Introduction

Mining, particularly sulfide mining, presents certain unavoidable ecological risks. Take for example the case of Torch Lake, in Michigan's upper peninsula, where copper was mined between the 1860's and the 1960's. Waste from the mining process was dumped into Torch Lake or onto its shoreline. Most of the lake's western shore and twenty percent of its bed was covered with the copper ore waste and with waste from the local smelter.

Today, Torch Lake is part of a U.S. Environmental Protection Agency Superfund site. Sediments in the lake are heavily contaminated with copper, a substance highly toxic to aquatic ecosystems. The density and diversity of the lake's bottom dwelling communities is extremely low. Windblown dust, groundwater contamination, and contamination in the water column contribute to concentrations of copper, arsenic, lead, and mercury that exceed Michigan's Water Quality Standards and violate human health and aquatic protection criteria promulgated under the federal Clean Water Act.

Not all sulfide mines will result in the severity of harm experienced at Torch Lake. Moreover, some of sulfide mining's ecological threats can be mitigated or avoided altogether.

Nevertheless, the decision to allow sulfide mining inevitably is a decision to permit some ecological harm. Whether this harm is worth the anticipated benefits of a mine is a question for policymakers and regulators. The decision to permit a sulfide mine guarantees environmental disturbance and degradation to a degree never exactly predictable.

Thus, the true "price" that local communities pay in exchange for anticipated benefits becomes known only as theoretical harms transform themselves into realties. For certain communities, such as Indian tribes, this "price" may be particularly devastating.

This publication's intent is to enhance the reader's understanding of the threats posed by sulfide mining, and to raise issues that should be considered before decisions concerning mine permitting are made.

Chapter One describes the sulfide mining process. Chapter Two describes the environmental threats posed by this process. Chapter Three explains why these threats are especially serious for Indian tribes who have reservations near mine sites, or who hunt, fish and gather in areas that may be affected by mining. Finally, Chapter Four will discuss Wisconsin's mining laws as they relate to environmental protection and note changes in those laws over time.

Acknowledgments

Research assistance provided by Rodolfo de la Cruz, Ph.D., University of Wisconsin–Madison (Chapter One), Larry T. Brooke, M.S., University of Wisconsin–Superior (Chapter Two), Todd Korb and Alison Mehlman.

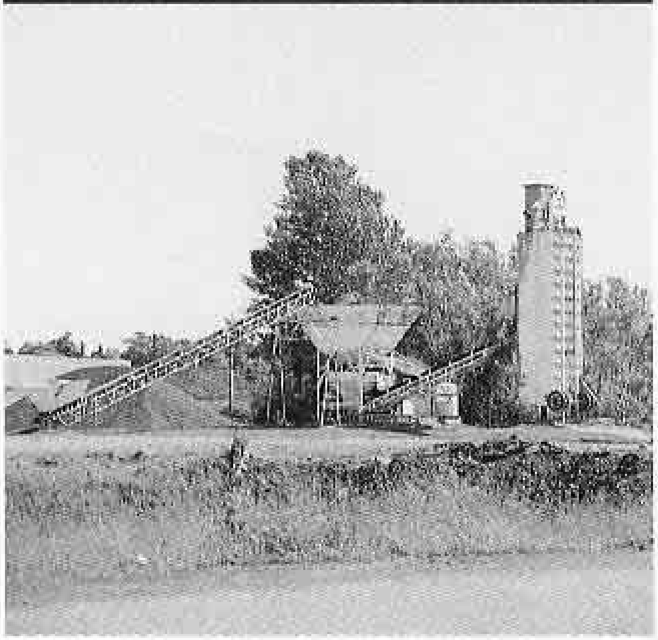
Analysis of cultural effects taken from Professor Charles E. Cleland, Professor Thomas P. Kasulis, and Professor Philip J. Handrick. Any errors or omissions are our own.

Editing provided by David J. Siegler.

Photograph (top right on cover and Chapter Two): Philip M. Hocker/Mineral Policy Center.

The Sulfide Mining Process

Chapter One



Mining is the process by which valuable minerals such as copper, lead, zinc, gold and silver, are extracted from the earth. Usually these minerals are not found in their pure or native form, but as components of other minerals. Copper, lead, and zinc often are bonded to sulfur, forming sulfide compounds. Thus, copper, zinc and lead mining is often referred to as sulfide mining, and the release of various forms of sulfur is an inevitable by-product of the metals' extraction.

Basic Geology and Exploration

Copper, zinc, and lead are widespread in the rocks of the earth's crust, but ordinarily in minute quantities. Copper accounts for only 0.0058% of the earth's crust by weight, and lead and zinc even less. Because of the rare geological occurrence of these minerals, they must be found in relatively high concentrations in order for mining to be economical.

For instance, at the Copper Range mine in White Pine, Michigan, copper constitutes an average of about 1.1% of the ore. At a proposed mine near Crandon, Wisconsin, the massive portion of the ore contains about .6% copper, 8.4% zinc, and .7% lead.

The first step in mining is to find commercially exploitable quantities and concentrations of minerals. Figure 1, page 2 shows mineral exploration and known deposits in portions of Wisconsin, Minnesota, and Michigan.

Discovery of a high mineral content in the soils and plants at a particular site, or geophysical identification of rocks and minerals with the electromagnetic characteristics of a sulfide orebody, can lead to further exploration. In this phase of exploration, the goal is to establish an orebody's geometry, minability, and amenability to processing. Extensive core drilling, metallurgical bulk sampling and testing, and other mine studies are conducted. The suitability of the orebody to either underground mining or open pit mining is also determined, based largely on the depth and size of the orebody.

Development and Mining

Development includes all the activities that must take place before the orebody can be mined. This involves construction of surface structures, access roads, power lines, and rail lines. If an open pit mine is constructed, development will also include removal of the rocks and soil covering the orebody. If an underground mine is built, development will include construction of access and ventilation shafts.

With either a surface or underground mine, any pit or shaft that is below the water table will naturally accumulate groundwater. The mine acts like a giant well by pulling in

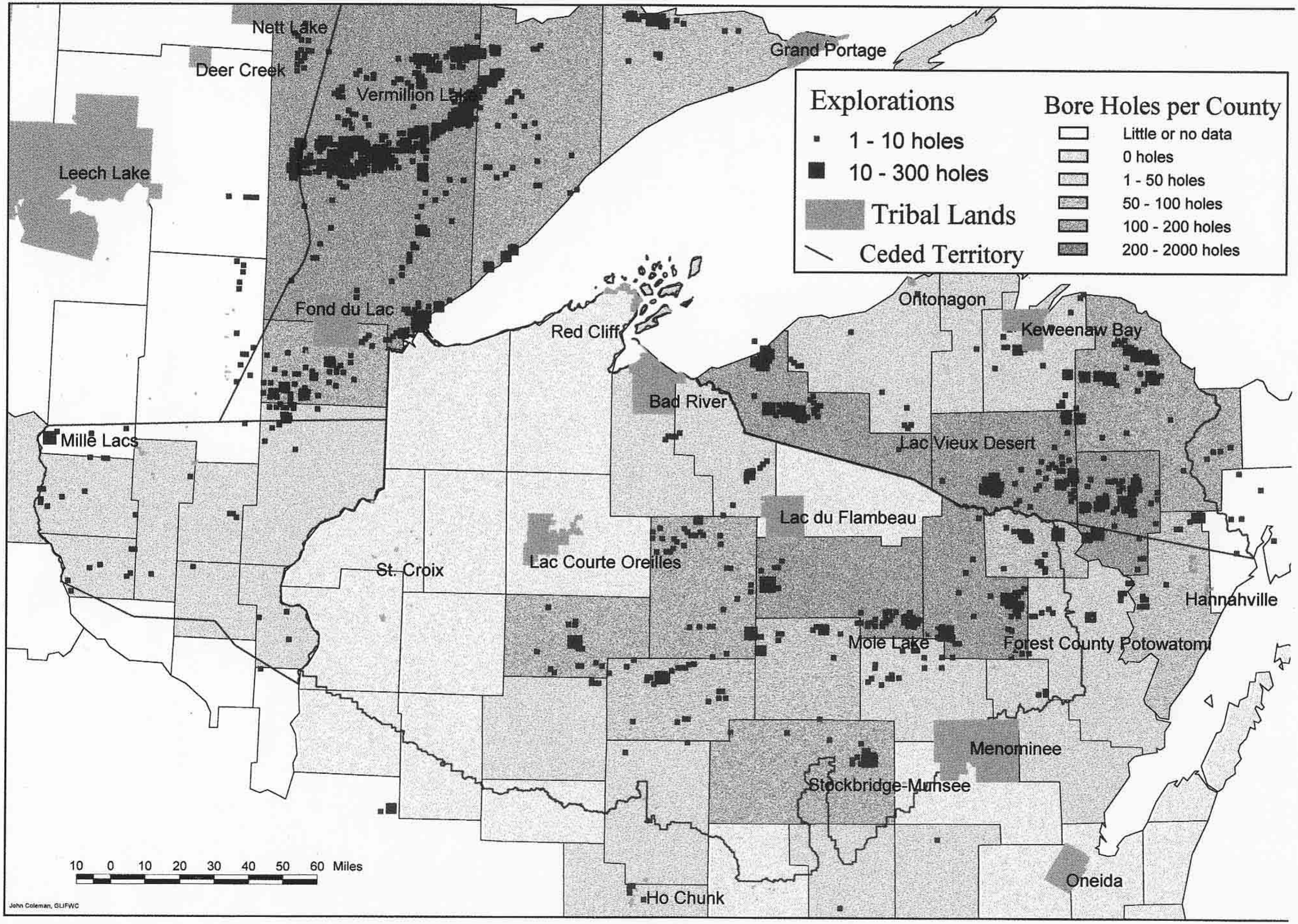


Figure 1. Mineral exploration in portions of Michigan, Wisconsin, and Minnesota. Note that reporting and drilling activity is voluntary in Michigan. The Michigan Department of Natural Resources estimates that the points on the Michigan portion of the map represent only about one-tenth of the actual drilling that has occurred.

water from the surrounding area. This water must be pumped out of the mine in order for miners to enter the mine and remove the ore. Pumping must continue until mining is finished and the mine is closed.

Access shaft at a mine in Michigan's Upper Peninsula.

Pumping groundwater from the mine, or dewatering, creates a cone of depression in the groundwater of the surrounding area. This may lower water levels in nearby wells. If the groundwater is linked to rivers or lakes, surface water levels also may be lowered. The size of the cone of depression and the extent of the impact on surface water will depend greatly on the area's geology.

