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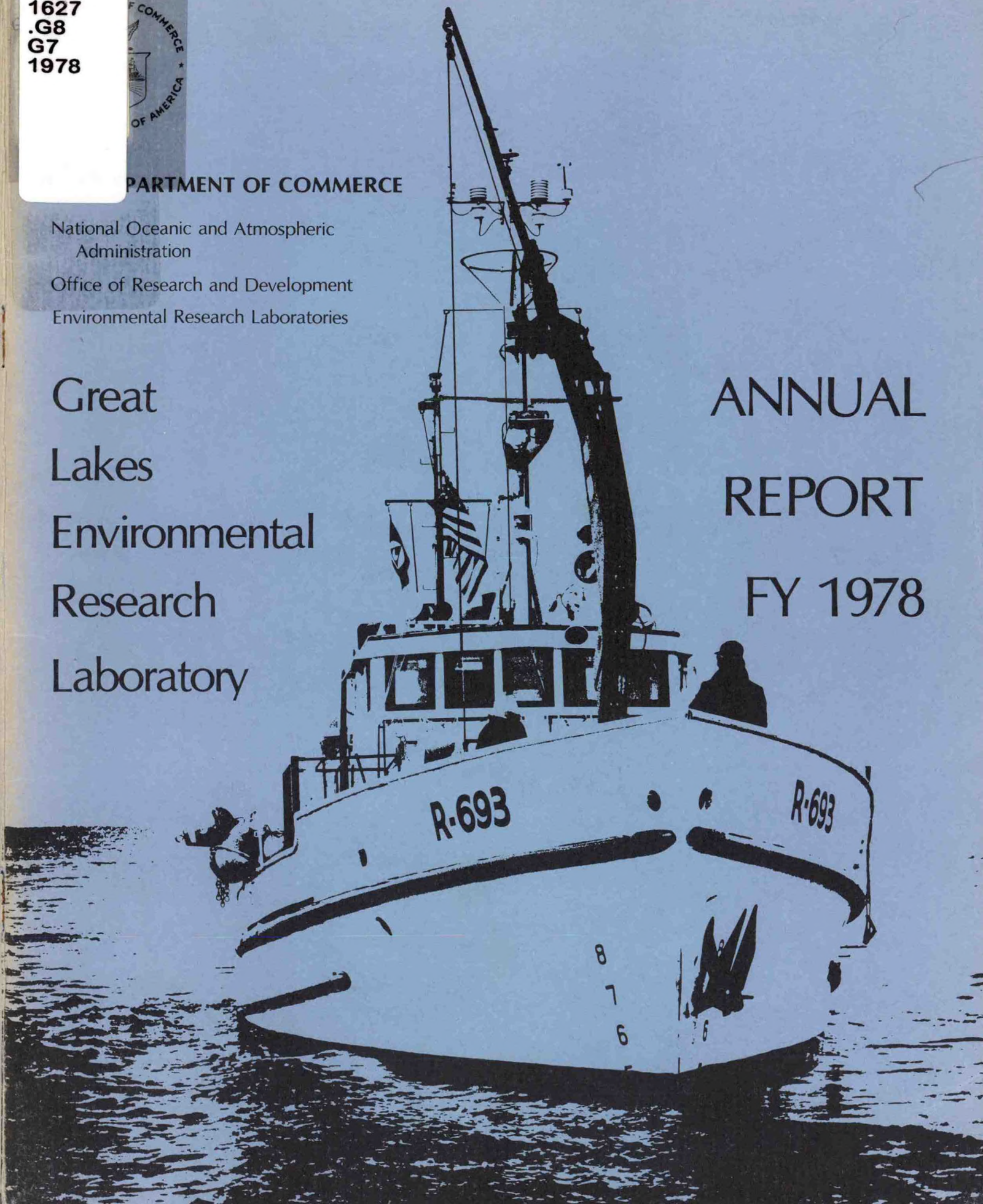
Environmental Research Laboratories

Great Lakes Environmental Research Laboratory

ANNUAL REPORT FY 1978



GREAT LAKES ENVIRONMENTAL RESEARCH LABORATORY

ANNUAL REPORT FY 1978

October 1978

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
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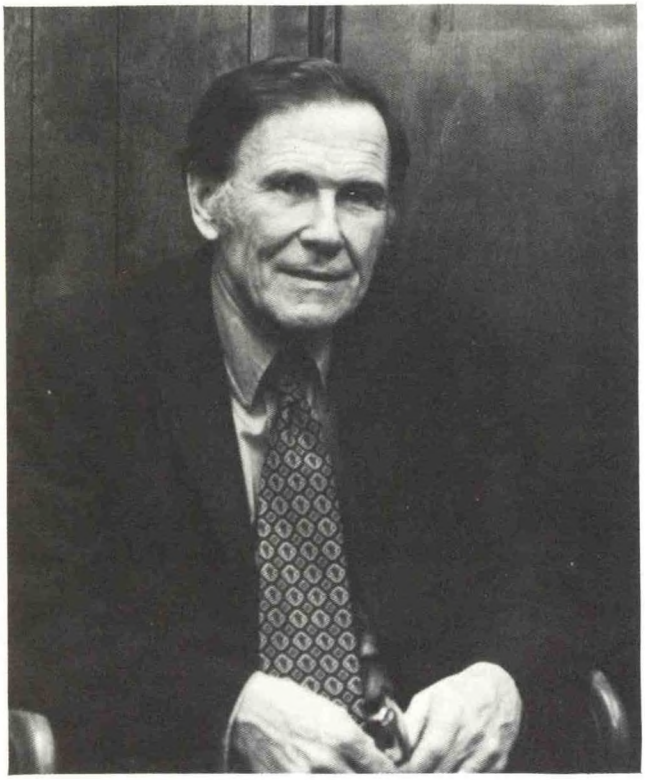
PREFACE



GLERL Director—Eugene J. Aubert.

The Great Lakes Environmental Research Laboratory (GLERL) has completed its fourth 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, private organizations, 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 many 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 the Great Lakes community of GLERL's 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 (IAGLR), 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 for graduate student participation in GLERL projects. Visiting scientists have in the past participated in GLERL research studies; this activity is continuing.

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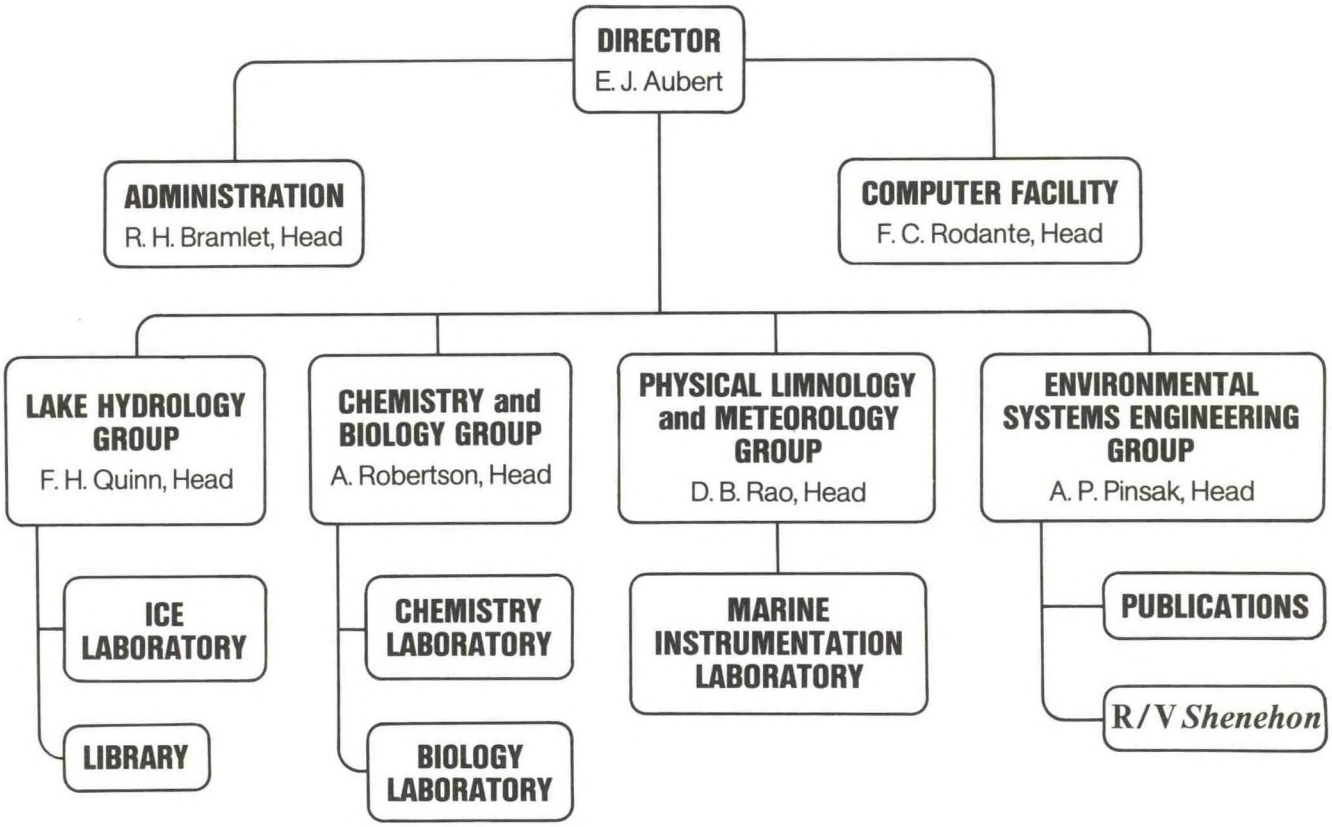
GLERL ORGANIZATION CHART



HIGHLIGHTS

The laboratory has completed its fourth year of operations in Ann Arbor. Research has evolved from a major Lake Ontario International Field Year for the Great Lakes (IFYGL) involvement to research addressing significant processes and problems on each of the five Great Lakes. Interagency and international involvement and advisory service activities continue to be vigorous. Experimental facilities have matured and are integrated with the project research.

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; this past year 3 percent of the laboratory budget came through interagency agreements. The dissemination of research results by publication or presentation and discussion at scientific and user meetings is a major GLERL product. During FY 1978, 40 papers authored by GLERL staff and 9 papers by contractors were published, and 40 papers prepared by GLERL staff were presented at meetings.

Research

Some major research accomplishments were in the area of mathematical modeling. Models developed at GLERL range from comparatively simple environmental engineering models to complex ecosystem and water movement models designed to simulate conditions over a long period.

- A mathematical model developed to predict the effect of waste abatement programs and human development in the drainage basin on Great Lakes phosphorus levels was used to test scenarios postulated by a working committee renegotiating terms of the International Great Lakes Water Quality Agreement. The model indicated that uniform measures applied throughout the Great Lakes Basin will not produce uniform levels of improvement. The most effective return for an investment in preventive or treatment measures will be achieved by varying standards in different locations.
- A hydraulic transient model of the upper St. Lawrence River was developed and tested to simulate the river flows and water surface elevations from Lake Ontario to the Moses-Saunders Power Dam near Massena, New York. The model, applicable to both open-water or ice-cover conditions, is being used to evaluate the effects of winter navigation on the water levels of Lake Ontario and the St. Lawrence River by GLERL, the Army Corps of Engineers, the St. Lawrence Seaway Development Corporation, and others.
- A numerical circulation model was successfully used to simulate the transport of mirex in Lake Ontario. When probable sources in the Niagara and Oswego Rivers were used, results approximated reasonably well the observed mirex concentrations.
- A dynamical storm surge model of Lake Erie was recently developed and is still being tested by the National Weather Service. Preliminary results are encouraging. This method will offer improved forecasts for large water level fluctuations on Lake Erie.
- Ecological modeling work included the application to Lake Ontario of a model designed to simulate seasonal changes in several types of plankton and chemicals in the upper and lower waters. Analysis of model output and data collected during 1972 indicated that in spring and fall phytoplankton net production is controlled by the interaction of incoming solar radiation and vertical mixing, in summer by silica and phosphorus limitation, and in late summer by zooplankton grazing.

But models are not created in a vacuum. They reflect our understanding of the processes, which can only be gained from experimental research and analysis of observations. Several GLERL accomplishments this past year centered on experimental research.

- As part of the IFYGL evaporation synthesis study, GLERL staff compared standard hydrological techniques for estimating evaporation, recalibrated the mass transfer method for use with Great Lakes data, and developed an improved aerodynamic technique incorporating boundary layer stability.
- A statistical climatology study recently completed relates winter severity in terms of maximum freezing degree-days to maximum ice extent in Lake Michigan. The study indicates that the 1976-77 winter in Lake Michigan, which produced maximum ice cover in excess of 90 percent, fell into the most severe of five severity classes on the basis of maximum freezing degree-days.
- Transport mechanisms for dissolved and particulate materials were studied in the nearshore region of southeastern Lake Michigan. A thin (<1 mm) organically enriched microlayer at the lake surface, the thermocline region (up to 10 m or more), and the near bottom nepheloid layer all were found to be significant in the transport of contaminants such as phosphorus, organics, and trace metals.
- Analysis of current and temperature data from the comprehensive 1976 field experiment in southern Lake Michigan revealed an intense and persistent

rotational oscillation with a period of nearly 4 days. This oscillation attained large amplitudes when forced by cyclical north-south wind impulses of similar frequency and dominated the kinetic energy spectra in both the stratified and unstratified seasons.

- A mathematical framework has been developed for the size-selective grazing exhibited by *Diaptomus*. Laboratory experiments with these Lake Michigan zooplankton had indicated the feeding pattern.

- Phytoplankton nutrient experiments in southern Lake Michigan indicate that primary productivity, chlorophyll production, and phytoplankton growth rates are coupled with variations in phosphorus turnover rates, silica concentrations, and silica to phosphorus ratios. Also, parameters describing the uptake velocity of phosphorus and silica are characteristic of phytoplankton in slightly enriched lakes and marine environments.

- An airborne laser altimeter was used to measure synoptic wave conditions over the entire of Lake Michigan during a fall storm. These data agreed well with the *in situ* Waverider measurements taken during the same storm. So far, this program has indicated the value of airborne laser measurements and tended to confirm theoretical knowledge of fetch-limited waves in southern Lake Michigan.

- A study of the consumptive use of water in the Great Lakes region indicates that in 1975 industry consumed 55 percent of the total water used by seven categories of water users, including municipal, rural-domestic, rural-stock, industrial, electric power generation, mining, and irrigation. By the year 2035, power generation is expected to become the greatest user, at 50 percent of the total consumption.

Advisory Services

In FY 1978 the GLERL advisory service responded to 600 requests for information, data, or reports. Presently 425 recipients are on the mailing list to receive regular distribution of GLERL publications. In addition, the laboratory supports the Great Lakes Sea Grant colleges in their advisory service activities. Thirty-two Draft Environmental Impact Statements were reviewed and commented upon in 1978.

International Field Year for the Great Lakes

The major GLERL accomplishment is the successful completion of the IFYGL program. GLERL provided the management expertise for NOAA's role as United States lead agency in this joint United States-Canadian program. This past year a report was published to document the U.S. IFYGL archive. In addition, the *Proceedings of the IFYGL Wrap-Up Workshop* were also published. Publication of *IFYGL—The International Field Year for the Great Lakes* is planned for next year, but 9 of the 13 chapters co-authored by United States and Canadian scientists are already in review and editing. This book will summarize and synthesize the findings and accomplishments of this major scientific program.

