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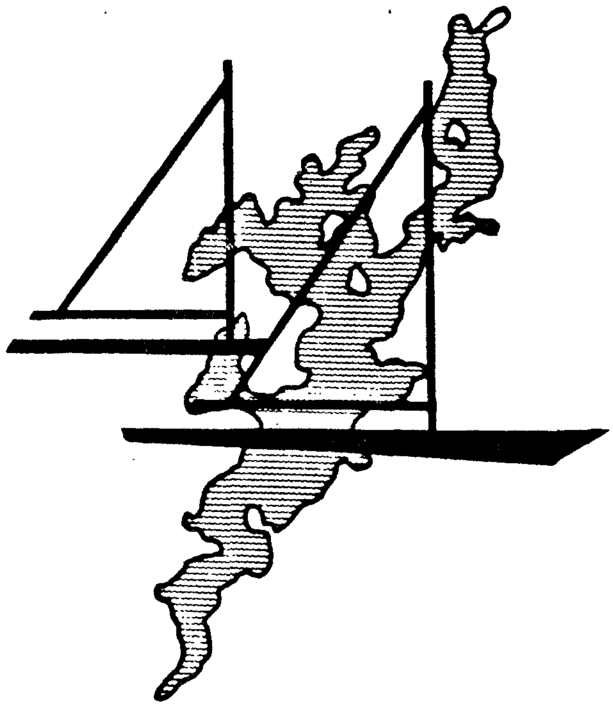
LAKE HOPATCONG



MANAGEMENT / RESTORATION PLAN

Prepared for: LAKE HOPATCONG REGIONAL PLANNING BOARD
State Park Administration Building, Landing, New Jersey / NOVEMBER 30, 1983

PRINCETON AQUA SCIENCE

789 Jersey Avenue • P.O. Box 151 • New Brunswick, New Jersey 08902 • (201) 846-8800

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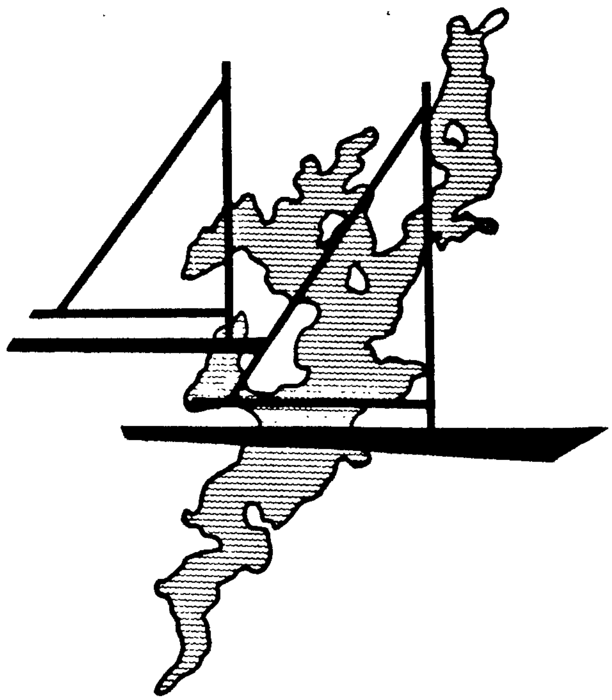

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H J R A

LAKE HOPATCONG REGIONAL PLANNING BOARD

Hopatcong Borough Jafferson Township Mount Arlington Borough Roxbury Township

Sussex County Morris County State of New Jersey

December 1, 1983

Mr. John Brzozowski
Division of Water Resources
NJ Department of Environmental
   Protection
P.O. Box CN-029
Trenton, NJ 08625

Dear Mr. Brozozowski:

The Lake Hopatcong Regional Planning (LHRPB) is pleased to submit the completed Diagnostic Feasibility Study for Lake Hopatcong conducted under contract to the New Jersey Department of Environmental Protection in accordance with Section 314 of the Clean Water Act, 33 USC 1251 _et seq_. and 40 CFR 35.1600 and NJAC-7:9-15.1 _et seq_.

This letter is our formal request for funding to implement the first steps in the plan as presented herein. This letter will briefly describe the results of the study, what the first implementation measures are, how they would be impleted, our request for funds, and our ideas for long term funding of the maintenance and restoration of the lake.

The major problems identified during the course of the study include:

1) Excessive growth of aquatic macrophytes
2) Excessive growth of planktonic and benthic algae
3) Severe oxygen depletion in the hypolimnetic waters extending up into the metalimnion.
4) Sediment accumulation
5) Accumulation of metals in the lake sediments
6) Degrading fishery

The causes of these problems all relate to the excessive development that has occurred in the watershed without regard for adequate wastewater and stormwater quality control. Currently the phosphorus loading rate is estimated at 0.357 $gm^{-2}yr^{-1}$ whereas the safe loading rate for Lake Hopatcong is 0.17 $gm^{-2}yr^{-1}$. The loading rates of other pollutants is given in the text of the study. The onsite waste disposal systems utilized in the basin account for 41% of the pollutant load and stormwater runoff accounts for 48%. This excessive nutrient loading to the lake and the basic morphometry of the lake are the causes of the nuisance aquatic weed and algae growth. This excess primary production is also responsible for the severe oxygen depletion and degrading fishery in the lake.

Lake Hopatcong State Park Administration Building,
Landing, New Jersey 07850

Mr. John Brzozowski
Division of Water Resources
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The accumulation of heavy metals (Pb, Zn, Cd) in the sediments can be attributed to the use of leaded gasolines in outboard motors and stormwater runoff into the lake. The sediment accumulation is also caused by stormwater runoff carrying particulates into the lake.

The basic plan for restoration and management of Lake Hopatcong can be divided into two parts.

1) Long term watershed management measures which address, for the most part, the causes of the problems in the lake. These long term measures include implementation of the 201 Facilities Plans in the basin and the development and execution of a stormwater quality management plan.

2) Short term immediate in-lake maintenance measures that address the symptoms of the problems. These measures include a weed harvesting program, public education, lake draw down, and continued monitoring of the lake.

Watershed Management Program

The LHRPB realizes that there is no "quick fix" to solving the watershed management problems and a long term plan for reducing these pollutant loads will have to be phased in, step-by-step over a period of years utilizing a number of water resources programs with funding from many sources. Therefore the LHRPB recommends:

1) The implementation of the 201 Facilities Plans for the basin. Except for Mt. Arlington the Step 1 plans for the entire basin are complete. However, each segment of the 201 plans carry separate priority numbers on the proposed NJDEP 201 facilities list. Also, the numbers assigned are such that implementation of these plans would be postponed for many years. In prioritizing DEP has not recognized the tremendous economic impact that the lake has in the immediate vicinity of the lake and the region. Therefore, the LHRPB recommends that:

a) All segments of the 201 Facilities Plans completed for the basin be unified under 1 priority number;

b) These projects be moved up on the priority list so implementation can be expected as soon as possible; and

c) Mt. Arlington Borough complete their Step 1 planning for that area within the Lake Hopatcong Basin.

2) The communities in the Lake Hopatcong basin develop an integrated comprehensive basin-wide stormwater quality management program. Specifically the board recommends:

a) Delegation of stormwater management planning to the LHRPB. The Boroughs of Hopatcong and Mt. Arlington have already taken this step. Proposals are currently pending with Jefferson and Roxbury.

b) The LHRPB will apply to the state of New Jersey for funds to carry out this management planning, however, these funds are <u>not</u> part of this request.

c) The implementation of a pilot project along Lakeside Drive. This pilot project is already on the drawing board and funds for construction of the sediment traps is being factored into the cost of improvements to Lakeside Drive. The funds to offset the additional design costs are part of this request. A second project is being developed in association with a development proposal in Hopatcong. This is being funded by the developer with land donated by the Borough.

3) Acquisition of the Liffy Island and adjacent shoreline as a natural park. The Township of Jefferson has voted to request funds under New Jersey's Green Acres Program to accomplish this end. The financial arrangements for this acquisition are outside the scope of this request.

4) Public Education - A public education program would be carried out by the LHRPB with possible assistance of the Sussex Co. 208 Program. The development of educational releases, conducting teacher workshops and continuation of the existing communications between the Board and the public. It is imperative that the general public be informed concerning the issues and importance concerning the lake. The preparation and desseminating of a periodic newsletter may be appropriate. The funds to begin this program are included in this request.

Numbers 3 and 4 above are recommended for immediate implementation. Also, delegation of stormwater management responsiblities is being pursued.

In-Lake Maintenance

While the various watershed management programs are phased-in over a period of years, the LHRPB is still faced with the problems of maintaining Lake Hopatcong so that it will remain a viable recreational resource that supports the recreation based economy of the watershed and the region. The lake's economic value to the area is immense and measures have to be taken immediately to protect this economic asset while watershed management measures can be implemented to correct the causes of the problems. Immediate in-lake steps to maintain and monitor Lake Hopatcong need to be started. These include aquatic weed harvesting program, lake draw down and continued monitoring. Dredging some areas in the lake is recommended but is not part of this request.

Therefore, the LHRPB is recommending for immediate implementation the following:

1) Weed Harvesting - The LHRPB would own the equipment and hire a contractor to execute the harvesting program. The Lake Management Subcommittee (LMS) of the LHRPB would oversee the performance of the contractor in the same way that they do now. The contractor would be responsible for maintenance of the equipment

and operation of the equipment. Each year the contractor will develop the harvesting program and present it to the LMS for approval. Progress reports on the conduct of the harvesting would be submitted on a regular schedule for review by the LMS. The contractor will be required to keep accurate daily records of the harvesting for examination by the LMS.

2) Phase II Monitoring - The monitoring program would have to be carried out by a certified laboratory. The monitoring would include chemical monitoring as well as an evaluation of the effectiveness of the harvesting program. The actual monitoring program would be overseen by the LMS and carried out by a contractor.

3) Lake Draw Down - The lake draw down program is currently a part of the program at Lake Hopatcong. This is instituted by the Division of Parks and Forestry in DEP with input from the LHRPB. This arrangement would remain as it is now. Any variation in the established schedule could be requested by the LHRPB but would be subject to the same involvement of local and state officials as now.

In summary, the items requiring funding for immediate implementation include:

1) Weed harvesting
2) Phase II monitoring
3) Lake drawdown
4) Public education program
5) Design of pilot stormwater project

The estimated budget to carry out this program over the next four years is presented in Addendum #1. The LHRPB is requesting funds to implement the five items listed above for the first two years of the project. This request if for $404,300.

An application for 50% of these funds ($202,150) should be submitted to EPA. To obtain these EPA funds state and local sources have to raise the matching $202,150.

It is anticipated that the annual budget for maintaining the lake after the first two years will range between $115,000 and $130,000 per year.

Various avenues for raising the additional matching funds and the on-going maintenance funds that are being explored include the following:

1) Application of user-fees to possibly include
   a) A share of revenues collected at the State Park
   b) Boat registration fee
   c) Slip fee and dock fee
   d) Launch fee

2) Obtaining legislation to allow the communities or board to raise additional revenues to help support the project.

3) Obtain an initial and annual appropriation from the State Legislature to fund the project through NJDEP to the LHRPB (see attached letter from Assemblyman Weidel).

4) Obtain annual appropriations from the Counties of Sussex and Morris to the LHRPB.

The LHRPB has conducted a public hearing on this project and have met with the councils of the constituent municipalities of Jefferson, Mt. Arlington, Hopatcong and Roxbury. Also, presentations were made to the Lakeland Mayors Association and the Sussex Co. Board of Chosen Freeholders. A meeting with the Morris Co. Freeholders is being scheduled. Also, a meeting between the LHRPB, the Lakeland Mayors, and several of our State Legislators was held on November 4, 1983.

Mr. John Brzozowski
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Currently, various activities concerning this project are proceeding and represent some dollar value from the local communities. These include:

1)	Annual dues to LHRPB from constituent municipalities and counties		\$ 8,460.00/year
2)	Application for Green Acres funds to obtain Liffy Island includes donation of Township held property (fair market Value)		\$50,000.00
3)	Planning and construction of detention traps along Lakeside Boulevard. Sussex Co. Freeholders committed to contributing 25% of entire project with additional state and federal funds.	Estimate	\$25,000.00 (county funds)
4)	Construction of detention basin at Highlands of Sussex development. Costs plus value of city-held property	Est.	\$12,000.00 (cost to Hopatcong Borough)
		Value	\$10,000.00
5)	In-kind services of the LHRPB	Value	\$ variable

Though these items may be a viable match for Federal funding they do not actually raise the additional funds necessary to implement the program. We are still in need of \$202,150 to implement the program for the first two years and the \$115,000 to \$130,000 per year to carry on the program after the initial two years.

At this time the LHRPB is requesting a state appropriation of \$205,150 for matching EPA funds. This may be the most viable alternative to begin implementation of the program.

In our discussions with local, county and state officials, the overall consensus of opinion is that the project should proceed as indicated in this letter. However, establishing the mix of funding to support the project's implementation remains elusive at this time.

As one might expect initial comment from local officials have favored obtaining state appropriations from the Legislature and the application of user fees. Increased contributions from local and county governments through additional tax revenues have been least popular. It is the board's position that some combination of all of these is probably the most equitable solution.

Those that live in the watershed of the lake benefit most from the lake and also have the greatest impact on the lake. Therefore, the concept that the local communities should contribute to the maintenance of the lake is justifiable. The fact that many lake-users come from outside the basin and the fact that the economic benefits of the lake are felt outside of the basin make the lake a regional resource and justify the collection of user fees, and the financial involvement of the state and county governments in the funding.

In addition, the fact that the lake is actually owned by the State of New Jersey and the state is collecting fees on the lake is further justification for state support.

It is imperative, however, that to the greatest extent possible the decisions concerning the lake be made locally since this is where the problems of a degrading lake have the greatest impact. Also, it is important that the lake and watershed are managed as a single unit and that decisions concerning its management transcend local parochial considerations. Therefore, as recognized in 1963, the role of protecting and restoring Lake Hopatcong is best delegated to LHRPB.

Mr. John Brzozowski
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I would like to take this opportunity to request a meeting as soon as possible between the LHRPB and NJDEP to explore and hopefully resolve the question of funding this project.

Sincerely,

LAKE HOPATCONG REGIONAL PLANNING BOARD

Eric Grove, P.E.
Chairman

EG/JDK/jmm

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GENERAL ASSEMBLY
OF NEW JERSEY
TRENTON

November 4, 1983

Honorable Thomas H. Kean, Governor
State of New Jersey
State House
Trenton, N.J. 08625

Dear Governor Kean,

I strongly urge you to consider providing $275,000 in the FY 1985 State budget for protection of Lake Hopatcong.

As you know. Lake Hopatcong is a major recreational facility in northern New Jersey serving many thousands of people each year. Unfortunately, the lake is rapidly deteriorating, becoming "eutrophic" or environmentally stagnant. Results of a professional two-year study conducted by Princeton Aqua Science noted that the combination of pollutants, street runoff, erosion, fertilizers, and malfunctioning septic systems is literally killing the lake; i.e. accelerating weed growth and inhibiting animal life.

The professional study includes a detailed schedule of corrective measures. The suggested $275,000 appropriation will provide a one-time payment of $180,000 for weed harvesting equipment, $70,000 in operation expenses, and $25,000 for lake monitoring and a public education program. Ideally, the $95,000 appropriation for maintenance, monitoring, and public education will be on-going.

Officials from the Department of Environmental Protection have stated that they are seeking funds for this long-term lake rehabilitation program in next year's State budget. If it is too late, at this time, to include these funds in next year's budget, I would ask that you support my efforts to provide a $275,000 supplemental appropriation during the next legislative budget hearings.

I know that you have made environmental protection a top policy priority of your administration. I hope that you will agree with me that preservation of Lake Hopatcong represents one such top priority and that it is unfair to require the four municipalities bordering on the lake to pay all restoration costs for a facility enjoyed by citizens throughout the State.

Sincerely,

Karl Weidel

KW:hkt
cc: Commissioner Hughey, Department of Environmental Protection
W. Carey Edwards, Chief Counsel to the Governor
Dean Gallo, Assembly Minority Leader

ACKNOWLEDGEMENTS

This Phase I Diagnostic-Feasibility Study of Lake Hopatcong was partially funded by the U.S. Environmental Protection Agency's 314 Clean Lakes Program. This project was administered by John Brzozowski and Debra Hammond, Lakes Management Program, Division of Water Resources, N.J. Department of Environmental Protection. The Lake Hopatcong Regional Planning Board and its constituents provided matching financial support and in-kind services. Members of the LHRPB are as follows:

Hopatcong Borough
Clifford Lundin, Jr.
Norman Lacy

Mt. Arlington Borough
Robert Lee, Jr.
William Nelson, Secretary

Sussex County
Eric Grove, Chairman

State Representative
Russell Myers, NJDEP
Elizabeth Price

Jefferson Township
Edwin Goldmann
Eugene Witt, Treasurer

Roxbury Township
Henry Leiber, Vice Chairman
Earl Crystal

Morris County
James Julian

Recording Secretary
Beverly Merritt

Sample collection, water quality monitoring, data analysis, and preparation of this document were by:

Princeton Aqua Science
789 Jersey Avenue
P.O.Box 151
New Brunswick, NJ 08902

The individuals primarily responsible for the preparation of this document were:

- John Cirello, Ph.D., P.E.
- John D. Koppen, Ph.D., Director Aquatic Sciences Program
  Project Director
- Stephen J. Souza, Ph.D.
  Project Manager
- Robert Conner
  Field Coordinator

The following individuals served as the technical support staff for this project:

- Stephen C. Pucke
- William P. Gregory
- Thomas Grenci
- Amy S. Greene
- Joseph Fallon
- Thomas Glenn

LAKE HOPATCONG MANAGEMENT/RESTORATION STUDY
EXECUTIVE SUMMARY

Lake Hopatcong is New Jersey's largest and most heavily utilized inland freshwater recreational resource for boating, swimming, fishing and water skiing. Its contribution to the economy of North Central New Jersey is immense. However, over the past 30 years there has been a significant decline in the water quality of the lake. The visible symptoms of this decline include massive algal blooms, excessive aquatic weed growth, depletion of oxygen in the deep waters (hypolimnion) of the lake, the accumulation of organic sediments, accumulation of heavy metals in the sediments and a general degradation of the fishery.

In recognition of the importance and problems of this resource the Lake Hopatcong Regional Planning Board (LHRPB) was created, pursuant to Article 10 of New Jersey's New Land Use Law, to develop measures to address the problems of Lake Hopatcong. The LHRPB initially conducted two studies and prepared a master plan for the basin; however, these studies did not fully address the issue of water quality. Through the 1970's with some help from the Sussex County 208 Planning Agency the LHRPB maintained a monitoring program, which did not fully quantify the sources of pollution to the lake. From 1979 to 1983 the Upper Musconetcong Sewerage Authority (MSA) and Jefferson Township completed Step I 201 Facilities Plans for all of the Lake Hopatcong basin except for Mt. Arlington. These studies documented the need for sewerage around the lake, focusing on the topic of wastewater disposal. Equally important issues of stormwater quality and management and restoration of the lake were not covered by these previous efforts.

Recognizing the need for a comprehensive watershed and lake management plan, the LHRPB obtained a grant from EPA through the New Jersey Department of Environmental Protection under Section 314 of the Clean Water Act. The objectives of this study were:

1. To identify and document water quality problems with Lake Hopatcong and to localize and quantify pollutant inputs.

2. To determine the current trophic status (degree of eutrophication, or aging) and limnological characteristics of the lake.

3. To develop a comprehensive basin-wide watershed management plan to reduce pollutant inputs to the lake.

4. To develop an in-lake restoration and management plan.

The study was begun in August of 1981 and completed in October of 1983.

CHARACTERISTICS OF LAKE HOPATCONG AND ITS WATERSHED

Lake Hopatcong is located in north-central New Jersey on the border between Sussex and Morris Counties. The lake covers 1087 ha (2686 acres), has a maximum depth of 17.7 m and an average depth of 5.5 m. It has 62.75 km (39 miles) of highly convoluted shoreline that forms many shallow inlets, bays and coves (Figure 1). The watershed covers 5480 ha (13,500 acres) of hilly New Jersey highlands. The watershed is underlain by precambrian metamorphic rock covered by sporadic glacial deposits. The major soil association is the Rockaway-Rock Outcrop-Whitman Association that tends to be acidic and is classified as being moderate to severe for septic tank absorption fields.

Seventy percent of the watershed is undeveloped forest and the other thirty percent, in the immediate vicinity of the lake, is covered with high and low density residential and commercial development.

Lake Hopatcong originally consisted of two bodies of water connected by a branch of the Musconetcong River. The lake as we know it today was created in 1827 by the construction of an 11 foot dam to create a reservoir for the Morris Canal. The dam increased the water area by 45%, resulting in much of the lake being extremely shallow; 11 feet or less in depth.

The major tributaries to the lake, Weldon Brook and Beaver Brook, drain approximately 5100 acres of forested watershed. These streams empty directly into Lake Shawnee (Figure 1) upstream of Lake Hopatcong, which in turn empties into Lake Hopatcong. The remainder of the watershed is drained by minor tributaries and immediate drainage to the lake.

THE PROBLEMS

Lake Hopatcong shows symptoms of advanced accelerated eutrophication. Eutrophication, the process of lake aging, is caused by excessive nutrient loadings and is characterized by algae growth and aquatic weeds. A lake's eutrophic state is most normally quantified by measuring the presence of chlorophyll a, as expressed in milligrams per cubic meter (mg m^{-3}).

During the course of this study, at the surface of the lake, maximum chlorophyll a concentrations ranged from 15.6 mg m^{-3} at mid-lake to a high of 64 mg m^{-3} in Woodport bay. These levels are well in excess of desirable levels. For comparison, the range of chlorophyll a values for commonly defined trophic levels are as follows:

Trophic Level Definition in Lakes

Trophic Classification	Chlorophyll a - mg m^{-3}
Oligotrophic (lowest nutrient levels)	less than 2.0
Mesotrophic (transition)	2.0-6.0
Eutrophic (excessive nutrients)	greater than 6.0

Source: USEPA Clean Lakes Program Guidance Manual

Chlorophyll a measures only planktonic algae standing crop. In addition to plankton, algae mats consisting primarily of the course filamentous blue-green algae (Lyngbya latissima) grow in the shallow coves and bays. In the summer, gasses accumulate under the mats causing them to float to the surface. These mats interfere with the recreational use of the lake and form an unsightly mass.

The occurrence of nuisance proportions of rooted aquatic plants in the shallow zone of the lake interfere with swimming and boating. The major nuisance species are Myriophyllum spicatum, Potamogeton amplifolius, Potamogeton crispus and Vallisneria americana. The low-growing Najas sp. is found in dense stands in the lake. Since it does not reach the surface, however, it generally does not interfere with surface recreational activities. The lake is treated each year with herbicides in an attempt to control these aquatic weeds.

Another symptom of eutrophication is the occurrence of oxygen depletion at the greater depths of the lake. Lake Hopatcong undergoes thermal stratification in the summer - according to the classical pattern found in most standing water bodies. During the summer, the organic matter produced in the lake settles down into the lower depths and decays, thereby depleting the oxygen in the deep water. Since the lake is thermally, and therefore, density stratified, the deep waters do not circulate to the surface where they can be oxygenated. In Lake Hopatcong, the oxygen demand due to primary production causes the lowest layer of the lake (hypolimnion) to become anoxic by the beginning of July (Figures 8 and 9). In fact, the oxygen demand is so great that the anoxic conditions gradually move upward toward the surface. This means that the environment for cold water fish is destroyed and viable reproducing populations are difficult to maintain.

Another side effect of oxygen depletion is that it creates conditions conducive to the recycling of phosphorus. Under most conditions phosphorus would be the nutrient that limits the production and growth of vegetation. In Lake Hopatcong, phosphorus in the sediments that would normally not be available for primary production is circulated upward where it can support more vegetation production and exacerbate the algae problem.

Due to the high primary production of vegetation in the lake there is incomplete degradation of organic matter and the excess accumulates as thick mucky sediment. This sediment characteristically has low redox potentials that also favor the recycling of phosphorus from the sediments into the water column.

Other problems in the lake involve the accumulation of heavy metals in the sediments and erosion of silt and sediment into the lake. Thirty sediment core samples were taken from several locations in the lake. These were analyzed for heavy metals. The surficial sediments, at the sediment-water interface had as high as 1220 mg kg^{-1} dry weight lead and 10 mg kg^{-1} dry weight cadmium. Sediment samples show that high sediment metal concentration are of recent origin.

CAUSES OF THE PROBLEMS

Excess nutrient inputs which support weed and algae growth are the primary cause of Lake Hopatcong's eutrophication problems. The element phosphorus is the main problem. The total external phosphorus load to Lake Hopatcong was estimated at 3655 kg yr^{-1} or 0.34 g m^{-2} yr^{-1} and with internal recycling the load is 4249 kg yr^{-1} or 0.39 g m^{-2} yr^{-1}. This is a substantial load and places the loading rate for Lake Hopatcong in the eutrophic range (Tables 49 and 51).

The story of Lake Hopatcong is similar to that of many lakes in the northeastern United States. Initially, many summer homes and resort hotels were built on the lakeshore. However, with improved transportation routes and the increased cost of maintaining two residences many of these seasonal homes were converted to year-round dwellings and along with the building boom of the 60's and 70's the area in the immediate vicinity of the lake became urbanized. Unfortunately, this development took place without adequate consideration of the impacts of the development on the lake.

All homes on Lake Hopatcong have on-site waste disposal systems. Many of these systems were sized for seasonal use only and never enlarged. Many are located in soils that have severe limitations for septic leach fields. In the development process, little consideration was given to stormwater control. To illustrate how development can affect the phosphorus load, if the basin had remained undeveloped, the phosphorus load to the lake would be approximately 1200 kg/yr or 0.11 g m^{-2} yr^{-1}. This is substantially below the permissible or oligotrophic loading rate of 0.17 g m^{-2} yr^{-1}. Figure 23 illustrates the trophic state of Lake Hopatcong with and without development.

The aquatic weed and benthic algae problem is further exacerbated by the physical dimensions of the lake. Approximately 45% of the lake area is 10 feet deep or less, and there is a large expanse of shoreline (39 miles). The combination of these two factors creates an extremely large shallow area where light can penetrate to the bottom with sufficient intensity and quality to support photosynthesis and consequently rooted weed and benthic algae growth. The erosion of sediment into the shoreline areas and the deposition of nutrient-rich internally produced organic sediment creates optimum conditions for aquatic plant and benthic algae growth.

The vast littoral area with its potential for primary production could, in itself, produce enough organic matter to cause oxygen depletion in the depths of the lake.

The accumulation of metals in lake sediments especially lead, can be attributed to the use of leaded gasolines in automobile and boat engines. The pathways of lead to the lake sediments include stormwater runoff from the streets; dry and wet deposition from the atmosphere; and the use of leaded gasoline in outboard motors. The highest concentrations of metals were found in restricted coves that received substantial stormwater runoff from residential streets (Landing and Crescent Cove). The change-over to unleaded gasoline in automobiles will substantially reduce this problem in the future. Through Extraction Procedure Toxicity Leachate Analysis (EP Toxicity) it was determined, however, that the metals do not leach into the water column. Analysis of fish tissues showed no appreciable bioaccumulation of metals.

A PLAN TO RESTORE AND MANAGE LAKE HOPATCONG

Evaluation of Lake Hopatcong's status, its problems and their causes was done to develop a plan to restore the quality of the lake and to preserve the lake's value as a major regional recreational resource. The plan recognized that most of Lake Hopatcong's problems with water quality degradation arise from the intense development that occurred along the shoreline of the lake without proper planning for wastsewater treatment and stormwater control. The plan also recognized that major changes need to be made with regard to this development, changes that require many years in order to be implemented.

The Lake Hopatcong Management and Restoration Plan presents recommendations that have both long range and more immediate impacts. The long range measures deal primarily with the causes of lake degradation; the more immediate measures are designed to treat the principal symptoms of degradation now being experienced.

Long Range Measures

1. Most of the basin (except Mt. Arlington) has been the subject of recent Sec. 201 Wastewater Facility Plans. The Jefferson Township plan recommended sewering the portion of that township located in the Hopatcong Basin. The Musconetcong Sewerage Authority's Facility Plan should result in sewering parts of the Borough of Hopatcong, Roxbury, and Landing. The Lake Hopatcong Management Plan recommends that these projects be implemented for their substantial positive impacts on water quality in Lake Hopatcong.

2. The Plan recommends that the municipalities of the watershed delegate to the Lake Hopatcong Regional Planning board the authority for stormwater management planning and implementation under NJAC 7:8. This would allow for development of an integrated basin-wide stormwater management program. New concepts in stormwater management can be implemented that would substantially reduce pollutant loads to the lake.

3. The Liffy Island area of the lake should be acquired by Jefferson Township to maintain this area as a natural park to protect it from future development, to preserve it as an aesthetic resource for all of the lake users, and to protect the fish spawning areas in the vicinity of the island.

4. Implement a public education program to inform citizens of the best management practices that they can implement individually and to develop support for the overall lake restoration program.

The long range measures proposed by the plan will take many years to accomplish, at a cost of millions of dollars. The short-term measures proposed are designed to maintain the lake in a usable condition during the period of implementation.

Short Term Measures

1. Aquatic Weed Harvesting. Weed control by chemicals do more to harm lake quality in the long run than to restore it in the short run. Therefore, it is recommended that aquatic weeds be harvested in order to remove nutrients and biomass from the lake.

2. Lake Drawdown. By coupling aquatic weed harvesting with controlled lake drawdown in the winter to expose the aquatic weeds, the weeds will be controlled in an ecologically sound manner and the lake sediments will be consolidated. Such action should significantly improve water quality and decrease internal nutrient loading.

3. Dredging. Some dredging is proposed in localized areas ot he lake where there is heavy deposition of silt.

4. Continued Monitoring. Lake monitoring programs should continue as a necessary means of identifying continued short-term improvement measures and documenting the impacts of both short-term and long range restoration measures.

IMPLEMENTING THE PLAN

A comprehensive, basin-wide plan to integrate a number of water resources programs has been developed. The plan is designed to provide comprehensive watershed management to reduce pollutant inputs to the lake, and to restore water quality through an in-lake restoration program. To implement the plan the following are required:

1. Adequate funding from several sources.

2. A single, basin-wide management organization.

It is proposed that the Lake Hopatcong Regional Planning Board expand its authority as a regional management organization and pursue legislation that will permit it to develop funds through nominal taxing power, user fees and grants. It is expected that necessary sewerage improvements will be made through existing local, state and federal funding sources related to EPA's Section 201 sewerage construction grant program.

The effort described in this report, funded by EPA's Clean Lakes Program, has provided a tremendous opportunity to those concerned with Lake Hopatcong's future and its value as a regional resource. The Lake Hopatcong Regional Planning Board serves as a focal point for public involvement and public awareness with regard to the deteriorating quality of the lake, and the means of restoring the lake. The proposed management plan, when enacted, will not only improve the quality of lake waters, but will help to maintain property values, the economic and recreational value of the basin, and the overall quality of life that prompted the original development of the Lake Hopatcong watershed.

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SECTION I

INTRODUCTION

A. HISTORY AND PURPOSE OF PHASE I DIAGNOSTIC-FEASIBILITY STUDY

The degradation of water quality and aesthetics of many of America's freshwater lakes and ponds spurred the conception and enactment of the Federal Water Pollution Control Act amendments of 1972 (P.L. 92-500), and of 1977 (P.L. 95-217). Both are collectively referred to as the Clean Water Act. Section 314 of the Clean Water Act authorizes the protection and restoration of publicly owned water bodies by communities through the use of State and Federal funding.

Lake eutrophication is a natural process which normally occurs slowly over thousands of years. The ontogeny of a lake is such that it proceeds from a low-productive state to an overly enriched, highly productive condition. Typically young lakes are clear, support a meager phytoplankton standing crop and a low density of aquatic macrophytes. Such lakes are termed oligotrophic. As the lake ages, its physical-chemical properties change as a result of watershed erosion and the transport of nutrients and sediments into the lake. The lake becomes increasingly productive, supports a higher density of phytoplankton and aquatic macrophytes, and begins to accumulate organic sediments. Very gradually the lake begins to fill in as these organic deposits accumulate and the aquatic macrophytes become increasingly established. Eventually the lake acquires a marshy or swampy characteristic. In time, the lake becomes completely filled and, in essence, the lake is considered "dead."

Although the ecological succession of a lake is a natural process, it can be greatly accelerated by human activities. Termed "cultural eutrophication," this speeding up of a lake's aging process is caused by increases in the amount and rate of nutrient and sediment exported by the watershed to the lake. Watershed urbanization, the discharge of insufficiently treated sewage, septic tank leakage, inadequate stormwater management, soil erosion, and the application of fertilizers all increase the nutrient load entering a water body. Increased nutrient loads stimulate productivity, and lead to the accelerated eutrophication of the lake.

The fact that a lake is eutrophic is realized when taste and odor problems, algal blooms, nuisance growths of aquatic plants, oxygen depletion, the accumulation of organic sediments and fish kills are observed. These symptoms indicate that the lake is overly productive. The changes in water quality associated with such symptoms may be sufficient to transform the lake from an important community asset, to an objectionable deficit. Many of these symptoms have been observed in Lake Hopatcong. They indicate a deterioration of the lake's water quality and signal the necessity to curtail further lake degradation through the initiation of sound lake restoration and watershed management practices. The first step in realizing this goal is supplied by the data and conclusions of this diagnostic study.

B. OBJECTIVES OF LAKE HOPATCONG STUDY

The following study conducted by Princeton Aqua Science (PAS) for the Lake Hopatcong Regional Planning Board (LHRPB) provides the data necessary to develop a comprehensive action plan for the effective restoration and management of Lake Hopatcong.

The objectives of this study were:

A. Compile and consolidate all of the historical data and studies of the lake.

B. Conduct a comprehensive limnological evaluation of the physical, chemical, and biological characteristics of the lake. Determine the actual trophic status of the lake and elucidate its major ecological relationships.

C. Gather all of the necessary information concerning the lake to address Appendix A of 40 CFR Part 35.1600, the specific statutes of the State of New Jersey, and the regulations outlined in NJAC 7:9-15.1 et seq.

D. In cooperation with the Lake Hopatcong Regional Planning Board (LHRPB) develop a comprehensive watershed management and lake restoration plan for Lake Hopatcong using best management practices (BMP), in lake restoration techniques, and stormwater management methods.

SECTION II

IDENTIFICATION OF LAKE HOPATCONG

A. LOCATION OF LAKE

Lake Hopatcong, New Jersey's largest inland lake, is located on the border of Sussex County and Morris County, New Jersey. The center of the lake is at $40^{o}56'17"$ x $74^{o}38'40"$.

To the north, the lake abuts Jefferson Township, and to the south, Roxbury Township. To the east the lake is bordered by Jefferson Township, Roxbury Township and Mt. Arlington Borough and to the west by Hopatcong Borough (Figure 1).

B. MORPHOMETRY OF LAKE

The morphometry and bathymetry of Lake Hopatcong were determined from USGS 7.5' Topographic Contour Maps, continuous recording fathometer readings, and calibrated sounding line measurements (Figures 1 and 2).

Lake Hopatcong has a total surface area of 1087 hectares (ha), a mean depth of 5.5 meters (m) and a maximum depth of 17.7 m (Table 1). Total inflow to the lake is 39.69 x $10^6 m^3 yr^{-1}$, while total outflow is 39.69 x $10^6 m^3 yr^{-1}$. The major tributaries to the lake are Beaver Brook and Weldon Brook, both of which flow into Lake Shawnee upstream of Lake Hopatcong. The maximum volume of Lake Hopatcong is 5.56 x $10^7 m^3$. Based on measured outflow and lake volume, the lake's hydraulic retention time is 623 days. This indicates that total volumetric water exchange occurs only once every 1.7 years. Discharge from Lake Hopatcong is regulated by a spillway located at Hopatcong State Park, Landing, N.J. Outflow is to the Musconetcong River, a tributary to the Delaware River.

Lake Hopatcong is a sprawling, irregularly shaped lake. It is composed of a number of shallow coves which eminate from the main body of the lake. Located in the extreme north end of the lake is Woodport Bay, a 156 ha shallow water ($\bar{x}$ depth 1.5 m) embayment. Flow from this large bay into the main lake is through a narrow passage. This impairs the flushing of Woodport Bay, and contributes to its physical, chemical, and biological features which are at times quite different than those observed in the remainder of Lake Hopatcong.

Along the western shore there are three large coves: Henderson Cove, Byram Cove, and Crescent Cove. Water depth in Henderson and Crescent Coves is typically less than 2.0 meters. Byram Cove is somewhat deeper with average water depth in excess of 2.5 meters. Outflow from Byram

Table 1

CHARACTERISTICS OF LAKE HOPATCONG, NEW JERSEY
AND THE ATTENDANT WATERSHED

Official Name	Lake Hopatcong
Location	Morris and Sussex Counties, New Jersey $40^{o}56'17" \times 74^{o}38'40"$
Area	1087 ha
Average Depth	5.49 m
Maximum Depth	17.7 m
Volume	$5.56 \times 10^{7} m^{3}$
Watershed Area	5482.7 ha
Watershed Area/Lake Area	5.0/1
Shore Line Development (D_L)	5.41
Shore Line Length	50,976 m
Hydraulic Retention Time	623 days; 1.71 yr.

Cove and Henderson Cove is fairly unrestricted. In contrast, outflow from Crescent Cove to the main basin of the lake is somewhat restricted primarily as a result of its long, narrow shape (Figure 1).

There are three major coves on the eastern shore: Great Cove, Van Every Cove, and King Cove. Water exchange between the main basin and the coves along the eastern shore is fairly free. Great Cove and Van Every Cove are comparatively deeper than the other coves of the lake. Their banks are relatively steep and depths of greater than 2.5 meters are fairly common. At the southern end of the lake there exists a shallow, narrow cove referred to in this report as Landing Channel. Outflow from Landing Channel is restricted primarily due to its long, narrow configuration, and the small amount of inflow to this embayment.

The main basin of the lake has depths ranging from 6 meters to a maximum of 17.7 meters. The main basin extends essentially from Bertrand Island north to Halsey and Raccoon Islands (Figure 2).

C. MAJOR TRIBUTARIES OF LAKE HOPATCONG

As previously mentioned, Beaver Brook and Weldon Brook are the primary tributaries of Lake Hopatcong. Other notable tributaries are Jaynes Brook and Mountain Brook, both of which discharge into Henderson Cove. There are a number of small unnamed tributaries which feed the lake. Some of these smaller tributaries are intermittent or of very low flow in the summer.

D. CLASSIFICATION OF WATERS OF LAKE HOPATCONG AND ITS TRIBUTARIES

FW-1 waters, because of their clarity, color, scenic setting, and other characteristics of aesthetic value or unique special interest have been designated by NJDEP to be set aside for posterity to represent the natural aquatic environment and its associated biota (N.J.A.C. 7:9-4.6). These waters shall be maintained as to qualify in their natural state and shall not be subject to any manmade wastewater discharges.

FW-2 waters according to N.J.A.C. 7:9-4.6 shall be suitable for public potable water supply after such treatment as shall be required by law or regulations. These waters shall also be suitable for the maintenance, migration, and propogation of the natural and established biota; primary contact recreation; industrial and agricultural water supply and any other reasonable uses.

Lake Hopatcong and its tributaries are classified as FW-2 Trout Maintenance waters. The lake is also designated as a potable water supply (N.J.A.C. 7:9-4).

SECTION III

DESCRIPTION OF WATERSHED OF LAKE HOPATCONG

A. GENERAL DESCRIPTION OF WATERSHED

Lake Hopatcong's watershed encompasses a total area of 5482.7 hectares (ha) exclusive of the lake's surface area. The ratio of watershed surface area to lake surface area is 5:1. Approximately 59% of the watershed is in Jefferson Township, while 20% is in Hopatcong, 11% in Sparta, 5% in Mt. Arlington and 5% in Roxbury. All except Sparta have shoreline on the lake.

To the east and west of Lake Hopatcong the topography rises abruptly from the lake and forms a series of ridges which parallel the lake's shoreline. The ridgelines delineate the eastern and western boundaries of the watershed. Contained within the eastern part of the watershed are sections of Jefferson Township, Roxbury Township, and Mount Arlington Borough. The western watershed envelops much of Hopatcong Borough. To the north the watershed extends to the Bowling Green Mountain ridgeline. The northwestern fringe of the watershed encompasses a section of Sparta Township.

B. GEOLOGY

The Lake Hopatcong watershed is located in the New Jersey Highland physiographic province, which is a portion of the Reading Prong of the New England Province. This is the oldest and most resistant rock formation in Morris and Sussex Counties. The watershed is characteristically underlain by hard, crystalline, resistant, Precambrian igneous and metamorphic rocks (Lucey, 1975). The paragneisses tend to be well foliated, well layered, and consist chiefly of biotite-feldspar- quartz gneisses and quartz-oligoclase leucogneisses (Young, 1971). In general, the character of rock in this area can be interpreted as highly metamorphosed marble, granite, and gneiss.

Lake Hopatcong valley is developed along a series of northeast trending fault blocks. Numerous flat top ridges occur throughout the area. Along most of Lake Hopatcong's perimeter, the land rises abruptly, lending a steep slope to most of the immediate topography. The lake's valley is bounded by two ridges which are orientated northeast to southwest, parallel to the fault blocks. The maximum elevations of these ridge tops are approximately 300 to 365 m above mean sea level (MSL). The elevation of the lake itself is approximately 185 m above MSL.

C. SOILS

The entire watershed was subject to relatively recent Pleistocene Epoch, Wisconsin stage glaciation. Sporatically overlaying the Precambrian bedrock is stratified glacial drift or till composed of clayey material with intermingled sand, gravel, rock fragments, and boulders. The soil textures thus tend to be variable, and depending on their location in the watershed, range from muck, to sandy loams, to gravelly, to stony loams (SCS, 1975). Soil depths range from 3 m or greater above bedrock, to zero to a few cm along the rock outcrop areas. The major soils of the basin are as follows:

Southern end of watershed:	Rockaway stony sandy loam/Hibernia stony loam
Southeastern side of watershed:	Rockaway stony sandy loam
Southwestern side of watershed:	Rockaway stony loam/Rockaway-rock outcrop
Northwestern side of watershed:	Rockaway-rock outcrop
Northeastern side of watershed:	Rockaway stony sandy loam/Rockaway-rock outcrop
Northern end of watershed:	Rockaway complex/Whitman stony loam

The major soil association is the Rockaway-Rock Outcrop-Whitman Association. These soils tend to be acidic. The U.S. Soil Conservation Service (1975) has defined these soils in terms of composition, permeability, and steepness of slope (Table 2). These soils occur mainly on ridge tops and side slopes, and Rockaway soils account for approximately 45% of the total composition of the association. The Rockaway soils are coarse textured, well drained, and dominately steep to very steep. They characteristically have gravelly loam or very stony loam surface layers. Rock outcrops may be totally exposed or covered by a thin soil layer. They are representative of areas where 20-90% of the surface is covered by granitic rock. Whitman soils are very poorly

Table 2

SOIL CHARACTERISTICS OF THE LAKE HOPATCONG WATERSHED

Soil series and map symbols	Foundations for dwellings— With basement	Foundations for dwellings— Without basement	Lawns, landscaping, and golf fairways	Septic tank absorption fields	Local roads, streets, and parking lots	Athletic fields	Picnic and play areas	Campsites, trailers, and tents	Sanitary landfill[1]
Adrian: Ad	Severe: frequent flooding; seasonal high water table at surface; low bearing strength.	Severe: frequent flooding; seasonal high water table at surface; low bearing strength.	Severe: seasonal high water table at surface.	Severe: frequent flooding; seasonal high water table at surface; low bearing strength.	Severe: frequent flooding; low bearing strength; seasonal high water table at surface.	Severe: frequent flooding; seasonal high water table at surface; low bearing strength.	Severe: hazard of flooding; low bearing strength; organic material; water table above a depth of 20 inches for 1 month or more during season of use.	Severe: frequent flooding; water table above a depth of 20 inches during season of use; low bearing strength.	Severe: frequent flooding; seasonal high water table at surface; low bearing strength.
Am	Severe: frequent flooding; seasonal high water table at surface.	Severe: frequent flooding; seasonal high water table at surface.	Severe: frequent flooding; seasonal high water table at surface.	Severe: frequent flooding; seasonal high water table at surface.	Severe: frequent flooding; seasonal high water table at surface; high frost-action potential.	Severe: frequent flooding; seasonal high water table at surface.	Severe: frequent flooding; seasonal high water table at surface.	Severe: frequent flooding; seasonal high water table at surface.	Severe: frequent flooding; seasonal high water table at surface.
Carlisle: Ca	Severe: seasonal high water table at surface; frequent flooding; low bearing strength; severe subsidence.	Severe: seasonal high water table at surface; frequent flooding; low bearing strength; severe subsidence.	Severe: seasonal high water table at surface; frequent flooding.	Severe: seasonal high water table at surface; frequent flooding.	Severe: seasonal high water table at surface; fre-quent flooding.	Severe: water table within 20 inches of surface for a month or more during season of use.	Severe: frequent flooding; water table within 20 inches of surface during season of use.	Severe: frequent flooding; seasonal high water table at surface; soil material high in organic matter.	Severe: seasonal high water table at surface; frequent flooding.
Cm	Severe: frequent flooding; seasonal high water table at surface; low bearing strength; severe subsidence.	Severe: frequent flooding; seasonal high water table at surface; low bearing strength; severe subsidence.	Severe: frequent flooding; seasonal high water table at surface.	Severe: frequent flooding; seasonal high water table at surface; low bearing strength.	Severe: frequent flooding; seasonal high water table at surface; low bearing strength; severe subsidence.	Severe: frequent flooding; seasonal high water table at surface; low bearing strength; severe subsidence.	Severe: water table above a depth of 20 inches for 1 month or more during season of use.	Severe: frequent flooding; water table above a depth of 20 inches during season of use.	Severe: frequent flooding; seasonal high water table at surface; highly organic material.
Hibernia: HbC	Severe: seasonal high water table perched at a depth of ½ foot to 1½ feet; lateral seepage above fragipan.	Moderate: seasonal high water table perched at a depth of ½ foot to 1½ feet.	Moderate: seasonal high water table at a depth of ½ foot to 1½ feet; stony surface layer.	Severe: seasonal high water table at a depth of ½ foot to 1½ feet; lateral seepage over fragipan.	Severe: seasonal high water table at a depth of ½ foot to 1½ feet; high frost-action potential.	Severe: seasonal high water table at a depth of ½ foot to 1½ feet.	Moderate: water table above a depth of 20 inches for short periods during season of use; strong slopes in some places.	Severe: water table above a depth of 20 inches for short periods during season of use; strong slopes in some places.	Severe: seasonal high water table perched at a depth of ½ foot to 1½ feet.
Hibernia—Continued HnD	Severe: seasonal high water table perched at depth of ½ foot to 1½ feet; slopes of 15 to 25 percent.	Moderate: seasonal high water table perched at depth of ½ foot; to 1½ feet; stone content moderately high. Severe: slopes of 15 to 25 percent.		Severe: seasonal high water table perched at depth of ½ foot to 1½ feet; slow permeability in fragipan; slopes of 15 to 25 percent.	Severe: seasonal high water table perched at depth of ½ foot to 1½ feet; slopes of 15 to 25 percent.	Severe: stone content excessive; strong and steep slopes.	Moderate: water table within 20 inches of surface for short periods during season of use; stone content moderately high; slopes of 8 to 15 percent. Severe: slopes of 15 to 25 percent.	Severe: stone content excessive; slopes of 15 to 25 percent.	Severe: seasonal high water table perched at depth of ½ foot to 1½ feet; strong and steep slopes.
Otisville: OtC	Moderate where slopes are 8 to 15 percent. Slight where slopes are 3 to 8 percent.	Moderate where slopes are 8 to 15 percent. Slight where slopes are 3 to 8 percent.	Severe: coarse texture; low available water capacity; low fertility; low organic-matter content.	Slight where slopes are 3 to 8 percent. Moderate where slopes are 8 to 15 percent; hazard of ground-water pollution.	Slight where slopes are 3 to 8 percent. Moderate where slopes are 8 to 15 percent.	Severe: coarse texture; low available water capacity; low fertility.	Severe: coarse texture; poor trafficability.	Severe: loose sand; poor trafficability.	Severe: rapid permeability permits ground-water pollution.
OtD	Severe: steep	Severe: steep	Severe: coarse texture; low available water capacity; low fertility; low organic-matter content.	Severe: steep slopes; hazard of ground-water pollution.	Severe: steep	Severe: steep	Severe: steep	Severe: steep	Severe: rapid permeability permits ground-water pollution.
Preakness: PsA	Severe: frequent flooding; seasonal high water table at a depth of 0 to 1 foot.	Severe: frequent flooding; seasonal high water table at a depth of 0 to 1 foot.	Severe: seasonal high water table at a depth of 0 to 1 foot.	Severe: frequent flooding; seasonal high water table at a depth of 0 to 1 foot.	Severe: frequent flooding; seasonal high water table at a depth of 0 to 1 foot.	Severe: seasonal high water table at a depth of 0 to 1 foot.	Severe: water table above a depth of 20 inches for 1 month or more during season of use.	Severe: water table above a depth of 20 inches during season of use.	Severe: seasonal high water table at a depth of 0 to 1 foot.
Preakness variant: Pw	Severe: frequent flooding; seasonal high water table at surface.	Severe: frequent flooding; seasonal high water table at surface.	Severe: seasonal high water table at surface.	Severe: frequent flooding; seasonal high water table at surface.	Severe: frequent flooding; seasonal high water table at surface.	Severe: seasonal high water table at surface.	Severe: water table above a depth of 20 inches for 1 month or more during season of use.	Severe: water table above a depth of 20 inches during season of use.	Severe: seasonal high water table at surface.
Ridgebury: RgA	Severe: seasonal high water table at a depth of 0 to 1 foot.	Severe: seasonal high water table at depth of 0 to 1 foot.	Severe: seasonal high water table at a depth of 0 to 1 foot; excessive stones	Severe: seasonal high water table at a depth of 0 to 1 foot.	Severe: seasonal high water table at a depth of 0 to 1 foot.	Severe: seasonal high water table at a depth of 0 to 1 foot.	Severe: water table above a depth of 20 inches or more during season of use.	Severe: water table above a depth of 20 inches during season of use.	Severe: seasonal high water table at a depth of 0 to 1 foot.

