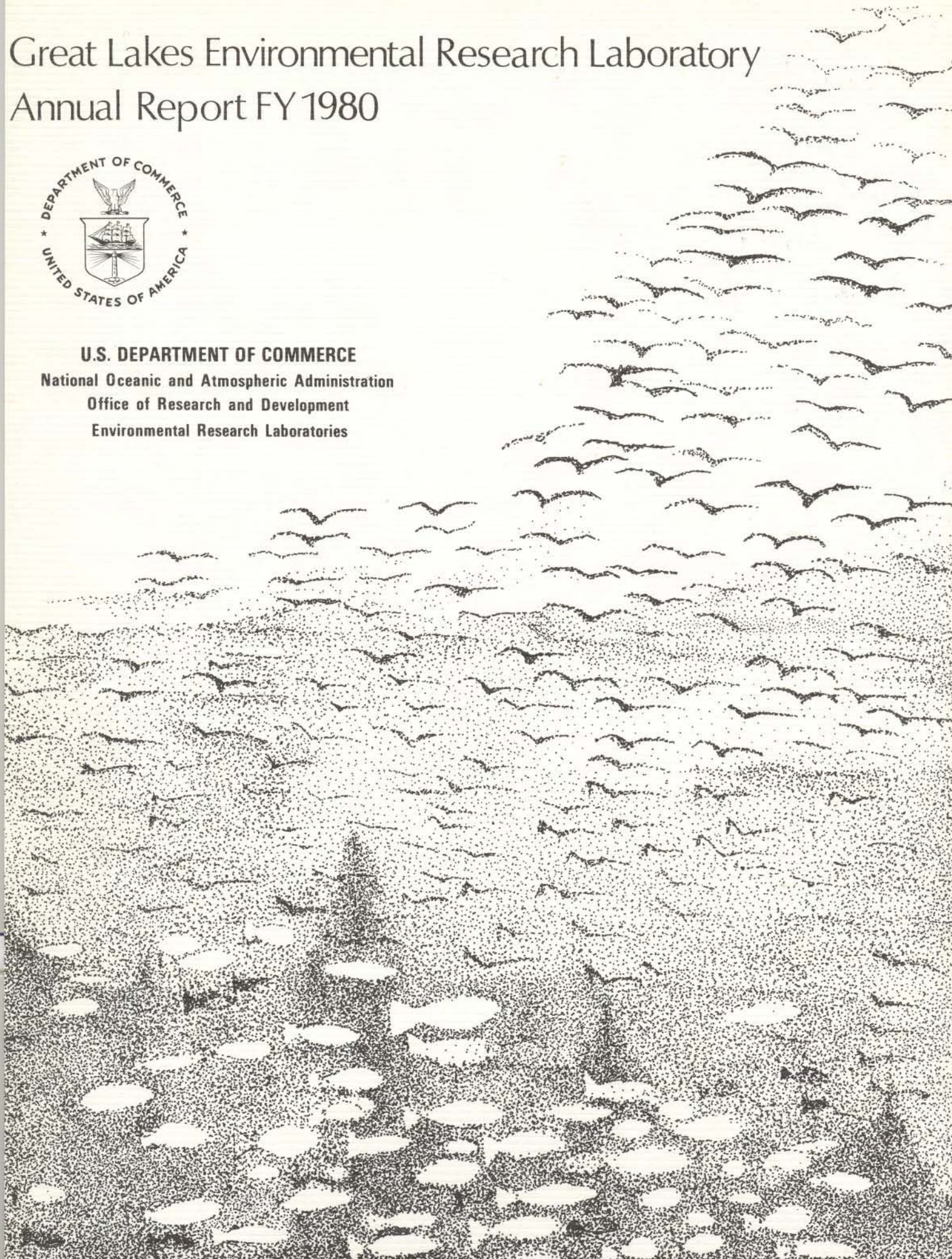
Great Lakes Environmental Research Laboratory Annual Report FY 1980

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



GREAT LAKES
ENVIRONMENTAL RESEARCH LABORATORY

ANNUAL REPORT FY 1980

December 1980

Eugene J. Aubert, Director

U.S. DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration
Office of Research and Development
Environmental Research Laboratories
Great Lakes Environmental Research Laboratory
2300 Washtenaw Avenue
Ann Arbor, Michigan 48104

NOTICE

The NOAA Environmental Research Laboratories do not approve, recommend, or endorse any proprietary product or proprietary material mentioned in this publication. No reference shall be made to the NOAA Environmental Research Laboratories, or to this publication furnished by the NOAA Environmental Research Laboratories, in any advertising or sales promotion which would indicate or imply that the NOAA Environmental Research Laboratories approve, recommend, or endorse any proprietary product or proprietary material mentioned herein, or which has as its purpose an intent to cause directly or indirectly the advertised product to be used or purchased because of this NOAA Environmental Research Laboratories publication.

PREFACE

The Great Lakes Environmental Research Laboratory (GLERL) has completed its sixth year of operation in Ann Arbor. Our mission at GLERL is to conduct research directed toward understanding the environmental processes and solving problems in resource management and environmental services in the Great Lakes and their watersheds. The environmental information developed is made available to NOAA, other government agencies, universities, industries, and individual citizens to aid them in their environmental services, plans, and operations.

Understanding the complex lake-land-atmosphere system of the Great Lakes Region and the many interactions that influence our lives in this region requires a team of scientists with different backgrounds working together on field, laboratory, and analytic investigations into the limnological, hydrological, and meteorological properties of the lakes, their basins, and the overlying atmosphere. The ultimate goal of the GLERL program is to understand the lake-land-atmosphere system to the extent that environmental simulation and prediction models can be built to provide sufficiently precise information on Great Lakes processes and phenomena to support enlightened use of the region's resources.

This *Annual Report* is intended to inform those outside GLERL of our capabilities, program, significant results, and plans for the future. It is also intended to encourage an exchange of information between the laboratory staff and those in need of environmental information for operational, planning, or management activities.

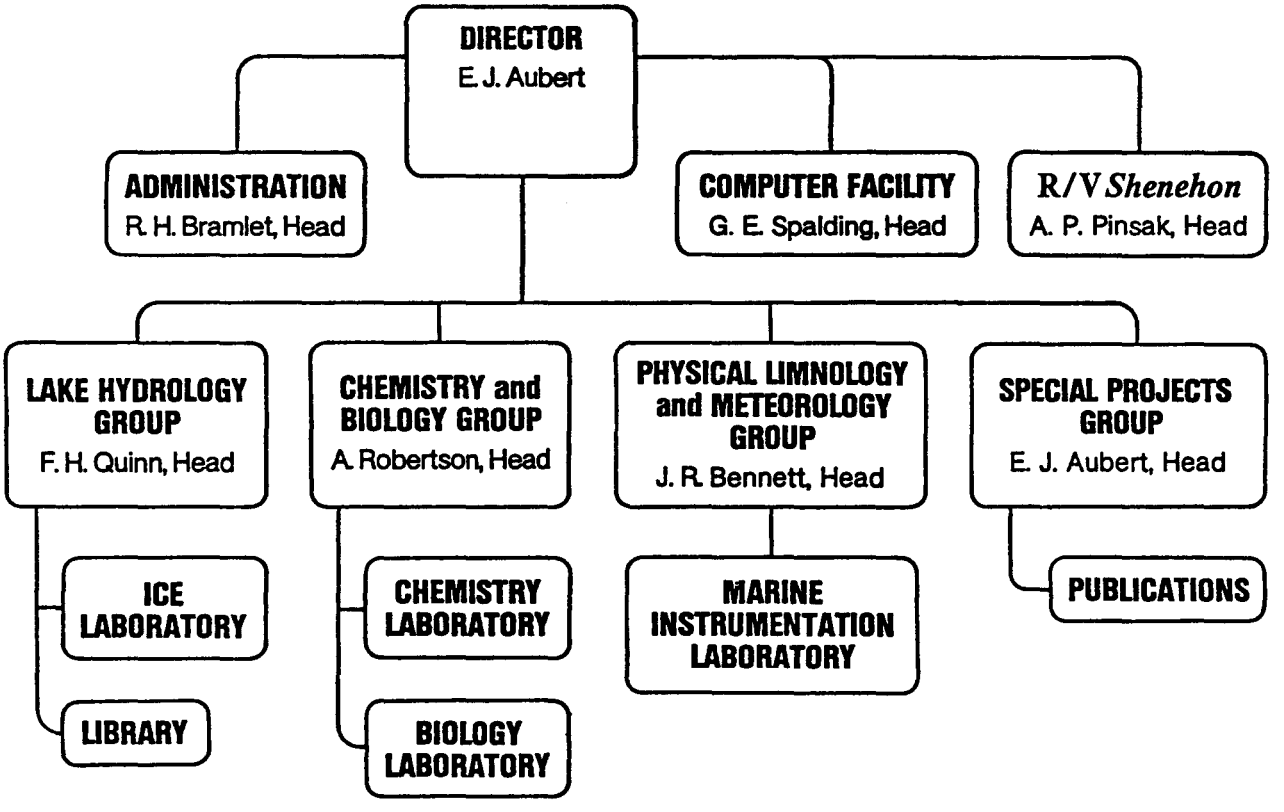
Examples of some of the major problem areas that the GLERL program addresses are lake water levels and connecting channel flow prediction—critical to erosion control, transportation, recreation, and power generation; lake ice prediction—critical to lake transportation and shoreline structure design and protection; lake circulation—critical to ecosystems analysis and an understanding of the transport and dispersion of pollutants; surface waves and oscillations—critical to lake transportation, boating, and the control of shore erosion and flooding; and the dynamics of certain chemical and biological properties and systems—critical to understanding and prediction of the natural ecosystem and human alterations in the ecosystem and to water quality, water supply, and fisheries management.

The GLERL staff has been and is working with Great Lakes regulatory and management agencies, in both Canada and the United States, to provide them with the research products, data, and expertise they need. GLERL staff serve as officers, board members, or committee members of such organizations as the International Joint Commission (IJC), the Great Lakes Basin Commission, and the International Association for Great Lakes Research, among others. These activities serve to provide an outlet for GLERL products and a means of identifying environmental problems requiring further study.

Other outlets for GLERL products include requests from private organizations and individual citizens. The scientific community is informed of the products through journal articles, NOAA Technical Reports and Memoranda, and presentations at society meetings. The location of GLERL in Ann Arbor with the University of Michigan provides the opportunity for cooperative research programs and for graduate student participation in GLERL projects. Visting scientists have participated in GLERL research studies on a continuing basis.

TABLE OF CONTENTS

GLERL ORGANIZATION CHART



HIGHLIGHTS

For 6 years the laboratory has been involved in research on significant processes and problems in the Great Lakes Region. GLERL research is diversified in form. As is shown by the organization chart, process research is aligned in four primary discipline areas. But problem-oriented multidisciplinary research, using staff from more than one group, is also conducted. The in-house research program is supplemented by grants and contracts with private institutions. In turn, GLERL supports the efforts of other government agencies. The dissemination of research results by publication or presentation and discussion at scientific and user meetings is a major GLERL product. During FY 1980, 56 papers authored by GLERL staff and 7 papers by contractors were published, and 36 papers prepared by GLERL staff were presented at meetings.

Research

The GLERL research program is in a continually evolving state amply evidenced by the year-to-year changes in all levels of scientific effort. Some research accomplishments during the past fiscal year are indicated below.

Further analysis of aquatic ecosystem models for Lake Ontario indicated that, during periods of little turbulence, depth variation of net production controls subsurface peaks in algal concentration and plankton sinking accentuates those peaks. Tests on a model of Saginaw Bay indicated that model coefficients contribute more to overall model output variance than initial conditions and nutrient loadings.

A team of scientists from GLERL, the University of Michigan, and the University of Wisconsin reviewed the state of knowledge and quantitative modeling of the phosphorus cycle. They concluded that most improvement of whole-system models and understanding of the phosphorus cycle will be obtained from combined experimental and modeling research of first-order processes.

Phytoplankton studies analyzed relationships between uptake kinetics of dissolved phosphorus and growth rates. Primary results on phytoplankton growth indicate that biological uptake of phosphorus is the primary mechanism involved and specific growth rates are closely coupled to the rate at which the dissolved phosphorus pool is being cycled. Zooplankton grazing studies investigated how copepods select seston of various sizes.

GLERL investigators initiated a program to deploy sediment traps at various locations and depths in Lake Michigan. The data gathered will make it possible to investigate the importance of contaminants related to particulate matter on a lakewide basis. Since pollutants tend to concentrate in bottom sediments, during a resuspension event the particulate matter plays a vital role in the solution chemistry of the lakes.

In cooperation with NOAA's Office of Marine Pollution Assessment (OMPA), a program was initiated to study the cycling, transport, and fate of toxic organic compounds. A systems analysis approach is being used. Starting with currently available models with simple first-order decay or steady-state approximations, the results of complementary process research experiments and other information entering the literature will be used to develop a series of improved models.

Analysis of long term lake level regional changes shows that Lake Erie's level has remained relatively constant with respect to the level of Lake Ontario and that the level of Lake Michigan-Huron has dropped slightly with respect to the level of Lake Erie since the late 1880's.

An improved method for computing lake-wide evaporation, using an aerodynamic procedure and taking atmospheric stability and ice cover into account, indicates high fall and winter and low spring and summer evaporation from Lake Superior.

Revision of the *Great Lakes Ice Atlas* continued, with over 1500 additional historic ice charts added to the existing computerized data base. Publication of the atlas is planned for 1982.

A study of the effect of the Niagara River ice boom on the Lake Erie ice cover at Buffalo, New York, showed no evidence that the operation of the ice boom has influenced the spring warm-up of Lake Erie and caused longer, colder winters in the area. The study was undertaken at the request of the International Niagara Board of Control.

The GLERL storm surge model, now in operational use by the National Weather Service for Lake Erie, was used to hindcast water level fluctuations at Buffalo. The storm surge model produces accurate forecasts and can provide timely warnings of dangerously high water levels if accurate wind forecasts are available.

The wave field on a track across Lake Michigan was recorded by airborne synthetic aperture radar in order to investigate the spatial variability of wind-generated waves. The recorded images showed a diverging wave field, with fairly uniform wavelength across the lake, except near the shores, and radar measurements agreed well with ground truth measurements at a tower on the eastern shore of the lake.

The oil spill model, developed last year, is being used operationally by both the National Weather Service and the U.S. Coast Guard. Applications include tracking oil and chemical spills, prediction of currents, and training-simulation exercises.

With the retrieval of current meters and water temperature recorders from Lake Erie, the data collection phase was completed for a study to examine the spatial and temporal variations of the basin-wide circulation. This study is one component of a multiagency, international survey directed by the IJC and supported by the U.S. Environmental Protection Agency to measure the physical, biological, and chemical properties of Lake Erie.

Boundary conditions from a model initially developed by NOAA's Techniques Development Laboratory were used to drive another model incorporating a dynamical method of predicting the details of winds around the lakes. The results were encouraging and the scheme is currently being tested against observed overlake winds.

Mathematical models developed at GLERL have been used in support of the Great Lakes Environmental Planning Study to appraise the effect of phosphorus availability in Great Lakes eutrophication management. The economic aspects of phosphorus control strategies are also being analyzed. A major conclusion of one such study was that, as objectives are approached, treatment costs grow exponentially.

