TECHNICAL PLAN
for the
GREAT LAKES
ENVIRONMENTAL
RESEARCH LABORATORY

U.S. DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration
Office of Oceanic and Atmospheric Research
Environmental Research Laboratories
Great Lakes Environmental Research Laboratory

Ann Arbor, Michigan January 1985

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Dr. Eugene J. Aubert, Director

January 1985

National Oceanic and Atmospheric Administration
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PREFACE

The Great Lakes Environmental Research Laboratory (GLERL) was established on April 24, 1974, to provide a focus for NOAA's environmental research on the Great Lakes. 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 functional statement, broadened recently, is as follows:

> Conducts integrated, interdisciplinary environmental research in support of resource management and environmental services in coastal and estuarine waters with a special emphasis on the Great Lakes. The laboratory performs field, analytical, and laboratory investigations to improve understanding and prediction of coastal and estuarine processes and interdependencies with the atmosphere, land, and sediments. It places special emphasis on a systems approach to problem-oriented environmental research in order to develop environmental service tools. It provides assistance to resource managers and others in obtaining and applying the information and services developed by the laboratory.

TABLE OF CONTENTS

FIGURES

TABLES

Introduction. This *Technical Plan*, the 11th in an annual series, documents the GLERL research program as of December 1984. Organized in terms of projects, it updates the Plan dated January 1984. This version of the *Technical Plan* outlines both the projects and tasks. 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 from those in existence 1 year ago because of additional accomplishments, evolution in senior staff, and redefinition of objectives. An evolution of the research structure has occurred and is continuing. The critical nature of the toxic organic problem in the Great Lakes, the urgency in its own right and interdependencies of the nutrient enrichment (eutrophication) problem to the Great Lakes ecosystem, and the critical need to develop improved methods of environmental prediction and simulation for resource development and use and for environmental protection is reflected in Projects 1, 3, 4, 5, 6, and 10. The evolving research plans addressing lake levels, flows, and water quantity management problems are documented in Projects 7 and 10. The research plans for improved information and methods of prediction of physical hazards, waves, storm surges, and lake ice are documented in Projects 2 and 8. The status of completed and discontinued tasks is noted in the background section of the respective project descriptions. Each completed task has a final task report on file that summarizes accomplishments.

Perspectives. This *Technical Plan* was prepared 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.

GLERL has a two-part mission: to conduct research directed toward better understanding of environmental processes in coastal and estuarine waters, especially the Great Lakes and their basin, and to assist in the solution of environmental problems of resource management, water-related activities, and environmental services. Our goal is to build useful environmental simulation and prediction models that provide suitably precise information to support the best possible use of the region's resources. To achieve this goal, there needs to be improved understanding of first-order processes and phenomena of the lake-land-atmosphere-sediment system. 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, and thereby spreading our staff too thin, or our accomplishments will be small owing to overcommitment of limited resources.

Planning Process. This 1985 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. A summary of the Great Lakes environmental problems and activities for project emphasis is contained in table 1.

Research Structure. The research sequence of figure 1 conceptually portrays the overall approach to our process and problem-oriented research. In problem-oriented research, our research objectives are defined to solve environmental problems of Great Lakes resource management or to develop or improve environmental services for Great Lakes activities. Scientific objectives are defined to improve our understanding of environmental processes in the interactive lake-land-atmosphere-sediment system so we can improve our problem-oriented simulation and prediction models. After suitable objective definition, an interdependent approach sequence includes data collection, analysis, modeling, and evaluation with various feedback loops. Few of our research projects address all components of this research sequence, although several projects have experimental, theoretical, and numerical modeling tasks. Our projects have a large degree of interdependence in the sense of this problem-oriented approach. 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.

Table 1.--*Project-problem emphasis*

Project		Problem
P-1	1.	Nearshore and boundary layer (air-water and water-sediment) processes and phenomena.
	2.	Importance of baroclinic and nonlinear processes.
	3.	Research to develop, test, and evaluate a hierarchy of improved numerical models to simulate and predict water movements and transport for use in spill prediction, and as required for transport of dissolved and particulate contaminants and ice in Projects 3, 4, 6, 8, and 10, and to identify first-order phenomena and processes that require experimental research investigations; models to support trade-off analyses in water-related activity planning, i.e., siting of water intakes, wastewater outfalls, etc.
	4.	Experimental research to further understanding of phenomena and processes as required to improve numerical prediction models (also applies to Project 2).
P-2	1.	Prediction of surface waves, wind tides, storm surges, seiches, and flooding; effects on sediment resuspension, disposition, and transport.
	2.	Climatology of waves and water level fluctuations.
	3.	Atmospheric boundary layer model; process parameterization; experimental studies.
	4.	Interdependent processes that relate offshore and nearshore waves and coastal currents.
P-3	1.	Transport and diffusion prediction of conservative properties and contaminants.
	2.	Process of particulate transport, sedimentation, resuspension, aggregation, and sediment mixing.
	3.	Simulation and prediction modeling.
P-4	1.	Key chemical biological processes of toxic organics cycling in the Great Lakes, e.g., sorption, photodecomposition, benthos uptake and release, bacteria uptake and release.
	2.	Simulation modeling of seasonal properties and budget modeling.
P-5	1.	Experimental research to improve understanding of processes of planktonic growth, dominance, succession.
	2.	Research to develop, test, and evaluate numerical models of lake ecosystems to better understand, to simulate, and to predict the seasonal cycle for a healthy system and for one stressed by excessive or deficient nutrients; transferrability of Great Lakes ecosystem models to other systems (also applies to Project 6).
P-6	1.	Experimental research to better understand first-order chemical and biological processes of eutrophication and nutrient cycling.
P-7	1.	Models to support trade-off analyses in water levels and flows and chemical and particulate transport in connecting channels and tributary rivers.
	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, thickness, transport, and breakup in the lakes, bays, harbors, and connecting channels.
	2.	Ice information to support ocean engineering, marine resource management, and winter navigation decision processes.
	3.	Research on ice dynamics as to improve understanding, statistical information, and prediction.
P-9	1.	Environmental advisory service.
	2.	Participation on Boards, Committees, and Task Forces of IJC, winter navigation extension, etc., to provide advice and products and to determine research needs.
P-10	1.	Environmental models and information to support decisions in water-related activities, resource development and environmental management.
	2.	Systems methods for analysis of balanced growth, i.e., marine resource development and use with environmental quality and utilizing concepts of benefits, risks, and costs.
	3.	Water resource studies and applications.
	4.	Integration of ecological with socio-economic information into a broad systems perspective.
P-11	1.	Great Lakes Long-Term Effects Research; environmental prediction and simulation with emphasis on the marine ecosystem and with stresses of toxic organics, nutrient enrichment and particle dynamics.
	2.	Research in numerical prediction of circulation, waves, particulates and the ecosystem of the Great Lakes and coastal regions.
	3.	Environmental research to develop improved understanding and prediction to support balanced and cost-effective growth and use of the marine resources with acceptable risks and costs.

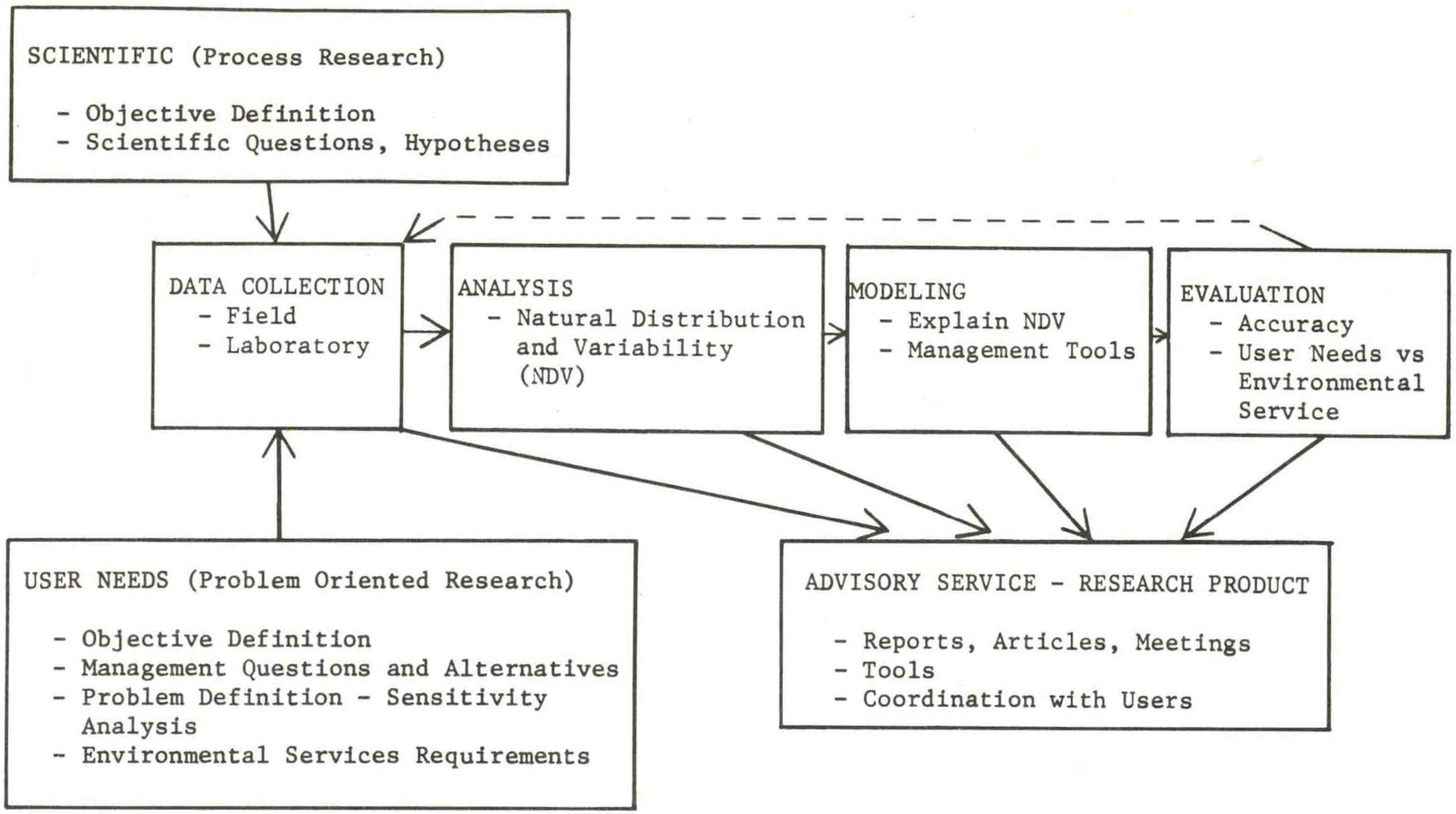

Figure 1.--*Research sequence.*

Project 1. WATER MOVEMENTS AND TEMPERATURE

Project Scientist. J.R. Bennett

Objectives.

(1) To develop improved climatological information (via observations, new instrumentation, and improved analysis) on the distribution and variability of coastal and offshore 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 information from objective (1) for both coastal and offshore regions.

(3) To improve the understanding of the physics of the lakes by analyzing the results of objectives (1) and (2).

(4) To extend the models developed in objective (2) 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 will be developed and tested for use in water resources planning.

Background. This project is concerned with observing and predicting certain aspects of the physical environment of the Great Lakes. In general, the physical state of these lakes can be predicted in terms of the distribution of temperatures, currents, waves, and water levels. Each of these variables has an impact on environmental, chemical, and biological processes and influences many user activities, such as water supply management, waste water management, power plant sitings, shipping, recreational boating, and shoreline erosion.

These physical processes have a wide range of space and time scales (fig. 2). Some phenomena, such as upwelling and coastal jets, are confined to nearshore regions, whereas others, such as mean circulations and seasonal stratifications, are lakewide. 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 in the lake, these different space/time scales need to be separated. This separation is also essential for applying the information to 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.

The primary emphasis in this project is on studies of circulation and stratification on coastal and lakewide scales and how these are impacted by seasonal and episodic changes in atmospheric forcing.

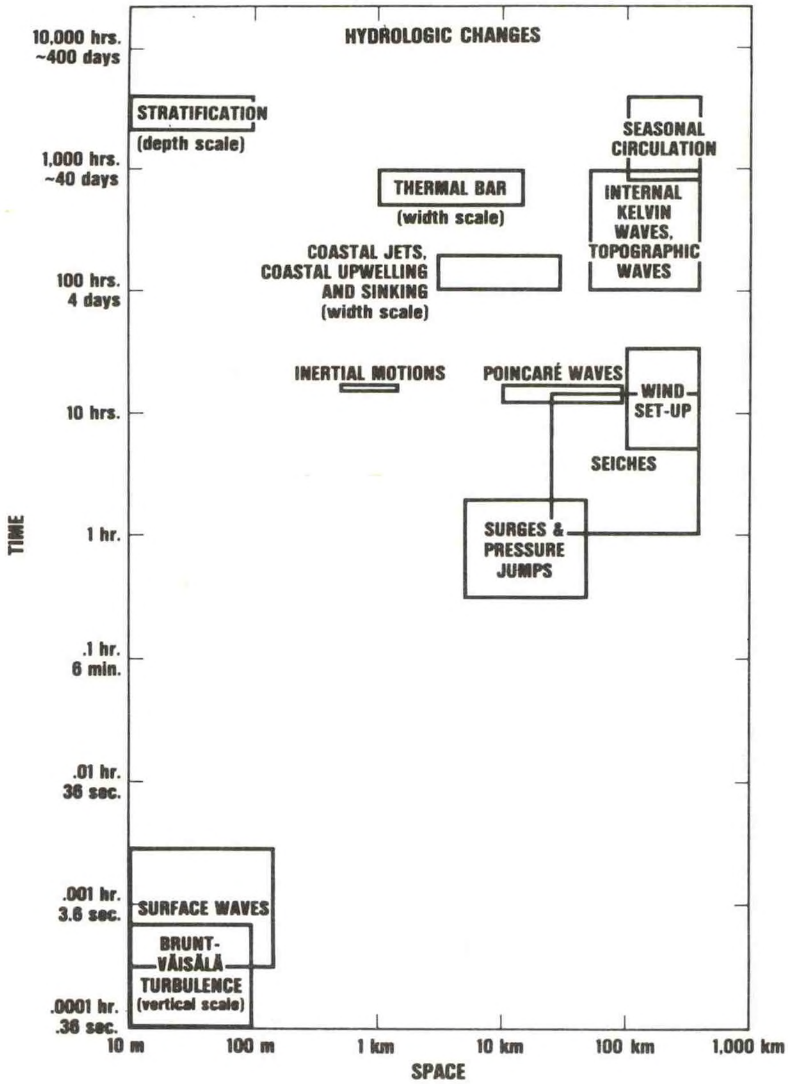

Figure 2.--*Scales of physical lake phenomena.*

The following research tasks have been completed and a task final report is on file:

Task 1.4, Computation of Rotational Normal Modes.

Task 1.5, Deep Currents.

Task 1.6, Advanced Current Measuring Techniques.

