Direct testimony of Exxon witnesses before the State of Wisconsin Division of Hearings and Appeals. Volume 1

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CRANDON PROJECT

DIRECT TESTIMONY OF
EXXON WITNESSES

BEFORE THE
STATE OF WISCONSIN
DIVISION OF HEARINGS AND APPEALS

APPLICATION OF EXXON CORPORATION FOR PERMITS TO BUILD AND OPERATE AN UNDERGROUND MINING AND ORE CONCENTRATING COMPLEX LOCATED IN FOREST COUNTY, WISCONSIN	IH-86-18

VOLUME I

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Additional witnesses - The following individuals may be called by Exxon as additional witnesses: Ms. Jennifer Monopolis or Mr. Raymond Mitro.

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TESTIMONY OF BARRY J. HANSEN

Q. Please state your name and occupation.

A. My name is Barry J. Hansen. I am employed by Exxon in Rhinelander, Wisconsin, as the Permitting Manager for the Crandon Project. In this capacity, I am responsible for the environmental and regulatory affairs associated with the Project, including all permitting activities.

Q. How long have you been the Permitting Manager for the Crandon Project?

A. Since February, 1983.

Q. Would you please briefly describe your educational and professional background?

A. My educational background includes a B.S. degree in metallurgy from the Montana School of Mines and graduate work in mineral engineering at the Henry Krum School of Mines, Columbia University. My experience in the mining industry includes eighteen years of metallurgical engineering and research before I joined Exxon in 1976 as a Senior Staff Engineer in Houston. My full-time involvement on the Crandon Project began in 1977 as the Chief Metallurgical Engineer, with subsequent assignments as Technical Service Manager and Surface Facilities Engineering Manager. My resume, which is EXHIBIT 100, provides more information about my background.

Q. What is the subject of your testimony today?

A. I will set the stage for other witnesses' testimony by giving a very general description of Exxon's Crandon Project and of the way the Project will affect the nearby communities and the natural environment. I will also introduce into the record the permit applications and feasibility reports on which Exxon relies during this hearing.

Q. Would you please describe the Project?

A. I will be happy to supply a general description of the Project. A detailed description of the individual facilities and operations will be provided by the other witnesses who will follow me.

EXHIBIT 101 is a map showing the location of the Project. The Project is designed to recover zinc, copper, and lead, and small quantities of gold and silver, from an orebody located approximately 5 miles south of Crandon in the Towns of Lincoln and Nashville. The orebody (EXHIBIT 102) contains approximately 67 million tons of ore and consists of two major ore types. The zinc resource amounts to about 42 million tons containing about 8.4 percent zinc, 0.6 percent copper, 0.7 percent lead, and smaller quantities of gold and silver. The nonferrous metals occur in a matrix of pyrite. Pyrite is iron sulfide. This occurrence gives rise to the name "massive sulfide" for this ore type. Our plan is to initially concentrate on this ore type and produce primarily zinc from the ore reserve.

The other major ore type is primarily a copper resource, and is designated as "stringer ore." Stringer ore consists of veinlets or stringers of copper and zinc minerals occurring in a matrix of quartz, which is silica. This ore amounts to about

25 million tons and contains about 0.7 percent zinc, 1.8 percent copper, a nearly negligible amount of lead, and even smaller amounts of gold and silver. Mining of the stringer ore would begin in approximately Year 17 of the Project, and would continue until the planned date of reclamation in the 32nd year of operation.

Q. Please describe the major facilities to be built for the Crandon Project.

A. (EXHIBIT 103) The mine and mill surface facilities will be located in a 115-acre area surrounding or adjacent to the main shaft and headframe. A portion of this area will be covered by buildings, roadways, parking lots, and ancillary facilities. The remaining area will either remain in its natural state or, if disturbed, will be landscaped for erosion control and general aesthetics.

As you can see from EXHIBIT 103, the mine waste disposal facility (MWDF) will be located in an area approximately one mile southeast of the mine and mill site. The MWDF is the tailings disposal site. This facility, consisting of four tailings ponds, will be designed and constructed for safe disposal of tailings generated from milling the ores. The tailings ponds will be constructed and reclaimed in stages over the operational life of the mine, and will ultimately occupy about 365 acres.

The reclaim water pond with two cells will be located adjacent to the northwest side of the MWDF and will utlimately encompass approximately 50 acres. Water will be recovered from the tailings ponds and other facilities and stored here for recycle to the mill.

A mine refuse disposal facility (MRDF), or landfill, will be located north of the tailings ponds and east of the reclaim pond. This facility will require an area of approximately 15 acres and will be used for the disposal of ordinary trash and refuse.

The mine and mill site and the MWDF area will be connected by a corridor containing the MWDF access road and the slurry and reclaim water pipelines. This corridor will extend from the eastern side of the mine and mill site to the southwest corner of the reclaim pond.

An access road will connect the mine and mill site to State Highway 55 at a point northwest of the site. A railroad spur will connect the mine and mill site to the Soo Line Railroad northeast of the site. An excess water discharge pipeline will extend from the mine and mill site area to Swamp Creek about six miles to the west.

Q. How will the ore be mined?

A. Mr. Don Moe will supply a detailed description of the mine. I would like to make the point that the mine will not be an open pit, surface mine (EXHIBIT 104). So that its mine will be the most efficient and the least environmentally disruptive, Exxon plans to sink shafts from the surface to the orebody, as much as 1,800 feet below ground. Ore will be mined underground and will be elevated to the surface where the metals will be recovered in the form of concentrates.

One of the most significant aspects of the mining method is the utilization of tailings, or mine waste, to fill the void resulting from the mining of the ore. Coarse fractions of the tailings, about one-half the weight of the ore, will be permanently disposed in mined out areas. This method allows a high recovery of the ore, prevents surface subsidence, and minimizes the surface disposal of wastes.

Q. What will happen to the ore after you remove it from the mine?

A. The process for the treatment of the ores includes crushing and grinding to liberate the zinc and copper minerals from the host rock. EXHIBIT 105 is a schematic drawing from which we can see what happens to the ore after it is lifted from the mine. It travels first to the coarse ore storage building, then to the concentrator where metals concentrates are produced. Concentrates of zinc, copper and lead are produced by a process known as flotation. Mine backfill is produced from the tailings by size classification. And finally, the tailings are disposed and water reused.

Flotation will produce a copper concentrate containing approximately 27 to 28 percent copper, a zinc concentrate containing 55 to 60 percent zinc, and a lead concentrate containing 50 to 60 percent lead. Precious metals -- gold and silver -- will be recovered with the individual concentrates. The concentrates will be dewatered by filtration and shipped by rail to other locations for processing into metals. There will be no smelting on site.

Mine backfill will be prepared by separating coarse fraction from the tailings by means of a cyclone separator. The mine backfill will then be pumped as a slurry back underground to fill the mining void.

Water will be removed from the fine tailings in the thickener and will be recycled to water treatment and the the concentrator for reuse. Fine tailings will then be pumped to the mine waste disposal facilities, or MWDF. The details of the mine waste disposal facility and the water treatment system will be described by Mr. Donald Moe and Mr. Michael Harris.

Q. Let me stop you there for a moment. Did Exxon investigate whether any of the mining wastes to be disposed of in the tailings ponds could be marketed instead?

A. Yes. Exxon investigated the potential marketability of both sodium sulfate, a waste product from the water treatment process, and pyrite, a by-product from ore processing. Sodium sulfate is used in the manufacture of detergents and by several pulp and paper mills, and there is a potential market for this product at mills in Wisconsin and other states in the Great Lakes region and in Canada. If a market for sodium sulfate is reasonably available at the time this product is generated, we will attempt to market it rather than dispose of it on site.

With respect to pyrite, our studies found that there is no market for pyrite in its basic form. By-products of pyrite either have no reasonably available market or would result in a greater potential for environmental pollution than would our proposed disposal of this product in the tailings ponds. Thus, unless market conditions should unexpectedly change, we intend to dispose of the pyrite in the tailings ponds. The studies I have referred to appear in the record as EXHIBITS 166 and 187.

Q. What would the Project look like?

A. EXHIBIT 106 is an artist's rendering showing the major mine and mill facilities. These will be discussed in greater detail by Mr. Don Moe. The mine facilities include the headframe, hoist house, mine air heaters, the east exhaust fans, and the mine backfill delivery system. Waste rock and ore produced during mine development will be stored on the pad north of the railroad tracks during mine construction. After the start of operations, the waste rock will be removed, crushed, and used as backfill underground, and the ore will be processed. The most distant facility in this rendering is the explosives storage magazine.

The ore treatment facilities include the ore storage building and an ore conveyor system. The concentrates are produced in the concentrator building and are shipped out by rail through the loadout tracks and the spur access to the Soo Line.

Ancillary facilities include the tailings thickener, the water treatment plant, discharge water lagoons, main electrical substation, and compressor house.

Shops, offices and laboratories are contained in the services building north of the employee parking lot, which is accessed through the main access road which leads from Highway 55.

Q. How long has Exxon been studying this Project?

A. The story of the Crandon discovery to this point has, in fact, been a long one. (EXHIBIT 107) Exxon started exploring in 1969 with airborne electromagnetic surveying. The presence of the orebody was indicated by the discovery of an anomaly in 1974. After additional geophysical testing, the presence of a mineral occurrence was verified by means of diamond drilling. The initial intersection with mineralization occurred July 4, 1975. The discovery date was initially considered to be an auspicious sign. Subsequent diamond drilling confirmed the presence of an orebody of potential commercial dimensions, and a public announcement was made in May 1976. The Project Development Team was organized in the latter part of 1976 and established in the field in Wisconsin in 1977. Exxon submitted a Notice of Intent to collect data to support a mining permit application July 1978.

Following intensive environmental and engineering studies, an Environmental Impact Report was submitted to the DNR in December 1982. The dialogue initiated with the DNR in the latter 1970's continued with additional intensity through 1985, with progress being made on the drafting of an Environmental Impact Statement. In May 1985, Exxon notified DNR of a significant change in the Project Plan. The mine was to be downsized. The initial emphasis would be on the development of the zinc resource. Copper is to be mined in the later years of the Project's life. Exxon revised its permit applications and Project description, and the DNR completed its Draft Environmental Impact Statement and released it for public distribution May 12, 1986.

Following public and agency review of the Draft Environmental Impact Statement, DNR revised its DEIS and released its Final EIS, together with the permit applications and the notice for this Master Hearing. That has lead us to this hearing today.

Since starting the development activities for the Crandon Project, Exxon has invested over $60 million in bringing the Project to this hearing stage. It is fair to say that this is the most intensely studied major industrial project ever undertaken in Wisconsin. The studies have been worthwhile because Exxon is committed to being a good neighbor, both in seeing to it that the nearby communities share fairly in the economic benefits of the mine and in assuring that the natural environment is protected.

Exxon has cooperated from the very beginning with the DNR and local governments. In the course of the studies of the mine's potential environmental effects, DNR staff members and their consultants have visited the site and have observed the work of Exxon's own researchers in progress. Exxon has shared its samples and data with the Department, and has cooperated with the Department's independent modeling and investigative efforts.

Q. What effect will this Project have on the nearby communities and the state?

A. If the permits are granted and if Exxon determines that it can profitably mine the ores under the conditions the DNR writes into the permits, Exxon will invest about $390 million to purchase the necessary equipment, materials, supplies and labor. (EXHIBIT 108) During the nearly 30 years of operations of the Project, Exxon will invest an additional $144 million in capital facilities. This is over and above the normal operating and maintenance costs. Over one-half of the

$144 million will be for facilities to protect the environment and for reclamation. The remainder will be to replace equipment and do the necessary development work.

Exactly how much of this large investment in equipment, supplies, and material will go to Wisconsin businesses is pretty much up to those businesses themselves. However, based on what we know about the potential suppliers, it is our estimate that about $94 million could be spent in the state during the construction period. Including construction wages, the total spending in the state for the construction of the Project could amount to $212 million.

The Crandon Project will be a direct and immediate benefit to the local, regional, and state economy. In addition to our spending, our studies show that for every dollar spent by Exxon during the construction, an additional $2.50 in business volume will be produced in Wisconsin.

The Project will employ as many as 1,200 workers during the estimated 3 year construction phase and over 600 workers during the operating years. Exxon expects that more than one-half of the operating workers will be people who already live in the area. Exxon's payroll during the operating years will be approximately $16 million annually, much of which will be spent in the communities near the Project. The mine will thereby benefit other local businesses, in turn generating more jobs.

One of the major beneficiaries of the Project will be the State of Wisconsin. The state has one of the highest mining taxes in the country. EXHIBIT 109 lists estimates of the various taxes Exxon will pay as a result of the Project. In addition to the more than $100 million in state corporate income taxes, the Project could potentially also pay more than $117 million in net proceeds tax during the Project's life. (These estimates were prepared by the Department of Revenue based on information submitted by Exxon.) It is interesting to consider the payment of net proceeds taxes, which is a unique tax applicable only to the mining industry. One of the more interesting features of the net proceeds tax is that at least one-half of the net proceeds tax would be saved for the future. The "Badger Fund," which was created by the mining tax law, would receive 40 percent of the net proceeds tax paid by the Company. In addition, the Project Reserve Fund would receive another 10 percent of the net proceeds tax.

Local jurisdictions will also benefit from the Project. Based on a preliminary estimate, the Project would more than double the Forest County tax base and would nearly triple the Crandon School District's valuation.

Forest County, where the mine is located, and the neighboring counties of Langlade and Oneida, which will also benefit economically from the Project, have been economically depressed for many years. Their per capita income is lower than the state and national average. Unemployment is higher. The Project will decrease unemployment and increase residents' income. According to the DNR's evaluation in the DEIS, the Project will have a net economic benefit to the area, and Exxon is confident that the DNR's conclusion is correct, as Dr. Luke and Dr. Huddleston will testify during these hearings.

Q. But the mine will close eventually.

A. That is true. In the case of a mine, one can predict how long it will take to extract the known amount of ore. To that extent, the mine is different from some other form of industrial development. But the difference is only one of timing. An automobile factory or a papermill or any other sort of industrial development will also close sometime in the future. There is never an everlasting guarantee. The many industrial plants we have seen shut down in recent years testify to that.

But, for as long as the mine operates, it will generate wealth for the community. In addition to the private sector resources, the state has two noteworthy public sector sources of benefits that remain after the mine closes. Nearly one-half of the net proceeds taxes paid by the mine will flow to trust funds. As I stated earlier, the Badger Fund is set up as a permanent trust fund and is to receive nearly 40 percent of the tax. The interest from this fund will continue to provide a stream of benefits for the state indefinitely, if it leaves the principal intact.

As I also mentioned, the Project Reserve Fund, among other purposes, is set up as a special redevelopment fund and is to receive about 8 percent of the tax paid. This fund will be available to local jurisdictions to help them make the adjustments after the mine closes. It is also available to fund economic developments to help offset the effects of the mine closing.

The wealth generated by the community during the mine operations, the skill area workers develop as a result of the mine, and the Project Reserve Fund will create a powerful partnership of resources available to the community. This partnership of resources will be at the command of local incentive and create an opportunity for area residents to plan for the closing by founding businesses or attracting other employers which will remain after the mine closes.

Q. How will the mine affect the environment?

A. Exxon is committed to its having minimal effects. During this hearing, many witnesses will testify in detail about the steps Exxon will take to avoid or to mitigate environmental impacts. Let me mention only a few of their conclusions.

A project of this magnitude will not be invisible. But very little will be seen from off the site. Mr. Schreiber, who designed the Project's landscaping, will testify that the Project will be largely inconspicuous. The headframe will be visible from only a few locations. As Dr. Kessler will testify, mine neighbors will hear something of the mine construction and operations, but from off site the sound will not be a nuisance.

Wetlands have been of special significance to us. As Mr. Hollands will testify, the Project has been designed so that its construction and operation will minimize impacts to wetland areas.

The DNR and Exxon together have paid very close attention during the environmental studies to the mine's effect on both the quantity and quality of ground water and surface water during mining operations. The water used in the ore concentrating process will be recycled. Any water contaminated by the mine or the mill will be treated with state of the art technology before it is discharged into surface waters. Mr. Harris will describe the water management and treatment systems. The discharge water will be piped about six miles so that it can be discharged into Swamp Creek below the point that the creek supports a trout population and below the point where it could affect the wild rice crops in Rice Lake which are so important to Native Americans.

Because the mine would otherwise flood, Exxon must divert ground water which flows toward the mine. Waters which cannot be intercepted before they enter the mine will be pumped from the mine and treated. Exxon's pumping will result in a drawdown of the ground water levels near the mine. That may affect the flow of streams and the levels of lakes nearby. Exxon believes the effects will be very slight, at most a few inches in nearby lakes. But even if they are more, Exxon has committed itself to correcting the drawdown's effects on streams and lakes. The public's rights in these water will not be harmed. Dr. D'jafari and Mr. Prickett will discuss the hydrology studies performed for the Project. Exxon will provide water to neighbors whose private wells are affected by the drawdowns.

Q. What will happen after the mine closes?

A. As Mr. Lewis will describe, unless there is an approved alternate use, the mine and mill facilities will be removed and the area will be returned to what it is today: a forest. A casual observer walking over the mine/mill site a few years after the mine closes will not easily recognize that a mine had been there.

The mine waste disposal facilities will still remain, but they will be sealed and covered and the embankments and the surface will also be returned to natural growth. The sealing of the waste on all sides will protect the ground water from contamination, and Exxon will monitor ground waters around the waste facilities until the DNR is confident that the mine waste will not harm them. Reclamation alone will cost $35 million, all of it to be borne by Exxon.

Q. As Permitting Manager, are you familiar with all state and local applications for permits or approvals which have been filed for the Crandon Project?

A. Yes, I am.

Q. Please identify EXHIBIT 110.

A. EXHIBIT 110 identifies and describes the permit applications, plans, and feasibility reports Exxon has filed with the DNR to fulfill statutory and regulatory requirements for mining the Crandon deposit. Those filings are identified in EXHIBIT 110 as EXHIBITS 111 through 127.

Q. Are there any DNR application requirements which Exxon has not yet satisfied?

A. No.

Q. Turning now to local requirements, please identify EXHIBIT 128.

A. EXHIBIT 128 identifies and describes EXHIBITS 129 through 156, which are all of the permit applications Exxon has filed with local governments with permitting jurisdiction over various Project activities, and the permits which have thus far issued in response to those applications.

Q. In addition to these exhibits, are there any other reports on which Exxon relies in support of its permit applications?

A. Yes. EXHIBIT 157 identifies EXHIBITS 158 through 195 and 199, each of which is a report prepared by Exxon or its outside consultants in the course of its planning for the Crandon Project. In addition, the Draft Environmental Impact Statement (DEIS) prepared by the DNR is identified as EXHIBIT 198.

5015R

EXHIBIT 100

RESUME

BARRY J. HANSEN

Permitting Manager
Crandon Project
EXXON COAL AND MINERALS COMPANY
P.O. Box 813
Rhinelander, WI 54501

(715) 369-2800

BACKGROUND SUMMARY

- **Management**

  Twenty-eight years of diversified management and technical experience in the engineering, design, and operation of mining and metallurgical projects, including copper, lead, zinc, cobalt, nickel, molybdenum, iron, silicon, gold and silver ores. Experienced in all phases of mineral project management, including geological evaluation, site selection, testing, pilot plant design and operation, plant engineering and design, economic feasibility studies, permitting, and public affairs programs.

  Also experienced in the operation of mineral and metal production facilities, with particular emphasis on technical trouble-shooting and problem solving. Such facilities have included concentrators, smelters, refineries, and agglomeration plants.

- **Specialization**

  Areas of specialization include the following:

  - Plant Engineering and Design

    Directed siting, engineering and design studies for mine surface plant, including waste disposal facilities, concentrator, and road and railroads.

  - Permitting of Mining Projects

    Directed the completion of environmental baseline and impact studies for the production of all permit applications and documents. Supervised all liaison with Federal and State permitting and regulatory authorities. Also directed and participated in a very active public affairs program involving personal contacts with community groups and electronic and print media.

  - Metallurgical Engineering

    Expert in a broad range of processing techniques, including mineral dressing, hydro- and pyrometallurgy. Developer of patented processes for nickel recovery and the treatment of complex sulfide ores. Reduced operating costs and improved recovery in the El Salvador molybdenum recovery plant, several Hanna iron ore operations, and the Riddle Nickel Smelter and Wenatchee Silicon Smelter.

EMPLOYMENT HISTORY:

1976 – Present **Exxon Minerals Company, Crandon Project**, Rhinelander, WI

Permitting Manager (1983 – Present)

Responsible for all Permitting activities, Public Affairs and Community Planning. Manages a task force composed of Environmental Specialists, Engineers, Public and Community Affairs personnel and attorneys.

- o Directed the completion of the Crandon Project Environmental Impact Report (EIR) and permit applications.
- o Directed the completion of a comprehensive Socioeconomic Study of the effects of the development of the Crandon Project.
- o Planned and directed an intensive effort of technical review and discussions with Wisconsin Department of Natural Resources.
- o Managed a comprehensive program of Public and Community Affairs activities.

Surface Facilities – Engineering Manager (1982-1983)
Technical Services Manager (1980-1982)

Responsible for all engineering of Surface Plant Facilities, Process Engineering and Environmental Studies for the Crandon Cu-Pb-Zn Project.

- o Directed the completion of the engineering of surface plant facilities, including concentrator, waste disposal, water treatment, road and railroad and support facilities including cost estimates.
- o Directed the completion of an Environmental Impact Report and all permit applications.
- o Directed the successful completion of siting and technical studies for the development of an effective waste disposal system (MWDF) in a sensitive environment.
- o Directed the development of innovative water treatment systems in a sensitive environment.

Chief Metallurgical Engineer (1976-1980)

Managed all aspects of the process development activites for the treatment of the complex Crandon ores, including geological evaluation, laboratory pilot plant studies and feasibility studies.

- Directed the successful completion of the development of the process technology for the Crandon ores.
- Directed the completion of a zinc refinery feasibility and siting study.
- Represented the mining industry as a member of the Metallic Mining Council in the development of rules regulating mining in Wisconsin.
- Conceived and directed the completion of waste characterization and by-product marketing studies that provided the bases for the waste disposal system.

1963 – 1976 **HANNA MINING COMPANY - RESEARCH CENTER,** Nashwauk, Minnesota

Senior Supervising Research Metallurgist (1969-1976)

Managed Hanna's non-ferrous extractive process R&D. Directed engineers and technicians in developing process technology for nickel laterite, complex sulfide ores and precious metals.

- Developed and managed Hanna's non-ferrous research capability in the areas of nickel laterite and sulfide ores. Recruited professional staff, designed and installed pilot plant capability which is now being utilized as a revenue-producing contract laboratory.
- Performed pilot plant investigations that resulted in major modifications of the process flowsheet of the Cerro Matoso Nickel Plant.
- Developed a patented process for the recovery of nickel and magnesia from low-grade laterite.
- Supervised the successful development of a patented process for the treatment of complex sulfide ores.
- Performed process evaluation of oeprating practices at the Riddle Nickel Smelter that resulted in a heavy media circuit that incrased plant through-put.
- Conducted numerous process evaluations for new project investigations for gold, nickel, cobalt, and copper deposits worldwide.

Research Metallurgist and Supervising Research Metallurgist
(1963-1969)

Supervised process R&D in iron ore concentation and agglomeration. Participated in design of three pelletizing plants and modification of a fourth.

- o Conducted laboratory and pilot plant studies that defined the process requirements for the pelletizing plants for the following projects: Carol Lake Expansion, Labrador; Butler Taconite and National Steel, Minnesota; Pilot Knob, Missouri.
- o Supervised the laboratory, pilot plant, and full-scale testing program that resulted in the successful development of a process that reduced regrinding requirements for pelletizing of Carol Lake concentrates.
- o Conducted full-scale plant testing of bentonite utilization practices at the Groveland Mine that reduced bentonite consumption by 5-6 lbs/ton.
- o Conducted numerous laboratory and pilot plant studies of the feasibility of pelletizing iron ores and concentrates from Australia, Brazil, Canada, Liberia, Norway and the U.S.

1959 - 1962 **ANDES COPPER MINING COMPANY**, El Salvador, Chile, South America

Metallurgical Engineer (1959-1962)

Initially Shift Boss during the start-up of the 24,000 TPD El Salvador Cu concentrator and moly plant. Supervisor of crushing plant, concentrator and moly plant.

- o Trained and supervised Chilean shift operators in the start-up and operation of the 24,000 TPD El Salvador Concentrator and Moly Recovery Plant.
- o Led process studies in Moly Plant that reduced copper depressant consumption by approximately $1,000/day with no change in metallurgical performance.
- o Introduced changes in operating practices in the Crushing Plant that increased operating time and reduced operating costs.
- o Initiated a program of metallurgical investigations that resulted in the incorporation of metallurgical characteristics into the production plan.

1958 - 1959 **ANACONDA COMPANY**, Anaconda, MT

Mineral Dressing Trainee for South American Operation

PUBLICATIONS:

"A Study of the Flotation Response, Zeta Potential and Contact Angle Measurements on Molybdenite in Constant Ionic Strength Electrolyte Solution," M.S. Thesis, Krumb School of Mines, Columbia University, October 1968.

"Pelletizing Research at Hanna Mining Company," Society of Mining Engineers, Fall Meeting, 1972.

"Developments in the Processing of Complex Copper Sulfide Concentrates," TMS Paper Selection A - 74-95, with A. A. Dor.

"U. S. Patent No. 4,125,588, Nickel and Magnesia Recovery from Laterites by Low Temperature Self-Sulfation," November 14, 1978.

"Needs for Employment and Public Services," Nicolet College Forum on Mining in Northern Wisconsin, Rhinelander, WI, February 16, 1978.

"Mining in Wisconsin," Wisconsin Educational Association Forum, Wisconsin's Tax Law Impact on Education, Milwaukee, WI, October 30, 1981.

"Optimization of Pyrite in Mine Waste Backfill," with R. A. Ford, Rapid Excavation and Tunneling Conference, San Francisco, CA, May 1981.

LECTURES:

Mining Topics
University of Wisconsin - Platteville, WI. Mining Department, 1985 and 1986.

Mining Project Development
University of Wisconsin - Oshkosh, WI. Course in Resource Geology, Winter 1979-1980.

Mining and Reclamation
University of Wisconsin - Madison, WI. Soils Department, Fall 1979.

Metallurgical Process Development at the Crandon Project
Metallurgical Seminar, Colorado School of Mines, Fall 1979.

OTHER:

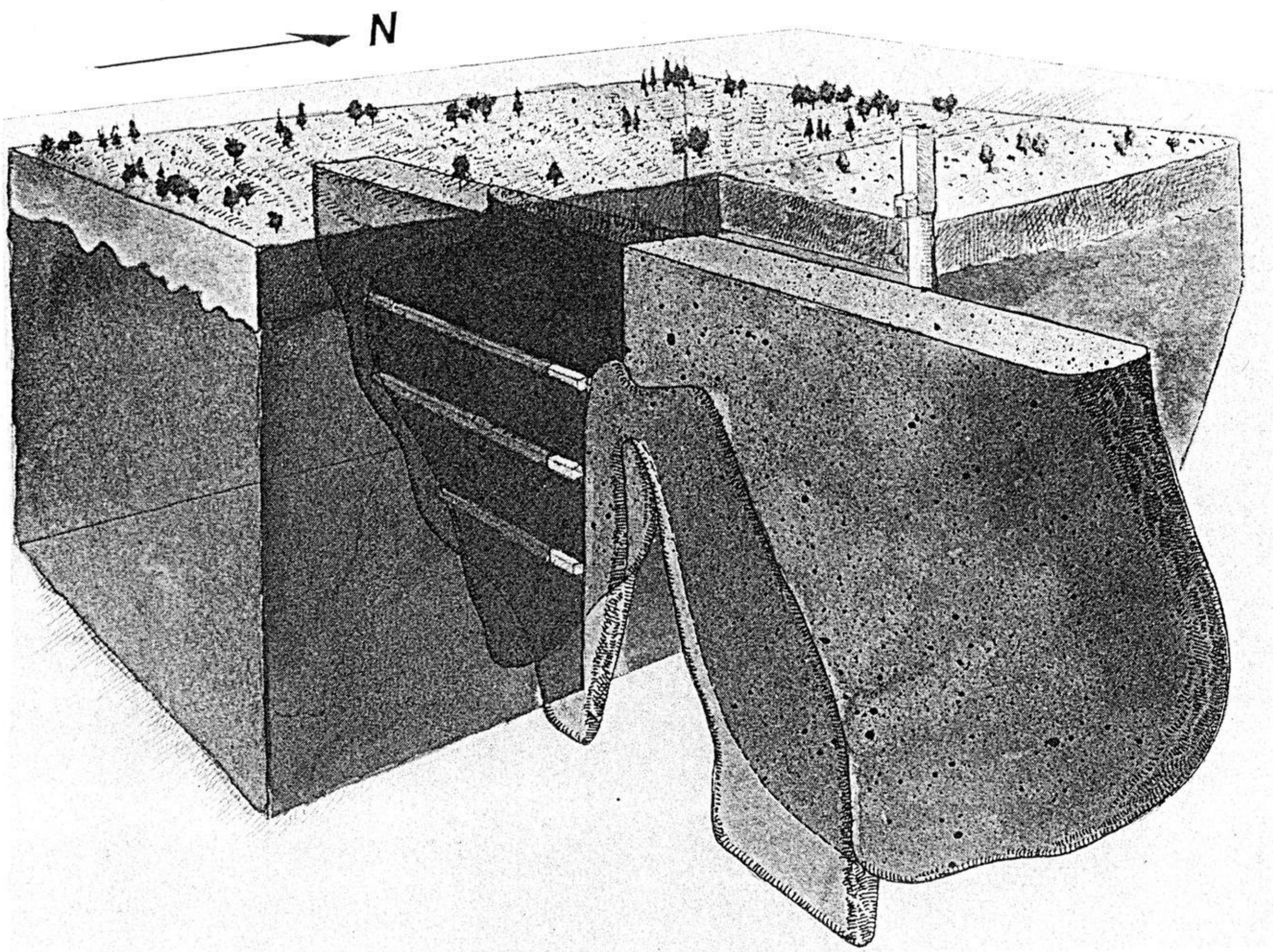
- Member, Editorial Review Board, Colorado School of Mines Quarterly.
- Member, representing the Mining Industry, of the Wisconsin Metallic Council, a Department of Natural Resources advisory body.
- Planned and directed Community Forums relating to mining and the Crandon Project.
- Past Chairman of the MPD Subsection Minnesota Section AIME.
- Program Chairman 50th Minnesota AIME Section Meeting.
- Minnesota AIME - Young Engineer of the Year - 1972.

EDUCATION:

1962 - 1963	Krumb School of Mines Columbia University
1954 - 1958	Montana School of Mines B.S. in Metallurgical Engineering

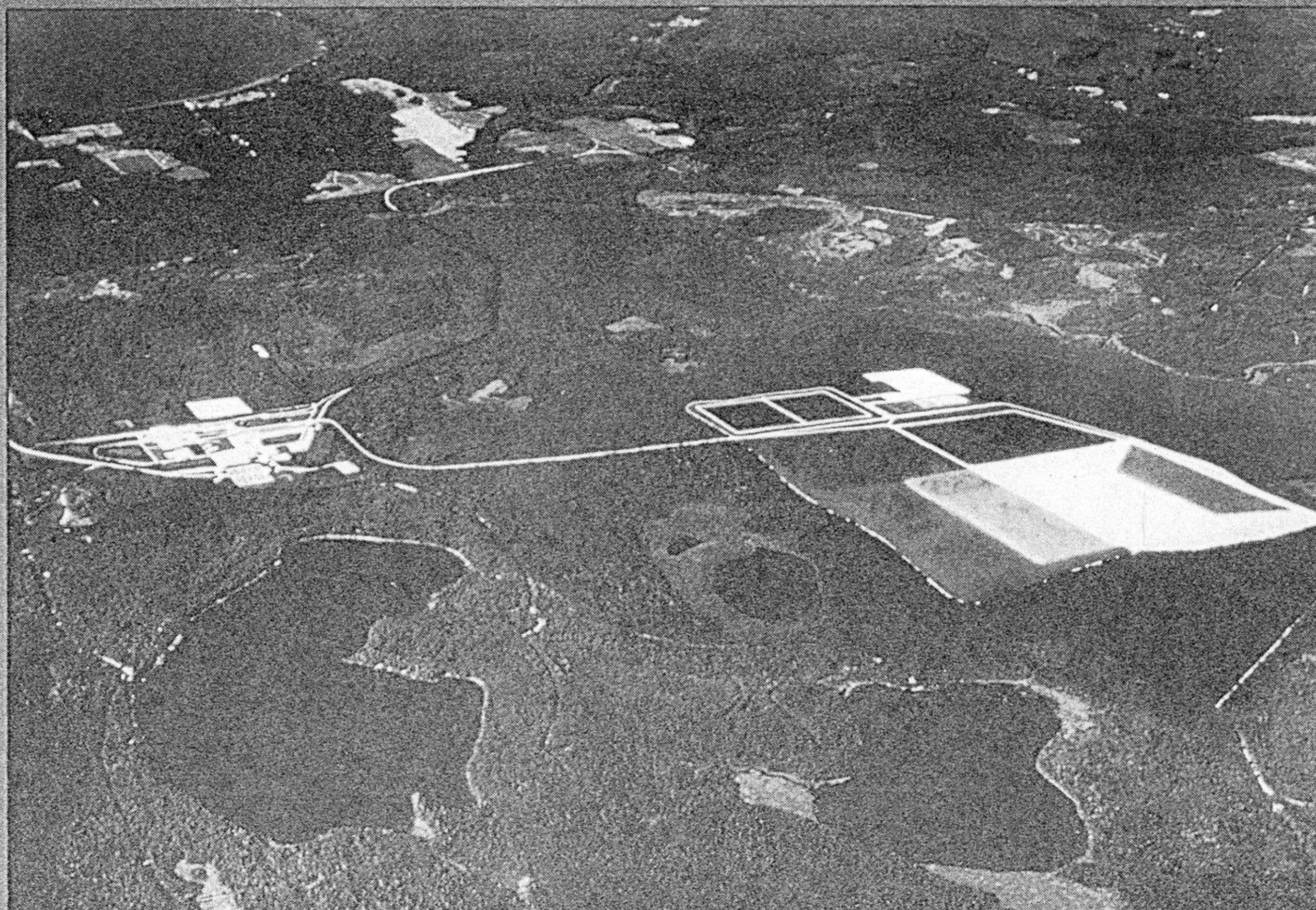
Regional Base Map

Crandon Ore Body

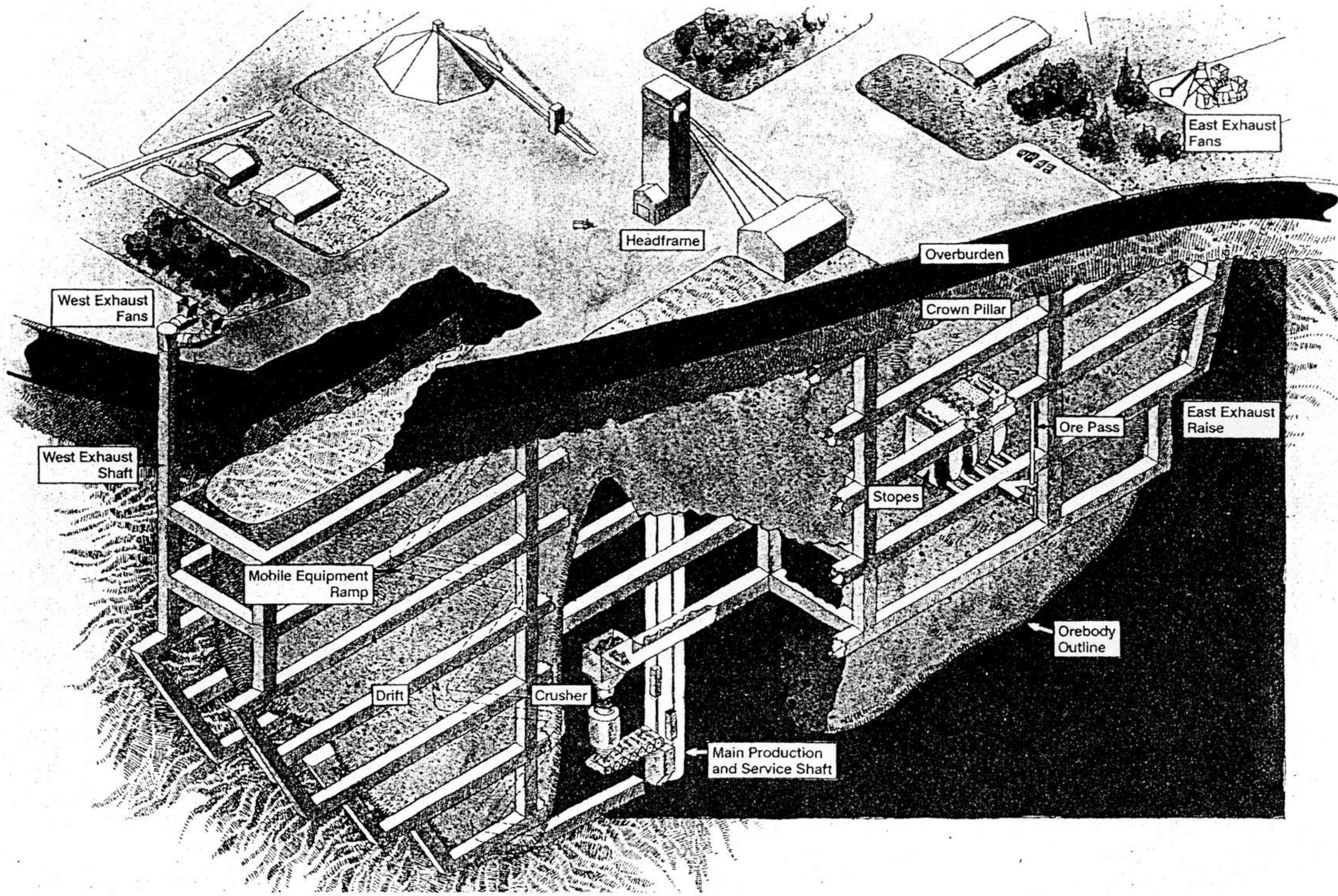


Legend
Massive Sulfide Ore
Stringer Ore

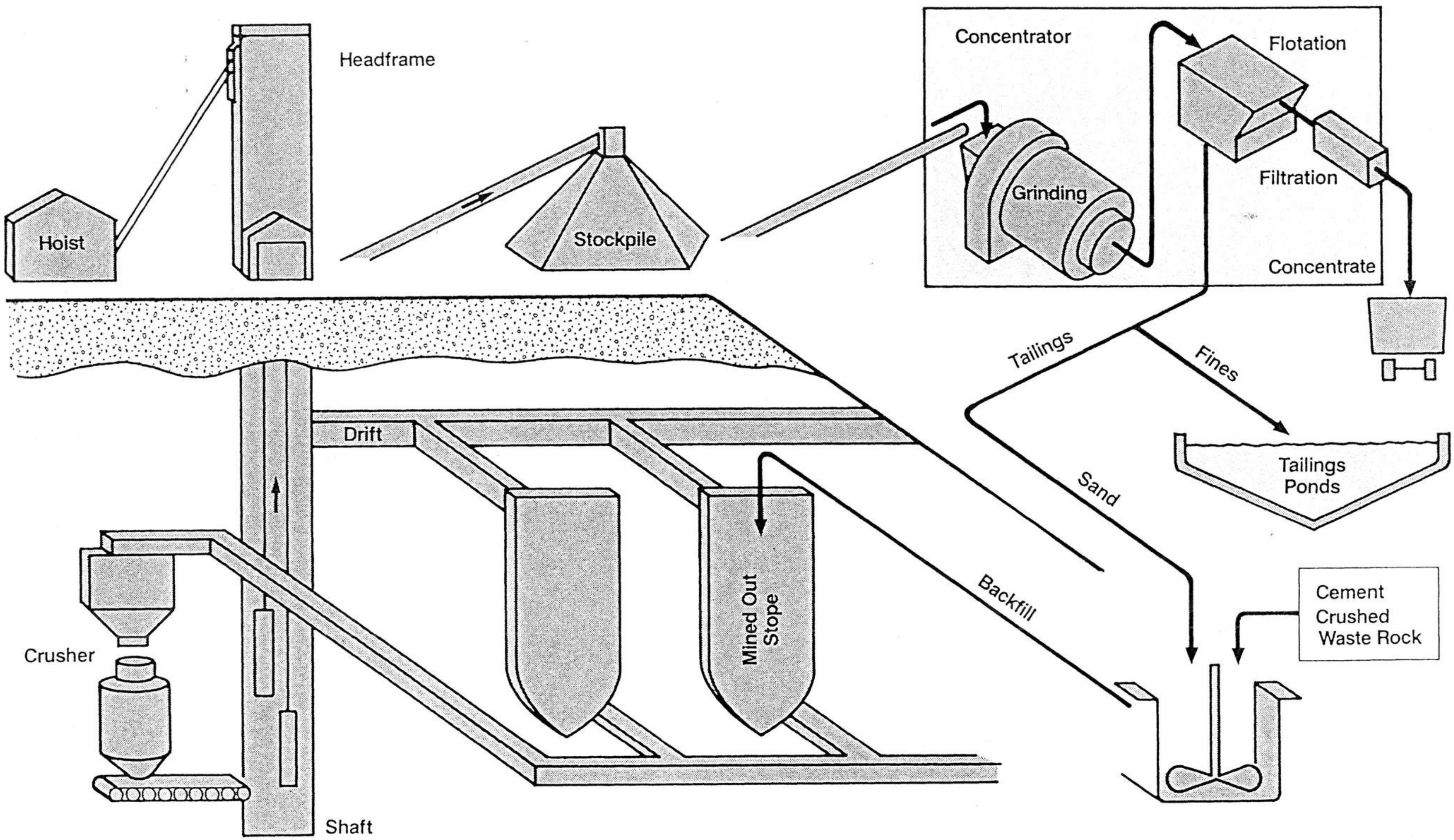
Project Site Area



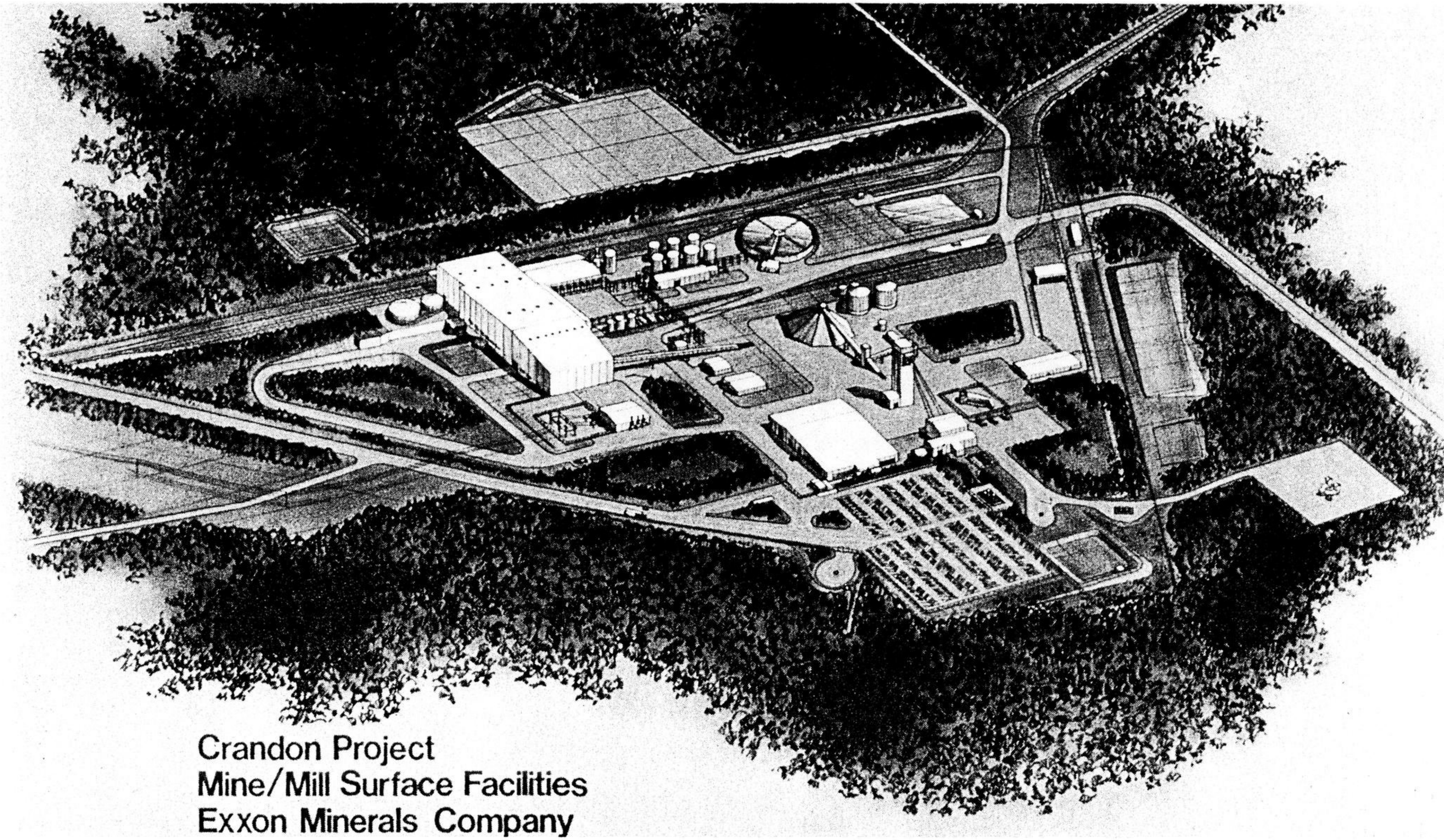
Mine Section



Ore Flow Schematic



Mine/Mill Site Rendering



Crandon Project
Mine/Mill Surface Facilities
Exxon Minerals Company

Crandon Project
Background

Discovery

- Exploration Started in 1969
- Exploratory Drilling in Mid-1975
- Public Announcement May 1976

Environmental Studies

Notice of Intent to Collect Data	-1978
Environmental Impact Report	-1982
Revised Project Plan	-1985
DEIS	-1986

Crandon Project
Key Economic Factors

Investment	**M$ (1985)**
Initial Capital	390
Operations	144
Total	534

State Tax Revenues (DOR Estimates)	**M$ (1985)**
Corporate Income Tax	102
Net Proceeds Tax	117
Total Tax	219

Employment	**Workers**
Construction (Peak)	1,200
Operation	620
Annual Payroll	$ 16M

Crandon Project

Estimated Taxes

	M$ (1985)
Corporate Income Tax	**102**
Net Proceeds Tax	**117.4**
Net Proceeds Tax Distribution	
Mining Impact Fund	40.6
Badger Fund	44.8
Forest County	8.3
Towns and Native American Communities	14.0
Project Reserve Fund	9.7

Source: Wisconsin Department of Revenue 1986.

EXHIBIT 110

EXHIBIT NUMBER	TITLE/DATE	STATUTORY & REGULATORY REQUIREMENT	DESCRIPTION
111	Mining Permit Application, Volume I dated January 1986 with May 1986 Addendum and Volume II dated December 1985 with May 1986 Addendum	Wis. Stat. 144.85 NR 132.06(1)	Includes a legal description of the mining site, land ownership information, wetlands considerations, the Environmental Monitoring and Quality Assurance Plan, Mine Plan, Reclamation Plan, reclamation cost estimates and financial responsibility statements.
112	High Capacity Well Approval Application for the Mine Ground Water Inflow Control and Drainage Systems, Volume I dated December 1985 with May 1986 Addendum and Volume II dated May 1986	Wis. Stat. 144.025(2)(e) NR 112.26(1)(d) Wis. Stat. 144.855(3)(b)	Covers the pumping of ground water from the mine and includes a description of the mine area geohydrology, ground water inflow into the mine, mine drainage systems and various alternatives, mine reclamation and ground water recovery and a hydrologic impact contingency plan.
113	High Capacity Well Approval Application for the Potable, Construction, and Contingency Supplement Water Wells and Transportation Systems, Volumes I and II dated December 1985 with May 1986 Addendum (Volume I)	Wis. Stat. 144.025(2)(e) NR 112.26(1)(d)	Covers two test wells, five water supply wells, 21 residential wells owned by Exxon, 27 private residential wells, and 5 proposed contingency supplement wells, and includes estimates of consumption, a discussion of hydrologic effects, various alternatives, construction specifications for proposed wells and a private water well survey.
114	Mine Waste Disposal Facility (MWDF) Feasibility Report dated December 1985	Wis. Stat. 144.44 NR 182.06	Addresses tailings disposal and includes a general project description; waste characterization and analysis; a discussion of waste management; discussions of terrestrial and aquatic ecosystems, land uses, geology and hydrology; the facility design and preliminary engineering regarding construction, operation, contingency plans, and closure and long-term care; an environmental evaluation; and discussions of various alternatives.

EXHIBIT NUMBER	TITLE/DATE	STATUTORY & REGULATORY REQUIREMENT	DESCRIPTION
115	Mine Refuse Disposal Facility (MRDF) Feasibility Report, dated November 1985	Wis. Stat. 144.44 NR 180.13	Covers the on-site solid waste landfill for refuse disposal and includes baseline geology, hydrology, land use, and environmental information; waste characteristics; preliminary facility design and location; water budgets; and an environmental impact assessment with a discussion of alternatives.
116	Air Quality Permit Application, Notice of Intent (NOI), dated December 1985	Wis. Stat. 144.392 & 144.391 NR 154.04	Includes a general project description; baseline topography, meteorology, and air quality; and an air quality assessment providing estimated air emissions and resultant ambient concentrations for total suspended particulates, sulfur dioxide, nitrogen oxides, carbon monoxide, hydrocarbons, and lead, plus six other metals, resulting from the entire project site.
117	Wisconsin Pollutant Discharge Elimination System (WPDES), Wastewater Discharge Permit Application, dated December 1985 with May 1986 Addendum	Wis. Stat. 147 NR 200.04	Covers the excess water discharge to Swamp Creek, erosion control facilities, and possible contingency and mitigation discharges to surface water. The application provides data on the project's water balance including estimated discharge volumes, discharge water quality, discharge locations and design specifications, as well as relevant project description information.
118	Water Treatment Facility Final Plans and Specifications, prepared by CH2M Hill, dated August, 1986	Wis. Stat. 144.04 NR 108.04	Submitted for DNR approval of EMC's planned wastewater treatment system for contaminated mine water, process water, and intercepted ground water if treatment is necessary. The report describes overall project water management, the treatment process and system design, influent and effluent water quality, applicable effluent requirements, sludge generation and disposal, construction schedule, and manpower requirements.

EXHIBIT NUMBER	TITLE/DATE	STATUTORY & REGULATORY REQUIREMENT	DESCRIPTION
119	Facilities Plan for the Exxon Minerals Company Mine/Mill Complex Sanitary Wastewater, prepared by CH2M Hill, dated November 1985	Wis. Stat. 144.04 NR 110.09	Covers the evaluation of various alternatives for treatment of the sanitary wastewater resulting from the project, concluding that an extended aeration activated sludge package plant is the most reliable and cost-effective sewage treatment alternative. The document includes the projected volume of sanitary wastewater, a general site description, identification of potential alternatives, evaluation criteria, and detailed analyses of the two best alternatives following an initial screening.
120*	Bridge over Swamp Creek for Access Road to Exxon Minerals Company, Crandon Project, and Appendix A - Hydraulic Analysis Input and Output, and Modeling Assumptions, dated April 1983	Wis. Stat. 31.23 NR 320.06	Covers the concrete girder, single span bridge which will carry the access road from State Highway 55 over Swamp Creek. Appendix A attached to this exhibit is also applicable to Exhibits 12 through 15.
121*	Bridge over Swamp Creek for Railroad Spur to Exxon Minerals Company, Crandon Project, dated April 1983	Wis. Stat. 31.23 NR 320.06	Covers the concrete girder, single span bridge which will carry the railroad spur from the Soo Line over Swamp Creek.
122*	Culvert for a Swamp Creek Tributary Crossing at Station Reference 509.70 of a Railroad Spur to Exxon Minerals Company, Crandon Project, dated April 1983	Wis. Stat. 30	Covers a 27" concrete or a 33" corrugated metal culvert pipe which will be placed in an unnamed tributary to Swamp Creek to carry drainage under the railroad spur.
123*	Culvert for a Swamp Creek Tributary Crossing Station Reference 511.8 of a Railroad Spur to Exxon Minerals Company, Crandon Project, dated April 1983	Wis. Stat. 30	Covers a concrete box culvert which will be placed in Creek 20-8, a tributary to Swamp Creek, to carry drainage under the railroad spur.

EXHIBIT NUMBER	TITLE/DATE	STATUTORY & REGULATORY REQUIREMENT	DESCRIPTION
124*	Culverts in Non-Navigable Drainages under the Access Road and Railroad Spur for Exxon Minerals Company, Crandon Project, dated April 1983	Wis. Stat. 30	Covers five 2-foot culverts which will be placed in minor non-navigable drainages along the access road. No culverts related to the railroad spur are included in this application.
125*	Water Discharge Structure at Swamp Creek, dated September 1983	Wis. Stat. 30	Covers the concrete outfall structure for the project's excess water discharge to Swamp Creek, plus the adjacent rip-rap which will be placed to prevent bank and stream bed erosion.
126*	Discharge Structures and Rip-Rap for Water Supplementation Facilities to Water Bodies affected by the Crandon Project Dewatering Activities, dated May 15, 1986	Wis. Stat. 30	Covers 11 concrete outfall structures and adjacent rip-rap which may be installed in conjunction with water supplementation facilities associated with Deep Hole Lake, Duck Lake, Little Sand Lake, Skunk Lake, Creek 12-9, Hemlock Creek, Hoffman Spring/Creek, Martin Spring/Creek 11-4, Swamp Creek, and Pickerel Creek.
127	Application for Withdrawal of Land from County Forest Status in Forest County, dated December 2, 1980	Wis. Stat. 28.11(11)	Filed by Forest County. Consists primarily of the Land Purchase Option entered into between Forest County and EMC on November 11, 1980 for approximately 880 acres of land within the project site boundary. DNR approval is required before this option can be exercised.

* Exhibits 120 through 126 are Joint State/Federal Applications for Water Regulatory Permits and Approvals covering activities within the ordinary high water level of waters of the state. The Federal Agency having jurisdiction over these activities is the U. S. Army Corps of Engineers. Each of the applications includes design specifications, hydrologic considerations, construction procedures, and environmental characteristics.

EXHIBIT NUMBER	TITLE/DATE	LOCAL JURISDICTION	DESCRIPTION
129	Land Use Permit Application for Railroad Spur Line, in Vicinity of Skunk Lake, dated June 26, 1984	Forest County	Covers the railroad spur line, which will connect the project facilities to the Soo Line, in the vicinity of Skunk Lake. Construction of the railroad spur will require a clearing about 100 feet wide. At its nearest point, the spur will be approximately 800 feet northwest of Skunk Lake.
130	Land Use Permit Application for Drainage Culvert at Railroad Station 511 + 80, dated June 26, 1984	Forest County	Covers a reinforced concrete box culvert which is intended to maintain drainage for Creek 20-8, plus the construction of the rail spur through the zoning area on both sides of the creek.
131	Land Use Permit Application for Railroad Bridge at Reference Station 516 + 70, dated June 26, 1984	Forest County	Covers the railroad spur's concrete girder bridge over Swamp Creek plus the construction of the rail spur through the adjacent zoning area.
132	Land Use Permit Application for Access Road Bridge at Reference Station 2810.05, dated June 26, 1984	Forest County	Covers the access road's concrete girder bridge over Swamp Creek plus the construction of the road through the adjacent zoning area.
133	Land Use Permit Application for Water Discharge Pipeline in Vicinity of Oak Lake, dated June 26, 1984	Forest County	Covers the buried water discharge pipeline, which will carry water from the project's treatment plant to Swamp Creek, in the vicinity of Oak Lake. At its closest point, the pipeline will be approximately 250 feet north of Oak Lake.
134	Land Use Permit Application for the Water Discharge Pipeline in Vicinity of Mole Lake, dated June 26, 1984	Forest County	Covers the buried water discharge pipeline, which will carry water from the project's treatment plant to Swamp Creek in the vicinity of Mole Lake. At its closest point, the pipeline will be approximately 325 feet south of Mole Lake.

EXHIBIT NUMBER	TITLE/DATE	LOCAL JURISDICTION	DESCRIPTION
135	Land Use Permit Application for Water Discharge Structure on Swamp Creek, dated June 26, 1984.	Forest County	Covers the concrete discharge structure at Swamp Creek, as well as the final portion of the discharge pipeline which will be located in the adjacent wetlands and rip-rap which will be placed to protect the stream bank. The discharge structure will be located approximately 30 feet from the main channel of Swamp Creek.
136	[Reserved]		
137	[Reserved]		
138	Land Use Permit, Railroad Spur Line, dated October 17, 1985	Forest County	Issued in response to Exhibit 129.
139	Land Use Permit, Drainage Culvert at Railroad Station 511.80, dated October 17, 1985	Forest County	Issued in response to Exhibit 130.
140	Land Use Permit, Railroad Bridge at Station 516.70, dated October 17, 1985	Forest County	Issued in response to Exhibit 131.
141	Land Use Permit, Access Road Bridge, dated October 17, 1985	Forest County	Issued in response to Exhibit 132.
142	Land Use Permit, Buried Pipeline in the Vicinity of Oak Lake, dated November 18, 1985	Forest County	Issued in response to Exhibit 133, with condition that construction cannot begin until approval for the same is obtained from the town of Nashville and the DNR.

