink-stained denim. The demurely lit old walls are hung with prints selected from the United States and eighteen other countries. The curator of prints and drawings from the Brooklyn Museum, Barry Walker, the juror for this 1984 competition, announces the awards to the attentive group. First prize goes to Frances Myers of Hollandale, Wisconsin.

In his foreword to the catalogue of that exhibit Barry Walker had remarks to make regarding Frances Myers. "Her new Wonder Woman series represents a radical departure from her earlier aquatints of Frank Lloyd Wright buildings. Whereas the earlier work had an austere elegance and cerebral beauty, the newer work is much looser and reveals a hitherto unsuspectedly playful sense of humor."

The "playful sense of humor" was in evidence last week, as I talked to Frances Myers in her studio in rural Hollandale. "Barry missed the boat on that one," she said. "I appreciate the award and the honor, but Wonder Woman is dead serious. Comic book doesn't imply comedy to me."

Hollandale is a small village forty-five minutes southwest of Madison, a few miles into Iowa County, in a pleasant region of farms, forests, spring-fed streams, and historic towns. Artists and craftsmen have traditionally been represented in the area. World famous painter Mark Tobey was born and raised not far away. Mineral Point is a recognized art center. Nick Englebert did some of his most important work in Hollandale, and remains of his outdoor sculpture can still be seen in the yard of his old dwelling.

Frances Myers has lived with her husband on a farm near Hollandale for the past fourteen years. Her studio is an ancient machine shed, not so far removed from its original farm function, still filled with machines and equipment, but these are now the machinery of the printmaker and the tools and gadgets and controlled space of the painter. There are three etching presses, tables for matting and framing, workbenches, and in the high-ceilinged end room, the old tractor garage, a north wall of glass outlines a jumble of easels and large canvases. She gestures. "My show in Chicago is in February. There is a lot to do."

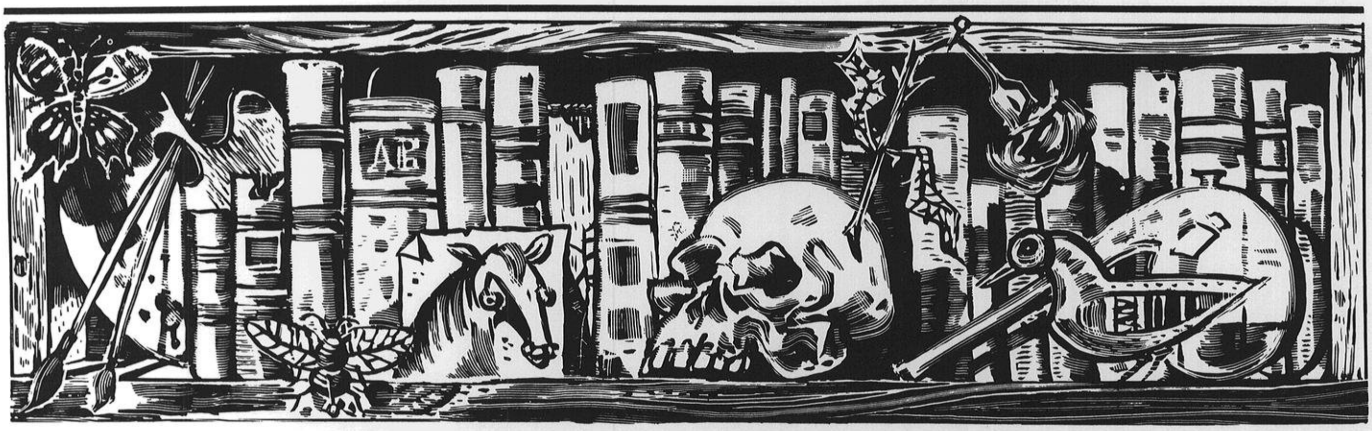
The prize at the Philadelphia Print Club was just one honor Frances earned in the past two years. Her prints were represented by invitation at important international biennials in England and Yugoslavia, there were purchase awards at the 20th Bradley National Print and Drawing Annual, and at the 28th North Dakota Print and Drawing Annual. She won second prize in prints at Art Quest, a national competition in all media with jurors from the Los Angeles Museum of Contemporary Art, the New Museum (New York), the San Francisco Museum of Modern Art, and the Art Institute of Chicago. She has work currently showing at the American Consulate in Leningrad, in a traveling show *Point of Departure*, which originated at the Elvehjem Musuem, and in *New American Graphics*, circulated throughout the Arabic world by USIS. There have been invitational shows in Michigan, Florida, New York, and California; a one-person show at the Wisconsin Academy gallery, and then the announcement this month that she has been awarded a major grant by the National Endowment for the Arts, her second in the past eight years.