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 local meteorology and ice formation and breakup (Project 8, Lake Ice). The distribution of currents and temperatures governs the diffusive and advective effect on dissolved and suspended substances in a lake (Project 3, Particle Dynamics). Hence, the processes and phenomena studied in this project provide the necessary background information for a proper interpretation and understanding of the results of several of the GLERL projects, e.g., Project 4, The Cycling of Toxic Organics, and Project 10, Environmental Systems Studies and Applied Modeling.

Approach. During the last few years, the Physical Limnology and Meteorology Group of the Great Lakes Environmental Research Laboratory (GLERL) has developed a lake circulation modeling system to facilitate the development of operational and research computer models. Because its design requires a vision of GLERL's long-term goals for research and its applications, the Physical Limnology Group's modeling system is a reflection of our long-term plan.

The modeling system was designed to meet the needs of seven applications:

(1) Basic Physical Limnology Research--Currents and Waves.

New techniques have been developed for comparing observational data to values generated by numerical models. Because the Great Lakes are simpler to survey than the oceans, the research has been very quantitative in the past and will continue to be so. This is particularly true for currents; the comparison of observed and predicted time series is common in the Great Lakes literature, but rare in the oceanographic literature. With the modeling capabilities we now have, we hope to further this research by comparing computed and observed oscillatory motions and trajectories.

(2) An Operational Storm Surge Model for Real-Time Forecasts and Climatological Studies.

Future work in this area can build on the operational model currently being used by the National Weather Service (NWS).

(3) An Improved Oil Spill and Trajectory Model.

GLERL's oil spill model has been used frequently for several years as a training and spill cleanup tool. An improved version will become operational later this year. The new model incorporates greater numerical accuracy, as well as operational improvements by users.

(4) A Planning Trajectory Model.

Many applied problems require long-term trajectory calculations with the option of calculating both future motions (*forward trajectories*) and past motions (*backward trajectories*) of particles. This model also needs the ability to calculate statistics of particle motion.

(5) A Dynamical Wave Forecast Model.

For several years we have been testing a simple numerical wave forecast model developed by Mark Donelan of the National Water Research Institute of Canada. This testing has come to the point where we see the potential for developing an operational prediction model within the next 2 years. Our approach would be to develop it in a manner similar to the oil spill model--as an interactive program run on GLERL's computer system.

(6) An Operational Ice Prediction Model.

The Physical Limnology and Meteorology Group has collaborated with the Hydrology Group to test and extend a model developed by Ralph Rumer and his group at the State University of New York at Buffalo. This task is not currently active, but could be reactivated if there is sufficient need for the model.

(7) A Sediment Dynamics Model.

We are in the initial stages of developing a sediment dynamics model suitable for examining the problem of contaminant transport in the Great Lakes. Progress to date has included development of general two-dimensional models of particle dynamics and dissolved substance concentration. Present effort is focused on modeling the deposition and erosion zones in the southern basin of Lake Michigan. To account for the effect of Ekman layer sediment transport, we use an analytic formulation for the vertical profiles of current and suspended matter. Eventually, this work will lead to a three-dimensional model of contaminant transport capable of dealing with time scales from days to decades. Results of the sediment trap study will be used to verify the model.

Table 2 summarizes the current status of these applications and gives the components required for them.

Of the seven applications, three are covered under other projects. Project 2 covers research on the storm surge and wave prediction models. Project 8 describes the development and verification of the ice prediction model.

Table 2.--*Applications of the lake circulation modeling system*

	Status*	Components used
Basic PL&M research	C	All
Storm surge model	C	A, B, C
Oil spill model	T	A, B, C, E
Planning trajectory model	P	A, B, C, E, G
Wave model	T	A, B, I
Ice model	P	A, B, C, D
Sediment dynamics	T	A, C, F, J

*C = Continuing.
T = In testing stage.
P = In planning stage.

Research on developing new numerical methods or new models is covered under Task 1.1, GLERL Lake Circulation Modeling System. The remainder of the tasks of this project are devoted to experimental verification of the models, to applying them to other research, or to improving our understanding of lake physics so that we can develop improved models.

Research for this year will focus on the following:

Task 1.1, We will explore the potential of the new CYBER-205 computer and develop numerical methods which will best utilize it to improve the models.

Task 1.2, The objective analysis and the oscillatory forcing methods will be tested against data from Lake Erie.

Task 1.3, A standardized data system for time-series data will be implemented.

Task 1.7, A method for thermal structure in lakes will be published.

Task 1.8, Data from fixed current meters and satellite-tracked drifting buoys will be used to verify the circulation and objective analysis models.

Task 1.9, The sediment dynamics model will be verified against observed patterns of sedimentation in southern Lake Michigan.

Task 1.10, The trajectory model will be verified using satellite-tracked drifters.

Task 1.11, An experimental program to measure currents in the bottom boundary layer will be coordinated with measurements of suspended sediments. The goal of this research is to improve the sediment dynamics model.

Task 1.12, Dye experiments will be analyzed to measure diffusion and to measure the effects of wind on the satellite-tracked drifters. This work will aid in verifying the trajectory model.

Grants and Contracts.

(1) Title. Internal Motion and Related Internal Waves in Lake Michigan and Lake Ontario as Responses to Impulsive Wind Stresses, Part II.

Principal Investigator. C.H. Mortimer (University of Wisconsin-Milwaukee).

Objective. Description of near-inertial period internal waves and currents in the lakes in terms of the Poincaré wave conceptual model.

(2) Title. Coupling of Physical and Biological Dynamics in Large Lakes.

Principal Investigator. C.H. Mortimer (University of Wisconsin-Milwaukee).

Objectives. To identify gaps in data needed for management actions on lakes, to optimize the design of experimental and monitoring programs, to fill these gaps, and to "listen" to relevant in-lake signals identifying critical responses of the real system.

Task 1.1. General Numerical Models for Computing Currents

Task Scientists. J.R. Bennett and D.J. Schwab

Objective. The objective of this task is to use our current observations to develop and verify a hierarchy of improved water quality and circulation models that will predict the fate of oil or toxic chemicals in the Great Lakes. In doing this, we will develop general numerical methods that can be applied to other physical problems, such as ice and wave prediction.

Task 1.2. Analysis of Lakes Erie and Michigan Data

Task Scientists. J.R. Bennett, G.S. Miller, and J.H. Saylor

Objectives.

(1) To describe and understand the circulation of Lake Erie, including the distributions and volumes of interbasin exchange processes.

(2) To study dynamical processes observed in Lake Michigan.

Task 1.3. Development of a GLERL Data Access System (GDAS)

Task Scientists. D.J. Schwab, G.S. Miller, and E.W. Lynn

Objective. The objective of this task is to establish a standardized data system for time-series data to permit easy access to various types of data and a system that is computer independent.

Task 1.7. Thermal Structure Forecasting

Task Scientists. M.J. McCormick, J.R. Bennett, and F.H. Quinn

Objectives.

(1) To evaluate three represenative thermocline models as forecasting tools for predicting offshore temperature profiles in the Great Lakes.

(2) To determine thermal structure response to high frequency signals in the global radiation distribution.

(3) To simulate low frequency thermal responses of Lake Superior to changes in meteorological conditions for simulating and forecasting lake evaporation for use in water supply and climatic studies and analysis.

Task 1.8. Rotational Mode Experiment

Task Scientists. J.H. Saylor and G.S. Miller

Objective. The objective of this task is to study the properties of the long-period vorticity waves in Lake Michigan.

Task 1.9. Modeling Transport of Toxic Substances

Task Scientists. J.R. Bennett and A.H. Clites

Objective. The objective of this task is to predict the temporal and spatial movement of toxics in the Great Lakes. A two-dimensional vertically integrated model and a three-dimensional, thermally stratified numerical model will be used to calculate currents in Lake Michigan. These currents will then drive a water quality model that will advect, diffuse, decay, settle, and resuspend particles and dissolved chemicals.

Task 1.10. Spill Model Verification Using Satellite-Tracked Drifter Buoys

Task Scientists. J.R. Bennett, A.H. Clites, J.E. Campbell, D.J. Schwab, and E.W. Lynn

Objectives.

(1) To verify the improved general-purpose spill model using data from satellite-tracked drifter buoys.

(2) To analyze the existing drifter buoy data base in conjunction with Vector Averaging Current Meter (VACM) data collected in Lake Michigan concurrently.

(3) To study the surface current patterns for specific areas of interest using satellite-tracked drifter buoys.

Task 1.11. Lakes Environment Benthic Boundary Layer Experiments

Task Scientists. J.H. Saylor and G.S. Miller

Objectives.

(1) To investigate and test available equipment for measuring currents, sediment concentrations, and other important parameters necessary for parameterization of bottom material resuspension and near-bottom sediment transport processes.

(2) To quantify the distribution of bottom current intensities as functions of both space and time in order to parameterize the distribution and frequency of resuspension events.

(3) To develop a coherent plan for continuing studies of boundary layer dynamics, which are closely coupled with concurrent investigations of particle dynamics.

Task 1.12. Lagrangian Effectiveness of Satellite-Tracked Surface Drifters

Task Scientists. M.J. McCormick, J.E. Campbell, and A.H. Clites

Objectives.

(1) To estimate gross slippage errors of current drifters used in the Great Lakes.

(2) To estimate the wind and wave components of slippage errors.

(3) To estimate patchiness scales and Lagrangian diffusivities from Lagrangian statistics.

Task 1.13. Modeling Particle Settling and Resuspension in Lake St. Clair

Task Scientists. A.H. Clites, J.R. Bennett, and T.D. Fontaine

Objectives.

(1) To interact with personnel from Projects 1 and 2 on changes to be made to WAVES model (Task 2.13) and sediment dynamics model (Task 1.9), which will account for shallow bottom effects on wave and current predictions.

(2) To develop the subroutines needed by the Task 1.9 model to predict particle settling and resuspension in shallow water environments.

Project 2. PREDICTION OF SURFACE WAVES, WATER LEVEL FLUCTUATIONS, AND MARINE WINDS

Project Scientist. D.J. Schwab

Objectives. To predict waves and other water level oscillations primarily generated by the wind, the objectives of this project are to

(1) Improve climatological information on the distribution and variability of surface waves, wind setups, surges, seiches, and marine winds.

(2) Develop and test improved statistical or dynamical models for predicting surface waves, wind setups, surges, seiches, and marine winds.

(3) Improve our understanding of the underlying physical processes by analyzing the results of objectives (1) and (2).

Background. The goals in Project 2 are similar to those in Project 1, namely, improved observation, analysis, and prediction. In contrast to Project 1, which deals with long-period processes, the surface wave and water level fluctuations considered here have short periods. 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 is 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 because of complicating factors such as shallow depths, limited fetch, and boundaries. In view of this, continued effort is necessary to develop theoretical and empirical lake wave models, and to test them with properly designed field studies.

Large, short-term fluctuations in the mean water level also occur in the Great Lakes as a result of wind forcing. The horizontal scale of this response is much wider than the small horizontal scale 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 lake 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 has generally not been available in routine weather observations or forecasts. In recent years, the deployment of NOMAD weather buoys in the Great Lakes during the shipping season by NOAA's National Data Buoy Center (NDBC) has helped considerably in providing open lake marine observations. In addition, Coastal-Marine Automated Network (CMAN) weather stations have been installed by NDBC on several islands and exposed shoreline locations around the Great Lakes. This project intends to make full use of these observations in developing climatogical information and in developing and verifying predictive models.

The following research tasks have been completed and a task report is on file:

Task 2.1, Surface Wave Observations and Analysis

Task 2.2, Free Oscillations of Lake Michigan

Task 2.3, Oscillations of Lake Huron

Task 2.4, Wind-Induced Changes in Water Levels on Lake Erie

Task 2.5, Prediction of Winds Over the Great Lakes

Task 2.6, Lake Michigan Surface Wave Measurements

Task 2.7, Testing and Evaluation of Wave Prediction Models

Task 2.8, Lake Superior Surface Wave Measurements and Analysis

Task 2.9, Lake Huron Storm Surges

Task 2.10, Lake Erie Surface Wave Measurements

Task 2.11, The Use of Water Level Measurements to Infer Wind Stress Over Lake Erie

Task 2.12, Lake Erie Directional Wave and Coastal Boundary Layer Measurements

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

Approach. The approach in this project includes field data collection, analysis, and model development, testing, and evaluation. Routine meteorological and marine observations will be obtained from NWS and evaluated for potential use in the development of climatological information and model verification. For surface waves, special data acquisition systems will be deployed to measure the lake and marine 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 setups 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 and NWS and NDBC observations.

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

- Evaluation of the operational Great Lakes numerical wave model.

- Climatological analysis of NDBC NOMAD buoy data and CMAN meteorological data.

- Comparison of wave height measurements by NOMAD buoy and Waverider buoy in Lake Erie.

- Development of wave statistics from wind statistics.

- Study of shoaling, refraction, and bottom friction effects on wind waves.

Grants and Contracts (completed in 1984).

Title. Airborne Radar Synoptic Wave Observations

Principal Investigator. G.A. Meadows (University of Michigan)

Objective. To compare model simulations of the synoptic wave field in Lake Erie to Side-Looking Airborne Radar (SLAR) observations of wave direction and intensity obtained by the NOAA P-3 aircraft in 1981. This comparison will provide further validation of the wave forecast model.

Task 2.13. Prediction of Wind-Generated Waves on the Great Lakes

Task Scientists. D.J. Schwab and J.R. Bennett

Objectives. The broad objective of this task is to improve Great Lakes wave forecasts by developing and testing improved wave models. The specific objectives addressed to meet this broad objective are

(1) To develop a parametric wave prediction model and implement it within the framework of the GLERL numerical modeling system developed in Task 1.1.

(2) To test the model in a hindcast mode against field data gathered in Tasks 2.12, 2.14, this task, and NDBC, NOAA, NOMAD buoy data.

(3) To test the model in a forecast mode against NOAA/NWS operational wave forecasts.

(4) To implement the model for operational use if it proves superior to current forecast methods.

Task 2.14. Great Lakes Wave Climate From NDBC Data

Task Scientist. P.C. Liu

Objectives.

(1) To synthesize wave, wind, and temperature data recorded from NDBC NOMAD buoys in the Great Lakes and to delineate climatological information on Great Lakes waves.

(2) To examine the individual, joint, and multivarate long-term distributions of the parameters and to develop statistical models for representation and prediction.

Task 2.15. Nearshore Transformation of Wind-Wave Characteristics

Task Scientist. P.C. Liu

Objectives.

(1) From detailed analysis of shallow water wave measurements made in Lake Erie (Task 2.12, LEX-81) to examine the finite depth effects on wave characteristics.

(2) Using the results developed in (1) to compare with available shallow water wave theories for their applicabilities.

(3) Developing modifications to the GLERL-Donelan wave model for shallow lake applications.

Project 3. PARTICLE DYNAMICS

Project Scientist. J.A. Robbins

Objectives.

(1) To characterize the physical and chemical properties of particulate matter in water and sediments of the Great Lakes.

(2) To characterize and quantify the temporal and spatial distribution of particulate material in water and sediments.

(3) To characterize the movements of particulate materials in water, as well as in sediments.

(4) To characterize and quantify sources of particulate materials in the lakes with emphasis on resuspension processes and rates.