Heightened levels of total phosphorus often occur in nearshore areas since most waste inputs to a lake are at its periphery. Since public use of water bodies is most intense in the coastal regions, modeling techniques to predict the effect of load reduction on nearshore water quality have been developed.

Since total phosphorus models are inadequate to characterize suspended sediments in coastal zone dynamics, GLERL scientists are designing and testing models that predict the transport and fate of various components of phosphorus. Such efforts have direct application in phosphorus management since most waste sources enter the Great Lakes in different soluble and particulate forms.

Advisory Services

During the past year, as part of GLERL's Advisory Service, over 1700 research products were provided in response to nearly 900 documented requests. Of these, 20 percent came from agencies in various levels of government and 80 percent from private individuals or groups outside government. This activity is in addition to regular mailings to a list of recipients who have indicated interest in a 6-month listing of one or more of the five types of GLERL publications. GLERL also supports the Great Lakes Sea Grant Colleges in their advisory service activities. There were eight Draft Environmental Impact Statements evaluated during the year.

International and Interagency Activities

GLERL staff members were active in several IJC boards and committees, including the Levels and Flows Advisory Board, International Great Lakes Technical Information Data Board, Aquatic Ecosystem Objectives Committee, International Great Lakes Diversions and Consumptive Use Reference Working Committee, and Phosphorus Management Strategies Task Force.

GLERL participated in the activities of the International Coordinating Committee on Great Lakes Hydraulic and Hydrologic Data, the Great Lakes Basin Hydromet Network Work Group, the Joint United States-Canadian Ice Information Working Group, the Coastal Zone Color Scanner Great Lakes Experiment Team, and the International Association for Great Lakes Research.

GLERL staff were also involved with activities of the Great Lakes Basin Commission as Alternate Department of Commerce Commissioners, and as members of the Great Lakes Basin Plan Committee, the Priorities Committee, the Coastal Zone Management Committee, the Standing Committee on Research and Development, the Long Range Planning Subcommittee, and the Great Lakes Environmental Planning Study.

Facilities

Engineers with the marine instrumentation laboratory, along with counterparts at the Marsh McBirney Corporation, solved a complex problem involving an isolated ground loop on a prototype electromagnetic current meter. In another project, the data transmission frequency for a wave measuring buoy was successfully modified. In a related effort, a solar-powered meteorological tower was equipped with an auxiliary wind generator for a study of Lake Erie waves.

The chemistry laboratory has included analysis for trace organics in components of the lake ecosystem. Polynuclear aromatic hydrocarbons are extracted from various ecological matrices by Soxhlet extraction and cleaned through chromatographic separation on Sephadex and silica. Separation and analysis are performed on a glass capillary gas chromatograph

and on a recently acquired liquid chromatograph equipped with ultraviolet and fluorescent detectors. An ultraviolet technique to separate and analyze organic and inorganic fractions of phosphorus containing dissolved material is under development, and initial results are promising.

During the latter portion of FY 80, the library implemented a computerized on-line system to expedite cataloging of dissertation and technical report literature. It offers the advantage of additional retrieval access points made practical only through automation.

The research vessel *Shenehon* succcessfully supported several water chemistry and biology experiments and buoy deployment-retrieval in Lakes Michigan and Erie.

STAFF AS OF SEPTEMBER 30, 1980

	Full Time Permanent	Temporary or Part Time
Office of Director	9	1
Chemistry and Biology Group	11	4
Lake Hydrology Group	9	1
Physical Limnology and Meteorology Group	13	2
Special Projects Group	3	3
Total	45	11

Assel, R. A.	LH	Lee, J. P.	OD
Aubert, E. J.	OD	Leshkevich, G. A.	LH
Bell, G. L.	CB	Liebig, J. R.	CB
Bennett, J. R.	PLM	Liu, P. C.	PLM
Bolsenga, S. J.	LH	Malczyk, J. M.	CB
Booker, H. L.	PLM	McCormick, M. J.	CB
Bramlet, R. H.	OD	Miller, G. S.	PLM
Burns, W. R.	SP	Morse, D. V.	SP
Carrick, B. J.	LH	Nalepa, T. F.	CB
Chambers, R. L.	CB	Noble, P. E.	OD
Chapra, S. C.	SP	Norton, D. C.	LH
Croley, T. E.	LH	Parker, R. K.	OD
Del Proposto, D. J.	OD	Peters, J. R.	PLM
Derecki, J. A.	LH	Pickett, R. L.	PLM
Dungan, J. E.	PLM	Pinsak, A. P.	SP
Eadie, B. J.	CB	Quigley, M. A.	CB
Field, L. P.	PLM	Quinn, F. H.	LH
Gardner, W. S.	CB	Robbins, J. A.	PLM
Grasso, J. O.	CB	Robertson, A.	CB
Gimes, J. E.	SP	Saylor, J. H.	PLM
Grumblatt, J. L.	PLM	Scavia, D.	CB
Hass, S. E.	OD	Schwab, D. J.	PLM
Herche, L. R.	OD	Slavens, D. R.	CB
Huang, J. C. K.	PLM	Soo, H. K.	PLM
Kelley, J. M.	SP	Spalding, G. E.	OD
Kelley, R. N.	LH	Tarapchak, S. J.	CB
Kistler, R. D.	PLM	Vanderploeg, H. A.	CB
Lawton, B. J.	LH	Willis, P. D.	OD

LH—Lake Hydrology Group
OD—Office of the Director
CB—Chemistry and Biology Group
PLM—Physical Limnology and Meteorology Group
SP—Special Projects Group

CHEMISTRY AND BIOLOGY

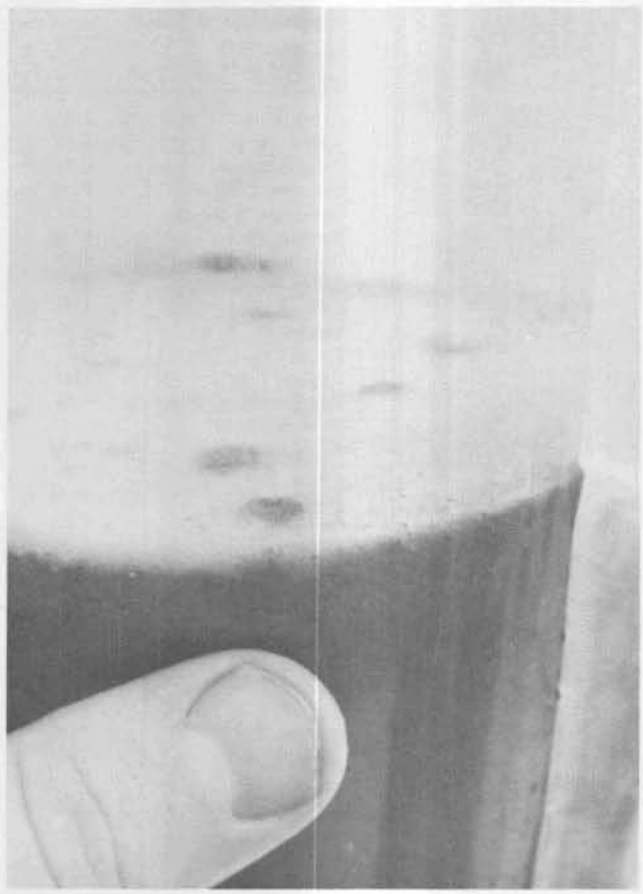
The work in chemistry and aquatic biology is concentrated in five principal task areas: dynamics of material movement in the nearshore zone, aquatic ecosystem models, planktonic succession, toxic organic cycling, and eutrophication and nutrient cycling. The program is aimed at understanding the existing lake conditions, recognizing the trends that have occurred, and developing the capability to predict the course of events given alternative approaches to the management of the lakes. In this respect, the program will provide information pertinent to a large number of problem areas relative to the use, protection, and conservation of the Great Lakes.

This information is of immense value to water resource managers in the Great Lakes Basin as they make decisions affecting water quality, power generation, commercial fisheries, and recreational uses of the lakes. Numerical models of the ecosystem can be used to forecast future conditions, to predict the results of implementation of various possible strategies, and to better understand the dynamics of lake biological and chemical phenomena. The variety and distribution of plankton types affect water supply taste and odor and play an important role in the entire ecosystem since plankters are a vital part of the lake food web. Water chemistry studies, by describing the constituents of the water at various sites and changes with time and with variations in temperature, currents, and loading, are particularly important to water quality determinations. The current emphasis is on understanding the cycling of nutrients and toxic organic compounds within the ecosystem.

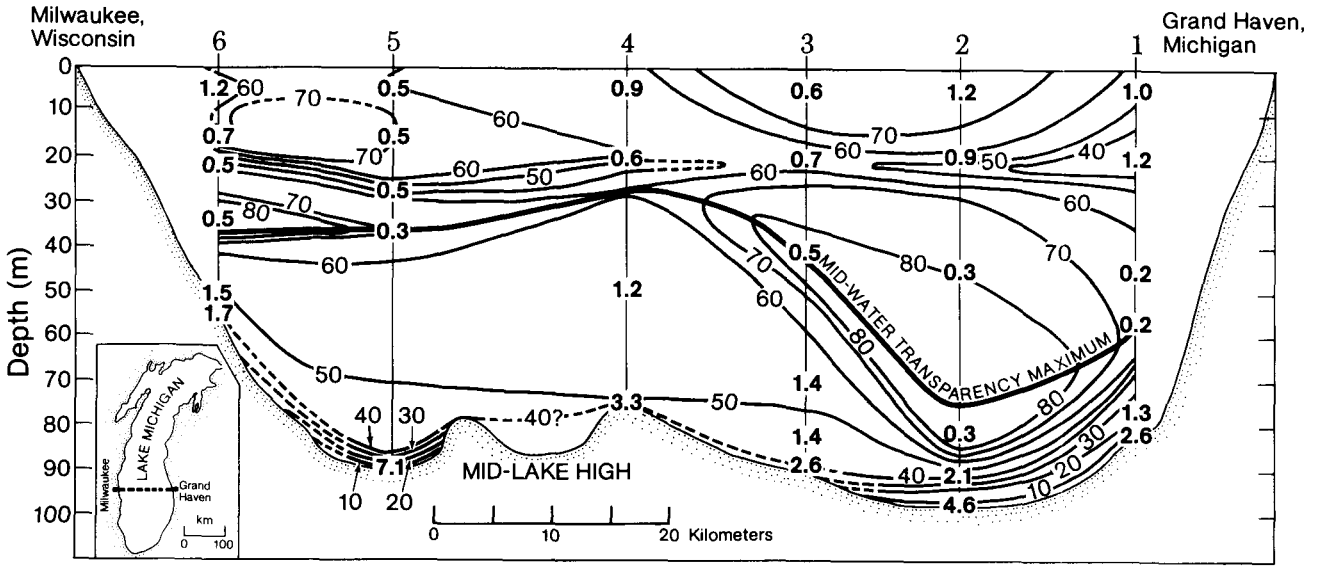
Dynamics of Material Movement in the Nearshore Zone

Pollutants tend to concentrate in the bottom sediments, where they eventually become buried. Particulate matter not only provides a direct mechanism for removing polluting substances from the water column, but also, during a resuspension event or some other mixing process, can actually serve as a major source. Thus, particulate matter plays a vital role in the solution chemistry of the lakes. Resuspension of the fine particles at the bottom of the lakes produces dense cloud layers called nepheloid layers.

In 1977 GLERL initiated a project to study the movement of contaminants from the nearshore zone into the lake. Early in the project, a nepheloid layer was discovered that appears to play a significant role in the cycling and transport of hydrophobic contaminants. During the past year the nepheloid layer was found across the basin. When this layer grows large,as it frequently does, significant quantities of toxic substances are injected back into the water column. The resuspension process is episodic in nature, becoming most vigorous during autumn and spring storm events. The strong winds and currents produced in a lake during storms result in deep mixing when large quantities of sediments from the shelf and slope are stirred up and mixed through the entire water column; this re-exposes the lake to the pollutants time and time again. These recurring events make it difficult to predict how long it may take toxic organics, trace metals, or phosphorus to be buried and sealed in the bottom sediments permanently and thus unavailable to the ecosystem.



Reworking of Lake Michigan sediments by oligochaete worms. A thin layer of foreign white sand has been spread over an intact sediment core (dark in photos). Within 48 hours, resident worms entered the white sand layer and began to deposit fecal material at its surface (dark mound at surface).



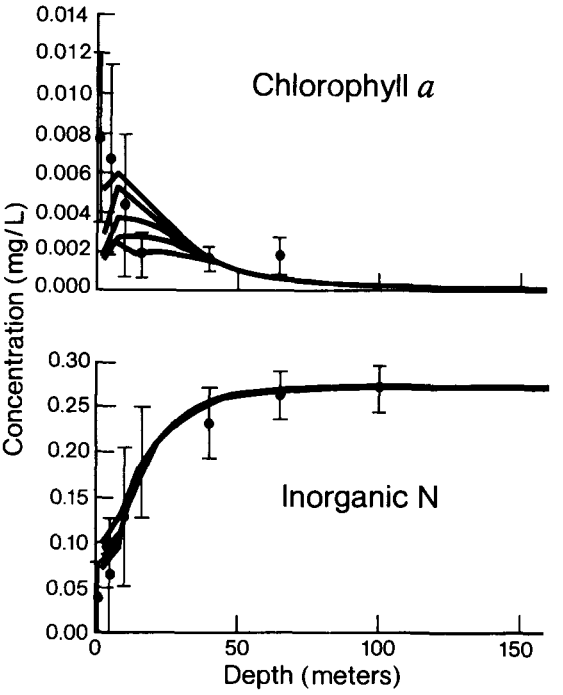
East-west cross section from Grand Haven, Michigan, to Milwaukee, Wisconsin, illustrating the vertical distribution of water transparency (percent) during August 21-22, 1979. Total suspended matter values (milligrams per liter) are superimposed along the station profiles.

In order to estimate the values of contaminants on a lakewide basis, GLERL investigators have initiated a program involving deployment of 111 sediment traps at 12 locations in Lake Michigan during mid-June, 1980, and their retrieval in late October, 1980. Station depths range from 50 to 250 meters. Preservatives in the collecting containers are chloroform (for nutrients, silica, major and minor elements, and inorganic carbon) and mercuric chloride (for toxic organics). After completion of field data collection, it is expected that analysis of the data, along with the results of some supporting programs, will yield loading and mass flux estimates far superior to the limited information now available.

Aquatic Ecosystem Models

This past year the aquatic ecosystem modeling emphasis was twofold. Use of an ecological model of Lake Ontario for analysis of interactions among biological, chemical, and physical processes was continued, and an analysis of uncertainty in an operational eutrophication model of Saginaw Bay, Lake Huron, was completed.

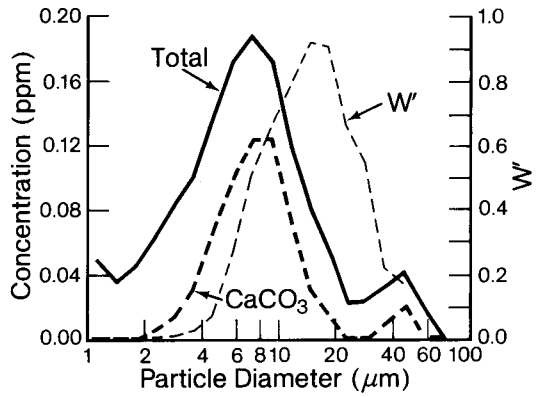
After comparisons of simulated and measured vertical profiles of biological and chemical properties in Lake Ontario indicated that the model is a good representation of the vertical structure in the lake, relative controls of that structure were analyzed. That analysis demonstrated that low turbulence in the upper strata of the water column is necessary for establishing a subsurface peak in algal concentration; however, low turbulence alone is not sufficient.