She commented on that award. "It is very satisfying because of the quality of their review panels, the competitiveness, and the size of the award, but I still feel a particular pleasure in the Print Club prize. I know that Barry Walker has been familiar with my work for a long period, and I greatly respect his judgment. And after all, the Print Club annual is the printmakers' superbowl."

My mind pictured the superbowl, and a flashing figure in star-spangled blue shorts and red boots. It was time to talk Wonder Woman. "She was a part of my childhood," Frances Myers said. "The comic book character, not Linda Carter. From about age seven to age twelve I saw her as a role model, as an influence in shaping my character. As a child in Racine I was part of a large and closely knit family. We had an unusually strong gender awareness, as my mother was a widow, struggling in a man's world. I had four sisters and one brother and the sibling politics always had sexual readings. My society wanted me to be Doris Day or Rita Hayworth; Wonder Woman offered me another option. I admired and tried to live up to her physical strength, her success through personal achievement and her noncompliance in the world of male power. It was a childhood crush gradually faded away. Recently, accidentally, I found her again and realized that she had even more contemporary codings."

As a printmaker Frances Myers has been admired for her aquatints of architectural subjects, ranging from pre-Columbian ruins to Art Deco buildings. In 1977 she entered upon a celebration of the works of Frank Lloyd Wright, in the form of an ambitious portfolio of prints, commissioned by Perimeter Press, Chicago. The project became an obsessive scrutiny, a masterful series of tributes, now properly seen as a collector's piece of unique value. "Eventually the intensity of the project exhausted me," she said, "and rebellion set in. I began making prints on copy machines of tawdry California bungalows and two-car garages. Even a San Francisco porno theater. I was satiated with high art and demanding technique. Now some of the rebellion is still there, but the content has shifted drastically." The recent prints are direct statements cut into the linoleum printing matrix or painted on plexiglass, to be printed in an intaglio press. The figurative tableau defines vaguely sexual allegories, dramatic confrontations, dynamic gender-centered pageantries. It is a magic theater. The repertory company includes, among others, Wonder Woman. Frances Myers states, with firmness, "My intent, at this moment, is to make humanistic rituals, with superstition and magic taking the place of religion."■

Warrington Colescott is Leo Steppat professor of art at UW-Madison. **Marylu Raushenbush** has photographed artists and their art for several years and exhibited these photographs at the Elvehjem Museum and the Madison Art Center.



BOOKMARKS/WISCONSIN

JAMES E. KEELER: Pioneer American Astrophysicist and the Early Development of American Astrophysics by Donald E. Osterbrock. New York: Cambridge University Press, 1984. 411 pp. $39.50.

By R. C. Bless

This biography of James E. Keeler, the first American astronomical spectroscopist of international stature, should appeal to a variety of readers. Keeler's career as a pioneer astrophysicist will interest astronomers with a taste for the history of their profession. It is also a useful book for anyone concerned with the growth of scientific professionalism in this country, since Keeler's brief career (he died in 1900 at age 42) reflects most of the facets of the rise of scientific research in America: the development of graduate studies, the application of new techniques of physics to astronomy, the establishment of professional journals and societies, and the growth of big science represented by the construction of large telescopes. Finally, for those particularly interested in Wisconsin this book offers as two of its major players George Ellery Hale and Edward S. Holden. The former founded Yerkes Observatory in Williams Bay, Wisconsin; the latter was the second director of Washburn Observatory at the University of Wisconsin-Madison, and later became the director of Lick Observatory and Keeler's boss. The author of this biography was for many years a professor of astronomy at UW-Madison, leaving in 1973 to become director of Lick Observatory.