International and Interagency Activities

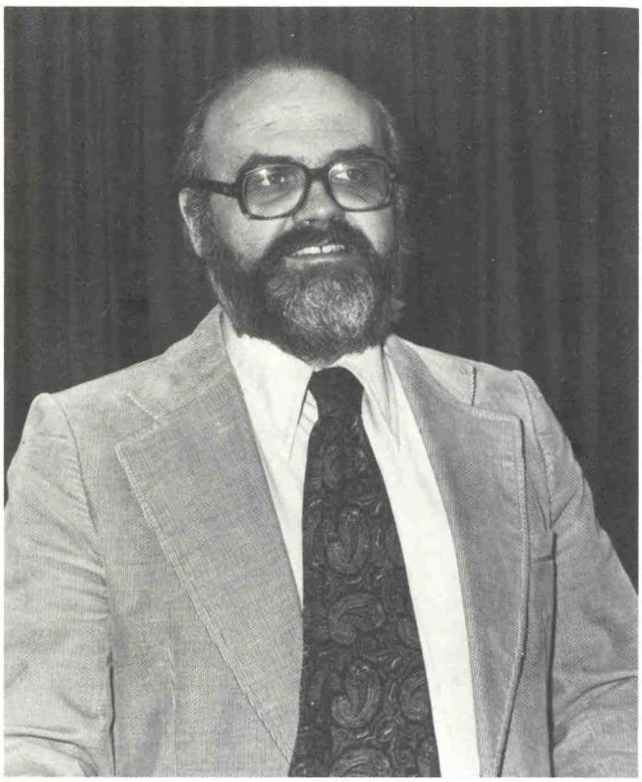
GLERL has continued to be active in international and interagency activities. Staff have participated in the review and updating of the Great Lakes Water Quality Agreement between the United States and Canada and on such boards and committees as the Water Quality Board Subcommittees on Surveillance and Water Quality Objectives; the Research Advisory Board and its Task Force on Environmental Mapping; the Interagency Technical Advisory Group of the Lake Erie Wastewater Management Study; and the Winter Navigation Working Committee, the Ice Information Work Group, and the Environmental Evaluation Work Group of the Great Lakes-St. Lawrence Seaway Navigation Season Extension Program. GLERL staff are also actively involved in the Great Lakes Basin Commission program as Department of Commerce Alternate Commissioners and as working members of the Great Lakes Basin Plan Committee, the Priorities Subcommittee, the Coastal Zone Management Committee, and the Standing Committee on Research and Development.

Facilities

The scope and accomplishments of the GLERL research program are dependent upon the facilities supporting it. Accordingly, several improvements were made in experimental capabilities this year. The chemistry laboratory upgraded its trace metal analysis capability by the addition of a graphite furnace to its atomic absorption spectrophotometer. The marine instrumentation laboratory developed a multiprobe *in situ* monitor for water transparency, temperature, and depth profile measurements.

A microprocessor recently developed by the marine instrumentation laboratory to test current meters detected production errors, which were corrected prior to deployment. Also, the Research Vessel *Shenehon,* the main shipboard operating facility, was used for a variety of successful water chemistry, biology, and physical experiments in Lake Michigan. The new articulating crane facilitated the deployment and retrieval of thermistors, suspended sediment traps, Waverider Buoys, and buoy strings with current meters.

CHEMISTRY AND BIOLOGY



Chemistry and Biology Group Head—Andrew Robertson.

(Photograph by R. L. Chambers.)

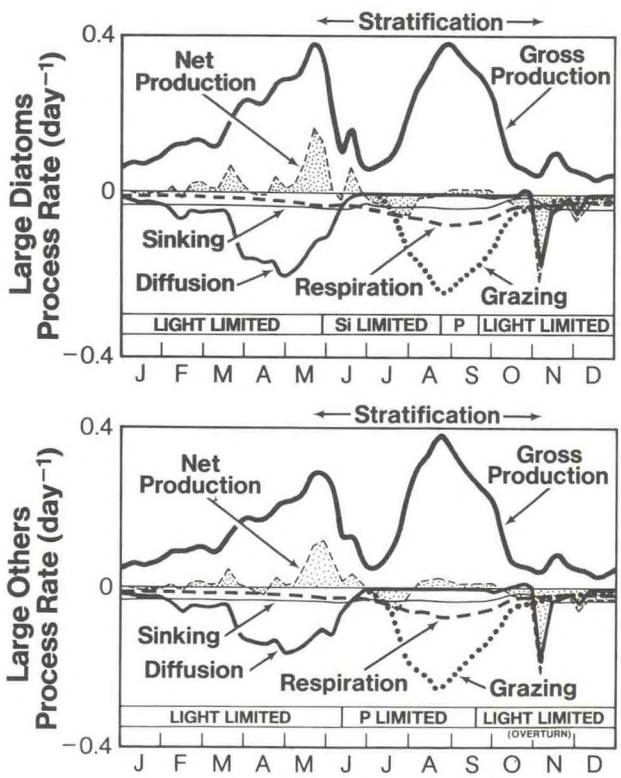
The work in chemistry and aquatic biology is concentrated in three principal task areas: ecosystems modeling, plankton studies, and water chemistry studies. The program is aimed at understanding the existing lake conditions, recognizing the trends that have occurred, and developing the capability to 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 as 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 variations in time, temperature, currents, and loading, are particularly important to water quality determinations.

Ecosystems Modeling

The numerical models formulated under this project aid in detailed examination of the interaction of the biological, chemical, and physical processes in the Great Lakes. Although most of the work so far has been developed for Lake Ontario because the massive IFYGL program provided the data needed for calibration, the models tested and found accurate for Lake Ontario are being adapted to other Great Lakes as the calibration data becomes available.

This past year the model of the upper and lower waters of Lake Ontario was analyzed in greater detail. This model, incorporating several different types of plankton and various chemical and nutrient loadings, simulates seasonal changes. Recent analyses indicate that in spring and fall net phytoplankton production is dependent on incoming solar radiation and vertical



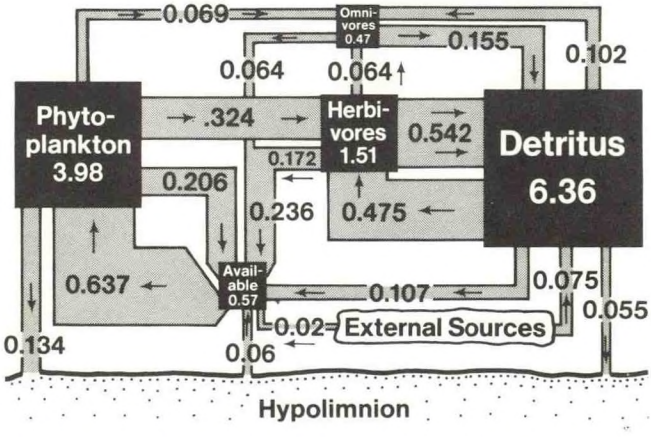
Seasonal variations of process rates of large diatoms and others. Net production is gross production minus that lost by sinking, diffusion, respiration, and grazing. Gross production is controlled by light in winter and spring and by nutrients in summer.

mixing of phytoplankton colonies and nutrients. But in summer silica and phosphorus are the limiting factors. In late summer zooplankton grazing is of primary importance and the availability of light is a lesser but significant influence; more light is backscattered by calcium carbonate particles in late summer as precipitation of that mineral is at a maximum owing to temperature conditions.

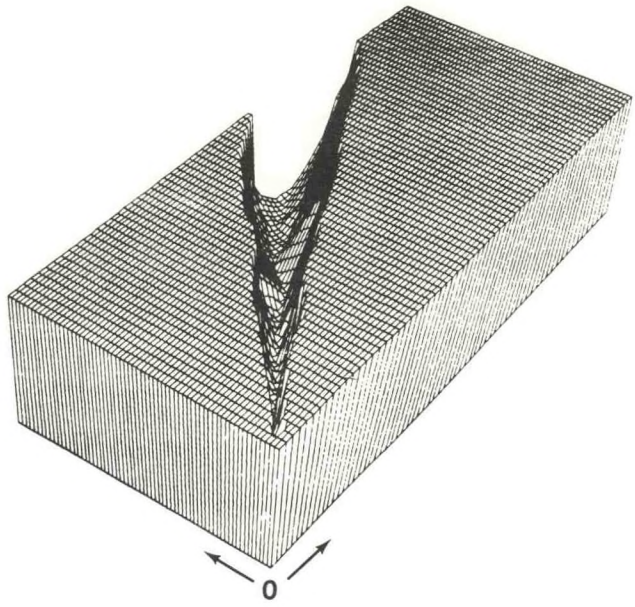
Because phosphorus plays such an important role in limiting phytoplankton production at certain times of the year, the phosphorus cycle in Lake Ontario was examined. Results indicate that in summer, during the period of stratification, phosphorus in forms available to phytoplankton originates primarily from plant and animal excretion or recycling. (Phytoplankton are concentrated in the epilimnion, or upper waters, because they need light.) Additions from lower waters (the hypolimnion) or external sources are negligible in comparison. This helps explain the great seasonal variation in available phosphorus concentrations when compared to total dissolved phosphorus concentrations: in the epilimnion in late summer there is less phosphorus in a form readily available to the phytoplankton and the thermocline set up during stratification forms a barrier that keeps phosphorus from moving up from the hypolimnion.

A multilayered one-dimensional temperature-diffusion model of Lake Ontario was completed. Although designed primarily to aid in the more accurate simulation of the magnitude and phasing of plankton blooms, the model will be useful as input to other areas, such as ice prediction work being done by the Lake Hydrology Group.

In a project combining the capabilities of both the Chemistry and Biology and the Physical Limnology and Meteorology Groups, an existing ecological



Schematic diagram of the phosphorus cycle in the epilimnion (upper waters) of Lake Ontario during late summer. Several factors combine to dwarf external sources.



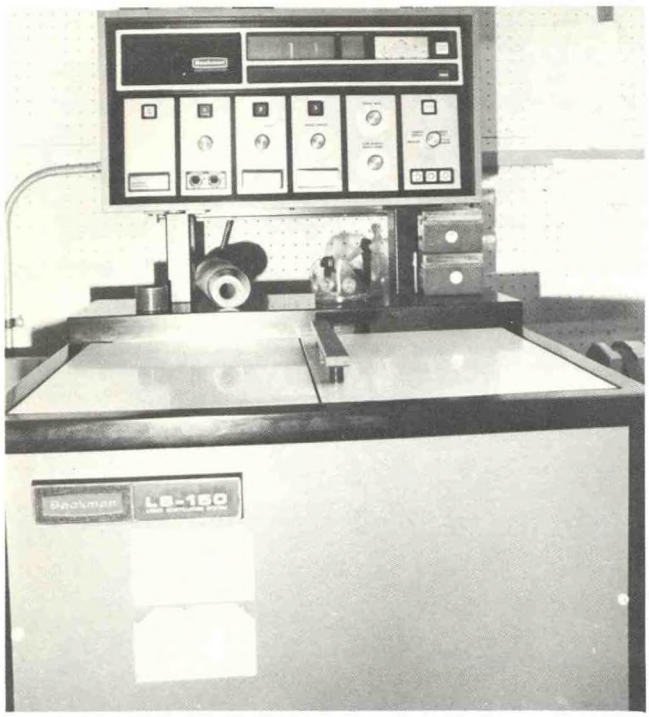
Computer plot of the temperature diffusion model results compared to observed data. This indicates that the two coefficients scientists were seeking are not unique (as they would be if the plot were bowl shaped), but rather a family of points; i.e., the coefficients are related to one another.

model developed by GLERL staff was coupled with a newly developed two-dimensional model simulating the hydrodynamics and thermal regime of a north-south transect in Lake Ontario. With this combined model, scientists will be able to examine the influence of physical phenomena, such as the spring thermal bar and large-scale circulation patterns, on the biological and chemical processes in Lake Ontario.

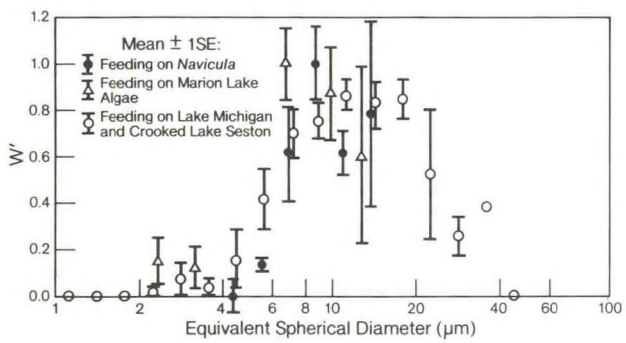
Plankton

Plankton studies have concentrated on the variables affecting the diversity and seasonal distribution of plankton types at an offshore station in Lake Michigan. Phytoplankton studies of *in situ* integral primary productivity, chlorophyll production, and phytoplankton growth rates were examined in view of variations in phosphorus turnover rates, silica concentrations, and silica to phosphorus ratios. It was found that the addition of phosphorus and silica to lakewater stimulates growth rates as indicated by increases in both photosynthesis and phytoplankton biomass.

Previously, zooplankton grazing experiments had indicated that the size of seston (phytoplankton and other particulate materials) is an important determinant in species-specific food selection. This past year the results were analyzed in detail and expressed as mathematical functions. Selectivities of *D. sicilis* and *D. oregonensis* were found to be relatively constant.



Liquid scintillation counter. Phytoplankton nutrient uptake is calculated with this instrument by the use of radioactive isotopes mixed with lake water samples.



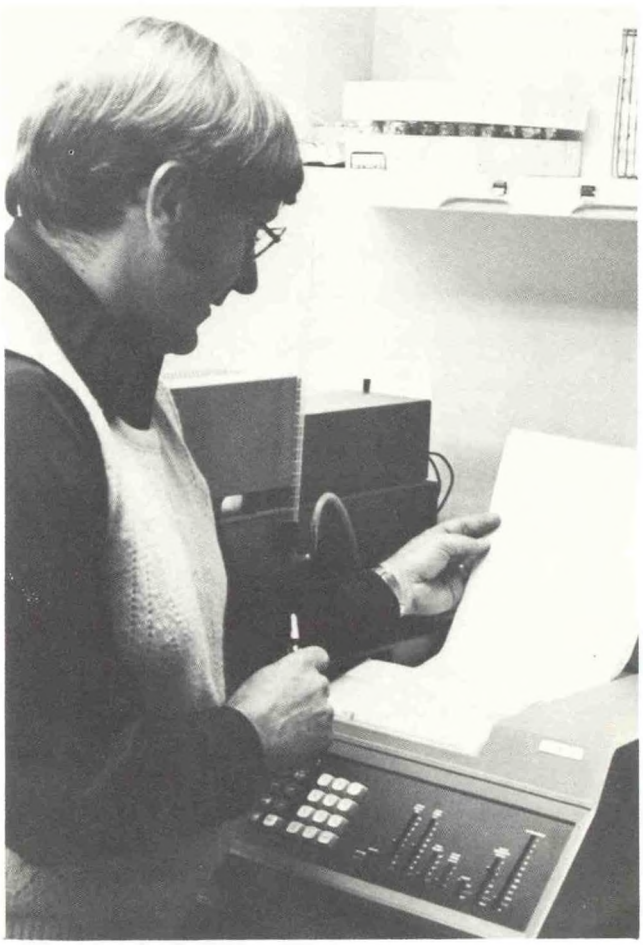
Mean selectivity coefficients (W''s) of feeding of *D. oregonensis* on varied size food. W' is the conditional probability that food of a particular size will be eaten if encountered.

Water Chemistry

Because it is generally accepted that the nearshore is most sensitive to increased loadings of contaminants and nutrients, GLERL water chemistry studies for the past 2 years have focused on the environment of the nearshore region of southeastern Lake Michigan. Once the sources and sinks of various materials have been identified and their transport and transformations traced, it should be possible to simulate biogeochemical cycles.

Recent studies have identified several significant transport sites. The first is a thin (<1 mm), organically enriched microlayer existing at the surface, which provides a site for extensive photooxidation. The second is the thermocline region, which exhibits a high particulate level and a maximum in chlorophyll. The third is the nepheloid layer, or the cloud of flocculated material that under normal conditions lies just above the sediment.

For example, the concentrations of particulate material in the nepheloid layer are often two or more times those in the hypolimnion. In the study area, the thickness of this interface between the sediment and the water can vary from a few centimeters to up to 10 m or more. This region is a zone of concentration for materials that significantly affect the lake ecosystem, such as phosphorus, organics, and trace metals. Important questions yet to be answered are whether



Scientist checking the readout from a gas chromatograph. This instrument is presently being used to separate land-derived from lake-derived hydrocarbons in sediment samples taken from the nearshore region of southeastern Lake Michigan.

materials sinking into this layer remain there indefinitely or are released into the water once more and, if they are liberated again, what factors control this. Initial experiments with phosphorus have indicated that a large fraction of that nutrient resuspended from the sediments is transported into the phosphorus-starved surface water.