Both surface and underground sulfide mines produce large amounts of solid waste. Most solid waste comes from waste rock and from ore processing byproducts. Waste rock is made up of the soil, rock and non-target materials that must be removed in order to reach and excavate the high mineral content ore. The amount of waste rock depends on the location and depth of the orebody. Processing byproducts, called tailings, consist of the leftover ore after the target minerals have been removed. Since the amount of mineral content in "high mineral content" ore is relatively small, the tailings generated in a mining operation are large. For example, each ton of copper ore only yields about 8-10 pounds of copper, leaving 1,990 pounds of tailings.

The waste produced from sulfide mining processes is not benign. Waste rock may contain radioactive materials. Tailings contain heavy metals, chemicals, and acid generating sulfide compounds, all of which are toxic to the environment in varying degrees.

There are a variety of underground mining methods. Most use stoping, a process involving the creation of large openings by removing ore. Some place backfill—often waste rock or tailings—in the empty spaces left after the ore has been removed. Backfill provides support for the mine workings so that more of the ore can be mined.

Extraction of the orebody itself involves a cycle of drilling, blasting, ore and rock loading, and transporting so that the ore can be processed and the target minerals recovered.

Beneficiation: Milling and Concentration

Today, most sulfide ore is not of a high enough grade to be shipped directly to a smelter. It must go through a process known as beneficiation, where the ore is milled and concentrated using various chemicals.

At Crandon Mining Company's proposed mine site in Forest County, Wisconsin, the massive part of the ore contains 8.4% zinc and .7% lead. After beneficiation, the lead/zinc concentrate will contain 55-60% zinc and lead, and thus can be shipped to a smelter more economically.

During milling, a series of machines crush the ore into fine particles, the largest being about the size of a grain of sand, so that it can be processed more easily. When the ore particles reach a size at which they are most susceptible to chemical treatment, they move to the concentration stage. Concentration can be accomplished in a number of ways.

Froth Flotation

Froth flotation is the most widely used method of beneficiating sulfide ores. Chemicals are used to produce a concentrate containing the targeted minerals. A list of some of these chemicals is found in Figure 3, page 13.

Froth flotation begins by adding chemicals to the milled ore, so that the surfaces of one or more minerals in the slurry will repel water and attract air bubbles. The air bubbles rise to the surface of the slurry where the resulting froth, which contains the valuable minerals, is skimmed and collected. The froth is then dewatered and thickened, and the resulting concentrate is sent to a smelter for further processing.

Some of the chemicals used in the flotation process may be used again to concentrate more ore. However, these chemicals are a significant byproduct of ore processing that ultimately must be disposed of.

Froth flotation is the beneficiation method proposed by the Crandon Mining Company. Figure 4, page 15 shows the chemicals that Crandon Mining Company proposes to use in its flotation process.

Some of these chemicals, such as copper sulfate, sodium cyanide and sodium dichromate, are known to be highly toxic to aquatic life. Other chemicals do not pose such serious environmental threats, but nevertheless will be used in large quanities. This is the case with lime.

Crandon Mining Company currently plans to process about 55 million tons of ore. About 31 million tons of this ore is called massive ore. For every ton of massive ore that would be beneficiated at the Crandon site, approximately 6.28 pounds of chemical reagents, including about 3.9 pounds of lime, would be needed. Approximately 97,340 tons of reagent, including 60,450 tons of lime, would be used over the life of the mine.

Gravity Separation

Gravity separation is a beneficiation method that separates solids of different specific gravities by suspending them in a fluid. The different settling rates of the solids allow the desired mineral to be extracted.

Leaching

Leaching involves pumping a chemical through broken or crushed ore to dissolve the valuable embedded minerals. The solution, made up of the chemical and the mineral, is known as a pregnant leachate solution. Mine operators may choose one of a number of techniques to recover the minerals from the leachate, including solvent extraction, electrowinning, ion exchange, or cementation.

There are four kinds of leaching processes. Dump leaching takes place on an unlined but impervious base surface. Vat leaching, a high production rate method, is conducted in a system of vats or tanks using concentrated extracting solutions (often sulfuric acid). Heap leaching takes place on a lined pad made of a synthetic material, asphalt, or clay. Heap leaching is used with low grade, crushed ore. Finally, in situ leaching extracts minerals from ore that is still in the ground.

The Copper Range Mining Company of White Pine, Michigan, has proposed in situ leaching to recover copper from mined out areas. Copper Range would blast support pillars, circulate a sulfuric acid solution through the rubble, and electrolytically recover copper from the pregnant leachate solution. The solutions would be regenerated and reused, yet eleven billion gallons of spent solution would be left in the mine at the completion of the project.

Waste Management

Beneficiation produces tailings and waste water as byproducts of mineral concentration. Tailings are the ore that is left over after the targeted minerals have been removed and are contained in a slurry of water and chemicals used in beneficiation.

Tailings pose serious threats to the environment and therefore must be isolated. They are often stored and contained in pits, or tailings management areas, that are lined with generally impermeable materials, such as clay or synthetic liners.

Tailings are allowed to settle in the pits so that some of the water may be collected. In addition, leachate collection systems below the liners are designed to trap liquids that have leaked through. Waste water and collected leachate normally are collected and reused or treated.

In some instances, tailings are used to backfill the mine. Tailings may be combined with cement or another material to provide structural support to the underground mine workings. This allows a greater percentage of an orebody to be removed.

Waste rock piles in Michigan's Upper Peninsula.

Smelting and Refining

Most sulfide mineral concentrates are smelted. The metals also may be refined depending on their intended commercial use. Smelting involves three separate steps: roasting, smelting, and converting.

Roasting is required for high sulfur concentrates. It oxidizes the iron in the concentrate and drives off sulfur dioxide. Smelting bonds most of the remaining impurities in the beneficiated (and, if necessary, roasted) ore into a molten slag, by combining the ore with a silica substance and heating it to high temperatures.

At the same time, the major metals combine with sulfur to form an impure mixture of metallic sulfides. Converting drives off the sulfur from the metallic sulfides, oxidizes the remaining iron, and removes it. After the silicate slag is discarded, only the nearly pure metals remain. Roasting, smelting, and converting can result in a metal that is up to 99% pure.

When a very pure metal is needed, such as copper for electronic applications, the extra step of refining can make a metal that is 99.99% pure. Refining can be done in a number of different ways, including fire refining, electro-metallurgical refining, vapormetallurgical refining, or high-pressure hydrometallurgy.

Reclamation

Reclamation, the last mining activity, is the rehabilitation and restoration of the project site to a state as close as possible to its original pre-mining condition. The goal is to eliminate, minimize, or mitigate physical or chemical environmental threats. While most reclamation consists of the removal of all mining support structures, and the revegetation and stabilization of the mine site, there is no single way to accomplish reclamation. Each case will differ, and the choice of reclamation measures will be influenced by such variables as climate, the physical characteristics of the mine site, the laws of the particular state where the mine is located, and the technical and economic feasibility of the reclamation project.

The Effects of Sulfide Mining on Ecosystems

Chapter Two

All mining has impacts on air, water, soil, and living organisms. Some are less severe than others; some can be prevented or mitigated; but some environmental damage is certain. Inevitably, the decision to permit mining guarantees environmental disturbance and degradation to a degree never exactly predictable.

Unfortunately, even the best available science and technology cannot prevent environmental damage. Thus, the decision to allow mining is not a question of whether to permit environmental damage. It is a determination of the nature and extent of the damage and uncertainty that is "acceptable" as a matter of public policy.

Proper public policy decisions can only be made by understanding the nature of the environmental threats posed and acknowledging that science and technology provide no guarantees.

Although all mining operations impact the environment, sulfide mining poses threats that are especially severe. All mining scars the earth and produces large amounts of waste. But sulfide mining, because of the characteristics of the ore, poses threats that are substantially different than many other types of mining.

This Chapter will document these threats by examining each phase of the sulfide mining process.

Only as these threats are realized, will communities near sulfide mines know the true "price" that mining carries. Decision makers must understand these threats before they can make informed choices about whether to encourage or even allow sulfide mining.

Environmental damage from mining rarely effects only individual components of ecosystems. For example, if mine dewatering lowers surface water levels, aquatic flora and fauna are affected.

Thus, the focus of this Chapter is on ecosystems: systems in which there is an interdependence and interaction between living organisms and their immediate physical, chemical and biological environments. In particular, aquatic ecosystems are examined because, if permitted, proposed mining in Northern Wisconsin will take place in a wet environment.

No attempt is made to detail every mitigation technique used to minimize the risk and severity of mining's environmental threats. Mitigation is discussed, however, where it is particularly vital in preventing widespread environmental damage.

An ecosystem can be threatened by sulfide mining operations when wastes containing polluting compounds enter and harm the physical or biological components of the ecosystem.

Mining's potential threats to ecosystems have been recognized for centuries. Writing the world's first mining textbook, Georgius Agricola observed in 1556:

> *The strongest argument of the detractors is that the fields are devastated by mining operations ... the woods and groves are cut down, for there is need of an endless amount of wood for timbers, machines and the smelting of metals. And when the woods and groves are felled, then are exterminated the beasts and birds, very many of which furnish a pleasant and agreeable food for man. Further, when the ores are washed, the water which has been used poisons the brooks and streams, and either destroys the fish or drives them away.*

Today, the underlying causes of the damage that Agricola described are well understood. For example, it is now known that ore processing byproducts include heavy metals and other toxic compounds that poison fish and their habitats.

Moreover, the history of sulfide mining in the United States illustrates the damage caused to ecosystems by acid mine drainage, heavy metal contamination, chemical process pollution, and sedimentation. It shows that, in places like Northern Wisconsin, damage is often felt first in aquatic ecosystems. A summary of the major effects of sulfide mining and its associated processes is found in Figure 2.

To prevent or mitigate pollution of ecosystems near mining sites, mining wastes must be isolated from the environment permanently. Unfortunately, isolation must be accomplished by human and mechanical means, and has never been completely successful.

As the Wisconsin Department of Natural Resources (DNR) notes, "There are no ideal metallic mineral mining sites which can be pointed to as the model approach in preventing acidic drainage industry-wide."

According to the DNR there are two reasons for this. First, the current "state of the art" technology for controlling mine waste has not been in use long enough to completely prove itself. Approved sulfide mining operations in northern Wisconsin will become testing grounds for the effectiveness of these technologies.

