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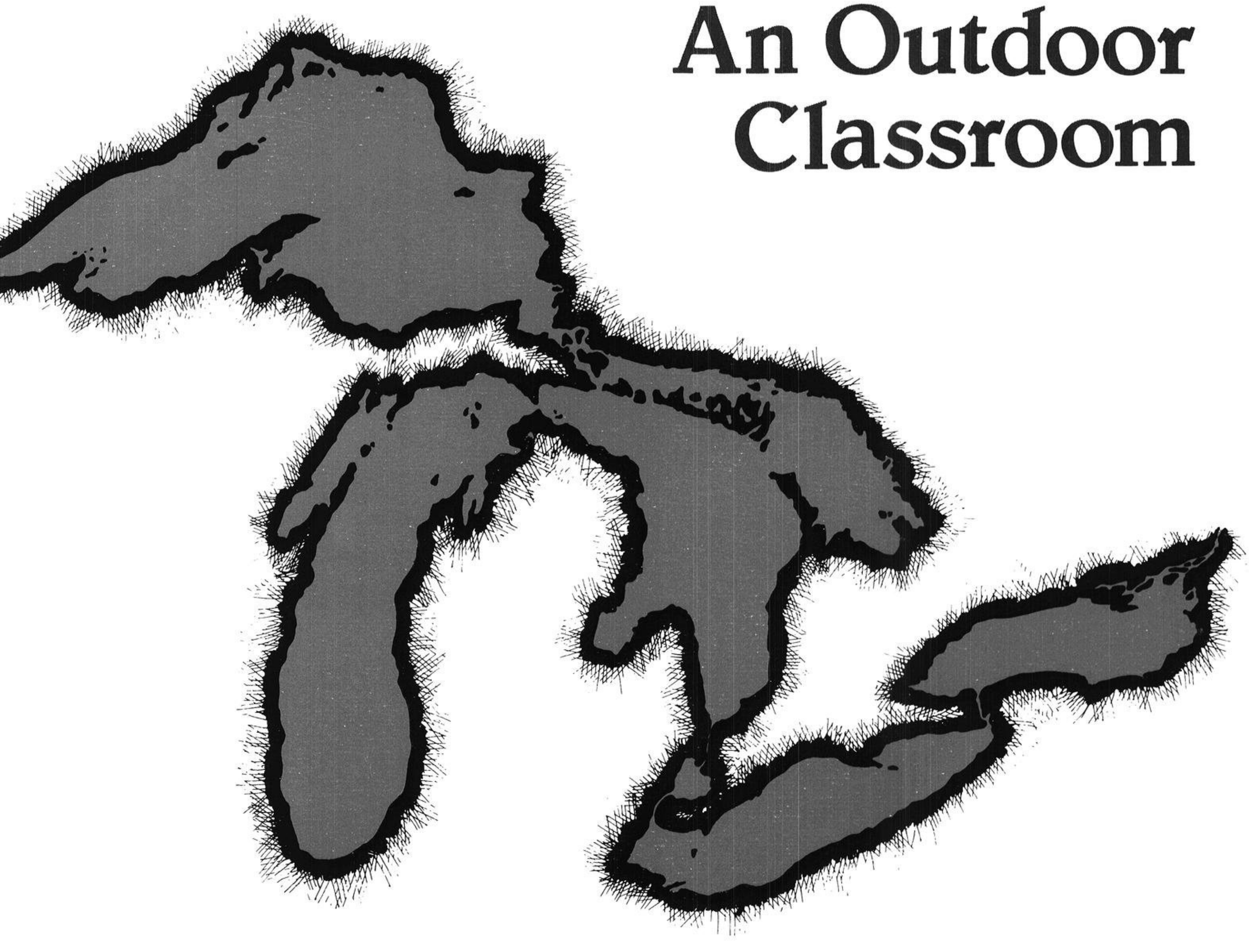
Volume 84, No. 2 December 1979

wisconsin engineer

THE GREAT LAKES

An Outdoor Classroom



wisconsin engineer

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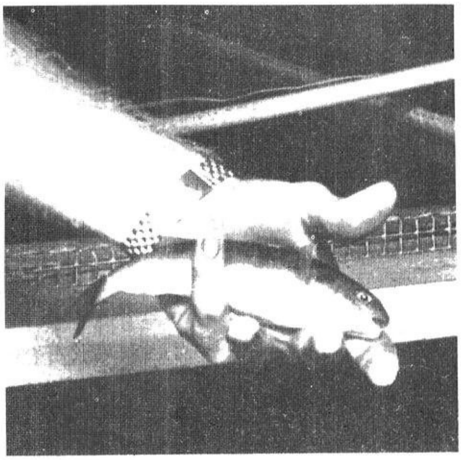

Page 17

Page 19

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Page 20

editorial

The Great Lakes

by Michael Pecht

An endangered species

This aerial view of the Great Lakes was taken by satellite.

The intention of this issue of the *Wisconsin Engineer* is to introduce to the reader the interrelationship between man and the Great Lakes. The Great Lakes may at first appear to be useful only for recreational activities such as boating and sport fishing. However, the Great Lakes are a source of fresh water and minerals as well as fish. They also provide a means of transportation and are used as a heat sink for electrical and nuclear power plants.

Some articles in this issue comment on how man's ignorance and negligence have resulted in environmental turmoil. Other articles point out how man's intelligence and concern is maintaining a more stable environment. People's attitudes and interactions with the Great Lakes will determine the value of the lakes in the future. Fortunately, a great deal of research is being conducted at the University of Wisconsin–Madison on many aspects of the Great Lakes. This research will hopefully lead to a better understanding of the environment and in particular our effects on the Great Lakes.