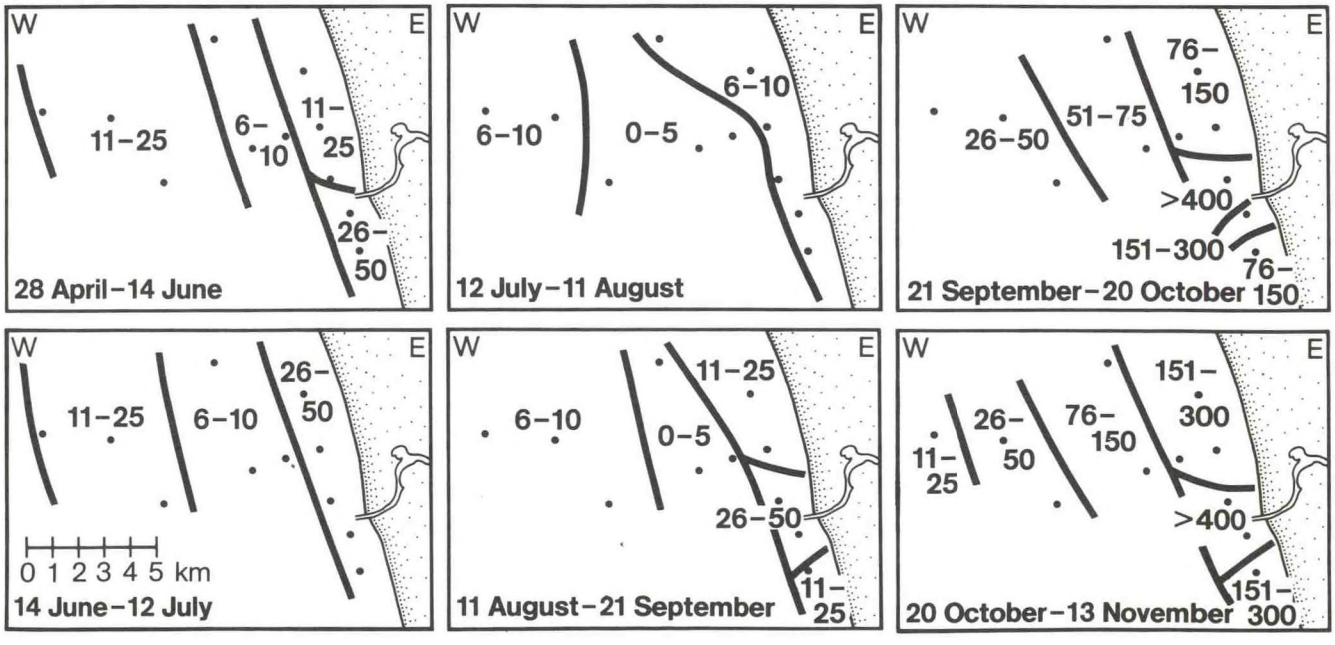
Presently, whitings (or precipitated calcium carbonate) seem to be important, large-scale factors in the ecosystem of the Lakes. Analyses have shown that they influence phytoplankton growth both because they scatter the light penetrating the water and because they transport nutrients after adsorbing them.

But there is a need for more research on the influence of whitings on the ecosystem in view of recent findings. A simple chemical model developed at GLERL has indicated that atmospheric carbon dioxide is an important element in the production of this chemical. Simulations predict that an increase in carbon dioxide to three times present levels, as has been projected, would halt formation of whitings.

Next Year . . .

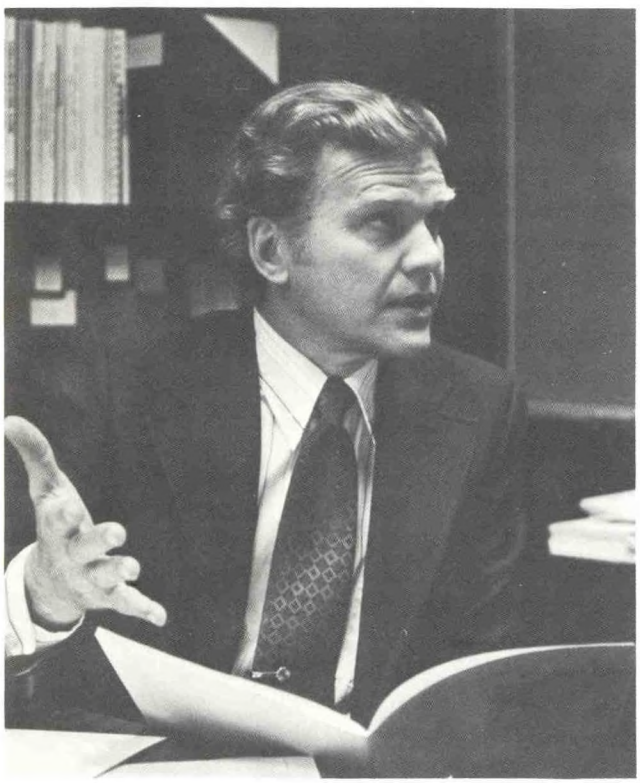
- The temperature-diffusion model will be tested and calibrated with data from other lakes. Simulated temperature profiles from each lake will then be used to calculate effective diffusion coefficients, which will drive a detailed one-dimensional ecosystem model.
- Techniques developed for aerospace research will be used to examine and evaluate the level of uncertainty of predictions made with eutrophication models.
- Investigations into phytoplankton nutrient preference will continue with examination of the species-specific assimilation rates of carbon. Autoradiographic techniques will be used to trace carbon-14 as it is used.
- Zooplankton feeding preference studies will progress into an examination of taste preferences. There is evidence suggesting that, when there is a range of food quality, selection is based on taste as well as size.
- After additional experiments on exchange and transport of materials in the nearshore area, the data will be analyzed and modeled.

1977 Sediment Accumulation at 1 m above the bottom ($g \cdot m^{-2} \cdot day^{-1}$)



Sediment trap accumulations 1 m above the bottom in the nearshore area off the mouth of the Grand River in southeastern Lake Michigan.

ENVIRONMENTAL SYSTEMS ENGINEERING



Environmental Systems Engineering Group Head—Arthur P. Pinsak.

The work of the Environmental Systems Engineering Group includes projects on environmental engineering models and applications and GLERL environmental information services. Objectives of 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.

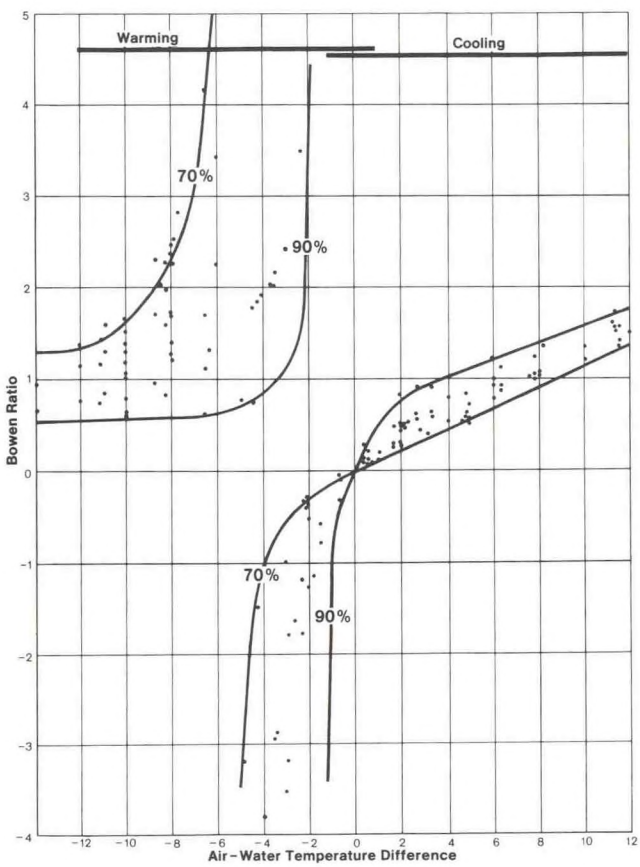
Current Great Lakes issues and environmental information requirements are determined in large part through participation of GLERL staff on various interagency, State-Federal, and international boards, commissions, committees, and work groups. Environmental information services involve continuing identification 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 Engineering Models and Applications

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

A lake-scale energy budget has been developed for Lake Ontario from the IFYGL data and analyses. This is an important factor in water quantity and ecosystems analyses and in climatological, ice, and meteorological forecasting, but estimates have generally been

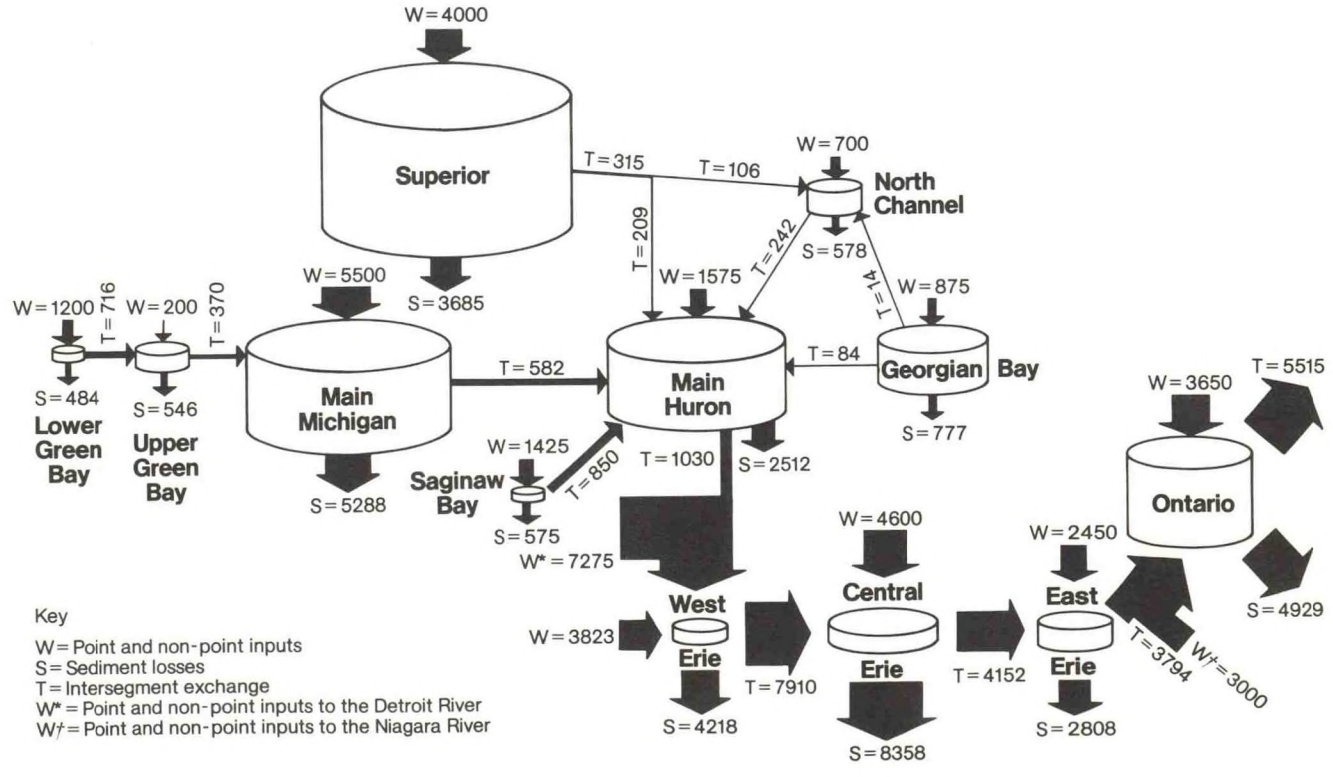


The Bowen ratio as a function of air-water temperature differences at 70 and 90 percent relative humidities. Calculation of the Bowen ratio, the ratio of sensible to latent heat, is necessary to evaporation estimates.

tenuous because of the measurement difficulty. Even though short-term variations can be significant locally, they tend to cancel each other on a whole lake scale. A major problem with the energy budget is the partitioning of sensible or conductive and latent or evaporative heat fluxes across the lake surface. Evaporation is a principal component in determination of water quantity in the Lakes. Most methods of determining the ratio of latent to sensible heat flux are based on air and water temperatures, vapor pressure differences, and a coefficient accounting for stability of the airmass over the lake. In an effort to find an easy, reasonably accurate method, GLERL staff analyzed the uniquely comprehensive IFYGL data base. Individual computations of the latent-sensible heat ratio are extremely sensitive and change nonlinearly and so cannot be averaged. Thus, the input variables must be averaged in time and space to reasonably estimate evaporative water loss. Although the coefficients of conductivity and diffusivity are sensitive in partitioning latent and sensible heat at a specific location, analysis indicates that application of one or the other of these coefficients has an insignificant effect on the accuracy of lake-scale evaporation estimates. Also the ratio is not sensitive to areal weighting but rather to temperature fields. The most important variable in development of an accurate estimate of lake evaporation is the surface temperature distribution. This can be determined with remote imagery.

A mathematical model that had been developed to simulate the movement and fate of phosphorus through the Great Lakes system was applied to management decisions. By predicting the effect of waste abatement programs and other human activities in the Great Lakes drainage basin on phosphorus concentrations in the Lakes, the model can indicate the trophic state to be expected if given policies are adopted. A significant finding is that uniform standards applied universally will not produce uniform levels of improvement. Standards should vary in different locations to provide an economical return for any investment in preventative or corrective measures.

This past year, the model was used to aid in determination of phosphorus loadings to be recommended in the renegotiation of the Water Quality Agreement between the United States and Canada. Given various options being considered, GLERL model results were compared with two others and found to be close enough to distinguish clearly between the various loading options.



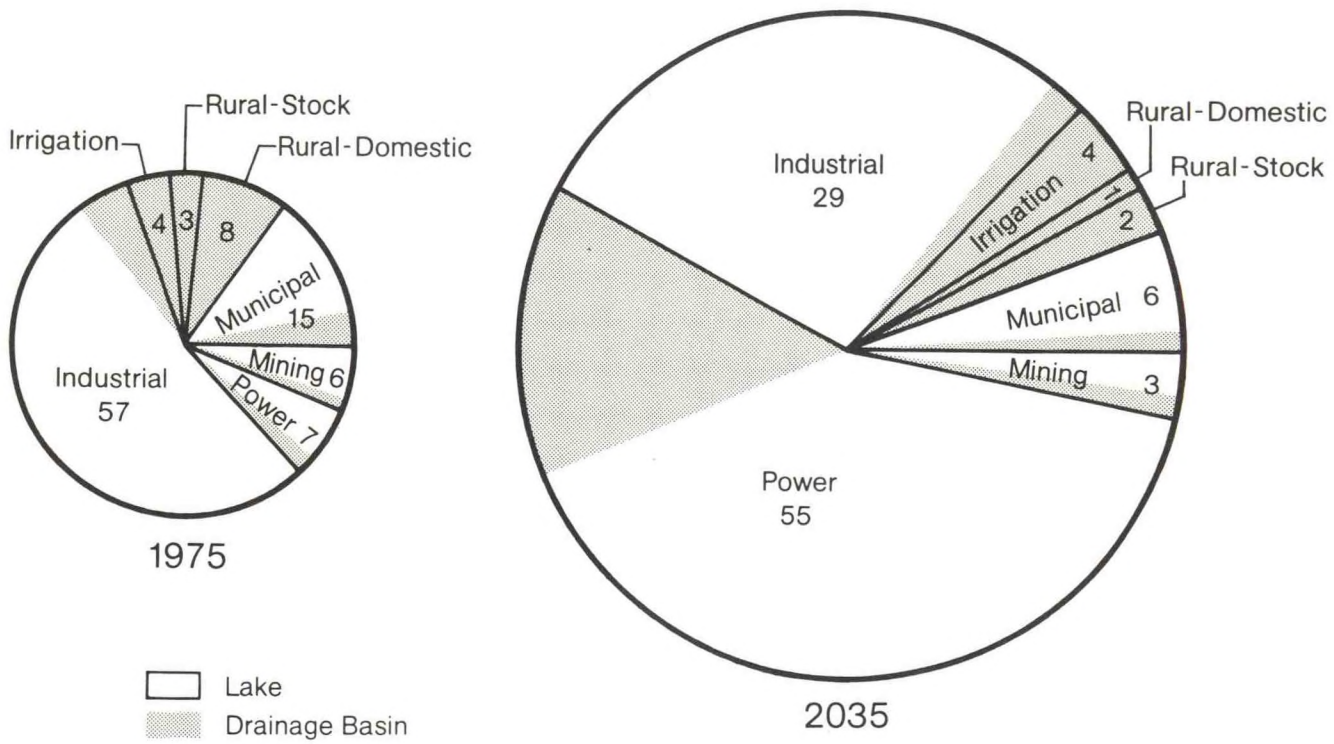
Schematic diagram of the flow of phosphorus through the Great Lakes. Note the large inputs from the Detroit and Niagara Rivers. The GLERL phosphorus model can calculate the impact of cultural patterns in population centers such as Detroit, Michigan, and Buffalo, New York.