Second, control technology effectiveness is dependent on the unique characteristics of each mining operation, the characteristics of the ore, and environmental characteristics of the site. Northern Wisconsin is characterized by complex hydrology and numerous lakes, streams, and rivers. This abundance of water contributes significantly to the degree of risk associated with sulfide mining.

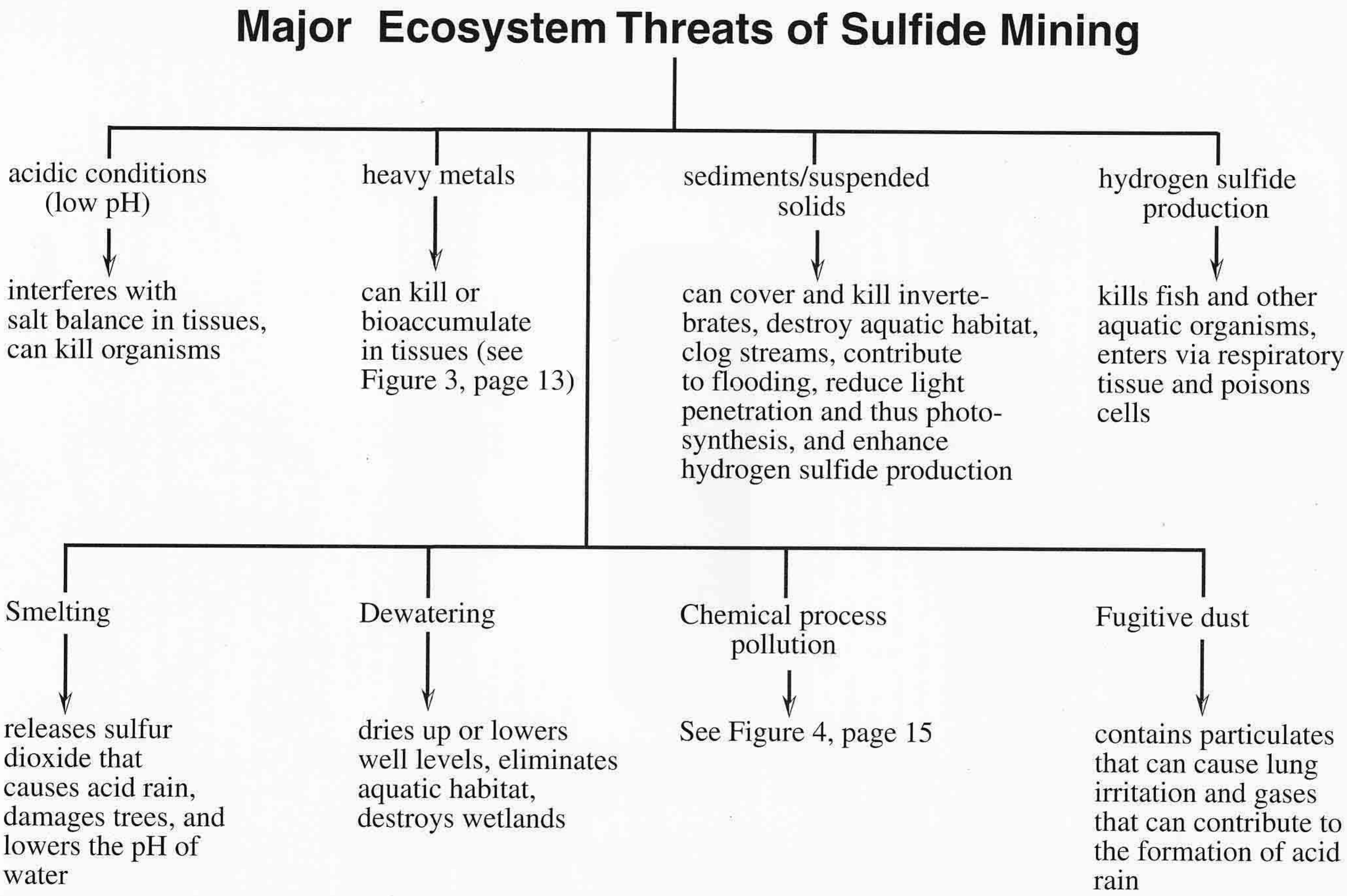
In addition, the complexity of the groundwater system leads to uncertain predictions of the behavior of pollutants within the system and the adequacy of pollution control measures. An abundance of water makes it more likely that pollutants will encounter and contaminate that water, and less likely that pollution controls will be completely effective.

A. Exploration

Mineral exploration poses a number of ecosystem threats. Drilling operations may penetrate multiple aquifers. This can cause water from different aquifers to mix, changing water chemistry. Aquifer elevations may also change, causing wells to go dry.

Drilling sludge, the material ground up and brought to the surface during drilling, may contain sulfide ore, heavy metals and other contaminants. The environmental threats posed by these pollutants are discussed in Section D below.

During exploration, land will be disturbed by road and drill pad building and by heavy equipment use. These activities can cause severe soil compaction, resulting in greater surface run-off and a long-term reduction in plant numbers and diversity. If a mine is developed, this land disturbance will be a minor part of the overall impact.



Major Ecosystem Threats of Sulfide Mining

acidic conditions (low pH)

interferes with salt balance in tissues, can kill organisms

heavy metals

can kill or bioaccumulate in tissues (see Figure 3, page 13)

sediments/suspended solids

can cover and kill invertebrates, destroy aquatic habitat, clog streams, contribute to flooding, reduce light penetration and thus photosynthesis, and enhance hydrogen sulfide production

hydrogen sulfide production

kills fish and other aquatic organisms, enters via respiratory tissue and poisons cells

Smelting

releases sulfur dioxide that causes acid rain, damages trees, and lowers the pH of water

Dewatering

dries up or lowers well levels, eliminates aquatic habitat, destroys wetlands

Chemical process pollution

See Figure 4, page 15

Fugitive dust

contains particulates that can cause lung irritation and gases that can contribute to the formation of acid rain

Figure 2. Major ecosystem threats of sulfide mining.

B. Development/Mining

To a great extent, the location of a sulfide mine dictates the nature and severity of ecosystem threats. For example, when an orebody is mined near a system of numerous, interconnected lakes, streams, and wetlands, the water itself can become contaminated easily, and can transport pollutants to other water bodies and aquifers, and to living organisms.

Mine development exposes the land to erosive forces by disturbing natural contours and land forms. Erosion and sedimentation are particular problems on steep slopes. When precipitation washes soil fragments downhill and carries them into nearby waterways, sedimentation results.

Sedimentation can have devastating effects on aquatic ecosystems. Sediments can cover and kill vegetation and invertebrates, destroy fish and wildlife habitats, and contribute to flooding by clogging streams and their floodplains, thus eliminating their capacity to absorb and hold run-off.

To a great extent, the location of a sulfide mine dictates the nature and severity of ecosystem threats.

Suspended sediments may also disrupt the ability of water to purify itself by reducing light penetration and thus photosynthetic activity. The accumulation of sediments on stream beds can enhance the production of hydrogen sulfide, a substance toxic to fish and other aquatic organisms.

Contaminated sediments, such as those that are acidic or contain heavy metals, pose additional threats similar to those caused by acid mine drainage and heavy metals contamination, discussed in Section D below.

Mine operators attempt to safeguard against erosion and sedimentation by regrading and revegetating slopes. However, problems exist with these techniques. Slopes built to stabilize the mine can be too steep, leading to further erosion. Flood events can also cause excessive erosion. Vegetative covers can compete with native plant communities if native vegetation is not used. If regrading and revegetation is not performed until mining is completed, erosion and sedimentation can continue throughout the active life of the mine.

Subsidence, or the collapse of the surface into mine workings, can be a threat to the surface ecosystem. Backfilling, one common technique used to prevent subsidence, creates its own problems.

Backfill is often made of tailings, which contain sulfide ores and chemicals employed in the concentrating process. If these materials come into contact with water that escapes from the underground workings, long-term contamination of surface and groundwater can occur.

Particulate and gaseous air pollution can result when solid ore is excavated, crushed, and transported to the surface. Particulates may effect human health if they are inhaled and can contain pollutants which may contaminate soil, water and vegetation. Gaseous air pollutants may contain sulfur dioxide, which irritates the lungs and can damage or even kill plants, especially conifers.

Dewatering the mine creates a cone of depression where groundwater is pumped away from the mine. This cone of depression can lower the water table for the entire area surrounding the mine. Wells in the area may be sucked dry. If nearby lakes and streams are connected to the water table their levels will be lowered as well.

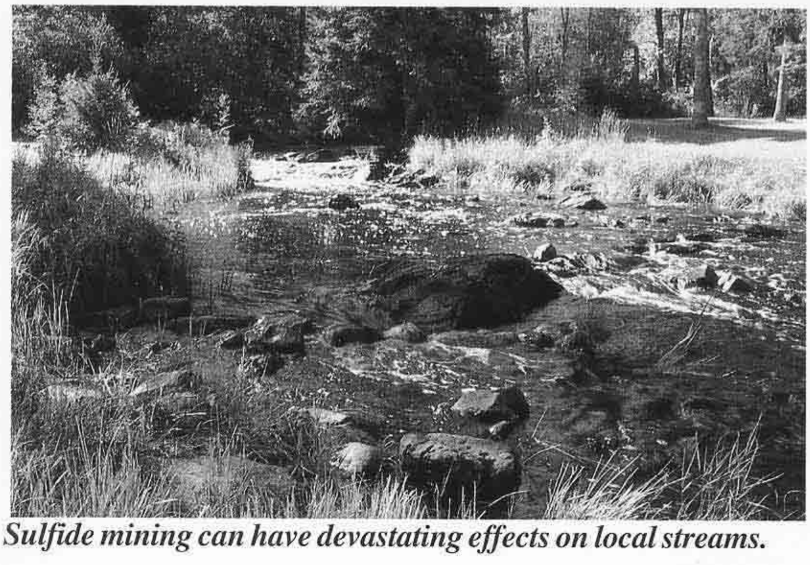
This can have drastic effects on some species, such as wild rice, which require shallow water habitats that could be destroyed by a drawdown. Lowering the water table can also destroy fish spawning grounds. To increase water levels and mitigate these impacts, mine operators sometimes pump water into lakes and streams. However, this bypasses the natural system, and may not adequately replicate its flow, temperature, oxygen, and water chemistry.