Soil series and map symbols	Foundations for dwellings— With basement	Foundations for dwellings— Without basement	Lawns, landscaping, and golf fairways	Septic tank absorption fields	Local roads, streets, and parking lots	Athletic fields	Picnic and play areas	Campsites, trailers, and tents	Sanitary landfill [1]
RfB	Severe: seasonal high water table at a depth of 0 to 1 foot; excessive stones.	Severe: seasonal high water table at a depth of 0 to 1 foot; excessive stones.	Severe: seasonal high water table at a depth of 0 to 1 foot; excessive stones.	Severe: seasonal high water table at a depth of 0 to 1 foot; excessive stones.	Severe: seasonal high water table at a depth of 0 to 1 foot; excessive stones.	Severe: seasonal high water table at a depth of 0 to 1 foot; excessive stones.	Severe: water table above a depth of 20 inches or more during season of use; excessive stones.	Severe: water table above a depth of 20 inches during season of use; excessive stones.	Severe: seasonal high water table at a depth of 0 to 1 foot; excessive stones.
RpD	Moderate: seasonal water table perched over fragipan may seep laterally; stone content moderately high, slopes of 5 to 15 percent. Severe: slopes of 15 to 25 percent.	Moderate: slopes of 5 to 15 percent, stone content moderately high. Severe: slopes of 15 to 25 percent.	Severe: stone content excessive; slopes of 15 to 25 percent.	Moderate: deep ditches may be needed, lateral seepage over fragipan, slopes of 5 to 15 percent, stone content moderately high. Severe: slopes of 15 to 25 percent.	Moderate: seasonal water table perched over fragipan; moderate frost-action potential; slopes of 5 to 15 percent. Severe: slopes of 15 to 25 percent.	Severe: stone content excessive; strong and steep slopes.	Moderate: stone content moderately high; slopes of 5 to 15 percent.	Severe: stone content excessive; slopes of 15 to 25 percent.	Severe: bedrock at depth of 4 feet; slopes of 15 to 25 percent.
RpE	Severe: very steep slopes.	Severe: very steep slopes.	Severe: very steep slopes.	Severe: very steep slopes.	Severe: very steep slopes.	Severe: very steep slopes.	Severe: very steep slopes.	Severe: very steep slopes.	Severe: very steep slopes.
Rockaway: RoB	Slight: water perched over fragipan for short periods; stony.	Slight	Moderate: moderate gravel.	Moderate: needs deep ditches in places; lateral seepage above fragipan.	Moderate: moderate frost-action potential.	Severe: excessive gravel.	Moderate: moderate gravel.	Moderate: moderate gravel.	Slight.
RoC	Moderate: strong slopes; water perched over fragipan may seep laterally.	Moderate: strong slopes.	Moderate: moderate gravel; strong slopes.	Moderate: needs deep ditches in places; lateral seepage above fragipan; slopes make special design and careful construction necessary.	Moderate: moderate frost-action potential; strong slopes; hazard of erosion.	Severe: excessive gravel; strong slopes.	Moderate: moderate gravel; strong slopes.	Moderate: moderate gravel; strong slopes.	Slight.
RpC	Moderate: very stony	Moderate: very stony	Severe: excessive stones.	Moderate: very stony	Moderate: very stony; moderate frost-action potential.	Severe: excessive stones; strong slopes in places.	Moderate: very stony; strong slopes in places.	Moderate: very stony; strong slopes in places.	Severe: excessive stones.
RrD	Severe: excessive stones; steep.	Severe: excessive stones; steep.	Severe: excessive stones; steep.	Severe: excessive stones; steep.	Severe: excessive stones; steep.	Severe: excessive stones; steep.	Severe: excessive stones; steep.	Severe: excessive stones; steep.	Severe: excessive stones.
RsC	Severe: rock outcrop; extremely stony.	Severe: rock outcrop; extremely stony.	Severe: rock outcrop; extremely stony.	Severe: rock outcrop; extremely stony.	Severe: rock outcrop	Severe: rock outcrop; extremely stony.	Severe: rock outcrop; extremely stony.	Severe: rock outcrop; extremely stony.	Severe: rock outcrop; extremely stony.
RsD	Severe: rock outcrop; steep.	Severe: rock outcrop; steep.	Severe: rock outcrop; steep.	Severe: rock outcrop; steep.	Severe: rock outcrop; steep.	Severe: rock outcrop; steep.	Severe: rock outcrop; steep.	Severe: rock outcrop; steep.	Severe: rock outcrop; steep.
RsE	Severe: rock outcrop; very steep.	Severe: rock outcrop; very steep.	Severe: rock outcrop; very steep.	Severe: rock outcrop; very steep.	Severe: rock outcrop; very steep.	Severe: rock outcrop; very steep.	Severe: rock outcrop; very steep.	Severe: rock outcrop; very steep.	Severe: rock outcrop; very steep.
Rock outcrop: Rt, RvF	Severe: rocky surface layer; steep.	Severe: rocky surface layer; steep.	Severe: rocky surface layer; steep.	Severe: rocky surface layer; steep.	Severe: rocky surface layer; steep.	Severe: rocky surface layer; steep.	Severe: rocky surface layer; steep.	Severe: rocky surface layer; steep.	Severe: rocky surface layer; steep.
Urban land: Ua, Ub Highly urbanized; present development prohibits other uses.									
Up	Moderate: gently sloping to steep.	Moderate: gently sloping to steep.	Moderate: moderate gravel; strongly sloping to steep in some places.	Moderate: strongly sloping to steep in some places; hazard of ground-water pollution.	Moderate: gently sloping to steep.	Severe: gently sloping to steep; excessive gravel.	Moderate: excessive slopes in places; moderate gravel.	Moderate: excessive slopes in places; moderate gravel.	Severe: rapid permeability in substratum; hazard of ground-water pollution.
Whitman: Wm	Severe: seasonal high water table at surface.	Severe: seasonal high water table at surface.	Severe: seasonal high water table at surface.	Severe: seasonal high water table at surface.	Severe: seasonal high water table at surface; high frost-action potential.	Severe: seasonal high water table at surface.	Severe: water table above a depth of 20 inches during season of use.	Severe: water table above a depth of 20 inches during season of use.	Severe: seasonal high water table at surface; very stony.
Whitman: Wo	Severe: seasonal high water table at surface.	Severe: seasonal high water table at surface.	Severe: seasonal high water table at surface.	Severe: seasonal high water table at surface.	Severe: seasonal high water table at surface	Severe: seasonal high water table at surface.	Severe: seasonal high water table at surface.	Severe: seasonal high water table at surface.	Severe: seasonal high water table at surface.

drained, they are formed from granitic and gneissic derived material, and are underlain by a shallow fragipan. Overall, this soil association tends to restrict development due to its shallow depth, limited permeability, and usually steep slopes (Tables 3, 4, 5, and 6) (Sussex County - 208 Agency, 1979).

Table 3

SOILS WITH DEVELOPMENT LIMITATIONS DUE TO SHALLOW DEPTH TO BEDROCK

Sussex County Soils

Shallow Depth to Bedrock -

		Slope
Na C	Nassau rocky silt loam	8 to 15%
Nf D	Nassau-Rock outcrop complex	15 to 25%
Ng	Nassau-Rock outcrop complex	extremely stony
Om B	Oquaga extremely stony loam	3 to 8%
Om D	Oquaga extremely stony loam	8 to 25%
Or D	Oquaga-Rock outcrop association,	moderately steep
Wm D	Wassaic silt loam	15 to 30%
Wn D	Wassaic-Rock outcrop association,	(extremely stony), moderately steep

Morris County Soils

Shallow Depth to Bedrock

None

Source: Sussex County, NJ. 208 Water Quality Management Plan, 1979.

Table 4

SOILS WITH DEVELOPMENT LIMITATIONS DUE TO INTERMEDIATE OR STEEP SLOPE

SUSSEX COUNTY

Intermediate Slopes (15 - 25%) -

	Slopes
Bf D - Bath gravelly loam	15 to 25%
Bg D - Bath very stony loam	8 to 25%
Ch D - Chenango gravelly fine sandy loam	8 to 25%
Cl D - Chenango cobbly sandy loam	15 to 35%
Hf D - Hazen gravelly loam	8 to 25%
Ho D - Hoosic gravelly loam	8 to 25%
Ot C - Otisville gravelly loamy sand	15 to 35%
Pa D - Palmyra gravelly fine sandy loam	8 to 25%
Ro D - Rockaway gravelly loam	15 to 25%
Rp D - Rockaway very stony loam	5 to 25%
Sw D - Swartswood gravelly loam	15 to 25%
Sx D - Swartswood-Lackawanna very stony soils	8 to 25%
Va D - Valois shaly loam	15 to 25%
Wh D - Washington loam	15 to 25%
Wk D - Washington very stony loam	15 to 25%
Wl D - Washington-Wassaic complex	15 to 25%
Ws D - Wooster loam	15 to 25%

Steep Slopes (25%+)
(together with areas of extensive Rock Outcropping)

	Slopes
Bf E - Bath gravelly loam	25 to 40%
Bg E - Bath very stony loam	25 to 40%
Hg E - Hazen-Palmyra gravelly sandy loams	25 to 45%
Nf E - Nassau-Rock outcrop complex	25 to 45%
Rp E - Rockaway very stony loam	25 to 40%
Rr D - Rockaway-Rock outcrop association	sloping and moderately steep
Rs F - Rock outcrop - Nassau association	very steep
Rt E - Rock outcrop - Oquaga association	steep
Rv E - Rock outcrop - Rockaway association	steep
Sx E - Swartswood-Lackawanna very stony soil	25 to 35%
Ws E - Wooster loam	25 to 35%

MORRIS COUNTY

Intermediate Slopes

Ot D - Otisville gravelly loamy sand	15 to 25%
Rr D - Rockaway extremely stony sandy loam	15 to 25%

Steep Slopes (25%+)
(Together with areas of extensive Rock Outcropping)

Rs C - Rockaway-Rock outcrop complex	3 to 15%
Rs D - Rockaway-Rock outcrop complex	15 to 25%
Rs E - Rockaway-Rock outcrop complex	25 to 45%
Rv F - Rock outcrop-Rockaway complex	steep

Source: Sussex County, NJ. 208 Water Quality Management Plan, 1979.

Table 5

SOILS WITH SEVERE DEVELOPMENT LIMITATIONS

Sussex County Soils

No Severe Development Limitations

	Slopes
Bg B - Bath very stony loam	3 to 8%
Pa C - (where mapped separately from CD) - Palmyra gravelly fine sandy loam	8 to 15%
Rh C - Riverhead sandy loam	8 to 25%
Sx B - Swartswood and Lackawanna very stony soils	3 to 8%
Wk C - Washington very stony loam	3 to 15%

Morris County Soils

No Severe Development Limitations

Pe C - Parker-Edneyville extremely stony sandy loams	3 to 15%
Rp C - Rockaway very stony sandy loam	3 to 15%

* included within figures for Pa D (see Table 11F)

Source: Sussex County, NJ. 208 Water Quality Management Plan, 1979.

Table 6
SOILS WITH HIGH WATER TABLES

Sussex County

Poor Drainage	Flood Plains	Wetlands
Al B - Albia gravelly loam	Ar - Alluvial land, wet	Lv - Livingston silty clay loam
Al C - Albia gravelly loam	At - Atherton loam	Ly - Lyons silt loam
Am B - Albia extremely stony loam	Ca - Carlisle muck	Lz - Lyons very stony silt loam
Cl C - Chenango cobbly sandy loam	Md - Middlesburg loam	Nh - Norwich silt loam
Cm B - Chippawa extremely stony loam	Pv - Pompton fine sandy loam, 0 to 3% slopes	No - Norwich very stony silt loam
Cn B - Chippawa silt loam	Pw - Preakness sandy loam	Wo - Whitman extremely stony sandy loam
Co B - Colonie loamy fine sand	Sm - Sloan-Wayland silt loams	
Co C - Colonie loamy fine sand	Sp - Swamp	
Fr A - Fredon loam	Wa - Wallkill silt loam	
Fr B - Fredon loam		
Ha - Halsey loam		
Hm B - Hibernia gravelly loam		
Hn B - Hibernia very stony loam		
Hn D - Hibernia very stony loam		
Ot C - Otisville gravelly loamy sand		
Ra B - Raynham silt loam		
Wt C - Wurtsboro gravelly loam		
Wu B - Wurtsboro very stony loam		
Wu C - Wurtsboro very stony loam		

Morris County

Poor Drainage	Flood Plains	Wetlands
Cc B - Califon very stony loam	Ad - Adrian muck	Wm - Whitman very stony loam
Hb C - Hibernia stony loam	Ae - Alluvial land	
Hl D - Hibernia very stony loam	Am - Alluvial land, wet	
Ot C - Otisville gravelly loamy sand	Cm - Carlisle muck	
Rg A - Ridgebury very stony loam	Mu - Muck, shallow over loam	
Rl B - Ridgebury extremely stony loam	Pv A - Preakness sandy loam, 0 to 4% slopes	

Source: Sussex County, NJ. 208 Water Quality Management Plan, 1979.

D. GROUNDWATER

Groundwater is defined as water at or below that level in the zone of stratification where all rock openings are filled with water under atmospheric pressure or greater. In the Lake Hopatcong area, groundwater occurs in the Precambrian bedrock aquifer and the Quaternary glacial stratified drift deposits. Of the two, the stratified drift aquifers are significantly more productive than the Precambrian bedrock aquifer (Miller, 1974; Gill and Vecchioli, 1965).

A fault zone which lies within the main basin of Lake Hopatcong (Young, 1971) serves as a hydrologic connection between the lake and the aquifer. During drought periods the lake acts to recharge the aquifer, but under normal conditions groundwater infiltration to the lake occurs (PAS, 1983).

Recharge via precipitation of the stratified drift aquifer which underlies much of the watershed is conservatively estimated to be $1.96 \times 10^2 m^3 km^{-2} day^{-1}$ during years of average rainfall (NJDEP, 1974). Recent studies have revealed that this recharge value may underestimate actual rates by as much as two-fold (Posten, in press). However, the NJDEP value is utilized in this study as the best aquifer recharge rate currently available. Using this value, gross annual aquifer recharge is $3.92 \times 10^7 m^3 yr^{-1}$ for the entire drainage basin. However, due to consumptive losses, the net annual recharge is $2.67 \times 10^7 m^3 yr^{-1}$.

E. LAND USE AND TYPE

Land use in the Lake Hopatcong watershed was identified on the basis of aerial photographs and zoning maps. Six land use categories were used to characterize the basin (Table 7). Watershed sub-basins were identified by use of topographic maps (Figure 1). Their area and the areas of specific land use within each of the 36 sub-basins are listed in Table 8.

The majority of the watershed is forested (70.7%). Much of this land is in the northern section of the watershed. High density and low density residential land use accounts for 24.7% and 1.2% of the watershed, respectively. The majority of urbanized land occurs along the southern, southeastern and southwestern shorelines. In seventeen of the sub-basins, over 50% of the available area has been developed in the form of high density and low density residential land use. These basins (Table 9) are associated with the major residential communities. In most of these basins the density of housing is the greatest along the lake's shoreline.

Commercial land use accounts for an additional 2.6% of the basin's total area. Most of this development is confined to the major traffic corridors which intersect the basin. The majority of the commercial properties are associated with marinas, convenience stores, or service related businesses, many of which cater to tourist trade. One industry is operating in the basin and is a quarry and asphalt manufacturing operation occupying approximately 11 ha most of which is in subwatershed number 10. The area associated with this land use has been included in the open, non-designated/disturbed category listed in Table 7. No significant acreage is utilized as farmland. This is probably due to the poor soils and steep slopes which predominate the majority of the watershed.

Table 7

DEFINITION OF LAND USE CATEGORIES

Category	Land Use
High Density Residential	One or more housing units/acre or 2.5 or more units/hectare.
Low Density Residential	Less than one housing unit/acre or less than 2.5 units/hectare.
Commercial	Business, industry, airports, and parking lots; land use in which the majority of the area is impervious.
Forested	Areas covered by an appreciable tree canopy.
Open Non-Designated/Covered	Vacant lots, parks, large lawn areas; land use which has vegetative cover but no appreciable tree canopy.
Open Non-Designated/Disturbed	Landfills and construction sites, areas of barren, undeveloped land characterized by exposed soils, lacking substantial vegetative cover.

Table 8

WATERSHED AND SUB-BASIN LAND USE ANALYSIS

Basin No.	Area (ha)	Area of Land Use Within Basin: Residential			Open		
		High Density	Low Density	Commercial	Covered	Distrubed	Forested
1	853.1	16.6		6.5			830.0
2	769.7	8.1		33.6			728.0
3	69.6	45.1	5.9				18.6
4	266.3	17.1	1.1				248.1
5	233.1	24.7		5.3	5.7		233.1
6	213.3	44.5	8.1	8.9			151.8
7	106.4	78.1		7.7			20.6
8	356.1	27.5					328.6
9	175.2	8.5		9.3		2.0	155.4
10	111.7	10.9				10.9	89.9
11	168.4	42.9					125.5
12	90.2	60.3		1.2			28.7
13	128.3	25.5					102.8
14	176.9	25.5					151.4
15	105.2	33.2					72.0
16	183.3	87.8					95.5
17	45.3	37.4		0.8			10.1
18	15.0		13.8				1.2
19	12.1	4.4					7.7
20	142.0	67.1		8.1			66.8
21	20.2	14.6		2.8			2.8
22	161.1	43.3		7.3			110.5
23	54.2	25.1	4.9	0.8			23.4
24	37.2	24.3	6.5	2.0	2.0		2.4
25	22.7	11.3					11.4
26	30.4	15.8					14.6
27	169.6	132.3		7.7	6.1		23.5
28	56.7	44.1		5.7	2.0		4.9
29	76.5	59.1		3.2	5.7		8.5
30	15.0	13.0					2.0
31	33.2	12.6	6.9	2.0			11.7
32	117.4	29.1	2.5	8.1	0.8		76.9
33	148.1	62.3		6.9			78.9

PRINCETON AQUA SCIENCE

Table 8 (continued)

Area of Land Use Within Basin

Basin No.	Area (ha)	Residential High Density	Residential Low Density	Commercial	Open Covered	Open Distrubed	Forested
34	93.9	77.7		2.8			13.4
35	198.3	132.3		10.1			55.9
36	27.1		13.0	4.0	2.8		7.3
TOTAL	5482.7	1354.7	67.1	144.8	25.1	12.9	3878.2

Table 9

SUB-BASINS WITH GREATER THAN 50%
OF AREA DEVELOPED AS URBAN LAND USE

Basin No.	Location	Area (ha)	% Developed as Urban Land Use: High Density Residential	Low Density Residential	Commercial
3	West Shore Lake Shawnee	69.6	64.8	8.5	
7	Woodport East	106.4	73.4		7.2
12	Prospect Point	90.2	66.9		1.3
17	Sperry Springs	45.3	82.6		1.8
18	Raccoon Island	15.0		92.0	
20	Espanong/Brady Park	142.0	47.3		17.9
23	David Cove/Elba Point	54.2	46.3	9.0	1.5
24	River Styx-North	37.2	65.3	17.5	5.4
26	Crescent Cove	30.4	52.0		
27	Hopatcong	169.6	78.0		4.5
29	Hopatcong/Ingram Cove	76.5	77.3		4.2
30	Point Pleasant	15.0	86.7		
31	Great Cove	33.2	38.0	20.8	6.0
34	King Cove	93.9	82.7		3.0
35	Landing	198.3	66.7		5.1
36	Landing	27.1	48.0		14.8

SECTION IV

DEMOGRAPHIC AND SOCIOECONOMIC ASPECTS

A. MAJOR TOWNS AND POPULATION CENTERS

Hopatcong Borough, Jefferson Township, Roxbury Township, Mount Arlington Borough, and Sparta Township are the major towns located within the lake's watershed. There are approximatey 34 small lake communities or population centers encompassed by these major towns (Table 10).

Table 10

MAJOR COMMUNITY CENTERS

Jefferson Township

- Lake Winona
- Woodport South
- Woodport North
- Lake Shawnee
- Lake Forest
- Tierney's Place
- Prospect Point
- Brady Park
- Waterways
- East Shores
- Nolan's Point
- Holiday Hills
- Felter Place
- Espanong

Roxbury Township

- Landing
- Silver Springs
- King Cove

Hopatcong Borough

- Woodcliff
- Henderson Bay
- Byram Cove
- Sperry Springs
- Bonaparte Landing
- Elba Point
- Hopatcong Hills
- Pickerel Point
- Ingram Cove
- Point Pleasant
- The Gardens
- River Styx
- Wildwood Shores
- Knollwood

Mount Arlington Borough

- Bertrand Island
- Van Every Cove
- Great Cove

B. DEMOGRAPHICS

The permanent resident population of the Lake Hopatcong watershed is 55,073 (U.S. Dept. Commerce, 1980) (Table 11). From 1970 to 1980 the average population increase in the major towns was 22.8%, but Hopatcong Borough experienced 71.6% growth. The total number of permanent housing units in the region is 19,926, an increase of 7,964 dwellings since 1970 (U.S. Dept. of Commerce, 1980), with the majority of residences being one family dwellings (Table 12). In the lakeside communities, the conversion of seasonal dwellings to year-round houses and new construction are responsible for the observed increases. Subsequently, cottage conversion has decreased the population size of seasonal residents. The overall result of this growth has been a continuous increase in population density from 1950 to present (Table 13), with some areas now reaching maximum development capacity (Levins and Moscowitz, 1977). Population estimates for the year 2000, project a steady increase in population of the area to approximately 20% over the currently observed figures (N.J. Dept. Labor and Industry, 1979). Many of the new housing units forecast for the region are expected to be garden apartments, town houses and other kinds of higher density housing. High density developments of this nature will not only increase the recreational demands placed on the lake, but accelerate the eutrophying process. This necessitates the development of a sound lake and watershed management plan.

Table 11

1980 CENSUS INFORMATION FOR MAJOR POPULATION CENTERS
ADJACENT TO LAKE HOPATCONG

Town	County	1960	1970	% Change 1960-1970	1980	% Change 1970-1980	White	Black	Other	Spanish	1960	1970	% Change 1960-1970	1980	% Change 1970-1980
Hopatcong	Sussex	3,391	9,052	167	15,531	71.6	15,139	169	223	454	1,019	4,456	337	6,081	36.5
Roxbury	Morris	9,983	15,754	57.8	18,878	19.8	18,362	119	397	317	2,774	4,688	69.0	5,938	26.7
Mt. Arlington	Morris	1,246	3,590	188	4,251	18.4	4,148	22	81	119	355	1,389	291	1,667	20.0
Jefferson	Morris	6,884	14,122	105	16,413	16.2	16,266	23	124	220	2,042	5,429	166	6,240	14.9

SOURCES: 1980 Census of Population and Housing
U.S. Department of Commerce, Bureau of the Census PH C80-V-32.

Population Characteristics in New Jersey
Department of Conservation and Economic Development.

Table 12

NUMBER OF SEASONAL DWELLING UNITS: LAKE HOPATCONG REGION*

	Hopatcong	Jefferson	Mt. Arlington	Roxbury	Total
1960	2,372[a]	1,812[b]	452[c]	1,164[d]	5,800
1970	1,604[e]	1,012[f]	269[f]	114[f]	3,000
1980	710[g]	770[h]	257[i]	109[g]	1,846

(a) 1965 Master Plan, Preliminary Report No. 1, Physical Characteristics and Population, Hopatcong Borough Planning Board.

(b) Master Plan of Jefferson Township, Jefferson Township Planning Board, 1962.

(c) Master Plan of Mt. Arlington, Mt. Arlington Planning Board, 1958 and projected to 1960.

(d) Levin, M.R. and M.S. Moskowitz, 1977.

(e) William Niesen, Economic Profile, Hopatcong Borough Planning Board, 1973.

(f) U.S. Census of Housing, 1970.

(g) U.S. Census of Housing, 1980.

(h) Elam and Popoff, Draft Wastewater Faciliites Plan, Township of Jefferson.

(i) Estimated from past census records.

*Modified from: Levin, M.R. and M.S. Moskowitz. 1977. Planing for an Inland Lake: Alternatives for Lake Hopatcong. Lake Hopatcong Regional Planning Board.

Table 13

POPULATION DENSITY PER SQUARE MILE, 1950-1980: LAKE HOPATCONG REGION

	Area in Square Miles	Populus/Square Mile			
		1950	1960	1970	1980
Hopatcong	10.80	108.6	314.0	838.2	1,438.1
Jefferson	44.30	61.9	155.4	318.8	370.5
Mt. Arlington	2.70	236.7	461.5	1,329.6	1,574.4
Roxbury	21.00	171.8	475.4	750.2	899.0

C. SOCIOECONOMICS

Income data for the Lake Hopatcong watershed indicates that the median family income for the area is approximately $23,500 (U.S. Dept. Commerce, 1980). Most of the work force is employed in skilled or professional positions.

Within the watershed, there are numerous service related business, such as restaurants, marinas, and convenience stores which cater to, and rely upon seasonal and tourist trade. The major industries within reasonable commuting distance of the lake are presented in Table 14.

Table 14

MAJOR INDUSTRIES AND BUSINESSES WITHIN REASONABLE COMMUTING DISTANCE OF LAKE HOPATCONG SUSSEX COUNTY

Company	Number of Employees	Product or Process
Accurate Forming Division Tyco Laboratories, Inc.	205	Fabricated metal products
Aerosystems Technology	169	Manufacturing
Air Filters, Inc.	75	Manufacturing
Americana Resort Hotel	600	Resort Hotel
Ames Rubber Corporation	625	Rubber products
Atlantic Service Company	51	Manufacturing
Challenge Industries, Inc.	67	Fabricated metal products
Dynapac Manufacturing, Inc.	374	Machinery
Flora Fashions, Inc.	66	Apparel
General Photo Products	54	Manufacturing
Hidden Valley	145	Ski area, recreation
Highlands Workshop/Easter Seal Society	77	Services
Ja-Bar Silicone Corporation	55	Rubber and/or plastic products
Jersey Central Power & Light Company	64	Public utility
Limestone Products Corporation	136	Mining and quarrying
Mack Wayne Plastics Company	180	Plastics
Metaltec Corporation	126	Fabricated metal products
Midlantic National Bank/S&M	113	Bank
Morley Shirt Company	340	Shirt company, apparel
The National Bank of Sussex County	81	Bank
National Community Bank	79	Bank

Table 14 (Continued)

Company	Number of Employees	Product or Process
Newco, Inc.	63	Manufacturing
New Jersey Herald	100	Printing, newspaper publishing
New Jersey Zinc Company	87	Mining and quarrying
Newton Garment Company, Inc.	52	Apparel
Plastoid Corporation	250	Manufacturing
Playboy Resort and Country Club	600	Resort hotel
Royal Business Forms	60	Printing
Schering-Plough	97	Chemical products
Selected Risks Insurance Company	674	Insurance company
United Foam Corporation	57	Chemical products
United Telephone Company New Jersey	200	Public utility
U.S. Mineral Products Company	136	Stone products
Vernon Valley/Great Gorge Ski Area	700	Ski area, recreation
Newton Memorial Hospital	575	Hospital
Tri-County Asphalt Company	30	Quarry

*Source: Industrial Directory Sussex County, 1981.

Table 14 (Continued)

MORRIS COUNTY

Company	Number of Employees	Product or Process
Allied Chemical Corporation (2 locations)	2,800	Chemical manufacturing, research and development
Automatic Switch Company	1,150	Electrical control equipment
B.A.S.F. Wyandotte Corporation	757	Corporate headquarters
Bell Telephone Laboratories (2 locations)	4,200	Communications research and development
Clay Adams Laboratory Systems	397	Surgical and Laboratory instruments
Crum & Forster Insurance Company	1,100	Corporate headquarters
Exxon Research & Engineering Company	1,200	Petro-chemical research and Engineering Services
Firemen's Fund	900	Corporate headquarters
General Public Utilities Corporation	460	Corporate headquarters
Interpace Corporation (2 locations)	530	Corporate headquarters concrete products manufacturing
Jersey Central Power & Light Company	3,534	Corporate headquarters
Kueffell & Esser Company (2 locations)	553	Corporate headquarters
The Mennen Company	648	Cosmetics and toiletries
Nabisco, Inc.	1,000	Corporate headquarters
Picatinny Arsenal	6,000	R&D - weapons command
Rowe International, Inc.	480	Vending machine and record manufacturing

Table 14 (Continued)

Company	Number of Employees	Product or Process
Sandoz, Inc.	1,367	Proprietary pharmaceuticals, manufacturing, research and development
Thatcher Glass Manufacturing Company	862	Glass bottles
Varityper Division	893	Office machinery and systems
Warner-Lambert Pharmaceutical Company	2,169	Ethical pharmaceuticals, manufacturing, research and development

*Source: Elam & Popoff, 1981.

D. RELATIONSHIP OF LAKE TO THE ECONOMY OF THE AREA

The majority of commerce in the Lake Hopatcong watershed is service related. These businesses derive much of their annual revenue in the summer, and their livelihood is directly connected to the condition of the lake. Marinas, restaurants, and motels/inns are representative examples. Decreased lake water quality will ultimately affect such businesses. Poor water quality would lead to the decreased recreational attractiveness of the lake and the loss of summer tourist trade. Statistics indicate that the majority of visitors to Hopatcong State Park are non-residents who have travelled to the area expressly for water-related recreation (Levin and Moscowitz, 1977). Maintenance of good water quality will insure the return of such tourists, and help promote business. Other benefits derived from improvement in water quality are related to recreational use by residents of the lake area as well as tourists. This aspect is discussed in detail in Section V.

Currently, aquatic macrophytes occur throughout the shallow (littoral) zone of the lake. In some areas weed beds are dense enough to impair the passage of power boats. Some parts of the lake experience phytoplankton blooms which persist throughout the summer and into fall. Such blooms are aesthetically displeasing, form slimy surface scums which discourage swimming, and may even pose a health hazard (Lundin, personal communication, 1982).

Large phytoplankton blooms and nuisance densities of aquatic weeds can also contribute to the seasonal decrease of oxygen in the deep sections of the lake due to their decomposition. This results in anoxic conditions in the hypolimnion of the lake. Lack of oxygen in these deep cold water sections of the lake prevents the establishment of a healthy cold water fishery and detracts from the recreational potential of the lake.

These factors detract from the recreational attributes of the lake. As the quality of recreation decreases, so will the drawing power of the lake. Although this may be a slow process, eventually it will effect the economic base of the area. This predicament is not necessarily unique to Lake Hopatcong, however due to the size, the history, and the proximity of the lake to the metropolitan area, the economic consequences of the lake's demise are substantial. Although the lake is much more than dollars, cents and ratables, the importance and intrinsic nature of the lake in the economic base of the watershed cannot be overlooked. Rather, it should serve as an additional impetus to initiate the restoration of this valuable recreational resource.

SECTION V

RECREATIONAL IMPORTANCE OF LAKE

A. HISTORY

Originally, Lake Hopatcong consisted of two bodies of water, Huppakong Lake and Woodport Pond, joined by a small stream. The first permanent inhabitants of Lake Hopatcong were the Neticong Indians. They maintained a sizeable settlement along the shores of Huppakong Lake. The Indians were driven out in the early 1700's by settlers lured to the lake area by the discovery of rich iron ore deposits in the surrounding hills. These deposits, the ample supply of wood for fuel, and the availability of a source of water power resulted by the mid-1700's in the establishment of an iron forge in the lake area. In 1750, a 5 foot dam was built at the outflow on the south shore of the lake for the purpose of obtaining water power for the forge and a saw mill. The forge was very active during the Revolutionary War, but due to lack of easily accessable wood fuel, became inoperative in 1829.

In the 1820's, the demand for Pennsylvania coal in the metropolitan New York City area led to the construction of the Morris Canal. In 1827, a new dam was built at the outlet of the lake to help supply water for the canal. The lake was raised an additional 6 feet, substantially increasing its original size. The lowlands between Huppakong Lake and Woodport Pond were inundated, resulting in the formation of one large lake. The Morris Canal was active from 1827 to the end of the Civil War, when at that time it could no longer compete with the rapidly developing railroads.

Although the railroads made the canal obsolete, they stimulated the resort industry of Lake Hopatcong. By rail, New York City was only two hours away. Many wealthy urban dwellers vacationed or maintained seasonal residences at the lake. Resort hotels, inns and summer cottages were constructed to accommodate the many summer tourists who visited Lake Hopatcong.

Between 1880 and 1920, numerous resort hotels, summer cottages and permanent homes were built, and Lake Hopatcong became recognized as a major tourist center. In 1920, the State of New Jersey assumed the rights to the waters of Lake Hopatcong, preserving the lake for recreation use, and in 1925 replaced the old Morris Canal dam with a new structure.

The era of greatest growth at Lake Hopatcong occurred after World War II, with the construction of many summer residences. By 1960, a trend toward year around residential developments became apparent, and presently most residences on the lake and in the watershed are year-round permanent homes. Recreational use by non-residents is still high, particularly on weekends. Access is generally gained to the lake by tourists at Lake Hopatcong State Park. The use by one-day and weekend visitors has reportedly decreased by 35% over the period from 1964 to 1974. In 1964, 145,000 visitors were counted at the State Park, but in 1975, the number was down to 95,000 (Levin and Moskowitz, 1977). The recent gasoline crises have resulted in a resurgence of Lake Hopatcong's popularity. The recreational use of Lake Hopatcong remains relatively high, and will continue due to the lake's proximity to the metropolitan New New York-New Jersey area and its recreational attributes.

B. LAKE USES

Lake Hopatcong is of vital economic, recreational, and aesthetic importance to the lakeland region. It provides water-based recreation for a large resident and tourist populus. The lake is also an intrinsic part of the region's economic base. It was assumed that with the development of the Delaware Water Gap National Recreation area, some of the existing recreational demand placed on the lake would decrease. However, with the postponement of the Tock's Island Dam, or its possible de-authorization, there will not be an alternate large-multi-use water body as had originally been planned. Because of the increasing cost of transportation, Lake Hopatcong should remain an important recreational resource due to its proximity to the metropolitan New York-New Jersey area. However, extensive recreational use of the lake will be highly dependent on the maintenance of reasonably good water quality.

Survey results indicate that the majority of people utilizing the lake are day visitors who reside in the Northeastern New Jersey-New York City area (LHRPB 1977). Most day visitors utilize the public facilities available at the State Park. Swimming is the most important activity for visiting lake users followed by boating, picknicking, and fishing (Table 15).

The demand placed on Lake Hopatcong in relation to boating is of prime consideration. Power boating, particularly outboard, generates noise and petroleum pollution. It is also readily affected by the establishment of dense aquatic macrophyte beds which tangle props and impede travel. The number of boats operating in the lake is estimated to be 400 on an average weekend day and 600-800 on a peak weekend day. Based on State Recreation Plan Standards, Lake Hopatcong should be able to accommodate as many as 900 boats at one time. The average boat operating in Lake Hopatcong, is 16 ft in length, powered by an 80 HP outboard motor, and owned by a male 25.8 years of age (Table 16). Most

TABLE 15

RECREATIONAL USE OF LAKE HOPATCONG

Activity	Recreation Days Per Year		Percent of People Listing Activity	
	Number	Percent	State Park	Lake
Swimming	73,500	64.8	90	90
Fishing	20,500	18.1	(a)	44
Boating	15,100	13.1	47 (b)	60
Water Skiing	3,100	2.7	(a)	38
Sailing	1,300	1.1	(a)	9
Picknicking	(a)		60	50
Amusement Park	(a)		22	17

(a) Not mentioned.

(b) Until 1976, a small excursion boat ran from the State Park and was popular with Park visitors (LHRPB 1977).

Each of these recreational activities are treated in the text in more detail.

From: Levin, M.R. and M.S. Moskowitz. 1977. Planing for an Inland Lake: Alternatives for Lake Hopatcong. Lake Hopatcong Regional Planning Board.

Table 16

SUMMARY OF MOTOR BOAT DATA

	Outboard	Inboard	Out/Inboard	Total
Average Horsepower	60.2	166.1	160.6	80.0
Mean Length (ft)	15.4	18.7	18.0	16.0
Hull Material				
Fiberglass	70.8%	38.7%	97.7%	73.3
Wood	14.4%	58.1%	-	14.6
Aluminum	13.6%	3.2%	2.4%	11.2
Steel	1.0%	-	-	0.7
Rubber	0.2%	-	-	0.2
Sex of Operator	91% male	89% male	*	91% male
Average Age of Operator	25.35 yrs	26.48 yrs	27.75 yrs	25.81 yrs
$\bar{X}$ Number of Persons on Board	3.01	3.53	3.27	3.10

* Inboard & Outboard combined.

From: Levin, M.R. and H.S. Moskowitz 1977. Planning for an inland lake: Alternatives for Lake Hopatcong. Lake Hopatcong Regional Planning Board.

boat operators also tend to be day visitors rather than local residents, this being particularly true on weekends.

Related to power boating is water skiing, and in Lake Hopatcong the majority of such activity occurs in Woodport Bay, King Cove, Byram Cove and in the vicinity of Halsey Island. At times, the density of boat traffic is so great that it interferes with water skiing activities.

Sailing is increasing in popularity at Lake Hopatcong. Some marinas offer sailboat rentals, as well as docking facilities. Canoeing, however, generates only minor activity on the lake. The attractiveness of the lake to canoeing is largely diminished by the intensive use of motor boats and their resulting wakes.

Lake Hopatcong is also the host for an annual hydroplane regatta. The race, which draws competitors from throughout the country, is held in early September.

The Hopatcong State Park beach is used very heavily by day visitors as it is the only non-commercial swimming facility. Additional facilities are provided by community beaches. Based on a survey conducted at the State Park (LHRPB, 1977), the average weekday visitor to the State Park is white, female, and travelled approximately 32 miles by car to use the lake. Typically weekday visitors are mothers and children who come to the park for a brief (4.0 hrs) stay. The average weekend user is black or Puerto Rican, male, and travelled 43 miles by car. Of the weekday users 43% live in the metropolitan New York-New Jersey region and 40% live in Morris and Sussex Counties, whereas of the weekend users, 78.5% are from the New York-New Jersey metropolitan area and only 6% live in

Morris or Sussex Counties. Thus the lake, and in particular the State Park, appears to provide an important weekend recreational site for urban residents.

For seasonal and year-round residents, swimming facilities are available in the form of lake association and private club beaches, town beaches, and private beaches (Levins and Moskowitz, 1977).

On the basis of existing data, and following the standard prescribed by the NJ State Outdoor Recreation Plan, it is felt that the swimming facilities presently available at Lake Hopatcong easily meet user demands (LHRPB, 1977).

Fishing is another popular activity for lake residents and day visitors. Bertrand Point, Nolan's Point, and Elba Point are the three more heavily fished areas of Lake Hopatcong. Panfish, bass, perch, and pickerel, are the most commonly landed fish. The lake has been stocked at times with walleye, and annually with trout.

Ice boating and ice fishing are the two major winter sports provided by the lake. When weather and ice conditions are favorable, the long narrow nature of the lake's main basin makes it highly suitable for ice boating. Most ice boating takes place in the Great Cove section of the lake. Ice fishing is very popular, with as many as 300 fishermen utilizing the lake on weekends. An annual ice fishing derby, sponsored by the Knee-Deep Hunting and Fishing Club of Lake Hopatcong, has attracted over 1000 fishermen.

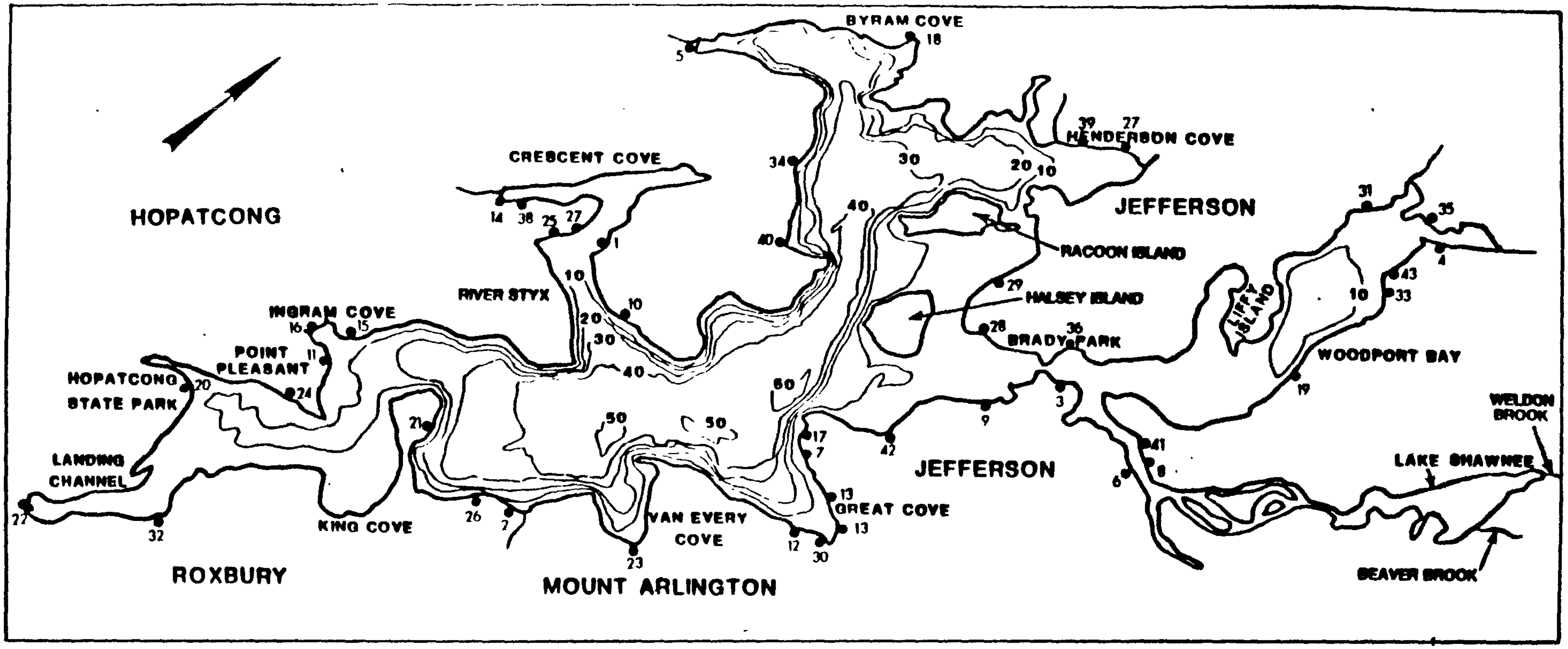
C. PUBLIC ACCESS TO THE LAKE

Public access to Lake Hopatcong for recreational purposes is not a problem since it is a state-owned lake. For year-round and seasonal residents there are a number of access points to the lake for swimming. These include private beaches, municipal beaches, commercial beaches, and Lake Hopatcong State Park which is the most important public access point. The state park has a large public swimming beach and boat launching area. It is the sole access point for "day trippers" who wish only to swim. There are 39 marina and docking facilities, of which 22 are commercial marinas equipped with launching areas and dock space (Table 17, Figure 3).

Table 17

LAKE HOPATCONG MARINAS AND LAUNCHING FACILITIES

Marina	Index No.	Private Facility	Club Facility	No. Rental Slips	Launching Ramp	Hoist	Winter Storage	Repairs	Fuel	Swimming Facilities
Arrowcrest	1	x		10						
Barnes Bros.	2	x		65	x	x	x	x	x	
Bridge Marine	3	x		152	x			x	x	x
Brights Marine	4	x		60	x					
Byram Cove Club	5		x	8	x					x
Chabon's	6	x		165	x					x
Dick Dowd's	7	x		5	x					
Dunn's Triangle	8	x		80	x					
East Shore Estates	9		x	20	x					x
Elba Point	10		x	25	x					x
Garden State Yacht Club	11		x	30	x					x
Great Cove Park	12	x		100	x	x				x
Hockenjos	13	x		30	x	x	x	x	x	
Hopatcong Hills	14		x	35	x					x
Ingram Cove Club	16		x	10	x					x
Jefferson House	17	x		15						
Knollwood Club	18		x	10	x					x
Lake Forest	19		x	85	s					x
L.H. State Park	20	State Park		0	x					x
L.H. Yacht Club	21		x	100	x	x				
Lakes End Marina	22	x		20	x			x	x	
Lee's Park	23	x		65	x		x	x	x	
Logan Hills	24		x	10	x					x
Light House	25	x		45						
Mt. Arlington Beach	26		x	5						x
Northwood Inn	27			10						x
Prospect Point	28	x		15	x	x	x	x	x	
Prospect Point Club	29		x	3	x					x
Sand Bat	30	x		100		x	x	x		x
Seyman's Cellar Bat	31	x		12						
Shore Hills Club	32		x	50	x					x
Smitty's Marina	33	x		90		x	x	x	x	
Sperry Spring	34		x	15						x
Sportsman Cove	35	x		10						
Tiny's Bar	36	x		24	x					
Traps Marine	37	x		85	x		x	x		
Village Marine	38	x		40	x			x	x	
Wayne's Marine	39	x		30	x	x	x	x	x	
Wildwood Shoes Club	40		x	15						
Willomay Park	41	x		25						x
Windlass	42	x		40						
Woodport Boat Basin	43	x		265	x	x	x	x	x	x



LEGEND

● 20 CONSULT TABLE 17 FOR NAME OF FACILITY

FEET

0 1000 2000

0 200 400

METERS

DEPTHS IN FEET

LAKE HOPATCONG REGIONAL PLANNING BOARD

LAKE RESTORATION AND MANAGEMENT STUDY

FIGURE 3

PUBLIC ACCESS POINTS, MARINAS, & LAUNCHING FACILITIES, ON LAKE HOPATCONG

pas

D. COMPARISON TO OTHER LAKES IN NORTHERN NEW JERSEY IN TERMS OF RECREATIONAL POTENTIAL AND USAGE

There are approximately 8 major public lakes or reservoirs, within an 80 km radius of Lake Hopatcong, which provide a recreational outlet for central New Jersey and NY-NJ metropolitan area residents (Table 18). The water quality of Lake Hopatcong is comparable, if not better than most of the other lakes, but poorer than that of Spruce Run, Wanaque, and Round Valley Reservoirs (USEPA, 1978). However, the recreational demand placed on Lake Hopatcong far exceeds that placed on the other lakes and reservoirs. This is due to a combination of the lake's proximity to major cities, the availability of public access points, its large size, and recreational outlets.

Table 18

COMPARISON OF MAJOR WATER BODIES IN THE VICINITY OF LAKE HOPATCONG

Water Body	County	Area km^2	Public Access	Available Recreation	Trophic State
Spruce Run Res.	Hunterdon, NJ	5.22	yes	a,b,d,f,g,h	eutrophic
Round Valley Res.	Hunterdon, NJ	9.51	yes	a,b,d,f,g,h	mesotrophic
Paulinskill Lake	Sussex, NJ	0.64	yes	a,b,c,d,e,f,g,h	eutrophic
Swartswood Lake	Sussex, NJ	2.00	yes	a,b,c,d,e,f,g,h	eutrophic
Wawayanda Lake	Sussex, NJ	1.03	yes	a,b,d,f,h	mesotrophic
Greenwood Lake	Passaic, NJ/ Orange, NY	7.77	yes	a,b,c,d,e,f,g,h	eutrophic
Pompton Lake	Passaic	0.83	yes	a,b,c,f,h	eutrophic
Wanaque Res.	Passaic	9.35	no	no recreational activities allowed	mesotrophic
Budd Lake	Morris, NJ	1.52	yes	a,b,c,d,g,h	eutrophic
Lake Musconetcong	Sussex, NJ/ Morris, NJ	1.33	yes	a,b,c,d,f,g,h	eutrophic
Lake Shawnee	Morris, NJ	0.20	no	a,b,d,f,g	eutrophic

a - fishing; b-swimming; c-boating, motor; d - boating, sail/electric motor; e - waterskiing; f - picnicking, camping; g - winter activities; h - miscellaneous.

SECTION VI

WATER QUALITY MONITORING PROGRAM

A. INTRODUCTION

In order to establish the existing conditions of the lake and its tributaries, ascertain historical trends in the degradation of the lake's water quality, and identify the interrelationships among the physical-chemical-biological components of Lake Hopatcong, a detailed water quality monitoring program was conducted. The goal of this program was to identify the problems of Lake Hopatcong and develop, from this data, an effective restoration action plan. The methodologies utilized in this study were designed to generate data which would provide a sound framework for the selection of appropriate restorative and management techniques. In this manner, the problems and features unique to Lake Hopatcong and its surrounding watershed will be properly addressed.

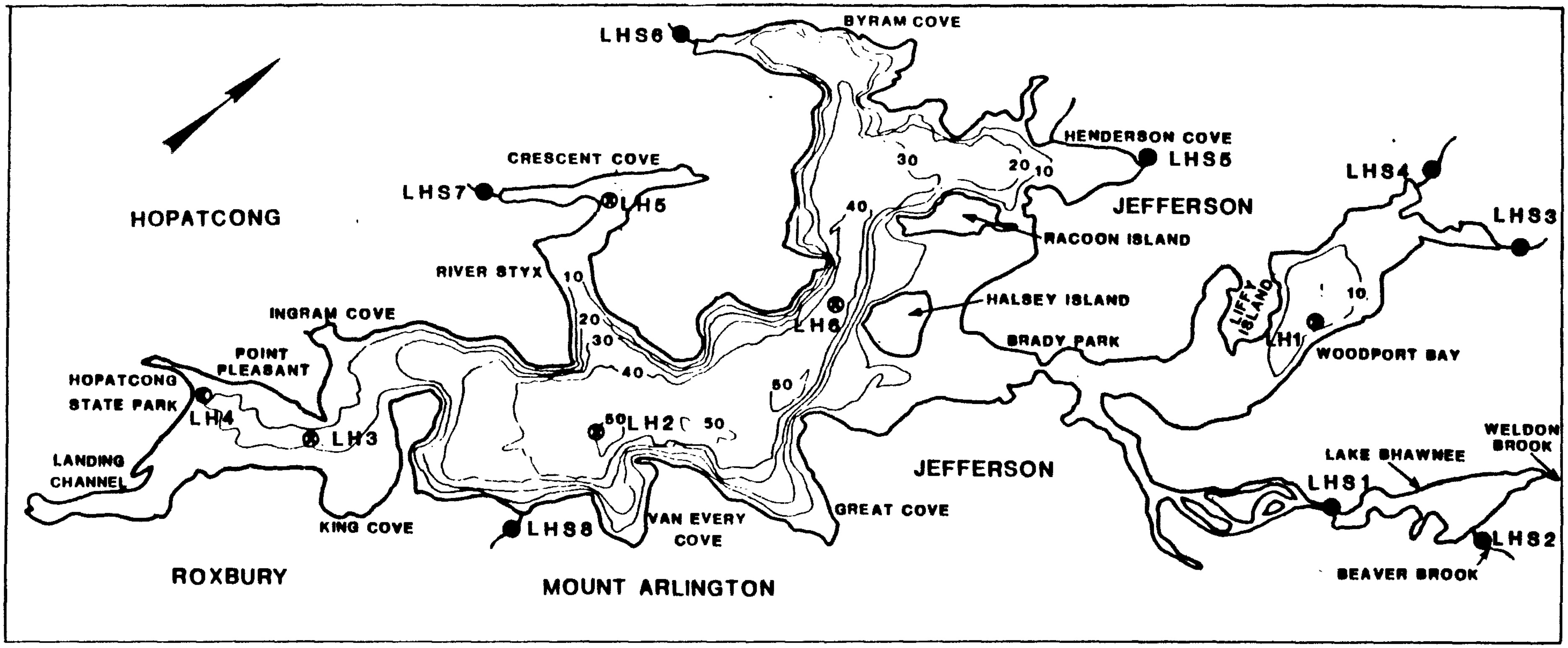
B. STATION SELECTION AND LOCATION

A total of 6 in-lake stations and 8 tributary stations were monitored on a regular basis (Table 19, Figure 4). The lake stations were monitored bi-weekly from April through September, and monthly the remaining months. The tributary stations were monitored on a monthly basis year-round. Additional stations were selected and monitored on a more infrequent basis for storm contributions, sediment composition, surveys of the fish, benthos, and macrophytes, and septic and sewage contributions. The location and frequency of these sampling programs will be addressed in those sections and sub-sections of this report which address these areas in more detail.

