TECHNICAL PLAN

for the

GREAT LAKES ENVIRONMENTAL RESEARCH LABORATORY

Dr. Eugene J. Aubert, Director

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

Ann Arbor, Michigan

January 1977

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NOTICE

PREFACE

The Great Lakes Environmental Research Laboratory (GLERL) was established on 24 April 1974 to provide a focus for NOAA's environmental research in the Great Lakes region. GLERL was formed by combining the staff of the International Field Year for the Great Lakes (IFYGL) Project Office, Rockville, Maryland, with the Limnology and Computer Divisions, Lake Survey Center, Detroit, Michigan. The Ann Arbor, Michigan, Laboratory was opened in August 1974.

GLERL's mission is to conduct research directed toward an understanding of the environmental processes and the solving of problems in resource management and environmental services in the Great Lakes and their watersheds. In support of this mission, the following central objectives have been established:

- To improve environmental information (e.g., statistical description, prediction, and simulation) concerning properties, processes, and phenomena of the Great Lakes and the Great Lakes watersheds.

- To develop improved environmental service tools, data, information, and consulting services to support the needs of users in government and private organizations.

- To provide an environmental advisory service, as appropriate.

The scope of GLERL's research includes field, analytic, and laboratory investigations into the limnological, hydrological, meteorological, and limnogeological properties of the Lakes, their basins, and the atmosphere.

This Plan, the third in an annual series, contains the rationale for our research program and describes the 12 active projects. This version was prepared to facilitate coordination and information exchange with Great Lakes water-related research and management agencies. Another version of this *Technical Plan* including detailed task descriptions was prepared primarily for GLERL research management purposes. Such task detail can be made available upon request.

TABLE OF CONTENTS

LIST OF FIGURES

TABLE

1.0 Introduction. This *Technical Plan* documents the GLERL research program as of December 1976, organized in terms of projects, and updates the Plan dated January 1976. This version of the *Technical Plan* details the projects and identifies task titles and objectives, but does not include other detailed task documentation. Projects are conceived as broad units of research of some duration. Tasks are shorter term and more definitive and identify products targeted for completion at a particular time.

The projects in this *Technical Plan* have evolved somewhat from those in existence 1 year ago due to GLERL's increased maturity, additional accomplishments, and redefinition of objectives. This is the last year for the formal IFYGL research program although the data archive will be useful indefinitely. The focus of each project has been sharpened. Also there are now fewer tasks; 7 tasks have been completed, 3 are inactive, and 3 new tasks have been added.

2.0 Perspectives. The detailed *Technical Plan* was prepared primarily for GLERL purposes. It represents a tool for managing the research program. This shorter version of the Plan is being distributed externally to facilitate coordination with managers, researchers, and users of GLERL products.

The GLERL research program is dynamic. Ideas and accomplishments are the keys to a successful research program. Since ideas and suggestions are encouraged at all levels, it is desirable to put in perspective what GLERL is trying to accomplish in the Great Lakes.

Our research mission includes both process-oriented and problem-oriented environmental research in support of Great Lakes resource management and environmental services. Our goal is to develop a sound scientific basis to be used for rational decisions associated with the development and use of our Great Lakes resources. Our comprehension of user needs for environmental information in relation to our capabilities and understanding of the relative importance of environmental problems influences the styling of the problem-oriented research program. And always, we must guard against undertaking too many unrelated projects and tasks, or our accomplishments will be small owing to overcommitment of limited resources.

2.1 Planning Process. This 1977 version of the *GLERL Technical Plan* was developed with several objectives in mind: (1) to sharpen the focus on key Great Lakes environmental problems and key environmental processes; (2) to sharpen the focus of project objectives; (3) to initiate multidisciplinary research where desirable; and (4) to identify new research initiatives, as appropriate. The planning process involved the following steps:

- Reviewing statutes, NOAA responsibilities, and the GLERL mission.

- Reviewing Great Lakes environmental problems.

- Establishing priorities.

- Selecting key problems and processes for future emphasis.

A more detailed description of the planning process is contained elsewhere.[1] A summary of the Great Lakes environmental problems and activities for project emphasis is contained in Table 1.

2.2 Research Sequence. While the ideas are not new, the research sequence of Figure 1 conceptually portrays the GLERL overall research approach. Problems for research investigation originate from either a scientific motivation or a user need. After suitable problem definition, an interdependent approach sequence includes data collection, analysis, modeling, and evaluation with various feedback loops. GLERL research products support an advisory service and include reports, articles, presentations, consultation, advice, and tools (e.g., data bases and models) for coordination with resource managers and the scientific community.

User needs involve the definition of the environmental problems (the issues and research needs) of importance to the user and an identification of the sensitivity of the user's activity to the environment. Relevant questions and management alternatives need definition pertinent to the environmental sensitivities. These considerations are then translated into environmental service requirements or project objectives.

In the scientific approach, project objectives likewise must be defined. Here the definition of objectives, products, and scientific questions are concerned with the state-of-the-art in description, understanding, and prediction of dependent variables of theoretical importance and significance to the natural distribution and variability of the Great Lakes and the Great Lakes watersheds. Studies to improve prediction require improved understanding of relevant phenomena and processes. Important scientific objectives were defined by a GLERL Workshop.[2]

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1 E. J. Aubert. *A Basis for the GLERL Research Program.* Manuscript in preparation.

2 A. P. Pinsak (ed.). 1975. *Proceedings of Workshop on Priority Great Lakes Environmental Research Initiatives.* National Oceanic and Atmospheric Administration: Boulder, Colorado.

Table 1. Project-Problem Emphasis

Project	Problem
P-1	1. Nearshore processes and phenomena. 2. Nearshore-open water relationships. 3. Models to support trade-off analyses in water related activity planning. 4. Transport and diffusion prediction.
P-2	1. Prediction of surface waves, wind tides, storm surges, seiches, and flooding. 2. Climatology of waves and water level fluctuations.
P-3	1. Limnological and meteorological research.
P-4, -5, -6	1. Nearshore processes and phenomena. 2. Nearshore-open water relationships. 3. Models to support trade-off analyses in water-related activities. 4. Long-range effects of pollution, overfishing, and man-induced changes.
P-7	1. Models to support trade-off analyses in water levels and flows in connecting channels. 2. Climatology of flows in connecting channels. 3. Water level and flow information to support ocean engineering and marine resource decision processes.
P-8	1. Prediction of ice formation and breakup in the Lakes, bays, and connecting channels. 2. Prediction of ice transport in the Lakes. 3. Ice information to support ocean engineering, marine resource management, and extension of navigation decision processes.
P-9	1. Environmental advisory service. 2. Participation on Boards, Committees, and Task Forces of IJC and GLBC to provide advice and products and to determine research needs.
P-10	1. Environmental models and information to support trade-off analyses in water-related activities.
P-11	1. Limnological and meteorological research of processes and mechanisms. 2. Prediction and simulation models.
P-12	1. Great Lakes waves and flooding prediction. 2. Fox-Wolf Level B Study. 3. Nearshore environmental problems and processes.

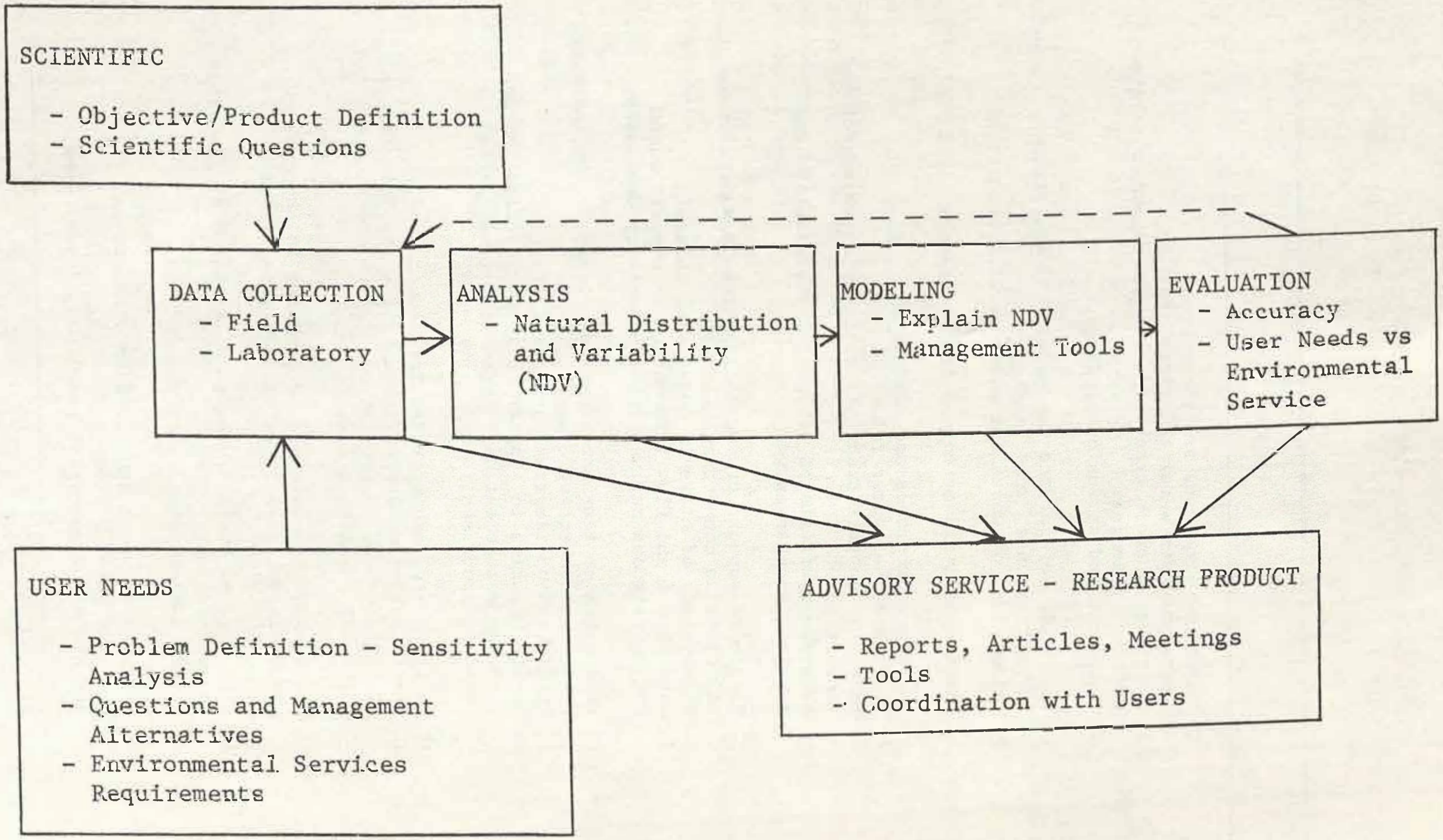

Figure 1. Research sequence.