(5) To characterize and quantify the ultimate sinks of particulate material, with emphasis on resuspension processes and rates.

(6) To identify and quantify chemical and biological processes affecting the hydrodynamic characteristics of particles.

(7) To develop mathematical models for the transformation and movement of particulate matter in water and sediments.

Background. Concentrations of many contaminants found in the Great Lakes tend to be determined by their association with particulate matter. Organic pollutants, such as chlorinated aromatics and polycyclic aromatic hydrocarbons, are very insoluble in the aqueous phase and rapidly sorb onto most solid substrates, particularly to small particles present in the water column. Such particles enter the lakes from the atmosphere, shoreline erosion, tributaries, *in situ* chemical and biological processes, and resuspension of sediments. Particles originating from these different sources carry variable amounts of organic pollutants and differ in their sorption capacities. How pollutants are distributed among various particle classes may determine whether or not their associated compounds are available to the biota, what settling and resuspension rates these compounds possess, and whether such compounds are subject to photolysis, bacterial degradation, etc. Other constituents are also strongly particle-associated. Many heavy metal contaminants and radionuclides, such as those resulting from nuclear testing or nuclear energy production, strongly sorb on particulate matter and acquire the hydrodynamic characteristics of their particle hosts. Moreover, the major nutrient cycles in the Great Lakes occur partly as a result of *in situ* particle production processes that convey nutrients to hypolimnetic waters, where intensified dissolution occurs. In addition, particulate material suspended in the water column may itself be regarded as a contaminant. Undesirable levels of turbidity in nearshore or shallow waters may result from dredge spoil operations, from dispersion of turbid river waters, and from short-term, high intensity resuspension events. Thus, to properly account for the concentrations, the transport, and the fate of many classes of contaminants, as well as major nutrients, it is essential to understand the hydrodynamic behavior of particulate matter in the lakes. The movements of particles in the water column are more complicated than the water mass movements themselves and are, therefore, of interest from a theoretical and modeling standpoint as well. Particles are subject to processes such as settling, aggregation (or disaggregation), or resuspension, which are not yet adequately characterized or properly represented by deterministic models.

The following research tasks have been completed and a task final report is on file:

Task 3.1, Characteristics of the Nepheloid Layer and Suspended Material in Southern Lake Michigan.

Task 3.2, A Model for Particle Aggregation and Disaggregation in a Turbulent Shear Layer.

Task 3.3, Carbon Dynamics.

Interrelationships With Other Projects. This project will depend upon modeling techniques and results of Projects 1 (Water Movements and Temperature) and 2 (Prediction of Surface, Waves, Water Level Fluctuations, and Overlake Winds) and will provide input at several levels to Projects 4 (The Cycling of Toxic Organics), 6 (Eutrophication and Nutrient Cycling), and 10 (Environmental Systems Studies and Applied Modeling). Application of radiometric methods, for example, can be expected to provide one means of parameterizing and calibrating the ecosystems models of Projects 4, 6 and 7 models describing the long-term response of the lakes to nutrient and contaminant loadings, Project 10. Projects 4, 6, and 10 in turn will inform the particle dynamics planning activity.

Approach. Particle dynamics research will be developed in several areas. In the area of particle fluxes and sinking rates, it is expected that short-term studies of mass fluxes using sediment traps will complement the longer term studies now underway (Task 3.1) and that new field methods may be developed to determine *in situ* particle sinking rates. Laboratory studies of the motions of individual particles in natural media may complement the field work. In the area of resuspension process research, efforts will be aimed at understanding the origins and significance of the benthic nepheloid layer by field work, including turbidity mapping and investigation of the relationships between resuspension and bottom currents. Such work may involve the development of new boundary layer observational and sampling devices, such as continuous turbidity and current measurements, devices for vertical sampling of the lower several meters of water, and continuous flow centrifuge water sampling or high volume filtration to collect gram quantities of particulate matter. Some of these approaches have now been undertaken. A new benthic boundary layer sampler developed by B. Lesht (Argonne National Laboratory) has been deployed and tested in Lake Michigan (Task 3.13) and will be applied to studies of erosion and deposition processes in Lake Superior (Task 3.14) and Lake St. Clair (Task 3.15). Field studies of resuspension may be complemented by laboratory investigations of resuspension of undisturbed sediments collected by specialized coring equipment. In the area of particle transformation processes, the research activity will be expanded to include studies of the chemical and biological factors that may alter the hydrodynamic properties of particulate matter, especially in the benthic nepheloid layer. Studies now include (Task 3.2) both particle aggregation and disaggregation modeling and laboratory experiments on the vertical dependence of particle distribution size aimed at verifying model calculations of particle aggregation processes. Studies may be initiated to examine the kinetics of aggregation of particles subject to chemical additions or presence of selected zoobenthos. A study is in progress (Task 3.12) to apply appropriate statistical techniques to characterize size distributions of particulate matter collected from Lake Michigan. Work begun in the area of carbonate particle dynamics (Task 3.3) may be enlarged to include the dynamics of all transient particles, that is, those whose lifetime in the water is comparatively short (days to months). Silica, as well as carbonate particulate material, is transient in this sense and its behavior in the water column is of both theoretical and practical interest. Both silica and carbonate particles probably scavenge contaminants from the epilimnion, but may release them in hypolimnetic waters. The hydrodynamic behavior of transient particles is strongly time-dependent and closely related to their kinetics of dissolution. Thus, field and modeling efforts in this area must be carefully approached and coordinated with kinetic studies made by other groups (Project 6, Eutrophication and Nutrient Cycling). In the area of sedimentation research, the particle dynamics project will provide sedimentation rate information for geochronological studies of contaminant fluxes in the Great Lakes. Rates of sediment accumulation combined with concentration data provide estimates of present and historical contaminant deposition. An initial task (Task 3.5) aimed at investigating the contaminant and nutrient fluxes in high sedimentation areas of the lakes will be expanded to include a contaminant deposition map on a lake-wide basis. The methods and results of this sedimentation study and radionuclide transport modeling (Task 3.7) will be applied to determine characteristics of sediment transport, deposition and storage of selected tracers in Lake St. Clair (Task 3.16). This Task is being developed as part of the multi-institutional Upper Great Lakes Connecting Channels Study. Another area of activity within the particle dynamics project is that of post-depositional movement of sedimentary materials. Studies (Task 3.6, Role of Zoobenthos in Vertical Sediment Transport) will be undertaken to determine the spatial scales and extent of sediment reworking by benthic fauna, the effect of particle reworking on solute transport across the sediment water interface, and factors affecting sediment reworking rates.

The approaches described are intended to characterize and parameterize processes for inclusion in comprehensive ecosystem and transport models for the behavior of particulate matter in the water column. Models will be developed in several levels as part of the particle dynamics program (Task 3.7). Vertically integrated transport models, successful in describing oil spills and dispersion of mirex into Lake Ontario, will be refined and applied to known fluxes of mass, radionuclides, and selected contaminants in the lakes. Development of vertically integrated transport models must go in two directions: (1) the accurate prediction of long-term deposition, such as sedimentation rates and deposition of contaminants in sediment, and (2) the description of the horizontal distribution and movement of contaminants, nutrients, and radiotracers on time scales on the order of days to months.

Horizontally integrated models combining transport and kinetic terms between various ecosystem compartments will be used to inform field research efforts. An ultimate aim of the particle dynamics project is to provide a basis for unified transport and ecosystems model.

Radiotracer methods (Task 3.4) will be developed as a tool for quantifying the collective motions of particulate matter in the lakes. Radiotracers have already proven to be of very considerable value for determination of whole-lake contaminant residence times, sedimentation rates, and the range and rates of sediment reworking (bioturbation). These parameters are of critical importance to most comprehensive ecosystem models of nutrients and contaminants. Further studies of these processes (sedimentation, bioturbation, and factors affecting overall residence times) will go forward under this program. However, there will be new initiatives to better identify radiotracer source terms, particle associations, and the collective motions of particles across in-lake boundaries. Radiolimnological investigations will include short-term studies of resuspension processes, determination of residence times of particulate matter (in the epilimnion, in the nepheloid layer, and in nearshore areas of the lakes), investigations of thermocline transport of particulate matter and of the long-term response of the lakes to quasi-conservative contaminants (Task 3.8), and measurements of the vertical the development of radiotracer methods will depend on the construction of the realistic models for the transport of particle-associated contaminants in the water column. In turn, knowledge of the distribution of radiotracers in the water and in sediments can serve to calibrate both transport and ecosystem models.

Unlike most organic contaminants, whose loadings are poorly known and whose fates are poorly characterized, many natural and man-made particles associated with radiotracers are exceptionally well-behaved. Radiotracers such as beryllium-7, lead-210, polonium-210, cesium-137, plutonium-238, and plutonium-239 have unique, comparatively well-defined sources and, for natural ones, a seasonal periodicity that can be accurately defined. In addition, radiotracers are not removed via photolysis or biological degradation, but are subject to removal only by outflow, which is generally negligible, and by radioactive decay, which is precisely known. Hence, radiotracers are ideally suited to calibration of ecosystems models and the approach within particle dynamics is to treat development of particle tracer methods as being parallel to, but lagging behind, that of toxic organic and nutrient cycling research efforts. Therefore, samples will be taken from the lakes that are subject to chemical and biological fractionation procedures equivalent to those of the lakes used for other projects. The nature of the associations of radiotracers with particulate matter will be investigated under Task 3.9.

Grants and Contracts.

(1) Title. Toxic Organic-Sediment Dynamics in the Great Lakes

Principal Investigator. S. Eisenreich (University of Minnesota)

Objective. To determine the history of deposition and post-depositional mobility and of transformation of organic contaminants in radiometrically characterized sediment cores.

(2) Title. A Study of Particle Dynamics

Principal Investigator. R. Rossmann (University of Michigan)

Objective. To determine the vertical distribution of selected major and minor elements in dated cores as a basis for interpretation of organic contaminant profiles.

(3) Title. Sediment Patterns in Lake St. Clair

Principal Investigator. B. Lesht (Argonne National Laboratory)

Objective. To determine relationships between bottom currents and sediment resuspension rates using a previously developed instrumented bottom-resting tripod.

Task 3.4. Development of Radiotracer Methods for Particle Dynamics Studies

Task Scientist. J.A. Robbins

Objectives.

(1) To develop techniques for analysis of radionuclides associated with particulate matter in the lakes (beryllium-7, cesium-137, lead-210, and polonium-210).

(2) To develop field methods for collection, filtration, and tracer scavenging of large volumes of water.

(3) To establish viability of laboratory and field methods by determination of radiotracer activites in sediments, trap materials, plankton, and dissolved and particulate components of water.

Task 3.5. Present and Historical Records of Contaminant Fluxes in High Sedimentation Areas of the Great Lakes

Task Scientists. J.A. Robbins and B.J. Eadie

Objectives.

(1) To make precise determinations of sedimentation rates, ages of individual layers of sectioned sediment cores, and ranges and rates of biogenic mixing using radiometric methods.

(2) To determine the concentration of selected elements and inorganic and organic chemical compounds in dated sediment sections.

(3) To develop models that quantitatively describe the history of deposition of contaminants and take into account processes such as transport and degradation within the sediment column.

(4) To use models to estimate the flux of contaminants from sediments into overlying water.

Task 3.6. Role of Zoobenthos in Vertical Sediment Transport

Task Scientists. J.A. Robbins and D.S. White (University of Michigan)

Objectives.

(1) To determine rates of sediment reworking by natural benthos populations.

(2) To relate benthic densities and reworking rates to sedimentation and nutrient deposition rates.

(3) To relate the vertical distribution of zoobenthos to sedimentation and mixing parameters determined radiometrically.

(4) To quantify the effects of benthos-mediated particle reworking on transport of solutes.

(5) To develop mathematical models of the effects of benthos on particle and solute transport in sediments.

Task 3.7. Particle Tracer Model Development

Task Scientist. J.A. Robbins

Objectives.

(1) To obtain optimal estimates of the flux of radionuclides to the Great Lakes.

(2) To develop a one-dimensional (horizontally averaged) model describing the short-term behavior of particle-associated tracers in the water column.

(3) To develop two-dimensional (vertically averaged) and whole, well-mixed lake (box) models describing the long-term time-dependence of radiotracer concentrations in the lakes.

(4) To interface models with those describing the behavior of organic contaminants.

(5) To calibrate models on the basis of known distributions of radiotracers in water, trap materials, and sediments.

(6) To use the models to predict distributions of tracers and to develop optimum field strategies.

Task 3.8. Response of Sediments to Long-Term Increases in the Concentrations of Conservative Substances in Overlying Waters

Task Scientist. J.A. Robbins

Objectives.

(1) To determine the distribution of conservative substances, such as strontium-90, chloride, and possibly tritium in pore waters of dated sediment cores.

(2) To develop models that properly describe transport of solutes and particles in sediments and are consistent with the known changes in levels of conservative substances in the water column.

Task 3.9. Multitracer-Particle Associations

Task Scientists. B.J. Eadie, N.R. Morehead, and J.A. Robbins

Objectives.

(1) To determine the equilibrium distribution (partition) coefficients for organic contaminants and radionuclides onto Lake Michigan particulate matter.

(2) To determine the dependence of the distribution coefficients on the concentration of solids in sediment-water suspensions.

(3) To determine the role of dissolved organic carbon on partitioning.

(4) To determine the effect of prolonged contact of tracers with sediments on the distribution coefficent for desorption.

Task 3.10. Flux Measurements in Lakes Michigan, Huron, and Superior

Task Scientists. G.L. Bell, B.J. Eadie, and J.A. Robbins

Objectives.

(1) To measure the primary and resuspension mass fluxes in Lakes Michigan, Huron, and Superior during thermally stratified and unstratified periods.

(2) To quantify the chemical fluxes for selected tracers in these lakes.

(3) To develop a model to simulate the process of settling and resuspension of particulates.

Task 3.11. Seasonal Variations in the Vertical Distribution and Transport of Short-Lived Radionuclides

Task Scientists. N. Hawley, J.A. Robbins, G.L. Bell, and B.J. Eadie

Objectives.

(1) To determine seasonal variations in the vertical distribution of particulate and dissolved short-lived (beryllium-7, polonium-210), as well as long-lived (lead-210, cesium-137) radionuclides in the open lake.

(2) To determine seasonal variations in the vertical distributions of the flux of these radionuclides.

(3) To determine seasonal variations in the distribution and storage of these radionuclides in sediment underlying the sampling site.

(4) To provide an experimental basis for development of whole lake and vertical transport models (Task 3.7).

Task 3.12. Statistical Techniques for the Analysis of Suspended Particles

Task Scientist. N. Hawley

Objectives.

(1) Develop statistical techniques which permit the quantitative characteristics of suspended particle populations based on

a. Particle-size distribution, and

b. Particle composition as a function of size.

(2) Use these techniques to quantify the differences in suspended populations.

Task 3.13. Investigation of Benthic Boundary Layer Sampling Techniques

Task Scientists. N. Hawley, B.J. Eadie, and J.A. Robbins

Objectives.

(1) To test existing equipment which sample in the bottom boundary layer.

(2) To use the data obtained to provide guidelines for the design of new instruments.