Recently, research was initiated to quantify the uncertainties of phosphorus model predictions. This evaluation technique needs to be considered in all types of forecasting. The product then becomes more useful to the manager or planner since he has, not only the most likely value, but also an estimate of the confidence he can place in a prediction.

Under a contract with the U.S. Army Corps of Engineers, GLERL is calculating present and projected consumptive use of water in the United States portion of the Great Lakes Basin to the year 2035 as a part of a joint United States-Canadian project. The Great Lakes Diversions and Consumptive Uses Study Board of the International Joint Commission designed the study. Consumptive use of water, that is, the volume taken out of but not returned to a system, has a significant and growing effect on Great Lakes water levels. Of the seven categories into which water users were divided, municipal, rural-domestic, rural-stock, industrial, electric power generation, mining, and irrigation, industry presently is the biggest consumer. But predictions are that by the year 2035 power generation will be the largest consumer at 50 percent of the total. As consumptive use increases, inclusion of this factor will become more essential to regulation of the Lakes at water levels most beneficial to all users.

A numerical model that had been developed to simulate water quality and transport within and through Lake St. Clair was modified to optimize simulation of the empirical data. Tributary inputs to the lake were moved from the confluence with the lake to a location upstream so that, instead of approximating an apparently constant unidirectional source in the lake, tributary inputs became a product of stream flow, advection, and diffusion into the lake. Another modification related to wind, a primary force driving lake circulation. Mean winds were used in early versions of the model, but these showed a persistent circulation bias when compared to empirical observations. Dividing wind into component directions and applying the resultant vector wind greatly improved the model fit. The modifications have immediate benefits in this specific application, but in the broader perspective they can be applied to improving similar types of models.

Compilation of *The IFYGL Atlas* was completed and it is now being edited for publication. This compilation in the form of maps, charts, and tables of data on the physical characteristics of Lake Ontario during the observational period from April 1972 to March 1973 will be a valuable tool for managers, engineers, scientists, students, and other individuals interested in



U.S. consumptive use of Great Lakes water by seven categories of users for 1975 and projected to 2035. During this period the total U.S. consumption is expected to increase from 114 m^3s^{-1} in 1975 to 440 m^3s^{-1} in 2035

resource development or impact of the lake on related developmental programs.

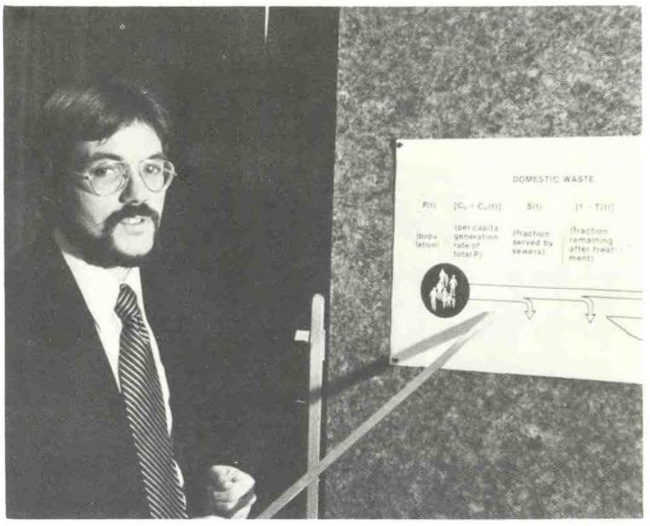
Environmental Information Services

The dissemination of the environmental information produced is vital to the accomplishment of the GLERL mission. The costs of scientific research cannot be justified if the results are not used. Thus, one of the earliest GLERL activities was the establishment of an advisory service as a means to provide scientific information in a form that is compatible with user needs.

This past year, as part of that service, GLERL provided 1000 research products in response to 600 documented requests. Of these, 30 percent came from agencies in various levels of government and 70 percent from private individuals or groups outside government. This is in addition to regular mailings to a list of 425 recipients who have indicated interest in receipt of a 6-month listing of available publications and of one or more of the 5 types of GLERL publications: Chemistry and Biology, Environmental Systems Engineering, Ice, Lake Hydrology, and Physical Limnology and Meteorology. 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. For example, since 1975 a forecasting technique developed by GLERL has been used to provide the St. Lawrence Seaway Development Corporation with forecasts of the date of freezeup on the St. Lawrence River so that international shipping traffic can have time to clear the Great Lakes before the locks are closed.

Draft Environmental Impact Statements (DEIS's) are reviewed and critiqued in support of NOAA's Office of Ecology and Environmental Conservation. 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, these DEIS's are required by law to be submitted by the company or agency planning the activity for review by all interested or affected entities. Last fiscal year, 32 Draft Environmental Impact Statements were reviewed.

Not all potential users know of GLERL and the range of services and products available. So other responsibilities carried out under this project are identification of and communication with potential users, determination of user interests and needs, and liaison between the laboratory and users. Attendance at workshops, conferences, and other scientific gatherings is one means of informing people about GLERL; certain special publications, such as the *Technical Plan* and this *Annual Report,* are others.



Scientist presenting the results of his modeling work. Personal contact is vital to making GLERL products useful to water resource managers and planners.

Next Year . . .

- Work will continue on uncertainty predictions for phosphorus model results.
- The Lake Ontario energy budget task will be completed with publication of the IFYGL Scientific Summary Report.
- *The IFYGL Atlas* will be published.
- The consumptive use study will be completed.
- Work will begin on development of a model hierarchy to address water quality and use problems identified in the Great Lakes Environmental Plan of Study.
- Work will begin on development of a model to simulate seasonal thermal variations and temperature structure in the Great Lakes system.

LAKE HYDROLOGY

Lake Hydrology Group Head—Frank H. Quinn.

The emphases of the Lake Hydrology Group are 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 Corps of Engineers, the Great Lakes shipping industry, the 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, but especially to those who navigate them. 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 Corps of Engineers, the U.S. Coast Guard, the National Weather Service, the St. Lawrence Seaway Development Corporation, the Great Lakes shipping industry, shoreline property owners and the general public.

Hydrology

This past year, the hydraulic transient model of the upper St. Lawrence River was completed, including calibration and testing. This finite difference model is capable of simulating water levels and river flows under either open-water or ice conditions. It is presently in use by the Army Corps of Engineers and the St. Lawrence Seaway Development Corporation to predict the effects of extending the navigation season on water levels in Lake Ontario. Other applications include a study of the effects of increased channel depths on levels and flows. The model also has great potential for predicting the effects of various ice conditions, such as hanging ice dams. (A hanging ice dam

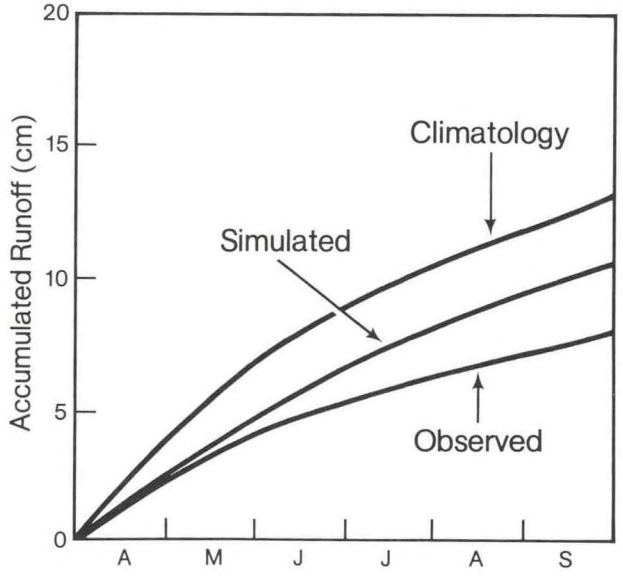
Tennis courts destroyed by high water levels on Lake Michigan. This kind of damage to shoreline structures could possibly be prevented if improved water level prediction information were used by shoreline property owners and managers responsible for water level regulation.

(Photograph by P. W. Sloss.)

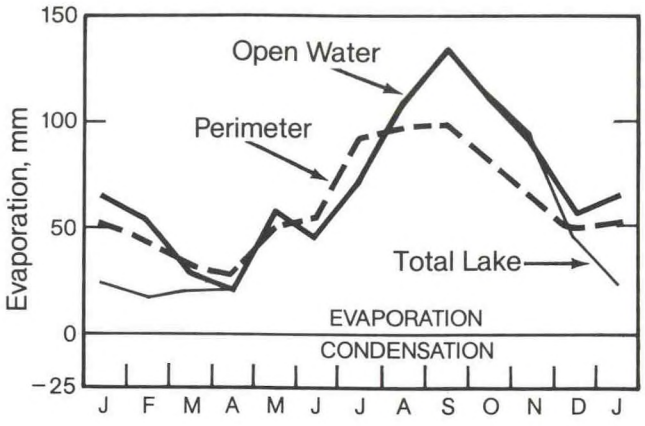
is a natural ice formation building from the surface ice cover downward and partially obstructing the flow of water in the manner of any incomplete dam.)

Last year a Streamflow Synthesis and Reservoir Regulation (SSARR) model developed by the Army Corps of Engineers and adapted by GLERL scientists to the southeastern Lake Michigan drainage basin was calibrated for the period 1961–73. In tests of the model's accuracy in forecasting runoff, this method was found to be a considerable improvement over climatology. Once calibration and testing are complete, this model will be of great value in the simulation of runoff, which in turn affects water levels and quality.

The IFYGL Scientific Summary Report on evaporation synthesis was completed this past year. This describes in detail the evaporation studies of IFYGL data, such as intercomparisons of the terrestrial water balance, energy balance, aerodynamic, and atmospheric water balance evaporation procedures. Significant accomplishments include the calibration of the mass transfer coefficient for use in the Great Lakes and the development of an improved aerodynamic technique incorporating boundary layer stability. This technique was used to compute daily Lake Ontario evaporation from data taken from the IFYGL overwater platforms. Former Great Lakes evaporation studies used a coefficient developed on a small lake (Lake Hefner).



Accumulated runoff for the year 1974, a year of low runoff, in the southeastern Lake Michigan drainage basin. Simulated values were calculated from the Streamflow Synthesis and Reservoir Regulation (SSARR) Model. As can be seen, the model is a great improvement over climatology, the standard method for calculating runoff.



Average annual Lake St. Clair evaporation for the period 1950–75. From December through March, when ice cover is greatest, lake evaporation is less than open-water evaporation.

A Lake St. Clair evaporation study was also completed. An important result was the quantification of the effect of ice cover on lake evaporation. Ice cover reduces annual evaporation from Lake St. Clair by an average of 100 mm, from an open-water value of 850 mm to 750 mm.

Another completed study involved international river flow coordination. An agreement was reached between the United States and Canada on values for monthly St. Clair and Detroit River flows for the period between 1959 and 1977. These estimates will form the base for future studies of the effects of the possible regulation of Lakes Huron, St. Clair, and Erie.

Also developed this past year was an automated methodology for calculating lake precipitation. The method, which uses the grid square technique and the Thiessen polygon procedure, has already been successfully applied to the Lake Ontario drainage basin.

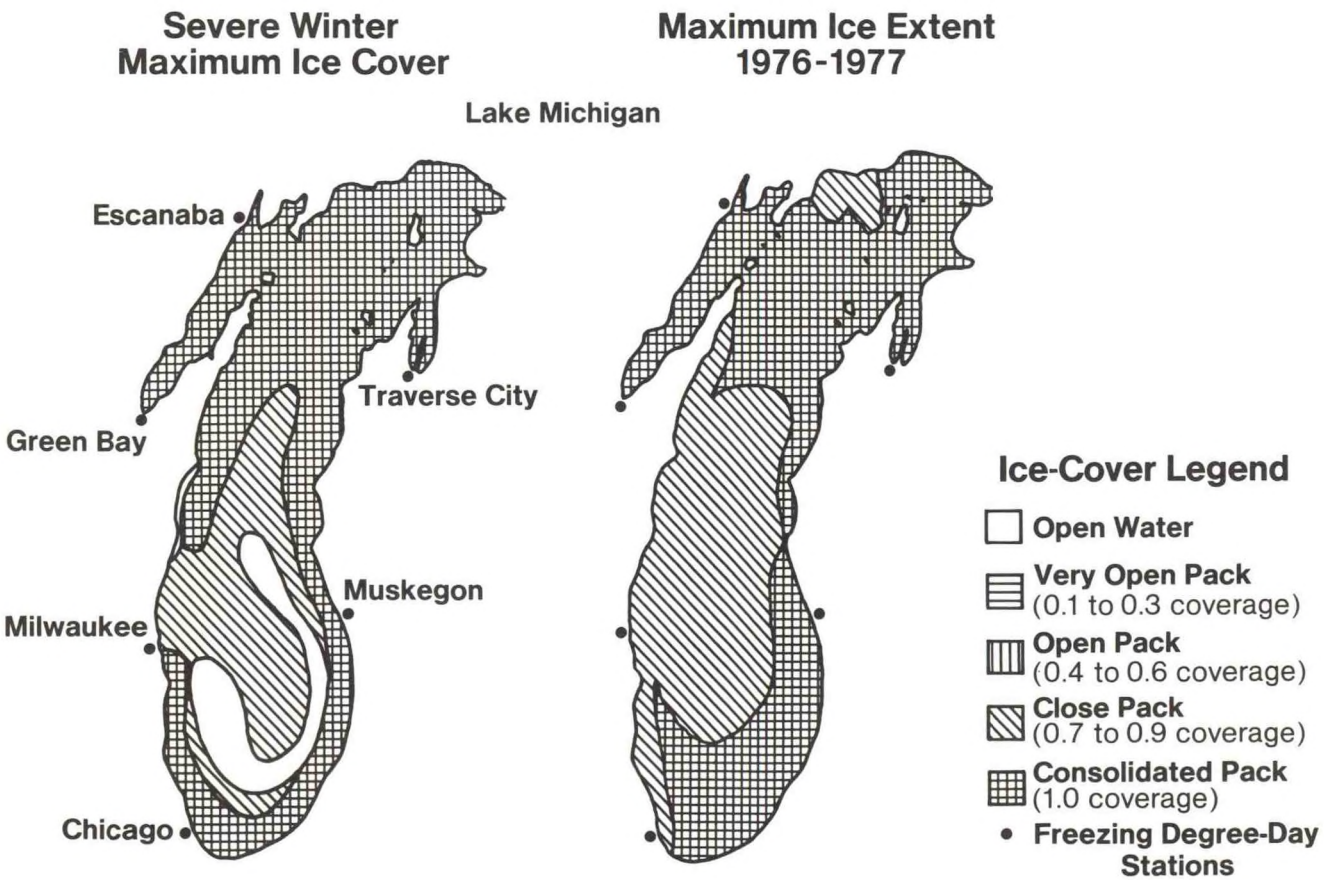
Ice

Because navigation on the Great Lakes and in the St. Lawrence River is so important to the economy of the area, planners in both the United States and Canada have long been trying to extend the navigation season. With this object in view, GLERL scientists have been seeking improved methods of forecasting ice breakup on the St. Lawrence River. An important step was taken this past year when a physically based computer simulation model was developed to simulate the temperature regime in the snow and ice cover on the St. Lawrence River. Initial testing by using a variation of the temperature profile model to simulate lake ice formation and breakup in lakes on the north slope of Alaska proved successful.