Data collection involves both field observations of the physical, chemical, and biological variables, using various facilities (e.g., ships, buoys, water chemistry laboratory, marine instrumentation laboratory, biology laboratory), and laboratory experiments or studies that use facilities to collect data in a controlled environment.

Analysis and modeling studies involve numerical and theoretical approaches. Analysis studies define the environmental variations and variability in space and time and organize data to improve our understanding of phenomena and processes. Mathematical models are developed to predict and simulate the environment to explain the natural distribution and variability. Prediction and simulation models must be evaluated for accuracy and in terms pertinent to the user's decision process.

All of these research activities support the GLERL advisory service function to provide environmental coordination and consulting services within the scope of the Laboratory to individuals and institutions - both government and private organizations. The problem-oriented research will develop improved tools to support the environmental services provided by GLERL and other NOAA components, e.g., National Weather Service.

3.0 Project 1. WATER MOVEMENTS AND TEMPERATURE

Project Scientist. D. B. Rao

Objectives. The objectives of this project are as follows:

(1) To develop improved climatological information on the distribution and variability of currents and temperatures, and to study their dependence on meteorological and hydrological forces.

(2) To develop and test improved numerical hydrodynamic models that can simulate and predict the temperature and current distributions in the Lakes.

(3) To develop and test improved models to simulate and predict the transport and diffusion of pollutants and to participate in coupling these models to aquatic ecology and water quality models. A hierarchy of such numerical models of different complexities will be developed and tested for use as tools in water resources planning.

(4) To improve the understanding of physical processes occurring in the lake by analyzing data and the results from the numerical models.

Background. Since NOAA is responsible for observing and predicting the environment, this project applies that mission to the physical state of the Great Lakes. The physical state of these lakes can be predicted in terms of the distribution of temperatures, currents, waves, and water level fluctuations. Each of these physical variables impacts on environmental, chemical, and biological processes and influences a multitude of user activities. Some examples of the latter are water supply management, waste water management, power plant sitings, shipping, boating, and shoreline erosion processes.

These physical variables in the lake describe various processes exhibiting a wide range of space and time scales (Figure 2). There are phenomena such as upwelling and coastal jets that are confined to near-shore regions and mean circulations and seasonal stratifications that are lake wide. The driving atmospheric forces (wind stress, pressure gradient, heat fluxes) also change seasonally and exhibit spatial and temporal variations. In order to form a coherent picture and to understand the various processes going on in the lake, these different space and time scales must be sorted. This sorting is also essential for using such information in user activities. For example, problems related to water supply management and power plant sitings are affected by the long-term characteristics of transport, whereas shipping and boating are affected by the short-term wave characteristics.

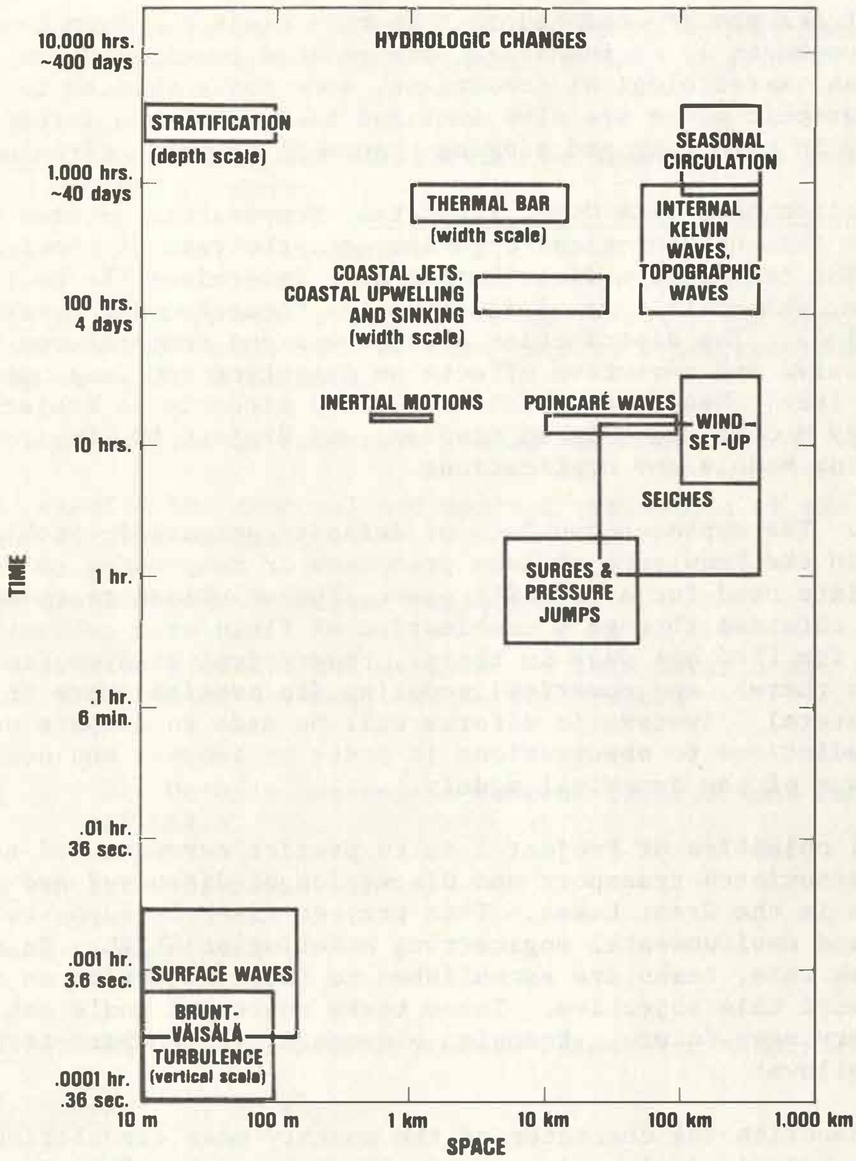

Figure 2. Scales of physical lake phenomena.

Several tasks are grouped together in this project. Even though the primary emphasis is on investigations related to circulation, stratification, and meteorological conditions, some tasks related to internal and topographic waves are also included because of the direct role they play in upwelling and sinking phenomena and mean circulations.

Interrelationships with Other Projects. Temperature governs the metabolic rate of biological organisms and the rate of chemical reactions. The temperature distribution also determines the heat content of a lake, which, in turn, influences ice formation and breakup (Project 8, Lake Ice). The distribution of currents and temperatures govern the diffusive and advective effects on dissolved and suspended substances in a lake. Hence Project 1 is related directly to Project 4, Aquatic Ecology Models and Related Studies, and Project 10, Environmental Engineering Models and Applications.

Approach. The approach consists of defining scientific problems based on gaps in the knowledge of lake processes or responding to problems of immediate need for a specific user. The solutions to these problems are then obtained through a combination of field data collection and analysis (to find out what is there), theoretical studies (to find out why it is there), and numerical modeling (to predict where it will be in the future). Systematic efforts will be made to compare numerical model predictions to observations in order to improve and define the limitations of the numerical models.

The final objective of Project 1 is to predict currents and temperatures and the associated transport and dispersion of dissolved and suspended materials in the Great Lakes. This project directly supports aquatic ecology and environmental engineering modeling at GLERL. In order to accomplish this, tasks are established to focus attention on specific steps toward this objective. These tasks represent goals achievable in the very near future. Examples of some of these short-term goals are as follows:

(1) To describe the character of the monthly mean circulations in Lake Ontario during winter and summer from the IFYGL data set.

(2) To describe the mean winter circulations in Lake Huron by means of a specific field study.

(3) To assess the ability of simple homogeneous numerical models to describe the observed winter circulations in goals (1) and (2).

(4) To describe the exchange of water between Lakes Michigan and Huron through the Straits of Mackinac and to investigate long period current oscillations in these Straits.

(5) To continue to build multilevel numerical hydrodynamic models and to verify them using IFYGL data from Lake Ontario.

3.1 Task 1.1. Distribution and Variability of Temperatures and Currents in Lake Ontario

Task Scientist. R. L. Pickett

Objectives. The general objective is to identify and explain the distribution and variability of Lake Ontario's temperatures and currents by using the 1972 IFYGL data.

Specific objectives of this task are as follows:

(1) To examine the temporal and spatial variations of the measured and derived variables.

(2) To explain these observed variations.

(3) To provide products for an atlas of Lake Ontario and input for the IFYGL water movements scientific report.

3.2 Task 1.2. Lake Ontario Lagrangian Current Observations and Analysis (IFYGL)

Task Scientist. J. H. Saylor

This task is inactive.

3.3 Task 1.3. Lake Ontario Water Movements Scientific Report (IFYGL)

Task Scientist. J. H. Saylor

Objectives. The objective of the IFYGL water movements scientific report is to summarize and synthesize the significant results of all water movement related research conducted on Lake Ontario as part of IFYGL. This summary effort will present in one document the major achievements accomplished to advance the knowledge of the physical limnology of Lake Ontario through research investigations of the IFYGL program.

3.4 Task 1.4. Lake Huron Current Studies

Task Scientist. J. H. Saylor

Objectives. The main objective of this task is delineation of the natural distribution and variability of currents in Lake Huron during both density stratified and unstratified seasons of the year. Steady state currents related to prevailing and persistent forcing by wind stress acting on the water surface and interdependent distributions of water density will be determined.

3.5 Task 1.5. Lake Superior Current Studies

Task Scientist. J. H. Saylor

This task is complete. A final report is on file.

3.6 Task 1.6. Flux Between Lake Michigan and Lake Huron

Task Scientist. A. P. Pinsak and J. H. Saylor

Objectives. Net exchange of water and its contained dissolved constituents and suspended material between Lakes Michigan and Huron and the factors responsible for the exchange will be systematically investigated during a single open water season to determine the impact of Lake Michigan on the water quality of Lake Huron.

3.7 Task 1.7. Current Study-Oswego Harbor

Task Scientist. G. S. Miller

This task is complete. A final report is on file.

3.8 Task 1.8. Lake-Scale Circulation Model

Task Scientist. J. C. K. Huang and P. W. Sloss

Objectives. The general objective of this task, under the overall GLERL missions and objectives, is to develop a flexible large-scale lake circulation model based on hydrodynamic and thermodynamic equations for the simulation of temporal and spatial variations of the mean circulation patterns and mean density distributions in the lake.

Specific objectives are as follows:

(1) To develop a Lake Ontario general circulation model applicable to other Great Lakes with minor alterations.