Ore removal processes can introduce a number of harmful chemicals into water. Oil released into waters from mining operations can form a thin film over the water surface, interfering with the reoxygenation of water, coating the gills of fish, and inhibiting the filtering capacity of mussels.

Nitrogen compounds from blasting materials can contribute to excessive weed growth in waterways. Spills of fuel, flotation reagents, cleaning solutions, pesticides and herbicides, paint solvents, and other chemicals used or stored at the mine site can cause soil, water or air contamination.

Discharged wastewater often is higher in temperature than receiving water. Water that is slightly elevated in temperature is lethal to some fish. Heat also interferes with the hatching of fish eggs. Increases in water temperature can cause an increase in the growth of nuisance plants.

Higher temperatures decrease dissolved oxygen in the water, at the same time speeding up oxygen-demanding biochemical reactions. As a result, oxygen may be depleted to a point where fish such as trout cannot survive, and the diversity of the aquatic community is severely diminished.



Sulfide mining can have devastating effects on local streams.

C. Beneficiation: Milling and Concentration

The primary ecosystem threat from milling, where the sulfide ore is crushed into particles no larger than a grain of sand, is particulate pollution. Dust that is allowed to escape into the environment during milling—called "fugitive dust"—can contaminate soil, surface water, and groundwater because it carries toxic elements such as heavy metals and radionuclides. These can be deposited on surrounding soils or surface water and be taken up in plant tissues.

Dust suppression systems spray water (sometimes with an additive) to reduce dust fallout from mine activities. In addition, mechanical methods can be used to control the formation of dust. Larger dust particles can be trapped in an artificially created cyclone, in which dust is thrown to the walls of the device, where it falls into a hopper.

Electrostatic precipitators can also be used. These devices electrically charge the dust, causing it to precipitate onto plates from which it can be removed mechanically or by washing. Fabric filters sometimes are used as dust removal devices, as are wet scrubbers that use water to pull dust from the air.

Dust control cannot be completely effective. Dust mitigation measures rely on mechanical systems that have design limitations, and that can and do fail.

Ore concentration uses a large number and amount of chemicals. See Figure 4, page 15. Some of these chemicals are relatively benign; some are highly toxic. They must be transported to and stored at the mine site until they are used in the concentrating process, and may cause harm to ecosystems if they unexpectedly leak or spill. These chemicals also are present in tailings in small amounts. The threats of chemicals contained in tailings are discussed in Section D and in Figure 4.

D. Tailings Management and Wastewater Treatment

Tailings represent sulfide mining's greatest single ecosystem threat. They contain sulfide compounds, heavy metals and unrecovered beneficiation chemicals. Tailings management areas, the mine workings themselves, and wastewater treatment facilities are used to contain and treat these wastes.

Wastewater and collected leachate from tailings management areas normally are sent to a water treatment plant. These treatment systems alter the characteristics of the water in a variety of ways. Acidity can be neutralized with the addition of lime or other agents. Lime, iron compounds, and aluminum sulfate are used to promote the settling of suspended solids. After treatment, water and useful chemicals may be recycled for use in mine operations such as ore processing, while wastes are stored in tailings piles or ponds.

When tailings escape from tailings management areas or from underground mine workings, contamination occurs. Tailings contain acid-generating material, toxic heavy metals, and chemical processing residue. Heavy rains can cause tailings management areas to overflow or even fail, washing toxic tailings into nearby waterways.

Fractures in mine walls may allow groundwater to transport tailings that have been used to backfill the mine, potentially contaminating ground- and surfacewater. Tailings also may be blown off the mine site from the tailings management area or from piles of waste rock, contaminating air and soil.

Tailings can cause acid mine drainage, heavy metals contamination, and chemical process pollution, each of which is discussed below.

Acid Mine Drainage

Acid mine drainage occurs when sulfide minerals that are exposed to oxygen and water produce sulfuric and other acids. Acidification occurs naturally within underground orebodies but at a very slow rate. Mining raises the sulfide minerals to the surface and crushes them, thereby exposing much more surface area to the effects of water and oxygen. At first, this process is slow, but as the system becomes more acidic, the rate of reaction speeds up dramatically. The bacteria *Thiobacillus ferroxidans*, common in acidic environments, acts as a catalyst in this process.

Uncontrolled acid generation results in an ecosystem with high levels of heavy metals, dissolved solids, sulfates, and acidity. The damage caused by acid mine drainage persists for long periods of time, perhaps hundreds or thousands of years, until all of the sulfur in the tailings is leached out. Acid mine drainage can kill fish and other aquatic life, and can severely contaminate surface and groundwater.

Hydrogen molecules in acid mine drainage combine with sulfide to form hydrogen sulfide molecules, known by their characteristic "rotten egg" odor. These molecules are highly toxic to freshwater ecosystems, and rise slowly through the water from the sediments where they are formed.

As hydrogen sulfide rises through the water, it loses its toxicity. However, if the water is already acidic, the hydrogen sulfide will persist for a longer time in the water. Consequently, its toxic effects will be more extensive. Hydrogen sulfide can kill fish and other aquatic organisms by entering through the respiratory tissues and poisoning the cells.

Acidic water can directly impact the health of ecosystems. As pH decreases to acidic levels, organisms cannot maintain the proper balance of salts in their tissues. Energy is required to accomplish the salt balance and as pH decreases, more energy is required.

When the pH decrease is prolonged, salt balance within the organism fails and the organism dies. In addition, low pH decreases the availability of nutrients required for proper plant growth and development.

The rate of acidic reactions can be slowed with the addition of buffering materials such as lime. However, to be effective, the chemistry of the waste material must be well-defined, an appropriate amount of proper buffering material must be added, and thorough mixing of the additive with the acid-generating wastes must be provided. If any of these criteria are not properly met, acidity may not be well-controlled.

The rate of acidification also can be reduced by eliminating contact between mine waste and air or water. Mine operators attempt to limit oxygen and water flow by covering tailings with wet or dry cover systems.

Wet covers use water to exclude oxygen from the tailings. Dry covers use layers of soil and/or synthetic membranes to exclude water. These systems may be effective in preventing oxygen and water from reaching the tailings.

Nevertheless, much of the technology behind these systems is new and its long term effectiveness is unknown. Tailings cover systems must be monitored and maintained permanently to prevent an ecological "time bomb."

Bactericides also slow the acidification process. They are applied to the surface of waste piles to kill the bacteria that speed up acid generating reactions. Bactericides degrade over time and cannot be relied on as a long term solution to acid formation. They can also damage ecosystems by killing naturally occurring bacteria in the vicinity of the tailings piles.

Heavy Metals Contamination

Waste rock, soils that cover and surround the orebody, dust, and tailings all contain metals. These metals may include lead, zinc, arsenic, antimony, selenium, silver, cadmium, cobalt, copper, mercury, manganese, aluminum, molybdenum, and nickel. Many of these metals are essential to life at very low levels. At higher levels, they cause metal toxicity. Minerals can escape into the environment by runoff or as fugitive dust. Groundwater contaminated with heavy metals also may contribute to the contamination of surface waters.

Metal	Acute Exposure Criteria in parts per billion[1] (at 100 mg/L hardness)	Chronic Exposure Criteria in parts per billion[2] (at 100 mg/L hardness)	Threat to the Ecosystem
Chromium III	1700	210	Highly toxic
Chromium IV	16	11	Highly toxic
Copper	18	12	Highly toxic: causes liver damage in fish and wildlife
Lead	82	3.2	Highly toxic: inhibits central nervous system functioning
Silver	4.1	0.12 may be harmful	Extremely toxic
Zinc	120	110	Highly toxic: causes deterioration of fish gills

[1] Level at which aquatic organisms may be safely exposed for one hour, once every three years.
[2] Level at which aquatic organisms are considered safe for long term exposure.

Figure 3. Characteristics of some of the heavy metals found in tailings.

Some of these metals form relatively insoluble compounds in water that will sink and be buried in the sediments. However, when the pH of the water decreases, as it does in the presence of acid, these metals become more soluble. When metals become soluble, they become available to react with organisms and can exert toxic effects. Figure 3 shows some of the characteristics of heavy metals that can be released into the environment by mining.

Human contact with heavy metal laden tailings poses health threats. Perhaps the worst case of heavy metal poisoning in the United States occurred at the Bunker Hill Mining Complex in Idaho. Lead, zinc, and silver mining occurred at Bunker Hill from 1885 until 1981, and periodically since 1981, depending on prevailing metals prices. Tailings were discharged directly into surface water until 1928, when a tailings impoundment was created. Wastewater from the impoundment was discharged untreated until 1974.

Environmental impact investigations of the Bunker Hill Complex were initiated in 1974 when symptoms of lead poisoning in children were discovered. The most severe lead poisoning occurred in the vicinity of the on-site lead smelter. Over 98 percent of the children living within one mile of the smelter had blood lead levels four times greater than the level at which effects can be seen.

Chemical Process Pollution

Beneficiation uses many chemicals. After ore processing, some chemicals persist in the tailings where they can come into contact with water and be carried away from the mine site. In addition, tailings and other mine wastes used to backfill the mine contain chemical residues. These can contaminate groundwater, which can then move through underground aquifers and discharge to surface waters. Figure 4 shows the characteristics of some of the chemicals commonly used in beneficiation.

E. Cumulative Effects

Cumulative impacts occur when individual impacts, happening simultaneously or consecutively, exert effects which are greater than the sum of their parts. Individual impacts can come from different sources within one mine or from sources at a number of different mines. For example, when several metals are blended in the effluent from one mine, they may combine to exert effects more toxic than those of any one metal individually. The effluents from several mines may also combine in this way.

Thus, even if the cumulative effects of one mine are adequately addressed, the development of several sulfide mines within an ecosystem can pose special threats to that system. Policymakers must consider how these cumulative impacts will be addressed when the potential exists for the development of several mines in proximity to one another. For example, a number of ore bodies have been discovered in Wisconsin, near the headwaters of the Wolf River. See Figure 5, page 16.

Operators are currently seeking permits to develop only one of the orebodies near Crandon. If future demand for metals increases and prices rise, the other orebodies could be mined, causing the potential for cumulative effects on the ecosystems in and around the Wolf River.

Cumulative effects from numerous mine developments can range from the combined effects of different water pollutants to impacts on species' habitats. The specific impacts that may occur will depend on the characteristics of the ore and the mining process, including the mineral content of the orebodies, the proposed mining method, the ore concentration method, and the plans for waste treatment and disposal.