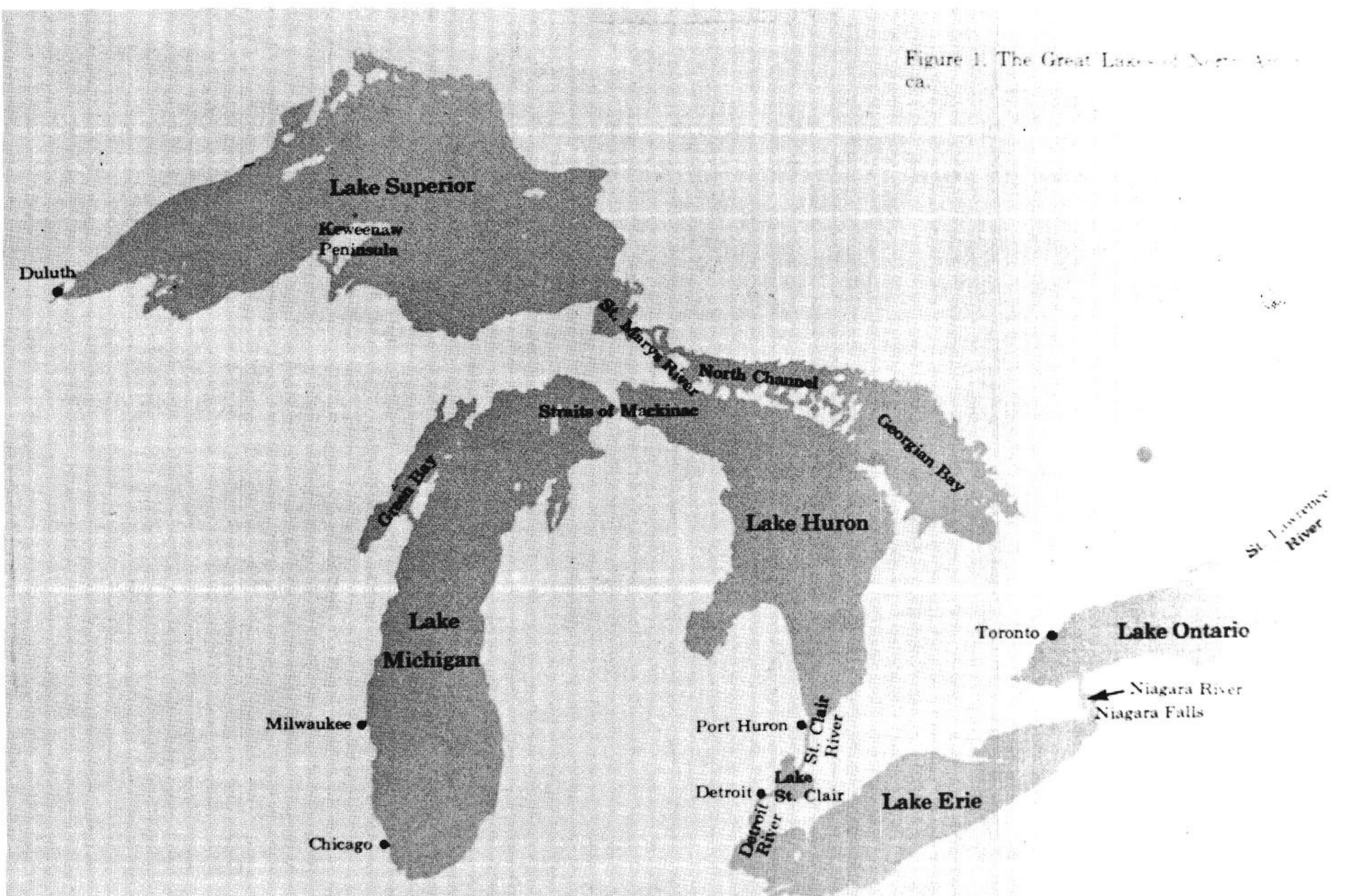


Figure 1. The Great Lakes of North America.

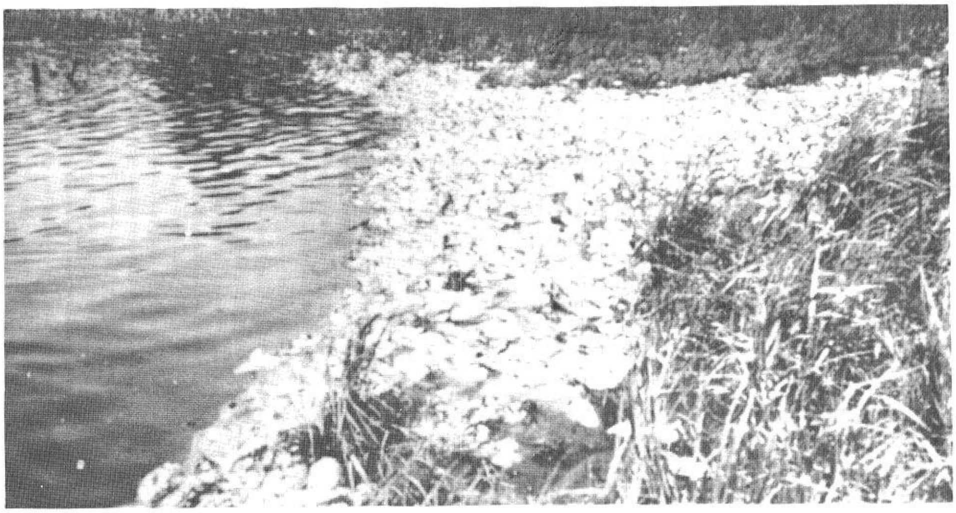
The Great Lakes

A history of problems

by Bob McDermot

Bob McDermot is a senior in mechanical engineering at UW–Madison. He is a regular contributor to The Wisconsin Engineer.

UW Sea Grant Institute



Pollution is not the only killer of fish; overpopulation of certain species of fish may result in a lack of food, oxygen and spawning grounds.

The Great Lakes are the largest reservoir of fresh water in the world, containing one-fifth of the world's fresh water supply. Yet, despite their tremendous size, they are fragile. The Great Lakes are a good example of how man often hurts himself and his environment in his neverending pursuit of progress.

In the very technical world in which we live, the work of the engineer affects nearly every aspect of our lives. Therefore, the engineer has a great responsibility to make sure that his work does not adversely affect the world today or in the future. He must avoid making the types of decisions that men in the past made which led to the present condition of the Great Lakes.

The Great Lakes today exist in a condition much different from that which existed before the surge of white settlers into the Great Lakes region. The activities of these settlers soon began changing the ecostructure of the lakes. Oftentimes, these people were unaware of the effect their presence was having on the Great Lakes. Many times they were aware, but unfortunately they really didn't care.

Today, there are still many activities going on which continue to cause ecological damage to the lakes. However, efforts are being made to **eliminate damage sources**, and because of these efforts, the condition of the Great Lakes has improved in the last five years.

Originally, the lakes' waters were as pure as rainwater. This was mainly due to the fact that much of the Great Lakes basin is composed of bedrock types that are highly resistant to leaching. In the north, the Lake Superior catchment and much of the Lake Huron catchment lie on igneous rocks of the Canadian Precambrian Shield which weather slowly, adding few nutrients to the water. In the south, most of the drainage in Lakes Michigan, Erie, and Ontario comes from glacial drift deposits that cover sedimentary rocks which yield more nutrients. The lakes had low dissolved salt content and were especially poor in phosphorous. The original nutrient-poor, oxygen-rich state of the Great Lakes is best described by the term "oligiotrophic."

However, the east-west orientation of the lakes attracted early settlers who recognized the value of this water transportation route through the Midwest. The combination of plentiful natural resources and accessibility led to concentrations of populations and industry which soon began dumping wastes into the lakes. These sewage and industrial wastes contained many nutrients and soon the nutrient level began rising to poisonous levels in the lower lakes. This led to a greatly increased growth of certain algae at the surface which lowered the oxygen level and eliminated many indigenous plant species by reducing water transparency. Oxygen became just about non-existent in the cold, lower strata, and as a result, fish that lay their eggs in the deep became extinct. The change in the lakes' ecosystem favored invading fish species, such as the alewife, at the expense of the indigenous chub, cisco, and lake herring.

The problem of nutrient pollution continued through the years. Finally in the past decade, an increased environmental awareness in this country and Canada has led to significant action being taken to eliminate the sources of nutrient pollution. Still, even today many cities and industries in the Great Lakes region have inadequate waste treatment facilities. It must be understood that these facilities cost great sums of money. The 1978 Environmental Protection Agency's need survey estimates that 2-1/2 billion dollars will be spent this year in Wisconsin to bring wastewater treatment up to 1983 standards. Time is also involved. Some standards are set five to ten years before compliance deadlines.

In the meantime the lakes continue to receive heavy loads of organic matter and phosphorous from detergents. The results of constructing many new sewage treatment plants in recent years can be seen in the decrease in seasonal blooms, a rapid development and death of algae populations, and an increase in oxygen content in the lakes. However, due to the fact that nutrients remain until flushed out of the lakes, immediate elimination of nutrient pollution cannot be expected, especially after such long-term abuse of the lakes.