(3) To develop a coherent plan for future work in the bottom boundary layer.

Task 3.14. Observations of Erosion and Deposition in Lake Superior

Task Scientist. N. Hawley

Objectives.

(1) Experimentally determine sediment erosion rates as a function of current velocity, sediment characteristics, and biological activity.

(2) Measure sediment erosion/deposition rates over times of weeks to months.

(3) Use the results to predict when, where, and at what rate deposition or erosion is most likely to occur.

Task 3.15. Sediment Transport in Lake St. Clair

Task Scientist. N. Hawley

Objectives.

(1) To make observations of bottom currents, wave activity, and water concentration in Lake St. Clair.

(2) To experimentally determine sediment erosion rates as a function of current velocity.

(3) To use these data to determine sediment resuspension and transport in Lake St. Clair.

Task 3.16. Transport and Fate of Particle-Associated Tracers in Lake St. Clair and the Connecting Channels

Task Scientist. J.A. Robbins

Objectives.

(1) To determine levels of selected stable and radioactive tracers in sediments of the Lake and connecting channels.

(2) To determine patterns of accumulation and storage of tracers in the system.

(3) To determine the extent and intensity of local integration processes such as biological and physical mixing.

(4) To determine system response times and "trapping efficiency" by comparison of present and historical sediment inventories with known time-dependent loadings.

(5) To reconstruct, in optimal cases, the time history of contamination from sedimentary records.

Project 4. THE CYCLING OF TOXIC ORGANICS

Project Scientists. B.J. Eadie and P.F.Landrum

Objectives.

(1) To develop a model hierarchy to simulate the cycling and transport of selected toxic organic substances in the Great Lakes.

(2) To perform laboratory and field experiments designed to provide information on various pathways and rates of removal of the toxic organics from the ecosystem.

Background. The leakage of toxic synthetic organic contaminants into aquatic ecosystems is a well-recognized global problem. The conclusion of a recent workshop cosponsored by GLERL--The Scientific Basis for Dealing With Chemical Toxic Substances in the Great Lakes---was that the Great Lakes are particularly susceptible because of high population density, con-centration of heavy industry, and slow (decade-century) flushing rates. Similar evaluations have been expressed by the Great Lakes Science Advisory Board, Water Quality Board, and Toxic Substances Committee of the International Joint Commission. Over 800 toxic contaminants have been identified to date within the Greats Lake ecosystem and the extent of the hazards for most of these are poorly understood.

While most of these contaminants were perceived to be detrimental to environmental quality, several toxic organics have been identified as a source of serious problems. High concentrations of DDT in Great Lakes fish severely impacted the herring gull population of the basin in the late 1960s and early 1970s. This once common predator is now beginning to reestablish itself, although high levels of PCB and TCDD may slow its recovery. PCB levels in Lake Michigan sportfish have been significantly above the FDA recommended level of 2 parts per million. It has been estimated that this contamination is costing the State of Wisconsin over $1 million per year, with costs for the entire basin many times this amount. A report by the National Research Council states that the Great Lakes are the largest reservoir of PCBs in the United States. Another identified problem is mirex in Lake Ontario. This compound, a fire ant pesticide manufactured in the basin, leaked into the lake and contaminated the fish to a level that resulted in a New York State ban on their commercial sale. Increased incidences of neoplasia (tumerous lesions) have been found in the fishes of the Great Lakes and tentatively attributed to relatively high concentrations of polynuclear aromatic hydrocarbons (PAH). High levels of dieldrin, toxaphenes, and dioxin have been measured, indicating that other real problems are out there waiting to be found.

In 1979, GLERL began a research program in cooperation with the Office of Marine Pollution Assessment (OMPA) (recently renamed the Ocean Assessment Division (OAD) of the National Ocean Services, NOAA), whose goal is the development of a capability to predict the environmental consequences of persistent synthetic organic contaminants in the Great Lakes ecosystem. The understanding of long-term cooperation with OMPA/OAD has allowed GLERL to develop cooperative agreements with several research institutions and to pursue a comprehensive research program focused on a few questions regarding the flow of selected organics within the Great Lakes. Much of the results generated in this program will be transferrable to coastal marine systems.

Attempts to model the fate of toxic organic compounds in aquatic ecosystems appear to provide a good first-order estimate of their long-term behavior. These models are excellent tools for assembling existing information, testing system sensitivity, and designing a coherent research program. In time, they will be useful tools in the decision-making process as well.

Since its creation in 1974, GLERL has specialized in the design and development of ecosystem models that simulate or predict the physical, chemical, and biological responses of the Great Lakes to imposed stresses. In this program, our efforts to date have focused on the development of system models, supported by the specific process research required for improvement, calibration and verification of these models. Modeling-experimental interactions enable us to make stepwise improvements in our understanding of the cycling, behavior, and fate of synthetic contaminants. Such information is necessary to identify the contaminants that pose the greatest threat to the environment, which organisms or regions within the lakes are most affected, what can be expectd in the years ahead, and what can be done to reduce the level of ecosystem stress.

Interrelationships With Other Projects. The major removal mechanism of most toxic organics is through sorption onto particulate matter and settling into the sediments. Thus, to understand and be able to simulate the transport and fate of toxic organics, we will need information supplied through Projects 1 and 3, which concern the characteristics and transport of particulate matter. Ecosystem dynamics will be obtained from Projects 5 and 6.

Approach. Many persistent toxic organics behave similarly in the aquatic environment; they are only slightly soluble and partition onto particulate material; they tend to photodecompose and evaporate as major removal pathways; they are generally resistant to microbial attack; and they concentrate in the sediments. This similarity of behavior makes a modeling approach attractive and recently, toxic cycling models have begun to appear in the literature. These models require compound-specific experimental rate process information, tailored for the ecosystem to which it is applied.

We propose to employ a systems approach in which a series of models will be developed. These include the calibration of an available equilibrium (fugacity) and steady-state model (EXAMS; EPA) for the Great Lakes: the development of a one-dimensional, time-dependent process model and the calibration of a two-dimensional, time-dependent transport model (modified oil spill) containing first-order decomposition and sedimentation terms. Our models will be continuously upgraded through the results of our process research experiments, both in-house and under contract, along with other information entering the literature. Carrying out process research and modeling simultaneously will allow us to continually determine the weakest or most sensitive areas in our systems approach and to define research necessary to address those specific problems. Ultimately, our goal is to combine calibrated ecosystem cycling models with system transport models.

Because of their existance in the Great Lakes and their solubility characteristics, the PCBs and PAHs have been the focus of our efforts to date. Field and laboratory studies on the rates of volatilization, photodecomposition, sorption onto particulates indigenous to the Great Lakes, aggregation, and settling have been designed to support our toxic organic cycling model.

Task 4.3 has been completed and a report is on file.

Grants and Contracts.

(1) Title. Partitioning and Cycling of Toxic Organics in the Great Lakes Ecosystem

Principal Co-Investigators. C.P. Rice (Great Lakes Research Division, Great Lakes and Marine Waters Center) and P.A. Meyers (Department of Atmospheric and Oceanic Science, The University of Michigan)

Objective. To determine the role particle suspension plays in the continued recycling of toxic organic compounds in the Great Lakes system.

(2) Title. Redistribution of Sediment-Bound Toxic Organics by Benthic Invertebrates

Principal Investigator. D.S.White (Great Lakes Research Division, University of Michigan)

Objective. To measure the effect of chronic exposure of trace organic contaminents on sediment reworking rates of benthic invertebrates.

(3) Title. Models for the Behavior and Fate of Long-lived Contaminants in the Upper Trophic Levels of the Great Lakes

Principal Investigator. J.E. Breck (Research Associate, Environmental Sciences Division, Oak Ridge National Laboratory)

Objective. To develop an upper trophic level model to examine contaminant transport in the Great Lakes.

(4) Title. Amino Acid Alteration as a Measure of Stress in Freshwater Benthos

Principal Investigator. J.P. Giesy (Department of Fisheries and Wildlife and Pesticide Research Center, Michigan State University)

Objective. To develop a sensitive chronic stress test for freshwater invertebrates and to employ it on benthic organisms of the Great Lakes.

Program Documentation.

° FY 79 and FY 80--Technical Plan/Proposal to OMPA: Cycling of Toxic Organics in the Great Lakes (February 1979).

- Semiannual Progress Report--The Cycling of Toxic Organics in the Great Lakes Ecosystem (April 1980).
- FY 82--PDP for OMPA: Contaminant Assimilative Capacity Initiative; Toxic Organics in the Coastal Region (Great Lakes) (June 1980).
- FY81--Proposal to NOAA/OMPA/Technical Plan: The Cycling of Toxic Organics in the Great Lakes Ecosystem (July 1980).
- AnnualProgress Report: The Cycling of Toxic Organics in the Great Lakes Ecosystem (October 1980).
- Oral Program Review to OMPA: Boulder, CO. (October 1980).
- Semiannual Progress Report (April 1981).
- FY 82 Proposal to NOAA/OMPA (July 1981).
- Annual Progress Report (October 1981).
- Oral Program Review to OMPA: Boulder, CO. (November 1981).
- Semiannual Progress Reports (April 1982, 1983, 1984).
- Annual Progress Reports (October 1982, 1984)
- FY 83-85 Proposal to OMPA (July 1982).
- Eadie *et al.* (1983). *The cycling of toxic organics in the Great Lakes: A 3-year status report.* NOAA Technical Memorandum ERL GLERL-45. 163 pp.

Task 4.1. Polynuclear Aromatic Hydrocarbons in the Great Lakes Ecosystem

Task Scientist. B.J. Eadie

Objectives.

(1) To develop analytical capability to accurately quantitate selected PAH's in different parts of the Great Lakes ecosystem.

(2) To quantify the levels of selected PAH's in parts of the Great Lakes ecosystem.

(3) To calibrate a first-order assessment model for PAH in Lake Michigan.

Task 4.2. Toxic Organic Modeling in the Great Lakes

Task Scientists. B.J. Eadie and J.A. Robbins

Objectives.

(1) To synthesize available information on the aquatic cycling of PCB's and PAH's into a numerical model hierarchy for the Great Lakes ecosystem.

(2) To aid in the identification of process research needs.

Task 4.4. The Effect of Environmental Factors on the Toxicokinetics of Polycyclic Aromatic Hydrocarbons in *Pontoporeia hoyi*

Task Scientist. P.F. Landrum

Objectives.

(1) To determine the toxicokinetics of the sediment-sorbed polycyclic aromatic hydrocarbons, phenanthrene and benzo(a)pyrene, in *Pontoporeia hoyi*.

(2) To investigate the influence of temperature, seasonal variability, geographical distribution, and sediment type on the uptake and depuration of selected PAH in *P. hoyi*.

(3) To examine the competitive interaction of various additional xenobiotic mixtures on uptake and depuration by *P. hoyi*.

Task 4.5. Vertical Dynamics of Toxic Organics in the Great Lakes

Task Scientist. M.J. McCormick

Objectives.

(1) To develop a mathematical model for predicting the vertical distribution of toxic materials in the Great Lakes.

(2) To identify research needs and estimate prediction uncertainties by first-order error propagation.

Task 4.6. Toxicokinetics of Representative Polynuclear Aromatic Hydrocarbons in *Mysis relicta*

Task Scientists. P.F. Landrum and W.A. Frez

Objectives.

(1) To modify current culture methodology used for maintaining *Pontoporeia hoyi* to maintain mysids.

(2) To design appropriate modifications of experimental test chambers to expose mysids to polynuclear aromatic hydrocarbons (PAH).

(3) To determine the uptake, depuration, and biotransformation rate constants for polynuclear aromatic hydrocarbons in this invertebrate.

(4) To determine the extent to which various environmental parameters affect the uptake, depuration and biotransformation rate constants for polynuclear aromatic hydrocarbons in *M. relicta*.

Task 4.7. Food/Sediment as a Source of Xenobiotics to *Pontoporeia hoyi* and Higher Trophic Levels

Task Scientist. P.F. Landrum

Objectives.

(1) To establish the relative importance of sediments as a source of organic xenobiotics to *P. hoyi*.

(2) To perform preliminary studies on the role of *P. hoyi* as a source of toxic organics to higher trophic levels.

Task 4.8. Toxicokinetics of Organic Xenobiotics in the Mayfly Larvae, *Hexagenia*

Task Scientists. P.F. Landrum and T.F. Nalepa

Objectives.

(1) To determine the uptake, depuration and biotransformation of selected PAH to mayfly larvae for parameterization of fate and transport models.

(2) To examine the relationship between respiration and toxicokinetics, to determine the efficiency of uptake of organics from water, the effects of the xenobiotics on the respiration rate, and/or role of oxygen consumption on biotransformation.

(3) To develope the empirical relationships between environmental variables and the toxicokinetic parameters.

Task 4.9. Phase Distribution and Sorption Kinetics of Organic Contaminants on Great Lakes Particulate Matter

Task Scientists. B.J. Eadie and N.R. Morehead

Objectives.

(1) To measure the equilibrium phase distribution of selected organic compounds in Lake Michigan.

(2) To identify and quantify the major variable which mediate phase distribution.

(3) To measure the rates of adsorption and desorption of selected organic compounds with Great Lakes particulate matter.

(4) To identify and quantify the major variables which mediate these kinetics.

Project 5. ECOLOGICAL SUCCESSION AND TRENDS OF GREAT LAKES BIOTA

Project Scientist. D. Scavia

Objectives.

(1) To describe and simulate plankton succession and pelagic carbon flow.

(2) To detect long-term trends in the biota of the Great Lakes and to determine their causes.

Background. The modeling of the ecology of the Great Lakes has so far been limited to including all the plankton and benthos species under a very few groupings. It is already obvious, however, that modeling at such a gross level will not be able to simulate a number of processes of immediate practical concern and will not provide a reliable capability to predict the effect of man's activities on Great Lakes ecosystems. 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 differ greatly in their ability to serve as food to higher levels in the food chain. Analysis of water quality control through manipulation of upper trophic levels (e.g., fish stocking) also requires information and models with more ecological detail. Thus, treating all plant and animal species alike obscures many of the processes and allows simulation of only the least complex relationships. This project attempts to detect and describe successional and other trends that have occurred or are occurring in populations of Great Lakes biota on both long and short time scales. It then attempts to determine the underlying mechanisms of these trends and to develop models simulating these situations.

Interrelationships With Other Projects. The results from this Project will be used to improve the treatment of nutrient cycling models of Project 6. Nutrient cycling models of Project 6 will be the template for models herein. Trend information will also be used in evaluating the effects of toxic organics and in modeling their cycling in Project 4. Data, analysis, and advice on water movements from Project 1 will be needed.

Approach. Our approach to achieve objective (1) will be a combination of field, laboratory, and model studies. Field investigations will measure changes in densities and characteristics of planktonic algae, zooplankton, and bacteria populations and assemblages over various time and space scales. Field programs will also estimate species-specific growth and loss rates of these populations, with initial emphasis on phytoplankton. These estimates of growth and loss, along with physical transport characteristics measured or estimated in this or other projects (e.g. Project 1), will be combined with changes in populations via numerical models to determine the adequacy of proposed hypotheses (i.e. models) for simulating plankton dynamics. These tests should provide continued evolution of research initiatives, eventually narrowing in on a concise statement (model) of plankton dynamics and succession. Laboratory studies will be carried out on specific process relationships that require further definition and are identified as critical by the field/modeling effort. Examples of this approach are the simulation analysis of Lake Washington ecosystem dynamics (Task 5.14) and the collected efforts of the Lake Michigan Ecosystem Experiment (Tasks 5.17-5.22).