By virtue of his own talents as well as good luck (in the form of patrons willing to subsidize his education), Keeler received his undergraduate training at Johns Hopkins University and, a few years later, spent the then customary year abroad studying in Germany. For four years after his graduation from Johns Hopkins, he worked for Samuel Langley at Allegheny Observatory in Pittsburgh. Langley was the first American practitioner of the "new" astronomy, that is, he was interested in the physical characteristics of celestial objects rather than in their position and motions (the "old" astronomy). Keeler was an able student and learned much from Langley, but soon became anxious to strike out on his own. Such an opportunity presented itself in an offer of a job at the embryonic Lick Observatory near San Francisco, where a telescope with a 36-inch diameter lens—then the world's largest—was to be installed.

In a reversal of the usual sequence of events, Holden became president of the University of California and resigned to take the directorship of Lick Observatory when it was completed in 1888. He had many good ideas for the observatory, but was an autocratic administrator and ultimately earned such epithets as "the Czar," "that contemptible brute," "the great I am," "an unmitigated blackguard," "the Great Mahatma," etc. (Nineteenth century invective seems to have been more imaginative that that of our own day.) Keeler, displaying his characteristic tact, managed to stay on reasonably cordial terms with Holden, however. It was during this period that he did perhaps his most important work, precision spectroscopy of gaseous nebulae. His measurements of the spectral lines emitted by these objects were the best being done at the time. Keeler made certain that leading astronomers in this country and Europe became familiar with his work, and he was quickly recognized as a talented observer and instrumentalist.

When the directorship of Allegheny Observatory became open (Langley having become the secretary of the Smithsonian Institution), Keeler won the position. At Allegheny he did the work which, though not his most significant, brought him the most widespread recognition. This was the demonstration through spectroscopy that the rings of Saturn were indeed composed of individual particles, as had been theorized some years earlier by the distinguished British theoretical physicist, Maxwell.

It was also during this second Allegheny period that he began having many contacts with Hale, that incredibly successful astronomical entrepreneur. In 1892 Hale convinced Keeler to become associate editor of *Astronomy and Astrophysics*; three years later the two of them transformed it into *The Astrophysical Journal* which, ninety years later, is probably the leading journal in its field. Keeler's eminence in astrophysics was aptly symbolized when Hale asked him to give the main astronomical address at the dedication of the 40-inch refracting telescope—the world's largest—at Yerkes Observatory in 1897.

The small telescope and cloudy skies at Allegheny increasingly frustrated Keeler and Hale tried to snag him for Yerkes. Instead, in 1898 he returned to Lick as director, succeeding the unfortunate Holden who had been forced to resign.

At Lick he quickly restored the morale of his staff, and establishing cordial relationships with his Berkeley colleagues, helped to improve the quality of astronomical training. To the surprise of his astronomers, Keeler decided not to use the 36-inch refractor for his research, but instead to refurbish the unused and rickety 36-inch reflector which Holden had obtained at a bargain price from Edward Crossley, a wealthy English amateur astronomer. Keeler, displaying his first-rate skills as an instrumentalist, soon had it in good working order. In his decision to use this telescope Keeler was again showing the forward-looking attitude that characterized all of his professional work. He realized that reflectors, heretofore little used for astrophysical work, were actually superior to refractors. (And in fact, the Yerkes 40-inch was the last large refractor made; all major telescopes since have been reflectors.) The photographs he took with the Crossley of star clusters, gaseous nebulae, and spiral galaxies enormously impressed astronomers. Unfortunately, he died before he could really begin to exploit this instrument.

Osterbrock has written an extremely interesting book which well describes Keeler the astronomer. Keeler the man does not emerge as clearly, however, possibly because nearly all of his personal papers and letters were destroyed in a 1923 fire. The author gives enough details (about eclipse expeditions, for example) to give some of the flavor and practical difficulties of late nineteenth century observational astronomy, as well as providing a broad sketch of the early development of American astrophysics.

R. C. Bless is a professor of astronomy at the University of Wisconsin-Madison.

UP COUNTRY: Voices from the Midwestern Wilderness compiled and edited by William Joseph Seno. Madison, WI: Round River Publishing Company, 1985. 242 pp. $11.95.