Nutrient pollution wasn't the only problem settlers brought to the Great Lakes. Lake Ontario, the eastern-most lake, was the victim of overfishing. The Atlantic salmon, until the late nineteenth century the dominant species in Lake Ontario, was fished extensively. By 1850 the salmon population had declined, and the fishermen, thinking the lake fished out, moved on to other lakes. The remaining salmon never recovered and later disappeared.

In the early and mid-nineteenth century, the forests were cleared for agriculture, lumber, fuel, etc. and by 1897, one observer described the western New York drainage area of Lake Ontario as "almost totally deforested." The loss of forest cover

Pollution of the Great Lakes is not only caused by direct industrial dumping, but also by contaminants released into the air.

over streams where salmon spawned resulted in an increase in stream water temperature. Water temperature is of great importance in the successful reproduction of salmon, and the increase in stream water temperature proved lethal for the Atlantic salmon of Lake Ontario.

The presence of the Atlantic salmon had always been a deterrent to the movement of alewives into the Great Lakes from the Atlantic Ocean. With the elimination of the Atlantic salmon, the small, six-inch long alewife slowly became established in Lake Ontario.

The alewives apparently moved into the Great Lakes through the Welland Canal, which was also the means by which a second major marine species, the sea lamprey, invaded the Great Lakes. The lamprey, an eellike parasite that is 1-1/2 feet long, moved through the Welland Canal by attaching itself to the bottom of boats. The warm stream temperatures caused by the deforestation of much of the Midwest proved to be nearly ideal conditions for lamprey spawning, and gradually the lamprey began to thrive in each of the Great Lakes. By the 1940's , the lamprey began to threaten the extinction of most of the lake trout and salmon in the lakes by attaching its bloodsucking mouth to the fish's side. The declining trout and salmon populations in turn favored alewife population growth in the lakes. Things began to look grim as it appeared that lampreys and alewives would soon be the undisputed rulers of the Great Lakes.

During the 1960's, that last straw had been reached. Commercial fishing catches of lake trout had plummeted, and alewife population explosions were resulting in massive numbers of alewives rotting on the beaches of Lake Michigan.

To combat the lampreys, a selective toxicant was used that would kill young lampreys in the spawning streams, but when applied carefully, would have little or no adverse effect on other species. The toxicant, TFM (3-trifluoromethyl-4-nitrophenol), was used on all the known lamprey-producing tributaries of Lakes Superior, Michigan, Huron, and Ontario. By the late 1960's, 80 to 90 percent of the lamprey population had been eradicated.

To combat the alewives, several salmon species, particularly the coho salmon of the Pacific Ocean, were stocked in the lakes. By 1970 the salmon were thriving in Lakes Michigan and Superior, devouring a steady diet of alewives. Today, salmon and lake trout fishing are excellent; however, yearly stocking is necessary since natural reproduction of these fish has been inadequate. The only salmon that seems to be thriving through natural reproduction is the small pink salmon which was unintentionally introduced into Lake Superior in 1956.

The newest environmental problem in the Great Lakes is that of chemical pollutants. It may be the most difficult problem to solve. Chemicals, particularly pesticides and chemicals used in making plastics, have been entering the lakes for years and continue to do so. They are difficult to deal with, being invisible, and they don't break down in nature. To make matters worse, these chemicals are easily transported in both air and water for hundreds of miles.

Many of these chemicals are very hazardous to the health of humans and wildlife. These chemicals have been showing up in game fish in high concentrations, and humans and animals who eat chemically contaminated fish are subject to accumulating large doses of some of these chemicals in their own body tissues. Because of the health hazards created by chemical pollution, the government has placed many restrictions on the catches of commercial fishermen and warned sport fishermen to decrease consumption of their catches.

One chemical pollutant, PCB's, have received a great deal of attention recently because, not only is it extremely poisonous, it has been showing up in Great Lakes predator fish in recent years at very hazardous levels. PCB stands for polychlorinated biphenyls, a family of compounds used in the past to produce inks, paints, plastics, hydraulic fluids, and "carbonless" paper. In very recent years, PCB's have been used mainly as a fire-retardant in the production of capacitors and electrical transformers.

The main problem presented by PCB's is that to destroy them, incineration at temperatures in excess of 2,200 degrees Fahrenheit is required. This is a temperature much greater than that at which most municipal incinerators operate. Therefore, most PCB's are never destroyed and often find their way into the lakes either by leaving incinerators up the stack into the air or by being washed into the water table from a landfill.

David Armstrong, professor of Civil and Environmental Engineering, in his Sea Grant sponsored research has found that most PCB's in the Great Lakes enter the system as either atmospheric fallout or industrial discharge. "PCB's from the atmosphere are impossible to trace and are difficult to control. Any industry that allows PCB's to go up in smoke must take partial blame. Industrial dumpers are more easily identified, but it is a time consuming investigation."

PCB's are not the only dangerous chemicals entering the Great Lakes; there are many others. One major source of toxic elements is atmospheric fallout. Among the most abundant of these are such trace elements as mercury, cadmium, copper, zinc, and lead which are present in the water at extremely low concentrations. However, the margin between required and toxic levels is often very fine, and present concentrations are becoming highly toxic to certain aquatic species.

Some trace elements kill aquatic organisms in concentrations of several parts per million of water. At lower levels, although not lethal, chemical pollutants can cause reduced photosynthetic rates in planktonic animals. Changes in planktonic organism populations can result in very undesirable changes in species concentrations in the lakes.

What makes matters worse is that some combinations of trace elements behave in a way such that the effect of mixture of elements is much greater than the sum of the effects caused by the elements taken individually. This type of behavior is called synergistic. On top of that, there are some trace elements that have the nasty tendency to ac-

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To help combat high populations of invading fish species; natural predator techniques, poison, and extensive fishing methods were used.

cumulate in the tissue of aquatic organisms.

Atmospheric trace elements that eventually settle into the waters of the Great Lakes have many sources including soil dust, automobile exhausts, and cement and steel manufacturing operations. The main source of airborne toxic elements, though, is the combustion of fossil fuels, particularly coal.

Herein lies a great problem. With the growing lack of faith in nuclear power in this country (for both economic and safety reasons), coal-fired power plants are being considered as a major source of power. This increased use of coal will lead to greater chemical pollution of the Great Lakes as many coal power plants will be needed to power industrial areas around the lakes.

Stack emissions travel up to one hundred miles downwind with most elements falling out within 35 miles of the source. Direct deposition on the surface of the lakes provides the major means of trace element pollution of the lakes. Some trace elements run off land into waterways, especially where deposition is accompanied by another pollution source, acid rain.

The Clean Air Act (1963) and its amendments led to the use of anti-pollution equipment on power plants and consequently the rates of deposition of trace elements appears to be declining in the Great Lakes region. This trend may be offset though in the future as reliance on coal power greatly increases.

Since chemicals are used so extensively in the United States, they will continue to be a major source of trouble for the Great Lakes ecosystem. A very sad example of the havoc chemical wastes have caused in America is the endangered existence of the American bald eagle. Its tragic decline in numbers can be attributed mainly to the pesticide DDT which was banned in 1972. DDT entered many waterways, especially the Great Lakes, through runoff. It soon accumulated in the fish which eagles ate. The DDT caused the eagles to lay eggs with very thin eggshells which were usually crushed or cracked during incubation. Thus the reproductivity of bald eagles declined dramatically. Today, seven years after DDT was banned, the bald eagle is showing slight signs of recovery.