For example, habitat fragmentation can result from the large surface area disturbed by mining operations. Land use changes have the potential to impact a variety of species, but are of particular concern for endangered or threatened species. Because the number of individuals in such species creates a concern for their survival, the degradation or destruction of any areas of habitat where the species is found is significant.

The extent to which cumulative impacts is an issue in Wisconsin, remains a matter of debate between mining proponents and mining opponents. To begin with, the number of mines that may be permitted in Northern Wisconsin is, at this point, a matter of speculation. Further, the complexities involved in analysing the interactive effects of the mines, makes predictions of cumulative impacts very uncertain. Nevertheless, the decision to permit one mine in an area where others may be proposed requires consideration of re-

Reagent	USEPA Water Quality Criteria[1]	Proposed For Use at Crandon Mine	Threat To The Environment
Potassium	None		Toxic at very high levels, causes salt imbalance
Sodium xanthates	None	*	Unknown
Thiocarbonates	None		Unknown
Kerosene, fuel oil, wood tar, coal-tar oil, pine oil	0.01 of the 96-hr LC50[2] for each oil		Toxic, impairs flavor of tissue, decreases dissolved oxygen in water
Aliphatic alcohols	None		Toxic
Polypropylene glycol methyl ether	None	*	Unknown
Methyl isobutyl carbinol	None	*	Unknown
Crysylic acid	None		Toxic, used in disinfectants
Copper sulfate	12 ug/L at 100 mg/L hardness[3]	*	Highly toxic to aquatic life
Sodium sulfide	2 ug/L	*	May increase hydrogen sulfide
Sulfur dioxide	2 mg/L	*	May decreases pH
Sodium cyanide	5.2 ug/L	*	Highly toxic to aquatic life
Zinc sulfate	110 ug/L at 100 mg/L hardness	*	Highly toxic to aquatic life
Starch	None	*	Breakdown products can deplete oxygen in water
Sodium dichromate	CrIII-210ug/L, CrIV-11ug/L Both at 100 mg/L hardness	*	Highly toxic to aquatic life
Sodium flouride	None		Used as insecticide, toxic
Sodium hydroxide	maintain pH between 6.5-9.0		Increases pH
Lime	None	*	May increase pH and hardness
Soda ash	maintain pH between 6.5- 9.0		Increases pH
Sulfuric acid	maintain pH between 6.5-9.0		Decreases pH
Sodium carbonate	None		May increase pH
Sodium silicate	None	*	May increase pH
Tannin	maintain pH between 6.5-9.0		May decrease pH, reduces metal toxicity
Complex phosphates	50 ug/L flowing water 25 ug/L lakes and reservoirs		May decrease pH, causes excessive excessive aquatic plant growth

[1] Numbers are the four day average concentrations that protect 95% of freshwater species.

[2] 96 hour LC50 is the concentration at which 50% of individuals die within 96 hours.

[3] ug/L = parts per billion; mg/L = parts per million

Figure 4. Characteristics of some of the chemicals used in ore processing.

gional and long term cumulative implications.

Regional impacts are a particular concern for the Chippewa tribes whose treaty-reserved rights extend throughout the northern portions of Wisconsin, Michigan and Minnesota (see Chapter 3). For example, if the ore from the proposed Crandon mine in Wisconsin were smelted in White Pine, Michigan, any environmental impacts that affect treaty rights at either or both locations, would have to be addressed.

F. Smelting/Refining

One of the primary threats from smelting and refining is the release of large amounts of sulfur dioxide. The history of the huge smelter in Trail, British Columbia illustrates the destructive effects of this chemical.

The Trail smelter opened in 1896. At its peak in the 1930s, it was emitting 10,230 tons of sulfur dioxide per month. Studies of the area performed between 1929 and 1936 found that almost no conifers within 12 miles of the smelter had survived, and found retarded growth in some species located as far as 39 miles away from the smelter.

Sulfur dioxide adversely affects and sometimes kills trees by acidifying the soil and injuring leaves and flowers. In addition, sulfur dioxide can react with oxygen and water to form sulfuric acid.

Sulfuric acid is a component of acid rain, which lowers the pH of water and may increase the production of hydrogen sulfide, both of which can be toxic to aquatic and terrestrial ecosystems.

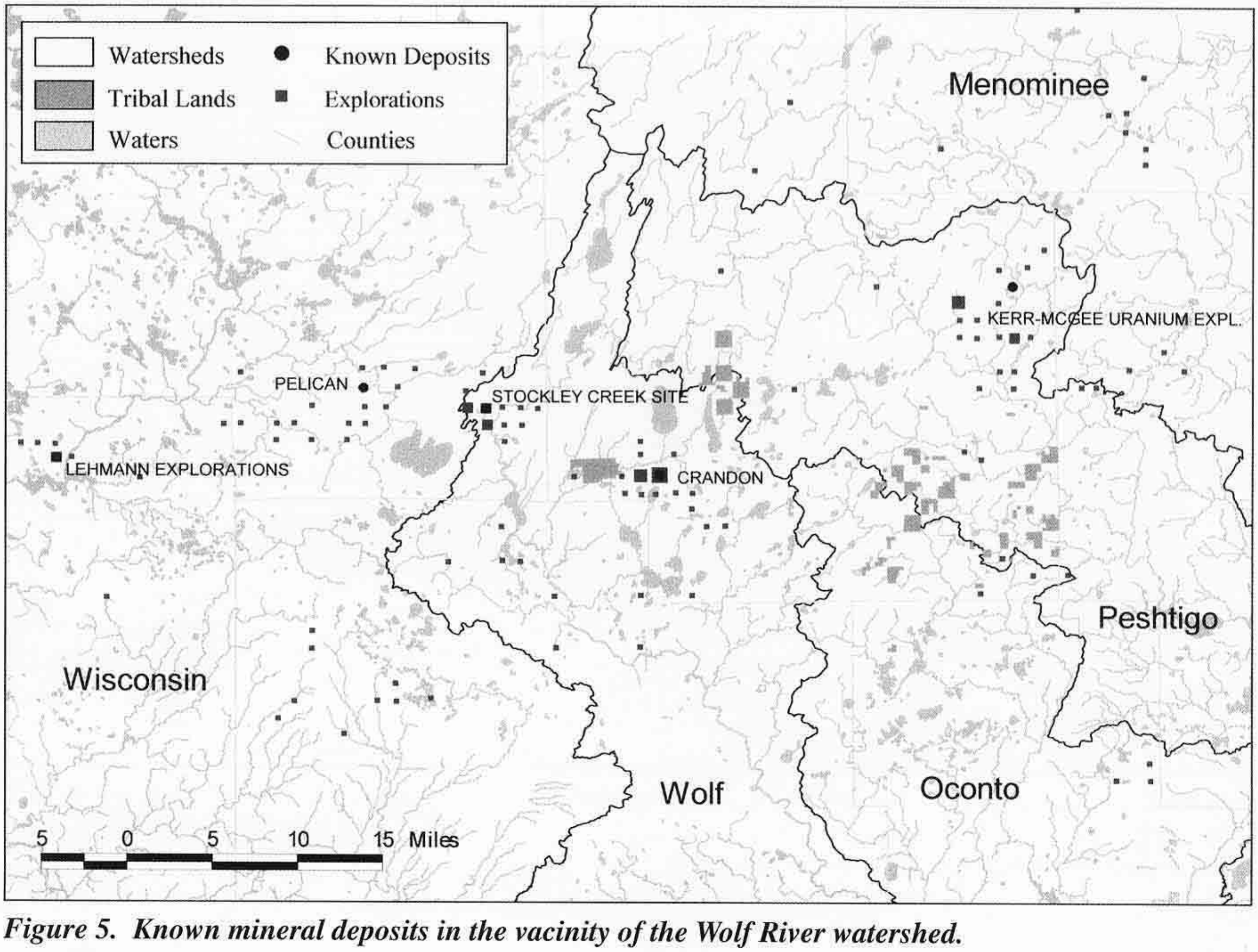


Figure 5. Known mineral deposits in the vacinity of the Wolf River watershed.

The Potential Effects of Mining on Indian Tribes

Chapter Three

Indian tribes in the northern portions of Wisconsin, Minnesota and Michigan are seriously threatened by sulfide mining operations in ways that are difficult for non-Indians to perceive. For Indian people, natural resource harvest is more than a means to provide food. It is a cultural activity that renews both the Indian person and the resource that is harvested.

Decisions that may affect the health or availability of these resources, must therefore, be made cautiously. By Indian tradition they must be made to ensure the protection of the resources for the next "seven generations." For example, undesirable consequences that will occur in the next 250 years will fail this cultural standard.

In the mid-nineteenth century, the Chippewa tribes of northern Wisconsin, northeastern Minnesota, and Michigan entered into treaties with the United States. As a result of these treaties, the Chippewa relinquished, or ceded, a considerable amount of land, now often referred to as the "ceded territory." See Figure 6, page 18.

Within this ceded territory, the tribes reserved for themselves the continued right to hunt, fish, and gather. Courts have established that tribes may still exercise these rights.

Beginning in the mid-nineteenth century and throughout the twentieth century, Chippewa reservations were established by treaty, executive order, or Congressional action as homelands within the ceded territory. Tribal rights within reservations are more extensive than in the ceded territory. Nevertheless, reserved rights in the remainder of the ceded territory were not affected by the establishment of these reservations.

Other Indian tribes can claim reserved rights similar to the Chippewa, although not all can claim off-reservation rights in territories ceded by treaty.

These tribes include the Forest County Potawatomi, Menominee, Stockbridge-Munsee, and Oneida tribes in northern Wisconsin, and the Hannahville Potawatomi, Little River, Grand Traverse, and Little Traverse tribes in northern Michigan.

Treaty, legislative, and judicial guarantees provide these tribes with solemn promises and legal protections that guarantee their right to maintain themselves as distinct cultural and self-governing political entities. Land use decisions that undermine a tribe's ability to continue in its traditional lifeways may violate these assurances.

Tribal reservations and reserved sovereign rights are fundamental to the preservation of Indian tribes as cultural and political entities. They provide continuities with culture, traditions, and the physical environment.

Most importantly, they sustain tribal lifeways that depend upon clean and healthy natural resources for cultural, subsistence, religious, medicinal and economic purposes.