The first multiagency winter ice report was completed: scientists from GLERL, the National Environmental Satellite Service, and the National Weather Service collaborated on this historical perspective of the 1976–77 winter. This forms the most comprehensive documentation of a year's ice cycle on the Great Lakes yet undertaken. The past 200 winters were examined for details of temperature and, when possible, ice extent and compared to the winter of 1976–77. Ice-cover data, while only available for the last 16 years, indicate that the winter studied was the most severe in that period. While temperature is the most important factor in the production of ice cover, other elements, such as the pattern of cold weather, also play a part. For example, continued cold with no significant periods of warmer weather was found to contribute to massive ice cover. Also, atypically cold weather patterns were found to be more influential when they occurred in the southern part of the Great Lakes than when they occurred in the northern part.

A more detailed investigation of the relationship between winter severity and maximum ice extent was the subject of a recent study of Lake Michigan. First, maximum freezing degree-days were used to classify each of the past 80 winters into one of five severity classes. Then the most recent 15 winters, for which winter severity class and maximum ice extent are well documented, were used to define the relationship between the two values. Finally, the last 15 winters were compared to the 65 winters before them. The conclusion was that the last 15 winters were colder than the norm for the entire period studied.

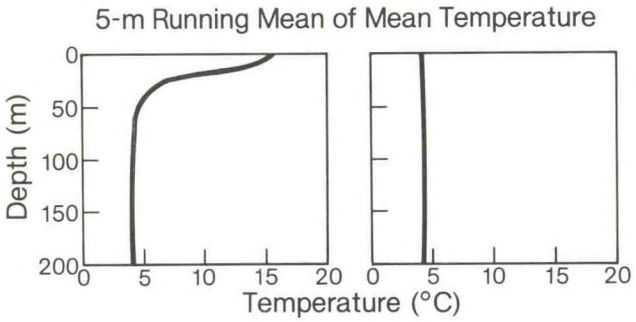
Work is continuing on the archiving of ice charts from the past 19 winters. First digitized, then entered into a computer, these data will be used to update and improve the Great Lakes ice climatology. In addition to these ice charts, air temperature data collected from 30 stations over an 80-year period (1897–1977) will be added to the computerized data base. Combined with the results of the above study on the relationship between freezing degree-days and maximum ice extent, the computerized climatology should be a major improvement over what presently exists. Although a climatology is basically descriptive, rather than predictive, very gross predictions can be made from it. The first task will be to determine how



Ice charts showing maximum ice extent for 1976–77 compared to severe winter maximum ice cover on Lake Michigan. A recent study indicated that the 1976–77 winter was severe in comparison with the past 80 winters.

fine an extrapolation can be made from year to year for the same area and a very similar time period.

Collection of bathythermograph data on Lake Superior continues in order to accumulate a data base for prediction studies. Winter water temperature data already collected were used to correlate the date of fall overturn and maximum ice extent for the following winter. Last year, temperature data were collected during the fall overturn. These will be used to document heat storage and, if possible, to develop a technique for long-range forecasting of the date of initial ice formation.



Graphs showing Lake Superior temperature changes with depth. The graph on the left is for 18-20 August 1976, just before the start of fall overturn. The graph on the right is for 16-17 December 1977, just after the end of fall overturn. At fall overturn temperature variations decrease until the lake is isothermal at 4°C.

Ice above and below the American Falls on the Niagara River. Ice on the Niagara River can affect power production.

Next Year . . .

- The hydraulic transient model of the upper St. Lawrence River will be refined and expanded. In particular, scientists hope to incorporate an ice-growth model and to improve the submodel dealing with the effects of ice roughness on flow.
- The automated lake precipitation technique will be applied to the Lake Superior Basin.
- Additional data will be collected as input to the St. Lawrence temperature regime model. Then work will begin on an experimental procedure to forecast the date of ice breakup.
- Data on additional winters will be collected for addition to the ice climatology.

PHYSICAL LIMNOLOGY AND METEOROLOGY

Physical Limnology and Meteorology Group Head—Desiraju B. Rao.

The work in physical limnology and meteorology is in two projects: (1) water movements and temperature and (2) surface waves and oscillations. The purpose of each project is to improve our understanding of basic processes so that we can better predict currents, temperatures, waves, and other variables. These predictions will, in turn, enable us to estimate chemical and biological properties of the Lakes that are important in diverse user activities, such as waste disposal, power generation, fisheries management, and water supply planning. In addition, waves and oscillations present potential hazards to shoreline property owners, ships, commercial and sport fishermen, recreational boating, etc.

The phenomena that need to be predicted vary in time scales from years to seconds, and in space scales from the length of a lake to a few meters. Of importance are such lake phenomena as seasonal circulations, internal Kelvin and Poincaré waves, topographic waves, coastal jets, upwelling and downwelling, thermal bars, and seasonal stratifications (water movements and temperature project) and wind set-ups, seiches, storm surges, and surface waves (surface waves and oscillations project). All of these studies encompass observational programs, data analyses, numerical simulations, and theoretical studies.

Water Movements and Temperatures

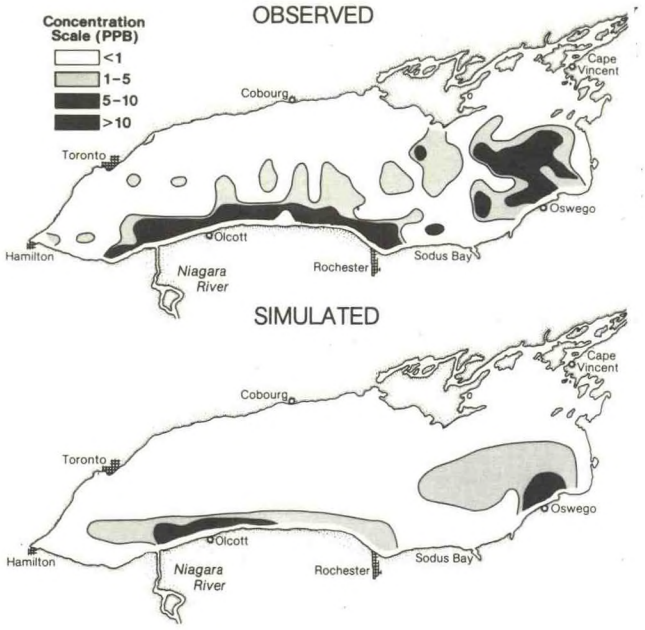
Last year a summary of the physical limnology accomplishments in Lake Ontario during the IFYGL was completed. It will be published in a volume containing the final summaries of each research area and is the concluding product of the IFYGL program.

Lake Michigan data taken in 1976 have revealed direct observational evidence of long period rotational waves. These waves cause oscillatory currents in the mid-lake basin, in addition to periodic flow reversals along the coasts. An intense and persistent rotational wave with a period of nearly 4 days was found in southern Lake Michigan. It attained large amplitudes when forced by north-south wind impulses of a similar frequency. This 4-day wave dominated kinetic energy spectra all year. Because similar periodicities were noted in the currents in Lake Huron during the winter of 1974-75 and in the Straits of Mackinac during 1976, those past data are being reexamined for evidence of such rotational waves.

In another study, the spread of a chemical called mirex, which was manufactured around Lake Ontario for many years, was reexamined. The compound has many uses (insecticide for fire ants, marine antifouling agent, fire retardant, smoke generator, etc.). Unfortunately, small quantities escaped during production and processing and ended up in the lake's sediments. The long-lived substance probably started leaking into the Niagara and Oswego Rivers around the late 1950's or early 1960's. Aided by water circulation, the mirex spread and settled along the south shore and in the eastern end of the lake. This accumulation resulted in the New York Department of Environmental Conservation imposing a Lake Ontario fish ban in September 1976.

A distribution of mirex concentrations has been observed in Lake Ontario's sediments. Since the only known sources are the Niagara and Oswego Rivers, lake currents must have carried the settling mirex eastward from the Niagara River as far as Rochester, New York. Similarly, the mirex sediment pattern off Oswego, New York, probably resulted from currents carrying mirex northward from the Oswego River mouth.

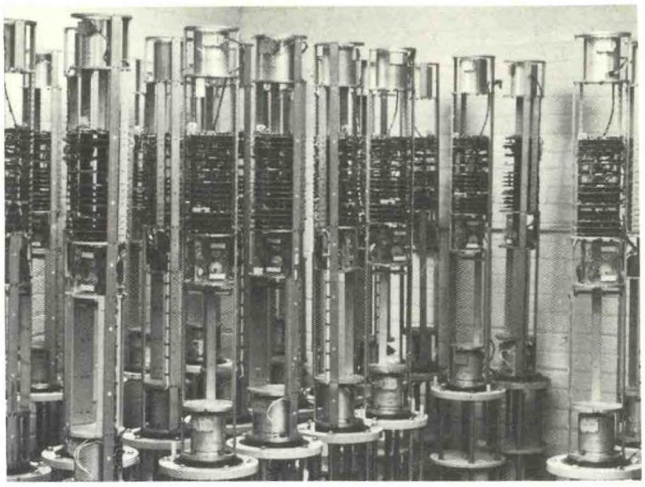
As a test of these hypotheses, a numerical model was driven with the climatological mean wind and with water quality calculations added. In the model,



Observed and simulated mirex concentrations in Lake Ontario sediments. One of the most important findings of this study was the value of comparatively simple simulation models.

sources of mirex at the Niagara and Oswego River mouths were allowed to advect, diffuse, and settle for 10 years. Most mirex from the Niagara River source moved parallel to the shoreline, spreading eastward as far as Rochester. Mirex from the Oswego River moved in an offshore direction. A comparison of the water quality model results with the mirex observations shows reasonable agreement. The main difference between the two is that the model results are very smooth, probably because a steady wind and a steady-state circulation model were used. Storms from various directions over the years undoubtedly stirred up the mirex and produced pattern irregularities. By running this model with various parameters, it can be adapted to similar contaminants in other lakes. Hence this study is important because it indicates the value of simple models in studying the fate of lake pollutants.

A section of Lake Michigan has also been the subject of a detailed circulation study. The array of current and temperature sensors deployed in Green Bay in May 1977 was retrieved in fall 1977 and spring 1978. Data on the exchange between the bay and Lake Michigan are being analyzed so that we can better understand water quality degradation in the bay. Large inputs of contaminants are introduced through the Fox River. A determination of the flushing rate and the interior circulation of the bay is essential to the planning of water quality improvements.

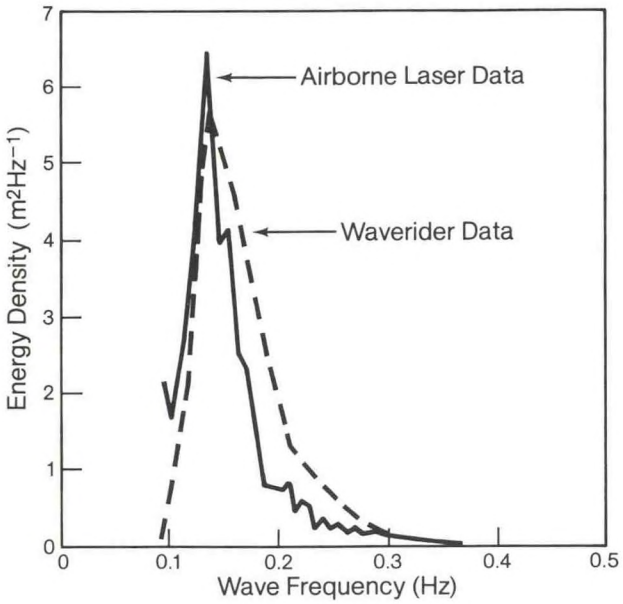


Current meters in storage for the winter. These instruments are basic to all circulation studies. To the right is an acoustical release used to free the meter string from the anchor so that the subsurface buoy can raise it to the surface for retrieval.

Surface Waves and Oscillations

Our analysis of wave data recorded from four wave staffs installed on a tower near Muskegon, Michigan, during 1977 has concentrated on calculating wave directions and directional spectra. Wave directions generally coincided with those of prevailing winds except when wind directions changed rapidly. Directional wave spectra were based on Fourier series analysis of cross-spectrum data from the staffs. The conventional method for a four-staff array is to use Fourier series representations. However, fitting a cubic spline surface to the wave staffs data and calculating the slopes and curvatures of the fitted surface yields an improved directional spectrum. This new procedure should allow reliable directional wave spectra to be obtained from a meager four-staff array.

In order to measure waves on a lake-wide scale, GLERL and the Atlantic Oceanographic and Meteorological Laboratories (AOML) undertook a cooperative effort. Waverider Buoy data were combined with wave data from an airborne laser during a storm on 20-21 November 1977. A comparison of spectra obtained from the Waverider Buoys show reasonably good agreement with those from the laser. The laser measurements have allowed us to produce a set of two-dimensional wave-height maps for Lake Michigan for each of the 2 days. Based on these preliminary maps, wave characteristics in southern Lake Michigan seem to agree with our theory concerning fetch-limited waves. In northern Lake Michigan, on the other hand, with its islands, rocky shores, and large



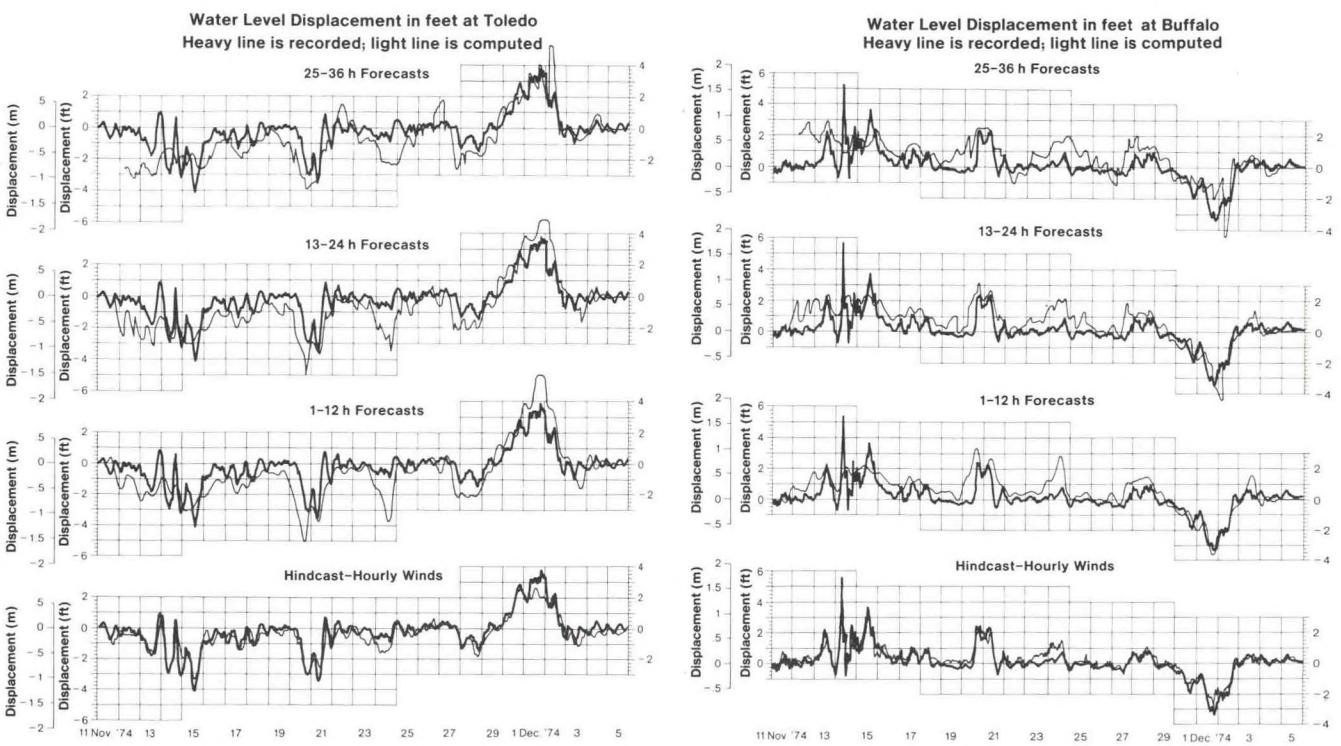
Energy density as a function of wave frequency as measured by airborne laser and by Waverider Buoy. This indicates that airborne lasers are an important new tool in wave studies, indeed the only tool that can be used for synoptic wave studies.

fetches to the south, the waves have complicated characteristics requiring further study.