(2) To make intercomparisons between field observations, especially the IFYGL data, and the simulated results for verification and tuning of the model.

(3) To provide time-dependent climatology for other lakes based on simulated output from similarly developed lake models with the incorporation of all essential physical processes included in the Lake Ontario model.

3.9 Task 1.9. Nearshore Circulation Model (Inactive)

Task Scientist. J. C. K. Huang and P. W. Sloss

Objectives. This task is mainly concerned with understanding fundamental aspects of nearshore processes and phenomena in the shallow water of the Great Lakes region. Physical processes in the nearshore zone are closely integrated with the overall processes in the lake basin. The major objective of this task is, therefore, to develop a fine mesh, limited area model (LAM) to couple to the large-scale general circulation model of the lake (LAKSCM) for the understanding of small-scale physical processes and natural phenomena in a limited area, especially in the nearshore zone of the lake. By using the limited area model as the service tool, emphasis will be put upon studies of mixing, dispersion, and diffusion phenomena along the shallow perimeter of the lake from certain independent sources and/or sinks of conservative properties, such as estuary discharges and power plant effluents. The limited area model will also be ideal for close intercomparisons with well-designed field observations, such as those carried out during IFYGL. This provides a powerful tool for the realistic tuning of the numerical model to be developed for Task 1.8, Lake-Scale Circulation Model. The activation of this task is dependent upon the results of Task 1.8.

3.10 Task 1.10. Current Flow through the Straits of Mackinac

Task Scientist. J. H. Saylor

Objectives. The objectives of this investigation are to determine the periods of significant oscillatory current flows through the Straits of Mackinac and to correlate the observed periods with oscillations of the water surfaces of Lakes Huron and Michigan. The data set of approximately 12-months duration to be collected in this experiment will be sufficient to examine with good statistical confidence waves as long as 5 days in period. Waves of interest in this study range from periods of 120 hours to 12 hours.

3.11 Task 1.11. Circulations in Homogeneous and Stratified Lakes

Task Scientist. D. B. Rao

Objectives. The general objective of this task is to understand the dynamics of long-term and transient circulations in lakes under homogeneous and stratified conditions. In particular, it is proposed to examine the effects of non-linearities and non-stationary winds on steady circulations and also the properties of coastal-trapped topographic and internal Kelvin waves during spring and summer stratifications and their relation to coastal circulations.

3.12 Task 1.12. The Currents of Southern Lake Michigan

Task Scientist. J. H. Saylor

Objectives. Objectives of the experiment are to define the spatial scale of coherent coastal currents in the southern basin of Lake Michigan, both in longitudinal length along the lake shore and in transverse width toward the center of the lake, to monitor and record episodes of upwelling and their effects on current structure, and to delineate circulation of the southern basin across a transverse cross section. Data will be used for further planning of continuing Lake Michigan investigations in succeeding years.

4.0 Project 2. SURFACE WAVES AND WATER LEVEL FLUCTUATIONS

Project Scientist. D. B. Rao

Objectives. In order to predict waves and other water level oscillations, this project needs to do the following:

(1) Improve climatological information on the distribution and variability of surface waves, wind set-ups, surges, and seiches.

(2) Develop improved theoretical and empirical models for the above phenomena for prediction purposes.

(3) Develop models for the atmospheric boundary layer above the Lakes to provide the necessary input into the above prediction models.

(4) Improve understanding of the physical processes involved so that numerical models can be improved.

Background. The goals in Project 2 are the same as in Project 1, Water Movements and Temperature, namely, improved observation, analysis, and prediction. In Project 1, the variables and scales to be studied were mentioned, as well as potential users of the resulting information. In contrast to Project 1, which deals with long period processes, surface wave and water level fluctuations considered here have short time scales. These phenomena are often hazards in activities such as shipping, recreational boating, and fishing and can result in loss of life and property damage; consequently, there is an urgent need for improved methods of forecasting these phenomena. Statistical information on waves and water level fluctuations are necessary in problems of ship design, shoreline protection, navigation, etc. In addition, waves and water level fluctuations facilitate processes of dispersion, shore erosion, bottom sediment resuspension, and flooding.

Theories are well developed for surface waves in deep water. In the Great Lakes, however, these waves are only poorly understood due to complicating factors such as shallow depths, limited fetch, and boundary effects. In view of this, continued effort is necessary to develop theoretical and empirical wave models and to test them with properly designed field studies.

Large water level fluctuations also occur in the Great Lakes as a result of atmospheric forcing. The horizontal scale of this response is large as opposed to the small horizontal extent of surface waves. The amplitude of this response may exceed both surface waves and hydrological changes, making it an important factor in shore erosion, shipping, and land use management. Also in this category of water level fluctuations are wind tides, surges, and seiches resulting from the passage of atmospheric disturbances. In predictions of both waves and water level fluctuations, details of wind, pressure, and temperature in the atmospheric boundary layer over the lake are important. Such information is not available in routine weather observations or forecasts. Hence, development and testing of numerical models for predicting the boundary layer profile is an essential part of this project.

Interrelationships with Other Projects. The lake-atmosphere boundary layer observations and analyses are common with Project 1, Water Movements and Temperatures. In view of the environmental hazards associated with waves, surges, etc., this project lends support to Project 9, Environmental Information Services. This project also is related to Project 7, Hydrologic Properties, since the extent of shoreline damage caused by waves and water level fluctuations is governed by hydrological changes of the lake levels.

Approach. The approach in this project includes field data collection; analysis; and model development, testing, and evaluation. For surface waves, special data acquisition systems will be deployed to measure the lake and atmospheric boundary layer. Analyses of field wave data should determine the effects of short fetch, partially developed waves, shallow water depth, and boundary layer processes. Studies on wind set-ups and seiches will involve an evaluation of the existing prediction techniques using available meteorological and water level data. Improved numerical models will be developed based upon both theoretical and empirical relationships. Such models will be verified by using data bases developed from field data collections.

In the near future, tasks under this project will focus attention on the following:

(1) Statistical analyses of Great Lakes wave data collected in previous years.

(2) Transient effects of strong wind episodes.

(3) Development and testing of simple storm-surge models.

(4) Examination of non-linear effects on waves.

4.1 Task 2.1. Surface Wave Observations and Analysis

Task Scientist. P. C. Liu

Objectives. The objectives of this task are as follows:

(1) To investigate the processes of generation, growth, and decay of wind-generated waves in the Great Lakes, their interactions with the atmospheric boundary layer, their linear and non-linear properties, and their correlations with various theoretical models.

(2) To provide seasonal, annual, and long-term wave statistics of fundamental importance to coastal sediment transport processes and to the design of lake vessels and beach erosion protective structures.

4.2 Task 2.2. Free Oscillations of Lake Michigan

Task Scientist. D. B. Rao

This task is complete. A final report is on file.

4.3 Task 2.3. Oscillations of Lake Huron

Task Scientist. D. B. Rao

This task is complete. A final report is in progress.

4.4 Task 2.4. Wind-Induced Changes in Water Levels on the Great Lakes

Task Scientist. D. J. Schwab and D. B. Rao

Objectives. The objective of this task is to develop improved dynamical methods for prediction of wind-induced changes in Great Lakes water levels associated with severe weather conditions.

5.0 Project 3. LAKE ONTARIO ENERGY BUDGET (IFYGL)

Project Scientist. A. P. Pinsak

Objectives. The objectives of this project are as follows:

(1) To establish the effects of each budget term on the total energy budget.

(2) To establish the general and specific properties of the energy budgets of individual lakes.

(3) To determine the effects of stored energy on the characteristics and motions of lake water.

(4) To provide input to forecasts of ice formation and decay, evaporation, water balance, and dissipation of heat entering the Lakes as these relate to navigation, power generation, lake regulation, weather forecasts, and projected trends of cultural stresses.

Background. The Energy Budget Panel is one of the core components of IFYGL. Numerous Canadian and United States scientists investigated the individual terms of the energy budget for Lake Ontario, including incident solar radiation, reflected solar radiation, net longwave radiation exchange, sensible heat transfer, evaporative heat, advected heat, and heat content of the lake.

These provide an assessment and input to an energy balance of Lake Ontario. Field investigations were conducted during April 1972-April 1973.

The energy budget is a fundamental factor in understanding the climatic effect of a water body on the atmosphere and surrounding area and, conversely, the effect of the atmosphere on the water body itself. The magnitude of certain components in the energy balance can greatly affect the agricultural potential in terms of the crop season in the basin. The heat content of the lake is controlled in large part by the magnitude of both incoming and outgoing radiation. The balance thus affects both ice and snow quantity and distribution in and peripheral to the Lakes. Despite the significance of the energy budget, most current calculations are based on estimates and generalizations.

Results will provide data to better understand ice and snow characteristics and to form a basis for the possible prediction of time of ice formation and decay on the Lakes, evaporation from the Lakes, water balance, and disposition of natural heat and thermal discharges into the Lakes.

Interrelationships with Other Projects. This project requires output from and provides input to Projects 1, Water Movements and Temperature; 6, The Dynamics of Material Movements in the Nearshore Zone; 7, Hydrologic Properties; 8, Lake Ice; 9, Environmental Information Services; and 10, Environmental Engineering Models and Applications, and constitutes a portion of Project 11, International Field Year for the Great Lakes (IFYGL). Evaporation estimates are a basic input to Task 7.3, IFYGL Evaporation Synthesis.

Approach. The energy budget program as it has been defined for IFYGL is actually an attempt to evaluate all the terms within the framework of a lake-scale energy balance. Changes in the heat content of the lake will be compared with all the factors that affect heat storage. Relative precision of measurement or estimation of each of the terms then becomes critical in an evaluation. One advantage of the situation where each budget term is being measured is that any one of them can be tested against the others. One problem with the energy budget technique is that it is not completely independent of other techniques. The sum of evaporative or latent heat and sensible heat exchange is a residual that is then partitioned by means of the Bowen Ratio, the elements of which are indigenous to the mass transfer technique. This ratio is generally expressed as

$$R = 6.4 \times 10^{-4} P(T_1 - T_2/e_1 - e_2),$$

in which P is atmospheric pressure (mb); T_1, T_2 are temperatures (°C) at the surface and some height; and e_1, e_2 are vapor pressures (mb) at T_1 and T_2, respectively.

Measurement of energy budget terms is accomplished by instrumented ships and by instruments and sensors on buoys, towers, aircraft, and land and island stations. Ship operations are designed to coincide with annual cyclical variations of thermal structure and lake heat to total depth. Aerial reconnaissance of ice conditions is supplemented by ground ice control. Systematic radiation measurements, cloud cover height, and thickness observations are obtained from all available sources. Net advected heat is calculated from measurements of the water volume and temperature flowing from the next upper lake, tributary runoff, surface runoff, precipitation, cultural inputs, ground water flux, and outflow from the lake.