By Maggie Blackbourn Korslin

When we pick up a newspaper any day, we can read exactly what happened at a particular event. Our counterparts in the seventeenth century weren't so lucky—and exciting things were happening all around them! Explorers were uncovering a whole new territory and, fortunately, often kept a journal of their activities.

Up Country: Voices from the Midwestern Wilderness gives us the chance to find out the details of their experiences. A compilation of journals, letters, and memoirs written by early adventurers in the Midwest, author William Seno's book spans the years from 1656, when French and English explorers first came upon the unseen wilderness, to 1832, when Chief Blackhawk surrendered in Illinois. Seno's passages give an accurate description of what the "up country," the term explorers gave to the Midwest, was like when they first began to explore and colonize.

Each chapter begins with Seno's explanation of the events taking place when the piece was written. He also explains the location as we know it today in the Midwest. For example, in a chapter called "Arm of Iron," Henri de Tonty, one of LaSalle's followers, arrives at a Potawatomi village. Seno explains in parenthesis that this village was near the site of Kewaunee, Wisconsin. Because he supplies the exact location, we get a good idea where the explorer was headed when the passage was written. Sometimes the early names were far more interesting than they are today. For instance, the Ohio was once known as the Ouaboukigou.

It's also interesting to note the explorers' perceptions of a certain area and what that area is actually like today. In a chapter called "Fatal Winter," Father Jacques Marquette, on a mission to christianize the Illinois Indians in 1674, describes his stay in what is now downtown Chicago. "During our stay at the mouth of the river, Pierre and Jacques kill three buffalo and four deer, one of which runs some distance with its heart split in two. We content ourselves with killing three or four of the many turkeys that come near our cabin."

We get the feeling of what it was like when the Europeans met the native Americans for the first time. In one chapter, Father Louis Hennepin, a Franciscan priest accompanying LaSalle, tells about being captured by the Sioux. "As we approached their village (at Mille Lacs Lake), the savages took all the articles of my portable chapel except the chalice, which they dared not touch. Seeing its glittering silver gilt, they closed their eyes saying it was a spirit which would kill them." For five months, Hennepin and others were held captive and lived day-to-day, not knowing if they'd be killed. "Toward the end of September we told the Sioux that we had to return to our French settlement. The great chief consented and traced on paper the route we were to take for 1,000 miles."

Seno chose some of the most descriptive passages ever written for *Up Country*. In one chapter Alexander Henry, a young trader, tells about the Indians' attack on the fort at Mackinac. He describes the uneasy feeling he gets when over 400 Indians come to the fort. After encouraging the English to watch a game of lacrosse between the Chippewas and the Sauks just outside the fort, the Indians toss the ball over the stockade and into the fort.

> "Suddenly, the Indians pulled weapons from under the blankets of their women, turned, and began slaughtering the startled English soldiers. Going to my window, I saw a crowd of Indians inside the fort, furiously cutting down and scalping every Englishman they found. In this dreadful interval, I saw several of my countrymen fall, and more than one struggling between the knees of an Indian, as they were scalped while yet living."

The entire book is illustrated with paintings and drawings by some of America's best frontier artists—Catlin, Remington, Eastman. Scattered between stories, they lend authenticity to Seno's work.

Three centuries later, we have journalists who are paid to tell us what is happening or how they feel. And these journalists have editors who tell them how to tell us the news. Seno's choices in *Up Country* give us the feeling of listening to the explorer tell his travels firsthand.

Maggie Blackbourn Korslin is an editor for Madison Family Insurance.

THE HOUSE: Poems by Bink Noll. Baton Rouge, LA: Louisiana State University Press, 1984. 56 pp. $6.95.

IMAGINING A REVOLUTION: Poems about Central America by Dennis Trudell. Madison, WI: Ojala Press, 418 Elmside Blvd., 1984. 28 pp. $2.50.

By Ray Smith

Decorum both graces and limits Bink Noll's personal history of domestic occasions, at its most fluent in an opening passage:

> Allow your hour among us to calm
> your opinions, your face, your gestures
> like the light flowing through linen sheets,
> the brass smiling at its own brightness.

