G L E R L

GREAT LAKES ENVIRONMENTAL RESEARCH LABORATORY

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Office of Oceanic and Atmospheric Research
Environmental Research Laboratories
Great Lakes Environmental Research Laboratory

Ann Arbor, Michigan

A Program Focused On The Great Lakes But With Wide General Applications To Lake And Estuarine:

- o natural hazards forecasting
- o management of water supply and water quality
- o development of ecosystem management strategies
- o fisheries management
- o water transportation

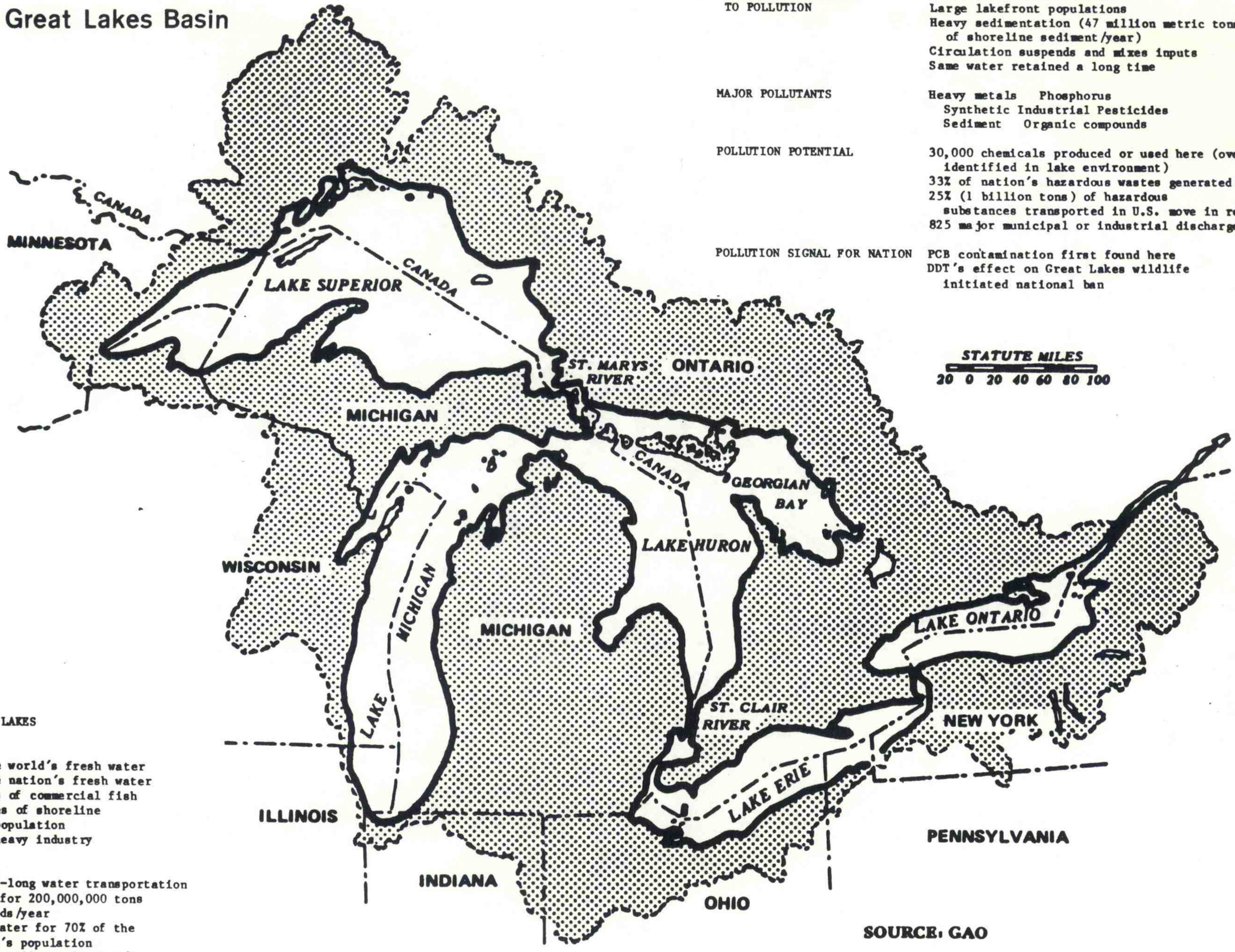
"The Great Lakes constitute an intricate freshwater ecosystem unparalleled in this world. They are of enormous geographical, spatial and temporal dimensions considering the extent of their drainage basins, water volumes and hydraulic retention times. The largest of these lakes is Superior with a basin and lake area of 209,789 square kilometers (81,000 square miles) and a hydraulic retention time of 183 years. The smallest is Lake Erie with a basin and lake area of 84,149 square kilometers (32,490 square miles) and a hydraulic retention time of 2.8 years. Approximately 30 percent of Canada's population and 20 percent of the United States' live in the Great Lakes basin and utilize its resources. Urbanization, industrialization and deforestation in the basin have caused environmental problems, particularly in the lower lakes, Erie and Ontario. These lakes have become polluted by a wide variety of industrial, municipal and agricultural wastes. The pollution has adversely affected water quality and aquatic resources.

. . . . .

The complexity of these issues warrants a large amount of research specific to the Great Lakes. If research is not adequate, it will be difficult to identify problems, understand the cause-effect relationships, predict ecosystem responses or behaviour, and ultimately improve the management of the Great Lakes. It is important to detect as early as possible subtle changes in water quality. Once problems have become obvious, solutions and recovery may take decades. If the problem is irreversible, recovery may never occur."

1982 Annual Report
Great Lakes Research Review
Great Lakes Science Advisory Board
Report to the International Joint Commission
November, 1982
Windsor, Ontario

The Great Lakes Basin



ESPECIALLY VULNERABLE TO POLLUTION	Industrial concentrations Large lakefront populations Heavy sedimentation (47 million metric tons of shoreline sediment/year) Circulation suspends and mixes inputs Same water retained a long time
MAJOR POLLUTANTS	Heavy metals Phosphorus Synthetic Industrial Pesticides Sediment Organic compounds
POLLUTION POTENTIAL	30,000 chemicals produced or used here (over 900 identified in lake environment) 33% of nation's hazardous wastes generated here 25% (1 billion tons) of hazardous substances transported in U.S. move in region 825 major municipal or industrial dischargers
POLLUTION SIGNAL FOR NATION	PCB contamination first found here DDT's effect on Great Lakes wildlife initiated national ban

THE GREAT LAKES

Have
20% of the world's fresh water
95% of the nation's fresh water
50 species of commercial fish
3,470 miles of shoreline
15% U.S. population
50% U.S. heavy industry

Provide
1,270 mile-long water transportation route for 200,000,000 tons of goods/year
Drinking water for 70% of the region's population
45 billion gallons of water/day withdrawn by residents and industry
5500 acres of beaches
2.5 million acres of water usable for recreation
491,000 acres of shoals and wetlands important to wildlife

SOURCE: GAO

LEGEND

----- GREAT LAKES BASIN DRAINAGE BOUNDARIES

GREAT LAKES ENVIRONMENTAL RESEARCH LABORATORY (GLERL)

- GLERL, established by NOAA in 1974 in Ann Arbor, MI, conducts research on the physics, chemistry, and biology of the Great Lakes and their connecting channels to improve understanding of environmental processes, to develop more precise scientific information and prediction, and to assist in solving problems in lake resource management, water-related activities, and environmental services. It is a multidisciplinary Federal research laboratory with a productive track record. GLERL has close working relationships and cooperative research projects with both United States and Canadian agencies and universities.

- RESEARCH FOCUS
  - Water Quality - Toxic chemicals and nutrient overenrichment impacting water quality, including: drinking water, the $160 million commercial and $1 billion sport fisheries of the Great Lakes, and water-contact recreation.
  - Water use and Management - Lake hydrology, specifically lake and river ice forecasting, is of major importance to shipping. Also, lake level forecasting, of great concern to shoreline property owners, shipping, engineering and hydropower interests, addresses consumptive use issue.
  - Physical Limnology and Hazards - Natural hazards such as waves, storm surges, flooding, ice, and chemical spills.