This project is scheduled to terminate with completion of IFYGL. The end product will be a synthesis of all the Canadian and United States analyses, determinations, and assessments into an energy budget of Lake Ontario and a report summarizing all of these relevant investigations.

5.1 Task 3.1. Heat Storage in Lake Ontario

Task Scientist. A. P. Pinsak

Objectives. Heat storage is a major factor in the energy budget equation and must be measured in any sort of objective analysis because thermal structure is so complex and variable in the Great Lakes.

The objectives of this task are as follows:

(1) To test and correlate various methods that can be used to measure and estimate heat storage.

(2) To calculate lake heat storage in terms of volume averaged temperature surveys and change in storage as expressed by the relationship $V_2 T_2 - V_1 T_1$.

(3) To apply output to computation of the energy budget of Lake Ontario as a part of IFYGL.

5.2 Task 3.2. Thermal Characteristics of Lake Ontario

Task Scientist. A. P. Pinsak

Objectives. Movement of water in lakes is mostly turbulent, and convection and wind mixing are generally regarded as major forces in heat transfer. However, differences exist concerning the relative significance of these energy sources.

The objectives of this task are as follows:

(1) To analyze temporal-spatial variations in the thermal structure within Lake Ontario.

(2) To correlate variations with forces acting on the lake.

(3) To define the natural distribution and variability of heat within the lake.

(4) To determine the relative significance of heat transfer mechanisms on a temporal-spatial basis.

5.3 Task 3.3. Advective Heat Exchange

Task Scientist. J. L. Grumblatt

Objectives. The advective heat exchange is quantitatively a minor term in heat budget studies in the Great Lakes. Its significance lies in the fact that it is one of the terms of the energy budget that may be manipulated by man with relative ease. Examination of advective heat exchange in the Great Lakes should be at those points of inflow and outflow critical to water balance estimates, but cultural and tributary inputs need to be evaluated.

5.4 Task 3.4. Energy Budget Analysis

Task Scientist. A. P. Pinsak

Objectives. Measurements and determinations of solar radiation, net radiation exchange, heat storage, sensible heat transfer, latent heat exchange, advective transfer, and ice and snow obtained in Lake Ontario during IFYGL will be used to establish an energy budget for the lake. These parameters vary significantly in both time and space.

The objectives of this task are as follows:

(1) To define the general and specific properties of the energy budget of a large dimictic lake.

(2) To evaluate all terms of the energy balance equation.

(3) To develop an annual energy balance of the lake. This description, while referring specifically to Lake Ontario in 1972, will be examined in the general sense as it may apply to the energy budget of any large dimictic lake.

(4) To provide an estimate of evaporation as a residual of the energy balance equation and to contribute these estimates for comparison with evaporation estimates obtained by using mass transfer and water budget techniques.

6.0 Project 4. AQUATIC ECOLOGY MODELS AND RELATED STUDIES

Project Scientist. A. Robertson

Objectives. The objectives of this project are as follows:

(1) To develop and test a series of models, at several levels of complexity, that realistically simulate the fluctuations in quantity in ecologically meaningful components of the Great Lakes ecosystems.

(2) To couple these models to models of the hydrodynamics of the Lakes in order to obtain the ability to simulate the three-dimensional distribution of chemical and biological properties.

(3) To use these ecological models to evaluate the present status of our knowledge and to identify areas of weakness that require further study.

(4) To carry out programs of data analysis and interpretation directed at answering questions about how to treat certain aspects of the modeling effort.

(5) To adapt the models in ways that fit them to be profitably used to aid in making management decisions.

Background. A great many of the problems that have been identified in the Great Lakes in recent years are closely related to the ecology of the Lakes. The solutions to such problems as conserving and increasing the fisheries, protecting the Lakes from toxic materials, and abating overenrichment by plant nutrients call for a thorough knowledge of the ecological relations within the Lakes. A substantial amount of this knowledge is already available. However, the Great Lakes ecosystems are so complex that there is a need for much more and better understanding before the resource managers really have the ability to predict the most efficient and beneficial manner in which to handle such problems.

A primary goal of GLERL's biology-chemistry program is to help provide information that will allow managers to evaluate, in a more rational and efficient manner, the ecological consequences of proposed actions. To determine what research should be conducted to meet this goal, it is necessary to evaluate the present status of knowledge and to identify the major stumbling blocks to increasing our understanding of the Great Lakes ecosystems.

Project 4 has been established to make this evaluation and identification. We will attempt to develop mathematical models of the Great

Lakes ecology at several levels of complexity, based on available knowledge. These models will be systematic representations of our present status at the level of complexity under consideration. We hope, then, through comparison of model output to real data, sensitivity analysis, and other techniques to identify the major inadequacies in the model and thus the areas most in need of active research efforts.

Interrelationships with Other Projects. This project relates to other projects as follows:

(1) The models developed for planktonic competition and succession in Project 5, Planktonic Succession, will be used to improve these aspects of the models in this project.

(2) Models of circulation and temperature developed by the Physical Limnology and Meteorology Group in Project 1, Water Movements and Temperature, will be used as the basis for modeling those aspects of this project.

(3) The studies on natural distribution and variability of lake properties conducted in Project 6, The Dynamics of Material Movements in the Nearshore Zone, will provide assistance for conceptualization and verification in this project.

(4) The models developed in this project will form the basis for some of the practical modeling applications carried out in Project 10, Environmental Engineering Models and Applications.

Approach. From the information available in the literature, the subdivisions appropriate for the level of complexity under consideration and the interrelations among these components will be conceptualized. Each functional relationship will then be developed from existing Great Lakes data bases. The models will be tested, tuned, and then verified by all available data, especially those from IFYGL.

As stated previously, a hierarchy of models at various levels of complexity is visualized. These will vary in the number of subdivisions included in the biological and chemical aspects and also in the number of vertical compartments. Studies will be conducted to determine the sensitivity of the models to level of complexity. The models will also be tested under various situations in an attempt to build a Great Lakes ecological model with high generality so the model can be used to predict the ecological conditions that will arise under various possible sets of future environmental conditions.

During model development, areas of important weakness in our knowledge will be continually identified and actions initiated to increase our ability to understand and model these areas. Where possible, tasks will be set up in this project to fill these needs, but this will also be done through contracts from GLERL to outside researchers and through making these priority research needs known to the Great Lakes research community and to the managers of research funding. Improvements in our knowledge of the Great Lakes ecology will be used to improve the models when such knowledge becomes available.

As the models improve, their potential for guiding management decisions will increase. When situations are identified where they are likely to be of assistance, they will be adapted to the situation of interest and made available. Such efforts will usually involve the Environmental Engineering Group, probably through tasks in Project 10, Environmental Engineering Models and Applications, but with continuing advice and assistance from the Chemistry-Biology Group.

6.1 Task 4.1. Level 1 Ecological Model

Task Scientist. B. J. Eadie

This task is complete. A final report is on file.

6.2 Task 4.2. Assessment of Lake Ontario Invertebrate Community

Task Scientist. A. Robertson

Objectives. The objectives of this task are as follows:

(1) To determine what invertebrate species have been reported in Lake Ontario.

(2) To update and correct the scientific names applied to these according to modern taxonomic opinion.

(3) To determine which of the species are of sufficient importance to the lake ecosystem to be considered in modeling the ecological processes within the lake.

6.3 Task 4.3. Three-Dimensional Ecological Model

Task Scientist. D. Scavia and J. Boyd

Objectives. The overall objective of this task is to develop an operational, three-dimensional, ecological model for Lake Ontario. This model will give us the capability of addressing problems in water quality, land use, fisheries, and other management aspects of the Lake

Ontario watershed. More specifically, the immediate objectives are as follows:

(1) To compare Tetra Tech model constructs with those developed in Tasks 4.1, Level 1 Ecological Model, and 4.4, Ecological Modeling, and to select the best descriptions of the chemical and ecological processes.

(2) To estimate and evaluate model coefficients and to calibrate the model to Lake Ontario IFYGL data.

6.4 Task 4.4 Ecological Modeling

Task Scientist. D. Scavia

Objectives. The objectives of this task are as follows:

(1) To develop a one-dimensional ecological model encompassing state-of-the-art mechanisms describing the more important biological and chemical processes of the Great Lakes. To expand the framework of the model to include additional compartments of interest.

(2) To evaluate the model with respect to construct realism and simulation accuracy.

(3) To test and evaluate model responses to input stresses.

(4) To develop a more refined formulation for phytoplankton growth limitation and sediment compartment dynamics.

7.0 Project 5. PLANKTONIC SUCCESSION

Project Scientist. A. Robertson

Objectives. The objectives of this project are as follows:

(1) To describe the process of succession in the plankton of the Great Lakes.

(2) To determine the mechanisms that control succession and the quantitative relationship of these mechanisms to that process.

(3) To develop an improved model of succession.

(4) To integrate the results from this study into the ecosystem models being developed under Project 4, Aquatic Ecology Models and Related Studies.

Background. The modeling of the ecology of the Great Lakes has so far been limited to including all the phytoplankton species under one or occasionally a couple of groupings. The same approach, combining a variety of species under one or a few headings, is also being used for the zooplankton. It is already obvious, however, that modeling at such a gross level will not be able to simulate a number of the processes of immediate practical concern. For example, different types of algae vary greatly in their potential to clog water intakes and to cause taste and odor problems. Also, different types of plankton vary greatly in their ability to serve as food to higher levels in the food chain. Thus, treating all types alike obscures many of the processes and allows simulation of only the least complex relationships. This project attempts to take a closer look at the control of the fluctuations of various types of plankton through investigation of the succession of planktonic types in space and time and of the mechanisms that control this process.

Interrelationships with Other Projects. The results from this project will be used to improve the treatment of the planktonic components in the ecosystem models of Project 4, Aquatic Ecology Models and Related Studies. Also, this study will be coordinated with Project 6, The Dynamics of Material Movements in the Nearshore Zone, in an attempt to understand the role of plankton in the movement of materials within the nearshore zone.