Our approach to achieve objective (2), focusing on the benthos, will be obtaining samples by the same methods and at the same locations and seasons as taken in past studies. The results from the two studies will be compared in order to determine whether changes have occurred. If changes are detected, the distribution of these changes in space and time, the magnitude of changes for various types of organisms, and the literature information concerning similar changes will be evaluated in an attempt to develop a hypothesis concerning the cause or causes of the changes.

The following tasks are completed and the final reports are on file:

Task 5.1, Variations in physical and chemical parameters, nutrient concentrations, and primary productivity in Lake Michigan.

Tasks 5.3 and 5.4 (combined), Feeding and Culturing of Great Lakes Cyclopoid Copepods.

Task 5.5, Seasonal Variations in Soluble Reactive Phosphorus Concentrations in Southern Lake Michigan.

Task 5.6 has been moved to Project 6.

Task 5.7, Studies on the Coulter Counter.

Task 5.8 Laboratory observation of selection and ingestion of algae in mixed assembleges by *Diaptomus*.

Task 5.9, *In Situ* Predation by *Mysis relicta* on Zooplankton in Lake Michigan.

Task 5.13, Consequences of Microscale Patchiness of Nutrient Supply.

Task 5.15 has been combined with Task 5.21.

Task 5.16 Nutrient-light regulation of phytoplankton growth in subsurface phytoplankton populations.

Grants.

Title. Phytoplankton Population Analysis for the Lake Michigan Ecosystem Experiment

Principal Investigator. E.F. Stoermer (University of Michigan)

Objective. To quantify algal population concentrations and changes in the water column due to growth, sinking, and grazing losses.

Service Contracts.

Picking and identifying chironomid larve--M. Winnell

Effect of zooplankton grazing on seston composition and settling dynamics--B. Glover

Enumeration of algal concentrations from zooplankton grazing experiments--A. Davies

Identification and enumeriation of zooplankton composition in the Lake Michigan Ecosystem Experiment--M.S. Evans

Identification and enumeriation of phytoplankton composition in the Lake Michigan Ecosystem Experiment--L. Feldt

Identification and enumeriation of phytoplankton composition in the Lake Michigan Ecosystem Experiment--E. Terriot

Task 5.2. Zooplankton Grazing

Task Scientists. H.A. Vanderploeg and S.J. Tarapchak

Objectives.

(1) To determine seasonal size-selective grazing rates by females of the four different species of *Diaptomus* found in Lake Michigan. Correlate food size selection and morphology of the filtering apparatus. Relate feeding rates to environmental parameters, such as kinds of algae available as food and temperature.

(2) To try out potentially promising narcotizing agents for use as zooplankton-specific killing agents for *in situ* studies of grazing, using the Gliwicz method (1968) automated by the use of the Coulter Counter.

Task 5.10. Phosphate Uptake and Phytoplankton Growth Rates in Southern Lake Michigan

Task Scientists. S.J. Tarapchak and L.R. Herche

Objectives.

(1) To investigate the relationships among, and the underlying physiologic causes of, variations in orthophosphate uptake and phytoplankton growth rates in southern Lake Michigan.

(2) To provide (a) physiological data for interpreting patterns in phytoplankton succession and phytoplankton nutrient competition, and (b) to test mathematical constructs describing phosphorus-limited phytoplankton growth in whole-lake ecosystem models.

Task 5.11. Analysis of Growth Rates of Phytoplankton Species in Southern Lake Michigan

Task Scientists. S.J. Tarapchak and H.A. Vanderploeg

Objectives.

(1) Document the seasonal succession pattern of algae in Lake Michigan and describe the significance of nutrient competition, algal sinking, and zooplankton grazing on this succession.

(2) Test the Schelske-Stoermer (1972) hypothesis that has been advanced to explain the development of blue-green algal populations in Lake Michigan.

Task 5.12. Long-Term Trends in Lake Michigan Benthic Fauna

Task Scientist. T.F. Nalepa

Objective. The objective of this task is to determine and interpret long-term trends in the benthic fauna of Lake Michigan.

Task 5.14. Twenty- to Thirty-Year Simulation and Analysis of Ecosystem Succession in Lake Washington

Task Scientists. G.A. Lang, D. Scavia, and J.T. Lehman (University of Michigan)

Objective. The objective of this task is to develop and test a phosphorus model of detailed spatial and temporal resolution.

Task 5.17. Lake Michigan Ecosystem Experiment--System Synthesis and Modeling

Task Scientists. D. Scavia, G.A. Lang, and G.L. Fahnenstiel

Objective. To combine process measurements made in Tasks 5.18-5.22 in a model of plankton dynamics and test prediction against observed changes for the purpose of evaluating models and experimental coverage of natural processes.

Task 5.18. Lake Michigan Ecosystem Experiment--Plankton and Particulate Nutrient Sinking Rates and Flux

Task Scientists. D. Scavia and G.L. Fahnenstiel

Objective. To measure vertical flux of planktonic algae and particulate nutrients on variable time scales (hours-weeks) for the purpose of determining loss from specific vertical strata.

Task 5.19. Lake Michigan Ecosystem Experiment--Bacterial Growth and Loss Rate

Task Scientists. D. Scavia and G.A. Laird

Objective. To determine growth and grazing loss rates of planktonic bacteria for the purpose of comparing bacterial carbon growth requirements to algal organic carbon release rates.

Task 5.20. Lake Michigan Ecosystem Experiment--Algal Grazing Losses

Task Scientists. D. Scavia and G.L. Fahnenstiel

Objective. To determine loss rates of algae (community and populations) due to zooplankton grazing for the purpose of estimating daily-averaged loss rates.

Task 5.21. Lake Michigan Ecosystem Experiment--*In Situ* Species Specific Growth Rates and Subsurface Phytoplankton Maxima in Lake Michigan

Task Scientists. G.L. Fahnenstiel and D. Scavia

Objectives.

(1) To determine the magnitude and role of species-specific in situ growth in the development and maintenance of subsurface phytoplankton populations.

(2) To determine species-specific photosynthesis vs. light relationships for surface and subsurface phytoplankton populations and compare those results with in situ measurements of primary production.

Task 5.22. Lake Michigan Ecosystem Experiment--Ambient Conditions

Task Scientists. D. Scavia, J.M. Malczyk, and W.S. Gardner

Objective. To measure ambient chemical, biological, and physical conditions and changes during ecosystem experiment and interpret changes in terms of nutrient cycling.

Task 5.23. The Selectivity and Feeding Rate Responses of a Copepod in Algal Mixtures: Concentration and Time History Effects

Task Scientists. H.A. Vanderploeg and J.R. Liebig

Objectives.

(1) Describe the selectivity and feeding rate response for the copepod *Diaptomus* in equilibrium with varying concentrations of mixtures of small and large algae.

(2) Examine effect of prior feeding history in a simulated algal patch on selectivity and feeding of a copepod encountering a new patch of phytoplankton having a different relative and total concentration of a small and large algae.

Task 5.24. Direct Observations on the Plant-Copepod Interface: The Rules of the Game

Task Scientists. H.A. Vanderploeg and G.-A. Paffenhöfer (Skidaway Institute of Oceanography)

Objectives. Describe: (1) the mechanisms of algal capture employed by *Diaptomus spp.*, (2) the defense mechanisms of the algae, and (3) microscale interactions between copepods and algae that could lead to the algae benefitting from a nutrient plume around the copepod.

Project 6. EUTROPHICATION AND NUTRIENT CYCLING

Project Scientist. W.S. Gardner

Objectives.

(1) To determine the sources, forms, movements, biogeochemical transformations, and ultimate fates of enriching substances in the Great Lakes.

(2) To quantify pathways of biochemical energy flow from nonliving organic material through microbes and benthic invertebrates.

(3) To develop conceptual models and provide data for simulation and predictive models of the cycling, fates, and effects of nutrients in the Great Lakes.

Background. An improved understanding of the effects of nutrients on ecological processes in the Great Lakes is needed to simulate and predict changes caused by increasing or decreasing inputs of these materials to the lakes. Knowledge about nearshore processes is particularly relevant because substances such as nutrients added to the Great Lakes tend to be concentrated in nearshore areas before becoming diluted by the large volumes of the open lakes. The most obvious and severe impacts of these added materials (e.g., undesirable species of plankton and fish, decreased quality of intake water, increased levels of organic materials, and reduced levels of oxygen in sediments) occur in nearshore zones, where human contact with the lakes is the greatest.

Increased comprehension of nutrient effects on organisms and water quality is needed to protect the lakes from further degradation and to reverse deleterious changes that have already occurred. Since phosphorus inputs from some sources have now been reduced, this information is also needed to understand and predict current and future ecological changes from reduced nutrient inputs to the lakes.

A comprehensive understanding of ecological processes in "healthy" lake systems is required to assess the impacts of added nutrients or other pollutants on stressed systems. To understand these processes, we must evaluate the movement of materials into and through nearshore zones and be able to predict the concentrations and biological activity 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. Since phytoplankton and bacteria are at the base of the food chain and have a dominant influence on lake water quality, an understanding of processes making nutrients available to these organisms is critical to predicting the impact of added nutrients on the lakes. Inputs of limiting nutrients also affect the types and amounts of consumer organisms in the lakes because energy fixed by primary production is the main force driving higher food chain dynamics. Knowledge of energy transformations through heterotrophic and consumer organisms is needed to understand how enriching substances will affect food webs in the lakes.

To determine the state of knowledge in nutrient cycling in nearshore regions of the Great Lakes, GLERL commissioned a multidisciplinary team to prepare a document on the status of phosphorus cycling information (Scavia and Moll, 1980). Project 6 is designed to fill research gaps suggested by this document and thereby provide process information needed to develop predictive ecosystem models of nutrient cycling in the Great Lakes.

The following research tasks have been completed and task final reports are on file:

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

Task 6.2, Analysis of the Lake Ontario Oxygen Profiles.

Task 6.4, IFYGL Chemical Intercomparison.

Task 6.5, Characteristics of Oswego River Plume.

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

Task 6.7, Water and Sediment Chemistry: Southern Lake Michigan.

Task 6.9, Presentation of Lake Survey Center (LSC)/GLERL Chemical Field Data, 1965-75.

Task 6.11, Characterization and Transport of Nearshore Material.

Task 6.15, Size Partitioning and Lability of Phosphorus in Southeastern Lake Michigan.

Task 6.16, Development of Methods to Chemically Speciate Dissolved Phosphorus and Organic Compounds in Lake Michigan.

Task 6.17, One-Dimensional Multilayer Ecological Model.

Task 6.18, Two-Dimensional Transport Ecological Model.

Task 6.20, Phosphorus Cycling in the Great Lakes--Theoretical Investigations.

Task 6.21, Uncertainty Analysis in Eutrophication Models.

Task 6.23, Effects of Small-Scale Heterogeneity on Nutrient Phytoplankton-Zooplankton Relationships.

Task 6.24, Effects of Feeding Rates and Food Types on Release of Nutrients by Zooplankton.

Task 6.25, Kinetics and Magnitude of Nutrient Release by *Daphnia magna* and Lake Michigan cladocera.

Task 6.26, Mineralization of Phosphorus and Nitrogen in Aerobic Lake Sediments by Benthic Invertebrates.

Task 6.29, Speciation of Dissolved and Particulate Phosphorus Components in Tributary and Lake Water and Sediments.

Task 6.32, Factors Affecting Nitrogen Release Rates of Two Species of Marine Copepods.

Task 6.12, Analysis of LSC/GLERL Limnological Data 1965-75; Task 6.19, Comparative Study of the Upper Great Lakes; and Task 6.27, Phosphorus Cycling in the Great Lakes--System Synthesis and Simulation, have been terminated. Task 6.13, Characteristics of the Nepheloid Layer and Resuspended Material in Southeastern Lake Michigan--Eadie and Bell, and Task 6.3, Carbon Dynamics--Eadie, have been moved to Project 3, Particle Dynamics. Task 6.22, Long-Term Trends in Lake Michigan Benthic Fauna--Nalepa, has been moved to Project 5.

Interrelationships With Other Projects. To understand materials transport, we will need input from Project 1 concerning water movement and from Project 2 concerning wave effects on resuspension of sediments. This project will also be closely connected with Project 3, Particle Dynamics, to help understand and model the transport of materials by particulate substances. Also, long-term eutrophication effects analyzed in Project 5, Plankton Succession, will impact research carried out in this project. The lipid research in Project 6 relates closely to studies of contaminant transfer dynamics in Project 4.

Approach. Simulation and prediction of nutrient cycling processes in lake ecosystems require an understanding of nutrient quantities and composition in system compartments and of processes moving phosphorus and other nutrients through the compartments. The state-of-the-art document summarized available information and identified research needs in phosphorus-cycling research. Project 6 research seeks to fill research gaps and provide information needed to simulate and test models of the cycling, fates, and effects of phosphorus and other nutrients in the lakes.

Figure 3 schematically outlines several important nutrient-cycling compartments and processes currently being investigated in Project 6.