EXHIBIT 128 (continued)

EXHIBIT NUMBER	TITLE/DATE	LOCAL JURISDICTION	DESCRIPTION
143	Land Use Permit, Buried Pipeline in the Vicinity of Mole Lake, dated November 18, 1985.	Forest County	Issued in response to Exhibit 134, with condition that construction cannot begin until approval for the same is obtained from the town of Nashville and the DNR.
144	Land Use Permit, Concrete Discharge Headwall, dated November 18, 1985	Forest County	Issued in response to Exhibit 135, with condition that construction cannot begin until approval for the same is obtained from the Town of Nashville and the DNR.
145	[Reserved]		
146	[Reserved]		
147	[Reserved]		
148	[Reserved]		
149	[Reserved]		
150	[Reserved]		
151	Metallic Mineral Mining Planned Development Application, Town of Lincoln, Forest County, Wisconsin, dated December 1985	Town of Lincoln	Contains general project information and describes baseline conditions, community impacts, overall project related impacts, reclamation, and monitoring and contingency plans. The contents respond directly to the requirements of Chapter 15 of the Town of Lincoln zoning ordinance. Town permits required by other chapters of the ordinance are listed in an appendix to this application, such that the town zoning committee referenced this one document for all required permit application information.
152	[Reserved]		

EXHIBIT NUMBER	TITLE/DATE	LOCAL JURISDICTION	DESCRIPTION
153	Metallic Mineral Mining Planned Development Application, Town of Nashville, Forest County, Wisconsin, dated January 1986	Town of Nashville	Contains general project information and describes baseline conditions, community impacts, overall project related impacts, reclamation, and monitoring and contingency plans. The contents respond directly to the requirements of Chapter 15 of the Town of Nashville zoning ordinance. Town permits required by other chapters of the ordinance are listed in an appendix to this application, such that the town zoning committee referenced this one document for all required permit application information.
154	[Reserved]		
155	[Reserved]		
156	[Reserved]		

EXHIBIT 157

EXHIBIT NUMBER	REPORT
158	Environmental Impact Report , Exxon Minerals Company, November, 1985
159	Geology of the Crandon Massive Sulfide Deposit, Lambe, R. N. & R. G. Rowe, Exxon Minerals Company, January, 1981
160	Supergene Weathering at the Crandon Deposit, Rowe, R. G., Exxon Minerals Company, April, 1982
161	Bedrock Permeability, Rowe, R. G., Exxon Minerals Company, May, 1984
162	Revised Reclamation Cap Design and Water Balance Analysis, Ayres Associates, November, 1985
163	Final Report Mine Hydrology Test Data Analysis, Crandon Project, Camp Dresser and McKee, May, 1982
164	Phase III Water Management Study, Volumes I, II, & III, CH2M Hill, December, 1982
165	Crandon Project, Pyrite Processing Update, Thomas L. Coefield Associates, June, 1986
166	Input Data Summary, Revised Crandon Project, Fiscal Impact Analysis, Thomas L. Coefield Associates, November, 1985
167	Geology Study and Study Methods, Dames & Moore, April, 1981
168	Ground Water Study and Study Methods, Dames & Moore, January, 1981
169	Hydraulic Relations Between Little Sand, Oak, Duck, Skunk, and Deep Hole Lakes and the Main Ground Water Aquifer, Dames & Moore, April, 1985
170	Water and Sediment Chemistry and Hydrology in Swamp Creek for the Crandon Project, Ecological Analysts, July, 1983

EXHIBIT 157 (continued)

EXHIBIT NUMBER	REPORT
171	Final Report on the Aquatic Biology of Swamp Creek for the Crandon Project, Ecological Analysts, August, 1983
172	Chemistry and Hydrology in Swamp Creek, Ecological Analysts, April, 1984
173	Aquatic Biology of Swamp Creek for the Crandon Project, January - December, 1983, Ecological Analysts, April, 1984
174	Hemlock Creek Riffle/Habitat Survey, Ecological Analysts, 1984
175	Results of Zooplankton Collections in Swamp Creek, 26-27 June, 1984, Tabular Summary, EA Science and Technology, September, 1984
176	Chemistry and Hydrology in Swamp Creek, 1984, EA Science and Technology, May, 1985
177	Qualitative Habitat Surveys of Four Streams in the Crandon Project Study Area, EA Science and Technology, May, 1985
178	Concentration of Inorganic Nonmetal Constituents in Aqueous Samples Received from Exxon Minerals, 6 June, 1985, - Tables, EA Science and Technology, September, 1985
179	Qualitative Habitat Surveys of Four Streams in the Crandon Project Study Area, EA Science and Technology, October, 1985
180	Miscellaneous Details and Analyses - Crandon Project Waste Disposal System, Golder Associates, September, 1982
181	Geohydrologic Characterization, Crandon Project Waste Disposal System, Golder Associates, October, 1982
182	Revised Impact Estimate of Exxon Crandon Project on Property Tax Rates in the Towns of Lincoln and Nashville, Crandon School District, and Forest County, Huddleston, J. R., December, 1985

EXHIBIT NUMBER	REPORT
183	Wetlands Assessment Report - Crandon Project, Normandeau Associates, Inc., and Interdisciplinary Environmental Planning, Inc., August, 1982
184	Hydrologic Water Balance of Selected Wetlands, Interdisciplinary Environmental Planning, Inc., December, 1982
185	Supplemental Wetlands Assessment Report - Crandon Project, Interdisciplinary Environmental Planning, Inc., August, 1983, and Errata, August, 1984
186	Pyrite Processing Study, Volumes I & II, Davy McKee, June, 1981
187	Ground Water Flow Model for Exxon Ore Body Near Crandon, Wisconsin, Thomas A. Prickett and Associates, January, 1982
188	Ground Water Inflow Model for the Proposed Crandon Mine, Thomas A. Prickett and Associates, December, 1982
189	Predictive Ground Water Inflow Modeling and Sensitivity Analysis for the Proposed Crandon Mine, Thomas A. Prickett and Associates, October, 1984
190	Definition of the Local Study Area, Socioeconomic Assessment, Crandon Project, Research and Planning Consultants, September, 1980
191	Forecast of Future Conditions, Socioeconomic Assessment, Crandon Project, Research and Planning Consultants, October, 1983
192	Rock Mechanics Testing and Engineering of Large Diameter Core, John D. Smith Engineering Associates, June, 1981
193	Evaluation of Surface Effects, Crandon Project, Exxon Minerals Company USA, John D. Smith Engineering Associates, April, 1982
194	Soil Boring and Laboratory Test Results of Little Sand Lake Drilling Project for Exxon Crandon Project Mine Development, STS Consultants, Ltd., April, 1982

EXHIBIT NUMBER	REPORT
195	Hydrogeologic Study Update for the Crandon Project, Volumes I & II, STS Consultants, Ltd., June, 1984
199	Letter Report Review of Lake Impact Studies Performed by Wisconsin Department of Natural Resources, Exxon Minerals Company, Crandon Project, IT Corporation, May 9, 1986 (ATTACHMENT I to letter from B. J. Hansen, Exxon Minerals Company to R. G. Schuff, DNR, dated June 30, 1986).

BEFORE THE
STATE OF WISCONSIN
DIVISION OF HEARINGS AND APPEALS

Application of Exxon Corporation for Permits to Build and Operate an Underground Mining and Ore Concentrating Complex Located in Forest County, Wisconsin	))))	IH-86-18

<u>TESTIMONY OF GERALD D. ORTLOFF</u>

GENERAL ENVIRONMENTAL BASELINE

Q. Would you state your name and address for the record?

A. My name is Gerald D. Ortloff. I live in Aurora, Colorado. My street address there is 15365 East Penwood Place.

Q. What subjects do you plan to discuss in your testimony?

A. I will be the first of four witnesses who will be summarizing the environmental baseline studies that are covered in Chapter 2 of EXHIBIT 158, Exxon's Environmental Impact Report, which is entitled "Description of the Environment." Together we will provide a detailed picture of what the environment in the Crandon Project area is now like, and of the various investigative and modeling work that was done to make these determinations. It is essential that we understand the underlying baseline so that we can make proper assessments of what the impacts from construction and operation of the Crandon Project might actually be. As will become clear during the course of this baseline testimony, this area has been studied and restudied from a multitude of different angles; surely few areas of the world are as well understood as this one.

I will be reviewing the environmental baseline covered in the EIR under the topics of ground water, surface water, aquatic ecology, terrestrial ecology, meteorology and air quality, land use and aesthetics, and archaeological and historical resources.

Immediately after my testimony, Mr. Roger Rowe will describe the geologic and hydrologic aspects of this area. Specifically, he will describe both the general geologic setting and the actual Crandon ore body itself, the effects that glaciers have had on the area, the geologic and engineering studies which have been made of the Project area, and the general hydrologic setting in the vicinity of the proposed mine.

After Mr. Rowe's testimony, Dr. Gerald Lauer will provide more detailed baseline information on the streams, springs, and lakes in the Project area and on the various study work that was performed to evaluate these water bodies.

At the conclusion of Dr. Lauer's testimony, Mr. Garrett Hollands will discuss the wetlands in the area of the Project site and describe the modeling and field work that was performed in evaluating these wetlands.

I should add here that various other witnesses in the course of their testimony will provide additional information on the environmental and socioeconomic baseline conditions in the Project area.

Q. Would you briefly review your educational and employment background?

A. A detailed resume appears as EXHIBIT 200 in the record. In brief, from March 1972 until September 1976 in my position as Environmental Advisor, and from September 1976 until April 1981 in my position as Regulatory Affairs Manager, I was responsible for the planning and the direction of environmental studies and environmental protection programs for the operations of Exxon Minerals Company and its predecessor organizations in the United States. My responsibilities included the planning and supervision of the program of environmental studies for the Crandon project, as well as working with the Wisconsin DNR, the

Public Intervenor, and the Metallic Mining Council in the development of an appropriate regulatory framework for the protection of the environment in mining and milling operations.

My formal training is in chemical engineering; I received my Bachelor of Science degree from Oklahoma State University in 1953. I am a Registered Professional Engineer, and I am a member of the American Institute of Chemical Engineers and of the Society of Petroleum Engineers. Prior to March 1972, as an employee of Exxon Production Research Company and its predecessor research organizations, I conducted theoretical, laboratory, and field research on methods for increasing the recovery of petroleum from subterranean reservoirs, on ground water hydrology, on water quality and treatment, on the solution mining of metals from naturally occurring ore deposits, and on air quality and mine ventilation in underground mining. I hold nine U.S. patents on processes and methods, and I have authored three technical papers published in engineering or scientific journals.

From April 1981 until my retirement from Exxon in September 1983, I directed the extensive environmental studies and environmental protection programs of the Colony Shale Oil Project in Colorado.

Q. What is meant by the term "baseline" as it is used in Exxon's Environmental Impact Report?

A. "Baseline" means the description of the environment as it exists before a proposed action is taken which may alter the environment.

Q. Why are baseline data important in a study of environmental impacts?

A. Baseline conditions are the reference against which environmental changes which may occur in the future can be measured. Also, since the effects of man's actions upon the environment often depend upon the state of the environment at the time he takes those actions, baseline measurements provide the starting point for predicting what changes will occur in the environment if specific actions are taken or if no action is taken.

Environmental impacts, particularly the more subtle ones, usually cannot be predicted with acceptable accuracy unless the starting condition of the environment is known.

Q. Are the baseline studies which have been done for the Crandon project of special importance?

A. Yes. Until our baseline measurements and observations were made, very little quantitative information existed on the condition of the environment in the study area. As a result of our baseline studies, a great deal of information has been compiled on the character of the environment in the Crandon study area. More baseline environmental data has been collected on the Crandon area than has been collected for any other mining project that I am aware of. This extensive data base provides solid footing for predicting the environmental impacts of mining and milling the ore from the Crandon deposit.

The extensive Crandon baseline data also were invaluable in evaluating project design and siting alternatives so that adverse environmental impacts could be minimized.

Q. How did such thorough studies come about?

A. Early in 1976, when we recognized that the Crandon deposit was a major ore body with substantial commercial potential, we began the preliminary planning for its development. We recognized at that time the need for reliable projections of the environmental impacts of developing the mine and of mining and milling the ore. These projections were needed not only to satisfy the requirements of the Wisconsin Environmental Protection Act, but also to allow us to design and locate the necessary facilities so that they will minimize environmental impacts.

In mid-1976 we solicited proposals from five major contractors with the expertise and resources necessary to carry out a thorough and comprehensive environmental study and to integrate that study with engineering studies to identify environmentally acceptable sites for the major mining, milling, and waste disposal components of the project. We accepted the Dames and Moore proposal in late 1976. The overall study plan was reviewed and approved by the DNR after several revisions to incorporate improvements suggested or requested by the DNR.

Q. How were the baseline studies carried out?

A. Dames and Moore fielded a multidisciplinary professional environmental study team headed by an experienced environmental scientist early in 1977. Most of the studies that were in the initial plan were carried out during 1977 and 1978. However, major additions to the baseline study, in aquatic ecology, wetlands, hydrology and water quality, were made as facility design and siting studies progressed during the period 1979 through 1985. These additions were needed primarily as a basis for predicting localized and specific impacts of the mine, mill and tailings disposal facilities.

The scientific and analytical methods that were used in the baseline research were those that are generally recognized and accepted by the professional research community in each specialized area of study. When sampling and analytical methods specified by the U.S. Environmental Protection Agency were applicable, those methods were used.

Work plans were reviewed by the DNR before field work was started. Rigorous quality control measures were applied in field sampling and in laboratory analyses. DNR observers accompanied the field investigators during a substantial part of the field studies, splitting samples for independent analyses and verifying methods and procedures. Raw data were provided to the DNR upon request.

Frequent reviews and planning sessions were conducted with Exxon's Crandon project team and with the staff of environmental specialists in Exxon's headquarters in Houston. We believe the frequent reviews contributed materially to the high quality of the baseline study.

Q. Taking the baseline topics in the order in which you gave them, would you begin with a brief summary of ground water occurrence in the vicinity of the Crandon ore body?

A. First, it will be helpful if I define some terms that I will be using throughout my testimony.

When I refer to the "site area," I mean the area bounded on the north by Swamp Creek, on the east by Ground Hemlock Lake and Hemlock Creek, on the south by Rolling Stone Lake, and on the west by the Pickerel Creek lowland system. I will illustrate this area by reference to EXHIBIT 201. Except for transportation links, a portion of the discharge pipeline and several of the contingency wells, all of the project facilities will be located in this site area.

"Environmental study area" means the locale generally within a radius of 5 miles of the site area. Measurable physical impacts of the Crandon project will be generally restricted to the environmental study area, so the baseline measurements and observations were concentrated in this area.

"Regional study area" means the physical setting within a radius of about 25 miles of the site area. The character of this larger study area helps put the features of the environmental study area into perspective.

In discussing ground water, I will be using the term "aquifer" frequently. An aquifer is a water-saturated underground formation that will yield sufficient water to wells or springs to make them practical sources of water supply.

As Mr. Rowe will describe in further detail, the principal aquifers in the region are in the glacial drift (glacially deposited sand and gravel) that lies on top of the volcanic bedrock. The bedrock is part of the southern province of the Canadian Shield. Most of the glacial drift deposits were left by the most recent glacial advance about 75,000 years ago, and, regionally, they range in thickness from a few tens of feet to about 300 feet. Ground water also occurs in the bedrock where permeability has been increased by fracturing and/or weathering, but wells in the bedrock typically yield only small amounts of water.

In the environmental study area, as in the region, the principal aquifer is in the glacial drift material. Ground water also occurs in locally fractured and weathered zones in the bedrock; however, the unfractured and unweathered bedrock typically is about a thousand times less permeable than the overlying sands and gravels, and it therefore yields very little water to wells drilled into it. Ground water in the fractured and weathered zones is in communication and quasi-equilibrium with that in the overlying main aquifer.

Ground water in the environmental study area exists principally under water table, or unconfined, conditions. The topography of the ground water surface is similar to that of the land surface above it, but on the ground water surface, the hills are lower and the valleys are shallower.

Within the generally unconfined aquifer system, zones of confinement or partial confinement result from the great variation in lithology (the composition of the subterranean material) and permeability in the glacial deposits. Also, perched aquifers of limited areal extent have been found above the principal aquifer. Technically speaking, a perched aquifer is unconfined ground water separated from the underlying ground water by an unsaturated zone. It is there because the percolation of ground water has been slowed or stopped by a layer of low-permeability material such as clay or silt.

Q. Does the ground water in the environmental study area move?

A. Yes, and in doing so, it interacts with the surface water system. Surface water from precipitation and runoff soaks into the ground in some areas and percolates downward to the water table. In other areas the water table intersects the ground surface, and ground water seeps out on the surface. These areas are called recharge and discharge areas, respectively. EXHIBIT 202 shows the locations and types of interactions between surface water bodies and the ground water system.

In addition to the direct infiltration of precipitation, several of the lakes--notably Oak, Little Sand, Duck, Deep Hole, Skunk, Walsh, St. Johns and Kimberly--are sources of recharge to the aquifer, since the elevation of the water surface in those lakes is higher than the main ground water table. The rate of recharge to the aquifer from those sources is limited, however, by the low permeability of the underlying soils.

Ground water discharges from the main aquifer primarily into surface drainages such as Hemlock, Swamp and Pickerel creeks.

Rolling Stone, Mole and Rice lakes also are located in ground water discharge areas and Ground Hemlock Lake is spring-fed. Some 34 spring seeps have also been identified in low-lying areas of the environmental study area.

The directions of ground water flow in the main aquifer are shown in EXHIBIT 203. Within the site area, ground water flows outward from the main recharge area in the uplands northeast of Little Sand Lake. Additional recharge comes from areas of infiltration to the northeast of the site area.

Ground water movement in the bedrock below the main aquifer is limited essentially to the weathered zone and the open fractures in the bedrock near its interface with the overlying main aquifer. Below the weathered zone, the bedrock is practically impermeable.

Other than the downward migration of water through the unsaturated zone from the ground surface to the water table in recharge areas, little vertical movement of ground water occurs as shown by the absence of large vertical hydraulic gradients in the saturated zone.

Q. What about the quality of the ground water?

A. Quality of the ground water in the glacial drift material is good. With the exception of occasional samples that show elevated concentrations of cadmium, iron, lead, manganese, and nitrate, the water meets applicable standards for drinking water.

The dissolved solids content of the water in the main aquifer is quite low. Most of the dissolved solids are the calcium and magnesium compounds that cause hardness, and the water is classified as moderately hard.

Hardness and the associated alkalinity and dissolved calcium concentrations in the main aquifer vary markedly across the site area. These variations are consistent with the regime of ground water recharge and discharge and with the chemical composition of the glacial soil materials with which the ground water interacts as it flows through those materials.

Within the bedrock, water quality in the fractured and weathered zone is very similar to that in the overlying glacial drift. In the deeper bedrock, however, the ground water is markedly more saline and is extremely hard. These chemical differences in quality are consistent with the conclusions reached in the hydrogeologic studies that ground water in the fractured and weathered zone of the bedrock is in communication with that in the overlying main aquifer, but that water in the deeper bedrock is essentially immobile.

Q. What are the existing uses of ground water in the environmental study area?

A. EXHIBIT 204 shows the area surveyed for existing water wells. Quantitative data were collected on more than 200 wells in the survey area, and we estimate that the total number of wells in the area is about 320. The vast majority of these wells are used for domestic purposes. A few provide water for public buildings, and water is also withdrawn from the vicinity of Mole Lake for irrigation of a potato farm. All of the wells in the inventory draw from aquifers in the glacial drift. Their depths range from 12 to 148 feet.

Q. Would you describe, as concisely as you can, the data gathering program on ground water?

A. The data came from measurements, tests, and samples from over 300 boreholes and piezometers that were installed over a seven-year period from February 1977 through March 1984. A piezometer is a well specially designed and constructed for measurement of water levels and for sampling. The locations of these sampling points were selected to give us both broad coverage of the entire site area and intensive sampling where facilities such as the mine and the waste disposal area may be located. The locations of these borings and piezometers are shown in EXHIBIT 205.

The scheduling of measurements and sampling at these locations was set to provide: (1) data at regular intervals over long periods of time so as to observe and measure variations with seasons and climatic conditions over the entire site area, and

(2) intensive data on spatial variation of ground water properties and aquifer characteristics in areas of special interest or concern, such as the immediate vicinity of the orebody. The schedule of measurements and sampling is presented in the EIR, Chapter 2.0, Section 2.3. Continuous recording of water levels in several piezometers served as a reference and a check on the periodic readings taken on the entire piezometer array.

The sampling of ground water from 50 wells or piezometers was scheduled to obtain data on ground water quality within the site area at regular intervals over long periods of time. The water samples were collected from these locations by pitcher pump or bailer after removing the standing water in the borings to ensure that a fresh sample of water from the water-bearing formation would be collected.

The samples were shipped on ice in insulated containers via air freight to the analytical laboratory on the day of sampling. The samples were handled, treated, and shipped in accordance with generally recognized and accepted best scientific practice. Wherever EPA-endorsed methods were applicable, those methods were used. Chemical analyses were begun in the analytical laboratory within 24 hours of sample collection. The sample container types and the sample preservatives used in the program are listed in Table 2.3-4 in the EIR. The chemical parameters and the frequency at which they were measured by the laboratory are shown in EXHIBIT 206. Table 2.3-5 in the EIR lists the analytical procedures used in the laboratory and the detection limits for those methods.

Methods used to measure or estimate the permeability, and other properties of hydrological significance, of soils, aquifers, and bedrock are described in the EIR, Chapter 2.0, Section 2.3. Those methods included both laboratory and field test procedures.

State-of-the-art quality control procedures were followed in all of the sampling and testing. Those procedures are elaborated in the EIR, Chapter 2.0, Section 2.3.

Q. That's all the questions I have on the baseline studies on the ground water systems. What were the objectives of the research on surface water in the environmental study area?

A. Our purpose was to evaluate the quantity and quality of water in the lakes and streams and to document and describe the seasonal variations in those characteristics.

Q. In pursuing your objectives, what properties did the study team observe and measure?

A. The field study team measured stream flow and lake levels, and collected samples for laboratory analysis to determine water quality and the character and composition of bottom sediment.

Q. Were these studies carried out over a sufficient length of time to provide adequate data on the seasonal variations you wanted to document?

A. Yes. The originally planned baseline data collection program was conducted during the three and one-half year period from April 1977 to November 1980. This period included both a very wet year (1978-1979) and an extremely dry summer (1977). That fortuitous occurrence let us collect data on the surface water system that are representative of a wide range of climatic conditions as well as during a period of relatively normal seasonal variations.

Following the originally planned program, additional data on specific areas of interest were collected in 1982, 1983, 1984, and 1985.

Q. Please give us a thumbnail sketch of the principal hydrologic features of the region and of the environmental study area as they were observed during the studies.

A. As shown in EXHIBIT 207, the Crandon project area is in the northern headwaters of the Wolf River basin. The Wolf River flows southward to Lake Poygan, about 100 miles south of Crandon, in Winnebago County. The Fox River drains Lake Poygan and Lake Winnebago northeasterly to Green Bay.

In the upper Wolf River basin, the relatively slowly flowing streams frequently pass through lakes and wetlands. Stream gradients are low, usually less than ten feet per mile.

The principal surface hydrological features of the northern end of the Wolf River basin are shown in the exhibit. The sub-basins, or major drainages, are delineated by the heavy solid lines, and each is drained by a clearly recognizable stream. The Crandon ore body lies under a watershed separating the Swamp Creek and Pickerel Creek drainages.

EXHIBIT 208 gives a closer view of the hydrological features of the environmental study area. The site area drains partly into the Swamp Creek drainage and partly into the Pickerel Creek drainage. Within each of these major drainages, the smaller drainage areas that were monitored by staff gages are shown.

The lakes within the environmental study area are classified by surface water hydrologists into three basic lake types:

(1) Seepage lakes--no inlets or outlets, or only an intermittent inlet and outlet.

(2) Drainage lakes--at least one inlet and an outlet. Water supply is primarily from stream drainage.

(3) Spring lakes--seldom have inlets, but always have a flowing outlet. Water supply is mainly from ground water inflow.

This classification system differs somewhat from that used in ground water hydrology, but does not conflict with it. In the environmental study area, the surface-hydrologist's seepage lakes are recharge lakes to the ground water hydrologist, and the spring lakes and the drainage lakes are discharge lakes in the ground water hydrology system.

EXHIBIT 209 shows the classification by surface hydrological characteristics of the principal lakes in the environmental study area.

Q. How does water quality vary in the various types of lakes?

A. The quality of the water in the spring lakes and the drainage lakes is similar, whether those lakes are in the Swamp Creek drainage or the Pickerel Creek drainage. Their water chemistry is similar to that in the main ground water aquifer and in the surface streams. Water in the seepage lakes typically contains less dissolved solids and shows lower conductivity, alkalinity, hardness, and pH than the water in the streams and drainage lakes. Table 2.4-22 in the EIR demonstrates these facts.

Q. In your earlier testimony, you classified the quality of the ground water in the main aquifer system as "good". Does that classification also apply generally to the surface water in the environmental study area?

A. Yes. As Dr. Lauer will testify in greater detail, the chemical quality of the surface water in the environmental study area is generally very good. The water meets drinking water standards for dissolved inorganic materials. Although there is some variability in the concentrations of various metals in the water and bottom sediments among the lakes and streams, no concentrations were found which are greatly outside the normal ranges for typical nonindustrial water and sediment. The variations observed are discussed fully in the EIR, Chapter 2, Section 2.4.

Q. What did the hydrological studies indicate about the water balance in the environmental study area?

A. The studies indicate that evapotranspiration is responsible for the loss of one-half to two-thirds of the annual precipitation in several sub-basins of the study area. Annual stream flow ranges from 3 to 60 percent of annual precipitation, because in some sub-basins, water soaks into the ground to recharge the aquifer system, while in others the runoff from precipitation is augmented by surface seepage from the aquifer system.

Q. Is sediment transport from the environmental study area of particular significance or concern?

A. No. The streams in the environmental study area carry only small quantities of sediment because the land is forested, soils are granular, slopes are moderate, stream velocities are low, and the lakes and wetlands are effective sediment traps.

Q. What is the flood potential in the environmental study area?

A. Flood potential is low in comparison to basins of similar sizes in other regions because of the high permeability of the soils, which allows water to soak in relatively quickly and continuously, and because the lakes and wetlands can store large volumes of water.

Q. Would you describe the data gathering program for the surface water hydrology studies?

A. The locations of the surface water gaging stations used are shown in EXHIBIT 210. Eighteen stream gaging stations were located at closely as practicable to the inflow and outflow boundaries of sub-basins, and in addition, data were available from two USGS continuous gaging stations. Stream flow rates were calculated from staff gage readings of water levels and calibrations of flow rate versus gage readings in accordance with USGS field procedures.

Lake levels were measured periodically at ten staff gage locations.

173 samples of solids suspended in the flowing streams were collected from 16 stream gaging locations.

EXHIBIT 211 shows the locations of stations utilized for sampling for water quality and bottom sediment. The stream sampling stations were selected to provide baseline data at locations upstream of, close to, and downstream of probable locations of major surface facilities for mining, milling, and mine waste disposal.

Two sampling stations were located on the Wolf River to obtain baseline water quality and bottom sediment samples upstream and downstream of its confluences with Swamp Creek and Pickerel Creek.

Sampling stations for water quality and bottom sediment were located in the lakes that were adjacent to the proposed locations of surface facilities or were in locations that could receive drainage from surface facilities.

The schedule of sampling for water quality and bottom sediment is fully detailed in the EIR .

Q. Were the sampling, preservation, shipping, analytical and quality control procedures for the surface water samples similar to those used in the ground water sampling program?

A. Yes. All samples were collected, treated and shipped in accordance with generally accepted and recognized best scientific practice. Wherever EPA-endorsed methods were applicable, they were used. State-of-the-art quality control procedures were used in all sampling and testing. Those procedures are fully explained in the EIR, Chapter 2, Section 2.4.

Q. Moving now to the study of aquatic ecology, please describe the program that was carried out.

A. Since changes in the aquatic ecological system are often the most sensitive indicators of changes in the aquatic environment, it is essential for the correct interpretation of future monitoring results to establish an accurate and rather detailed baseline. That baseline must define the existing ecological relationships and the existing range of spatial and seasonal variation in the composition and abundance of aquatic life. The aquatic ecology baseline study was designed to do that.

EXHIBIT 212 shows the locations in the environmental study area where aquatic life was sampled. The rationale for the location of these sampling stations was the same as the rationale for locating the stations for water quality sampling, namely, to obtain samples of both microscopic and macroscopic aquatic plants and animals sufficient to describe their populations at sites upstream, downstream, and adjacent to proposed locations of mine and mill facilities. Sampling was done in all four seasons of the year to observe the seasonal variations in populations and types of organisms present. Samples of aquatic organisms were collected, and the seasonal abundance and the types of organisms in the following categories were determined:

-- Phytoplankton (free-floating microscopic plants, e.g., algae).
-- Zooplankton (free-floating microscopic animals, e.g., rotifers).
-- Periphyton (microscopic plants attached to solid substrates).
-- Aquatic macrophytes, e.g., wild rice, water lilies.
-- Benthic macroinvertebrates, e.g., worms, snails, insects.

Fish studies were also done during ice-free periods. Because of the selectivity of the various fish sampling methods, the team used gill and fyke netting, beach haul or minnow seining, electroshocking and minnow trapping methods to ensure minimum overall bias in the sampling program. EXHIBIT 213 shows the locations where fish populations were sampled. Larval fish (fry) were sampled at stations in Oak and Little Sand Lakes, and a trout redd (nest) survey was conducted in several of the creeks to locate spawning areas of the brook trout.

To establish baseline metals concentrations in the tissues of the aquatic organisms, samples of several species of aquatic macrophytes, benthic invertebrates, and fish were collected for analysis. Concentrations of chlorophyll a were determined in phytoplankton samples.

The scheduling of the sampling and analyses is detailed in the EIR, Chapter 2.5. As in all of the studies, state-of-the-art quality control procedures were used in the sampling and analyses. These procedures are described in the EIR, Chapter 2.5.

Q. Recognizing that a very large quantity of data was collected and that highly detailed and specific conclusions were drawn from the data, could you summarize the major results?

A. The detailed conclusions and correlations developed in the aquatic ecology studies required some 60 tables and figures in the EIR as well as about 100 pages of text, and Dr. Lauer will be providing you with a more detailed summary. The broad conclusions were these:

1. Although golden-brown algae dominated the phytoplankton samples from all of the lakes, the distribution of various taxa or types of zooplankton, periphytic algae, and aquatic macrophytes correlates with the hardness of the water in the lake.

2. Rotifers and copepods dominated the zooplankton in the hard water lakes (Rice and Rolling Stone). Copepods dominated in samples from the clear water seepage (soft water) lakes (Little Sand, Oak), and rotifers dominated in samples from the colored seepage (soft water) lakes (Duck, Deep Hole, Skunk).

3. Diatoms dominated the periphytic algae in all water bodies. Diatoms *Cocconeis placentula* and *Achnanthes minutissima* dominated the hard water drainage systems, and *Tabellaria fenestrata* and *T. flucculosa* dominated in the soft water lakes.

4. Hard water and soft water lake types each have distinctive aquatic macrophytic flora. Distribution of the flora within each lake is influenced by water depth and basin morphometry. Wild rice, which was found only at Rice Lake, covered extensive areas of the lake.

5. Benthic macroinvertebrate distribution and abundance appears to depend primarily on habitat characteristics, namely, substrate type, current velocity, and dissolved oxygen content of the water.

6. Minnows dominated the fish in the larger creeks, and brook

trout and mottled sculpin dominated the small headwater creeks. Black bullhead, white sucker, yellow perch and/or sunfish species dominated in the drainage lakes and in the Wolf River.

7. The fish community structure upstream and downstream of Rice Lake is similar, but the variations which do exist suggest that Swamp Creek above Rice Lake should be classified as a cold-water fishery, while Swamp Creek below Rice Lake is a warm-water fishery.

8. The Wolf River is an important recreational fishery. Three fish species--white sucker, shorthead redhorse, and northern pike--could migrate from the Wolf River into Swamp Creek. However, significant migration of northern pike into Swamp Creek is unlikely because of the low numbers of that species in the Wolf River near its confluence with Swamp Creek.

9. Within the environmental study area, stream segments totaling about 7 miles are classified as Class I trout streams, and another 20 miles of streams are classified as Class II trout streams.

10. Fewer fish species were found in the seepage lakes than in the drainage lakes; yellow perch dominated in the seepage

lakes.

11. <u>Potamogeton</u> <u>confervoides</u> (algal-leaved pondweed), an aquatic plant listed by the Wisconsin DNR as a threatened species, was identified from shoreline debris found at Duck Lake, but no rooted specimens were found. A search for this species, which may occur in acidic bogs, was conducted in the remainder of the environmental study area, but no specimens were found.

No other aquatic plants or animals designated as threatened or endangered by the Wisconsin DNR or the U.S. Fish and Wildlife Service were observed or are known to occur in the environmental study area.

Q. Are any of the aquatic organisms in the environmental study area particularly sensitive to habitat disturbance or to water or air pollution?

A. The baseline studies identified the trout streams, the wild rice in Rice Lake, and the threatened algal-leaved pondweed, if it is present in the environmental study area, as sensitive receptors. Brook trout require clear, cold water streams with relatively high dissolved oxygen content. The sensitivity of wild rice to environmental factors is a matter of continuing debate, but plant density, changes in water levels at certain stages of its growth, water temperature, water quality and sediment composition all appear to influence the growth and productivity of wild rice.

No single chemical constituent of water has been identified as the controlling factor in the growth of wild rice under natural conditions.

Q. That completes my questions about the aquatic ecology baseline. What work was done to define the existing terrestrial ecology?

A. The terrestrial ecology study was designed and carried out to identify and describe the major terrestrial communities in the environmental study area and in the site area, and to provide the data base necessary for evaluating the potential environmental impacts on those communities.

The program included:

(1) Soils description.

(2) Identification of important plant and animal species and documentation of their distribution and relative abundance.

(3) Mapping of principal plant communities and selected wildlife resources.

(4) Evaluation of the regional significance of the plant and animal populations.

Q. What criteria were used to determine whether a plant or an animal is important?

A. Species or communities were considered important if:

(1) The species or community is commercially valuable or is a recreational resource.

(2) The species is endangered, threatened, or rare.

(3) The species or community affects the well-being of another species considered commercially valuable, of recreational value, or threatened, endangered, or rare.

(4) The species, population, or community is critical to the function of the ecosystem.

Q. When was the field work done for this study?

A. The field work was done during the period from February 1977 through October 1978. EXHIBIT 214 shows the general locations where various field programs were carried out. Additional field work was conducted in 1982, 83 and 84. This work was primarily directed toward the wetlands.

Q. What information existed on the terrestrial ecology of the area before this baseline study?

A. There are very few existing vegetation or wildlife studies that were useful in evaluating the resources of the site area. However, DNR reports on forest resources, deeryard management, annual surveys of bald eagle and osprey nests, game and furbearer harvests, and censuses of the ruffed grouse and the American woodcock were valuable for guidance in the site area and as primary data for the environmental study area.

Q. Would you describe, as concisely as you can, each of the studies listed in EXHIBIT 214?

A. The soils classification and mapping of the site area was done by the Soil Conservation Service unit at Rhinelander. It required field investigation of the soil types along with the interpretation of aerial photographs.

Vegetation in the environmental study area and in the site area was mapped from normal color and infrared aerial photographs. Quantitative sampling of the vegetation was also done in the site area. Sampling transects were chosen to be representative of the three principal plant communities in the site area; namely, the Aspen-Birch, Northern Hardwood, and Swamp Conifer communities. Along each transect, the overstory, the upper understory, the lower understory, and the ground layer were analyzed, and a relative importance value was calculated for each plant species present.

In addition to the quantitative sampling of the site area, seasonal observations and sample collections were made in 1977 in both the environmental study area and the site area, and again in 1978 in the site area to ensure the inclusion of plants in special habitats and those of limited local distribution.

Vegetation samples taken in June 1978 from 27 locations in the environmental study area were analyzed for metals content to provide the baseline data necessary to measure any future changes in metals uptake.

Amphibians and reptiles were included in the seasonal wildlife and plant surveys, and site area surveys specifically for amphibians and reptiles were made in 1977 and 1978.

Bird censuses were made seasonally in 1977 and 1978. Special surveys of migrating waterfowl, waterfowl boards, and drumming ruffed grouse were conducted at times likely to allow observation of maximum populations. Songbird surveys were conducted in winter, spring, and summer of 1977 and 1978. The bird survey locations are shown in EXHIBIT 215.

A census of white-tailed deer was made, and small mammals were trapped for identification in the site area locations shown in EXHIBIT 216.

Q. What were the conclusions of the terrestrial ecology studies?

A. I'll try to summarize concisely the large amount of information that is in some 30 figures and tables and about 75 pages of text in the EIR.

The site area, like most of the surrounding region, is forested by predominantly second growth northern hardwood poletimber. Most wildlife species common to northern Wisconsin are present in the site area, and the wildlife community in the site area is typical of that in the surrounding region.

When the location, extent, and quality of the terrestrial resources of the site area are compared to those of the surrounding region, there are a few unusual resources, but no unique ones. The unusual resources are a bur oak swamp near Skunk Lake; the wild rice beds in Rice Lake; a possible occurrence of algal-leaved pond weed (a threatened species) in Duck Lake; breeding bald eagles, ospreys, Cooper's hawks and red-shouldered hawks; and a small population of southern flying squirrels. The only threatened or endangered animal species found in the site area (the bald eagle, the osprey, the Cooper's hawk, and the red-shouldered hawk) are also found throughout northern Wisconsin.

The site area has few functional relationships to the terrestrial resources beyond the site area, primarily because of the site area's similarity to the environmental study area and to the surrounding region. The only major functional linkage is for migratory wildlife species.

Important sensitive receptors in the terrestrial community in the environmental study area include the bald eagle, the osprey, and the common loon. These species are sensitive to habitat disturbance and may also be disturbed by nearby human activity.

The inventory of terrestrial plant and animal species obtained in the studies provides an excellent baseline against which environmental effects of mining and milling can be measured by future monitoring programs.

Q. What were the objectives of the meteorology and air quality baseline research program?

A. The objectives were to document the pre-construction air quality and to characterize the meteorological conditions that affect dispersion and dissipation of airborne contaminants. Achievement of these objectives would provide the baseline for comparison with future monitoring results and would also provide the necessary data for predicting impacts of emissions from mine facilities on air quality.

Q. Were those objectives achieved?

A. Yes. The data collected in the baseline study of meteorology and air quality in the environmental study area along with data from other sources in the region, such as the weather stations at Nicolet College at Rhinelander and at the Wausau Municipal Airport, have allowed us to characterize the existing air quality and have provided the meteorological history necessary to predict atmospheric dispersion.

Q. What data were collected in the environmental study area?

A. Since there were no air quality monitoring programs operating within 25 miles of the project site, three monitoring stations were set up in the locations shown in EXHIBIT 217. Station 1 was the meteorological station where wind speed, wind direction, temperature and precipitation were recorded, and where sulfur dioxide and total suspended particulates (TSP), or dust, concentrations were monitored. At Stations 2 and 3, TSP concentrations were monitored.

Q. Over what period of time were these monitoring stations operating?

A. Station 1 was the first station installed. Meteorological data and TSP samples were collected from late March 1977 through December 1978. Precipitation and sulfur dioxide monitoring were begun in November 1977. Stations 2 and 3 were added to the program in January and February 1978, respectively. TSP monitoring at Stations 2 and 3, as well as sulfur dioxide monitoring at Station 1 were begun at the request of the DNR after the initial monitoring program was started.

Q. What quality control measures were employed in the monitoring program?

A. The monitoring equipment was calibrated at quarterly intervals and after any maintenance procedures, and calibration records were sent to the DNR after each calibration. The DNR observed the calibration procedures for the air quality monitors and audited the entire air quality monitoring program. Table 2.1-2 in the EIR summarizes auditing and certification activity by the DNR.

In the field, data sheets, daily logs, and checklists were used to ensure proper data collection, calibration, and maintenance. Laboratory procedures were subject to state-of-the-art quality control measures required by the EPA and by the analytical laboratory. The quality control program is fully described in the EIR, Chapter 2, Section 2.1.

Q. What laboratory analyses were performed and what methods were used in those analyses?

A. EPA-approved analytical methods were used wherever such methods existed and were applicable. In cases where EPA had not recommended or approved specific analytical methods, the laboratory used generally accepted analytical procedures.

TSP and sulfur dioxide concentrations were determined by EPA-approved methods. Characterization and classification of the dust collected by the TSP samplers was done by microscopic examination. The collected dust particles were characterized as mineral matter, biological matter, or combustion products, and they were further classified by particle size.

At the request of the DNR, composite samples of dust collected each quarter at Station 1 were analyzed for lead, zinc, cadmium, copper, mercury, and arsenic.

Q. What principal conclusions were reached in the baseline study of meteorology and air quality?

A. The predominant wind direction in the vicinity of the Crandon project site is from the south through southwest, and the average velocity is a little over 7 miles per hour.

Dust (TSP) concentrations at all 3 sampling locations were quite similar, and were all well below the levels set as primary and secondary air quality standards by the State of Wisconsin and the EPA.

Particle characterization showed that the airborne dust collected in the environmental study area is, on the average, composed of 45 percent mineral matter such as quartz, calcite and clays, characteristic of soil, 45 percent biological matter such as pollen, plant debris and insect parts, and 10 percent combustion products, or soot. About half of the particulate matter collected over the entire data collection period was in smaller than 30-micron particles.

Lead concentrations averaged about 7 percent of the National Ambient Air Quality Standard. Other trace elements analyzed were frequently at concentrations too low to be detected and when detected, were at very low concentrations.

Sulfur dioxide was not detectable in the ambient air throughout the monitoring program.

In summary, air quality in the environmental study area is high, as would be expected, since there are no significant sources of air pollution or odorous emissions within ten miles of the ore deposit.

Q. How was the information on land use obtained?

A. By literature search, by interviews with state and local government units, and by aerial photography and field reconnaissance.

Q. What are the land uses in the environmental study area?

A. About 77 percent of the land area is used for forestry; 12 percent is used for recreation, 6 percent for residences and institutions, 5 percent for agriculture, and less than 1 percent for transportation, business and industry. The major land uses are shown in EXHIBIT 218.

Q. Is most of the land in private ownership?

A. Yes. About 85 percent is in private ownership.

Q. What are the public lands?

A. Most of the land in public ownership is county forest land. The remainder is distributed among state trust and DNR lands, the county airport, a county park, and township land which includes 3 town parks.

Q. Who owns the forest lands?

A. About 43 percent of the forested area is owned by private companies, 38 percent is owned by individuals, and 19 percent is in public ownership. About 15 percent of the forested land has been entered into either the Forest Crop Law program or the Woodland Tax Law program.

Q. What are the principal recreational uses of the land in the environmental study area?

A. Fishing, hunting, swimming, boating, automobile camping, snowmobiling, sightseeing and picnicking are all popular recreational activities in the environmental study area.

Q. Where are the centers of recreational activity?

A. EXHIBIT 219 shows the locations of the principal recreational resources.

Within the environmental study area are 31 lakes covering a total of about 6,100 acres and some 27 miles of designated trout streams. The streams are frequently used by anglers. Eleven of the lakes have public access, and they are the centers of water-based recreation in the environmental study area. Six of the larger lakes (Metonga, Lucerne, Little Sand, Crane, Rolling Stone, and Bishop) are generally considered suitable for fast power boating and water skiing. Public swimming is permitted at the Forest County Veterans Memorial Park on Lake Metonga. Canoeing is possible in parts of Swamp Creek downstream of its confluence with Outlet Creek.

Popular land-based activities in the environmental study area are picnicking, camping, and hunting. Public camping facilities are available at the Forest County Veterans Memorial Park and at private campgrounds at Rolling Stone Lake, Lake Metonga, the Lily River, and near Rice Lake. Public picnic areas are located at the Veterans Memorial Park, and picnic tables are located in town parks at Mole Lake, Rolling Stone Lake and in private campgrounds.

In winter, snowmobiling and cross-country skiing are popular. There are about 57 miles of snowmobile trails in the environmental study area. There are no designated free-of-charge public ski trails, but there are ample opportunities for cross-country skiing on unplowed logging roads and trails.

A total of about 17,000 acres of public lands and tax law lands are open to recreational activity, although no facilities have been provided for specific recreational uses.

Q. Where are residences and institutions located?

A. EXHIBIT 218 shows that residential use is concentrated around the larger lakes. Little Sand Lake, the lake nearest the ore deposit, has a developed shoreline with 44 residences. Many of the residences on the northwest shore of Little Sand Lake, as well as near the other lakes in the environmental study area are 1-and 2-room seasonal cottages. Other residences are widely scattered along roads in the area.

The town nearest the ore deposit is the unincorporated community of Mole Lake, which in 1982 had a population of 262.

There are four institutional buildings in the study area. They are the Nashville Town Hall, the Sokaogan Chippewa Tribal Council Building, the Mole Lake School, and the Waba Nun Nung Gospel Chapel.

Q. What are the agricultural uses?

A. EXHIBIT 218 shows the agricultural lands in the environmental study area. Hay, alfalfa, oats and potatoes are the principal crops. Cattle raising and dairying are also significant agricultural activities. In 1980, about 800 cattle were reported in the study area.

Q. What are the transportation-related land uses?

A. As shown in EXHIBIT 101, the environmental study area has a relatively well-developed system of state and county highways and town roads. The weight limit on the roads is generally 18,000 pounds per axle, but this may vary with conditions. During the spring thaw, county and town roads have a limit on total weight of 24,000 pounds per vehicle.

A branch of the Soo Line crosses the east side of the study area. This branch extends from Wisconsin Junction through Crandon and extends south to Milwaukee. No passenger service is offered.

The Crandon Municipal Airport, with an asphalt main runway and a grass runway, is located about 3 miles north of the ore deposit. The main runway is open year-round and the grass runway is open from April 1 to December 1. The main runway is lighted from dusk to dawn. There were about 1250 takeoffs and landings per year in the 1980-81 period. There is no regularly scheduled passenger service.

Q. What are the principal aesthetic values in the environmental study area?

A. The gently rolling terrain, lakes, streams, forest lands and wildlife contribute to the scenic value. Seasonably, the autumn colors, the snow scenes, and spring flowers are aesthetic attractions. There are no designated scenic areas such as state parks or National Landmarks in the study area.

Q. Are any of the land uses in the environmental study area considered to be particularly sensitive to air pollution?

A. Experts generally agree that hospitals, nursing homes, schools, recreation areas, and residences are sensitive receptors of air pollution. There are no hospitals or nursing homes in the environmental study area. The nearest institutional sensitive receptor is the Mole Lake School. As I discussed earlier in my testimony, there are several recreation areas and concentrations of residences in the environmental study area. These uses would be sensitive receptors of air pollution.

Q. Were archaeological and historical resources in the site area surveyed and evaluated?

A. Yes.

Q. Who did this specialized work?

A. Archaeological research teams from Beloit College and the Great Lakes Archaeological Research Center (GLARC, Inc.) did the inventories and evaluations of the archaeological and historical resources. The MacDonald and Mack Partnership did special evaluations of three building clusters that had been identified by the Beloit College inventory as having potential historical significance.

Q. What guidelines were followed in the work?

A. All of the investigations were designed and conducted in accordance with the standards of the Wisconsin Archaeological Survey, Inc. and the Historic Preservation Division of the State Historical Society of Wisconsin. Those standards meet the requirements of the National Historic Preservation Act of 1966.

Q. What were the conclusions of the research teams?

A. The Beloit College team identified and evaluated artifacts or features at 14 locations in the 3760 acres they surveyed. Eleven of those sites were found to be ineligible for the National Register of Historic Places. Three locations were recommended for additional evaluation by an architectural historian. The detailed evaluation of these sites, which included building groups, was done by the MacDonald and Mack Partnership, with the conclusion that the structures lacked historical significance.

GLARC, Inc. inventoried about 1079 acres and identified 12 artifact locations or features. Of these, two prehistoric sites were evaluated as eligible for the National Register of Historic Places. Six sites related to logging activity in the late 19th and early 20th centuries are considered as potentially eligible for the National Register. Recommended mitigation for all of these sites is preservation in place. None of these sites will be disturbed by project construction or operation.

Q. Were these conclusions confirmed by other, independent experts?

A. Yes. The results of the investigations were reviewed by qualified experts of the Historic Preservation Division of the State Historical Society of Wisconsin. Their conclusions confirmed those of the research teams.

Q. Mr. Ortloff, does that conclude your testimony?

A. Yes.

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EXHIBIT 200

RESUME OF EDUCATION AND PROFESSIONAL EXPERIENCE

GERALD D. ORTLOFF

EDUCATION:

Oklahoma State University- Bachelor of Science in chemical engineering- May 1953.

PROFESSIONAL EXPERIENCE:

May 1953 - April 1958--- Research Engineer, The Carter Oil Company, Tulsa, Oklahoma. Conducted theoretical and laboratory research on new processes for increasing the production of petroleum from natural subterranean reservoirs.

April 1958 - October 1960--- Research Group Head, Jersey Production Research Company, Tulsa, Oklahoma. Supervised theoretical, laboratory and field research on the volumetric sweep efficiency of miscible displacement processes in porous sandstone reservoirs.

October 1960 - April 1964--- Project Leader, Jersey Production Research Company, Tulsa, Oklahoma. Conducted and supervised laboratory research on additives and techniques for improving the performance of the waterflooding process in subterranean sandstone reservoirs containing viscous crude oils.

April 1964 - July 1964--- Research Section Head, Jersey Production Research Company, Tulsa, Oklahoma. Supervised all research on waterflooding as a secondary oil recovery process.

July 1964 - July 1965--- Special Projects Engineer, Imperial Oil Ltd., Edmonton, Alberta, Canada. Conducted engineering studies of petroleum reservoirs in western Canada.

July 1965 - March 1972--- Senior Research Specialist, Esso Production Research Company, Houston, Texas. Conducted and supervised theoretical, laboratory, and field research on waterflooding processes in fractured-matrix oil reservoirs; on the ground-water hydrology of the Highland uranium deposit in the Powder River Basin, Wyoming; on the solution mining of copper and uranium; on water quality and treatment; and on air quality and mine ventilation in underground mining.

March 1972 - September 1976--- Environmental Advisor, Minerals Department, Exxon Company, U.S.A., Houston, Texas . Planned and directed the environmental studies and environmental protection programs for exploration, mining, and milling operations.

September 1976 - September 1980--- Regulatory Affairs Manager, Exxon Minerals Company, U.S.A. , Houston, Texas . Directed the environmental protection programs and all licensing and permitting activity for mining and milling operations in the U.S.

September 1980 - April 1981--- Manager, Environmental and Regulatory Affairs, Exxon Minerals Company, Houston, Texas. Directed the environmental protection programs and licensing and permitting activity for world-wide mining and milling operations.

April 1981 - October 1982--- Regulatory Affairs Manager, Colony Shale Oil Project, Exxon Company, U.S.A., Aurora, Colorado. Directed the environmental programs and permitting activity for the planned commercial shale oil project.

October 1982 - September 1983--- Resident Manager, Colony Shale Oil Project; President, Battlement Mesa, Inc., Grand Junction, Colorado. Managed the final phase-down of the Colony project, directed the continuing environmental studies and land reclamation program. Planned the ongoing development of the Battlement Mesa community.

September, 1983 - Present--- Self-employed technical and management consultant, Aurora Colorado.

PROFESSIONAL ACHIEVEMENTS AND RECOGNITION:

Registered Professional Engineer - State of Oklahoma

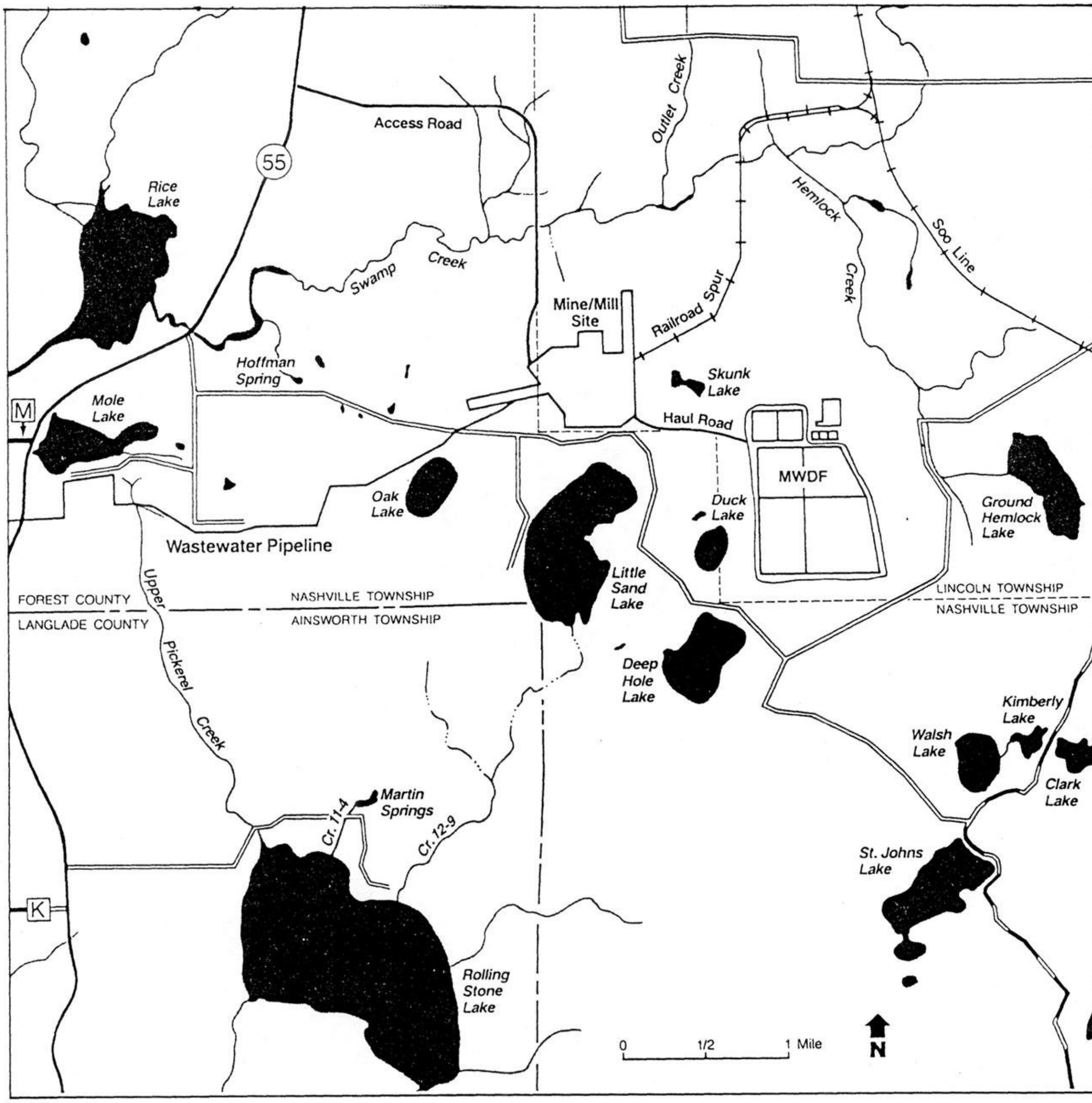
Member, American Institute of Chemical Engineers

Member, Society of Petroleum Engineers

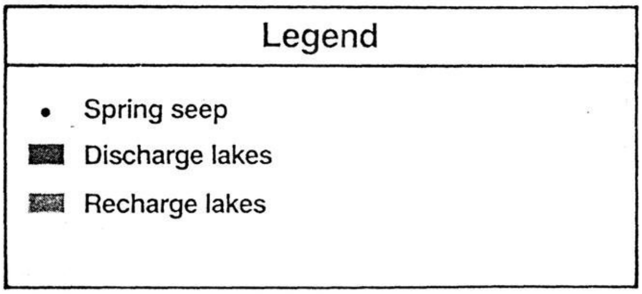
Nine U.S. Patents

Three publications in scientific and technical journals

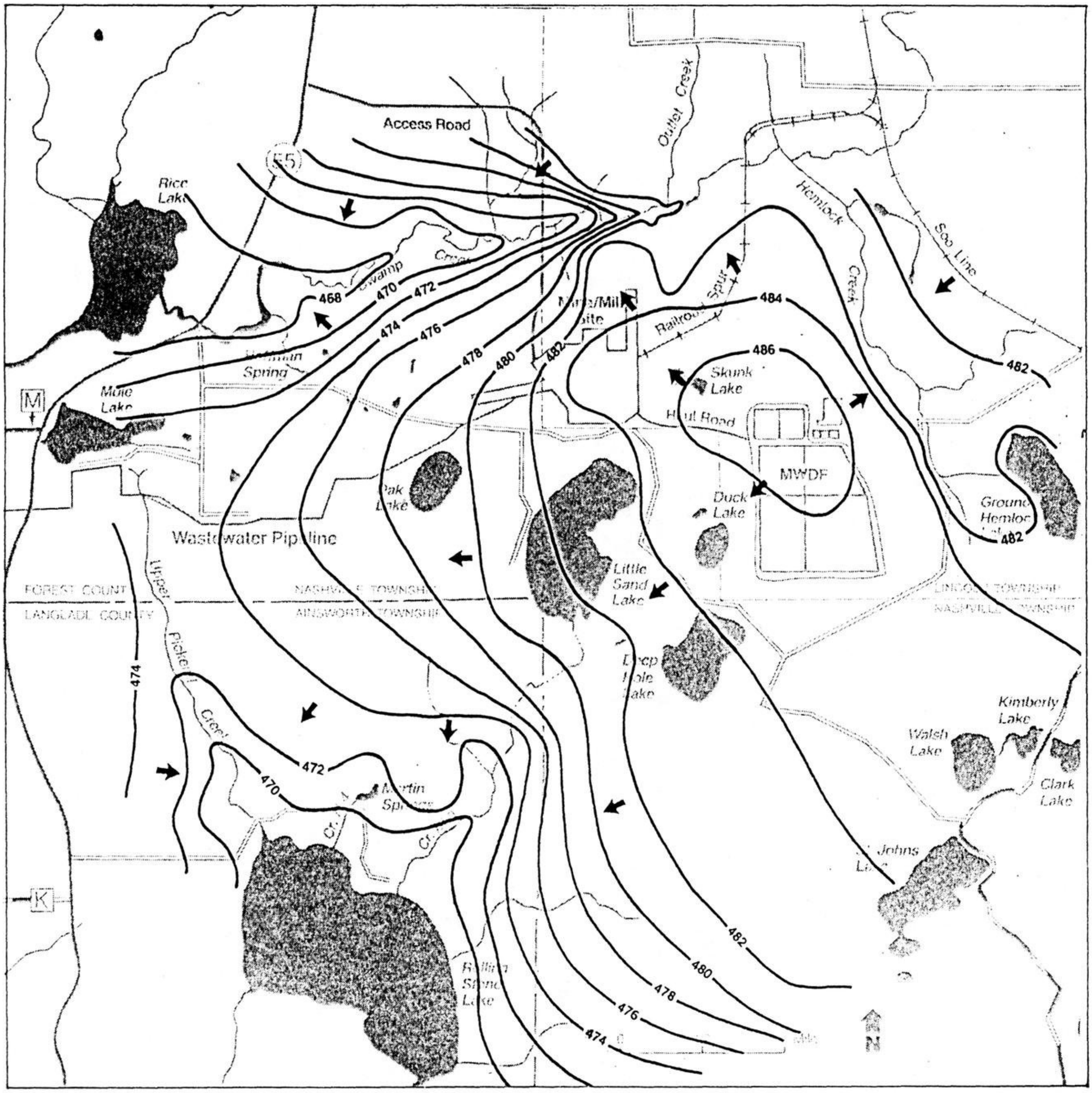
Project Area Map



Surface Water/Ground Water
Interaction

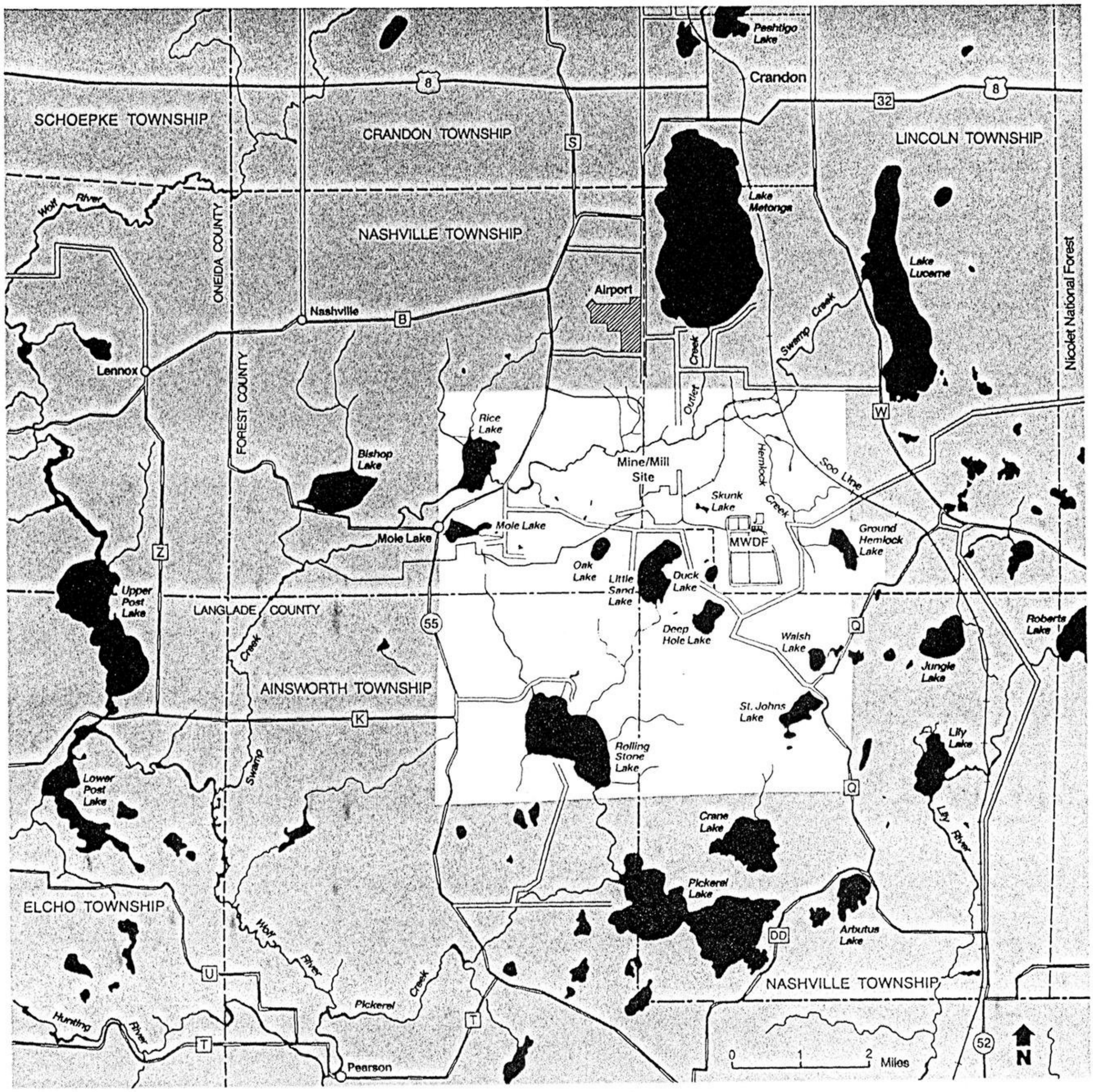


Potentiometric
Surface Contours



Legend
Ground water contours in meters above sea level
General ground water flow direction