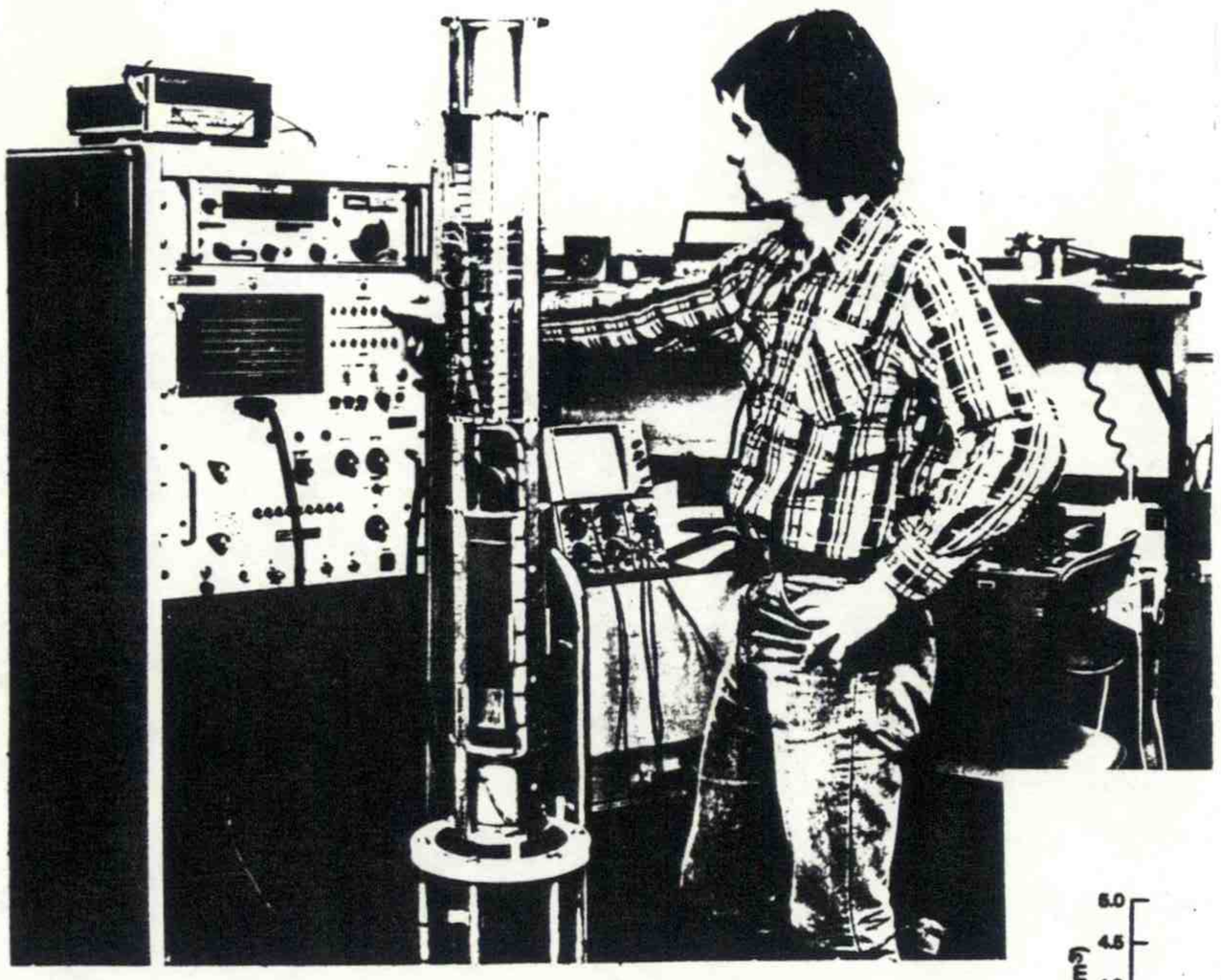
- FUNDING
  - FY 1985 budget is $3.8 million, 68 FTE employees.
  - Eliminated in Administration's budgets in FY '83, '84, '85, and '86; restored by Congress in FY '83, '84, and '85.
  - GLERL will close at end of FY '85 unless Congress restores FY '86 funding.

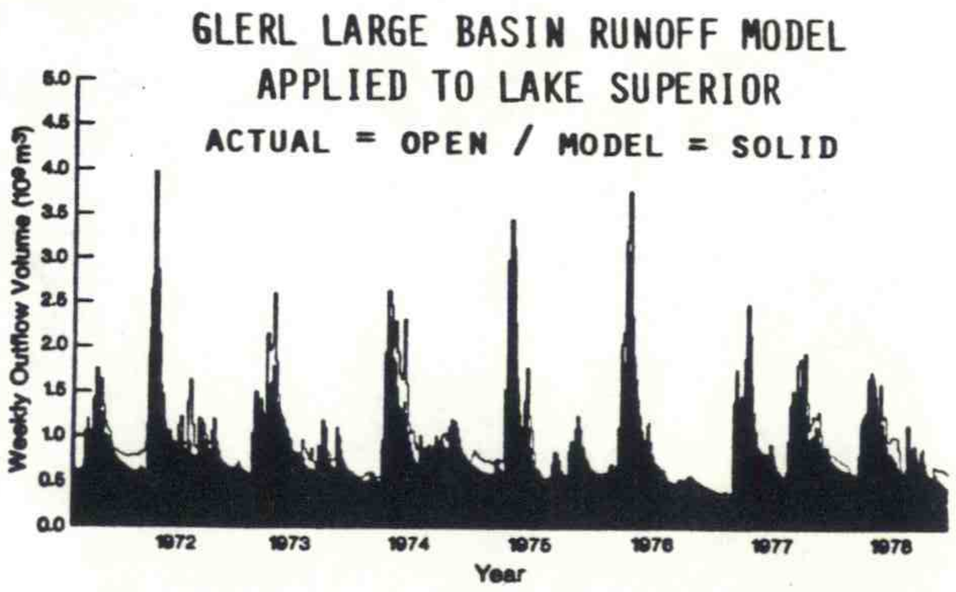
- USERS OF GLERL RESEARCH include NOAA, EPA, Fish and Wildlife Service, Corps of Engineers, Coast Guard, St. Lawrence Seaway Development Corporation, Great Lakes Commission, International Joint Commission, State agencies, local governments, industry, universities, and the general public.

- IMPORTANCE OF GLERL TO REGION AND TO CANADIAN-UNITED STATES RELATIONS
  - GLERL constitutes largest, by far, Federal research presence on the Great Lakes.
  - GLERL provides very active advisory service of economic and scientific information to private sector groups and individuals.
  - The eight Great Lakes State governments do not have the financial resources or management and coordination mechanisms to replace the GLERL research and advisory programs.
  - GLERL is the only remaining United States research entity on the Great Lakes with a Federal focus to complement the large Canadian Great Lakes research effort.
  - The Canadian Government has formally registered its concern through diplomatic notes in 1983 and 1984 that the Administration's proposed budget reductions affecting Great Lakes research, including the elimination of GLERL vitiates the 1978 Canada-United States Great Lakes Water Quality Agreement.
  - The 1000-mile international border that Lakes Superior, Huron, Erie, and Ontario constitute has historically been a prime concern of the International Joint Commission (IJC), formed to carry out the 1909 Boundary Waters Treaty. The IJC has responsibility for coordinating implementation of the 1978 Water Quality Agreement. The Water Quality Board and other boards of the IJC depend on GLERL as the remaining U.S. research presence in the region.