Table 19

IN-LAKE AND STREAM SAMPLING STATIONS

Designation	Location
Stream Stations:	
LHS 1	Lake Shawnee Dam overflow
LHS 2	Outfall from Weldon Brook into Lake Shawnee
LHS 3	Outfall from Lake Wenona into Lake Hopatcong
LHS 4	Stream under Prospect Point Road at north end of Woodport Bay
LHS 5	Jayne Brook at Lakeside Avenue
LHS 6	Stream under Maxim Drive that flows into southwest end of Byram Cove
LHS 7	Stream under Crescent Road with storm sewers that flow into southwest corner of Crescent Cove
LHS 8	Stream at foot of Altenbrand Road
Lake Stations:	
LH 1	Woodport Bay
LH 2	Main basin, off Chestnut Point
LH 3	Point Pleasant
LH 4	In vicinity of spillway near Hopatcong State Park
LH 5	Center of Crescent Cove
LH 6	Southwest side of Halsey Island



LEGEND

- ● STREAM SAMPLING STATIONS (LHS)
- ⊗ LAKE SAMPLING STATIONS (LH)

FEET: 0 — 1000 — 2000

METERS: 0 — 200 — 400

DEPTHS IN FEET

LAKE HOPATCONG REGIONAL PLANNING BOARD

LAKE RESTORATION AND MANAGEMENT STUDY

FIGURE 4

LAKE AND STREAM SAMPLING STATIONS

C. METHODS AND MATERIALS

1. In-Lake Sampling Program

A non-metallic Kemmerer sampling bottle was used to collect in-lake water samples. The water column at lake stations LH1, LH3, and LH6 was sampled 0.5m below the surface, and 0.5m above the bottom. Lake Station LH2, the deepest spot in the lake, was sampled at six depths; 0.5m, 3.0m, 6.0m, 9.0m, 12.0m, and 0.5m above the bottom. Samples were collected from only one depth, halfway between surface and bottom, at the shallow lake stations LH5 and LH4.

Water quality samples were collected, preserved, and transported to PAS laboratory facilities for analysis following EPA accepted methods. Quality control was in keeping with the guidelines developed by the State of New Jersey as detailed in the Quality Control Assurance Plan for the PAS Laboratory (PAS, 1982).

In situ measurements of air temperature, wind speed and direction, surface water temperature, and Secchi disc transparency were recorded for each sampling station. The temperature/dissolved oxygen profile at each station was measured using a Rexnord portable temperature/ dissolved oxygen probe. The pH of each sample was determined immediately upon collection.

Water samples to be analysed by the PAS laboratory, were dispensed from the Kemmerer sampling bottle into polyethylene containers. Four 1 liter samples were obtained at each sampling depth for each lake station. One was preserved with sulfuric acid, another with Lugol's solution, and the remaining two left unpreserved. From each of the appropriately preserved bottles, the following parameters were analysed as per

Standard Methods for the Examination of Water and Wastewater 14th ed. (1975), and in accordance with 40 CFR 136 et. seq.

Preserved with sulfuric acid

- total kjeldahl nitrogen
- nitrate and nitrite-nitrogen
- ammonia nitrogen
- total nitrogen
- total phosphate-phosphorus

Preserved with Lugol's solution

- whole phytoplankton

No preservative

- chlorophyll a, b, and c; phaeophyton (1 liter)
- orthophosphate-phosphorus
- suspended solids
- turbidity
- alkalinity
- specific conductance
- hardness
- pH

Net phytoplankton and zooplankton were also collected at each station on each sampling date except during ice cover. A 60 micron net was used to collect phytoplankton and a 153 micron net was used to collect zooplankton. Both nets were towed obliquely, at an approximate depth of 0.5 meters, for a set duration (usually 1 minute), and a set speed (usually 0.5 knots). Samples were transferred to 10 ml vials. The 60 u net sample was preserved with a formalin-copper sulfate solution whereas the 153 u net sample was preserved with a buffered formalin-rosebengal solution. Phytoplankton were identified to genus.

In addition to the above routine analyses, periodic sampling of the benthos, aquatic plants, fish, and sewage/septage related bacteria were conducted.

Benthic samples were collected using a 229 mm x 229 mm x 229 mm Ekman dredge. Bottom samples were sifted through 2000 mm and 1000 mm screens, the retained organisms picked, transferred to 10 ml vials, and preserved with a formalin-rosebengal solution. In the laboratory, organisms were identified to the lowest possible taxa following the criteria of Pennak (1978), Ward and Whipple (1966), and Merritt and Cummins (1978).

A survey of the lake's fishery was conducted using haul seine equipment. Species were identified in the field, and their weight, length, sex, and total numbers recorded.

A combination of SCUBA and surface techniques were employed to determine the extent, density, and species composition of the aquatic macrophytes of Lake Hopatcong. Transects were established from which samples were collected and semi-quantitative observations made. At a number of sites, all plants within a 1000 cm^2 quadrant were harvested. Upon return to the laboratory, the plant material was washed, sorted, and identified to species. The wet weight, ash weight, and organic content were determined. In addition, the concentration of total phosphorus, total kjeldahl nitrogen, and metals of a few sub-samples were measured. The chemical and biological methodologies recommended in Standard Methods for the Examination of Water and Wastewater, 14th ed. (1975), and Weber (1973) were followed.

The sediments of the lake were sampled using a K-B freefall coring device. The depth of the sediments were recorded in the field along with observations related to the color, texture, and oxic nature of the sediments. Sediment cores were iced upon collection and transferred in an upright position. Immediately upon return to the laboratory the redox potential of the sediments were recorded using an Orion Research redox probe. The sediment cores were then frozen. The frozen cores were extruded from the core tubes and cut into three strata (top, middle, and bottom). The following analyses were performed on each of these subsamples:

particle size
organic matter
total phosphorus
total nitrogen

A composite sample from each core was analyzed for persistent organics and heavy metals. E.P. toxicity tests were also conducted on the leachate of the sediments. All analyses were performed in accordance with Standard Methods for the Examination of Water and Wastewater, 14th ed. (1975) and 40 CFR 136 et. seq.

Fecal coliform, total coliform and fecal streptococcus bacteria were periodically monitored. The membrane filter methodology outlined in Standard Methods for the Examination of Water and Wastewater 14th ed. (1975) was followed. Data were reported as most probable number (MPN) per 100 ml.

2. Stream Sampling Program

Monthly surface grab water samples were collected from mid-channel at each of the stream stations. A total of eight tributary stations were sampled. The location of each station is noted on Figure 4, and listed in Table 19.

Future reference to these stations will be made using the LHS nomenclature.

Samples were collected in two 1 liter polyethylene containers. One container was preserved with sulfuric acid, and the other left unpreserved. Samples were stored on ice and transported to PAS laboratory facilities for analysis. From the appropriately fixed containers, the following parameters were analysed:

Preserved with sulfuric acid

- total kjeldahl nitrogen
- nitrite and nitrate-nitrogen
- ammonia nitrogen
- total nitrogen
- total phosphate-phosphorus

Non-preserved

- orthophosphate-phosphorus
- suspended solids
- turbidity
- specific conductance
- alkalinity
- hardness

In-situ measurements of pH, air and water temperature, and windspeed and direction were recorded, and general meteorological conditions noted.

Precipitation in the watershed was measured and recorded by a LHRPB volunteer. Precipitation records maintained by the National Oceanic Atmospheric Administration (NOAA) for the Lake Hopatcong area were used as a means of verifying their accuracy.

3. Point Source Sampling Program

There are four sewage treatment plants (STPs) located within the watershed of Lake Hopatcong which discharge to the lake's tributaries. Each point source discharge was identified by name, location, New Jersey Pollution Discharge Elimination System (NJPDES) permit number, receiving stream, and maximum allowable flow.

Physical, chemical and biological parameters were monitored at each point source. Samples were collected by means of grab and automated samplers, and composited over peak four-hour flow (10:00 to 14:00). The following parameters were analysed:

BOD_5
Suspended Solids
pH (in situ)
Fecal coliform
Temperature
Total organic carbon
Total phosphorus

Orthophosphate-phosphorus
Total kjeldahl nitrogen
Nitrite and nitrate-nitrogen
Ammonia nitrogen

Peak four hour flow composite data were evaluated with respect to loading of nutrients, sediment, organics and biochemical oxygen demand. Data were compared and evaluated relative to the National Eutrophication Survey data, NJPDES data, and existing permits for the point sources.

4. Evaluation of Septic Contributions

Nutrient contributions associated with improperly operating on site waste disposal systems were assessed. Although such nutrient loads were ultimately quantified using the methodology outlined in NES Working Paper #175 (USEPA, 1976), various survey techniques were employed to determine the potential number of failing septic systems in the immediate (100-200 m) proximity of the lake's shoreline.

Potentially failing systems were located by means of aerial infrared photography and the use of portable fluorescence-conductivity meter, commonly called a "septic snooper".

The infrared aerial photographs of the lake basin were taken by EPA personnel using a wing-strut mounted enviropod camera. The photographs were shot in March 1982 at an altitude of 350 meters (1,000 ft).

An in-lake survey of possible septic plumes was conducted using the "septic snooper". With the septic snooper mounted in a small boat and the sampling probe lowered overboard and submerged 0.5 m, a continuous scan of fluorescence and conductivity was obtained as the boat motored slowly around the lake's perimeter. Background fluorescence and conductivity were factored through calibration of the unit at a deep water mid-lake station. Full details regarding the calibration and use of the unit are presented in the "ENDECO Type 2100 Septic Leachate Detector System Operators Manual" (Kerfoot, 1980).

D. TROPHIC STATE ANALYSIS

Emphasis was placed on the role of phosphorus in determining the productivity of Lake Hopatcong. For most temperate lakes, phosphorus is found to be the element which limits the amount of primary production, as represented by algae or aquatic plant growth. The importance of phosphorus stems from its low availability in the water column relative to the phosphorus requirements of algae and aquatic plants in photosynthesis and subsequent tissue production. As a result, phosphorus is usually depleted from the lake before other nutrients and thus becomes the factor that limits primary production.

A number of models have been developed which empirically calculate the trophic state of a water body on the basis of a few key parameters. The more commonly used models are reviewed by Reckhow (1979) in regard to their derivation, strength, shortcomings, and potential bias. In general, using annual TP loading, hydrologic, and morphometric data the spring total phosphorus concentration of a lake can be fairly accurately predicted. This information is important in that it provides an estimate of the amount of TP available for utilization by primary producers at the onset of the growing season. This is a determining factor of summer productivity in most lakes.

The Dillon (1974) model is one of the more popular and accurate models (Equation 1).

Equation 1: $$[P_s] = \frac{L\ (1-R)T}{\bar{Z}}$$

Where: $[P_s]$ = Spring total phosphorus concentration (gm^{-3})
L = Areal Load ($gm^{-2}yr^{-1}$)=annual TP load/lake surface area
Z = Mean depth (m)
T = Hydraulic retention (yr)
R = Phoshorus retention

Developed primarily for use with phosphorus-poor Canadian Shield lakes, it has been verified for use with north temperate, nutrient enriched lakes (Reckhow, 1977). Although a robust model, it may underestimate spring total phosphorus in highly enriched lakes, and overestimate spring total phosphorus in lakes with a large areal water load (ratio of lake outflow:lake surface area). Neither of these cases apply to Lake Hopatcong.

The phosphorus retention coefficient, R, of equation 1, is an important part of the model. It can be calculated on the basis of hydrologic data using a number of empirical models. In lakes which flush infrequently, as is the case for Lake Hopatcong, a model developed by Ostrofsky (1978) provides an accurate prediction of phosphorus retention. That model (equation 2) was used in this study to calculate R.

Equation 2: $$Rp = 0.201e^{(-0.0425qs)} + 0.5743e^{(-0.00949qs)}$$

Where: Rp = Phosphorus retention
qs = Areal water load = $\frac{\text{Annual Outflow from Lake}}{\text{Surface Area of Lake}}$
e = Exponential of natural log e= 2.718

The spring total phosphorus concentration generated by Equation 1, was plotted on a trophic status graph developed by Dillon (1974) for use in conjunction with that model. The graph is provided with acceptable and dangerous loading levels. By plotting L(1-R)T vs. Z, an estimate of the lake's trophic status is obtained. This procedure was carried out for existing lake conditions using TP loading data calculated from unit areal phosphorus loading computations.

The calculated spring total phosphorus concentration of Lake Hopatcong is more meaningful when assessed in terms of lake productivity. That is, how much in-lake productivity, in the form of algae or aquatic macrophyte biomass, can be expected given a certain amount of phosphorus. The chlorophyll a model of Dillon and Rigler (1974) was used in this study (Equation 3).

Equation 3: $$\log_{10}[Chla_s] = 1.449 \log_{10} [Psp] - 1.136$$

Where: $[Chla_s]$ = Summer chlorophyll a ($mg\ m^{-3}$)
$[P_{sp}]$ = Spring total phosphorus ($mg\ m^{-3}$)

The model was developed for use in lakes which have nitrogen:phosphorus ratios greater than 12:1 (potentially phosphorus limited). Such is the case for Lake Hopatcong where spring and summer nitrogen:phosphorus ratios are often >12:1 (USEPA, 1976).

It should be noted that the final predicted maximium chlorophyll a concentration is really a measure of <u>potential</u> primary production and general lake conditions. Other factors that affect primary production such as shading or competition for nutrients by macrophytes and benthic algae mats are not accounted for in the model. Thus, one expects discrepancies between actual measured values and predicted values of maximum chlorophyll-a in plankton samples. It may therefore be more appropriate to consider these values chlorophyll a equivalents, an estimate of total potential lake productivity.

An additional method was utilized to determine trophic status. The Trophic State Index (TSI) of Carlson (1977) was calculated from the mean summer Secchi disc transparency depth using the relationship:

Equation 4: $$TSI\ (SD) = 10\left(6 - \frac{Ln\ SD}{Ln\ 2}\right)$$

Where: TSI (SD) = trophic status based on summer Secchi disc transparency

Ln = natural log

This in turn can be related to chlorophyll a concentration (mg m^{-3}) using the relationship (Carlson, 1977):

Equation 5: $$Ln\ SD = 2.04 - 0.68\ Ln\ Chl\ a$$

Where: SD = Secchi disc transparency depth (m)

Chla = Chlorophyll a concentration (mg m^{-3})

As Secchi disc depth is an easily measured parameter, this provides the user with a fairly easy means of determining both the trophic state of the lake and the maximum chlorophyll-a concentration to be expected under such conditions.

The utility of both the Dillon model and Carlson's TSI is in the future management of the lake. Through these models, it will be possible to easily obtain a preliminary estimate of how changes in phosphorus loading will affect the trophic state of the lake, without the need to conduct a sampling program of the depth and scope of this study.

SECTION VII

POINT SOURCE MONITORING

A. INTRODUCTION

Point sources are defined as discrete discharge sites, from which nutrients are exported in a quantity and concentration amenable to treatment or removal (Uttormark, et al., 1974). Both municipal and industrial sewage treatment plants (STPs), are typical examples of point sources. Significant quantities of nitrogen compounds (ammonia, nitrate, nitrite) and phosphorus compounds (soluble, organic and inorganic forms) are components of the treated effluent normally discharged from STPs. The point source load of nutrients may be, in itself, of sufficient magnitude to promote the growth of algae and aquatic macrophytes (Edmonson, 1972). Such loads are often recognized as important causative agents in the accelerated eutrophication of lakes and ponds.

Since point source loads eminate from discrete sites, they are more readily and easily controlled or treated than nutrients contributed from diffuse sources. Sewage diversion and advanced wastewater treatment, by physical, chemical or biological means, are but two options which can substantially decrease total point source nutrient loads to lakes. In addition, when demonstrated to be a necessary and cost effective means for the protection or maintenance of water quality, the advanced treatment of point source effluents can be legally mandated (USEPA, 1980). Thus, although point source nutrient contributions can be sizable, their discrete nature makes them a more easily managed component of a lake's nutrient budget.

All point sources within the Lake Hopatcong drainage basin that are permitted by the New Jersey Pollution Discharge Elimination System (NJPDES) were identified. The name, location, permit number, receiving stream, and measured mean flow for each point source were tabulated (Table 20).

Table 20

SEWAGE TREATMENT PLANTS WHICH DISCHARGE INTO LAKE HOPATCONG TRIBUTARIES

Name of Plant	Location	Permit No. NPDES	Receiving Stream	Type of Treatment	Average Flow $m^3 \cdot day^{-1}$
The Consolidated School*	Route 181 Jefferson Twp., Morris County	NJ0021156	Marsh which drains into Lake Hopatcong	Extended Aeration	4
Arthur Stanlick School*	East Shawnee Trail, Jefferson Twp., Morris County	NJ0021105	Marsh which drains into Lake Shawnee	Activated sludge with sand filtration beds	9
Our Lady of the Lake School*	Dunlop Road Mt. Arlington Morris County	NJ0026239	Unnamed tributary to Lake Hopatcong	Activated sludge with sand filtration beds and dosing tank	4
Mt. Arlington Knolls Apartment,	Building 7 Henry Court Mt. Arlington Morris County	NJ0026212	Unnamed tributary approximately ½ mile upstream from Lake Hopatcong	Activated sludge with sand filtration beds and dosing tank	85

*Operates only during school year.

B. LOCATION AND DESCRIPTION OF POINT SOURCES

There are four point sources which discharge to tributaries of Lake Hopatcong. These are Arthur Stanlick School, Consolidated School, Our Lady of the Lake School, and Mt. Arlington Knolls Apartments sewage treatment plants (STPs). Discharge from the schools occurs only during school hours, and only during the school season. Loads contributed by these three plants were calcuated on only a nine month basis to properly account for vacation periods during which the schools are not operating. In our study, four-hour composites (10:00 am to 2:00 pm) were collected and analyzed for suspended solids, nutrients, and organics (Table 21). The annual point source loads contributed by each STP were calculated using the total nitrogen, total phosphorus and total suspended solids as measured in our study and the reported mean flows. These data were compared to data obtained in other studies (Table 22).

PRINCETON AQUA SCIENCE

POINT SOURCE MONITORING DATA FOR SEWAGE TREATMENT PLANTS DISCHARGING TO LAKE HOPATCONG TRIBUTARIES

Parameter	Consolidated School	Stanlick School	Lady of the Lake School	Mt. Arlington Knolls Apartments
NPDES No.	NJ0021156	NJ0021105	NJ026239	NJ0026212
Sampling Date	5-6-82	5-6-82	5-6-82	5-6-82
Mean Flow $m^3 \cdot day^{-1}$	4	9	4	85
Total Phosphorus $mg \cdot l^{-1}$	2.29	2.96	5.50	4.91
Ortho Phosphate $mg \cdot l^{-1}$	0.834	1.57	1.95	2.97
Total Kjeldahl Nitrogen $mg \cdot l^{-1}$	0.672	0.616	24.36	4.53
Nitrate Nitrogen $mg \cdot l^{-1}$	2.412	2.059	1.980	1.616
Ammonia Nitrogen $mg \cdot l^{-1}$	0.364	0.224	23.38	2.70
Organic Nitrogen $mg \cdot l^{-1}$	0.308	0.392	0.980	3.27
Total Organic Carbon $mg \cdot l^{-1}$	8.4	7.7	15.5	7.0
Total Suspended Solids	8.0	5.3	100.0	4.0

Table 22

POINT SOURCE LOADING TO LAKE HOPATCONG
AS MEASURED DURING DIFFERENT SAMPLING PROGRAMS

Sewage Treatment Plant	Load kg yr^{-1}								
	Total Phosphorus			Total Nitrogen			Total Suspended Solids		
	NES	5-29-80***	5-6-82	NES	5-29-80	5-6-82	NES	5-29-80	5-6-82
Consolidated School*	5.96	0.12	3.01	550.07	27.1	4.07	-	18.40	10.51
Arthur Stanlick School**	-	0.14	3.06	-	69.8	7.98	-	0	15.67
Our Lady of the Lake School	5	-	7.23	50	-	34.7	-	-	131.40
Mt. Arlington Knolls Apartments	185	-	152	550	-	192.4	-	-	124.1

*Flows from Consolidated School changed from NES estimate of 10.4 m^3d^{-1} to measured flow of 4 m^3d^{-1}.

**Adjusted to account for TP retention in Lake Shawnee.

***From Elam and Popoff, Wastewater Facilities Plan.

C. SAMPLING RESULTS

Note, the NES calculated TN and TP load reported for the Consolidated School has been modified (Table 22). In the NES report (USEPA, 1976; Appendix A), the mean flow computed for the Consolidated School is 104 m^3d^{-1} as opposed to actual measured mean flow of 4 m^3d^{-1}. The discrepancy results from the fact that the NES data was obtained by using an estimated daily flow of 0.3874 m^3/capita/day, the typical default value utilized for residential water use. The NES calculated flow is a gross overestimate, and is refuted by reports which show the plant to be operating at low flow conditions (Elam and Popoff, in prep), as well as measured flow data (NJDEP, 1979). Therefore, the load attributed to the Consolidated School in the NES report is an overestimate of the actual load discharged to Lake Hopatcong.

Of the four package plants, the effluent characteristics of the Our Lady of the Lake's plant are the poorest. Based on samples collected on 5/6/82, the concentrations of TKN, TP, TSS, TOC and NH_3-N are greater in the effluent of this plant than in the effluent of the other three plants. It is possible that on the date of sampling that the plant was in a state of upset, as sampling conducted on other dates reveal better effluent quality (USEPA, 1976; Elam and Popoff, in prep.). Closer monitoring of this plant is recommended as discharge of poor quality effluent into the lake will stimulate algal and macrophyte growth, particularly in the immediate vicinity of the discharge point.

This same point can be made relative to the concentration of TP in the effluent of all four plants. Note, that in all cases the concentration of TP in greater than 1 mg/l^{-1}. It is well established in the literature that a TP concentration in excess of 0.01 mg l^{-1} is sufficient to stimulate and sustain algal blooms in phosphorus limited systems.

D. POINT SOURCE LOADING TO LAKE HOPATCONG

Based on the data presented in Table 22, The annual point source load of TP to the lake is calculated to be 165.3 kg. This load accounts for nutrient retention by Lake Shawnee. Our data indicate that point source TP contributions to Lake Hopatcong amount to only 3.9% of the total annual TP load. Approximately 92% of the point source load is contributed by the Mt. Arlington Knolls Apartment STP.

SECTION VIII

SEPTIC SYSTEM MONITORING

A. INTRODUCTION

Properly operating onsite wastewater disposal systems usually contribute very little to the nutrient budget of lakes (Lee, et al. 1978). In contrast, faulty systems contribute a significant nutrient load which can stimulate the development of aquatic primary producers to nuisance densities (Kerfoot, 1979). Total phosphorus loads associated with domestic wastewater (kitchen, toilet, bath, and laundry) can be as much as 1.5 kg/capita/yr (Ligman, et al., 1974). Faulty septic waste disposal systems located close to the shoreline could therefore have a serious impact on the trophic status of the lake.

In many lakefront developments, failing septic systems are often attributed to oversaturation of the leach field due to a seasonal elevation of water table height, hydraulic overloading of the system due to overcrowding of vacation homes and conversion of seasonal dwellings to permanent dwellings, or the formation of clogging mats in the leach field which significantly impair wastewater percolation. These problems are often compounded by installation of systems of improper design or capacity, and by use of septic systems in areas with soils of poor absorptive quality. All the above conditions reduce the ability of the soils to properly remove nutrients by sedimentation, absorption, filtration or biochemical oxidation (Otis, 1979). The area in immediate proximity to the lake's shoreline will also be more sensitive to these conditions due to water table height and limited soil depth available for bacterial degradation and soil absorption (Kerfoot, 1980). This may result in the discharge of waste-contaminated groundwater plumes from these shoreline dwellings and the localized elevation of sediment-nutrient concentrations. In turn, by reducing or eliminating such discharges noticeable improvements in water quality and substantial reduction in localized plant growth can be garnered (Otis, 1979).

B. DENSITY OF SEPTIC SYSTEMS

Virtually the entire shoreline of Lake Hopatcong and its feeder lakes, Lake Shawnee and Lake Winona, has been developed as high or low density residential housing. Often, the developed areas of the lake have housing which extends three tiers or more from the lake's shore. The majority of dwellings are single family, permanent residences and all use onsite disposal systems (septic systems) for the treatment of domestic wastes. This degree of lakefront development carries with it the potential for the export of significant nutrient loads of septic origin.

Some of the more heavily developed areas of the lake's shoreline are the communities of Lake Shawnee, Woodport North, Brady Park, Waterways, East Shores, Byram Cove, Crescent Cove, River Styx, Ingram Cove, Point Pleasant south to the State Park, Landing channel, and King Cove.

C. COMPATIBILITY WITH SOILS

The predominate soil types occurring along the shoreline of Lake Hopatcong are the Rockaway, Rockaway-rock outcrop, and Hibernia stony loam soils (SCS, 1975; SCS, 1976). These soils are characterized as being severely limited in terms of use in septic system leach fields. For the most part, the shallow depth to bedrock is responsible for this restriction. In addition, many of the developments occur in areas where the slope is fairly steep (8-15%) or in areas along the lake's shore where seasonally the water table is high. The combined effects of shallow soils, steep slope, and high water table make much of the area immediately surrounding the lake unsuitable for the use of onsite waste disposal.

D. SEPTIC SNOOPER STUDY RESULTS

In order to determine the importance of septic systems on nutrient loading to the lake, a portable fluorescence-conductivity meter, commonly called a "septic snooper", was used to detect improper domestic wastewater discharge. The discharge, referred to as a septic plume, is caused by the faulty operation of onsite disposal systems, and results from the active emergence of septic waste contaminated groundwater into the lake (Kerfoot, 1980). Under such conditions the septic effluent has not had sufficient time to percolate through the soils, and is usually characterized by elevated organic and inorganic concentrations.

Septic leachate entering the lake carries with it dissolved nitrate, ammonia, phosphate, and organic substances. These nutrients stimulate the growth of bacteria, algae and aquatic macrophytes. This can have serious effects on use of this water in recreational or potable water applications.

Septic leachate surveys were conducted of the entire shorelines of Lake Hopatcong and Lake Shawnee using an ENDECO 2100 Septic Leachate Detector System. As water is pumped through the "septic snooper", conductance and fluorescence are monitored continuously. In principal, wastewater effluent is partly comprised of a mixture of near UV fluorescent organics derived from laundry whiteners, surfactants and natural degradation products, and conductive inorganics, such as chloride (Cl^-) and sodium (Na^+). By monitoring these parameters in the form of fluorescence and conductivity, a leachate plume can be detected as it eminates from the shoreline. This results in three general conditions:

1. Elevated fluorescence
2. Elevated conductance
3. Elevated fluorescence and conductance

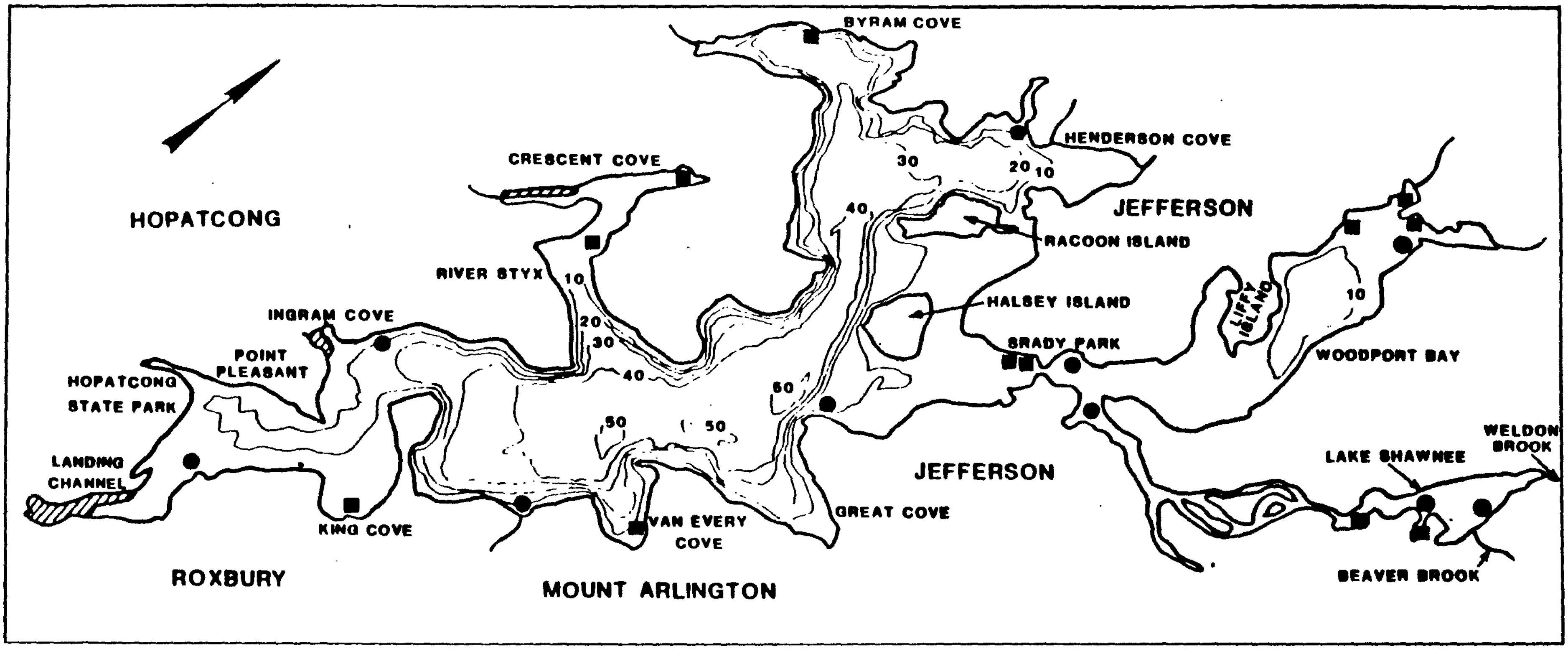
The third condition is indicative of septic contamination whereas the other two may indicate "grey water" contamination, groundwater intrusion, or discharge from streams, bogs, or marshes. At those sites where both fluorescence and conductivity were elevated, water quality and bacteriological samples were collected. Analysis of these samples help verify or refute the existence of a septic plume.

A number of plumes were encountered in the survey of Lake Shawnee and Lake Hopatcong. Plumes of both a discrete and a broad nature were observed. The former suggests that the septic inflow originates from a single dwelling, whereas the later suggests a wide scale failure of systems within that particular area.

The surveys of the Hopatcong, Roxbury, and Mt. Arlington shorelines were conducted in July and August of 1982. The surveys of the Jefferson and Shawnee shorelines were conducted in September of 1982.

In general, broad plumes were detected in areas where the housing density is high, particularly in coves or embayments in which water exchange is infrequent or restricted. The hydrodynamics of these embayments probably facilitates the retention of septic leakage and contributes, somewhat, to the elevated readings. However, not all embayments with restricted flushing characteristics displayed elevated readings. Rather, it was in those areas where the housing density was high that elevated "snooper" readings were recorded.

A total of 21 plumes were detected along the Lake Hopatcong shoreline and 6 along the Lake Shawnee shoreline (Figure 5). Of the 21 plumes detected in Lake Hopatcong, 7 were associated with groundwater intrusion or tributary inflow. The same conditions were responsible for 3 of the



LEGEND

■ DISCRETE SEPTIC PLUME

▨ BROAD SEPTIC PLUME

● NATURALLY INDUCED PLUME (GROUNDWATER, STREAM, MARSH, ETC.)

FEET 0 1000 2000

0 200 400 METERS

DEPTHS IN FEET

LAKE HOPATCONG REGIONAL PLANNING BOARD

LAKE RESTORATION AND MANAGEMENT STUDY

FIGURE 5
OCCURENCE OF SEPTIC PLUMES IN LAKE HOPATCONG AND LAKE SHAWNEE

pas

plumes detected in Lake Shawnee. Three of the plumes detected in Lake Hopatcong were very broad, indicating the occurrence of large scale septic failures in those areas. Specifically, the southwestern side of Crescent Cove, most of Ingram Cove, and most of Landing channel displayed such conditions (Figure 5). The remaining plumes were of the discrete variety with some being associated with the seepage or discharge of grey water effluent into the lake.

In Lake Shawnee, the four detected septic plumes were of the discrete variety. The plume of most notable magnitude was observed in an embayment along the eastern shore of the lake. This plume may actually represent the discharge from the Arthur Stanlick School Sewage Treatment Plant. Effluent from this STP is discharged to a small marsh which empties into Lake Shawnee in the vicinity where the plum was detected. The remaining plumes were of much lower magnitude (Figure 5).

Water quality and bacteriological samples were taken at the site of high magnitude plumes to help support the finding of the "septic snooper" data. In most cases, the concentration of nutrients (total phosphorus, nitrate, nitrite, or ammonia) were not significantly different than that commonly recorded for the surface waters of either lake. However, the bacteriological samples did yield fecal coliform and fecal streptococcus counts greater than normally observed in the lake at that time of year. The total plate counts were too low to make any valid conclusions on the source of the bacteria as based on fecal coliform/fecal streptococcus ratios.

E. INFRARED AERIAL ANALYSIS

Potentially failing septic systems can also be identified by means of infrared aerial analysis. The leach fields of failing systems are detected due to their more intense red hue. The infrared analysis of the Lake Hopatcong watershed was impeded by the poor quality of the photographs which were inadvertently overexposed. As a result, only overt failures could be identified. A total of 33 were observed along the Lake Hopatcong shoreline. A concurrent study of the Lake Shawnee area disclosed an additional 4 overt failures (Elam and Popoff, in prep.)

F. SEPTIC LEACHATE CONTRIBUTIONS TO LAKE HOPATCONG

On the basis of infrared and septic snooper data, questionnaire responses, geohydrology data, and soil permeability characteristics, it is concluded that there exists a serious problem related to the use of onsite disposal systems in the Lake Hopatcong watershed. Septic failures have contributed to the development of dense growths of aquatic macrophytes. Septic related impacts tend to be most pronounced in those areas where broad septic plumes were detected. Specifically, Crescent Cove, Ingram Cove and Landing Channel are three areas of the lake where wide scale septic inputs are known to occur. It is in these same areas that very dense beds of Myriophyllum, Vallisneria and Potamogeton are observed. It is recognized that the limited flushing of these embayments exacerbates the septic failure problem. However, the nature of the soils, height of the water table, and the density of homes along most of the lake's shoreline presents a situation whereby septic failures of notable severity could occur in any of the highly developed areas of the lake. The importance of septic leachate on the nutrient budget and eutrophication of the lake is probably greatest in the spring when, as a result of elevated water table height and poor soil permeability, the effective sorption of leachate nutrients by soils during percolation is reduced. Unfortunately, this is the same time of year when macrophyte metabolism and growth is occurring at a maximum rate (Wetzel, 1975).

The nutrient load contributed to the lake as a result of onsite disposal systems was quantified using the methodology outlined in NES Working Paper #175 (USEPA, 1976). The number of dwellings within 100-200 m of the lake's shoreline was determined from current census data (U.S. Dept. of Commerce, 1980), and actual counts from aerial photos. This information was supplemented by data collected in conjunction with the 201 Municipal Sewage Facility studies presently being conducted in the watershed of Lake Hopatcong (PAS, in prep; Elam and Popoff, in prep).

Particular attention was paid to the number and location of septic failures reported in the Board of Health records of the municipalities surrounding the lake.

A total of 5400 units were found to occur within 100 meters of the lake's perimeter. For the Lake Hopatcong area, the average population density is 2.6 capita/dwelling (U.S. Dept. of Commerce, 1980). The total population living near the lake's shore is thus 14,040. The NES septic loading coefficients of 0.114 kg TP/capita/yr and 4.263 kg TN/capita/yr were utilized to calculate septic load. The resulting loads of TP and TN contributed by septic systems are computed to be 1600.6 kg and 59,852.5 kg respectively.

Although these loads may seem high, they were calculated using loading coefficients which assume that the septic systems in question <u>are operating properly</u>. In the Lake Hopatcong watershed, approximately 20% to 30% of the septic systems are suspected of operating faulty as based on septic snooper, aerial photography, Board of Health, and soil compatability data. Thus the loads generated by this study are reasonable, and probably slightly <u>underestimate</u> actual septic inputs to the lake.

SECTION IX

CONTRIBUTIONS FROM NON-POINT SOURCES AS CALCULATED FROM UNIT AREAL LOADING DATA

A. UNIT AREAL LOADING METHODOLOGY

The majority of the annual nutrient load contributed to lakes in rural and semi-rural watersheds originate from nonpoint sources (Dillon and Rigler, 1975). Overland runoff of stormwater has been demonstrated to be the primary vehicle of such nutrient/sediment loads (Uttormark, 1979).

The National Eutrophication Survey of Lake Hopatcong concluded that the majority of nutrient and sediment contributions to Lake Hopatcong originate from nonpoint sources (USEPA, 1976). In order to more accurately quantify the magnitude of nonpoint source loads and investigate the relationship between land use practices and nutrient/sediment export, a detailed sub-basin analysis of land use-unit areal loading was conducted.

Estimates of the annual load of total phosphorus (TP), total nitrogen (TN), and total suspended solids (TSS) entering the lake via nonpoint sources, were calculated using unit areal loading (U.A.L.) methodology (Uttormark, et al, 1974, USEPA, 1980). Annual nonpoint source loads were calculated for the entire watershed. Loads were calculated for each sub-basin (Table 23), and each land use category (Table 24), in order to quantify their relative contributions to the total nonpoint source load.

Table 23

NON-POINT UNIT AREAL LOAD (kg yr^{-1}) OF TOTAL PHOSPHORUS, TOTAL NITROGEN AND TOTAL SUSPENDED SOLIDS TO LAKE HOPATCONG

Sub Basin	Area (ha)	TP Load	% Total	TN Load	% Total	TSS Load	% Total
1	853.1	190.8	7.9	2564.2	8.2	266700	6.2
2	769.7	204.0	8.5	2504.4	8.0	332600	7.7
3	69.6	41.4	1.7	314.6	1.0	96030	2.2
4	266.3	64.1	2.7	815.1	2.6	96445	2.2
5	233.1	69.3	2.9	791.7	2.5	122230	2.8
6	213.3	81.8	3.4	796.6	2.5	164170	3.8
7	106.4	78.4	3.3	561.6	1.8	192150	4.5
8	356.1	88.4	3.7	1101.4	3.5	137150	3.2
9	175.2	53.5	2.2	614.1	2.0	97050	2.3
10	111.7	33.4	1.4	433.0	1.4	66075	1.5
11	168.4	59.7	2.5	595.7	1.9	117175	2.7
12	90.2	55.9	2.3	421.4	1.3	132575	3.1
13	128.3	41.3	1.7	435.8	1.4	76700	1.8
14	176.9	51.1	2.1	576.8	1.8	88850	2.1
15	105.2	41.2	1.7	388.1	1.2	84400	2.0
16	183.3	89.7	3.7	751.1	2.4	199475	4.6
17	45.3	30.8	1.3	223.4	0.7	74525	1.7
18	15.0	3.7	0.2	43.5	0.1	3060	0.1
19	12.1	2.6	0.1	35.1	0.1	2805	0.1
20	142.0	79.3	3.3	583.5	1.9	183300	4.3
21	20.0	16.5	0.7	116.1	0.4	41100	1.0
22	161.1	68.0	2.8	630.2	2.0	143425	3.3
23	54.2	27.3	1.1	226.0	0.7	60230	1.4
24	37.2	25.2	1.1	188.7	0.6	59300	1.4
25	22.7	11.4	0.5	94.1	0.3	25450	0.6
26	30.4	15.6	0.7	127.7	0.4	35250	0.8
27	169.6	124.1	5.2	895.5	2.9	303715	7.1
28	56.7	47.1	2.0	322.5	1.0	113025	2.6
29	76.5	55.7	2.3	407.9	1.3	135405	3.1
30	15.0	10.8	0.5	76.0	0.2	26500	0.6
31	33.2	17.2	0.7	142.9	0.5	37505	0.8
32	117.4	51.9	2.2	476.1	1.5	110645	2.6
33	148.1	76.3	3.2	637.0	2.0	171925	4.0
34	93.9	69.3	2.9	487.6	1.6	169950	4.0
35	198.3	133.2	5.6	981.6	3.1	318975	7.4
36	27.1	11.7	0.5	115.6	0.4	21545	0.5
Fallout on Lake		271.8	11.3	10870.0	34.6	--	--
TOTAL	5482.8	2392.8		31346.6		4303460	

PRINCETON AQUA SCIENCE

Table 24

NON-POINT UNIT AREAL NUTRIENT AND SEDIMENT LOAD (kg yr^{-1})
TO LAKE HOPATCONG SUMMARIZED BY LAND USE CATEGORIES

Annual Load (kg yr^{-1})

Parameter	Residential		Commercial	Open Areas		Forest	Dry Fall-out on Watershed	Dry & Wet Fallout on Lake	Total
	High	Low		Covered	Exposed				
Total Phosphorus	1083.8	16.8	217.2	7.5	7.8	775.7	11.0	271.8	2391.6
Total Nitrogen	6773.5	167.8	1448.0	125.5	129.0	9695.5	2193.1	10870.0	31402.4
Total Suspended Solids	2709400	13420	579200	10040	25800	969550	--	--	4307410

pas

In most cases, mean loading coefficients (Uttormark et al., 1974, USEPA, 1980) were used (Table 25). Open-covered land use was ascribed the same loading values as range-pasture land. Open-disturbed land use was ascribed the same nutrient loading values as agricultural land, but the total suspended solids loading coefficient was increased to 2000 kg yr^{-1} to account for the more erodable nature of exposed soils.

A more accurate assessment of loading from urban land was achieved by developing specific loading coefficients for the major types of urban land use. From the available range of urban loading coefficients (Table 25), unit areal loading relationships were selected for high density residential, and commercial applications. Loading coefficients were developed which best reflected the influence of population density, impervious surfaces, vehicular traffic, storm sewers, etc. on the loads eminating from these urban land use categories. The mean urban loading coefficients were used for the high density residential categories, whereas the minimum urban loading coefficients were used for low density residential applications. Commercial land was assigned loading coefficients double the mean urban loading values. The use of these modified export coefficients appear more appropriate than lumping these categories under a single land use heading as is done by using the average EPA loading coefficient.

Nutrient loads entering the lake via direct precipitation and dry fallout into the lake itself, and by dry fallout onto the watershed were also estimated using average loading coefficients.

Throughout the entire 5482.7 ha watershed, less than 5 ha are actively farmed. As these lands are scattered throughout the watershed their contribution to the nutrient and sediment load of the lake is not very great. No steps were taken to develop agricultural loading coefficients. Rather, these lands were included in the open-covered category.

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Table 25

APPROXIMATE RELATIONSHIP BETWEEN LAND USE AND UNIT AREAL LOADING FROM NONPOINT SOURCES

	Average (kg ha^{-1} yr^{-1})			Range (kg ha^{-1} yr^{-1})			As Used in This Study (kg ha^{-1} yr^{-1})		
	TN	TP	TSS	TN	TP	TSS	TN	TP	TSS
Forest[a]	2.5	0.2	250	1-10	0.005-1	40-400	2.5	0.2	250
Range/Pasture[a]	5	0.3	400	2-10	0.2-0.6	10-1,000	5.0	0.3	400
Cropland[a]	10	0.6	1,600	1-40	0.03-0.7	300-4,000	10.0	0.6	1,600
Urban[a]	5	0.8	2,000	2-20	0.25-5	200-5,000	SEE TEXT FOR DETAILS		
Feedlots[a]	1,000	250	--	700-1,500	100-400	--	1,000	250	--
Precipitation[b,c]	10	0.25	--	1-100	0.25-1	--	10.0	0.25	--
Open-Disturbed[d]							10.0	0.6	2,000
Open-Covered[e]							5.0	0.3	400
Dryfall on Watershed							0.4	0.002	--

[a]Applied to watershed area.

[b]Applied to lake surface area.

[c]For 102 cm (40") per year.

[d]Assumed same as agricultural application, but ascribed higher TSS value to account for lack of cover.

[e]Assumed same as range/pastureland.

FROM: Clean Lakes Program Guidance Manual EPA 440/5-81-003, 1980.

pas

Sub-basins 1 through 4 drain into Lake Shawnee, a headwater of Lake Hopatcong. In all lakes, a certain fraction of the nutrients and sediments which enter the lake will be retained due to settling. The amount of material which is retained is a function of the lake's hydrology, particularly its flushing rate. Lakes with prolonged hydraulic retention (i.e. infrequent flushing) have a greater propensity to retain materials as a result of sedimentation. In order to accurately calculate nonpoint source loading to Lake Hopatcong, it was necessary to account for retention by Lake Shawnee. Emphasis was placed on calculating phosphorus retention due to that nutrient's important role in the accelerated eutrophication of lakes. Equation 2 (Ostrofsky, 1978) was used to compute phosphorus retention. A value of 0.406 was obtained (Table 26). Thus the nonpoint source TP loads for sub-basins 1 through 4 were multiplied by (1.0-0.406) to account for the sedimentary loss of TP in Lake Shawnee.

The annual U.A.L. loads for TP, TN, and TSS were obtained by first calculating the loads exported from each land use for each sub-basin. By summing the sub-basin contributions, the total loads generated by all nonpoint sources in the watershed were obtained (Table 27).

Table 26

PHOSPHORUS RETENTION IN LAKE SHAWNEE

Empirical Calculation Using Ostrofsky Model (1978):

$$Rp = 0.201e^{(-0.0425qs)} + 0.5743e^{(-0.00949qs)}$$

where: Rp = Phosphorus retention

qs = Areal water load = $\frac{\text{Annual Discharge } m^3\ yr^{-1}}{\text{Lake Surface Area } m^2}$

Annual Discharge from Lake Shawnee* = $9.0 \times 10^6 m^3 yr^{-1}$

Surface Area of Lake Shawnee** = 20.2 ha

$$qs = \frac{9.0 \times 10^6 m^3 yr^{-1}}{202{,}000\ m^2} = 44.6\ m\ yr^{-1}$$

$$Rp = 0.201e^{(-0.0425)(44.6)} + 0.5743e^{(-0.00949)(44.6)}$$

$$Rp = 0.030 + 0.376$$

$$Rp = 0.406$$

% TP Retention = 40.6

*Source: Calculated empiracally, verified using USEPA, 1976, NES Report
**Source: Sussex County, NJ 208 Water Quality Management Plan

Table 27

NUTRIENT-SEDIMENT INPUTS TO
LAKE HOPATCONG AS CALCULATED WITH THE
UNIT AREAL LOADING MODEL

U.A.L. Model

$$M_j = \sum_{i=1}^{n} \left[\Sigma a(ha) + \Sigma b(ha) = \Sigma c(ha) + \Sigma d(ha) + \Sigma e(ha) + \Sigma f(ha) + \Sigma g(ha) + \Sigma h(ha) \right]$$

Mj = Annual load for TP, TN, TSS; kg yr^{-1}

a···h = loading coefficient for specific land use; kg $ha^{-1}yr^{-1}$ summed for each sub-basin

a = High density residential
b = Low density residential
c = Commercial
d = Open area, covered
e = Open area, exposed
f = Forest
g = Dryfall on watershed
h = Dryfall - precipitation directly into lake

ha = area of land use; hectares

ANNUAL NONPOINT SOURCE LOAD

Total Phosphorus*	2188.9 kg yr^{-1}
Total Nitrogen	31402.4 kg yr^{-1}
Total Suspended Solids	4307410 kg yr^{-1}

*Adjusted to account for phosphorus retention in Lake Shawnee

B. NON-POINT SOURCE LOADING TO LAKE

The U.A.L. nonpoint source TP and TN loads were found to be very different than the nutrient loading estimates generated by the EPA in its 1976 survey of Lake Hopatcong (USEPA, 1976) (Appendix A). The annual TP and TN nonpoint source loads as calculated using U.A.L. methodology are 2188.9 kg yr^{-1} and 31,402.4 kg yr^{-1}, respectively (Table 27). In comparison, the EPA calculated nonpoint source loads for TP and TN are 625 kg yr^{-1} and 40,875 kg yr^{-1}.

It should be noted, that the TSS load predicted for the basin is conservative. Soil loss will be greater in construction sites and open-disturbed areas where the vegetative cover has been removed.

Individual sub-basin nutrient loads range frorm 2.6 kg yr^{-1} to 204.0 kg yr^{-1} for TP, and 35.1 kg yr^{-1} to 2564.2 kg yr^{-1} for TN. This variability is related to differences in the size and the predominate land use activity in each sub-basin. In general, those sub-basins which are predominately urban contribute greater TP and TN loads per hectare than other land use categories. This indicates the importance of watershed urbanization on nutrient/sediment loading to lakes. As the area of impervious surfaces increases, so does overland sheet runoff and the storm water transport of materials to the receiving water body. This results primarily from the loss of natural areas for water percolation and nutrient retention.

Although the U.A.L. data serve as a preliminary estimate of existing nonpoint nutrient/sediment loading, the true utility of the U.A.L. approach is in its use in quantifying changes in nutrient loading which result from changes in watershed land use. In this manner, increases in nutrient loading resulting from further watershed urbanization can be determined fairly easily (Souza and Perry, 1977). These data suggest that a substantial amount of phosphorus and nitrogen compounds are entering the lake from nonpoint sources. In addition, the majority of the load is probably transported to the lake or its tributaries via stormwater runoff.

SECTION X

CONTRIBUTIONS FROM NON-POINT SOURCES AS CALCULATED FROM STORM AND BASELINE TRIBUTARY LOADS

A. STREAM MONITORING PROGRAM

Physical and chemical data collected from 8 major tributaries over the 12 month study period are presented in Appendix B. These data represent the physical and chemical properties of the lake's major tributaries under various flow conditions, including storm events.

1. Gaged Streams

Due to drainage patterns in the Lake Hopatcong watershed, it was possible to gage inflow to the lake at only two locations, LHS 4 and the spillway of the Lake Shawnee Dam, LHS 2 (Figure 4). The sub-basins drained by the gaged tributaries represent approximately 38% of the total watershed. Flows were monitored at the gaged stations from March 1982 through July 1982. A 90°, V-notch weir was erected at LHS 4. Weir readings were converted to discharge (m^3d^{-1}) using the appropriate discharge formula (Anon., 1978). Discharge from Lake Shawnee was computed from head height measurements taken at the lip of the spillway, and converted to discharge (m^3d^{-1}) using a modified broad crested weir formula (Table 28).

2. Non-Gaged Streams

Non-gaged tributary discharge was calculated using an empirical precipitation-stream discharge formula (Table 28). Rainfall was measured with a "Clear-View" rain gage and monitored by LHRPB personnel. This rainfall data was verified through comparison with NOAA Climatological Department rainfall data measured for the general Lake Hopatcong area (NOAA, 1981-1982). These data proved to be in close agreement. Monthly rainfall data was substituted into the empirical discharge formula, along with the watershed area of each tributary, and a runoff coefficient, calculated as per Dunne and Leopold (1978), to yield the monthly discharge from each tributary. The sum of these data represents the annual tributary hydrologic contribution to the lake as measured from August 1981 to August 1982. Flows were normalized as per USEPA, 1975 (Table 28).