Early summer vertical profiles of algae (chlorophyll a) and nutrients (nitrogen compounds—NO_3 and NO_2). The continuous profiles represent model output at 6-day intervals and the crossed vertical lines represent lake-wide averaged International Field Year for the Great Lakes data ± 1 standard deviation.

Depth variation of net biological production in the presence of low turbulence causes peaks. Plankton sinking in the presence of low turbulence (even if net biological production is constant with depth) causes subsurface peaks. Overall implications are that, in the presence of low turbulence, depth variation of net production controls subsurface peaks; plankton sinking accentuates those profiles.

A task that began last year and ended this year involved testing the sensitivity of prediction error in eutrophication models to errors in initial state variables, model coefficients, and nutrient loadings. Of the three sources of error, model coefficients contribute the most to overall model output variance. Comparisons of model output variance to that of Saginaw Bay measurements indicate that, although model errors are large, they are comparable to measurement variances caused by spatial gradients.



Contribution of calcium carbonate ($CaCO_3$) to the total particle size spectrum and the filtering efficiency curve (W') for *Diaptomus sicilis* on September 6, 1978. W' is the conditional probability that a particle of a given size will be ingested if encountered.

Plankton Succession

Phytoplankton studies in 1980 have focused on evaluating relationships between the uptake kinetics of dissolved phosphorus and phytoplankton growth rates, as well as on carbon-14 autoradiographic analysis of species-specific assimilation rates of carbon by phytoplankton in Lake Michigan. Analysis of kinetic data has revealed the following: 1) biologic uptake, not abiotic fixation, of phosphorus is the primary mechanism of uptake, 2) specific growth rates of phytoplankton are closely coupled with the rate at which the dissolved phosphorus pool is being cycled, and 3) net plankton are more efficient than nannoplankton in assimilating dissolved phosphorus. The latter observation implicates nutrient factors in addition to zooplankton grazing as an important environmental determinant in regulating nannoplankton abundance. Analysis of autoradiographic preparations reveals that fluctuation in cell numbers do not reflect the rates at which phytoplankton are growing in lakes and that high photosynthetic rates of algae are associated with favorable surface to volume ratios.

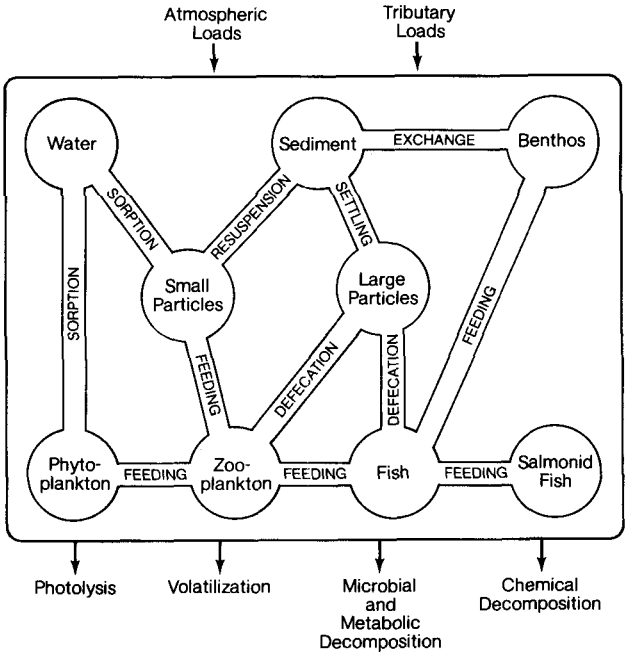
Zooplankton grazing studies have focused on the process by which copepods of the genus *Diaptomus*, the most important group of herbivores in the Great Lakes, select seston (phytoplankton and other particulate material) of different sizes. It was recently discovered that calcite whitings in Lake Michigan have a potentially negative effect on zooplankton feeding. GLERL scientists, using methods developed at GLERL, measured the particle-size spectrum of calcite and of total seston. The calcite crystals were found to represent a significant proportion of the total particle-size spectrum. Furthermore, the particle-size spectrum of calcite falls within the size range of particles selected by *Diaptomus*. Feeding studies have confirmed that *Diaptomus* ingests great quantities of calcite crystals. As a result, food intake and survival should decrease during calcite whitings. It was hypothesized that whitings lead to a shift in the zooplankton community to species that prey on particles either smaller or larger than the calcite crystals. Laboratory studies on the feeding of *Diaptomus* are continuing. These studies were designated to develop a feeding model that predicts amounts of different kinds of food *Diaptomus* will eat under varying conditions of food supply.

The freshwater shrimp *Mysis relicta* is an important predator of zooplankton, and *Mysis*, in turn, is an important food for Great Lakes' fishes. Previous studies of *Mysis* predation have been limited to a few feeding experiments performed under artificial conditions in the laboratory. To evaluate and quantify the significance of *Mysis* predation on zooplankton, GLERL developed special field equipment and methods to examine their feeding *in situ*. During 1979 *in situ* feeding experiments were performed in Lake Michigan from spring through fall under varying conditions of species composition and abundance of zooplankton. Results indicate that, the *in situ* studies gave predation rates that were 10 to 50 percent higher than those observed under the more artificial conditions of previous laboratory studies. Like the laboratory studies, the *in situ* study showed that *Mysis* prefers copepod nauplii and Cladocera above all other prey. Moreover, the study showed that the Cladocera largely escape predation by vertically migrating into warm surface waters, where *Mysis* will not enter.

Toxic Organic Cycling

GLERL, with the support of NOAA's OMPA has initiated a program on the cycling, transport, and fate of toxic organic compounds in the Great Lakes. The objective is to determine where selected contaminants are within the ecosystem, what their expected residence time in any location or phase will be, how rapidly and into what they will decompose, and where they will finally reside under conditions of long term, low-level leakage into the environment or a major loading from some point source.

GLERL scientists will use a systems analysis approach to develop a series of models. The intent is to adapt currently available models, which are primarily first-order decay approximations or steady-state simulations, as well as to develop a time-dependent ecosystem cycling model. The models will be continually upgraded through analysis of the results of process research experiments, done both in-house and under contract, along with other information entering the literature. Carrying out process research and modeling simultaneously will allow continual determination of the weakest or most sensitive areas in the systems approach and definition of research necessary to address these specific problems.

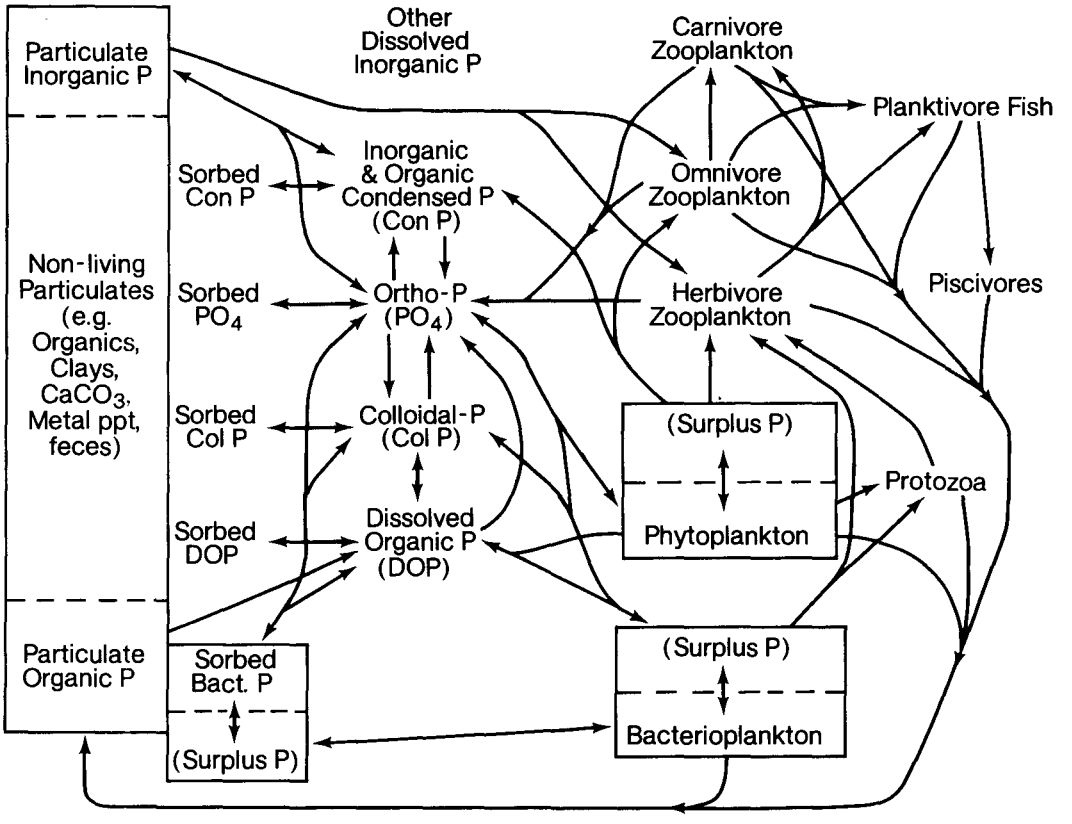


Conceptualized ecosystem compartments for toxic organic model.

Eutrophication and Nutrient Cycling

The work this year in eutrophication and nutrient cycling was designed to organize and produce documentation of the state-of-the-art in phosphorus cycling, a first-cut quantitative model of the cycle, and a detailed research plan for further investigation into limnological and management aspects of phosphorus in the nearshore regions of the Great Lakes. A team of scientists from GLERL, the University of Michigan, and the University of Wisconsin collaborated on development of a first-cut conceptual model indicating that significant improvements of whole-system models and understanding of the phosphorus cycle will be obtained most effectively by more directed, detailed analysis and development of submodels at the process level.

Work was also initiated on estimation of the relative compostion of the phosphorus pools and measurement of the bacterial concentration and activity in the nearshore zone of Lake Michigan. In the first area, a liquid chromatographic system was assembled and used to separate organic compounds from lake water on the basis of molecular size. A micromethod was also developed to analyze water samples for inorganic (acid hydrolyzable) and organic (ultraviolet oxidizable) phosphorus compounds. The bacterial dynamics investigation is being performed under contract by the University of Michigan; it has so far consisted of field sampling near the Grand River outfall in Lake Michigan to test hypotheses on the distribution and activity of bacteria in the nearshore zone of the Great Lakes. Preliminary findings indicate that bacterial numbers show considerable spatial and temporal variability. More bacteria were observed in the immediate outfall of the Grand River than 13 kilometers offshore, and they were more abundant in June and July than in May.



Conceptualized movement of phosphorus in Great Lakes water.

LAKE HYDROLOGY

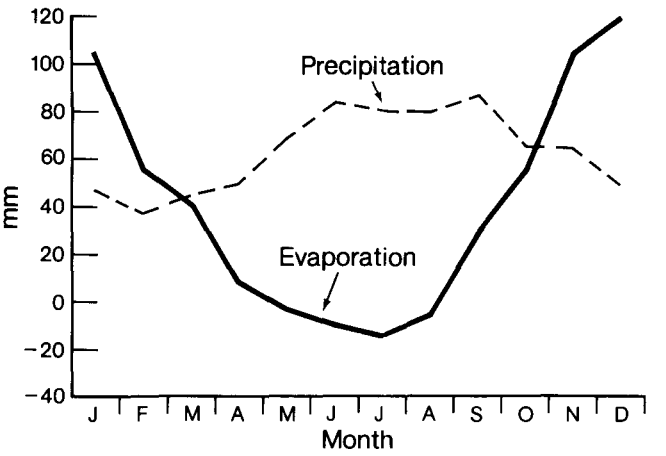
The emphasis of the Lake Hydrology Group is on the hydrologic cycle, including channel hydraulics, and on ice research. The objectives of the hydrologic work are to develop improved methods of prediction and simulation of lake levels, connecting channel flows, and flow in tributary streams and to improve understanding of the hydrologic processes. The objectives of the ice work are to improve the prediction of freezeup, breakup, areal extent, and thickness of ice in the Great Lakes and their bays, harbors, and channels and to improve understanding of the natural variability and optical properties of ice cover. The work involves an integrated program of data collection, data base development, analysis, prediction, model development and testing, and advisory service.

Prediction and simulation information on lake levels and flows is necessary for water resource planning and management and for the solution of problems in water supply, water quality, shore erosion, hydropower, navigation, recreation, and flooding. Primary users of hydrologic information are the U.S. Army Corps of Engineers, the Great Lakes shipping industry, the U.S. Environmental Protection Agency, recreational boating enthusiasts, the power utilities, the Great Lakes States, and the general public.

The amount, type, and extent of ice on the Great Lakes is of interest to all those who use the lakes in winter. Prediction information on Great Lakes ice is of value to winter navigation, shoreline engineering, hydropower generation, water supply management, and waste disposal. Primary users of ice information are the U.S. Army Corps of Engineers, the U.S. Coast Guard, the National Weather Service, the St. Lawrence Seaway Development Corporation, the Great Lakes shipping industry, and the general public, including shoreline property owners.

Hydrology

Highlights during the past year include the completion of a study to determine the individual monthly evaporation values for Lake Superior using an improved aerodynamic procedure that includes atmospheric stability and that takes winter ice cover into consideration. Evaporation from Lake Superior removes approximately 500 millimeters of water from the lake surface, representing a major water loss. The loss has an important impact on various aspects of lake hydrology dealing with the hydrologic water balance, lake levels, and lake regulation. Although normal yearly evaporation averaged over the period

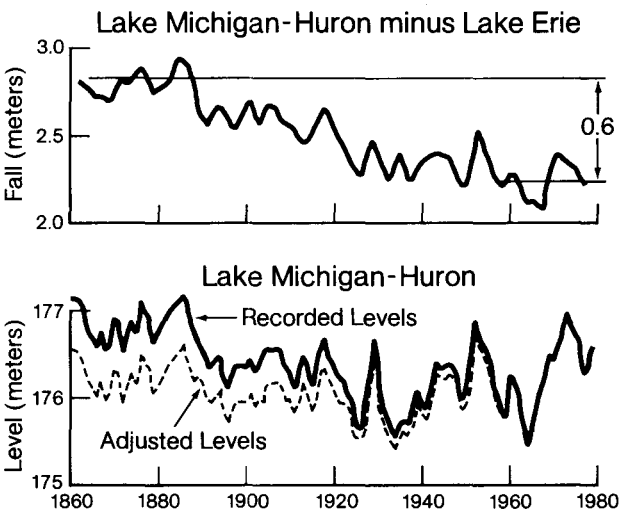


Lake Superior average monthly evaporation compared with Lake Superior monthly precipitation.

1942-75 removes approximately 500 millimeters of water from the lake surface annually, it varies substantially from year to year. A monthly analysis indicated high evaporation values during fall and winter and low values during spring and summer. The high fall and winter evaporation values are due to the tremendous heat storage of the lake. Condensation frequently occurs on the lake during the low evaporation season.