GLERL Activities

Experimental and Theoretical Research





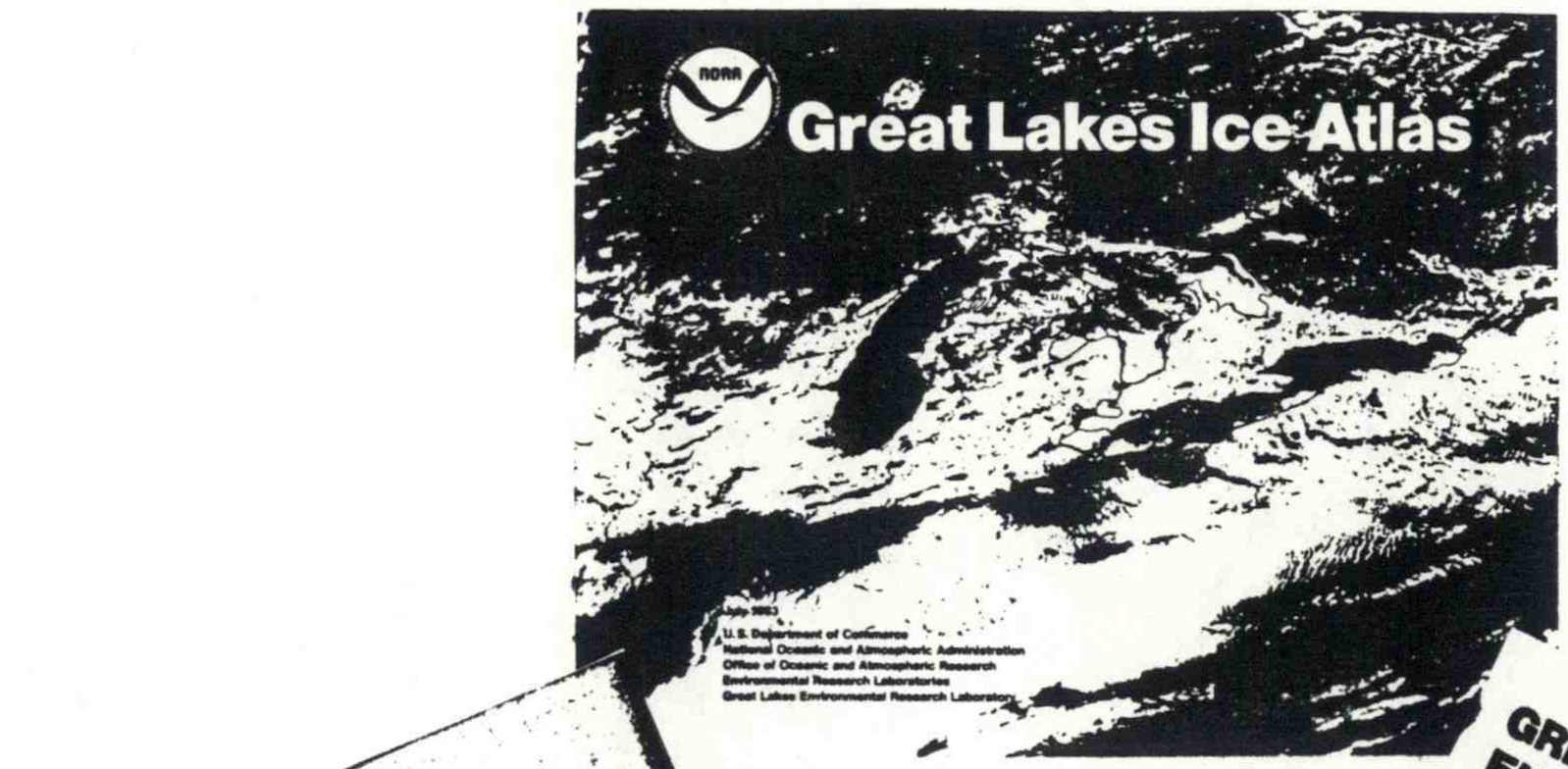
- Water Quality (Toxic Contaminants and Nutrient Overenrichment)
  - movement, behavior, and fate of contaminants
  - natural vs. anthropogenic pollutant inputs: nutrient overenrichment
  - particulate matter fluxes and early sediment diagenesis
  - effects of pollutants: ecosystem dynamics; bioaccumulation; and trophic transfer
  - food chain interactions and biological energy transformations
  - development of management strategies using optimization, risk assessment, and uncertainty analysis techniques

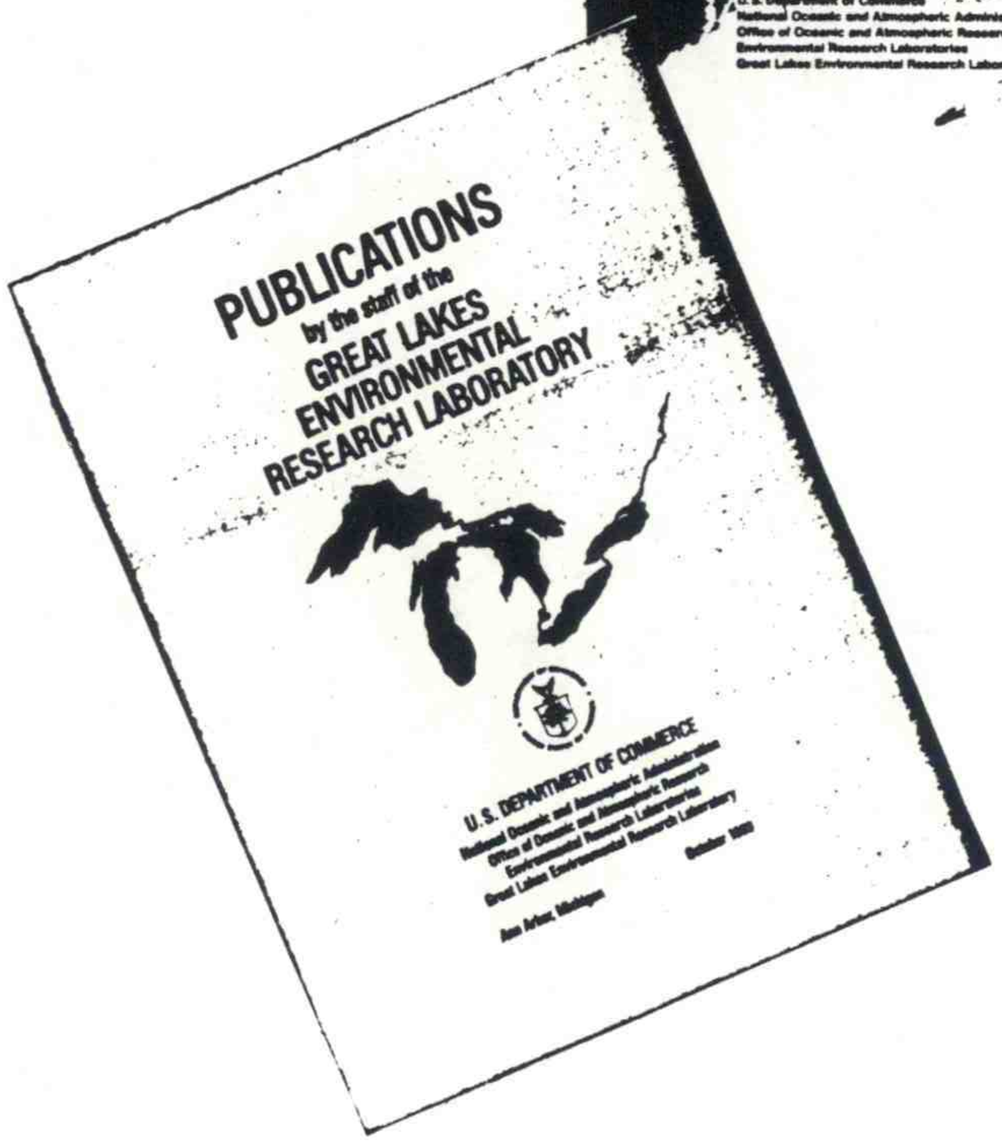
- Water Quantity
  - hydrologic cycle and river flow
  - lake and river levels - responses to natural and anthropogenic perturbations
  - impact of consumptive use vs. diversion

- Hazards
  - wind waves, basin runoff, and flooding
  - ice formation and movement
  - currents and sedimentation patterns
  - spill models: prediction of dispersion and transport