The Great Lakes ecosystem has been violated in many ways not mentioned here. In a country where the pursuit of profit is the number one concern of the business world, many corporate decisions have often been made with no regard to environmental impact. In the process, an unhealthy environment for all living things, including humans, is created. In the future, the pursuit of profit will have to coexist with a respect for the world in which we live. Luckily, the Great Lakes have weathered much of the abuse man has thrown at them. The Great Lakes are not dead; at present they are doing fairly well. Given the proper amount of time, respect, and care, the Great Lakes will gradually recover from past neglect and will flourish in the future. ■

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Coastal erosion

Where have all our beaches gone?

by Art Vawter

Art Vawter is a junior in engineering mechanics at UW–Madison. His article presents a valuable application of engineering mechanics.

Coastal erosion and bluff landslides are a cause of extensive property damage on the Great Lakes. The understanding and control of this problem is extremely complex due to the large number of variables involved. Composition, geometry, and usage of the slope, groundwater action, wave action, frost and ice action and weathering are crucial factors but are difficult to quantify. In general, the erosion and bluff slide is dealt with by geotechnical and coastal engineers with a knowledge of geology, geomorphology (the study of the configurations and evolution of land forms) and soil mechanics.

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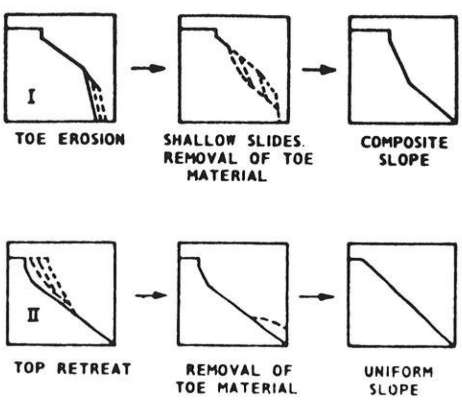


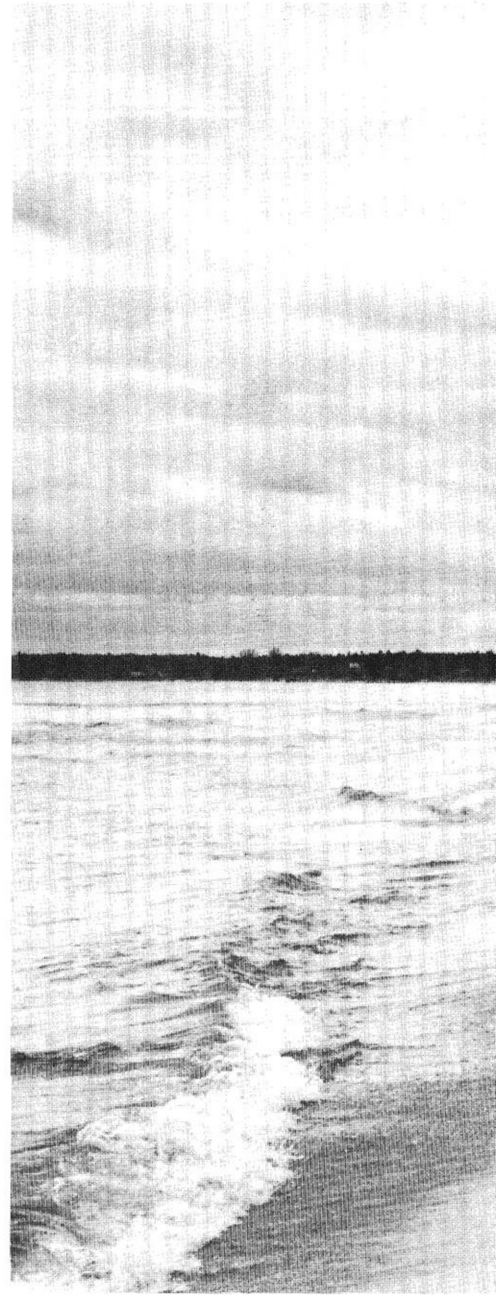
The analysis of coastal erosion and/or bluff stability is complex. Professor Edil's drawings are models of two types of bluff changes.

Tuncer Edil, a professor in both Engineering Mechanics and Civil and Environmental Engineering at the University of Wisconsin, considers wave action to be the most damaging factor in coastal erosion. It is the wave action at the toe (base) of a coastal bluff which is the primary factor responsible for changes in slope geometry. Wave action is a function of the duration and intensity of storm activity, fluctuations in water level, wind velocity, inshore and offshore bathymetry (the depth of the water), composition of the material at the toe of the slope, and manmade structures.

The force of a wave can be broken into two component forces. One force component, called the active part is perpendicular to the shoreline. It is the active part of the wave force which directly attacks and erodes the intact toe material which in turn affects the steepness of the bluff face and threatens its stability.

The other force component, called the passive part, is responsible for the removal of material which collects at the toe of the bluff. This material may be from degradation of the bluff face due to active wave action or from material deposited there by the passive part of the wave action at a previous time. The movement of material parallel to the shore is referred to as littoral drift.

The problem of coastal erosion is usually broken into two parts. The first deals with active wave action at a particular location. In such a case the dynamic nature of the local slope geometry must be known. The second deals with the large scale coastal erosion problem based on passive wave action. In this case the overall stabilization of a whole shoreline must be weighed against such factors as environmental desirability and cost.



Structural solutions are generally applied to the localized erosion problem where loss of property or safety considerations make such solutions necessary and feasible. One method of slowing down the effects of active wave action consists of directly armoring the toe of the shoreline against wave attack. Seawalls, UW Sea Grant Institute

Left: Wave action has changed the geometry of the shoreline.

Below: This is an example of degradation of bluffs due to coastal erosion.

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bulkheads or revetments (slabs of demolished cement or other rock structures) are all used to stop active wave action. However, over a long period of time the wave action will undermine the foundation of even these structures. But because they are inexpensive, revetments are the most common form of coastal stabilization used on Lake Michigan. However, contaminants in the materials may be released into the water causing local pollution.

Another structural solution is to build up a protective beach to dissipate the wave energy before it gets to the erodible toe material of the bluff. This can be achieved by offshore breakwaters, groins, jetties, perched beaches and artificially nourished beaches. On Lake Michigan, groins are the most widely used of this type of protection. A groin is a wall structure made out of wood or metal pylons or plastic tubes filled with sand. They are placed perpendicular to the shoreline in shallow water to slow down the removal of the existing beach by littoral drift. With the use of a groin and by littoral drift, a beach can be formed or maintained. However the shoreline usually develops a saw tooth pattern where material is built upon only one side of the groin. If a gale typical of Lake Michigan came from a direction opposite to that of the usual littoral drift, the material may shift over to the opposite and possibly unwanted side of the groin.

In general, solutions must be tailored to the specific site. Moreover for any solution to be effective, an understanding of the pertinent factors such as wave action must be known. ■

Breaking the ice

New research on a cold topic

by James Brekke

James Brekke is a graduate student and a teaching assistant in engineering mechanics at UW–Madison. His interest in the mechanics and properties of materials is shown in his article.

In the last 15 years the study of new materials and their properties has developed significantly. However the study of ice and its properties is still in its infancy. For the last 45 years ice has basically been broken either by dynamiting or ramming with a ship.

Ice breakage is needed to supply military and scientific stations in the remote areas of the polar regions. It is also necessary to escort cargo ships carrying grain and oil to the upper midwestern states during the winter months on the Great Lakes.