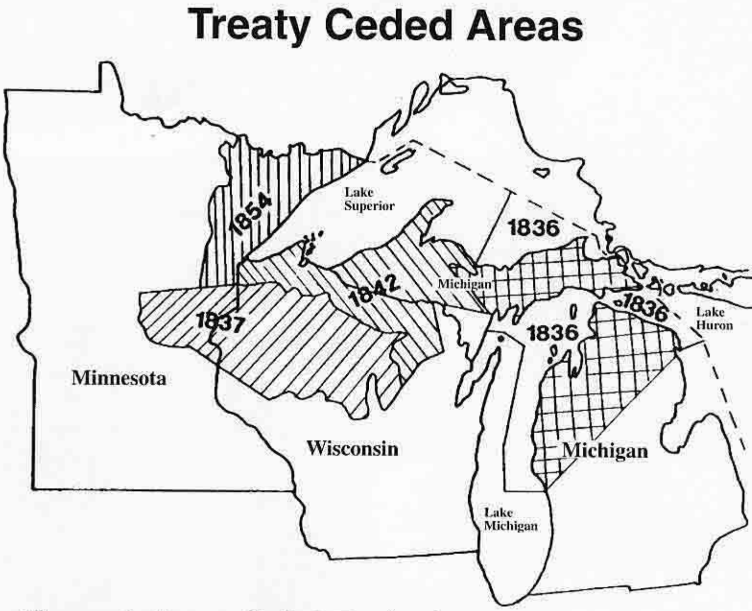


Figure 6. Treaty Ceded Territories.

Mining can affect these fundamental aspects of tribal life and culture in a number of ways:

- Tribal members may lose harvest and usage opportunities, due to destruction of fish and wildlife habitat and disruption of migration patterns, closure of public lands, or contamination of water, air, or soil.
- Habitats that support fish, wildlife, and plants used by tribal members may be altered, disrupted, or destroyed.
- The economic value of resources harvested by tribal members may be lost.
- Indian culture may suffer from altered, disrupted, or destroyed natural resource usage patterns.

These effects may cause the reservations to fail in sustaining the purposes for which they were established, and may diminish the ability of both on- and off-reservation harvesting to support the tribal lifeway.

The Indian view of land sharpens the importance of maintaining the sustainability and environmental integrity of the relatively small land base left to the tribes. As distinguished from traditional European thinking, the general Indian orientation is more towards space than towards time. Thus the importance of a particular geographic spot can no more be moved to a different location than the importance in European history of a particular event can be moved to a different time.

A reservation, if rendered incapable of supporting Indian lifeways, simply cannot be sold and replaced by another plot of land. Commonality of place, as much as of past, defines an Indian tribe. The ties that bind society and culture together are tethered to the earth. If a tribe's traditional lands lose the ability to support life, those ties can badly fray.

The history of Grassy Narrows, a Chippewa reserve located near Kenora, Ontario, illustrates the significance of the relationship between a tribe and its land, and the disastrous consequences that can occur when a tribe is removed from its traditional homelands.

Grassy Narrows gained international attention in 1970 when mercury poisoning, caused by pollution of the local river, was discovered among tribal members. A full range of human tragedy and social disintegration has since been documented among the people of Grassy Narrows. However, the poisoning only exacerbated a social disintegration that had begun years earlier as the result of a forced relocation of the reserve by the Canadian Department of Indian Affairs. Demoralization, apathy, and alienation followed, accompanied by violent death, illness, and family breakdown. Those studying the relocation have called it "a true disaster to the lives of those involved."

Mining can disrupt elements of the ecosystem that are critical to Indian cultural and political survival. As Chapter 2 illustrates, a range of impacts can disrupt resources on and around mine sites. When resource use is disrupted or curtailed, tribes suffer.

Impacts to natural resources most likely will occur in those counties where mineral exploration has shown that mine development is possible. For example, the five counties of northern Wisconsin where the majority of mineral exploration has occurred are Oneida, Marathon, Rusk, Price and Forest. The Wisconsin Chippewa tribes took approximately one quarter of their total off-reservation walleye harvest in 1990 from lakes in these counties. See Figure 7. In 1993, they took almost a fifth of their total off-reservation deer harvest from these counties.

One of the most important resources to many of the tribes in northern Wisconsin, Minnesota, and Michigan is wild rice. The Menominee tribe takes its very name from the Menominee word for wild rice.

Wild rice remains an important unifying feature of Chippewa society and culture. Wild rice is central to the Chippewa tribes' migration story and their settlement in the Great Lakes region; their prophesy directed them to journey until they found the "food that grows upon the water." When the Chippewa reached the shores of Lake Superior, they found the wild rice growing on the waters, and they knew their 500 year journey was over. Figure 7 shows some of the lakes where tribes harvest this important resource.

Because rice is extremely dependent on water levels, a drawdown in water levels due to mine operations could result in the loss of rice stands. The effect of that loss is explained by Frances Van Zile, a member of the Sokaogon (Mole Lake) Chippewa: "There is no substitute for wild rice. My whole way of being as an Indian would be destroyed. I can't imagine being without it. And there is no substitute for this lake's rice."

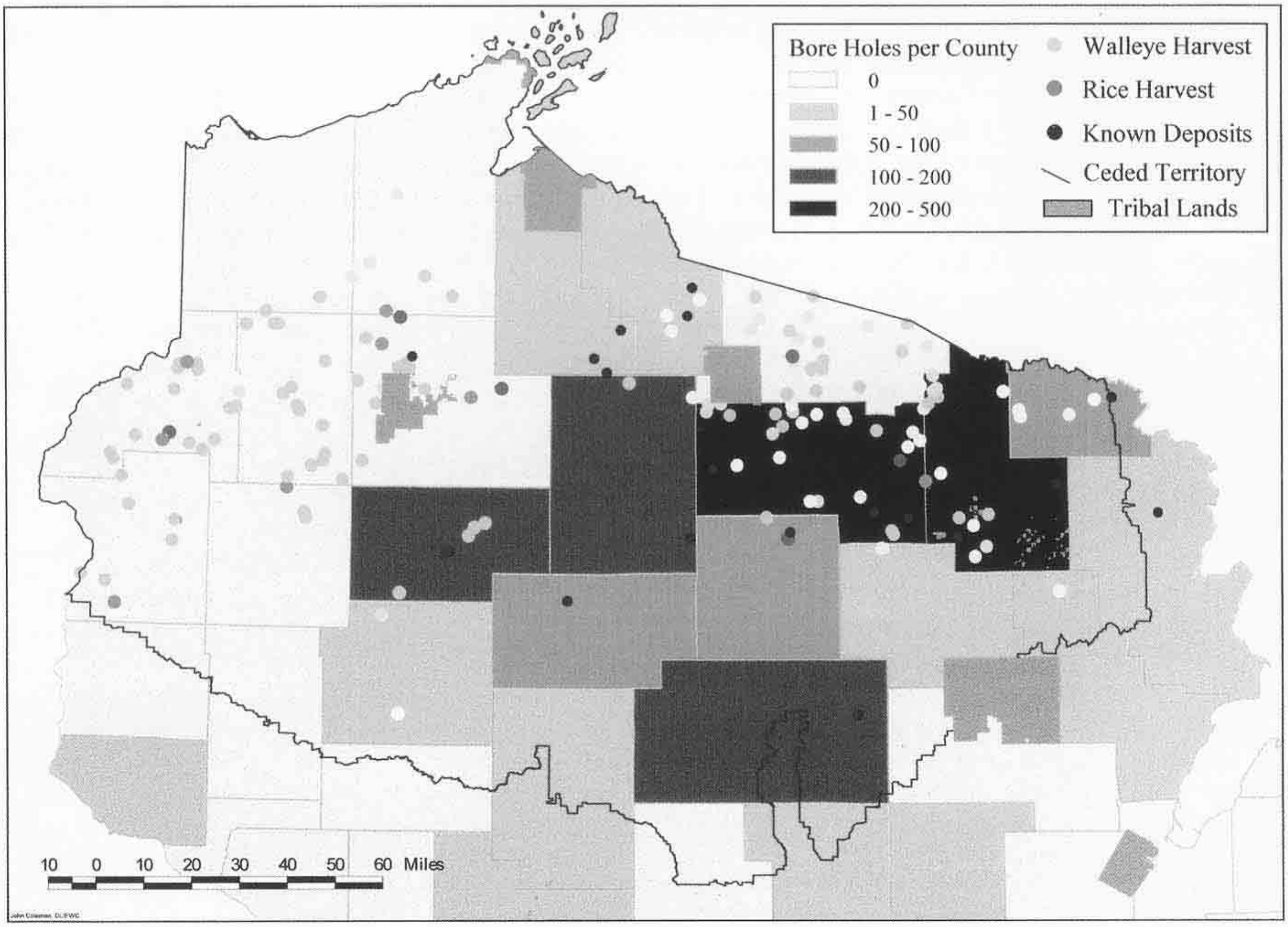


Figure 7. Mineral exploration in Wisconsin's ceded territory and off-reservation lakes where walleye and wild rice are harvested.

Winnowing wild rice.

This depth of feeling and belief regarding natural resources underlies the unique character that the region's tribes bring to their relationship with the natural world.

When hunting, fishing, or gathering, the members of these tribes conceptualize their role not only as part of the natural order, but also as part of the supernatural order. The rituals attendant to their hunting, fishing, and gathering activities, and their ceremonial use of the plants, animals, and fish, are activities meant to assure not only the perpetuation of the creatures but also of themselves.

Three aspects of the Indian view of nature inextricably link the perpetuation of humans to the perpetuation of the natural world. In contrast to the mainstream European view, in Indian belief systems the line between human and non-human beings is ambiguous:

- Persons are found throughout the material and spiritual world; personhood is not limited to humans. All persons, whether human or non-human, have rights.
- Humans are not the creator of the world, but rather are weak and pitiable creatures, dependent on non-human persons to survive. Thus, the proper attitude toward the natural world is one of humility and gratitude.
- The relationship of humans to the rest of nature is one of reciprocity. Animals, for example, will offer themselves to the hunter as an act of pity for our weakness. If the hunter does not in return feel regret and gratitude, the natural world will withdraw its cooperation.

Given this world view, the alteration or destruction of plant and animal communities to serve human needs, without proper respect for the non-human persons involved, and without care for the response nature will show to such ill treatment, invites disaster not only for the environments affected, but for the humans too.