GLERL Activities

Advisory Services



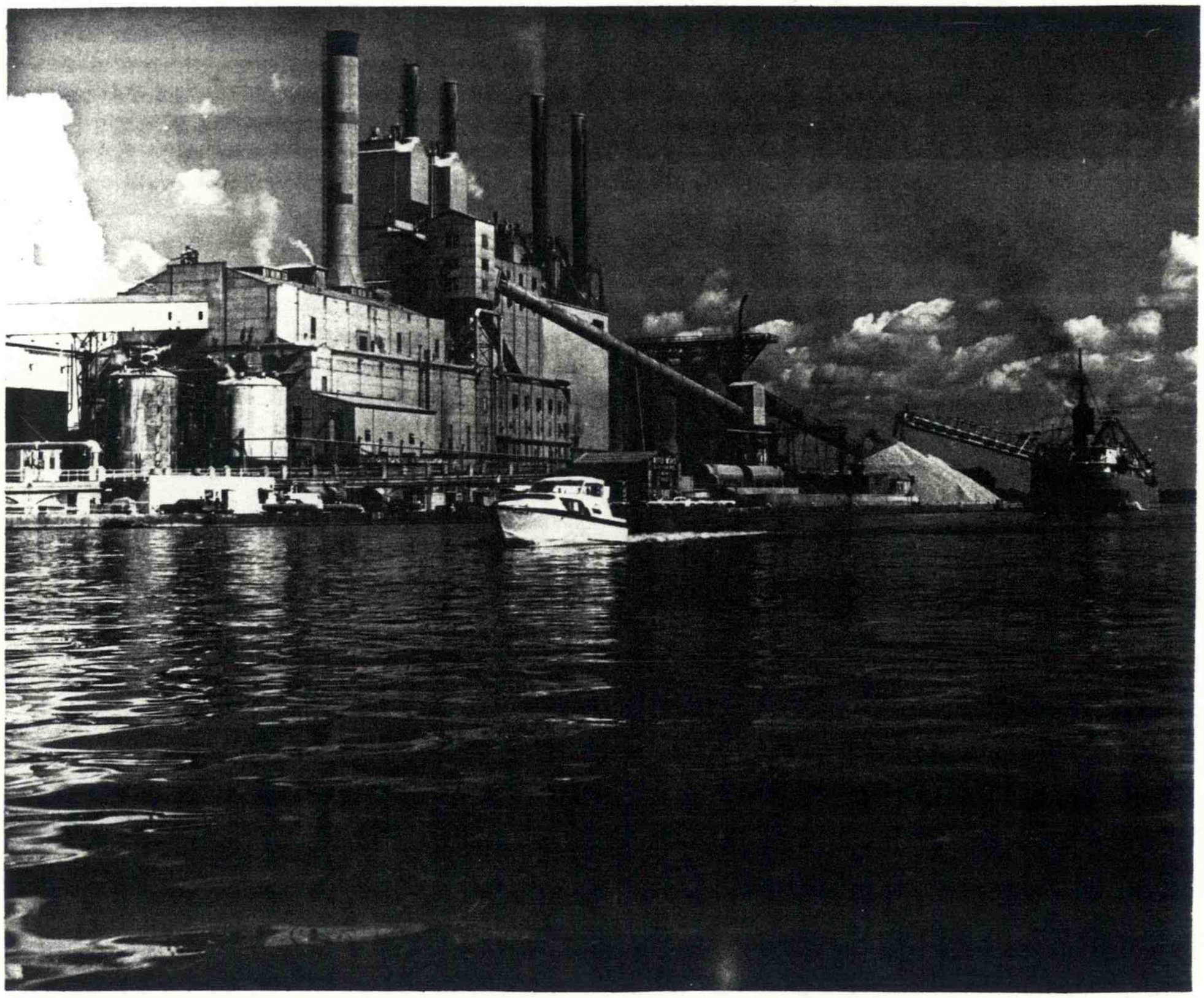


- Dissemination of Scientific and Technical Products and Information
  - FY '84: 4200 scientific, technical, and information products in response to 2000 specific requests

- Assist Resource Managers with Applications of GLERL Products

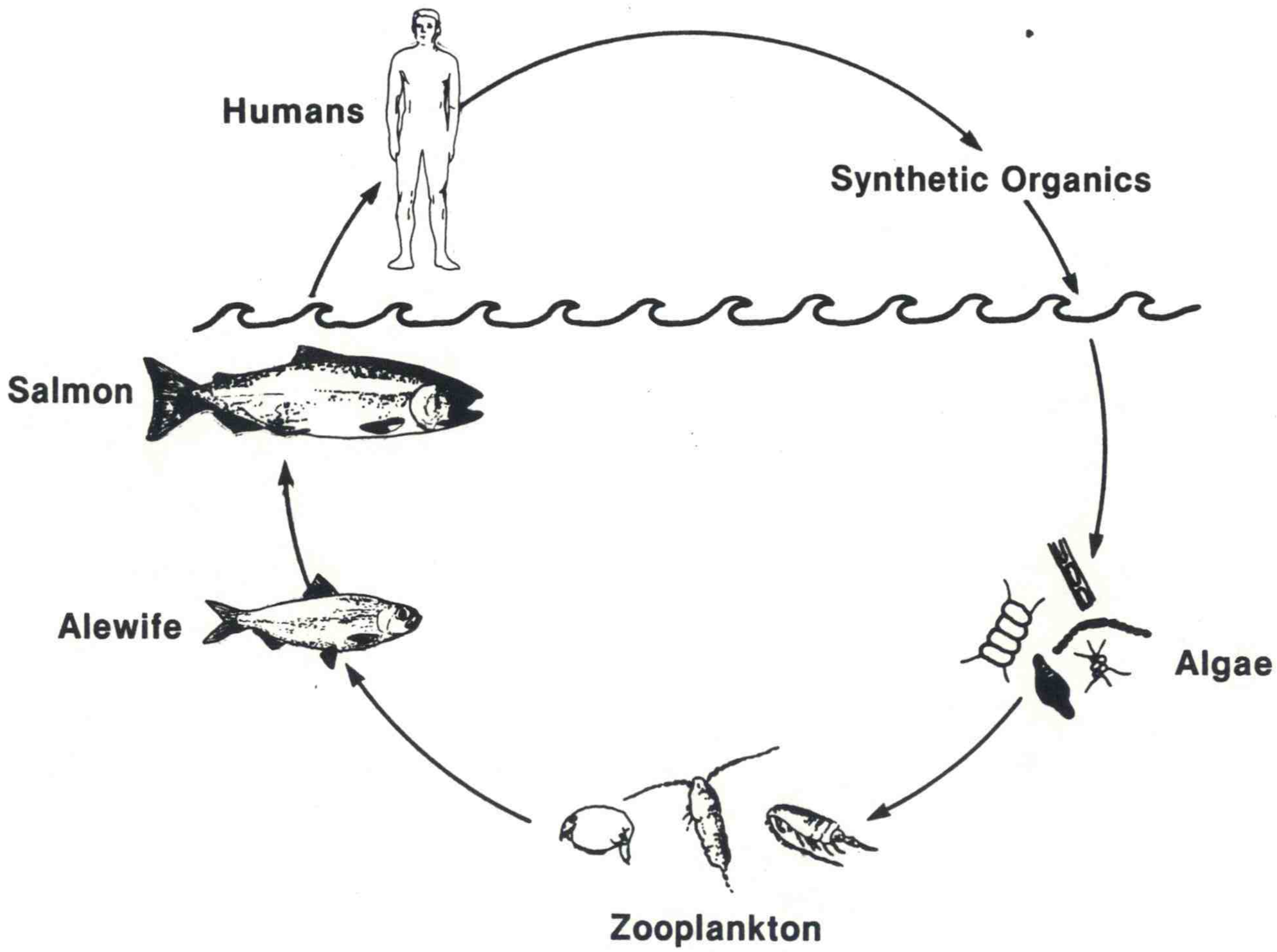
- GLERL Computer-Based Models
  - accessible to outside users by direct communications with GLERL computer
  - available for transfer to outside users for implementation on their computer

Waste Disposal



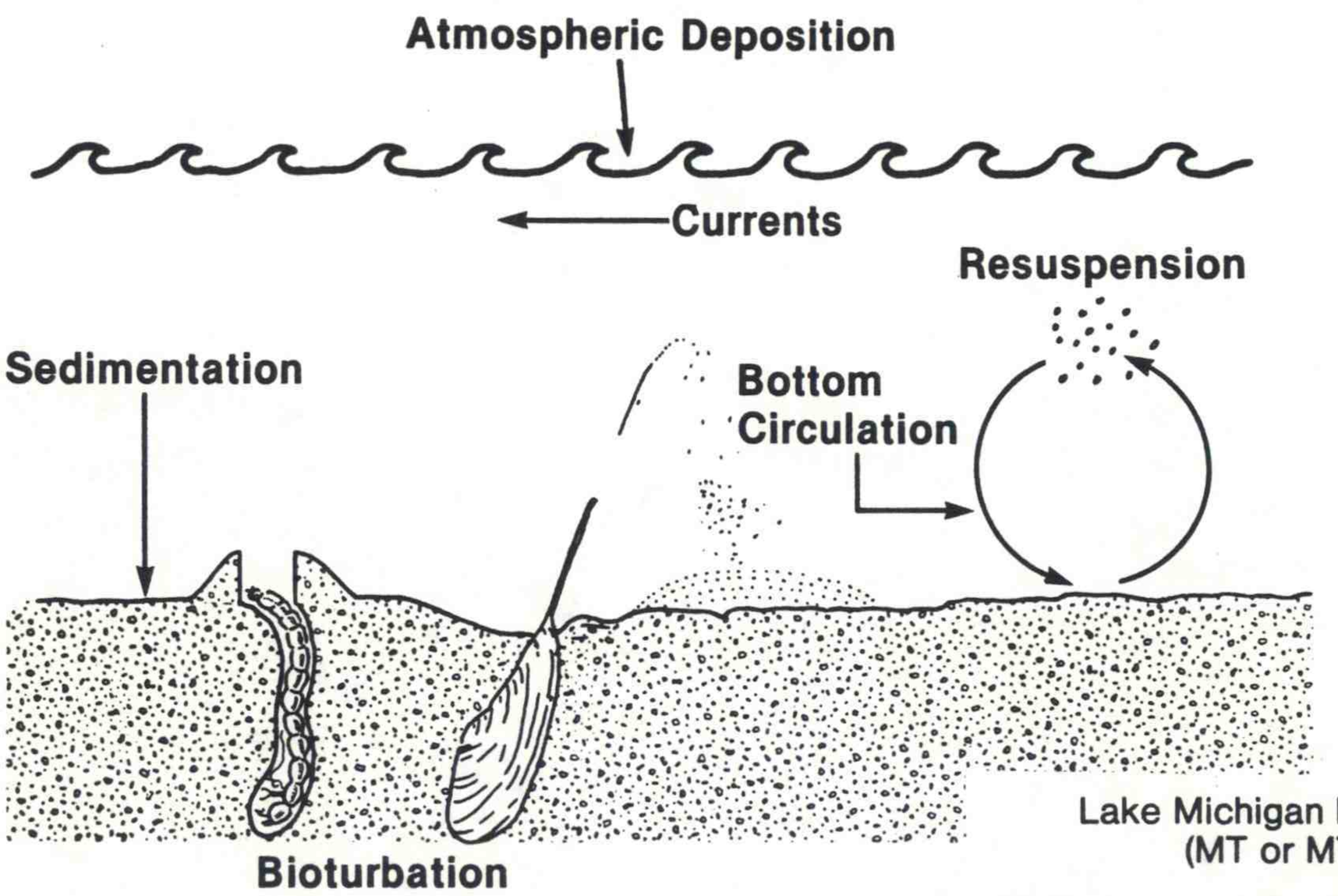
Power generation, industry, and waste disposal are among the users dependent on water supply and are thus found concentrated in coastal areas. Although dependent on water supply, these activities also may affect water quality by discharging pollutants such as toxic organics and excess nitrogen and phosphorous. Since the Great Lakes contain over 800 major municipal or industrial dischargers and receive over 20 billion gallons of waste per day, the potential for contamination of the Great Lakes is especially great. Water quality and sediment studies conducted by GLERL provide information required for the management of activities affecting the quality of the Great Lakes and other water resources of the U.S.