Approach. Many factors, such as light, climate, nutrient concentration, amounts of toxic materials, temperature, intensity of predation, etc., have some effect on the concentration of phytoplankton in a lake. Of these, two, nutrient competition and zooplankton grazing, seem to be of major significance in controlling phytoplankton succession. Laboratory studies using selected Great Lakes species will be conducted to determine the rates of nutrient uptake under various conditions. These results will be generalized and the hypotheses developed tested in the field. This type of research will include radioactive tracer studies and autoradiographic techniques. Zooplankton grazing studies will be conducted by using various foods to determine food selectivity under a variety of conditions. Again attempts will be made to generalize the results and test the hypotheses in the field. Besides contributing to an understanding of phytoplankton succession, the grazing experiments will increase our knowledge of the competition of zooplankters for food and of the way in which this affects their succession. Further studies will be conducted with zooplankton in an attempt to increase our knowledge of their population dynamics and the way in which this affects succession. This work will include investigation of reproductive and growth rates. In the long term, the results from these studies will be coordinated in an attempt to develop an improved model of the relationshp between the phytoplankton and herbivorous zooplankton and of the succession within these two groups. The results from this project will be used to improve our handling of phytoplankton and zooplankton and the relationship of these two in the models of Project 4, Aquatic Ecology Models and Related Studies.

7.1 Task 5.1. Phytoplankton Nutrient Competition

Task Scientist. S. J. Tarapchak

Objectives. The general objectives of this task are as follows:

(1) To investigate phytoplankton nutrient competition in order to explain some of the more important aspects of seasonal succession in Great Lakes phytoplankton communities, especially in Lake Michigan.

(2) To investigate phytoplankton succession in conjunction with zooplankton grazing and selectivity in the Great Lakes. (See Task 5.2, Zooplankton Grazing.)

(3) To generate descriptive and experimental data on phytoplankton growth phenomena relevant to ecological model development and verification.

(4) To generate background or experimental data on the short-term fluctuations of selected chemical and biological variables in an offshore environment of Lake Michigan.

7.2 Task 5.2. Zooplankton Grazing

Task Scientist. H. A. Vanderploeg

Objectives. The overall purpose is to develop an adequate general expression for food selection by individual zooplankton species and to determine the effect of grazing by the entire zooplankton assemblage on the summer succession of phytoplankton species in Lake Michigan. In the near term, emphasis is being placed on developing a model of selective grazing for various species of *Diaptomus* found in the Great Lakes.

7.3 Task 5.3. Culturing of Great Lakes Zooplanktonic Crustaceans

Task Scientist. A. Robertson

Objectives. The objective of this task is to develop methods for continuous culturing in the laboratory of several of the more important species of crustacean zooplankton in the Great Lakes.

7.4 Task 5.4. Feeding of a Cyclopoid Copepod

Task Scientist. A. Robertson and T. F. Nalepa

Objectives. The objective of this task is to determine the feeding rate of *Cyclops vernalis* on prey of various sizes.

8.0 Project 6. THE DYNAMICS OF MATERIAL MOVEMENTS IN THE NEARSHORE ZONE

Project Scientist. A. Robertson

Objectives. The objectives of this task are as follows:

(1) To determine the dynamics of the physical movements and chemical transformations of selected polluting and enriching substances within the nearshore zone.

(2) To determine the sources and ultimate fates of these materials.

(3) To determine the spatial and temporal scales of variability for the concentrations of these materials.

(4) To develop mathematical models of the dynamics and fates of these materials within the nearshore zone.

Background. The nearshore zone is the primary site where pollutants and enriching substances are added to the Great Lakes. These substances tend to be concentrated in these areas before becoming diluted by the large volumes of the open lake. Thus, the most obvious and severe impacts of these substances are usually noted in this zone. This is especially unfortunate as most of man's uses and contacts with the Lakes are concentrated in these same nearshore areas.

Given the importance of this zone and the severe stress to which it has been exposed, it is surprising to find that it has not received as much study nor is it as well understood as the open lake. Obviously, increased understanding of the effects of polluting and enriching substances on the organisms and water quality conditions are needed if we are to protect these areas from further degradation and are to reverse the deleterious changes that have already occurred. To do this, we must understand the movement of materials into and through this zone and be able to predict the concentrations of substances at selected sites of interest. This calls for examining and understanding the local and system effects of introduced materials as well as their sources, sinks, and modes of transport and for determining whether apparent sinks are permanent or only temporary storage sites.

Recently several studies, e.g., those conducted by the International Reference Group on Great Lakes Pollution from Land Use Activities (PLUARG) and IFYGL, have gathered large amounts of data in this zone. However, these data were gathered with little regard to possible aliasing due to selection of temporal and spatial scales. Thus, studies on the variability of properties in regard to such scales are warranted to allow use of the existing data and to aid in the planning of future data gathering experiments.

Interrelationships with Other Projects. In order to understand materials transport, we will need input from Project 1, Water Movements and Temperature, concerning water movement and from Project 2, Surface Waves and Water Level Fluctuations, concerning wave effects on resuspension of sediments. This project will be coordinated with Project 4, Aquatic Ecology Models and Related Studies, both in helping to define areas of research need and in supplying information and submodels to aid in improving the ecological modeling effort. It will also be closely connected with Project 5, Planktonic Succession, in an attempt to understand and model the transport of materials by plankton.

Approach. Field and laboratory work will be directed toward the analysis of logical process subsystems, such as carbon/oxygen, nutrients/pigments, organics/trace metals. Parameters will be compared to conservative properties and differences determined will be related to in situ or trans-boundary processes. Available data sets will be statistically analyzed to determine if significant patterns are discernible on a larger temporal/spatial scale.

Higher frequency variability (on the order of hours to days) of subsystems will be analyzed, as technology allows, to determine the necessary sampling network to accurately characterize the variables.

The nearshore regime will be sampled and analyzed to determine the effects of turbulent mixing compared to in situ reactions and sedimentation processes. Available plume models will be coupled with chemical equilibrium models and sediment transport models to try to elucidate the complex kinetics of this region.

8.1 Task 6.1. Physical-Chemical Study of the Detroit River, Lake St. Clair, and the St. Clair River

Task Scientist. A. P. Pinsak

Objectives. A systematic field investigation was undertaken in which vertical and lateral distribution as well as variations with respect to time of the chemical and physical properties of water in the St. Clair and Detroit Rivers and Lake St. Clair and of their immediate environment will be analyzed. The program will define the natural distribution and variability of significant characteristics and their relation to the immediate environment. This type of systematic analysis is essential in forecasting water quality and estimating the nature and magnitude of past events as an aid in optimum management of the Lakes for multiple competing uses. The project was designed to complement existing data and continuing programs in this connecting waterway between Lakes Huron and Erie.

8.2 Task 6.2. Analysis of Lake Ontario Oxygen Profiles

Task Scientist. B. J. Eadie

Objectives. The objectives of this task are as follows:

(1) To examine spatial and temporal changes in hypolimnion oxygen concentration in Lake Ontario.

(2) To evaluate the extent of O_2 depletion and its relation to biological productivity.

(3) To evaluate any long-term trends in hypolimnion O_2 depletion.

8.3 Task 6.3. Chemical Dynamics

Task Scientist. B. J. Eadie

Objectives. The objectives of this task are as follows:

(1) To determine the time scales required to characterize selected components of the chemistry of Lake Michigan.

(2) To analyze the relationship between fluorometry and pigments from data collected during the 1976 field season.

8.4 Task 6.4. IFYGL Chemical Intercomparison

Task Scientist. A. Robertson

This task is complete. A final report is on file.

8.5 Task 6.5. Characteristics of Oswego River Plume

Task Scientist. G. L. Bell

Objectives. The objectives of this task are as follows:

(1) To define the chemical and physical characteristics of the Oswego River discharge in the harbor and the area of mixing in the adjacent portion of Lake Ontario on a time-spatial basis.

(2) To determine the effects of the water and sediment influx on the adjacent lake.

(3) To describe the areal distribution under varying conditions and to attempt to relate distribution to causative forces.

(4) To estimate the time for water-borne effects to be dissipated.

8.6 Task 6.6. Chemical-Physical Variability in Southern Lake Michigan

Task Scientist. G. L. Bell and R. L. Chambers

Objectives. The objectives of this task are as follows:

(1) To describe the broad aspects of the spatial and temporal variability of selected chemical-physical parameters in the nearshore environment at sites chosen to reflect a wide range of conditions.

(2) To compare the nearshore and open-lake environment.

(3) To establish gradients through the nearshore environment.

8.7 Task 6.7. Interstitial Water and Sediment Chemistry: Southern Lake Michigan

Task Scientist. R. L. Chambers

Objectives. The objectives of this task are as follows:

(1) To determine chemical relationships between phosphorus, iron, manganese, organic carbon, and humic acids at the sediment-water interface with respect to sediment-grain size.

(2) To identify general time-spatial distribution patterns of these chemical species in the nearshore zone in the vicinity of the Grand River at Grand Haven, Michigan.

8.8 Task 6.8. Distribution of Benthic Invertebrates

Task Scientist. T. F. Nalepa

Objectives. The objectives of this task are as follows:

(1) To determine the quantitative and qualitative distribution of the benthic meiofauna.

(2) To investigate the relationship between the distribution of the meio- and macrofauna and such factors as depth, sediment particle size, and sediment organic carbon.

(3) To determine the extent of seasonal and annual variation in these populations.

(4) To determine the vertical distribution of meio- and macrofauna in the sediment and of selected microcrustacea in the sediment-water column.

8.9 Task 6.9. Presentation of LSC/GLERL Chemical Field Data, 1965-75

Task Scientist. B. J. Eadie and G. L. Bell

Objective. To edit and catalog the data collected on all the Great Lakes by the Lake Survey Center (LSC) and GLERL during 1965-75 and to provide this summarized data to the scientific community.

8.10 Task 6.10. The Effect of the Grand River's Spring Runoff on Lake Michigan

Task Scientist. B. J. Eadie

Objectives. The objectives of this task are as follows:

(1) To survey water quality offshore of the Grand River mouth following an "event" such as spring runoff. Water quality is defined by concentrations of contaminants such as total suspended matter (TSM), nutrients, and toxic substances.

(2) To identify general distribution patterns and transport mechanisms of contaminants contributed by the river.

(3) To assess the general impact of the tributary loading to the lake under event conditions.

(4) To assess the general impact of wind-induced resuspension of sedimentary material on the water quality of the area and its significance relative to tributary input.

8.11 Task 6.11. Characterization and Transport of Nearshore Material

Task Scientist. B. J. Eadie, R. L. Chambers, and J. D. Boyd

Objectives. The objectives of this task are as follows:

(1) To quantify and characterize the material transported by the Grand River plume.

(2) To qualitatively describe the mechanisms of nearshore/offshore movement of this material.

(3) To develop and calibrate a nearshore model for the Grand River area to synthesize the movement of conservative and nonconservative substances.