The development of a major mine, of a scale such as the one proposed near Crandon, is one of the largest single land-use alterations that humans can make to the natural environment. Even if the environmental impacts discussed in Chapter 2 are minimized, the traditional Indian worldview would see a project that so utterly alters the landscape as far overstepping the proper role of humans in the natural world. If the environmental harms that are usually attendant to mining do occur, they will have consequences that are categorically antithetical and unequivocally unacceptable to the Indian way of life.

These consequences also take on a moral dimension: the harm to the rights of non-human persons would be co-extensive with the environmental harm. In a morally reciprocal world, such a violation of rights must have dire consequences for humans.

A number of tribes have determined that proposed mining projects would have unacceptable impacts on their reservation homelands, their off-reservation harvest rights, and their culture and society. Tribes, including the Sokaogon Chippewa, Lac du Flambeau, Menominee, Forest County Potawatomi, and Oneida, oppose the proposed Crandon project in Wisconsin. Particularly for the Sokaogon Chippewa, whose reservation lies less than two miles from the proposed mine site, this proposal constitutes a threat to their traditional lifeway, and indeed to their very existence as a culturally distinct people.

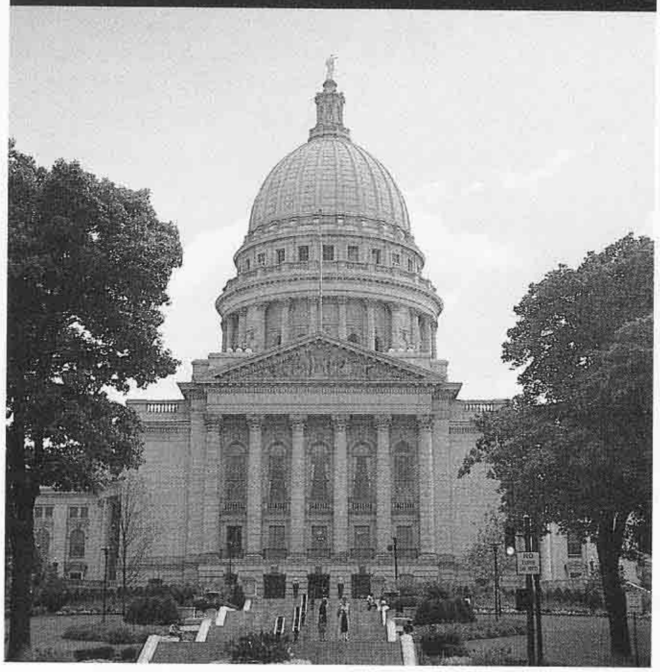
The impact of mining on Indian tribes in northern Wisconsin, Minnesota and Michigan goes far beyond the ability of tribal members to find appropriate fish and wildlife to serve at meals or ceremonial feasts. It includes the specter of a world in which humans are left to fend for themselves, cut off from the assistance of nature, and physically and spiritually changed. Mining poses risks to Indian tribes that are significantly different than those faced by other populations.

Consequently, any mine-permitting process must give full weight to the effect a permit issuance would have on Indian tribes, and must afford Indian tribes full participation to ensure that those affects are properly understood. This process must be governed by principles ensuring that applicable treaties, legislation, and judicial guarantees of tribal rights are not violated.

Even though tribes are uniquely affected by mine permitting decisions, they are not usually the decision makers. Therefore, state and federal decision makers bear a special responsibility to ensure the protection of tribal lifeways.

Mining Regulation in Wisconsin

Chapter Four



The decision to permit a sulfide mine is undeniably controversial because of the myriad threats from sulfide mining. Socio-economic and environmental costs and benefits are hotly debated by a project's proponents and opponents.

State and federal laws are designed to engender rational discourse, to assure effective evaluation of the risks associated with mining proposals, and to safeguard against environmental degradation caused by mining.

Federal laws include the Clean Water Act, the Clean Air Act, and the Resource Conservation and Recovery Act. The Environmental Protection Agency generally has jurisdiction under these acts. The Army Corps of Engineers also has jurisdiction if wetlands will be dredged or filled.

States may take over the responsibility for promulgating and enforcing regulations under many provisions of these federal acts. States also have their own independent authority to regulate mining. As a combined result of state mining regulatory power and state assumption of federal regulatory power, states are often the primary regulators of mining activity within their borders.

This Chapter will examine the laws of one state, Wisconsin, as they relate to sulfide mining and the protection of the environment. Not every aspect of Wisconsin mining law is discussed. This chapter will highlight some of the changes in Wisconsin mining laws over time, explore ways in which mining is regulated differently than other industries, and show where mining laws grant discretion to the DNR to tailor its permits to accommodate what those laws refer to as the "...special requirements of metallic mining operations. ..."

Wisconsin's general environmental statutes and particular mining laws leave a great deal of discretion to the DNR. This discretion is a twin-edged sword—it could be used to curtail or to promote sulfide mining in the state. According to a 1995 state court ruling, the DNR could use its discretion to completely ban sulfide mining. Conversely, the DNR has the discretion to grant variances from a number of legal requirements or otherwise generally encourage sulfide mining.

Such a broad grant of discretion leaves the door open for political considerations to influence rulemaking and permitting decisions. A recent development suggests that if political considerations do become a stronger force within the permitting process, decisions based on those considerations may go unchallenged.

In 1995, the Wisconsin legislature restructured the Wisconsin Public Intervenor's Office. This office was established to advocate for the environment on behalf of the citizens of the state. It performed an independent watchdog function and was empowered to sue state agencies for failure to follow environmental rules and regulations. Now, funding and staff have been reduced and the office has been made a part of the DNR, the agency it is supposed to watch over. In addition, the office no longer has the power to sue the DNR for failing to follow environmental rules and regulations. No longer an independent voice monitoring or challenging DNR decisions, the Wisconsin Public Intervenor's office has effectively been abolished.

An examination of Wisconsin law reveals that mining is, in many cases, not regulated under laws of general applicability, but has evolved a separate set of particularized rules and regulations. These rules leave the DNR wide latitude to determine permitting conditions. Whether this scheme provides for an appropriate balance between the threats inherent in sulfide mining and the economic development that mining may bring is an issue for state policymakers to consider.

One factor that should be weighed in determining the appropriateness of this system is the ultimate disposition of profits from metallic mining. Foreign ownership of land in Wisconsin is regulated by statute. The law was originally enacted in 1887 as a general prohibition against foreign ownership, but was repealed and recreated in 1983 to include numerous exceptions to the prohibition, notably an exemption for land that is to be used for mining activities.

This provides an opportunity for foreign-owned mining companies to prospect and mine in Wisconsin and drastically increases the number of companies that could apply for permits to mine in the state.

Mining regulation in Wisconsin dates back to the 1850's when laws to ensure proper accounting of ore collections were enacted. Codified at what is now chapter 107 of the Wisconsin Statutes, these laws were expanded over the years to include provisions for contracts, surface water diversions, resolution of conflicting claims, and compensation for personal or property injury incurred as a result of mining activity. In addition to chapter 107, the Wisconsin legislature has enacted a number of other laws that deal with the potential environmental effects of the mining process.

In 1973, the Metallic Mining Reclamation Act (subchapter V, chapter 144, Wisconsin Statutes) was enacted. This act and the regulations promulgated under it by the DNR regulate the three phases of mining: exploration, prospecting, and actual mining. Permits are required for each phase. The statutes specify that permits should not be issued unless certain conditions are met and certain assurances are made. These conditions, however, are not always the same as those that must be met by other industries.

Wetland water quality standards that apply to most activities are set out in the Wisconsin Administrative Code, ch. NR 103. The chapter is meant to protect wetlands from some of the damaging effects of development and to protect the public interest in maintaining healthy wetlands. However, wetland alterations that are a result of mining or prospecting activities are not subject to regulation under chapter 103. They are regulated elsewhere.

The well-being of wetland ecosystems is dependent upon regulatory protections.

Under chapter NR 103, activities in wetlands are allowed only if the activity will not cause significant adverse impacts. However, under the sections that govern prospecting and mining in sulfide deposits, wetland alterations that result in significant impacts can be made if the applicant demonstrates that the site constitutes a viable site (defined as technically and economically feasible), causes the least overall adverse environmental impact, and will minimize wetland loss.

These conditions are based on the underlying decision that a certain amount of wetland degradation is acceptable in order to allow mining. The amount of wetland degradation allowed is, in large part, left to determinations of what constitutes a "viable site," what the "least" impact is, and whether wetland loss has been "minimized."

Wisconsin groundwater standards governing metallic mineral mine waste (Wisconsin Administrative Code, chapter NR 182) acknowledge that no tailings management area, referred to as a land disposal site, "...can provide the perfect containment, regardless of engineering design and operations standards. ..." Wisconsin's clear policy is to accept the inevitability of groundwater contamination and its goal is to attempt to minimize it.

Wisconsin's groundwater standards do not apply on the actual mining site. They begin to apply at the "compliance boundary," which may be 1200 feet, or about 4 football field lengths, from the mine site. Within the compliance boundary monitoring is required, and if there is a reasonable probability that standards will be violated at the boundary, the DNR may order the mining operator to take action to remedy the problem.

Wisconsin's mining policy is nevertheless clear—groundwater pollution is acceptable on mining sites. Given the hydrologic complexities associated with many potential mining sites, this could lead to the pollution of groundwater outside of the compliance boundary.

Wisconsin's regulations exempt mining wastes used to backfill underground mines from some of the usual requirements for disposal of solid and hazardous wastes. Backfilling instead is regulated under less stringent provisions that simply require backfill not to cause violations of groundwater quality standards and not to adversely affect public health or welfare. This may result in backfilling taking place without particularized regulations. Surface mines backfilled with mining wastes are exempt from certain requirements pertaining to location criteria, minimum design and operation requirements, and recordkeeping.