The House is Noll's third book of poetry, following *The Center of the Circle* (1962) and *The Feast* (1967). Its urbane conversational mode has the virtues of precision and a tempered wit.

But slackness comes in, the prosody slipping proseward. "Guests," which concerns the ritual deportment of polite dinner, isn't very interesting and the rhetoric flattens without some wanted twist in vision in place of "Stomachs fill only / to quicken wits. We are all safe / until right after the farewell quips."

"Emptying the Birthplace," describing the poet's return to sell his childhood home where he encounters "pickles / put up thirty years ago" by his mother, holds the moving line "I have finished knowing her." Its sequel, "The Inheritors," continues the theme more discursively and with some confusing syntax ("Today they who are buried in New Jersey, their souls / are exiled in Wisconsin").

Muted conflict enters *The House* with "Angel" and "Divorce" ("I wish her a prosperous amnesia"). And "Hunger" and "The Hovel" bring a social dimension, again tending to expository statement ("Men who live in hovels are not citizens"). "Commonweal" gives a supplementary glimpse of what the poet elsewhere calls "my residential vision": "The house is a way for the city to flower."

Noll memorializes domestic tranquility, ennui, sometimes a lurking horror, with minimal verbal-muscular excitement. "Walls" shows the proseward tendency which will become formally apparent in the prose of paragraphs of "The Hive" and "Groceries":

> They stand for primal
> solitude where he can't be seized
> and are central to growth of law.
> Autocracy, ownership, greed
> and xenophobia are what
> Robinson Crusoe's all about.

A classroom expository rather than a poetic statement.

Poems that show Noll's manner at its best include "Nightlight," the sustained experience of a half-walking excursion out of bed to check for an imagined prowler, and "Thirty-two Lines To Post Inside the Medicine Chest." The latter achieves a speech cadenced and textured just enough for memorable communion:

> Dear unseen brother, I wish you
> two miracles. . .
> that you'll close this door and not see
> your face at all, the way dogs don't,
> who have no immortal longings,
> and that you'll enjoy years from now
> a small wild casual death like
> the squirrel we picked up off the lawn.

"The Linens," "The Hive," an inventory concerned with storing "my hoard, safekeeping," and "When the Summer Clothes Are Brought Down" commemorate occasions of the domestic year in prose paragraphs. So does "Groceries" which self-indulgently details a shopping day, the odors and sights while putting away "fish, baked goods, butchery, bananas, green peppers," the author "a reporter of soups, liking the idea of cereals, of barnyard, and orchard."

"The Dressing Room," about appearance calculated with amorous innuendo toward everyone, hitting the high C's of urbanity, restores the more comfortable mode of preened diction.

In Noll's concluding pages, "What I Would Save in Case of Fire" lists finches, pictures of parents, a sterling punch bowl, family heirlooms—"It's homesickness that is taking the form of a catalog for a way of life achieved and ending." "The Lock" sums up his retrospective look:

> The lock has not made me feel good,
> only intact—like my purchases.
> I have not honored the unknown
> nor allowed the curious to know.

The domestic complacencies of vicissitudes and the measured phrasing of *The House* are a world apart from *Imagining a Revolution.* And Dennis Trudell's homemade chapbook contrasts in format to the well-tailored Louisiana State Press production, suggesting this poet's urgent sense of mission and the priority for him of message over form.

In sometimes nearly raw outrage Trudell evokes the continuing horror of events in Latin America enacted with United States complicity.

The first eleven out of a total of twenty poems "were written to photographs by Susan Meiselas collected in *Nicaragua* (Random House, 1981)." They have the requisite surrealist imagery as in "Faces Under Soft-Brimmed Caps":

> These are the faces
> that must kill the pride in their own villagers' eyes—
> that must crush the anger to a dollarlike shape
> while plucking their own interior eyes
> with the tong of days. . . ."

(Elsewhere these are "men with clenched shadows," in a cartoonlike imagery that recalls Mexican mural painting.) "The Dead Often Wear. . ." notes "The stained shirt that is removed" but which "may be hidden somewhere like a grenade / The dead often shine one last time." Trudell confronts the terrible difficulty and importance of getting such imagery into the mind below the surface rush of our cinematic homogenizing daily news.