8.12 Task 6.12. Analysis of LSC/GLERL Limnological Data, 1965-75

Task Scientist. G. L. Bell and B. J. Eadie

Objectives. The objective of this task is to analyze the GLERL data base constructed for Tasks 4.1, Level 1 Ecological Model; 6.6, Chemical-Physical Variability in Southern Lake Michigan; and 6.9, Presentation of LSC/GLERL Chemical Field Data, 1965-75. Specifically the following questions will be addressed:

(1) Does there exist a chemically defined nearshore zone which differs from the main lake and how can it be identified?

(2) Can historical lake productivity be described through CO_2 gas exchange calculations?

(3) Can adequate information be deduced from the data to develop a model for the SO_4 cycle?

(4) What effect does $CaCO_3$ formation have on light transparency and photosyntheses?

(5) What factors produce the vertical and horizontal variations in light transmission in the deep-lake environment?

9.0 Project 7. HYDROLOGIC PROPERTIES

Project Scientist. F. H. Quinn

Objectives. The objectives of this project are as follows:

(1) To develop a hydrologic data base of sufficient quality for both scientific and water resource studies of the Great Lakes. Parameters to be included are precipitation, runoff, ground water, evaporation, connecting channel flows, changes in lake storage, and beginning-of-month lake levels.

(2) To develop improved numerical models to predict and simulate the water levels and flows through the Great Lakes system. Models to be developed include hydrologic response models of the entire system, hydraulic transient models for the connecting channels, water supply prediction models, and watershed hydrologic models.

(3) To develop improved understanding of the hydrologic processes of the Great Lakes Basin as they relate to objective (2) above.

(4) To provide a Great Lakes advisory service on water supply parameters, water levels, and flows.

Background. An understanding of lake hydrology is fundamental for water resource studies of the Great Lakes. The processes governing water depletion and replenishment are contained in the hydrologic cycle, which integrates the relationships between water supplies and losses and the resulting lake levels and flows. Knowledge of water supplies and flows is necessary for water quantity, water quality, shore erosion, hydropower, navigation, recreation, flooding, and prediction studies of the Great Lakes system. In addition, the knowledge gained from the precipitation, runoff, and ground water studies can be applied to such highly diverse areas as agriculture, municipal water supplies, land use, tributary flooding, and basin recreation.

The lake hydrology research is conducted under NOAA's broad mission, given by Reorganization Plan No. 4, to conduct research relating to the water quantity of the Great Lakes. This includes research conducted as part of NOAA's support of interagency and international committees such as the Great Lakes Basin Hydromet Work Group, the International Coordinating Committee for Great Lakes Basin Hydraulic and Hydrologic Data, and the International Field Year for the Great Lakes.

The research results from this project support many users, ranging from NOAA operational elements such as the National Weather Service and the National Ocean Survey to marine resource decision makers and the general public. Also included among the primary users are the Corps of Engineers, the Environmental Protection Agency, and various boards of the International Joint Commission.

The hydrologic properties research falls into four broad interrelated program areas. These are descriptive hydrology, process hydrology, hydrologic modeling, and hydrologic applications. Descriptive hydrology includes the "state-of-the-art" research tasks, whose primary purpose is to provide a climatologic hydrologic data base for the hydrologic modeling and applications programs, while process hydrology includes the research studies designed to push the "state-of-the-art." The hydrologic modeling work consists of the development, calibration, and testing of process response models to simulate the complex interrelationships that exist between the hydraulic and hydrologic processes within the Great Lakes and their immediate environment. The preceding research supports the hydrologic applications program. Most of the lake hydrology advisory services are included here.

A hydrologic response model and Detroit and St. Clair Rivers transient models have been developed to date. These models are currently being used in conjunction with a hydrologic data base to provide an advisory service on water levels and flows. Typical users of this service are the general public, the Great Lakes states, international commissions, and Federal agencies.

It is expected that, as the base of scientific knowledge increases, Great Lakes system models will be developed. Increased hydrologic advisory services will provide a sound basis for systematic consideration of the more intensive multipurpose use of the Lakes that is certain to develop with growth of the region's population and economy.

Interrelationships with Other Projects. This project will provide input to Project 3, Lake Ontario Energy Budget (IFYGL); Project 8, Lake Ice; and Project 10, Environmental Engineering Models and Applications.

Approach. Under the descriptive and process hydrology programs, data are being collected and analyzed on such lake hydrology factors as inflow, outflow, precipitation, runoff, and evaporation in order to obtain a better understanding of their interrelationships and their effects on the Great Lakes. Descriptive hydrology tasks will include evaporation studies, beginning-of-month lake levels and change in storage studies, lake runoff studies, and some Detroit and St. Clair Rivers flow studies. Hydrologic monographs and data reports containing the latest information on the Great Lakes will be compiled and published for use by Federal and state agencies, the Great Lakes Basin

Commission, the general public, and the International Coordinating Committee for Great Lakes Hydraulic and Hydrologic Data.

Process hydrology research will emphasize overlake precipitation studies, evaporation synthesis studies, rainfall-runoff studies, snow melt and ablation studies, and investigations of temperature effects on lake volumes.

The development of hydrologic models includes hydrologic response models of the Great Lakes system, hydraulic transient models of the connecting channels, conceptual basin runoff models, and water supply prediction models.

Some typical applications are connecting channel flows for the International Joint Commission and Corps of Engineers water quality studies, causes of Great Lakes long-term water level fluctuations, Great Lakes river basin studies, water supply forecasting, and development of an automated procedure for Great Lakes precipitation computations.

9.1 Task 7.1. Lake Precipitation

Task Scientist. S. J. Bolsenga

Objectives. The objectives of this task are as follows:

(1) To define Great Lakes precipitation patterns and amounts by using existing data bases.

(2) To provide accurate precipitation input for water resource and water forecasting studies, including development of a monthly precipitation data base to support hydrologic modeling and to develop a method to be used by the National Ocean Survey in calculating values for their monthly *Great Lakes Precipitation Bulletin*.

9.2 Task 7.2. Lake Evaporation

Task Scientist. J. A. Derecki

Objectives. The objectives of this task are to determine accurate monthly values of water loss from the Lakes through evaporation for incorporation into the hydrologic data base and to establish relationships with the interrelated factors.

9.3 Task 7.3. IFYGL Evaporation Synthesis

Task Scientist. F. H. Quinn

Objectives. The objectives of this task are:

(1) To synthesize best estimates of Lake Ontario evaporation during IFYGL.

(2) To obtain a constant for the mass transfer equation for Lake Ontario.

9.4 Task 7.4. Water Levels and Flows Simulation

Task Scientist. F. H. Quinn

Objectives. The main objectives of this task are as follows:

(1) To use the Great Lakes hydrologic response model for specific management problems involving the water quantity in the Lakes, such as evaluation of precipitation augmentation, determination of effects of diversions on the water levels, and effects of ice retardation in the connecting channels.

(2) To use hydraulic transient models for specific problems involving the water quantity in lakes and connecting channels, such as water quality and pollution studies, lake inflow and outflow studies, and more accurate connecting channel flow determinations.

(3) To investigate and report on various factors which impact upon the water levels and flows, such as lake effects of long-term barometric pressure variations and effects of water temperature changes on lake volume.

9.5 Task 7.5. Great Lakes Shoreline Flooding

This task has been deleted.

9.6 Task 7.6. Great Lakes Beginning-of-Month Levels

Task Scientist. J. A. Derecki

This task is complete. A final report is on file.

9.7 Task 7.7. Conceptual Watershed Modeling of the Great Lakes Basins

Task Scientist. A. J. Potok

Objectives. The objectives of this task are as follows:

(1) To develop a digital model(s) which will:

A. Simulate runoff response of the entire Great Lakes watershed to an anticipated time series of climatological conditions.

B. Most accurately simulate a detailed hydrologic response of an individual watershed(s) in the Great Lakes region.

(2) To use the model(s) as a water resource tool to attain improved forecasting of runoff to the Great Lakes and other water resource management functions.

9.8 Task 7.8. Hydrologic Forecasting

Task Scientist. F. H. Quinn

This task is complete. A final report is on file.

9.9 Task 7.9. Connecting Channels Transient Models

Task Scientist. F. H. Quinn

Objective. The main objective of this task is to develop, test, and document one-dimensional hydraulic transient models of the Detroit, St. Clair, and Niagara Rivers for use in flow simulation in the connecting channels.

9.10 Task 7.10. Lake Michigan Evaporation

Task Scientist. J. A. Derecki

Objectives. The objectives of this task are to determine accurate monthly values of water loss from Lake Michigan through evaporation for incorporation into the hydrologic data base and to establish relationships with the interrelated factors.

9.11 Task 7.11. Lake Superior Regulation Analysis

Task Scientist. F. H. Quinn

Objectives. The objectives of this task are as follows:

(1) To determine the effect of Lake Superior regulation on Lake Superior levels and outflows and the resulting impact on the levels of Lakes Michigan, Huron, St. Clair, Erie, and Ontario.

(2) To better understand the role of Lake Superior regulation in the current high lake levels.

10.0 Project 8. LAKE ICE

Project Scientist. F. H. Quinn

Objectives. The objectives of this project are as follows:

(1) To develop improved climatological information on the formation, growth, and decay of the Great Lakes ice cover.

(2) To develop numerical models and techniques to simulate and forecast the freezeup, breakup, areal extent, and thickness of the Great Lakes ice cover.

(3) To define the natural distribution and variability of the physical, chemical, and optical characteristics of the Great Lakes ice cover.

(4) To provide a lake ice advisory service.

Background. An understanding of the Great Lakes ice cover is necessary for many water resource and engineering studies of the Great Lakes. Knowledge of the ice cover and its properties is necessary for winter navigation, shoreline engineering, hydropower generation, water supply forecasts, and pollution studies. In addition, the knowledge gained from the ice studies can be applied to such highly diverse areas as ship and icebreaker design and the monitoring of atmospheric pollution.

The lake ice research is conducted largely under NOAA's broad mission, given by Reorganization Plan No. 4, to conduct research relating to the ice cover of the Great Lakes. This includes research conducted as part of NOAA's support of interagency and international committees, such as the Winter Navigation Demonstration Program and the International Field Year for the Great Lakes. The Winter Navigation Demonstration Program, authorized by Congress in 1970, has given impetus to Great Lakes ice studies. GLERL participation in this program is through membership on the working committee and the Chairmanship of the Ice Information Work Group. Research in many areas, including ice forecasting, is being supported by the program. In addition, GLERL (formerly LSC) was requested by an exchange of letters between the Administrator of the St. Lawrence Seaway Development Corporation and the Administrator of NOAA to develop freezeup and breakup forecasts for the St. Lawrence River.