Table 28

PERTINENT EQUATIONS USED IN THE CALCULATION OF TRIBUTARY CONTRIBUTIONS

Equation 6

Calculation of discharge from a 90° V notch Weir

Discharge (ft^3s^{-1}) = $2.50H^{5/2}$

where: H = gage height of water passing through weir
(converted to m^3s^{-1} using 0.02832 conversion factor)

Equation 7

Modified Broad Crested Weir Formula for the Calculation of Discharge over the Lake Shawnee Spillway

Discharge (ft^3s^{-1}) =

where: H =
(converted to m^3s^{-1} using 0.02832 conversion factor)

Equation 8

Empirical Precipitation - Stream Discharge Equation

Q = ABC

where: Q = Discharge
A = Area of Watershed ($m^2 \times 10^4$)
B = Monthly Precipitation ($m \cdot month^{-1}$)
C = Runoff Coefficient

Table 28 (continued)

Equation 9

$$\text{Annual load} = 74.604\ \bar{c}\ ys \sum_{1}^{12} NF_i$$

where:

$\bar{c}$ = mean nutrient concentration of sampled stream

NF_i = normalized flow for i th month

$y = 10^{b(\overline{\log NF} - \overline{\log MF})}$

$S = \sum_{1}^{12} (NF\ 10^{b(\log NF_i - \overline{\log NF})} / \sum_{1}^{12} NF_i$

$\overline{\log NF}$ = mean log normalized flow

$\overline{\log MF}$ = mean log monthly flow for year sampled

b = average adjustment regression coefficient for TP and TN calculated for Northeastern United States

b = 0.06 for TN

b = 0.11 for TP

B. NON-POINT LOADING TO LAKE

Nutrient loads were calculated for gaged and non-gaged tributaries. The concentration of total phosphorus (TP) and total nitrogen (TN) was measured at each of the sampled tributaries on a monthly basis. These data were used in conjunction with the normalized discharge data to compute the annual TP and TN tributary loads (Table 29). Loads were obtained by multiplying the normalized monthly discharge data and the measured mean monthly TN and TP concentration to yield the mean monthly TN and TP load.

As point sources discharge upstream of LHS 2 and LHS 8, the nutrient loads calculated for these tributaries represent both point source and non-point source loading. In addition, an unpermitted discharge from a gravel slurry processing operation was discovered at the headwaters of LHS 4. The loads eminating from this tributary, particularly the sediment load, is affected by this point source.

The total phosphorus and total nitrogen loads contributed by the monitored tributaries are 576.621 kg TP yr^{-1} and 11628.4 kg TN yr^{-1}. There are additional tributaries which were not monitored during the course of this study. The loads contributed by those tributaries are accounted for in the U.A.L. computed non-point source loads (Section XII).

It is recognized that the nutrient loads generated using the above methodologies probably have an inherent average absolute error of 14% (Scheider, et. al., 1979). However, these calculated values are the best available estimate of nutrient loading to Lake Hopatcong. Although these loads are roughly double those computed in the N.E.S. study, they appear to be much more representative of tributary related nutrient flux to Lake Hopatcong.

Table 29

NUTRIENT CONTRIBUTIONS FROM MONITORED TRIBUTARIES

ANNUAL NUTRIENT LOAD (kg yr^{-1})

Stream Station*	Total Phosphorus**	Total Nitrogen**
2	270.5	4928.1
3	33.5	875.4
4	71.6	1136.5
5	19.6	179.3
6	24.5	1915.1
7	68.6	1264.4
8	86.2	1329.5

*See Figure 4 for station locations.

**2 and 4 calculated using measured stream flow and measured mean monthly nutrient concentrations. Remaining stations load calculated using empirically derived flow and measured mean monthly nutrient concentrations.

SECTION XI

THE EXISTING LIMNOLOGICAL CONDITION OF LAKE HOPATCONG

A. INTRODUCTION

The limnological study of Lake Hopatcong quantifies its physical, chemical, and biological properties. These data have been used to characterize the existing condition of the lake as related to water quality and pertinent ecological interactions. They are also utilized in the identification of those problems which have or threaten to contribute to the deterioration of the lake. This section of the report is therefore of great importance. The data contained herein serves as the technical foundation upon which the future management and restoration of the lake will be based.

B. HISTORICAL WATER QUALITY

As New Jersey's largest inland water body, Lake Hopatcong has been the subject of numerous studies. The fishery, aquatic macrophytes, phytoplankton dynamics, and water quality of the lake have been investigated. As a result, a substantial data base exists for Lake Hopatcong.

A minor assessment of the lake's water quality was conducted by NJ Division of Fish and Game as a part of a fishery survey of the lake (NJ Dept. C.E.D., 1950). The lake was found to thermally stratify during the summer. From July through August the hypolimnion was devoid of oxygen. The anoxic zone reportedly extended from a depth of 10 meters to the lake bottom in the central main basin of the lake, and from a 5 meter depth in the deeper sections of Woodport Bay. The lake was observed to be slightly alkaline (7.3 pH) at the surface but slightly acidic (6.7 pH) at greater depths. In general, the lake was considered to be of acceptable environmental condition.

A more intensive study of the lake's water quality was conducted as part of the EPA National Eutrophication Survey (USEPA, 1976). The objective of the study was to investigate nutrient sources, loads, and impacts and summarize the trophic state of the lake. The results of that study concluded that Lake Hopatcong was receiving a nutrient load below that considered sufficient to stimulate or support nuisance algae blooms. The lake was reported to be of low to moderate primary production (Chlorophyll a concentrations of 5.5 mg m^{-3} to 27.7 mg m^{-3}), and low secchi disk transparency (0.6 m to 1.08 m). In the summer, oxygen became depleted at depths greater than 5 meters. Of the various nutrient sources, non-point tributary inputs (surface runoff) contributed the most to the annual total phosphorus budget (33.8%).

Sewage treatment plants, septic leakage, and direct precipitation contributed 26.7%, 24.8%, and 14.7% of the annual TP load, respectively (Appendix A).

In 1978 through 1980, a detailed investigation of the lake's macrophyte and phytoplankton communities was conducted (EAC, 1980). Analysis and discussion of these data will be covered in upcoming sections of this report. In summary, that study concluded that certain sections of the lake are plagued by nuisance densities of aquatic macrophytes. It advocated mechanical weed harvesting as a means of maintaining macrophyte standing crops at acceptable densities, and demonstrated, through an experimental harvesting program, the benefits accrued through such an operation. In addition, the study concluded that the phytoplankton community was dominated by diatoms and bluegreen algae. Chlorophyll concentrations, a measure of productivity, were greatest in Woodport Bay and River Styx, substantiating the highly productive nature of these two sections of the lake.

In 1974 a sampling program designed to monitor lake water quality was developed under the auspices of LHRPB. A number of physical-chemical parameters as well as bacteriological samples were examined at several locations throughout the lake. The majority of the samples were taken at the surface, although the deepest section of the lake, near Nolan's Point, was occasionally sampled. These data provide a basis for the examination of recent water quality trends.

Dissolved oxygen concentrations were observed to steadily decrease throughout the summer months even at the surface water stations. Although the dissolved oxygen concentration of the hypolimnion was not observed to become depleted, concentrations did approach anoxia, and reached levels unacceptable for the existence of most aquatic organisms.

Total phosphate, orthophosphate, nitrate, and ammonia were typically measured at concentrations indicative of an overly enriched system. However, the analytical methodology employed in these surveys was somewhat inconsistent. In addition, the measured concentrations were often near or at the analytical detection limit making these data somewhat suspect. Even in view of these potential shortcomings, the data do indicate that the lake's total phosphate concentration is sufficient enough to support nuisance algae blooms.

The data collected in these previous studies are indicative of conditions and characteristics normally associated with a eutrophic water body. Nutrient concentrations are high, a substantial volume of the lake becomes anoxic following thermal stratification, and the level of primary production is at times excessive. All are symptoms of accelerated eutrophication and are associated with water bodies of deteriorating environmental condition.

The objectives of our study include the assessment of the lake's trophic status, identification and quantification of nutrient sources, and analysis of the lake's ecological relationships. The historical data base provide a source of reference or comparison for the findings of our study. In addition, some of the data are used to supplement our study.

Table 31

PROPORTION OF LAKE VOLUME AT VARIOUS DEPTHS

Depth	Contour	Volume Between Successive Contour	Volume at or Above Each Contour
m	ft	m^3	m^3
0-1.52	0-5	1.406×10^7	1.406×10^7
1.52-3.05	5-10	1.052×10^7	2.46×10^7
3.05-4.57	10-15	7.30×10^6	3.19×10^7
4.57-6.09	15-20	6.30×10^6	3.82×10^7
6.09-7.61	20-25	5.60×10^6	4.38×10^7
7.61-9.13	25-30	4.71×10^6	4.85×10^7
9.13-10.65	30-35	3.66×10^6	5.22×10^7
10.65-12.17	35-40	2.75×10^6	5.50×10^7
12.17-13.69	40-45	1.86×10^6	5.69×10^7
13.69-15.21	45-50	5.00×10^5	5.74×10^7
15.21-16.73	50-55	1.57×10^5	5.76×10^7*
TOTAL VOLUME		5.74×10^7	

*Error due to rounding figures.

2. Temperature

The lake is dimictic, that is, it undergoes complete mixing twice a year, once in the spring and once in the fall. The lake becomes thermally stratified in late June and remains so through August and into early September (Figure 6). The thermocline forms at a depth of approximately 9 m and fluctuates only slightly in depth from the surface throughout the period of stratification. The volume of the epilimnion is 48.5×10^6 m^3 while that of the hypolimnion is 8.9×10^6 m^3.

The temperature of the surface waters varies with ambient temperatures, ranging from 0^oC to 27^oC (Appendix C). The more elevated summer temperatures are recorded for the shallow embayments. The temperature of the deeper waters of the lake (>9 m) is more consistent ranging from 1.0^oC to 18^oC.

3. Dissolved Oxygen

Following summer stratification, the difference in density between the surface and bottom waters is great enough to minimize mixing of these two layers. This is important in relation to internal recycling of nutrients, productivity, and especially oxygen depletion. Dissolved oxygen concentration measurements taken concurrent with temperature, show that following stratification oxygen depletion commences in the deep non-mixed hypolimnion of the lake (Figures 7a, 7b, 7c, and 7d). In May, immediately following the establishment of the thermocline, there is 6.35×10^4 kg of oxygen in the hypolimnion. By the end of June, the oxygen content of the hypolimnion at depths greater than 12 meters has become completely exhausted (Figures 8a, 8b, 8c, and 8d). Bacterial

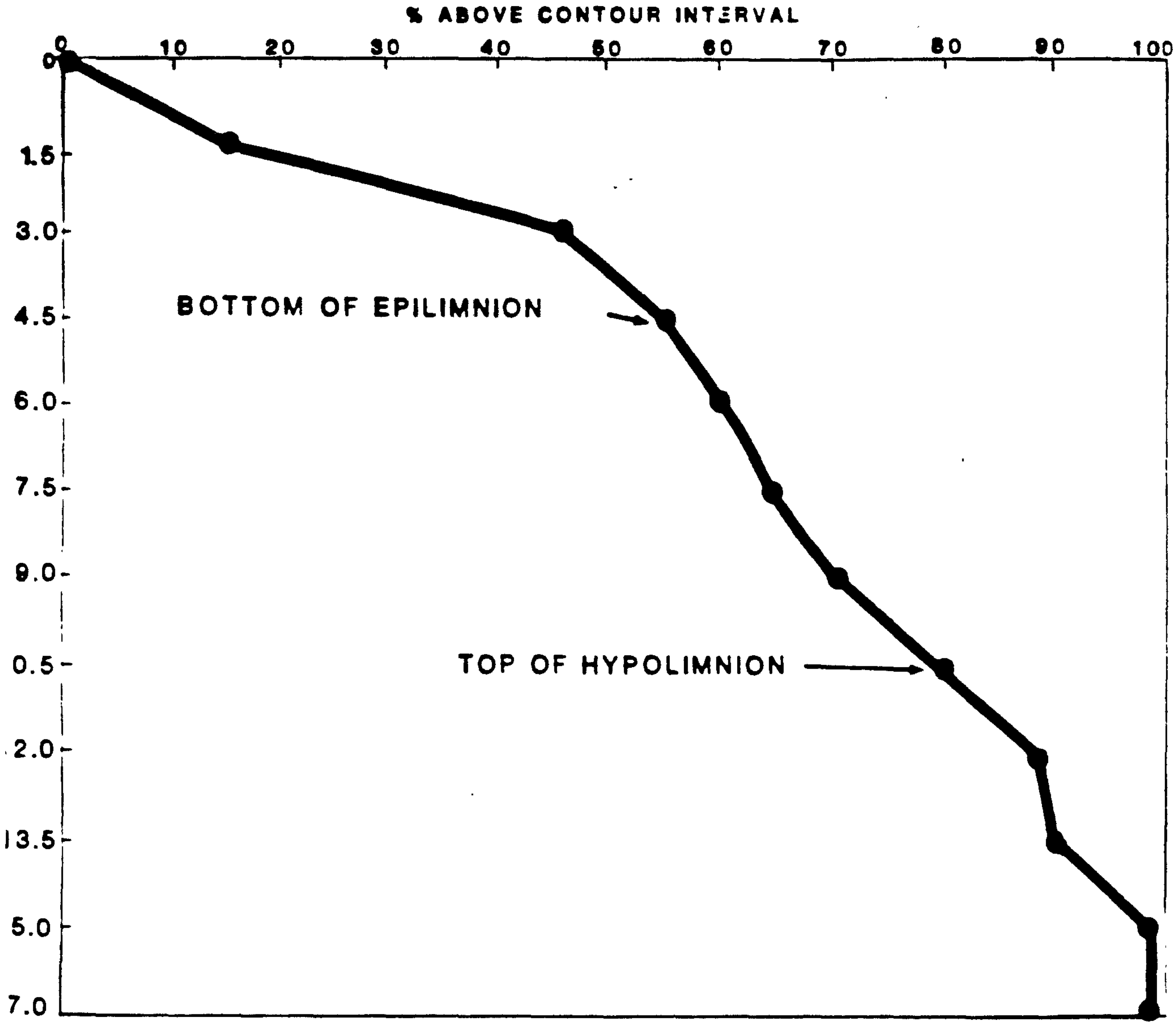


FIGURE 6
HYPSOGRAPHIC CURVE OF LAKE HOPATCONG

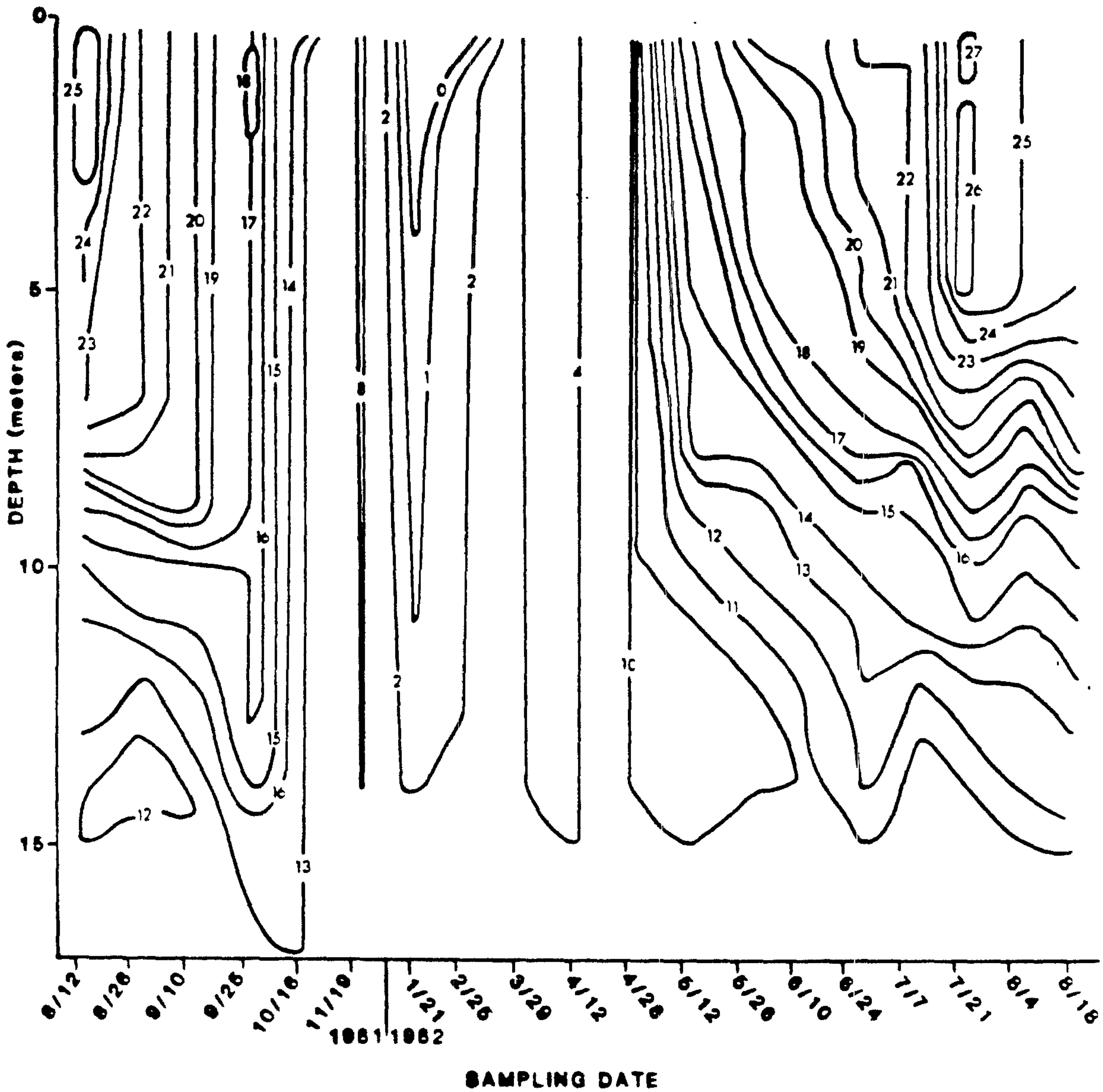


FIGURE 7
THERMAL ISOPLETHS FOR LAKE HOPATCONG

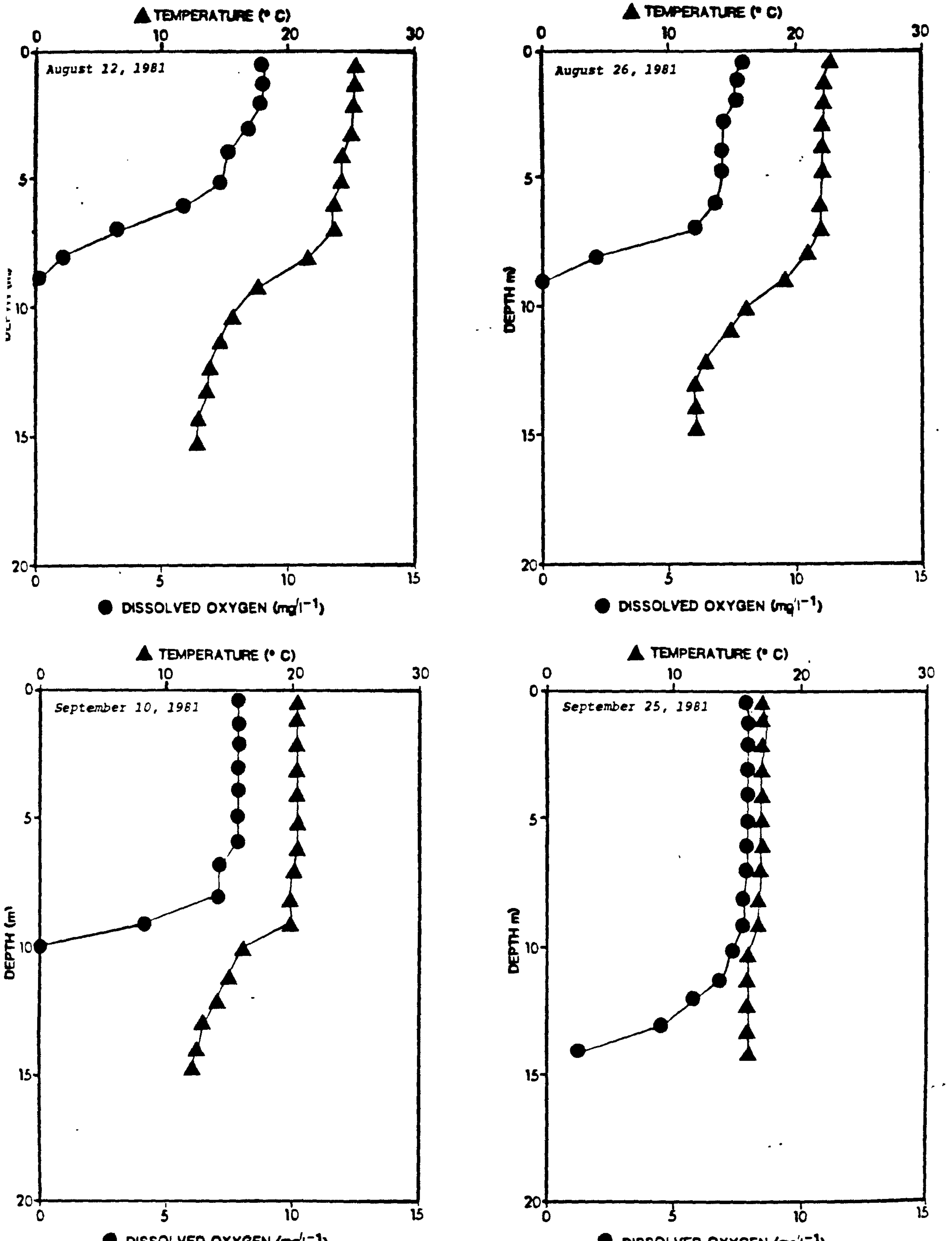


FIGURE 8A

DISSOLVED OXYGEN-TEMPERATURE PROFILES FOR LAKE HOPATCONG, SUMMER 1981

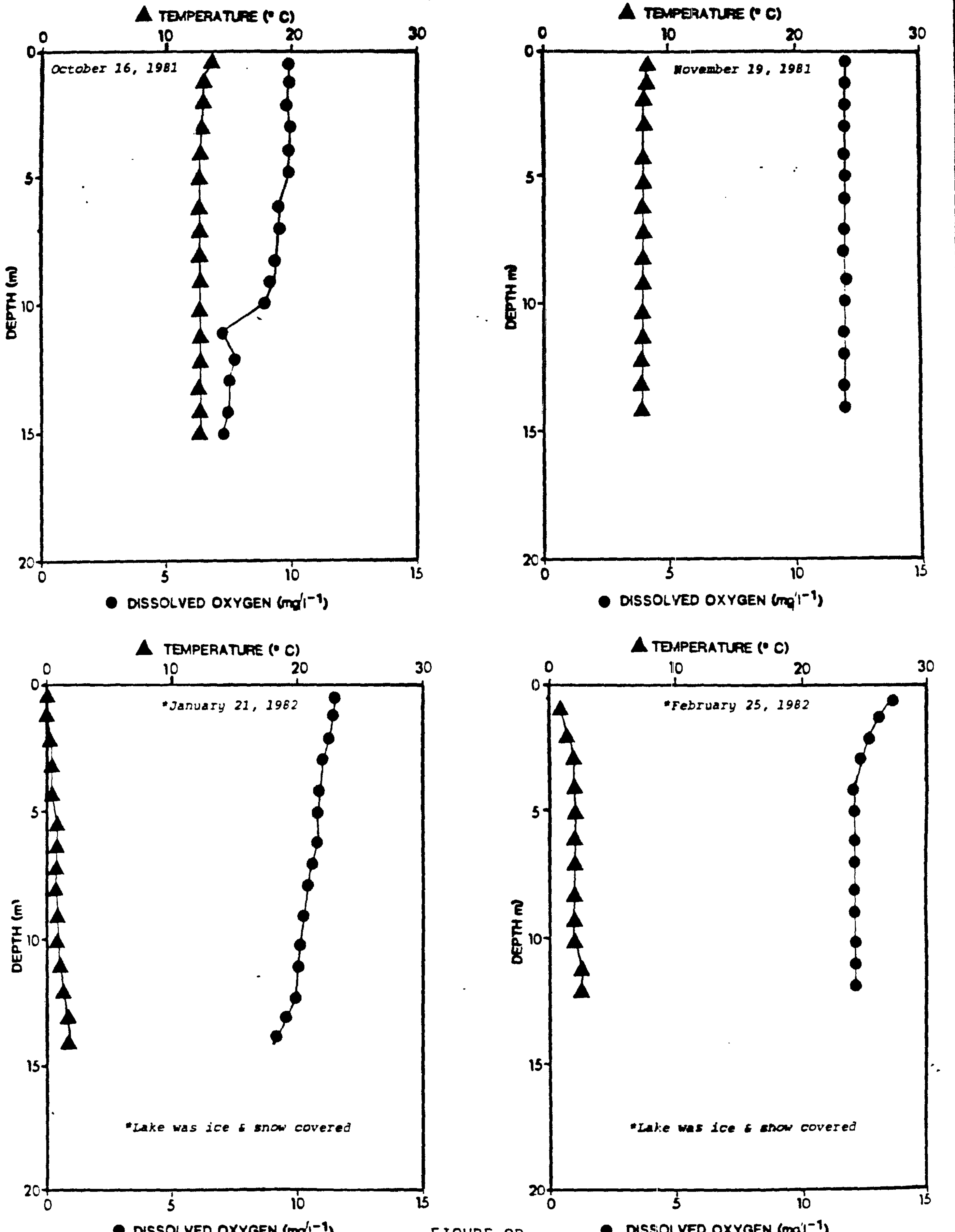


FIGURE 8B

DISSOLVED OXYGEN-TEMPERATURE PROFILES FOR LAKE HOPATCONG, FALL-WINTER 1981-1982

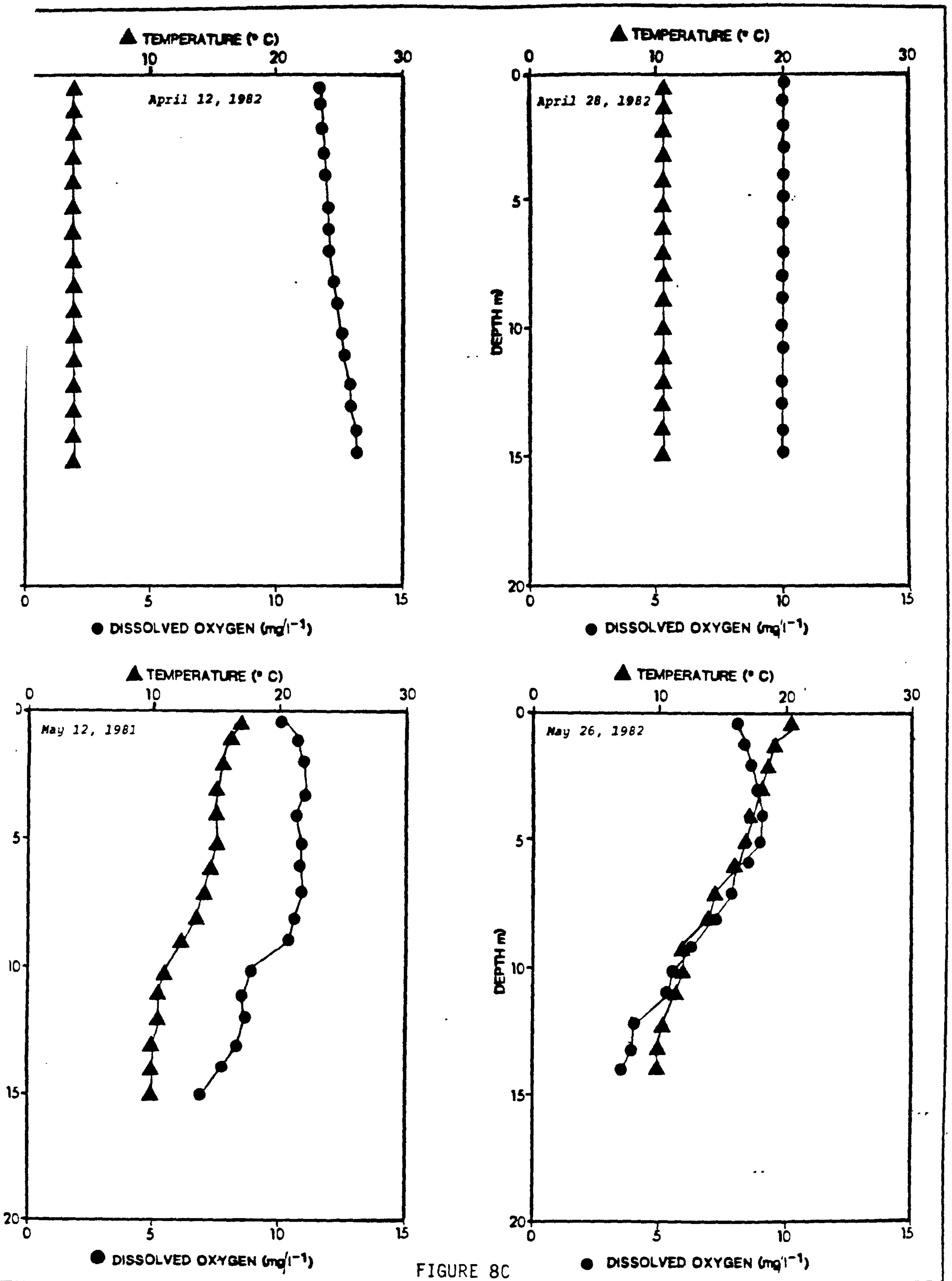


FIGURE 8C

DISSOLVED OXYGEN-TEMPERATURE PROFILE FOR LAKE HOPATCONG, SPRING 1982

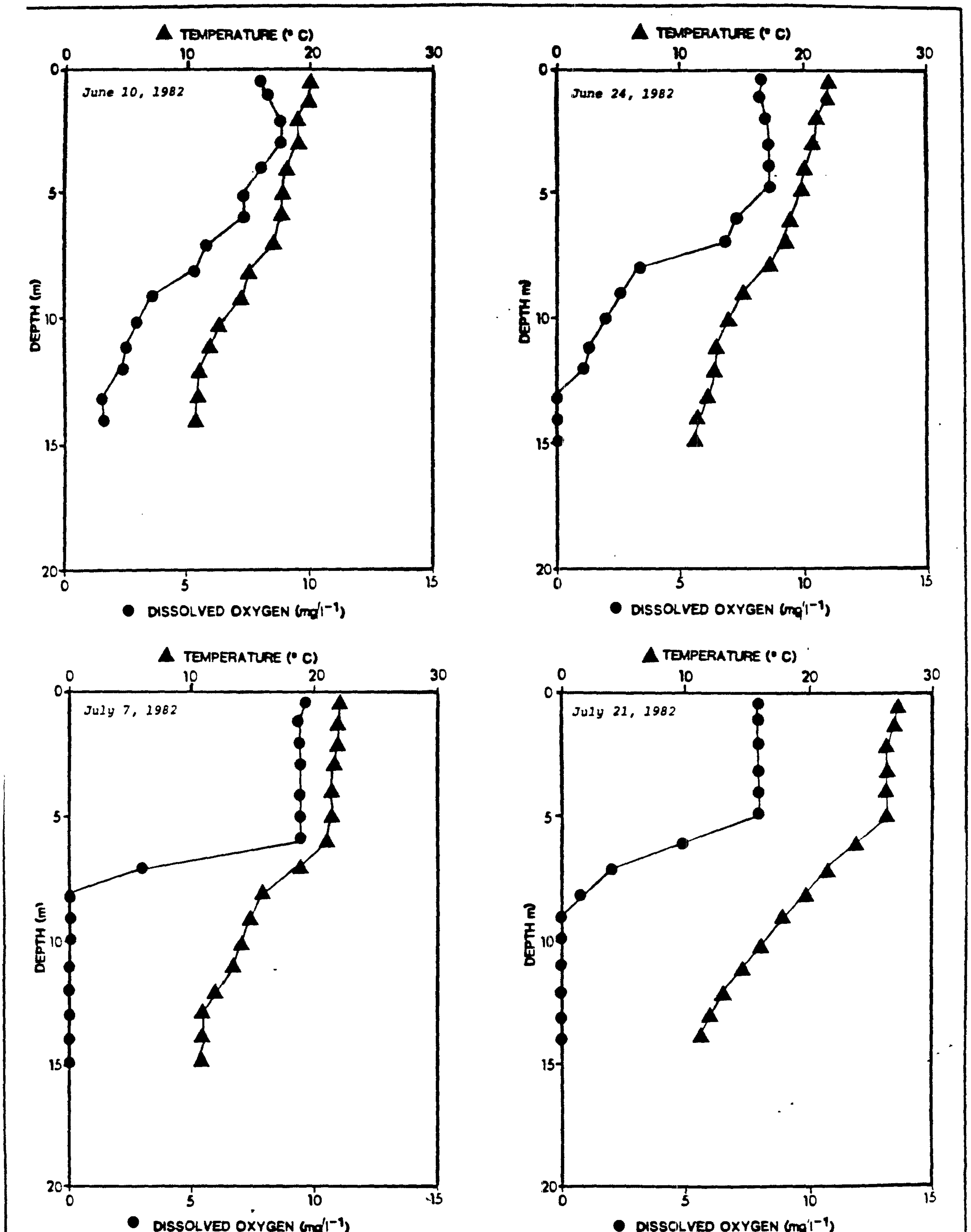
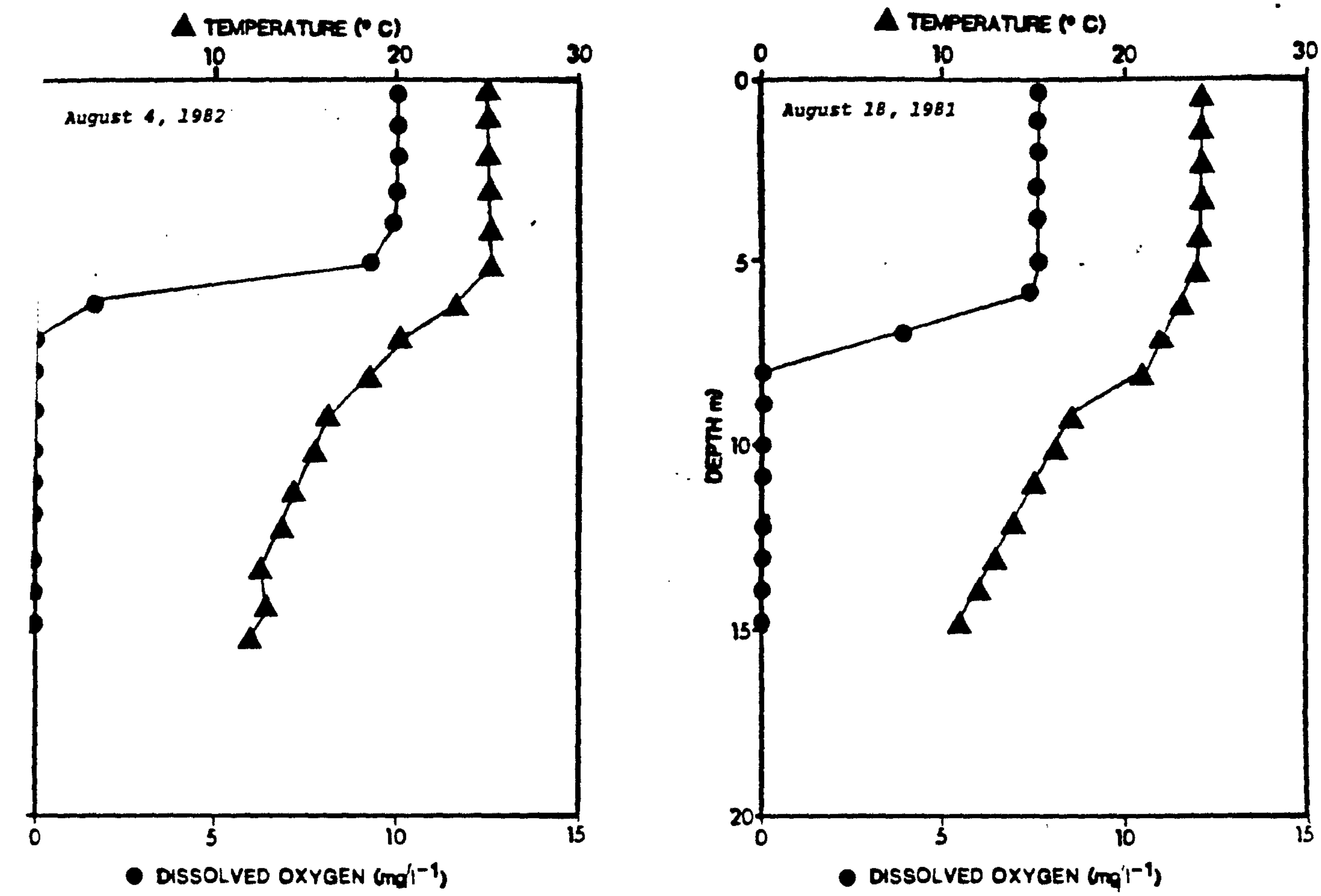


FIGURE 8D

DISSOLVED OXYGEN-TEMPERATURE PROFILES FOR LAKE HOPATCONG, SUMMER 1982



continued FIGURE 8D

DISSOLVED OXYGEN-TEMPERATURE PROFILES FOR LAKE HOPATCONG, SUMMER 1982

respiration, associated with the decomposition of allochthonous and autochthonous material, is responsible for the depletion of dissolved oxygen in the profundal zone of the lake.

This condition exerts two major impacts on the environmental inter-relationships of the lake. First, the depletion of D.O. in the cool deep sections of the lake results in the loss of valuable fish habitat, particularly for cold water species such as trout. Approximately 9 x 10^6 m^3 of lake's volume, which could serve as excellent fish habitat, are lost due to unacceptable D.O. concentrations. Second, as the D.O. approaches zero, physical-chemical properties of the lake's sediments change. Specifically, the REDOX potential, the proportion of free electrons and protons, is altered. This results in the liberation of phosphorus, normally complexed with iron and aluminum ions, from the sediments into the overlying water column. When the lake undergoes overturn in the fall, much of the sediment liberated phosphorus is mixed into the euphotic layer where it is utilized by the algae. Consequently, an autumnal algae bloom is observed. In addition, as will be discussed in following sections, short-term, storm-related mixing can also result in some volumetric exchange between the epilimnion and hypolimnion, even during stratification. This is particularly true if the hypolimnion approaches anoxia at depths just below the thermocline (Figures 9 and 10). The nutrients transported into the euphotic zone following such short-term mixing events may lead to the development of summer algae blooms (Kortmann, et al., 1982).

4. pH, Alkalinity and Hardness

The pH of Lake Hopatcong is essentially neutral. Annual mean pH values for the lake, as recorded at the various stations range from 6.83 to 7.05 (Table 32). The average pH at LH 1, LH 2, and LH 6 at all depths, is slightly acidic, while the average pH at LH 3, LH 4, and LH 5 is

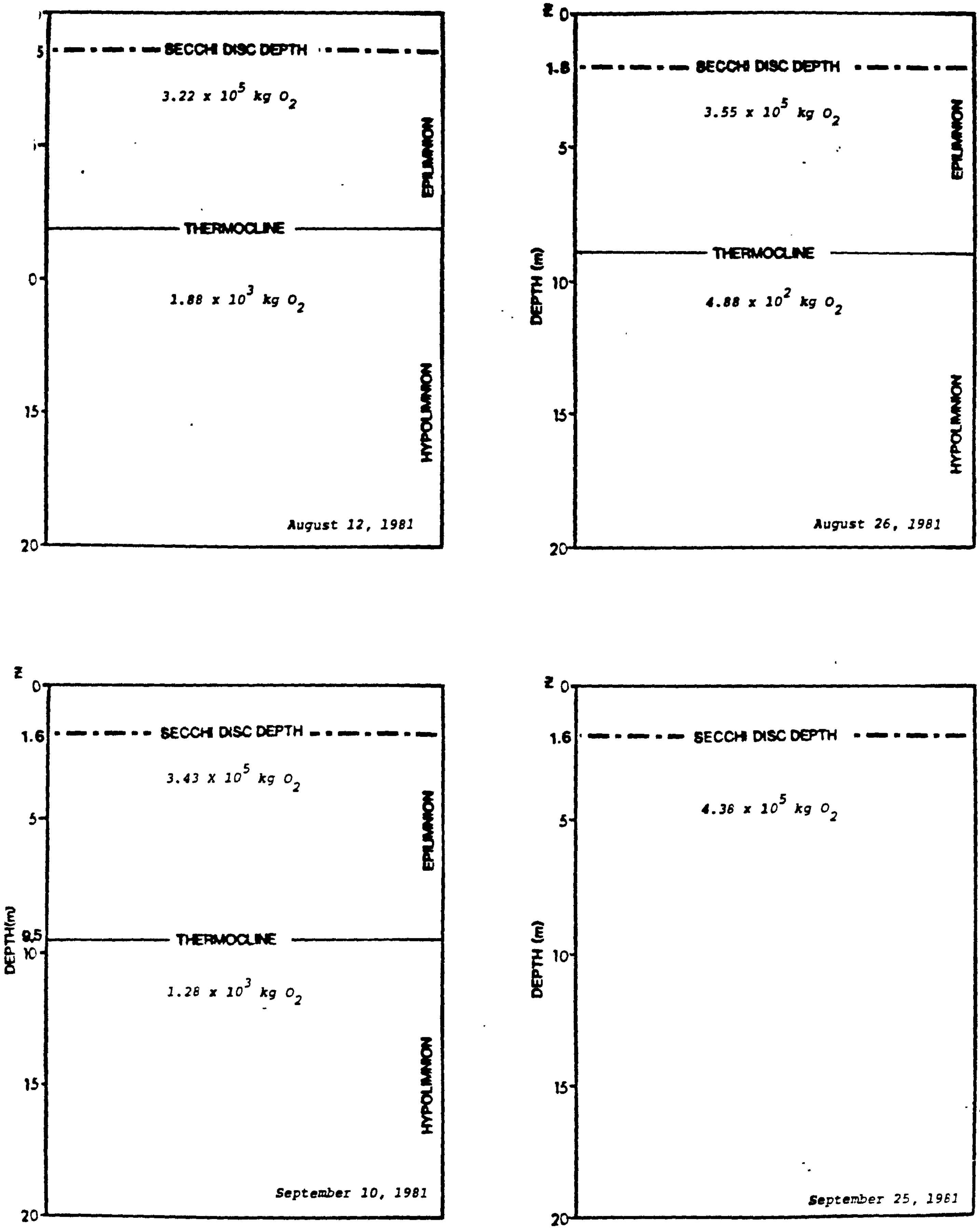


FIGURE 9A

CHANGES IN THE OXYGEN CONTENT OF THE EPILIMNION AND HYPOLIMNION OF LAKE HOPATCONG, SUMMER 1981

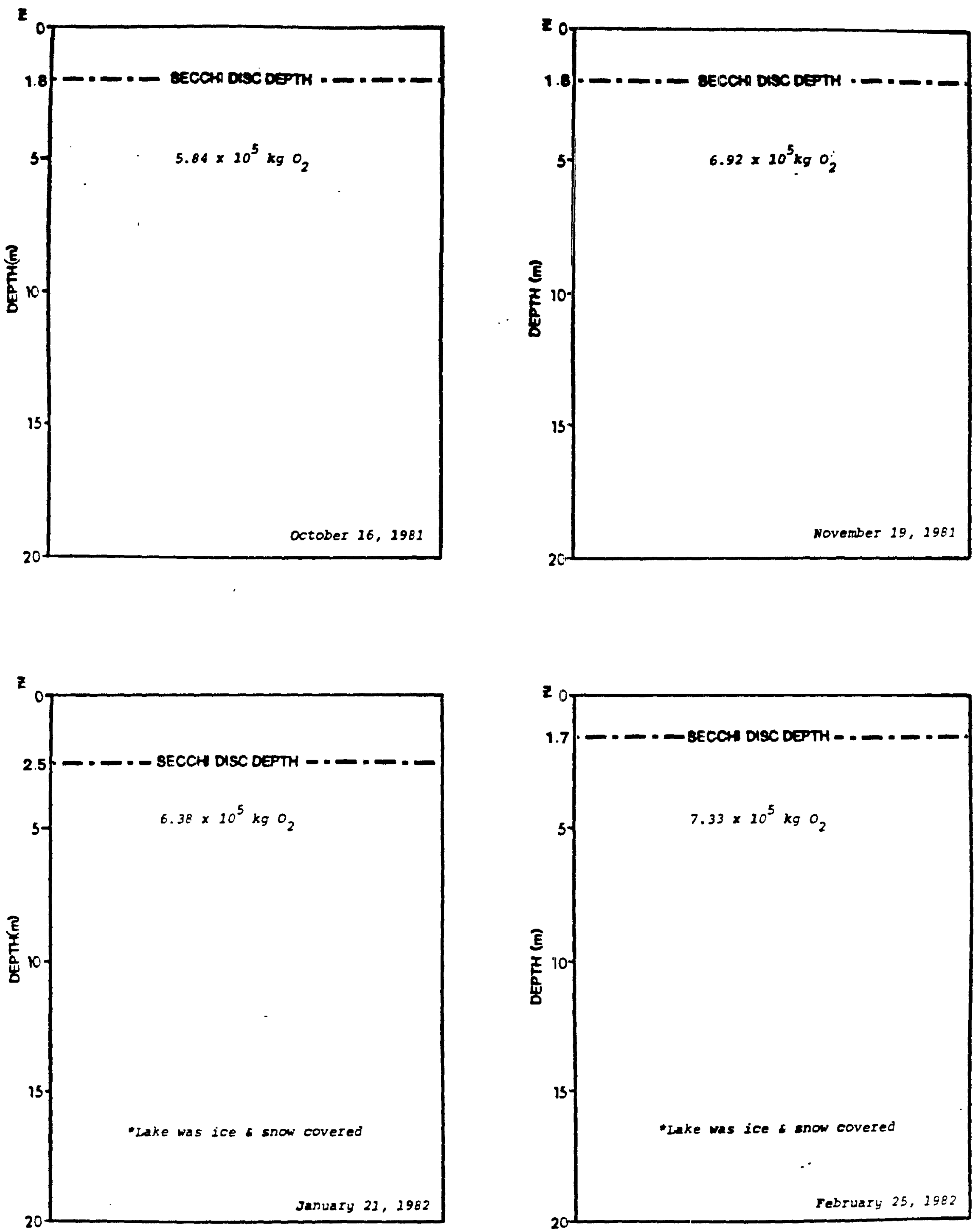


FIGURE 9B

CHANGES IN THE OXYGEN CONTENT OF THE EPILIMNION AND HYPOLIMNION OF LAKE HOPATCONG, FALL-WINTER 1981-1982

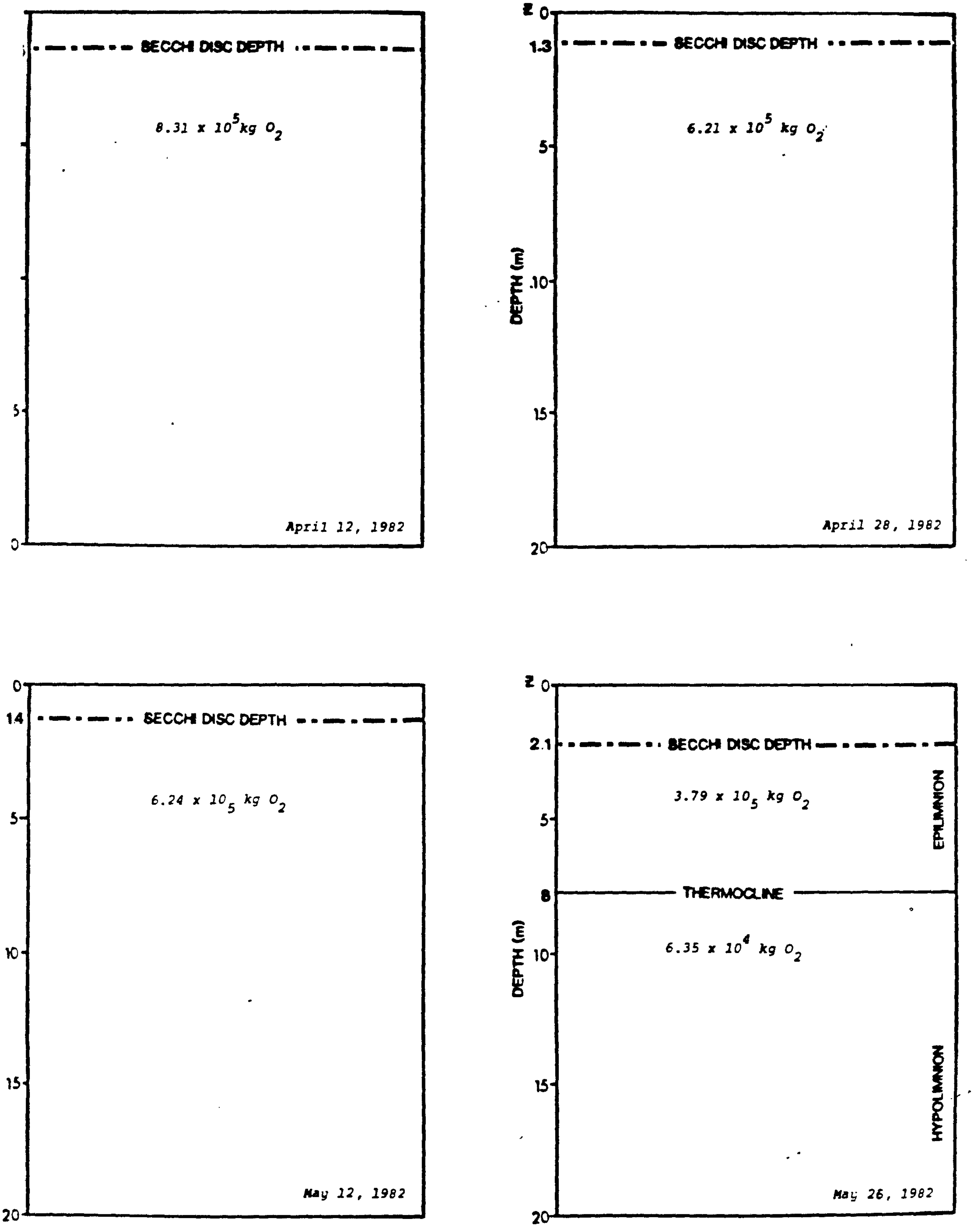


FIGURE 9C

CHANGES IN THE OXYGEN CONTENT OF THE EPILIMNION AND HYPOLIMNION OF LAKE HOPATCONG, SPRING 1982

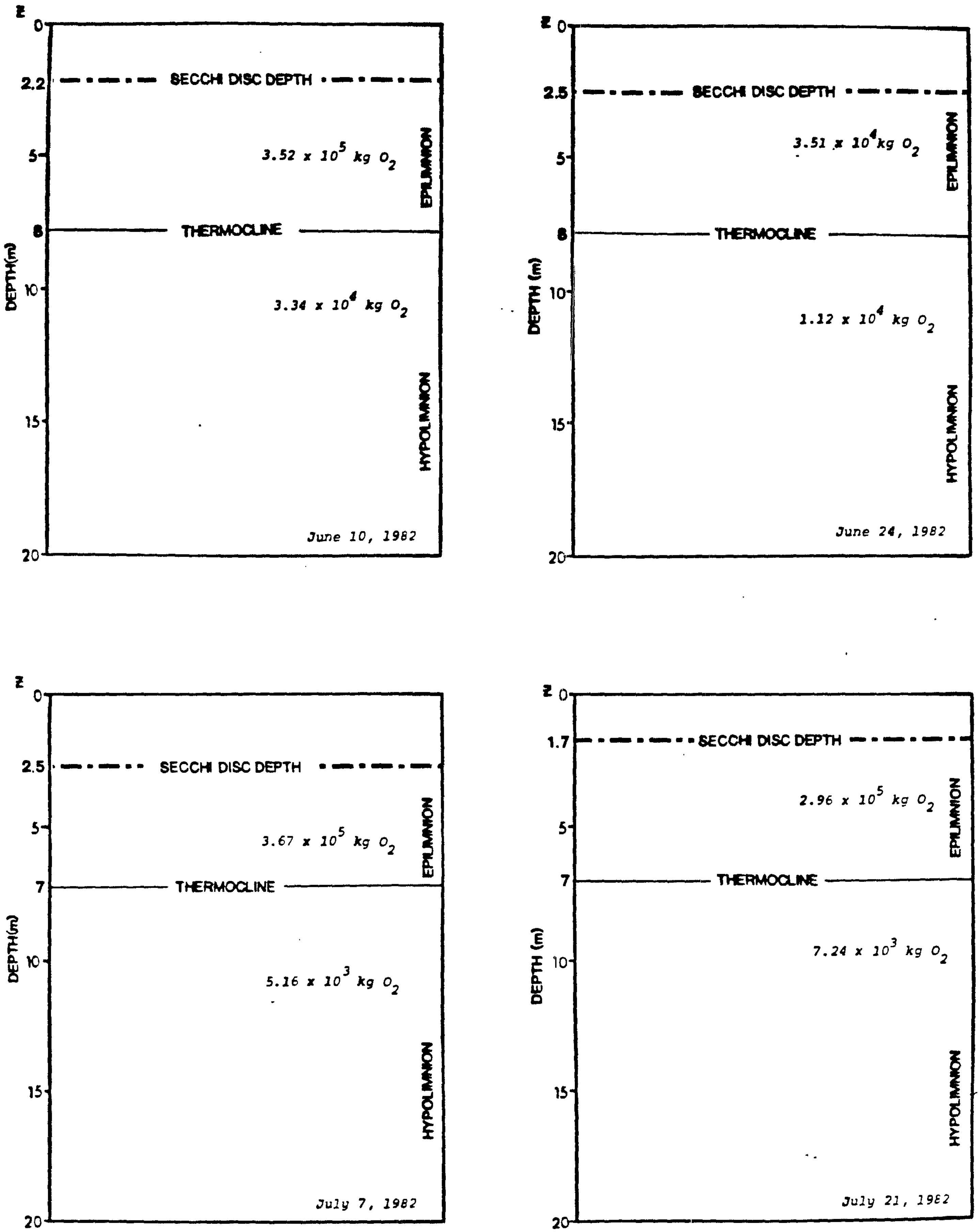
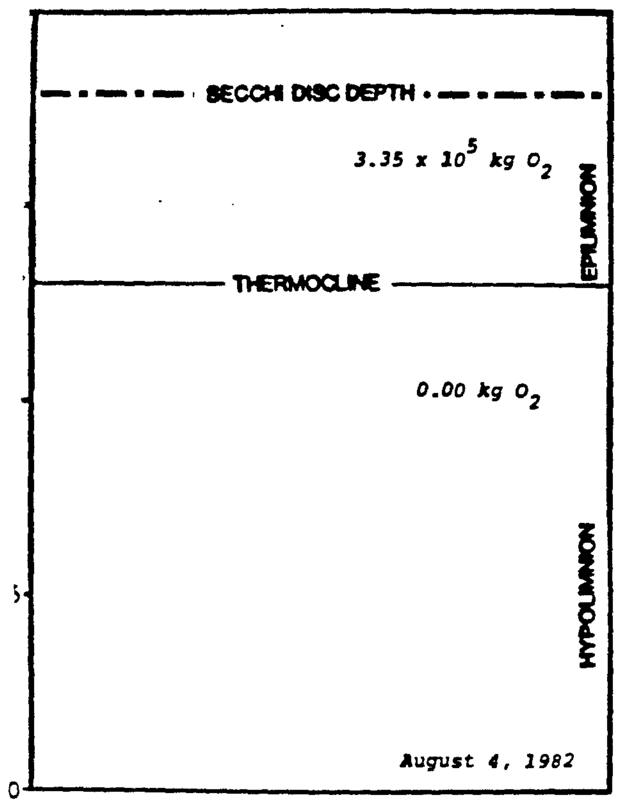
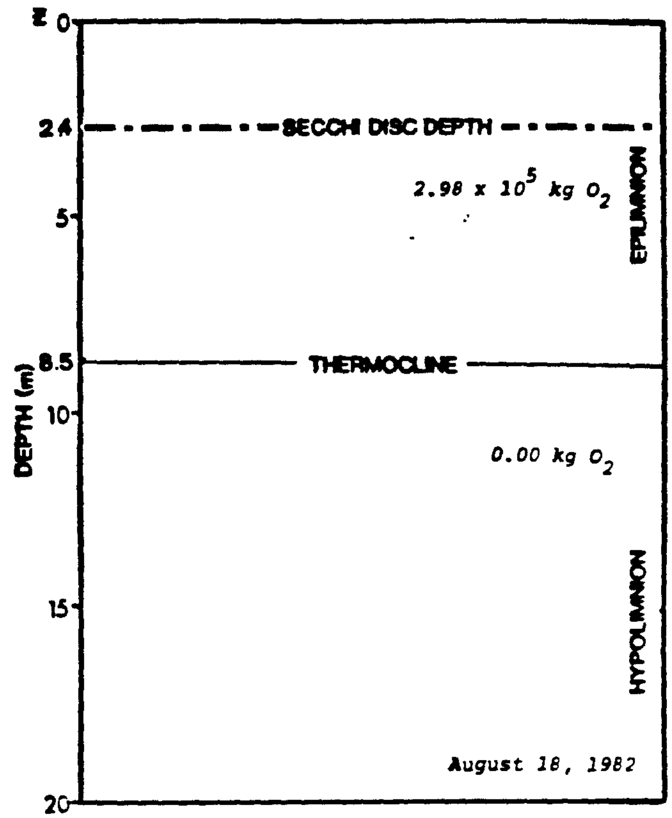