Icebreaking ships first came into use in the late 1930's and early 1940's. Most of these early icebreakers were 110-foot tugboats. The *Mackinaw* is one such ship still used on the Great Lakes. In general these early icebreakers are capable of breaking only 12-14 inches of ice continuously. To break thicker amounts of ice the icebreaking ship rams the front of its hull on top of the ice. Water is then quickly pumped to ballasts in the front portion of the hull to increase the weight on the ice. It is the combined weight of the ship and the pumped water which breaks the ice. The icebreaker must then back up, pump out the water and repeat the process. This method is slow and tedious but effective. For example the 269 foot long, 6500 ton *Westwind* (first commissioned in 1944) is capable of breaking through only 14 inches of ice continuously but can break up to 12 feet of ice by the method described above. The *Westwind* is still used on the Great Lakes during the winter months and on the arctic circle during the summer.

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Without ice-breaking techniques, shipping on some of the Great Lakes would be halted during the winter months.

The 9th Coast Guard District is in charge of all icebreaking activities in the Great Lakes. Recently four new 140-foot long icebreaking tug boats have been designed and built by the Coast Guard to service this region. One of these boats, the *Mobile Bay,* whose home port is Sturgeon Bay, Wisconsin, is, according to Chief Petty Officer Joe Amato, "a typical example of the improvements in these new icebreakers." The *Mobile Bay* is designed to cut 18-20 inches of ice continuously although in practice it has continuously cut 27 inches of ice with a snow cover of one foot. It uses a system which forces air bubbles out of the sides of the hull thereby lubricating the hull to reduce friction forces during icebreaking. However when confronted with thick ice the *Mobile Bay* must resort to ramming and backing or dynamite blasting.

A less primitive solution to the ice-breaking problem depends on a better understanding of ice as a material. Ice is a very unique and complex material. Although it appears to be hard and strong, it has a breaking strength (ultimate strength) between 0.82 and 5.5 psi on tension and between 1.7 and 42.6 psi on compression. In comparison, rubber has an approximate breaking strength of 3000 psi on tension and wood has an approximate breaking strength of 8000 psi on compression. Ice is also not as brittle as expected. Its tendency to deform is one thousand times that of wood and ten thousand times that of glass.

The reason ice is so complex is because its strength properties depend on structural differences such as the amount of air in the ice, the temperature of the ice, and the age of the ice. These factors need to be analyzed to fully take advantage of ice breakage.

Ali Seireg, a professor in the Mechanical Engineering department at the University of Wisconsin, is presently conducting research on ice breakage. He is forming mathematical models based on finite element analysis. These simulate the response of water and ice to an explosive or an impcting object such as the hull of a ship. The amount of ice breakage and the shape can then be optimized by changing the location of the explosive in the model or the geometry of the impacting object. For example, Professor Seireg's model can determine when to place explosives so a large channel or a small circular hole will be formed.

Two other methods of ice breakage which exploit the nonsymmetric properties of ice are based on pre-stressing the ice. The first method involves a hovercraft which is loosely attached to the front of an icebreaker. The hover craft applies a jet force of air pressure on the top surface of the ice sheet. This will pre-stress the ice so its top surface will be on compression and the under surface will be on tension. Since ice is weaker in tension, if a crack can be initiated on the bottom surface of the ice, fracture of the ice is not difficult to accomplish. Similarly, air pressure can be applied under the ice surface, thus placing the under surface on compression and the top surface on tension. In this case the top surface would be cracked to initiate a crack which would lead to breakage of the ice.

The practicality and efficiency of some of the ideas discussed here are unproven. However with the present research and technology ice-breaking techniques will be improved. ■

The Coast Guard is in charge of ice breakage on the Great Lakes. This is the "Mobile", whose home port is Sturgeon Bay, Wisconsin.

The Liberty ships

Catastrophic failures

by Chris Guy

Chris Guy is a graduate student and a teaching assistant in engineering mechanics at UW–Madison. His focus of study is on composite material and fracture analysis.

Perhaps Fate was having a laugh at the expense of the engineering profession when a class of World War II ships was named the Liberty ships. For the Liberty ships tended to behave like the Liberty Bell—they fractured.

The *Schenectady,* a large tank vessel fractured while tied up at its dock, in still water. A report on the incident reads, "Without warning the deck and sides of the vessel fractured just aft of the bridge superstructure. The fracture extended

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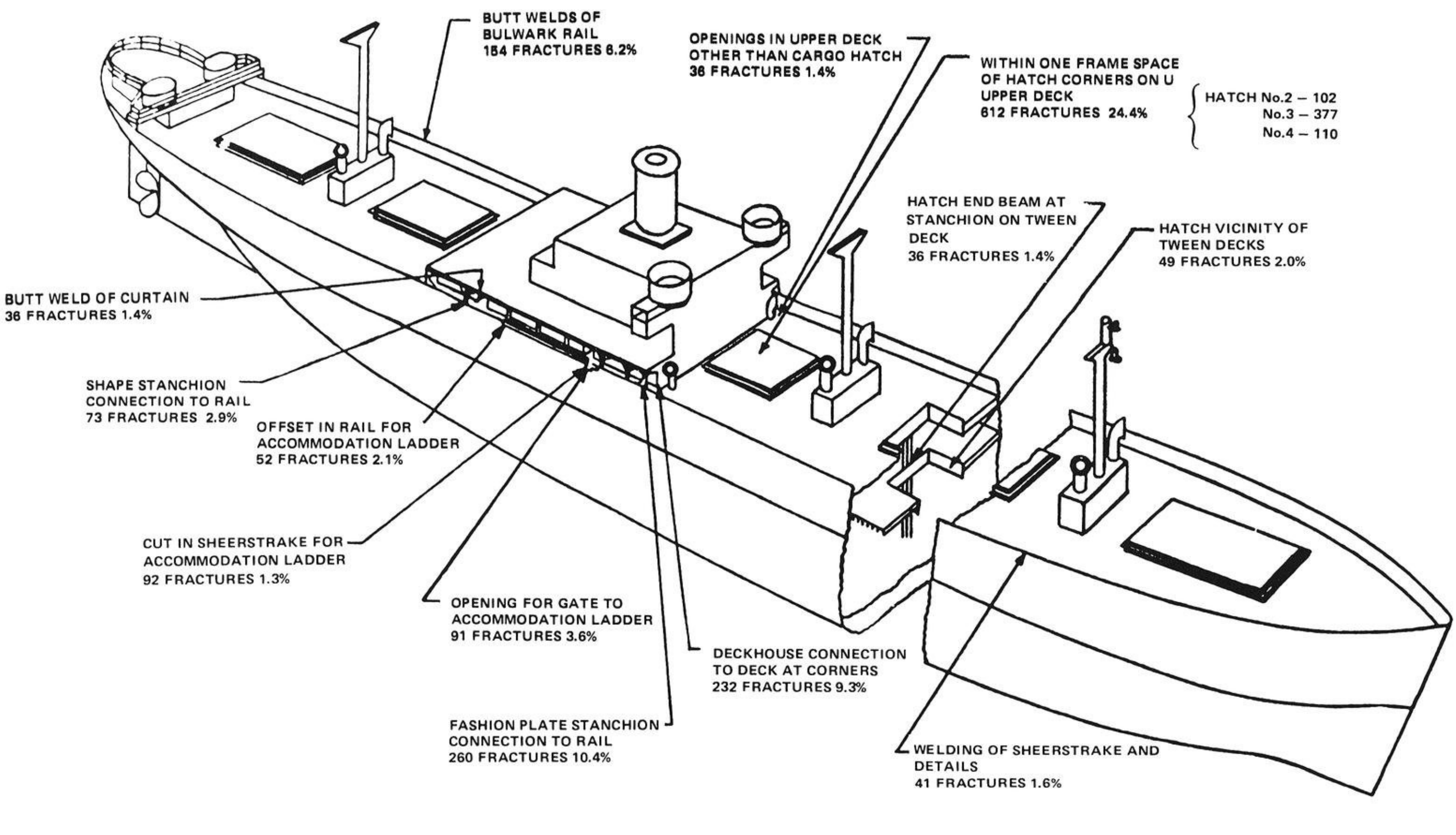

almost instantaneously to the turn of the bilge port and starboard. The vessel jack-knifed and the center portion rose so that no water entered the hull."[1]