Water Well Survey Area



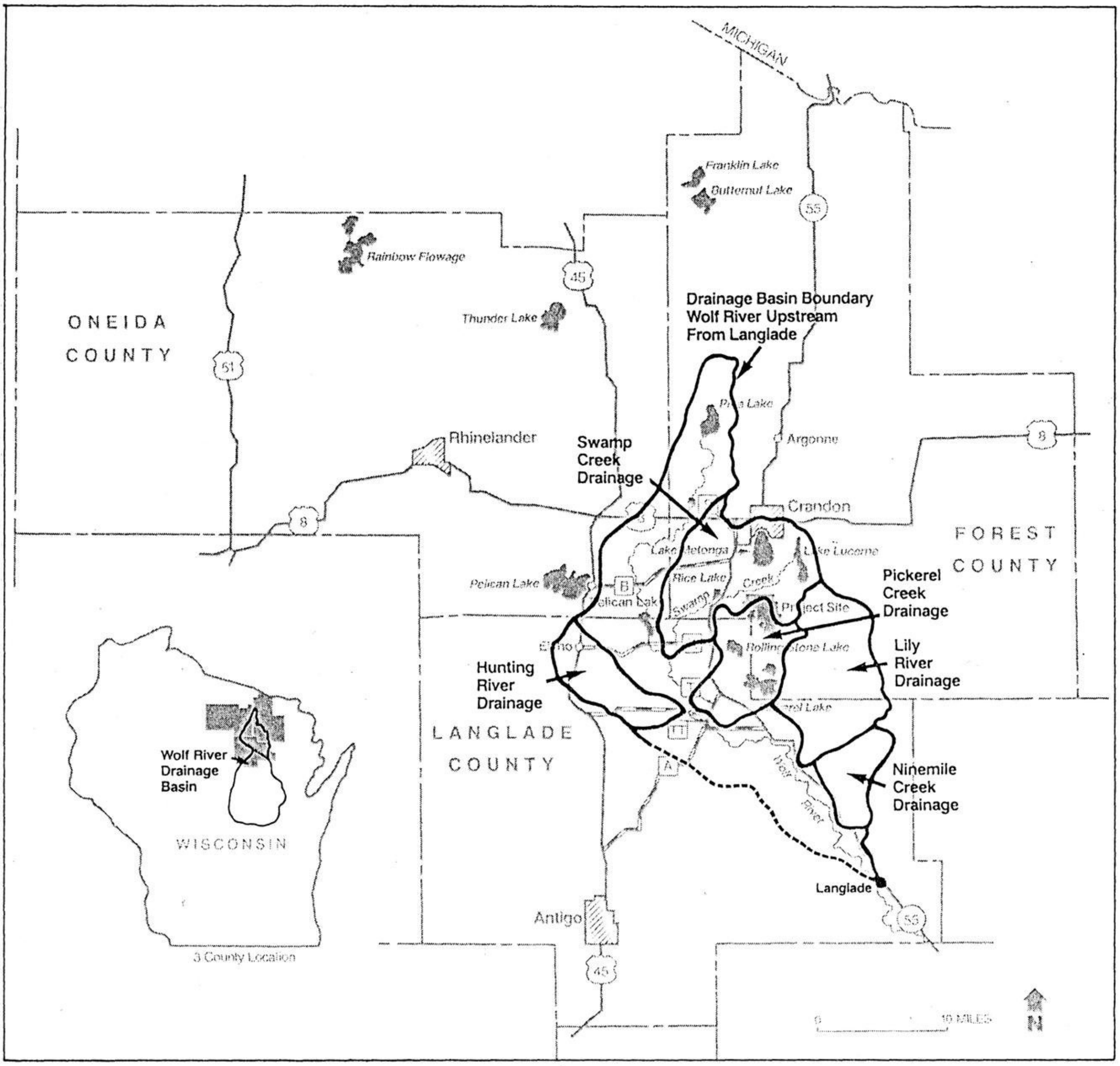
Bore Holes And Piezometers

Ground Water
Analysis Program

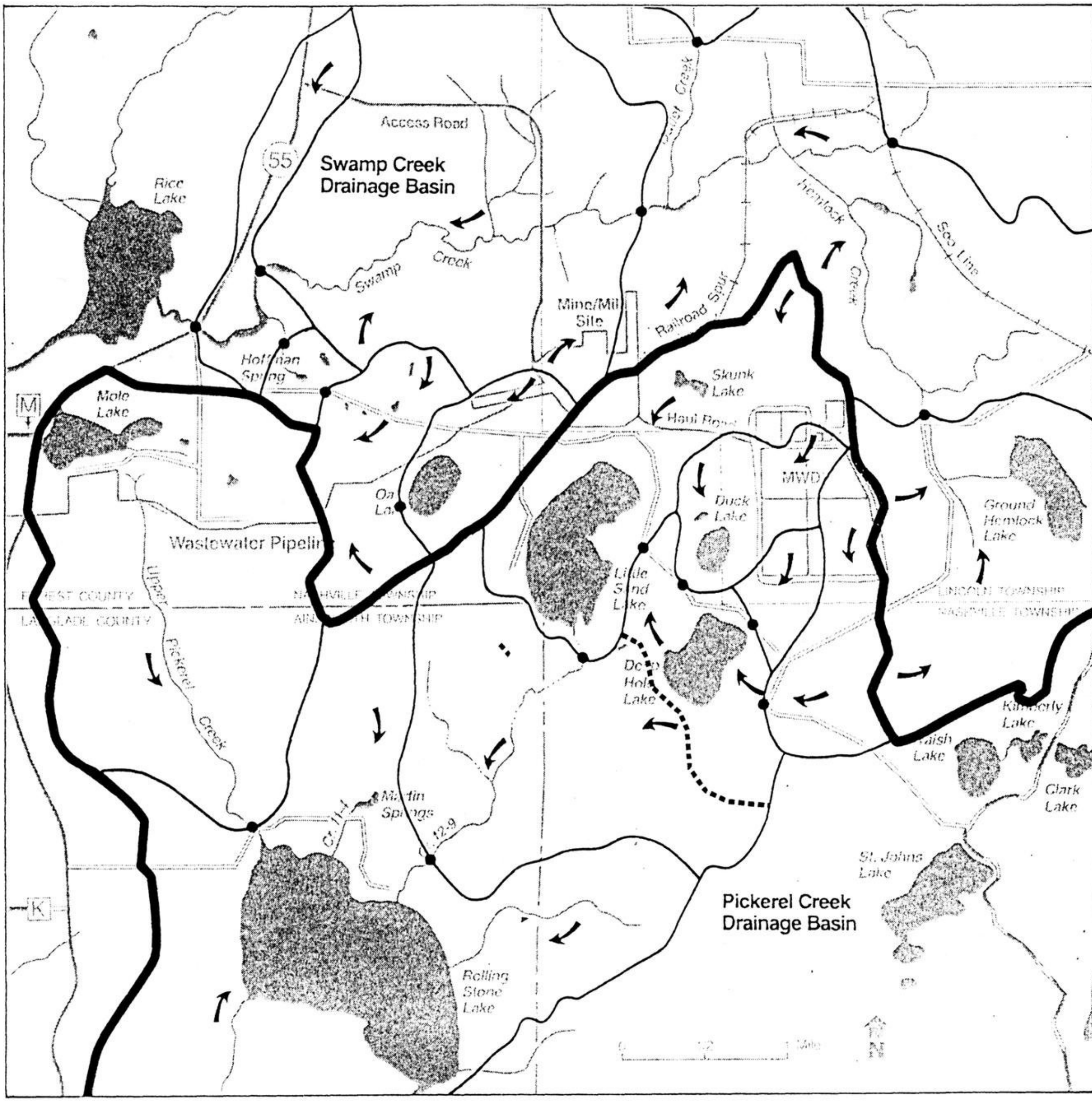
Parameter	Monthly	Seasonal
Total alkalinity		
Specific conductance		
pH		
Total hardness		
Total dissolved solids		
Chemical oxygen demand		
Total phosphorus (P)		
Anions		
Arsenic		
Chloride		
Cyanide, total		
Fluoride		
Nitrate nitrogen (N)		
Total phosphate (PO_4)		
Sulfate		
Cations		
Aluminum		
Barium		
Cadmium		
Calcium		
Chromium, total		
Cobalt		
Copper		
Iron		
Lead		
Magnesium		
Manganese		
Mercury		
Molybdenum		
Nickel		
Selenium		
Silver		
Zinc		

Wolf River Drainage Basin

Upstream From Langlade



Surface Water Drainage



Legend

- Principal watershed
- Staff gage watershed
- Poorly defined watershed
- Direction of surface drainage
- Staff gage location

Lake Classification

Based on Surface Hydrology

Seepage Lakes	Drainage Lakes	Spring Lakes
Swamp Creek Basin		
Oak	Rice	Ground Hemlock
Pickerel Creek Basin		
Little Sand Duck Deep Hole Skunk St. Johns	Rolling Stone	

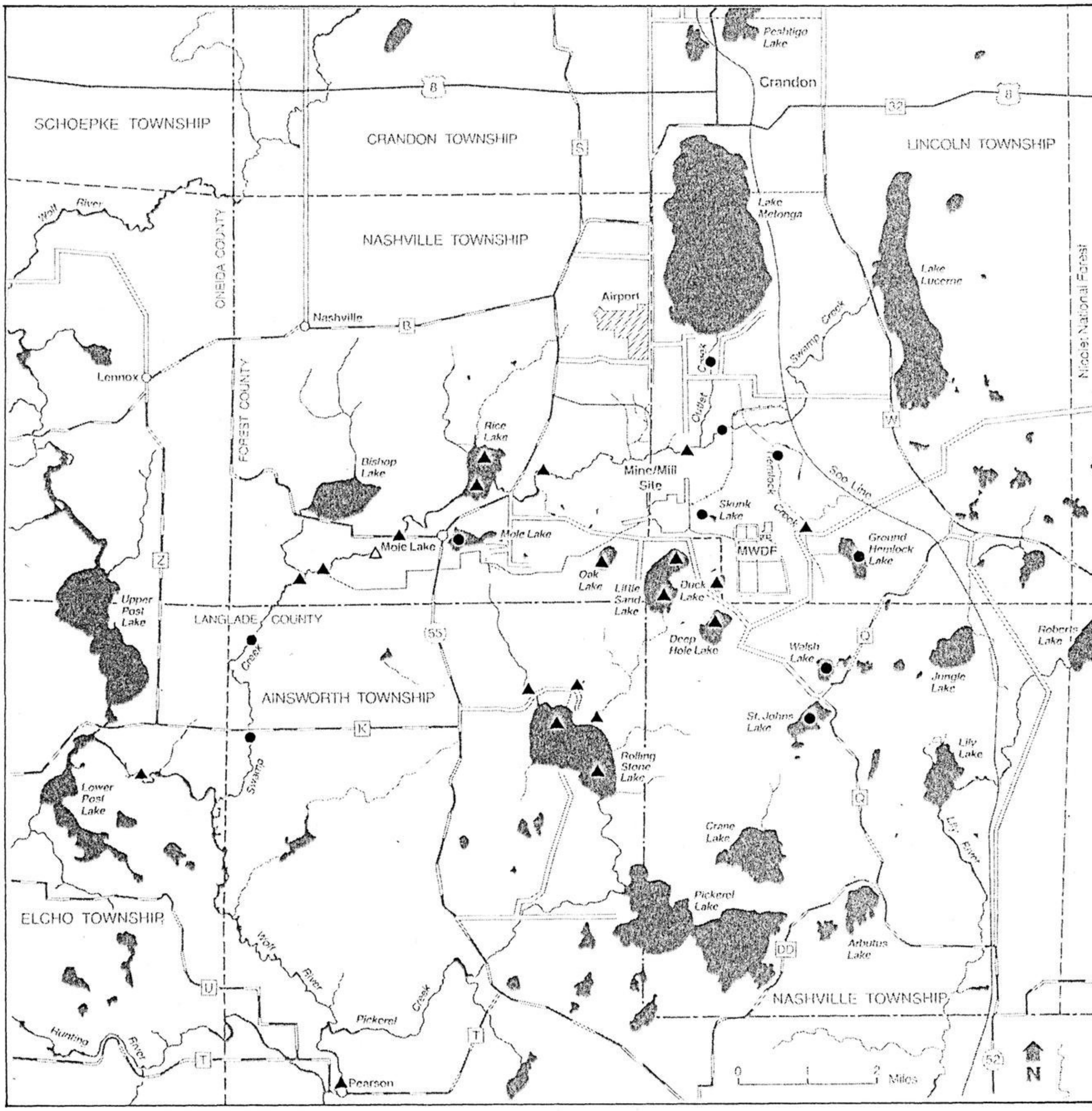
Surface Water Gaging Stations

Legend

• Surface Water Gaging Station

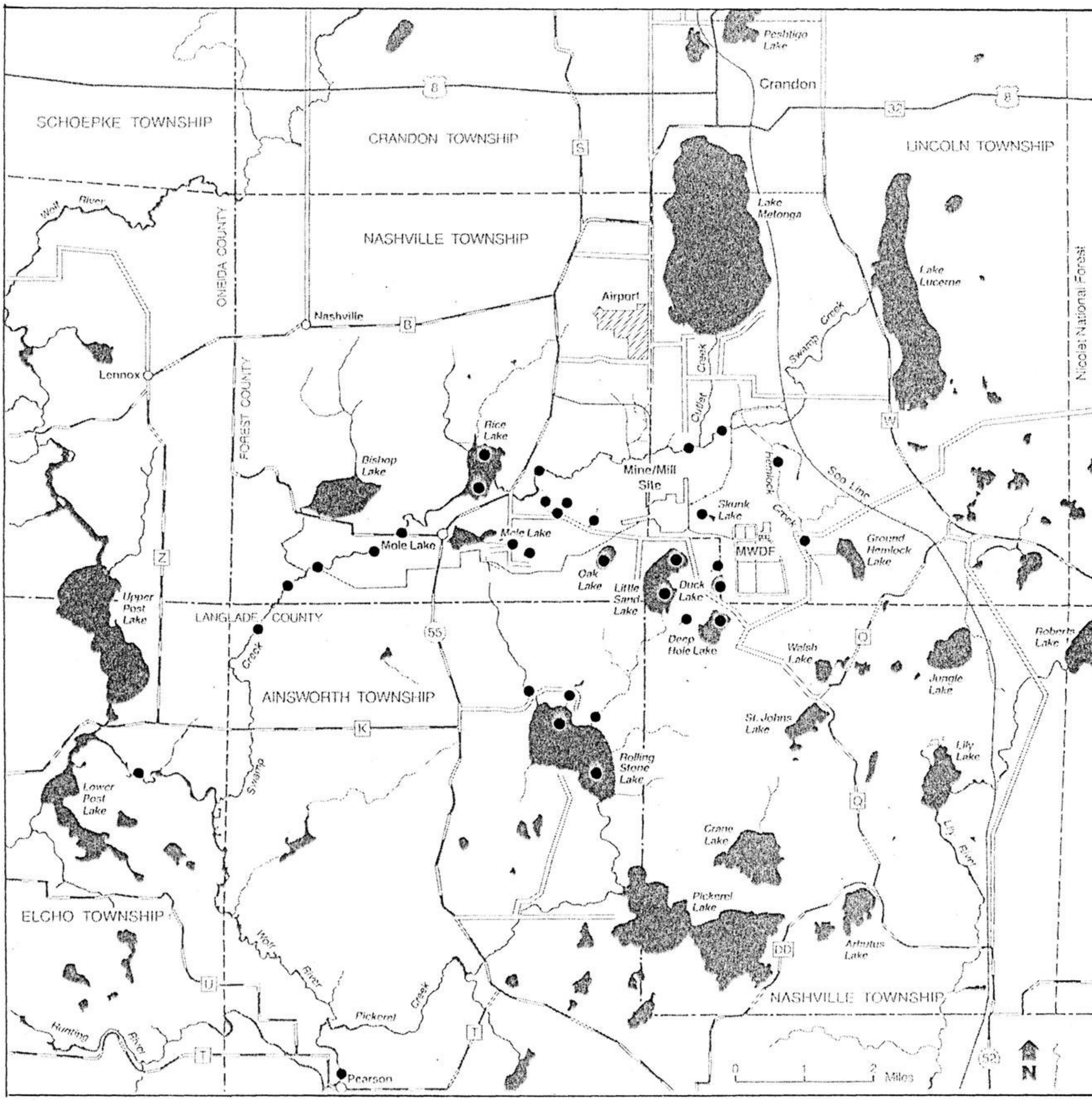
Water and Sediment

Sampling Stations



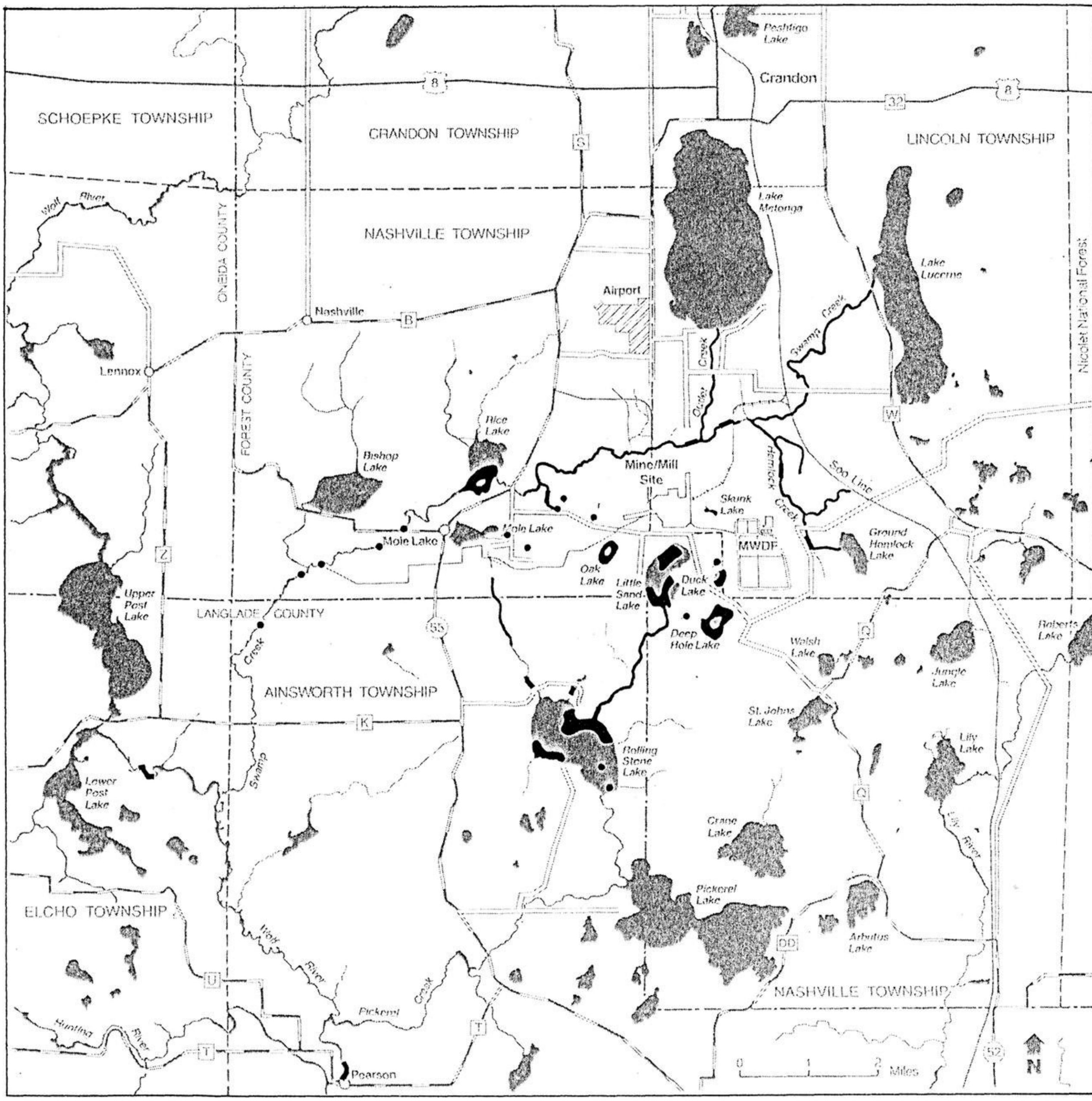
Legend
● Water sampling station
▲ Water and sediment sampling station
△ Sediment sampling station

Aquatic Ecology
Sampling Stations



Legend
● Aquatic Ecology Sampling Station

Fish Sampling Locations



Legend

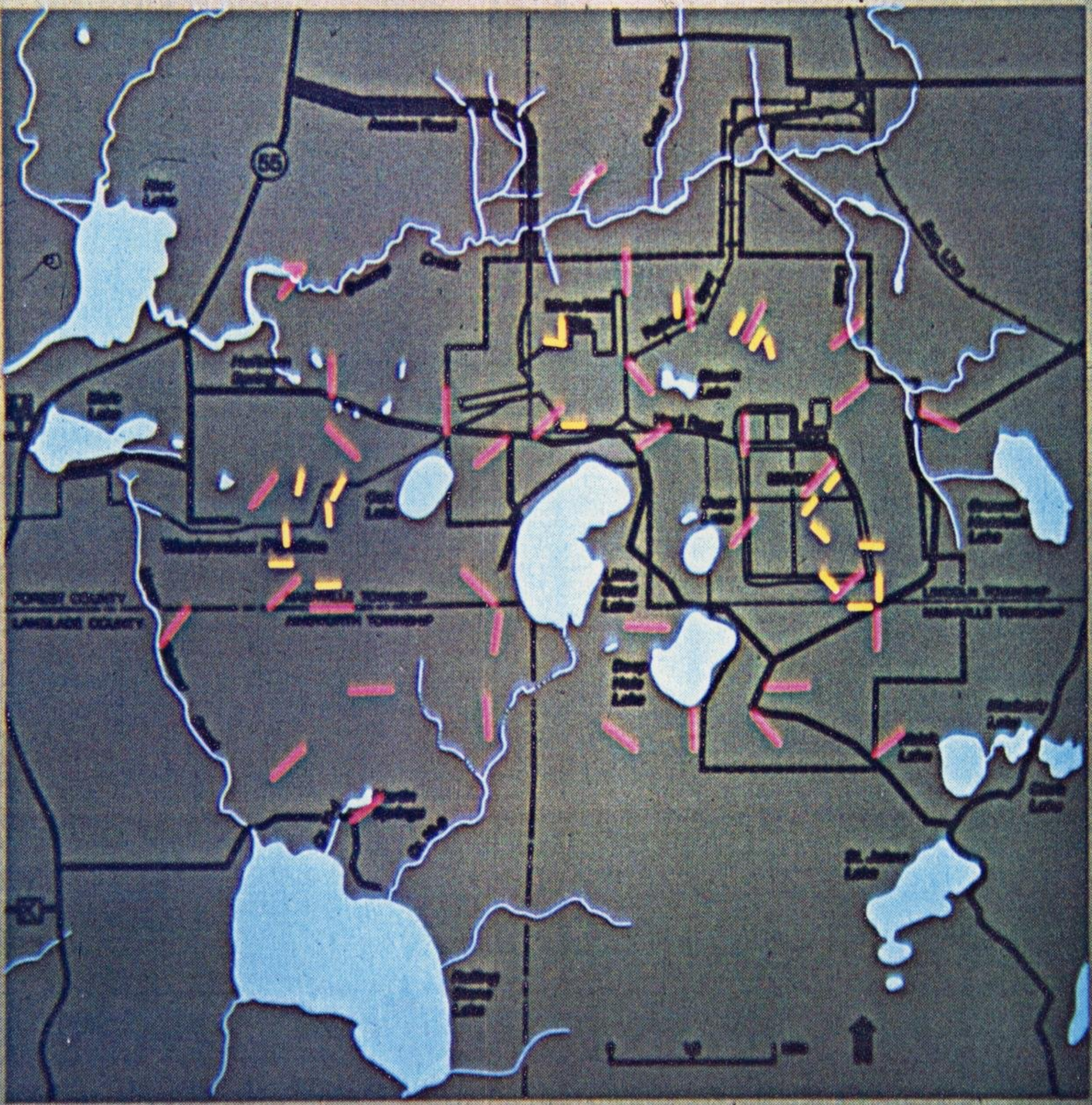
- Fish Sampling Location
- Trout Redd Reconnaissance

Terrestrial Ecology Sampling

Task	Environmental Study Area	Site Area
General Reconnaissance		
Soils Classifications		
Vegetation		
Mapping		
Quantitative sampling		
Seasonal collections		
Tissue analyses		
Amphibians and Reptiles		
General surveys		
Birds		
Avian surveys		
Migrating waterfowl surveys		
Waterfowl brood surveys		
Grouse surveys		
Mammals		
Snap trapping		
Deer trail counts		

Bird Survey Locations

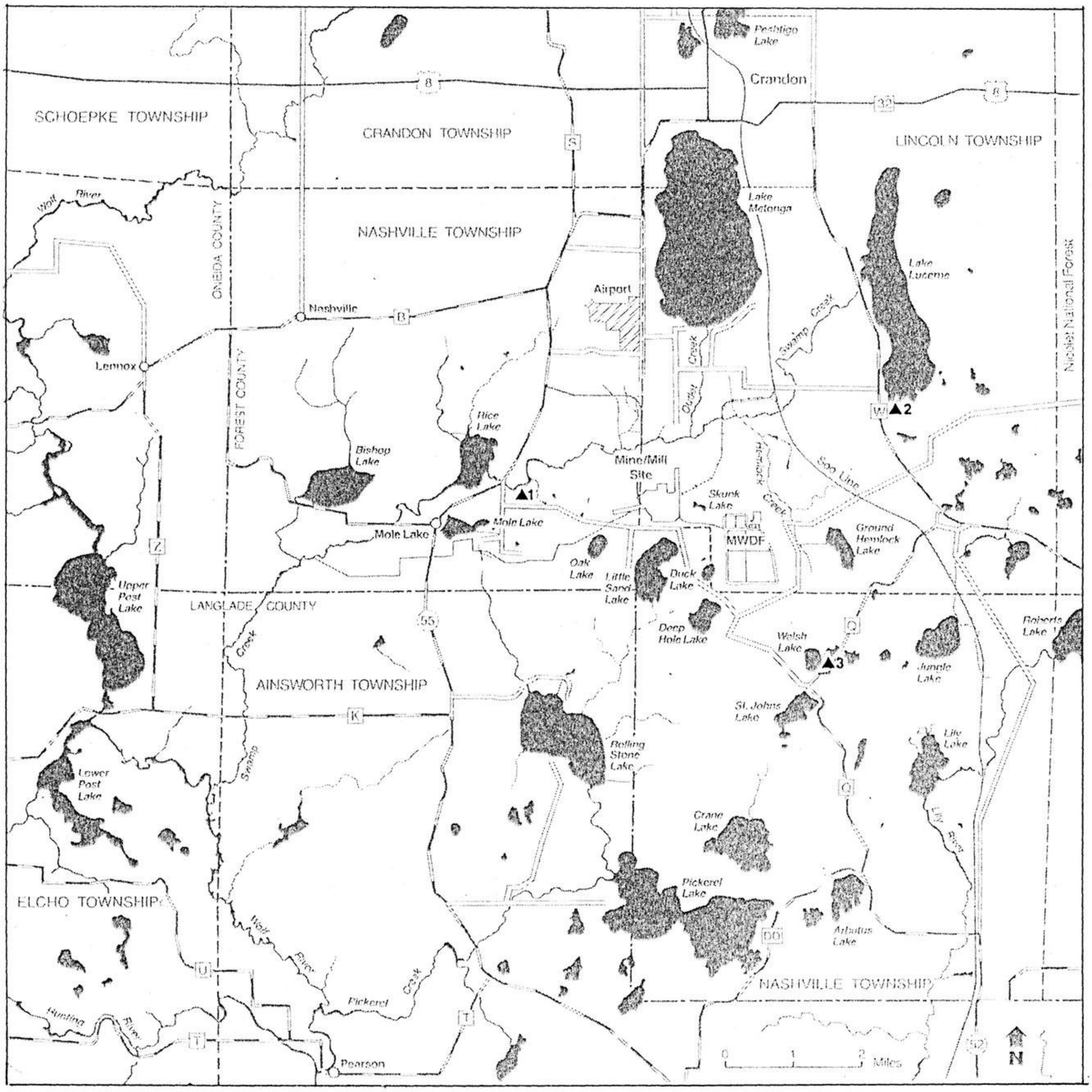
Mammal Survey Locations



Legend

- Deer trail transect
- Small mammal trapline in site area

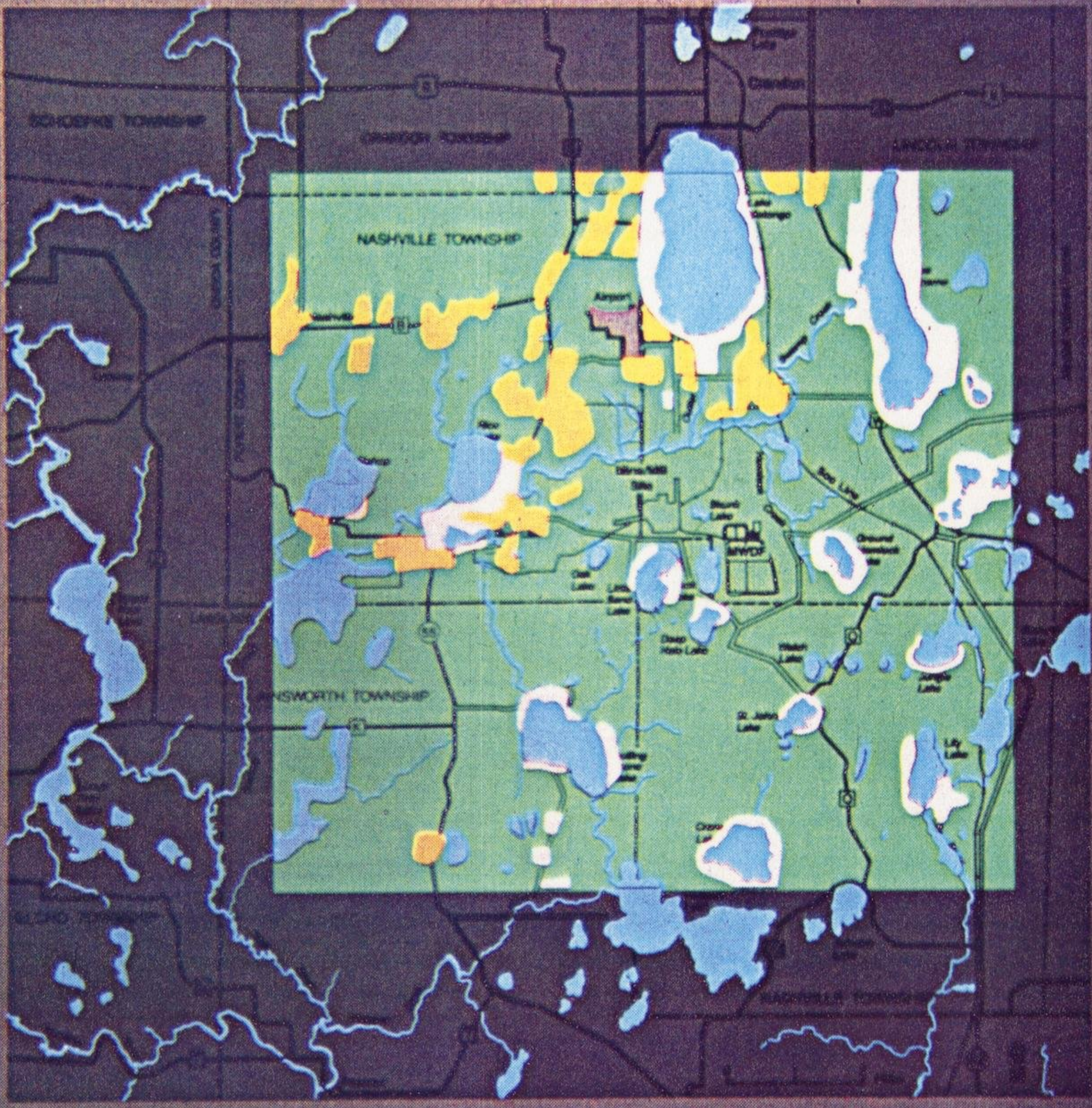
Air Monitoring Stations



Legend

▲ Station Locations

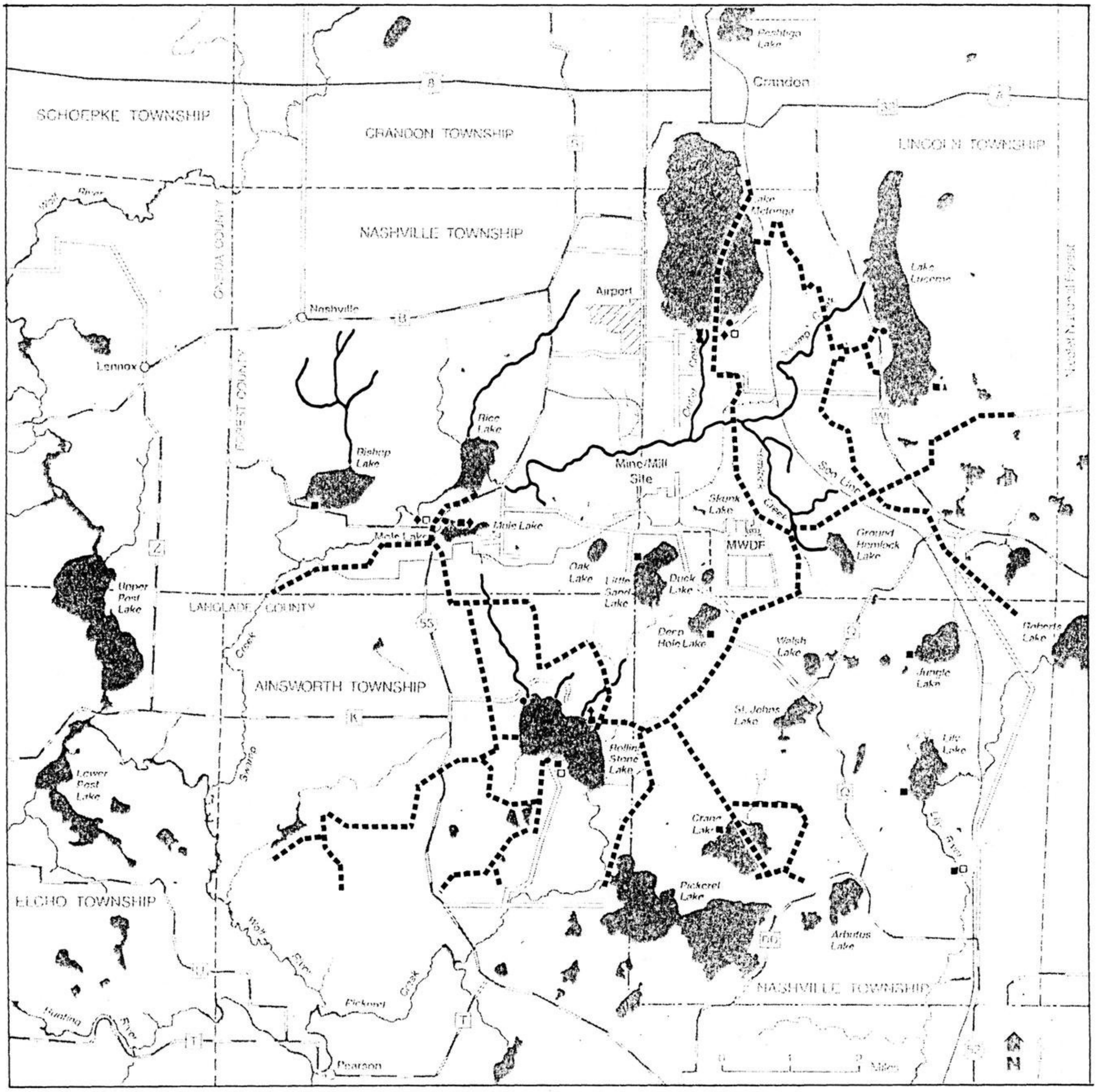
Land Use
In Environmental Study Area



Legend

- Agriculture
- Residential/Institutional
- Forestry
- Recreational
- Transportation

Recreational Resources



Legend

- Snowmobile trail
- Trout streams
- ■ Public lake access site
- □ Camp grounds
- ♦ Parks
- ● Boat rentals

Regional Base Map

BEFORE THE
STATE OF WISCONSIN
DIVISION OF HEARINGS AND APPEALS

Application of Exxon Corporation for Permits to Build and Operate an Underground Mining and Ore Concentrating Complex Located in Forest County, Wisconsin	))))	IH-86-18

TESTIMONY OF R. G. ROWE

GEOLOGICAL BASELINE

Q. Please state your name, address and occupation.

A. Roger Rowe

15403 Windy Cove

Houston, Texas

Geologist

Q. Please describe your education and experience.

A. I have a Bachelor of Science and a Master of Science degree from the University of Minnesota, Duluth and Bowling Green State University, respectively. I have been employed by Exxon Minerals Company since 1968. About 10 of those years have been spent as an exploration geologist looking for ore bodies throughout the midwest, Rocky Mountain States, and the southwestern USA. Since 1977, I have been working on Crandon

Project feasibility studies, project design, site management and permitting activities. A more complete description of my qualifications may be found in my resume, which is attached as EXHIBIT 222.

Q. What role have you played in the planning of the Crandon Project?

A. My role has been one of understanding the geology of both the deposit and project site. Geologic activities were focused on the typical objectives of ore body delineation, ore reserve estimation, glacial and bedrock stratigraphic studies, and general site investigation. Results from these programs formed the basis for the Project's preliminary feasibility studies. Further geologic investigations have provided criteria for project design, site management, and operational permitting. Activities have included mine entry definition drilling, developing geostatistical reserve modeling, large diameter core drilling for pilot plant metallurgical testing, rock mechanics testing, and mine site geohydrologic studies which included detailed studies of glacial stratigraphy, pumping test programs, and mine inflow computer modeling.

Q. What is the subject of your testimony today?

A. I will describe the geologic and hydrologic aspects of the Project. I have divided my testimony into five parts. I will first describe the geologic setting of the Crandon metal deposit. Then I will describe the ore body itself. Thirdly, I will discuss the effects that glaciers have had on the area; that is, I will discuss the materials which have been deposited on top of the ore body by glaciers. Fourthly, I will describe the geologic and engineering studies which have been conducted in the project area. And, lastly, I will describe the hydrologic studies conducted in the area.

The Crandon ore body and its environment have been studied in great detail. I have visited many mining projects throughout North America in my twenty years in this business, but have never seen a project studied as thoroughly as Crandon. A thorough understanding is important because mining affects the local environment. Because we know and understand the environment of the Crandon project so thoroughly, we can confidently predict the effects mining will have on that environment.

Q. What studies have you relied on in preparing this testimony?

A. A list of the reports covering the major studies that I relied on is presented in Table 1 of my prefiled testimony. That table also provides, for each report, the corresponding exhibit number as it appears in this hearing record.

TABLE 1

REPORT	EXHIBIT #
Environmental Impact Report, Exxon Minerals Company, 1985, Volume II, Section 2-2	EXHIBIT 158
Geohydrologic Characterization, Crandon Project Waste Disposal System, Golder Associates, October, 1982	EXHIBIT 181
Geology Study and Study Methods, Dames & Moore, April, 1981	EXHIBIT 167
Ground Water Study and Study Methods, Dames & Moore, January, 1982	EXHIBIT 168
Hydrogeologic Study Update for the Crandon Project, STS Consultants, Ltd., June, 1984	EXHIBIT 195
Lambe, R. N. and R. G. Rowe, Geology of the Crandon Massive Sulfide Deposit, Exxon Minerals Company Report, January, 1981	EXHIBIT 159
Mine Hydrology Test Data Analysis, Crandon Project, Camp Dresser and McKee, May, 1982	EXHIBIT 163
Mine Waste Disposal Facility Feasibility Report, Exxon Minerals Company, December, 1985	EXHIBIT 114
Prickett, T. A., Ground Water Flow Model for Exxon Ore Body Near Crandon, Wisconsin, Thomas A. Prickett & Associates, January, 1982	EXHIBIT 187
Rock Mechanics Testing and Engineering of Large Diameter Core, John D. Smith Engineering Associates, September, 1981	EXHIBIT 192
Rowe, R. G., Bedrock Permeability, Exxon Minerals Company, May, 1984	EXHIBIT 161
Rowe, R. G., Supergene Weathering at the Crandon Deposit, Exxon Minerals Company, April, 1982	EXHIBIT 160
Soil Boring and Laboratory Test Results of Little Sand Lake Drilling Project, STS Consultants, Ltd., April, 1982	EXHIBIT 194

Q. Please describe the regional geologic setting of the Crandon Project.

A. The bedrock in the Crandon area is part of an ancient volcanic environment. The rocks were created in much the same manner as Mt. St. Helens in Washington with one exception: at Crandon the volcano was under the ocean.

The volcanic rocks at Crandon are part of a larger band of volcanic rocks which stretch from Ladysmith on the west to Pembine on the east as seen in EXHIBIT 223. Nearly all of these volcanic rocks were created under the ocean. Orebodies like the Crandon deposit formed in these rocks.

After the volcanic activity ended about 1.8 billion years ago, Northern Wisconsin was involved in a period of mountain building. Pressures within the earth folded and uplifted the rocks into huge mountains, much like the Rockies. The orebodies contained within these volcanic rocks were hidden deep within the mountains.

In the millions of years since the mountains were formed, wind and water have slowly been tearing the mountains down grain by grain. Mountains which may have been as high as the Rocky Mountains have been worn down to the present elevation of 1,500 feet above sea level. The mountains are now gone and the

Crandon area is what was once the foundation of the mountains. The Crandon orebody was hidden in the mountain roots, to be exposed only after millions of years of erosion.

About two million years ago, the first of four massive sheets of ice - glaciers such as now cover Greenland and Antarctica - covered much of the northeastern United States. The last of those ice sheets withdrew from the Crandon area only about 7,000 years ago. The glaciers hid the Crandon orebody once again, covering it this time with sand and gravel one hundred to two hundred feet thick. It was not until the coming of the electronic age that man was able to invent a device which could detect hidden orebodies beneath thick sand and gravel deposits.

Q. Is there likely to be a powerful earthquake in the Crandon area while the mine is in operation?

A. No. Northern Wisconsin and the Upper Peninsula of Michigan are among the most stable areas in the United States.

Q. Please describe the bedrock and the Crandon orebody.

A. To describe the orebody, we need to back up in time about 1.8

billion years, back to when the volcanos were active. On the ocean floor, perhaps 2000 feet deep, hot fluids from deep within the earth were pouring onto the ocean floor. These fluids contained dissolved metals and sulfur.

Similar outpourings have been found on the floor of the present day Atlantic Ocean and are called "black smokers." Metals accumulating on the ocean floor around the black smokers can become ore deposits similar to the Crandon orebody.

The Crandon deposit is really two orebodies. The first is a zinc rich deposit which formed from the "black smoker" type of setting. This deposited a blanket of zinc ore on the ocean floor up to 200 feet thick. This zinc rich blanket is called "Massive Ore,". The terminology "Massive Ore," has nothing to do with how big or small, rich or lean the orebody is, but is just an expression meaning the orebody is composed dominantly of sulfur-rich minerals.

The second orebody lies underneath the blanket of massive ore. The blanket of massive ore on the ocean floor trapped the rising hot fluids beneath it. It would be like trapping the moisture in the garden by putting a plastic sheet over the garden. The hot fluids containing rich copper metals were trapped in the cracks in the rock. The cracks in the rock were created by earthquakes and internal earth pressures.

Eventually the rocks cooled and the fluids containing copper hardened in the cracks. This formed what we call "Stringer ore", ore with a string-like appearance. Both bodies were then still lying flat.

The massive ore lay like a blanket on the ocean floor and the stringer ore lay in cracks in the rock beneath the massive ore blanket.

Next, nearby volcanos began to erupt once again. The orebody was buried beneath hundreds of feet of volcanic materials much as Spirit Lake was buried beneath the volcanic rocks when Mt. St. Helens erupted. The orebody was now entombed in rock, not to be seen again for 1.8 billion years.

As discussed earlier, the rocks of Northern Wisconsin were then lifted up into high mountains. The flat-lying Crandon deposit was also uplifted and tilted, as a magazine might be tipped on edge. The orebody was tipped to almost, but not quite vertical. It now tilts slightly toward Crandon.

Q. Please describe what the orebody looks like today.

A. EXHIBIT 224 is what is called a geologic plan view. It is as if we were looking down on the rocks from an airplane. It shows the orebody is about one mile long in an east-west direction, and averages about 200 feet wide from north to south. EXHIBIT 225 is a geologic cross section, meaning it gives a view such as we would have if we sliced into a layer cake so that we could look at the layers. The cross section is a slice made from north to south across the orebody, and gives us the view we would have if we were looking west at the orebody. It shows that the orebody extends to a depth of more than one-half mile. The rocks to the north of the orebody are called the hanging wall while rocks to the south are called footwall. The words hanging wall and footwall are mining terms, and indicate which rocks would be hanging above you and which rocks would be under foot if you mined a section of the orebody.

The next EXHIBIT, number 226, is a table which shows the number of tons of ore contained in each of the orebodies, and the percentage of metal in each ore. In summary, there are about 67 million tons of ore. The massive ore is rich in zinc, and also contains small quantities of copper, lead, silver and gold. The stringer ore is less rich, which the predominant metal being copper, and much smaller quantities of zinc, lead, silver and gold.

Q. Please describe the glacial materials which now lie on top of the orebody.

A. Glacial material is the sand, gravel, silt and clay left behind after the glaciers melted. Most of the glacial material in the vicinity of Crandon came from northeastern Wisconsin, the Upper Peninsula of Michigan, or perhaps southern Ontario. It is important to understand the glacial materials because most of the ground water moves through the glacial materials. Since mining will have an impact on the water, the glacial material must be thoroughly understood before that impact can be defined.

The most important item we need to know about the glacial materials is their permeability. Permeability simply means the capacity for moving water. The size and shape of the spaces between soil particles determines how much water can pass through a particular material. Permeability can be expressed in two ways:

1. The rate at which water can move a given distance in a given interval of time, e.g., 6 inches per day.

2. The volume of water which will move through a given area in a given interval of time, e.g., two gallons per square feet per day.

Both of the above mean the same thing. One value can be quickly converted to the other value. In my discussions, I will express permeability using the second method because most people can relate to "gallons" better than anything else. However, subsequent witnesses may use the first method simply because it is more accepted terminology.

The glacial materials were deposited in layers. Before water movement can be determined we must know what kind of glacial materials make up these layers and how these layers were distributed. The layers of glacial materials at the project site fall into one of four categories:

1. Coarse grained stratified drift;
2. Fine grained stratified drift;
3. Till; and
4. Lacustrine.

Q. Do the four categories differ in permeability?

A. Yes, but before I go into any explanation of the above categories the term aquifer must be explained. An aquifer is simply material below the surface capable of producing water from a well. Permeability in an aquifer is higher than in a non-aquifer.

In the Crandon Project area, the glacial layers which are made up of coarse grained stratified drift or fine grained stratified drift are the aquifer layers. If you were going to put in a well, you would want your well point driven into one of these two layers. The till and lacustrine layers are non-aquifer. Wells in these layers would probably not produce enough water for household use.

Coarse and fine grain stratified drift are aquifers because of the way they were formed. When the glaciers melted they left behind a sandy material containing much silt and clay called "till." The high silt and clay content give the till a low permeability. However, the melting glaciers produced enormous quantities of water. The streams melting from the glaciers washed some of the till and removed much of the silt and clay. That is, the streams produced a product much like what can be seen at a local gravel pit, where silty pit-run material is put through a "wash plant" in order to produce a clean product for cement or roadwork. Coarse and fine grained stratified drift has been through nature's "wash plant". The layer called till has not been through the "wash plant".

The last category of glacial material is called lacustrine. Lacustrine is a geologic term meaning lake bottom material, usually silt and clay. Lacustrine layers in the project area are not widespread, indicating glacial lakes were small, smaller than present day lake sizes. The five present day lakes that are closest to the mine (Little Sand, Oak, Duck, Deep Hole and Skunk) all have such lacustrine deposits beneath them. These deposits, whether beneath present day lakes or ancient glacial lakes, are very impermeable compared to glacial tills.

EXHIBIT 227 shows two cross section slices through the environmental study area. The layers of glacial materials are exposed in the cross section. The fine and coarse grained stratified drift, which is aquifer, is shaded orange.

Q. How have you learned what kinds of rocks lie beneath the surface at the Project?

A. The orebody was discovered in 1975 by core drilling with a diamond bit. Since that time, 261 core holes have been drilled into the bedrock. This represents over 300,000 feet, or approximately 60 miles, of core. EXHIBIT 228 is a view of the surface of the ground showing where most of these holes were drilled.

Nearly everything we know about the orebody and surrounding rocks was obtained from detailed evaluations of the 300,000 feet of drill core. This basic data derived from drill cores are the basis for a host of geologic and engineering studies.

Rock mechanical data is recorded on a geologic log. This type of data is used in engineering studies to determine how strong the rocks are and how large the underground openings may be. At this step, we record such information as the percent core recovery, a rock quality designation (RQD), the total fracture count, and bedding angles.

The next step is to record data about various geologic conditions. Such data provides the building blocks for detailed geologic studies that help us determine how and why the orebody was formed, and the shape of the different ore zones. Data is also recorded about how weathered the rock is, which is essential for determining how water will move through the rocks. So, we record weathering data, rock alteration, the percent sulfide minerals, the percent economic minerals, rock structure, rock types and rock textures.

Finally, we mark the intervals which are to be assayed or which need to be preserved for laboratory testing.

Since not all the secrets the rock holds can be seen, pieces of core were taken to the laboratory and additional data was extracted by microscopic examination, chemical analyses, or electronic testing.

The Crandon mining geologic staff executed a broad range of geologic and stratigraphic studies of the deposit, some of which aided in project design and others of which provided a geologic framework for permitting requirements. Major studies carried out either on-site or in Exxon Minerals research facilities are listed in Table 2 of my prefiled written testimony.

In addition, the geological team was involved with a variety of tasks related to preliminary project engineering and feasibility studies, which are listed in Table 3 of my prefiled written testimony.

Q. What did you learn about the metals in the orebody?

TABLE 2

GEOLOGIC STUDIES

a)	Volcanic Stratigraphy	- Determining how rock was created
b)	Petrography	- Microscopic studies of rock types
c)	Sulfide & Silicate Mineralogy	- Microscopic & chemical studies of minerals
d)	Ore Microscopy minerals	- Microscopic studies of ore
e)	Hydrothermal Alteration	- How did ore fluids change rock
f)	Supergene Weathering	- How surface waters affected near surface rock
g)	Metal zoning	- How metal ratios vary in deposit
h)	Ore genesis	- Where did ore fluid come from
i)	Major & Trace Element Geochemistry	- Chemical analysis
j)	Oxygen & Sulfur Isotopes sulfur	- Determine source of oxygen &
k)	Fluid Inclusions	- What is composition & temperature of ore fluids
l)	Age dating	- How old is the deposit
m)	Structural studies	- How has rock been fractured
n)	Depositional history	- How did deposit form

TABLE 3

PROJECT INVESTIGATIONS

a) Mill Site Geologic Evaluation

b) Tailing Basin Site Geologic Evaluation

c) Main Shaft Site Investigation and Pilot Hole Drilling

d) Surface Ramp Site Investigation

e) Underground Back Sampling Program Plan

f) Site Area Glacial Stratigraphy

g) Soil Sampling for Environmental and Design Purposes

h) Initial Site Geohydrologic Investigations

i) Stope Wall Competency and Dilution Studies

A. Metals such as copper, lead, zinc or iron seldom exist as a pure metal in the ground. For example, the atom of zinc (Zn) combines in nature with an atom of sulfur (S) to form a molecule called sphalerite (ZnS). When millions of these molecules combine and grow into crystal, it is called the mineral sphalerite. At Crandon, the primary zinc mineral is sphalerite. Unfortunately, in ore bodies waste products are also present with the ore minerals. These waste products are called "gangue", and at Crandon are predominantly pyrite, quartz and chlorite.

Two steps are necessary to free the zinc and produce a pure metal. The first is removing the gangue, which will be done in Crandon in the ore concentrator (Mill). Next, the molecule of sphalerite (ZnS) must be "broken" to separate the zinc (Zn) from sulfur (S). The second process, called smelting, will not be done at Crandon.

Q. Have there been any metallurgical tests conducted on the Crandon ores?

A. Metallurgical tests were conducted on the Crandon ore to determine the engineering parameters necessary for mill design, to determine how fine the ore must be ground to free minerals from gangue and to determine the kind and quantity of chemicals necessary to separate the various minerals. Several tests were conducted between 1977 and 1985. Ore for these tests came from both 1-7/8" and 6" drill cores.

Q. Were the cores also used in designing the mine?

A. Yes. Mechanical engineering data acquired from Crandon cores included compressive strength, tensile strengths, fracture data, inherent stress, Youngs' modules, Poisson's ratio and ultimate strain.

The rock mechanics data were statistically evaluated and rock mass properties summarized. Design elements addressed included rock mass strength zones, stope spans, pillar dimensions, stope sequencing, blasting procedures and surface stability.

Q. Can one estimate ore reserves from the cores?

A. Yes. An ore reserve is an estimate of the tons and grade of the ore. There are two major types of ore reserves reported: global reserves, which is the total mineral resource in the deposit, and mine recoverable reserves, which is a measure of the portion which can be extracted.

Most companies will report global reserves before a mine plan is developed. Afterwards, most companies report the mine recoverable reserve, which is commonly 10-20% less than the global reserve.

A conventional ore reserve is one which is developed manually from the ore bands put on cross sections along with the drill holes and assay grades. Grades are assigned to mining stopes based on any of several statistical methods. Until 1983 the Crandon ore reserves were calculated using conventional methods.

Since 1983 Crandon ore reserves have been generated using a state of the art technique called geostatistics. Geostatistics is a highly sophisticated computer method for developing ore reserves using high powered mathematical and statistical techniques. Once the program is developed, an entire ore reserve can be calculated in several hours, compared to perhaps several months using conventional methods. Geostatistics is especially efficient when a new reserve must be calculated to accommodate a change in the mining plan. The recoverable reserves from the Crandon mine are shown on EXHIBIT 226.

Q. What other analyses were made from the drill cores?

A. We examined what is called supergene weathering, or the process or processes which cause the physical disintegration and chemical decomposition of bedrock. Water causes this break-up of the rock by four processes: oxidation, leaching, clay development and fracturing.

A weathering intensity rating has been applied to the bedrock. Weathering is considered strong when two or more of the processes are strongly developed. Moderate weathering refers to the strong development of one process. Where there is only moderate leaching, the weathering intensity is rated low. Weak weathering is the grade for only traces of weathering, where the rock is almost like unweathered rock.

EXHIBIT 229 illustrates a typical weathering profile. Notice the spike penetrating downward in the massive ore. This weathering profile is important because ground water will migrate into the mine along these weathering channels.

Q. Were cores analyzed for the presence of asbestiform materials?

A. Yes, dozens of rock samples and ore were evaluated for the presence of asbestiform minerals. High powered conventional and electron scanning microscopes were used. No asbestiform minerals were found, primarily because the rocks have not undergone sufficient heat and pressure in past ancient geologic environments to create asbestiform minerals. The tailings were also tested and did not show any asbestiform minerals.

Q. Were studies made to detect radioactivity?

A. Yes. Programs have been conducted to characterize the radioactivity that may be associated with the Crandon orebody. Results from all the testing programs showed that the composition and levels of radioactivity in soil, waste rock, ore, and granite outcrop was at background level in the area.

Q. Was drilling also used to study the glacial materials above the bedrock?

A. Yes. Glacial drilling programs were conducted to obtain subsurface information in the environmental study area and the site area. The initial drilling program began in February, 1977 and subsequent drilling activities have continued intermittently through 1985. EXHIBIT 205 shows the location of the individual borings which have been drilled within the environmental study area.

The samples of soil from the borings and the boring holes provide opportunities for a variety of testing work.

This work provided information on the thickness of glacial material, historic and genetic glacial stratigraphy, and a variety of hydrologic parameters critical to the understanding of the ground water system. Much of this data is input data for hydrologic computer modeling of ground water flow, ground water drawdown and solute transport.

There have been over twenty separate glacial boring programs conducted in the years 1977 through 1985. Five geotechnical contractors have been responsible for conducting those drilling programs. Table 4 of my prefiled written testimony lists each boring program, the number of holes drilled, the geotechnical contractor and the reason for the borings.

Q. How were the glacial materials tested?

A. A variety of tests were conducted on material from glacial holes, as listed in Table 5 of my prefiled written testimony.

TABLE 4

PROGRAM	NO HOLES	CONTRACTOR	REASON FOR PROGRAM
DMA	41	Dames & Moore	General site
DMB	34	Dames & Moore	General site
DMC	3	Dames & Moore	General site
DMI	10	Dames & Moore	Ramp
DMP	3	Dames & Moore	General site
DMS	2	Dames & Moore	General site
DW	3	Dames & Moore	Open pit
TW	3	Dames & Moore	Pump testing
WW	3	Dames & Moore	Pump testing & water wells
640	35	Golder Associates	MWDF site 40
641	75	Golder Associates	MWDF site 41
STS-B	11	Soils Testing Service	Mill site
AR	6	Soils Testing Service	Bridge
RR	2	Soils Testing Service	Railroad
EX	39	Soils Testing Service	MWDF site 41 & general
WP	14	Soils Testing Service	MWDF site 41 & general
STS	18	Soils Testing Service	Lakes & Wetlands
RP	15	Soils Testing Service	Reclaim pond
BE	9	Braun Engineering	Pump test, orebody
CDM	20	Camp Dresser-McKee	Orebody
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TABLE 5

TESTS PERFORMED ON GLACIAL MATERIALS

TESTS	REASONS FOR TESTING
Sieve and hydrometer Analysis	- Determine soil classification. - Grain size analysis for Hazen's Approximation.
Permeability	- Investigation of aquifer characteristics. - Mine water inflow. - Soil characteristics.
Carbonate Pebble Analysis	- Soil attenuation. - Aid in glacial history interpretation.
pH	- Soil attenuation. - Aid in glacial history interpretation.
Clay Analysis	- Soil attenuation. - Aid in glacial history interpretation.
Compaction	- Soil mechanics
Triaxial	- Soil mechanics
Chemical Analysis	- Water quality

Samples of the various glacial soil materials encountered were selected for testing in the soils laboratory of the various geotechnical consulting firms. Tests were performed to determine various physical properties of the soil materials including particle size by both sieve and hydrometer analysis, carbonate pebble content, Atterberg limits, moisture content, pH, color, and clay mineral species. American Society for Testing and Materials (ASTM) procedures were used to perform these tests of the soil material samples.

Q. Were the soils beneath lakes also tested?

A. Yes. Three separate drilling programs were conducted between March, 1982 and October, 1985 to obtain sub-surface geologic and hydrological data from beneath local lakes and adjacent wetlands. The lakes involved were Little Sand, Skunk, Duck, Deep Hole and Oak.

In March, 1982 borings were drilled from the ice surface of Little Sand Lake to determine the type of soils beneath the lake. The borings indicated that the material beneath the lake bed was mostly silty clay and varied from 11-21 feet thick.

In February, 1984 one boring was drilled from the ice surface in Skunk, Deep Hole, Duck, and Oak Lakes to determine the type of soil beneath those lakes. The borings indicated that the materials beneath the lake beds consist of silty clay. The thickness of the lake bottom soils for each lake was as follows: Skunk, 2 feet; Oak, 17 feet; Deep Hole, 27 feet; and Duck, 51 feet.

During November 1985, eight well points were set in auger holes in wetlands immediately adjacent to Skunk and Duck Lakes. Results indicate the wetlands were once part of the original lake, and materials beneath the wetlands are silty clay, similar in consistency and thickness to the two previous lake drilling programs.

The eighteen holes from the lake drilling programs just described, coupled with fifteen boreholes near the shorelines of the lakes and fifteen boreholes within a few hundred feet of the shorelines from previous drilling programs, provide a pool of 48 drill holes from which to construct the stratigraphy beneath and adjacent to the lakes.

EXHIBIT 230 is an interpretative cross section through Little Sand, Deep Hole, and Duck lakes. All five project area lakes are glacial kettle lakes formed by the melting of a large block of ice trapped in the glacial material. The base of the bowl-shaped lowermost clay layer (lacustrine) represents the original size and shape of the lake. Immediately after glacial retreat, erosion was rapid because vegetation was not established. Silts and clay winnowed from nearby glacial tills settled out in lake bottoms, rapidly forming a thick clay layer. Near the original shoreline, washed sands interfingered with the clays. Data indicate that sand on the present lake shorelines are underlain by clays, indicating the original lake dimensions were somewhat larger than present.

Q. Please describe the hydrologic studies made for the Crandon project.

A. Geology is the science of the earth and rocks. Hydrogeology is the science which studies how water moves through the rocks and soils. At the Crandon Project, we have conducted numerous scientific studies to learn how, where, and why water moves through the glacial materials and bedrock.

Q. What do the hydrologic studies show about area permeabilities?

A. As I testified earlier, permeability is the capacity of a rock or soil to move water. This capacity can be expressed as the volume of water which will move through a given area in a given interval of time. As an example, a soil which has the capacity to move water at a rate of twenty gallons per square foot per day is ten times more permeable than a soil which has the capacity to move water at a rate of two gallons per square foot per day.