Current research in Project 6 can be categorized into five general subject areas:

1. Distribution and metabolism of benthic organisms (Task 6.8, 6.40).

2. Mechanisms of nutrient regeneration from sediments (Tasks 6.14, 6.33, 6.34, 6.36, 6.39).

3. Detritus-benthos energy transformations (Tasks 6.37, 6.41).

4. Microbial cycling of nutrients and energy (Tasks 6.30, 6.35, 6.42, 6.43).

5. Nutrient regeneration by zooplankton (Tasks 6.28, 6.38).

6. Bioavailability of phosphorus from outside sources (Task 6.31).

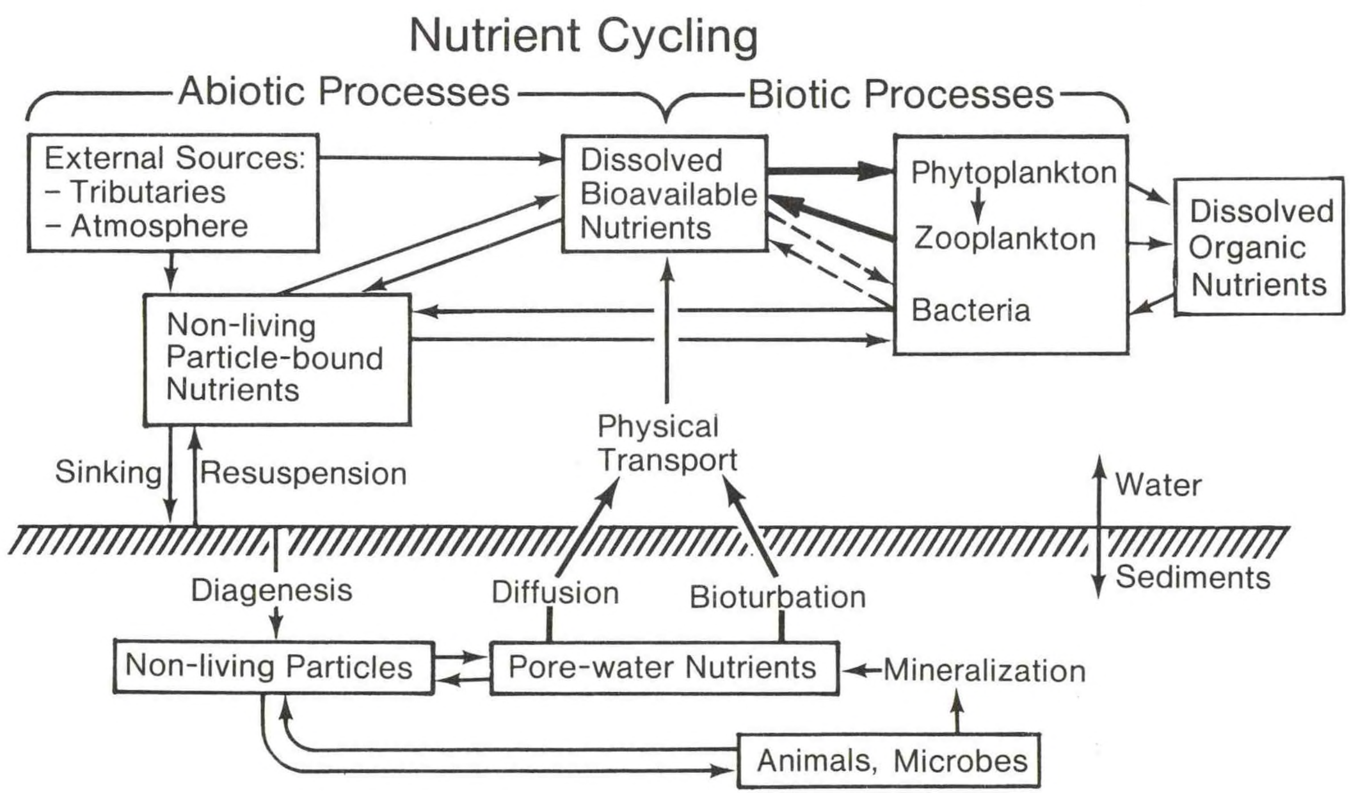

Figure 3.--*Schematic diagram of phosphorus compartments (enclosures) and processes (arrows) important to nutrient cycling in nearshore zones of the Great Lakes.*

Results from these studies will provide data needed for models being developed in Projects 5 and 10.

Literature Cited.

Scavia, D., and Moll, R.A., eds. 1980. *Nutrient cycling in the Great Lakes: A summarization of factors regulating the cycling of phosphorus.* Great Lakes Research Division Special Report No. 83.

Task 6.8. Distribution of Benthic Invertebrates

Task Scientist. T.F. Nalepa

Objectives.

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

(2) To document both temporal and spatial variations in these populations and to examine potential factors causing these variations.

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

(4) To partition the rate of sediment oxygen uptake into its various components and thus determine the relative importance of the bacteria, meio-, and macrofauna in total community respiration.

Task 6.14. The Role of Benthic Animal Communities in Nutrient Regeneration Processes of Southern Lake Michigan

Task Scientists. M.A. Quigley and T.F. Nalepa

Objectives.

(1) To determine the extent of nutrient regeneration from nearshore sediments and to evaluate the importance of benthic animal activities in influencing such regeneration.

(2) To determine the vertical distribution of animals in sediments in relation to vertical profiles of nutrients, dissolved oxygen, organic carbon, water content, and particle-size distribution.

Task 6.28. Direct Measurement of Ammonia and Phosphorus Release by Zooplankton in Suspensions of Food

Task Scientists. H.A. Vanderploeg and W.S. Gardner

Objectives.

(1) To develop a method for measuring ammonia and phosphorus release by zooplankton feeding in suspensions of inactive algae.

(2) To use the method to relate ammonia and phosphorus excretion to amount of algae ingested.

Task 6.30. Phosphorus-Phytoplankton Dynamics in Lake Michigan

Task Scientist. S.J. Tarapchak

Objective. The objective of this task is to evaluate the role of secondary limitation of algal growth by silica on phosphorus cycling in the epilimnion of an offshore station in Lake Michigan.

Task 6.31. Biological Availability of Phosphorus From Atmospheric Precipitation and Other Sources

Task Scientists. W.S. Gardner, G.L. Fahnenstiel, and B. Manny (Great Lakes Fishery Laboratory, U.S. Fish and Wildlife Service)

Objective. The objective of this task is to determine to what extent phosphorus-starved Great Lakes phytoplankton can use phosphorus from atmospheric precipitation (normal and acidified).

Task 6.33. Nutrient Mineralization in Aerobic Lake Sediments: Benthic Invertebrate-Microbial Interactions

Task Scientists. W.S. Gardner and T.F. Nalepa

Objective. The objective of this task is to determine the relative importance (and interactions) of benthic invertebrates and microbes in mineralizing nutrients in aerobic lake sediments.

Task 6.34. Pelletization of Lake Michigan Sediments by the Amphipod *Pontoporeia hoyi*

Task Scientists. M.A. Quigley and T.F. Nalepa

Objectives.

(1) To identify *P. hoyi* feeding mode (continuous versus intermittent) throughout individual size class and season.

(2) To determine particle size selection and sediment throughput rates of *P. hoyi* feeding in Lake Michigan sediments with respect to how such processes affect nutrient regeneration from sediments to overlying water.

(3) To describe the fate of *P. hoyi* fecal pellets including decomposition and disintegration rate, incidence of coprophagy and probability of permanent burial.

Task 6.35. Mechanisms of Release and Uptake of Dissolved Organic Nutrients in Lake Michigan

Task Scientists. G.A. Laird, W.S. Gardner, D. Scavia, and G.L. Fahnenstiel

Objectives.

(1) Estimate release rates of labile dissolved organic nutrients by phytoplankton in Lake Michigan.

(2) Estimate the quantitative importance of this material to nutrient regeneration in Lake Michigan.

Task 6.36. Dissolved Phosphorus Release Rates From Lake Michigan Sediments and Relation to Benthic Invertebrate Abundances

Task Scientists. T.F. Nalepa, W.S. Gardner, and M.A. Quigley

Objectives.

(1) To obtain phosphorus release rate measurements on intact sediment cores from several locations in Lake Michigan.

(2) To estimate the quantitative significance, relative to other phosphorus inputs, of sediment phosphorus release in Lake Michigan.

(3) To determine the relation between sediment phosphorus release rates and benthic invertebrate abundances.

Task 6.37. Lipid Content and Energy Flow Through *Pontoporeia hoyi* and Other Benthic Invertebrates in Lakes Michigan and St. Clair

Task Scientists. W.S. Gardner, E.A. Cichocki, W.A. Frez, and T.F. Nalepa

Objectives.

(1) To develop micromethodology to extract, purify, and measure lipids in individual benthic macroinvertebrates.

(2) To determine lipid content and seasonal trends in *P. hoyi* and other important Great Lakes macroinvertebrates.

(3) To estimate the total and area-specific caloric content of macroinvertebrates in Southern Lake Michigan and Lake St. Clair.

(4) To estimate the importance of *P. hoyi* in energy transfer from detrital material to small fish (and other *P. hoyi* predators) in southern Lake Michigan.

Task 6.38. Nitrogen Excretion Rates of Two Estuarine Zooplanters, *Parvocalanus crassirostris* and *Acartia tonsa*, as Related to Temperature and Composition of Food

Task Scientists. W.S. Gardner and G.-A. Paffenhöfer (Skidaway Institute of Oceanography)

Objectives.

(1) To determine ammonium excretion rates for two species of copepods that are common in estuaries of the southeastern United States.

(2) To evaluate the effects of food type and temperature on excretion rates of these zooplankters.

Task 6.39. Nutrient Release from Sediments of Lake St. Clair and Connecting Channels

Task Scientists. T.F. Nalepa, M.A. Quigley, and W.S. Gardner

Objectives.

(1) To quantify the release of phosphorus and silica from sediments in Lake St. Clair and connecting channels.

(2) To assess the relative importance of benthic invertebrates, microbial activities, and diffusion in the release process.

(3) To estimate the quantitative significance, relative to other nutrient sources, of sediment nutrient release.

Task 6.40. Benthic Invertebrate Research in Lake Superior with a Submersible

Task Scientists. T.F. Nalepa and M.A. Quigley

Objectives.

(1) To determine benthic invertebrate distribution patterns and to relate distributions to sediment characteristics, particularly microbial activity.

(2) To examine feeding patterns of *Pontoporeia hoyi*.

(3) To examine the sampling efficiency of the Ponar grab sampler.

Task 6.41. Effects of Starvation on the Physiology and Nutrient Cycling Rates of *Pontoporeia hoyi*

Task Scientists. W.S. Gardner, J.M. Gauvin, and T.F. Nalepa

Objectives.

To determine nutrient release rates and lipid content in *P. hoyi* on freshly collected animals and during various stages of food deprivation.

Task 6.42. Phosphorus Cycling in the Lake Michigan Microbial Food Web: Phytoplankton-Bacterial Competition

Task Scientist. S.J. Tarapchak

Objective. To determine if heterotrophic bacterioplankton compete with phototrophic phytoplankton for dissolved inorganic phosphorus in lake waters.

Task 6.43. Planning Task: Phosphorus Cycling in the Microbial Food Web in the Great Lakes System

Task Scientist. S.J. Tarapchak

Objective.

(1) To identify specific important scientific themes within the area of microbial dynamics-phosphorus cycling and to plan a research project integrated with current and projected research interest in the Ecosystems and Nutrient Dynamics Group and the Synthetic Organics and Particle Dynamics Group.

Project 7. HYDROLOGIC PROPERTIES

Project Scientists. F.H. Quinn and T.E. Croley II

Objectives.

(1) To develop improved water supply and lake level forecasting techniques for large lake basins and estuaries.

(2) To develop improved mathematical models for simulating the effect of past hydrologic conditions and future scenarios on the water supplies, levels, and flows of the Great Lakes and their connecting channels.

(3) To enhance our understanding of the impact of climatic variability and change on the water resources of the Great Lakes.

(4) To develop improved understanding of the hydrologic processes of the Great Lakes Basin.

(5) To develop and maintain a hydrologic data base of sufficient quality for both scientific and water resource studies of the Great Lakes.

(6) To assist in the solution of water quality management problems.

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

The project 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 various boards of the International Joint Commission and the International Coordinating Committee for Great Lakes Basic Hydraulic and Hydrologic Data. The research from this project supports many users, ranging from 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 the various boards of the International Joint Commission.

The hydrologic properties research is primarily oriented toward the mathematical modeling of the individual processes comprising the hydrologic cycle. This research consists of the development, calibration, testing, and application 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. Comprehensive data bases on pertinent hydrologic parameters, such as precipitation, runoff, evaporation, and temperatures, have been developed to support the models. Experimental programs are carried out as required to fill gaps in both theory and data.

A hydrologic response model of the Great Lakes Basin, the supporting GLERL large basin rainfall/runoff model, and unsteady flow models of the Detroit, St. Clair, and St. Lawrence Rivers have been developed to date. These models are currently being used in conjunction with the hydrologic data base to provide an advisory service on water levels and flows and to assess the value of new data collection programs. Typical users of this service are the general public, Federal agencies, international commissions, the Great Lakes States, and various departments of Environment Canada.

It is expected that, as the base of scientific knowledge increases and as data acquisition in near real-time improves, 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.

The following research tasks have been completed and task final reports are on file:

Task 7.1, Lake Precipitation.

Task 7.2, Lake Evaporation.

Task 7.3, Evaporation Synthesis.

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

Task 7.8, Hydrologic Forecasting.

Task 7.9, Connecting Channels Transient Models.

Task 7.10, Lake Michigan Evaporation.

Task 7.11, Lake Superior Regulation Analysis.

Task 7.12, St. Lawrence River Hydraulic Transient Model.

Task 7.14, GLERL-SEA Cooperative Effort: Upland Erosion in the Great Lakes Basins.

Task 7.15, Development and Application of Climatic Water Balance Models for the Lake Erie, Lake Ontario, and Lake Superior Drainage Basins.

Task 7.16, Travel Time in the Great Lakes Channels for Operational Spill Applications.

The following task has been deleted:

Task 7.5, Great Lakes Shoreline Flooding.

Interrelationships With Other Projects. The energy balance at the water surface is the primary driving force for thermal structure forecasting (Project 1, Water Movements and Temperature). Shoreline damage caused by waves and water level fluctuations is governed by changes in the lake levels (Project 2, Prediction of Surface Waves, Water Level Fluctuations, and Overlake Winds). The data and models generated by this project will also provide input to Project 8, Lake Ice, and Project 10, Environmental System Studies and Applied Modeling.

Approach. Hydrologic data are being collected and analyzed on such variables as precipitation, runoff, air temperature, evaporation, and groundwater. The data are used to maintain the GLERL hydrologic data base for support of mathematic models, research on the hydrologic processes and a hydrologic advisory service. 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 general public, and the International Coordinating Committee for Great Lakes Basic Hydraulic and Hydrologic Data.

Research into the hydrologic processes will emphasize rainfall-runoff studies, evapotranspiration assessments, snow melt and ablation studies, connecting channel hydraulics under ice conditions, and overland sedimentation processes. The main thrust of the project is the development and application of mathematical models of the various hydrologic processes for forecasting and simulation studies. Typical models include basin runoff models, overland erosion models, evaporation models, unsteady flow models of the connecting channels, and water supply prediction models. In the near term, the modeling effort will concentrate on the development of basin-runoff models for each of the Great Lakes Basins. Both conceptual and climatic water balance configurations will be used. These models will interface with the Great Lakes hydrologic response model as part of an integrated Great Lakes system model. The use of these models for forecasting will be supported in real time with the development and incorporation of near real-time data acquisition. Research effort will also continue on the modification of the unsteady flow models for ice conditions.

Experimental studies will be conducted when required to fill in knowledge or data gaps. In the near term, the experimental work will be concentrated on connecting channels winter regime hydraulics and on erosion research.

Some typical applications include connecting channel flow for the International Joint Commission, U.S. Geological Survey, and Great Lakes states water quality studies, determining causes of Great Lakes long-term water level fluctuations, Great Lakes river basin studies, and water supply forecasting. A major application currently underway is to develop, in conjunction with the International Technical Information Board of the International Joint Commission, an improved hydrometeorological forecast system for the Great Lakes.

Task 7.4. Water Levels and Flows Simulation

Task Scientist. F.H. Quinn

Objectives.

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

(2) To use the hydraulic transient models for specific problems involving the water quantity in the 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 factors that impact upon the water levels and flows.

(4) To update the GLERL hydrologic data base.

Task 7.7. Great Lakes Basins Runoff Modeling

Task Scientist. T.E. Croley II

Objectives.

(1) To develop digital models that will

 a. Simulate runoff responses of each of the Great Lakes Basins to time series of climatological conditions.

 b. Simulate the hydrologic response of individual watersheds in the Great Lakes Region reasonably accurately.