Another ship, the *Joel R. Poinsett,* was underway in the North Atlantic when "a loud report, followed by two smaller ones, was heard, the engines were stopped, and a general alarm was given. Immediately afterward, the forward end of the ship separated from the after end and floated away."

In a period of three years starting in 1942, eight ships broke in two, resulting in the loss of 26 lives. Out of 2,710 Liberty ships there were 978 fractures of varying degrees of seriousness. These ships were welded merchant vessels that were being manufactured rapidly to meet the demands of the war effort.

The fracture problem was quite puzzling since the basic ship design was one of the older and more developed engineering designs. However, welding was a relatively new technique in shipbuilding and it was thus suspected that fractures were occurring because the ships were welded rather than riveted. Yet investigations revealed that welding was not the primary culprit. The true cause of the fractures was a combination of two factors: temperature and geometry.

The steel used in these ships was a relatively ductile mild steel. Therefore fracture should have occurred only after considerable deformation and plastic strain. Also according to the theory of strength of materials, one would expect the fracture face to be at a 45° angle and to appear silky. The fractures, however, were square breaks and the surface had a granular texture typical of brittle material failures. It was eventually found that a property change, due to temperature, took place in the mild steel. It is now known that there exists a temperature, called the transitron temperature, below which mild steel may lose up to 6000% of its strength and behave in a brittle manner. Since the transition temperature can be as high as 40°F it is no wonder why so many ships had structural problems.

The problem was further aggravated by the interior ship design. Cargo hatch openings had square corners resulting in large stress concentrations. Investigations of the fractured ships found that "every fracture examined started in a geometrical discontinuity or notch . . ."

The solution to these problems consisted of redesigning the ships with rounded hatch corners and more gradual changes in shape of other crucial internal structures, and using metals with a lower transitron temperature. ■

Studies of ship fractures have changed the basis of modern ship design. Temperature as well as geometry, and material properties must be considered as criteria for proper design.

[1] All quotations in this story are taken from the Final Report of a Board of Investigation convened by Order of the Secretary of the Navy to Inquire into "The Design and Methods of Construction of Welded Steel Merchant Vessels"; Government Printing Office, Washington: 1947.

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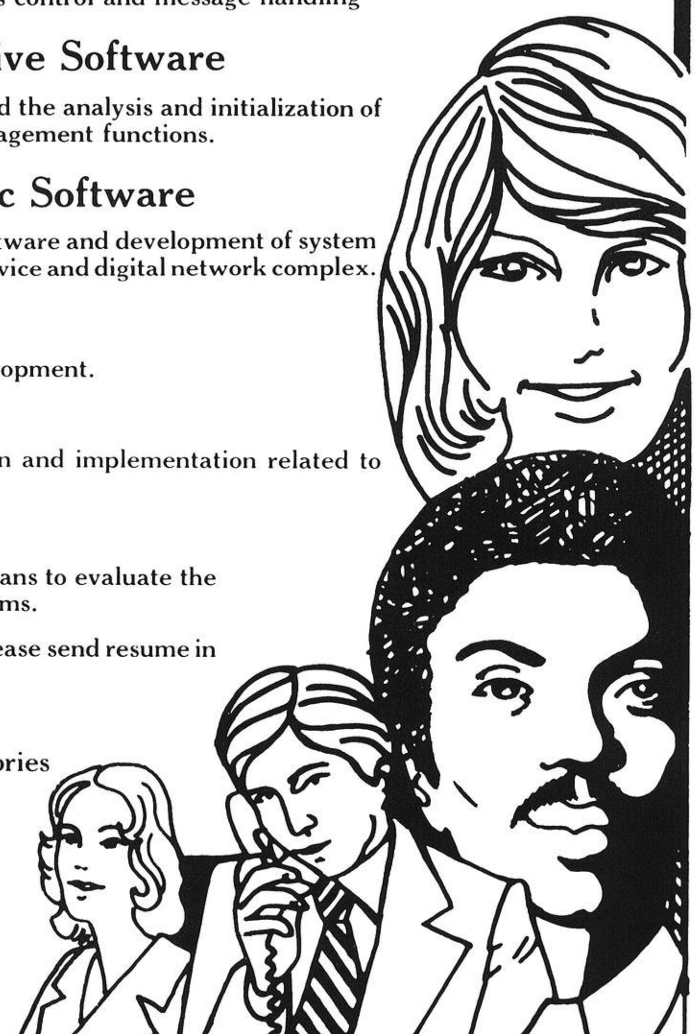

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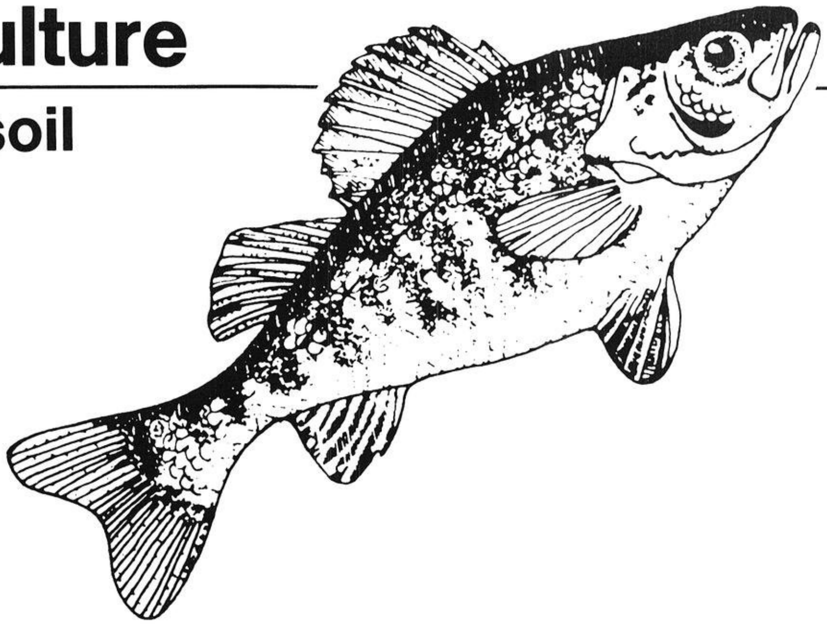
Perch aquaculture

Farming without soil

by Glenn Pecht

Glenn Pecht is a sophomore in civil engineering at UW–Madison. He graduated from Woodstock High School in India. Perch is one of his favorite foods which he missed while living there.