Before 1982, local governments had been authorized to adopt standards related to solid waste disposal facilities that were more strict than those standards imposed by the state. In 1982, Wisconsin's legislature revoked that local authority, making the state

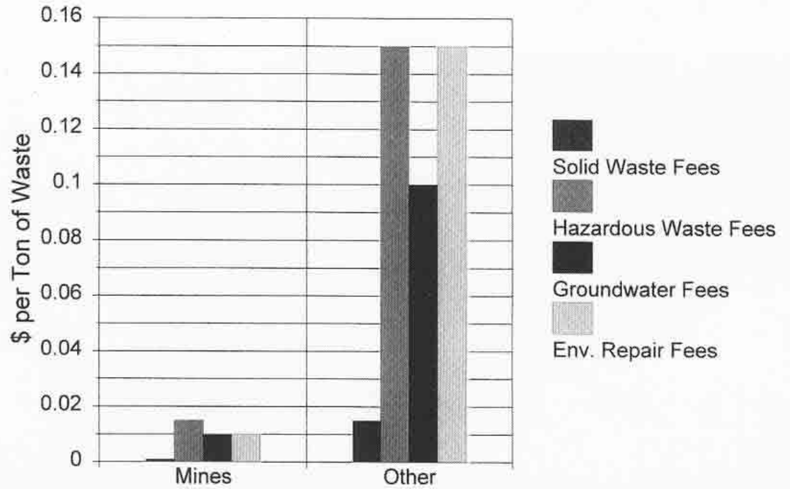


Figure 8. Fees charged to mining companies compared to most other Wisconsin companies.

the only regulator of these facilities. Mining companies must still comply with local zoning ordinances and must apply for zoning permits and approvals required by local law. Additionally, local governments may form local impact committees and enter into local agreements with mining companies. This allows the local governments to have some say in determining what the effects of mining on their locales will be. Without substantive mining regulatory authority, however, the adequacy of these provisions to protect local concerns is substantially diminished from the pre-1982 situation.

In order to tailor mining permits to fit particular circumstances, rules allow variances and exemptions from a number of prospecting and mining regulations.

The fees paid by mining companies are not the same as those paid by other disposers of solid and hazardous wastes. The statutory solid and hazardous waste long-term care provisions require operators of nonapproved solid waste disposal facilities to pay a fee for each ton of solid or hazardous waste that is disposed.

Most operators pay 1.5 cents per ton for solid waste and 15 cents per ton for hazardous waste. Mine waste, however, is charged at rates ranging from only .1 cent per ton to 1.5 cents per ton, even for the most hazardous tailings. The groundwater fee for generators of mining waste is also different than the fee charged to generators of other solid waste: 1 cent per ton for mine operators and 10 cents per ton for others.

Mine operators also get a break on the statutory environmental repair fee. The fee normally ranges from 15 cents to 50 cents per ton of waste received at the facility, depending on the type of waste and the date received. The environmental repair fee for mining waste, however, is one cent per ton. The fees for waste other than mining waste increased in 1989 while the fees for mining waste remained the same. Given the large amount of waste mining produces, it might be argued that the only way to make mining economically feasible is to charge fees lower than those charged to other industries. A serious question remains whether the fees charged generate adequate funds to provide protection against the elevated risks posed by mining. Figure 8 summarizes these fees.

Wisconsin's mining taxation laws have been changed over time to make mining more attractive. In 1977, the Legislature eliminated the severance tax on metallic mineral mining and replaced it with a net proceeds tax. Before 1977, the state tax was based on the amount of metal taken from the land. Now taxes are collected only when mining companies register a profit. Moreover, in 1981, the maximum rate for the net proceeds tax for metallic mineral mining was reduced from 20% to 15%. Because these changes make metallic mineral mining in Wisconsin more economical, they also make it more likely.

In order to further tailor mining permits to fit particular circumstances, rules allow variances and exemptions from a number of prospecting and mining regulations. For example, a variance can be granted to exempt a mining company from any requirement of Wisconsin Administrative Code chapter NR 131, which governs metallic mineral prospecting, or chapter NR 132, which governs metallic mineral mining. Such rules have been promulgated.

Exemptions must not violate any other law or rule and must be consistent with the overall policy that the regulations purport to implement. Exemptions or variances must not endanger public health, safety, or welfare, or the environment. The decision to grant or deny an exemption or variance will turn on an interpretation of the terms "endanger," "public health, safety, or welfare," and "consistent with," all of which can be construed narrowly or broadly depending on the circumstances.

Exemptions have been granted. Wisconsin's mining criteria prohibit mine siting within 300 feet of a navigable river or stream.

However, an exemption was granted enabling a mine to be located only 140 feet (less than half a football field's length) from the Flambeau River in Rusk County. The DNR concluded that the variance would not create any additional threat to the surrounding environment.

The Flambeau Mine in Rusk County, Wisconsin, is located just 140 feet from the Flambeau River. (Photo courtesy of the Wisconsin DNR.)

Wisconsin's officials contend that the state's mining laws are among the toughest in the nation. Yet, the question remains how these laws, which appear so designed to encourage metallic mineral mining, can adequately protect against the many and inevitable ecosystem threats that such mining poses.

Conclusion

Policymakers and regulators inevitably balance trade-offs in determining whether sulfide mining takes place in northern Michigan, Wisconsin and Minnesota.

Mining will create jobs; it will also cause environmental damage. The number of jobs created can be predicted with some accuracy; the amount of environmental damage cannot.

Many communities in the United States are now paying the price of unwise policies with regard to sulfide mining: acid mine drainage, heavy metals contamination, and other environmental degradation.

Indian tribes with reservations and off-reservation harvest rights in northern Wisconsin, Michigan and Minnesota are particularly susceptible to the impacts of sulfide mining. Their cultures mandate respect for the earth, and humility and gratitude for the resources it provides. In the Indian view, the perpetuation of natural resources is tied to the perpetuation of humans. Loss or contamination of natural resources thus affects Indian culture in ways far beyond the loss of a food source.

New technologies intended to mitigate or prevent environmental damage from sulfide mining are being developed but remain untested.

Thus, wisdom counsels a conservative course for mining policy and permitting decisions. Particularly in a region so abundant in water resources, the threats of sulfide mining are real and are potentially devastating.

In the case of the proposed Crandon mine in Wisconsin and similar sites elsewhere, policymakers must consider whether they wish irreplaceable watersheds to be testing grounds for these new technologies.

Ultimately, these decision makers must be prepared to bear the legacy should these technologies prove inadequate to prevent widespread environmental damage.

References

Introduction

Hartig, John, H. and Neely L. Law, *Progress In Great Lakes Remedial Action Plans*, Wayne State University, Detroit, MI, 1994.

Chapters 1 and 2

Barbour, Michael G., Jack Burk, and Wanna Pitts, *Terrestrial Plant Ecology*, The Benjamin/Cummins Publishing Company, Menlo Park, CA, 1980.

Brooke, Larry T., *Effects of Mining Mineral Bearing Sulfide Rich Ores on the Aquatic Ecosystem*, September 1995, (unpublished, on file with the Great Lakes Indian Fish and Wildlife Commission).

de la Cruz, Rodolfo V., *Overview of Sulfide Mining*, January 13, 1995, (unpublished, on file with the Great Lakes Indian Fish and Wildlife Commission).

Down, Cristopher Gordon, and John Stocks, *Environmental Impact of Mining*, Wiley Publishers, New York, 1977.

Foth and Van Dyke, *Notification of Intent to Collect Data and Detailed Scope of Study*, February 15, 1994. Crandon Mining Company.

Jones, Gareth et al., *Environmental Science, The Harper Collins Dictionary*, Harper Collins Publishers, New York, NY (1992).

Michigan Department of Natural Resources, *Solution Mining Update*, July 18, 1995.

United Nations Environment Programme, *Environmental Aspects of Selected Non-Ferrous Metals (Cu, Ni, Pb. Zn, Au) Ore Mining, A Technical Guide*, UNEP/IEPAC Technical Report Series No. 5, Paris, France, 1991.

U.S. Department of Agriculture Forest Service General Technical Report INT-35, *Anatomy of A Mine from Prospect to Production*, Revised July 1993.

U. S. Environmental Protection Agency, Draft Technical Resource Document, *Extraction and Beneficiation of Ores and Minerals*. Volume 2: Lead/Zinc. Office of Solid Waste. Washington, D.C. n.d.

U. S. Environmental Protection Agency, Draft Technical Resource Document, *Extraction and Beneficiation of Ores and Minerals*. Volume 4: Copper. Office of Solid Waste. Washington, D.C. n.d.

Wisconsin Department of Natural Resources, *The Cumulative Impacts of Mining Development in Northern Wisconsin*, June 1992.

Wisconsin Department of Natural Resources, Public Service Commission, *Final Environmental Impact Statement, Exxon Coal and Minerals Co. Zinc-Copper Mine*, Crandon, Wisconsin, November 1986.

Wisconsin Department of Natural Resources Bureau of Solid & Hazardous Waste Management, *An Overview of Mining Waste Management Issues in Wisconsin*, July 1995.

Chapter 3

Cleland, Charles E., Larry Nesper, and Joshua Cleland, Draft Report, *The Potential Cultural Impact of the Development of the Crandon Mine on the Indian Communities of Northeastern Wisconsin*, March 14, 1995 (on file with Great Lakes Indian Fish and Wildlife Commission).

Deloria, Vince Jr., *God Is Red*, Dell, New York, NY, 1973.

Erikson, Kai T., and Christopher Vecsey, *A Report to the People of Grassy Narrows*, in C. Vescey and R. Venables, AMERICAN INDIAN ENVIRONMENTS: ECOLOGICAL ISSUES IN NATIVE AMERICAN HISTORY, Syracuse University Press, Syracuse, New York, 1980.

Geisler, Charles C., *Land Ownership, Control and Use as Sources of Social Impacts: The Sokaogon Chippewa Case*, in C. Geisler et al, eds. INDIAN SIA: THE SOCIAL IMPACT ASSESSMENT OF RAPID RESOURCES DEVELOPMENT ON NATIVE PEOPLES, University of Michigan Natural Resources Sociology Research Lab, Ann Arbor, MI, 1982.

Gill, Sam D., *Native American Religions*, Wadsworth, Belmont, CA, 1982.

Shkilnyk, Anastasia M., *A Poison Stronger than Love, the Destruction of an Ojibwa Community*, Yale University Press, New Haven, Connecticut, 1985.

Chapter 4

Mudrey, M.G. Jr., T.J. Evans, R.C. Babcock, Jr., M.L. Cummings, Jr., E.H. Eisenbrey, G.L. LaBerge, *Case History of Metallic Mineral Exploration in Wisconsin, 1955 to 1991*, in CASE HISTORIES OF MINERAL DISCOVERIES, Volume 3. Society for Mining, Metallurgy, and Exploration, 1991.

Wisconsin Statutes, Chapters 70, 107, 144, and 710. Wisconsin Administrative Code, Chapters NR 103, 131, 132, and 182.

Color maps compiled by: Coleman, John, Great Lakes Indian Fish and Wildlife Commission Environmental Modeling Unit, Madison, Wisconsin, 1995.