FIGURE 9D

CHANGES IN THE OXYGEN CONTENT OF THE EPILIMNION AND HYPOLIMNION OF LAKE HOPATCONG, SUMMER 1982





continued FIGURE 9D

CHANGES IN THE OXYGEN CONTENT OF THE EPILIMNION AND HYPOLIMNION OF LAKE HOPATCONG, SUMMER 1982

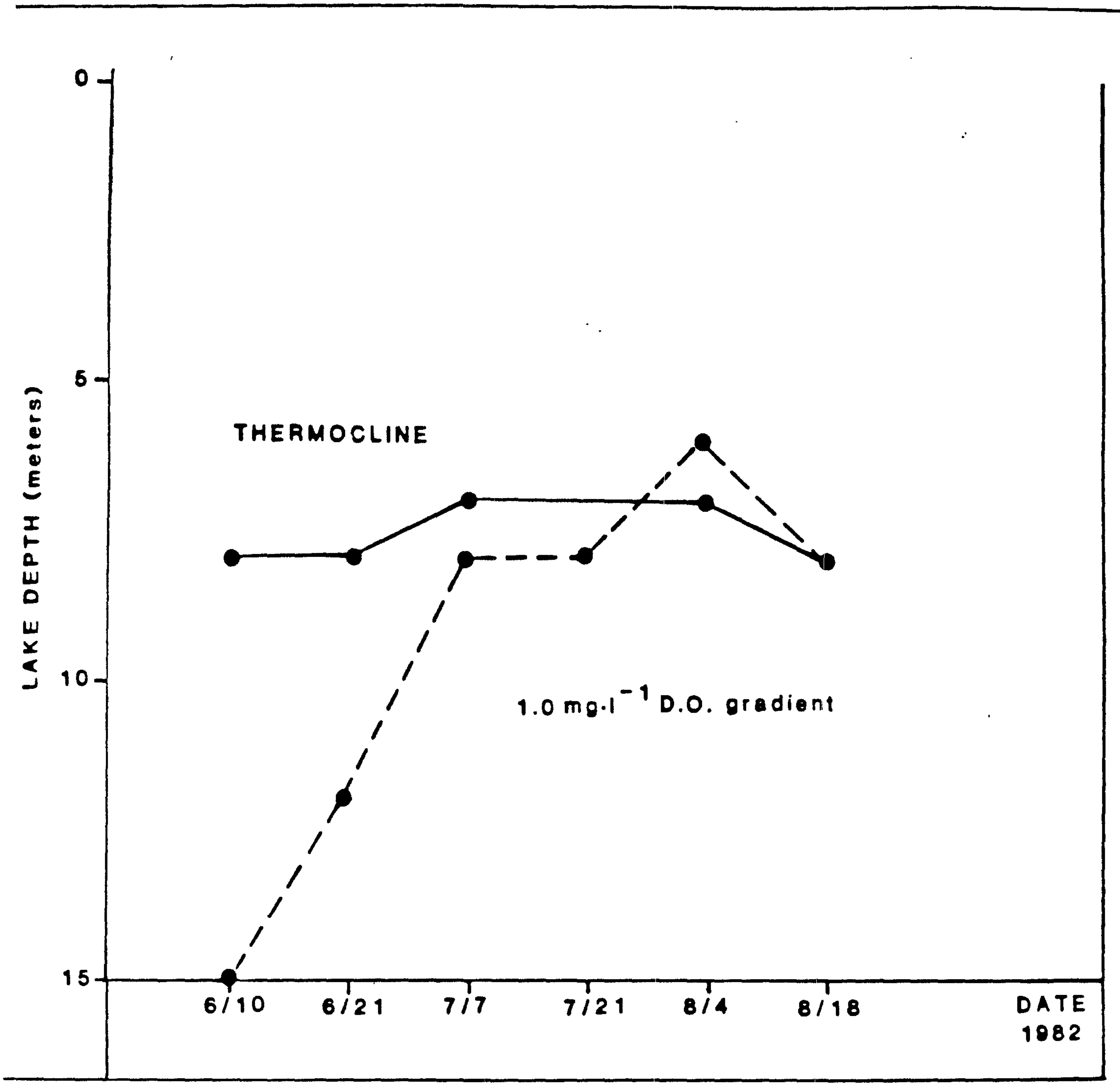


FIGURE 10
Depth of 1.0 mg.l-1 D.O. Gradient as Related to the position of the Thermocline during the summer of 1982

Table 32

MEAN CONCENTRATION OF IMPORTANT
PHYSICAL-CHEMICAL PARAMETERS OF LAKE HOPATCONG

Station No.	*Depth (m)	(spu) pH	Concentration in mg l^{-1} Alkalinity as ($CaCO_3$)	Total Hardness as ($CaCO_3$)	Dissolved Silica	Chloride	Total Suspended Solids	(NTU) Turbidity	(µmho) Specific Conductance
LH 1	0.5	6.84	27.7	59.0	1.50	33.2	9.70	24.4	138
	1.5	6.83	26.1	57.9	1.61	32.8	9.61	20.8	135
LH 2	0.5	6.89	26.2	53.0	2.27	37.9	4.65	9.74	133
	3.0	6.85	24.3	52.0	2.12	39.4	5.52	10.4	137
	6.0	6.86	24.6	52.2	2.43	38.1	4.38	7.12	135
	9.0	6.87	26.5	53.3	3.15	39.5	7.38	13.9	133
	12.0	6.87	26.8	53.0	4.07	38.9	11.0	20.2	135
	14.0	6.90	28.6	53.1	5.06	37.6	9.38	28.5	137
LH 3	0.5	7.03	28.4	53.9	2.07	39.1	5.77	9.34	136
	2.5	7.00	26.5	52.8	2.09	38.5	7.91	10.9	138
LH 4	0.5	7.06	27.0	54.7	2.16	38.5	6.52	12.1	136
LH 5	1.0	7.05	26.2	56.9	2.09	43.4	5.76	7.84	150
LH 6	0.5	6.92	24.0	51.5	2.39	39.1	8.01	11.9	135
	11.0	6.89	27.9	52.9	4.35	40.8	10.9	18.6	133

*Sampling depths were slightly variable with the majority of the samples collected at the specified depths.

slightly alkaline. The former three stations are in the northern end of the lake, whereas the latter three are in the southern end of the lake. In addition, the pH, as measured at LH 1, LH 3, LH 4, and LH 5, display greater temporal variability than do the remaining in-lake stations. Photosynthetic induced pH shifts, related to the productivity of aquatic macrophytes is probably responsible for the observed variability (Halstead and Tash, 1982).

Lake Hopatcong has a low to moderate buffering capacity, as indicated by alkalinity concentrations which range from approximately 24 to 29 mg l^{-1} $CaCO_3$ (Table 32). The lake is also of moderate hardness, 52 to 59 mg l^{-1} $CaCO_3$. Total hardness measurements (as $CaCO_3$) are fairly consistent throughout the lake both on a temporal and spatial basis. However, alkalinity values display substantial variability (6 to 35 mg l^{-1} $CaCO_3$), particularly in the summer. The most pronounced variability is observed at stations LH 1, LH 3, LH 4, and LH 5, and is caused by photosynthetically induced shifts in the carbonate equilibria of the lake.

5. Specific Conductance

The mean specific condunctance of the lake ranges from about 133 to 150 mho) (Table 32). Specific conductance, a measurement of salinity expressed as the reciprocal of resistence to electrical flow, is proportionately related to the dissolved ion content of the water. The greater the ion content, due to carbonates, chlorides, sodium, magnesium, etc., the higher the specific conductance. In Lake Hopatcong, the concentration of ionic material is typical for moderately soft water, open drainage lakes.

6. Suspended Solids and Turbidity Effects on Lake Transparency

The concentration of total suspended solids displays both temporal and spatial variability. Mixing events and storm contributions appear responsible for the observed variability and abrupt and localized changes in TSS concentrations commonly measured.

Turbidity values typically reach maximum levels in August at all surface water stations. Peak turbidity values coincide with summer algae blooms, and are probably the result of increased algal cell densities. A similar phenomenon is observed at LH 2 at depths greater than 9.0 m, and at LH 6 at 13.5 m. In these cases, the increased turbidity observed during the summer appears related to the sinking of senescent algal cells. The hypolimnetic water, because of its cooler temperature, is of greater density. As the scenescent cells pass into the denser layers of the lake, their settling velocity decreases, the cells accumulate, and turbidity bands are formed.

7. Nutrients

The concentrations of nitrate (NO^3-N), ammonia (NH_3-N), and total kjeldahl nitrogen (TKN) follow a seasonal pattern typical for eutrophic waterbodies (Table 33).

Nitrate concentrations, as measured at the lake surface, typically decrease from spring to summer but increase in the fall at all stations. The summer decrease is attributed to uptake and utilization of nutrients by phytoplankton cells. Although the data is somewhat variable, examination of nitrate concentrations as related to lake depth as measured at LH 2, the deepest spot in the lake, reveal some fairly

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Table 33

MEAN SEASONAL CONCENTRATION OF NITRATE, AMMONIA, AND TOTAL KJELDAHL NITROGEN

		Mean Concentration mg l^{-1}								
		Spring (April-June)			Summer (July-Sept)			Fall-Winter (Oct-March)		
Station No.	*Depth (m)	NO_3-N	NH_3-N	TKN	NO_3-N	NH_3-N	TKN	NO_3-N	NH_3-N	TKN
LH 1	0.5	0.124	0.120	0.232	0.085	0.096	0.234	0.296	0.062	0.230
	1.0	0.118	0.294	0.430	0.038	0.107	0.236	0.046	0.028	0.698
LH 2	0.5	0.088	0.177	0.397	0.026	0.082	0.284	0.136	0.084	0.387
	3.0	0.078	0.123	0.258	0.142	0.081	0.149	0.124	0.063	0.196
	6.0	0.098	0.196	0.361	0.081	0.075	0.169	0.121	0.134	0.264
	9.0	0.135	0.191	0.316	0.072	0.177	0.223	0.105	0.091	0.245
	12.0	0.091	0.219	0.361	0.064	0.328	0.498	0.126	0.084	0.202
	14.0	0.098	0.269	0.469	0.174	0.600	0.728	0.173	0.065	0.364
LH 3	0.5	0.108	0.115	0.332	0.054	0.073	0.279	0.112	0.050	0.222
	2.5	0.114	0.090	0.219	0.064	0.060	0.149	0.162	0.049	0.196
LH 4	0.5	0.120	0.273	0.474	0.043	0.116	0.222	0.105	0.056	0.212
LH 5	1.0	0.181	0.311	0.436	0.074	0.075	0.206	0.201	0.113	0.182
LH 6	0.5	0.082	0.216	0.370	0.097	0.060	0.134	0.184	0.106	0.190
	11.0	0.090	0.334	0.428	0.327	0.234	0.302	0.097	0.106	0.185

* Sampling depths were slightly variable with the majority of samples collected at the specified depths.

interesting information (Figure 11). From the time of spring overturn until the lake stratifies there is a continual increase in nitrate in the profundal zone of the lake. This is attributable to the decomposition of detritus and the liberation of nitrogen compounds. After stratification, nitrate concentrations decrease. This occurs because as the hypolimnion becomes devoid of oxygen, NO_3-N is utilized as an alternate electron donor, in the place of oxygen. This process, termed denitrification, involves the bacterial assimilation and conversion of nitrate to nitrogen. Upon destratification and fall turnover, NO_3-N concentrations increase once again in the deeper layers.

The concentration of ammonia at the surface is consistently greatest in the spring at all stations, and typically decreases through the summer and fall (Table 33). At the deep water station, LH 2, summer concentrations of NH_3-N increase during the summer at depths greater than 12.0 m. Increased ammonia concentrations are associated with thermal stratification, oxygen depletion, and changes in the REDOX potential of the sediments. Ammonia is produced through the bacterial decomposition of organic deposits and liberated into the overlying waters thereby enriching the hypolimnetic waters.

Total kjeldahl nitrogen concentrations at the surface of the lake tend to decrease from spring to summer but increase in the fall at most lake stations. In general, the concentration of TKN is greatest during the summer at lake depths greater than 12.0 m.

The concentration of orthophosphate (PO_4-P) is fairly consistent at the surface for all stations from spring through summer (Table 34). During the fall-winter period a slight decrease in PO_4-P is observed. In the spring and fall-winter periods, the PO_4-depth profile reveals fairly consistent concentrations from surface to bottom as measured at LH 2.

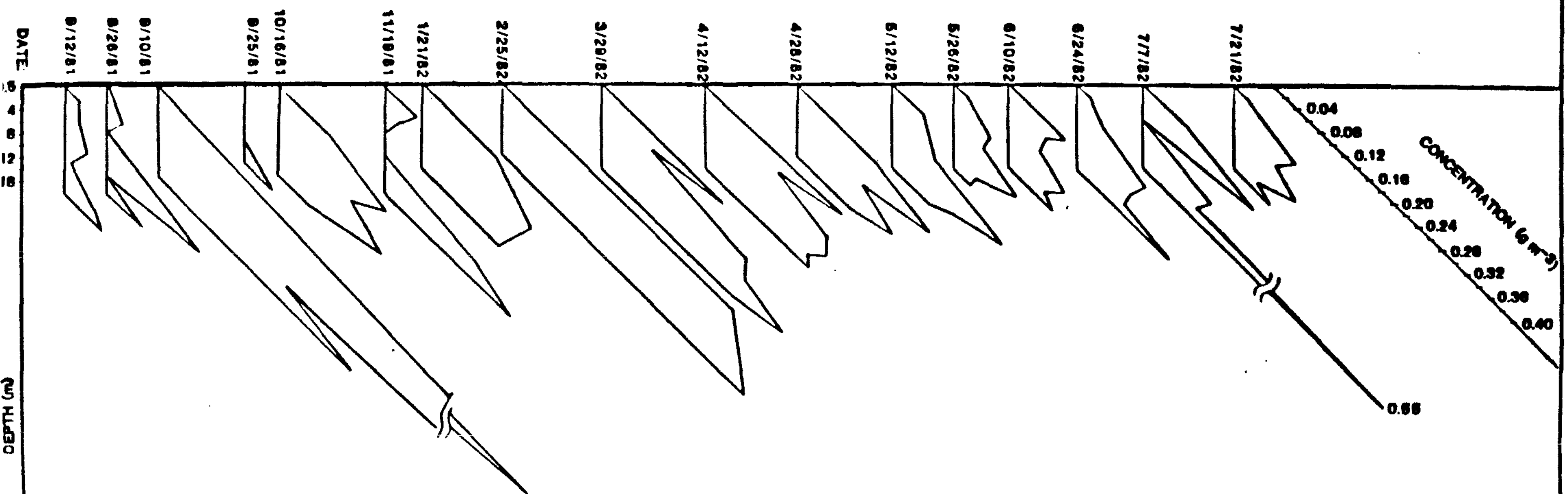

FIGURE 11

TEMPORAL CHANGES IN THE NITRATE-NITROGEN PROFILE OF LAKE HOPATCONG

MEAN SEASONAL CONCENTRATION OF ORTHOPHOSPHATE AND TOTAL PHOSPHORUS

		Mean Concentration mg l^{-1}					
		Spring (April-June)		Summer (July-Sept)		Fall-Winter (Oct-March)	
Station No.	*Depth (m)	PO_4-P	TP-P	PO_4-P	TP-P	PO_4-P	TP-P
LH 1	0.5	0.018	0.035	0.017	0.071	0.008	0.019
	1.5	0.020	0.024	0.016	0.098	0.007	0.028
LH 2	0.5	0.009	0.023	0.012	0.036	0.008	0.023
	3.0	0.013	0.022	0.009	0.042	0.008	0.019
	6.0	0.009	0.017	0.008	0.058	0.007	0.032
	9.0	0.009	0.026	0.009	0.049	0.008	0.029
	12.0	0.010	0.021	0.024	0.110	0.006	0.026
	14.0	0.013	0.020	0.053	0.181	0.007	0.016
LH 3	0.5	0.013	0.017	0.011	0.069	0.008	0.020
	2.5	0.011	0.021	0.011	0.046	<0.007	0.046
LH 4	0.5	0.013	0.017	0.010	0.084	0.008	0.026
LH 5	1.0	0.016	0.028	0.010	0.089	0.008	0.064
LH 6	0.5	0.012	0.031	0.011	0.039	0.009	0.026
	11.0	0.008	0.111	0.022	0.141	0.010	0.039

* Sampling depths were slightly variable with the majority of samples collected at specified depths.

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In the summer, however, a noticeable increase in PO_4-P occurs at depths greater than 9.0 m. This increase is attributed to the liberation of PO_4-P from the sediments following the depletion of oxygen in the hypolimnetic zone of the lake.

Total phosphorus (TP) concentrations increase slightly from spring to summer, but decrease from summer to fall-winter period at all surface water sampling sites (Table 34). A net accumulation of TP occurs in the hypolimnion during the summer following stratification (Table 34, Figure 12). TP liberation is attributed to changes in the sediment REDOX potential resulting from oxygen depletion in the profundal, tropholytic zone of the lake. The mean TP concentrations at 12 and 14 m in the spring are 0.010 and 0.013 g m^{-3} respectively. In the summer, the mean concentrations at these same depths increase to 0.110 and 0.181 g m^{-3} respectively, an increase of approximately 10 fold. Thus, a substantial amount of TP is being liberated from the sediments. In the fall, immediately following the autumnal overturn, much of this TP is circulated into the euphotic zone where it can be utilized by primary producers. This often leads to a fall algae bloom.

There are numerous studies which document the complex limnological inter-relationship of hypolimnetic oxygen depletion, sedimentary regeneration of dissolved phosphorus, and subsequent stimulation of algal productivity. The amount of TP liberated from the sediments can contribute significantly to the total phosphorus budget of a eutrophic waterbody, and may, in itself, be sufficient to stimulate excessive productivity (Freedman and Cassale, 1977; Welch and Rock, 1980). More than half of the total phosphorus budget of a lake can originate from internal phosphorus loading (Larsen, et. al., 1981). Typically, the liberation of phosphorus from the sediments during summer stratification is 15-25% of the annual TP load of a eutrophic waterbody. The potential TP load associated with sediment release can be calculated using various loading coefficients (Nurnberg, in press; Kortmann, et. al., 1982; USEPA, 1980). A conservative approach was used in selecting that

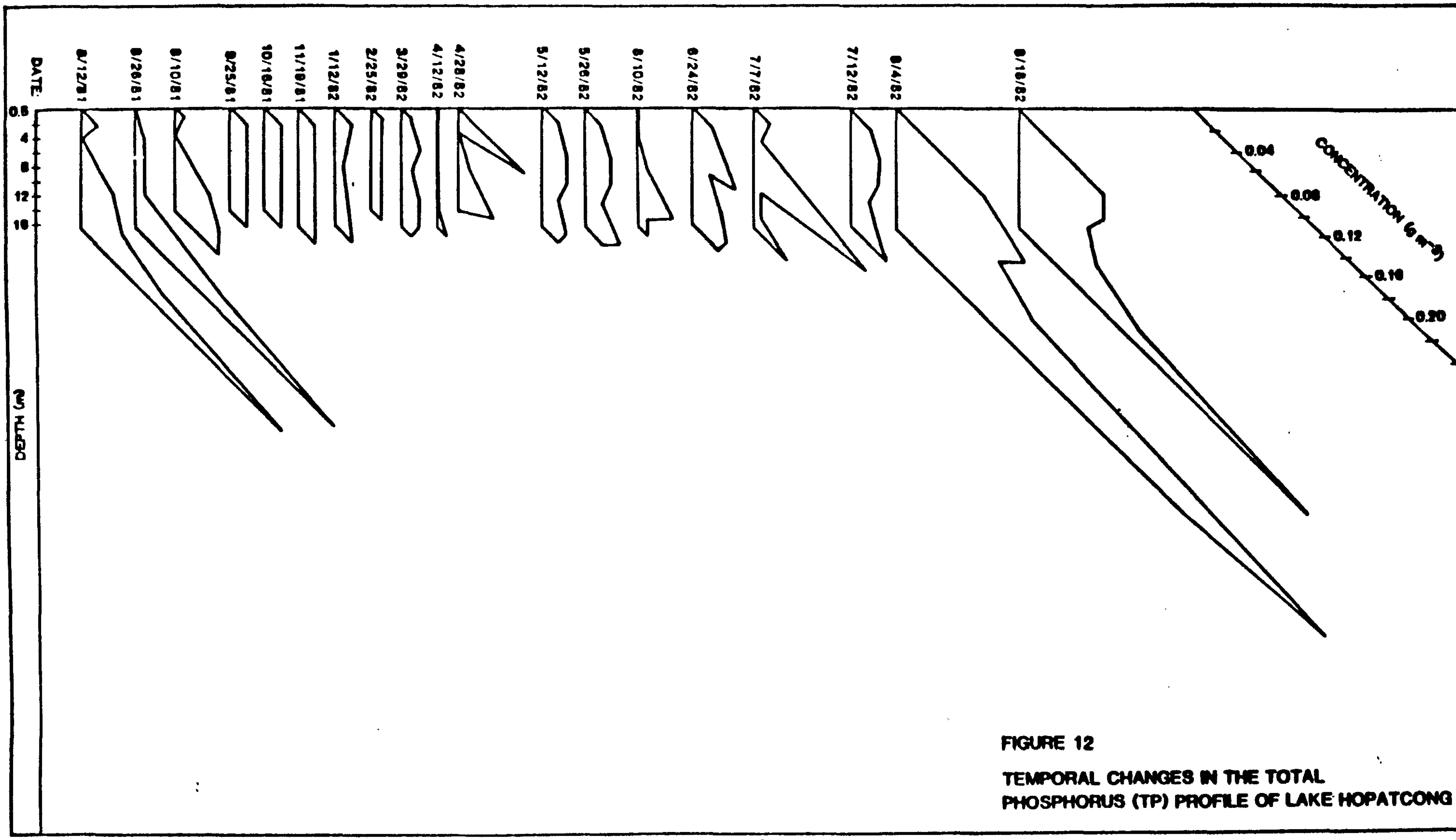

FIGURE 12

TEMPORAL CHANGES IN THE TOTAL PHOSPHORUS (TP) PROFILE OF LAKE HOPATCONG loading coefficient which best estimated the sediment release rate of TP in Lake Hopatcong. A loading coefficient of 6 mg m^{-2} day^{-1} was selected based on morphometry, hydrology, sediment TP concentrations, and the general water quality of the lake (Nurnberg, in press). The temperature-dissolved oxygen profiles indicate that from 9 m to the bottom, the hypolimnion remains anoxic for approximately 60 days (Figure 8). During this period of time, the area of the lake overlaid by anoxic water totals m^2. Utilizing the loading coefficient of 6 mg m^{-2} day^{-1} in conjunction with this data yields an internal TP load of kg yr^{-1}. This load represents the amount of phosphorus annually liberated from the sediments. Since the destratification of the lake proceeds over a very short period of time (Figure 8), the majority of the internal TP load is probably circulated into the trophogenic zone. In addition, the depth of the anoxic boundary relative to the thermocline is such that storm events can "erode" the hypolimnetic layer (Figure 10). The significance of this phenomena is that storm events can potentially mix phosphorus rich hypolimnetic water into the trophogenic zone, and stimulate algal blooms (Kortmann, et. al., 1982).

D. BIOLOGICAL DATA

1. Microbiology

Part of the natural bacterial population of the lake consists of coliform organisms which are derived from surface runoff. Fecal coliform bacteria, however, are derived from human and animal wastes. The presence of these bacteria is an indication of potential sewage pollution. It is important to note that fecal coliform bacteria themselves are not pathogenic but are indicators of the possible presence of certain pathogenic organisms such as typhoid or dysentery bacteria.

In order to quantify the extent of the bacterial contamination of the lake, PAS conducted in-lake bacteriological sampling as well as a review of historical bacteriological data.

Six stations within the lake were sampled a total of ten times between April and December 1974 (Levins and Moskowitz, 1977). The results of this sampling program indicate low fecal coliform counts in the spring with an increase as the summer approaches. One possible explanation for this increase is the influx of seasonal residents to the area with the resultant increase in recreational activity and septic system usage and failures. A significant increase in fecal coliform bacteria numbers occurred on 9/3/74. Since this corresponds to the Labor Day holiday weekend the inference can be made that the heavy holiday use of the lake and surrounding area is responsible for bacterial contamination. However, this particular sampling occurred on a rainy day. Fecal coliform bacteria in the watershed, whether of human or animal origin, would be carried into the lake via surface runoff. This would greatly increase the number of these bacteria.

A statistically significant increase in coliform bacteria was also observed during the holiday weekends of Memorial Day, July 4th, and Labor Day, of 1974 and 1975 (Levins and Moskowitz, 1977).

In an effort to study and update the extent of this potential this problem sampling and bacteriological analyses were conducted in 1982. All samples were collected, handled, and analyzed as per Standard Methods for the Examination of Water and Wastewater 14th ed. (1976). No correlation between bacteria counts and holiday weekends was indicated by those data.

A survey of the entire lake shoreline was conducted during the summer of 1982 with an Endeco Type 2100 Septic Leachate Detector System ("Septic Snooper"). Bacteriological sampling and analyses were an integral part of this survey. Those results are treated in a separate section of this report (Section VIII).

2. Phytoplankton

Chlorophyll is a photosynthetic pigment found in phytoplankton, algae and aquatic macrophytes. Its concentration in the water column is often used as an indirect measurement of the density of phytoplankton. As chlorophyll is rapidly degraded upon the death of phytoplankton cells, it is reflective of the density of live photosynthetically active cells. In lake restoration studies the concentration of chlorophyll is often used as a means of expressing in-lake productivity associated with phytoplankton. The concentration of chlorophyll a, b, and c were monitored and contrasted to the concentrations of various nutrients as a means of assessing the seasonality of water column productivity in Lake Hopatcong.

Monthly chlorophyll a values for three sampling sites are compared in Figure 13. This figure points to several factors affecting the growth of algae. The most obvious peaks in chlorophyll values are observed in the spring and fall when optimal sunlight is available for growth. In addition, it is at these times that available nutrients increase due to the seasonal overturn which promotes the mixing of nutrient rich water and stimulation of algal growth. In winter the concentration of chlorophyll a decreases due to the lower algal productivity caused by a decrease in available sunlight and colder temperatures. Fluctuations in the chlorophyll concentrations are due to a variety of factors, including seasonal conditions, the rate of horizontal and vertical mixing of the water, temperature, day length and rapid changes in the composition of plankton populations.

Algal populations with the greatest growth rates occur at LH 1, which is a shallow, enclosed area where the optimal conditions are more likely to exist (Figure 13). At LH 2 algal growth is more constant but occurs at a much slower rate. Chlorophyll a production at site LH 5 is on the average lower than at site LH 1 even though it too is a shallow,

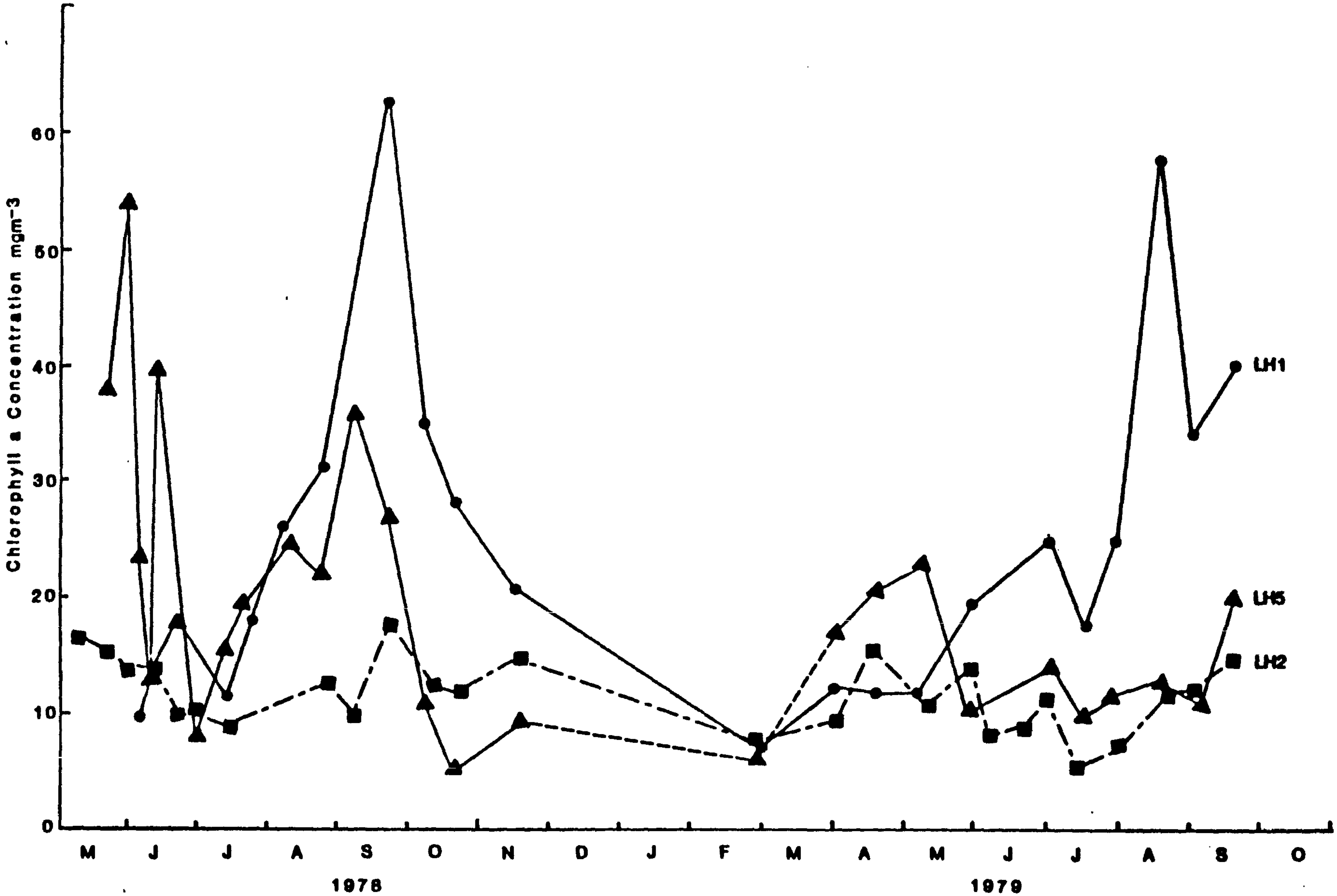

FIGURE 13
TEMPORAL CHANGES IN THE CONCENTRATION OF CHLOROPHYLL A AT STATIONS LH1, LH2 AND LH5

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enclosed area. A possible explanation for this is competition for nutrients by macrophytes which also limit available sunlight through shading.

Secchi disc transparency readings provide another indication of algae standing crops. As algae populations increase, Secchi disc transparency decreases (Figure 14). At LH 1 and LH 5, which have the highest chlorophyll a concentrations, the lowest Secchi disc transparency readings are recorded. At these sites the density of the algae populations result in turbid conditions which increase the attenuation of light.

As discussed earlier algae growth is dependant on the availability of nutrients as well as sunlight. Figure 15 illustrates the correlation between nutrient availability and chlorophyll a concentrations. Peak concentrations of nitrate are measured during the spring following ice-out and lake turnover. Orthophosphate and total phosphate reach peak concentrations during the fall turnover of the lake. Although high nutrient concentrations exist during the winter months ice cover inhibits the penetration of sunlight and thus limits the growth of algae.

Whereas chlorophyll a is found in all types of algae, the proportion of chlorophyll b and c vary in the different planktonic groups. Chlorophyll b and c can differentiate green and euglenoid algae from diatoms and dinoflagellates, respectively. In Woodport Bay, the presence of green and euglenoid algae, exhibited as chlorophyll b, appears to be relatively constant, whereas the density of diatoms and dinoflagellates fluctuate seasonally (Figure 16).

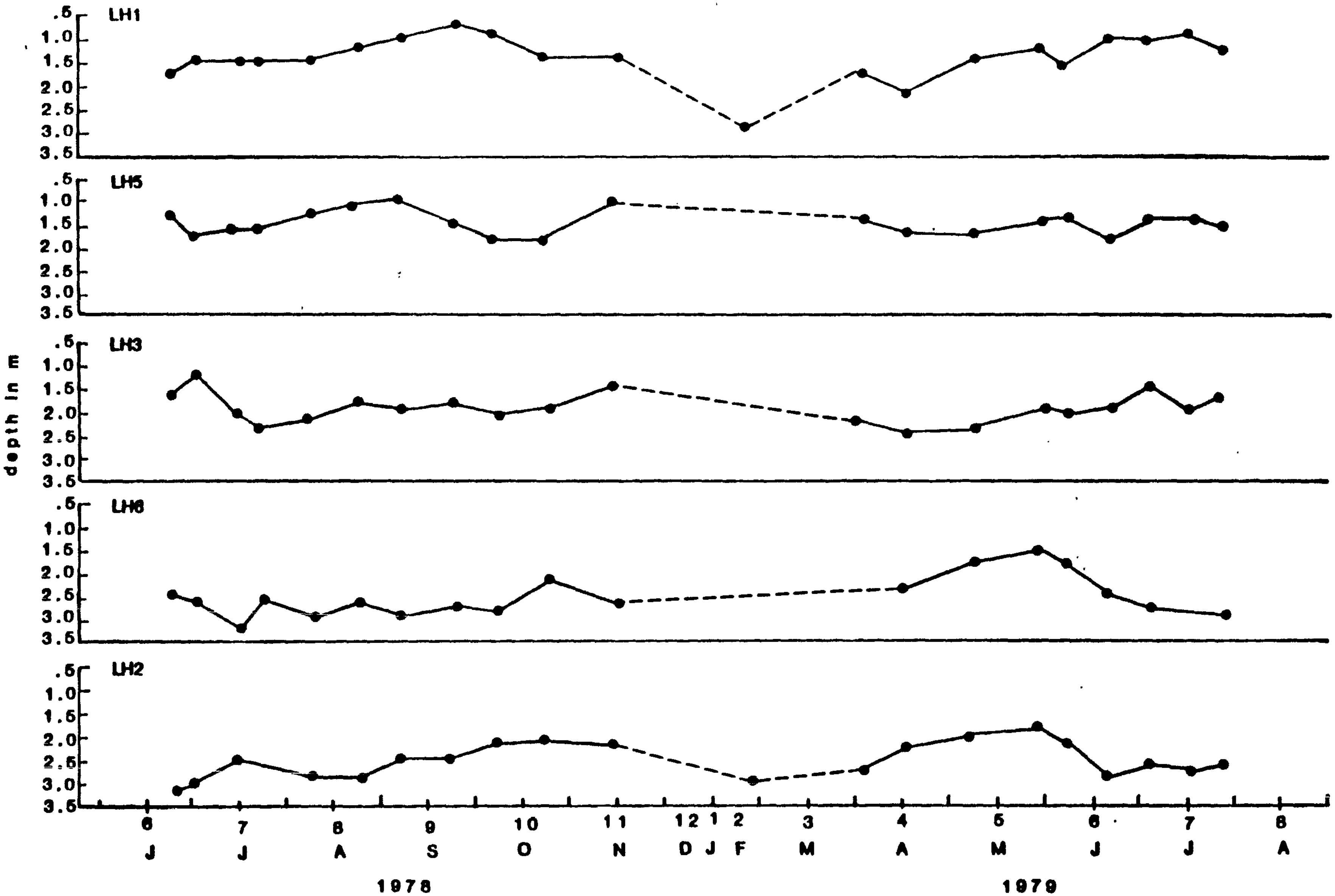

FIGURE 14
SECCHI DISC TRANSPARENCIES FOR 5 SITES
ON LAKE HOPATCONG

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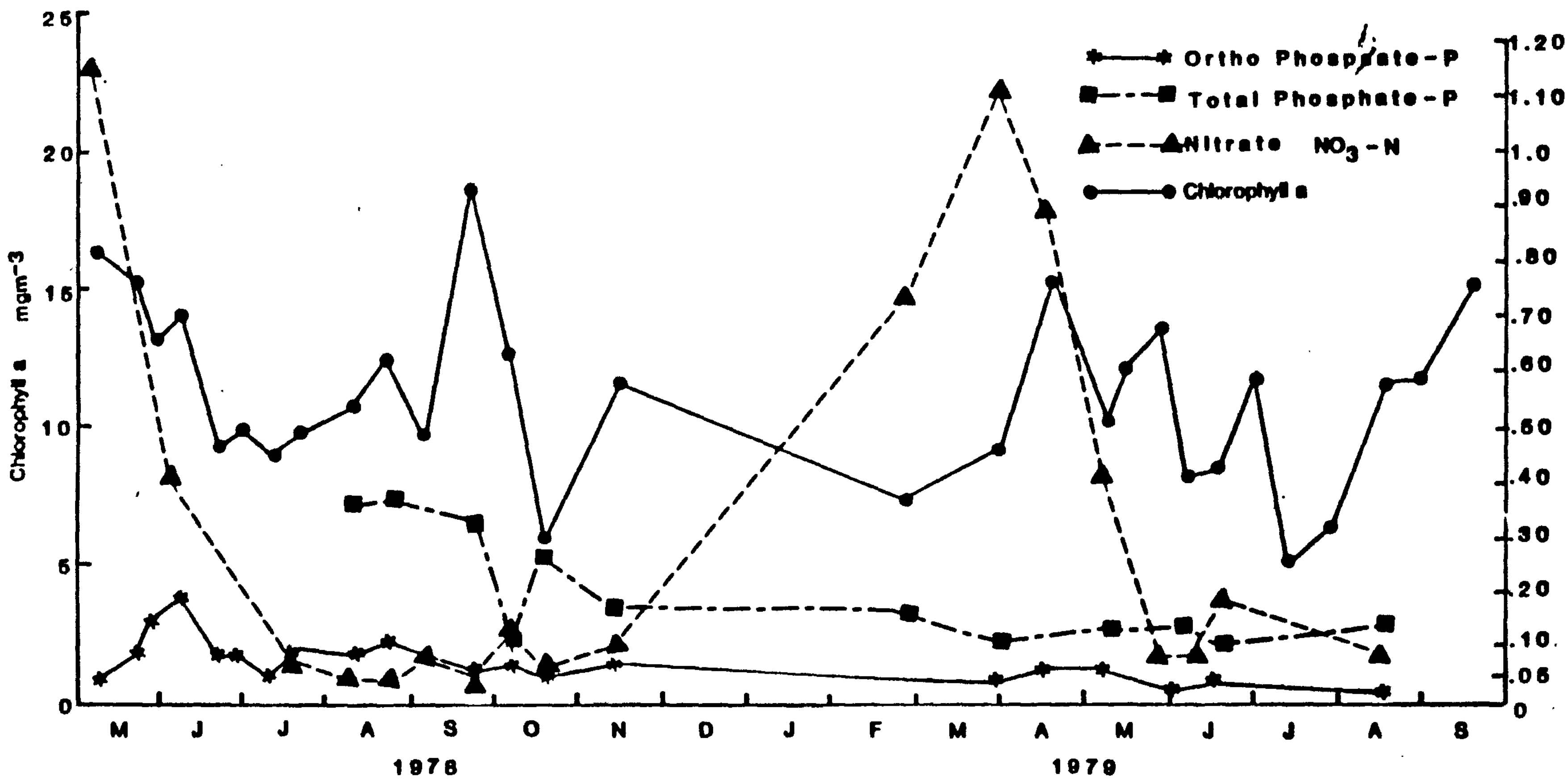

FIGURE 15
CHANGES IN THE CONCENTRATIONS OF CHLOROPHYLL A
AS RELATED TO CHANGES IN THE CONCENTRATION
OF ORTHOPHOSPHATE-P, TOTAL PHOSPHATE – P AND NITRATE – N
AT STATION LH2 , 0.5 METER DEPTH

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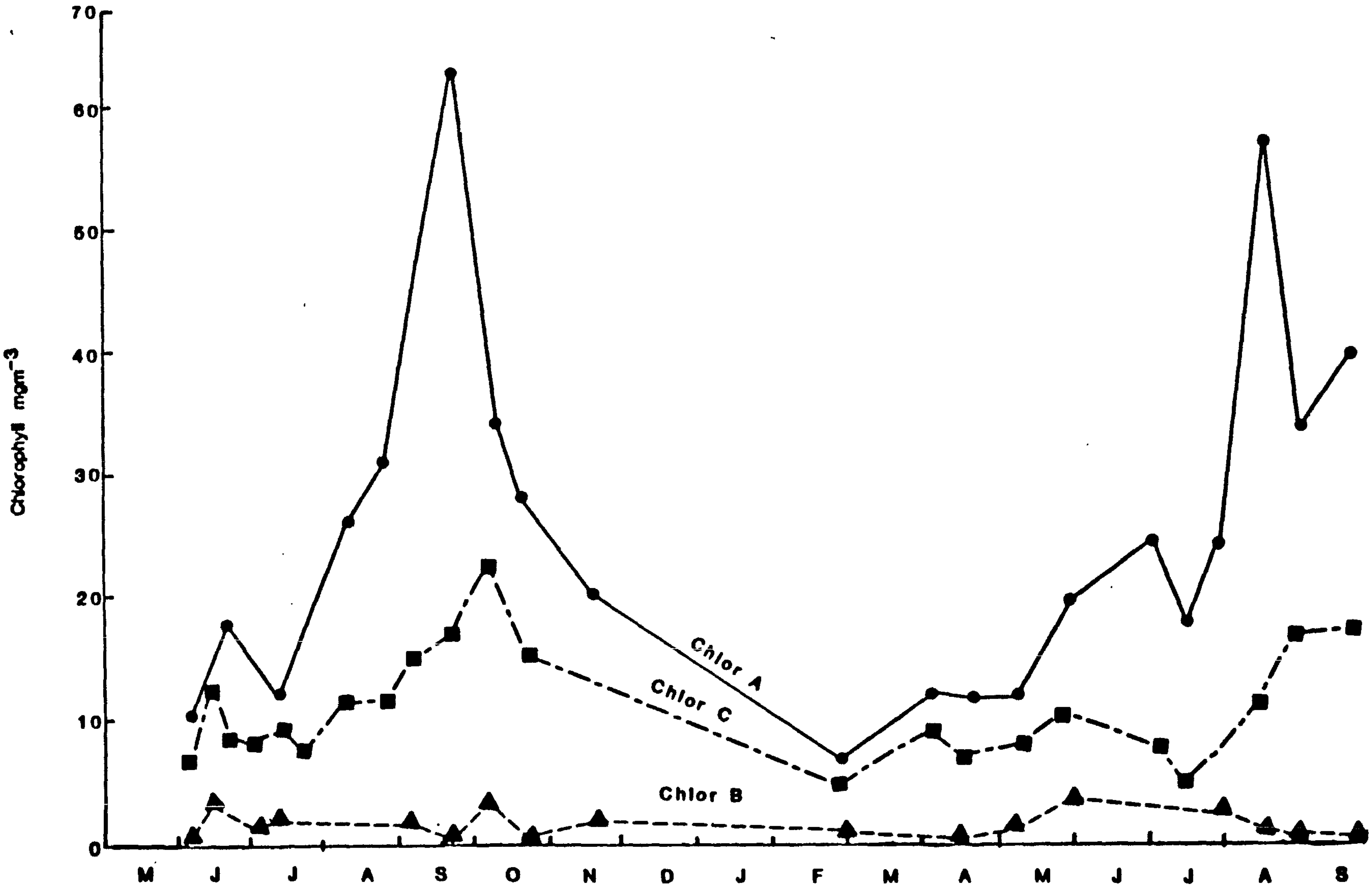

FIGURE 16
TEMPORAL CHANGES IN CHLOROPHYLL A, B AND C
IN WOODPORT BAY , LH1

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Another parameter by which further delineation between diatoms and dinoflagellates of the chlorophyll c group can be made is free silica. Diatoms use silica to produce cell walls or shells called frustules. The concentrations of free silica are lowest at sites of greatest diatom growth, LH 1, LH 3, and LH 5 (Figure 17). At the deep water sites, LH 2 and LH 6, silica levels are lower near the surface than near the bottom where the lack of sunlight prohibits the growth of diatoms and other phytoplankters. In addition, at lake depths below the euphotic zone, dead cells become decomposed and the silica, once a component of the frustules, is remineralized.

An example of the interrelation between silica and chlorophyll c is presented in Figure 18 developed from data collected at site LH 1. As the chlorophyll c concentration increases (diatom density increase), the concentration of silica decreases and vice versa.

a. Distribution and Abundance by Division

Proportionally the phytoplankton samples from all three stations were dominated by diatoms (LH 3 = 51%; LH 2 = 63%; LH 1 = 45%). At LH 1 and LH 3 blue green algae were second in terms of dominance (LH 1 = 35%; LH 3 = 25%), but were third at LH 2 (13%). The green algae were second in dominance at LH 2 (dominated 21% of samples) and third at LH 1 and LH 3 (dominated 15% and 19%, respectively). Chrysophytes dominated the samples 5% of the time at LH 1 and LH 3 and 3% at LH 2.

With few exceptions, the seasonal distribution is predictable with diatoms dominating generally in spring and blue-greens generally dominating in the warmer months of August and into September. The much greater overall unit densities at LH 1 in the summer are attributed generally to large increases in numbers of blue-green algal units.