Another study involves the analysis of the winter flow regimes of the St. Clair and Detroit Rivers. The mathematical unsteady flow models of the upper St. Clair River have been improved by inclusion of wind stress and additional cross sections to take into account the rapidly varying bathymetry. Problems were encountered with the current meters that were to have been used last year to monitor winter flows. These problems have been corrected by the manufacturer and a winter deployment of the instruments is planned.

Continuing progress has been made on the analysis of lake level regimen changes since 1860. Knowledge of these changes is necessary to place the current high lake levels in historical perspective. The regimen changes result from man-induced activities, such as navigation dredging, sand-gravel mining in the connecting channels, and various diversions into and out of the system. The level of Lake Erie appears to have remained relatively constant with respect to the level of Lake Ontario over the period of record. Initial analysis indicates that, since the late 1880's, the level of Lake Michigan-Huron has dropped about 0.6 meter with respect to the level of Lake Erie. Accompanying figures show that the current Lake Michigan-Huron water levels beginning in 1970 are, when compared



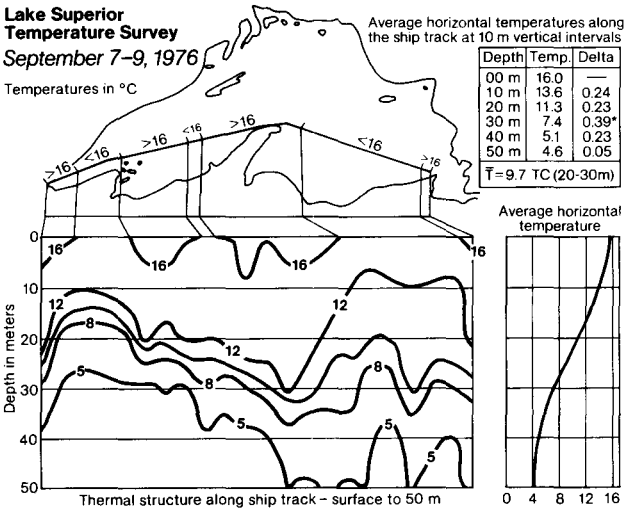
Great Lakes water level comparisons showing a) difference in elevation (fall) between Lakes Michigan-Huron and Erie and b) recorded Lake Michigan-Huron levels and levels adjusted to represent the current outlet conditions.

with current outlet conditons, the highest in the last 100 years.

Ice

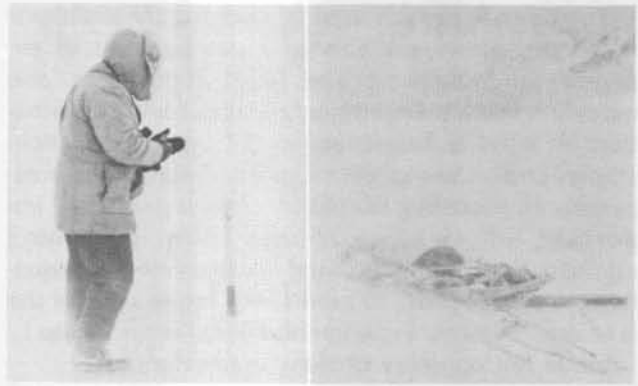
A major study was undertaken during the past year at the request of the International Niagara Board of Control to determine if the Niagara River ice boom, installed every winter since 1964-65, has prolonged the Lake Erie ice cover at Buffalo and thus caused significant changes in the spring warm-up of Lake Erie and longer, colder winters in the area. The study showed no evidence that the operation of the ice boom has influenced these aspects of winter severity. A statistical analysis of a temperature series at Buffalo compared with one for Lockport, New York, did not reveal any statiscally significant cooling in the climate at Buffalo related to the operation of the ice boom. A comparison of the water temperature at the city of Buffalo water intake as recorded in pre- and post-boom years also indicated that the ice boom has not had an impact on the timing of the spring rise in the Lake Erie water temperature at Buffalo. The temperature trend has been one of increasing winter severity from 1893 to 1918, decreasing winter severity from 1920 to 1958, and increasing winter severity again from 1958 to present. Winters have become colder since the installation of the ice boom, but these colder winters are part of a general climatic trend toward more severe winters beginning in 1958.

Progress continued in the analysis of data collected during 21 winter and 25 fall temperature surveys conducted across Lake Superior between 1972 and 1979. On each normal ship crossing between the eastern and western ends of the lake, 25 temperature vs. depth profiles spaced 24 kilometers apart on the lake surface were made. In 1980 the temperature data were edited and the 10-meter-layer temperature and heat content calculated for 20 layers from the surface down to 200 meters. The seasonal temperature variation for each layer was examined with regression analysis. In 1981 the temperature field and heat storage calculations will be completed and emphasis placed on further defining the seasonal and spatial characteristics of these data.



Lake Superior temperature survey, September 7-9, 1976, showing average horizontal temperature along the ship track at 10-meter vertical levels.

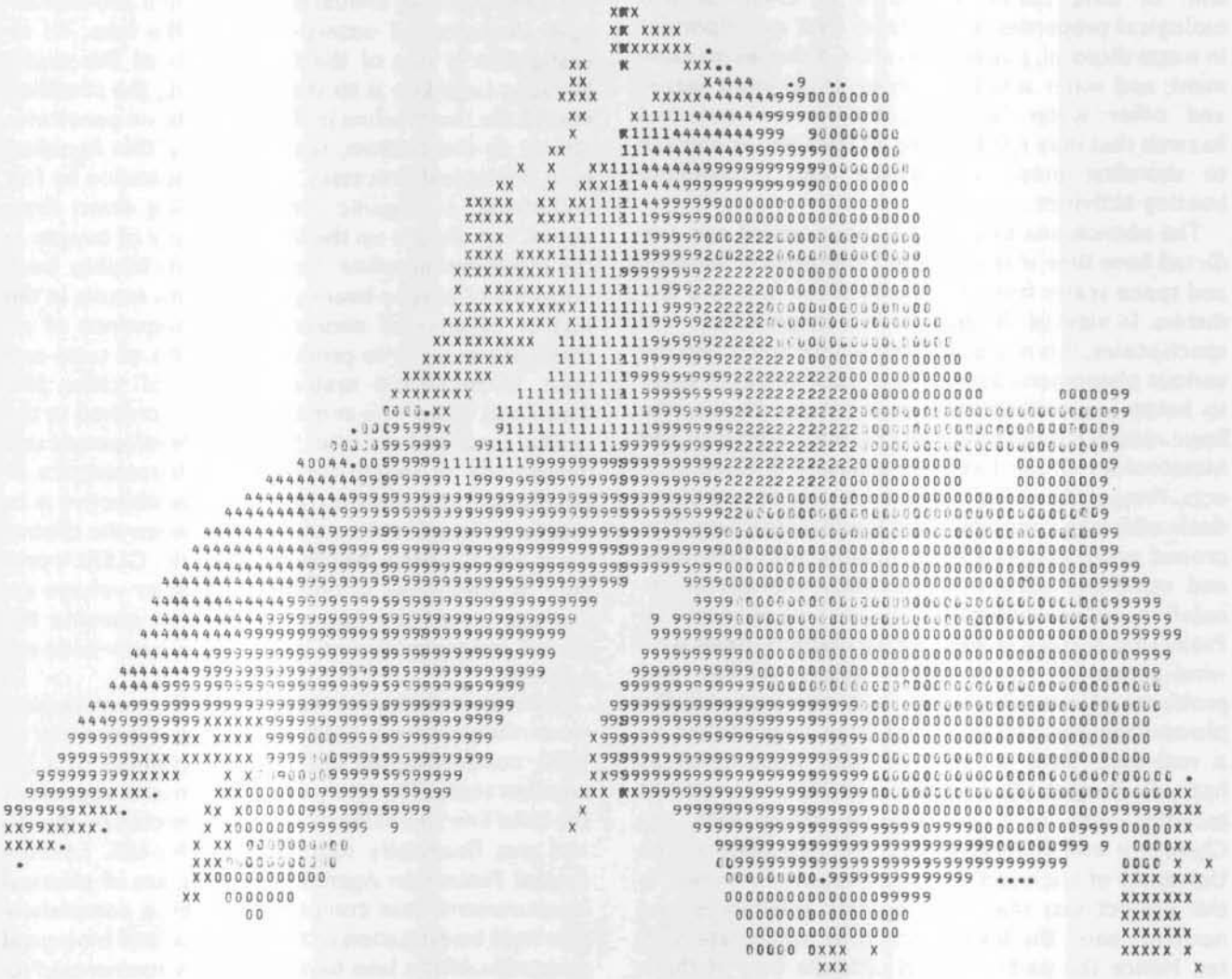
The simultaneously recording scanning spectroradiometer system developed last year has been used this year to acquire additional spectral reflectance measurements of a variety of ice types common to the Great Lakes. Studies on natural ice metamorphism are planned for the 1980-81 season. The high accuracy of the measurements has enabled researchers to record heretofore undetected measurement errors due to poor cosine response of the hemispherical diffusers. In a combined effort, personnel from the Environmental Research Institute of Michigan, the University of Michigan, and GLERL developed a method to correct this error mathematically. Since no diffuser operates with a true cosine response, the



GLERL technician preparing to collect data on radiation transmittance through ice in the photosynthetically active range.

technique represents an advance that can be applied to a variety of types of field data.

The data reduction phase of the *Great Lakes Ice Atlas* revision was completed this year with the addition of over 1500 additional historic ice charts, for Lakes Huron, Erie, St. Clair, and Ontario, to the existing computerized ice-cover data base for Lakes Superior and Michigan. These charts covered winters from the early 1960's to the late 1970's. In 1981 these data will be analyzed to produce a revised ice-cover climatology for each Great Lakes. Average and extreme ice cover and percent of the lake's total area that is ice covered will be calculated for standard periods throughout the winter.



Digitized chart of ice-cover concentration for March 7, 1974. Dots (●) indicate no data; numbers from 0 to 9 indicate percent of the lake's surface area that is from 0 to 90 percent ice covered. Areas 100 percent ice covered are shown by X's. Each number or symbol represents a 5 x 5 km cell of the lake.

PHYSICAL LIMNOLOGY AND METEOROLOGY

The Physical Limnology and Meteorology Group studies the physical variables describing the lake environment and the way in which these variables change as a result of external forces. The relevant physical characteristics of the lakes are currents, temperature, water level fluctuations, and the characteristics of the lake sediments and suspended matter. The primary driving forces are the wind stress acting on the lake surface and the heat exchange between the lake, the atmosphere, and the rivers. The primary emphasis of the program is on developing and testing models that will improve the capability of predicting these variables. These prediction models will, in turn, permit estimates of chemical and biological properties on the lakes that are important in waste disposal, power generation, fisheries management, and water supply planning. In addition, waves and other water level oscillations are potential hazards that may result in loss of lives and in damage to shoreline property, shipping, and recreational boating activities.

The phenomena that need to be modeled and predicted have time scales ranging from years to seconds and space scales from the length of the lake to a few meters. In view of this tremendous range in time and space scales, it is necessary to separate and group the various phenomena according to their scales in order to better understand and model them. Hence, the basic research program in the Physical Limnology and Meteorology Group has been arranged in three projects. Project (1), water movements and temperature, deals with lake circulation and thermal structure. This project encompasses studies dealing with lake-wide and nearshore circulation, seasonal changes in circulation, and upwelling and downwelling phenomena. Project (2), surface waves and oscillations, deals with wind-generated waves, storm surges, seiches, and problems of overlake winds. It is necessary for the phenomena grouped in Project (2) to be predicted on a real-time basis in view of their importance as hazards. Project (3), particle dynamics, was started recently, and is a cooperative effort with the Chemistry and Biology Group and scientists at the University of Michigan. The prime reason for initiating this project was that toxic organic substances and nutrients enter the lake attached to particulate matter. Hence the pathways and ultimate fate of these pollutants in the lakes depend on the movement of various types of particulate matter through the lake environment.

The basic approach used in studying the problems in all the above projects is a combination of experimental (laboratory and field), theoretical, and modeling studies. Experimental data provide information on what is happening in the lake. Theoretical studies predict new phenomena and help plan new experiments. Modeling studies try to incorporate the important physical processes into governing mathematical equations and extrapolate the equations in time in order to predict the future state of the lake environment. Experimental data, in turn, help to validate the accuracy of these predictions.

Water Movements and Temperature

Because Lake Erie is the shallowest of the Great Lakes, it suffers most severely from pollution inputs. Even though the condition of Lake Erie has improved in recent years, an annual problem called anoxia—oxygen depletion of waters—plagues the lake. Its investigation is one of the focal points of this study. Because Lake Erie is so shallow, during the stratified season the thermocline in the central basin penetrates almost to the bottom, leaving a very thin hypolimnion. Biological processes, such as respiration by fish and decay of organic material sifting down from above, rapidly use up the limited supply of oxygen in the hypolimnion, while the thermocline inhibits fresh infusions of oxygen-bearing waters. This results in the loss of oxygen—or anoxia. The consequence of all these processes is to produce problems of taste and odor in municipal water supplies of cities like Cleveland, Ohio. The anoxia is mainly confined to the central basin of Lake Erie. Since the development and persistence of anoxia depends on characteristics of circulation (and stratification), a prime objective is to measure the movement of water between the central basin and the other basins of Lake Erie. GLERL's program is attempting to quantify the water volume exchanges across the basins and also to examine the spatial and temporal variability of the basin-wide circulation.

Current meters and water temperature recorders were retrieved from Lake Erie during the summer of 1980, completing the data collection phase of a circulation study. The study was performed in support of the Lake Erie surveillance program directed by the IJC and was financially supported by the U.S. Environmental Protection Agency. Our program of physical measurements was complemented by a comprehensive field investigation of the chemical and biological properties of the lake by the U.S. Environmental Protection Agency and the Canadian National Water Research Institute. Analysis of the collected data will be completed next year and the results integrated into

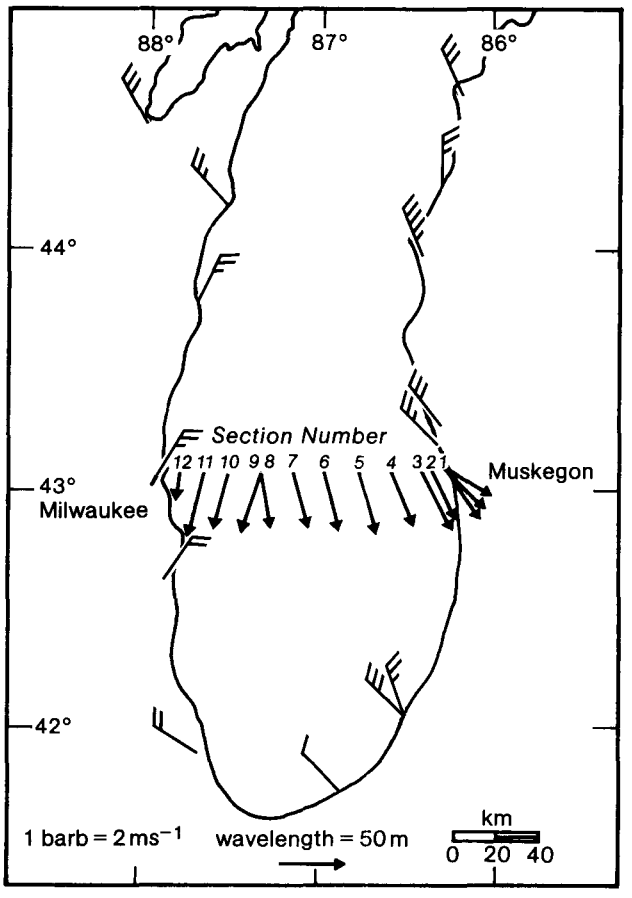
an IJC report describing the current trophic state of the Lake Erie water mass and its response to recent intensive cleanup efforts.