The research results from this project support many users, ranging from NOAA operational elements, such as the National Weather Service, to marine resource decision makers, the Great Lakes shipping industry and the general public. Also included among the primary users are the Corps of Engineers, the St. Lawrence Seaway Development Corporation, and the Great Lakes power utilities.

The lake ice studies began in 1963 with initial work on lake ice distribution. This task has been continued to date with a series of technical reports documenting each year's ice cover. In addition, an ice climatology report, *The Great Lakes Ice Atlas,* was compiled and published.

As part of the forecast studies a St. Lawrence River freezeup forecast was developed and tested for three winters. As a result of these efforts, the National Weather Service initiated freezeup forecasts for the St. Lawrence River in October 1975.

Studies on the optical properties of ice began during the 1975-76 winter season with a field program to investigate the diurnal and seasonal variation of the albedo of the various ice types common to the Great Lakes. The program was initiated in response to a need for an accurate definition of the albedo for ice prediction models and for use as basic ground signature input for remote sensing analysis of the ice cover. Field consulting assistance was provided to the Buffalo District Corps of Engineers for use in the International Niagara River Board's Buffalo Harbor ice breakup model.

The results of the studies are currently being used to provide an advisory service on Great Lakes ice. Typical users are international boards and commissions, Federal agencies, consulting engineers, and the general public.

Interrelationships with Other Projects. This project will provide input to other GLERL projects, such as Project 3, Lake Ontario Energy Budget (IFYGL); Project 4, Aquatic Ecology Models; Project 5, Planktonic Succession; Project 7, Hydrologic Properties; and Project 9, Environmental Information Services.

Approach. The lake ice research falls into four broad interrelated program areas. These are ice distribution, ice characteristics, optical properties, and ice forecasting. Ice distribution includes the studies undertaken to develop improved climatological information on the formation, areal growth, and decay of the Great Lakes ice cover.

The ice characteristics program is concentrating on studies to define the thickness and stratigraphy of the Great Lakes ice cover. It also provides information useful in modeling the cycle of ice formation to decay and associated phenomena, such as ice jams, forces on shore structures, ice movement, and ecological effects.

Investigations of the optical properties of ice currently involve determination of the ice albedo for the total solar spectrum and the hemispherical transmittance of ice in the photosynthetically active range. The information will be used to improve understanding of winter lake energy budgets and the associated improvement in ice forecasting models and to develop an understanding of primary productivity under wintertime conditions.

The ice forecasting program encompasses studies designed to develop, test, and improve techniques for short- and long-range forecasts of ice formation, ice growth, and ice decay. The technical development of the forecasts is coupled with a continuing assessment of the needs of users, including the National Weather Service, which in many cases issues the operational forecasts.

10.1 Task 8.1. Lake Ice Distribution

Task Scientist. R. A. Assel

Objectives. The primary objectives of this task are as follows:

(1) To develop improved climatologic information on the formation, areal growth, and decay of the Great Lakes ice cover.

(2) To provide an advisory service on Great Lakes ice-cover distribution.

10.2 Task 8.2. Ice Forecasting

Task Scientist. R. A. Assel

Objectives. The objectives of this task are to develop, test, and improve techniques for short- and long-range forecasts of the following:

(1) Ice formation.

(2) Ice growth (thickness and areal extent).

(3) Ice decay.

Significant benefits will accrue to those involved in shoreline management and engineering, water level forecasting, and winter navigation.

11.0 Project 9. ENVIRONMENTAL INFORMATION SERVICES

Project Scientist. C. F. Jenkins and A. P. Pinsak

Objectives. The objectives of this project are as follows:

(1) To define an information system of value to Great Lakes resource managers and planners in their decision-making activities.

(2) To develop an information system to meet the needs of the Great Lakes community.

(3) To coordinate information needs and exchange.

Background. This project is basic input to the program to make the GLERL products most valuable to Great Lakes inhabitants and indirectly to the entire United States. Determining the environmental information requirements associated with Great Lakes activities is vital to GLERL because this effort will shape the future program of applied research and will focus the efforts within the existing program. The establishment and direction of an advisory service fulfills a mission objective in providing the mechanism for the use of GLERL products.

A basic prerequisite to accomplishment of GLERL mission objectives in conformance with guidance in Executive Order No. 4, to provide environmental assessment and evaluation, is an understanding within GLERL of the problems involving environmental stress and of how environmental factors are considered when decisions are made on the use of Great Lakes resources. The GLERL staff must provide research products that are understood and applied correctly to the solution of planning, management, or operational problems. Products that are misunderstood or misused will decrease the value of the GLERL research effort as a tool to be used by Great Lakes managers.

Participation on boards, commissions, task forces, and committees is an essential part of the GLERL program to define user needs, to develop a desirable product and to maintain viable interest and participation in programs concerned with Great Lakes water quality, quantity, and characteristics and water- and land-related resource development and management.

Interrelationships with Other Projects. This project relates to all the projects and tasks within GLERL in that it provides both a basis for establishment of projects as well as a means for the application of the output of the projects.

Approach. This project provides the means of establishing and maintaining communication between GLERL and Federal, state, and local government agencies, institutions, private organizations, and the general public. Identification will be made of the individuals who require environmental information for problem-solving, and interactions will be held with these individuals to determine their needs for an environmental information system. User contact will be through membership on regional and international boards and commissions, workshops, and public appearances as well as through interactions with Federal, state, and local agencies. These activities will provide user requirement information to GLERL as well as advisory service products to the user.

Information requirements will be structured in such a way as to provide guidance to GLERL in developing short- and long-range program objectives to satisfy the maximum number of most urgent needs. These requirements will provide a basis for the formation and operation of an advisory service. The advisory service staff will maintain communication with users of GLERL information and will work as the catalyst to bring GLERL staff expertise and products to the user and expedite their application. This established link with the Great Lakes community will greatly enhance the practical use of GLERL products.

Products. This project will provide a periodically updated set of user requirements, environmental information in a form useful to the Great Lakes community, and services for the application and interpretation of environmental information. This information system will consist of data, analyses, simulation/prediction techniques, and models formatted or designed for application to resource management problems.

Memberships on such boards and commissions as the International Joint Commission Research Advisory Board, Water Quality Board, Upper Lakes Reference, and PLUARG, the Extension of the Navigation Season Board, the Great Lakes Basin Commission, and the Corps of Engineers Lake Erie Wastewater Management Study provide forums to disseminate GLERL research results to the international user community and to maintain a current awareness of user needs.

Draft environmental impact statements (DEIS's) will be evaluated for the Great Lakes region as input to Department of Commerce reviews.

Advisory services are provided to Federal, state, and local units. Liaison is maintained with the three Great Lakes Sea Grant institutions.

11.1 Task 9.1. Environmental Information Requirements

Task Scientist. C. F. Jenkins and A. P. Pinsak

Objectives. The objectives of this task are as follows:

(1) To define the Great Lakes problems requiring environmental information for their solutions.

(2) To define an information system of value to Great Lakes resource managers and planners in their decision-making role.

11.2 Task 9.2. Advisory Service

Task Scientist. C. F. Jenkins

Objectives. The principal objectives of this task are as follows:

(1) To provide information in a form useful to the Great Lakes community (particularly for planning and decision-making activities).

(2) To provide services for the application and interpretation of the environmental information and/or techniques or models provided.

12.0 Project 10. ENVIRONMENTAL ENGINEERING MODELS AND APPLICATIONS

Project Scientist. E. J. Aubert

Objectives. The objectives of this project are as follows:

(1) To develop and test improved simulation and prediction models and other tools for user applications to support trade-off analyses in water resource planning and management of water-related activities in the Great Lakes.

(2) To develop a basis for rational decisions for the development and use of Great Lakes resources.

Background. Accurate scientific information is a prerequisite for effective environmental management. In its absence, the decision maker must rely on economic, social, and political considerations or on intuition. Thus, decisions affecting the environment have often been made without the benefit of current scientific knowledge. This project hopes to improve the transfer of an environmental information model, statistical tabulation, and atlas.

The expression of natural processes in a mathematical framework has advanced considerably over the past decade. Methodology developed in a technological context has been applied to a variety of natural systems and processes. The approaches range from those based on scientific principles to those of an empirical nature and address such problems as eutrophication, lake water levels, and fisheries management. While many of the developments have been made in marine systems, the possibilities for application to the Great Lakes have been well documented.

Unfortunately, models have at times been represented as panaceas, capable of answering every environmental question. This can only be avoided by close interaction with the user and careful explanation of the capabilities and limitations of the model. If done properly, the capability of the model of organizing large and varied information for the decision maker will be optimally exploited.

Many water-related activities and users in the Great Lakes have decisions which involve management and planning of land use, water use, and water resources. The following needs are cited as typical of the requirements being addressed by this project:

(1) Develop environmental engineering models to support trade-off analysis of water resource plans involving alternative structural and non-structural projects (Great Lakes Basin Commission).

(2) Develop environmental engineering models to support Coastal Zone Management trade-off analyses between conflicting land and water uses (Office of Coastal Zone Management and Great Lakes States).

(3) Develop environmental engineering models to support decisions of Great Lakes water quality management (International Joint Commission institutions).

(4) Develop environmental engineering models on the possible long-term effects of pollution and man-induced changes on Great Lakes marine ecosystems [NOAA - PL 532, Sec. 202(a)].

Interrelationships with Other Projects. This project is potentially related to all of GLERL's scientific research projects to the extent that their results can be incorporated into the solution of an environmental decision. Several projects are developing models which are of a scientific nature but which could be modified to answer management questions. These include Project 1, Water Movements and Temperature; Project 2, Surface Waves and Water Level Fluctuations; Project 4, Aquatic Ecology Models and Related Studies; Project 7, Hydrologic Properties; and Project 8, Lake Ice. Project 9, Environmental Information Advisory Services, will support this project by establishing communication between the GLERL scientist or engineer and the decision maker.

Approach. This project primarily develops information of use to decision-makers. This is done by developing engineering models, by analyzing all data sets, and by applying prediction or simulation techniques. In all applications, the GLERL engineer or scientist will interact closely with the user as a team member to insure that the model is developed to answer suitable questions and that the results are properly interpreted. At present, the approach will consist of initiatives in the following three areas:

(1) Information reports. Data will be summarized in a form comprehensible to both the layman and the scientist as a result of data analysis and the application of models to systematically analyze alternatives as in a trade-off analysis.

(2) Application of existing models. The laboratory will maintain a library of computerized models and other techniques which can be applied directly or with minor modification to general classes of environmental problems.

(3) Development of models. When a problem-oriented environmental model is needed but not available, development will proceed under this project, if appropriate.