New field work this year focused on waves in Lake Superior with three Waveriders deployed near Silver Bay, Minnesota, and Copper Harbor and Deer Park, Michigan. The sensors cover the western, middle, and eastern parts of the lake.

Storm surges are also part of the waves and oscillations project. In 1978 a dynamical storm-surge forecast program developed for Lake Erie was tested by the Techniques Development Laboratory during the months of November and December 1977 and April 1978. During December the water level at Buffalo, New York, exceeded the monthly mean by over 6 feet (1.8 meters) on four occasions. The forecast program gave an adequate prediction of one of the peaks at least 24 hours before it occurred. Another surge was predicted 12 hours in advance and another two peaks were forecast 8 hours before they occurred. This method offers improved guidance for warning of large water level fluctuations of Lake Erie.

Two areas on Lake Huron are also particularly sensitive to high and low water levels, Bay City on Saginaw Bay and Port Huron on the St. Clair River at the

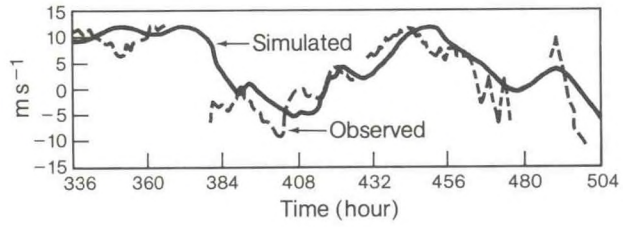


Water level displacement at Toledo, Ohio, and Buffalo, New York, as calculated by the storm surge model from wind forecasts available 1-12, 13-24, and 25-36 hours in advance. Note that the hindcasts made from recorded hourly winds show excellent agreement with observed values.

southern end of Lake Huron. The dynamical storm surge model is being modified for specific application to these areas.

At the same time, systematic attempts to compare methods of predicting surface waves on the Lakes have been started. All methods will be compared to each other and to observational data. In addition, a new technique for wave prediction is being developed by the University of Michigan under contract to GLERL.

Since winds over the Lakes play the major role in wave and storm surge prediction, research was begun on dynamical techniques for predicting these winds from weather observations and forecasts around the Lakes. GLERL's model is closely tailored after the boundary layer model at NOAA's Techniques Development Laboratory. The technique employs numerical solutions to the dynamical equations and includes the shape of the Lakes and lake temperatures and waves. This model will be tested against both field data and existing empirical methods.



Simulated and observed wind speeds over Lake Michigan. An improved dynamical model of forecasting overlake wind speeds from land wind observations and forecasts will increase the accuracy of wave and storm surge models.

Next Year . . .

- In cooperation with the Environmental Protection Agency, a large array of current meters and other sensors will be deployed in Lake Erie to examine inter-basin flux and lake-scale circulation.
- Analysis of the current and temperature data from southern Lake Michigan and Green Bay will continue.
- The storm surge model will be extended to Lake Huron and evaluated with the National Weather Service.

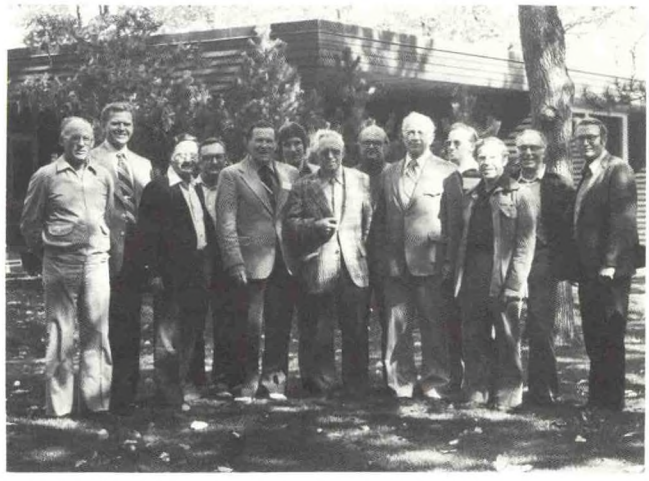
INTERNATIONAL FIELD YEAR FOR THE GREAT LAKES (IFYGL)

IFYGL, a multiagency, joint United States–Canadian program of environmental and water resource research, was initiated in 1972 to study Lake Ontario and its drainage basin. The central objective was to improve understanding and to create and refine simulation models of the lake environment to provide an improved scientific basis for management of Great Lakes water resources. Data collection was started in 1972 and completed in 1973. A major accomplishment of 1978 was the completion of the analysis phase. The reporting phase will be completed in 1979.

The 78 U.S. analysis tasks, including studies of the operant physical, chemical, and biological processes in the lake, were completed. There have been 349 articles and reports published on these results, in addition to the NOAA publication of 21 regular *IFYGL Bulletins* updating the status of the research being done, 7 Technical Manuals documenting certain aspects of the program in detail, and a volume publishing the proceedings of a special American Geophysical Union symposium on IFYGL. These reports were distributed to 450 institutions or individuals in the United States and to 250 in Canada. From this cooperation and exchange of research results, there emerged an improved knowledge of the temporal and spatial distribution and variability of physical, chemical, and biological properties. Finally, numerical models were developed and tested to simulate and predict phenomena related to water quantity, quality, and circulation, as well as to living resources in Lake Ontario.

This past fiscal year a report was published to document the IFYGL archives at the National Climatic Center in Asheville, North Carolina. Entitled *IFYGL Data Catalog: United States Data Archive* (NOAA Technical Memorandum EDIS NCC-3), this volume includes data collected by both United States and Canadian scientists. These data are available to all interested users.

Concluding the *IFYGL Bulletin* series, the proceedings of the IFYGL Wrap-Up Workshop were published this past year as *IFYGL Bulletin* No. 22. The workshop was convened to critically assess the achievements and, in some cases, weaknesses of the program. Present were 61 United States and Canadian scientists who participated in 1 of the 6 disciplinary panels: Atmospheric Boundary Layer, Chemistry and Biology, Energy Balance, Lake Meteorology, Terrestrial Water Balance, and Water Movements, and in one of the interdisciplinary panels: Evaporation Synthesis and the Great Lakes Ecosystem. In addition to reviewing the accomplishments of IFYGL, the participants iden-



The IFYGL management team. From left to right, they are David W. Witherspoon, Environment Canada; Arthur P. Pinsak, GLERL, NOAA; W. Jack Christie, Ontario Ministry of Natural Resources; C. Frederick Jenkins, GLERL, NOAA; Eugene J. Aubert, GLERL, NOAA; David W. Phillips, Atmospheric Environment Service; William J. Drescher, U.S. Geological Survey; Andrew Robertson, GLERL, NOAA; T. Lloyd Richards, Atmospheric Environment Service; Peter G. Sly, Canada Centre for Inland Waters; Donald N. Jeffs, Ontario Ministry of Environment; Ira C. Brown, Environment Canada; Nelson A. Thomas, U.S. Environmental Protection Agency.

tified priority research problems and developed recommendations for future Great Lakes research.

The IFYGL Wrap-Up Workshop was thought provoking. A selection of the major conclusions and recommendations are included here.

The real significance of this program is that it is unique in scope and depth. Practical Great Lakes management problems involve long-term environmental forcing and response times ranging from 1 year to decades or centuries. Resource managers are frequently required to make decisions quickly that will influence the long-term future. Yet ecosystem and water movement simulation models for long time periods (greater than 1 year) have a high degree of uncertainty. While such models can be improved by research, in the near term only engineering applications are feasible to apply the modeling state of knowledge to resource management decisions, specific sites, and available alternatives. Only a program of the magnitude of IFYGL could have provided the insight into processes and variability and the raw data necessary to develop, test, and calibrate both kinds of models to a high degree.

As a consequence of the long lead time necessary to significantly improve ecosystem, water movement, and hydrologic simulation and prediction models, there is a need for a government body or institution to support research in basic science separate from and in addition to engineering solutions to today's environmental problems. The management experience gained in organization and direction of such a large cooperative, multidisciplinary project as IFYGL is a scientific resource that can be efficiently applied to the problems that remain both in Lake Ontario and in other water environments.

A book entitled *IFYGL — The International Field Year for the Great Lakes* is now in preparation. The purpose is to summarize and synthesize the accomplishments of this research program. Of the 13 chapters to be co-authored by United States and Canadian major participants, 9 have been prepared and are in the scientific review and editing process. The remaining four chapters will be completed and the volume published in 1979.

In spite of some setbacks and instrument failures, IFYGL accomplishments of planned objectives were substantial and impressive. The IFYGL archive is unique and will be useful for many years, e.g., for numerical model development and testing. New techniques and instruments found effective in studying the Lake Ontario environment can be adapted to the other Great Lakes. Future limnological research will benefit from the failures, as well as the successes, of IFYGL.

Finally, from the perspective of the IFYGL attainments, a new set of research problems and questions has been identified and sequenced according to priority. The IFYGL program has been completed, but its benefits will be apparent for many years to come.

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 the future GLERL research program.

International Joint Commission (IJC)

GLERL participates in many of the activities of the IJC. Various staff are involved in committee and subcommittee work. These include work on the Research Advisory Board that provides the IJC with information on the state-of-the-art in Great Lakes research and recommends research programs. Also included is participation on the Scientific Basis for Water Quality Criteria Committee, the Pollution From Land Use Activities Reference Group, the Surveillance Subcommittee of the Water Quality Board, the Environmental Mapping Task Force, and the Federal Support Committee to the U.S. Cochairman of the Water Quality Board. The Scientific Basis for Water Quality Criteria Committee provides advice on the water quality objectives for pollutants in the Great Lakes; the Pollution From Land Use Activities Reference Group is assessing the significance and sources of pollution from land drainage to the Great Lakes and will develop recommendations on remedial measures. The Surveillance Subcommittee provides an annual assessment of the environmental quality of the Lakes, defines problem areas, and coordinates the surveillance activities of the many different agencies.

GLERL staff participated in the review and updating of the Great Lakes Water Quality Agreement between the United States and Canada that resulted in the 1978 Agreement.

Great Lakes Basin Commission

GLERL staff are involved in the Great Lakes Basin Commission as Alternate Department of Commerce Commissioners, members of the Great Lakes Basin Plan Committee (formerly the Comprehensive Coordinated Joint Plan Committee), the Priorities Committee, the Coastal Zone Management Committee, the Standing Committee on Research and Development, 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. A major effort has been development of a process to analyze effects of plans at all levels and to include public participation in the process.

The Priorities Committee develops guidelines and criteria for establishing priorities of the Federal or federally supported Great Lakes Basin water resources 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 the state pollution control plans on the water quality of the Great Lakes.

Winter Navigation Program

GLERL is working in support of the Army Corps of Engineers in a multiagency program to examine the feasibility of extending the navigation season throughout the Great Lakes system. The Ice Information Work Group is chaired by a GLERL staff member. Also, GLERL has membership on the Winter Navigation Working Committee and the Steering Committee of the Environmental Planning Task Force, and represents NOAA in the Environmental Evaluation Work Group. The laboratory provides data on the physical and structural character of lake ice; on ice formation, growth, and decay; and on the effects of winter navigation on shore properties. In addition, a marine environmental service is provided to shippers during the extended season.

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 and hydrologic data 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 Hydromet Network Work Group Study

The Great Lakes Basin Hydromet Network Work Group, with membership from NOAA, the U.S. Geological Survey, and the 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.

Lake Erie Wastewater Management Study

The Lake Erie Wastewater Management Study is a multiyear 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 participate on the Interagency Technical Advisory Group in review of study programs and recommendations.

International Association for Great Lakes Research (IAGLR)

Members of GLERL actively participate in the activities of IAGLR. They hold membership on the Publications Committee (Chairperson) and the Board of Directors.

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 Instrument 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. They work closely with GLERL researchers to ensure that instruments are compatible for the purposes of the experiment.

In July 1978, in support of a study to measure waves in Lake Superior, a remote meteorological measurement system, powered by solar panels and lead acid batteries, was established on the lake shore at Copper Harbor. The meteorological data, together with data from Waverider Buoys deployed off Silver Bay, Copper Harbor, and Deer Park were frequency multiplexed, summed, and transmitted on a phone line to Ann Arbor, where the signals were recorded and simultaneously displayed with a local time clock. A translator was built to synchronize the various signals with speed compensation for the playback to a Hewlett Packard 9603A system for data reduction. It had to be designed with careful attention to the constraints of both existing operational software and hardware on the Hewlett Packard 9603A system and the various formats of the raw data input.

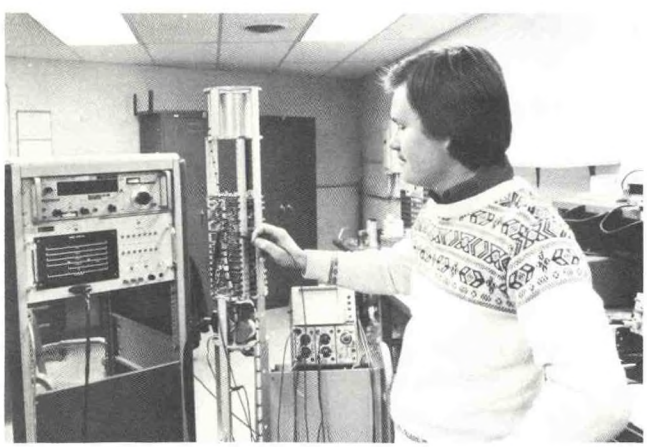
A general purpose programmable data acquisition and reduction micro-computer system, with a Zilog Z-80 central processing unit that had been developed and implemented by GLERL staff was used this past year to run stringent tests on current meters. These tests uncovered a production error on the part of the manufacturer, who was alerted. This system saved GLERL and other users wasted time and effort by uncovering the error.

A multiprobe *in situ* monitor for water quality was adapted for transparency, temperature, and depth measurements. When these data were displayed on a plotter, the resulting plot confirmed the increase in turbidity around a thermocline .

R/V *Shenehon*

GLERL operates the R/V *Shenehon* to support field activities. The ship, a converted T-boat, is 65.6 feet in length and 17.7 feet across the beam and has a 6.5-foot draft, a 600-nautical-mile range, and a cruising speed of 10 knots. For the deployment and retrieval of heavy instruments, there is a hydraulic articulated crane with a 1630-pound lifting capacity at 21-foot extension. Forward and aft winches handle wire and cable. An on-board laboratory facilitates the conduct of onsite chemical and biological experiments.

During 1978 the ship operated in Lake Michigan out of the Army Corps of Engineers facility at Grand



Technician testing a current meter in the marine instrumentation laboratory. The success of a field program is dependent on the accuracy and reliability of the instruments used.

R/V *Shenehon* crew raising sediment traps. This water chemistry study was just one of many supported by the ship last year.

(Photograph by A. P. Pinsak.)

Haven, Michigan, providing direct or logistical support to several GLERL projects.