Hundreds of permeability tests have been conducted on the soils at the Crandon project, using many different methods. One of the most commonly used methods uses the borehole from which the soil samples were taken. A well point is lowered down the borehole to the place where the test is to be made. The borehole beneath and above the well point is packed with clay (EXHIBIT 231). The wellpipe is then filled with water and the rate at which the water falls in the pipe is recorded. By a series of mathematical calculations, the capacity of the soil interval for moving water can be determined.

Q. What is the permeability of glacial soils at the mine site?

A. EXHIBIT 232 is a table showing the permeability of the four main layers of glacial materials: coarse grained stratified drift, fine grained stratified drift, till and lacustrine.

It is important to remember that permeability is only a measure of capacity to move water. The quantity of water which will actually move through a material depends upon the pressure forcing the water through the pores.

Q. How does water move through the glacial materials?

A. EXHIBIT 233 is a cross section from approximately Swamp Creek on the west through the orebody and mine waste disposal facility to Hemlock Creek on the east. The coarse and fine grained stratified drift is represented in orange, the till in green and lacustrine in red. The heavy line represents the top of the groundwater or water table. Hydrologists often call it the potentiometric surface.

Most of the upland areas are till. When it rains, water slowly moves downward through the till to the water table as represented by the solid arrows. After arriving at the water table, water will seek the easiest flow path. The coarse and fine drift is the easiest flow path because it is about ten times more permeable than the till. As I stated earlier, the coarse and fine drift can produce significant quantities of well water. Drift is called an aquifer. The till is not considered an aquifer because it will seldom produce significant quantities of water.

The open arrows on this diagram illustrate the likely flow path of the water. When downward moving water reaches the water table in the aquifer, it will begin to move horizontally. If the water encounters till when it reaches the water table, the water will continue to move downward until it reaches the aquifer before significant horizontal migration occurs.

The direction that the water moves through the aquifer is determined by the laws of nature. There is a water table high in the vicinity of the MWDF. Water moves radially outward from this high in all directions. The radial outward path is not uniform, however, because water will follow the aquifer, the easiest flow path. As the aquifer pinches and swells, the direction and volume of flow will be modified.

Since the water moves horizontally through the aquifer, it must be going somewhere. Water goes to the discharge areas, where it once again comes to the surface to enter streams and lakes on its inevitable course to the Mississippi River and on into the Gulf of Mexico. The discharge areas around the project are Swamp Creek to the north, Upper Pickerel to the west, Hemlock Creek to the east, and Rolling Stone, Pickerel, Crane and Walsh Lakes to the south.

Q. Did you also measure the permeability of the bedrock?

A. Yes. As with glacial materials, the permeability of bedrock has been determined by several different methods. One of the most common methods was setting a well point in a borehole as described for the glacial materials.

The bedrock in the vicinity of the Crandon project does not have any natural or primary porosity like the soils. In other words, there are no natural pores or gaps between the mineral grains to carry water. The rock does, however, have a secondary porosity, which was created in two different ways. First, cracks or fractures have developed in the rock due to pressures within the earth. Secondly, supergene weathering may dissolve some of the minerals, thereby creating a porous rock. Nearly all bedrock contains a few fractures. The fracture density generally decreases with depth. Because the fractures are sparse and most fractures do not have any space between them, permeability in the bedrock at the project is very low.

EXHIBIT 229 was presented earlier and illustrates a typical weathering profile in the bedrock over the orebody. Our test work has shown that there is a wide range of permeabilities associated with the different weathering categories in the footwall, the Crandon formation and in the hanging wall.

EXHIBIT 234 is a simplified diagram showing the permeabilities associated with different weathering zones.

Q. How will the presence of the mine affect the water movement?

A. One cannot assume water will flow from the glacial aquifer into the bedrock just because the glacial aquifer is present in the mine site area and because the supergene weathering has created permeability in the orebody. Exxon has spent many years conducting studies to determine whether water will flow from the glacial aquifer to the orebody, how much will flow, and how that water will get to the bedrock.

The following chronology outlines the studies which were conducted and why they were conducted:

Detailed soil sampling of the glacial materials over the mine site was done to determine what soil layers were present and how they were distributed. Cross sections were constructed to display the layers.

A detailed evaluation of the supergene weathering of the bedrock was also made. Cross sections and plan maps were constructed which defined the permeability of the weathered zones.

A pumping test program was conducted to determine whether water was moving between the glacial aquifer and orebody. This was a three phase program.

In the drilling program several large pumping wells were drilled and many adjacent holes were used to monitor water depths.

Then came the pumping program in which the wells were pumped individually for 172 hour periods and water levels in dozens of monitoring wells in bedrock and glacial material were recorded.

Finally, in the evaluation phase, several months were spent carefully evaluating results. Those results told us that water does move from the glacial aquifer to the orebody and approximately where that water movement occurs. It did not tell us how much water would move.

EXHIBIT 235 illustrates the mine site hydrology. Studies have defined the glacial layers, bedrock weathering and how water moves through this environment. The water in the glacial aquifer does not flow readily or uniformly into the orebody. The till layer lying on top of bedrock impedes the flow. There is a red clay rich basal till over much of the eastern half of the orebody which virtually stops all significant water flow in the areas where it is present. The upper several feet of bedrock is usually clay rich, especially in the hanging wall. This further impedes water movement. All these factors produce a resistance to the water in the glacial aquifer as it is trying to flow into the weathered portion of the bedrock. This resistance to flow, which encompasses both the lower part of the glacial materials and the upper part of the bedrock, is called the "Resistive layer".

These studies provide the data base and framework for detailed hyrdrogeologic computer modeling studies which determine how much water will flow into the mine and determine what the regional ground water impacts of that mine water inflow will be. That topic will be covered by the hydrogeologists later in this hearing.

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EXHIBIT 222

RESUME

ROGER G. ROWE

EDUCATION:

Bowling Green State University	M.S. Geology, March, 1971
University of Minnesota - Duluth	B.S. Geology, December 1967

EMPLOYMENT HISTORY:

Staff Geologist Headquarters Geology, Exxon Minerals Company, Houston, Texas.

Involved in Crandon hydrogeologic evaluation, including field and contract supervision of glacial overburden drilling programs, geophysical activities, piezometer installation, data interpretation and stratigraphic studies. Includes detailed studies of area lake stratigraphy, and contract supervision and support for site area impact and mine site impact computer modeling. Wrote geologic and hydrogeologic sections of the EIR, and responded to DNR comments. Prepared geologic and hydrogeologic testimony for master hearing and town hearings. Supervised large core drilling program, providing 50 ton bulk sample for mill design and metallurgical testing. Continued work on geostatistical ore reserve development. Assisted in preparing in-house feasibility study reports. Responsible for computer graphics for Crandon and other projects. Provide geologic and computer support for exploration projects throughout the USA. Involved in evaluation of base and precious metal exploration targets in the U.S.A.

03/80 - 08/83 Senior Minerals Geologist, Engineering Geology, Crandon Project, Exxon Minerals Company, Rhinelander, Wisconsin.

Responsible for engineering geology focused on providing criteria for project design, site management, and operational permitting. Supervised large diameter core (150mm) bulk sample acquisition (40 tonne) for metallurgical bench tests. Assisted in rock mechanics studies. Designed data base management systems for geologic, rock mechanics and hydrologic data on an HP-3000 computer system. Worked with geostatisticians on development of a computer block model for Crandon ore reserves. Conducted detailed stratigraphic and ore correlation studies and crown pillar investigations. Intimately involved in all aspects of mine hydrogeology including: problem definition, design of pump test program, pump test field supervision, execution of contracts for data evaluation and design and supervision of extensive glacial stratigraphic study.

03/77 - 03/80 Senior Minerals Geologist, Predevelopment Geology, Crandon Project, Exxon Minerals Company, Rhinelander, Wisconsin

Responsible for predevelopment target evaluation which included target delineation, core logging, and field supervision. Conducted a variety of geologic and stratigraphic studies, including volcanic stratigraphy, hydrothermal alteration, supergene weathering, ore genesis and depositional history. Produced a complete set of sections and plans which included overlays for hydrothermal alteration, supergene alteration, quartz veining, sulfide distribution and ore. Participated in project engineering and feasibility studies, including: site condemnations, shaft site investigations, underground bulk sampling program plan, stope wall competency, dilution studies and soil sampling for environmental and design purposes.

03/72 - 03/77 Senior Geologist, Exploration, Exxon Minerals Company, Tucson, Arizona.

Involved in all aspects of porphry, skarn-porphry, skarn and massive sulfide exploration in New Mexico and Arizona. Responsible for reconnaissance, target generation, drilling and reclamation. Supervised field crews involved in a variety of exploration activities.

03/71- 03/72 Geologist, Exploration, Exxon Minerals Company, Denver, Colorado.

Involved in skarn, skarn-porphry and massive sulfide exploration in New Mexico and central Arizona. Responsible for reconnaissance target development and target drilling. Supervised airborne EM Survey and follow-up of central Arizona greenstone belt.

09/69 - 03/71 Teaching Assistant, Bowling Green State University, Bowling Green, Ohio.

Assisted in teaching Introductory Geology and lab courses to undergraduate students.

06/70 - 09/70 Geologist, Exploration, Humble Oil and Refining company, Duluth, Minnesota.

Summer employment while in graduate school. Involved in massive sulfide exploration in Minnesota and Upper Peninsula of Michigan.

06/68 - 09/69 Geologist, Exploration, Humble Oil and Refining Company, Duluth, Minnesota.

Explored for massive sulfides in Minnesota and Upper Peninsula of Michigan. Involved in both operation and eventual supervision of field crews in a variety of exploration methods, including geologic mapping, geochemical sampling, ground EM, and I.P. Became involved with airborne EM surveys, interpretation of data, and ground follow-up.

01/68 - 06/68 <u>Earth Science Teacher, Jefferson Jr. High School, Minneapolis, Minnesota.</u>

Taught various earth science courses for one semester.

06/67 - 09/67 <u>Assistant Geologist, Minnesota Geological Survey, Duluth, Minnesota.</u>

Geologic mapping of greenstone terrain in the bush of northeastern Minnesota.

PUBLICATIONS:

Rowe, Roger G., 1982, Rock Mechanics Testing of Large Diameter Core at the Crandon Deposit: Issues in Rock Mechanics, Twenty-third Symposium on Rock Mechanics, Richard Goodman, editor.

Rowe, Roger G. and Hite, Richard, 1983, Applied Geology - The Foundation for Mine Design at Exxon Minerals Company's Crandon Deposit, In: Applied Mining Geology, A.J. Erickson Jr., Editor, SME, p. 9-28.

Lambe, Robert N. and Rowe, Roger G., 1986 Volcanic History, Mineralization and Alteration of the Crandon Massive Sulfide Deposit, Wisconsin. To be published in Economic Geology, late 1986.

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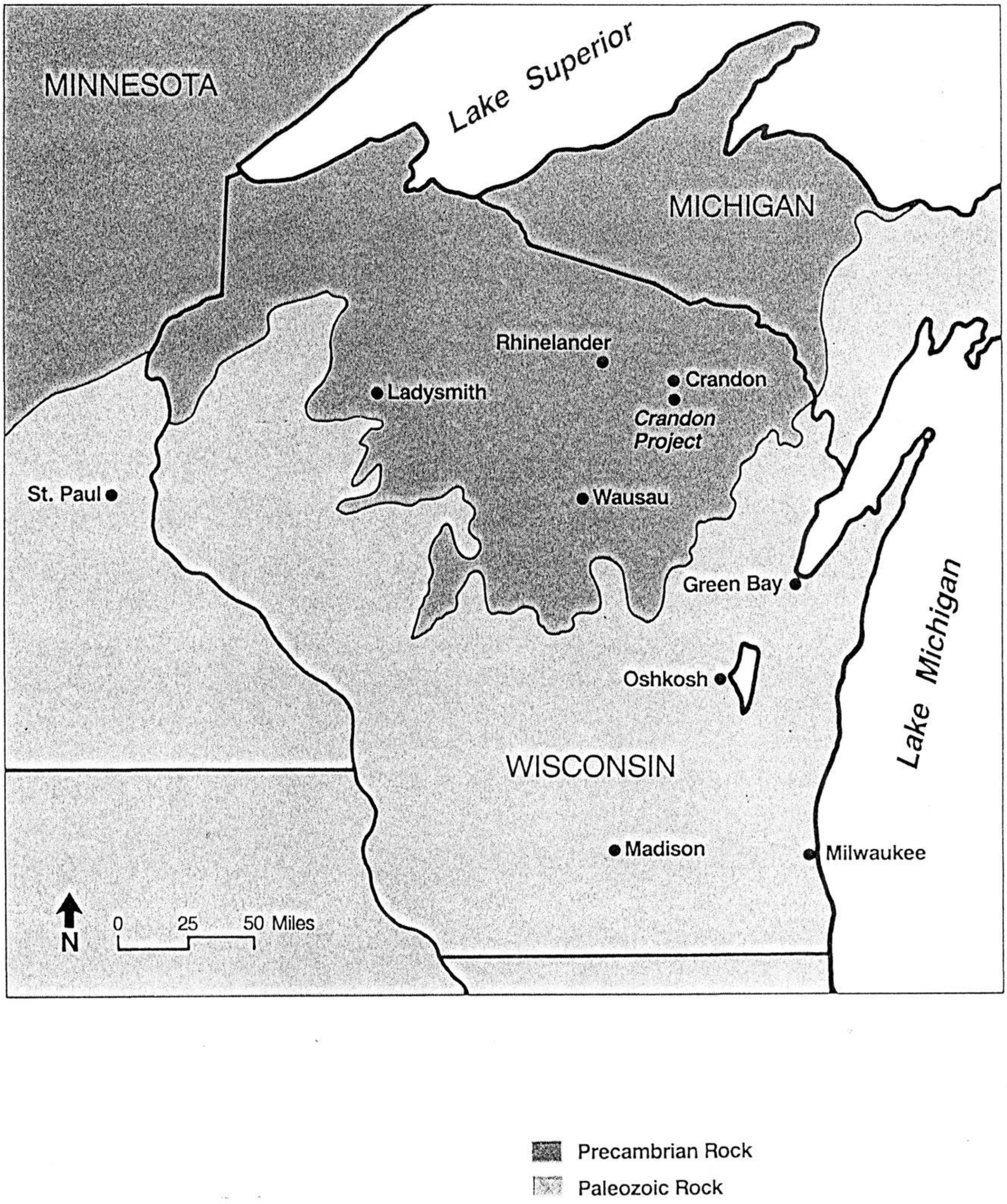
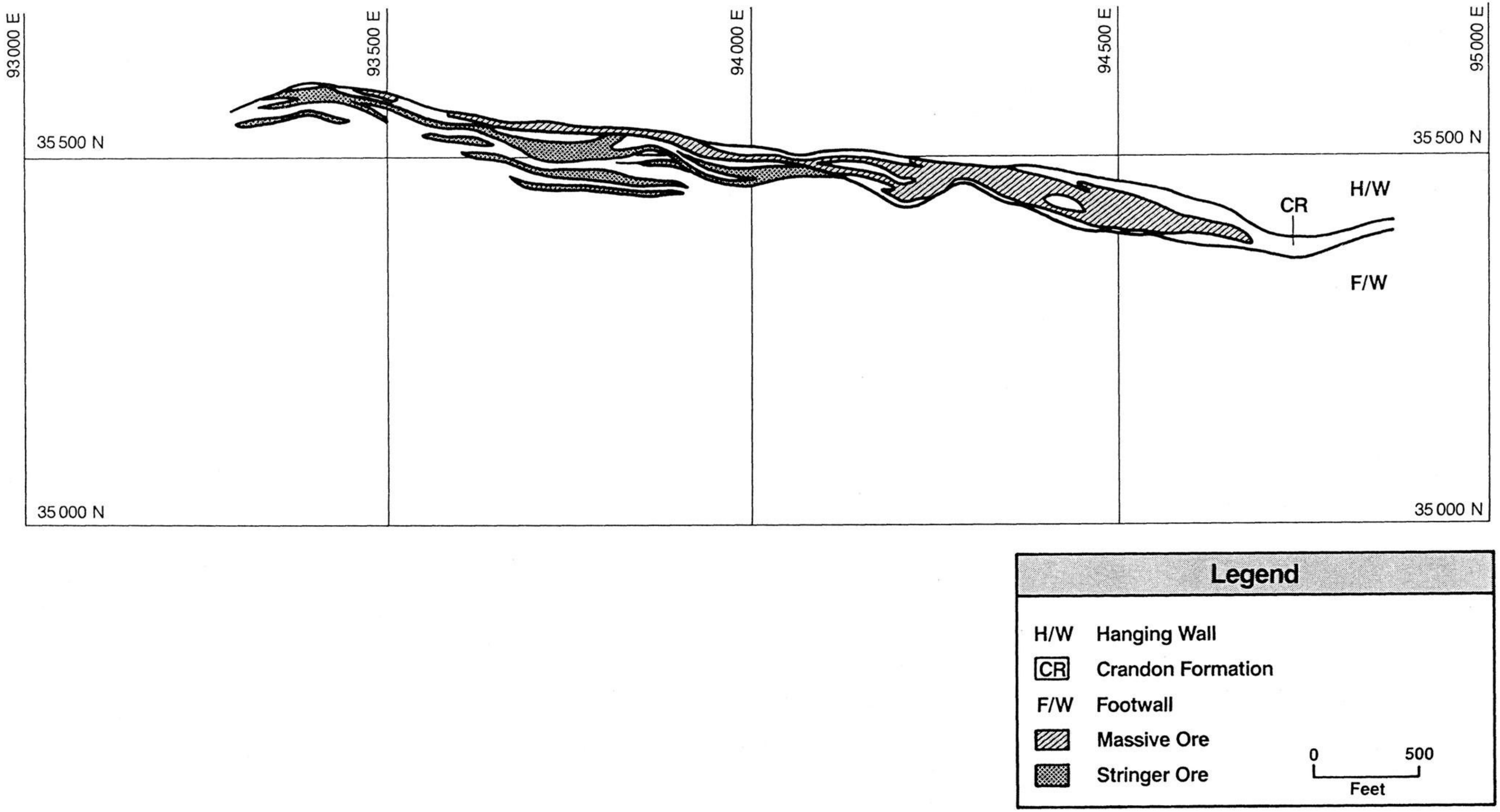
Wisconsin
Geological Map



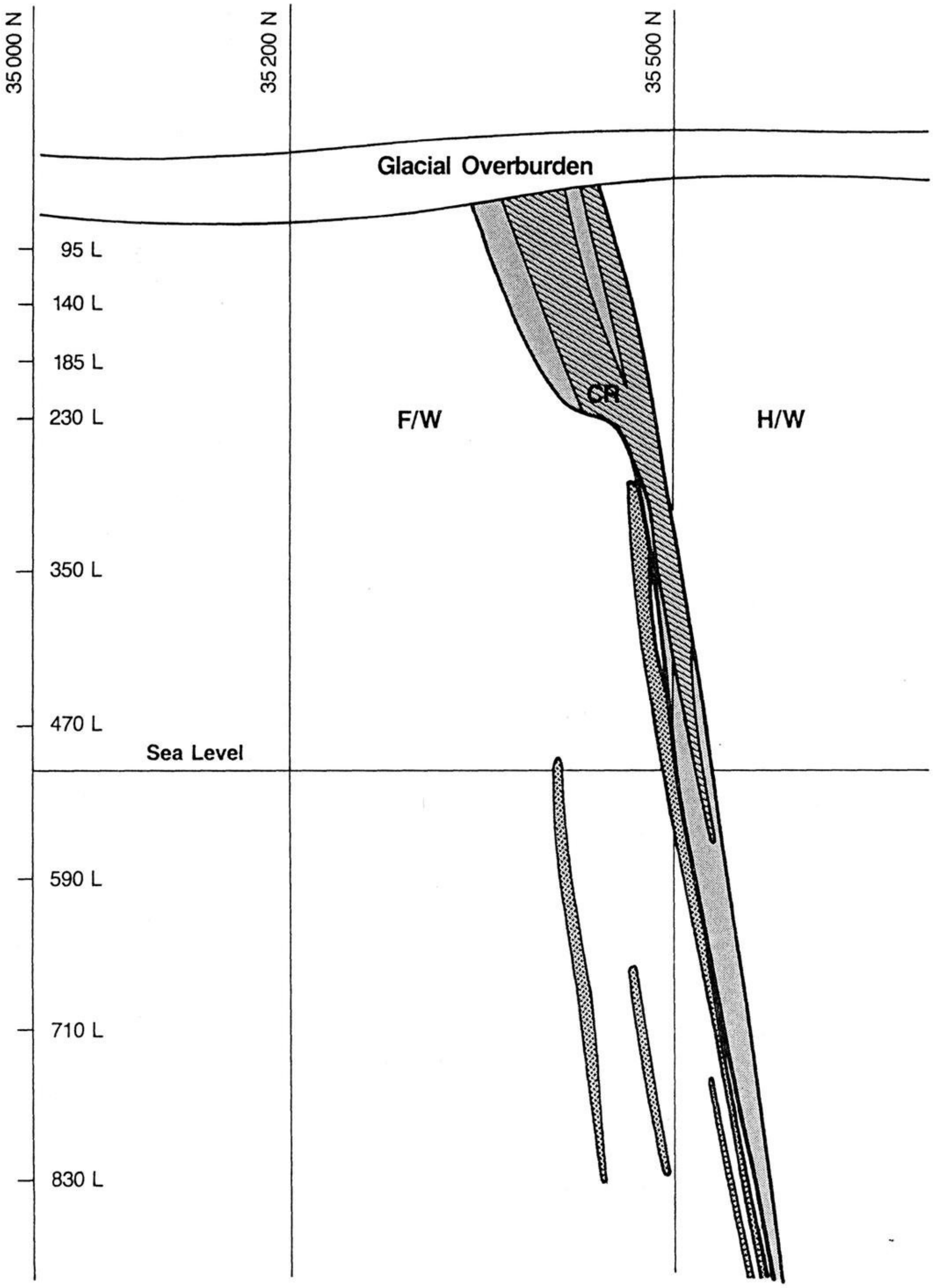
Geologic Plan Map

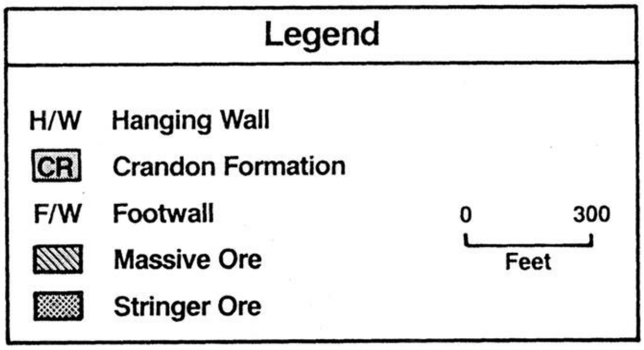
230 Meter Level



Geologic Cross Section

94,290 East

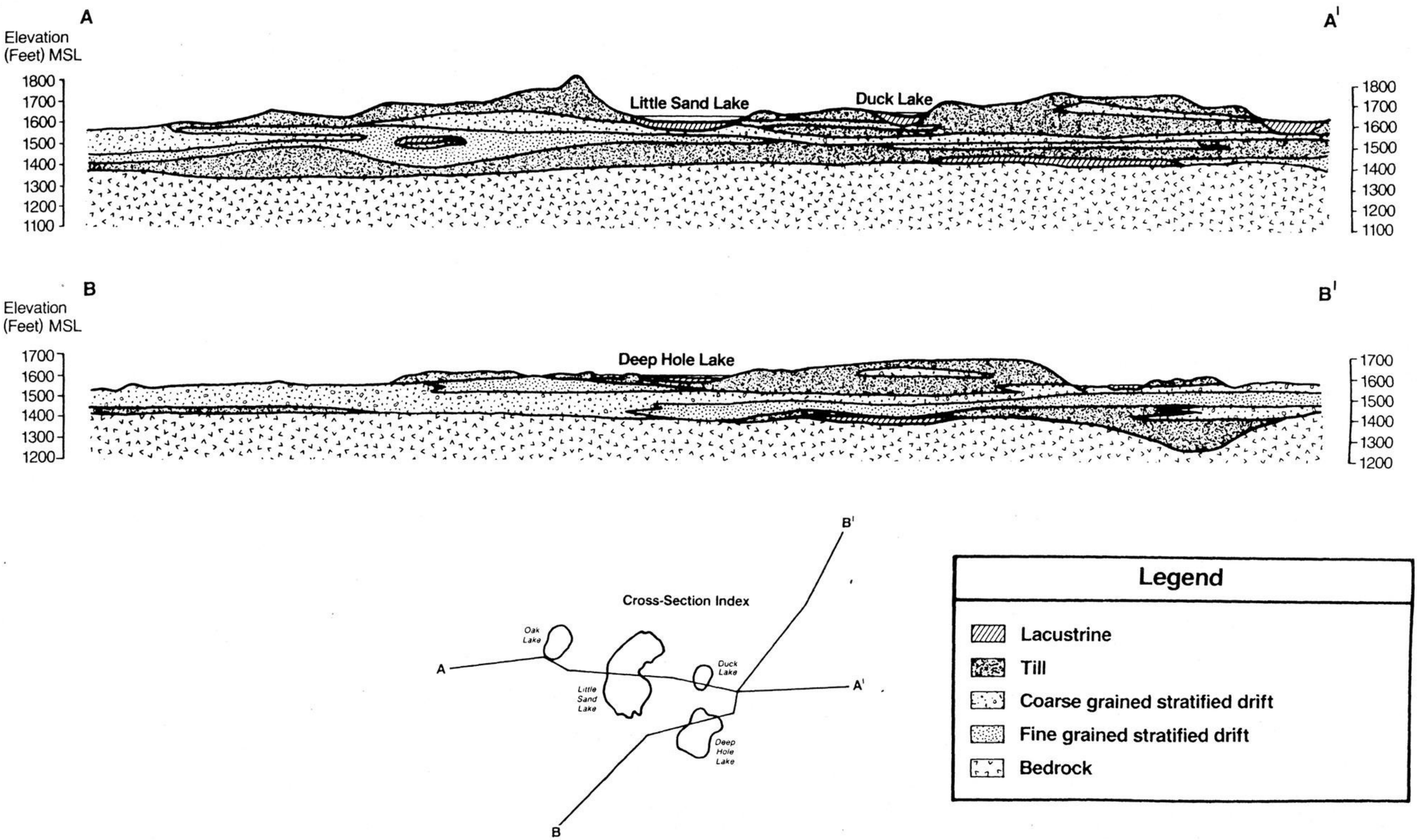




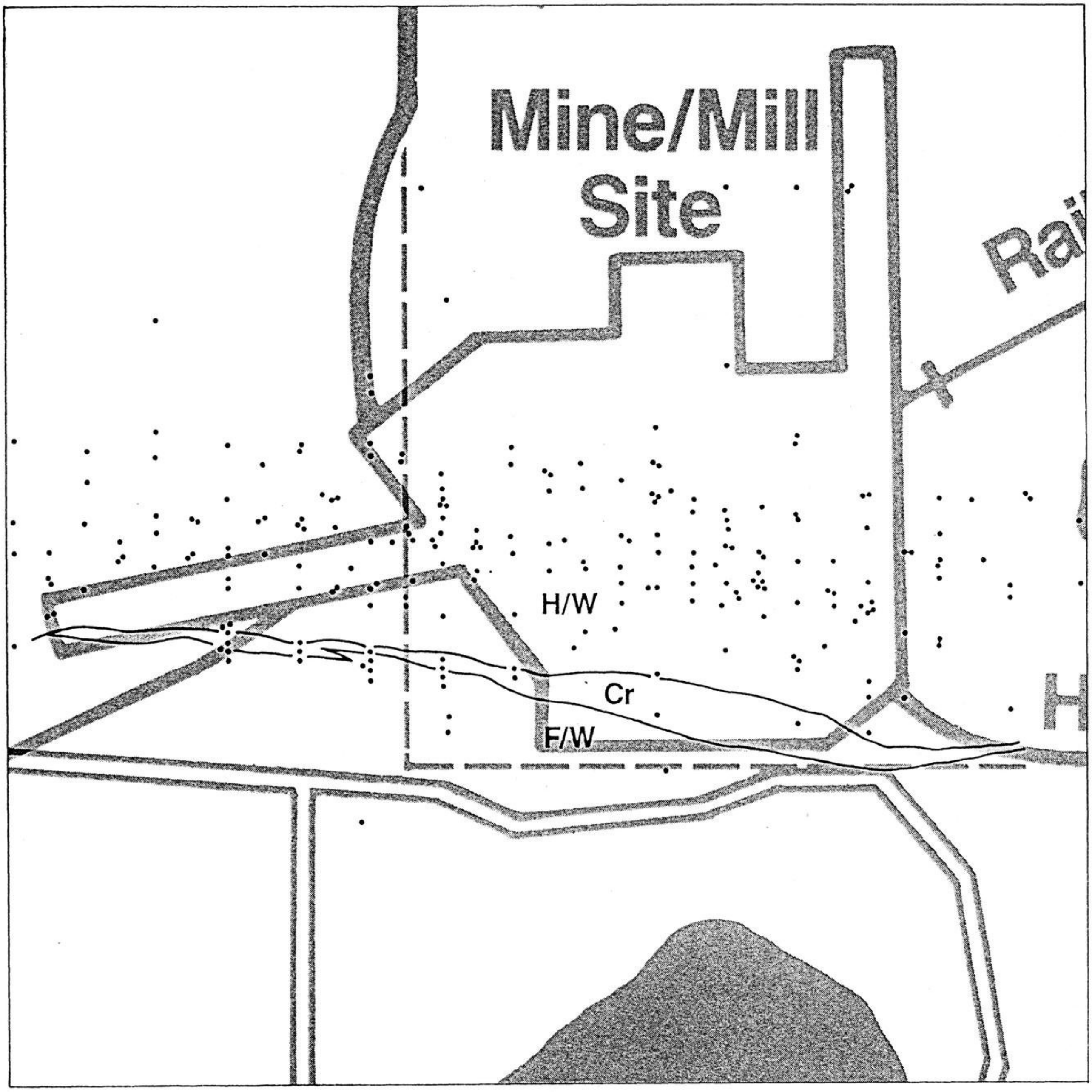
Recoverable Reserves

Type	Tonnage (Million Tons)	Zinc %	Copper %	Lead %	Silver oz/t	Gold oz/t
Massive Ore	42	8.4	0.6	0.7	1.6	0.04
Stringer Ore	25	0.7	1.8	0.03	0.3	0.01
Total	67	5.6	1.0	0.5	1.2	0.03

Glacial Cross Section



Bedrock Core Hole Locations



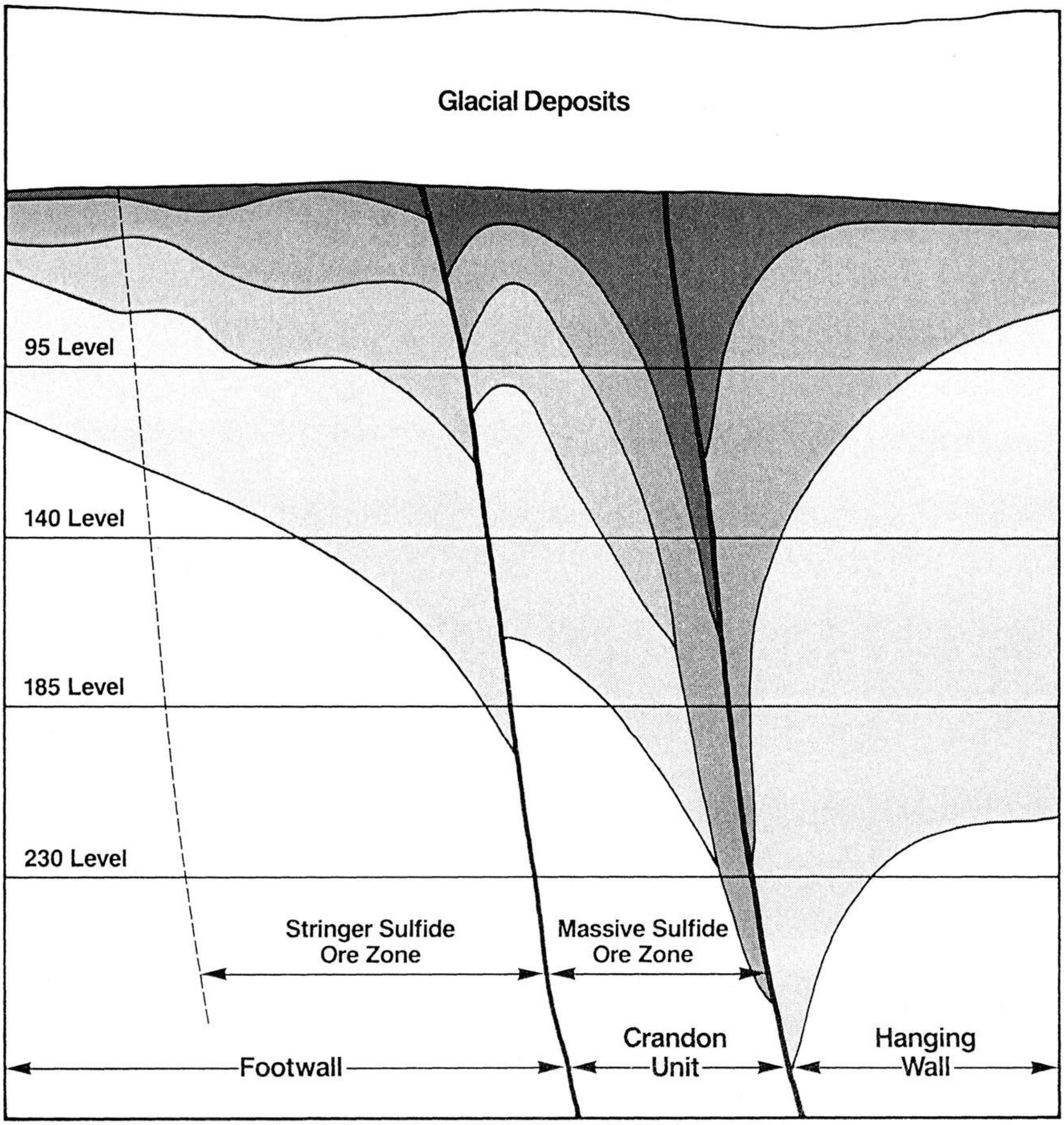
Legend

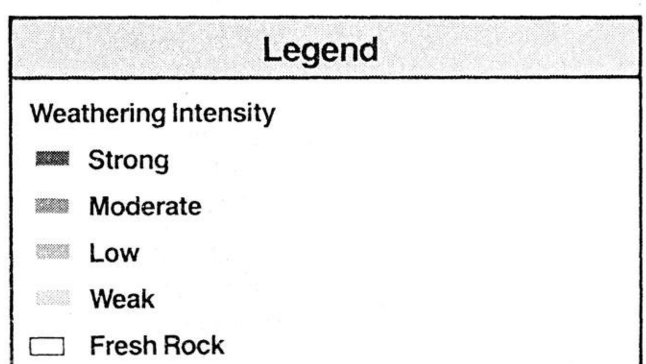
H/W — Highwall

Cr — Crandon Ore Body

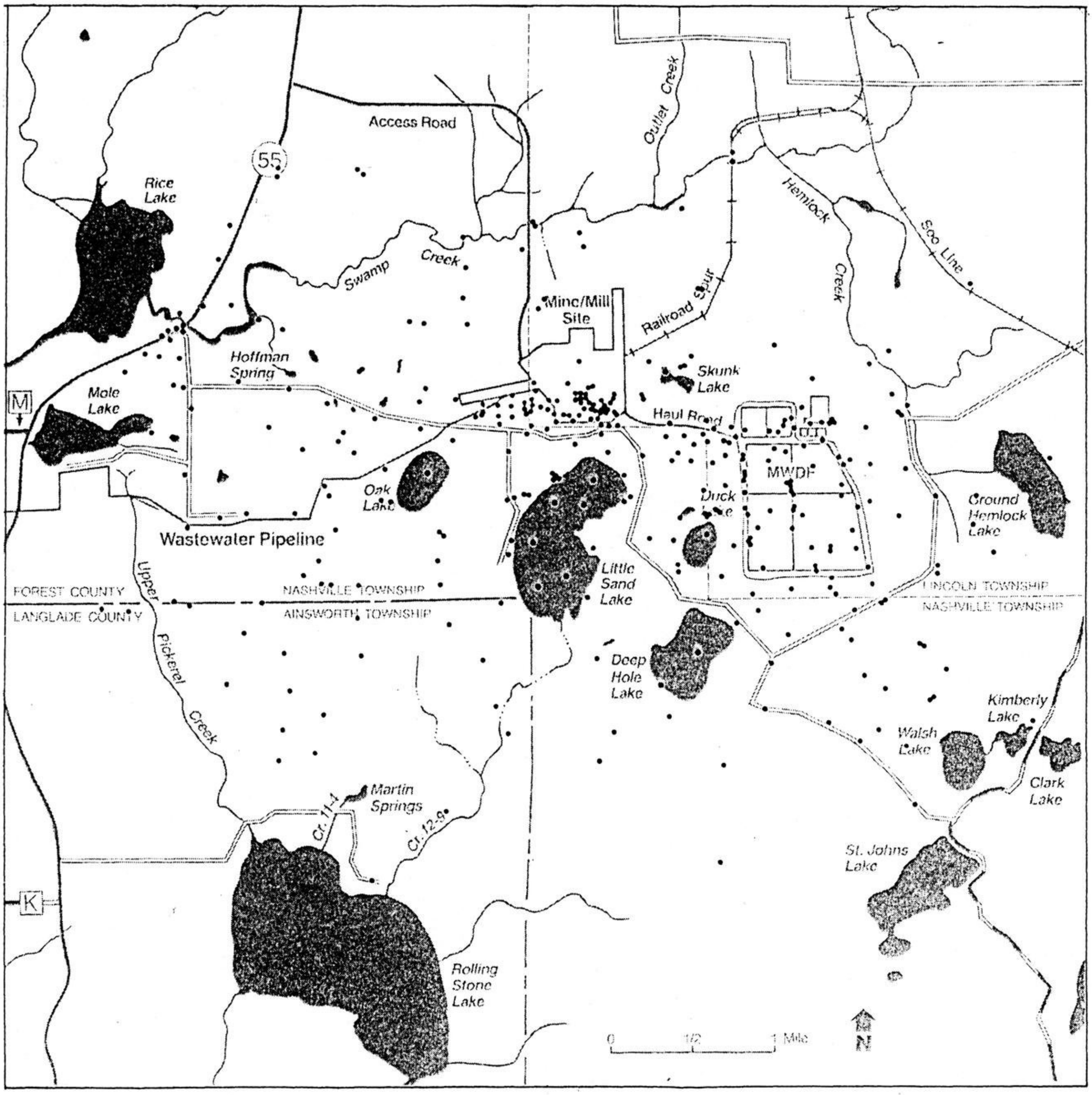
F/W — Foot Wall

Generalized Weathering Profile

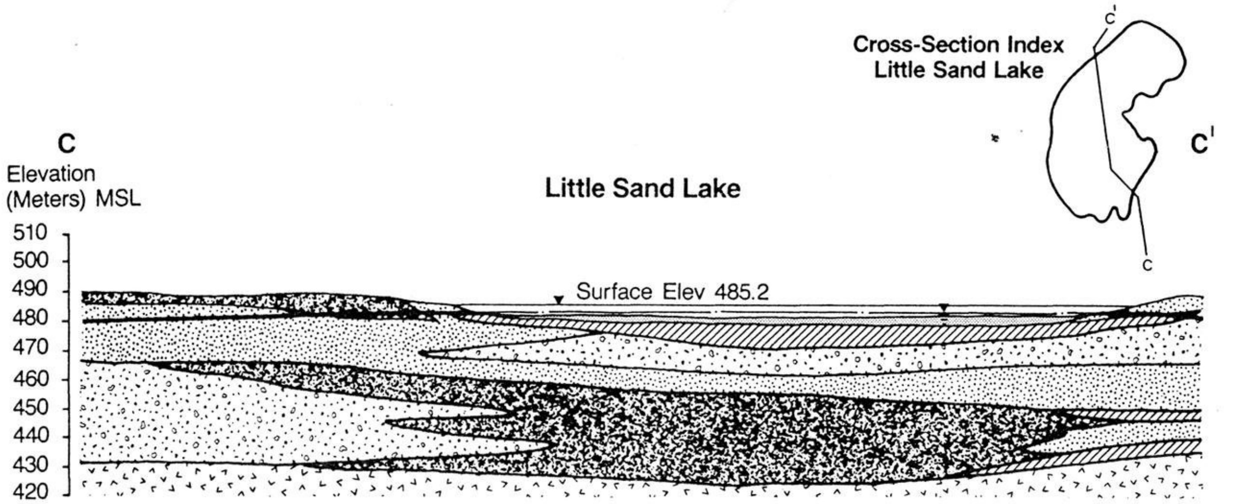


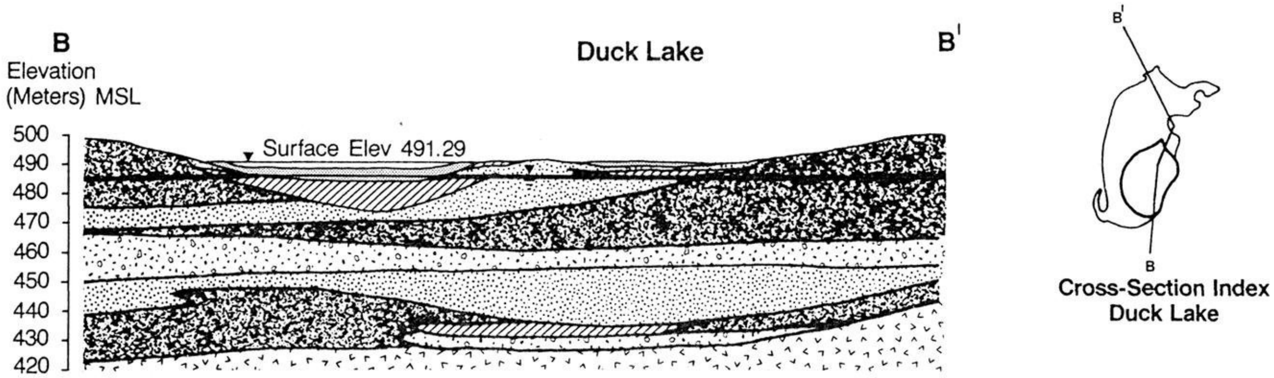


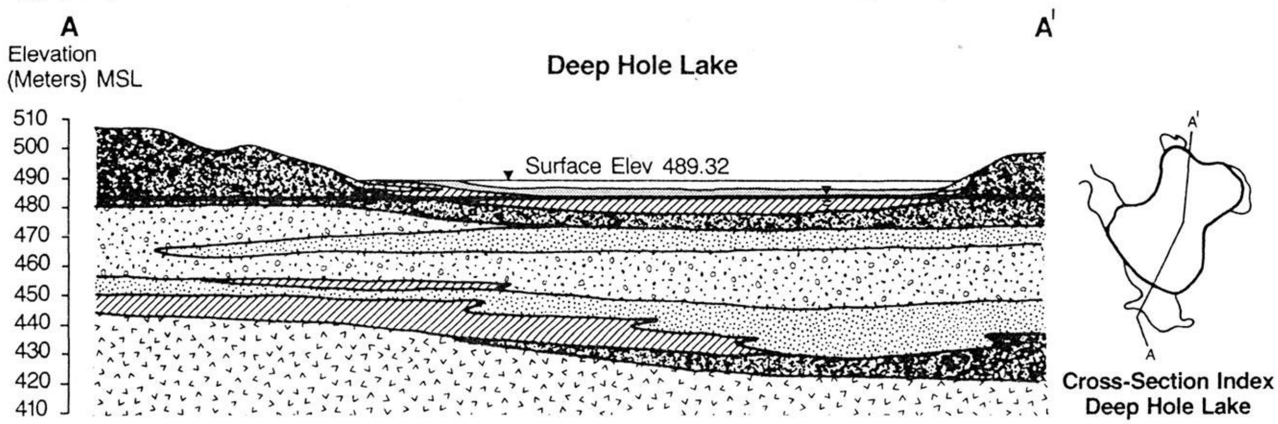
Bore Holes And Piezometers

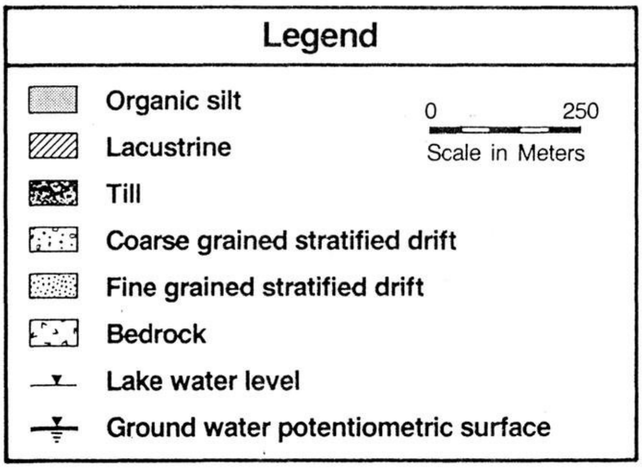


Glacial Cross Sections
Under Lakes

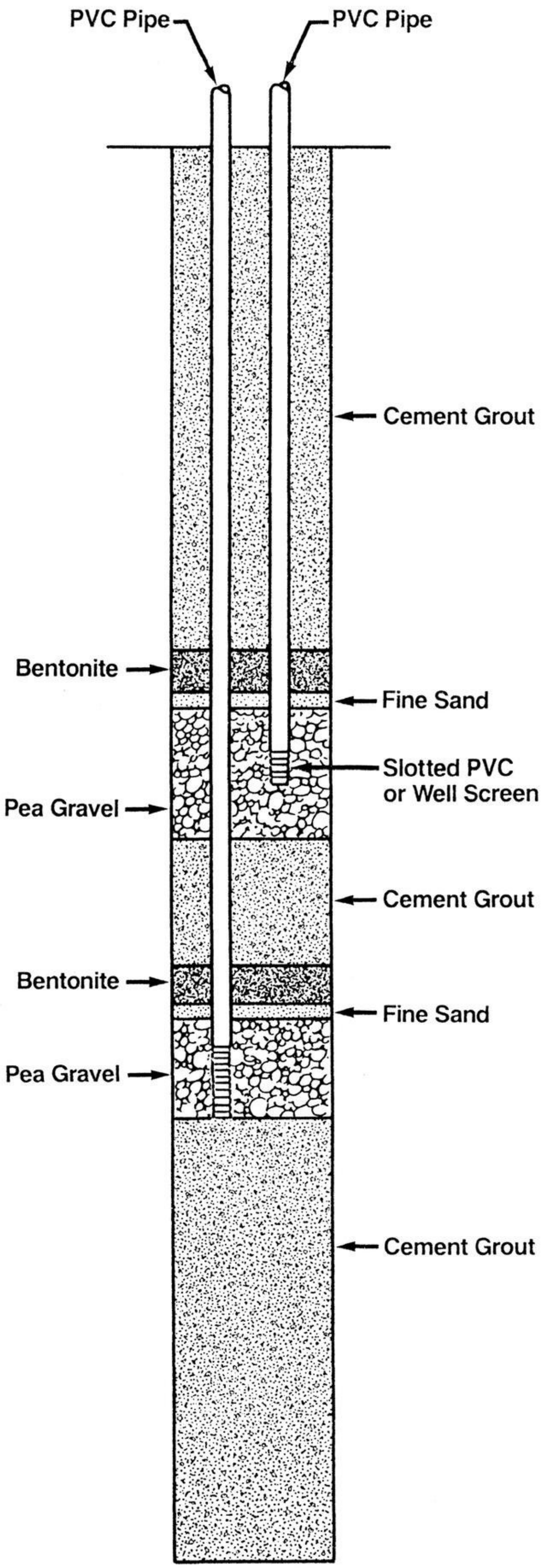








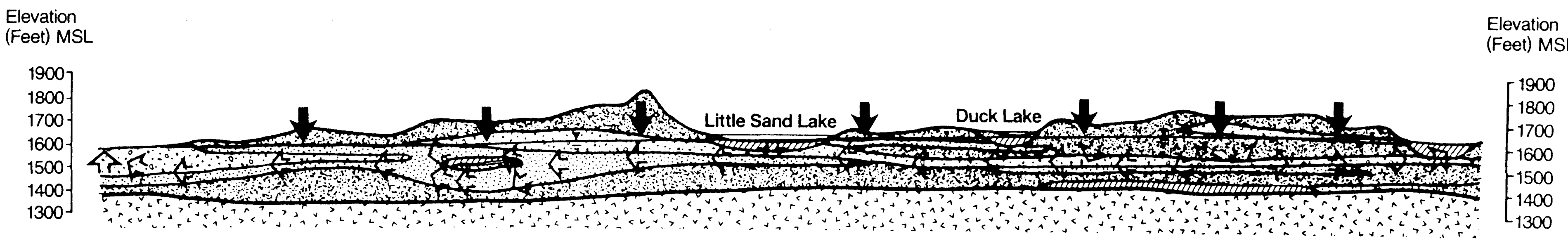
Piezometer Construction

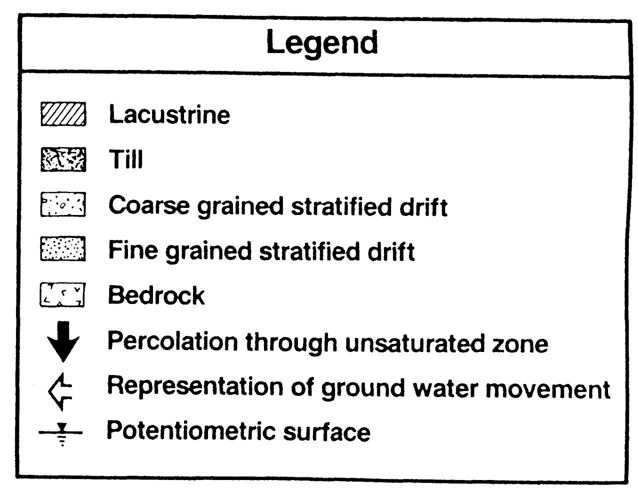


Glacial Material Permeabilities

	Gallons Per Day	Gallons Per Minute (or equivalent)
Coarse Drift	85 gpd/ft^2	0.06 gpm/ft^2 (1 cup)
Fine Drift	42 gpd/ft^2	0.03 gpm/ft^2 (1/2 cup)
Till	12 gpd/ft^2	0.008 gpm/ft^2 (2 tbs)
Lacustrine	0.01 gpd/ft^2	0.000007 gpm/ft^2 (1/500 tbs)

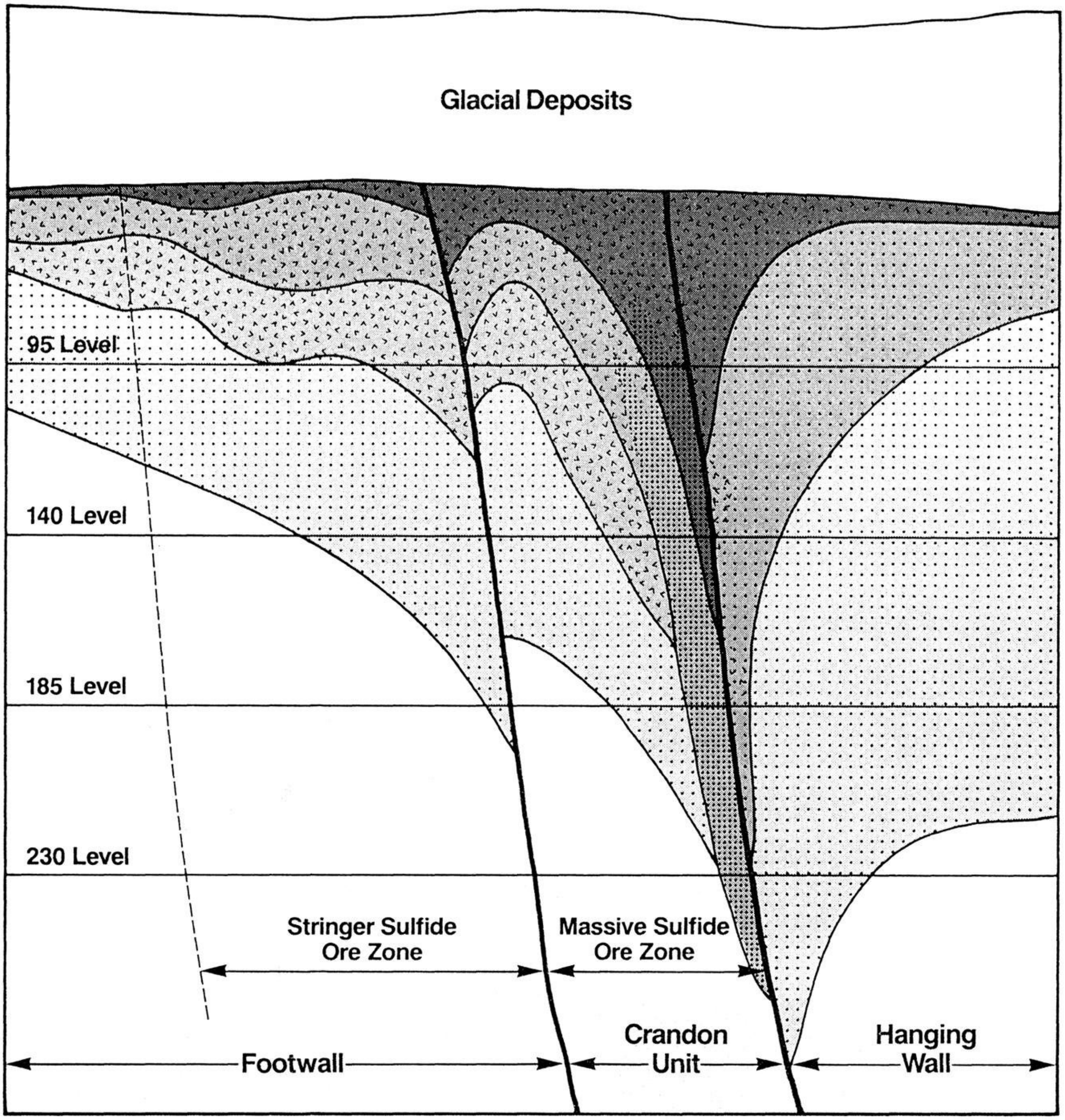
Ground Water Flow Cross Section



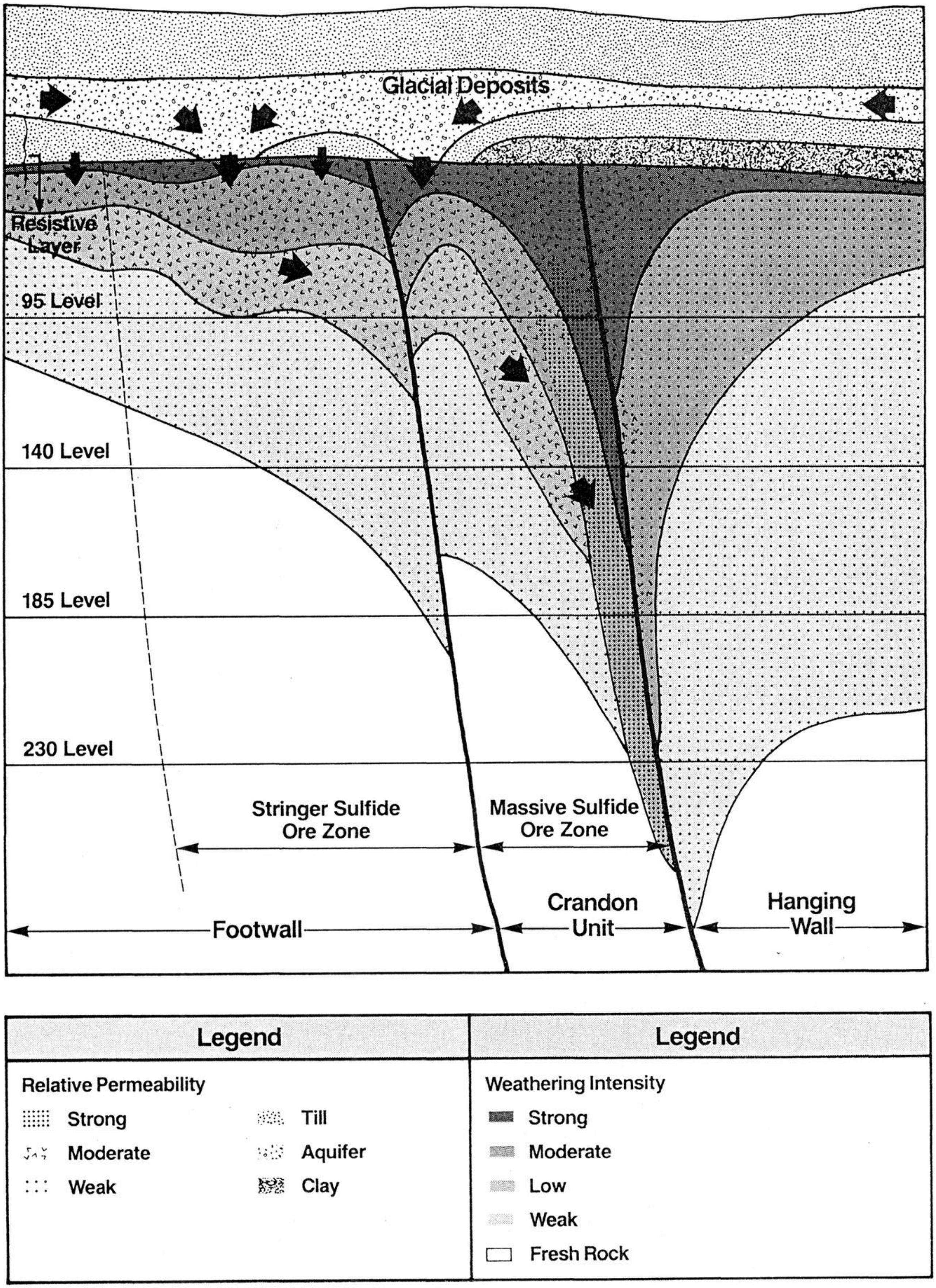


Generalized Weathering Profile

Permeabilities



Legend	Legend
Relative Permeability	**Weathering Intensity**
Strong	Strong
Moderate	Moderate
Weak	Low
	Weak
	Fresh Rock


Glacial Deposits
Resistive Layer
95 Level
140 Level
185 Level
230 Level
Stringer Sulfide Ore Zone
Massive Sulfide Ore Zone
Footwall
Crandon Unit
Hanging Wall
Legend
Relative Permeability
Strong
Moderate
Weak
Till
Aquifer
Clay
Legend
Weathering Intensity
Strong
Moderate
Low
Weak
Fresh Rock

BEFORE THE
STATE OF WISCONSIN
DIVISION OF HEARINGS AND APPEALS

Application of Exxon Corporation for Permits to Build and Operate an Underground Mining and Ore Concentrating Complex Located in Forest County, Wisconsin	))))	IH-86-18

TESTIMONY OF DR. GERALD J. LAUER

PART I: SURFACE WATER BASELINE

Q. Please state your name.

A. Dr. Gerald J. Lauer.

Q. Where do you live, Dr. Lauer?

A. 25 Mine Road, Monroe, New York 10950.

Q. What is your occupation?

A. I am a biologist and am engaged in environmental research and consulting.

Q. By whom are you employed?

A. I am employed by EA Engineering, Science, and Technology, Inc., which is based in Baltimore, Maryland, with offices in New York; Cincinnati; Chicago; Lincoln, Nebraska; and Lafayette, California.

Q. What is your position at EA Engineering, Science, and Technology, Inc.?

A. I am a Board Member, Senior Vice President, Treasurer, and Senior Consultant.

Q. Would you please briefly discuss your educational background and your work experience?

A. These are set forth in detail in my resume, which appears in the record as EXHIBIT 242. In brief, I obtained a Bachelor of Science degree from Quincy College, Illinois, and a Masters and Ph.D. in Biology with a major in Limnology from the University of Washington, Seattle. My professional employment dates back to 1955 and includes work with the State of Illinois Health Department, Quincy College, the University of Washington, the U.S. Public Health Service Division of Water Supply and

Pollution Control, the U.S. Fish and Wildlife Service, the Philadelphia Academy of Natural Sciences, New York University's Department of Environmental Medicine, and Ecological Analysts, Inc. (now named EA Engineering, Science, and Technology, Inc.)

My work during the past 30 years has been devoted almost entirely to ecological research and assessments of the effects of human activities on the functioning of ecosystems, with particular emphasis on the environmental fate and effects of pollutants, hydrologic and physical habitat alteration on water quality, aquatic life, and environmental and human health.

Q. Would you also please discuss the background and experience of EA Science and Technology?

A. EA Science and Technology and its parent company EA Engineering, Science, and Technology, Inc., are independent, multidisciplinary environmental research and engineering consulting firms. Our parent company was founded in 1973 as Ecological Analysts, Inc. As a result of growth and diversification, in 1985 the name of the firm was changed to its present name(s) to better reflect its diversity of locations and capabilities. Common practice has been to simply call our firm "EA," a convention I will follow hereafter.