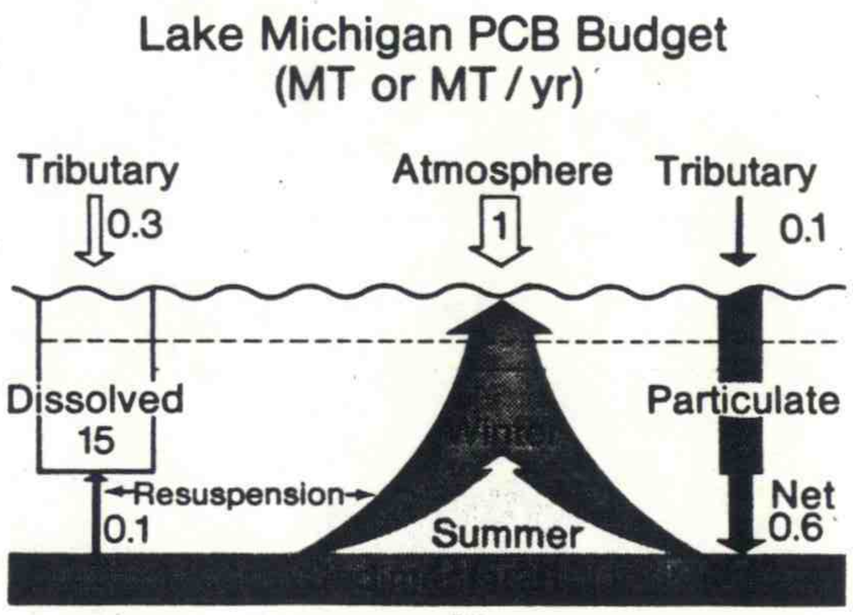
Toxic Trophics: The Vicious Circle



Over 30,000 chemicals are produced in the Great Lakes basin, and the use of toxic synthetic organic chemicals for pest and weed control increased substantially there during the 1970's. As of early 1985, over 900 of these chemicals have been found in the Great Lakes. Chemical contaminants such as PCB's are deposited in lakes and rivers, where they adhere to suspended particles such as biological debris. Ingestion of contaminant-laden particles by tiny aquatic organisms can then result in accumulation of the contaminant within these organisms and passage up the food chain to fish and humans. Research at GLERL includes identifying and modeling the sources, sinks, and pathways of synthetic organics within the aquatic environment and determining the degree of transfer up the food chain. This type of information is critical nationwide for the management of important commercial and recreational fisheries, as well as for public health considerations.

Fate and Recycling of Toxics
(PCB's, DDT, . . .)



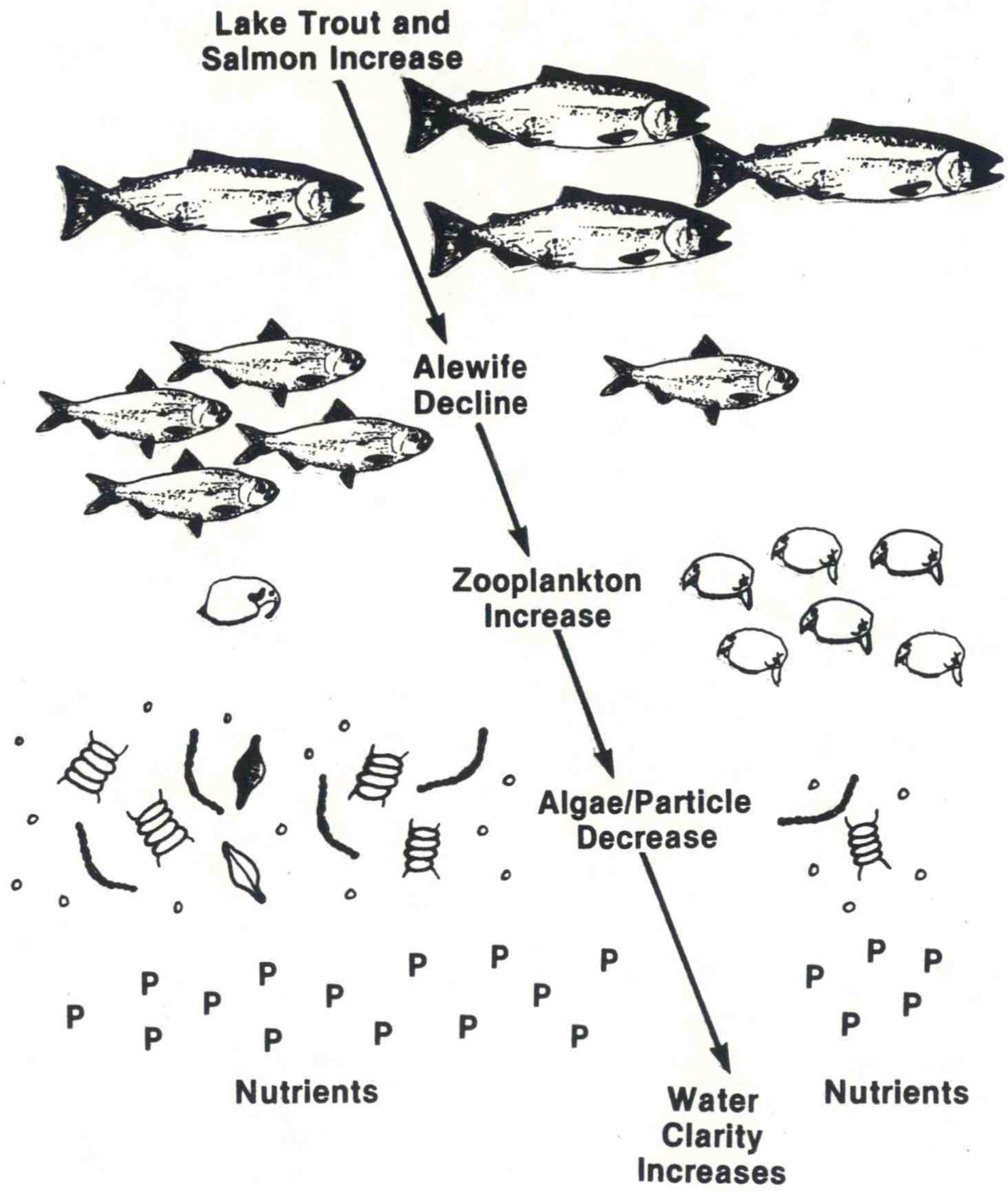


Since toxic chemicals may attach to particles which settle to the bottom, sedimentation might appear to cleanse aquatic systems of pollutants. However, bottom sediments may be only a temporary repository. Bottom currents redistribute or resuspend sediments, allowing more time for contaminants to re-enter the water column. Bottom-dwelling (benthic) organisms disaggregate the sediment while feeding and burrowing, making it more susceptible to resuspension. Some burrowing organisms even act like verticle conveyor belts and transfer deeper sediments to the surface. In this way pollutants may accumulate in the benthic organisms and re-enter the food chain. GLERL scientists are conducting experiments to measure and model such processes. For example, GLERL has developed models of PCB distribution in Lake Michigan and found that resuspension is a major source of PCB's to the water column in winter.