"Masaya, Nicaragua" makes an unsorted litany of protest, a crowding detail and assertion not realized in the texture that powers verse into experience.

"Strangers," the first piece after the eleven written to photographs, attains a more whole and moving speech and focus. It recalls Denise Levertov's question-and-answer poem about Vietnam and succeeds for the same reason—a selective, honed dialogue absorbing the sense of conflict:

> You are Northamerican. You have mountains of agony
> to move through.
> We love and fear you, and we await you.

Ray Smith, a Wisconsin poet and retired teacher-librarian, lives now in Vashon, Washington.

AROUND THE SHORES OF LAKE MICHIGAN: A GUIDE TO HISTORIC SITES by Margaret Beattie Bogue. Madison: The University of Wisconsin Press, 1985. 383 pp. Cloth $35. Paper $19.95.

By Dennis Ribbens

Lake Michigan: 307 miles long; as much as 118 miles wide; 22,300 square miles large; a shoreline of 1,660 miles; 923 feet deep; surrounded by dunes, clay cliffs, limestone bluffs, dairy farms, northern forests, orchards, steel mills, hundreds of cities and villages, and millions of people. Other guidebooks to this important area have been written. Two things separate Margaret Bogue's book from the others. First, it has the ring of someone who really knows what she is talking about. Whether in the longer introductory historical essays or in her specific comments on some community's historic buildings or harbor, Bogue demonstrates a firsthand knowledge. The book is packed with information. Clearly Bogue has done her reading and her walking. And second, the book has merit not only as a guidebook, but also as a history of the Lake Michigan region. It introduces the reader to the history of the area at large and of the communities that border the lake. The subtitle of the book identifies the primary but not only objective of the book. To use Bogue's words, "this book is designed to provide . . . insights into the political, economic, and cultural history of the [Lake Michigan] area, from the time of the prehistoric Indians to the present . . . to those who travel Lake Michigan's shores." But Bogue additionally provides information which will help travelers enjoy the lake's natural environment, by commenting, for example, on park facilities and unusual natural features. Many illustrations and maps are provided.

The first quarter of this 383-page book contains brief general essays on the history of the Lake Michigan area. Fully one-third of this material is given over to history prior to 1830, resulting in a historic imbalance in favor of the earliest time period, a pattern which tends to characterize most of the later brief community histories as well. Several of these overview essays are excellent introductions to Lake Michigan history, in particular those covering transportation, forestry, mining, fishing, and the development of cities. In the essay "Cities and Towns" Bogue demonstrates how well she is able to bring together a mass of information from all around the lake, thereby providing a fascinating comparison of development in different parts of the region.

The body of the work, "Around the Lakeshore," follows the shoreline of Lake Michigan from Chicago northward and back down the east side, covering 182 separate locations, 16 in Illinois, 61 in Wisconsin, 98 in Michigan, and 7 in Indiana. Quantitatively the book demonstrates a slight Wisconsin bias. Twenty-three pages are devoted to Milwaukee in contrast to only 26 to Chicago. The 61 Wisconsin sections take up approximately 120 pages whereas the 98 Michigan sections are covered in 80 pages, a disparity which the greater population density on the west shore of Lake Michigan alone probably cannot account for.

The brief community histories are for the most part very well done, especially in their attention to various ethnic groups. However, some community histories are little more than summaries of industrial development supplemented with brief demographic information. For each community both a brief history and a list of points of interest are included. Bogue's bias runs toward architecture, especially churches and mansions of the wealthy. Likewise the Lake Michigan communities which receive comment are with few exceptions nonrural. Little attention is given to the evolving ethnic groups and the economies of the rural areas around Lake Michigan. Although environmental issues are taken up in the earlier historic overviews, eroding or improving environmental conditions are largely ignored by the community histories.

Inevitably fault can be found with a book of this sort in one way or another. For example, the inclusion of Pulaski and St. Nazianz seems questionable. Arcadia is omitted. The fishing activities of Fairport and Gills Rock are not mentioned. Inadequate directions are given to some of the sites. Some communities get short shrift.