EA has a staff of about 250 persons distributed among six regional offices in Maryland, New York, Ohio, Nebraska, California, and Illinois. EA's diversified staff performs research, environmental assessments, consulting, engineering investigations, and environmental engineering design and construction management services for a comprehensive array of different kinds of programs and projects.

Q. Were you and your firm retained by Exxon Corporation in connection with the Crandon Project?

A. Yes, we were.

Q. When were you retained?

A. EA was first retained by Exxon to work on the Crandon Project in April 1982.

Q. What was your assignment from Exxon with respect to this project?

A. My firm and I were initially retained by Exxon to evaluate the potential effects of the proposed discharge of treated mine water from the mine/mill complex into Swamp Creek. This required that we undertake an extensive investigation of baseline conditions in Swamp Creek and an investigation of how the discharge of treated mine water would affect the water quality of the creek and the biota in the creek.

Exxon subsequently requested that we extend our analysis to all of the area creeks, streams, springs, and lakes that might be affected by the construction and operation of Crandon Project facilities. Here again, this required that we evaluate baseline conditions for these water bodies, as well as the potential quantitative and qualitative impacts to these waterbodies resulting from the construction and operation of the Crandon Project facilities. By "quantitative" impacts, I mean the impacts to water quality, aquatic life, stream flow, and lake levels that can be expressed in numerical terms. By "qualitative" impacts, I mean the impacts to water quality habitat, aquatic life, and resource use which can be perceived but cannot be reasonably expressed in quantitative terms.

Q. Can you describe the nature of the work that was done by you and your colleagues at EA in connection with these assignments?

A. The work performed by EA was of three types:

1. Literature reviews were conducted to assess and summarize existing baseline information on the streams, springs, and lakes that might be affected by construction and operation of the Crandon Project.

2. Field studies, supported by laboratory analyses, were undertaken to provide additional needed baseline information on chemical quality, hydrology, biology, and habitat characteristics for various of the waterbodies in the area of the proposed project, with particular emphasis on Swamp Creek in the vicinity of the proposed treated water discharge from the Crandon Project.

3. Interpretive assessments were performed to evaluate the probable effects of project construction and operation on water quality, aquatic life, and other uses of the waterbodies in the vicinity of the proposed Crandon Project.

Q. What was the geographical area covered by those study efforts?

A. Our study area was primarily in the highlighted area you see on EXHIBIT 243. As you can see, this area extends to about a 4-mile radius of the ore body. In addition, EA performed dissolved oxygen studies downstream in Swamp Creek to Highway K, about 6 miles from the ore body, and fish and benthic invertebrate sampling and qualitative habitat surveys of Swamp Creek to within about 1 mile upstream of the Highway K Bridge, also about 6 miles from the ore body.

Q. What were the lakes for which EA compiled baseline information?

A. These were Skunk Lake, Little Sand Lake, Duck Lake, Deep Hole Lake, Oak Lake, and Rolling Stone Lake.

Q. What kinds of baseline information did EA compile for each of those lakes?

A. Information was compiled for each lake as to its location (distance from the ore body), size, depth, water surface elevation, type of lake, shoreline cover, water quality, fish and other aquatic life, and recreational uses.

Q. What streams were included by EA's studies?

A. EA compiled baseline information on Swamp Creek, Hoffman Creek, Hemlock Creek, Upper Pickerel Creek, Creek 12-9, Martin Spring, Creek 11-4, and Hoffman Spring and Creek. Because of the proposed discharge of treated water from Exxon's Crandon Project to Swamp Creek, considerably more study effort was devoted to Swamp Creek than to the other streams.

Q. What kinds of baseline information did EA compile for each of those streams?

A. Physical data such as nearest distance from the ore body, length, depth, width, gradient, flow, and bottom substrate type; water quality information for up to 13 parameters of general interest; fish, other aquatic life, shoreline vegetation, amount of contiguous wetlands; and recreational use.

Q. What was the nature of the additional study effort by EA on Swamp Creek and other waterbodies?

A. The core studies were of water chemistry, sediment chemistry, hydrology, and aquatic biology of Swamp Creek conducted during the period April 1982 through 1984 in the vicinity of the proposed discharge of treated project water to Swamp Creek. In addition, numerous shorter-term topical studies were conducted by EA in 1984 and 1985. These included:

1. Density and percent occurrence of drifting macroinvertebrates collected from Swamp Creek in May 1984.

2. Monitoring of cadmium concentrations in Swamp Creek water for 20 consecutive days in 1984.

3. A Hemlock Creek Riffle/Habitat Survey in 1984.

4. Collection of zooplankton in Swamp Creek in June 1984.

5. A Winter Dissolved Oxygen Survey of five lakes in the Crandon Project area in May 1985.

6. Qualitative Habitat Surveys of four streams in the Crandon Project study area in May 1984.

7. Chemical analyses of aqueous samples in June 1985.

8. Chemical analyses of well water samples from four stations.

9. Surveys (habitat) for four lakes in the Crandon Project study area in 1985.

10. Qualitative Habitat Surveys of four streams in the Crandon Project study area.

11. Evaluation of the biological and water quality impacts that might result from pumping treated water into Duck and Little Sand lakes to mitigate drawdown of water levels projected during project operation.

12. Opinion regarding DNR-Recommended Minimum Lake Levels, submitted October 1985.

13. Water quality and aquatic biology impact assessment for the Crandon Project, submitted December 1985.

Q. Did you prepare reports of your work and findings?

A. Yes, EA prepared a number of reports setting forth detailed information on the scope of our work and the nature of our findings, both quantitative and qualitative. I have listed these reports in Table 1, which is included with my prefiled written testimony. That table provides cross-references between these reports and the exhibit numbers of the exhibits contained in this hearing record.

TABLE 1

EA REPORTS AND DATA SUMMARIES

EA Reports and Data Summaries	Technical Area for Which Report Was Used: Fish & Invert	Zoo.	Chem.	Exhibit #
Water and Sediment Chemistry and Hydrology in Swamp Creek for the Crandon Project - July 1983			X	170
Chemistry and Hydrology in Swamp Creek, 1983 - April 1984			X	172
Chemistry and Hydrology in Swamp Creek, 1984 - May 1985			X	176
Final Report on the Aquatic Biology of Swamp Creek for the Crandon Project - August 1983	X			171
Aquatic Biology of Swamp Creek for the Crandon Project, January - December 1983 - April 1984	X			173
Hemlock Creek Riffle/Habitat Survey - 1984	X			174
Qualitative Habitat Surveys of Four Streams in the Crandon Project Study Area - May 1985	X			177
Qualitative Habitat Surveys of Four Streams in the Crandon Project Study Area - Report Submitted October 1985	X			179
Concentration of Inorganic Nonmetal Constituents in Aqueous Samples Received from Exxon Minerals, June 6, 1985 - Tables Submitted September 1985			X	178
Results of Zooplankton Collections in Swamp Creek, June 26-27, 1984 - Tubular Summary Submitted September 1984		X		175

Q. Dr. Lauer, what will be the scope of your testimony?

A. I will testify in two parts. Today, I will testify with respect to the baseline information for creeks, streams, springs, and lakes in the area of the Crandon Project. Later in these proceedings, I will give testimony with respect to the net impacts of the Crandon Project on these area waterbodies and the biota dependent on them.

Q. What do you mean by "net impacts"?

A. By that I mean what the impacts will be when the mine is constructed and the Hydrologic Impact Contingency Plan which Mr. Schroeder will describe is fully implemented.

Q. Will you for today's purposes outline generally what your testimony will cover?

A. Mr. Ortloff has already described the surface water bodies in this study area in general terms. I will be expanding on his testimony to provide, for each of the water bodies which may be affected by the construction and operation of the proposed mine, a brief description showing its characteristics divided into various pertinent subcategories. For ease of reference, I would like to refer throughout to EXHIBIT 243, which shows the locations of the surface water bodies I will be discussing. I would also point out that, in my prefiled written testimony, I have included tables summarizing the most pertinent parameters for all of the water bodies we studied. Table 2 summarizes this information for the lakes. I would propose in my testimony to summarize this information for each lake.

Q. Very well. Would you begin with Skunk Lake?

A. Skunk Lake is the smallest (6 acres) and shallowest (maximum depth = 6 feet) lake in the study area. It is a seepage lake. It is a soft water (average hardness = 15 mg/liter), acidic lake (average pH = 5.8) that frequently experiences low (1 mg/liter) dissolved oxygen concentrations during the winter. This is important because low dissolved oxygen and pH may be limiting to certain kinds of aquatic life. Metal concentrations are low and comparable to the other lakes in the study area, but nutrient levels (especially total phosphorus) are generally higher than in surrounding lakes.

No fish are present in Skunk Lake. Similarly, only 20 kinds (taxa) of macroinvertebrates were found during the baseline

TABLE 2 CHARACTERISTICS OF SIX LAKES IN THE CRANDON PROJECT STUDY AREA

	Lakes					
	Skunk	Duck	Deep Hole	Oak	Little Sand	Rolling Stone
Physical Characteristics						
Surface area (acres)	6	26	97	51	248	672
Surface elevation (range in feet)	1,596.48–1,598.26	1,610.23–1,612.25+	1,604.96–1,607.10+	1,632.11–1,634.21	1,590.82–1,592.96	1,534.95–1,535.84
Trigger point for mitigation (feet)	1,597.01	1,610.59	1,605.00[a] (1,605.23)[b]	NA	1,591.00[c] (1,591.51)[d]	NA
Depth, maximum (feet)	6	10	10	47	21	12
Volume (acre-feet)	7.8	127	885	N.D.	1,970	N.D.
Type of lake	Seepage	Seepage	Seepage	Seepage	Seepage	Drainage
Distance from orebody (miles)	0.4	1.1	1.5	0.9	0.4	3.5
Substrate type	Muck	Muck	Muck, sand, gravel, rubble	Muck, sand gravel	Muck, sand gravel	Muck, sand, gravel, detritus, rubble
Average Water Quality (1977-1978)						
pH (units)	5.8	5.0	6.0	6.0	5.4	7.7
Dissolved oxygen range (ppm)	.4-10.5	0.5-13.9	1.3-14.8	3.0-13.8	2.5-15.5	1.1-13.2
Hardness (ppm)	15	15	16	11	11	92
Alkalinity (ppm)	10	3	5	4	2	85
Specific conductance (umhos/cm)	27	30	30	23	28	117

a. December through March.

b. April through November.

c. January through March and July through December.

d. April through June.

N.D. Not Determined

1604R/3

TABLE 2 (Cont.)

	Lakes					
	Skunk	Duck	Deep Hole	Oak	Little Sand	Rolling Stone
Total phosphorus (ppm)	.20	<.03	<.04	<.02	<.03	.03
Ammonia (ppm)	1.57	1.28	.48	.16	.24	.55
Nitrate (ppm)	<.17	<.24	<.11	<.07	<.17	<.13
Copper (ppb)	<11	< 5	< 3	< 3	< 5	< 1
Mercury (ppb)	.1	.1	.1	.1	.1	.1
Zinc (ppb)	9	19	12	9	19	7
Turbidity (FTU)	2.9	2.0	1.4	1.3	1.1	2.1
Biology						
Number of fish species	0	3	6	9	12	11
Dominant fish species	0	Yellow perch	Yellow perch	Yellow perch Golden shiner	Yellow perch, Bluegill, Pumpkinseed, Bullheads	Yellow perch Bluegill, Bullhead
Macroinvertebrates	20 taxa	53 taxa	69 taxa	46 taxa	67-73	75-89
Zooplantkon	29 taxa	30 taxa	28 taxa	27 taxa	25-30	29
Phytoplankton	41 taxa	36 taxa	55 taxa	78 taxa	70-81	43
Shoreline vegetation	Dry mesic or mesic northern hardwoods	Bog	Dry mesic or mesic northern hardwoods	Dry mesic or mesic northern hardwoods	Dry mesic or mesic northern hardwoods	Dry mesic or mesic northern hardwoods
Amount of adjacent wetlands (acres)	5	22	35	15	20	1,067
Recreational Use						
Number of dwellings	0	0	0	0	44	65
Fishing pressure	None	Very light	Light	Light	Light	Moderate
Boating/Swimming	None	Very light	Light	Light	Moderate	Moderate

5009R/5

studies." Macroinvertebrates" are animals without backbones, and normally range in size from approximately 1/4" to about 4" long. These include worms, insect larvae, crayfish. Those macroinvetebrates that we found on or in the bottom of a water body we know as "benthos." Midges dominate the sparse benthic community with aquatic earthworms also being relatively common. The phytoplankton community -- which consists of microscopic-sized plants which live suspended in the water -- was represented by 41 taxa, and dominated by golden-brown algae. Green algae are also common. The zooplankton community -- which consists of microscopic-sized invertebrates living suspended in the water -- was represented by 29 taxa and dominated by rotifers. There are no dwellings on Skunk Lake, and it receives little or no recreational usage.

Q. You indicated that Skunk Lake is a seepage lake. What is a seepage lake?

A. Seepage lakes have water levels at higher elevations than the ground-water table. Therefore, they receive little to no input from the ground water. Rather, they lose water by seepage outward and down through underlying sediment and soil formations toward the ground-water table. The predominant sources of water for these lakes are direct rainfall and surface runoff. The chemical water quality reflects these sources, being generally soft, with low alkalinity and pH.

Q. Which of the lakes in the study area are seepage lakes?

A. Skunk, Duck, Deep Hole, Oak, and Little Sand lakes are seepage lakes.

Q. Are there any other types of lakes in the study area besides seepage lakes?

A. Yes, drainage lakes. These have water elevations that are typically lower than the ground-water table. Therefore, they receive inflow of ground water from seeps, springs, and streams fed by ground water. The chemical quality of drainage lakes is similar to the ground water except for periods after rains when the lakes also receive surface runoff. Typically, the water in the drainage lakes, such as Rolling Stone Lake, has higher hardness, alkalinity, dissolved solids, and pH than the seepage lakes. However, water in the seepage and drainage lakes in the study area generally have similar concentrations of total phosphorus, nitrate, and metals.

Q. Are there other drainage lakes in the study area in addition to Rolling Stone Lake?

A. Yes, Ground Hemlock and Rice lakes. As shown in EXHIBIT 243, these drainage lakes are all located considerably further away from the mine/mill site than are the seepage lakes.

Q. Would you please summarize the baseline information for Little Sand Lake?

A. Little Sand Lake, located 0.4 miles south from the ore body, is the largest seepage lake in the study area, covering 248 acres. It has a maximum depth of 21 feet and has a variety of bottom substrates including muck, sand, and gravel. As its name suggests, sand is the dominant substrate. It is a clear, soft-water lake (mean hardness of 11 ppm). Nutrient and metal concentrations are low. Dissolved oxygen concentrations ranging from 2.5 to 15.5 mg/liter have been measured in Little Sand Lake. Its average pH of 5.4 is lower than any of the lakes discussed here, except Duck Lake.

A total of 12 species of fish have been reported from the lake. Panfish, mainly yellow perch, bluegill, pumpkinseed, and bullheads, dominate the fish community. Largemouth bass is the only gamefish encountered with any regularity. Walleye and northern pike were rare during the baseline studies. The DNR no longer stocks Little Sand Lake, and the current status of these two species is unknown. During the baseline studies in the study area, Little Sand Lake yielded more kinds (taxa)

(70-81) of phytoplankton than any of the lakes discussed here. Golden-brown and blue-green algae usually dominated the community. A total of 67-73 macroinvertebrate taxa were found at the two stations sampled during the baseline studies. The benthic community of Little Sand Lake is dominated by midges, with aquatic earthworms and caddisflies occasionally being detected. The zooplankton community of Little Sand Lake is comparable to that in the surrounding lakes in terms of number of taxa, but different in terms of composition in that it was dominated by copepods while the communities in most of the surrounding lakes are dominated by rotifers.

Little Sand Lake has approximately 44 dwellings on it, but receives only light fishing pressure. Recreational use for other water sports, such as swimming and boating, can be characterized as moderate.

Q. What about the baseline information for Duck Lake?

A. Duck Lake is a small (26-acre), shallow (maximum depth = 10 feet) seepage lake located 1.1 miles from the ore body. Its bottom consists entirely of muck. Duck Lake is the most acidic of the lakes in the study area, with an average pH of only 5.0 measured during baseline studies. This pH is low enough to prevent many species of fish from using the lake. Low dissolved oxygen concentrations (0.5 mg/liter) probably further limit the aquatic communities; the lake approaches being a winterkill lake. A "winterkill lake" is a lake which, because of its shallow depth, either freezes to the bottom during the winter or is almost completely depleted of its oxygen. Thus, a winterkill lake cannot sustain a fish population. Like the other seepage lakes in the study area, Duck Lake has soft water. Metal concentrations are low as are nutrient concentrations, though the latter are somewhat higher than in most of the surrounding lakes.

Duck Lake contains only three species of fish: yellow perch, black bullhead, and central mudminnow. Yellow perch is by far the most abundant of the three. All three species are tolerant of low pH values. Duck Lake also has fewer kinds (taxa) of phytoplankton (36) than any of the six lakes that are compared here. The sparse phytoplankton community was usually dominated by golden-brown algae. In contrast to the reduced phytoplankton community, the zooplankton community of Duck Lake was comparable to that found in the surrounding lakes, both in terms of number of taxa (30) and composition (rotifers dominated). Duck Lake had more macroinvertebrate taxa (53) than Oak or Skunk lakes (20-46 taxa), but fewer than Deep Hole, Little Sand, or Rolling Stone lakes (67-89 taxa). The benthic community of Duck Lake was dominated by aquatic earthworms and midges.

There are no dwellings on Duck Lake, and it receives very light use for fishing, boating, or other water-related recreational activities.

Q. Please summarize the baseline information for Deep Hole Lake.

A. Deep Hole is a moderate size (97 acres), shallow (maximum depth = 10 feet), seepage lake located 1.5 miles from the ore body. It has a variety of substrates including muck, sand, gravel, and rubble. Like the other seepage lakes in the study area, it is a soft water lake, but it is less acidic than several of the surrounding lakes. Dissolved oxygen concentrations ranging from 1.3 to 14.8 mg/liter have been reported. Nutrient and metal concentrations are low.

Baseline studies and subsequent verification studies by the WDNR have resulted in the capture of only six species of fish from Deep Hole Lake. Yellow perch is by far the most abundant species. At one time, Deep Hole Lake was used as a walleye rearing pond by the WDNR. The WDNR no longer uses the lake for this purpose, and the present abundance of walleye in the lake is unknown. Deep Hole Lake contains a relatively large number

(69) of macroinvertebrate taxa, with midges strongly dominating the benthic community. The phytoplankton and zooplankton communities of Deep Hole lake were comparable to those in the surrounding lakes, both in terms of composition and number of taxa.

There are no dwellings on Deep Hole Lake, and it receives only light pressure for fishing and other water-related recreational activities.

Q. What about Oak Lake?

A. Oak Lake is a small (51 acres), but deep (maximum depth = 47 feet) seepage lake located 0.9 miles from the ore body. The substrate is composed of muck, sand, and gravel. It is the only perched lake in the study area -- that is, its bottom lies above the ground-water table.

The water in Oak Lake is slightly acidic (average pH = 6.0) and very soft (average hardness = 11 mg/liter). Nutrient and metal concentrations are low. Dissolved oxygen concentrations range from 3.0 to 13.8 mg/liter.

Nine species of fish have been reported from the lake, with yellow perch being the most numerous species. Golden shiners are also common. Largemouth bass are more common in Oak Lake than in any other lake in the study area. Oak Lake supports a large number of kinds of phytoplankton (78 taxa), but contains fewer macroinvertebrate taxa than any of the six lakes discussed here except for Skunk Lake. The number of taxa and composition of the zooplankton community is comparable to that found in the surrounding lakes.

Oak Lake has no dwellings along its shore, and receives only light fishing and recreational pressure.

Q. Please summarize the baseline information for Rolling Stone Lake.

A. Rolling Stone is the largest lake (672 acres) in the study area, but it is quite shallow (maximum depth = 12 feet). It differs from the lakes already discussed in that it is further from the ore body (3.5 miles) and is a drainage rather than a seepage lake. This means that it is a lake that receives a predominant portion of its water from ground water inflow. It contains a variety of bottom substrates including muck, detritus, sand, gravel, and rubble.

As opposed to the five seepage lakes discussed previously, Rolling Stone Lake is a moderately hard-water, alkaline lake. However, like the seepage lakes, Rolling Stone is low in nutrients and metals. Dissolved oxygen concentrations as low as 1.1 mg/liter have been reported.

Despite its relatively large size, only 11 species of fish have been reported. Yellow perch is the most numerous species, followed by bluegill and black bullhead. Gamefish (largemouth bass, walleye, and northern pike) are rare to uncommon. Rolling Stone Lake contains more kinds (75-89 taxa) of macroinvertebrates than any of the surrounding lakes. Aquatic macrophytes are also more common in Rolling Stone Lake than in the surrounding lakes. The zooplankton community is comparable to that in other study area lakes, but it contains fewer phytoplankton taxa than most of the surrounding lakes.

Rolling Stone Lake has about 65 dwellings (including some resorts) along its shoreline. It receives moderate fishing, boating, and swimming pressure.

Q. Turning now to the creeks and springs in the study area, Dr. Lauer, would you please summarize the baseline information for Swamp Creek?

A. Table 3 in my prefiled written testimony sets forth the most pertinent parameters for the creeks and springs. My testimony here will give you a synopsis of the information contained there. Let me also refer back to EXHIBIT 243, which shows the portion of Swamp Creek we studied. Because of differences in biota and subsequent classification, Swamp Creek can be divided into two segments: upper Swamp Creek, which is that portion of the stream upstream of Rice Lake; and lower Swamp Creek, which is that portion downstream of Rice Lake.

The upper portion of Swamp Creek, which begins in Lake Lucerne, is about 8 miles long, and has an average width of about 15 feet and average depth of about 1 foot. It is located 1 mile from the ore body. At Highway 55, it has an average annual flow of 31.7 cubic feet per second (cfs), with the Q7,2 and Q7,10 values estimated to be 11 and 8 cfs, respectively. You will be hearing quite a bit about Q7,2 and Q7,10 values during the course of this hearing. The "Q7,2 value" is the lowest predicted flow that would occur in any 7 consecutive days once in two years, based on historical data. The "Q7,10 value" is similar, except it refers to the lowest predicted seven-day flow once every ten years.

Although sand is the predominant substrate, areas of muck are found in the slower portions of the stream, while gravel and rubble substrates are found in the high velocity portions of the

TABLE 3 CHARACTERISTICS OF SIX STREAMS IN THE CRANDON PROJECT STUDY AREA

	Streams						
	Lower Swamp Creek	Upper Swamp Creek	Hoffman Spring-Hoffman Creek	Hemlock Creek	Upper Pickerel Creek	Creek 12-9	Martin Spring-Creek 11-4
Physical Characteristics							
Length (miles)	7.5	8.0	0.5	2.4	2.3	1.6	0.5
Average depth (feet)	>1.0	1.0	0.5	1.0	1.0	1.0	0.3
Average width (feet)	23	23	8.0	14	>10	9.0	5.0
Distance from orebody (miles)	3.5	1.0	1.8	1.6	2.9	1.4	2.8
Gradient (feet/mile)	8.1	8.1	8.1	2.5	4.3	35	31
Flow, average (cfs)	>50	31.7	0.59	5.9	1.8	4.7	.58
Flow, Q7,2 (cfs)	19	11	0.30	2.0	0.6	1.5	.30
Flow, Q7,10 (cfs)	15	8	0.15	1.4	0.4	1.1	N.D.
Trigger point flow (cfs)	NA	17.5	0.55	2.7	1.0	2.5	0.4
Substrate	Muck, sand, gravel	Muck, sand, gravel, rubble	Muck, sand, gravel	Muck, sand, gravel	Muck	Muck, sand gravel	Muck, sand, gravel
Type of stream (Classification)	Warm water	Cold Water	Cold Water	Cold Water	Warm Water	Cold Water	Cold Water
Average Water Quality (1977-1978)							
pH (units)	6.2-7.9	7.3	7.4	7.4	6.9	7.4	6.9
Temperature range (C)	0-29	0-21.0	9.6	0-22.0	0-18.0	0-23.9	0-23.0
Dissolved oxygen, range (ppm)	1.1-12.2	4.5-15.0	10.0	3.2-14.4	5.5-12.2	5.2-13.7	3.0-9.0
Hardness (ppm)	64-120	103	137	107	83	108	93
Alkalinity (ppm)	41-116	97	135	101	73	100	84
Specific conductance (umhos/cm)	98-235	135	179	136	92	132	123
Total phosphorus (ppm)	<.1-0.5	< .03	0.2	.02	.06	.04	.06
Ammonia (ppm)	<.01-.16	< .34	N.D.	<.29	.70	<.34	.90
Nitrate (ppm)	0.02-0.27	<.15	0.03	< .18	<.22	<.17	.10
Copper (ppb)	<1-22.8	< 5	3.0	< 5	< 4	< 5	< 2
Mercury (ppb)	<.25- <.3	< .1	< 0.5	< .1	< .1	< .1	< .1
Zinc (ppb)	0.7-78	6	22	<5	6	9	5
Turbidity (FTU)	N.D.	2.0	N.D.	2.8	1.5	1.2	1.8

N. D. Not Determined

TABLE 3 (Cont.)

	Streams						
	Lower Swamp Creek	Upper Swamp Creek	Hoffman Creek	Hemlock Creek	Upper Pickerel Creek	Creek 12-9	Creek 11-4
Biology							
Number of fish species	32	29	14	26	8	9	17
Dominant fish species	Minnows	Minnows, White sucker	Brook trout, M. sculpin	Minnows & B. stickleback	Perch, Sculpin Brook trout	Sculpin, Perch	Minnows
Macroinvertebrates	220 taxa	135 taxa in riffles, 122 taxa in pools	N.D.	112 taxa	82 taxa	82 taxa	82 taxa
Periphytic algae	N.D.	93-104 taxa	N.D.	71 taxa	80 taxa	49 taxa	86 taxa
Shoreline vegetation	Wet mesic or wet northern forest	Wet mesic or wet northern forest	Wet mesic or wet northern forest	Wet mesic or wet northern forest	Wet mesic or wet northern forest	Wet mesic or wet northern forest	Wet mesic or wet northern forest
Amount of adjacent wetlands (acres)	3,479	See Lower Swamp Creek	20	180	1,164	23	N.D.
Recreational-Use							
Fishing pressure	Very light	Light	Very light	Light	Very light	Light	Very light

stream. The upper portion of Swamp Creek is the only stream in the study area that possesses an appreciable amount of riffle habitat.

Upper Swamp Creek is a moderate hard-water stream that has neutral pH values. Temperatures during the summer get as high as 70° F. Daytime dissolved oxygen values range from 4.5 to 15.0 mg/liter. Nutrient and metal concentrations are low. Swamp Creek upstream of Highway 55 is classified by the WDNR as a Class II trout stream. This means some reproduction takes place but not enough to maintain a desired level of trout population. Two small areas in the upper reaches of Swamp Creek which were identified during the baseline studies are suitable for spawning. Although 29 species of fish have been reported from upper Swamp Creek, the stream is dominated numerically by minnows, with the common shiner being particularly abundant. Nearly half (13 species) of the 29 species reported from upper Swamp Creek belong to the minnow family. White suckers are also abundant. Mottled sculpin and brook trout are common.

Benthic sampling yielded 135 and 122 macroinvertebrate taxa from riffle and pool habitats, respectively. The pool habitat was dominated by midges, with aquatic earthworms, snails, and clams also being common. Midges were common in the riffle habitat, but were not as dominant as they were in the pool habitat. Other groups commonly collected from the riffle habitat were caddisflies, mayflies, and snails. Diatoms consistently dominated the periphyton community. Fishing pressure is light on upper Swamp Creek.

Lower Swamp Creek consists of a segment of the stream located about 3.5 miles from the ore body that is about 7.5 miles long with an average width of about 35 feet and depth of about 1 foot. At County Trunk Highway M, the average annual flow is in excess of 50 cfs, while the flow under Q7,2 and Q7,10 conditions is estimated to be 19 and 15 cfs, respectively. Sand is the predominant substrate, with smaller amounts of muck and even smaller amounts of gravel also present.

Water quality is comparable to that in upper Swamp Creek with two notable exceptions. First, lower Swamp Creek gets much warmer during the summer (temperatures as high as 89°F have been recorded). Second, dissolved oxygen values are lower. Values as low as 1.1 mg/liter have been recorded in lower Swamp Creek during the night. Because of the warmer water temperatures, lower Swamp Creek is considered to be a warmwater stream. A total of 32 species of fish have been reported from lower Swamp Creek, more than from upper Swamp Creek or any other stream in the study area. Minnows dominate the fish community of lower Swamp Creek, with common shiner and hornyhead chub being particularly abundant. Rock bass, yellow perch, and black bullhead are also common. Northern pike are present, but are rare to uncommon depending on location.

Lower Swamp Creek also has a diverse benthic community, with over 220 taxa having been reported. The amphipod Hyalella azteca is the most abundant macroinvertebrate in lower Swamp Creek. Other common groups are aquatic earthworms, snails, mayflies, and midges. A survey of the zooplankton community revealed that densities were low (typically 1 per liter) and that rotifers dominate the sparse zooplankton community. Fishing pressure is very light on lower Swamp Creek. Canoeing may occasionally take place.

Q. Please summarize the baseline information for Hoffman Spring and Hoffman Creek.

A. Hoffman Creek is a small stream that originates at Hoffman Springs and travels about 0.5 miles before joining upper Swamp Creek. It is 1.8 miles from the ore body, and averages only 8 feet wide and 0.5 feet deep. Flow data are extremely sparse, but estimates of 0.59, 0.3, and 0.15 cfs can be made for average annual, Q7,2 and Q7,10 flows, respectively.

The substrate is a mixture of muck, sand, and gravel, with ground-water seeps evident in several locations. Samples collected in June, 1985 indicated that Hoffman Creek is a moderately hard, slightly alkaline stream. Metal and nutrient concentrations were low.

Despite its small size, 14 species of fish have been reported from Hoffman Creek. Brook trout and mottled sculpin are the dominant species. The WDNR considers it a Class II trout stream; a considerable spawning area exists just downstream of Hoffman Springs. Qualitative studies that we performed in 1985 showed that a diverse benthic community was present and that amphipods and clams were the most numerous groups. A diverse, though not abundant, caddisfly community was also present. Fishing pressure on Hoffman Creek is very light.

Q. Would you please summarize the baseline information for Hemlock Creek?

A. Hemlock Creek originates in Ground Hemlock Lake and flows northward for 2.4 miles before joining Swamp Creek. It averages 1 foot deep, 14 feet wide, and lies 1.6 miles from the ore body. The available flow data indicate that it has an average annual flow of about 5.9 cfs and Q7,2 and Q7,10 flows of 2.0 and 1.4 cfs, respectively. A recent Habitat Survey showed that fine sand was the predominant substrate. No riffle areas were found. Numerous beaver dams were present.

The water of Hemlock Creek is moderately hard and slightly alkaline (average pH = 7.4), with dissolved oxygen values ranging from 3.2 to 14.4 mg/liter. The maximum water temperature measured during the baseline studies was 72°F. Nutrient and metal concentrations are low.

Given its limited size, Hemlock Creek supports a diverse fish community. A total of 26 species have been reported, of which exactly half are members of the minnow family. Common shiner and northern redbelly dace are the most abundant minnows. Brook stickleback is also common. Panfish and gamefish are rare to uncommon. The WDNR classifies Hemlock Creek as a Class II trout stream. During the baseline studies, a small area in Hemlock Creek was identified as being suitable for brook trout spawning. In a more recent 1984 survey, however, we found that this area is now silted over. We found no trout. It seems likely that the trout population may have declined from earlier years because of siltation associated with the extensive beaver activity in the stream.

A total of 112 benthic taxa were collected from Hemlock Creek during the baseline studies. Midges were the most abundant group, but mayflies, aquatic earthworms, snails, and clams were also quite common. Diatoms completely dominate (greater than 98 percent) the periphyton community in Hemlock Creek.

By the "periphyton community," I mean those microscopic plants that live attached to some firm substrates, such as stones, submerged limbs and plants, and so forth. Fishing pressure on Hemlock Creek is light.

Q. What about Upper Pickerel Creek?

A. Upper Pickerel Creek, which is located 2.9 miles from the ore body, originates in the wetlands just south of Mole Lake, and flows southward for 2.3 miles before entering Rolling Stone Lake. Upper Pickerel Creek is 10 feet wide and averages about 1 foot deep. The average annual flow is about 1.8 cfs, while Q7,2 and Q7,10 values are estimated to be 0.6 and 0.4 cfs, respectively. Muck is the only substrate present.

The average pH in upper Pickerel Creek is 6.9, and the maximum recorded temperature is 64°F. Dissolved oxygen values are consistently higher than 5 mg/liter. Metal concentrations are low, but the nutrient concentrations are higher than in any of the other streams in the study area, except Creek 11-4.

Upper Pickerel Creek has a poor fish community, both in terms of numbers of species and numerical abundance. For example, three collections during the baseline period yielded only 50 fish representing only six species. Two other species have since been collected. The total of 8 species is the lowest for any stream in the study area. The sparse community is dominated by yellow perch, brook trout, and mottled sculpin. Upper Pickerel Creek is not considered to be a trout stream by the WDNR. A total of 82 macroinvertebrate taxa were collected from Upper Pickerel Creek during the baseline studies, with midges being the most numerous group. Aquatic earthworms, isopods, and clams were also common. Diatoms consistently dominated the periphyton community. Fishing pressure on Upper Pickerel Creek is very light.

Q. Please summarize the baseline information for Creek 12-9.

A. Creek 12-9 originates in the wetlands adjacent to the southern shore of Little Sand Lake, however, stream flow from the lake is intermittent. From its point of origin, Creek 12-9 flows southward for 1.6 miles before entering Rolling Stone Lake. It has an average width of 9 feet, and an average depth of 1 foot. It is located 1.4 miles from the ore body. The average annual flow is estimated to be 4.7 cfs, while Q7,2 and Q7,10 flows are estimated to be 1.5 and 1.1 cfs, respectively. Sand is the most common substrate, but areas of muck, gravel, and rubble are also present. Creek 12-9 has the highest gradient (35 feet/mile) of any stream in the study area.

The average pH during the baseline studies was 7.4. However, in 1985 we measured values as low as 5.2 during a period when the acidic waters of Little Sand Lake were composing the bulk of the flow in the stream. Water temperatures as high as 75°F have been reported. Dissolved oxygen values are consistently greater than 5 mg/liter. The water is usually moderately hard, but in 1985 we measured values as low as 9 mg/liter. Metal and nutrient concentrations are low.

Creek 12-9 has a poor fish fauna, and one that is quite similar to Pickerel Creek. Three collections during the baseline studies yielded only 22 fish representing 7 species. Two additional species are known, bringing the total to nine. Mottled sculpin and yellow perch are the most commonly collected species. The WDNR classifies Creek 12-9 as a Class II trout stream, and a small area of the stream considered suitable for trout spawning was identified during the baseline studies. Benthic collections during the baseline studies yielded 82 taxa, the same number as in Pickerel Creek. Midges dominated the benthic community, with clams being the only other group that was common. Diatoms dominated the periphyton community in the spring and fall, while diatoms and golden-brown algae were co-dominants during the summer. Fishing pressure is light on Creek 12-9.

Q. Finally, Dr. Lauer, would you please summarize the baseline information for Martin Spring - Creek 11-4?

A. Creek 11-4 originates at Martin Springs, from which it flows southward for 0.5 miles before entering Rolling Stone Lake. It is the smallest stream in the study area, averaging only 5 feet wide and 0.3 foot deep. Although data are sparse, estimates of average annual and Q7,2 flows of 0.58 and 0.3 cfs, respectively, have been derived. The Q7,10 flow has not been estimated. Creek 12-9 has one of the highest gradients (31 feet/mile) among the streams in the study area. It is located 2.8 miles from the ore body. Though areas of muck and gravel are present, sand is the predominant substrate.

The waters of Creek 11-4 are near neutral (mean pH = 6.9) and moderately hard. Dissolved oxygen values ranging from 3.0 to 9.0 mg/l have been reported, and temperatures as high as 73°F have been measured. Metal concentrations are low, but nutrient concentrations are higher than in most of the streams in the study area. For its small size, Creek 11-4 has a diverse fish community. A total of 17 species have been reported, with minnows dominating the community. Northern redbelly dace are particularly abundant. Although the WDNR classifies Creek 11-4 as a Class II trout stream, no trout were collected during the baseline studies, nor during more recent Habitat Surveys that were conducted. Benthic studies during the baseline period yielded a total of 82 taxa from Creek 11-4. In contrast to the other Rolling Stone Lake tributaries, which were dominated by midges, the benthic fauna of Creek 11-4 was dominated by aquatic earthworms, with isopods and clams also being numerous. As was the case in Creek 12-9, the periphyton community of Creek 11-4 was dominated by diatoms in the spring and fall, while diatoms and golden-brown algae were co-dominants during the summer. Creek 11-4 receives little or no fishing pressure.

Q. Thank you, Dr. Lauer. Later in this hearing, we will ask you to resume your testimony and to review for us how the construction and operation of Crandon Project facilities may affect the surface water bodies and biota you have just described.

5018R

EA SCIENCE AND TECHNOLOGY

A Division of EA Engineering, Science, and Technology, Inc.

EXHIBIT 242

GERALD J. LAUER, Ph.D.
Senior Environmental Scientist

Dr. Lauer formulates and interprets company policy and approves contracts with clients. He appoints Directors of Operations and Programs and approves hiring of senior key staff. He is responsible for ensuring implementation of quality control/quality assurance procedures and reviews project study plans and interpretive reports to assure fulfillment of study objectives and scientific validity of results. He devotes approximately 70 percent of his time to environmental research and impact assessments and 30 percent to consultation and testimony for EA's clients.

EXPERIENCE:

AQUATIC ECOLOGY: Conducted research on biological responses to variations in water chemistry, temperature, hydrologic characteristics, bottom substrate, and depth in lakes and streams. Taught graduate aquatic ecology and advised graduate students on thesis research for six years.

WATER QUALITY AND ENVIRONMENTAL TOXICOLOGY: Conducted research for 12 years on the sources, environmental fate, and effects of radionuclides, heavy metals, insecticides and herbicides. This research included development of sampling and analytical methods for studies of transport, deposition, degradation, persistence, and transport of chemicals in air, soils, water, and biota. Conducted biomonitoring field studies and controlled laboratory bioassays to determine the acute and chronic toxicity of pollutants and their concentration and bioaccumulation in food pathways leading to fish, wildlife, and man. Investigated the cause of fish kills using general survey and specific autopsy techniques. Conducted pilot-plant studies of measures to remove pesticides from municipal water supplies. Supervised bioassay and chemical analytical laboratories. Performed tiered, integrated assessments of toxic potential for effluent toxics control programs, effluent toxic allocations, and development of site-specific water quality criteria. Prepared published papers, reports, and testimony for Section 401 water quality certification of proposed steam electric, pumped storage, and hydroelectric generating stations. Performed literature review to evaluate potential human health effects from heavy metals contamination of drinking water and seafood.

SOLID AND HAZARDOUS WASTE: Directed the preparation of four "NEPA type" draft environmental impact statements (DEISs) for disposal sites, including secure landfills for disposal of hazardous wastes, liquid chemical waste treatment facilities, sludge burial facilities, municipal waste landfills, an acid neutralization facility, a foundry sand disposal area, and scrap metal recovery operations. Key issues addressed were site suitability; hydrogeology and proposed engineering design; alternative sites, designs, and technologies; transportation routes and hazards; socioeconomic effects; natural resources; environmental and human health (air quality, surface and groundwater quality, noise, odors, dust) mitigation measures to avoid or control pollution; and compliance with existing and emerging federal and state regulations on storage and disposal of hazardous materials. Sponsored DEISs, served as a witness in public hearings, participated in negotiations among the parties, and assisted attorneys with preparation of briefs in support of applications for permits pursuant to state and federal (RCRA) regulations. Performed prior-to-purchase environmental suitability screening of sites for land burial of solid hazardous wastes to assess potential for compliance with existing and proposed federal (RCRA, TSCA, DOT) and state regulations on transportation, storage, and disposal of hazardous materials. Directed a literature review and assessment of the effects of disposal of municipal wastewater treatment plant sludge at an ocean dump site. Participated in investigations of active and inactive chemical waste disposal sites to assess hazard-risk to the environment and human health.

<u>IMPACTS OF THERMAL DISCHARGES</u>: Supervised preparation of study plans and performance of studies to assess the effects of thermal discharges at numerous sites on streams, lakes, estuaries, and the ocean. Administered construction and operation of a thermal bioassay laboratory designed to study the time-dose response of aquatic organisms (particularly fish eggs and larvae) to rapid changes of water temperature. Responses examined were survival, preference-avoidance behavior, and prey-predator interactions. Results were used to establish design and operational criteria for minimizing adverse effects on aquatic life pumped through cooling systems. Prepared interpretive chapters for environmental reports and numerous demonstrations pursuant to Section 316(a) of PL 92-500. Provided testimony in many extensive hearings before state and federal agencies, including the NRC and U.S. EPA.

<u>IMPACTS OF WATER PROJECTS, INTAKE STRUCTURES, AND TRANSPORT SYSTEMS</u>: Conducted and directed numerous studies to evaluate (1) effects of impingement on intake screens and passage through cooling water systems on aquatic life, (2) pumped storage and hydroelectric generating facilities, and (3) water diversion tunnels, canals, and impoundments on habitat for aquatic life, wildlife, and waterfowl, including threatened, rare, or endangered species such as the shortnose sturgeon, loon, bald eagle, whooping crane, and the interior least tern. Prepared interpretive reports and testimony pursuant to U.S. EPA, AEC, NRC, FERC, U.S. Army Corps of Engineers, and state regulations; these included Section 401 water quality certifications.

SITING AND IMPACT ASSESSMENT: Experienced in screening and auditing proposed and existing sites and facilities for compliance with state and federal environmental regulations and for assessing risk to the environment and human health. Prepared EISs, Section 316 demonstrations, FERC Exhibits, and U.S. NRC 4.2 environmental assessments for projects ranging from floating and land-based nuclear power stations, major pumped storage hydroelectric generating stations, and hazardous waste disposal facilities to such smaller projects as dredging and dredge spoil disposal, landfilling for marina development, and wastewater treatment systems. Presented testimony on these projects before appropriate state and federal agencies.

CRITICAL REVIEWS: Directed and participated in critiques of the technical validity of numerous proposed 316(a) guidelines documents, RCRA regulations, water quality criteria, and state water quality standards. These critiques carefully evaluated whether information cited was the most appropriate, up-to-date, quality information available; whether it was cited accurately; and whether it was interpreted and used in a scientifically valid manner. Comments and recommendations were prepared and testimony was presented on proposed water quality standards for New York, Pennsylvania, Ohio, Indiana, Michigan, and Illinois and on proposed TSCA regulations before the U.S. EPA. Conducted extensive literature reviews and prepared monographs on the sources, fate, environmental and human health effects, and analytical procedures for pollutants.

MANAGEMENT: Over 20 years of experience with management of multidisciplinary environmental research and impact assessment programs involving up to 350 staff members and budgets up to 10 million dollars. Experienced in program planning, budgeting and budget control, staffing, personnel, contracts management, and quality assurance/quality control for programs involving the efforts of biologists, chemists, engineers, geologists, health scientists, hydrologists, statisticians, information specialists, and computer, editorial, and publications personnel.

EDUCATION:

Ph.D. and M.S. (biology-limnology), University of Washington, Seattle, Washington	1959-1963
B.S. (biology), Quincy College, Quincy, Illinois	1956
U.S. Public Health Service, In-Service Management Training	1960-1965

Gatton, McNally Associates, Management Training Series: Management for Effective Performance — 1977-1979

PREVIOUS EXPERIENCE:

NEW YORK UNIVERSITY DEPARTMENT OF ENVIRONMENTAL MEDICINE
- Assistant Director, Laboratory for Environmental Studies — 1969-1975
- Adjunct Associate Professor of Biology — 1970-Present

ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA
- Coordinator of Environmental Consulting — 1967-1969

U.S. DEPARTMENT OF THE INTERIOR,
- Ohio State Univ., Associate Professor and Leader, Ohio Cooperative Fisheries Unit — 1966-1967

U.S. PUBLIC HEALTH SERVICE,
- Region IV, Atlanta, Georgia, Lcdr, Principal Investigator, Pesticide Pollution Studies Program — 1960-1965

FERGUSON-FLORISSANT HIGH SCHOOL, Missouri,
- Biology and Chemistry Teacher — 1959-1960

UNIVERSITY OF WASHINGTON, Seattle, Washington
- Research assistant to Professor W.T. Edmondson on alkaline lakes research — 1956-1959

QUINCY COLLEGE, Quincy, Illinois
- Research assistant to Dr. Troy C. Dorris on studies of the Mississippi River — 1955-1956

ILLINOIS PUBLIC HEALTH DEPARTMENT, Springfield
- Biologist Aide for stream pollution surveillance and enforcement — 1955

PROFESSIONAL ACTIVITIES:

Ecological Society of America
American Society of Limnology and Oceanography
American Fisheries Society
Water Pollution Control Federation
National Association of Environmental Professionals (Board of Directors)
Hudson River Environmental Society (Board of Directors)
American Association for the Advancement of Science
Outstanding Young Men of America (1968)
American Nuclear Society Standards Committee
American National Standards Institute (ANSI) Chairman

Biological Communities Task Force of the Rockefeller Foundation's Hudson Basin Project (1973-1974)
New York Academy of Sciences
American Society for Testing and Materials

PUBLICATIONS AND PRESENTATIONS:

Jinks, S.M., G.J. Lauer, and M.E. Loftus. 1981. Advances in techniques for assessment of ichthyoplankton entrainment survival, *in* Fifth National Workshop on Entrainment and Impingement (L.D. Jensen, ed.), pp. 91-110. Prepred by Ecological Analysts, Inc., Sparks, Md.

Beck, A.P., G. Poje, and G.J. Lauer. 1981. Acute Survival of Striped Bass (*Morone saxatilis*) Larvae Exposed to Rapid Hydrostatic Pressure Change Simulating Conditions for a Proposed Pumped Storage Electric Generating Facility at Cornwall, N.Y. (In press).

DelPup, J., J. Fava, E. Perry, R. Kapp, P. LeClare, G. Lauer, and D. Versteeg. 1981. Scientific validity of EPA water quality criteria for priority pollutants: Vol. I. *of* Protection of Aquatic Life.

Lauer, G.J., J.R. Young, and J.S. Suffern. 1981. The best way to assess environmental impact is through the use of generic and site-specific data, *in* Fifth National Workship on Entrainment and Impingement (L.D. Jensen, ed.), pp. 21-34. Ecological Analysts, Inc., Sparks, Md.

DelPup J., P. LeClare, R. Stadelmaier, W. Going, and G. Lauer. 1980. An assessment of the potential impact on human health from operation of a chemical waste management system, *in* Proceedings of the 1980 National Conference on Control of Hazardous Material Spills, pp. 270-276.

Occhiogrosso, T.J., W.T. Waller, and G.J. Lauer. 1979. Effects of heavy metals on benthic macroinvertebrate densities in Foundry Cove on the Hudson River. Bull. Environ. Contam. Toxicol. 22:230-237.

Cannon, T.C., S.M. Jinks, L.R. King, and G.J. Lauer. 1978. Survival of entrained ichthyoplankton and macroinvertebrates at Hudson River power plants, *in* Fourth National Workshop on Entrainment and Impingement (L.D. Jensen, ed.), pp. 71-90. Ecological Analysts, Inc., Melville, N.Y.

Jinks, S.M., T. Cannon, D. Latimer, L. Claflin, and G.J. Lauer. 1978. An approach for the analysis of striped bass entrainment survival at Hudson River power plants, in Fourth National Workshop on Entrainment and Impingement (L.D. Jensen, ed.), pp. 343-350. Ecological Analysts, Inc., Melville, N.Y.

Ginn, T.C., W.T. Waller, and G.J. Lauer. 1976. Survival and reproduction of Gammarus spp. (Amphipoda) following short-term exposure to elevated temperatures. Chesapeake Sci. 17(1):8-14.

Kneip, T.J., H.I. Hirshfield, G.J. Lauer et al. 1975. Cadmium in an Aquatic Ecosystem: Distribution and Effects. Prepared for the National Science Foundation by New York University.

Lauer, G.J., W.T. Waller, and G.R. Lanza. 1975. Interfaces of steam electric power plants with aquatic ecosystems. Environ. Let. 9(4):405-430.

Ginn, T.C., W.T. Waller, and G.J. Lauer. 1974. The effects of power plant condenser cooling water entrainment on the amphipod Gammarus sp. Water Res. 8:937-945.

Lauer, G.J., W.T. Waller, D.W. Bath, W. Meeks, R. Heffner, T. Ginn, L. Zubarik, P. Bibko, and P.C. Storm. 1974. Entrainment studies on Hudson River organisms, in Proceedings of the Second Workshop on Entrainment and Intake Screening (L.D. Jensen, ed.), pp. 37-82. Cooling Water Studies for Electric Power Research Institute Research Project RP-49, Rept. No. 15. Johns Hopkins Univ., Dept. of Geography and Environmental Engineering.

Kneip, T.J. and G.J. Lauer. 1973. Trace metal concentration factors in aquatic ecosystems: Vol. V of Progress in Analytical Chemistry. Plenum Press, New York.

Lauer, G.J. and W.T. Waller. 1973. Problems and potential solutions to biological entrainment and chemical discharge, in Proceedings, 1972 Conference on Water Quality: Siting and Operation of Nuclear Power Plants. Atomic Industrial Forum, Inc.

Wrenn, M.E., J.W. Lentsch, M. Eisenbud, G.J. Lauer, and G.P. Howells. 1973. Radiocesium distribution in the water, sediment, and biota in the Hudson River estuary from 1964 through 1970, in Proceedings, Third National Symposium on Radioecology.

Lauer, G.J. 1972. The Response of Aquatic Organisms to Transitory and Chronic Exposure to Elevated Temperatures. Interim Report prepared for Commonwealth Edison by Environmental Analysts, Inc.

Lauer, G.J. 1970. Chemical aspects of the New York bight and estuaries: Water chemistry of the lower Hudson River, in Proceedings, Symposium on Water Pollution in the Greater New York Area (A.A. Johnson, ed.). Gordon and Breach, New York.

Lauer, G.J. 1969. Osmotic regulation of *Tanypus nubifer*, *Chironomus plumosus*, and *Enallagma clasum* in various concentrations of saline lake water. Physiol. Zool. 42(4):381-387.

Lauer, G.J. 1968. Some effects of metals on aquatic life, in Proceedings, Symposium on Mineral Waste Utilization. Illinois Inst. of Technology Research Inst., Chicago.

Lauer, G.J., H.P. Nicholson, W.S. Cox, and J.I. Teasley. 1966. Pesticide contamination of surface water by sugar cane farming in Louisiana. Trans. Am. Fish Soc. 95(3).

U.S. Public Health Service. 1965. Ashley River Pollution Study. Southeast Water Laboratory, Charleston.

Grzenda, A.R., G.J. Lauer, and H.P. Nicholson. 1964. Water pollution by insecticides in an agricultural river basin, Part II: The zooplankton, bottom fauna, and fish. Limnol. Oceanogr. 9(3).

Lauer, G.J. 1964. Sugar cane, pesticides, and water in Louisiana. Amer. Sugar Cane Technol. Proc. 11:46-52.

Nicholson, H.P., A.R. Grzenda, G.J. Lauer, W.S. Cox, and J.I. Teasley. 1964. Water pollution by insecticides in an agricultural river basin, Part I: Occurrence in river and treated municipal water. Limnol. Oceanogr. 9(3).

Dorris, T.C., B.J. Copeland, and G.J. Lauer. 1963. Limnology of the middle Mississippi River, IV: Physical and chemical limnology of river and chute. Limnol. Oceanogr. 8(1).

Grzenda, A.R., G.J. Lauer, and H.P. Nicholson. 1962. Insecticide contamination in a farm pond, Part II: Biological effects. Trans. Am. Fish. Soc. 91(2).

Nicholson, H.P., J.F. Webb, G.J. Lauer, R.E. O'Brien, A.R. Grzenda, and D.W. Shanklin. 1962. Insecticide contamination in a farm pond, Part I: Origin and duration. Trans. Am. Fish. Soc. 91(2).

SELECTED REPORTS AND CONSULTING EXPERIENCE:

The American Petroleum Institute (API)--

- Prepared a Monograph on Ammonia: Toxicity, Chemistry, and Fate in the Environment.
- Prepared a Monograph on Chromium: Toxicity, Chemistry, and Fate in the Environment.
- Prepared technical comments on U.S. EPA's Proposed Effluent Toxicity Documents.

CECOS, International--Prepared Draft Environmental Impact Statements (DEISs) to the New York State Department of Environmental Conservation on hazardous waste management and disposal facilities.

City of New York Department of Environmental Protection--Assessed the environmental effects of disposal of municipal sewage sludge in the Atlantic Ocean and land-based alternatives to disposal in the ocean.

The Fertilizer Institute (TFI)--

- Reviewed the literature on the toxicity, fate, and sources of ammonia in surface waters.
- Analyzed STORET ambient ammonia data.
- Consulted TFI's comments on U.S. EPA's proposal to list ammonia as a Toxic Pollutant under the Clean Water Act.

The Inter-Industry Cyanide Group--Conducted an overview and analysis of the literature on chemistry, fate, toxicity, and detection of cyanide in surface waters.

Keystone Bituminous Coal Association--Conducted technical review and prepared comments on State of Pennsylvania proposed revisions of water quality for ammonia, cyanide, iron, phenol, and total dissolved solids as influenced by several stream flow scenarios.

Orange and Rockland Utilities, Inc.--Prepared Bowline Point Generating Station 316(a) Demonstration.

Pennsylvania Power and Light Company--Conducted technical review and prepared comments on State of Pennsylvania proposed revisions of water quality criteria.

Power Industry Advisory Committee to ORSANCO--Prepared comments on proposed water quality standards for main stem of Ohio River.

Utility Water Act Group (UWAG)--

- Conducted technical review and prepared comments on U.S. EPA-proposed water quality criteria for the priority pollutants cadmium, copper, nickel, zinc, arsenic, chlorophenols, polynuclear aromatic hydrocarbons, chloroform, asbestos, chromium, and mercury.

- Conducted technical review and prepared comments on U.S. EPA draft guidelines for deriving water quality criteria for the protection of aquatic life.

- Prepared comments on U.S. EPA's proposal to list ammonia as a toxic pollutant under the Clean Water Act.

Lisbon Treatment Plant, Inc.

- Performed biomonitoring tests and evaluation of treated and untreated Chemline Run effluent.

- Performed tiered integrated toxicity assessment to determine whether the untreated Chemline Run discharge would endanger aquatic life in the west fork of Little Beaver Creek, Ohio.

Twin Valley Conservation Association, Inc.--Prepared biological assessment of the proposed Twin Valley Water Resources Project, Nebraska.

Central Platte Natural Resources District (Nebraska)--Participated in "An Evaluation of Historical Flow Conditions in the Platte River as Related to Vegetation Growth and Habitat Use by the Endangered Whooping Crane and Bald Eagle and the Threatened Interior Least Tern."

Interstate Task Force on Endangered Species--Contributed to an evaluation of "Migration Dynamics of the Whooping Crane, with Emphasis on Use of the Platte River in Nebraska."

Numerous Clients--Directed studies and assessments of survival rate of fish and other aquatic life through steam electric plant cooling water systems and hydroelectric plant turbine systems.

Study Areas-Surface Waters

BEFORE THE
STATE OF WISCONSIN
DIVISION OF HEARINGS AND APPEALS

Application of Exxon Corporation for Permits to Build and Operate an Underground Mining and Ore Concentrating Complex Located in Forest County, Wisconsin	) IH-86-18

TESTIMONY OF GARRETT G. HOLLANDS

PART I: WETLANDS BASELINE

Q. Please state your name.

A. Garrett G. Hollands.

Q. Where do you live, Mr. Hollands?

A. 9 Scar Hill Road, Boylston, Massachusetts 01505.

Q. By whom are you employed?

A. I am employed by Interdisciplinary Environmental Planning, Inc., which is commonly referred to as IEP, Inc. IEP is based in Northborough, Massachusetts.

Q. And what is your position with IEP?

A. I am its Vice President/Senior Geologist and a principal of the firm.

Q. Would you please briefly discuss your educational background and your work experience?

A. My resume, which appears in the record as EXHIBIT 247, is a synopsis of my professional experience. In brief, I have a Bachelors of Arts degree in Geology in 1966 from the State University of New York at Buffalo and a Master of Sciences degree in Geology from the University of Massachusetts at Amherst. From 1967 to 1970, I served in the United States Army Corps of Engineers, serving as, among other things, an instructor of photogeology, aerial photography, map reading and terrain analyses. I have worked in both government agencies and private industry, and since 1975 have been a Senior Geologist and a Principal with IEP, Inc. My primary role has been as manager of the Wetlands Division. In that capacity I have served as geologist and project manager in performing thirteen townwide wetland projects and over five hundred site specific wetland analyses in more than sixty towns in the Commonwealth of Massachusetts. Clients on these cases have included state and federal agencies, various local boards and commissions, and private industry.

I have also worked with the Massachusetts Audubon Society in preparing various wetland publications. In addition, I have served as a Director and Vice President of the Massachusetts Association of Conservation Commissioners, which is the major environmental organization in Massachusetts involved in wetland protection.

Q. Would you also please discuss the background and experience of IEP, Inc?

A. IEP, Inc. was founded in 1975 to offer interdisciplinary scientific assessments of environmental problems. IEP consists of seventy-one individuals, including various kinds of geologists, surface water hydrologists, meteorologists, biologists, limnologists, hazardous waste specialists, environmental planners and engineers. The company is divided into various discipline groups, including wetland management, hazardous waste, groundwater supply, surface water hydrology, lakes management and planning sections. In the wetland management section, consisting of 11 full-time professionals, we offer a variety of services including wetland boundary mapping, inventories of wetland natural resources, determination of wetland functions and values, the rating of wetland functions and the analyses of impact of wetlands and the means to mitigate those impacts. Different kinds of wetland projects that we conduct include municipal planning and site specific wetland mapping, identification of wetland resource areas, wetland enhancement and management, wetland impact identification and mitigation, wetland construction and replication, pond design and rehabilitation, site planning to minimize wetland impacts, wetland permit filing, formulation of wetland regulations and bylaws, and public education regarding wetland issues.

Q. Were you and your firm retained by Exxon Corporation in connection with the Crandon Project?

A. Exxon retained the firms of Normandeau Associates, Inc. of Bedford, New Hampshire and IEP, Inc. to perform various wetland studies. Dennis Magee of Normandeau Associates and I were the principal investigators and the individuals who performed most of the work on this project.

Q. When were you retained?

A. In January of 1981.

Q. What was your assignment from Exxon with respect to this project?

A. IEP, Inc. and Normandeau Associates, Inc. were retained by Exxon to perform three general activities concerning wetlands. First, we were requested to undertake a comprehensive examination of the Crandon Project study area to locate and map wetlands that occur within that area. In the process of doing this, we also developed and utilized a wetland inventory method which was then used to assess the functional quality of those wetland areas.

These wetland mapping and assessment activities enabled Exxon to design the Crandon Project facilities so as to avoid or at least minimize impacts to wetland areas.

Second, after our surveys had been completed Exxon personnel frequently consulted with us as Exxon made various siting and design decisions with respect to the Crandon Project facilities. On these occasions we advised Exxon of the relative impacts to wetlands that would result from the various siting and design alternatives.

Finally, Exxon asked us to determine what impacts to wetlands in the study area could result from the design and operation of the Crandon Project and we aided Exxon in writing various sections of the Environmental Impact Report.

Q. Did you prepare reports of your work and findings?

A. The major report that was generated by this work is called Wetlands Assessment Report - Crandon Project, prepared by Normandeau Associates, Inc. and Interdisciplinary Environmental Planning and dated August 1982. This report describes methods and results, and includes a separate map volume containing detailed wetland maps of the study area and a separate bound report containing the technical appendices. That report appears in the record as EXHIBIT 183. We also prepared a report entitled Supplemental Wetland Assessment Report, Crandon Project, dated August, 1983. This report is similar to the Wetlands Assessment Report but is supplemental in that it investigated additional wetland areas. This report appears in the record as EXHIBIT 185. IEP also prepared the 1982 report entitled Hydrologic Water Balance of Selected Wetlands, which appears as EXHIBIT 184. This report investigated the existing and proposed water balances for wetlands that would be affected by the Mine Waste Disposal Facility. We also aided Exxon in preparing Chapter 4 of the Environmental Impact Report, which is EXHIBIT 158 in the record.

Q. Mr. Hollands, what will be the major focus of your testimony?

A. I will testify in two parts. Today, I will testify with respect to my assessment of the wetlands in the area as they currently exist and will explain how we went about making our assessments. Later in these proceedings I will give testimony with respect to the impacts of the Crandon Project on these area wetlands. That testimony will essentially have two themes: first, how project facilities were designed and located to minimize impacts to wetlands; and second, what are the remaining potential impacts to wetlands.