Water Quality

The Great Lakes support a $160 million/year commercial fishery as well as a $1 billion/year sport fishery. There are fifty commercial species of fish, such as lake trout, chub, alewife, and yellow perch, while recreational fisheries include primarily coho salmon, chinook salmon, and lake trout. The success and management of the fisheries in the Great Lakes and other aquatic systems is dependent on water quality information. The Great Lakes Environmental Research Laboratory studies the effects of water quality and other factors on living resources in order to predict the effects of man-induced changes on aquatic ecosystems.

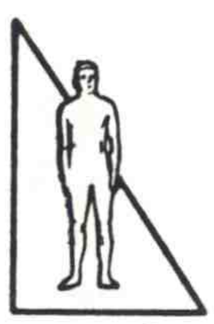
Water Quality and Ecosystem Management



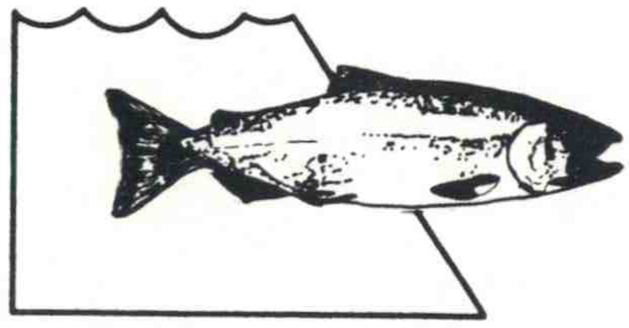
Nutrients such as phosphorus, silicon, and nitrogen are crucial to the growth of the tiny plants (phytoplankton) and animals (zooplankton) in aquatic ecosystems. These organisms form the base of the food web and thus represent the building blocks which support commercial and recreational fisheries. However, too much nutrients can affect water quality by causing excess growth of algae, which decreases water clarity. A common management approach is to improve water clarity by controlling nutrients in order to limit the growth of algae. Scientists at GLERL have suggested that there may also be a connection between water clarity and stocking the lakes with large fish for recreational fishing. By increasing the salmon and lake trout, the number of smaller fish such as alewives decreases due to predation by large fish. The decrease in smaller fish, which prey on zooplankton, permits the number of zooplankton to increase. Finally, since zooplankton then graze on algae and particles, there would be fewer algae and particles, and hence, clearer water. These results demonstrate the kind of critically important ecosystem studies and management information which GLERL provides.

Food Chain and Energy Studies

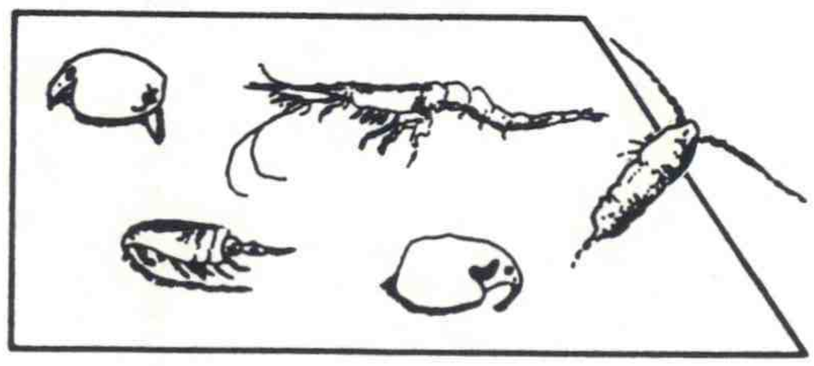
Classical Food Pyramid



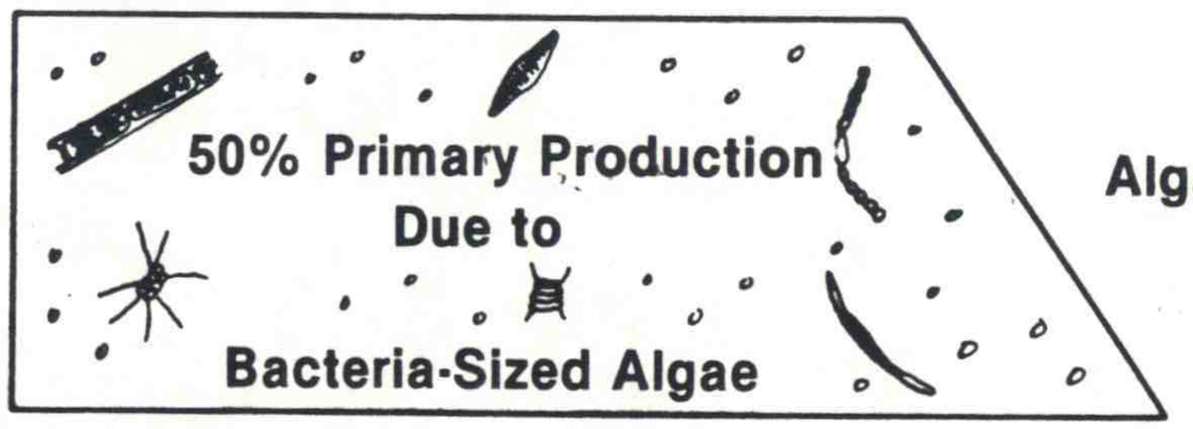
Man



Fish



Zooplankton



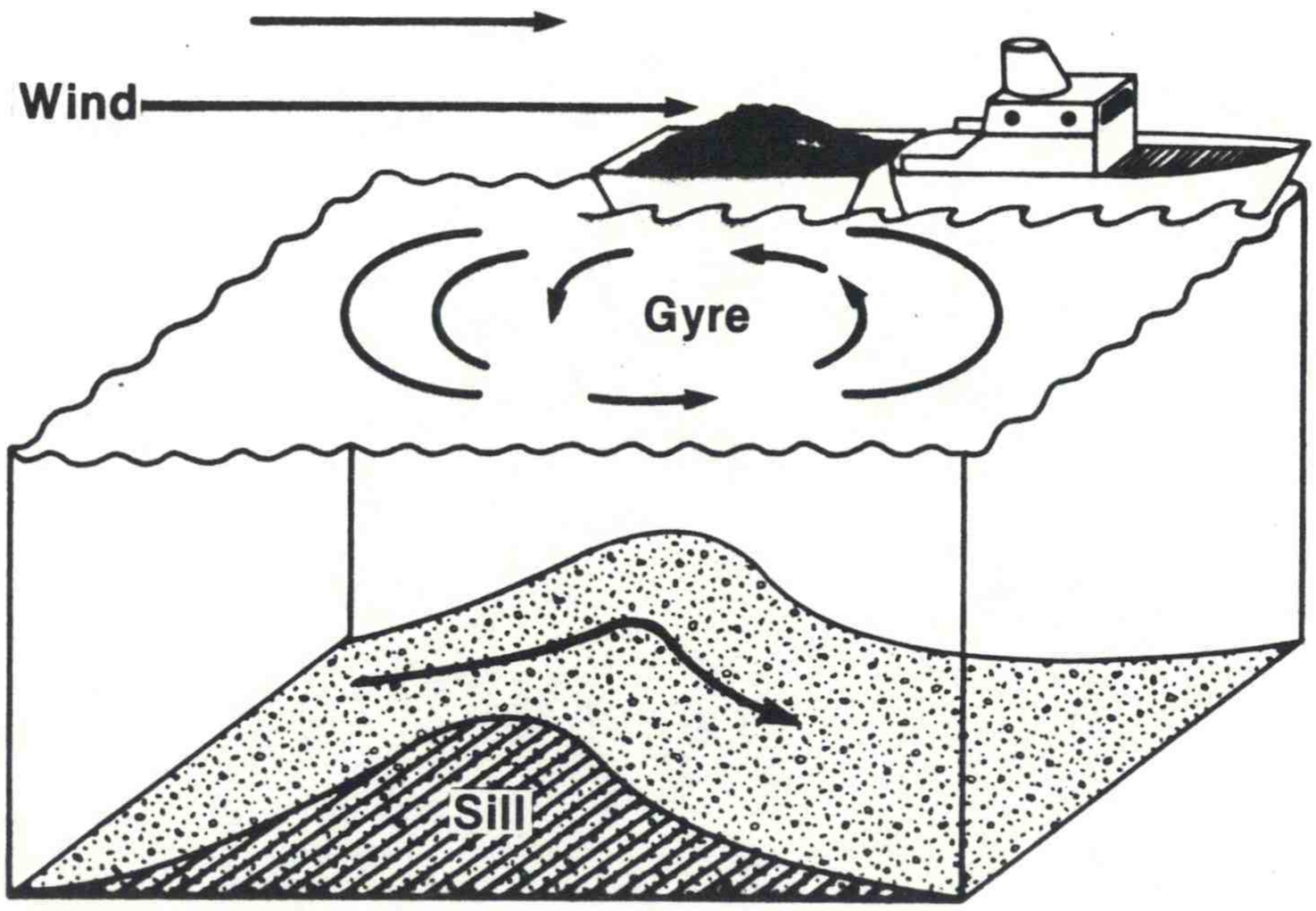
Algae

Bacteria-sized phytoplankton (cyanobacteria) were found to constitute a major, but previously unrecognized, component of the aquatic food chain. During a 1983 field experiment, GLERL scientists found that bacteria-sized phytoplankton were not only abundant, but were growing at a rate of two to four cell divisions per day and were responsible for approximately 50% of the total primary production in Lake Superior. In turn, these cyanobacteria appeared to be the primary food for very small zooplankton (microzooplankton). Studies such as this help fill gaps in our understanding of aquatic food web relationships and provide the basis for predicting fisheries productivity.