12.1 Task 10.1. Maumee Bay Level B Study

Task Scientist. A. P. Pinsak

This task is complete. A final report is in preparation.

12.2 Task 10.2. Phosphorus Model

Task Scientist. S. C. Chapra

Objectives. The objective of this task is to investigate the feasibility of simulating long-term trends of total phosphorus in the Great Lakes by using social and economic factors as forcing functions.

12.3 Task 10.3. Lake-Scale Water Quality Model

This task was deleted in November 1975. The research is now being conducted under Tasks 4.3, Three-Dimensional Ecological Model, and 4.4, Ecological Modeling.

12.4 Task 10.4. Monitoring Water Characteristics

This task has been transferred to Project 8, Lake Ice, to support lake ice forecasting.

12.5 Task 10.5. Atlas of Lake Ontario Physical Properties

Task Scientist. C. F. Jenkins

Objectives. The objectives of this task are to develop pertinent analysis information, to prepare a summary publication for an atlas of selected data and analysis results to depict the physical environment observed during the IFYGL, and to develop and present this information in a form useful for engineering and design purposes as well as for future research purposes.

13.0 Project 11. INTERNATIONAL FIELD YEAR FOR THE GREAT LAKES (IFYGL)

Project Scientist. E. J. Aubert and C. F. Jenkins

Objectives. The objectives of this project are as follows:

(1) To successfully complete the data management, archiving, analysis, and modeling activities of IFYGL as internationally agreed to in the *IFYGL Technical Plan.*

(2) To maximize the analysis and modeling results within the available time and resource constraints; to document the elements of the program so that the IFYGL data and analysis results are of the highest possible utility in furthering the understanding of the Great Lakes and in aiding the Great Lakes resource managers in their planning and decision-making capacity.

Background. IFYGL was conceived as a part of the International Hydrological Decade (IHD) - 1965 to 1975 - and is a joint Canadian-United States program of environmental and water resources research in the Great Lakes, specifically Lake Ontario and its basin. The National Research Council in Canada and the National Academy of Sciences in the United States are responsible for general policy as related to the studies of worldwide water resources. In 1970 NOAA was made the lead agency for administering the United States part of the program and for coordinating this with the Canadians. The IFYGL Project Office was formed under the Associate Administrator for Environmental Monitoring and Prediction. As of April 1974, the IFYGL Project Office was incorporated into the new Great Lakes Environmental Research Laboratory under ERL. The IFYGL results are expected to provide a scientific basis for improved Great Lakes management activities related to water quality and quantity and environmentally sensitive operations.

IFYGL includes six major components and a synthesis program as follows:

(1) Terrestrial Water Balance.

(2) Lake Energy Budget.

(3) Water Movement.

(4) Evaporation Synthesis.

(5) Atmospheric Water Balance.

(6) Chemistry and Biology.

(7) Atmospheric Boundary Layer.

An intensive 1-year field observation program was mounted on Lake Ontario and in its basin from 1 April 1972 through 31 March 1973 to provide a comprehensive data set including physical, chemical, and biological parameters. Over 600 scientists from Canadian and United States government agencies, universities, and private industry participated in the program. The data archive and analysis results will provide a stimulus to Great Lakes applied research for many years to come.

Interrelationships with Other Projects. This project will provide data and analysis results for use in Task 10.5, Atlas of Lake Ontario Physical Properties. Project 3, Lake Ontario Energy Budget (IFYGL), is an integral part of the IFYGL program as are the following tasks: 1.1, Distribution and Variability of Temperatures and Currents in Lake Ontario; 1.2, Lake Ontario Lagrangian Current Observations and Analysis (IFYGL); 1.3, Lake Ontario Water Movements Scientific Report (IFYGL); 1.7, Current Study-Oswego Harbor; 6.2, Analysis of Lake Ontario Oxygen Profiles; 6.4, IFYGL Chemical Intercomparison; 6.5, Characteristics of Oswego River Plume; and 7.3, IFYGL Evaporation Synthesis. Several other projects and tasks are partly involved with IFYGL, e.g., Task 2.1, Surface Wave Observations and Analysis.

Approach. The IFYGL program will continue to be monitored, coordinated, and managed through both direct funding and management by GLERL and the IFYGL Joint Management Team, Joint Steering Committee, and interagency agreements. Additional research tasks in analysis and modeling will be added to fill gaps in the research, to maximize the usefulness of the products, and to fully use the data collection. The Environmental Data Service of NOAA will continue to carry out the data management and archiving activities under the general direction of GLERL. The analysis work in each of the seven major scientific discipline areas (panels) will be monitored through the Joint Management Team. Task work is also being carried out under contract and interagency funding.

Products. This project has produced or will produce the following products:

(1) Data archive (documented) at National Climatic Center in Asheville, North Carolina.

(2) Sets of published reports documenting individual projects and tasks.

(3) *IFYGL Technical Plan* (four volumes).

(4) *IFYGL Bulletins* (quarterly).

(5) *IFYGL Technical Manuals.*

(6) *IFYGL Summary Scientific Report Series* covering:

A. Terrestrial Water Budget Program.

B. Biology and Chemistry Program.

C. Boundary Layer Program.

D. Energy Balance Program.

E. Lake Meteorology Program.

F. Water Movements Program.

G. Evaporation Synthesis Program.

H. IFYGL Program Summary.

14.0 Project 12. PROGRAM DEVELOPMENT

Project Scientist. E. J. Aubert

Objectives. The objectives of this project are as follows:

(1) To facilitate the development of multidisciplinary research programs within the mission and objectives of GLERL and of significance to the Great Lakes region.

(2) To define environmental issues and research needs of importance to Great Lakes resource management and environmental services pertinent to the GLERL mission and objectives and to develop preliminary program documentation.

(3) To undertake pilot, feasibility, or other preliminary research studies as pertinent in order to refine problem definition and research approach.

(4) To achieve incremental support either through channels or from other agencies consistent with NOAA policies and good research management practice.

Background. IFYGL is a multidisciplinary research program for which GLERL has the NOAA U.S. lead agency responsibility. It has been GLERL's experience that multidisciplinary research programs have merit and can produce the critical research mass required to attack broad objectives in limnology, hydrology, meteorology, and limnogeology. As an example of GLERL program definition, a workshop of future Great Lakes research initiatives was held at GLERL in October 1974, and subsequent analysis of this project identified Great Lakes nearshore problems and processes as a logical follow-up to IFYGL. This new multidisciplinary research program has broad research objectives with both a scientific and a user orientation.

Interrelationships with Other Projects. This project is potentially related to all other GLERL research projects. In addition, the project relates to other components of NOAA and other government agencies where the potential for joint research programs is explored and, if mutually advantageous, joint research plans developed.

Approach. This project involves the problem and program definition phase of research for large or multidisciplinary objectives. Here the approach includes the definition of environmental issues and research needs pertinent to resource development, resource management, and environmental hazards. Activities include defining achievable research objectives, organizing the research program, developing viable technical and financial plans, defining feasibility and pilot studies, developing and testing required data acquisition systems, and developing and testing simulation and prediction models. These tasks frequently involve other units of NOAA and other agencies.

14.1 Task 12.1. Nearshore Environmental Problems and Processes

Task Scientist. E. J. Aubert

Objectives. The broad objective of this task is to develop and test methods and tools of environmental systems analysis to support land use and water use planning and management of the coastal zone, the nearshore, and the Lakes themselves. A building block approach will be used to develop a simulation modeling capability for all Great Lakes regions. Numerical models will be developed to simulate the natural environment and man-induced changes for one region. Such models will later be transferred to other regions and expanded as required to include other natural environments and man-induced changes.

The specific objectives of this task are as follows:

(1) To undertake program development.

(2) To identify specific user problems and scientific objectives of importance to water use and related land use development and management.

(3) To develop project plans and a project proposal.

(4) To coordinate project plans within NOAA and with potential users and participatory agencies.

(5) To undertake pilot studies, as appropriate.

14.2 Task 12.2. Great Lakes Waves and Flooding

Task Scientist. E. J. Aubert

Objectives. The overall objectives are to develop and test improved systems of observation, analysis, and prediction and improved climatology of Great Lakes wind waves, storm surges, wind tides, seiches, and flooding. Such improved environmental service supports the needs of the general public, navigation and transportation, fishing, recreational boating, shoreline erosion, coastal engineering, and the Housing and Urban Development (HUD) insurance program.

The specific objectives of this task are to undertake program development to formulate technical and financial plans, to undertake pilot studies as appropriate, and to prepare program documentation.

14.3 Task 12.3. Fox-Wolf River Basin Study

Task Scientist. E. J. Aubert and A. P. Pinsak

Objectives. The broad objective of this study planned by the Great Lakes Basin Commission is to undertake a water resources level B planning study of the Fox-Wolf River Basin and Green Bay. GLERL's role in the study team is as follows:

(1) To develop a set of water quality models compatible with other elements in the study for the Lower Fox-Green Bay system and capable of simulating the response of the water bodies to pollutant loads.

(2) To use these models in conjunction with a study team on water quality problems to conduct a trade-off analysis of the various management alternatives for the next 15-25 years.

The specific objectives of this task are in the nature of program development and they are as follows:

(1) To participate with the Great Lakes Basin Commission and the Wisconsin Department of Natural Resources in developing a plan of study for the Fox-Wolf River Basin and Green Bay.

(2) To further define the desired GLERL role for participation in the Fox-Wolf River Basin Study and to modify our proposal as necessary.

(3) To undertake preliminary development or modification and testing of additional environmental engineering models, as appropriate.

14.4 Task 12.4. Great Lakes Ocean Color Applications

Task Scientist. E. J. Aubert, A. Robertson, A. P. Pinsak, D. B. Rao

Objectives. The broad objectives of this task are as follows:

(1) To develop quantitative procedures for estimating concentrations of chlorophyll, calcium carbonate, and other suspended particulate material from the Nimbus G coastal zone color scanner (CZCS) data.

(2) To monitor fields of chlorophyll, calcium carbonate, and other suspended particulate material.

(3) To develop techniques and evaluate the usefulness of CZCS and other remotely sensed data to diagnose surface currents and physical phenomena.

(4) To use CZCS data in combination with in situ observations to evaluate simulation models for Great Lakes ecosystems, water quality, and circulation.

The specific objectives of this task are as follows:

(1) To participate with other NOAA units in planning a NOAA CZCS FY 1979 initiative.

(2) To further define GLERL's role in Phase 1 Great Lakes validation and certification experiments and Phase 2 Great Lakes applications.

(3) To undertake program development, including preliminary studies as required to maximize the likelihood of success of this NOAA/GLERL initiative.