Q. Mr. Hollands, what is a wetland?

A. A wetland is an area where water is near or at the land surface for a sufficient portion of the growing season to give rise to a wetland vegetative community. Also, wetlands are areas where hydric soils are found. Hydric soils are those that have formed where water has occurred at or near the land surface for a considerable time. They consist of both mineral soils and organic soils. There are many different definitions of what is a wetland but the definition which I just gave is the most commonly accepted definition. It is generally felt that in order for an area to be classified as a wetland you must have at least three parts present. Those parts are a wetland vegetative community, wetland soils and wetland hydrology. Across the country you find a wide variety of wetland definitions but all of those wetland definitions generally incorporate the three parts that I just described.

Among experts working in the field, there can be different opinions as to where the exact boundary of the wetland is because the boundary between wetland plants, soils and hydrology and upland plants, soils and hydrology is generally transitional. It is generally not an extremely sharp boundary. In many cases, the transition zone between wetland and upland can extend for a wide area, in some cases, hundreds of feet. The area's past land uses also can affect the location of the wetland boundary. I would like to use two slides at this point to show examples of actual wetlands on the Crandon site. The first slide is of wetland F-37 (EXHIBIT 248) which is typical of a lakeside shallow marsh associated with Deep Hole Lake, a high value uncommon type of wetland found on the site. The second slide shows a typical deciduous wooded swamp, wetland F-65 (EXHIBIT 249), which is a common type of wetland found in the study area. Wetlands less than a quarter acre were not assessed, but were mapped.

Q. Mr. Hollands, what is the value of a wetland?

A. Only recently has there been a public awareness that wetlands are indeed very valuable parts of our landscape and are worthy of protection. Until the late 1960's wetlands were considered as wastelands, swamps infested with vermin, areas which generated diseases. Accordingly, wetlands were dredged, drained, filled and altered to the point where a large part of our nation's wetlands were lost. This resulted in dramatic decreases in fish and waterfowl populations dependent upon wetlands, an increase in flooding, and a decrease in the qualities of lake and stream waters. In response, the scientific community began to investigate the roles that wetlands play and their values to man. In the late 1960's, Congress and state legislatures began enacting statues to protect wetlands. By the mid-1970's, these laws had evolved into substantive statutes and regulations capable of protecting wetlands.

Q. Are there such laws here in Wisconsin?

A. Yes, Wisconsin has some of the most comprehensive laws in the nation respecting protection of wetlands. With respect to mining activities, such as those proposed as part of the Crandon Project, these criteria are set forth in N.R. 132.06(4) of the Wisconsin Administrative Code. That regulation provides a very comprehensive definition of the various functions of wetlands, sets forth criteria that must be considered in assessing the relative values of various wetlands, and provides that mining activities must be designed and carried out so as to minimize wetlands losses and cause the least overall adverse environmental impact to wetlands.

Q. Were you, then, guided by the provisions and criteria of N.R. 132.06?

A. Yes. That regulation was our benchmark both as we went about assessing the value of wetlands in the Crandon Project area and as we evaluated the potential impacts to wetlands that might result from various design and location alternatives. Our reports which I have identified earlier discuss in great detail each of the many elements set forth in N.R. 132.06. I would propose in my testimony today to provide you with a summary of the elements we considered, to explain how we went about evaluating those elements, and finally to provide you with our assessments of the baseline characteristics of the wetlands in the Crandon Project area.

Q. Mr. Hollands, you earlier mentioned some of the functional values of wetlands - protecting fish and waterfowl, providing flood protection, and contributing to the water qualities of lakes and streams. Would you please expand a bit on what are the various functions of wetlands?

A. I would refer you here to N.R. 132.06(4), which provides a detailed analysis of the various functions that wetlands serve. EXHIBIT 250 summarizes these functions which must be evaluated pursuant to N.R. 132.06(4).

Q. Mr. Hollands, referring the EXHIBIT 250, what is the "biological function" of a wetland?

A. The biological function of a wetland is its ability to provide habitat for all wild plants and wild animals. It is also the primary productivity value which a wetland has.

Q. What is the "hydrologic support function" of a wetland?

A. The hydrologic support function of a wetland is the ability of a wetland to maintain downstream aquatic ecosystems through maintaining water quality and quantity.

Q. What is the "ground water function" of a wetland?

A. The ground water function of a wetland is the ability of a wetland to serve either as a recharge area or a discharge area for ground water flow. That is, many wetlands which serve as a recharge area have the ability to store water and allow that water to slowly infiltrate through the wetlands' soils and into the underlying aquifer recharging that aquifer. Other wetlands that have a discharge function have the ability to regulate the rate at which water leaves an aquifer and enters a surface water stream.

That regulation of flow in many cases creates storage of ground water within the aquifer.

Q. What are the "storm and flood water storage functions" of a wetland?

A. Many wetlands have the ability to store inflowing stormwater for a period of time and to release that stormwater to downstream areas. This storage of floodwaters in many cases results in the leveling out of peak discharges from tributary streams, resulting in a decrease in stream flow peak discharge and a decrease in downstream flooding.

Q. What is the "shoreline protection function" of a wetland?

A. The shoreline protection function of a wetland is the ability of vegetative communities growing on the edge of an open body of water to mitigate damages that may result from wave action and stream flow. In many cases, it is an erosion protection function. In other cases, it may be a buffering of stormwater or stormwaves to prevent damage to other wetland or upland areas.

Q. What is the "water quality maintenance function" of a wetland?

A. The water quality maintenance function of a wetland is the ability of a wetland to accept in-flowing contaminated water, to allow contaminated water to interact with the wetland vegetative community and soils, and discharge cleaner water than what came in to downstream areas.

Q. What are the "cultural and economic functions" of a wetland?

A. The cultural and economic functions of a wetland relate to the value that a wetland may have for monetary reasons such as the harvesting of wild rice or the production of timber products. The cultural aspects of a wetland may relate to various cultural activities that may occur in association with a wetland.

Q. What is the "recreational function" of a wetland?

A. The recreational function of a wetland is the value that a wetland may have to human beings for recreational uses. Some wetlands are used for hunting and fishing activities. Others may be used for bird watching or other recreational activities that could occur specifically within wetland vegetative communities.

Q. What is the "aesthetics function" of a wetland?

A. A wetland is a portion of the landscape and many wetlands have a very different aesthetic quality to them than surrounding uplands. Wetlands that have broad views across them in many ways serve to open up the landscape and provide for pleasing views.

Q. What is the "educational function" of a wetland?

A. Some wetlands can be used as outdoor classrooms. They may have particular characteristics which make them more suitable than other types of wetlands for elementary, high school, or university groups to go to those wetlands and learn about the plants and animals that occur within them.

Q. What is the "regional context function" of a wetland?

A. The regional context function of a wetland relates to the fact that our wetlands are not single entities. They are normally part of riverine systems. The value that an individual wetland has may be small but that value when added to other small downstream wetland values can become a very large value.

Q. What is meant by the "regional scarcity of wetland type"?

A. The regional scarcity of wetland types relates to the amount of wetland area of a particular vegetative community type in comparison to the amount of that type of wetland vegetative community found within a given region. In the case of the Crandon Project the region was defined as that area of the Wolf River drainage watershed above the Town of Langlade.

Within that region there occur a wide variety of wetland types such as shrub swamps, wooded swamps and marshes. The wetlands of the Crandon Project study area can be assessed as an individual wetland within the Crandon Project study area only or as a percentage of the overall larger area of the wetlands of the region. Some types of wetlands are more common than others. For example, aquatic beds within the region are relatively scarce in comparison to wooded swamp communities.

Q. What is meant by the "relationship to aquatic study areas, sanctuaries and refuges"?

A. The State of Wisconsin has designated various areas as aquatic study areas, sanctuaries or wildlife refuges. Wetlands may be part of those aquatic study areas, sanctuaries and refuges or they may be upstream of those areas and contribute to the quality of those downstream areas.

Q. How, then, did you go about assessing all of these various functions?

A. Let me give you a general overview of our approach before moving on to the details. I should emphasize at the outset that, in many ways, this was a pathbreaking effort. It has been pathbreaking in at least two respects.

First, when we performed our work in 1981 and 1982, there were few published wetland assessment procedures, none specific to N.R. 132.06 (4), and no one generally recognized wetland assessment procedure. Existing assessment methods were very simplistic, lacking the detail necessary to satisfy the requirements of N.R. 132.06(4). We therefore had to design our own, drawing on procedures we had previously used in other states, along with the procedures set forth in N.R. 132.06(04). In reality the law requiring wetland assessment was enacted before procedures for assessing them were developed. Although other assessment procedures have since been developed, I believe our method has withstood the test of time and has produced results that are comparable to or better than those that would be obtained pursuant to other published assessment procedures.

I believe our efforts have been pathbreaking in a second respect: Given the enormous amount of data we collected -- ranging from aerial infrared photography to field examinations of each wetland in the large study area -- I believe it is fair to say that the 158 wetlands in the Crandon Project study area are among the most thoroughly assessed wetlands in my experience.

Our assessment procedures consisted of several steps as seen in EXHIBIT 251. First, we had to identify where the wetlands are in the Crandon Project study area. This began with a review of existing maps and aerial photography. When we had determined that these existing data were insufficient, we undertook our own aerial photography and mapping efforts. Wetlands were delineated on aerial photographs and transferred to 1"=400' scale orthophoto topographic maps. The maps were modified based on our field inspections.

The second step was to design models for the various functions I earlier discussed so that we could determine through a scoring method the relative value of each wetland. This semi-quantitative method has its limitations. One cannot rely too extensively simply on a "raw score" for a wetland given all of the various considerations involved. There are elements of judgment that enter into the semi-quantitative approach, and the results must always be considered along with a qualitative judgment that one makes from actually observing and studying the area. Our approach, more thoroughly discussed in our reports, was therefore both semi-quantitative and qualitative. But the semi-quantitative scores computed through the models that we used were quite valuable. They enabled us to determine a "mean" and to flag the "above average" and "below average" wetlands. The semi-quantitative approach was therefore a valuable tool in planning and in making comparisons among various wetlands.

Once we had created the various functional models, it was necessary to go out into the field to collect the data that would be used in these models as well as in making the qualitative judgments referred to above. We used a multi-disciplinary team in collecting data. A botanist and a geologist inspected every single wetland in this area and inventoried all 158 wetlands larger than one-quarter acre. For each, we assembled a comprehensive inventory of the wetland's ecological parts -- its vegetative, topographic, hydrologic, geologic and socioeconomic elements.

Our final step was to put all of the data we had collected into the models and compute scores for the various functions for all of the wetlands we had studied. Putting all of the various functional scores together, we also computed overall scores for the relative values of the wetlands. We also modified our inventorying efforts based on the observations and analyses we had performed in the field. Our semi-quantitative findings, along with our qualitative assessments of the various wetlands, are set forth at great length in the Crandon Project <u>Wetlands Assessment Report</u> and the <u>Supplemental Report</u>.

Q. Mr. Hollands, before moving on to the details of these various steps and your actual findings, let me ask you about your statement that "no one generally recognized wetland assessment procedure existed" when you performed this work in 1981 and 1982. Is there such a generally recognized procedure now?

A. A wetland assessment procedure has been developed since the time of our work and is now the most generally accepted approach to wetlands assessment. It is known as the "Adamus System," named after its author, Paul Adamus. The Adamus System was sponsored by the United States Fish and Wildlife Service and was developed initially for the United States Department of Transportation for use in determining the wetland impacts of highway construction. The Adamus System was developed in 1983. I believe it is a very fine approach to wetlands assessment. I say that for two reasons. First, the U.S. Fish and Wildlife Service asked me, along with 35 other wetland experts, to review the draft procedure as Adamus was putting it together in 1983. That group had various input into the procedure in its draft form. Second, my colleagues and I have used the Adamus System since it was published, and we believe it produces suitable results for project planning decisions.

Q. What are the differences between the assessment procedure you used for the Crandon Project and the wetland procedure embodied in the Adamus System?

A. There are similarities between the two procedures both in the data used and in the results obtained. Both employ a semi-quantitative approach and must therefore be used only as one tool in making ultimate determinations about the value of a given wetland. The major distinction between the two is that the approach we used on the Crandon Project yielded "above average" and "below average" values for wetlands. The Adamus System, on the other hand, yields "high", "medium", and "low" values for the wetland assessed. Moreover, only seven of the fourteen functions evaluated by the Adamus System are comparable to the ten functions addressed by our model. Essentially, however, the two systems yield very comparable results.

Q. In your professional opinion, would the assessment of wetlands in the Crandon Project area change significantly if one had used the Adamus System (if it had existed at the time) instead of the system that IEP developed?

A. In my professional opinion, the two systems yield very comparable results. I say that for two reasons. First, we have used both systems on various projects and know that the results obtained are in fact comparable in the great majority of cases.

Second, we compared the two systems with respect to a random sampling of the wetlands analyzed for this very project, and we confirmed that the results are very close.

Q. Turning to the various steps in your assessment process, Mr. Hollands, you mentioned that the first step was to map the wetlands in the area. What was the nature of that work?

A. The Wisconsin Department of Natural Resources and Dames and Moore had earlier mapped the wetlands of the Crandon Project study area at small scale. This work was done primarily by aerial photograph interpretation with little "ground truthing." The small scale maps do not allow for a great deal of definition as to where wetlands occur. Also, only wetland areas of large size were mapped.

When IEP and Normandeau got involved in the wetland assessment project, we reviewed this earlier work and found that it was not of sufficient scale, detail or accuracy for adequate assessment purposes. Thus, we reviewed the existing aerial photography that Exxon had to see if it could be used for wetland mapping and we discovered that Exxon had a wide variety of types of aerial photography covering the study area including panchromatic (black and white) aerial photography, true color aerial photography, and color infrared aerial photography of a wide variety of scales and qualities and coverages. In addition, we discovered that Exxon had a very good orthophoto topographic map at a scale of 1"=400'. We worked out with Exxon a flight plan and specifications for additional color aerial photography to be flown.

This aerial photography was flown and we used this new aerial photography, as well as the other previously existing aerial photographs, to delineate all the wetland areas and then transferred those delineated wetland boundaries onto the orthophoto topographic map. By doing this, we were able to delineate all wetlands in the study area, to include those less than one-quarter acre in area. We were able to delineate the various hydrological connections between the different wetland areas that, in many cases, give rise to the values of the wetlands. This had not been done by previous investigators. As shown on Exhibit 254, each wetland greater than one-quarter acre was assigned a letter for its watershed and a number starting with 1 at the low point of the watershed. Wetlands along riverine systems were divided by changes in hydraulic reach. The wetland watershed systems were assigned letters, i.e. watershed A-Z. We also determined the vegetative communities of each wetland from the aerial photography and entered the various vegetative community boundaries onto the wetland maps.

With draft wetland maps prepared, we were then in a position to go out into the field with the maps and aerial photography to inspect and inventory each wetland. Various elements appearing on the maps, wetland boundaries, wetland watersheds, and the vegetative community boundaries were verified and modified on the basis of our field inspections.

Q. You mentioned that IEP developed its own model for use in its work on the Crandon project. What was the genesis of that model?

A. Starting in 1975, IEP began detailed mapping assessment of wetlands on a town-wide scale in Massachusetts. At the same time, we developed a method for inventorying the various natural resource parts of a wetland and transferring that resource data into a relative rating of each wetland for the various wetland functions that are protected by Massachusetts law.

We did a number of town-wide wetland mapping projects that enabled us to perfect our inventorying methods, our mapping methods and our assessment methods, and we produced a number of documents for various municipalities in Massachusetts that told them which wetlands were their high value wetlands and which ones were their low value wetlands. These determinations of wetland values were then used by the town conservation commissions regulating wetlands in deciding whether proposed projects should be allowed or denied. We also performed similar work for the Commonwealth of Massachusetts, including an extensive study of Cape Cod wetlands.

These methods were based in large part on our professional experience and judgment, but also were based upon extensive surveys of the different literature concerning wetland assessment that existed in the 1970s. Heavy emphasis was put upon some of the methods that the U. S. Army Corp of Engineers was using and also the work that was done by Professor Larson and Professor Golet from the University of Massachusetts and the University of Rhode Island, respectively.

Thus, when we were asked by Exxon to become involved with wetland assessments for the Crandon Project, basically we had already developed and had tested with about five years of experience a method of going into the field and inventorying wetlands, and taking that inventory and establishing the value of each wetland for different wetland functions. For the Crandon Project we took that earlier Massachusetts experience and modified it to meet the requirements of NR 132.06(4) of the Wisconsin Administrative Code. We also modified our modeling procedures as necessary to take into account site specific conditions that occur at the Crandon Project. For example, surficial geology at the Crandon Project differs slightly from the typical surficial geologic materials found in Massachusetts. On the Crandon Project area the clayey glacial tills are denser than the sandy glacial tills found in Massachusetts. Thus, the runoff characteristics of upland areas in the Crandon Project area differ slightly from similar uplands in Massachusetts. The climatic conditions that occur in the Crandon Project area are also different from the Massachusetts area. In the Crandon Project area there are about 31 inches of rainfall per year whereas in Massachusetts there are about 42 inches of rainfall. Therefore, some of the hydrogeologic characteristics of our modeling were altered to reflect these differences in precipitation and hydrogeology.

Before we finalized the method that we used on the Crandon Project area, we met with Wisconsin Department of Natural Resources wetland personnel and gave them a presentation showing them the methods that we had used in Massachusetts and the methods we were proposing to use on the Crandon Project. We modified our proposed methods based upon these discussions. In particular, we added the strictly qualitative approach to our method, an approach that was not new to us as we had already used it in other projects in Massachusetts.

Q. What was your model designed to determine, and what are its elements?

A. We actually developed 10 different models to evaluate the various wetland functions that I discussed earlier. These models enabled us to compare the function and value of any given wetland to others in the study area. In preparing each of the functional models, we needed first to identity those physical and biological factors which govern each of the functional values. We then needed to identify those data elements necessary to measure each of these physical and biological factors, and to determine the appropriate weight to give to these different data elements and how to go about rating differences among the elements. These decisions were guided in large measure by the requirements of NR 132.06 and were also based on extensive discussion among Normandeau, IEP, Exxon and the Department of Natural Resources.

Q. Could you give us an example of the structure of one of these models and what you mean by "physical and biological factors which govern each of the functional values"?

A. Let me here refer you to EXHIBIT 252, which illustrates the hydrologic support model. This model assesses the ability of a wetland to influence water quality and quantity in downstream wetlands and to maintain downstream ecosystems. As you can see, there are a number of elements that make up the model: size of the wetland, its topographic configuration, the dominant hydrologic type, fluctuations in water level, whether the wetland has an outlet or an inlet, and the percentage of the wetland which borders on open water. As you can see from the right-hand column, we assigned "conditions" to each of these elements. For example, the element of "size" could be assigned a condition of large, moderate, or small. You will see that each of these conditions was assigned a given weight.

As you can see from the second column, each of the various elements was also assigned a weight to account for the fact that some of the elements, such as size, hydrologic type, the presence of an outlet, and the percentage of the wetland bordering on open water, are more important to the hydrologic support function than are other elements.

As seen from the bottom of this figure, it is possible under this model for any given wetland to have a hydrologic support functional value ranging from 6 to 66.

Q. You mentioned that IEP used a number of other functional models. What were they designed to assess?

A. Although I do not propose to review each of the other nine models in the same amount of detail, let me briefly explain what each model is and what it was designed to do.

The biological function model was designed to assess the primary productivity of the botanical and zooogical communities living in the wetland.

The ground water function model was designed to assess the ground water recharge or discharge role a wetland has and its influence on the ground water table.

The storm and floodwater storage function model looks at a wetland's ability to store floodwaters and reduce peak discharges downstream.

The shoreline protection model enabled us to assess the ability of each of the wetlands in the Crandon Project area to prevent erosion by waves and current.

The water quality maintenance model assesses the ability of a wetland to improve inflowing contaminated water and to discharge cleaner water.

The cultural/economic model looks at a wetland's value to man from a cultural and economic viewpoint.

The recreational model examines the value of any given wetland from the standpoint of man's recreational activities.

The aesthetics model examines the wetland's scenic value to man.

The educational function model, the final model, assesses the value the wetland has for formal educational purposes, actually or potentially.

The next step in the assessment method was to use the inventory data to assign a qualitative value for each function. This is extremely difficult, and requires the considerable exercise of professional judgment. Those elements of the inventory believed to be of most qualitative value were listed and for each a subjective rating of high, medium or low was assigned for each wetland of special interest as shown on EXHIBIT 253. Again, the data yielded are a valuable tool but are not the final word. The semi-quantitative method numbers are used along with qualitative assessments. Together, the two methods allow decision makers to determine the value of the given wetland as compared to others and to allow for the appropriate design and location of facilities. All of this is set forth at great length in our reports.

Q. Mr. Hollands, you mentioned earlier that after identifying the wetlands and developing the models to evaluate the functions of these wetlands, IEP then went into the field to observe each of the wetlands and to gather data. Would you describe that process for us?

A. There was one further necessary step before commencing our field work: the development of an inventory format that would allow collection of the required data with maximum efficiency. We developed a Wetland Inventory Form that served three functions. First, it enabled us to summarize all the resource elements required as input for the wetland function models. Second, it provided a checklist to promote consistency in the evaluation and inventory process from one wetland to the next. Third, the form became a permanent description of the wetland and a record of our inventory procedures. The inventory form contained a listing of those resource elements required by the 10 functional models. Under each major heading were subheadings containing various choices. Using this form, the inventory team was required to make a choice as to which condition under the subheading best described the wetland in question. Upon completion of the inventory, the elements that had been checked were entered into the appropriate functional models for the evaluation of each function.

Q. Very well. And when the Wetland Inventory Form had been developed, you were then ready to go into the field?

A. Yes. We used a 2-man team consisting of Dennis Magee, a botanist, and myself, a geologist. Additional personnel including wildlife biologists (Dr. Mitcher and Dr. Berry) and a hydrogeologist (Walter Mulica), were used as necessary. The team assessed each wetland larger than one-quarter acre.

Q. How many wetlands were inspected?

A. We inspected a total of 158 wetlands in the approximately 11-square mile study area. At each wetland, we walked into the wetland where the vegetative community was analyzed by the team biologist. He identified the various plant species that he could see and recorded these plant species on the Inventory Report. The geologist examined the wetlands topography, hydrology and soils. At each wetland a peat probe was used to determine the thickness of the soils. Depending upon the size of the wetland, we made many inspections into the interior of the wetland. In addition, we walked around the entire boundary between the wetland and the upland, inspecting the wetland and the upland characteristics of the wetland basin. The biologist was continuously identifying the various vegetative communities and the specific plants that were found there and the geologist was continuously looking at the surficial geologic deposits of the area, the soils of the wetland, and the various hydrologic characteristics of the wetland and the adjoining upland areas. Specific attention was given to the wildlife characteristics of each wetland, such as looking for salamander egg masses in open bodies of water.

Decisions concerning the choice of the proper conditions of each element were determined in the field. If one of the conditions could not be adequately answered, additional field inspections were made until it could be. Each wetland was photographed and various samples of plants and soils were obtained as required. At each wetland the boundary at one location was flagged to show the typical boundary condition between wetland and upland. The location of these boundary determinations were shown on the topographic map. Each inlet and each outlet of the wetland was investigated in the field. Observations were made concerning the amount and quality of water flowing into and out of the wetland. Any seeps or springs that may have occurred around the edges of the wetlands were also located and investigated.

Upon leaving each individual wetland, the inventory sheets were completely filled out, with the exception of some of the area measurements that had to be made from maps back in the laboratory.

Q. And when your field work was completed, Mr. Hollands, what was the next step?

A. We then entered the data from each Wetland Inventory Form into each of the 10 models, and computed "scores" for each wetland. In addition, we reviewed the team's descriptions of each wetland and assessed the qualitative nature of each wetland. These two approaches - the semi-quantitative approach based on our 10 models, and the qualitative approach - enabled us to identify above-average versus below-average wetlands. With this information, Exxon was then in a position, in consultation with us and with the DNR, to locate and design Crandon Project facilities so as to minimize overall impacts to wetlands and to ensure that the mining facilities and operation would result in the least overall adverse environmental impact to wetlands. This information also enabled us to determine what the remaining potential impacts to wetlands might be.

Q. Mr. Hollands, would you illustrate for us, using a typical wetland area as an example, how the various models fit together along with the qualitative evaluations that were made in the field to enable you to render a judgment with respect to the value of the wetland?

A. Let us examine wetland F-66, which is located here (referring to EXHIBIT 254, a map of the area). As seen on EXHIBIT 253 we found that the wetland has a medium value for wildlife. For example, the amount of edge that was found in this wetland, qualitatively, was given a high value. On the other hand, the amount of water to vegetative cover was low. There were really no open waterbodies found in this wetland -- it was entirely forested. The surrounding habitat of the upland surrounding the wetland had a medium value to its variability, thus, it had a medium value for wildlife. A high, a low and a medium value for the wildlife aspects of this wetland result in an average or medium value for wildlife function.

With respect to the hydrological characteristics of this wetland and some of its hydrologic values, we found that it had a very low percentage of open water, and the percentage of wetland bordering open water was low. Thus, this wetland had a very low value for the function of shoreline protection.

Looking at the recharge potential for this wetland, it was given a low rating because it lies in an area that is primarily glacial till and has a very low ability to discharge water from it to the underlying ground water system because of the low permeability of the till. It was rated qualitatively as having high ability for storage of floodwaters based upon the fact that it has a very limited outlet. The wetland has a very high evapotranspiration value since it is densely forested, therefore, it is felt that qualitatively it has a high value for flood storage. Its relationship to downstream aquatic ecosystems is moderate. It falls in a position above and below other wetlands. It has an inlet and an outlet, but the outlet is ephemeral in nature and does not flow all year. Its living filter capacity, or ability to cleanse inflowing water and discharge cleaner water, was considered to be medium because of the contact of inflowing water to the organic soils and the plants of the wetland. The water spreads out through the wetland and has a high ability to interact with those parts of the wetland that would clean any contaminated water flowing water into it and discharge cleaner water in the downstream areas. Therefore, it was considered to have a high living filter function.

Q. Mr. Hollands, we will reserve your evaluations of Exxon's siting and design decisions and your judgment respecting the potential impacts to wetlands until later in the master hearing. Now that you have described what your work was and how you did it, would you describe for us your evaluations of the baseline conditions of the wetlands in the Crandon Project area?

A. Let me refer here back to EXHIBIT 254. We found that the vast majority of the wetlands were of average overall value. No wetland was found to be of no value, and very few were of either very high or very low value. The higher value wetlands were those associated with lakes or large streams, such as Swamp Creek. Average wetlands were generally those associated with small headwater tributary streams. Low value wetlands were all small in size and are perched.

The top ten ranked wetlands were all associated with a lake or large stream. Wetland T4 ranked highest and is a large conifer swamp associated with Swamp Creek. F37 ranked second and is a large marsh, a lakeside wetland, of Deep Hole Lake. F28, the lakeside wetland of Duck Lake, ranked sixth. F2, a marsh and wooded swamp associated with the outlet stream of Little Sand Lake, ranked tenth.

The wetlands of the F61-F66 chain ranked moderate overall. These wetlands are smaller in size, perched on glacial till, and are associated with a small ephemeral headwaters tributary stream.

An example of a low value wetland is F81, a small marsh which is perched on glacial till and isolated hydrologically as it has no inlet or outlet. Thus, it has no additive value to pass downstream to contribute to other wetlands' functions.

The majority of the study area wetlands are coniferous swamps, with deciduous swamps being the next most common vegetative type. Aquatic bed and marsh are the least common types.

Q. Thank you Mr. Hollands. We will resume your testimony later in the hearing process.

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EDUCATION
University of Massachusetts—Amherst
M.S. in Geology, 1975
State University of New York at Buffalo
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PROFESSIONAL EXPERIENCE
IEP, Inc., 1975 to present
Senior Geologist, Principal
- Project manager, geologist, air photo interpreter and environmental planner to investigate the geologic and hydrologic framework of wetlands including mapping, inventory and evaluation of wetlands in 13 town-wide mapping projects and over 500 site specific wetland cases in more than 60 towns in Massachusetts.
- Mapped the surficial geology and subsurface geology for town-wide and site-specific groundwater resource studies and geotechnical projects.
- Conducted detailed monitoring programs for numerous hazardous waste sites.
- Provided expert witness testimony, written and oral, for clients including private citizens, municipal agencies and the Commonwealth of Massachusetts.
- Participated as a geologist in a team effort concerning methods of evaluating development impacts on wetlands and methods to mitigate them: *Wetlands Guidebook*, Massachusetts Audubon Society.
- Served as environmental planner on 30 private development projects.
- Mapped, inventoried and evaluated the hydrologic function of wetlands at the proposed Crandon Mine Site for Exxon Minerals Corporation.
- Directed and inspected numerous borings and test pits for geotechnical and hydrogeologic investigations.
- Directed numerous hydrogeologic studies to determine septic system feasibilities and impacts.

University of Connecticut—Storrs, 1981 Spring Semester
Lecturer, Department of Natural Resources Conservation, Aerial Photograph Interpretation

Rhode Island School of Design, 1979 Spring Semester
Lecturer, Photogeology and Terrain Analysis

Jason M. Cortell and Associates, Waltham, Massachusetts, 1972-1975
Chief-Geology Section, Ecosystems Division
- Managed and conducted over 40 geotechnical investigations in Massachusetts, New Hampshire, New York, Connecticut, New Jersey, Pennsylvania, Maryland, Wisconsin and Utah.
- Participated in 9 highway impact studies.
- Developed water resources impact assessment guidelines for federal Department of Transportation and the Department of Housing and Urban Development.

Ontario Department of Mines, 1966.
Geologist
- Mapped the bedrock geology of 125 square miles.

Military Service, United States Army, 1967-1970.
- Instructor of Photogeology, Aerial Photography, Map Reading and Terrain Analysis; Topographic Engineering Branch; Department of Topography; U.S. Army Engineering School, Fort Belvoir, Virginia.
- Combat Intelligence Officer, 27th Engineers Battalion (combat) Vietnam.
- Combat Engineer Platoon Leader, Executive Officer and Acting Company Commander, Company C; 27th Engineers Battalion (combat) Vietnam.

PUBLICATIONS
Hollands, G.G., 1973. *History of deglaciation of southern Erie County, western New York*, Geological Society of America Abstracts with Programs v.5,no.2.

Hollands, G.G., 1975. *Surficial geology of the Colden quadrangle and history of deglaciation of southern Erie County, New York*, Unpublished Masters Thesis, University of Massachusetts—Amherst.

Garrett G. Hollands
Vice-President
Senior Geologist

PUBLICATIONS *(continued)*

Mulica, W.S. and Hollands, G.G., 1977. *Groundwater resource management - a basis for townwide master planning, Stow, Massachusetts,* Journal of Groundwater, v.15,no.4,p.324.

Mulica, W.S., Hollands, G.G. and Yonika, D.A., 1978. *A methodology for determining significant groundwater features in eastern New England,* Geological Society of America Abstracts with Programs, Northeastern Section, v.10.no.2.p.77.

Mulica, W.S. and Hollands, G.G., 1978. *Application of hydrologic planning to municipal groundwater resource protection in eastern New England,* American Water Resources Association Annual Meeting-Abstracts.

Hollands, G.G. and Mulica, W.S., 1978. *Application of morphological sequence mapping of surficial geological deposits to water resources and wetland investigations in eastern Massachusetts,* Geological Society of America Abstracts with Programs, Northeastern Section v.10,no.2,p.470.

Mulica, W.S., Hollands, G.G. and MacGregor, M.A., 1981. *Phosphorus and nitrogen enrichment of kettle lakes, Plymouth, Massachusetts,* Geological Society of America Abstracts with Programs, National Meetings, v.13,no.7.

Mulica, W.S. and Hollands, G.G., 1981. *The role of wetlands in hazardous chemical impact evaluations,* Geological Society of America Abstracts with Programs, National Meetings, v.13,no.7.

Hollands, G.G., 1983. *Application of the new Wetland Regulations for site development,* Wetland Regulations (84-10) Massachusetts Continuing Legal Education, Boston, Massachusetts.

Hollands, G.G. and Flynn, N.C., 1983. *Methods to determine the boundary of Bordering Vegetated Wetlands to solve problems inherent in the New Wetlands Regulations,* Wetland Regulations (84-10) Massachusetts Continuing Legal Education, Boston, Massachusetts.

Hollands, G.G., 1985. *Assessing the relationship of groundwater and wetlands,* in press, Proceedings of the National Wetland Assessment Symposium, Association of State Wetland Managers.

Hollands, G.G., and Magee, D.W., 1985. *A method for assessing the functions of wetlands,* in press, Proceedings of the National Wetland Assessment Symposium, Association of State Wetland Managers.

GUEST LECTURES

University of Lowell
Massachusetts Association of Conservation Commissions
Massachusetts Audubon Society
University of Massachusetts—Amherst
Boston University
U.S. Fish and Wildlife Society
Department of Environmental Quality Engineering
Massachusetts Home Builders Association
Rhode Island Society of Land Surveyors
Radcliffe College
Boston Society of Civil Engineers
Conservation Law Foundation
New England Environmental Conference
Sierra Club
Society of Wetland Scientists

PROFESSIONAL SOCIETY MEMBERSHIP

Geological Society of America
Society of Economic Paleontologists and Mineralogists
The Society of Sigma Xi
Friends of the Pleistocene
Society of Wetland Scientists

GOVERNMENT SERVICE

Member-Conservation Commission, Boylston, Massachusetts, 1974 to 1985.

Chairman-Earth Removal Board, Boylston, Massachusetts. 1973-1981.

Director-Massachusetts Association of Conservation Commissioners, 1978 to 1984.

Geologist-Committee to Review the Proposed New Wetlands Regulations, Wetlands Division, Massachusetts Department of Environmental Quality Engineering, 1982.

Chairman, Technical Subgroup, Wetlands Program Review Board, Massachusetts Department of Environmental Quality Engineering. 1983 to 1986.

Participant, National Wetlands Values Assessment Workshop, U.S. Fish and Wildlife Service. 1983 to present.

Lakeside Wetland

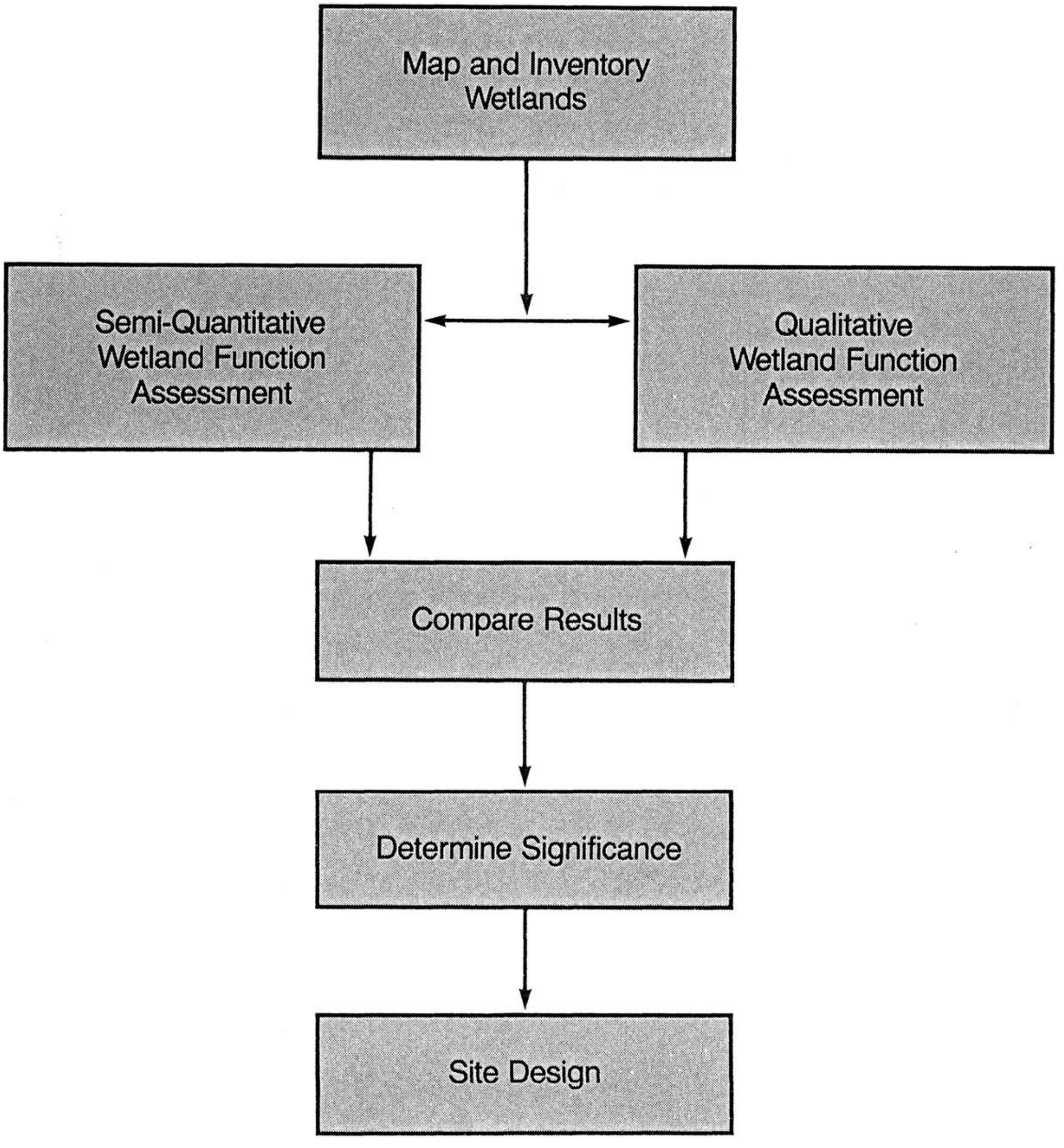
Forested Wetland

Wetland Functions—NR 132

1. Biological Function
2. Hydrologic Support Function
3. Ground Water Function
4. Storm and Floodwater Storage Function
5. Shoreline Protection Function
6. Water Quality Maintenance Function
7. Cultural and Economic Function
8. Recreational Function
9. Aesthetics Function
10. Educational Function

Wetlands Assessment Method

Flow Chart



Project Area Wetlands

Legend

- Lakeside Wetland
- Perched Wetland
- Water Table Wetland

Hydrologic Support
Function Model

Elements	Element Weight	Condition Weight	Conditions
Size	4	3	Large ≥ 4.6 acres
		2	Moderate 1.1-4.5 acres
		1	Small ≤ 1.0 acres
Topographic Configuration	1	3	Semi-closed basin
		2	Valley
		1	Hillside
		0	Closed basin
Dominant Hydrologic Type	5	1	Condition 1
		2	Condition 2
		3	Condition 3
		4	Condition 4
		5	Condition 5
		0	Condition 6
Water Level Fluctuation	2	2	Low
		1	High
Outlet	4	2	Perennial Outlet
		1	Ephemeral Outlet
		1	Ground Water Outflow
		0	Absent
Inlet	1	2	Perennial
		1	Ephemeral
		0	Absent
Percent Wetland[1] Bordering on Open Water	4	1	33%
		2	34-66%
		3	67-100%
		0	Does not border

Range 6-66[2]
Mean 36

[1]Applies only to those wetlands with an outlet.
[2]Total value for one inlet and one outlet only.

Wetland Assessment Examples

Example of major elements used to qualitatively assess wetlands

Wetland No.	Dominant Wetland Type	Amount of Edge	Water/ Cover Ratio	Surrounding Habitat Variability	% Bordering Open Water	Recharge Potential	Water Storage	Discharge to Downstream Aquatic System	Living Filter Capacity	Size	Total
F66	Conifer Swamp	High	Low	Medium	Low	Low	Medium	Low	Medium	Medium	Medium

Example of Semi-quantitative assessment method

Wetland No.	Biological Function	Hydrologic Support Function	Ground Water Function	Storm and Floodwater Storage Function	Shoreline Protection Function	Water Quality Maintenance Function	Cultural and Economic Function	Recreational Function	Aesthetics Function	Educational Function	Total
F66	94	48	33	99	0	68	51	38	31	10	472
Model Ranges	29-158	6-70	20-68	31-123	3-32	18-98	11-57	11-74	9-66	7-24	145-770
Model Mean	93	38	44	77	17	58	34	42	37	15	457

Conclusion: Both methods show F66 to be a slightly above average wetland.

BEFORE THE
STATE OF WISCONSIN
DIVISION OF HEARINGS AND APPEALS

Application of Exxon Corporation for Permits to Build and Operate an Underground Mining and Ore Concentrating Complex Located in Forest County, Wisconsin	))))	IH-86-18

TESTIMONY OF DONALD E. MOE

MINING PERMIT AND FEASIBILITY REPORTS

Q. Please state your name, affiliation, and title.

A. My name is Donald E. Moe. I am employed by Exxon Coal and Minerals Company and hold the position of Design Engineering Manager, Crandon Project. In this position I oversee all of the design engineering associated with the project, including both in-house work and that done by outside contractors.

Q. Will you describe your educational and work background?

A. In 1973 I received a Bachelor of Arts degree in Mathematics from Carroll College in Helena, Montana, and went on to the

Montana College of Mineral Science and Technology where I received my Bachelor of Science Degree in Mining Engineering in 1974.

I have been employed by Exxon for the last ten years and have prior experience with two other mining companies. I am a registered professional engineer in the states of Wisconsin and Wyoming. My experience within the mining industry has included various engineering and management positions including mine engineer, underground mine superintendent, technical superintendent, and engineering manager. I have been in my current position as Crandon Project Design Engineering Manager for the past three years. As Design Engineering Manager, it has been my responsibility to coordinate the engineering work for both the underground mine and surface facilities and to ensure that the proper technical expertise was applied where needed. This included the supervision of technical personnel and programs both within Exxon and through the use of outside contractors.

Q. Do you have a resume providing further details on your qualifications?

A. Yes. It appears as EXHIBIT 257 in the record.

Q. What will be the scope of your testimony on the Crandon Project?

A. My testimony is in support of the Mine Permit application and various feasibility reports which Exxon has filed with the state.

The Mine Permit covers a number of different matters, including facilities design and construction, mining operations, risk assessment and contingency planning, monitoring, and reclamation. These matters, which are all covered in our application, will be addressed by different witnesses. I will be concentrating today on the Mine Plan, which was prepared in accordance with Section 144.85(3)(a) of the Wisconsin Statutes and Section NR 132.07 of the Wisconsin Administrative Code. Immediately after my testimony, Mr. Howard Lewis of Exxon will provide testimony on project reclamation plans. Later in this hearing, Mr. Dick Herbst of Exxon will give testimony on the environmental monitoring and quality assurance plans associated with the project, including the preblasting survey. All of this testimony will be in support of our Mine Permit application.

I will also be testifying in support of various feasibility reports and other documents which pertain to specific facilities associated with the proposed mine. These facilities are the mine waste disposal facility (MWDF), the mine refuse disposal facility (MRDF), and the water reclaim ponds.

Taken together, my testimony will provide a detailed description of the design, construction, and operation of both the underground mine and the surface facilities associated with the mine. I will also review the general construction and operation schedule, and give an evaluation of the risks associated with the project. My testimony, in other words, should provide you with a full picture of the what, when, and how of the Crandon Project.

Q. What are the applications and reports that you have referred to?

A. Exxon's Mine Permit application consists of two volumes and appears in the record as EXHIBIT 111. Volume 1 contains the Monitoring and Quality Assurance Plan and the Mine Plan; Volume 2 contains the Reclamation Plan. As I mentioned earlier, subsequent testimony will cover the Reclamation and Monitoring Plans. This two-volume application was submitted to the Department in revised form in January 1986 in accordance with Chapter NR 132 of the Wisconsin Administrative Code.

The MWDF is covered by the "Mine Waste Disposal Facility Feasibility Report," which Exxon submitted to the DNR in revised form in December 1985 in accordance with the requirements of Chapter NR 182. That report appears in the record as EXHIBIT 114.

The MRDF is covered by the "Mine Refuse Disposal Facility Feasibility Report," which Exxon submitted in revised form to the Department in November 1985 in accordance with the requirements set forth in NR 180.13(6). That report appears in the record as EXHIBIT 113.

Details of the reclaim ponds are included in Appendix B of the "Water Treatment Facility Final Plans and Specifications," September 1986 by CH2M Hill, Inc. That document appears in the record as EXHIBIT 118.

I should add here that all of these documents contain a great amount of detailed information, much of which is required by the governing statutes and regulations. My testimony, which will be based on the documents I have just cited, will only touch on the highlights.

Q. Very well. Would you first please describe the location of the proposed Crandon Project?

A. As you can see from EXHIBIT 258, the project site, which includes the underground mine and surface facilities, is located in Forest County about five miles south of Crandon, Wisconsin. In total, the project site area encompasses approximately 3,971 acres of which about 715 acres will be disturbed and reclaimed over the project life.

Q. Looking first at the underground operation, what mining method will be used for this project?

A. The primary mining method will be blasthole open stoping with backfilling. However, other variations of sublevel stoping and cut-and-fill stoping methods may also be used.

Q. These mining methods sound complicated. Describe for us how the mining will be carried out.

A. It sounds complicated but, in fact, is standard mining industry practice. However, before I describe the mining method it will be helpful to define some terms that I will use in my testimony. Looking at EXHIBIT 104,

(1) A "shaft" is a vertical opening developed from the surface through the rock strata to gain access to the ore and provide openings where air can enter and exit the mine.

(2) Horizontal tunnels called "drifts" are advanced in rock from the shaft to the various work areas in the mine.

(3) A work area in the mine where ore is removed is called a "stope." Here, a series of holes are drilled into the rock, loaded with explosives, and detonated to break and fragment the rock into pieces.

(4) Ore from the stopes will be transported to the "crusher," where the rock will be reduced to 8 inches or less in size.

Present plans call for a vertical shaft approximately 1,800 feet deep with a diameter of 24 feet. This shaft will provide access to the mine for the purposes of transporting workers and materials, as well as for the hoisting of ore and waste rock to the surface. The shaft will contain various services, including power cables and mine water discharge pump columns. Intake air for mine ventilation will enter through this facility.

At each end of the orebody, exhaust air moved by surface mounted fans will exit the mine through an exhaust ventilation shaft. The exhaust ventilation shafts will be concrete-lined in the zone through the overburden.

The nearly vertical orebody will be divided into horizontal main mining levels approximately 300 to 400 feet apart in depth. These main level drifts, or horizontal tunnels, will be large enough to provide clearance for the load-haul-dump (LHD) vehicles, similar to front-end loaders, trucks, and other vehicles used in the mining process. These drifts will generally be 15 ft. wide and 12 ft. high. Levels will intersect the main shaft for worker and materials access and intake ventilation.

A ramp will connect mine levels to allow movement of equipment, supplies, and personnel throughout the mine.

During production from the mine, the orebody will be divided into mining blocks, or stopes. The stopes will be accessed at the top and midpoint by drifts for drilling and blasting the ore from the stope. At the bottom of the stope, a horizontal drift will provide access for the LHD vehicles to remove the broken rock.

A permanent bridge, or crown pillar, of bedrock directly beneath the glacial overburden will be purposely excluded from mining activity. This bedrock barrier will maintain surface stability and prevent subsidence of overburden materials.

Beneath the crown pillar, stoping methods will be arranged to maintain local rock mass integrity and avoid disturbance of the crown pillar. The mining methods provide for backfilling following ore extraction. Mining will generally proceed from depth and the ends of the deposit extremities toward the surface, with mining directly below the permanent crown pillar planned for the final portion of the orebody life. These practices, combined with the fact that approximately 10 percent of the potentially minable ore below the crown pillar will be left in place as pillars throughout the mine, will ensure perpetual stability of the mine area bedrock surface and glacial overburden.

Turning then to the actual mining of a stope shown on EXHIBIT 259, an initial vertical opening called a slot raise will be developed through the entire height of the stope. Blastholes will be drilled adjacent to the raise opening, and the opening enlarged by blasting adjacent ore with explosives, which will drop down into the drawpoints at the stope block base.

This process of blasting ore into a larger opening will continue until all ore within the block has been broken into manageable pieces. As the ore is broken, it will be withdrawn through the drawpoints at the base of the stope. Production blasting will be done normally at the end of a shift. At rated capacity, three to six stopes will be operating in the mine at any given time.

Once a stoping block has been completely emptied, it will be backfilled to provide support for the wall rock before the adjacent blocks are mined. This will allow maximum recovery of the ore and ensure stability of the rock mass during operation and after abandonment, and it will also minimize the requirements for surface disposal of process wastes.

The blasthole open stoping operation does not require personnel to enter the large open stopes at any time. All stoping operations will be conducted from the horizontal tunnels, or drifts. Ground support methods will be used, where required, to maintain the strength and safety of the mine workings.

Q. You mentioned that methods in addition to blasthole open stoping will be used. What are they?

A. On the uppermost mine levels, where the ore and other surrounding rocks have been somewhat weakened by weathering, cut-and-fill mining methods will be employed. These methods will involve removal of horizontal lifts of ore approximately 13-16 feet thick. The void created by each horizontal mining pass will then be backfilled prior to mining the next lift. This approach will limit the size of the unsupported stope walls, and thereby will ensure safe working conditions. Less than 10 percent of the orebody will require use of this secondary, but conventional, mining method.

Q. How will the underground ore transport and primary crushing operations work?

A. In EXHIBIT 259, we can see that ore will be removed from the stopes on drawpoint levels at approximately 300 to 400-foot vertical intervals using rubber-tired, diesel-powered LHD units. For stope drawpoints on the lower levels, LHDs and trucks will haul directly to the crusher coarse feed bins. On the upper mining levels, ore will be transported by an LHD to a vertical opening, or shaft, leading down to the main haulage level; we call these passes. Ore and waste passes will be spaced at convenient locations along the orebody to limit the horizontal haulage distance.

On the haulage level, 26 to 40-ton trucks will be loaded through chutes. Trucks will dump into coarse feed bins over the crusher with one bin each for ore and waste rock.

The crusher will be installed below the main haulage level. This crusher will be capable of crushing rock at a rate of approximately 550 tons per hour. The crusher will reduce the ore from 24 inches in size to less than 8 inches in size. Crushed rock will be transferred by conveyor to the main shaft where it will be hoisted to the surface in large buckets that we call "skips".

Dust suppression and/or collection systems will be used to control dust generated by the handling of the broken ore and rock. At some points, these will be water sprays or foggers. At other points, a system of ducting will collect dust for transport to a collector similar to those used for insertable collector installations. In still other areas, the flow of fresh air will dilute and remove dust from the mine workings.

Q. What will be the ventilation system in the mine?

A. Looking back at EXHIBIT 104, fresh air will enter the mine through the main production shaft. About 35 percent of this air will be heated by natural gas fired heaters during the winter to maintain a minimum air stream temperature of 40°F in the main shaft. The air heaters will be located to the east of the main shaft.

Controlled amounts of this fresh air will be drawn from the shaft on each operating mine level, passed through the various working places, and collected in an exhaust air system.

Ultimately, the exhaust air will be routed back to the surface through exhaust air shafts located at each end of the orebody. Main fans installed on the surface at the top of the exhaust air shafts will be used to move air through the mine. Fans with a total capacity of approximately 850,000 cubic feet per minute will move the air through the mine.

A system of booster fans will be installed at appropriate points in the ventilation system to ensure proper air quality in all active working places. Additionally, smaller auxiliary fans and air ducts will be used to route fresh air to mine areas that are not on a completed ventilation circuit. Ventilation doors and regulators will also be used where necessary to control the air streams. The ventilation system will be regularly monitored and adjusted as necessary to maintain adequate levels of ventilation in all parts of the mine.

The planned techniques for ventilation control are in common use throughout the underground mining industry. These techniques have been refined and proven through many years of use.

Q. How will the waste rock be handled during mine operations?

A. Much of the primary mine development will be done outside the ore zone, thus producing waste rock. The amount of waste rock produced at any given time will vary depending upon the number of openings being advanced in waste versus ore. It is estimated that over the life of the mine, more than seven million tons of waste rock will be produced. Some of the uncrushed waste rock will be retained in the mine and used directly as stope backfill.

Waste rock that is hoisted to the surface will be diverted to the mine backfill plant. Here, the waste will be further crushed to approximately 3/4-inch size for regular addition to the mine backfill. A small portion of the uncrushed waste rock that has been hoisted to the surface will also be used during MWDF pond construction.

Q. How will stope backfill be used in the underground mine?

A. Mine backfill will consist primarily of the sand-size fraction of the mill tailings, but will be supplemented with waste rock retained underground, crushed waste rock added on the surface, and possibly glacial sands. Backfill slurry containing approximately 70 percent solids will be pumped in two buried pipelines from the surface backfill preparation facilities to a pair of holes located on the south side of the plant area.

These holes will be cased through the overburden and fitted with four to six inch diameter distribution pipes.

Backfill will be placed hydraulically into the stopes through openings near the top, and will be retained at the bottom by bulkheads constructed of either reinforced concrete or timber. Necessary drainage facilities will be placed in the stope before filling commences to collect and carry backfill drainage water from the stope.

Cement will be added to the backfill when needed to provide stability so that the column of fill will stand unsupported and enable complete removal of the ore in the adjacent stopes. About one-half of the total fill placed in the mine will contain cement.

Q. How will ground water that seeps into the mine be handled?

A. The mine water pumping system has been designed to handle 2,600 gallons per minute of ground water inflow which is much greater than the expected average of 1270 gallons per minute which will be described later. Mine backfill transport water is estimated to be 270 gallons per minute of which 40 percent will be retained as moisture in the backfill. A minor amount of excess potable water will be a component of mine water.

In EXHIBIT 260, we can see schematically how ground water will be collected by an interceptor system of drainage galleries and drill holes in the rock above the active mine workings. This intercepted water will be collected and pumped to the surface in a separate pipe column. Water not collected in the interceptor system and which flows into the mine workings will be collected in ditches and local mine level sumps. Here, solids will be settled, and the water will then be conducted via pipelines and boreholes to the main mine sumps. Backfill water will be collected at backfilled stopes and will flow through pipelines and/or boreholes to the main sumps. The main sump installation will be on a lower mine level near the main production shaft.

Q. What if water flows into the mine at a rate in excess of 2,600 gallons per minute?

A. The flow of water into the mine will increase gradually as the mine is developed. Over the first three years, the inflow of water into the mine will increase slowly to an expected average of 1270 gpm as the workings expand. This will give ample time to evaluate options to handle the unlikely event of mine inflow greater than the current design capacity.

In the unlikely event that mine water inflow exceeds the design capacity of 2,600 gallons per minute, there are several contingency options. First, the excess inflow could potentially be controlled by pumping water from surface wells or by grouting from underground. Second, mine pumping systems will be designed for the conservative maximum inflow of 2,600 gallons per minute, including installed spare pump and discharge line capacity for a total capacity of 4200 gpm. Surface storage capacity will exist in the reclaim and tailings ponds for temporary handling of excess inflow. The total freeboard volume in the reclaim pond, for example, is 210 acre-feet, or enough for a surge of 1,000 gallons per minute of excess mine pumpage for over one and one half months, which will allow sufficient time to take appropriate action.

Q. Will any other facilities be located underground?

A. Yes. There will be various fuel storage and handling installations, maintenance shops, lunch rooms, and bathrooms.

Q. Would you now give us a more detailed understanding of what happens to the ore and waste after it leaves the mine?

A. Looking at EXHIBIT 106, after ore is hoisted to the surface, it will be conveyed to the covered coarse ore stockpile, which has approximately two mill days of capacity. Coarse ore will then be transferred onto a conveyor for delivery to the concentrator building.

Ore and waste rock from initial mine development will be transported by truck from the headframe to a prepared laydown area north of the concentrator. The pad will be constructed with an impermeable bentonite liner that will prevent run-off water from getting into ground water. Recovery of ore from this storage pad will be managed so that the bentonite and soil liner beneath the storage area will remain in place throughout the project life. While this storage area is planned for preproduction ore, it will be maintained and reactivated as needed to store ore that cannot be immediately processed or used for equipment staging or for concentrate storage.

A small bin to the east of the coarse ore storage facility will be used to contain hoisted waste rock. Waste rock delivered to this bin will be crushed to be used as supplemental mine backfill.

Q. Will ore be crushed on the surface prior to being processed through the concentrator?

A. Only preproduction ore--also called mine development ore--will be crushed on the surface. This is the ore material mined prior to completion of the underground crusher. Approximately 250,000 tons of this ore will be crushed in a temporary mobile crusher so that it is less than 8 inches in size. This crusher, which will operate during the first two years of production, will be located near the coarse ore storage building such that the crushed material can be fed to the ore stockpile.

Q. How are the valuable minerals separated from the waste to produce concentrates?

A. The recovery of valuable minerals from the ore will take place in the concentrator building located northwest of the mine production shaft. The equipment required for extracting the zinc, copper, and lead minerals from the coarse ore will be housed in this building.

EXHIBIT 261 shows a schematic of how the process works. The recovery of the valuable minerals from the ore begins in the grinding circuit. Coarse ore will be conveyed from the coarse ore stockpile directly to a semiautogenous (SAG) mill and ball mill grinding circuit. Here, water will be added to the ore.

A SAG mill is a large horizontal cylinder with heavy steel liners that grinds ore by the tumbling action of both the ore and steel grinding balls.

Fine grinding of the ore will be done in a conventional ball mill. As the mill rotates and the ore and water slurry pass through the mill, the impact and abrasion of the ore and steel balls will reduce the ore size to liberate the minerals.

The slurry of fine particles from the grinding circuit will then be pumped to aerator/conditioners for the addition of air and reagents before it flows to the flotation circuit for concentrate recovery. In the flotation section liberated zinc, copper, and lead mineral particles will be selectively recovered as mineral-rich froths. With selective flotation specific sulfide mineral particles adhere to air bubbles generated in the flotation cells and float to the surface in the form of a froth which collects at the top of the cell. The sulfide mineral froth is then skimmed to separate it from the waste rock slurry or tailings.

Using various reagents, specific minerals may be made to either adhere to an air bubble or to remain in the slurry. The use of these chemical reagents permits the separation and recovery of the metal sulfides as concentrates.

The concentrates of the zinc, copper, and lead minerals will be pumped to separate dewatering and filtering facilities to prepare them for shipment.

Q. What is the dewatering and filtering process?

A. The zinc, copper, and lead concentrates will contain 25 to 35 percent solids by weight with the balance being water. These slurries will be pumped to thickeners as the first step in the dewatering process. The thickened concentrate will contain 55 to 60 percent solids by weight and will be further dewatered using pressure filters. These filters can produce final concentrates with residual moisture levels of about 10 percent by weight.

The concentrate at this point can be transported on a conveyor but is moist enough that it will not produce dust.

Q. Will you briefly describe the concentrate handling and transportation processes?

A. The concentrate will normally be loaded directly into railcars using covered conveyor belts located beneath the filters. When railcars are not available, the conveyor belts beneath the filters can reverse direction and place the concentrate in a temporary storage area beneath each filter area. The temporary storage space will be able to hold about 2 days' production of zinc concentrate, 6 days' production of copper concentrate, and 19 days' production of lead concentrate.

Concentrate will normally be shipped from the project site in 70 to 100-ton railcars at an estimated rate of 15-20 cars per day. Loaded railcars will be covered and shipped to North American refining facilities or to port facilities for shipment to overseas destinations.

Q. What other ancillary facilities are contained in the concentrator building?

A. Ancillary facilities located within the concentrator building include the concentrator control room, reagent storage and mixing area, spill control facilities, and metallurgical and environmental laboratories.

Q. What happens to the waste material or tailings that remain after the concentrates are recovered?

A. As I testified earlier, the underground mining methods planned require stope backfill to stabilize the peripheral in-place rock after the ore is mined. Mine backfill will consist of the coarse fraction of the mill tailings, excess waste rock, and may also require make-up sand from an off-site source. During the milling process, the rock is ground and the density of the material changes such that the total volume of tailings is about twice that of the original in-place rock; therefore, only about one-half of the tailings can be returned underground.

The tailings will be separated with the coarse fraction being pumped to the waste rock crusher/backfill mixing plant located east of the coarse ore stockpile for use underground. Here the coarse portion of the tailings will be mixed with crushed waste rock and pumped to bore holes connected to the underground delivery systems. Facilities will also be provided near the waste rock crusher to meter and mix cement into the backfill when required. The cement storage bins will be located north of the backfill crusher near the railroad tracks.

The fine portion of the tailings separated in the backfill preparation facility will be pumped to a thickener. The tailings thickener will be about 200 feet in diameter, and will be used to settle and dewater the tailings.

After settling, the thickened fine tailings slurry will then be pumped in a buried pipeline to the tailings disposal facility which we call the Mine Waste Disposal Facility (MWDF).

The water recovered from the thickener overflow will be recycled directly to the backfill process as make-up water or will be recycled to the mill via the reclaim water pond.

Q. Before turning to the MWDF and its neighboring facilities located southeast of the mine/mill site, let me ask you to complete your discussion of the other facilities associated with the site.

A. Going back to EXHIBIT 106, we can see that an employee and visitor parking area, with a gatehouse, will be located on the south side of the mine/mill site. The parking area will have asphalt paving with concrete curbs and gutters.