The potential for accidents involving commercial vessels has increased in recent years with the increase in shipping on the Great Lakes. If an accident does happen, it is necessary to be able to answer questions regarding the spread of any oil spilled from the ship's fuel tanks, the drift of the cargo, and possibly the drift of the disabled or abandoned ship itself. In anticipation of these questions, a Great Lakes spill model was developed. Using available lake circulation and oil spill models, GLERL set up a computer program that is run by answering a series of questions. The program was designed for operation from either a portable (briefcase size) computer terminal or a teletype unit. Either device requires only a standard electrical outlet and a telephone to operate the model. The oil spill model has been used several times this year operationally by both the U.S. Coast Guard and the National Weather Service. Applications by those agencies have included tracking of oil and chemical spills, prediction of currents, training and simulation exercises, and prediction of the location of disabled sailboats.

One reason current predictions are so difficult is that the Great Lakes are so deep that the rotation of the earth significantly influences their currents. As a consequence, once current patterns are formed by the wind, rotation of the earth can cause them to reverse direction in a few days. Understanding these reversals requires study of the long-period oscillations (rotational modes) of the lakes—a difficult mathematical problem. A technique to compute the periods and shapes of these modes was recently developed. In the future, the technique will be applied toward understanding observed current oscillations.

Surface Waves and Oscillations

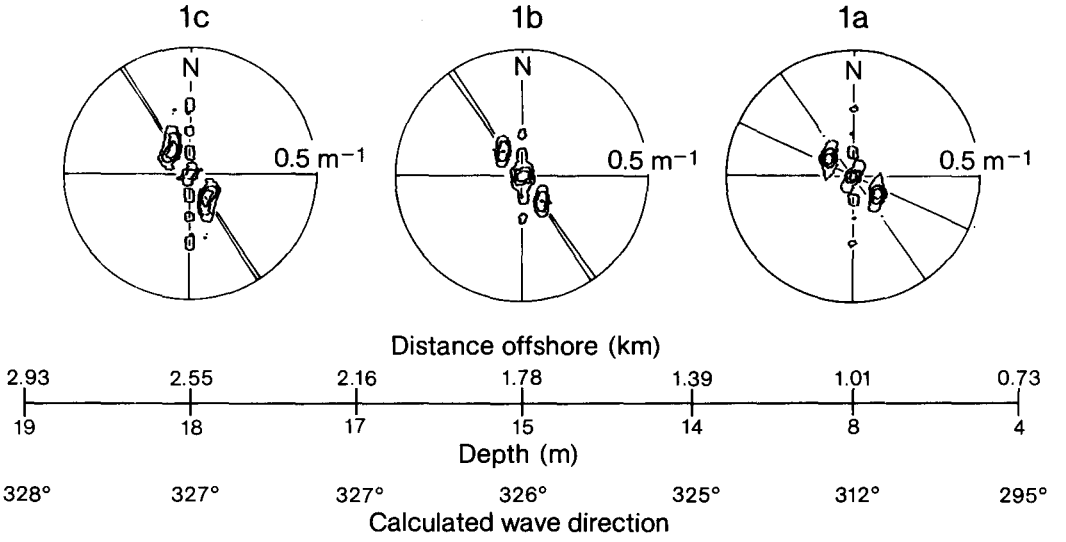
In order to gain a better understanding of wave generation growth, and decay, GLERL asked the Environmental Research Institute of Michigan to record the wave field on a track across Lake Michigan from a plane with synthetic aperture radar. Synthetic aperture radar provides photographic-like images of the wave field, from which wavelength and wave direction can be determined. The recorded images, analyzed by GLERL and the Environmental Research Institute of Michigan scientists, showed a diverging wave field with fairly uniform wavelength across the lake except near the shores. A detailed analysis of the waves near the eastern shore showed that wavelengths decreased and wave direction changed



Wave directions and wavelengths determined from synthetic aperture radar images of the surface of Lake Michigan on a track from Muskegon, Michigan, to Milwaukee, Wisconsin. The wave directions follow the diverging pattern of the wind field.

as the waves came closer to shore, which is in agreement with classical wave refraction calculations. The direction and wavelengths of waves measured at the GLERL solar powered research tower on the eastern shore of the lake agreed very well with those determined from the synthetic aperture radar. The use of remote sensing tools promises to provide new insights into the spatial variability and propagation of waves on the Great Lakes.

An important aspect of the study of wind-generated waves is their spatial variability, which is produced by the effects of islands, curved coast lines, and changes in bottom topography, in addition to the changes in fetch (overwater travel distance of air). Such a study is greatly facilitated by a remote sensing technique to measure the waves over an entire lake, particularly during strong wind conditions. To investigate this problem, GLERL and the Sea-Air Interaction Laboratory carried out a cooperative program in which an airborne laser profilometer was used to map the waves during a fall storm in Lake Michigan. Ground truth to validate the



Directional wave spectra of synthetic aperture radar images from a flight across Lake Michigan. These three spectra taken offshore of Muskegon, Michigan, clearly show the refraction of waves as they approach the shore. The waves are about 50 meters long and travel from northwest to southeast.

airborne measurements was provided by two Waverider buoys deployed in the lake. The measurements were made during the passage of an intense frontal system. Waves were measured both ahead of and behind the front to include areas with different atmospheric stabilities. The analyses show that atmospheric stability plays a distinctive role in wave growth processes. Specifically, it is evident that the fetch required to generate a wave condition for an unstable atmosphere is shorter than that required to generate the same wave condition for a stable atmosphere. Therefore, an unstable atmosphere usually generates higher waves for the same wind speed. During growth, peak energy shifts to lower frequencies, as expected. Our analysis suggests this is due to nonlinear energy transfer. For larger fetch cases, however, the actual growth appears to be mixed, with phases of exponential growth and overshoot effects.

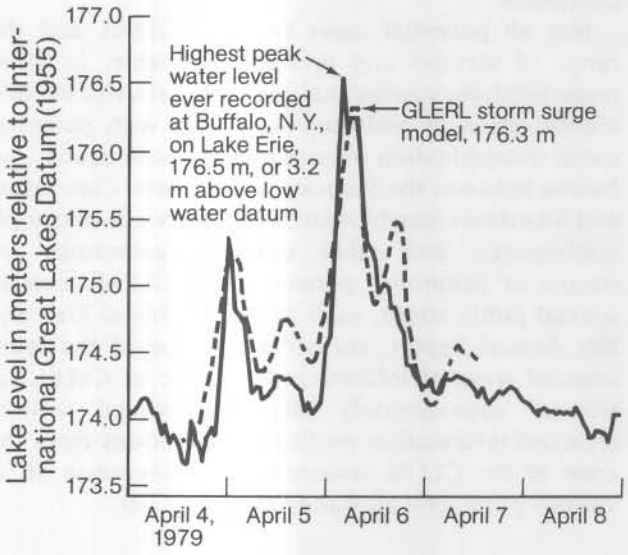
The study of wind-generated surface waves in the Great Lakes has benefited from NOAA's Great Lakes long term wave measurement program. NOAA's Data Buoy Office deployed two NOMAD buoys during 1979, one in central Lake Superior and the other in northern Lake Michigan. In 1980 three more buoys were added in eastern Lake Superior, northern Lake Huron, and western Lake Erie. Plans are to deploy still three more buoys during 1981 in western Lake Superior, southern Lake Michigan, and central Lake Huron. The availability of these wave data, together with simultaneous measurements of wind speed, wind direction, air and water temperature, etc., will significantly supplement GLERL's wave measurement program. This year, one effort in the area will be to examine these data in connection with GLERL's own data and with published oceanic wave measurements as well. The NOMAD data are of high quality and will be very useful for the study of wave processes and the improvement of prediction models. Research comparing various wave prediction models has progressed to the stage of testing several models against wave observations from the National Data Buoy Office operational buoys in Lake Superior and Michigan.

Preliminary tests of a dynamical method of predicting the details of winds around the lakes were encouraging, and we are actively testing this model against observed overlake winds. The model is driven by boundary conditions from a larger scale version developed by NOAA's Techniques Development Laboratory. The model's accuracy in forecasting the details of land winds and water levels around Lake Erie has been tested.

In 1981 a major experiment is planned for Lake Erie to study the directional variation of the wave spectrum in the wave refraction zone, the dissipation of the wave spectrum due to bottom friction, and the momentum balance in the coastal boundary layer. An instrumented research tower, three Waveriders, and seven current meters will be deployed near the southern shore of Lake Erie between Conneaut, Ohio, and Erie, Pennsylvania. In addition, a University of Michigan group will make wave and current measurements in the surf zone. With this collaboration, GLERL researchers hope to be able to follow waves from the deep water, where they are generated

by wind, through the surf zone, and to measure currents simultaneously in the offshore wind-driven region and in the nearshore wave-driven region.

In contrast to the wind-generated waves, which are of small spatial and temporal scale, storm surges represent a response of the whole lake to large-scale disturbances. Wind-induced storm surges on Lake Erie contribute to flooding and shoreline erosion. Low water levels on the upwind end of the lake can be a hazard to navigation.



Actual water level data from Lake Erie compared with levels as calculated by the GLERL storm surge model.

The mean water level of Lake Erie during 1979 and 1980 was 0.9–1.2 meters above the low water datum, which means the lake is now approaching the record high levels of 1972 and 1973. When high lake levels are augmented by seasonal storm surges, there is a potential for flooding and shoreline damage. The GLERL storm surge model, now in operational use by the National Weather Service for Lake Erie, was used to hindcast the water level fluctuations at Buffalo on April 4–7, 1979. The recorded water level of 176.5 meters above International Great Lakes Datum 1955 (3.2 meters above low water datum) at 4 a.m. on April 6, 1979, was an all-time record for Buffalo. The GLERL model used observed winds from four weather stations around Lake Erie to calculate a peak water level of 176.3 meters. Accurate storm surge forecasts, such as might be provided from the GLERL model, can give timely warnings of dangerously high water levels.

Coastline flooding. Wind-generated storm surges can cause considerable property damage to low-lying areas on the downwind side of a lake.

SPECIAL PROJECTS

The work of the Special Projects Group includes programs on environmental engineering models and applications and GLERL environmental information services. The objectives of the environmental engineering models and applications projects are to develop, test, and apply improved simulation and prediction models and other tools as a basis for rational decisions in development and use of Great Lakes natural resources.

Current Great Lakes issues and environmental information requirements are determined in large part through participation of GLERL staff on various interagency, State-Federal, and international boards, commissions, committees, and work groups. Environmental information services involve continuing identification of new users and their needs, dissemination of GLERL products and other environmental information, and response to environmental information requests.

The combination of environmental engineering models and applications and environmental information services provides an information system and expertise to assist in the solution of Great Lakes issues and problems. Such involvement establishes a direct two-way channel for our scientific expertise and tools, ascertains research needs to provide guidance in our program planning, and identifies substantive areas for GLERL participation in interagency research.

Environmental Information Services

The dissemination of scientific products in a form compatible with user needs is vital to the fulfillment of the GLERL mission. Since the costs of research cannot be justified if the results are unused, a principle GLERL activity is the maintenance of an advisory service as a means of providing scientific information in a form compatible with user needs.

This past year, as part of that service, GLERL provided over 1700 research products in response to nearly 900 documented requests. Of these, 20 percent came from agencies in various levels of government and 80 percent from private individuals or groups outside government. This is in addition to regular mailings to those who have indicated interest in receipt of a 6-month listing of available publications (330 addresses) and one or more of the five types of GLERL publications: chemistry and biology (165 addresses), environmental systems engineering (150 addresses), ice (147 addresses), lake hydrology (177 addresses), and physical limnology and meteorology (186 addresses). But publications are just one form of environmental information. Also included are predictions and simulations produced from environmental models, forecasts and forecast techniques, descriptive or analytical information on the present or past status of one or more limnological characteristics of a lake or of the system, and data bases.

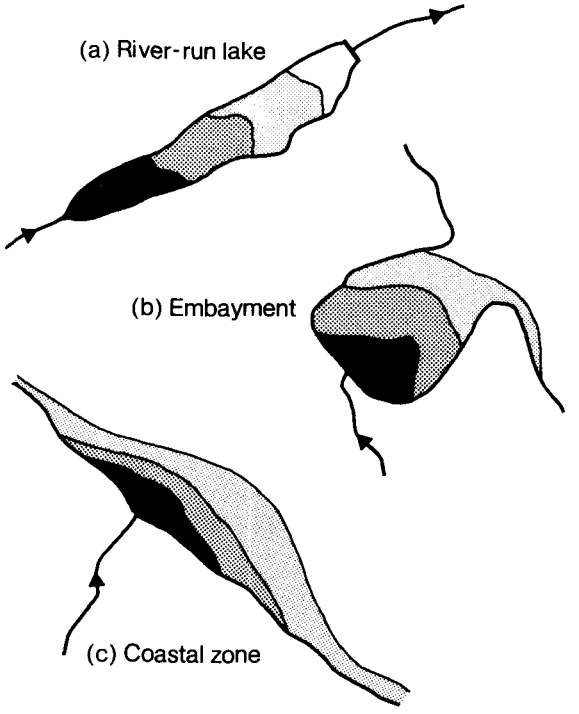
Draft Environmental Impact Statements are reviewed and critiqued in support of NOAA's Office of Ecology and Environmental conservation. The Draft Environmental Impact Statements are required by law to be submitted by the company or agency planning the activity for review by all interested or affected entities. They are intended to ensure that proposed activities in and around the lakes have been designed to have little or no long term adverse effects on the environment.

Not all potential users know of GLERL and the range of services and products available, so other responsibilities carried our under this activity include identification of and communication with potential users, determination of user interests and needs, and liaison between the laboratory and users. Committee and board memberships and attendance at workshops, conferences, and other scientific gatherings are means of informing people about GLERL; certain special publications, such as the *Technical Plan* and this *Annual Report*, are others. In one of the more unusual ways of informing the public of GLERL activities, approximately 300 unscheduled visitors received information on GLERL operations from the crew of the GLERL research vessel *Shenehon* at its various ports-of-call during the past year.

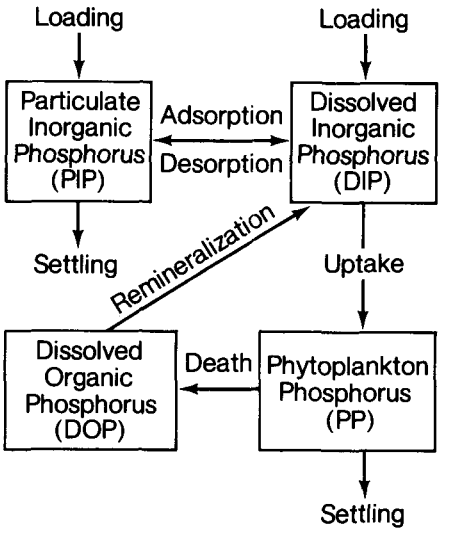
Environmental Engineering Models and Applications

By quantifying the various aspects of a system, environmental models allow managers to try out projected management alternatives or possible scenarios quickly and without harmful effects. Models developed by the Special Projects Group have been used for guidance in real decision-making situations.