(2) To interface the lake basin watershed models with the Great Lakes Hydrologic Response Model so that the watershed models provide the runoff component to the response model.

Task 7.13. St. Clair and Detroit River Winter Flow Regimes

Task Scientist. J.A. Derecki

Objectives.

(1) To determine the winter flow variability and characteristics of the St. Clair and Detroit Rivers.

(2) To use the measured data to verify and/or recalibrate the existing St. Clair and Detroit River mathematical transient models.

(3) To reassess the St. Clair and Detroit River 1959-78 winter monthly flows for international coordination by the River Flow Subcommittee of the International Coordinating Committee for Great Lakes Basic Hydraulic and Hydrologic Data.

Task 7.17. Great Lakes Hydrological Forecasting

Task Scientist. T.E. Croley II

Objectives.

(1) To develop digital models for making deterministic and probabilistic forecasts of soil moisture, runoff, net basin supply, and lake levels in near real-time for the Great Lakes Basins.

(2) To develop and maintain a hydrologic data base in a near real-time fashion of sufficient quality for scientific and water resource studies and for up-to-date forecasts and outlooks.

(3) To investigate use of system-wide forecasting in lake-level regulation determinations.

Task 7.18. Investigation of Large-Scale Short Period Variations in Detroit River Flows

Task Scientist. F.H. Quinn

Objective. To investigate the magnitudes of large-scale flow variations in the Detroit River induced by Lake Erie wind setups and storm surges.

Task 7.19. Lake Champlain Water Supply and Flood Forecasting

Task Scientist. T.E. Croley II

Objectives.

(1) To apply the GLERL Large Basin Runoff Model to the Lake Champlain Basin.

(2) To develop techniques for making water supply and flood forecasts in near real-time for the Lake Champlain Basin.

(3) To transfer the models and forecast techniques to the Northeast River Forecast Center of the National Weather Service for operational use.

Task 7.20. Investigation of Changes of Lake Storage in Lakes Superior and Erie

Task Scientist. F.H. Quinn

Objective. To investigate the roles of thermal expansion and computational procedures in computing the change-in-storage component of the water balance of Lakes Superior and Erie.

Task 7.21. The Water Supply of the Great Lakes: Past, Present, and Future

Task Scientist. F.H. Quinn, E.J. Aubert, and T.E. Croley II

Objective. The objective of this task is to provide relevant background on perceived Great Lakes water supply, water supply problems, NOAA/GLERL role in hydrologic research, monitoring, and management.

Task 7.22. Unsteady Flow Model of Entire St. Clair River

Task Scientist. F.H. Quinn

Objective. To develop an unsteady flow model of the St. Clair River from Lake St. Clair to Lake Huron including tributary stream inputs capable of simulating flows on hourly and daily time scales.

Project 8. LAKE ICE

Project Scientist. F.H. Quinn

Objectives.

(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 freeze-up, breakup, areal extent, and thickness of the ice cover of the Great Lakes and their connecting channels.

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

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, the monitoring of atmospheric pollution, and the siting of nuclear and fossil fuelled power plants.

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 and completed in 1979, gave impetus to Great Lakes ice studies. GLERL participated in this program through membership on the working committee and the Chairmanship of the Ice Information Work Group. In addition, GLERL (formerly Lake Survey Center) has agreed by an exchange of letters between the Administrator, St. Lawrence Seaway Development Corporation, and the Administrator of NOAA to develop freeze-up 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 (NWS), to marine resource decision makers, the Great Lake 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 concentrations. These concentration studies have resulted in 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 in 1969.

As a corollary, an 81-year air temperature data base for the nearshore areas of the Great Lakes has been developed. The data base has been used to evaluate the winter severity of the past 80 winters and to classify the winters on which the ice-cover climatology for a revised ice atlas will be based. A recently completed study requested by the International Niagara Board of Control analyzed the climatic impact of the Niagara River ice boom on the temperature regime of the Buffalo, NY, area.

As part of the forecast studies, a St. Lawrence River freeze-up model and forecast technique was developed and tested for three winters. As a result of these efforts, the NWS initiated freeze-up 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 using pyronometers (300-3000 nm) 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.

Photosynthetically active range detectors were subsequently acquired to study the transmittance of radiation through ice in the 400-700 nm range. A model was developed and the published results represent the most complete and accurate information source available on this subject. Finally, two scanning spectroradiometers were configured to simultaneously measure upward and downward radiation over ice and snow in the 300-1100 nm range. Field studies using these instruments have provided the first measurements of spectral radiation over ice and snow in the Great Lakes.

The results of the various 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.

Task 8.1, Ice Distribution; Task 8.2, Ice Forecasting; Task 8.3, Nearshore Ice Thickness and Stratigraphy; Task 8.4, Winter Navigation; Task 8.5, Ice Information Archiving and Advisory Service; Task 8.6, Water Temperature Observations; Task 8.7, Optical Properties of Ice; Task 8.9, St. Lawrence River Ice Breakup Forecast; Task 8.10, Revision of the Great Lakes Ice Atlas; Task 8.11, St. Marys River Ice Forecasts; Task 8.13, Great Lakes Ice Dynamics Modeling; and Task 8.14, Verification of Ice Transport Model, have been completed and a final task report is on file for each.

Interrelationships With Other Projects. This project will provide input to other GLERL projects, such as Project 6, Eutrophication and Nutrient Cycling; Project 5, Planktonic Succession; Project 7, Hydrologic Properties; and Project 9, Environmental Information Services. It will receive input from Project 1, Water Movements and Temperatures.

Approach. The lake ice research falls into four broad, interrelated program areas. These are ice distribution, ice characteristics, optical properties, and ice forecasting. In the ice distribution program, ice charts depicting the extent, concentration, and surface features of the Great Lakes ice cover have been collected for past winters by United States and Canadian government agencies. The data collection, which began about 1960, consists of both visually observed and remotely sensed observations and are used to document the ice cycle on the individual Great Lakes for each winter of record. The data have been digitized with a 5-km-grid resolution to establish a computerized data base of ice concentration and age. These data will be analyzed and published in a revision of the *Great Lakes Ice Atlas* and in a series of technical memoranda describing in greater detail the variation of ice concentrations in the individual lakes. The archiving of ice concentration data from ongoing programs is being accomplished at the National Snow and Ice Data Center at Boulder, CO. It is planned to review the additional data collected by other agencies in approximately 10 years and to revise the *Ice Atlas* at that time, if warranted. If improved high resolution satellite imagery, such as LANDSAT, become available on a more frequent interval in the future, research may be undertaken to develop an automated program to delineate the concentrations and types of ice from the digital satellite tapes using the reflectance catalog from the GLERL optical properties field program.

The ice characteristics program involves the collection and analysis of data on ice thickness, stratigraphy, and surface features, such as ice ridging and keeling. At the present time, an ice thickness and stratigraphy data collection program at 30 nearshore stations throughout the Great Lakes has been completed. The data analysis involves the use of both temporal and spatial techniques to relate the ice processes with the meteorological forcing parameters to develop a better understanding of the formation, growth, and decay. Data will also be collected and analyzed on various surface features in carefully selected areas of the Great Lakes. It is anticipated that both remotely sensed and manually obtained data will be collected.

The ice forecasting program encompasses studies designed to develop, test, and improve techniques for short- and long-range forecasts of ice formation, ice growth, ice decay, and ice transport. These include the development of mathematical models depicting the ice processes along with the collection of experimental data for the model calibration and verification. Current research is concentrated on the development of a surface energy balance model that simulates ice decay on the St. Lawrence River, on studies to investigate the heat storage characteristics of Lake Superior using fall and winter expendable bathythermographic data collected during a 8-year field program and on ice dynamics modeling. The technical forecast development is also coupled with a continuing assessment of user needs, in particular the National Weather Service which, in many cases, issues the operational forecasts.

Investigations of the optical properties of ice currently involve determination of the ice albedo of the total solar spectrum, the hemispherical transmittance of ice in the photosynthetically active range, and the spectral reflectance in the 300-1100 nm range. The information will be used to improve understanding of winter lake energy budgets and associated improvements in ice forecasting models; to develop an understanding of primary productivity under wintertime conditions; and to provide pertinent ground truth for remote sensing studies.

Task 8.8. Lake Superior Heat Storage (Summer Maximum to Winter Minimum)

Task Scientist. R.A. Assel

Objective. The objective of this task is to define Lake Superior heat storage from the time of its maximum value in summer to its minimum value in winter for use in modeling water temperature decline and ice formation in Lake Superior.

Task 8.12. Investigation of the Spectral Reflectance of Great Lakes Ice Cover

Task Scientist. G.A. Leshkevich

Objectives.

(1) To evaluate the influence of atmospheric conditions and ice surface metamorphosis on the shortwave and near-infrared spectral reflectance of ice surfaces.

(2) To develop methods for estimating area-wide shortwave ice albedos and for identifying different ice types in the Great Lakes ice cover from remotely sensed data.

Project 9. ENVIRONMENTAL INFORMATION SERVICES

Project Scientist. S.J. Bolsenga

Objectives.

(1) To define environmental information needed to solve problems in coastal and estuarine waters with special emphasis on the Great Lakes.

(2) To determine the environmental information needs of Great Lakes and estuarine resource users, managers, and planners for their decision-making activities.

(3) To coordinate and facilitate application of GLERL products to identified user needs.

(4) To provide a participatory advisory service to meet the needs of the Great Lakes and estuarine community.

Background. This project provides basic input to the GLERL research program to ensure that GLERL products are of optimum use to Great Lakes inhabitants and indirectly to the entire United States and Canada. Determining the environmental information requirements associated with Great Lakes use and development is vital to GLERL because this effort shapes the future program of 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 mechanisms 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 with water- and land-related resource development and management.

Interrelationships With Other Projects. This project relates to all the projects and tasks within GLERL, providing both a basis for initiation of projects and a focus for the application of project results.

Approach. The approach to development and provision of environmental services includes a five-step sequence.

(1) Processing information requests

(2) Commission, committee, interagency activities

(3) User needs definition

(4) Direct provision of information

(5) Product development

The advantage of this approach is its flexibility in that any one or all of these five steps can be expanded, contracted, or focused, depending on needs, or on in-house capability to address needs, with a responsive product still being generated.

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. Individuals who require environmental information for problem solving are identified, and interactions are held with these individuals to determine their needs for an environmental information system. User contact is 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 provide user requirement information to GLERL and lead to development of user-oriented products and advisory services.

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 information 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.

Publications such as the Congressional Record are periodically surveyed to identify bills introduced that are pertinent to GLERL mission and program responsibilities. In addition, GLERL is often asked to comment on such legislation. It is felt that an awareness of these items by laboratory management is essential in the responsiveness of GLERL to public needs. As these and other relevant bills are enacted into law, specific issues and research needs are identified and incorporated, as appropriate, into the GLERL program or are recommended as program development initiatives.

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. The information will consist of data, analyses, reports, simulation/prediction techniques, or models formatted or designed for application to the planning, decision-making, and management activities of users, including the general public; industries; Federal, State, and local agencies; planning commissions, and public organizations.

Memberships on such boards and commissions as the Levels and Flows Advisory Board; Technical Information Network Board; Health of Aquatic Communities Work Group; Task Force for Lake Michigan Surveillance; Task Force for In-Place Sedimentary Contaminants; the St. Marys, St. Clair, and Detroit Rivers and Lake St. Clair Task Force of the Surveillance Work Group; the Aquatic Ecosystem Objective Committee Work Group; the Modeling Task Force of the Science Advisory Board; the Lake Erie Task Force of the Surveillance Work Group, all of the International Joint Commission, help to maintain a current awareness of user needs. In addition, a GLERL staff member serves on the Natural Resources Management Committee (Subcommittee on Land and Air, Subcommittee on Water) of the Great Lakes Commission. GLERL staff participated in the activities of the International Association of Sediment Water Science, the International Coordinating Committee on Great Lakes Hydraulic and Hydrologic Data, the Regional Response Team for Spills of Oil and Hazardous Substances, Joint United States-Canadian Ice Information Working Group, the International Association for Great Lakes Research (President, Secretary), Science Education Administration of the U.S. Department of Agriculture, NOAA-U.S. Geological Survey Coordinating Committee for Hydrologic Research, International Association for Hydrologic Research, the Interagency Great Lakes Hydromet Steering Committee, and the National Research Council Panel on Niagara River Ice Boom Investigations. The laboratory has recently become involved in an international (United States-Canada) and interagency (United States: Environmental Protection Agency, NOAA, Corps of Engineers, Fish and Wildlife Service, Michigan Department of Natural Resources; Canada: Department of the Environment, Environmental Protection Service; Department of Environment, National Water Research Institute; Inland Water Directorate; Department of Fisheries and Ocean; Ontario Ministry of the Environment) multiyear study on water quality and marine pollution problems in the upper Great Lakes connecting channels (St. Clair River, Lake St. Clair, Detroit River, St. Marys River). The primary marine pollution issues to be addressed are synthetic organic pollutants and nutrient overenrichment. A GLERL staff member is a member of a management committee developing a detailed study plan for the research and monitoring program. Other GLERL staff will be involved in conducting the research after the planning phase. Activities involving participation with other NOAA units included the Marine Environmental Quality Task Force, Quality Assurance Working Group, Manned Undersea Research and Technology Program--National Marine Fisheries Service, New Bedford Harbor PCB Contamination Assessment Team, Marine Environmental Quality Review, and the Estuarine Review. GLERL staff participated in several Sea Grant activities including the University of Wisconsin Site and Subprogram (Microcontaminants) Reviews, and the Ohio State University Site Review. In a joint program with the Ohio State Sea Grant, GLERL is developing a recreational planning guide for Lake Erie. GLERL has also worked extensively with the NWS and the Atmospheric Environment Service of Canada on an operational, interactive wave model. These memberships and affiliations serve to maintain a current awareness as well as provide a forum to disseminate GLERL research results to the international user community.

Draft environmental impact statements (DEIS) for the Great Lakes Region are evaluated as input to Department of Commerce reviews.

Contracts and Grants.

Title. Draft Environmental Impact Statements

Principal Investigator. Various selected experts depending on DEIS scope.

Objective. To prepare environmental impact statement review comments for the Great Lakes Region as requested.

Task 9.1. Environmental Information Requirements

Task Scientist. S.J. Bolsenga

Objectives.

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

(2) To determine the information types and forms of value to Great Lakes and estuarine resource managers and planners in their decision-making role.

Task 9.2. Advisory Service

Task Scientist. S.J. Bolsenga

Objectives.

(1) To provide information in a form useful to the Great Lakes and estuarine community, particularly for planning, management, and development activities.

(2) To facilitate the application and interpretation of the environmental information and/or techniques or models provided in a timely and efficient manner.

Project 10. ENVIRONMENTAL SYSTEMS STUDIES

Project Scientist. T.D. Fontaine

Objectives.

(1) To undertake studies of the effects of man-induced changes on the Great Lakes environment and the possible impact of these effects on uses of the lakes.

(2) To develop and apply system analysis methods, such as optimization analysis and risk assessment, to the solution of problems of importance to Great Lakes resource use and management.