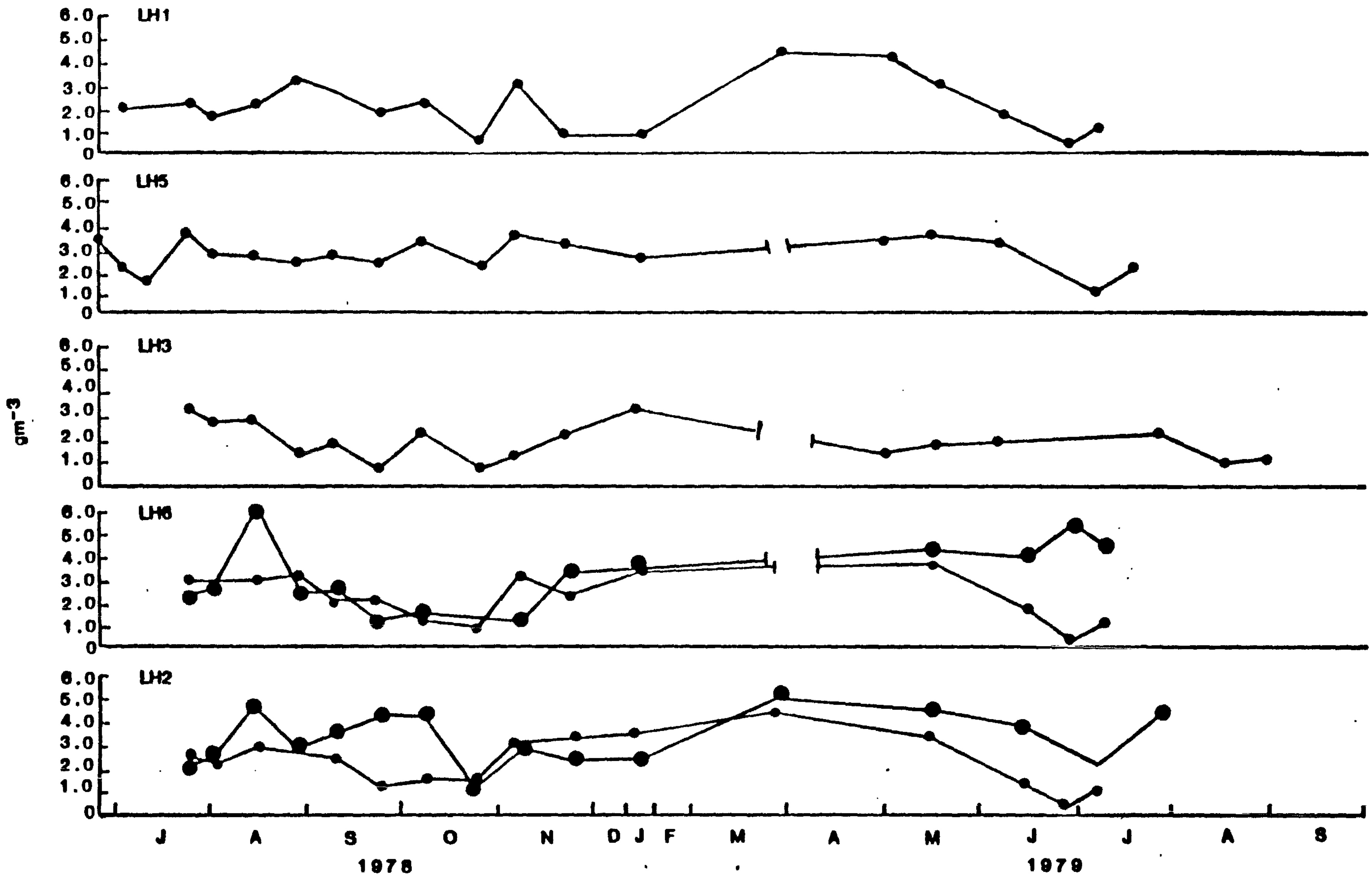

FIGURE 17
SILICA CONCENTRATIONS ($g\text{-}m^{-3}$) FOR 5 SITES
ON LAKE HOPATCONG DURING 1978 AND 1979

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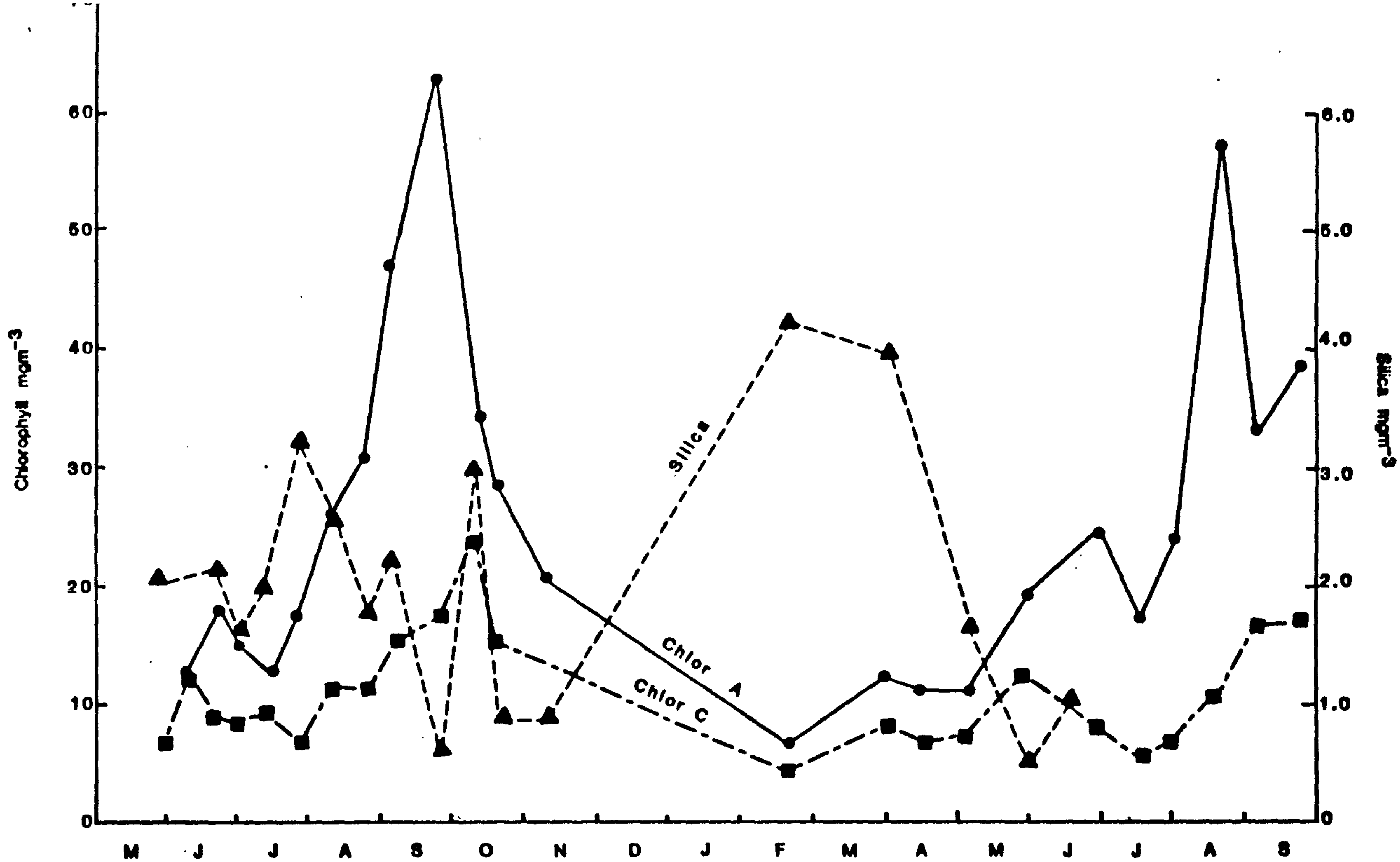

FIGURE 18
TEMPORAL CHANGES IN CHLOROPHYLL A , CHLOROPHYLL C
AND SILICA IN WOODPORT BAY, LH1.

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The biomass of the algal genera expressed as volume (m^3) is summarized in Table 35. The centric diatom genus Melosira had the greatest volume biomass at all three stations. At LH 1 this was followed by Gleocystis, Pediastrum, Coccoid greens, and Scenedesmus. At LH 3 Melosira was followed by Coccoid greens, Dinobryon, Gleocystis, and Pediastrum; at LH 2 it was followed by Synedra, Coccoid green, Tabellaria and other centric diatoms.

Table 35

LAKE HOPATCONG PHYTOPLANKTON VOLUME DATA

	LH 1							LH 3							LH 2						
	RANK	FREQ%	Occurrence as Dominance					RANK	FREQ%	Occurrence as Dominance					RANK	FREQ%	Occurrence as Dominance				
			1	2	3	4	5			1	2	3	4	5			1	2	3	4	5
Melosira	1	97	25	1	2	2	0	1	87	22	3	1	2	2	1	58	8	5	4	1	1
Coccoid Green	4	100	1	4	5	9	7	2	100	3	16	8	3	0	3	100	8	11	6	4	2
Dinobryon	6	67	4	2	2	2	1	3	81	3	7	2	4	2	16	84	5	4	2	2	2
Gleocystes	2	68	2	3	1	6	8	4	76	5	2	5	3	3	6	82	2	0	3	5	6
Pediastrum	3	91	0	14	4	5	2	5	59	0	3	6	8	4	9	24	2	2	2	2	1
Synedra	11	88	2	1	2	0	1	6	89	3	1	2	1	3	2	92	4	2	1	0	2
Tabellaria	7	94	0	2	2	4	1	7	89	1	0	5	6	4	4	89	5	5	5	1	2
Scenedesmus	5	91	0	2	5	1	10	8	87	0	2	2	6	8	7	66	0	1	4	3	4
Oocystes	15	67	0	0	0	0	0	9	57	0	0	2	0	1	11	53	0	0	0	5	1
Centric Diatom	10	97	0	1	0	1	1	10	100	0	1	1	4	2	5	100	0	3	5	8	4
Chroococcus	14	36	0	1	2	0	0	11	49	0	0	2	2	1	12	50	0	1	2	1	2
Peridinium	16	15	0	1	0	0	0	12	14	0	1	1	0	1	13	18	1	0	2	1	2
Anabaena	8	79	0	0	4	2	2	13	51	0	0	1	0	3	16	58	0	0	0	1	0
Trachelomonas	12	55	0	0	0	0	1	14	62	0	0	0	1	3	10	37	1	0	2	2	1
Collosphaerium	9	39	0	1	2	0	0	15	22	0	0	0	0	0							
Microcystes								16	65	0	0	0	0	0							
Asterionella	13	91	0	0	0	2	1								14	74	0	0	0	1	5
Glenodinium															8	37	1	2	0	2	3
Total # Samples	33							37							38						
Avg. Val. Dom.	1.0×10^{10}							1.0×10^{9}							1.6×10^{9}						

3. Aquatic Vegetation

An important part of any lake eutrophication study is a survey of the aquatic macrophyte (weed) communities of that lake. In excessive densities, emergent and semi-emergent plants can drastically hinder the recreational uses of a water body. These weeds impede the movement of boats and swimmers and make fishing difficult.

An abundance of aquatic macrophytes also causes drastic diurnal fluctuations in dissolved oxygen levels in the water column. During the day, photosynthesis takes place in the euphotic zone of the lake causing an increase in dissolved oxygen. During the night, however, these same plants cease to produce oxygen, and respire causing a drastic decrease in dissolved oxygen. This may prove taxing to fish species which can not tolerate low dissolved oxygen concentrations. Oxygen is also depleted by the bacterial decomposition of dead plant material that has settled to the bottom of the lake.

Associated with the decay of plant material is the liberation of various nutrients essential to plant growth. These nutrients are usually chemically complexed with the sediments but under anoxic conditions are released and recycled into the water column. This may facilitate either algal blooms or further growth of macrophytes. In addition, the rooted macrophytes utilize the sediment bound nutrients. Such plants rely on their roots and rhizomes to "tap" into this nutrient pool (Prentki, 1979).

Another detrimental consequence associated with the death of aquatic macrophytes is the filling in of the lake. Deposition of allochthonous organic material may represent a significant component of accumulated sediment, particularly in shallow bays which flush infrequently.

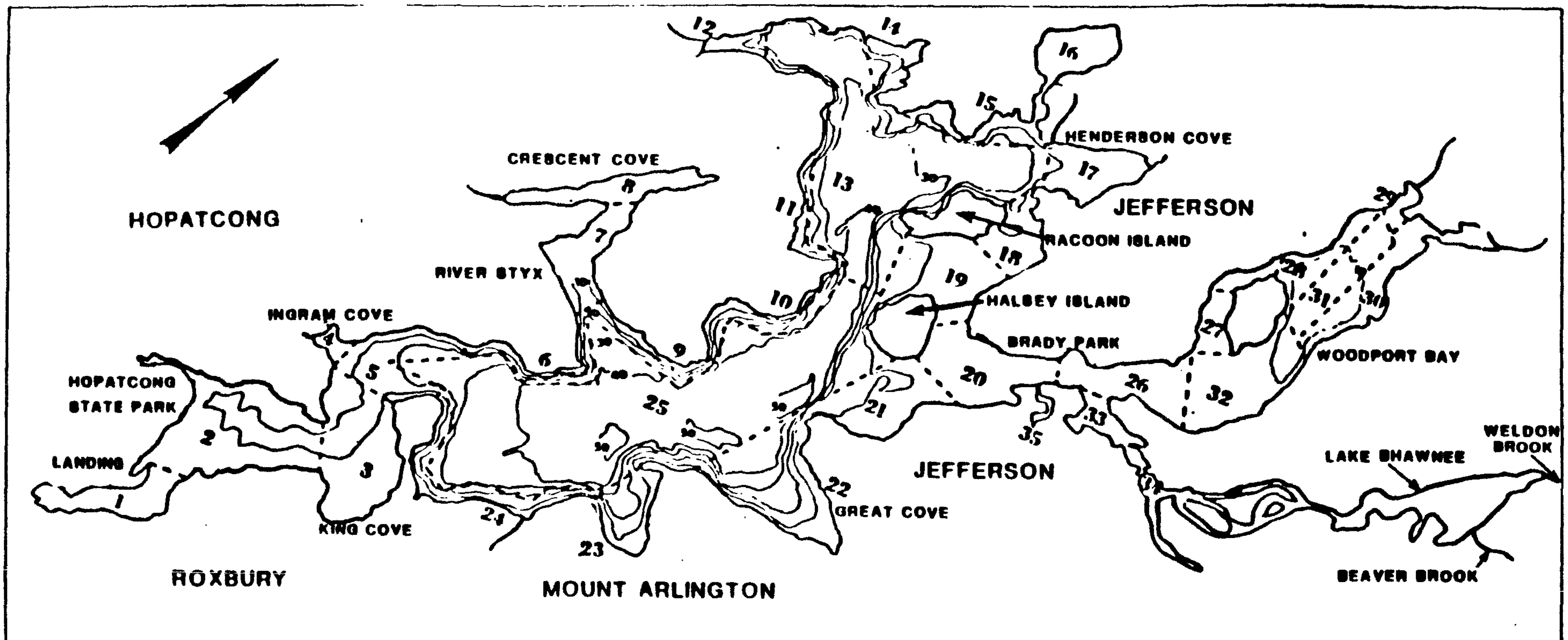
The goal of any management plan should not be to totally eliminate all aquatic macrophyte. A certain amount of weed growth is desirable. As well as being aesthetically pleasing, these weeds serve as forage and shelter for many fish and invertebrate species. Also, complete elimination of these plants may lead to the development of nuisance algal blooms.

The aquatic macrophytes were sampled, identified and mapped in an intensive survey of Lake Hopatcong conducted during the growing season (May-September) of 1978 and 1979. A combination of methods were used including surface reconnaissance, grapple, and SCUBA. The selection of a particular method was dependant primarily on the depth and clarity of the water. In addition, continual observations of the vegetation were made on each date of in-lake sampling from August 1981 through August 1982.

During the study, 250 transects were examined by the techniques described above to determine the species composition, relative abundance, and dominant species.

The emphasis of the macrophyte survey was placed on defining the different vegetative associations within the various bays and coves of the lake. Therefore, the lake was divided into 35 zones for the purpose of simplifying data analysis (Figure 19). A summary of the 1978 findings is presented in Table 36. Table 37 summarizes the problem species identified in the aquatic macrophyte survey.

The southern end of the lake encompassing the Landing Channel, State Park area, Pt. Pleasant, and King's Cove to Ingram's Cove was dominated by Myriophyllum spicatum, Najas guadalupensis, and Valisneria americana. These plants often reach the water's surface. A fairly homogenous plant community in this entire area is not surprising as the substrate is,



LEGEND

10 MACROPHYTE ZONE

FEET 0 1000 2000

0 200 400 METERS

DEPTHS IN FEET

LAKE HOPATCONG REGIONAL PLANNING BOARD

LAKE RESTORATION AND MANAGEMENT STUDY

FIGURE 19

LAKE HOPATCONG MACROPHYTE ZONES

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Table 36

DISTRIBUTION AND ESTIMATED ABUNDANCE OF
AQUATIC MACROPHYTES IN LAKE HOPATCONG

	Zone*																																			Number	
Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	of Zones	%
Myriophyllum spicatum	S	P	C	S	P	N	S	S	N	N	N	N	S	-	N	-	S	S	S	S	S	N	S	N	N	S	P	P	C	P	N	P	C	A	P	23	70%
Valioneria americana	P	P	P	D	P	S	S	C	P	S	S	P	N	-	S	-	P	C	P	P	S	P	P	P	S	C	C	P	C	P	S	C	C	C	C	31	94%
Najas guadalupensis	P	A	A	P	A	C	C	P	A	A	A	A	S	-	A	-	C	C	C	A	A	C	C	P	S	A	P	C	P	C	S	A	A	C	C	33	100%
Najas flexilis	S	S	N	N	N	S	N	N	N	N	N	N	N	-	N	-	N	N	N	N	N	N	N	S	N	N	S	N	N	N	N	N	N	S	S	8	24%
Nitella flexilia	P	S	S	N	S	0	S	S	N	P	P	P	S	-	P	-	S	S	P	C	P	C	P	P	S	C	P	S	P	C	S	P	C	C	S	31	94%
Potamogeton amplifolius	N	S	S	P	P	S	P	S	S	P	P	N	N	-	S	-	P	S	P	N	S	S	P	S	N	S	S	P	S	C	S	S	P	A	P	28	85%
Potamogeton diversifolius	S	S	N	N	N	N	S	N	N	S	S	N	N	-	N	-	N	N	S	N	N	N	S	N	N	S	S	N	N	N	N	N	N	S	S	10	30%
Potamogeton gramineus	N	S	N	N	N	N	N	N	N	N	N	N	N	-	N	-	N	N	N	S	N	N	N	N	N	N	N	N	N	N	N	N	N	S	S	4	12%
Potamogeton orispus	S	S	S	N	N	N	N	N	N	N	N	N	N	-	N	-	N	N	N	N	S	S	N	N	N	N	N	N	N	N	N	N	N	S	N	6	18%
Potamogeton perfoliatus	N	N	N	N	N	N	N	N	N	N	N	N	N	-	N	-	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	P	P	2	6%
Potamogeton epihydrus	N	N	N	N	N	N	N	N	N	N	N	N	N	-	N	-	N	N	N	N	N	N	N	N	N	N	S	N	N	N	N	N	N	S	N	2	6%
Sagittaria graminea	S	N	N	N	N	N	S	N	N	N	N	N	S	-	N	-	N	S	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	C	C	7	21%
Nuphar advena	S	N	N	N	N	N	N	N	N	N	N	N	N	-	N	-	N	N	N	N	N	N	N	N	N	N	C	N	N	N	N	N	N	A	P	4	12%
Nymphea odorata	N	N	N	N	N	N	N	N	N	N	N	N	N	-	N	-	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	C	N	1	3%
Branenia schreberii	N	N	N	N	N	N	N	N	N	N	N	N	N	-	N	-	N	N	N	N	N	N	N	N	N	N	P	N	N	N	N	N	N	C	S	3	9%
Potamogeton robbinsii	N	N	N	N	N	N	N	N	N	N	N	N	N	-	N	-	N	N	N	N	N	N	N	S	N	N	N	N	N	N	N	N	S	S	N	3	9%
Utricularia vulgaris	N	N	N	N	N	N	N	N	N	N	N	N	N	-	N	-	N	N	N	N	N	N	N	N	N	N	P	N	N	N	N	N	N	P	S	3	9%
Myriophyllum sp.	N	N	N	N	N	N	N	N	N	N	N	N	N	-	N	-	N	N	N	N	N	N	N	N	N	N	P	N	N	N	N	N	N	S	N	2	6%
Nymphea sp.	N	N	N	N	N	N	N	N	N	N	N	N	N	-	N	-	N	N	N	N	N	N	N	N	N	N	P	N	N	N	N	N	N	N	N	1	3%
Lyngbya lattisma[1]	S	N	N	N	N	N	A	A	N	N	N	S	S	-	P	-	A	P	S	N	N	N	S	N	PS	N	N	C	N	S	P	N	N	N	N	14	42%
TOTAL SPECIES ENCOUNTERED	10	9	6	4	5	5	8	6	3	6	5	4	5	-	5	-	6	7	7	5	6	6	7	6	3	6	13	6	5	6	5	5	6	18	13	-	-

[1]This is a blue-green algae that forms dense benthic mats.

*Shown in Figure 19.

N = None
S = Sparse
P = Present
C = Common

A = Abundant (codominant)
D = Dominant
PS = Pure Stand

Table 37

IDENTIFIED PROBLEM AQUATIC MACROPHYTE SPECIES IN LAKE HOPATCONG

Myriophyllum spicatum	milfoil
Potamogeton sp.	pond weed
Nuphar advena	yellow water lily
Valisenaria americana	water celery
Najas sp.	bushy pond weed
Lyngbya lattisima*	

*blue-green algae which forms dense mats on bottom of lake.

with little variation, mostly mucky throughout this portion of the lake. Depths here are mostly less than 3 meters allowing light penetration to the bottom and facilitating the development of dense to moderate weed growth. Some of the other observed macrophytes are Potamogeton crispus and Najas flexilis as well as Nitella flexilis a filamentous green algae.

Ingram Cove is a shallow cove (less than 2 m) with a bottom consisting mostly of muck. Once again Myriophyllum spicatum and Valisneria americana are found in dense concentrations. Potamogeton ampifolius is also a predominate species. Najas guadalupensis and Nitella flexilis are also present.

Myriophyllum spicatum, Valisneria americana, Najas guadalupensis and Lyngbya lattisma, a blue-green algae, are the dominant species in the River Styx/Crescent Cove area. Their dense growth, especially in Crescent Cove, is a result of the mucky substrate and shallow nature (less than 2 m) of that area.

Byram Cove showed a diversity of species composition. The mucky bottom in the Turtle Point area supports Najas guadalupensis and Elodea nutalii as the dominant species. As the depth increases to a maximum of 13 m toward Byram Bay, the substrate becomes more rocky and Nitella flexilis, with no rooting requirements, becomes dominant. Byram Cove near Knollwood contains a mixed rock, sand, and muck bottom with an accompanying mixture of predominant plant species. Besides Najas guadalupensis and Nitella flexilis; Myriophyllum spicatum, Potamogeton ampifolius, and Valisneria americana were observed to be dominant in this area of the lake.

Henderson Cove is another shallow, soft-bottomed area with moderately dense weed growth dominated by Myriophyllum spicatum, Najas guadalupensis, Potamogeton ampifolius as well as the algae Lyngbya lattisma.

Both Van Every Cove and Great Cove on the western side of the lake are deeper areas (up to 16 m deep) and therefore support only moderately dense to very sparse growth of aquatic macrophytes. Najas guadalupensis and the algae Nitella flexilis were found to be dominant in both coves with Myriophyllum spicatum and Valisneria americana codominant in Great Cove.

The deepest portion of the lake is the open, mid-lake area with depths up to 17 m. Since light penetration to the bottom occurs only in the shallow areas of the lake, plant growth was found to be very sparse with only the algae Nitella flexilis occurring as the dominant species in the upper euphotic zone of this section of the lake. Najas guadalupensis and Lyngbya lattisma were the only other species observed in the mid-lake area.

A very productive area in terms of macrophytic growth is Stump Cove. The entire cove is shallow (maximum depth approximately 1.5 m) and supports a dense and diverse plant community structure. Among the dominant plant species encountered are Myriophyllum spicatum, Valisneria americana, Najas guadalupensis, Nuphar advena, and Brasenia schreberii. Here too, the mucky bottom is conducive to plant growth.

Rather sparse vegetation was found in the center of Woodport Bay. The depth (up to 6 m) would account for this. Lyngbya lattissima and algae with no rooting requirements, appeared to be the dominant species with Valisneria americana, Najas guadalupensis, Nitella flexilis, and Potamogeton ampifolius also collected.

Woodport Cove at the extreme north end of the lake has a mucky bottom and is very shallow (less than 2 m). Dense growths of Myriophyllum spicatum and Valisneria americana were encountered along with Najas guadalupensis, Potamogeton ampifolius, and Nuphar advena.

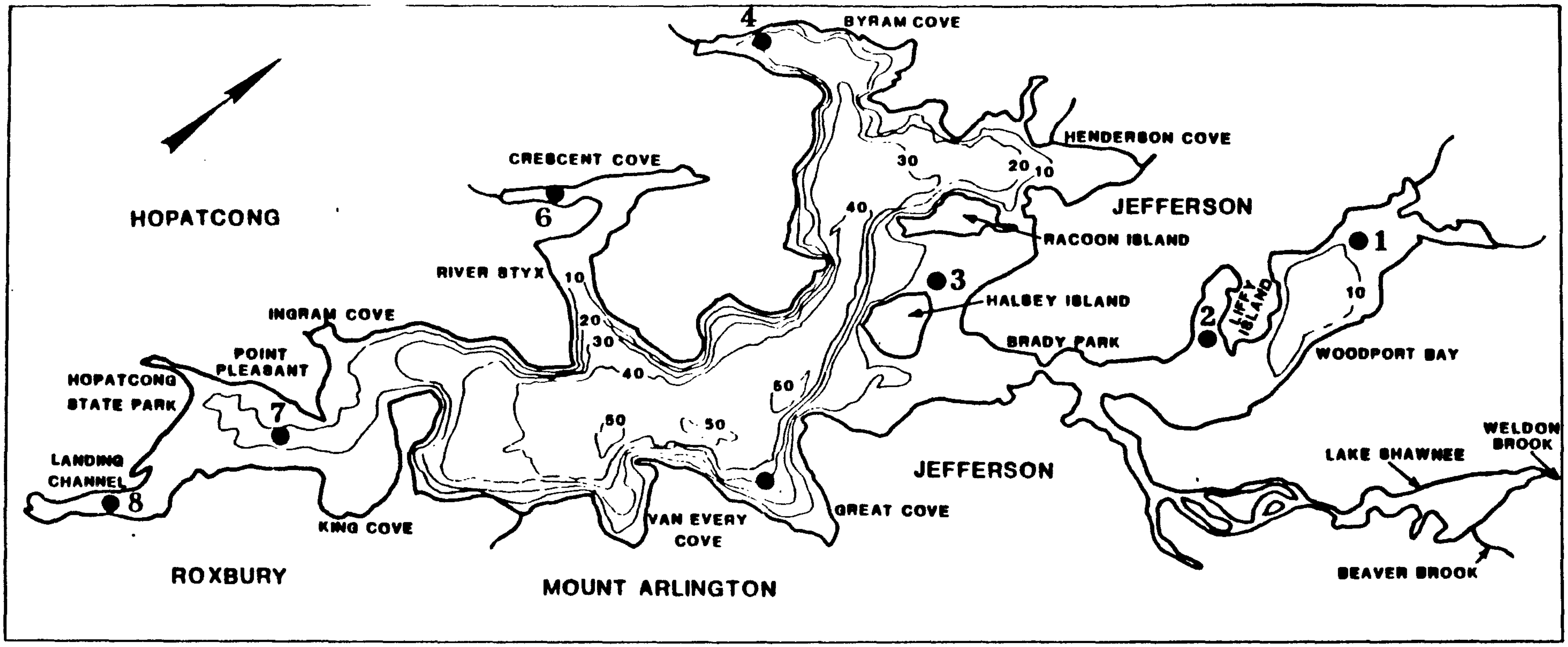
4. Benthos

On April 13, 1983 bottom grab samples were taken with an Ekman Dredge at eight locations throughout the lake (Figure 20). All samples were taken at sites where water depth ranged between 1 and 2 meters. Samples were sorted using 1000 µm and 500 µm screens. Organisms were identified to lowest possible taxon. Species diversity and percent composition were computed (Table 38). These data were used along with field observations to assess the benthic community structure and sediment-fauna ecological relationships.

Station #1, in Woodport Bay, was characterized by a high species diversity and eveness. In this shallow section of the lake the sediments are highly organic. Oxygen levels at the mud-water interface, while possibly becoming depressed at times, do not become depleted. Chrionomids and tubificids, low D.O. tolerant species, were found along with Gastropods which cannot tolerate very low D.O.'s for extended periods (Pennak, 1978).

Station #2 in the Liffy Island, Stump Cove area, is shallow, and characterized by dense stands of aquatic macrophytes. The sediments at this site are also highly organic being composed of partially decomposed plant tissue. The thick peat-like sediment had an anaerobic odor. Tubificids were found in the muck, while Gastropods were found associated with the Nuphar shoots. Species diversity and eveness were low; however, this could be a result of sampling difficulty due to the abundance of aquatic macrophytes.

The Station 3, Halsey Island, sample was dominated by Chironomids; hence, low species diversity and eveness. The sediments of this site are comprised mostly of moderately coarse sand and little organic matter. The density of macrophytes is sparse. The combination of



LEGEND:

2 ● BENTHOS SAMPLING SITES

FEET
0 1000 2000

0 200 400
METERS

DEPTHS IN FEET

LAKE HOPATCONG REGIONAL PLANNING BOARD

LAKE RESTORATION AND MANAGEMENT STUDY

FIGURE 20
LAKE HOPATCONG BENTHIC
INVERTEBRATES SAMPLING STATIONS

pas

Table 38

DISTRIBUTION AND PERCENT COMPOSITION OF
BENTHIC INVERTEBRATES SAMPLED IN
LAKE HOPATCONG

		Station															
		1		2		3		4		5		6		7		8	
Organism*		# org.	% comp.	# org.	% comp.	# org.	% comp.	# org.	% comp.	# org.	% comp.	# org.	% comp.	# org.	% comp.	# org.	% comp.
CRUSTACEA																	
Gammaridae	Sideswimmers, Scuds							1	1.54	2	7.41	75	92.6			1	0.467
Gammarus sp.																	
Asellidae	Aquatic sow-bugs							6	9.23			1	1.23			5	2.34
Asellus sp.																	
INSECTA																	
Chrionomidae	Midges	3	30.0			88	98.9	41	63.1	1	3.70					180	84.1
MOLLUSCA																	
Gastropoda	Snails	3	30.0	5	71.4	1	1.10	6	9.23	21	77.8			3	100	17	7.94
Pelecypoda	Clams							4	6.15							6	2.80
OLIGOCHAETA																	
Tubificidae	Aquatic Worms	4	40.0	2	28.6					2	7.41	5	6.17			5	2.34
Limnodrilus sp.																	
Naididae	Aquatic Worms									1	3.70						
Najas sp.																	
HIRUDINEA	Leeches																
Glossiphoniidae		—		—		—		7	10.8	—		—		—		—	
Total No. Organisms		10		7		89		65		27		81		3		214	
Species Diversity**		1.089		0.5983		0.0617		1.205		0.8255		0.5807		0		0.6463	
Eveness***		0.9909		0.8632		0.0890		0.6724		0.5131		0.5284		0		0.3607	

*Identification according to Pennak, Robert William. Fresh Water Invertebrates of the United States, 2nd ed. John Wiley & Sons, New York, New York, 1978.

**As per Shannon-Weiner Diversity Index where: $\text{Diversity} = \ln N - \frac{1}{N}[\Sigma(n_i \ln n_i)]$

where: N = total number of individuals of all species
n_i = number of indivicuals of the i^{th} species

$$\text{Eveness} = \frac{\bar{H}}{\ln S}$$

where: $\bar{H}$ = Shannon-Weiner Index
S = number of species

Station #7, off Point Pleasant, had low species diversity or eveness as only snails were collected. This area, at the time of our sampling was covered by dense stands of aquatic macrophytes. The density of the weeds hindered the use of the bottom dredge and may have resulted in a biasing of the sample.

Landing Channel (Station #8) was characterized by fairly high species diversity, low eveness, and a very high total number of organisms. Sediments of this area are mucky, very organic, with a high detrital component. This substrate is also covered by mats of Najas sp. The vast majority of the benthic assemblage was comprised of Chironomids. Their ability to tolerate low dissolved oxygen levels has benefited them in this environment where an anaerobic odor was detected upon sediment collection. Also observed here were Gammarids, Asellids, Gastropods, Pelecypods, and Tubificids.

5. Fishery

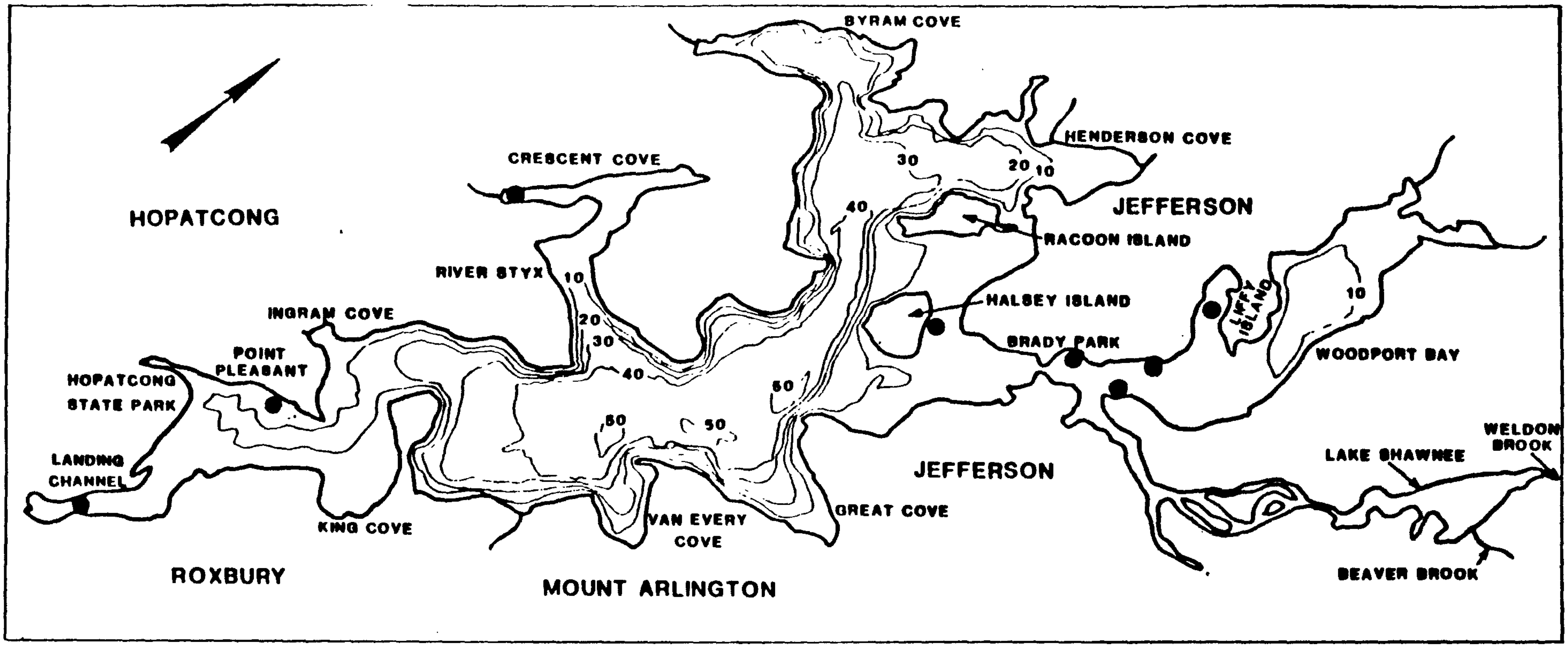
The fish community of Lake Hopatcong was sampled by haul seine at eight sites (Figure 21). The location of the sample sites was determined by accessibility, substrate and weed density. Attempts were made to acquire samples from most of the main sections of the lake.

Samples were collected with a nylon 15 m bag seine, of 1 1/2 cm stretch mesh and 1 1/4 m depth. The seine was "played out" by boat 18 to 20 m from shore. The combined length of the net and the haul lines resulted in an approximately 35 m radius sweep being made for each seine haul.

Upon landing the seine, the length and weight of each specimen was recorded. A triple beam balance was used to measure fish weight. All identifications were made in the field. A small number of specimens were returned to the laboratory. These fish were preserved in a 10% formalin solution. Notes were taken in relation to the sex, presence of gravid females, or the occurrence of males guarding nests.

These data were assessed in conjunction with historical fisheries data, fish stocking records, and data provided by the Lake Hopatcong Knee Deep Hunting and Fishing Club.

Historically, Lake Hopatcong has provided good to excellent fishing for largemouth bass, pickerel, and pan fish (NJDCED, 1950). Pickerel were considered to be the most sought after and landed game fish in the lake. This species provided excellent fishing. Their growth rate was at that time considered very good and many large specimens were routinely caught. Largemouth bass and smallmouth bass provided only fair to good fishing. However, yellow perch were considered an excellent game fish in Lake Hopatcong. These fish were taken in large numbers not only in



LEGEND

● HAUL SEINE SAMPLE

FEET 0 1000 2000

0 200 400 METERS

DEPTHS IN FEET

LAKE HOPATCONG REGIONAL PLANNING BOARD

LAKE RESTORATION AND MANAGEMENT STUDY

FIGURE 21
FISH SAMPLING SITES

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the summer, but in the winter when many of the larger individuals were caught. White perch were found to be abundant and had a growth rate which was considered to be excellent. However, this species was greatly under utilized in the lake. Other pan and game fish which were found in the lake were crappie, pumpkinseed, bluegill, red-breasted sunfish, white catfish, and northern brown bullhead (Table 39).

Of the various pan and game fish sampled, yellow perch were dominant, by number, followed by pickerel, pumpkinseed, and brown bullhead. This data is biased, however, in that it accounts only for the measured specimens. In reality, far more bluegill and pumpkinseed individuals were encountered than measured. In addition, forage fish such as alewife, golden shiner, and minnows were taken in very large numbers.

Although the stocking of the lake with cold water game fish was not highly recommended (NJDCED, 1950) Lake Hopatcong has been and continues to be stocked. During World War I, an experiment was conducted regarding the stocking of landlocked salmon. The program was unsuccessful. Since then, the lake has been stocked with brown trout, rainbow trout, and walleye (Stizostedion vitreum vitreum). The walleye project proved fruitless, but the trout stocking project has had limited success and continues to be a popular venture. At present, 1000 to 1500 fish are stocked annually on a "put and take" basis. The depletion of hypolimnetic oxygen in the deeper parts of the lake during the summer, and the lack of suitable spawning sites does not favor the establishment of a self-supporting trout population.

The results of our study (Tables 40 and 41) indicate that various sections of the lake have diverse community assemblages. The observed differences appear to be a function of weed density, substrate, and water depth.

Table 39

HISTORICAL SPECIES LIST

Salmo trutta	Brown trout (reported)
Salvelinus gairdnerii	Rainbow trout
Micropterus salmoides	Largemouth bass
Micropterus dolomieu	Smallmouth bass
Ambloplites rupestris	Rock bass
Pomoxis nigromaculatus	Crappie, Calico bass
Lepomis macrochirus	Bluegill
Lepomis gibbosus	Pumpkinseed
Lepomis auritus	Red breasted sunfish
Acantharchus pomotis	Mud sunfish
Enneacanthus gloriosus	Bluespotted sunfish
Morone americana	White perch
Esox niger	Chain pickerel
Esox americanus	Grass pickerel
Perca flevescens	Yellow pickerel
Ictalurus nebulosus	Northern brown bullhead
Ictalurus catus	White catfish
Notorus gyrinus	Tadpole madtom
Etheostoma nigrum olmstedi	Johnny darter
Fundulus diaphanus	Freshwater killifish
Alosa psuedoharengus	Alewife
Erimyzon oblongus	Creek chubsucker
Notemigonus crysoleucas	Golden shiner
Notropis sp.	Minnows
Umbra pygmaea	Mudminnow

Table 40

SPECIES LIST FOR FISH OF LAKE HOPATCONG*

Lepomis macrochirus	Bluegill sunfish
Lepomis auritus	Red breasted sunfish
Lepomis gibbosus	Pumpkinseed
Micropterus salmoides	Largemouth bass
Pomoxis nigromaculatus	Black crappie
Perca flavescens	Yellow perch
Esox niger	Chain pickerel
Notropis sp.	Shiner
Notemigonus crysoleucas	Golden shiner
Alasa pseudoharengus	Alewife
Ictalurus nebulosus	Brown bullhead

*Based on PAS haul seine survey.

PRINCETON AQUA SCIENCE

Table 41

LIST OF SPECIES TAKEN AT LAKE STATIONS

Species	Station * 1	2	3	4	5	6	7	8	9
Lepomis macrochirus	11	SEE TEXT	2	2	2	1	10		27
L. auritus			1	1			2		
L. gibbosus			4	8	10	3	22		1
Micropterus salmoides	3				2				2
Pomoxis nigromaculatus	2		2	1					
Perca flavescens	4		4	12	6				3
Esox niger	1			2			1		2
Notropis sp.			5		4			4	
Notemigonus crysoleucas	7		13	8	31				
Alosa pseudoharengus			71	72	1				
Ictalurus nebulosus				1					
Total No. Organisms	28		102	107	56	4	35	4	35
Species Diversity**	1.54		1.11	1.18	1.38	0.56	0.91	0	0.83
Eveness Index***	0.859		0.534	0.537	0.709	0.808	0.656	-	0.516

*Station Locations:

1. Liffy Island, north side
2. Liffy Island, south side
3. Woodport Bay, south of Liffy Island
4. Woodport Bay, Callaghan's Island
5. Woodport Bay, north of Brady Bridge
6. Halsey Island, northeast side
7. River Styx, Crescent Cove
8. Point Pleasant
9. Landing Channel

**As per Shannon-Weiner Diversity Index where Diversity = $\ln N - \frac{1}{N} \Sigma [ni \ln (ni)]$

where N = total number of individuals of all species

ni = number of individuals of the i^{th} species

***Eveness = $\frac{\bar{H}}{\ln S}$ where $\bar{H}$ = Shannon-Weiner Index

S = number of species

Analysis of the fishery relative to species diversity, evenness, and total number of fish collected reveals that the lake north of Brady Bridge (Woodport Bay) to be the most productive section of the lake. The aquatic macrophytes in this area appear to provide suitable habitat for prey and forage organisms, as well as suitable habitat for nesting and growth of juvenile fish.

Station #1 on the north side of Liffy Island proved to have the highest species diversity and evenness of all stations. The total number of fish caught, however, was not great due to the rocky, stumpy nature of the lake bottom. The nature of the substrate impeded sampling somewhat. Bluegill sunfish (Lepomis macrochirus) and golden shiner (Notemigonus crysoleucas) were well represented in the sampling along with adult largemouth bass, pickerel, and perch.

The south side of Liffy Island (Station #2) is an area of abundant weed growth. The density of weeds hindered sampling. However, on the basis of observation and the limited success of our sampling efforts, this area appears to be an important nursery area. An abundance of young-of-the-year centrarchids, including largemouth bass, were sampled.

Stations #3, #4 and #5 all were characterized by high species diversity and intermediate evenness. These three stations yielded the greatest total number of fish with a total of eleven different species being represented. Golden shiners were the most common fish at Station #5 while the alewife (Alosa pseudoharengus) was the most prevalent species at Stations #3 and #4. Both shiners and alewife provide suitable forage for important game fish such as bass and pickerel. Alewife, due to preferential feeding behavior, can potentially disrupt the species composition of the lake's zooplankton community and indirectly lead to increased algal densities. As a result of their feeding ecology, large zooplankters are preferentially preyed upon. This results in a zooplankton assemblage composed essentially of smaller forms. The smaller oganisms are less effective in reducing the density of the phytoplankton through grazing. In addition, the smaller forms tend to recycle phosphorus, via excretion, much more rapidly than do the larger forms. As a result, phytoplankton numbers are not as effectively controlled and may even be stimulated (Shapiro, 1978). Thus, the occurrence of alewives in Lake Hopatcong is important to both the lake's fishery, and its phytoplankton dynamics. It will need to receive closer attention in relation too the restoration of the lake.

The fishery on the northeast side of Halsey Island (Station #6), while showing a fairly high evenness, was characterized by both a very low total number of fish and low species diversity. In this section of the lake the sediments are very sandy and weed growth is sparse. In close proximity to this sampling site is the deep main body of the lake. Hypolimnetic oxygen depletion occurs in the deep section of the lake throughout summer months resulting in loss of approximately 20% of the lake as viable fish habitat. This is important in that these waters remain cool all summer and were it not for low D.O. would be excellent trout habitat.

The Crescent Cove/River Styx section of the lake (Station #7) is another shallow, weedy area. Species diversity, total number and evenness were fairly high. Centrarchids (sunfish) were the dominant members of the fish community. Fish were observed guarding nests. Also observed, but not captured for positive identirication was what appeared to be a common carp (Cyprinus carpio). In addition, on a separate date the common goldfish (Carrasius auritus) was collected. The occurrence of these species may prove significant in relation to both the fishery and nutrient budget of the lake. Both fish, but especially carp, due to their foraging behavior, often disrupt suitable spawning sites and habitat necessary for many other fish including game species. In addition, these fish have been demonstrated to play an important role in the in-lake recycling of phosphorus (Lamarra, 1975). The amount of nutrients excreted by these fish and liberated during their bottom feeding activities can be substantial (Lamarra, 1975, Shapiro, 1978). It should be noted that no fishery survey of the lake, including our own, has yet to determine if a viable population of carp is actually established in the lake. However, efforts should be made to eliminate these fish from the lake, or maintain their population to a minimum, before any negative effects are observed.

The sampling site of least species diversity and evenness was Station #8 at Point Pleasant. Only one fish species was collected; however, the lack of a suitable landing site for the seine may have biased the sampling effort.

Station #9 in the Landing Channel was characterized by relatively high values for species diversity and total number of organisms and intermediate evenness. This shallow water area has a highly organic substrate and variety of aquatic macrophytes. In addition, a small island composed essentially of stumps is located in the center of the channel. These various components of the habitat seem to provide fairly good cover. However, in this section of the lake, unlike in Stump Cove, sunfish, notably bluegills, greatly predominate the population, causing it to be more unbalanced and less diverse.

In general the fishery of Lake Hopatcong appears to be in fairly good shape. Although our sampling indicates there is an overabundance of sunfish and an underabundance of game species, or method of collection prohibited adequate sampling of most larger fish. Review of records maintained by the Knee Deep Hunting and Fishing Club of Lake Hopatcong show the lake to be an excellent largemouth bass and pickerel fishery and a fair trout fishery. The lake still holds the record catch for channel catfish (1978), white perch (1950), and brook trout (1958).

Preservation of the Liffy Island, Stump Cove area is highly recommended due to the nursery nature of this area. A reduction in weed densities in Crescent Cove and Landing would probably improve the fishing inthese areas. Not only would such action improve access and angling, but would aid in the foraging success of adult bass and pickerel on the numerous sunfish which overpopulate these two embayments.

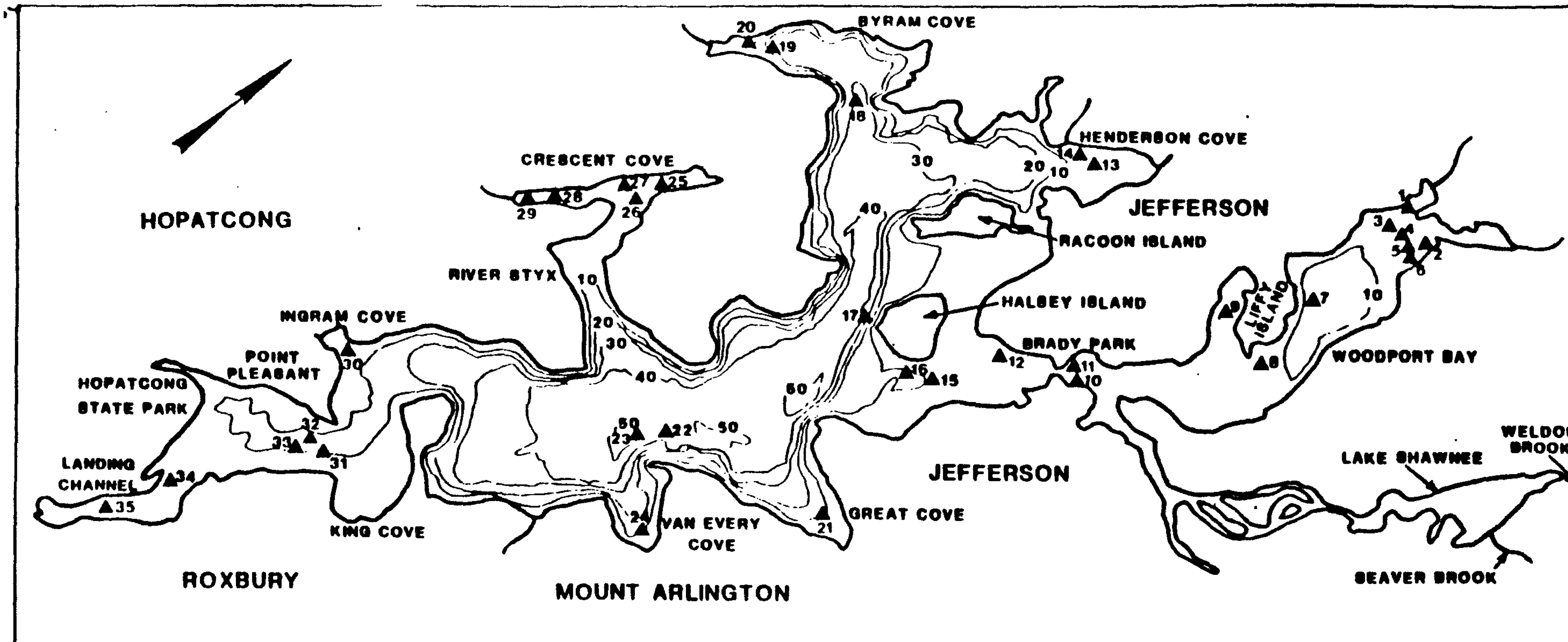
E. SEDIMENT CORE ANALYSIS

Lake sediment samples were collected from thirty-five locations within the lake (Figure 22) on four sampling dates between May and December of 1982. These sites are in the proximity of marinas, major sources of surface runoff, areas of possible future dredging activities, and in restricted coves with limited flushing capabilities.

The sediments were sampled by means of a K-B freefall brass sediment core sampler fitted with plastic (cellulose acetate butyrate) core tubes. The core samples were returned to the laboratory and frozen for preservation and for ease of handling.

Penetration of the sediment core sampler varied with the firmness of the substrate. The cores collected ranged in depth from approximately 25 to 50 cm below the mud-water interface. Subsamples of approximately 3 cm in depth were taken from the top, middle, and bottom portions of the cores for chemical and physical analyses (Table 42). In addition, the sub-samples from four of the cores were composited and analyzed using EP toxicity test procedures (Federal Register, 1980). Grain size analysis was also performed (Folk, 1968). The results of these analyses are included in Table 43.