A number of mathematical water quality models have been developed as an aid in predicting the average total phosphorus concentration of each of the Great Lakes as a function of their loadings. Although the average concentration indicates the general state of each lake, there are management questions that require more detailed approaches. In particular, since most waste inputs enter a lake at its periphery, heightened levels of total phosphorus occur in the nearshore areas and embayments. Because public use and perception of the water bodies is most intense in these coastal regions, scientists in the



Overhead views of some incompletely mixed systems. The dark shaded areas represent heightened phosphorus levels near river mouths, and the arrows designate the direction of flow.



Schematic of multispecies model needed to simulate phosphorus dynamics in the nearshore zones of lakes.

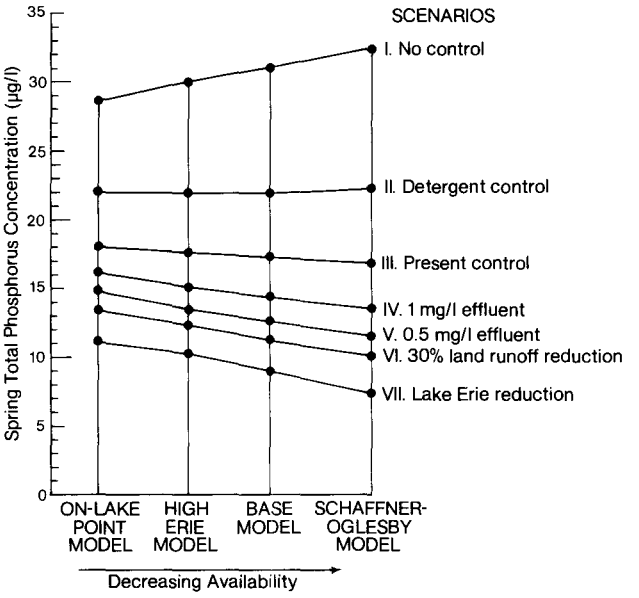
Special Projects Group have been developing modeling techniques to predict the effect of load reductions on nearshore water quality.

However, due to the importance of suspended sediments to coastal zone dynamics, total phosphorus models are inadequate for their characterization. In order to remedy this, GLERL scientists are deriving and testing models that predict the transport and fate of various components of phosphorus. This research has direct consequences for phosphorus management since various waste sources enter the Great Lakes in different soluble and particulate forms. For example, the phosphorus from municipal treatment plants tends to be soluble, whereas land runoff phosphorus is more strongly associated with particulate matter. Since the latter is partially mitigated by the cleansing mechanism of settling, its treatment would have less of an effect on a lake than control of soluble point sources. This differentiation between settling and non-settling forms of phosphorus is referred to as positional availability. Aside from its significance in eutrophication studies, this research affects the modeling of many toxic contaminants that tend to associate strongly with particulate matter.

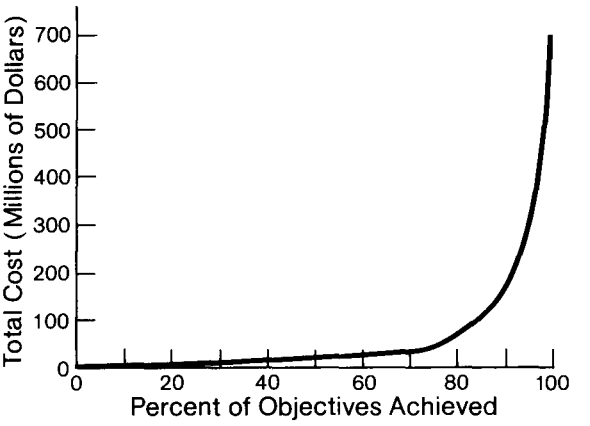
The Great Lakes Environmental Planning Study is a program developed by the Great Lakes Basin Commission to ensure that the latest predictive and analytical techniques developed by the scientific community are accessible to decision makers. GLERL is actively involved in the Great Lakes Environmental Planning Study in a variety of ways. Mathematical models developed at GLERL have been used to appraise the effect of phosphorus availability on Great Lakes eutrophication management. The spill model described earlier has been used to predict the effect of contaminant spills on critical areas of the system. In addition to these simulations, economic aspects of phosphorus control strategies are being analyzed. An analysis of treatment levels needed to meet water quality objectives for the least cost was recently developed. A major conclusion of this investigation was that, as objectives are approached, treatment costs grow exponentially. Present research is dealing with the question of whether the benefits of futher reductions can be economically justified.

Under a continuing contract with the U.S. Army Corps of Engineers, GLERL completed the Great Lakes Consumptive Uses Study. The results will be used by the Corps to modify the Great Lakes Levels Plan according to the projected use and diversion of the lakes' waters.

Study efforts during the past fiscal year focused on two primary tasks: verification and modification of water use estimates, and preparation of the joint United States-Canadian study report. The first task



The effect of positional availability on model predictions—spring total phosphorus concentrations in the year 2000 as calculated by four versions of the model with decreasing availability of phosphorus to phytoplankton. Note that with decreasing positional availability the predictions are more responsive to control measures since less of the loading plays a part in controlling lake response.



Plot of total cost of wastewater treatment (in millions of dollars) needed to achieve phosphorus management objectives in the lower Great Lakes. Note that costs escalate as the complete achievement of objectives is approached.

was undertaken to ensure that water use estimates represented the best available information on usage trends. The fact that initial water use projections indicated a significant impact on lake levels served as an impetus for thorough verification. Power and manufacturing water use estimates were modified to reflect a mix of closed cycle and once-through water use systems. The assumption of a mix was thought to be more feasible than one of uniform closed cycling. Municipal consumptive use estimates were altered to reflect a mix of water conservation and current use measures to the year 2035. These changes in the three largest water use sectors resulted in a slight modification of total consumptive use projections.

The second task of preparation of the joint report required coordination and compilation of individual United States and Canadian study reports and data. This document will serve as an extensive data and information base for water managers and scientists in the Great Lakes Region. It will be used directly in the formulation of a lake levels regulation plan and should also prove useful for future study of diverse uses of the lakes' water resources and associated environmental, social, and economic effects.

INTERNATIONAL AND INTERAGENCY ACTIVITIES

The GLERL program includes support activities for and participation in the work of many other agencies in both the United States and Canada. This is one of the mechanisms whereby our research product is used; in addition, we obtain information on requirements for environmental information to support planning and management activities. This user need information is helpful in shaping future GLERL research programs.

International Joint Commission

GLERL staff members actively participate in a wide variety of the activities of the IJC. Both committee and subcommittee work is involved, including participation in activities of the Aquatic Ecosystem Objectives Committee of the Science Advisory Board. Several specific water quality objectives were approved and substantial progress was made this year on developing a true ecosystem objective. Also included is participation in the International Great Lakes Diversions and Consumptive Use Reference Working Committee. This Committee has provided information to the IJC relevant to water supply and the Great Lakes Regulation Plan. In related areas, GLERL holds membership on the Levels and Flows Advisory Board and the Technical Information Network Board. GLERL staff members have provided considerable input to studies leading to the formation of the International Great Lakes Technical Information Data Board. Senior GLERL scientists have conducted studies for and participated in the activities of the Phosophrus Management Strategies Task Force.

The International Coordinating Committee on Great Lakes Hydraulic and Hydrologic Data

Because much of the Great Lakes data base is used internationally, Canadian and United States users of hydraulic and hydrologic data formed a Coordinating Committee in 1953. The objectives of this committee are to reach agreement upon hydraulic, hydrologic, and related physical data concerning the Great Lakes; to assist agencies in pursuing studies requiring international data; to provide basic data to anyone with a recognized need; to reach agreement on methods and procedures for measuring, collecting, and storing pertinent data; and to publish coordinated data. GLERL participates on the River Flow Subcommittee with a charge to coordinate tributary stream inflow to the Great Lakes system, to coordinate studies of flow in the connecting channels and the St. Lawrence River, and to establish procedures for updating and disseminating river flow data.

Great Lakes Basin Commission

GLERL staff are involved in the Great Lakes Basin Commission as Alternate Department of Commerce Commmissioners and as members of the Great Lakes Basin Plan Committee, the Priorities Committee, the Coastal Zone Management Committee, the Standing Committee on Research and Development, the Long Range Planning Committee, and the Great Lakes Environmental Planning Study.

The Great Lakes Basin Plan Committee has responsibility for developing an approach to identifying and coordinating water and related structural and non-structural near- and mid-term programs designed to enhance the economic, environmental, and societal aspects of the Great Lakes Basin. The Priorities Committee develops guidelines and criteria for establishing priorities of the Federal or federally-supported Great Lakes Basin water resource initiatives for consideration by the National Water Resources Council. The Coastal Zone Management Committee coordinates, exchanges, and develops information pertinent to the Coastal Zone Management activities of the Great Lakes States. The Standing Committee on Research and Development assists Priorities Committee and Great Lakes Basin Plan Committee activities and develops improved research coordination, particularly for the Great Lakes portion of the basin. The Great Lakes Environmental Planning Study is analyzing the accumulative system effects of state pollution control plans on the water quality of the Great Lakes.

International Association for Great Lakes Research

Members of GLERL actively participate in the activities of the International Association for Great Lakes Research. They hold membership on the Awards and Publications Committees.

International Field Year for the Great Lakes (IFYGL)

The technical work of this multiagency, joint United States-Canadian program is complete. The publication *IFYGL Atlas—Lake Ontario Summary Data* was published this year. The atlas provides a hardcopy record of both the atmospheric and lake data in tabular and graphic format. The book *IFYGL—The International Field Year for the Great Lakes* will be ready for printing in early CY 1981. The publication summarizes the major scientific achievements resulting

from analytical and numerical simulations of the dynamical events recorded in the IFYGL data bases. Thirteen chapters, plus appendices, dealing with subjects covering the meteorology and hydrology, as well as the limnology and biology-chemistry, of Lake Ontario are included.

Great Lakes Basin Hydromet Network Work Group

The Great Lakes Basin Hydromet Network Work Group, with membership from NOAA, the U.S. Geological Survey, and the U.S. Army Corps of Engineers, was formed to determine specific alternatives, with time-frames and cost estimates, for implementing, improving, and expanding U.S. Great Lakes Basin hydrologic monitoring. GLERL is one of the NOAA members of this work group, the aim of which is to improve lake level forecasts and water resource management. The group recently completed its work and forwarded the final report to the NOAA Administrator and the heads of other agencies involved.

Joint United States-Canadian Ice Information Working Group

A GLERL staff member is the U.S. Cochairman of this group, which has a primary mission to coordinate the gathering and dissemination of ice information and data for the Great Lakes.

Winter Navigation Program

In the past, GLERL has worked in support of the U.S. Army Corps of Engineers in a multiagency program to examine the feasibility of extending the navigation season in the Great Lakes. Because a large portion of the demonstration program has been completed, much of GLERL's involvement has ended. However, GLERL staff continue to participate in an *ad hoc* capacity to advise the Corps on environmental studies that should be conducted prior to operational implemention of winter navigation extension.

Lake Erie Wastewater Management Study

The Lake Erie Wastewater Management Study is a multiyear U.S. Army Corps of Engineers program to design and develop a demonstration wastewater management program for the rehabilitation and environmental repair of Lake Erie. GLERL staff participated on the Advisory Group that reviewed study programs and recommendations.

Regional Response Team for Spills of Oil and Hazardous Substances

GLERL provides the Department of Commerce members to the Coastal Regional Response Team, chaired by the U.S. Coast Guard, for spills of oil and hazardous substances in the Great Lakes. The purpose of the Regional Response Team is to facilitate cleanup of oil spills and hazardous substances in the Great Lakes and their connecting channels. In addition to participating in committee activities, GLERL has developed tools that can be used by members of this group, such as the oil spill model.

Great Lakes Experimental Team—Coastal Zone Color Scanner

GLERL staff members, including the crew of the research vessel *Shenehon,* are cooperating with scientists from the National Aeronautics and Space Administration (Lewis) to conduct a region-wide evaluation of a coastal zone color scanner for remote sensing of a variety of water quality parameters.

FACILITIES

GLERL's laboratory and support facilities are an integral part of its research program. These are housed in three leased buildings in Ann Arbor, with a total space of about 19,000 square feet, and in a 10,000 square foot warehouse and dock facility in Monroe, Michigan.

Marine Instrumentation Laboratory

The marine instrumentation laboratory staff selects, calibrates, repairs, and, when necessary, adapts or designs instruments to collect data in the lakes and their environs. Engineers and technicians in this unit work closely with GLERL researchers to ensure that instruments are compatible with the purpose of the experiment.

This past year engineers with the laboratory worked closely with their counterparts at the Marsh McBirney Corporation to solve an isolated ground loop problem affecting a model 585 electromagnetic current meter. Extensive changes produced a modified prototype, which was successfully tested in September 1980. The production units will be used to measure under-ice flows in the St. Clair River.

Considerable effort was expended during the year on retrieving several current meter moorings in Lake Erie. The unusual amount of time was required because of a defective lot of batteries used to power the acoustic releases for these mooring strings. A 25-foot surplus vessel equipped with side scanning sonar helped to locate eight of the strings.

A Datawell Waverider buoy transmitter was successfully modified for a data frequency transmission change from 27 to 40 megahertz. This unit was tested over land for a range of 10 kilometers at a proposed field site on Lake Erie. The buoy is currently being compared with a 27-megahertz unit in the lake 11 kilometers from our Monroe dockage facilities. In a related project, a meteorological tower formerly used on Lake Michigan was reactivated for a wave study in Lake Erie. R. M. Young meteorological sensors and an auxiliary wind generator (to supplement solar cells), for power, have been added to the system. The Lake Michigan data show that shortages of power from the solar cells were likely in mid-October, but that expected winds were more than sufficient to power the instruments with a wind generator.

A new carriage for a transparency meter was fabricated to reduce the path length to 0.5 meter, facilitating a higher output in turbid waters. The unit also provides additional protection to the sensor and ease in optical alignment owing to greater rigidity.

A microprocessor system in the marine instrumentation laboratory. This is used to design new data translation equipment to meet the specific needs of certain research efforts.

Chemistry Laboratory

This past year, the chemistry program has included analysis for trace organics in components of the lake ecosystem. Polynuclear aromatic hydrocarbons are extracted from various ecological matrices by Soxhlet extraction and cleaned through chromatographic separation on Sephadex and silica. Separation and analysis are performed on a glass capillary Hewlett-Packard gas chromatograph and on our recently acquired Waters liquid chromatograph equipped with ultraviolet and fluorescent detectors. Yields are calculated by recovery of carbon-14 labeled spikes introduced into the original sample matrix. Initial results indicate that yields are averaging 80+ percent recovery and our quantitative precision for selected compounds is approximately ±15 percent.

Our nutrient program has been expanded with the acquisition of a second liquid chromatograph, which is devoted to analysis of molecular size distributions of dissolved nutrients and has recently been successfully adapted to nitrogen kinetic studies on zooplankton. An ultraviolet technique to separate and analyze organic and inorganic fractions of phosphorus-containing dissolved material is under development. Initial results are promising.