In Wisconsin, the Friday fish-fry is a tradition. Walleye, smelt and the popular yellow perch are a few of the fish often offered at restaurants and taverns. However, because of large commercial fish catches and increases in contaminants in the Great Lakes, lake perch may soon disappear from menus.

Lakes Erie and Michigan produce about 95 percent of the lake perch caught for human consumption. Over three-fourths of these fish are consumed in Wisconsin. In a year when there's been a good harvest over 20 million pounds of lake perch are eaten in Wisconsin.

The largest amount of lake perch for the midwestern states is supplied by the Lake Erie commercial fishery. In 1969 this fishery provided 33 million pounds of lake perch to the market, but by 1974 the number had declined to 15 million pounds and it is still declining.

To catch up to the increased demand for lake perch the Sea Grant Program is conducting research into perch aquaculture. Perch aquaculture is the science of raising fish. It involves expensive equipment such as tanks and fish-rearing facilities, a fresh water supply, special fish feeds and a lot of human experience. Professor Harold Colbert writes, "Like any other type of farming venture, to be successful fish farming requires certain skills and knowledge, hard work, investments and considerable luck."[1]

One major aspect of perch aquaculture is water reuse. The idea is to use a fixed volume of water for a particular aquaculture system. Since the wastewater from the system is not suitable for perch culture it must be partially treated. A typical water reuse system at the University of Wisconsin–Madison consists of three points. First, a water clarifier removes most of the suspended solids. Next a pressure sand filter further clarifies the water and finally ammonia, a toxic product of fish metabolism, is converted to nitrate using a biological filter.

A second major aspect of perch aquaculture is obtaining a reliable supply of fingerlings less than one year old and one to three inches in length, at a reasonable cost. Fingerlings have been available from wild stock; however, their quality has been variable. In general fingerlings must "be as free of disease as possible, be efficient converters of feed, be fast growers and should develop into fish of a quality that will meet market demands."[2] The University of Wisconsin–Madison is presently involved in research to develop the technology to produce such fingerlings.

Prices for lake perch have climbed at a tremendous rate. However, in the last few months the retail price has fallen almost a dollar a pound. This decline has been attributed to perch aquaculture and to increased perch production in Lake Erie. Thus lake perch aquaculture is supplying the consumer with a fresh, high quality product at a reasonable cost. ■

[1]Colbert, H. E., "Aquaculture' Raising Perch for the Midwest Market," Univ. of Wisc. Sea Grant College Program, Advisory Report #13, June 1975.

[2]Colbert, H. E., "Perch Fingerling Production for Aquaculture," Proceedings of a Conference held at the Univ. of Wis., Univ. of Wis. Sea Grant College Program, Advisory Report #421, Dec. 12, 1977.

The Great Lakes

Clean water source or garbage disposal unit?

by Hank Haslach

Hank Haslach was a graduate student and is presently a lecturer in the engineering mechanics department at UW–Madison.

After nearly ten years of environmental cleanup efforts, Great Lakes pollution levels are still far below accepted standards for human and wildlife health. A five-year study by a joint U.S. Canadian Commission states that there are forty-eight problem areas on the Lakes, one more than in 1977. Only 71 percent of the facilities in the U.S. and 73 percent of those in Canada were in compliance with hazardous chemicals and nutrient discharge regulations in 1978.

The Great Lakes, once a major fishing grounds and still the drinking water source for lakeside communities, have been seriously degraded by industrial wastes and municipal sewages. Some cities pour sewage into their own drinking water and recreational beaches. The city of Milwaukee was successfully sued in 1979 by the State of Illinois for polluting northern Illinois drinking water which also forced the closing of many swimming beaches.

Phosphorus is a major pollutant in the Great Lakes. Ironically, municipal sewage plants are the principle sources of the phosphorus. Phosphorus is a nutrient which by encouraging phytoplankton growth lowers the oxygen content of the water.

Other toxic organic substances with irreversible effects have been found in many forms of higher lake life. "The Commission recommends banning the manufacture, import, and use of certain of these substances, including PCB's, PBB's, alderin, dieldrin and DDT and its derivatives . . . whose entry into the environment is difficult to control, if their use is permitted." For example, in Lake Michigan, coho salmon showed PCB levels of from twenty to fifty times the standard. Bloater chubs contained dieldrin twice the standard, when in 1969 they contained less than the standard.

Mercury levels were above the standard in whitefish, lake trout and suckers near the shore in Lake Ontario. Radium has been found in drinking water at Serpent Harbor on the North Channel.

But shoreline polluters are not the only source of the problem. The public has recently become aware of "acid rain" in which sulphuric dioxide is carried in rain clouds and deposited far from its source. "Atmospheric inputs may be responsible," reports the summary, "for up to 40 percent of the loadings of certain pollutants to the lakes, including phosphorus, heavy metal, toxic organic contaminants, and sulphur dioxide, which contributes to the acid rain phenomenon."

It is easy to make recommendations but hard to implement them. The dangers of asbestos in the taconite tailings dumped in Lake Superior by the Reserve Mining Company have been known for years, but attempts to halt the dumping have been headed off in the courts.

The report summary suggests that enforcement and control should be carried out through issuance of permits. "All existing activities and all planned or potential development that may lead to water quality degradation (should) be subjected to an analysis that will ensure that degradation be prevented. Proponents of development should be required to assure Governments, before they are given approval to proceed with such development, that degradation will not occur."

The weakness of such a system is pointed out clearly in the report. "EPA and the States need to improve their followup system on violators. It would be useful if EPA had the power to levy administrative fines commensurate with the costs industry saved through the delay. Some of the States have administrative authority to assess fines or receive payments to some degree and are, as a result, able to avoid lengthy court proceedings in some situations.

Among the most troublesome items in industrial permit development are the delays in effluent guideline development occasioned by lawsuits filed by industry, and the long proceedings needed to adjudicate permits opposed by industry."

In these cases however, "To offset the advantages gained by a company which does not meet a pollution control limit on time, the United States has a 'penalty policy' to request the court to set fines which are at least as large as the firm's economic savings from delaying installation and operation of treatment equipment. The intention is to create equity for the firms which have met effluent limits in accordance with the law."

Further, environmental groups have been forced to challenge laxity by government agencies in setting and enforcing strict guidelines. Since personnel switch back and forth between industry and regulatory agency jobs, there is often a cozy relationship between industry and the agency. Citizen political action which leads to a voice in corporate and real estate development decisions is one possible solution. ■

All quotations in this story are taken from *Water Quality of the Upper Great Lakes.*

A fish story

Instabilities in the Great Lakes

by Ken Jaworski

Ken Jaworski is a junior at UW–Green Bay. He is taking courses in both environmental studies and journalism.

One of the most abundant resources which the Great Lakes offer is fish. Unfortunately, man has abused this resource. He has dwindled the fish population of certain high-value fish species and has so polluted the waters to make many fish inedible. Yet realizing his mistakes, man has managed to correct many of them and has been, so far, quite lucky.

During the 1830s to1890s the fishing industry of the Great Lakes prospered with a plentiful supply of such high-value fish species as lake trout, yellow perch, and whitefish. However, as the number of people in the Great Lakes region grew, so did the fishing industry. Recognizing the need to monitor the growing fishing industry, the government established the United States Fish Commission in 1871 and the Wisconsin Fisheries Commission three years later.