The services building will house major shops, a garage, a warehouse, worker change and shower facilities, and managerial and administrative offices. The shops and warehouse will provide service support and maintenance for the process and mobile equipment. A fire truck and an ambulance will be housed in the garage area. The warehouse will stock maintenance and replacement parts and tools.

A building located east of the coarse ore storage building will be used for processing and storage of drill cores.

Lubricant storage and cold storage buildings will be located east of the concentrator building. Lubricants, paints, and cleaning materials for both the mine and mill will be stored in the unheated lubricant storage building. The unheated cold storage building will be used to store miscellaneous large and cumbersome mechanical parts.

A covered storage area will be located on the east side of the project site. This structure will be an open shed-type facility for storing pipe, pipe fittings, and other parts that require covered storage.

The area south of the covered storage facility will be used for storage of timber, steel, pipe, and other bulk materials that can be stored outside. The storage area will have a graveled surface.

Topsoil and mulch resulting from site clearing and grubbing activities will be stored on the east side of the site. This will provide easy access to these materials for landscaping and reclamation activities.

An explosives magazine and storage area will be located approximately 1,800 feet north of the point where the railroad tracks enter the project site. This area will be provided with fenced security.

The sewage treatment system will handle sanitary wastes from the surface facilities and underground mine. The system will consist of a small package treatment plant utilizing an activated sludge process with extended aeration. Mr. Harris will testify later about this system in greater detail.

Bulk storage tanks for fuel oil will be located above grade to the east of the parking lot. Fuel oil will be required for the underground mining equipment, surface mobile equipment, and emergency power generators.

Fuel for use underground will be transferred from the bulk fuel tanks to two measuring tanks located next to the fuel delivery borehole. A fueling station located east of the tailings thickener will dispense fuel to surface mobile equipment. The fueling station will have one diesel fuel tank and one gasoline tank, both of which will be buried. The fueling station will be designed in accordance with applicable state and federal codes.

Q. Looking at the artist's rendering (EXHIBIT 106), what is the facility at the northeast corner of the concentrator building?

A. That is the water treatment plant, which is designed to treat water pumped from the mine for discharge and to treat process water from the concentrator for reuse. Facilities will also be provided to monitor the quality of the various treated waters to ensure that the treatment systems are functioning properly and producing effluent of desired quality. Excess mine water that has been processed through the water treatment plant will be pumped to discharge lagoons located in the northeast area of the site. These lagoons are designed to retain water for approximately 48 hours prior to pumping to Swamp Creek. This will enable sampling of the treated water and allow for corrective action should the water treatment plant encounter an upset condition. Mr. Harris will describe these treatment facilities in more detail in his testimony.

Q. Will any new water wells be required to supply the project needs?

A. Yes but only for drinking, reagent mixing and pump seals. Potable water will be taken from a new well to be located approximately 0.5 mile southwest of the mine/mill site, as seen in EXHIBIT 201. From that well and pumphouse, underground piping will carry the water to the fresh water tank in the plant area. A separate system of pumps and pipelines will distribute the potable water to points of use. It is anticipated that treatment of this water will not be required. However, a chlorinator treatment system will be provided and available for use if necessary. Additional wells required as part of the Hydrologic Impact Contingency Plan will be covered in later testimony by Mr. Carlton Schroeder.

Q. How will access to the project site area be provided?

A. A new access road will be constructed. The road will consist of two 12-foot wide lanes with 8-foot wide shoulders. A single-span bridge constructed of prestressed concrete girders supported by concrete abutments will cross Swamp Creek. The road will connect with State Highway 55 and proceed in a southeasterly direction for 3.0 miles to the site.

Rail service to the site will be required. The rail spur will be routed from the main Soo trunk line northeast of the site. The spur will consist of a single track approximately 2.7 miles long and three 3,280-foot long sidings located near the connection to the trunk line. A single-span bridge over Swamp Creek will be constructed of prestressed concrete girders supported on concrete abutments.

Railroad track will be provided in the complex for concentrate loading and handling of bulk materials and supplies. A captive locomotive will be used to move railcars within the site and between the site and sidings.

Q. Would you briefly describe the electric power and natural gas facilities that are required for the project?

A. Electric power for the Crandon Project will be delivered at 115 kV from the Wisconsin Public Service Corporation (WPSC) power grid serving the area to a main substation located within the site.

As shown in EXHIBIT 262, the 115-kilovolt powerline from WPSC will originate from the Venus substation approximately 18 miles from the project site. The transmission line will follow a route from the Venus substation along U.S. Highway 8 toward Crandon and then south across a private right-of-way to the main access road for the project. WPSC will be responsible for construction of the transmission line to the terminal structure of the main project substation.

During any loss of power from the WPSC 115-kV system, it will be necessary to supply emergency power to certain underground and surface equipment for safety and environmental protection reasons. Emergency diesel generators will be available to supply emergency power. These will be located at the project substation.

Natural gas will be used for winter season heating of the underground mine ventilation air, for general heating of buildings and facilities, and in the water treatment plant. Natural gas will be supplied by WPSC from an existing pipeline running generally east-west approximately eight miles north of the site. A 6-inch pipeline extension will be constructed from the existing pipeline to a metering station located within the mine/mill site.

The gas will be distributed by underground pipeline from the metering station to the points of use in the mine/mill site.

Q. Mr. Moe, would you please describe the steps that have been taken to ensure that a power supply will be available at the mine site when required?

A. We are negotiating a contract with Wisconsin Public Service Corporation, the utility that will serve the mine with electricity and gas. The contract, which will be reviewed by the Wisconsin Public Service Commission, provides for an allocation of the cost to construct the necessary electrical lines from the Venus substation to the site, the installation and ownership of the necessary switchgear and transformers on the site, and for the subsequent furnishing of power. We are also making suitable arrangements with Wisconsin Public Service Corporation for supplying natural gas. As I have indicated, all of these arrangements will be explained to and, as required, will be reviewed by the WPSC.

Q. Is it necessary for the Wisconsin Public Service Commission to issue any permits in connection with this project?

A. Yes. Application has been made for the issuance of a Certificate of Public Convenience and Necessity (CPCN) to permit the construction of the power line from the Venus substation to the site. That application is complete. There will be another hearing before the Wisconsin Public Service Commission following this hearing. We expect at the conclusion of that hearing that the Public Service Commission will issue the necessary CPCN to Wisconsin Public Service Corporation to permit the construction of the line. We anticipate no problems in obtaining all of the necessary permits and making the contractual arrangements for electric power and natural gas.

Q. Before moving to the southeast to look at the MWDF, let me ask you this final question about the mill operations. You mentioned that Exxon will use chemical reagents in the concentrator processes. What will be the reagent handling procedures?

A. Various chemical reagents will be used in both the concentrator and in the water treatment processes. The reagent storage and handling areas will be designed to keep reagents segregated and provide for worker safety while transporting bulk reagents and during reagent preparation.

Any reagent spills would be recovered and saved for use. Nonreturnable reagent containers, such as bags, will be disposed in the mine refuse disposal facility or in a licensed solid waste facility. Drums are generally returnable and reusable.

A more detailed discussion of reagent spill control measures, reagent use, and reagent addition points in the process can be found in Section D of the Mine Permit application.

Q. Are there other spill control facilities associated with the project?

A. Yes. In addition to the system of concrete sumps and divider walls contained in the reagent preparation area inside the concentrator building, other outside storage tanks will be placed inside earthen or concrete dikes to contain any spillage or tank rupture. A good example of this is the bulk diesel fuel storage tanks. Here, the two 15,000-gallon tanks will be placed inside earthen dikes. The area around the tanks inside the dikes will be lined to prevent any tank leakage from seeping into the surface soils. The entire volume inside the dikes is large enough to contain the volume of both tanks and handle the extremely unlikely condition of both tanks being full and rupturing at the same time. If such a condition happened, the spilled fuel would be contained inside the dikes and would be safely removed without discharge to the environment. A detailed spill control plan will be developed prior to operations and will be contained in the Spill Prevention, Containment and Control Plan.

Q. May we now turn to the MWDF? What is its purpose?

A. The primary function of the MWDF will be to provide for environmentally compatible surface disposal of the waste generated from the mining and processing of the ore. Nearly all of the waste will be ground rock produced during the milling of the ore. The MWDF will consist of earthen ponds constructed primarily from site area soil materials. The ponds will be lined with a bentonite modified soil mixture with a drain system placed over the liner. The facility will be sized to provide storage capacity for the fine tailings, reclaim pond sludge, and water treatment plant sludges.

EXHIBIT 201 shows the MWDF in relation to the mine/mill site, the access road, the railroad spur, and the adjacent water reclaim ponds. Four ponds will be used over the productive life of the mine. They will be sequenced in construction, operation, and reclamation to accommodate the production of tailings from the mill. A construction support area will be required to contain the liner and drain processing facilities.

The MWDF has been designed to have an approximate earthwork balance during construction, operation, and closure. That is, most soils required for facility construction can be obtained from excavation of the ponds. Some limited quantities of fill required for final reclamation contouring will require the development of a "borrow area" north of the MWDF. Temporary storage of soil and other materials will also occur during the MWDF construction and operations.

Q. What are the other project facilities located near the tailings ponds?

A. As shown in EXHIBIT 263, there are two other facilities -- the mine refuse disposal facility (MRDF), which is our term for the sanitary landfill, and the water reclaim ponds.

As you can see, the landfill will be located east of the water reclaim ponds. It is designed to hold the solid waste or trash that results from the Crandon project. It will have three cells and will be developed one cell at a time. Seepage of leachate from the refuse material in each cell will be controlled by the construction of a liner in the bottom and along the sides of each cell.

The two reclaim ponds will be located close to the MWDF to reduce operating cost and land disturbance. The ponds serve mainly to hold and transfer water between the MWDF and the mill and a location between the two facilities minimizes the water handling system.

The reclaim ponds will utilize a lining system which will consist of an upper and lower synthetic membrane liner separated by a soil layer.

The lining system will be continuous across the pond bottom and sides. Riprap will be provided along the upper areas of the inside embankments to protect the lining system.

Q. What will be the size of each of these facilities?

A. The tailings disposal facility - MWDF - consisting of four ponds, will require about 360 acres. The MRDF - sanitary landfill - with three cells for solid waste disposal, will require about 15 acres. The reclaim water ponds will require about 50 acres. In addition to these facilities, a construction support area of 25 acres will be required and a 40 acre borrow site area will be needed to supply fill for final contouring during site reclamation. The total area of disturbance for the above facilities is approximately 495 acres. However, because of facility sequencing and phased site reclamation, the maximum disturbance at any one time will be about 290 acres during the construction of the fourth tailings pond.

Q. Looking first at the MWDF, how was the size of this facility established?

A. The size of the MWDF is based on the amount of fine tailings unsuitable for return to the mine as backfill that will be generated during the life of the mine. The Crandon orebody is currently estimated to have about 67 million tons of recoverable mine reserves. Applying reasonable values of 40% by weight of fine tailings per orebody ton and final tailings density of 108 pounds per cubic foot results in a fine tailings disposal volume of 11,467 acre-feet.

In addition to the fine tailings, the design has allowed for up to 200 acre-feet of volume requirement for the sludges produced from the water treatment process throughout the mine life. The proposed facility design provides a design waste storage volume of 13,388 acre-feet, thus yielding a storage volume contingency of about 15 percent.

In addition to the waste materials described above, the water treatment process produces sodium sulfate as a by-product. In all likelihood this material will be marketed and there will be no need for on-site disposal. However, provision has been made to provide capacity for all necessary storage within the MWDF. The estimated total sodium sulfate volume of 105,000 cubic yards (65 acre-feet) and the volume of the containment dikes that would be required are adequately provided for in the facility contingency volume.

Tailings pond freeboard above the normal water level when the pond is full has been designed to meet the requirements of NR 182. "Freeboard" is the distance from the water level, when a cell is completely filled, to the top of the embankment.

Calculations by Golder Associates indicated that a 3-foot freeboard was sufficient to prevent overtopping of waves under worst-case storm conditions.

Q. Generally, how will tailings pond construction and operation proceed?

A. The general procedure at the MWDF will be to construct, operate and reclaim each of the four tailings ponds in sequence over the mine life. In this manner the total amount of area disturbed at any one time can be minimized.

Q. Will you briefly describe the overall embankment design for the MWDF?

A. EXHIBIT 264 shows a typical section through one of the ponds.

The inside slopes of the pond embankments will be 4 feet horizontal to 1 foot vertical (4H:1V) to accommodate placement of the pond lining system. The outside slopes will be 3 to 1, horizontal to vertical, designed conservatively for stability and maintainability. The glacial till soils to be used in the embankments are excellent construction soils and could be placed at steeper slopes if desired. The 3 to 1 horizontal to vertical outside slopes were also chosen with consideration for reclaimed facility aesthetics, allowing blending into the surrounding topography. The 4 to 1 horizontal to vertical inside slopes have been chosen primarily to facilitate construction of the bentonite-modified soil liner and other seepage control system layers. With these relatively flat slopes, conventional road building equipment can be used to install the seepage control system.

Q. Has an analysis been made of the overall safety of the embankment design?

A. Yes. The technical studies have evaluated both the stability of the embankment slopes under static and seismic conditions and the design freeboard. The design takes into account precipitation, wind velocity, and process shutdown.

The stability analysis of the design slopes with respect to major slope failure indicates that the minimum factors of safety for static and seismic conditions are 2.1 and 1.8, respectively. The stability analysis was conducted with conservative assumptions about the conditions of the embankment system, conditions which we believe will never exist. A simplified Bishop's method (a standard analytical technique) of analysis was used by Golder Associates to assess stability. As previously described, the safety factors against both deep or shallow slope failure exceeded 1.8 in all cases (even under seismic loading) for the proposed embankment design, indicating that the slopes are stable.

Q. What measures have been incorporated into the tailings pond design to prevent or minimize seepage of contaminated water out of the facility and into the surrounding environment?

A. The major design concepts incorporated in the engineering of the tailings pond are the provisions for a liner and leachate collection (underdrain) system over the entire inside area of each pond. "Leachate" is fluid in the tailings in the ponds, and is removed by the drain system that I will describe. The purpose of the liner and the underdrain system is to minimize the volume of leachate that enters the surrounding glacial till soils. "Seepage" is that small amount of leachate that escapes the system.

Analyses performed for the MWDF leachate management system indicate that the most efficient and feasible design is a bentonite-modified soil liner and multi-layer blanket underdrain. EXHIBIT 264 presents the design selected for the MWDF liner and drain system and the estimated permeabilities of each component.

The drain system consists of a 12" upper filter layer, a geotextile filter--that is, a woven fabric--a 6" to 12" drain layer with leachate collection pipes and an 8" bentonite/soil liner. The filter layer has been designed to transmit leachate to the drain layer and also to inhibit migration of tailings into the drain layer. Similarly, the geotextile will prevent fine-grained particles in the filter layer from getting into the drain. The drain layer has been selected to provide sufficient hydraulic capacity to accommodate estimated leachate volumes from the filter layer.

All of the ponds will utilize a full drain system below the entire tailings area to collect and remove seepage water.

Leachate will be removed from each of the four tailing ponds by pumping from one of the two underdrain discharge pipelines installed in each tailings pond along the embankments on the east and west sides of the MWDF. This is an important design feature of the leachate collection system in that pond drainage water can be pumped from either of the two pipelines in the event portions of the system become inoperative.

Q. Going back to your EXHIBIT 264 for a moment, in practical terms what does a liner permeability of 1.6 x 10^{-9} feet per second mean?

A. The permeability value represents a measure of how fast water or tailings fluid can move through the material. For the liner it means that a drop of water would take several years to move through the 8 inch thick liner.

The total estimated maximum MWDF seepage rate through the liner system, as proposed in this design, is less than 15 gallons per minute and occurs approximately at the time of closure of the last tailings pond. This seepage rate is equivalent to a seepage rate of less than one tenth of a gallon per minute per acre over the approximate 180 acres of lined tailings ponds, or about one and one-third cups per acre per minute. The estimated maximum seepage rate for each individual pond during operation is less than 5 gallons per minute.

Q. What techniques will be used for the tailings pond construction to ensure the design standards for the seepage control system are met?

A. To begin with, the embankments will be constructed by placement and compaction of glacial till soils excavated from within the reclaim pond and tailing ponds. The glacial till soils in the site area provide an excellent source of structurally stable and workable materials for constructing the embankments.

The embankments are designed for surface erosion control, maintenance and other considerations in addition to providing adequate structural stability. For aesthetic purposes, erosion control and maintenance concern, 3.0 horizontal to 1.0 vertical slopes have been selected for the embankment exteriors. Vegetation can be established and maintained on these slopes. The interior (upstream) slopes of the embankments have been designed at 4.0 horizontal to 1.0 vertical. This slope is sufficiently flat to facilitate construction of the liner, underdrain system, and slope protection. Excavation will be conducted with scrapers and the soils will be hauled directly to the embankment for placement and compaction or stockpiled in the construction support area for use in preparing liner and drain material and for later use as a filter blanket.

The liner will be constructed by mixing bentonite with surface till in designed proportions and will be properly moisture-conditioned so that, when it is placed and properly compacted, the design performance of criteria-minimum permeability will be obtained.

Bentonite is a form of clay that, when moistened, swells to fill voids. The development of this blended till will start with the removal of oversize material (greater than 3/4 inch) using a conventional screening process. The till will then be placed in a temporary stockpile.

Stockpiled screened till will then be loaded via a conventional front-end loader to a hopper feeding a shredder unit to break up any clods or clumps of soil in preparation for transport to the mixing plant. It will then be conveyed to a hopper where powdered bentonite is added. Both bentonite and till will travel up the conveyor to be deposited in a mixing chamber ("pugmill") consisting of two counter-rotating, horizontal paddle augers. The paddles of each auger are pitched to both mix and transport the mixture down the axis of the mixing chamber. A regulated flow of water will be added to the traveling bentonite and till mix as it passes the third point moving through the mixing chamber. Water conditioning will be controlled as a function of the till's moisture content measured before mixing begins and adjusted as moisture conditions change to achieve the design target moisture.

At the end of the mixing box the moisture-conditioned bentonite amended till will be discharged into a dump truck for direct haulage to the tailings pond for liner construction.

Liner placement will begin with a single 4-inch compacted layer to be followed shortly thereafter by a second layer of bentonite amended till resulting in a total 8-inch thickness of compacted liner. These layers will be generally placed parallel to one another but offset laterally such that "seams," or joints, in overlying layers do not coincide.

Placement of loose liner material will be via a paving machine similar to that used in road construction. Dump trucks will empty into the paver hopper and move along with the track-mounted spreader as it delivers a uniform loose layer thickness of liner soil atop the subgrade or underlying liner layer. The loose layer will then be compacted with several passes of a vibratory smooth drum roller. The compacted liner material will provide a suitable surface for vehicular traffic without being damaged. Surface stability will be similar to that of subbase and base course layers in typical highway construction.

After installation of the liner, the drain and filter soil layers will be constructed to protect the liner from potential damage. The entire process will be closely monitored for quality assurance.

Drain layer material will be prepared in the construction support area by screening and washing till using standard processing technology. Till will be screened to remove oversize material greater than 2 inches in size and again screened to remove the fine fraction--that portion passing a standard 40 mesh screen. The screened product will then be washed to produce a free-draining clean coarse sand and gravel to be used as the drain material in the seepage collection system.

The drain and filter layers will be constructed by grading the soil material over the liner. A geotextile filter will be placed on top of the drain gravel prior to placement of the filter soil. Installation of the drain pipeline system will occur during placement of the drain layer.

All facets of construction of the MWDF will be inspected and tested to ensure conformance to material and performance specifications.

A field quality control lab will be established at the mixing plant site to facilitate both the testing of liner and reclamation seal materials as they are prepared, and to augment other field testing to be conducted in conjunction with the pond seepage control system and reclamation cap.

Q. After construction of the first tailings pond, how will the MWDF operate?

A. As mentioned previously, the proposed MWDF will be developed by sequential construction, filling, and reclamation of the other tailings ponds at about seven-year intervals.

Waste products from the mill will be transported to the MWDF by pipeline. The tailings will be pumped at approximately 55 percent solids concentration, by weight, from the mill to the disposal ponds. The water treatment plant sludge will be transported as a pumpable slurry to the tailings thickener and from there with the tailings in the pipeline. Excess mine waste rock, reclaim pond sludge and water treatment plant by-product sodium sulfate sludge will be transported by truck to the MWDF.

The pipelines in the immediate tailings pond area will be constructed only as needed, depending on which pond is in operation. The tailings and return water pipelines will be constructed along the embankment crests within the MWDF. The pipelines for the facility will be buried from the mill to the MWDF.

The tailings, in the form of a slurry, will be pumped from the concentrator and will be discharged into the tailings pond. In the pond, the tailings solids settle out to the bottom and the free water is removed from the top and pumped to the reclaim ponds and then to the water treatment plant where it is treated and re-used in the concentrator.

Q. Once the ponds have been filled with tailings, what steps will be taken to reclaim the area?

A. At the end of operation and after all remaining tailings water has been pumped to the reclaim water ponds, the surface of a tailings pond will be covered with a cap composed of six layers as shown on EXHIBIT 265. The lowermost (or first) layer, composed of glacial till, will be used to grade the final pond surface to between a 1 and 2 percent slope. The second layer will be composed of a bentonite-amended soil seal to prevent surface water from percolating through the tailings. The seal will be an overall 8-inch minimum thickness consisting of two 4-inch thick layers of liner placed in a manner similar to that described for the pond liner. The upper layer will be placed so that seams between construction passes are offset. The third layer, placed atop the bentonite-amended soil seal, will be a 40-mil thick polyethylene membrane. Fourth, there will be an 8-inch coarse sand and gravel layer which creates a drainage system above the membrane to facilitate drainage of the cap and to minimize hydrostatic head on the seal. Atop the drain layer a geotextile filter will be placed to minimize migration of silt and fine sand into the drain layer from the final cover soils. The final layer is composed of 5 feet of glacial till to provide a cover for the seal and drain layer and a medium for plant growth. The top 9-12 inches of the 5 foot thick cover will be topsoil which was originally stripped and salvaged from the site area.

A typical tailings pond cross-section showing the relationship between the initial pond configuration, the final tailings surface at completion of pond operation and the final reclamation cover is shown on EXHIBIT 265.

The final tailings surface slope is estimated to be 0.5 percent based on an evaluation of the settling and drainage characteristics of the slurried tailings. Construction of the glacial till and reclamation cover will result in a final surface slope ranging between 0.5 and 2 percent. Soil material, some of which will come from the upper regions of the confining embankments, will be used to construct the glacial till cover layer. The remaining soil requirements will come from stockpiles developed during the previous construction phase or from the borrow area.

The drain layer and composite seal effectively reduce migration of rain water through the seal to a negligible amount. Nevertheless, for purposes of analyzing overall MWDF performance, a rain water seepage rate has been assumed at about 1.5 gpm over the entire area -- about 1/3 gpm per 100 acres. This final assumed seepage through the composite seal and hence through the tailings mass and pond bottom has been used in evaluating overall MWDF seepage characteristics and performance through the use of ground water models. Dr. D'Jafari of D'Appolonia will cover this in more detail when he testifies on ground water impacts.

The drain layer will channel infiltration through the reclamation cap to the perimeter and internal embankment crests of the MWDF where it will infiltrate downward. EXHIBIT 266 presents the configuration of the drain layer as it terminates in the embankment area. This system approaches, as nearly as possible, the restoration of initial site hydrologic patterns upon completion of the final reclamation in the MWDF area. Surface runoff, which originally occurred throughout the area occupied by the MWDF, still can occur although probably to a lesser degree since final reclamation grades are low. Infiltration which occurred prior to development of the MWDF will still occur, but its pattern will be changed slightly since the cap drain system redirects infiltration to the MWDF perimeter and internal embankments where it infiltrates. Outside the MWDF embankments there should be relatively little change in infiltration quantities or patterns.

As shown on EXHIBIT 267, the final reclaimed grades and configuration of the MWDF site are designed to be compatible with the topography in the surrounding area. The highest elevation of the facility after reclamation is 1,750 feet above sea level.

An initial vegetative cover will be included with the reclamation work but the cover is planned to eventually become a forest ecosystem developed by indigenous species succession.

The proposed final uses for the MWDF area are forestry and recreation. A more complete discussion of reclamation and final uses is included in the Reclamation Plan testimony to be given by Mr. Lewis.

Q. Mr. Moe, in your opinion, to a reasonable degree of scientific certainty, does the MWDF design ensure that seepage of leachate will be substantially minimized?

A. Yes. The calculations that we have performed demonstrate that seepage from the MWDF should be essentially eliminated after reclamation. However, as I mentioned earlier we assumed a 10 percent failure of the cap for modeling purposes. As Dr. D'jafari will testify later, even with this assumption, the modeling has shown that the quality of the ground water will be protected and that it will meet the applicable regulatory criteria.

Q. In the unexpected event that there is more seepage from the tailings ponds than all of your investigations and calculations lead you to believe will occur, is there a Contingency Plan that can be implemented to remove from the environment any discharges from the tailings ponds that might be damaging to the environment?

A. Yes. In the event that there is more seepage from the tailings ponds than we expect or some accident occurs that permits a greater volume of seepage to take place, there is a Contingency Plan that can be implemented in time to prevent any significant damage to the environment. First, I should note that there is a Monitoring Plan that will be discussed in greater detail by Dick Herbst in later testimony. The Monitoring Plan will tell us what is happening in the region around the tailings ponds and give us an early warning as to any unexpected discharges from the tailings ponds that have to be dealt with. It should be noted that the seepage rate here is very slow and there will be ample time to respond to any unexpected discharges. In the event that our monitoring indicates that some action should be taken to prevent contaminants seeping from the tailings ponds from reaching Hemlock Creek or any other body of water that might be affected, the Contingency Plan can be implemented. It consists essentially of drilling a series of interceptor wells around the tailings ponds. We can then pump from those wells to remove the contaminants that have seeped into the ground water table from the tailings ponds.

Q. Is there sufficient experience with such systems to give you assurance that, if the Contingency Plan is triggered, it will adequately protect the environment?

A. Yes. Exxon and the mining industry generally have a great deal of experience in controlling fluid flow in aquifers. This experience generally comes from the area of solution mining, where solutions are used to extract valuable minerals from underground formations. This technique is used very successfully in the recovery of uranium.

Q. Turning now to the sanitary landfill, which has also been called Mine Refuse Disposal Facility (MRDF), what is the purpose of this facility?

A. The landfill will be utilized to dispose of non-hazardous wastes and refuse within the project site area. Disposal of potentially hazardous wastes such as petroleum, chemical and other hazardous wastes will be at off-site facilities by specialty contractors. As I earlier testified, mill tailings will be stored in the tailings impondment.

The wastes and refuse to be disposed of at the landfill will be generated during the anticipated 36-year period of construction, operation, and reclamation of the Crandon Project.

Q. What specific types and quantities of waste will be put into the landfill?

A. The estimated quantity of construction waste is 1,525 tons. Approximately 60%, or 900 tons, may be characterized as solid waste from construction crews, packaging wastes, and scrap metals. This figure is derived from estimated weekly waste quantities. Similar refuse quantities were derived based on estimates of daily per capita waste production. Construction waste totaling 625 tons, or 40% of the total construction refuse and waste quantity, will consist of waste construction materials such as concrete formwork, metal siding and roofing, metal liner panel, dry wall and insulation. The total construction refuse and waste material quantity will be generated during the 3-year project construction period.

The total quantity of operations refuse to be deposited is approximately 47,000 tons. This was estimated based on a work force of 650 people generating 2.5 tons per capita of refuse per year for 29 years. It is expected that the refuse will consist of the following materials:

Material	Percentage
Paper and Garbage	75
Plastic	5
Wood	5
Metal	10
Miscellaneous	5

Additional solid waste refuse including tires, scrap metal and miscellaneous items of scrap or waste material will be returned to vendors or sold to scrap dealers to be recycled or ultimately reused.

Petroleum products and chemical wastes, including waste oil, hydraulic fluids, lubricants, solvents, degreasers, waste fuels, and waste chemical residue, will be returned to recyclers where suitable. Any non-recyclable waste will be disposed of by a specialty disposer properly licensed to receive such wastes.

Potentially hazardous wastes including those from laboratories, machine or repair shops, and spill residues, will be disposed of through a specialty disposer. All applicable regulations covering handling, transfer and disposal of the wastes will be followed.

The quantity of refuse and waste generated during reclamation of the Crandon Project facilities is estimated to be 2,500 tons. Reclamation wastes will consist primarily of solid waste from operating and construction/demolition personnel and activities. Typical materials might include insulation, dry wall and minor scrap wood and metal that are non-salvageable, unburnable or not suitable for direct burial.

The total waste quantity anticipated from construction, operation and reclamation is therefore approximately 51,000 tons. Assuming an in-place density for the refuse of 1,000 pounds per cubic yard, the waste will occupy a volume of approximately 102,000 cubic yards. At a five parts refuse to one part cover ratio, total volume required for refuse and daily cover will be approximately 122,000 cubic yards. The three cells have a total design capacity of 122,000 cubic yards, excluding the final cover. The actual lifetime of each cell will depend on the periodical waste generation rates.

Q. What was the general process for locating and designing the MRDF?

A. The location and design process for the proposed MRDF followed the criteria indicated in NR 180.13(3). This facility as designed and positioned near the tailings facility complies with all NR 180 locational criteria.

Q. Please describe the general layout and filling sequence for the landfill.

A. The proposed landfill is composed of three contiguous cells aligned in an east-west direction, Cell 1 being the westernmost cell and Cell 3 being the easternmost cell. The MRDF or landfill will be located just north of the MWDF. Access to the facility is from the southwest where the top of the dike will be joined to the MWDF access road.

The filling sequence will begin with Cell 1 and end with Cell 3. Cell 2 construction will be completed prior to closure of Cell 1. During the operation of Cell 2, Cell 1 will be reclaimed and Cell 3 will be constructed. Cell 2 will be reclaimed during the operation of Cell 3. Upon termination of operation of Cell 3, its reclamation will begin.

Q. How much earth work is involved in the construction of the MRDF?

A. The construction of the MRDF requires the use of on-site glacial till material for dike construction and the preparation of liner and final cover. In addition, material is required to be used for daily cover of the refuse.

The total excavated material will be approximately 116,000 cubic yards. Some of this material will be used for embankment construction, daily refuse cover, and liner and drain construction. The final cover volume is approximately 79,000 cubic yards. Any imbalances will be handled in conjunction with the other construction and reclamation activities for the MWDF.

Q. How will seepage from the refuse material be controlled?

A. Seepage of leachate from the refuse material in each cell will be controlled by the construction of a liner in the bottom of each cell which is identical to the liner in the tailings ponds.

The construction of the liner and drain system is depicted in cross section diagrams on EXHIBIT 268. This liner and drain system will be continuous over the bottom and inside slopes of each cell. The inside slopes of the cells will be 4 horizontal to 1 vertical to facilitate placement of the lining system.

Leachate will percolate down through the refuse and be transmitted through the filter and drain layers and will then encounter the relatively impermeable liner, where it will be collected in the drainage system and transported to a manhole at the southwest corner. At that point, a float activated pump will pump the leachate into the reclaim pond. Cleanout access pipes will extend up the interior side slopes to facilitate maintenance of the collection system.

Q. Are there any provisions to handle gases that might be generated from the refuse?

A. Any gases that are produced from the refuse material will be vented. The final layer of refuse will be graded so that a 2% slope is maintained from the north to the south end of the cell. Final cover will be placed above the refuse in each cell.

Q. Can you describe the general operating procedures for the MRDF?

A. The MRDF is proposed to be operated as a sanitary landfill. NR 180.13 of the Wisconsin Administrative Code requires that all of the solid waste be completely covered with at least six inches of earth after each day of operation. The rate of deposition of refuse in the facility may vary from the construction phase to the operational phase of the Crandon Project. Whether refuse is deposited on a daily or weekly basis, an operator will utilize earth-moving equipment to spread the refuse and compact it. Each day's volume of waste will be covered with the required six inches of earth.

The filling will progress from the northeast to the southwest corner in 6 foot lifts. This will allow surface water to drain freely from the sides and through the refuse to the southwest corner of the cell. The surface water will enter the manhole and be pumped to the reclaim pond prior to treatment at the water treatment plant. Access to the manhole in the southwest corner will be maintained during the filling of each cell by addition of sections of five foot diameter prefabricated concrete cylinders.

Truck access to the bottom of each cell will be maintained from the southwest corner of the dike down a ramp with a grade of 10% or less. This will consist of a temporary access road constructed on the filter layer using glacial till.

Q. After a cell is filled, how will the site be reclaimed?

A. After the refuse capacity of each cell is utilized, a seven layer final cover will be constructed which is identical to the one used for the tailing pond which I have previously described. The cross section on EXHIBIT 268 shows the details of the final MRDF cell cover.

Following grading of the final cover, herbaceous vegetation will be established to stabilize the soil surface and to minimize erosion. The revegetation program will allow natural ecological succession to occur at the site. Plant communities compatible with adjacent undisturbed communities will be allowed to develop. Further discussion on the site reclamation plans will be given by Mr. Lewis.

Q. Will you now describe the location and function of the reclaim ponds?

A. The reclaim ponds are located on the north end of the MWDF as shown in EXHIBIT 263. This location will have the least land disturbance and operating cost. The ponds will generally serve to hold and transfer recycle water between the MWDF and the mill.

The specific functions of the reclaim ponds include:

1) Provide capacity to store surface runoff for all process-related surface facilities;
2) Allow sufficient residence time for settling of fine particulate matter;
3) Allow sufficient residence time for natural evaporation,

oxidation, and biological processes to occur and thereby control the concentrations of certain chemical constituents in the water to be recycled to the mill; and

4) Storage of mine water during construction.

Mr. Michael Harris of CH2M Hill will elaborate on the function and use of the reclaim ponds.

Q. Can you give a summary of the facility construction and design?

A. The construction techniques used for the reclaim ponds will be very similar to those used for the MWDF and MRDF. All embankment materials, with the exception of the synthetic lining and rock slope facing materials, will consist of the soil excavated from the pond interiors. The reclaim ponds inside embankment slopes will be one vertical to four horizontal to facilitate installing the pond lining system. As shown on EXHIBIT 269, both of the reclaim pond cells will utilize the same lining system. A multi-part lining system will be used consisting of two synthetic membrane liners. The membranes will be protected by placing an eight-inch carbonate-free sand underdrain and vent layer between the membranes. The upper membrane will then be covered by 1.5 feet of sand. The lining system will be continuous across the pond bottom and sides. Since the ponds have two synthetic liners, little or no water will seep through and there should be no freeze-thaw effects. Also, the pond will be filled with water. Frost effects on the outer shell and crest of the embankments will not affect embankment performance. Rip-rap will be placed along the upper areas of the inside embankments to further protect the lining system and prevent wave erosion.

The bottom of the reclaim pond will slope gently (about 1%) from a high point in the center to the inside boundary of the pond embankment. Any water entering the underdrain will be collected in a perforated perimeter pipe at the inside toe of the embankments. Six standpipes will be installed in each cell from the perimeter collection pipe to the pond embankment crest. The standpipes will be periodically checked to see if any seepage has entered the underdrain system. The standpipes will be sized to allow insertion of a submersible pump in the event any seepage has to be removed from the underdrain.

The drain layer will also serve as the venting mechanism for gases that might build up between the synthetic liners. Additional perforated pipe running through the center area of the cells, and connected to the perimeter collection pipe, will ensure complete venting of the entire pond area. Final venting will be achieved through the standpipes connected to the perimeter collection pipe.

The double liner and drain and vent system concept was developed as a precautionary safety feature. In the unlikely event the primary synthetic liner system develops a leak, the leakage will be collected in the underdrain and removed. The back-up synthetic liner will impede leakage from the drain towards the underlying aquifer. Minimal leakage is expected from the synthetic liner. Therefore, there will be negligible seepage head on the underdrain and consequently negligible seepage loss from the total system.

In the event that the liner in one of the cells has to be repaired, the cell will be drained and the necessary repairs made. There is flexibility in the water management system to allow operations to continue with one cell.

Q. Would you give us a more detailed understanding of the operation of the water reclaim ponds?

A. The retention volume in the water reclaim ponds and tailings ponds will provide storage capacity for excess water from the water management system. The two-cell pond system will ensure adequate retention time in the ponds and prevent short-circuiting of water through the pond system. The reclaim ponds are designed to ensure that temporary interruptions of service of any of the components in the system do not cause a complete shutdown of the mine or concentrator. When the water level in the reclaim ponds is at the maximum normal operation level, the freeboard depth provides ample additional capacity. Reclaim ponds A and B each have a minimum design freeboard of 10 feet above maximum operating water level. The first seven feet of the freeboard in the reclaim ponds will hold approximately 20 days of water flow at a rate of 1,385 gallons per minute. The freeboard in the reclaim ponds is designed to contain the volume of the probable maximum precipitation (PMP) event. A minimum of three feet of freeboard will be maintained.

The two largest streams that flow to the reclaim pond--from the tailings thickener and the MWDF--will contain small amounts of particulate matter. The amount of settled solids that will accumulate in the reclaim pond over the life of the Project has been estimated to be no more than 140,000 cubic yards. This estimate is based on the volume of water expected to flow through the pond with an average suspended solids concentration of 415 ppm, and a settled solids density of 50 percent solids by weight. This volume of sludge can be contained in the reclaim pond system without affecting its operation. The settled sludge will occupy 16 percent of the total normal operating volume and will occupy a depth of 3.2 feet if divided evenly between the two ponds.

If removal of settled solids from the reclaim ponds is necessary, suitable methods will be used that would not damage the pond liners and would still allow continued operation of both ponds. A small floating suction dredge with depth control on the suction head could be used. In practice, a small depth of settled solids (approximately 1.0 foot) would not be removed to maintain an additional layer over the lining system. If the estimated 140,000 cubic yards of settled solids were distributed evenly over the final tailings surface of pond T4, the depth of sludge would be approximately 0.8 foot. During reclamation of tailing pond T4, there will be ample time for proper management of the sludge through drying or blending with tailings or cover soil. The sludge could also be incorporated into the thick till grading layer planned as the first step in reclamation of the tailings pond.

Q. After completion of milling, how will the reclaim ponds be reclaimed?

A. Upon completion of milling, the water in the reclaim ponds will be treated for discharge and the pond basins reclaimed. The reclaim pond liners, rock slope protection materials, and water treatment sludge contained therein will be placed in tailings pond T4 before it is reclaimed. The reclaim pond area will be regraded with the glacial till soils that formed the reclaim pond embankments. Mr. Lewis will give further testimony on the overall site reclamation.

Q. One final question on the MWDF, MRDF, and reclaim ponds. What is your best engineering judgment as to the amount of seepage that can be expected from these facilities?

A. We have calculated those rates and verified them through extensive laboratory experiments. Based on this work on the effective design performance, we project that, under long-term steady-state conditions, there will be essentially no seepage from any of these facilities.

Q. Now that you have given us a thorough overview of the design and operation of all of the various facilities associated with this project, Mr. Moe, will you review for us the project construction schedule?

A. The planned sequence and estimated duration of the construction activities are shown on EXHIBIT 270.

The duration of the construction phase is controlled by the time required to develop the main shaft and headframe, the east exhaust shaft, and to perform the necessary underground mine preproduction development. The sequence of critical activities for mine development consists of site preparation for the main and east exhaust shafts, freezing the ground at the shaft sites, excavating and lining the shaft collars to bedrock, erecting the shaft headframes, sinking the shafts to their appropriate levels, and subsequent development of the mine haulage ways, initial stopes, and underground ore handling facilities.

Approximately 30 months will be required for shaft sinking and underground development before production can begin. The time required for construction of the surface facilities is less. Therefore the construction of surface facilities will be governed by the need for facilities to support mine development operations. Thus, the first priorities are environmental protection systems--such as surface drainage basins for runoff control, sewage treatment facilities, and mine waste water treatment facilities--and a permanent power supply, a concrete batch plant, and access roads. Construction of the general facilities buildings and the concentrator, coarse ore storage, and miscellaneous tanks and thickeners will be completed when the mine production makes operation of the concentrator feasible.

Many factors have potential for affecting the construction schedule. These factors include inclement weather, delays in equipment deliveries, and design modifications.

Q. When construction begins how will the site be prepared?

A. Site preparation will be performed in two stages. Initially, the site will be cleared of trees and shrubs and then rough-graded. Immediately following this, those areas not required in the early phases of construction development will be reseeded to control erosion and runoff. Final grading of the reseeded areas will be performed as dictated by the requirements of the construction schedule.

During clearing and grubbing, marketable trees will be cut and removed from the site. Tree stumps and brush will be mulched and stockpiled for use in land restoration. Any stumps or other grubbing materials that cannot be chipped for mulch will be disposed by burning.

Existing topsoil from all cleared and grubbed areas will be stripped and saved. This same general site preparation technique will be used for all major facilities.

Any large boulders encountered during the site preparation activity will be moved to the edge of the site area. These boulders will be crushed, used as rip-rap in the MWDF area, or used in the mine operation.

Erosion control at the site will be developed during rough grading. To the extent possible, the permanent surface drainage systems will be used for runoff control.

Q. Will the project construction activities require the use of on-site batch material processing plants?

A. Yes. Two separate batch plants will be used on the Project construction site. The first, a temporary concrete batch plant, will be located southeast of the main shaft. This facility will provide the concrete for the surface buildings and for underground mine construction.

A second processing plant will be located in the tailing ponds construction area. This plant will be used to prepare liner material for the tailing ponds, reclaim water ponds, refuse facility, surface water drainage basins, and the preproduction ore storage pad.

Q. What are the primary nonmetallic materials used during construction and where will they likely come from?

A. The primary nonmetallic materials needed for construction of the Project are sand, gravel, and bentonite. Sand and gravel will be used for concrete, asphalt pavement, and road and railroad construction. Most of this material will likely be supplied by local contractors. Bentonite, to be used primarily for the tailings pond liners, will be obtained from off-site and delivered by truck or rail.

Q. What temporary facilities are required for construction?

A. The need for temporary facilities during construction will be minimized by using permanent facilities wherever possible. However, some temporary structures will be required.

Temporary facilities such as construction offices for Exxon and the contractors, storage and workshop buildings for contractors, a concrete batch plant, potable water, electric power, and sanitary facilities will be required at the site until permanent buildings are completed.

A temporary parking area will be provided until the permanent parking area is completed during the second construction year.

Temporary laydown areas for the storage of building materials and equipment will be provided on the site adjacent to structures under construction.

The temporary concrete batch plant and aggregate stockpile area will be established in the first year of construction to provide the necessary concrete supply. This batch plant will be removed during the third year of construction when all concrete has been placed.

Potable and construction water will be provided by on-site wells now in existence and new wells to be installed during the first year of construction.

During the first six months of construction and until the permanent substation is completed, temporary on-site power will be furnished from an existing utility company line and by on-site generators. By month seven the main 115 kV powerline will have been installed and the first transformer energized.

In accordance with applicable regulations and good practice, chemical toilets for construction personnel will be provided on-site. Wastes will be collected and disposed off-site by an approved contractor. When the sanitary disposal system is completed, early in the construction period, sanitary wastes will be disposed at this facility. The use of chemical toilets will continue throughout the construction period because some work locations will not be conveniently located near permanent toilet facilities.

A security fence enclosing the site will be installed by the end of construction year one. A clear area on each side of this fence will be maintained. Temporary fences within the construction site may be installed by Exxon or the contractors. All fences will be approved by Exxon with respect to location and type prior to erection.

Little Sand Lake Road will be used for access during construction until the permanent access road is constructed and then as secondary access until the mine/mill construction activities are completed.

Q. Briefly describe the construction of the access road.

A. Within the limits of construction, the right-of-way corridor for the new access road will be cleared and grubbed of trees and shrubs in the same manner as I described earlier. Based on preliminary engineering for the access road, approximately 35 acres of right-of-way will be cleared. Suitable areas along the right-of-way will be chosen to temporarily stockpile the topsoil. Erosion control methods will be implemented during construction to minimize the impact of surface water runoff.

Roadways will be graded and a base of suitable material will be placed and compacted. It is anticipated that this base material will be acquired from local commercial sources.

Construction processes for the pavement will follow normal practice used in the area. A central plant will batch and mix the pavement materials followed by truck transfer to the site where paving machines will be used.

Disturbed areas along the access road right-of-way will be topsoiled, fertilized, and seeded. At the completion of access road construction, any unused topsoil will be hauled to the permanent topsoil stockpile.

Q. How will the mine surface facilities be constructed?

A. The mine surface facilities, including the hoist and compressor house, headframe, and mine air heater, will be constructed using typical construction techniques.

A steel headframe will be erected at the east exhaust/development shaft along with a small hoist house to contain the shaft sinking and development hoist. After mine construction is complete, this shaft and headframe will be converted to handle exhaust ventilation fans and the emergency escape hoist.

Q. How will the mine shafts be constructed?

A. The plan for development of the mine includes construction of three vertical shafts.

Each shaft will have a concrete-lined collar through the glacial overburden and weathered rock. Collar construction will include stabilization and hydraulic control by ground freezing, followed by excavation and concrete lining within the protective frozen soil cylinder.

The stabilized ice wall will be formed by closed circuit circulation of a cooling fluid (typically calcium chloride brine) through a circular pattern of vertical steel cased boreholes containing brine tubes. Monitor boreholes will also be provided to measure ground water levels, ground temperatures, and for detection of brine leakage. With this temporary ground stabilization method, no foreign materials are introduced to the ground water or surrounding soils.

After the collar is frozen, excavation will proceed using a crane and clam shell for removal of loose material, followed by pavement breakers or rock drills and explosives to break up larger boulders. Chipping hammers will be used to trim the walls of the excavation to the proper diameter. Upon completion of the excavation, a reinforced concrete collar will be poured in place. This collar will be approximately 2 feet thick and will reach from surface into competent bedrock to ensure a firm foundation. At the interface of the collar, the bedrock, and the overburden, inert grout will be pumped under pressure through holes in the collar and into the rock and glacial formations to provide a watertight seal.

Once excavation and lining of a shaft collar are complete, the protective ice wall and the surrounding soils will be allowed to thaw. Abandonment of the freeze pipes will include:

1) Removal of brine for off-site disposal by the freezing contractor;
2) Clean water flushing of freeze pipes;
3) Mechanical perforation of freeze pipe casings at the soil-rock interface at the hole bottom; and
4) Filling of the freeze pipe with cement.

When the collar sections of the main shaft are completed, the concrete tower headframe will be erected and used in shaft construction and then in mine development and operations. A steel headframe will be erected over the east exhaust shaft and will be used for shaft construction and mine development. This structure will then remain in place and serve as an emergency hoisting facility for secondary escape from the mine.

Conventional excavation of rock will commence at the main shaft and at the east exhaust shaft concurrently. This will be by drilling holes in the rock, blasting, excavation of the broken material, and lining the shaft interior with concrete.

Q. After shaft sinking, how will the mine be developed?

A. Upon completion of the east exhaust shaft, horizontal level development will commence, as shown schematically in EXHIBIT 104. Horizontal tunnels, called drifts, will be driven westward to intersect the main shaft. An equipment ramp to the main haulage level will be constructed. Drift development on the main haulage level will begin upon completion of the main shaft and hoist installations. Preproduction mining on the lower mine levels and the sublevel between them will prepare the initial stope blocks, or mining areas, for production. The ramp will provide for interlevel equipment movement and access to the maintenance shop.

The underground ore handling facilities will be constructed upon completion of the main production shaft. These facilities will consist of coarse ore and waste bins, crusher facilities, belt conveyors, and a loading pocket installation. Ore and waste passes will connect these facilities to the upper mine levels.

Q. How will waste rock from the mine development be handled?

A. Waste rock generated during shaft sinking operations and preproduction mine development will be stockpiled on the preproduction ore and waste storage pad on the north side of the site. A portion of the stored waste rock will be used for MWDF slope protection. The remainder will ultimately be crushed and returned to the mine as backfill.

Q. What are the structures that will be constructed for the mill facilities?

A. The mill facilities have been categorized as follows:

1) Buildings with concrete foundations, structural steel frame and insulated structural walls and roof;
2) Buildings with concrete foundations, concrete block walls and insulated metal roof; and
3) Process structures such as thickeners, tanks, conveyors and pipe racks supported on concrete foundations.

Construction of these facilities will follow typical industrial plant construction practices.

Q. What will be the site preparation procedures for the mine waste disposal facility (MWDF) and the water reclaim ponds?

A. Site preparation for the MWDF and reclaim ponds will be completed in phases so that only the area actually required for construction in a particular phase will be cleared and grubbed. Only a portion of the total area will be under development at any one time.

The site preparation procedures for the waste disposal and reclaim pond area will include clearing and grubbing, separation of marketable timber, and burning or mulching of tree stumps and brush. Suitable topsoil will be stockpiled for future use.

All wetland deposits (peats, mucks, and other organics) will be removed from the MWDF area during excavation and used as top dressing or mulch on the embankments. Wetlands within the embankment areas will also be removed down to firm subsoils prior to any embankment construction.

The excavated organic materials will be temporarily stored adjacent to the excavation area to allow drainage and then used as top dressing on embankments and other areas where vegetation is to be established.

The outside faces of the containment berms of the tailings and reclaim ponds will be graded at 3H:1V slope and will be stabilized by application of topsoil, hydro-mulching and revegetation.

Q. What will be the construction schedule and procedure for the tailings disposal facility (MWDF) and the water reclaim ponds?

A. As I have already indicated, construction of the MWDF has been scheduled in such a way that completion of each of the tailings ponds occurs as it is required for disposal of tailings. The limited construction season in the area requires the concentration of construction efforts during the May through November period.

Scrapers will excavate and haul material directly to the embankment for placement and compaction or to a stockpile area located adjacent to the construction support area for later use. Portions of the stockpiled soil will be used for preparing liner and underdrain material. The remainder will be placed in a long-term stockpile for future use.

Q. What will be the construction schedule for the mine refuse disposal facility (MRDF)?

A. The first cell of the mine refuse disposal facility (MRDF) will be built at the inception of construction activities and should be available within 6 months after start of Project construction. This will allow most construction waste to be disposed in the MRDF.

Like the MWDF and reclaim water ponds, the MRDF will be developed in stages so that only the area actually required for construction will be cleared. As I have already testified, the MRDF is similar to the MWDF and water reclaim ponds in the design and construction of the lining and leachate collection systems. Construction of this facility will occur during the same time frame as the reclaim ponds.

Q. Would you briefly describe the construction of the major pipelines and water discharge structure?

A. Pipelines are required to transport tailings slurry to the tailing ponds, thickener overflow water to the reclaim pond, water from the reclaim pond to the mill and treated water to the Swamp Creek discharge. Pipelines will be constructed of high-density plastic pipe and will be buried below the frost line to avoid frost damage.

Excavation will be by trenching machine or backhoe, and after installation of the pipeline, backfilling will be sequenced to keep open excavations to a mimimum during construction. All pipelines will be pressure tested prior to placement in the trench. The trench will be backfilled with excavated materials of suitable quality.

Instrument cable will be buried with the pipe. The cable will be used as a metal source for pipeline-locating instruments.

The water discharge pipeline to Swamp Creek will be buried as discussed above within a 50-foot right-of-way. The discharge structure at Swamp Creek will be constructed using a backhoe for excavation, minor grading, and placement of rip-rap.

A similar technique will be used to install the reclaim water and thickener overflow water pipelines associated with the reclaim ponds, and the decant and underdrain water pipelines from the tailing ponds.

Pipeline routes will be reseeded but will be kept clear of trees and brush to permit vehicular passage for periodic inspection. Pump stations will be located close to the tailings thickener and at the reclaim ponds.

Other pipelines associated with Exxon's program for mitigating surface-water impacts from the ground water drawdown will be built on an as-needed basis. Carlton Schroeder will be describing those to you later in his testimony.

Q. Earlier you mentioned the construction of the access road. Will there be any other road construction?

A. A gravel surface haulage road will be constructed from the mine and mill site to the waste disposal area. This road will also accommodate the tailings transport and reclaim water pipelines. Construction methods employed in building the haulage road will be similar to those used in construction of the access road.

Q. Briefly describe the activities involved in the construction of the railroad spur.

A. Construction of the railroad spur will be completed in Years 1 and 2 of the Project. Construction will consist of the following: (1) clearing and grubbing; (2) installation of railroad spur track and siding track, including culverts, grading, bridge structure, and crushed aggregate ballast; and (3) application of topsoil, fertilizer, seed, and mulch. An estimated 45 acres will be cleared and grubbed within the right-of-way.

Construction will start on the single span bridge across Swamp Creek when the access corridor has been cleared sufficiently to allow workers and equipment into the area.

Wetland soil materials excavated for construction of the railroad spur will be used as top dressing along the railroad spur embankments or cut side slopes.

Q. What type of equipment will be used during the construction of the surface facilities?

A. The types of equipment which will be used for the construction of the surface facilities will be typical of any industrial construction project. The heaviest concentration of construction equipment operation will occur during the summer months of the first 2 years of construction. During the winter months there will be a marked reduction in the intensity of equipment operation.

Q. Now that you have reviewed the construction schedule for us, would you give us an idea of the operating schedule?

A. The operating schedule for the Project will be three shifts per day, seven days per week. This schedule formed the basis for determining the quantity and sizes of mine and plant equipment, plus water, tailings disposal, and personnel requirements.

Q. And how long will the mine remain in operation?

A. Let me here refer back to EXHIBIT 270, which illustrates the construction, operation, and reclamation schedules for the Project. Mine and mill production begin at the mechanical completion of the facility construction period. Mine production from the zinc portion of the orebody will then continue for about 16 years. Given favorable economic conditions at that time, the copper or stringer ore would be mined for an additional 13 years. The total mine and mill operations would then be about 29 years.

Reclamation of the facilities would then take about four years followed by the long term monitoring and care period.

The total project duration from the start of construction, through production and reclamation will be about 36 years.

Q. Let me turn for a moment, Mr. Moe, to Exxon's siting of all of the facilities you have described today. What criteria governed the selection of these locations?

A. Our sitings decisions were governed in part by sheer physical necessity, in part by good operating practice, and in part by some very stringent state criteria governing the placement of mine facilities. For example, the location of the orebody dictates that we must locate the headframe and mine shaft close to the orebody, and the location of the headframe in turn requires that we locate mill facilities within a relatively close area so as to maximize efficient operations.

With respect to legal requirements, Wisconsin has very stringent rules governing the location of facilities that may impact upon wetlands. Mr. Garrett Hollands will subsequently testify about these criteria and Exxon's efforts to ensure that the location and design of site facilities minimize impacts to wetlands. There are other regulatory siting criteria as well. For example facilities must be located outside of flood plain areas, must avoid osprey and eagle nests, and must be located no closer than certain specified distances to rivers and streams, lakes, highways, public parks, and private and public water supply wells . Our siting of project facilities complies with all of these criteria. For example, the mine shaft facilities are located on the north side of the orebody to keep them out of the buffer area around Little Sand Lake.

Further details on project siting are set forth in the documents I identified at the outset and in reports that will be discussed by Mr. Hollands later in this hearing.

Q. Could you give us some examples of how Exxon went about making its sitings determinations?

A. Let me take the MWDF and the access road as examples.

As discussed in the MWDF Feasibility Report, Exxon considered numerous alternative sites for the MWDF. The choice eventually narrowed to locations described as "Area 40" and "Area 41," which are illustrated in EXHIBIT 365. Area 41 is the site we ultimately chose.

Mr. Hollands, informed us that, while locating the MWDF in Area 40 would result in the filling of somewhat fewer wetlands than Area 41, the Area 40 wetlands, which as you can see are located close to Rolling Stone Lake, are much more valuable in terms of the functions they serve. Thus, Area 41 was preferable from an overall wetlands standpoint.

Area 41 also make best sense for other environmental reasons. For example, Area 41 has a greater unsaturated flow path to the ground water than does Area 40, and the predominant ground water flow path to the surrounding surface waters is longer from Area 41 than from Area 40. This longer flow path through both the unsaturated and saturated soils would provide significant increased opportunity for attenuation of any seepage from the MWDF. Similarly, the pipeline corridor from the mill site to Area 41 would be less than one-fourth the distance required for a corridor to Area 40. This will minimize the disturbance of land areas and the potential for environmental impacts.

We also found that construction at Area 41 would involve less earthwork, which is important from both an environmental and an economic perspective, and generally would result in the least capital cost. So, balancing all of these factors, we concluded that Area 41 was the best site for locating the MWDF.

Turning to the access road, we were advised by Mr. Hollands that the route we ultimately chose -- Alternative "B-1" -- would result in the filling of approximately two additional acres of wetlands that route E could avoid. Route A-1 would affect approximately seven acres of wetlands, four more than would route B-1. Other factors, however, weighed in favor of route B-1 over route E. For example, Route B-1 would cause less disturbance to residential structures, would require less Project-related traffic to pass through the Sokaogon-Chippewa Community, and would intersect Highway 55 at a location that is considered safer than the intersection of route E and Highway 55. Taking all of these factors into account, we concluded that the route we chose will be the best from both an environmental and operating standpoint.

In summary, as presented in great detail in the reports I have identified, Exxon's sitings decisions were based on comprehensive data collection and evaluation efforts, on detailed engineering evaluations, and on the application of professional judgment. In my professional opinion, the sites chosen are technically feasible and economically viable, comply fully with all regulatory siting criteria, and will have the least overall environmental impact of all sites considered during the evaluation process.

Q. Mr. Moe, how has Exxon accounted for risks associated with the Project?

A. Exxon and its consultants have designed the Crandon Project in accordance with good engineering design standards and accepted industry practices. Of course, there is always some remaining level of risk. This is so whether one is constructing an industrial facility, driving down the highway, or sitting in his living room watching TV.

In accordance with Section NR 132.07(3)l of the Wisconsin Administrative Code, Exxon performed an assessment of remaining risks after we had completed our design of the mine. Our analysis ranged from chemical spills to forest fires to systems failures to aircraft crashing into mine facilities. Our goal was to identify and assess possible accidental health and environmental hazards and to develop appropriate contingency measures with respect to these hazards. Consistent with the regulations, we have also developed detailed emergency notification procedures. All of this work is set forth in detail in section D of the Mine Permit application.

Q. As a result of Exxon's risk assessment, Mr. Moe, did you identify any aspect of the project that warranted redesign or modification?

A. No we did not. As I stated earlier, we have sought from the outset to design the mine so that it will operate safely and in an environmentally sound manner. We have uncovered no risks that would suggest the need to redesign mine facilities or operation. Those remote risks that can never be completely eliminated are covered by various appropriate response measures.

Q. Finally, Mr. Moe, let me return to the Mine Permit application and the other reports and documents that you identified at the outset of your testimony. In your opinion, do those documents address all the applicable permit elements set forth in the Wisconsin Statutes and the Wisconsin Administrative Code?

A. For brevity, my testimony has only summarized the highlights of the information contained in the documents I identified earlier. Moreover, as I stated at the outset, other Exxon witnesses will be testifying later on specific aspects of the facilities and operations covered by these documents. It is my opinion, however, that these permit applications and reports comply with all elements of the government statutes and regulations.

Q. Thank you, Mr. Moe.

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EXHIBIT 257

DONALD E. MOE

EDUCATION: B. A. Mathematics - 1973 Carroll College, Helena, MT
B. S. Mine Engineering - 1974 Montana College of Mineral Science & Technology Butte, MT

REGISTRATION: Professional Engineer - Wyoming
- Wisconsin

EXPERIENCE:

1983-Present Design Engineering Manager, Crandon Project, Exxon Minerals Company

Manage the engineering work for all of the facilities associated with the Crandon Project. Ensure that the proper technical expertise is applied. Supervision of technical personnel and programs within Exxon and through the use of outside contractors.

Coordinate the input to the design basis with other Exxon affiliates. Manage the preparation of the capital and operating cost estimates and coordinate the economic evaluation of project alternatives.

Responsible for the preparation of budgets and scheduling of manpower. Reviewed permit related submittals for technical consistency with engineering work. Provide technical input and support in addressing environmental questions related to facility design, construction scheduling, manpower planning, and mine/mill production.

1982 Sr. Engineering Associate Mining, Crandon Project, Exxon Minerals Company

Supervision of mine engineering and geological staffs. Responsible for the mine design and evaluation of alternative plans. Coordinated economic evaluations to optimize project economics. Compiled budgets and manpower requirements.

1981-1982 Technical Superintendent, Highland Operations, Exxon Minerals Company

Supervised technical staff for the underground mine, surface mine, solution mine, metallurgical testing, environmental testing, and geological reserve work. Reviewed technical design and long range project economics. Interfaced with operations superintendents to ensure proper implementation of mine planning and facilities improvements. Carried out long range reclamation planning and evaluation of alternatives.

1980-1981 Underground Mine Superintendent, Highland Operations, Exxon Minerals Company

Responsible for the safe and efficient production from the underground mine. Coordinated work of engineering, geology operations, and maintenance. Prepared budgets and financial evaluations of mine plan alternatives.