Hazards

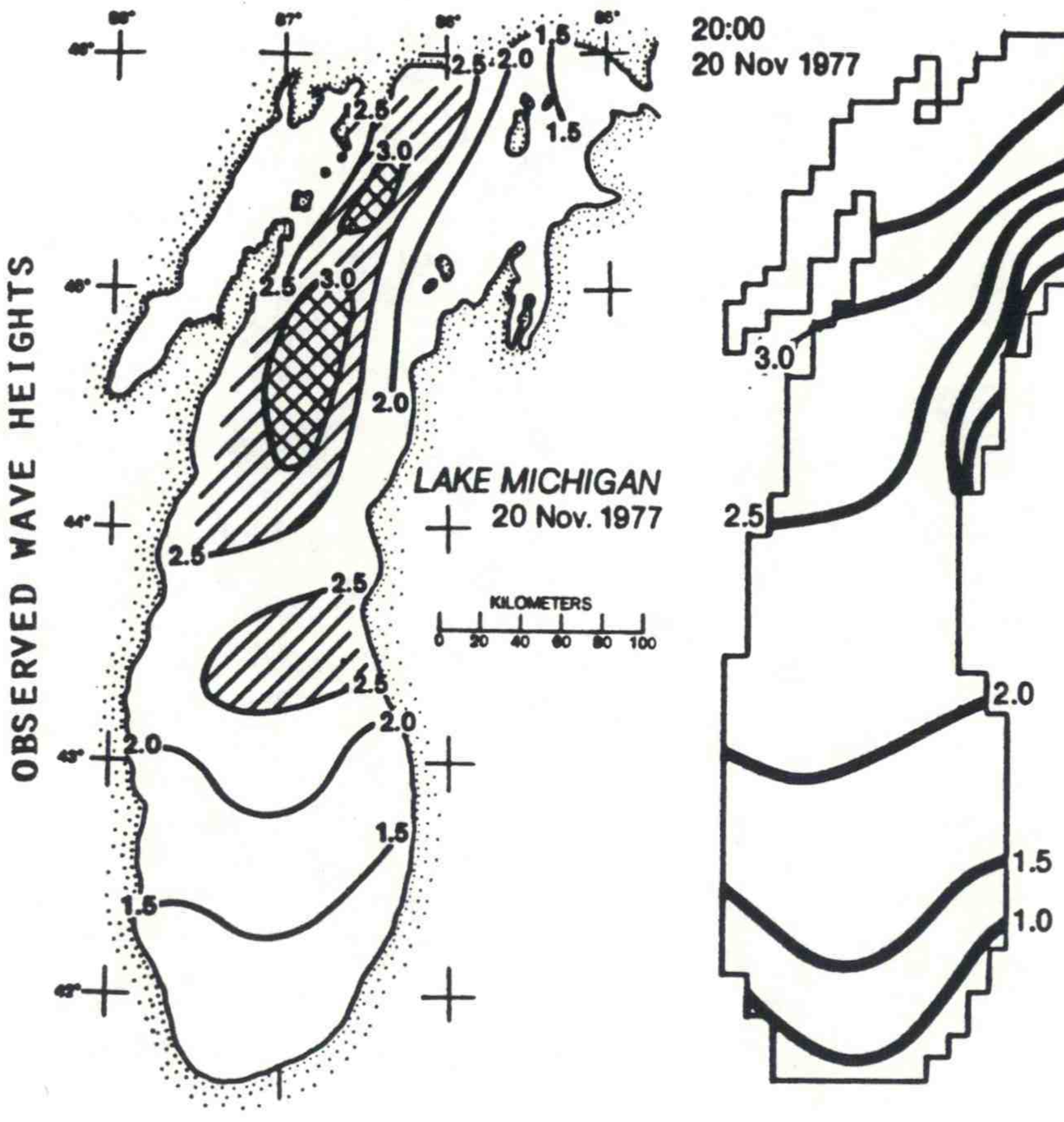
The Great Lakes are bordered by a heavily developed shoreline, including Chicago and Detroit. The Great Lakes basin also includes 15% of the U.S. population and 50% of the heavy industry. Communities and industry locate along the coast to take advantage of the water supply and navigable waterway. However, they are in turn susceptible to hazards, such as changes in the lake levels, the effects of winds and waves, and the effects of ice formation and movement. Navigation may be impeded by ice formation and sediment deposition, particularly in the narrow channels between the lakes. Research at GLERL investigates the physical variables which describe the lake environments. GLERL also develops models to provide improved capabilities for predicting lake characteristics important to coastal communities for waste disposal, power generation, fisheries management, water supply planning, navigation, and hazards mitigation.

Lake Circulation



In the Great Lakes, which receive over 40 million metric tons of new sediment per year from shoreline erosion, information on the fate of sediments is most important for planning dredging activity and navigation. Knowledge of physical phenomena such as water circulation, in turn, is necessary for predicting the transport of sediments and sediment-bound pollutants. Information on circulation is also needed for predicting oil spill dispersion and planning search and rescue operations, where accurate information on surface currents may make the difference between life and death. Improved models of lake circulations are being developed and tested at GLERL. For example, an oil-spill model for Lake Erie has been developed by GLERL and is available to outside users via telephone links to the GLERL computer system. This model is currently being used by the Coast Guard to predict spill trajectories and to aid in search and rescue activities.

Wave Modelling/Prediction



GLERL WIND WAVE MODEL

Recreational boating and fishing are major uses of inland lakes and waterways. In the Great Lakes, with over 5500 acres of beaches and over 2.5 million acres of water useable for recreation, tourism and recreation together represent a $1 billion per year industry. The safety of the public pursuing these activities is dependent on reliable weather forecasts, particularly of winds and waves. Wave activity is dependent on the complex interaction of wind speed, direction and duration, and friction between water and land. GLERL has developed a Wind-Wave Model to forecast wind-generated waves in the Great Lakes. As shown above, model predictions agreed quite well with actual wind and wave data obtained from Lake Michigan. It is already in use by the National Weather Service and has been used over 150 times this year by United States and Canadian weather forecasters, scientists, and university staff, who access it directly on the GLERL computer.