But the book remains overwhelmingly useful and interesting. It is a great book to sit down and read cover to cover. It is a great book to keep in the car or suitcase while traveling. And it is a great book to have on one's shelf for reference. Probably my greatest complaint is its clumsy, wider-than-high format which makes is hard to use as a guidebook. In any case, this is one Lake Michigan guidebook that will become water and food stained, worn and torn, possibly lost, but in any case, read and used. What higher recommendation can a book receive?

Dennis Ribbens is university librarian at Lawrence University, Appleton.

GROWING SEASON by Alden R. Carter. New York: Coward-McCann, 1984. 276 pp. $13.95.

CRAZY QUILT by Jocelyn Riley. New York: William Morrow, 1984. 215 pp. $11.50.

ROOT RIVER RUN by David Kherdian. Minneapolis: Carolrhoda Books, 1984. 160 pp. $9.95.

By Richard Boudreau

For some years now the designation children's literature has been strangely out of whack. The Lilliputian spread between those books at the preteen end of the scale and those at the late teen end has become Brobdingnagian. While the former have altered but slightly, the latter, better called adolescent novels, now raise serious contemporary problems, problems once ignored or denied—rape, premarital sex, abortion, incest, homosexuality. They deal with these issues in a frank and open manner, in language that real kids actually use. Of the books under review here, two belong to that category; only the third seems appropriate to the old designation of children's literature.

The first, *Growing Season*, by Alden R. Carter of Marshfield, looks at the conflict of the emerging adult caught in the crosscurrents of obligations to his parents and his family and obligations to himself and his own future. Exchanging an enclosed neighborhood in Milwaukee for the wide open spaces of mid-state Wisconsin is wrenching enough for eighteen-year-old Rick Simons; 240 acres are, after all, not a postage stamp yard in the inner city. But when the demands of that farm keep him from the graduation ceremony back in the city; force him to endure blood, sweat, and tears for an entire summer; and threaten finally to keep him from pursuing his life's goal of becoming an architect, his forebearance wears thin.

All of the narrative is played out within an unusual family infrastructure: mom, pop, and six children, only two, Rick and Pam, their natural offspring. The four adoptees all have special problems which Rick, as the oldest, must help solve too. The story line is basically simple, but the complications of these interrelationships, family and otherwise, twist about in sometimes humorous, sometimes tragic fashion. There are a couple of *deus ex machinas* along the way, but they are handled well, and like most adolescent novels today, the denouement is not perfect, not fully satisfying—to the main character or to the reader.

But that's life. Indeed that seems to be Carter's aim—to present a straight-from-the-shoulder telling in modern terms of the age-old dilemma of the generation gap. And he does it well. Having Rick as the narrator helps; having fleshed-out, individual characters around Rick helps too. This is a first book for Carter, and it won an American Library Association Best Book for Young Adults designation. A second novel by him, called *Wart, Son of Toad*, has already been advertised for upcoming publication.

Not everybody's mother pulls a butcher knife on the paper boy or throws down the Christmas tree to smash all the glass ornaments. Of course, not everybody's grandmother physically kicks her daughter when she's down (or when she's up) either. Those are some of the zany—but hardly humorous—past happenings that set the stage for this second novel for adolescents by writer Jocelyn Riley of Madison. Even so there is a sort of black humor possible in the face of such adversity, such as when son Ron, with great tolerance, refers to his mother as "our friendly neighborhood lunatic."

Riley's first novel, the award-winning *Only My Mouth Is Smiling*, introduced Grandmother Lily, mother Elaine, daughters Merle and Diane, and Ron. That book concerned the children's bizarre, difficult, and long summer, living in a shabby little house on lonely Lake Lune in Wisconsin's northwoods while their mother slipped further and further over the edge. Later that fall while their mother was "weirding out," the children had the added problems of adjusting to school in the nearby "cow town." None coped well, and it all came to an end with the incarceration of their mother and the return of the children to the Chicago suburb to live with their grandmother.

Crazy Quilt starts out well with Merle, as narrator, presenting her immediate problems: her adjustment to junior high, made difficult by a wildly rebellious classmate, Jinx Normandale; the introduction of her grandmother's new boyfriend, whose presence threatens their already uneasy living arrangement; and the attempts of her mother to get out of the hospital and back into their lives. But there are serious problems with the book. In spite of its beginning, it's unclear where the story is heading. Nor does anything involving occur until the second half—and that's too long a dry spell. Actions by several characters appear unmotivated or dictated by whimsy, a sort of literary cheating best exercised sparingly.