Biology Laboratory

The biology laboratory includes modern equipment and instrumentation. A multichannel Coulter Counter is routinely used to measure particle size selection and zooplankton grazing on natural lake algae and

Scientists using the liquid scintillation counter in the GLERL biology laboratory.

seston. An array of instruments, including a liquid scintillation spectrometer, is used to investigate nutrient uptake, growth rates, competition for nutrients by algae, and cycling rates of selected algal nutrients. Facilities also include a full complement of sampling gear and instrumentation, growth chambers, stereo and inverted microscopes, and cultured populations of phytoplankton and zooplankton species for model studies. A mobile trailer has been fitted for lakeside investigations on the physiology and feeding rates of planktonic and benthic organisms.

Ice Laboratory

The ice laboratory makes it possible to extend the winter measurement season and to expand opportunities for measurement of ice characteristics. The facility is composed of a work room and an ice storage room. The work room, held at -7.0°C, can be used to calibrate instrumentation for the ice research program in an environment similar to that encountered in the field, as well as to conduct experiments on natural ice harvested in previous field seasons. The interior walls are painted flat black to facilitate optical experiments. Ancillary equipment includes a high-intensity light source, a mercury line source, and an optical bench. Adjacent to the work room is a smaller room held at -29.0°C for the storage of natural ice samples. The facility also provides low-temperature storage for a limited number of field samples from the chemistry-biology program and serves as a calibration room for testing a variety of instruments for the marine instrumentation laboratory, including current meters.

Computer Laboratory

The computer laboratory staff supports the work of GLERL scientists by writing, debugging, and testing programs to meet the scientists' specifications; advising scientists and technicians in the writing, adapting, and maintenance of FORTRAN programs; and creating retrieval subroutines to access field data. Programs are entered through a remote communications processor connected to a CDC 750 computer located at the Environmental Research Laboratories (ERL) in Boulder. In addition, programs and data can be entered by means of 13 interactive terminals located at GLERL.

A Tektronix terminal, also connected to the CDC 750, is used for graphical display of machine-processed data on a cathode ray tube. Hard copy of the display can be obtained in seconds and microfilm copy can be printed in Boulder and returned to GLERL by mail.

In some cases, before a data base can be created or analyzed on the CDC 750, the raw field data must be converted from analog to digital form and edited. A Hewlett-Packard 9603A scientific measurement and control system performs the above functions and, in so doing, serves as a link between instruments in the field and the more sophisticated computer hardware. For example, Lake Erie wave data is presently being telemetered and transmitted by land line directly to the Hewlett-Packard system. Data collected and edited on that system are written on industry-compatible magnetic tape for transfer to the CDC 750 system.

R/V *Shenehon*

The primary platform used in support of open-lake field investigations is the *Shenehon*. The vessel is a converted T-boat 65.6 feet long, with a 6.5-foot mean draft, a 600-nautical-mile cruising range, and a 10-knot cruising speed. A hydraulic articulated crane with a 1630-pound lifting capacity at 21-foot extension can be used for deployment and retrieval of heavy instrument moorings, and winches handle hydrographic wire and multiconductor cable (200 meters) for sample casts and *in situ* measurements of water variables. An on-board laboratory facilitates onsite physical, chemical, and biological experiments. A major upgrading of the *Shenehon* navigational equipment took place in 1980. This greatly increases the capability and precision with which the ship can return to an exact site in the lakes for equipment retrieval. New equipment includes navigational radar, a LORAN C navigation system, and an autopilot.

During FY 1980 the ship was based at the U.S. Army Corps of Engineers' yard at Grand Haven, Michigan.

Space was also provided at that location for mobile, shore based laboratories and warehouse facilities. The range of ship operations in FY 1980 included Lakes Michigan and Erie.

An extensive program to further understanding of the dynamics of materials movement was conducted in Lake Michigan with the help of the *Shenehon*. Sediment traps were deployed at 12 sites in the spring and recovered in the fall. Five trap strings were redeployed to obtain winter data. Water samples were collected to determine total suspended matter, and particle size analysis was conducted to determine the amount of material settling to the bottom and into the benthic food chain.

In another effort in Lake Michigan, GLERL scientists cooperated with scientists from the National Aeronautics and Space Adminstration during three *Shenehon* cruises to collect ground truth for a coastal zone color scanner detector head aboard the Nimbus 7 satellite. Physical, biological, and chemical data were collected in support of the program.

The *Shenehon*. This GLERL research vessel has supported a wide variety of chemical, biological, and physical programs on Lakes Michigan and Erie during the past year.

Organic phosphorus, dissolved organic carbon, conductivity, and molecular size separation data were collected during three cruises in conjunction with GLERL's ongoing program to study the chemistry of the lakes. Cruises were coordinated with research relating to the nepheloid layer. Transects were also run off the mouth of the Grand River in Lake Michigan to compare the chemistry of river water in the nearshore zone to that of the offshore zone.

The *Shenehon* was used as a platform to study benthic organisms, in addition to sediments and toxic organics, in southwestern Lake Erie. Samples of benthic organisms were also collected in southern Lake Michigan during three cruises to determine long term changes in benthic organism abundance. Some of the sites were originally sampled as many as 50 years ago. By re-examining benthic populations at these sites, inferences can be made regarding the changing trophic status of the lake.

Support was also provided to the Physical Limnology and Meteorology Group by assisting in retrieving previously deployed current meters in Lake Erie and by setting anchors for an instrument tower on the south shore of that lake. Finally, at its various ports-of-call during the past year, approximately 300 people from the public sector visited the *Shenehon* and were briefed on the GLERL operations program.

Library and Information Services

The GLERL library collection consists of research materials in climatology, hydrolology, hydraulics, ice, limnology, mathematical modeling, meteorology, oceanography, sedimentation, wave motion, and their environmental impacts upon the Great Lakes Basin. The library receives over 260 current periodical and serial titles. In FY 1980 approximately 800 books and reports were added to the collection through cataloging and recataloging procedures.

Library staff provide on-line literature searches to GLERL scientists through NOAA's Computerized Information Retrieval Services. The staff also accesses the BRS Message Switching System (Bibliographic Retrieval Service, Inc.) to transmit on-line information between NOAA libraries. Participation in the National Journalink Union List facilitates the sharing of periodical resources between the GLERL library and other libraries.

During the latter portion of FY 1980, the library implemented the GLERL Library Automated Retrieval System (GLARES). This on-line system is used to expedite cataloging of dissertation and technical report

literature. GLARES also offers the advantage of additional retrieval access points made practical only through automation.

FY 1981 plans call for: 1) automated cataloging of books through the Ohio College Library Center on-line cataloging system and 2) expanded resource sharing through participation in a regional, multitype library cooperative concept, which will operate within a new statewide structure.

Publications Section

Publications are a major GLERL product and a critical part of our efforts to make research findings available to a broad spectrum of users for application to environmental problems and decisions.

The publications section has responsibility for the preparation of manuscripts, including editing, typing, proofing, and procurement of graphics. Editing, typing, and proofing of manuscripts are provided on an in-house basis, while graphics and photographic services continue to be procured under contract. Manuscripts are formatted according to the requirements of the publication form: articles and notes in professional journals, NOAA Technical Reports and Memoranda and Data Reports, or in-house reports. During the last fiscal year, 41 manuscripts were processed in the GLERL publications section.

Every 6 months, a listing of GLERL publications is sent to a mailing of individuals who have requested that list, and requests are filled until supplies are exhausted. Copies of publications are also available through the National Technical Information Service.

PUBLICATIONS

A 6-month listing of available publications can be obtained from

Advisory Service
Great Lakes Environmental Research Laboratory
2300 Washtenaw Avenue
Ann Arbor, Michigan 48104

Assel, R. A. 1980. *Great Lakes degree-day and temperature summaries and norms, 1897-1977.* NOAA Data Report ERL GLERL-15.

Assel, R. A. 1980. Maximum freezing degree-days as a winter severity index for the Great Lakes, 1897-1977. *Mon. Wea. Rev.* 108:1440-1445.

Assel, R. A., Boyce, D. E.†, DeWitt, B. H.†, Wartha, J.†, and Keyes, F. A.† 1979. *Summary of Great Lakes weather and ice conditions, winter 1977-78.* NOAA Technical Memorandum ERL GLERL-26.

Bell, G. L. 1980. *Eastern Lake Ontario and Oswego and Rochester Harbors chemical and physical characteristics data for 1971.* NOAA Data Report ERL GLERL-8.

Bell, G. L. 1980. *Eastern Lake Superior chemical and physical characteristics data for 1968.* NOAA Data Report ERL GLERL-5.

Bell, G. L. 1980. *Lake Erie chemical and physical characteristics data for 1965.* NOAA Data Report ERL GLERL-2.

Bell, G. L. 1980. *Lake Erie chemical and physical characteristics data for 1967.* NOAA Data Report ERL GLERL-4.

Bell, G. L. 1980. *Lake Huron chemical and physical characteristics data for 1966.* NOAA Data Report ERL GLERL-3.

Bell, G. L. 1980. *Lake Ontario chemical and physical characteristics data for 1972.* NOAA Data Report ERL GLERL-9.

Bell, G. L. 1980. *Lake St. Clair and St. Clair and Detroit Rivers chemical and physical characteristics data for 1974.* NOAA Data Report ERL GLERL-12.

Bell, G. L. 1980. *Northern Lake Michigan chemical and physical characteristics data for 1970.* NOAA Data Report ERL GLERL-7.

Bell, G. L. 1980. *Oswego Harbor, New York, chemical and physical characteristics data for 1972.* NOAA Data Report ERL GLERL-10.

Bell, G. L. 1980. *Southern Lake Michigan chemical and physical characteristics data for 1975.* NOAA Data Report ERL GLERL-13.

Bell, G. L. 1980. *Straits of Mackinac chemical and physical characteristics data for 1973.* NOAA Data Report ERL GLERL-11.

Bell, G. L. 1980. *Western Lake Superior chemical and physcial characteristics data for 1969.* NOAA Data Report ERL GLERL-6.

Bolsenga, S. J. 1979. Determining overwater precipitation from overland data: The methodological controversy analyzed. *J. Great Lakes Res.* 5:301-311.

Bolsenga, S. J. 1980. *New observations on the daily variations of natural ice albedo.* NOAA Technical Memorandum ERL GLERL-27.

Boyd, J. D.* 1980. Metalimnetic oxygen minima in Lake Ontario, 1972. *J. Great Lakes Res.* 6:95-100.

Chambers, R. L., and Eadie, B. J. 1980. *Nearshore chemistry in the vicinity of the Grand River, Michigan.* NOAA Technical Memorandum ERL GLERL-28.

Chapra, S. C. 1980. Application of the phosphorus loading concept to the Great Lakes. In *Phosphorus Management Strategies for Lakes*, Ed. R. C. Loehr, C. S. Martin, and W. Rast, pp. 135-152. Ann Arbor: Ann Arbor Science.

Chapra, S. C. 1980. Simulation of recent and projected total phosphorus trends in Lake Ontario. *J. Great Lakes Res.* 6:101-112.

Chapra, S. C., and Sonzogni, W. C.† 1979. Great Lakes total phosphorus budget for the mid-1970's. *J. Water Pollut. Control Fed.* 51:2524-2533.

Derecki, J. A. 1979. Note on estimates of Lake St. Clair evaporation. *J. Great Lakes Res.* 5:216-220.

Derecki, J. A. 1980. *Evaporation from Lake Superior.* NOAA Technical Memorandum ERL GLERL-29.

Derecki, J. A., and Potok, A. J.* 1979. Regional runoff simulation for southeast Michigan. *Water Resour. Bull.* 15:1418-1429.

DeWitt, B. H.†, Kahlbaum, D. F.†, Baker, D. G.†,Wartha, J. H.†, Keyes, F. A.†, Boyce, D. E.†, Quinn, F. H., Assel, R. A. Baker-Blocker, A.†, and Kurdziel, K. M.† 1980. *Summary of Great Lakes weather and ice conditions, winter 1978-79.* NOAA Technical Memorandum ERL GLERL-31.

†Not affiliated with this laboratory.

*No longer affiliated with this laboratory.

†Not affiliated with this laboratory.

Eadie, B. J., Bell, G. L., Chambers, R. L., Malczyk, J. M., Stankevich, E. A., and Langston, A. L.* 1980. *The effects of dredging on the chemical characteristics of the Grand River.* NOAA Data Report ERL GLERL-14.

Great Lakes Environmental Research Laboratory. 1979. *Annual Report for the Great Lakes Environmental Research Laboratory.* Ann Arbor: Great Lakes Environmental Research Laboratory.

Hollan, E.†, Rao, D. B.*, and Bauerle, E.† 1980. Free surface oscillations in Lake Constance with an interpretation of the "wonder of the rising water" at Konstanz in 1549. *Arch. Meteorol. Geophs. Bioklimotol.,* Ser. A, 29:301-325.

Jenkins, C. F., ed.* 1980. *IFYGL Atlas—Lake Ontario Summary Data.* Ann Arbor: Great Lakes Environmental Research Laboratory.

Liu, P. C. 1979. *Spectral growth and nonlinear characteristics of wind waves in Lake Ontario.* NOAA Technical Report ERL 408-GLERL14.

Liu, P. C., and Ross, D. B.† 1979. GLEX-77—An experiment for measuring synoptic storm waves in Lake Michigan (abstract). *Bull. Am. Meteorol. Soc.* 60:1250.

Malczyk, J. M., and Eadie, B. J. 1980. *Collection, preparation, and analysis procedures employed and precision achieved in the chemical field program, 1976-79.* GLERL Open File Report.

Nalepa, T. F., and Quigley, M. A. 1980. Freshwater macroinvertebrates. *J. Water Pollut. Control Fed.* 52:1686-1703.

Nalepa, T. F., and Quigley, M. A. 1980. *The macro- and meiobenthos of southwestern Lake Michigan near the mouth of the Grand River, 1976-77.* NOAA Data Report ERL GLERL-17.

Pickett, R. L. 1979. *Preliminary tests of GLERL circulation models.* GLERL Open File Report.

Pickett, R. L. 1980. *Great Lakes spill model operating instructions.*GLERL Open File Report.

Pickett, R. L. 1980. Observed and predicted Great Lakes winter circulation. *J. Phys. Oceanogr.* 10:1140-1145.

Pinsak, A. P. 1979. Major users and current consumptive use of water in the Great Lakes Basin. In *International Great Lakes Diversions and Consumptive Uses Study,* pp. 9.1-9.9. Detroit: U.S. Department of the Army.

Potok, A. J.* and Quinn, F. H. 1979. A hydraulic transient model of the upper St. Lawrence River for water resources studies. *Water Resour. Bull.* 15:1538-1555.

Quinn, F. H. 1980. *Impact of increased consumptive use on Great Lakes water levels.* GLERL Open File Report.

Quinn, F. H. 1980. *Intercomparison analysis of Detroit River dynamic flow models.* GLERL Open File Report.

Quinn, F. H. 1980. Note on wind stress effects on Detroit River discharges. *J. Great Lakes Res.* 6:172-175.

Quinn, F. H., Assel, R. A., and Gaskill, D. W. 1980. *An evaluation of climatic impact of the Niagara ice boom relative to air and water temperature and winter severity.* NOAA Technical Memorandum ERL GLERL-30.

Reckhow, K. H.†, and Chapra, S. C. 1979. A note on error analysis for a phosphorus retention model. *Water Resour. Res.* 15:1643-1646.

Richardson, W. S.†, and Schwab, D. J. 1979. *Comparison and verification of dynamical and statistical Lake Erie storm surge forecasts.* NOAA Technical Memorandum NWS TDL-69.