To provide a data base for verification of an equilibrium model of the carbon system and for determination of time scales of variability, the R/V *Shenehon* measured selected chemical components and characteristics in and around the mouth of the Grand River. Dissolved oxygen, water temperature, light transmittance, carbon dioxide, organic carbon, calcium carbonate, and chlorophyll were examined in this operation.

Suspended sediment traps attached to subsurface floats were maintained through the open water season. Material collected will be used to identify transport modes, to locate sources and sinks of particulate material, and to determine alteration processes and rates.

Biology experiments supported by the ship this past year include both plankton and benthic studies. Plankton net tows, water samples, and temperature data were collected at regular intervals. These data will be used in studies of seasonal species-specific zooplankton grazing. Benthic meiofauna distribution, sediment particle size, and organic carbon content of surface sediments were observed *in situ* during a SCUBA operation. These are being used to determine seasonal variations in population and to relate distribution to those environmental variables crucial to the existence and well-being of the benthic meiofauna.

In support of several projects designed to describe and characterize circulation patterns, the ship was used to deploy and retrieve current meters. In the northern portion of Green Bay, current meters were retrieved after having been in place for 1 year. The data generated will also be used to quantify the exchange of water between Green Bay and Lake Michigan. Current meters and thermistors were deployed and later retrieved along the eastern shore of Lake Michigan.

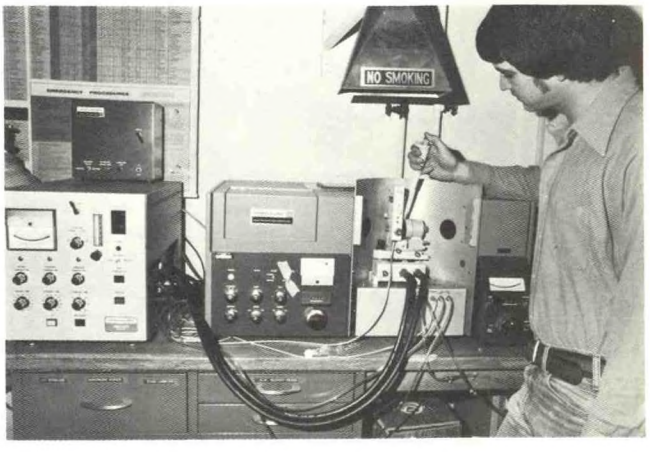
Biology Laboratory

The biology laboratory includes modern equipment and instrumentation. A multichannel Coulter Counter is used routinely to measure particle size selection and zooplankton grazing on natural lake algae and 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 outfitted for lake-side investigations on the physiology and feeding rates of planktonic and benthic organisms.

Technician calibrating the Coulter Counter in the biology laboratory. This instrument is being used to count particles in zooplankton grazing experiments.

Chemistry Laboratory

This past year the chemistry laboratory upgraded its trace metal analysis capability by the addition of a graphite furnace to the atomic absorption spectrophotometer. This has been used to analyze for selected trace metals in the dissolved and particulate state in nearshore southeastern Lake Michigan. The



Technician using the atomic absorption spectrophotometer to analyze water samples in the chemistry laboratory. The graphite furnace added this past year upgrades the trace metal analysis capability.

AutoAnalyzer II has again been used to measure nutrient (i.e., nitrogen and phosphorus) levels in Lake Michigan nearshore water samples. Techniques recently developed for the analysis of sedimentary and particulate nutrients have given excellent results. Meanwhile, the analysis of organic and inorganic carbon has continued. The techniques used in the analysis were tested and evaluated: ±5 percent precision is now possible for most types of samples. Lipid fractions were extracted from a number of samples in our study area. The gross cycling of lipids will be used as a first approximation of the cycling of polycyclic aromatic hydrocarbons. Direct extraction techniques for carbon are presently being tested. When operative, a capillary glass system recently obtained for the gas chromatograph will be used to aid in that extraction.

Ice Laboratory

An ice laboratory has been added to extend the season and expand the capabilities for the study and measurement of ice characteristics. The new facility is composed of two rooms, a work room and an ice storage room. The work room, held at +20°F, can be used to calibrate instruments in a temperature environment close to that in which they will be used. This assures the greatest possible accuracy in field experiments. The interior walls are painted flat black to facilitate optical experiments, such as the measurement of spectral radiation transmission through ice slabs. Adjacent to the work room is a smaller room held at −20°F for the storage of natural ice samples and the growth of ice crystals.

Scientist calibrating a radiometer in the ice laboratory. More accurate readings are obtained when the instrument has been calibrated in a temperature environment close to that in which it will be used. This workroom is kept at +20°F.

Computer Laboratory

The computer laboratory staff supports the work of GLERL scientists by writing, debugging, and testing programs written to the scientists' specifications, advising scientists in the creation, use, or alteration of programs, and creating retrieval subroutines to access field data. Programs are entered through a UNITECH (UT-1) Remote Communications Processor connected to a CDC 6600 computer located at the Environmental Research Laboratories in Boulder, Colorado. Recently, seven local telephone numbers were added to provide a link between Texas Instrument Silent 700, Model 745, Portable Data Terminals and the CDC 6600. This has provided interactive access and greater convenience for GLERL scientists.

A Tektronix 4014-1 Graphical Display Terminal, also connected to the CDC 6600, is used for graphical display of data on a cathode ray tube. Hard copy of the display can be obtained in seconds and microfilm

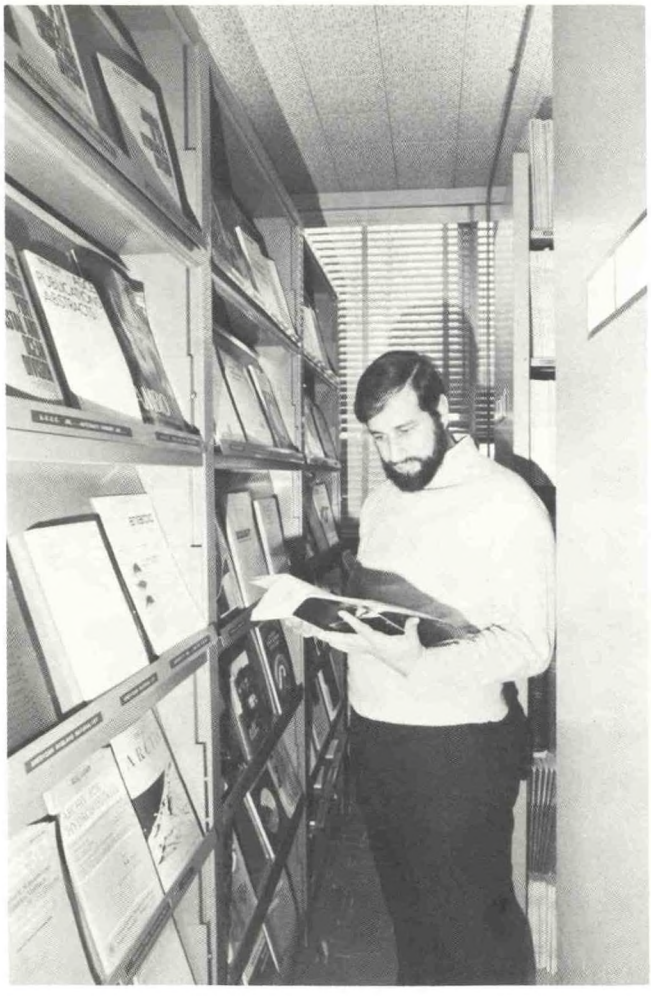
Computer specialist loading a disc pack into the Hewlett-Packard 9603A Scientific Measurement and Control System. Measurement tapes taken directly from instruments must be converted from analog to digital, reduced, and edited on this system before they can be analyzed on the CDC 6600 Computer.

copy can be printed in Boulder and returned to GLERL by mail.

Before a data base can be created, much less analyzed, on the CDC 6600, the raw field data must be converted from analog to digital and edited. The Hewable data discarded), and edited. The 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.

Library

The GLERL library has a small, growing collection of periodicals, technical reports, books, and reference materials; however, its main support of the research effort is in the form of services. Library staff are responsible for acquisition of printed materials, microfiche, and microfilm, for interlibrary loans; and for on-line literature searches.



Scientist browsing at a periodical rack in the library. Issues or titles not available can often be obtained through interlibrary loans.

About 70 percent of all interlibrary loans are obtained from the University of Michigan holdings. Regular access to this, one of the largest library systems in the world, is an invaluable research aid. The remaining 30 percent are obtained from other private or government research libraries, especially other NOAA libraries. This past year GLERL has become part of a new system for facilitating interlibrary loans between selected NOAA libraries. This is the Bibliographic Retrieval Service, Inc., (BRS) message service, which will significantly speed up response time. This is just one example of the additional cooperative networking that NOAA libraries are using to provide better services to scientists.

On-line literature searches are conducted through NOAA's Oceanic and Atmospheric Scientific Information Service (OASIS). This computerized data base indexes technical literature and research in the environmental sciences.

Publications Section

The final link in the research sequence is the dissemination of information to users, whether these are other scientists, water resource managers, or private citizens. Publications are a very important form of communication. The publications section has responsibility for the preparation of manuscripts, including editing, typing, proofing, procurement of graphics, and when appropriate, pasteup. Manuscripts are formatted according to the requirements of the publication form: articles and notes in professional journals, NOAA Technical Reports and Memoranda, or in-house reports. During the last fiscal year, 30 manuscripts were processed in the GLERL publications section.

Currently, editing of manuscripts is facilitated by an IBM Mag Card II Selectric Typewriter. Owing to the large volume of work, plans are to augment or replace this with more sophisticated equipment.

CONTRACTS AND GRANTS DURING FY 1978

Principal Investigator	Institution	Title
H. E. Allen	Illinois Institute of Technology	Trace Metal Species
A. M. Beeton	University of Michigan	A Cooperative Program in Great Lakes Long-Term Effects Research
E. F. Brater	University of Michigan	Estimating Runoff From Ungaged Drainage Basins
R. P. Canale	University of Michigan	Phytoplankton Nitrogen Utilization
C. W. Chen	Tetra Tech, Inc.	Calibration of a Three-Dimensional Ecological Hydrodynamic Model for Lake Ontario
G. T. Csanady	Woods Hole Oceanographic Institution	Coastal Circulation
B. H. DeWitt	Bernard DeWitt and Associates, Inc.	1977-78 Great Lakes Composite Ice-Cover Charts and Technical Description
J. E. Gannon	University of Michigan	Role of Predacious Rotifers
T. Green	University of Wisconsin	Current Measurements in the Coastal Zone of Eastern Lake Michigan
S.J. Jacobs	University of Michigan	A Parametric Model for Wave Prediction
G. F. Lee	University of Texas (Dallas)	Biological Characteristics of the Nearshore Waters of Lake Michigan
J. C. Makarewicz	State University of New York (Brockport)	Dynamics of Lake Michigan Plankton
C. H. Mortimer	University of Wisconsin	Inertial Motion Examined by Episode in Large Stratified Lakes
R. H. Reckhow	Michigan State University	Use of Selected Lake Models for Policy Evaluation
R. R. Rumer	State University of New York (Buffalo)	Ice Transport by Wind and Waves in the Great Lakes
R. R. Rumer	University of Delaware	Effects of Wind and Waves on Ice Transport
R. A. Sweeney	State University of New York (Buffalo)	Copepod Life History

STAFF AS OF 30 SEPTEMBER 1978

	Full Time Permanent	Commissioned Officers	Temporary or Part Time
Office of Director	10	0	1
Chemistry and Biology Group	11	0	4
Environmental Systems Engineering Group	6	0	4
Lake Hydrology Group	9	1	1
Physical Limnology and Meteorology Group	16	0	2
Total	52	1	12

Assel, R. A.	LH	Langston, A. L.	CB
Aubert, E. J.	OD	Lawton, B. J.	LH
Bell, G. L.	CB	Lee, J. P.	OD
Bennett, J. R.	PLM	Leshkevich, G. A.	LH
Bermann, L. F.	CB	Liu, P. C.	PLM
Bermick, S. J.	OD	Longanecker, M. J.	OD
Bolsenga, S. J.	LH	Malczyk, J. M.	CB
Booker, H. L.	PLM	McCormick, M. J.	CB
Boyd, J. D.	PLM	Miller, G. S.	PLM
Bramlet, R. H.	OD	Miller, T. C.	PLM
Burns, W. R.	ESE	Nalepa, T. F.	CB
Carrick, B. J.	LH	Norton, D. C.	LH
Cavanaugh, E. J.	ESE	Parker, R. K.	OD
Chambers, R. L.	CB	Pickett, R. L.	PLM
Chapra, S. C.	ESE	Pinsak, A. P.	ESE
Congdon, S. W.	ESE	Potok, A. J.	LH
Del Proposto, D. J.	OD	Quigley, M. A.	CB
Derecki, J. A.	LH	Quinn, F. H.	LH
Doughty, B. C.	PLM	Ranson, M. L.	ESE
Dungan, J. E.	PLM	Rao, D. B.	PLM
Eadie, B. J.	CB	Robertson, A.	CB
Gales, J. E.	LH	Rodante, F. C.	OD
Grasso, J. O.	CB	Royse, G. B.	PLM
Grimes, J. E.	ESE	Saylor, J. H.	PLM
Grumblatt, J. L.	PLM	Scavia, D.	CB
Herche, L. R.	ESE	Schwab, D. J.	PLM
Hill, R. L.	OD	Soo, H. K.	PLM
Hodson, A. W.	OD	Stankevich, E. A.	CB
Huang, J. C. K.	PLM	Tarapchak, S. J.	CB
Jenkins, C. F.	ESE	Vanderploeg, H. A.	CB
Kelley, J. M.	ESE	White, B. J.	PLM
Kelley, R. N.	LH	Willis, P. D.	OD
Kistler, R. D.	PLM		

LH—Lake Hydrology Group.
OD—Office of the Director.
CB—Chemistry and Biology Group.
PLM—Physical Limnology and Meteorology Group.
ESE—Environmental Systems Engineering Group.

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

Aubert, E. J. 1978. Cross-panel considerations. *IFYGL Bull.* 22:96–103.

Aubert, E. J. 1978. Relevance of IFYGL. *Verh. Internat. Verein. Limnol.* 20:317–323.

Bennett, J. R. 1977. A model of Lake Ontario's circulation. *IFYGL Bull.* 21:38–43.

Bolsenga, S. J. 1977. Lake-land precipitation relationships using northern Lake Michigan data. *J. Appl. Meteorol.* 16:1158–1164.

Bolsenga, S. J. 1977. Preliminary observations on the daily variation of ice albedo. *J. Glaciol.* 18:517–521.

Bolsenga, S. J. 1977. *The radiation balance over a continuous snow surface: A review.* GLERL Open File Report.

Bolsenga, S. J. 1978. *On the use of multispectral radar to define certain characteristics of Great Lakes ice.* NOAA Technical Memorandum ERL GLERL-17.

Bolsenga, S. J. 1978. *Photosynthetically active radiation transmission through ice.* NOAA Technical Memorandum ERL GLERL-18.

Bolsenga, S. J. 1978. A technique for estimating monthly global radiation. *Water Resour. Bull.* 14:679–688.

Boyd, J. D., and Eadie, B. J. 1977. Evaluation of U.S. IFYGL chemical data at the master stations. *IFYGL Bull.* 21:49–61.

Boyd, J. D., and Eadie, B. J. 1978. *Temperature and dissolved oxygen data for Lake Ontario, 1972 (IFYGL).* NOAA Technical Memorandum ERL GLERL-21.

Danek, L. J.*, and Saylor, J. H. 1977. Measurement of the summer currents in Saginaw Bay, Michigan. *J. Great Lakes Res.* 3:65–71.

Derecki, J. A. 1978. *Description of the method used by the Great Lakes Environmental Research Laboratory to determine flows in the St. Clair and Detroit Rivers for the River Flow Subcommittee.* GLERL Open File Report.

Gannon, J. E.†, and Robertson, A. 1978. Development of checklists on Great Lakes biota. *J. Great Lakes Res.* 4:104–105.