With few exceptions, the data indicate the presence of higher levels of the measured metals in the upper strata of the cores than in the middle and lower strata. Since the sediments in the upper strata of the cores are those most recently deposited, it can be assumed that these metals have been deposited in increasingly greater amounts in "recent" years. the exact time period of this deposition cannot be stated without performing sophisticated dating analyses on the sediments but the



LEGEND

▲ SEDIMENT CORE

FEET

0 1000 2000

0 200 400

METERS

DEPTHS IN FEET

LAKE HOPATCONG REGIONAL PLANNING BOARD

LAKE RESTORATION AND MANAGEMENT STUDY

FIGURE 22

LAKE HOPATCONG SEDIMENT CORE SAMPLING SITE

pas

Table 42

LAKE HOPATCONG SEDIMENT CORE ANALYSIS
(mg kg^{-1} dry weight except where noted)

Station*		Pb	Al	Fe	Zn	Hg	Cd	Depth of Sample in Inches	REDOX m volts
		Parameters							
1.	top	126	22,200	51,200	381	0.097	1.36	1	-125
	middle	181	23,500	43,600	418	0.094	1.32	6.5	
	bottom	54.7	26,800	26,600	256	0.101	0.677	12	
2.	top	314	17,400	21,500	889	0.267	3.70	1	-105
	middle	129	10,500	19,000	627	0.199	3.04	5.5	
	bottom	9.99	3,160	6,660	163	0.177	2.39	10.75	
3.	top	168	17,800	19,600	586	0.302	3.66	1	
	middle	7.61	16,300	9,420	126	0.229	1.38	5.5	
	bottom	5.28	12,500	6,830	115	0.238	1.78	10.5	
4.	top	105	23,000	16,500	832	0.219	2.66	1	
	middle	104	26,600	17,000	967	0.243	2.39	4.5	
	bottom	15.5	26,000	9,740	544	0.279	1.30	9.5	
5.	top	71.6	23,500	17,100	609	0.258	2.05	1	
	middle	89.1	19,100	13,300	594	0.253	2.73	5.5	
	bottom	7.32	14,900	8,510	174	0.188	1.33	11.25	
6.	top	156	12,300	15,500	556	0.440	2.35	1.5	
	middle	74.8	15,200	15,800	825	0.315	2.72	6	
	bottom	53.9	15,800	13,400	396	0.185	1.68	12	
8.	top	101	7,610	11,600	246	0.198	1.87	1	
	middle	279	17,200	23,800	585	0.212	3.42	4.5	
	bottom	70.4	6,430	7,470	241	0.067	1.24	9.75	
9.	top	171	7,370	16,400	355	0.372	2.21	1	-40
	middle	97.2	4,380	11,000	199	0.246	1.25	7.5	
	bottom	6.92	1,190	4,630	27.7	0.209	<0.837	14	

PAS

Table 42 (continued)

Station*		Pb	Al	Fe	Zn	Hg	Cd	Depth of Sample in Inches	REDOX m volts
		Parameters							
10.	top	140	19,000	29,900	762	0.358	2.88	1	-105
	middle	139	15,400	21,000	529	0.157	1.78	6.5	
	bottom	29.2	14,000	13,700	202	0.246	<0.484	12.5	
11.	top	197	10,500	24,500	487	0.080	2.20	1	-100
	middle	72.8	11,600	18,400	299	0.168	1.07	5.5	
	bottom	13.6	1,980	9,560	56.5	0.105	0.609	11.5	
12.	top	70.0	6,850	8,030	185	0.073	1.69	1	+5
	bottom	4.01	4,100	4,150	16.4	0.017	<0.142	9	
13.	top	469	8,970	37,600	1,730	<0.066	5.35	1	-105
	middle	58.4	5,620	15,400	172	0.082	<1.41	6.5	
	bottom	13.0	2,510	7,760	51.9	0.505	<1.12	12	
14.	top	684	10,200	33,100	2,300	0.357	10.2	1	-100
	middle	175	9,340	20,500	782	0.263	5.06	6.5	
	bottom	10.5	10,400	9,850	131	0.087	0.670	12	
15.	top	32.0	4,280	6,680	118	0.036	0.342	1	-170
	middle	5.30	10,600	6,350	42.2	0.047	<0.176	5.5	
	bottom	3.65	3,860	5,370	18.9	0.026	<0.147	11	
16.	top	11.6	2,330	3,680	41.0	0.016	<0.151	1	+220
	bottom	3.33	4,710	5,050	14.9	0.057	<0.140	8	
17.		561	24,800	46,300	1,240	0.308	3.85	1	-200
18.	top	294	16,300	26,500	978	0.168	3.10	1	-90
	middle	41.1	12,800	14,000	343	0.117	1.06	8.5	
	bottom	12.5	24,500	13,700	155	0.058	<0.216	17	
19.	top	287	10,900	22,200	794	0.057	2.65	1	-90
	middle	90.9	12,300	15,200	350	0.129	1.35	7.5	
	bottom	14.7	20,600	16,400	182	0.113	<0.288	14.75	

PRINCETON AQUA SCIENCE

Table 42 (continued)

Station*		Pb	Al	Fe	Zn	Hg	Cd	Depth of Sample in Inches	REDOX m volts
		Parameters							
20.	top	262	16,600	30,000	895	0.286	2.9	1	-100
	bottom	21.8	12,300	24,300	163	0.082	0.397	9.5	
21.	top	43.1	2,910	10,600	124	0.027	0.364	1	-70
	bottom	7.39	7,660	6,350	65.0	0.029	<0.172	7.5	
23.	top	95.3	15,100	26,800	274	0.177	1.51	1	
	bottom	31.8	13,500	21,100	145	0.142	1.30	3.5	
24.	top	134	6,250	16,400	304	0.130	1.03	1	-80
	bottom	16.3	25,400	5,840	66.1	0.057	0.231	6.5	
25.	top	345	20,300	23,700	821	0.110	4.69	1	
	middle	17.8	4,590	8,500	78.9	0.164	0.811	5.5	
	bottom	5.50	3,950	6,040	55.0	0.226	<0.722	11.5	
26.	top	445	33,300	50,600	2,010	0.913	20.1	1	
	middle	62.4	30,200	19,500	440	0.183	1.63	6.5	
	bottom	8.81	35,200	13,300	130	0.151	0.927	13	
28.	top	352	50,000	23,200	1,080	0.316	3.41	1	
	middle	60.4	24,900	14,500	322	0.051	1.57	6.5	
	bottom	9.88	29,100	16,100	146	0.213	1.08	13.25	
29.	top	506	25,100	56,700	619	0.113	2.51	1	-140
	middle	123	20,900	30,500	427	0.146	1.58	5.5	
	bottom	17.0	26,200	17,600	119	0.130	1.17	11.25	
30.	top	237	11,600	24,500	8,430	0.074	1.70	1	-190
	middle	17.3	29,800	10,600	137	0.084	0.310	6.5	
	bottom	14.5	16,600	16,800	131	0.017	1.86	12.5	
31&32	top	400	12,500	21,800	984	0.422	8.08	1	-50
	middle	29.5	5,830	13,500	68.3	0.360	1.06	10.5	
	bottom	13.7	9,080	13,400	36.0	0.338	1.15	20	

Table 42 (continued)

Station*		Pb	Al	Fe	Zn	Hg	Cd	Depth of Sample in Inches	REDOX m volts
		Parameters							
33.	top	45.7	15,700	23,800	833	0.138	4.15	1	
	middle	22.9	4,410	10,900	90.2	0.245	1.23	5.5	
	bottom	18.1	2,940	4,380	77.6	0.184	0.552	11.25	
34.	top	600	37,800	26,000	1,410	0.340	3.69	1	-45
	bottom	68.9		10,000	183	0.229	<1.10	8	
35.	top	1,100	17,100	35,300	1,680	0.847	10.2	1	-85
	bottom	1,220	16,600	35,900	2,450	1.19	10.9	8.5	

*Stations 7, 22, 27, and 31/32 treated separately for EP toxicity and bulk analysis of metals and pesticides.

Table 43

GRAIN SIZE ANALYSIS OF
COMPOSITE SEDIMENT CORES

	Station No.			
Sediment Fraction	7	22	27	31&32
% sand	68.3	63.7	71.7	72.8
% silt	18.6	16.0	6.22	16.4
% clay	13.0	20.2	22.0	10.8

assumption can safely be made that the uppermost strata of sediments correspond to the tremendous increases in man's activity on and near the lake within the last 10 to 50 years.

An attempt was made to correlate increased levels of lead in sediments near marinas. The suspicion was that due to the presence of lead in gasoline, any gasoline entering the water either by spills or through outboard motor exhaust would significantly increase the lead concentration in the sediments (Kuzminski and Hogan, 1974). This was found to be the case especially where marinas are located in restricted coves such as Crescent Cove, Henderson Cove, and Landing Channel. Water does not flush through these areas to facilitate the diluting of lead in the water column. This lead, therefore, remains in the cove and becomes incorporated in the muds of the cove through sedimentation and precipitation.

Another contributor of lead to the lake's bottom is surface runoff. This is also a major source of zinc entering the lake as lead and zinc are among the most prevalent toxic heavy metals found in stormwater runoff (Wilber and Hunter, 1975).

These coves are surrounded primarily by high density residential areas close to the lake shore. In addition, Crescent Cove and Henderson Cove have steeply banked surrounding land areas. These factors would dramatically increase runoff with its pollutant load into the lake. The Landing Channel also has primarily high density residential as well as commercial land uses in close proximity to the lake. This is also an area of heavy automobile traffic along such major arteries as Lakeside Boulevard, Shippenport Road, and Mt. Arlington Boulevard.

The concentrations of zinc and lead in urban runoff have been quantitatively related to the levels of zinc in automobile tires (an average of 0.73%) and lead in gasoline. As a result of that analysis it has been shown that the average deposition of these metals on road surfaces are 0.0030 g zinc/vehicle km and 0.0049 g lead/vehicle km (Christensen and Guinn, 1979). It would, therefore, be expected that surface runoff from these roads would have substantial levels of these metals. The high concentrations of lead and zinc in the sediments from the Landing Channel could be a result of this runoff. It would be interesting to see if the sediments from this area contain lower levels of lead in the future due to the increased use of unleaded gasoline in automobiles.

A review of Table 42 shows that at some sampling stations at which low levels of zinc and lead would be expected (those with watershed sub-basins of low density residential or forested land uses) there are relatively high concentrations of these metals. Most notably are cores from Stump Cove and from the deep water area southwest of Halsey Island. Heavy boat traffic could account for this anomaly. Also, the mixing of the water column during the breakdown of thermal stratification could bring these contaminants from other areas of the lake.

The far north end of Woodport Bay is an area which does not fit the pattern of decreasing lead and zinc concentrations with increasing depth into the sediments. The quarry operation with its resultant increase in runoff of sediment into the lake could be responsible for this phenomenon. The "clean" soil is likely serving to dilute the lead and zinc coming in by road surface runoff.

Aluminum and iron were found to be present in concentrations very much greater than those of the other measured metals. This is as expected since these metals are part of the background matrix. The trend for increasing aluminum and iron levels in the more recent sediments is likely due to the same sort of processes such as land development with its resultant increase in surface runoff as those responsible for that trend with respect to lead and zinc.

Four sediment samples from different parts of the lake underwent EP toxicity and grain size analyses. The latter analysis is important because a great portion of the pollutional potential of street surface contaminants is associated with the fine, silt and clay-like material (Sartor, Boyd, and Agardy, 1974). Table 43 illustrates this phenomenon. It can be seen that with only one exception an increase in silt and clay size particles from station to station parallels an increase in the lead and cadmium levels in those bulk sediments.

Cadmium, like zinc is found in the rubber of automobile tires (Owe, Craul, Halverson, 1982) and thus is carried into the lake with road surface runoff. The deterioration of galvanized pipe is another source of cadmium in the environment (Standard Methods, 15th ed.). Again an increase in land development and automobile traffic has likely led to the observed increase in cadmium concentrations in the upper strata of lake sediments.

Detectable levels of mercury were found in three of the four sediment samples analyzed for that metal. The source of mercury in street surface contaminants has not been identified (Sartor and Boyd, 1972), but mercury is released into the atmosphere from burning of fossil fuels and from its use as a fungicide and germicide (O'Connor and Stanford, 1979).

Both phenol and chromium were detected in all four of the sediments analyzed for those contaminants. Road surface runoff again is believed to be their source as oils and tars contain phenol (Standard Methods, 15th ed.) and chromium is used to plate automobile bumpers and trim (Sartor and Boyd, 1972).

No cyanide was found in any of the sediment samples. This is not surprising since the persistance of cyanide in water is variable. It is decomposed by microorganisms in both anaerobic and aerobic environments (O'Connor and Stanford, 1979).

Endrin and toxaphene, two components of pesticides, were detected in two and one core samples, respectively. Spray application of these chemicals by governmental agencies and/or homeowners in the Crescent Cove and Point Pleasant areas of the lake is suspected to be their means of release into those watershed sub-basins.

No herbicides were found to be present in any of the core samples tested for those contaminants.

Table 44 contains the results of the analysis on the extract from the four cores that underwent EP toxicity analysis. It is evident that no significant amount of leaching of contaminants from the sediment took place under the acid conditions (pH 5.0) of the extraction procedure. This result is significant when dealing with a New Jersey lake where acid-precipitation is prevalent.

Table 44

METALS AND PESTICIDES ANALYSIS OF
COMPOSITE SEDIMENT CORES

	Bulk Analysis				EP Toxicity Elutriate			
	Station No.				Station No.			
	7	22	27	31&32	7	22	27	31&32
*Mercury	0.136	0.114	<0.040	0.202	<0.00007	<0.00007	0.027	<0.00007
*Lead	236	545	165	131	0.009	0.026	0.007	<0.005
*Cadmium	4.44	8.41	9.52	3.45	<0.001	0.003	0.002	<0.001
*Phenol	2.88	0.667	0.360	0.908	<0.007	0.008	0.021	<0.007
*Cyanide	<7.56	<6.01	<8.0	<10.1				
*Chromium	22.8	25.9	9.28	7.74	<0.008	<0.008	<0.008	0.010
**Lindane	<6.05	<4.81	<6.4	<8.07	<1.0	<1.0	<1.0	<1.0
**Endrin	<6.05	<4.81	112	258	<1.0	<1.0	<1.0	<1.0
**Toxaphene	<60.5	<48.1	<64.0	<80.7	<10.0	<10.0	<10.0	<10.0
**Methoxychlor	<6.05	<4.81	<6.40	104	<1.0	<1.0	<1.0	<1.0
**2,4,-D	<7.56	<6.01	<8.00	<10.1	<1.0	<1.0	<1.0	<1.0
**2,4,5-TP Silvex	<7.56	<6.01	<8.00	<10.1	<1.0	<1.0	<1.0	<1.0

*Bulk sample concentration in mg kg^{-1}, EP-toxicity concentration in mg l^{-1}.

**Bulk sample concentration in μg kg^{-1}, EP-toxicity concentration in μg l^{-1}.

SECTION XII

HYDROLOGIC-NUTRIENT BUDGET

An important step in the development of a successful lake restoration action plan is the accurate calculation of the hydrologic and nutrient budgets. These data provide insight relevant to the nutrient dynamics of the lake. The magnitude and frequency of hydrologic contributions affect nutrient loading, sedimentation and lake flushing rate. The nutrient budget quantifies the relative importance of various nutrient sources on the lake's annual nutrient load, and is the principal component in the calculation of lake trophic state.

A. HYDROLOGIC BUDGET

The hydrologic budget for Lake Hopatcong was calculated from tributary flow, surface runoff, precipitation, evaporation, and groundwater infiltration data.

1. Precipitation/Evaporation

Precipitation data was obtained from NOAA monitoring records for the general Lake Hopatcong area (NOAA, 1981; NOAA, 1982). These data were compared to rainfall data collected by LHRPB volunteers. Both data sets were found to agree reasonably for those months where simultaneous collections were available for comparison (Table 45). The total precipitation which fell during the study period (August, 1981 to August, 1982) amounted to 108.65 cm. This is approximately 12 cm less than the average annual precipitation for the basin (Table 46). Surface runoff to the lake, hydrologic loading due to precipitation falling directly into the lake, and normalized stream flows were calculated on

Table 45

RAINFALL FOR LAKE HOPATCONG BASIN (CM)

Month	Historical 1951-1973	1981-1982 LHRPB	1981-1982 NOAA	(+/-) Difference Between NOAA and LHRPB
August 1981	12.75	-	3.73	-
September 1981	9.39	-	6.95	-
October 1981	9.39	-	11.10	-
November 1981	11.40	-	3.66	-
December 1981	10.50	-	10.44	-
January 1982	7.73	-	10.30	-
February 1982	8.17	-	8.71	-
March 1982	10.08	-	5.99	-
April 1982	10.78	11.81	13.21	+1.40
May 1982	9.34	7.95	8.05	+0.10
June 1982	9.74	16.99	16.10	-0.80
July 1982	11.05	10.54	10.41	-0.13
Total	120.34		108.65	
ADDITIONAL DATA				
August 1982		12.09	13.45	+1.36
September 1982		10.01	8.95	-1.06
October 1982		3.56	3.65	-0.09

Table 46

PRECIPITATION-EVAPORATION

EVAPORATION FROM LAKE

(1) 32.5"/yr

(2) 69% of which occurs between May and September

32.5"/yr = 82.55 cm yr^{-1} mean

$$\frac{82.55 \text{ cm}}{120.35 \text{ cm}} \times \frac{x}{108.65 \text{ cm}} = 74.5 \text{ cm lost in 1981-1982}$$

108.65 cm - actual precipitation
\- 74.5 cm - estimated evaporation
34.15 cm - net gain via precipitation

Surface area of lake = 10.87 x $10^6 m^2$

Net gain via precipitation = 34.15 cm yr^{-1} = 0.3415 m yr^{-1}

TOTAL INFLOW DUE TO RAINFALL

3.712 x $10^6 m^2 yr^{-1}$

the basis of the measured rainfall data. The hydrologic load associated with precipitation into the lake was corrected for evaporation using the evaporation isopleths developed by Hely, et al (1961) for Morris and Sussex Counties.

2. Tributary Inflow

Flows eminating from Lake Shawnee and from the stream which drains sub-basin 10 (LHS 4) were monitored. This represents approximately 38% of the total watershed, and therefore a sizable portion of the lake's hydrologic load. The height of water flowing over the Lake Shawnee dam was measured and utilized in a modified broad crested weir formula to determine daily flows. The discharge of the small stream which drains sub-basin 4 was monitored through the use of a 90^{o} V-notch weir. Weir readings were recorded daily and converted to flow using the appropriate discharge formula (Anon, 1978).

Hydrologic inputs from the remainder of the basin were determined using an empirical precipitation-stream discharge formula (Eq. 6), based on measured average monthly precipitation data. This approach was necessitated as the majority of inflow to the lake is non-gagable. The inflow data obtained by this method is a reasonble estimate, comparable, in terms of inherent error, with measured discharge methods (Scheider, et al, 1979).

Unfortunately, the weir and dam data, due to a variety of reasons, were deemed inadequate for incorporation into the hydrologic budget. As a result, all tributary inflows were computed using the empirical-precipitation formula. Using this method, tributary inflow for the study year was calculated to be $19.61 \times 10^6 m^3 yr^{-1}$. Surface runoff directly entering the lake accounted for an additional $3.47 \times 10^6 m^3$. Precipitation falling directly into the lake totaled $11.81 \times 10^6 m^3$, but

Table 47

HYDROLOGIC BUDGET FOR
LAKE HOPATCONG

Inflow	$10^6 m^3 yr^{-1}$	% Total
All Tributaries*	19.61	49.4
Surface Runoff which Directly Enters Lake**	3.47	8.7
Precipitation-Evaporation	3.72	
Groundwater Infiltration	12.89	9.4
TOTAL INFLOW	39.69	100.00
Outflow		
Musconetcong River	39.69	100.00
TOTAL OUTFLOW	39.69	

*Flow obtained using empirically generated data (Q = ABC), normalized using N.E.S. Methodology (USEPA, 1975).

**Flow obtained using empirically generated data (Q = ABC).

$8.09 \times 10^6 m^3$ were lost due to evaporation from the lake's surface. The total hydrologic inflow for the study year was thus $26.8 \times 10^6 m^3$ (Table 47).

3. Outflow

Outflow from the lake, measured on a daily basis by Lake Hopatcong State Park personnel, totals $39.69 \times 10^6 m^3 yr^{-1}$ for the period of August 1981 through July 1982. It should be noted that outflow from the lake is the combined result of flow over the lip of the dam and through the lake's floodgates. Outflow through the flood gates is regulated by personnel of Lake Hopatcong State Park. Minimum discharge from the lake is mandated by law to be $2.9 \times 10^4 m^3 d^{-1}$. During the winter of 1981-1982 the lake was drawn down approximately 2.5 m in order to prevent ice damage to docks and launches. The outflow from the lake therefore represents water in excess of the lake's volumetric capacity as well as water artificially released during the drawn down operation (Table 48).

4. Groundwater

The difference between total hydrologic losses and measured or calculated hydrologic inputs is $12.89 \times 10^6 m^3 yr^{-1}$. This difference is attributable to the groundwater inflow to the lake and its tributaries which occurred during the study year. The accuracy of this value is in part verified through the use of groundwater runoff coefficients developed by Posten (1982) for predominately forested watersheds in Passaic County, New Jersey. The results of this analysis indicate that $15.87 \times 10^6 m^3 yr^{-1}$ of groundwater is contributed to Lake Hopatcong under average conditions, as based on a groundwater runoff rate of $7.925 \times 10^2 m^3 d^{-1} km^{-1}$, applied to a watershed area of $54.827 \ km^2$. This groundwater inflow data represents the hydrologic inputs to both the lake and its tributaries. As the tributary hydrologic loads are based on surface runoff, it is necessary to include the groundwater inputs, in order to develop a complete hydrologic budget. The computed average value agrees quite well with the estimated groundwater inflow for the study year. Total precipitation for the study period was less than the average annual rainfall for the area, thus explaining the discrepancy between the observed and predicted groundwater contributions. Thus, our groundwater input value, although derived as the difference between hydrologic loss and surface hydrologic inputs, appears to be a reasonably valid estimate.

Table 48

OUTFLOW FROM LAKE HOPATCONG

Month	Volume of Water Discharged $m^3 \times 10^5 \cdot month^{-1}$
August 1981	2.32
September 1981	2.67
October 1981	4.82
November 1981	11.4
December 1981	77.6
January 1982	64.3
February 1982	53.6
March 1982	35.0
April 1982	30.6
May 1982	38.4
June 1982	51.9
July 1982	24.3
TOTAL	$3.969 \times 10^7 m^3 yr^{-1}$

B. NUTRIENT BUDGET

The nutrient budget of the lake was developed from the loading data associated with point sources, septic tanks, wet and dryfall directly into the lake, gaged and non-gaged tributary inflow, and surface runoff directly entering the lake. For total phosphorus, the internally generated load, resulting from the liberation of sediment bound phosphorus under anoxic conditions, was also accounted for in the nutrient budget. The means by which these various components of the nutrient budget were calculated, are discussed in detail in the previous sections.

The annual total nitrogen (TN), total suspended solids (TSS), and total phosphorus (TP) loads contributed to the lake during the study period are 92,866.5 kg TN yr^{-1}, 3,943,225 kg TSS yr^{-1}, and 3,884.8 kg TP yr^{-1}. Of the annual TN load 23.6% is contributed by non-point sources such as direct surface runoff and tributary loading (Table 49). Septic tank leakage contributions account for 64.5% of the annual TN load, indicating that a very serious septic related problem exists in Lake Hopatcong. For phosphorus, surface runoff and septic leakage are the two main sources of total phosphorus to the lake (Table 49). Surface runoff inputs, accounted for by tributary loads, as well as runoff which directly enters the lake, are 38.1% of the annual TP load. Septic related inputs represent 37.7% of the annual TP load. The magnitude of the septic component of the lake's TP budget attests to the serious impacts on lake water quality resulting from the leakage of septic effluent into Lake Hopatcong. It also acknowledges the need to abate this load as addressed in the Upper Musconetcong River Basin Wastewater Facility Plan (PAS, 1983).

The point source load presently contributed to the lake are meager (Table 49). Three of the four STPs are facilities which service public schools. The population size, intermittency of flow, and generally low

Table 49

NUTRIENT - SEDIMENT BUDGET FOR LAKE HOPATCONG

Nutrient Sediment Source	Total Phosphorus		Total Nitrogen		Total Suspended Solids	
	$kg\ yr^{-1}$	% Total	$kg\ yr^{-1}$	% Total	$kg\ yr^{-1}$	% Total
Non-Point Sources						
Gaged Streams*	339.0	8.0	6056.7	6.5	537973***	
Monitored Streams**	75.3	1.8	5336.6	5.8	848325***	
Remaining Non-Point Sources***	1202.4	28.3	10511.8	11.3	2556645	
Wet-Dryfall Directly to Lake	271.8	6.4	10870.0	11.7	0	
Septic Tanks	1600.6	37.7	59852.2	64.5	0	
Point Sources						
	165.3	3.9	239.2	0.3	281.7	
Internal Recycling						
Hypolimnetic Recycling	595.0	14.0	0		0	
TOTAL	4249.4		92866.5		3,943,225	

*Streams for which gaged flow data and nutrient/sediment concentrations measured. Does not account for load contributed by the Stanlick School STP.

**Streams for which flow data obtained empirically, and nutrient/sediment concentrations measured. Does not account for load contributed by the Mt. Arlington Knolls Apartment and Our Lady of the Lakes School STP.

***Non-monitored tributaries and surface runoff, loads calculated using U.A.L. methodology.

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volumes of effluent discharged by these plants act to make their contributions minimal. In addition, effluent from the Arthur Stanlick School is discharged first to a marsh which in turn flows into Lake Shawnee. Both water bodies reduce the trophic impact of the effluent on Lake Hopatcong.

A deficit in the preparation of the lake's nutrient budget is the failure to account for loading during storm events. Although the loads generated with the empirical precipitation-stream flow formula accounts for some of the storm related inputs, the nutrient loads associated with the first flush storm inputs were not measured. Attempts were made to measure storm loadings, but the short time of concentration characteristic of most of the monitorable tributaries resulted in the first flush occurring prior to the initiation of the sampling operations. Tuffey and Trama (1975) have demonstrated that only high intensity storms (>4.0 cm total rainfall) generate a substantial increase in nutrient loading and that the majority of that load is associated with the first flush. Other studies also conclude that the first flush of storms contributes the majority of the nutrient/sediment loads (Wanielista, et al, 1982). The TP and TN therefore presented in Table 49 are actually conservative and probably underestimate the full extent of storm related loading to Lake Hopatcong.

For essentially the same reasons as mentioned above, the TSS load to Lake Hopatcong was generated using the U.A.L. methodology discussed in detail in Section X. The loads obtained using this method incorporate, to an extent, the storm related contributions. Nevertheless, the TSS loads listed in Table 49 are also conservative and most likely underestimate the total annual load. Measured baseline, low flow loads for TSS totaled 159,842 kg yr^{-1}. This load represents the actual contribution of sediments to the lake under non-storm conditions. The large difference between the total TSS load and the baseline load (3,783,383 kg yr^{-1}) is attributed to storm related inputs including overland surface runoff contributed directly to the lake. This difference may appear substantial, but it has been demonstrated that in semi-rural areas 2,250 kg $ha^{-1}yr^{-1}$ of soil are annually lost. For a watershed the size of Lake Hopatcong (1,087 ha) this amounts to a typical annual load of approximately 2,450,000 kg yr^{-1}.

SECTION XIII

TROPHIC STATE ANALYSIS

The data presented in the previous sections are integrated and discussed in this section as they relate to the trophic status of Lake Hopatcong. Emphasis is placed on the role of phosphorus. The total phosphorus loading data is utilized in conjunction with empirical deterministic models to predict the trophic status of the lake under existing conditions. This data is in turn used along with measured physical, chemical, and biological data to formulate an overall view of the lake's present environmental condition.

A. PHOSPHORUS AS A LIMITING NUTRIENT

Nutrients, particularly phosphorus, fertilize a waterbody and stimulate the increased development of phytoplankton and/or aquatic macrophyte standing crop. The increased fertilization of a lake by natural means, is a step in the aging of a lake, and, to an extent, may prove beneficial to the lake's biota. As phytoplankton and macrophyte densities increase, the number of zooplankton, macro-invertebrates and fish which can be supported in the lake also increases. However, a point is reached where the amount and rate of nutrient loading to the lake exceeds the lake's assimilative capacity. That is, the amount of nutrients contributed to the lake leads to the development of nuisance densities of phytoplankton and aquatic macrophytes. As a result water transparency decreases, boating and swimming is impaired, and the lake loses some of its aesthetic character. In addition, as these plants and algae decompose or respire, the oxygen content of the water decreases potentially resulting in a condition where the amount of oxygen in the lake is insufficient for the support of fish. By this point symptoms such as dense bluegreen algal blooms, floating mats of aquatic weeds, obnoxious odors, and fish kills become evident.

It is therefore desirable to have a means available by which the impact of nutrient loading to the lake can be assessed. This is, in essence, the purpose and utility of the various trophic state analysis models. With only a few key pieces of data related to the morphometry and total phosphorus loading of the lake, it is possible to determine the existing trophic status of the lake with a reasonable degree of accuracy (Dillon, 1974; Reckhow, 1979; USEPA, 1980). In addition, these models can be used to predict the future degradation or improvement of a lake as a result of changes in nutrient loading.

The empirical models of Dillon (1974), Ostrofsky (1978), and Dillon and Rigler (1974) were utilized, in the assessment of Lake Hopatcong's trophic status (Equations 1, 2, and 3). Based on the total phosphorus load contributed by the various sources, it is possible to identify the lake's existing trophic state. As phosphorus is considered to be the typical limiting nutrient (USEPA, 1976) in Lake Hopatcong, emphasis was placed on its role in accelerating the eutrophication of the lake.

B. PHOSPHORUS RETENTION//CRITICAL LOADING

The existing TP load to the lake is 4249.4 kg yr^{-1}. Of the external load, 73.0% is retained in the lake on an annual basis (Table 50). Using this data, in conjunction with the trophic state model of Dillon (Equation 1), a spring TP concentration of 0.033 g m^{-3} is predicted (Table 51). The mean spring TP concentration measured during the monitoring study was 0.024 g m^{-3} indicating good agreement between the measured and predicted TP concentration. The predicted spring TP concentration is an indicator of lake trophic state and can be used to predict summer in-lake productivity. The good agreement between the observed and predicted spring TP values verifies the accuracy of the model in predicting both existing and future lake conditions.

The existing phosphorus load annually contributed to Lake Hopatcong exceeds the loading limit considered "dangerous" for lakes of similar hydrology and morphometry (Figure 23). That is, the existing TP load is sufficient to support and sustain nuisance density algae blooms. For comparative purposes, if the entire watershed was never developed, and the land was still forested, the annual TP load to the lake would be 1200 kg yr^{-1}, approximately the "permissible" loading limit (Figure 23). Under such conditions the lake would be classified as slightly mesotrophic. At present, the lake is classified as eutrophic.

Table 50

PHOSPHORUS RETENTION
IN LAKE HOPATCONG

$$Rp = 0.201e^{(-0.0425\ qs)} + 0.5743e^{(-0.00949\ qs)}$$

where:

Rp Phosphorus Retention

qs Areal water load = $\dfrac{\text{annual outflow from lake } m^3\ yr^{-1}}{\text{surface area of lake } m^2}$

Annual discharge of Lake Hopatcong = $39.67 \times 10^7\ m^3\ yr^{-1}$.

Surface area of Lake Hopatcong = $10.87 \times 10^7\ m^2$

$$qs = \frac{39.67 \times 10^7\ m^3\ yr^{-1}}{10.87 \times 10^7\ m^2} = 3.40\ m\ yr^{-1}$$

$$Rp = 0.201e^{(-0.0425)(3.40)} + 0.5743e^{(-0.00949)(3.40)}$$

$$Rp = 0.174 + 0.556$$

$$Rp = 0.730$$

% TP Retention = 73.0%

Table 51

TROPHIC STATE ANALYSIS OF LAKE HOPATCONG USING THE CRITERIA OF DILLON (1974)

Parameter	Value
Annual Load	4249.4 kg yr^{-1}
Areal Load (L)	0.391 g m^{-2} yr^{-1}
Phosphorus Retention (R)	0.73
Hydraulic Retention Time (T)	1.71 yr
Mean Depth (Z)	5.49 m

Predicted spring TP concentration (g m^{-3}) = $[P_s] = \frac{L(1-R)T}{Z}$

$$[P_s] = \frac{0.391\ g\ m^{-2}\ yr\ (1-0.73)(1.71\ yr)}{5.49\ m}$$

$$[P_s] = \frac{0.181\ g\ m^{-2}}{5.49\ m}$$

$$[P_s] = 0.033\ g\ m^{-3}$$

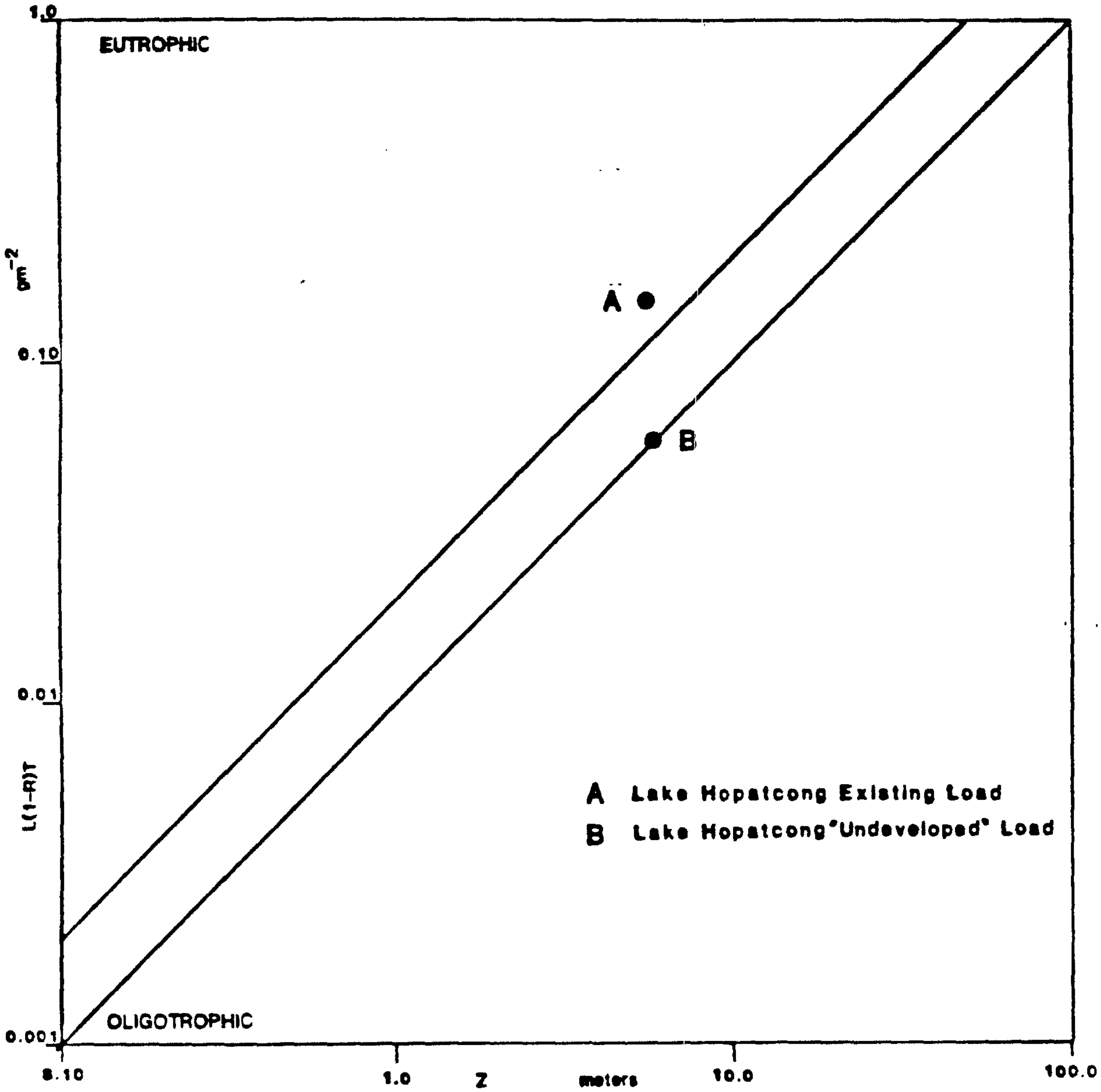

FIGURE 23
TROPHIC STATUS OF LAKE HOPATCONG UNDER EXISTING LOADING CONDITIONS AND UNDEVELOPED LOADING CONDITIONS

C. PHOSPHORUS-CHLOROPHYLL EQUIVALENT RELATIONSHIP

The information obtained through the trophic status model is more illustrative when expressed in terms of lake productivity. That is, how much primary production will result given a certain TP load. Expression of trophic status in such a context is usually more informative in that it relates directly to observable water quality conditions. Such information characterizes just how "green" a lake will become if enriched with a certain amount of phosphorus. To accomplish this task the phosphorus-chlorophyll model of Dillon and Rigler (1974) was employed (Equation 3). The resulting data, expressed in the form of chlorophyll a equivalents, represents the estimate of the maximum amount of primary production (algae) which can be expected under the indicated TP loading, hydrologic and lake morphometric conditions.

The existing annual TP load of 4249.4 kg is predicted to yield a maximum chlorophyll a (Chl a) concentration in the summer of 18.6 mg m^{-3} (Table 52). The mean chlorophyll a concentration typically measured in Lake Hopatcong in the summer ranges from approximately 10 mg m^{-3} to 30 mg m^{-3} depending on where in the lake samples are collected (Section XI). On individual dates, concentrations approaching 70 mg m^{-3} Chl a have been measured in the Woodport Bay area of the lake. The model is thus fairly accurate in assessing the productivity of the lake as represented by chlorophyll a.

Table 52

PREDICTED MAXIMUM CONCENTRATION OF CHLOROPHYLL A FOR LAKE HOPATCONG DURING THE SUMMER MONTHS

$$Log_{10}[Chl] = 1.583\ Log_{10}[P] - 1.134$$

where:

[Chl] = Summer Chlorophyll a concentration (mg m^{-3})

[P] = Spring Total Phosphorus concentration (mg m^{-3})

Log_{10} = Log Base 10

$$Log_{10}[Chl] = 1.583\ Log_{10}[33\ mg\ m^{-3}] - 1.134$$

$$Log_{10}[Chl] = 2.404 - 1.134$$

$$Log_{10}[Chl] = 1.270$$

$$[Chl] = 18.6\ mg\ m^{-3}$$

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Table 53

PREDICTED MEAN SUMMER CHLOROPHYLL A CONCENTRATION (mg m^{-3})
DEVELOPED FROM MEASURED MEAN SUMMER SECCHI DISC
DEPTHS (m) FOR VARIOUS SECTIONS OF LAKE HOPATCONG

Section of Lake	Measured Summer Mean Secchi Depth	Predicted Summer Mean Chl a Concentration	Observed Summer Mean Chl a Concentration
Woodport Bay	0.525	51.8	34.84
Byram Bay	1.30	13.66	11.20
Mid-Lake	1.63	9.79	9.30
Point Pleasant	1.58	10.25	14.12
State Park	To bottom	Could not be computed	7.28
Crescent Cove	1.33	13.21	6.70

pas

It should be noted that both the Dillon-Rigler model (Equation 3) and the Carlson model (Equation 4) underestimate total in-lake productivity in that neither assess the relative contributions of aquatic macrophytes. It is recognized that in Lake Hopatcong it is aquatic weeds which present the most serious problems resulting from accelerated lake eutrophication. In view of the concentration of TP measured in the sediments and an annual retention of 73% of the external TP load, an ample nutrient source exists for the growth and development of aquatic macrophytes. These weeds have been shown to obtain the majority of their nutrients from the sediments (Prentki, 1979). In view of this data, competition between macrophytes and algae occur mostly in relation to shading and a reduction of the euphotic zone which reduces the density of phytoplankton in the littoral zone of the lake. In addition, since macrophytes are capable of utilizing to a great extent sediment nutrient sources, their growth and development is probably largely independent of external TP loads. In turn, when these plants die, the TP component of their tissue is remineralized and incorporated in the sediments. A cycle of regeneration-remineralization thus becomes established. A decrease in the external load of TP to the lake may therefore have no substantial impact on reducing the density of weeds in the lake.

Also, the decomposition of senescent algal cells and dead plant tissue decreases the dissolved oxygen (D.O.) content of a lake, particularly in the hypolimnion during summer stratification. The phosphorus load to the lake has a direct effect on the depletion of oxygen in the hypolimnion, as it is this nutrient which limits the theoretical density which the phytoplankton community can attain. An increase in phosphorus loading increases algal densities. These cells eventually die and sink into the profundal zone of the lake where they are decomposed by bacteria. During the summer, the deep waters of the lake do not mix with the upper oxygenated layers, and conditions develop leading to the eventual depletion of D.O. in the hypolimnion. As mentioned previously, the depletion of D.O. (anoxia) in the hypolimnion causes these cool deep waters to be incapable of supporting fish life. In addition, anoxic conditions in the hypolimnion leads to a change in the REDOX potential of the sediments and the subsequent liberation of phosphorus.

E. OXYGEN DEPLETION RATE

It is possible, by knowing the annual TP loading rate, the area of the lake, and its hydraulic retention time to predict the oxygen deficit rate (ODR) in the hypolimnion following stratification (Welch and Perkins, 1979). This analysis was carried out for Lake Hopatcong and compared to the rate of oxygen depletion measured during the summer of 1982 (Table 54). An ODR of 409 mg $m^{-2}d^{-1}$ is predicted for Lake Hopatcong. During our study, at the time of initial lake stratification the D.O. content of the hypolimnion was 6.35×10^{10} mg O_2. According to the predicted ODR, the lake should become anoxic from 8.0 m to the bottom in approximately 53 days. The results of our study reveal that oxygen depletion in the hypolimnion of the lake occurred in about 77 days. The observed and predicted ODR's are in fair agreement and indicate that in roughly 2 months following stratification the water below a depth of 8 m will be devoid of oxygen. Oxygen depletion occurs sooner (within 30 days) at depths greater than 12 m. The lack of oxygen at depths greater than 9 meters persists until the fall overturn. More importantly, the concentration of D.O. in the hypolimnion falls below the typical minimum concentration (5 g m^{-3}) for fish soon after the lake stratifies (Figures 8 and 9). According to the ODR model, as phosphorus loading is increased, depletion of the lake's hypolimnetic oxygen reserve will occur at an increasing rate.

Table 54

OXYGEN DEFICIT RATE FOR
LAKE HOPATCONG
DURING SUMMER STRATIFICATION

$\text{Log}_{10}\ \text{ODR} = 1.58 + 0.37\ \text{Log}_{10}\ (\text{LT})$

where:

ODR = oxygen depletion rate mg $m^{-2}\ d^{-1}$
L = areal phosphorus load mg $m^{-2}\ yr^{-1}$
T = hydraulic residence time yr
Log_{10} = Log base 10

$\text{Log}_{10}\ \text{ODR} = 1.58 + 0.365\ \text{Log}_{10}[(391\ \text{mg}\ m^{-2}\ yr^{-1})(1.71\ yr)]$

$\text{Log}_{10}\ \text{ODR} = 2.61$
$\text{ODR} = 409\ \text{mg}\ O_2\ m^{-2}\ d^{-1}$

F. EXISTING TROPHIC STATUS

The data generated by all the predictive models indicate that Lake Hopatcong is eutrophic. This should not be construed as meaning that Lake Hopatcong is grossly polluted. Many eutrophic water bodies have very acceptable water quality conditions, provide excellent fishing, and meet the recreational needs of its users. However, as is the case of Lake Hopatcong, the amount of nutrient loading and resulting degree of lake enrichment is excessive, causing deteriorating trophic conditions. Eventually this will seriously impact both the recreational and water quality attributes of the lake. As previously mentioned, many of the symptoms of accelerated eutrophication have been oserved in Lake Hopatcong. The contribution of nutrients from septic systems and stormwater discharge appear to be the primary causative agents in the degradation of the lake's water quality, as these two sources comprise the largest fractions of the annual phosphorus budget (Table 49).

SECTION XIV

LAKE MANAGEMENT AND RESTORATION PLAN

A. General Plan

Lake restoration and management plans are designed to improve or maintain the status of a waterbody conducive to its major use be it recreation, potable water supply or aesthetics. A sound lake management plan should emphasize a reduction in the influx of pollutants to the lake. Only by decreasing the amount of nutrients, heavy metals, pesticides, sediments, etc. transported to the lake will long term improvements in water quality be realized. This is achieved through watershed management, product modification, and diversion of contaminants away from the lake. In addition, in-lake restoration measures should be included in the management plan. In-lake techniques are often successful in decreasing internally regenerated nutrient loads; however, their major benefit is that they improve the appearance of the lake. Measures such as weed harvesting, dredging, alum application, and algacide/herbicide treatment increase water transparency, decrease the density of algae and macrophytes, and help short-circuit the internal regeneration of nutrients. These in-lake techniques improve the recreational attributes of the waterbody and help ameliorate the effects of the influx of pollutants. Because they treat the symptoms and not the causes of lake eutrophication though, these measures typically provide only short term relief. Since a fundamental objective of the Clean Lakes Program is to maximize obtainable public benefits attainable through lake improvement, a combination of watershed management and in-lake restoration measures is recommended (USEPA, 1980). In this manner, relatively immediate improvements in water quality and lake usage will be realized as well as the long-term abatement or control of pollutant contributions.

The diagnostic study has identified those factors responsible for the degradation of Lake Hopatcong's water quality. Some of these factors are related to the morphometry and hydrologic retention time of the lake. The infrequent flushing of the system coupled with the existence of numerous shallow embayments and coves make the lake naturally susceptible to filling, aquatic plant development, and the accumulation of pollutants in the muds. Other factors are directly attributable to the development of the watershed. The influx of nutrients associated with stormwater and septic leachate are largely responsible for the over productive nature of the lake. As a result, nuisance densities of aquatic weeds and unsightly algae blooms develop throughout the extensive shallow coves and embayments.

The LHRPB recognizes that in order to restore and properly manage Lake Hopatcong, it will be necessary to develop a management plan which addresses the basic causes of the lake's degradation. Only by addressing and rectifying the causes rather than the symptoms of accelerated eutrophication will improvements be effective and long lasting. The two most pervasive causes of Lake Hopatcong's accelerated eutrophication are the excessive influx of nutrients from septic systems and stormwater. Together these sources of pollutants account for over 75% of the annual total phosphorus load (Table 49). In order to minimize the contributions from these two sources of pollutants, a combination of stormwater quality management and the construction of a wastewater collection and treatment system is required. Specific recommendations relevant to these issues will be detailed in the management plan.

In addition to watershed management, it will be necessary to develop in-lake restoration programs as part of the management plan. The LHRPB realizes that the implementation of watershed management programs is expensive and may take years to complete. However, the problems of Lake Hopatcong are immediate and need to be addressed without delay. As New Jersey's largest lake, Lake Hopatcong has had a long history of serving as one of the state's most important recreational areas. The combination of the lake's size, recreational opportunities, and aesthetic attributes attracts thousands of tourists annually. As such, the lake represents an important component of the area's economic base. For the general Lake Hopatcong area, water based recreation is the major source of revenue as is evidenced by the multitude of marinas, restaurants, lodges, etc. Such services related businesses cater largely to the summer tourist trade. It is without a doubt that the majority of these businesses would not exist if the lake was no longer a viable recreational resource. It is unfeasible to rely solely on watershed management programs to improve the lake's status. The lake and the economy of the area cannot wait to see such programs through to completion. Rather, action which can immediately improve the condition of the lake must be implemented in conjunction with a watershed management program. Therefore, an in-lake restoration program is recommended. The key elements of this program include lake level drawdown, aquatic macrophyte management, spot dredging, and possibly nutrient inactivation.

A public education program should be developed in conjunction with the management plan. The objective of this program will be to provide the residents of the watershed with information regarding the proposed management and restoration of the lake. Through this effort, the public can become aware of the action which can be taken collectively and individually to help improve the lake. In addition, through a well coordinated public education program, wider acceptance of the management plan will be gained as the public becomes increasingly aware of the problems of the lake and how they can be corrected.

The scope of the proposed management plan relative to the nature of work involved, the size of the lake and its watershed, and the magnitude of the problems which need to be rectified require that a concerted effort be made in the implementation of the management plan. The successful implementation of the management plan requires the integration of many water resource programs involving a number of levels of government and is dependent on various sources of funding for millions of dollars. This will involve a great deal of coordination. The Lake Hopatcong Regional Planning Board would best serve the function of coordinating and implementing th restoration and watershed management plan for the lake to successfully see the lake and watershed management plan through to its completion. Also, it is proposed that the Lake Hopatcong Regional Planning Board seek legislation to expand its authority which will permit it to develop funds through nominal taxing, power, user fees and grants.

B. Evaluation of Alternatives

The objective of the lake restoration management plan developed for Lake Hopatcong is the improvement in lake water quality, aesthetics, and recreational potential through the effective management of those factors which have led to the degradation of the lake. The management plan will emphasize the reduction in the external nutrient and sediment loads to the lake as the main means of abating the accelerated eutrophication of Lake Hopatcong. Secondly, it will act to decrease the effects of eutrophication which have become manifested and threaten the environmental and recreational status of the lake. Finally, it will consider measures by which the internal sources of nutrient loading can be decreased.

1. Watershed Management

Reduction in the external nutrient load will be accomplished using watershed management methods. In contrast, in-lake techniques will be employed to ameliorate the visible effects of eutrophication and possibly decrease internal nutrient loading.

The applicability of various watershed management alternatives was assessed in relation to the problems of Lake Hopatcong (Table 55). Review of the alternatives indicates that stormwater detention, erosion control, sewering, stormwater management, land use control, and elimination or improved treatment of existing point sources are all applicable watershed management measures. Of the aforementioned, stormwater management, stormwater detention and sewering will provide the greatest reduction in nutrient/sediment loading to the lake. Land use control ordinances will prove very useful in establishing guidelines by which future development-related perturbations can be avoided or mitigated. Although erosion control and elimination of existing point

Table 55

EVALUATION OF WATERSHED MANAGEMENT ALTERNATIVES FOR LAKE HOPATCONG

	WATERSHED MANAGEMENT ALTERNATIVES									
Observed Lake Problems	Diversion of Inflows	Treatment of Inflows	Stormwater-Detention On-site-Regional	Erosion Control	Sewering	Existing Point Sources	Land-Use Controls Ordinances	Stormwater Management Plan	Public Education	Product Modification
1. Nuisance Aquatic Plant Growth	B	B	A	D	A	A	A	A	A	A
2. Nuisance Phytoplankton Blooms	B	B	A	D	A	A	A	A	A	A
3. Nuisance Benthic Algae Mats	B	B	A	D	A	A	A	A	A	A
4. Hypolimnetic Oxygen Depletion	B	B	A	D	A	A	A	A	D	A
5. Siltation	B	B	A	A	D	D	A	A	A	D
6. Influx of Nutrients	B	B	A	A	A	A	A	A	A	A
7. Degrading Fishery	B	B	A	D	A	D	A	A	D	A

KEY:

A: Recommended for Lake Hopatcong; would substantially address this problem.

B: May contribute to solving specific problems but not practical for Lake Hopatcong.

C: May help problem but not sufficient benefit to implement.

D: Does not address problem.

E: May exacerbate the problem.

sources will help improve the lake, these areas of concern should respectively be addressed under stormwater management and construction of a regional sewage system. Both diversion of inflow and treatment of inflow are not feasible watershed management techniques for Lake Hopatcong. Public education, as mentioned previously, will help inform the residents of the watershed of measures which they can take upon themselves to improve the lake. Closely related to this is product modification. Through public education and product modification the use of non-phosphate detergents, proper maintenance of septic systems, and modification in the type, application method, or amount of lawn fertilizers can be stressed.