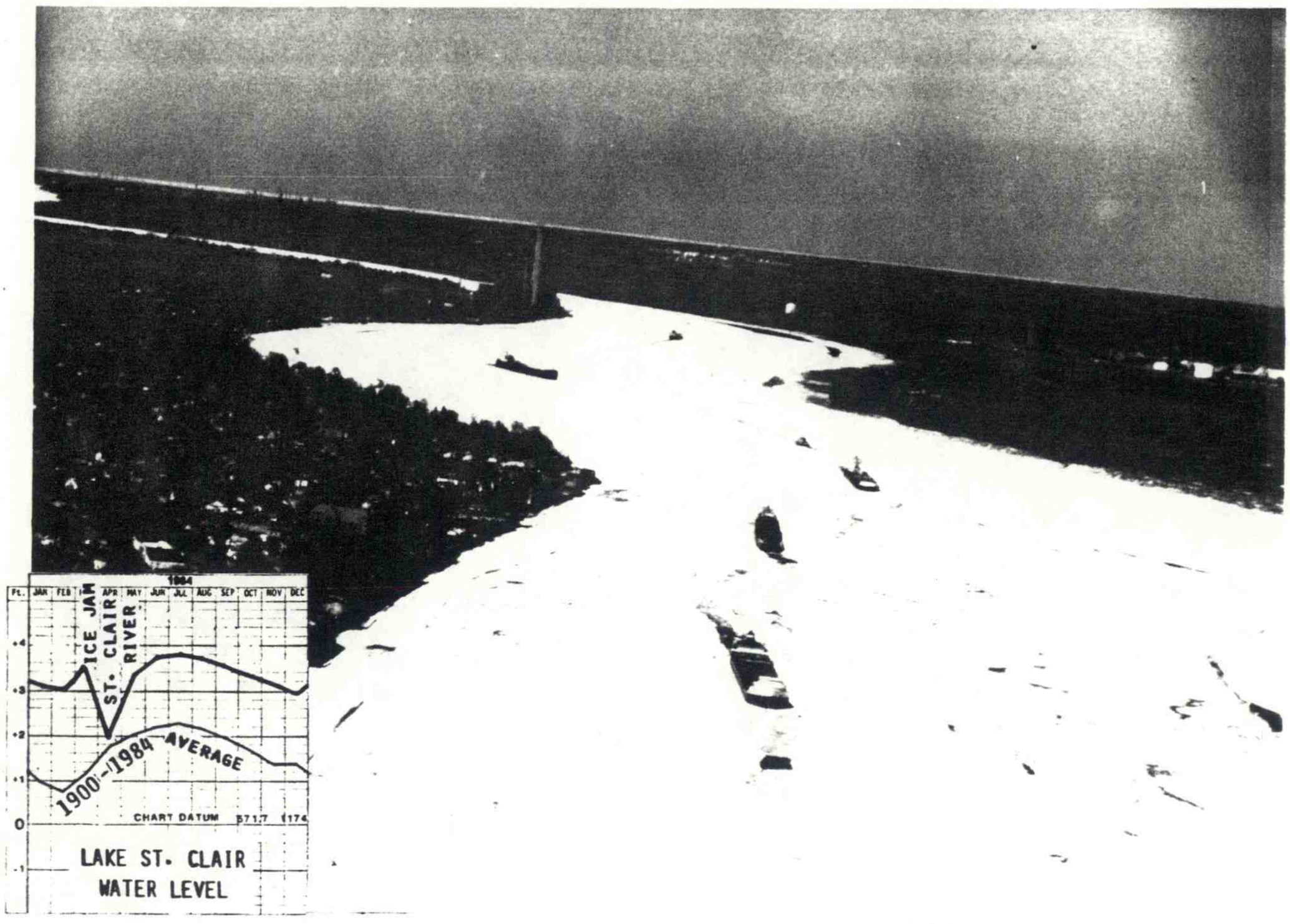
Lake Levels and Basin Runoff

Coastline structures may be damaged or destroyed by high lake levels, such as these tennis courts north of Chicago. Thus predictions of water supplies, lake levels and basin runoff are necessary for shoreline development as well as management of water resources, waste disposal, power generation, transportation and recreation. The Great Lakes region is particularly dependent on accurate water supply information, since the Great Lakes contain 95% of the nation's surface fresh water supply, and provide some 45 billion gallons of water per day for both municipal and industrial use. (In comparison, New York City's daily requirement is about 1.4 billion gallons per day.) The Large Basin Runoff Model, developed at GLERL, uses physical data to predict weekly to monthly basin runoff volumes. The rainfall and runoff data in turn are incorporated into the GLERL Hydrologic Response Model, which is used to calculate the water balance and flow for the entire Great Lakes system. These models may also be applied to other water basins and lakes, such as the Great Salt Lake, which during 1984-1985 reached a 100-year record high lake level, with an estimated economic loss already reaching some $500 million as of March 1985.

Ice Formation

The safety and efficiency of commercial shipping rely not only on accurate depth, wind and wave information, but also on forecasts of ice conditions. More accurate ice forecasting would allow better planning for the length of the shipping season, and potentially increased profits for industry. This is especially important for the Great Lakes, which provides a 1270-mile waterway for the transport of about 175 million tons of bulk commodities per year. In addition, knowledge of ice properties and conditions is valuable for the design and siting of coastal structures, shoreline erosion management, and power generation. GLERL conducts ice studies to provide improved information on ice formation, movement, extent, and break-up. For instance, the Ice Atlas produced by GLERL in 1984 shows seasonal changes in ice cover of the Great Lakes and is already a standard reference on the subject.

Connecting Channels



THE ST. CLAIR RIVER, WINTER 1984

Water supply in the Great Lakes is affected by ice formation, particularly in the narrow connecting channels between the lakes. GLERL's continued development of the Hydrologic Response Model for the Great Lakes includes improving the representation of the effects of winter conditions and ice cover on water supply. In 1984, a record ice jam on the St. Clair River blocked shipping and produced a severe drop in the water level in Lake St. Clair, due to the damming effect. The GLERL Hydrologic Response Model was used to predict the impact this ice jam might have on lake levels and flows. The Army Corps of Engineers also made significant use of GLERL Ice Forecasting Techniques for the St. Mary's River.

National Applicability

- The processes that determine water quality are similar in the oceans and in fresh water bodies. Thus, while management of toxic contamination and other water quality issues clearly vary from site to site, studies by GLERL on these processes may be applied to national water quality problems.

- The management of all fisheries resources relies on knowledge of both the natural and man-made factors which affect the food chain. Thus information provided by GLERL on the variables affecting Great Lakes organisms can help predict the effects of human activities on fisheries in other lakes and waterways.

- The increasing demand for fresh water continues to expand beyond state and even national borders. Models of water supply and lake level such as those developed by GLERL are considered for use on other lakes and drainage basins, such as the Great Salt Lake.

- GLERL conducts studies on physical hazards such as winds, waves, and ice conditions. Those hazards exist nationwide and GLERL results can be useful to other coastal developments that experience these conditions.

International

The Great Lakes are shared by both the United States and Canada, so that much of the data on the Great Lakes is used internationally. The activities at GLERL support international research planning and management programs. For instance:

- The International Joint Commission (IJC), a six-member commission of United States and Canadian representatives, was established in response to the 1909 Boundary Waters Treaty. GLERL staff are very active in a wide variety of IJC committees and boards, such as the Levels and Flows Advisory Board, the Surveillance Subcommittee, and the Task Force on Modeling.

- The implementation of the 1978 Water Quality Agreement between the United States and Canada is coordinated by the IJC. Under the 1978 Water Quality Agreement, research is to be oriented toward water quality research priorities identified by the Science Advisory Board. Research conducted at GLERL in the areas of toxic organics, nutrient and ecosystem dynamics, and water supply modeling provides support toward fulfillment of the Water Quality Agreement. GLERL also provides the principal U.S. research presence in the Great Lakes.

- Under the 1978 Water Quality Agreement, GLERL staff participate in a number of United States-Canadian cooperative studies. For instance, GLERL has recently become involved in the interagency and international study on water quality in the upper Great Lakes connecting channels. GLERL scientists also participate actively in the International Association for Great Lakes Research (IAGLR).

- The Great Lakes Charter was established among the United States states and Canadian provinces bordering the Great Lakes in response to concern about consumptive uses and diversions of water from the Great Lakes. GLERL would be expected to provide information on the effects of such activities on the Great Lakes.

Sediment Trap Design, Deployment, and Recovery Techniques.
Users: Coastal Studies Institute, Louisiana State University; University of Michigan; Argonne National Laboratory; National Water Research Institute; Inland Waters Directorate; and Canada Centre for Inland Waters

Dynamic Mixing Model for Sediment Tracer Distribution.
Users: Case Western Reserve University and Pacific Marine Environmental Laboratory, NOAA

Sedimentation Estimation Methods.
Users: University of Michigan, University of Indiana, University of Minnesota, Electric Power Research Institute, and Canada Centre for Inland Waters

Water Column Sediment Monitoring Procedures.
User: IJC

Large Basin Runoff Models.
Users: IJC, U.S. Army Corps of Engineers, and consulting engineers

Climatic Water Balance Models.
User: Atmospheric Environment Service-Canada

Water Supply Forecasting Procedure.
Users: U.S. Army Corps of Engineers and IJC

Low-Level Radiometric Measurements for Sedimentation Studies.
User: Pacific Marine Instrumentation Laboratories

Autoradiographic Measurements.
User: University of Michigan

Lipid Analysis in Small Samples.
User: University of Michigan

Lake Ontario Phytoplankton Model.
User: University of Minnesota

Nutrient Measurement.
Users: University of Michigan, U.S. Fish and Wildlife Service, and U.S. EPA

Improved Wind Direction Measuring Instruments for Shipboard Applications.
User: R.M. Young Co.

Wave Forecast Model.
Users: NWS, Canada Centre for Inland Waters, U.S. Army Corps of Engineers, and University of Michigan

Improved Hazardous Spill Model.
Users: U.S. Coast Guard, NWS, and University of Michigan

Commercial Fishing Zone Area Calculations.
User: NOAA Sea Grant