Great Lakes Environmental Research Laboratory. 1977. *Technical Plan for the Great Lakes Environmental Research Laboratory.* Ann Arbor: Great Lakes Environmental Research Laboratory.

Grumblatt, J. L. 1977. *Heat advection in Lake Ontario, 1972–73.* GLERL Open File Report.

Huang, J. C. K. 1977. *A general circulation model for lakes.* NOAA Technical Memorandum ERL GLERL-16.

Huang, J. C. K. 1977. Simulation study of the North Pacific Ocean. In *Symposium on Modeling of Transport Mechanisms in Oceans and Lakes,* pp. 21–34. Ottawa, Ontario: Marine Sciences Directorate.

Huang, J. C. K. 1978. Numerical simulation studies of oceanic anomalies in the North Pacific Basin. I: The ocean model and the long-term mean state. *J. Phys. Oceanogr.* 8:755–778.

Huang, J. C. K. 1978. Response of the NCAR general circulation model to North Pacific sea surface temperature anomalies. *J. Atmos. Sci.* 35:1164–1179.

Jenkins, C. F. 1978. The joint Canadian-United States Great Lakes research project, IFYGL. *Ambio* 7:98–105.

Kohberger, R. C.†; Scavia, D.; and Wilkinson, J. W.† 1978. A method for parameter sensitivity analysis in differential equation models. *Water Resour. Res.* 14:25–29.

Liu, P. C. 1977. A summary of IFYGL surface wave studies. *IFYGL Bull.* 21:44–48.

Nalepa, T. F. 1978. Freshwater macroinvertebrates. *J. Water Pollut. Control Fed.* 50:1301–1313.

Pickett, R. L., and Bermick, S. 1977. Observed resultant circulation of Lake Ontario. *Limnol. and Oceanogr.* 22:1071–1076.

Pinsak, A. P., and Rodgers, G. K.† 1978. Energy balance panel. *IFYGL Bull.* 22:40–58.

Potok, A. J. 1978. *Analysis of the effect on Lake Ontario water levels of maintaining year-round safe navigation depths in the St. Lawrence River.* GLERL Open File Report.

Quinn, F. H. 1978. Hydrologic response model of the North American Great Lakes. *J. Hydrol.* 37:295–307.

*No longer affiliated with this laboratory.
†Not affiliated with this laboratory.

Quinn, F. H. 1978. Lake Superior regulation effects. *Water Resour. Bull.* 14:1129–1142.

Quinn, F. H., and den Hartog, G.† 1978. Evaporation synthesis panel. *IFYGL Bull.* 22:59–68.

Rao, D. B. 1977. Free internal oscillations in a narrow, rotating basin. In *Symposium on Modeling of Transport Mechanisms in Oceans and Lakes,* pp. 391–398. Ottawa, Ontario: Marine Sciences Directorate.

Rao, D. B. 1978. A numerical procedure for computing resonant periods of natural water bodies. In *Proceedings, Conference on Tsunamis,* pp. 159–165. Ottawa, Ontario: Marine Sciences Directorate, Department of Fisheries and the Environment.

Richards, T. L.†, and Aubert, E. J. 1978. Introduction. *IFYGL Bull.* 22:1–3.

Robertson, A., and Scavia, D. 1978. Ecosystem and water quality modeling during IFYGL. *Verh. Internat. Verein. Limnol.* 20:311–316.

Robertson, A., and Jenkins, C. F. 1978. The joint Canadian-American study of Lake Ontario. *Ambio* 7:107–112.

Saylor, J. H., and Boyce, F. M.† 1978. Water movements panel. *IFYGL Bull.* 22:69–84.

Scavia, D. 1977. Modeling in water management. *Bioscience* 27:688.

Strong A. E. †, and Eadie, B. J. 1978. Satellite observations of calcium carbonate precipitations in the Great Lakes. *Limnol. Oceanogr.* 23:877–887.

Tarapchak, S. J., and Wright, R. F.† 1977. Three oligotrophic lakes in northern Minnesota. In *North American Project—A Study of U.S. Water Bodies,* Ed. L. Seyb and K. Randolph, pp. 64–90. Corvallis, Oregon: U.S. Environmental Protection Agency.

Thomas, N. A.†; Nalepa, T. F.; and Robertson, A. 1978. Biology-Chemistry program during IFYGL. *Verh. Internat. Verein. Limnol.* 20:304–310.

†Not affiliated with this laboratory.

PRESENTATIONS

Allender, J. H.†, and Saylor, J. H. 1978. Mixing times in southern Lake Michigan. 21st Conference on Great Lakes Research, 9–11 May 1978, at the University of Windsor, Windsor, Ontario.

Assel, R. A., and Quinn, F. H. 1978. A historical perspective of the 1976–77 Lake Michigan ice cover. 21st Conference on Great Lakes Research, 9–11 May 1978, at the University of Windsor, Windsor, Ontario.

Bennett, J. R. 1977. Long-term simulation of Lake Ontario circulation. Great Lakes Marine Environment Seminar, 11 October 1977, at the University of Michigan, Ann Arbor, Michigan.

Bolsenga, S. J. 1978. Determining precipitation over the Great Lakes from overland data: The methodological controversy analyzed. 21st Conference on Great Lakes Research, 9–11 May 1978, at the University of Windsor, Windsor, Ontario.

Boyd, J. D. 1978. Metalimnetic oxygen minima in Lake Ontario. 21st Conference on Great Lakes Research, 9–11 May 1978, at the University of Windsor, Windsor, Ontario.

Chambers, R. L. 1978. Nearshore sedimentation in southeastern Lake Michigan. North-Central Section Meeting of the Geological Society of America, 1–2 May 1978, Ann Arbor, Michigan.

Chambers, R. L.; Eadie, B. J.; and Robertson, A. 1978. The variability of chemical properties and dispersal of particulate material. Coastal Workshop, 21–23 February 1978, Sundridge, Ontario.

Chapra, S. C. 1978. Application of the phosphorus loading concept to the Great Lakes. Annual Meeting of the American Society of Limnology and Oceanography, 19–22 June 1978, Victoria, British Columbia.

Chapra, S. C. 1978. Phosphorus loading design for the lower Great Lakes. 21st Conference on Great Lakes Research, 9–11 May 1978, at the University of Windsor, Windsor, Ontario.

Charlesworth, L. J.†; McBride, R. T. J.†; and Chambers, R. L. 1978. Grain-size distribution characteristics and environmental analysis of Maumee Bay bottom sediments. North-Central Section Meeting of the Geological Society of America, 1–2 May 1978, Ann Arbor, Michigan.

Eadie, B. J. 1977. The $CaCO_3$ cycle in the Great Lakes. Great Lakes Research Division Seminar Series, 15 November 1977, Ann Arbor, Michigan.

Eadie, B. J. 1978. Nimbus G Coastal Zone Color Scanner calibration/validation experiments for 1978–79. Great Lakes Coastal Zone Color Scanner Workshop, 26–27 April 1978, Cleveland, Ohio.

Eadie, B. J., and Robertson, A. 1977. Applications of multispectral sensing to the Great Lakes. Meeting of the Federation of Analytical Chemistry and Spectroscopy Society, 14–16 November 1977, Detroit, Michigan.

Eadie, B. J., and Chambers, R. L. 1978. Nearshore sediment chemistry in southeastern Lake Michigan. North-Central Sectional Meeting of the Geological Society of America, 1–2 May 1978, Ann Arbor, Michigan.

Eadie, B. J.; Chambers, R. L.; and Robertson, A. 1978. Physical and chemical properties of particulates in the nearshore zone of Lake Michigan. Coastal Workshop, 21–23 February 1978, Sundridge, Ontario.

Huang, J. C. K., and Sloss, P. W.* 1978. Responses of a Great Lake to the mean steady and time-dependent atmospheric forcing: Homogeneous case. 1978 Annual Meeting of the American Geophysical Union, 17–21 April 1978, Miami Beach, Florida.

Leshkevich, G. A., and Assel, R. A. 1978. Description of an automated process for digitizing two-dimensional ice-cover information. 21st Conference on Great Lakes Research, 9–11 May 1978, at the University of Windsor, Windsor, Ontario.

Liu, P. C. 1977. Higher order spectra and stationarity of wind waves. Fifth Conference on Probability and Statistics in Atmospheric Sciences, 15–18 November 1977, Las Vegas, Nevada.

Liu, P. C. 1978. Higher order wave spectra. 16th Conference on Coastal Engineering, 28 August–1 September 1978, Hamburg, Germany.

Nalepa, T. F. 1978. Zoobenthos sampling in southeastern Lake Michigan: Vertical distribution and sieve size efficiency. 26th Annual Meeting of the North American Benthological Society, 10–12 May 1978, Winnipeg, Manitoba.

Pinsak, A. P. 1977. Mission responsibilities and interagency program coordination of the Great Lakes Environmental Research Laboratory. Annual Meeting of the League of Women Voters, Lake Michigan Inter-League Group, 20 October 1977, St. Joseph, Michigan.

†Not affiliated with this laboratory.

*No longer affiliated with this laboratory.

Pinsak, A. P. 1977. Water futures of Lake Michigan. National Audubon Society Seminar on Lake Michigan Issues, 30 September-2 October 1977, Milwaukee, Wisconsin.

Pinsak, A. P. 1978. Application of the Bowen ratio to evaporation estimates over a dimictic lake. 21st Conference on Great Lakes Research, 9-11 May 1978, at the University of Windsor, Windsor, Ontario.

Pinsak, A. P. 1978. Energy budget for Lake Ontario. Seminar, 6 July 1978, at Ohio State University, F. T. Stone Laboratory, Put-in-Bay, Ohio.

Potok, A. J., and Derecki, J. A. 1978. Evaluation of runoff simulation for southeast Michigan with SSARR watershed model. 21st Conference on Great Lakes Research, 9-11 May 1978, at the University of Windsor, Windsor, Ontario.

Rao, D. B. 1977. Free and forced oscillations in lakes. Seminar, 11 October 1977, at Andhra University, Waltair, India.

Rao, D. B. 1977. Some dynamical aspects of lake circulation and modeling. Seminar, 4 October 1977, at Andhra University, Waltair, India.

Rao, D. B. 1978. A review of the physical limnology program at GLERL. Seminar, 16 March 1978, Burlington, Ontario.

Scavia, D. 1977. Applied ecosystem approach to water quality management. Water Resource Management Course, 16 November 1977, East Lansing, Michigan.

Scavia, D. 1977. Problems in ecological modeling for management. School of Public Health, Environmental Monitoring Course, 8 November 1977, at the University of Michigan, Ann Arbor, Michigan.

Scavia, D. 1977. A simulation analysis of biological and chemical properties in Lake Ontario during IFYGL. Great Lakes and Marine Environment Lecture Series, 13 December 1977, Ann Arbor, Michigan.

Scavia, D. 1978. The role of modeling in investigating large-scale, interdisciplinary problems. Coastal Workshop, 21-23 February 1978, Sundridge, Ontario.

Scavia, D., and Robertson, A. 1978. Examination of phosphorus recycling and control of productivity in Lake Ontario. 41st Annual Meeting of the American Society of Limnology and Oceanography, 19 June 1978, at the University of British Columbia, Victoria, British Columbia.

Schwab, D. J. 1978. Analytic and empirical response functions for storm surges on Lake Erie. International Symposium on Long Waves in the Ocean, 7 June 1978, Ottawa, Ontario.

Tarapchak, S. J. 1978. Molybdate-catalyzed hydrolysis of soluble reactive phosphorus in Lake Michigan. 41st Annual Meeting of the American Society of Limnology and Oceanography, 19 June 1978, at the University of British Columbia, Victoria, British Columbia.

Tarapchak, S. J.; Bigelow, S. M.*; and Rubitschum, C.* 1978. The Chamberlain-Shapiro isobutanol extraction method and its application to soluble reactive phosphorus measurements in Lake Michigan. 21st Conference on Great Lakes Research, 9-11 May 1978, at the University of Windsor, Windsor, Ontario.

Tarapchak, S. J.; Chambers, R. L.; Bigelow, S. M.*; and Rubitschum, C.* 1978. A comparison of three methods for measuring soluble reactive phosphorus. 21st Conference on Great Lakes Research, 9-11 May 1978, at the University of Windsor, Windsor, Ontario.

Tarapchak, S. J.; Smith, R.*; Quigley, M. A.; Lukasiewicz, J.*; and Malony, L. M.* 1978. Interpretation of phytoplankton multiple nutrient limitation experiments at an offshore station in Lake Michigan. 21st Conference on Great Lakes Research, 9-11 May 1978, at the University of Windsor, Windsor, Ontario.

Vanderploeg, H. A. 1977. Problems with aperture-tube overlap in analyses of seston-size distributions in lake water. 10th Coulter Counter User Conference, 3 October 1977, Chicago, Illinois.

Vanderploeg, H. A. 1978. Seasonal particle-size selection and grazing by *Diaptomus* in Lake Michigan. 21st Conference on Great Lakes Research, 9-11 May 1978, at the University of Windsor, Windsor, Ontario.

*No longer affiliated with this laboratory.

CONTRACTOR PUBLICATIONS

Bennett, J. R. 1977. Non-linearity of wind driven currents. In *Symposium on Modeling of Transport Mechanisms in Oceans and Lakes,* pp. 91-98. Ottawa, Ontario: Marine Sciences Directorate.

Bennett, J. R. 1978. The circulation of large lakes. In *Upwelling Ecosystems,* ed. R. Boje and M. Tomczak, pp. 223-234. Berlin: Springer-Verlag.

Birchfield, G. E., and Lunde, A. T. 1977. *A time-dependent model of a coastal boundary layer with friction.* Northwestern University Applied Mathematics Technical Report No. 7710 prepared for GLERL by Northwestern University under Contract No. 04-4-022-37.

Csanady, G. T. 1977. The coastal boundary layer. In *Studies in Geophysics: Estuaries, Geophysics, and the Environment,* Chapter 6. Washington, D.C.: National Academy of Sciences.

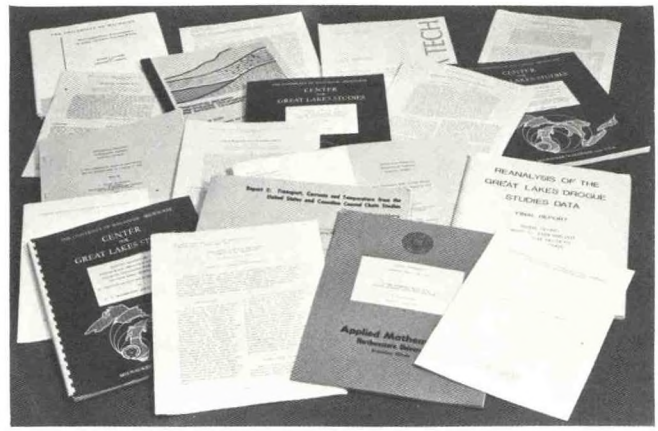
Csanady, G. T. 1978. The arrested topographic wave. *J. Phys. Oceanogr.* 8:47-62.

Gannon, J. E., and Stemberger, R. S. 1978. Zooplankton (especially crustaceans and rotifers) as indicators of water quality. *Trans. Amer. Micros. Soc.* 97:16-35.

Marmorino, G. O. 1978. *Time-series plots of Lake Ontario currents, temperatures, and winds (IFYGL, winter 1972-73).* Special Report No. 36 prepared for GLERL by the University of Wisconsin-Milwaukee, Center for Great Lakes Studies, under Contract No. NOAA-3-35468.

Rumer, R. R.; Crissman, R. D.; and Wake, A. 1978. *Dynamics of ice transport in large lakes.* Final Report prepared for GLERL by the University of Delaware, Department of Civil Engineering, under Contract No. NOAA-03-6-022-35236.

Stoermer, E. F., and Ladewski, T. B. 1978. *Phytoplankton associations in Lake Ontario during IFYGL.* Special Report No. 62 prepared for GLERL by the University of Michigan, Great Lakes Research Division, under Grant No. NOAA-04-4-022-32.



Reports prepared by contractors over the last few years. The expertise of outside scientists under contract to GLERL is an important supplement to in-house research.

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