The first action these commissions focused on was the planting of both native and exotic species of fish. From Wisconsin's first fish hatchery, located in Milwaukee, lake trout, whitefish, and imported rainbow trout, brown trout and Atlantic salmon were planted into Lake Michigan. However by 1922, catches of fish had dropped 10 percent due to fishing pressure, larger and faster boats, and better netting techniques.

It is interesting to consider the changing fish population around this period of time. Fish native to the Great Lakes had decreasing populations. Therefore more native and exotic fish were stocked. But it is not easy to successfully stock fish. For example, the stocking of Atlantic salmon was halted in 1932 when the fish failed to establish itself on the Upper Great Lakes even though it was native to Lake Ontario. Meanwhile carp, a scavenger fish, entered Lake Michigan from fish farms by way of floods, and smelt entered the Great Lakes because of a mistake in a salmon-raising project in Michigan's Crystal Lake. Both of those fish are presently harvested in large numbers as animal feed.

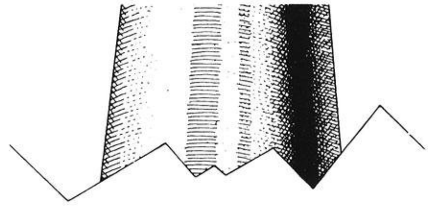
But the biggest change in fish population came with the building of the Welland Canal. The Welland Canal was built to connect the Atlantic Ocean with Lake Erie. This allowed sea lamprey and alewives to enter the Great Lakes, along with the ships for which the canal was built.

Sea lamprey were first seen in Lake Erie in 1910 and twenty-five years later they were in Lake Michigan. In 1958, the chemical TFM was developed in Europe to kill the sea lamprey larva and has been a success in reducing their numbers in the Great Lakes. However in 1952 the sea lamprey had reduced the lake trout population by 95 percent and no lake trout were harvested from 1955 to 1960.

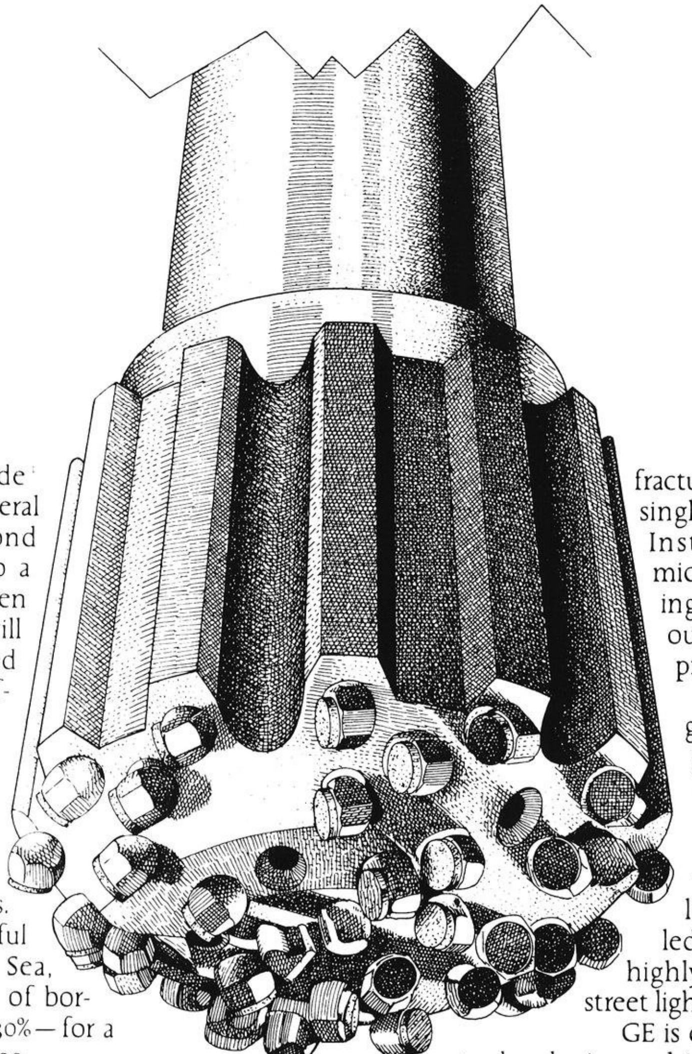
The alewives, free of their ocean predators, produced rapidly and competed for food and spawning grounds with the other fish. In 1966 the U.S. Fish and Wildlife Service began to reintroduce lake trout into Lake Michigan as a predator of the alewives. Coho salmon were also introduced at this time. But by 1972 the 15.8 million coho salmon stocked in the lake had managed to reduce the alewife population by only 5 percent. Today it is estimated that 90 percent of all Lake Michigan fish are alewives. Commercial fisherman have partially capitalized on this. For example, the catch of alewives in 1967 reached 41.9 million pounds for the use of cat food and fertilizer. However the alewife population is still growing faster than other fish can eat them or man can harvest them.

Presently Wisconsin alone stocks 700,000 coho salmon, 1.2 million chinook salmon, 900,000 lake trout, 700,000 brown trout, 1 million rainbow trout and 100,000 brook trout into Lake Michigan each year. Because of this extensive stocking program, the fish population of Lake Michigan has become quite acceptable. Yet the pollution problem has grown worse. This problem can be summarized by quoting the Wisconsin license manual given to all licensed fishermen. It reads, "Persons fishing in Wisconsin waters should be aware of the potential risk involved with frequently eating certain fish which have been contaminated by . . . PCB's." Furthermore the Wisconsin Division of Health advises that trout and salmon over 20 inches from Lake Michigan and carp should be eaten no "more than one meal or 1/2 pound (of fish– per week."

The history of the fish of the Great Lakes is filled with crisis. While many of the crises have been corrected, problems still exist. The problem of an unstable fish population is being relieved by human intervention. High-value fish species are being stocked. However, the problems will never be completely solved if man continues to overharvest the fish and pollute the environment. ■



With this drill bit, GE is putting diamonds back into the earth.



The diamond is Man-Made diamond developed by General Electric. Man-Made diamond crystals are pressed into a polycrystalline "blank." When this blank is attached to drill bits like the one pictured here, it provides a highly efficient cutting tool to probe deep into the earth.

Drill bits which include diamond blanks can as much as double the penetration rates of steel bits in drilling for oil and gas. In one of the most successful applications in the North Sea, these drill bits cut the cost of boring through shale by nearly 30%—for a total saving of close to $300,000.

Two remarkable engineering breakthroughs were required for the development of these drill bits. First came the synthesis by GE of Man-Made diamond itself. Pioneering the technology of heating and pressurizing carbon established GE as a leader in superpressure science.

The polycrystalline diamond blank microfractures because of its structure. Natural cleavage planes of mined diamond (right) cause it to break off in larger pieces.

Then GE invented the technology which compacts the small, powdery Man-Made diamond into far larger disks (as large as 12 mm. in diameter by as much as 1 mm. thick). Since these disks are composed of many nonaligned crystals, they resist the massive destructive fracturing which occurs in large, single-crystal natural diamond. Instead, these disks tend to microfracture, constantly exposing new cutting edges without destroying the diamond product.

Creating new engineered materials is an important example of research in progress at GE. Recent developments include a proprietary epoxy catalyst that's cured by ultraviolet light. GE work in ceramics led to the Lucalox® lamp—a highly energy-efficient form of street lighting.

GE is constantly investigating new technologies and innovative applications for existing technologies—in such areas as electrical distribution systems, electronic components, environmental systems. This takes talent—engineering talent—not just in research and development, but in design and manufacturing, application and sales.

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