1976-1980 Mine Engineer, Supervisory Mine Engineer, Technical Coordinator, Highland Operations, Exxon Minerals Company

Various positions in technical area. Responsibilities included ventilation planning, implementing a rock mechanics program, supervision of mine engineering, and surveying activities, coordinating work between operations and technical staff, and long range planning.

1974-1976 Mine Engineer, FMC Corporation

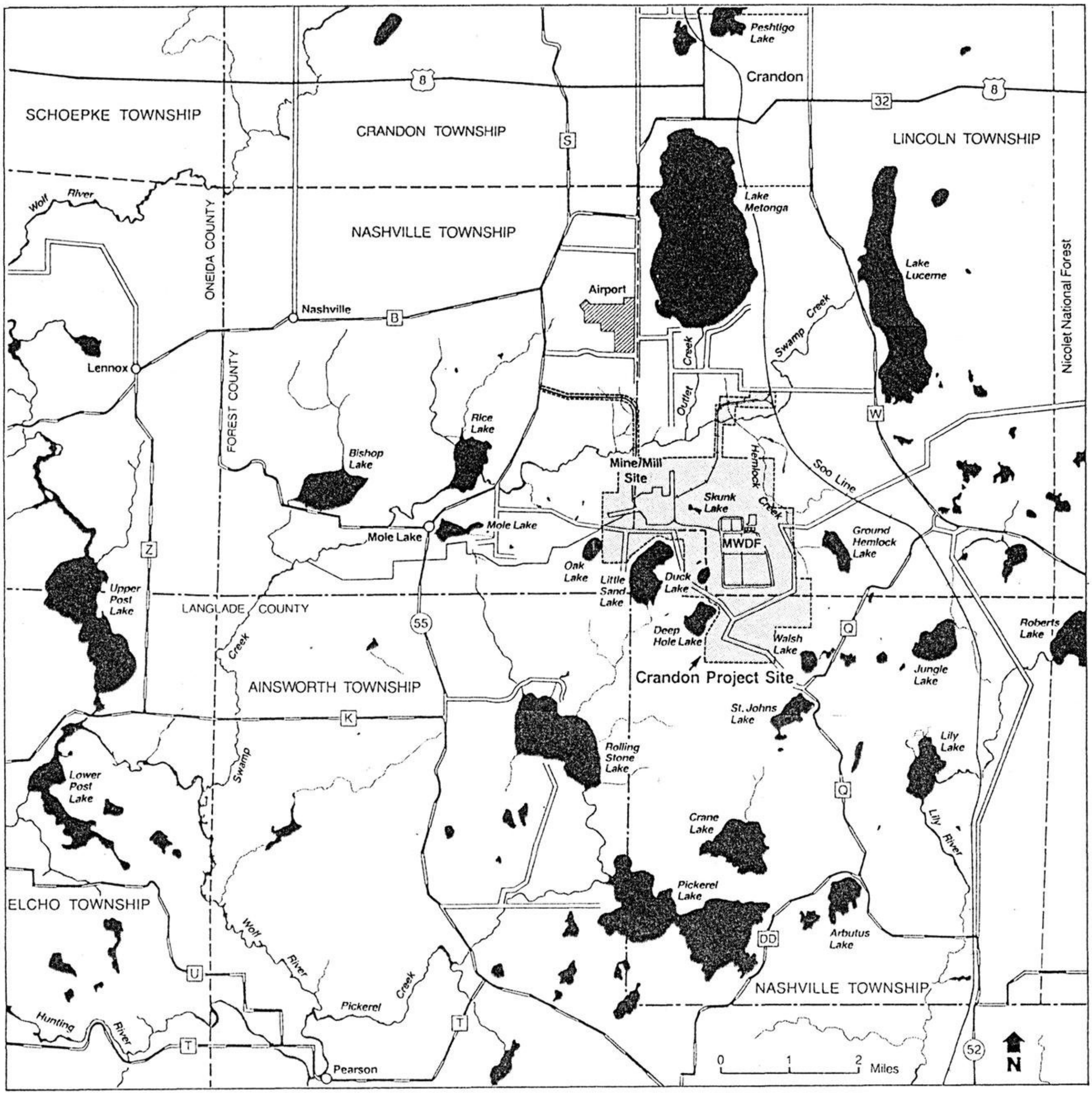
Ventilation and rock mechanics engineering, mine planning, equipment replacement studies, and relief supervision for operational personnel.

1972-1974 Mine Engineer, Contract Miner, Anaconda Mining Company

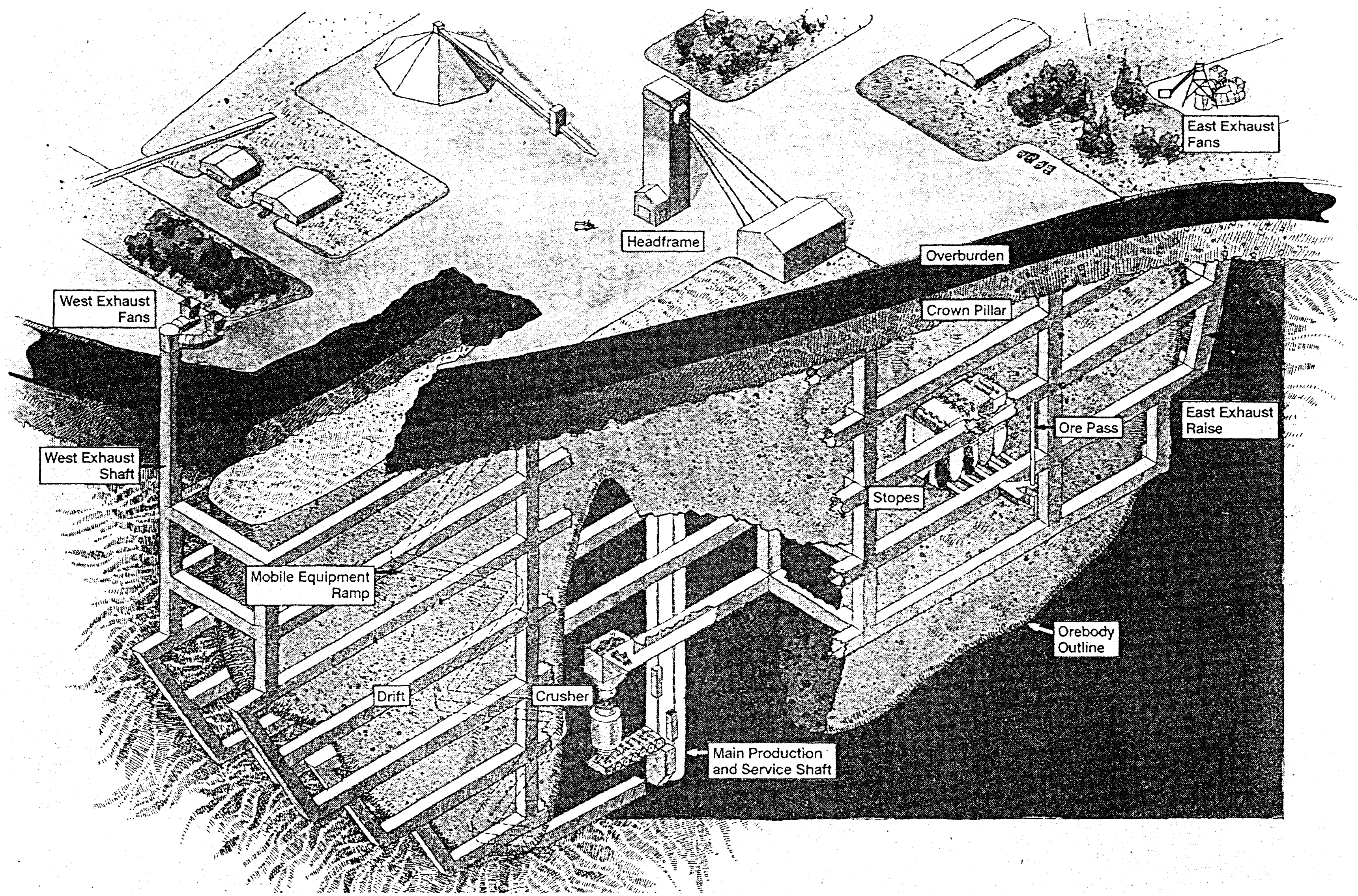
Engaged in contract stope mining, drift repair, contract measuring, and mine survey work.

0821R

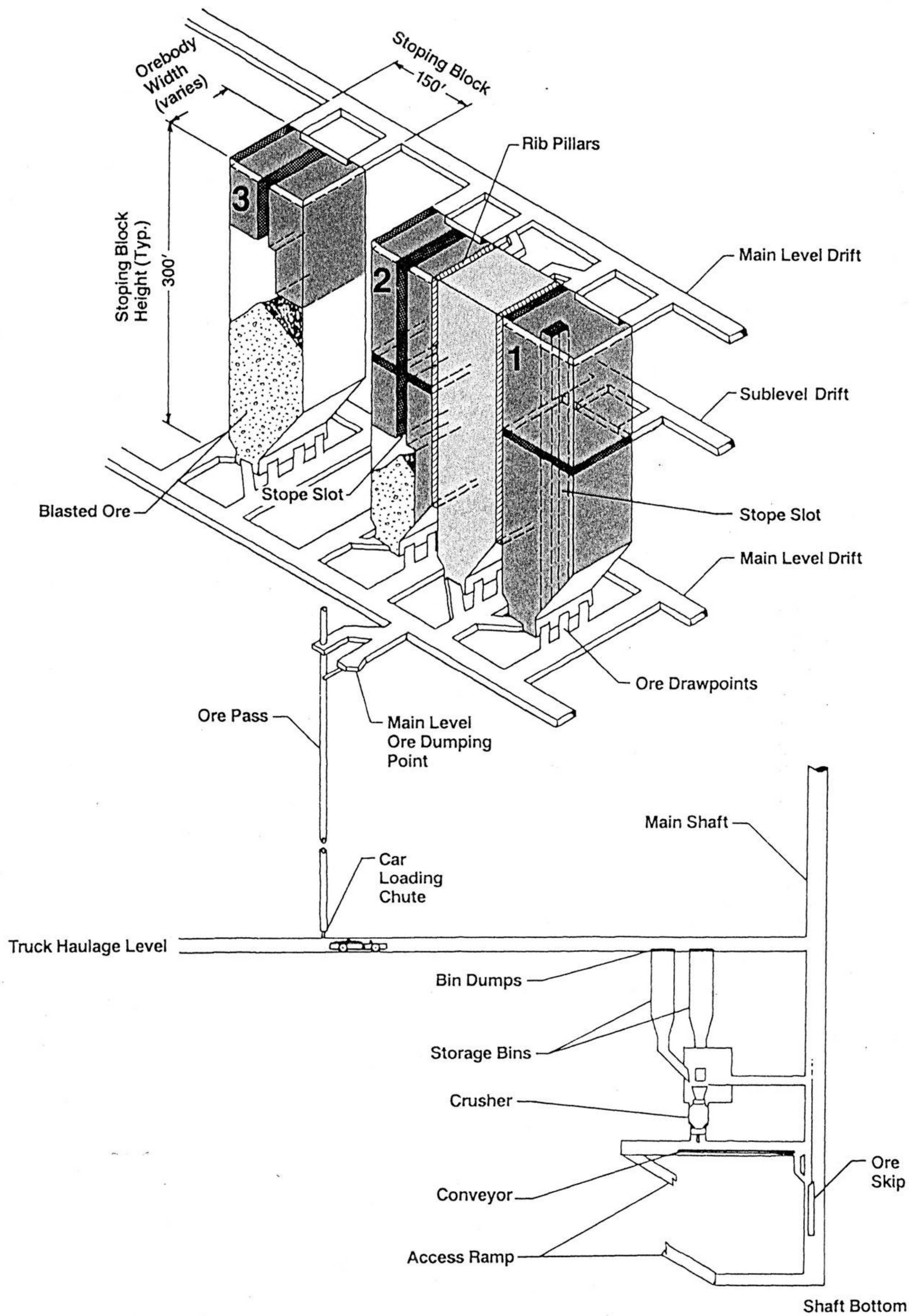
Crandon Project Site



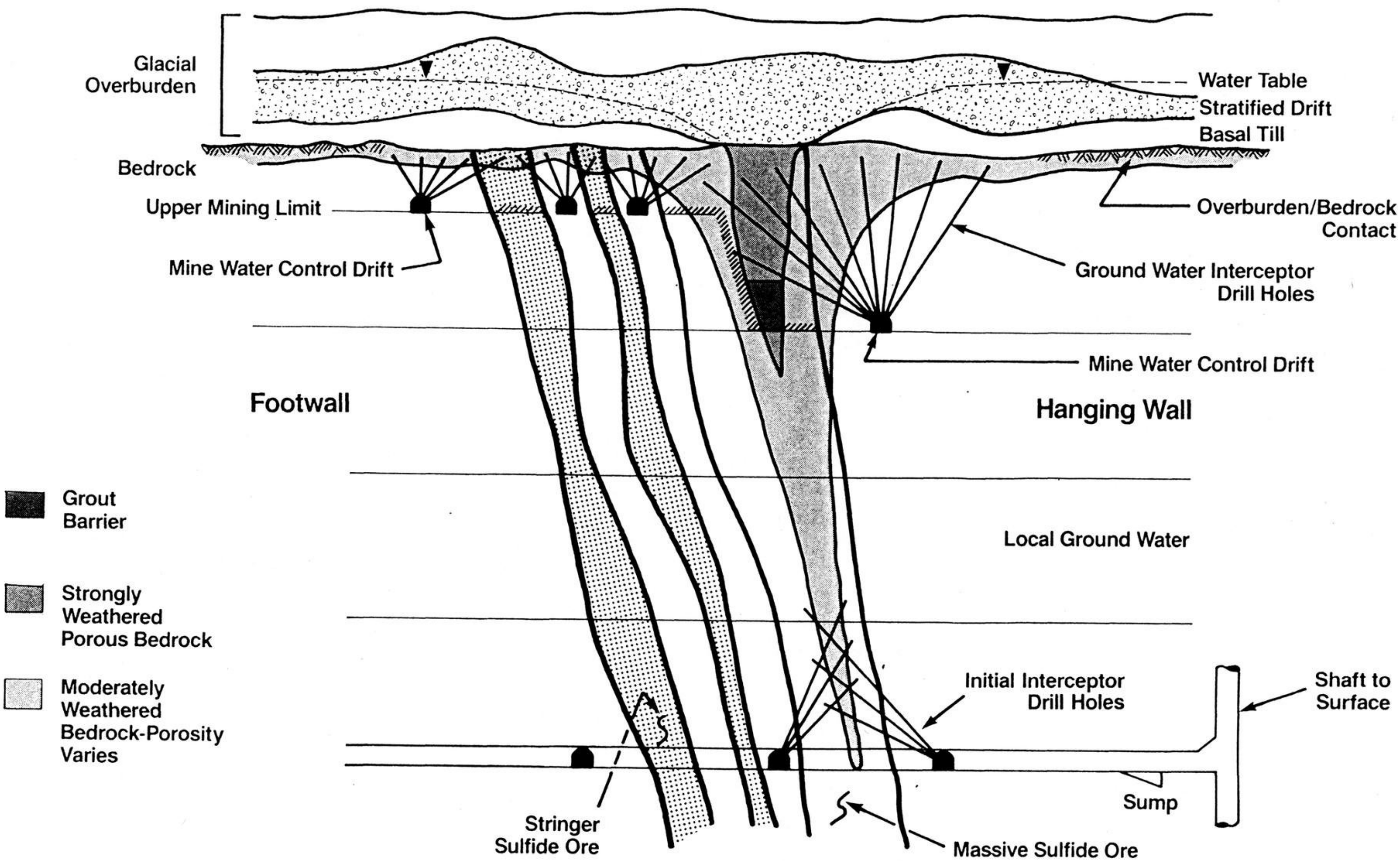
Mine Section



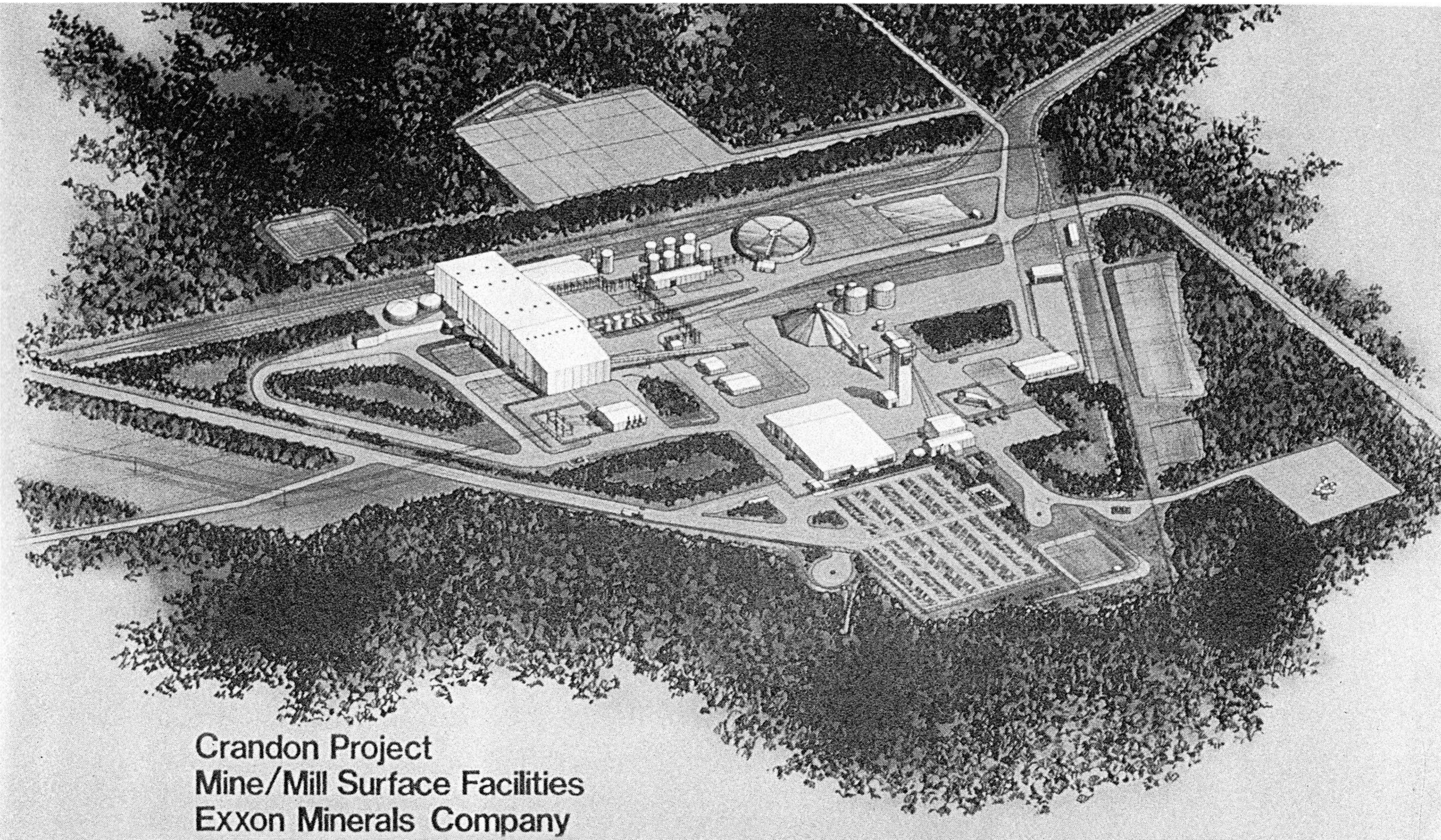
Mining Method



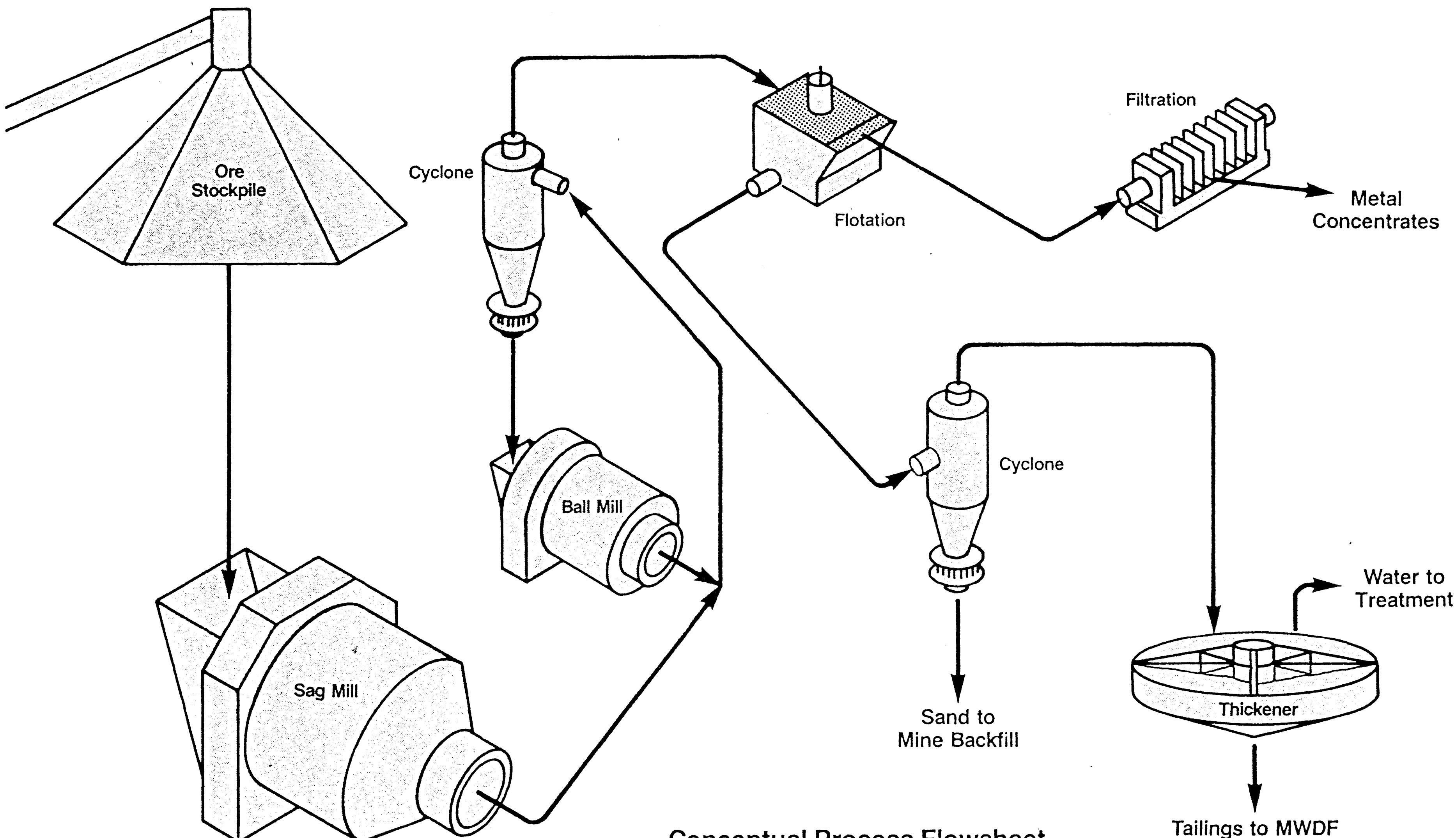
Ground Water Interceptor System



Mine/Mill Site Rendering

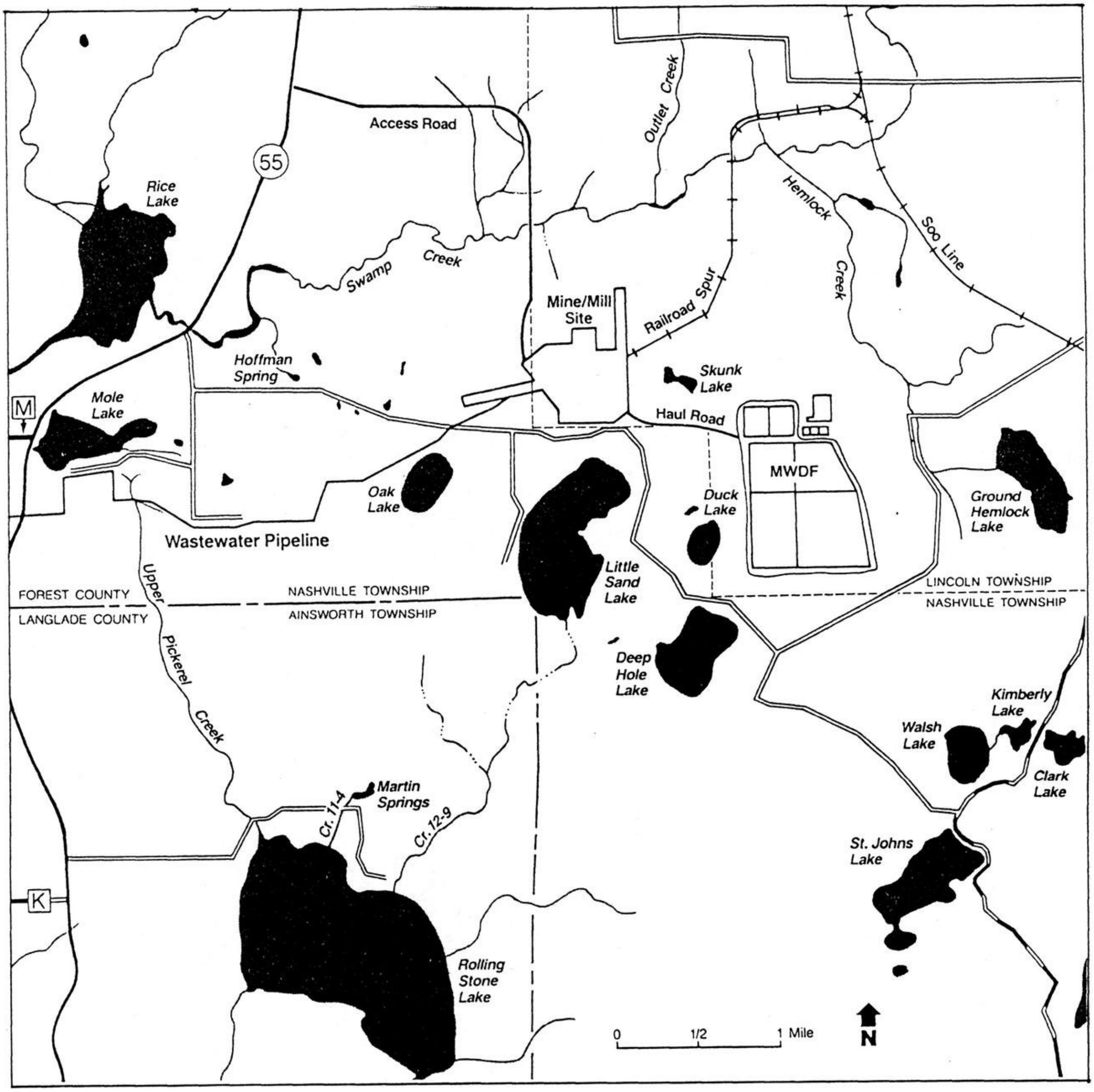


Mill Process Flow Sheet

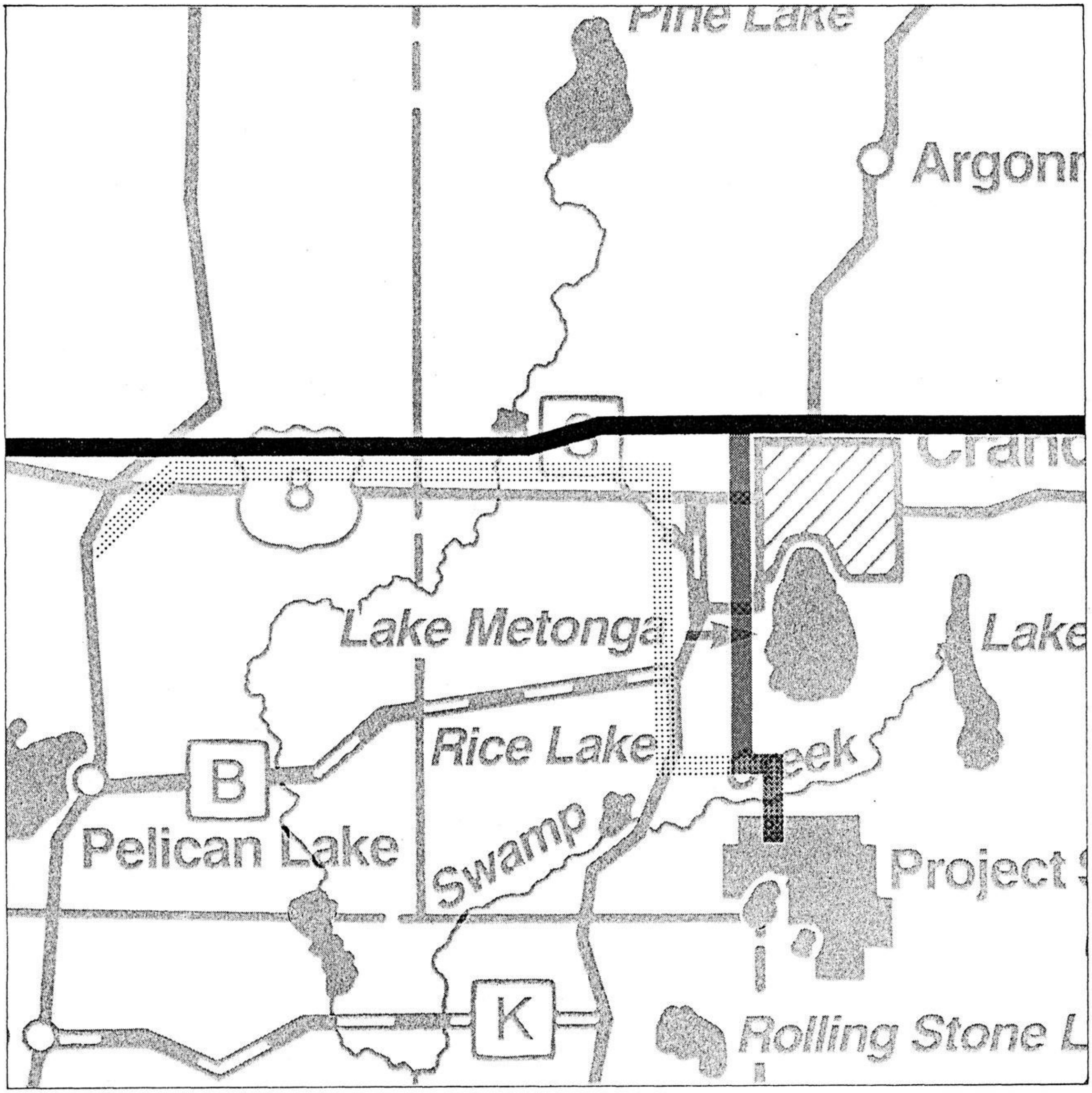


Conceptual Process Flowsheet

Project Area Map

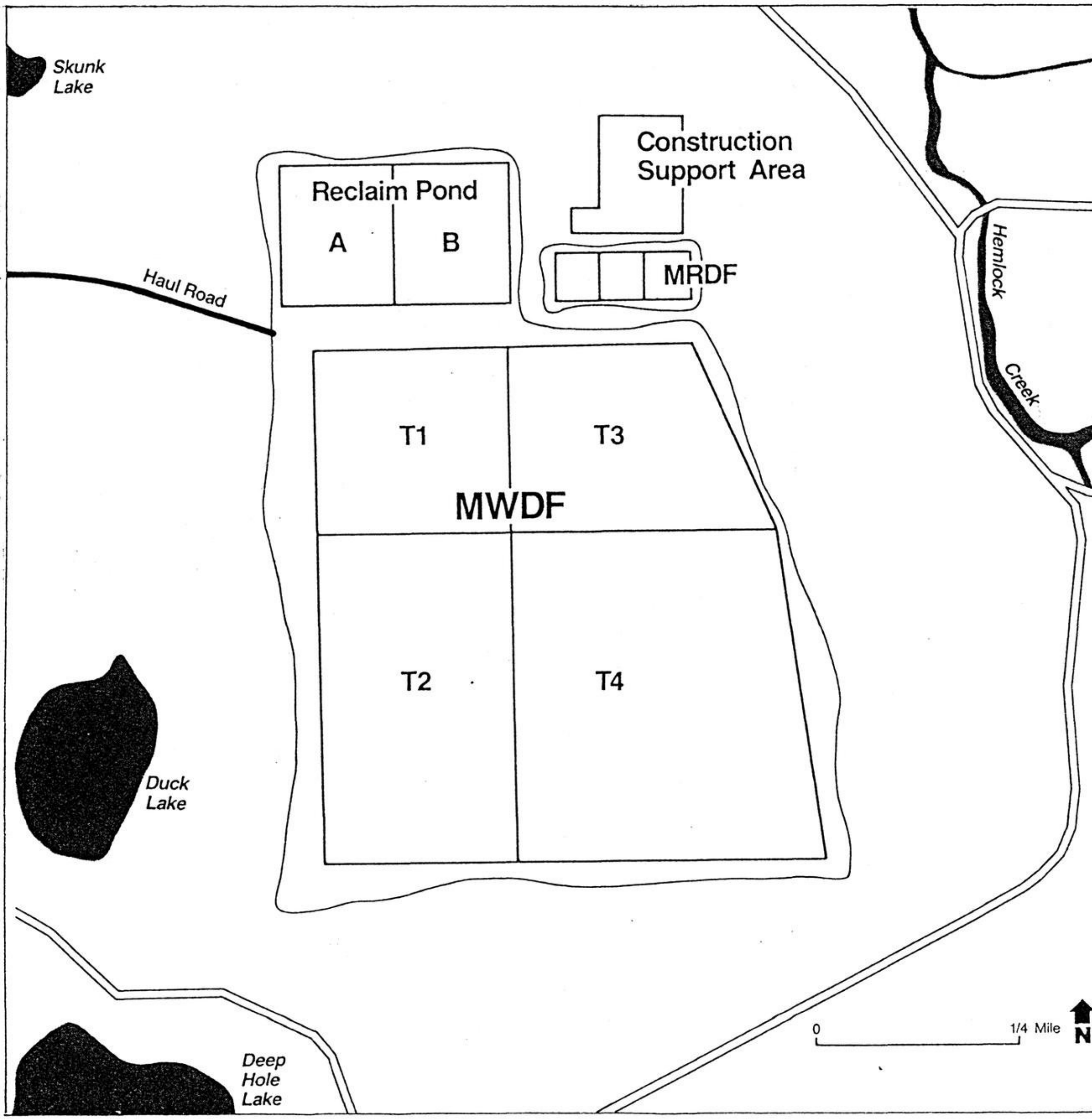


Utility Corridors

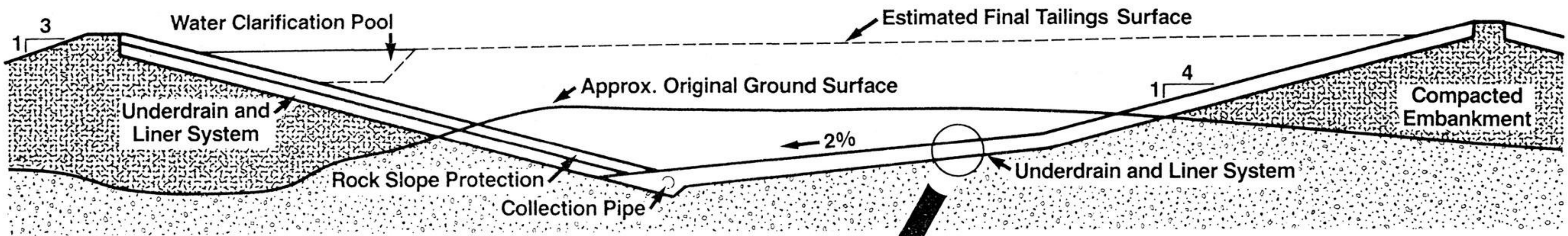


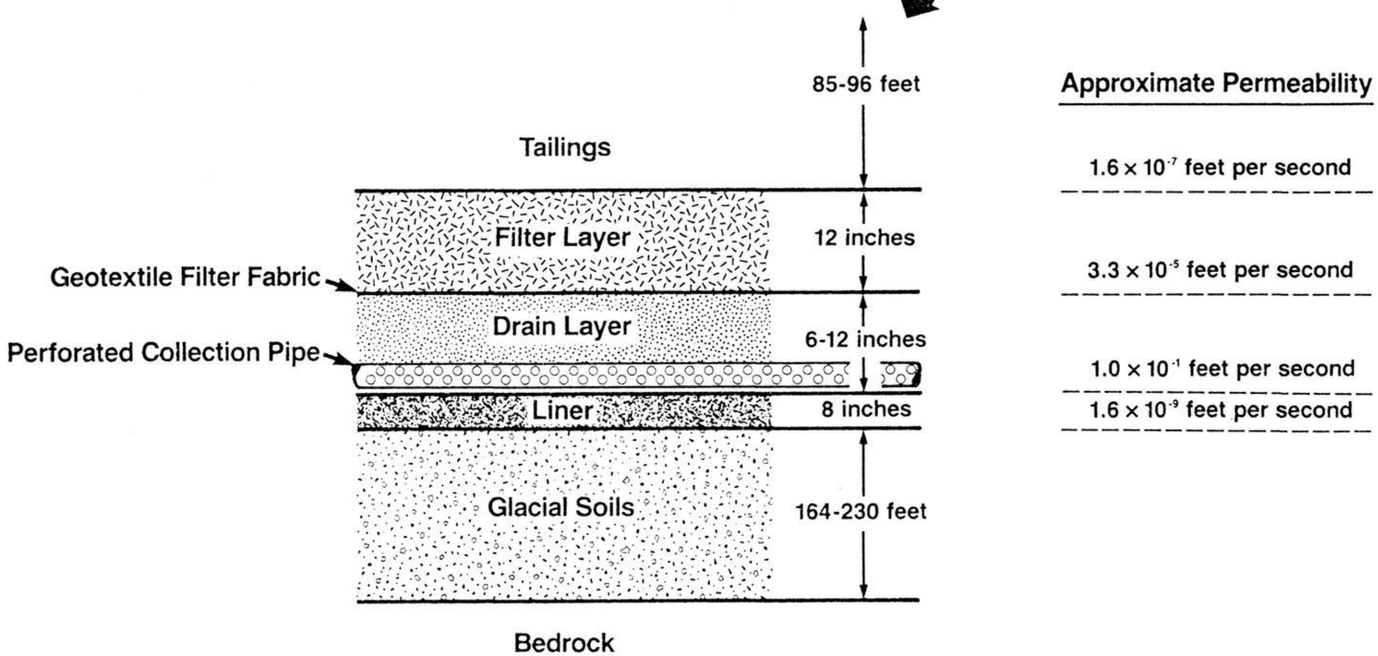
Legend
Existing natural gas line
Proposed natural gas line route
Proposed electric line route

MWDF Area
Mine Waste Disposal Facility



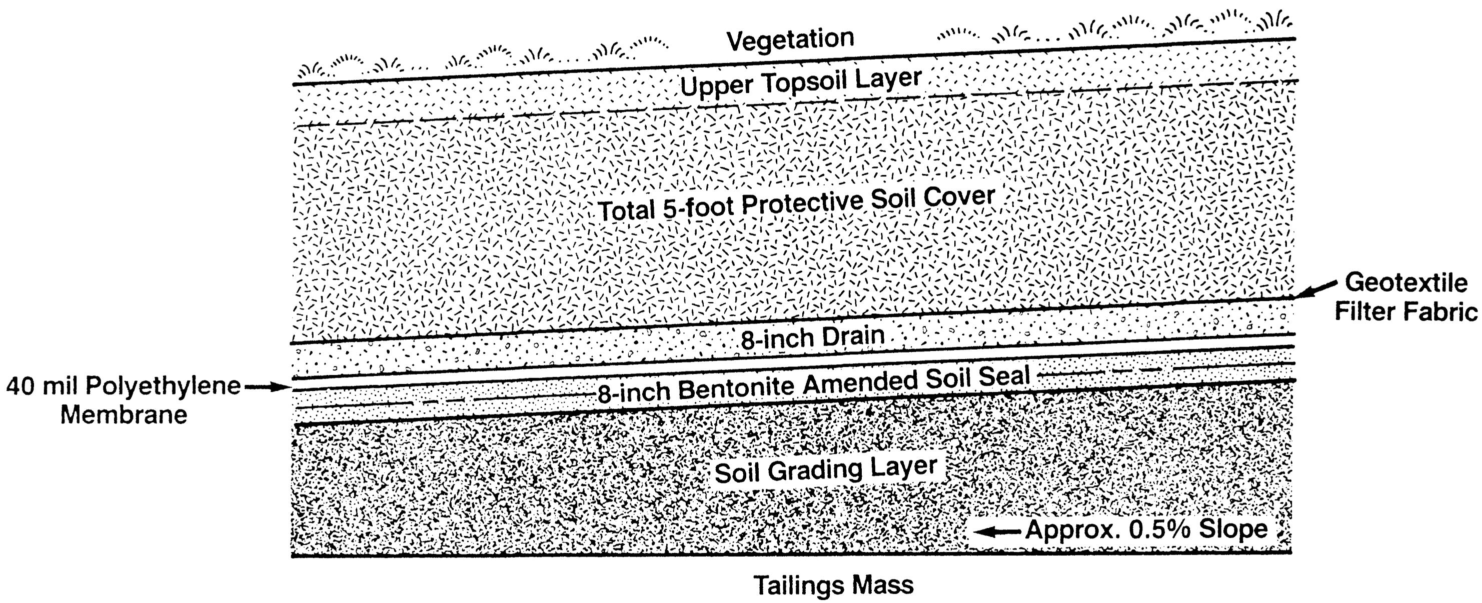
Typical MWDF Section

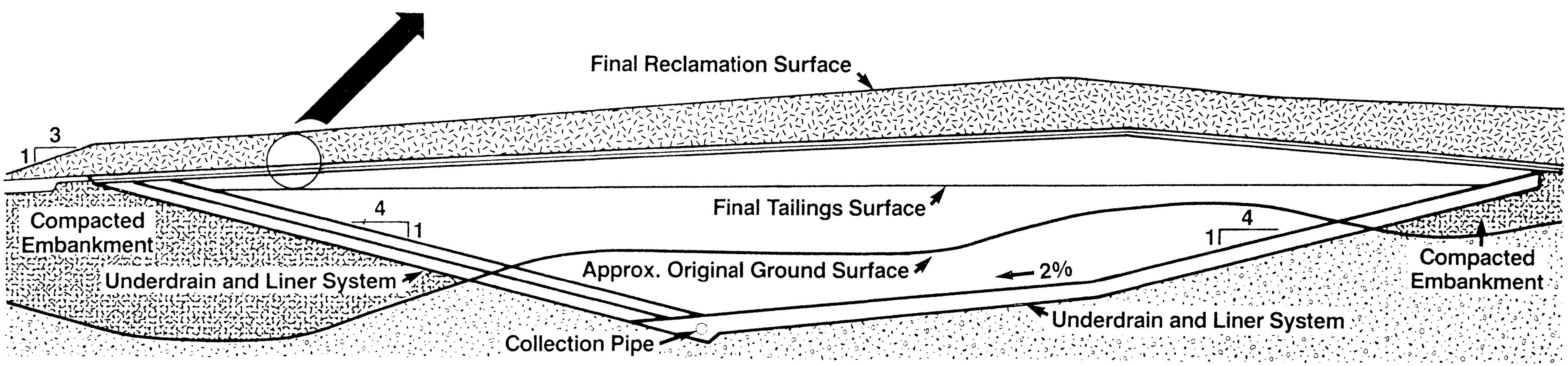




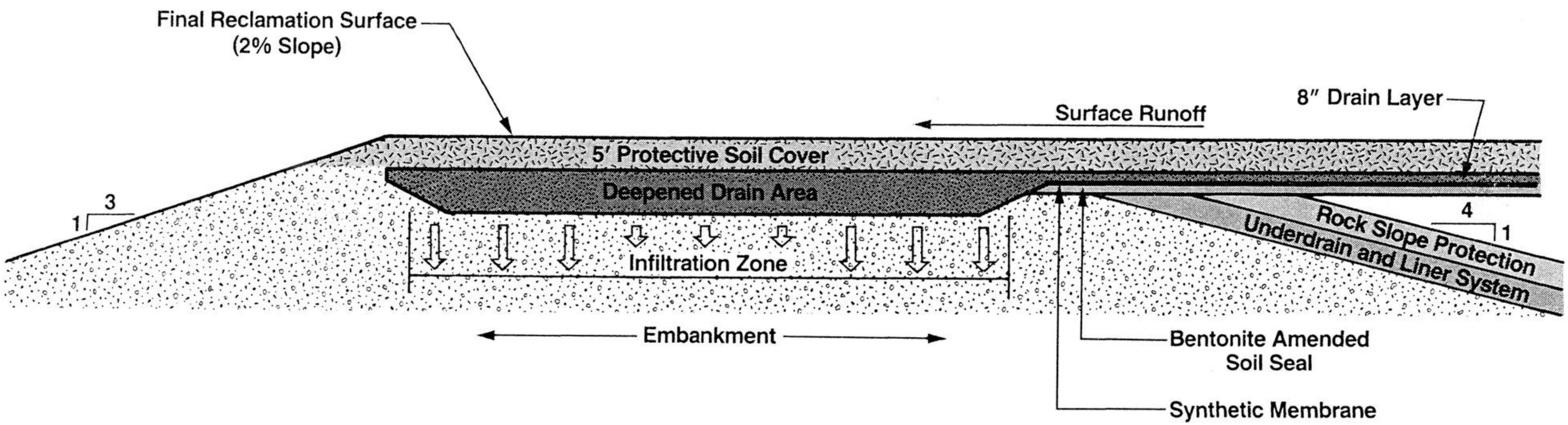
MWDF Reclaimed Section

265



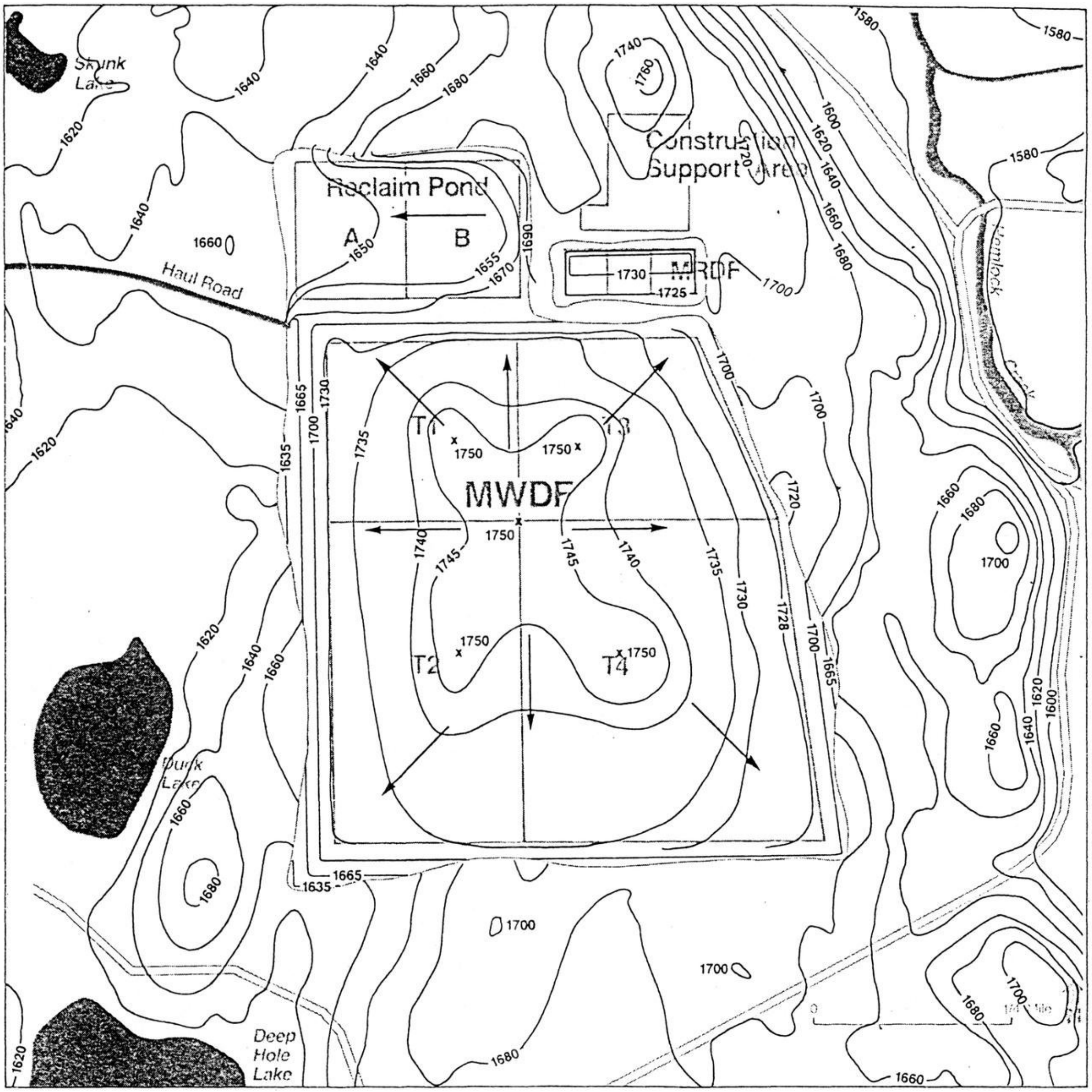


Embankment Drain Detail

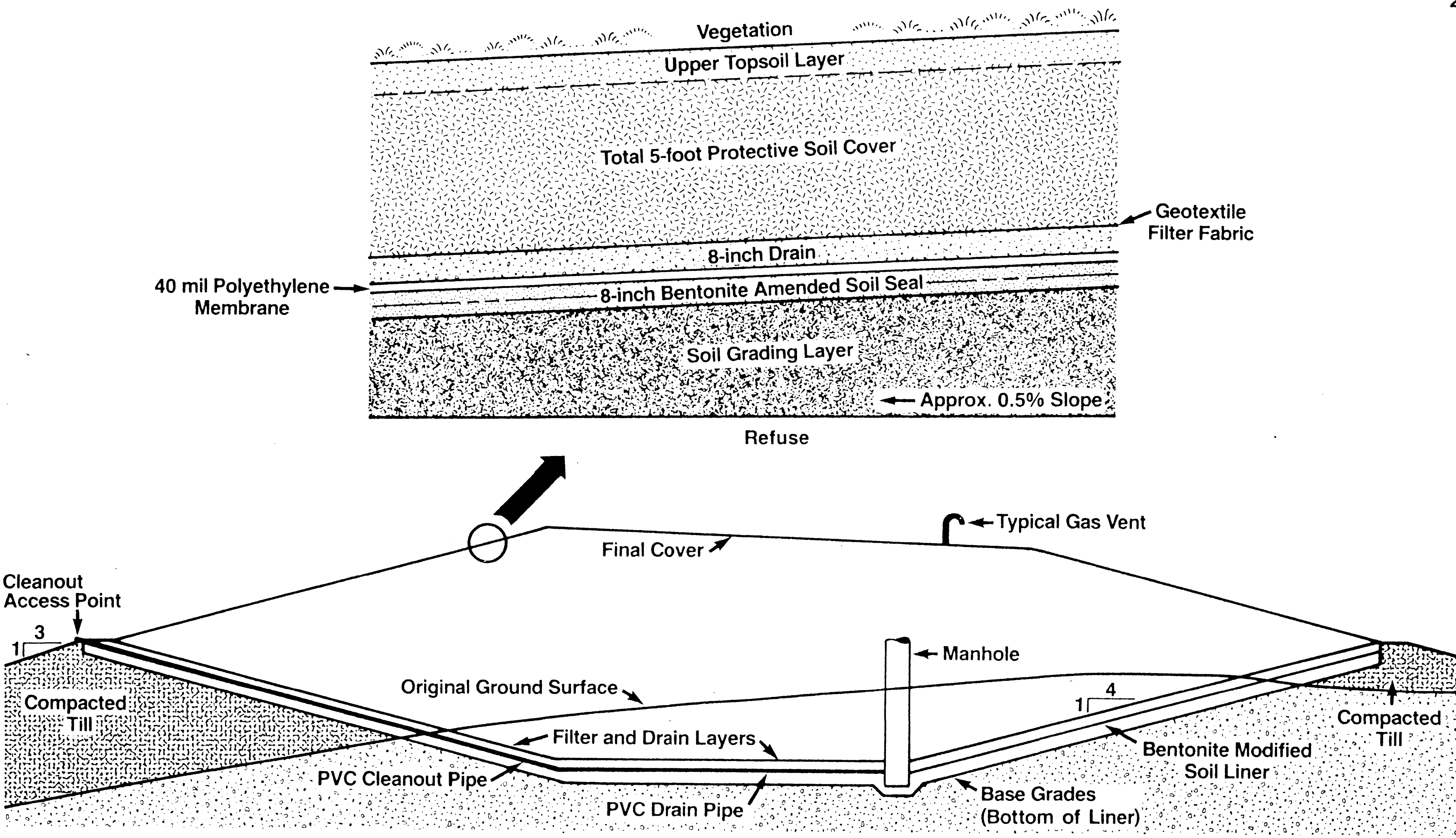


Reclaimed Surfaces

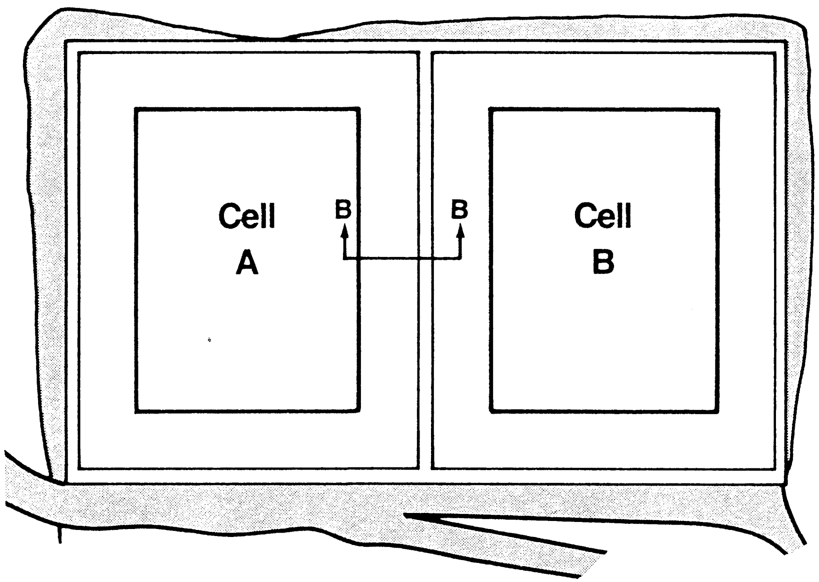
MWDF Area



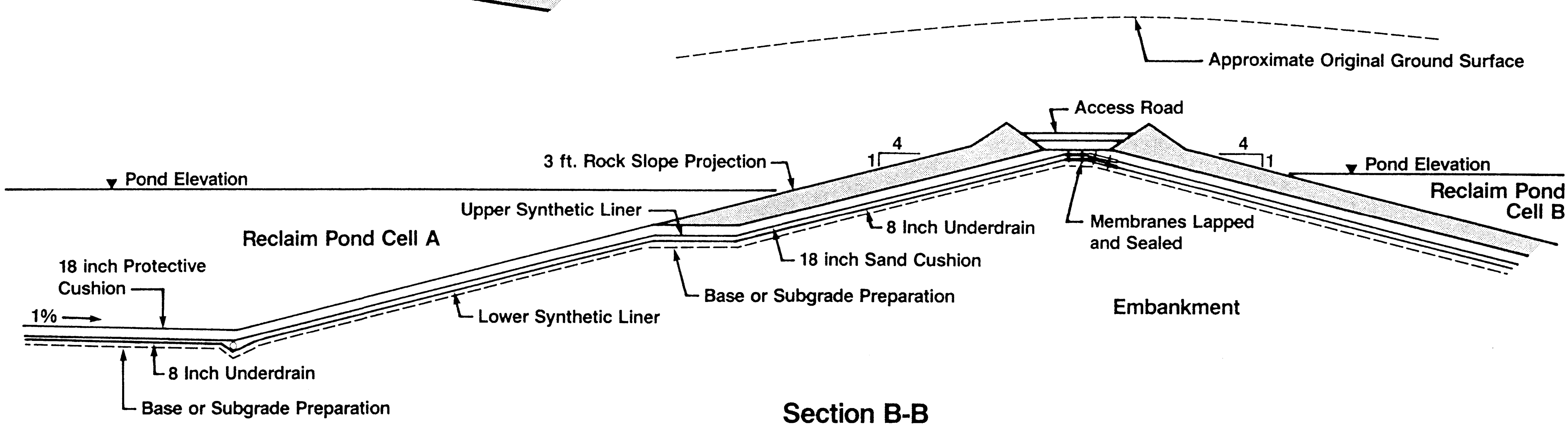
Typical MRDF Section



Reclaim Pond Section

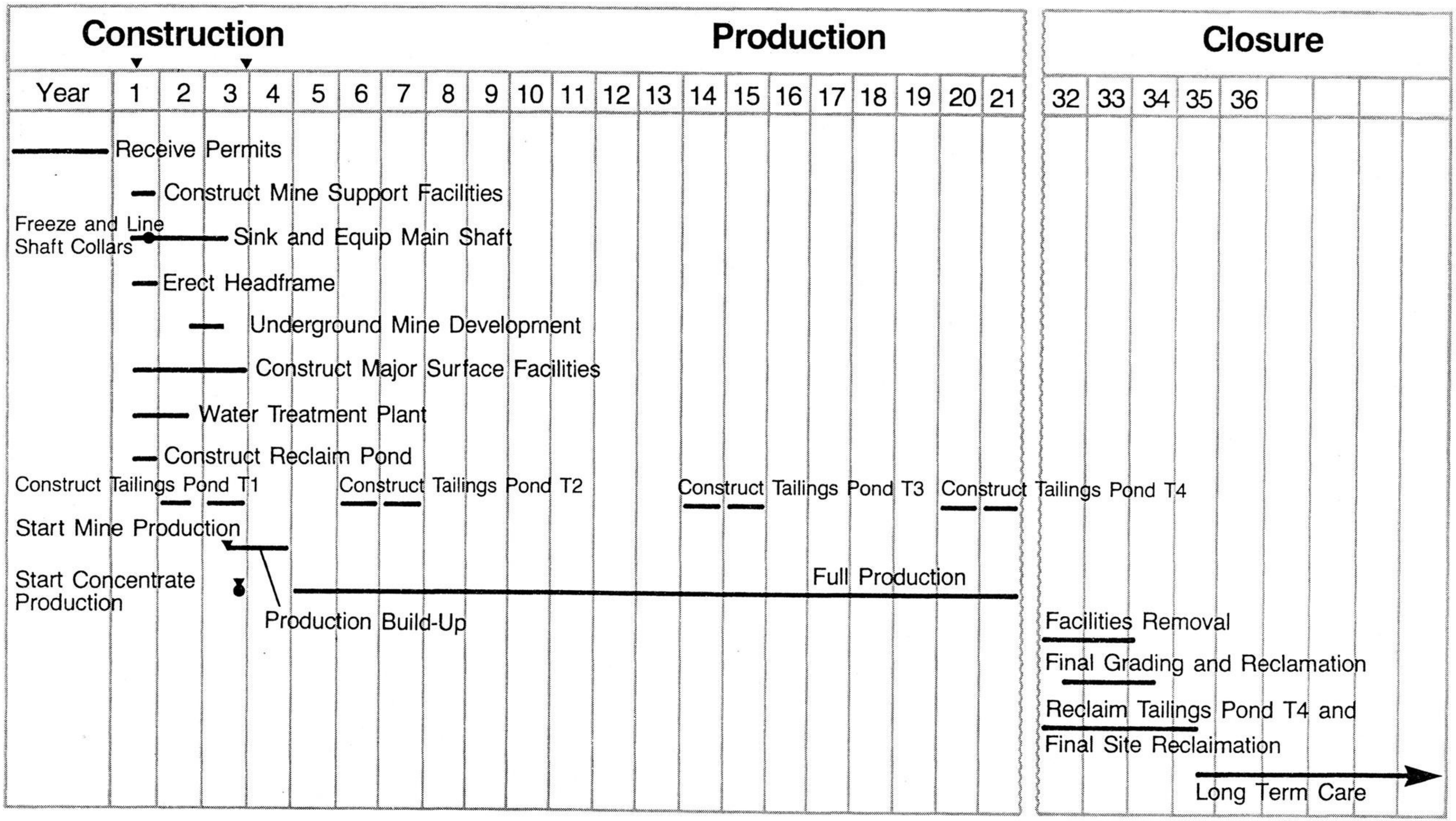


Cross Section Index



Section B-B

Project Schedule



Sites 40 & 41

Legend

- Eagle/Osprey nest
- Deer yard limits
- Area within 1000' of lakes
- Area below 1600' elevation
- Indian land