(3) To develop scientific information useful to the determination of the pollution assimilative capability of the Great Lakes and marine coastal waters in an attempt to minimize costs and risks in pollution management.

(4) To develop and test simulation and prediction models for use in developing wise and cost-effective environmental management strategies.

Background. While one primary goal of GLERL is to conduct fundamental research on the Great Lakes ecosystem, another primary goal is to synthesize information from this research and develop models to assist in the solution of environmental problems and to help guide management decisions. Further, a long-term goal of NOAA's overall marine pollution program is to provide, through research on pollution-related or resource-use problems of the coastal United States, information that can be used in management decisions that balance acceptable risks with acceptable costs. Thus, by putting practical perspectives on pollution and environmental perturbations, this project addresses major responsibilities of GLERL, as well as NOAA and the Department of Commerce in general.

In meeting the above goals, integrated assessments of ecological and socioeconomic information will be conducted. System analysis techniques, such as risk assessment, cost-effectiveness analysis, optimization analysis, and cost-benefit analysis will be used, where appropriate, to aid in interpreting and communicating results. In using these techniques, it will be imperative to make their limitations and inherent assumptions clearly understood. The application of such techniques to establish an optimal blend of economic and environmental practices is a major obective of NOAA's marine pollution program.

The following research tasks have been completed and a task final report is on file:

Task 10.1, Maumee Bay Level B Study.

Task 10.2, Phosphorus Model.

Task 10.5, Atlas of Lake Ontario Physical Properties.

Task 10.6, Modeling of Spills in the Great Lakes.

Task 10.7, Study of Consumptive Uses of Great Lakes Waters.

Task 10.8, Phosphorus Model Refinements and Applications.

Task 10.10, Great Lakes Water Quality Alternatives.

Task 10.11, Application of the Phosphorus Loading Concept to Incompletely Mixed Systems.

Task 10.13, Great Lakes Environmental Planning Study.

Task 10.14, Toxic Substances Budget Model for the Great Lakes.

Task 10.15, Applications of Risk Assessment to Water Quality Management.

Task 10.17, WATERSHED--A Management Technique for Choosing Among Point and Nonpoint Control Strategies.

Task 10.19, Relative Importance of Pollutant Loadings.

The research of Task 10.3, Lake-Scale Water Quality Model, was transferred to Project 4, Aquatic Ecology Models, in November 1975. Task 10.4, Monitoring Water Characteristics, was transferred to Project 8, Lake Ice. Task 10.9, Atlas of Great Lakes Eutrophication, was incorporated in Task 10.13. Task 10.12, Thermal Characteristics of Lake Ontario, Task 10.16, Perspectives on Relative Risks of Chemical Contaminants Found in the Great Lakes, and Task 10.18, Lake St. Clair Assessment, were terminated due to staffing changes and internal priorities.

Interrelationships With Other Projects. Because it is interdisciplinary and is designed to synthesize or interpret research results for practical implications, Project 10 relates to, and will use, the results of other GLERL research. Thus, it is intended that GLERL research will be collectively used in this project to help address environmental problems. Moreover, the results of Project 10 will be an input to the environmental information services of GLERL, outlined in Project 9.

Approach. Project 10 will focus its efforts on a variety of temporal and spatial scales depending on the question under investigation. An overriding theme, however, will be to consider questions in a holistic way so that the long-term economic and ecological consequences of environmental decisions are clearly understood. Targeted for investigation are the fate, transport, and behavior of nutrients and toxic substances in Great Lakes ecosystems. Also of interest are the effects that manipulations such as dredging, water diversions, introduction of exotic species, and habitat destruction have on the health of Great Lakes ecosystems and their surrounding regional economy. Of concern is defining how ecosystems may change in response to various perturbations and how such changes may in turn change (1) the fate, transport, and behavior of contaminants, and (2) economically and otherwise desirable food web relationships. Also of interest is the definition of ecological engineering methods that can be used to enhance desirable properties of the ecosystem. For instance, wetland areas can be created that might enhance fish and waterfowl productivity.

The research emphasis described above is integrative and synthesis oriented. Research results from within and outside of GLERL will be drawn upon heavily. A by-product of this integrative approach will be enhanced research coordination among GLERL staff themselves, as well as with scientists and engineers from other organizations.

In putting practical perspectives on pollution and environmental perturbations, the following tools will be used to organize our thoughts and understanding of ecological-socioeconomic interactions in the Great Lakes region:

(1) ecosystem models;

(2) contaminant fate, transport, and behavior models;

(3) combinations of (1) and (2) above;

(4) quantitative methodologies such as uncertainty and risk analyses, cost-benefit analyses, cost-effectiveness analyses, optimization analyses and combination approaches thereof; and

(5) qualitative judgments such as those obtained through expert opinion.

Techniques such as optimization, uncertainty and risk analysis are exceptionally useful but seemingly underutilized tools in water resources planning efforts. In applying these techniques to investigations of phosphorus control measures in all the Great Lakes (Task 10.21) and ecological-economic trade-offs in the Upper Great Lakes Connecting Channels (UGLCC) (Tasks 10.24 and 10.25), efforts will focus on defining their limitations and constraints.

Task 10.20. Lake Erie Area Environmental and Recreational Atlas

Task Scientists. S.J. Bolsenga and C.E. Herdendorf (Ohio State University Sea Grant)

Objective. To prepare an atlas that is descriptive of conditions, processes, and both natural and man-developed features of the coastal and offshore waters of Lake Erie that will be of value to recreational users and developers of recreational facilities.

Task 10.21. Coupling a Time Dependent Model of Great Lakes Phosphorus Dynamics with a Dynamic Optimization Model for Phosphorus Control Strategies

Task Scientists. T.D. Fontaine and B.M. Lesht (Argonne National Laboratory)

Objectives.

(1) To modify Chapra's (1983) steady-state phosphorus model and optimization program to determine how optimal phosphorus control strategies are affected by year to year variability in inputs, weather conditions, economic factors, changes in land use patterns, etc.

(2) To determine if optimal phosphorus control strategies that are derived by steady state models will be more or less useful than strategies that are derived which take into account year to year variabilty in inputs.

(3) To conduct an audit of how well a time-dependent version of the Chapra and Sonzogni (1979) model predicts measured Great Lakes total phosphorus trends.

Task 10.22. Ecosystem Model for the Connecting Channels and Lake St. Clair

Task Scientist. T.D. Fontaine

Objectives.

(1) To develop a model which conceptually addresses major ecological processes in the UGLCC study area.

(2) To simulate the model developed in (1) in order to understand and explain observed patterns of system behavior.

(3) To develop ecological models of the UGLCC study area in such a way that they or their output can be used in management oriented applications.

(4) To help focus and guide the course of data collection and process oriented research.

Task 10.23. Lake St. Clair Phosphorus Model

Task Scientists. T.D. Fontaine and G.A. Lang

Objectives.

(1) To develop a data base which quantifies the major inputs, losses and storages of Lake St. Clair phosphorus. To quantify the variability associated with these data.

(2) To develop and test models for simulating phosphorus dynamics in Lake St. Clair.

(3) Based on the results of (2), investigate how phosphorus models for Lake St. Clair can be improved.

Task 10.24. Generic Contaminant Model for the Connecting Channels and Lake St. Clair

Task Scientists. T.D. Fontaine and B.J. Eadie

Objectives.

(1) To develop a generic model for simulating contaminant transport, behavior and fate in the connecting channels and Lake St. Clair.

(2) To develop or obtain a data base which quantifies the major inputs, losses and storages of selected contaminants associated with the upper Great Lakes connecting channel study area; to quantify the variability associated with these data; to use such data in testing the generic contaminant model.

Task 10.25. Risk and Uncertainty Analysis of Ecosystem, Trace Contaminant, and Phosphorus Models for the Connecting Channels and Lake St. Clair

Task Scientist. T.D. Fontaine

Objectives.

(1) To use ecosystem models developed in task 10.22 for evaluating risks and uncertainties associated with ecosystem management strategies.

(2) To use phosphorus models developed in task 10.23 for evaluating risks and uncertainties associated with phosphorus management strategies.

(3) To use contaminant models developed in task 10.24 for evaluating risks and uncertainties associated with contaminant management strategies.

Task 10.26. Optimization and Cost-Benefit Analyses of Ecosystem, Trace Contaminant, and Phosphorus Management Strategies in the Upper Great Lakes Connecting Channels

Task Scientist. T.D. Fontaine

Objective. To develop least cost management strategies for the UGLCC that will meet or exceed environmental protection constraints.

Project 11. PROGRAM DEVELOPMENT

Project Scientist. E.J. Aubert

Objectives.

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

(2) To define environmental issues and research needs of importance to marine resource management and environmental services pertinent to the GLERL mission and objectives and to develop preliminary program docu-mentation (program development plans).

(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. Program development includes the preparation of a research proposal and the associated staff work to document and sell the proposed research through the NOAA budget channels and to other agencies. NOAA program documents include the Program Development Plan (PDP) and the Technical Development Plan (TDP); other agency program documents include the Proposal to Study (PTS) and Plan of Study (POS). Program development can also identify future research directions for our ongoing and evolving research program within available resources.

Program development may include exploratory research or convening of a workshop, as necessary, to assist in defining research problems or issues, research objectives, and approach. 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-on to IFYGL. This multidisciplinary research program has broad research objectives with both a scientific and a user orientation.

During 1979, program development in Task 2, Great Lakes Waves and Flooding, focused on participation with other ERL oceanographic laboratories in the development of research plans for improved Marine Prediction Services. In FY 81, NOAA assigned this accelerated research on Great Lakes and ocean waves a low priority and it has not survived the budget process. No wave initiatives were undertaken since FY 81 owing to low funding priority. Currently the development of improved NOAA Ocean Service Centers is a priority of the Administrator. Program Development should facilitate the development of improved wave prediction techniques and technology transfer to the NWS within the GLERL base budget.

During 1979, program development continued to focus on Task 11.6, Long-Term Effects of Man-Induced Changes on the Ecosystem. A PDP "Great Lakes Long-Term Effects Research" was prepared in May 1978 and submitted as part of the NOAA FY 80 improvement in Marine Ecosystem Investigations. Two critical Great Lakes pollution problems were identified: toxic organics and nutrient enrichment. This PDP addressed long-term research that would have resulted in significant expansion of the GLERL research program in physical processes, ecosystem dynamics, and environmental systems. This proposed research initiative identified a new comprehensive program in research and monitoring in response to Section 202 of the Marine Protection, Research and Sanctuaries Act (PL92-532), and is a logical expansion and follow-on to major segments of the GLERL research program in Projects 1, 2, 4, 5, 6, and 10. An initiative was prepared for the FY 81 Budget decision package Marine Ecosystem Investigations to investigate the complex Great Lakes eco-system and the effects of human-introduced nutrients and toxic organics. In May 1979, a Technical Plan on Toxic Organic Cycling in the Great Lakes Ecosystem was prepared and submitted to NOAA-RD-OMPA; it was accepted and resulted in the initiation of this new long-term program in July 1979. It is as a result of this Program Development success that the GLERL research program in this Technical Plan was reoriented to initiate the three new projects P3--Particle Dynamics, P4--Toxic Organic Cycling, and P6--Eutrophication and Nutrient Cycling.

A proposed initiative entitled "Toxic Organics in the Coastal Region" was prepared for the FY 82 budget line item Marine Ecosystem Investigations to expand upon this toxic organics cycling research initiated in FY 79. The Toxic Organics PDP was later incorporated into the OMPA PDP Contaminant Assimilative Capacity that had partial success in the FY 82 budget process, but was outside the NOAA OMB mark. We continued to support OMPA in developing a Contaminant Assimilative Capacity Initiative for FY 83, although the degree of overlap of OMPA and GLERL interests and the possible expansion of GLERL Toxic Organics and numerical modeling research remains to be determined. Because of the expansion of the GLERL research program in Marine Pollution with no accompanying staff expansion, we have initiated a Cooperative Program with the University of Michigan.

A marine quality research proposal "Toxic Organics at the Sediment-Water Interface" was prepared and submitted for FY 85 support under line item Ocean and Great Lakes Assessment and Research. This proposal was briefed to the Administrator and turned down by DOC; we were sufficiently encouraged that an updated version was prepared and submitted for FY 86 as "Containment Sediment Dynamics." This initiative focuses on estuaries, toxic organic problems and issues, the cycling of toxic organic contaminants, multidisciplinary (physical, chemical, biological, geological), particulate-dissolved-contaminant dynamics at the sediment-water interface. The program has three projects: simulation and prediction modeling, experimental process studies, and marine assessment research. While approved by OAR and NOAA, this FY 86 initiative was again turned down by DOC. Due to both the scientific interest and the critical national need for improved information on the sources, fate, and effect of synthetic organic compounds, this initiative is being resubmitted for FY 1987. The new NOAA Marine Environmental Quality Committee may facilitate NOAA support for this marine research program.

The following tasks have been completed: Task 1, Nearshore Environmental Problems and Processes; Task 3, Fox-Wolf River Basin Study; Task 4, Great Lakes Ocean Color Application; Task 5, Effects of Carbon Dioxide Increase on Large Lake Ecosystems.

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 are developed.

Approach. This project involves the problem and program definition phase for research projects or tasks that represent a significant change from the existing GLERL projects or tasks and that usually require augmented resources to carry out. 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.

Task 11.6. Ocean and Great Lakes Assessment and Research

Task Scientists. E.J. Aubert, J.R. Bennett, B.J. Eadie, T.D. Fontaine, W.S. Gardner, F.H. Quinn, and Others

Objective. The specific objective of this task is to participate with the Office of Oceanic and Atmospheric Research (OAR), the National Ocean Service (e.g., OMS/OAD and NMPPO), the National Marine Fisheries Service (NMFS), and the NOAA Marine Environmental Quality Committee on scientific planning of coastal and estuarine assessment and research activities directed toward improved understanding and prediction of natural marine ecosystems, physical phenomena, and the impact of man-induced stresses on the ecosystem; and developing a sound scientific basis for management decisions, pertinent to marine resources, marine pollution, and environmentally sensitive marine activities.

(1) To define the scientific program that should be pursued on the Great Lakes and the estuarine regions of the coastal oceans.

(2) To develop detailed documentation for the budget process.

(3) To develop a budget (FY 1987) initiative and research proposal/plan as appropriate.

An issue paper "NOAA Research in the Great Lakes" provides a broad framework for what Great Lakes research needs doing, including research goals, major issues and research needs, and broad objectives consistent with the NOAA Marine Pollution Program Plan: FY 1982-86.

GLERL will take the OAR program development lead in Marine Pollution. A draft 10-page proposal in "Marine Quality Research--Contaminant Sediment-Water Dynamics" will be updated and submitted as an FY 1987 budget initiative.

Task 11.7. Efects of Calcite Whitings on the Lake Michigan Ecosystem

Task Scientists. D. Scavia, J.R.Bennett, S.J. Bolsenga, B.J. Eadie, G.L. Fahnenstiel, W.S. Gardner, J.A. Robbins, and H.A. Vanderploeg

Objective. To plan a coordinated research effort on the effects of calcium carbonate precipitation on the Great Lakes ecosystems.

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