Scavia, D. 1979. Examination of phosphorus cycling and control of phytoplankton dynamics in Lake Ontario with an ecological model. *J. Fish Res. Board Can.* 36:1336-1346.

Scavia, D. 1980. An ecological model of Lake Ontario. *Ecol. Modeling 8:49-78.*

Scavia, D. 1980. The need for innovative verification of eutrophication models. In *Workshop on Verification of Water Quality Models,* EPA Report No. EPA-600/9-80-016, pp. 214-225. Athens, Georgia: Environmental Protection Agency.

Scavia, D. 1980. *Uncertainty analysis of a lake eutrophication model.* Ph.D. thesis, the University of Michigan, Ann Arbor, Michigan.

Scavia, D., and Bennett, J. R. 1980. Spring transition period in lake Ontario—A numerical study of the causes of the large biological and chemical gradients. *Can. J. Fish. Aquat. Sci.* 37:823-833.

Scavia, D., and A. Robertson, ed. 1980. *Perspectives on Lake Ecosystem Modeling.* Ann Arbor: Ann Arbor Science.

Schwab, D. J. 1980. *The free oscillations of Lake St. Clair—An Application of Lanczos' procedure.* NOAA Technical Memorandum ERL GLERL-32.

*No longer affiliated with this laboratory.

†Not affiliated with this laboratory.

*No longer affiliated with this laboratory.

†Not affiliated with this laboratory.

Schwab, D. J., Liu, P. C., and Shuchman, R. A.† 1980. Comparison of wind wave spectra determined from synthetic aperture radar imagery and from a tower in Lake Michigan (abstract). *Eos Trans. AGU* 61:262.

Schwab, D. J., and Sellers, D. L. 1980. *Computerized bathymetry and shorelines of the Great Lakes.* NOAA Data Report ERL GLERL-16.

Schwab, D. J., Liu, P. C., Soo, H. K., Kistler, R. D., Booker, H. L., and Boyd, J. D.* 1980. Wind and wave measurements taken from a tower in Lake Michigan. *J. Great Lakes Res.* 6:76-82.

Thomas, N. A.† Robertson, A., and Sonzogni, W. C.† 1980. Review of control objectives: New target loads and input controls. In *Phosphorus Management Strategies for Lakes,* Ed. R. C. Loehr, C. S. Martin, and W. Rast, pp. 61-90. Ann Arbor: Ann Arbor Science.

*No longer affiliated with this laboratory.

†Not affiliated with this laboratory.

†Not affiliated with this laboratory.

PRESENTATIONS

Assel, R. A. 1980. Maximum freezing degree-day climatology and winter severity index for the Great Lakes, 1897-1977. 23rd Conference on Great Lakes Research, May 19-22, 1980, at Queen's University, Kingston Ontario.

Aubert, E. J. 1980. ERL program in marine assessment. NOAA Research and Development Retreat, June 16, 1980, Berkeley Springs, West Virginia.

Aubert, E. J. 1980. Great Lakes anthropogenic problems—The challenge of management. Symposium on New Ground: A Coming of Age for Natural Resources, April 8, 1980, at the University of Michigan, Ann Arbor, Michigan.

Bell, G. L, Chambers, R. L., and Eadie, B. J. 1980. Evidence of a concentrated benthic suspended (nepheloid) layer in the Great Lakes. 23rd Conference on Great Lakes Research, May 19-22, 1980, at Queen's University, Kingston, Ontario.

Chambers, R. L. 1979. The chemistry and biology program at GLERL. Ninth grade science class at Tappan Junior High School, December 12, 1979, Ann Arbor, Michigan.

Chapra, S. C. 1980. Application of phosphorus loading models to river-run lakes and other incompletely mixed systems. International Symposium on Inland Waters and Lake Restoration, September 8-12, 1980, Portland Maine.

Chapra, S. C. 1980. Management and analysis of Great Lakes eutrophication. 13th Argonne Universities Association-Argonne National Laboratory Biology Symposium: Biological Aspects of Ecosystem Restoration, April 21-22, 1980, Argonne, Illinois.

Chapra, S. C., and Dobson, H. F. H.†1980. Lake Ontario is changing: A progress report on evidence of eutrophication trends. Second Winter Meeting of the American Society of Limnology and Oceanography, January 31-February 4, 1980, at the University of Southern California, Los Angeles, California.

Chapra, S. C., and Wicke, H. D.* 1980. Systems approach for phosphorus management in the Great Lakes. American Society of Civil Engineers, Planning and Management Division, Annual Meeting, July 29-August 1, 1980, Green Bay, Wisconsin.

†Not affiliated with this laboratory.

*No longer affiliated with this laboratory.

Dobson, H. F. H.†, and Chapra, S. C. 1980. Lake Ontario phosphorus management: Assessment of within-lake trends, 1977-79. 23rd Conference on Great Lakes Research, May 19-22, 1980, at Queen's University, Kingston, Ontario.

Eadie, B. J., and Gardner, W. S. 1980. Polycyclic aromatic hydrocarbons in sediments and associated benthos in the Great lakes. Second Symposium on Environmental Analytical Chemistry, June 17-21, 1980, at Brigham Young University, Provo, Utah.

Gardner, W. S., and Malczyk, J. M. 1980. Automated microtechnique to measure organic and inorganic phosphorus in aqueous solutions: Application to lake water and atmospheric precipitation samples. Second Symposium on Environmental Analytical Chemistry, June 17-21, 1980, at Brigham Young University, Provo, Utah.

Huang, J. C. K. 1979. Rotational waves in a shallow basin. 1979. Annual Meeting of the American Geophysical Union, December 3-7, 1979, San Francisco, California.

Leshkevich, G. A. 1980. Categorization of northern Green Bay ice cover using LANDSAT-1 digital data—A case study. 23rd Conference on Great Lakes Research, May 19-22, 1980, at Queen's University, Kingston, Ontario.

Liu, P. C. 1980. An experiment for measuring synoptic storm waves in Lake Michigan. Third Conference on Ocean-Atmosphere Interaction of the American Meteorological Society, January 30-February 1, 1980, Los Angeles, California.

Liu, P. C. 1980. A measurement of slope, curvature, and directional spectra of wind waves in Lake Michigan. 17th Conference on Coastal Engineering, March 23-28, 1980, Sydney, Australia.

McCormick, M. J., and Scavia, D. 1980. A multilayered ecological model of Lake Ontario. 23rd Conference on Great Lakes Research, May 19-22, 1980, at Queen's University, Kingston, Ontario.

Nalepa, T. F. 1980. Efficiency of various screens in estimating abundance and biomass of the macro- and meiobenthos. 23rd Conference on Great Lakes Research, May 19-22, 1980, at Queen's University, Kingston, Ontario.

Pickett, R. L. 1980. Improvements in the GLERL spill model. Seminar, September 10, 1980, at the National Weather Service Forecast Office, Ann Arbor, Michigan.

†Not affiliated with this laboratory.

Pickett, R. L. 1980. Operation of the GLERL spill model. Seminar, May 7, 1980, at the Ninth Coast Guard District Headquarters, Cleveland, Ohio.

Pinsak, A. P., Quinn, F. H., Jenkins, C. F.*, and Wicke, H. D.*, 1980. Consumptive use of water in the Great Lakes Basin and its impact on lake levels. 23rd Conference on Great Lakes Research, May 19-22, 1980, at Queen's University, Kingston, Ontario.

Quinn, F. H. 1980. The hydrology of the Great Lakes. 1980 Spring Meeting of the American Geophysical Union, May 22-28, 1980, Toronto, Ontario.

Reckhow, K. H.†, and Chapra, S. C. 1980. Monte Carlo simulation for the estimation of lake modeling errors. Second Winter Meeting of the American Society of Limnology and Oceanography, January 31-February 4, 1980, at the University of Southern California, Los Angeles, California.

Saylor, J. H. 1979. Rotational waves in the Great Lakes and their significance in large-scale mixing processes. Symposium on Problems of Coastal and Estuarine Zones, XVII General Assembly of the International Union of Geodesy and Geophysics, December 13-15, 1979, Canberra, Australia.

Scavia, D. 1980. An ecological systems approach to Great Lakes water quality analysis. American Society of Civil Engineers, Planning and Management Division, Annual Meeting, July 29-August 1, 1980, Green Bay, Wisconsin.

Scavia, D., and Bennett, J. R. 1980. Analysis of biological versus physical control of large gradients associated with Lake Ontario's thermal bar. 23rd Conference on Great Lakes Research, May 19-22, 1980, at Queen's University, Kingston, Ontario.

Scavia, D., and Moody, J. L. 1980. Effects of stochastic properties on a seasonal plankton model of eutrophication. Annual Meeting of the American Society for Limnology and Oceanography, June 16-19, 1980, Knoxville, Tennessee.

Schwab, D. J., Liu, P. C., and Shuchman, R. A.† 1980. Comparison of wind wave spectra determined from synthetic aperture radar imagery and from a tower in Lake Michigan. 1980 Spring Meeting of the American Geophysical Union, May 22-28, 1980, Toronto, Ontario.

Schwab, D. J., and Rao, D. B.* 1980. Objective analysis of currents in a homogeneous lake. 1980 Spring Meeting of the American Geophysical Union, May 22-28, 1980, Toronto, Ontario.

Sonzogni, W. C.†, and Chapra, S. C. 1980. Phosphorus availability—Significance to modeling and management. 23rd Conference on Great Lakes Research, May 19-22, 1980, at Queen's University, Kingston, Ontario.

Tarapchak, S. J. 1980. The utility of silica: phosphorus ratios in predicting diatom limitation by phosphorus or silica. 23rd Conference on Great Lakes Research, May 19-22, 1980, at Queen's University, Kingston, Ontario.

Tarapchak, S. J. 1980. Variations in dissolved phosphorus turnover rates and phytoplankton growth rates at an offshore station in Lake Michigan. 23rd Conference on Great Lakes Research, May 19-22, 1980, at Queen's University, Kingston, Ontario.

Tarapchak, S. J., and Slavens, D. R. 1980. Biological uptake of radiophosphorus in lake water. Second Winter Meeting of the American Society of Limnology and Oceanography, January 31-February 4, 1980, at the University of Southern California, Los Angeles, California.

Tarapchak, S. J., and Slavens, D. R. 1980. Comparative uptake of phosphorus and carbon by different size fractions of Lake Michigan phytoplankton. 23rd Conference on Great Lakes Research, May 19-22, 1980, at Queen's University, Kingston, Ontario.

Vanderploeg, H. A. 1980. Feeding of *Diaptomus sicilis* on mixtures of *chlamydomonas* species of different sizes is passive and mechanical. Annual Meeting of the American Society for Limnology and Oceanography, June 16-19, 1980, Knoxville, Tennessee.

Vanderploeg, H. A. 1980. The significance of $CaCO_3$ whitings to zooplankton in Lake Michigan. 23rd Conference on Great Lakes Research, May 19-22, 1980, at Queen's University, Kingston, Ontario.

*No longer affiliated with this laboratory.

†Not affiliated with this laboratory.

*No longer affiliated with this laboratory.

†Not affiliated with this laboratory.

CONTRACTOR PUBLICATIONS

Bowie, G. L., Chen, C. W., and Dykstra, D. H. 1980. *Lake Ontario ecological modeling, phase III.* Tetra Tech Report No. TC-3942 prepared for GLERL by Tetra Tech, Inc., under Contract No. NOAA-03-78-B01-29.

Lee, G. F., and Jones, R. A. 1979. *Water quality characteristics of the U.S. waters of Lake Ontario during the IFYGL and modeling contaminant load-water quality response relationships in the nearshore waters of the Great Lakes.* Report prepared for GLERL by Colorado State University under Grant No. 03-6-022-35196.

Makarewicz, J. C., Baybutt, R. I., and Damann, K. 1979. Changes in the apparent temperature optima of the plankton of Lake Michigan at Chicago, Illinois. *J. Fish. Res. Board Can.* 36:1169-1173.

Ou, H. W., and Bennett, J. R. 1979. A theory of the mean flow driven by long internal waves in a rotating basin, with application to Lake Kinneret. *J. Phys. Oceanogr.* 9:1112-1125.

Reckhow, K. H., and Simpson, J. T. 1980. A procedure using modeling and error analysis for the prediction of lake phosphorus concentration from land use information. *Can. J. Fish. Aquat. Sci.* 37:1439-1448.

Rumer, R. R., Wake, A., Chieh, S., Fukumori, E., and Tang, G. 1980. *Internal resistance of lake ice.* Report prepared for GLERL under Contract No. NA79RAC00124.

Stemberger, R. S., Fuller, D. R., and Beeton, A. M. 1979. *Role of predacious rotifers in Great Lakes plankton dynamics.* Final Report prepared for GLERL by the University of Michigan, Great Lakes Research Division of the Great Lakes and Marine Waters Center, under Grant No. 04-7-022-44012.

CONTRACTS AND GRANTS DURING FY 1980

Principal Investigator	Institution	Title
A. M. Beeton	University of Michigan	A Cooperative Program in Great Lakes Long Term Effects Research
A. M. Beeton	University of Michigan	The Cycling of Toxic Organic Substances in the Great Lakes Ecosystem
J. A. Bowers	University of Michigan	*In Situ* Predation by *Mysis Relicta* on Zooplankton
J. A. Bowers	University of Michigan	*Mysis* Feeding Studies
E. F. Brater	University of Michigan	Estimating Runoff From Ungaged Drainage Basins
C. W. Chen	Tetra Tech, Inc.	Calibration of a Three-Dimensional Ecological Hydrodynamics Model for Lake Ontario
G. T. Csanady	Woods Hole Oceanographic Institution	Coastal Circulation
G. T. Csanady	Woods Hole Oceanographic Institution	Mass Exchange Mechanisms
B. H. DeWitt	Bernard DeWitt and Associates, Inc.	Summary of Great Lakes Weather and Ice Conditions
S. J. Jacobs	University of Michigan	A Parametric Model for Wave Prediction
S. S. Killham	University of Michigan	Species Specific Growth Rates of Phytoplankton
J. F. Kitchell	University of Wisconsin (Madison)	Predator-Prey Models for Great Lakes Fishes
J. T. Lehman	University of Michigan	Formulation of Zooplankton in Lake Ecosystem Models
G. A. Meadows	University of Michigan	The Growth and Decay of the Coastal Boundary Layer
R. A. Moll	University of Michigan	Bacterial Dynamics
C. H. Mortimer	University of Wisconsin (Milwaukee)	Inertial Motion Examined by Episode in Large Stratified Lakes
C. H. Mortimer	University of Wisconsin (Milwaukee)	Coupling of Physical and Biological Dynamics in Large Lakes
K. H. Reckhow	Michigan State University	Use of Selected Lake Models for Policy Evaluation
C. P. Rice	University of Michigan	Studies in PCB's
R. R. Rumer	State University of New York (Buffalo)	Ice Transport by Wind and Waves in the Great Lakes
R. R. Rumer	State University of New York (Buffalo)	Internal Resistance of Lake Ice
H. T. Shen	Clarkston College	Ice-Cover Effects on Hydraulic Transient Analysis
M. S. Simmons	University of Michigan	Assimilation Rates of Carbon in Great Lakes Phytoplankton
R. A. Sweeney	State University of New York (Buffalo)	Copepod Life History

☆U.S. GOVERNMENT PRINTING OFFICE: 1981—JACKET 750—889