Root River Run is the story of David Kherdian's growing-up years in Racine in the forties. Fortunately, his reminiscences about those struggles and the added one of being both Armenian and American are more happy than sad, light than dark, humorous than tragic. Setting that upbeat tone is a short introductory sketch of what was perhaps his first vivid memory of his home town—his mother taking him to the movie house and on a walking tour to Monument Square near the lake.

Episodic in structure, the story touches on several difficulties and adventures faced by the young Armenian American: the problem of names, no problem at all for David, but for his friends, Garabed, Esahag and Khatchik, requiring adoption of the strange-sounding Chuck, Eas and Harry; the adventures of going after bait, from buying a slab of liver from an Armenian butcher eternally amused at the American nickel's Indian head and buffalo, to floundering around in the Root River looking for crabs; the embarrassment of David over his father's fractured English even though he knows his father's wisdom in Armenian; the confusions of school, where the teacher, "Kidney Beans," is bested by a parent of an Armenian boy who dirtied his pants in her classroom but who avenges herself by flunking nearly all the Armenian kids that year.

Root River Run is touted as the final book in a Kherdian trilogy, the first two being *The Road from Home*, about his mother's sufferings during the persecution of the Armenians by the Turks during World War I, and *Finding Home*, about his mother's coming to this country and setting up a home in Racine. Though true as far as family, setting, and chronology are concerned, such a suggestion is misleading. Those books were for a general audience, this one is for an adolescent; those were about his mother, this is about him; those were in third person, this is in first person. On its own terms *Root River Run* is a story filled with some finely told, warm, and humorous chapters, though the interest of the story line is not sustained throughout.

Carter's book so far stands complete; Riley's is a sequel to an earlier one; Kherdian's is supposed to be the last of a trilogy. In each the protagonist is a teenager trying to find himself, to define himself against family and culture, and to grow into a complete, self-reliant individual. Children's literature, yes, but hardly easy bedfellows. *Growing Season* is certainly intended for the later adolescent; *Crazy Quilt* for the middle adolescent; *Root River Run* for the early or perhaps even the preadolescent.

Richard Boudreau teaches American literature at UW-La Crosse.

New Books to Note

RIVER CITY MEMOIRS by Dave Engel. Wisconsin Rapids; South Wood County Historical Corporation, 1984. 120 pp. $13.95. The third volume of local history in this series; the first volume was reviewed in the March 1984 Wisconsin Academy Review, p. 77.

KENOSHA KALEIDOSCOPE: Images of the Past by Don Jensen. A collection of historical vignettes appearing over twenty-one years in the Kenosha News.

THE EVE OF REVOLUTION: An Antiwar Memoir by Jim Missey. Stevens Point: Portage County Historical Society, P.O. Box 672, 1985. 36 pp. $3.50 postpaid. A UW-Stevens Point English professor remembers the campus during the difficult years of the Vietnam War to attempt to understand the impact of the war on society.

A REFLECTION OF TIME: A History of the Wisconsin Union Art Program and Collection by Jody Schmitz. Madison: University of Wisconsin, 1985. 32 pp. Available from the Wisconsin Union, 800 Langdon St., Madison 53706 for $1.00 postage. The history of one of the largest collections of original Wisconsin art in the state, with illustrations and essays on selected artists from the collection.

BIRDS OF THE APOSTLE ISLANDS by S. A. Temple and J. T. Harris. Hartland, WI: Wisconsin Society for Ornithology, 1985. Available from WSO Supply Department, 246 North High Street, Randolph, WI 53956 for $1.00 plus postage. 62 pp. Detailed descriptions of habitats on the islands, the migration of birds through the islands, and the status of birds that breed and spend the winter.

WISCONSIN ACADEMY REVIEW

Second-class Postage
Paid at Madison, WI

1922 UNIVERSITY AVENUE
MADISON, WISCONSIN 53705

Address Correction Requested