2. In-Lake Management

The second aspect of Lake Hopatcong's management plan includes in-lake measures which will improve the aesthetic and recreational attributes of the lake and reduce internal recycling of nutrients. Although some of these measures are considered cosmetic, that is they only improve the lake's appearance, they will aid greatly in maintaining the lake as a viable recreational resource.

When faced with the problem of a degrading economic resource, implementation of an in-lake maintenance program is essential in order to protect the viability of the resource while the causes of the lake's problem are being addressed. It is felt that a rigorous, well coordinated in-lake maintenance program would help generate the public support needed to implement the more costly watershed management measures.

Some in-lake restoration measures such as selective discharge, hypolimnetic aeration, and dilution/flushing are alternatives which at this time do not appear feasible for implementation (Table 56).

Table 56

EVALUATION OF IN-LAKE RESTORATION ALTERNATIVES FOR LAKE HOPATCONG

IN-LAKE RESTORATION AND MANAGEMENT ALTERNATIVES

Observed Lake Problems	Dredging	Nutrient Inactivation	Lake Bottom Sealing	Selective Discharge	Hypolimnetic Aeration	Dilution Flushing	Biological Controls	Sediment Exposure-Dessication	Aquatic Weed Harvesting	Chemical Weed and Algae Control	Individual Home Owner BMPs	Public Education	Fisheries Management
1. Nuisance Aquatic Plant Growth	B	D	D	D	D	D	B	E/A*	A	E	A	A	D
2. Nuisance Phytoplankton Blooms	B	A	A	C	C	C	B	D	E	E	A	A	D
3. Nuisance Benthic Algae Mats	B	C	D	D	D	D	B	C	A	E	A	A	D
4. Hypolimnetic Oxygen Depletion	D	A	A	C	B	B	D	D	C	E	A	A	D
5. Siltation, Accumulated Sediments	A	D	D	D	D	D	D	A	C	D	A	A	D
6. Nutrient Loading	B	A	A	C	B	B	B	C	A	E	A	A	D
7. Degrading Fishery	C	D	A	E	C	D	E	E	C	D	A	A	A

KEY:

A: Recommended for Lake Hopatcong; would substantially address this problem.

B: May contribute to solving specific problems but not practical for Lake Hopatcong.

C: May help problem but not sufficient benefit to implement.

D: Does not address problem.

E: May exacerbate the problem.

*Dependent on type of plant.

Likewise, the use of biological controls such as the white amur, Tilapia or specific pathogens have also been eliminated due to state regulations and the inherent dangers associated with the introduction of exotic species.

The remaining in-lake measures considered feasible for incorporation into the management plan of Lake Hopatcong include aquatic weed harvesting, selective dredging, sediment exposure and compaction, chemical weed and algae control, fisheries management, and possibly nutrient inactivation/bottom sealing.

In addition, through public education individual lake front property owners can be made aware of the best management practices (BMPs) which they can employ to help improve the lake. Through a public education and participation program important "grass root" support for the overall management plan can be maintained. At the same time, through public involvement a sense of personal accomplishment in the restoration and clean up of the lake is generated.

The benefits, projected costs and method of implementation for each of the in-lake and watershed management techniques will be discussed in detail.

C. The Selected Management Plan

1. Watershed Management

a. Point Sources (Sewage Treatment Plants)

In Section VII, the various point source discharges to Lake Hopatcong were identified and their annual load quantified. The annual point source load of total phosphorus (TP) is 165.3 kg, which represents 3.9% of the total annual TP load to the lake (Table 49). Due to the discrete nature of point source contributions, they are a fairly easily controllable source of nutrients to the lake.

The LHRPB recommends the following concerning point source contributions to Lake Hopatcong:

1. Additional point source discharges to Lake Hopatcong or its tributaries should not be allowed. This includes package plants associated with high density developments as well as municipal facilities.

2. The existing NJDEP waste load allocation should be left as is, but phosphorus standards for the tributaries to the lake should be upgraded.

3. The design capacity of the existing plants should not be expanded or exceeded, but the NJPDES permits should be modified to mandate routine TP analysis.

4. Monitoring reports should be forwarded to the LHRPB as a means of keeping the LHRPB informed on plant operation. When permit violations are discovered, the LHRPB would report directly to the appropriate local or state government branch for action.

5. In order to properly deal with future growth in the Lake Hopatcong basin, the wastewater disposal problem of the entire watershed has to be addressed. Most of the basin (except Mt. Arlington) has been the subject of recent Section 201 Wastewater Facility Plans. The Jefferson Township plan recommended sewering the portion of that township located in the Hopatcong Basin. The Musconetcong Sewerage Authority's Facility Plan should result in sewering parts of the Borough of Hopatcong, Roxbury, and Landing. The Lake Hopatcong Management Plan recommends that these projects be implemented for their substantial positive impacts on water quality in Lake Hopatcong, [redacted].

b. Onsite Waste Disposal Systems (Septic Systems) and Sewering

Nutrient contribution from septic systems represents a substantial component of the annual TP load of Lake Hopatcong. As detailed in Section VIII, approximately 1601 kg yr^{-1} of TP, 37.7% of the annual TP load, is contributed by septic systems. It should be noted that this estimate is conservative, being generated from loading coefficients developed for properly functioning systems operating in suitable soils. The results of this study indicate that this is a basin-wide problem, but is more severe in the densely populated waterfront areas of the lake.

The LHRPB recommends the following actions concerning onsite waste disposal in the Lake Hopatcong watershed:

1. That the municipality of Mount Arlington become actively involved in the Upper Musconetcong River Drainage Basin 201 facility plan study.

2. In order to enact an effective regional plan it is necessary that a concerted effort be made to fully integrate the sewering of the watershed and move ahead with the recommendations of the Jefferson and Upper Musconetcong 201 Facilities Plans.

3. The development of a septage management plan may be worthwhile pursuing. The municipalities within the watershed may wish to establish a management structure to optimize the operation and maintenance of existing septic systems. Although this would, at best, only slightly decrease septic contributions to the lake, it would provide a framework to insure that existing septic systems would be maintained in the best state possible.

4. All communities within the Lake Hopatcong watershed should prohibit the construction of onsite waste disposal systems within 200 meters of the lake or its tributaries unless extreme precautions are taken to prevent nutrient inputs to these waters. It may be necessary to utilize innovative and alternative systems, particularly in areas where soil conditions are not ammenable for the use of conventional onsite systems.

5. When onsite failures occur, a reevaluation of the soils in which the failed systems are located should be made. This reevaluation should be based on soil grain size, cation

exchange capacity, seasonal water table height and not perc rates alone. Only systems suitable for the use in those areas with soil limitations should be constructed (USEPA, 1981).

6. The health officers of the communities in the watershed should rigorously inspect and follow up on septic system complaints.

7. The LHRPB should appoint personnel to constantly monitor the actions of the communities with regard to septic system failures and review proposed plans for new and replacement systems. These actions will enable the LHRPB to monitor the trends in the Lake Hopatcong basin and guide their actions appropriately.

8. As a means of making the public aware of innovative types of systems an educational program should be developed. The Sussex County Planning Department has published a Septic System Guide for the Sussex County Area (Sussex County Board of Chosen Freeholders, June 1982). This program would also benefit local health officers and township engineers by providing them with insight relative to possible alternative designs. This information will better enable the proper enforcement and use of appropriate systems.

The LHRPB is not insensitive to the costs of sewering. However, it must be emphasized that because of the lake's prolonged hydrologic detention time, pollutants and nutrients (particularly phosphates) will tend to accumulate in the lake. These accumulated nutrients represent an internal nutrient source which further sustains the eutrophication of the lake. Due to the density of houses in close proximity to the lake's shore, the unsuitable nature of these soils for onsite treatment of domestic waste, and the inadequate design of many of the onsite disposal systems, septic waste continues to pollute the lake. By removing most of the developments from onsite disposal systems through incorporation into a regional sewage system, a major source of nutrients to the lake would be eliminated. Such action would prove to be extremely beneficial to the restoration of Lake Hopatcong. As this process is expensive and lengthy, incorporation of the above suggestions related to onsite disposal, and proper septic management will help mitigate some of the existing impacts.

c. Non-Point Source Controls

Aside from septic systems, which are traditionally considered nonpoint sources, surface runoff is the second major contributor of pollutants to Lake Hopatcong. Stormwater pollutants result from:

1. soil erosion,
2. leaching of lawn fertilizers,
3. transport of debris, animal waste, oils and greases, etc. from streets and other impervious surfaces,
4. natural background contributions.

As a watershed becomes increasingly developed the extent of impervious area (roof tops, roads, parking lots, etc.) increases. A corresponding increase in the quantity and rate of stormwater runoff is also realized (Heaney, et al., 1976). The quality of the runoff, however, decreases and may contain significant quantities of nutrients, sediment, and other pollutants. In Lake Hopatcong 41.2% of the annual TP load is contributed via stormwater inputs. Unfortunately, because of the diffuse nature of these inputs, reduction or control of such pollutant loading is difficult.

A number of methods do exist which, largely through passive treatment, can substantially decrease the pollutant load associated with stormwater. Among the measures considered feasible are treatment of inflows, stormwater detention, erosion control, land use control and development of a stormwater management plan (Table 55).

It is much easier and cost effective to allow for proper stormwater quality control in developing areas than it is to attempt to retrofit systems following construction. In developing areas Best Management Practices (BMPs) can be used to abate, control or treat stormwater runoff. Such BMPs are implemented through planning, legislation, and enforcement. The objectives of these BMPs are to maximize onsite detention or retention, prevent overdevelopment or land misuse, and minimize the impact of construction activity. In this way, potential problems are anticipated and alleviated before they can add to the degradation of the lake.

In sections of the watershed which are already developed, only a limited number of BMPs are available for implementation. In these areas it may be necessary to retrofit existing stormwater collection systems. In developed areas, stormwater quality can be improved through the use of:

1. sedimentation ponds and traps,
2. detention basins,
3. infiltration pits, trenches and dry wells,
4. trench drains,
5. level spreaders,
6. grass swales,
7. porous pavement,
8. frequent street sweeping,
9. rooftop storage and gradual stormwater release,
10. natural filters (e.g. sheetflow through vegetated areas).

The New Jersey Stormwater Management Act P.L. 1981, c. 32 was recently passed and ammended the Municipal Land-Use Law (MLUL) N.J.S.A. 40:55D-1 et seq. To implement this act NJDEP adopted regulations N.J.A.C. 7:8 which stipulate the practices that are to be incorporated into stormwater management plans. Once developed, the Stormwater Management Plan becomes an integral part of the municipal master plan as provided by Section 28 of the MLUL.

To develop an integrated stormwater quality management plan for the entire basin it is recommended that the municipalities deligate that authority to the LHRPB. The Borough of Hopatcong and Mt. Arlington have passed resolutions favoring this approach. The LHRPB would then pursue the acquisition of funds to conduct this planning.

The storm water planning process takes place in two phases: The Phase I is targeted at preventive measures applied during the site plan and subdivision review process. It identifies existing control requirements and establishes plans and ordinances in order to meet the standards in the regulations, at least in the short term.

The Phase II plan provides for the long term comprehensive planning of alternative preventive storm water management measures in conjunction with remedial stormwater management measures. A Phase II storm water management plan is to be based upon a detailed analysis of alternative storm water management approaches on an integrated or regional basis. The Phase II plan consists of a system of non-structural and/or structural storm water management programs which mitigate flooding and non-point source pollution.

A major aspect of storm water quality management is to decrease the rate and quantity of runoff. Thus, for stormwater quality control a requirement for detention requires prolonged retention of a small design storm, either a one year frequency, 24 hour storm using rainfall distribution recommended for New Jersey by the U.S. Soil Conservation Services, or a storm of 1 1/4 inches of rainfall in 2 hours. Under the regulations, provisions should be made for retention and release of stormwater so as to evacuate 90% of the detention basin in approximately 18 hours in the case of residential development and 36 hours in the case of other developments.

Where soils are sufficiently permeable, the objectives should be to have zero runoff from a development site under conditions of the 1 1/4 inch quality storm.

New development, including construction of detention basins, should be avoided in flood plains. The design of detention basins should be examined to determine the adequacy of proposed detention measures during the 100 year flood.

Although the New Jersey regulations emphasize the use of detention basins, many of the other aforementioned stormwater quality improvement measures can be employed. In the construction of detention-type structures many of the innovative concepts related to design and sizing presented by Wanielista, et al. (1982) should be considered.

The first step in developing a stormwater management program should be the evaluation of the existing stormwater collection system of the entire watershed. Expenditure of funds on retrofitting or construction of new stormwater treatment structures is more effective if those areas which would benefit most greatly are first identified.

Action should be taken by the municipalities of the watershed to ensure that their master plans, sub-division regulations and zoning ordinances are consistent with the objective of reducing non-point source loading to Lake Hopatcong.

Currently the Sussex County Engineer, State of New Jersey and the Borough of Hopatcong are planning improvements to Lakeside Drive in Hopatcong. Currently this project is being redesigned to include stormwater detention structures to assist in trapping suspended material that would be discharged into Ingram Cove.

Also, in cooperation with the developer of a development in Hopatcong, a dual release detention basin is being designed to regulate stormwater quantity and quality. This detention basin will be sized to control and treat by detention the runoff from 11 acres of residential watershed including the new development.

The site plan review committee of the LHRPB, through cooperation with local government should be allowed to review proposed developments in the watershed as related to its impact on the lake. The LHRPB will act as a disseminator of information and provide to the local governing bodies recommendations related to the abatement or mitigation of potential development related problems on a case specific basis. In this respect, the LHRPB will work together with local, county and state agencies. The LHRPB has already established this rapore with some of the municipalities in the watershed and wishes to continue this cooperative effort. In this manner, development related environmental degradation of the lake can be greatly decreased. It should be remembered, that the conditions which have arisen in the lake are largely the result of small incremental additions of pollutants. If such additions are allowed to continue, restoration efforts and money will be wasted.

By implementing all of the above watershed management measures it will be possible to greatly reduce the annual pollutant load to the lake. More specifically, sewering the basin and eliminating the point source contributions should reduce the annual TP load by about 40%. Construction of retention basins and retrofitting of the existing stormwater collection system could realistically decrease the annual TP load by an additional 15%. These structures will also be of great importance relative to the reduction of nutrient/sediment inputs from new developments. In this manner further degradation of the lake can be more adequately controlled.

An intrinsic part of the Lake Hopatcong Restoration and Management Plan is the acquisition of Liffy Island and its preservation as a passive recreation area. Liffy Island is one of the two last remaining "natural" lakeside areas which have not been developed. This parcel of land, located along the western shore of Woodport Bay, presently provides valuable habitat for wildlife. Deer, woodchucks, redwing blackbirds, great blue herons, and a variety of waterfowl are among the wildlife commonly sited. Oak, hickory, chestnut, beech and maples constitute the trees found on the island. Some of these trees are mature specimens as much as 75 years old.

Along the perimeter of Liffy Island, in Stump Cove, there exists a floating tussock marsh. This habitat is very unique, and in conjunction with the aquatic macrophytes and reeds also found in Stump Cove, appear to serve as a nursery area for game fish species. An examination of the fishery of the Liffy Island area reveal a very diverse fish community to be present. In addition, a large number of young of the year specimens have been collected in this area.

In keeping with the scope of the Lake Hopatcong Management and Restoration Plan, action has been taken to acquire Liffy Island (Appendix 3). The island and its associated wetland would be incorporated into a "natural park" and serve as a passive recreation area. Through such action this unique ecosystem can be preserved.

2. In-Lake Management

In comparison with watershed management measures, in-lake management/ restoration techniques are designed largely to treat the effects of accelerated eutrophication rather than the causes. As previously mentioned, some in-lake restoration techniques are considered cosmetic (i.e. improve the lake's appearance), but are important and legitimate methods by which to maintain the viability of the lake as a recreational resource. Others, however, not only improve the appearance of the lake but act to reduce internal recycling of nutrients. As has been demonstrated in other lake restoration studies, failure to account for and control internal nutrient recycling can often decrease the effectiveness or delay the response of a lake to reductions in external contributions of nutrients (Welsh and Rock, 1980).

In Lake Hopatcong the development of nuisance densities of aquatic macrophytes during the summer greatly affects its recreational potential. This problem is most pronounced in the shallow embayments of the lake. It is in these areas where water depth, light penetration, and sediment chemistry favor the establishment of aquatic macrophytes. Unfortunately, in Lake Hopatcong more than half of the lake's total area is conducive for the development of dense stands of aquatic macrophytes. The magnitude of this problem increases annually, and although the lake continues to be a viable recreational area, boating, swimming and fishing are becoming increasingly impaired.

The development of nuisance densities of aquatic macrophytes also effects the trophic status of the lake. Phosphorus and nitrogen are incorporated into the tissue of plants upon their growth and development. In this respect the plants act as nutrient sinks. However, this is only a temporary condition, in that upon their death and decay, these tissue bound nutrients become remineralized and either liberated into the water column or incorporated into the sediments.

This process leads to the further development of phytoplankton or macrophytes. A "self-perpetuating" system, independent of external loading, can therefore develop. If the concentration of nutrients in the sediment becomes excessive, as is the case in Lake Hopatcong, a reduction in the external nutrient load may not ellicite an improvement in the status of the lake. It is therefore important that some in-lake action be taken to control aquatic macrophyte growth and the accumulation of nutrients in the sediments.

Treatment of macrophytes with chemical herbicides acts only to speed up the natural senescence and die off of the plants. This form of treatment may actually exacerbate the problem. Harvesting of the plants, however, physically removes tissue bound nutrients from the lake. Harvesting would result in the removal of only a minor amount of nutrients relative to annual external inputs. However, as a maintenance measure primarily, the density of aquatic macrophytes should therefore be controlled through the use of mechanical weed harvesters. Lake level drawdown can be employed to augment this program. The limited use of aquatic herbicides is approved for use only in areas inaccessible to the harvester, such as in the vicinity of docks and piers.

More specifically, the aquatic macrophyte control program proposed for Lake Hopatcong should encompass the following recommendations.

1. As a means of augmenting the mechanical harvesting of weeds a periodic drawdown of the lake should be implemented. For two consecutive years, the lake should be lowered by at least 2 meters (6 ft). Drawdown could commence in late September. The lake would remain drawn down until early January at which time release of water from the dam would be reduced consistent with downstream requirements.

In most cases drawdown alone is not an efficient means of weed control unless the sediments can be exposed for 1 to 2 months and the targeted nuisance species is susceptible to exposure. In Hopatcong, water lillies (Nuphar spp.) are the only target species which would be greatly affected by drawdown. Other problem species such as elodea (Elodea canadensis) or milfoil (Myriophillum spp.) usually show no response, while pondweed (Potamogeton spp.) may even increase in density. However, if used in combination with other lake management techniques, drawdown can be an effective method of in-lake restoration (Cooke, 1980). The success of dredging, sediment covering and fishery management are augmented by lake level drawdown and sediment exposure. Drawdown facilitates the compaction and dewatering of sediments thereby reducing their flocculent nature. This aids in reducing internal regeneration of nutrients and turbidity problems resulting from lake sediment resuspension.

2. In association with lake level drawdown, the use of mechanical weed harvesting is recommended in the control of aquatic macrophytes. Weed harvesting would be initiated in late spring after some macrophyte growth had occurred. A harvester with a 7 to 10 ft cutter head and capable of cutting to depths of 5 feet would be employed. Cut weeds would be removed from the lake. To facilitate the harvesting process and increase the efficacy of the operation, a transporter unit(s) should be used to transport and unload the cut weeds offshore. Through such efforts the nutrients and organics normally remineralized upon the decomposition of plant tissue are also removed. This reduces the benthic oxygen demand of the sediments and helps short circuit the internal recycling of nutrients, particularly phosphorus. (See Appendix 8)

The objective of aquatic macrophyte control should not be the total erradication of aquatic plants, but the control of undesirable macrophyte species at non-nuisance densities. In this manner, swimming, boating and lake aesthetics are improved but no detrimental effects on the fishery are ellicited. If all the weeds in a lake are removed, including nuisance species, such as elodea or milfoil, the fishery will suffer. Young fish as well as forage species rely on these weeds for cover and refuge. Zooplankton, aquatic insects and other invertebrate forms which are fed upon by fish also utilize the weed bed as habitat. These plants, when at acceptable densities, thus serve an intrinsic and important role in the ecosystem dynamics of a lake.

Thus, although aquatic macrophyte harvesting is essentially a treatment of a symptom rather than a cause of accelerated lake eutrophication it yields a number of results which will benefit Lake Hopatcong.

1. It will enhance recreation on the lake.

2. It will remove some phosphorus; albeit a minor amount (300 kg TP) compared to the annual external load, and help short circuit internal recycling.

3. Removal of the cut weeds will decrease the organic load, and subsequently decrease the benthic oxygen demand of the system.

In the vicinity of docks and piers it may be necessary to use chemical treatment to control weed densities. The application of herbicides should be carried out by a licensed applicator in late spring. As weeds treated in this manner are not removed from the lake, the associated organics and nutrients become remineralized upon decomposition. Thus, efforts should be taken to largely restrict the chemical treatmment of weeds to those areas inaccessible to mechanical harvesters.

[1] On the basis of our harvesting trials on Lake Hopatcong and analysis of plant tissues, a once-a-year harvest of 300 acres of weeds of similar composition and density to the trial site would, based on our loading rate of the annual 0.391g x m^{-2}/yr^{-1} phosphorus, remove approximately 9% of all phosphorus loading. If a second harvest could be accomplished within the course of a year, and an equivalent of 600 acres harvested, the amoung of removal could be approximately doubled to Ca 18% of the normal annual load.

A limited spot dredging program should be conducted in Lake Hopatcong. Sediment removal from Landing Channel, Crescent Cove, Ingram Cove and the northwest most arm of Woodport Bay is recommended. It is in these sections of the lake where the deposition of sediments has greatly reduced lake depth. Dredging of these accumulated sediments would benefit the lake, and in particular these coves, in three main ways.

1. Increase the overall depth,

2. Destroy the roots and rhizomes of aquatic macrophytes thereby reducing their density,

3. Remove the nutrients and organic material which are associated with these deposits and act to stimulate and support the development of aquatic macrophytes.

Actions have been taken to decrease future sediment loading to these sections of the lake. Thus, the benefits accrued through dredging should be long term.

Throughout the basin, strict ordinances regulating fishing, dock, pier and bulk head construction, and lake shore encroachment are presently in effect. In Landing, Ingram Cove and Crescent Cove, the deposition of sediment has occurred as a result of development related construction, bank erosion, and stormwater inputs. The autochthonous generation of organic sediment in the form of decaying plant tissue has also contributed to the filling of these sections of the lake. The construction of stormwater detention basins or other devices designed to intercept and passively treat stormwater will help decrease the storm-related sediment load. In the Crescent Cove area, a regional detention basin which will service an approximately 45 hectare (111 acre) sub watershed is presently in the planning stage. In Ingram Cove, along Lakeside Boulevard, the retrofitting of the existing stormwater collection system with sediment trap structures has been funded and is awaiting implementation. Such measures will markedly decrease the sediment load to these two coves.

The northwestern most cove of Woodport Bay has been seriously impacted over a number of years by eroded sediment from a nearby quarry. Action has been taken to rectify this problem. Temporary soil erosion control measures have been implemented to curb these inputs to the lake. In addition, a plan for pollutant loading reductions is being developed in conjunction with NJDEP relative to negotiation for a NJPDES permit. At this point there is a concensus to completely eliminate surface water discharges from this site. Stormwater runoff will be contained in a detention basin, and through percolation discharged to the groundwater. In addition, other measures such as stream bank stabilization, proper site grading, and slope stabilization should help rectify the erosion problem.

The implementation of these site-specific sediment control measures should help insure that those sections of the lake where dredging is recommended will not rapidly fill in following sediment removal.

The annual internal phosphorus load regenerated from the sediments under anaerobic conditions represents about 15% of the total annual load. Measures could be taken to reduce this phosphorus source through the hypolimnetic application of alum. The objective of this operation would be to "strip" phosphorus from the hypolimnion of the lake and at the same time seal the lake bottom. Approximately 29.5 hectares (73 acres) of lake bottom would be affected. This entire area represents that section of the lake which is deeper than 12.0 meters.

d - dominant

SPECIES	COMMON NAME	Marsh	Nuphar	Mainland	Liffy Isl.
*Musaceae					
Sphagnum sp.					
Lycopodiaceae					
Lycopodium obscurum	Ground pine				c
L. complanatum	Ground cedar				c
Osmundaceae					
Osmunda regalis	Royal fern	r			
Polypodiaceae					
Adiantum pedatum	Maidenhair fern			r	
Pteridium aquilinum	Bracken fern			r	
Thelypteris palustris	Marsh fern	c			
Dryopteris marginalis	Shield fern				c
Pinaceae					
Pinus strobus	White pine				r
Typhaceae					
Typha angustifolia (latifolia x angustifolia ?)	Cattail	d			
Sparganiaceae					
Sparganium sp.	Bur-reed	r			
Najacaceae					
Potamogeton confervïodes	Pondweed	c			
Alismataceae					
Sagittaria rigida	Arrow-head	c			
Hydrochoritaceae					
Vallisneria americana	Tape-grass		c		
Gramineae					
Panicum sp.	Panic-grass				r
Cyperaceae					
Eleocharis fallax	Spike rush	d			
Carex aquatilis	Sedge	c			
C. stricta	Sedge	d			
Araceae					
Arisaema triphyllum	Jack in the Pulpit			c	c
Lemnaceae					
Lemna sp.	Duckweed	c			
Juncaceae					
Juncus bufonis	Toad rush				c

*Nomenclature from Gleason & Cronquist (1963)

SPECIES	COMMON NAME	Marsh	Nuphar	Mainland	Liffy Isl.
Liliaceae					
Smilacina racemosa	False solomon's seal			c	c
Maianthemum canadense	Lily of the valley			c	c
Uvularia perfoliata	Bellwort				c
Polygonatum biflorum	Solomon's seal			c	c
Medeola virginiana	Indian cucumber root			c	
Iridaceae					
Iris sp.	Blue flag				r
Orchidaceae					
Goodyera pubescens	Downy rattlesnake plantain				
Salicaceae					
Salix discolor	Pussy-willow	c			
Populos grandidentata	Large-toothed aspen			r	
Juglandaceae					
Carya ovata	Shagbark hickory			r	c
C. ovalis	Pignut hickory			c	c
Betulaceae					
Ostrya caroliniana	Hop-bornbeam			c	c
Betula lenta	Sweet birch			d	d
B. populifolia	Grey birch			r	
B. alleghaniensis	Yellow birch			c	c
Fagaceae					
Fagus grandifolia	Beech			c	c
Castanea dentata	Chestnut			c	c
Quercus alba	White oak			d	d
Q. prinus	Chestnut oak			d	d
Q. valutina	Black oak			c	c
Q. palustris	Pin oak			c	c
Polygonaceae					
Rumex orbiculatus	Great water dock	c			
Polygonum persicaria	Smartweed			c	
Caryophyllaceae					
Stellaria media	Chickweed				c
Nymphaeaceae					
Nuphar advena	Water lily		d		
Magnoliaceae					
Liriodendron tulipifera	Yellow poplar			c	c
Ranunculaceae					
Actea pachypoda	Baneberry			c	c
Aquilegia canadensis	Columbine			r	
Ranunculus abortivus	Small flowered crowfoot				c
Hepatica americana	Hepatica				c
Anemonella thalictroides	Rue anemone				r

SPECIES	COMMON NAME	Marsh	Nuphar	Mainland	Liffy Isl.
Lauraceae					
Sassafras albidum	Sassafras			r	
Lindera benzoin	Spice bush			r	
Hamamelidaceae					
Hamamelis virginiana	Witch hazel			c	c
Rosaceae					
Spiraea tomentosa	Steeplebush	d			
Potentilla simplex	Cinquefoil			c	c
Rubus hispidus	Dewberry				c
Agrimonea sp.	Agrimony				c
Rosa palustris	Swamp rose	c			
Amelanchier sp.	Shad bush			c	c
Fabaceae					
Desmodium nudeflorum	Tick trefoil			c	c
Oxalidaceae					
Oxalis stricta	Sheepsorrel				c
Geraniaceae					
Geranium maculatum	Geranium			c	c
Anacardiaceae					
Toxicondendron radicans	Poison ivy			r	r
Aceraceae					
Acer saccharum	Sugar maple			c	r
A. rubrum	Red maple	d		c	c
A. saccharinum	Silver maple				c
Balsaminaceae					
Impatiens biflora	Touch me not	c			
Vitaceae					
Vitis sp.	Grape				r
Parthenocissus quinquifolia	Virginia creeper			c	c
Treadenum virginicum	Marsh St. John's wort	c			
Elatinaceae					
Elatine americana	Waterwort	c			
Violaceae					
Viola spp.	Violets			c	c
Araliaceae					
Aralia nudicaulus	Wild sarsaparilla			c	c
Umbelliferae					
Sanicula trifoliata	Black snakeroot			c	r
Cornaceae					
florida	Flowering dogwood			c	c
					r

SPECIES	COMMON NAME	Marsh	Nuphar	Mainland	Liffy Isl.
Clethraceae					
Clethra alnifolia	Sweet pepper bush	d			
Ericaceae					
Monotropa uniflora	Indian pipe				r
Chimophilia maculata	Spotted wintergreen				r
Pyrola elliptica	Shinleaf				r
Rhodendron viscosum	Swamp azalea	c		c	c
Kalmia latifolia	Mountain laurel				c
Gaultheria procumbens	Wintergreen			c	c
Gaylussacia baccata	Black huckleberry			c	c
Vaccinium corymbosum	Highbush blueberry			c	c
V. vacillans	Lowbush blueberry			c	c
Prinulaceae					
Lysimachia quadrifolia	Loosestrife				c
L. terrestris	Loosestrife	r			c
L. thyrsiflora	Loosestrife	c			
Oleaceae					
Fraxinus americana	White ash			c	c
Polemoniaceae					
Phlox paniculata	Phlox	r			
Labiatae					
Scutellaria epilobilifolia	Marsh skullcap	c			
Lycopus uniflorus	Bugle weed	c			
L. americanus	Horehound	c			
Hedeoma pulegioides	Hedeoma				r
Collinsonia canadensis	Horse balm			r	
Scrophulariaceae					
Verbascum thapsus	Mullein			r	
Rubiaceae					
Mitchella repens	Partridge berry			c	c
Cephalanthus occidentalis	Buttonbush	c			
Galium palustre	Marsh bedstraw	c			
G. aparine	Whoreled loosestrife				c
Caprifoliaceae					
Viburnum acerifolium	Maple leaf vidurnum			c	c
Compositae					
Bidens sp.	Beggar ticks	c			
Erechtitis hieracifolia	Fireweed				r
Solidago spp.	Goldenrod			r	r
Aster divaricatus	Woodland aster			c	c
Eupatorium rugosum	White snakeroot			c	c
Prenanthes spp.	White lettuce			c	c

Alum, in the form of aluminum sulfate, would be added to the hypolimnion using a submergible manifold. The correct concentration of alum will be determined on the basis of analyses conducted just prior to the application. The concentration of phosphorus, the pH, and the alkalinity of the hypolimnion will determine the dosage rate and concentration of the alum. Application would occur in mid-August after hypolimnetic phosphorus release has commenced but before lake turnover. In this manner adequate precautions could be taken to help insure that the sediment-liberated phosphorus is inactivated before it can be circulated into the trophogenic zone. The specifics concerning cost and manpower allocation are yet to be fully developed. However, based on previous studies, the cost for an operation of this magnitude may exceed $25,000 in the cost of alum alone. On the other hand, a single treatment could yield as much as 5 or 6 years of control of the internal phosphorus load (Cooke, et al., 1982).

3. Public Education and Involvement Program

An integral portion of the management plan is a public education and information program. This program is already established to some extent. Throughout the study, the LHRPB has kept the public informed as to the interim findings and proposed solutions. This has been accomplished through several avenues, including:

1. News releases to local newspapers.

2. Special public meetings to discuss the issues that offset the lake.

3. Monthly public meetings of the LHRPB.

4. Presentations of papers at conferences and Technology Transfer Seminars.

5. Involvement in the decision-making process of the surrounding communities.

6. Special presentations to the various officials and professionals of the communities in the watershed.

7. Active participation in the data gathering activities of the study.

8. Information to watershed residents concerning Best Management Practices they can follow to assist in reducing pollutant loads to the lake.

However, the LHRPB recognizes that, as well as being informed, the public has to be involved. The residents of the basin are being requested to support the plan by working with the LHRPB and by helping finance it through revenues. The public has to feel that the plan and the lake are their's and that they have an obligation to implement the plan and protect the lake.

Local citizens have been especially helpful in contacting their elected representatives and gaining support for the project. The public and public officials at all levels of government must become more fully aware that Lake Hopatcong is the most important economic resource in the basin. The economic welfare of the area thus depends upon the quality of Lake Hopatcong as a recreational resource. This effort has to be continued and intensified if the proposals made herein are to be implemented.

Continued strong leadership in the LHRPB is essential and continued leadership by the LHRPB is necessary for implementation of the plan.

4. Institutional Arrangements

a. Introduction

The proposed lake restoration and watershed management plan are only as good as the ability of local, state and federal institutions to see them through. The institutional arrangements for implementing the plan presented in this report are complicated by the fact that Lake Hopatcong is located in two counties. The number of agencies, laws, regulations and levels of government that are involved with implementing the program makes the task extremely complicated.

For example, the levels of government that will be involved include:

State of New Jersey

Borough of Hopatcong
Jefferson Township
Roxbury Township
Mount Arlington Township
Morris County
Sussex County
New Jersey Department of Environmental Protection (DEP)
New Jersey State Legislature
Morris County Soil Conservation District
Sussex County Soil Conservation District
Morris Canal and Banking Company

Federal Government

U.S. Environmental Protection Agency
U.S. Army Corps of Engineers

Therefore, it is essential that one local organization is made responsible for coordinating and implementing the plan. The organization serving this coordinating function at this time is the Lake Hopatcong Regional Planning Board (LHRPB).

The LHRPB recommends that the State of New Jersey pass legislation recognizing the LHRPB as the agency authorized to implement and oversee the management/restoration plan. The first steps have already been taken under Article 10 of the New Jersey Municipal Land Use Law (Ch. 291) by creating the LHRPB. The area of jurisdiction of the LHRPB would be the boundaries of the Lake Hopatcong watershed.

To provide for the long term management of Lake Hopatcong, the State of New Jersey should examine the Wisconsin Lake Management Law (Appendix 4). This law allows a Lake Management District (LMD) to assess taxes throughout the LMD up to 2.5 mills, apply for, receive and administer grants, and assess user charges to develop and implement lake management and restoration and watershed management programs. However under the Wisconsin law

> "The district does not have zoning power on either the land or the water but may ask counties, towns, cities and villages to enact needed ordinances or any other measures necessary to improve and protect the conditions of public inland lakes."

The LHRPB should continue coordinating with the various political entities to maintain and improve Lake Hopatcong as a viable recreational resource. It should be the LHRPB's responsibility to implement the management and restoration plan in cooperation with the various governmental and private institutions. Also, as an independent organization they should review and comment on all proposals, master plans, development and regulations that affect Lake Hopatcong.

b. Municipalities

The municipalities within the watershed of Lake Hopatcong should, in cooperation with the LHRPB examine all aspects of the master plans and ordinances to insure that they are consistent with maintaining and improving water quality in Lake Hopatcong. Areas of major concern for Lake Hopatcong include:

1. Wastewater treatment and disposal, including onsite systems
2. Operation of waste treatment plants
3. Stormwater quality control
4. Soil erosion and sediment control

Since stormwater has been identified as the largest contributor of pollutants to Lake Hopatcong, the impacts of all activities, including planning, construction, road repairs, and construction should be assessed in relation to their effect on the lake. Stormwater quality management should be prioritized in the planning process. Where possible, old stormwater systems should be retrofitted with innovative passive stormwater treatment basins and systems to reduce nonpoint source pollutant load. In this respect, N.J.A.C. 7:8 should be used as a guideline for storm water management activities.

Presently, all watershed management activities would have to be implemented by local and county governments with assistance from the state. Therefore, the municipalities should, in conjunction with LHRPB, move to implement the recommendations in this plan. In addition, they should continue to support the objectives and activities of the LHRPB.

In addition to the above, the following are sepcific recommendations which will aid in the acceptance and implementation of the lake restoration plan:

1. Each municipality should examine, strengthen, enforce, and/or adopt storm runoff control and erosion control ordinances and septic system ordinances.

2. The master planning process and zoning ordinances should channel development toward areas which will have no impact on lake water quality.

3. Once new master plans and ordinances are adopted the communities should insist on rigid compliance with the plan. The temptation to zone by parcel through variances and zoning adjustments should be resisted. A municipality can have excellent master plan and ordinances, however, fail to achieve their goals because of lack of enforcement.

4. Tighten up ordinances to include Environmental Impact Statements for all major and minor subdivision projects.

D. ENVIRONMENTAL EVALUATION

1. Will the project displace people?

No.

2. Will the project deface existing residences or residential areas?

The construction of detention basins and the retrofitting of existing stormwater collection systems with sediment traps may temporarily disrupt residential areas during the construction phase. The installation of sanitary sewers may have similar effects on residential areas. The environmental impact of implementing the 201 facilities plans in the basin are specified in these plans. Residential land use will not be impaired.

3. Will the project be likely to lead to changes in land use pattern or an increase in development pressure?

No. There already exists high pressure to develop the remaining open area immediately surrounding the lake. The proposed plan incorporates the aquisition of Liffy Island as a passive recreation area and will thereby reduce development pressure. Other means which will mitigate or greatly reduce the impact of future watershed development on the lake are the main thrust of the watershed management plan.

4. Will the project adversely effect prime agricultural land or activities?

No.

5. Will the project adversely affect parkland, public land or scenic land?

No. As Lake Hopatcong is an aquatic state park, its restoration will in essence enhance parkland. In addition, the acquisition of Liffy Island and its maintenance as a passive recreation area will increase the recreational attributes of the lake.

6. Will the project adversely affect lands or structures of historic, architectural, archaeological, or cultural value?

No.

7. Will the project lead to a significant long-range increase in energy demands?

No. The most significant increase in energy usage will be associated with harvesting of aquatic macrophytes. This will be an annual maintenance measure and there will be some increase in energy demand. It is anticipated that the harvester would be used approximately 200 hours per month. According to literature provided by vendors, the average fuel usage for the size harvester which will be used on Lake Hopatcong is 0.83 gal/hour. This results in a total fuel usage of 664 gals. over a four month period. At a price of $1.50 per gallon of fuel, the projected costs of added energy expenditure is approximately $1000 per year.

Energy usage associated with dredging or alum treatment should be minimal as these restoration measures will not be implemented on an annual basis.

8. Will the project adversely affect short-term or long-term ambient air quality?

Due to construction of sediment/pollution traps and passive treatment devices as well as installation of sanitary sewer lines there may be a short term decrease in air quality relative to the generation of dust from construction sites. Proper sediment erosion and dust control practices will minimize such impacts. Increased emissions associated with the machinery used in construction activities, dredging, weed harvesting, or alum application may result. However as these equipment are fitted with emission control devices, their impact should be negligible.

9. Will the project adversely affect short-term or long-term noise levels.

No. A temporary increase in noise associated with construction or maintenance activity related with the restoration of the lake may result. All construction and maintenance vehicles will be equipped with the proper noise pollution control devices, thus increase in noise related to the restoration of the lake should be minimal. There will be some increase in noise associated with weed harvesting.

10. If the project involves the use of in-lake chemical treatment, will it cause any short-term or long-term effects?

The use of chemicals to control weed growth will be advocated only in those areas inaccessible to mechanical harvesters. The dosage, application rate, and coverage area will be much less than currently treated on an annual basis by the state. Thus the potential for toxicity problems associated with the use of herbicides should be much less upon implementation of this plan than it is under existing conditions.

"Jar tests" will be run prior to the application of alum to determine proper dosage. (Alum application will be closely monitored to prevent possible aluminum toxicity problems.) When applied at the proper application rate, alum has been found not to ellicite any adverse environmental impacts on the biota of the system other than reduce algal densities, a positive feature.

11. Will the project be located in a floodplain?

    Yes, in part.

12. Will structures be constructed in the floodplain?

    It is conceivable that some of the passive stormwater treatment structures (i.e. detention basins, catch basins, sediment traps etc.) will be constructed in floodplains. However, the construction of such structures will be in compliance with Executive Order 11988:

    "To minimize the impact of floods or human safety, health and welfare, and restore and preserve the natural and beneficial values served by floodplains..."

13. If the project involves physically modifying the lake shore, its bed, or its watershed, will the project cause any short or long-term adverse effects?

    Dredging will be limited to only a few small areas of the lake. Recolonization of these areas by benthic organisms should not be a problem due to the limited nature of the dredging operation. Destruction of aquatic macrophytes will occur; however, this is desirable and will enhance the quality of the lake. Following dredging, attempts will be made to improve, to an extent, available habitat to encourage improvement in the lake's fishery.

14. Will the project have a signifant adverse impact on fish and wildlife, wetlands or other wildlife habitat?

No. The lowering of the lake has in the past been permitted by the Division of Fish and Game, NJDEP, and is not considered to have an adverse impact on the fish or benthos of the lake. The other proposed restoration actions should actually improve the fishery of the lake by reestablishing and protecting fishery habitat, reducing weed densities, minimizing siltation and the influx of pollutants, and improving water quality.

15. Have all feasible alternatives to the project been considered in terms of environmental impacts, resource commitment, public interest and cost?

Yes. All feasible alternatives have been thoroughly examined and analysed. The proposed plan is the most cost effective restoration program for Lake Hopatcong. It is also characterized by a minimal potential negative environmental impact. The efficacy of the proposed plan will be greatly diminished if only part of the plan is implemented. In order to preserve the integrated nature of this plan it is important that both the watershed and in-lake restoration measures be implemented in full.

16. Are there other measures not previously discussed which are necessary to mitigate adverse effects from the project?

The lowering of the lake, mechanical weed harvesting, and chemical weed treatment will cause a temporary imposition on lake usage. Such impositions will be most lengthy in relation to lake drawdown.

Offsite disposal of the dredge spoils through the use of trucks will increase vehicular traffic and may cause some damage to roads.

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GLOSSARY OF LAKE AND WATERSHED MANAGEMENT TERMS[1]

Aeration: A process in which water is treated with air or other gases, usually oxygen. In lake restoration, aeration is used to prevent anaerobic condition or to provide artificial destratification.

Algal bloom: A high concentration of a specific algal species in a water body, usually caused by nutrient enrichment.

Algicide: A chemical highly toxic to algae.

Alkalinity: A quantitative measure of water's capacity to neutralize acids. Alkalinity results from the presence of bicarbonates, carbonates, hydroxides, salts, and occasionally of borates, silicates, and phosphates. Numerically, it is expressed as the concentration of calcium carbonate that has an equivalent capacity to neutralize strong acids.

Allochthonous: Describes organic matter produced outside of a specific stream or lake system.

Alluvial: Pertaining to sediments gradually deposited by moving water.

Artificial destratification: The process of inducing water currents in a lake to produce partial or total vertical circulation.

Artificial recharge: The addition of water to the groundwater reservoir by activities of man, such as irrigation or induced infiltration.

Assimilation: The absorption and conversion of nutritive elements into protoplasm.

Autochthon: Any organic matter indigenous to a specific stream or lake.

Autotrophic: The ability to synthesize organic matter from inorganic substances.

Background loading of concentration: The concentration of a chemical constituent arising from natural sources.

Base flow: Stream discharge due to groundwater flow.

Benthic oxygen demand: Oxygen demand exerted from the bottom of a stream or lake, usually by biochemical oxidation of organic material in the sediments.

Benthos: Organisms living on or in the bottom of a body of water.

Best management practices: Practices, either structural or non-structural, which are used to control nonpoint source pollution.

Bioassay: The use of living organisms to determine the biological effect of some substance, factor, or condition.

Biochemical oxidation: The process by which bacteria and other microorganisms break down organic material and remove organic matter from solution.

Biochemical oxygen demand (BOD), biological oxygen demand: The amount of oxygen used by aerobic organisms to decompose organic material. Provides an indirect measure of the concentration of biologically degradable material present in water or wastewater.

Biological control: A method of controlling pest organisms by introduced or naturally occurring predatory organisms, sterilization, inhibiting hormones, or other nonmechanical or nonchemical means.

Biological magnification, biomagnification: An increase in concentration of a substance along succeeding steps in a food chain.

[1]U.S. EPA. 1980 Clean Lakes Program Guidance Manual. EPA Report No. EPA 440/5-81-003.

Biomass: The total mass of living organisms in a particular volume or area.

Biota: All living matter in a particular region.

Blue-green algae: The phylum Cyanophyta, characterized by the presence of blue pigment in addition to green chlorophyll.

Catch basin: A collection chamber usually built at the curb line of a street, designed to admit surface water to a sewer or subdrain and to retain matter that would block the sewer.

Catchment: Surface drainage area.

Chemical control: A method of controlling pest organisms through exposure to specific toxic chemicals.

Chlorophyll: Green pigment in plants and algae necessary for photosynthesis.

Circulation period: The interval of time in which the thermal stratification of a lake is destroyed, resulting in the mixing of the entire water body.

Coagulation: The aggregation of colloidal particles, often induced by chemicals such as lime or alum.

Coliform bacteria: Nonpathogenic organisms considered a good indicator of pathogenic bacterial pollution.

Colorimetry: The technique used to infer the concentration of a dissolved substance in solution by comparison of its color intensity with that of a solution of known concentration.

Combined sewer: A sewer receiving both stormwater runoff and sewage.

Compensation point: The depth of water at which oxygen production by photosynthesis and respiration by plants and animals are at equilibrium due to light intensity.

Cover crop: A close-growing crop grown primarily for the purpose of protecting and improving soil between periods of permanent vegetation.

Crustacea: Aquatic animals with a rigid outer covering, jointed appendages, and gills.

Culture: A growth of microorganisms in an artificial medium.

Denitrification: Reduction of nitrates to nitrites or to elemental nitrogen by bacterial action.

Depression storage: Water retained in surface depressions when precipitation intensity is greater than infiltration capacity.

Design storm: A rainfall pattern of specified amount, intensity, duration, and frequency that is used as a basis for design.

Detention: Managing stormwater runoff or sewer flows through temporary holding and controlled release.

Detritus: Finely divided material of organic or inorganic origin.

Diatoms: Organisms belonging to the group Bacillariophyceae, characterized by the presence of silica in its cell walls.

Dilution: A lake restorative measure aimed at reducing nutrient levels within a water body by the replacement of nutrient-rich waters with nutrient-poor waters.

Discharge: A volume of fluid passing a point per unit time, commonly expressed as cubic meters per second.

Dissolved oxygen (DO): The quantity of oxygen present in water in a dissolved state, usually expressed as milligrams per liter of water, or as a percent of saturation at a specific temperature.

Dissolved solids (DS): The total amount of dissolved material, organic and inorganic, contained in water or wastes.

Diversion: A channel or berm constructed across or at the bottom of a slope for the purpose of intercepting surface runoff.

Drainage basin, watershed, drainage area: A geographical area where surface runoff from streams and other natural watercourses is carried by a single drainage system to a common outlet.

Dry weather flow: The combination of sanitary sewage and industrial and commercial wastes normally found in the sanitary sewers during the dry weather season of the year; or, flow in streams during dry seasons.

Dystrophic lakes: Brown-water lakes with a low lime content and a high humus content, often severely lacking nutrients.

Enrichment: The addition to or accumulation of plant nutrients in water.

Epilimnion: The upper, circulating layer of a thermally stratified lake.

Erosion: The process by which the soils of the earth's crust are worn away and carried from one place to another by weathering, corrosion, solution, and transportation.

Eutrophication: A natural enrichment process of a lake, which may be accelerated by man's activities. Usually manifested by one or more of the following characteristics: (a) excessive biomass accumulations of primary producers; (b) rapid organic and/or inorganic sedimentation and shallowing; or (c) seasonal and/or diurnal dissolved oxygen deficiencies.

Fecal streptococcus: A group of bacteria normally present in large numbers in the intestinal tracts of humans and other warm-blooded animals.

First flush: The first, and generally most polluted, portion of runoff generated by rainfall.

Flocculation: The process by which suspended particles collide and combine into larger particles or floccules and settle out of solution.

Gabion: A rectangular or cylindrical wire mesh cage (a chicken wire basket) filled with rock and used to protect against erosion.

Gaging station: A selected section of a stream channel equipped with a gage, recorder, and/or other facilities for determining stream discharge.

Grassed waterway: A natural or constructed waterway covered with erosion-resistant grasses, used to conduct surface water from an area at a reduced flow rate.

Green algae: Algae characterized by the presence of photosynthetic pigments similar in color to those of the higher green plants.

Heavy metals: Metals of high specific gravity, including cadmium, chromium, cobalt, copper, lead, mercury. They are toxic to many organisms even in low concentrations.

Hydrograph: A continuous graph showing the properties of stream flow with respect to time.

Hydrologic cycle: The movement of water from the oceans to the atmosphere and back to the sea. Many subcycles exist including precipitation, interception, runoff, infiltration, percolation, storage, evaporation, and transpiration.

Hypolimnion: The lower, non-circulating layer of a thermally stratified lake.

Intermittent stream: A stream or portion of a stream that flows only when replenished by frequent precipitation.

Irrigation return flow: Irrigation water which is not consumed in evaporation or plant growth, and which returns to a surface stream or groundwater reservoir.

Leaching: Removal of the more soluble materials from the soil by percolating waters.

Limiting nutrient: The substance that is limiting to biological growth due to its short supply with respect to other substances necessary for the growth of an organism.

Littoral: The region along the shore of a body of water.

Macrophytes: Large vascular, aquatic plants which are either rooted or floating.

Mesotrophic lake: A trophic condition between an oligotrophic and an eutrophic water body.

Metalimnion: The middle layer of a thermally stratified lake in which temperature rapidly decreases with depth.

Most probable number (MPN): A statistical indication of the number of bacteria present in a given volume (usually 100 ml).

Nannoplankton: Those organisms suspended in open water which because of their small size, cannot be collected by nets (usually smaller than approximately 25 microns).

Nitrification: The biochemical oxidation process by which ammonia is changed first to nitrates and then to nitrites by bacterial action.

Nitrogen, available: Includes ammonium, nitrate ions, ammonia, and certain simple amines readily available for plant growth.

Nitrogen cycle: The sequence of biochemical changes in which atmospheric nitrogen is "fixed," then used by a living organism, liberated upon the death and decomposition of the organism, and reduced to its original state.

Nitrogen fixation: The biological process of removing elemental nitrogen from the atmosphere and incorporating it into organic compounds.

Nitrogen, organic: Nitrogen components of biological origin such as amino acids, proteins, and peptides.

Nonpoint source: Nonpoint source pollutants are not traceable to a discrete origin, but generally result from land runoff, precipitation, drainage, or seepage.

Nutrient, available: That portion of an element or compound that can be readily absorbed and assimilated by growing plants.

Nutrient budget: An analysis of the nutrients entering a lake, discharging from the lake, and accumulating in the lake (e.g., input minus output = accumulation).

Nutrient inactivation: The process of rendering nutrients inactive by one of three methods: (1) Changing the form of a nutrient to make it unavailable to plants, (2) removing the nutrient from the photic zone, or (3) preventing the release or recycling of potentially available nutrients within a lake.

Oligotrophic lake: A lake with a small supply of nutrients, and consequently a low level of primary production. Oligotrophic lakes are often characterized by a high level of species diversification.

Orthophosphate: See phosphorus, available.

Outfall: The point where wastewater or drainage discharges from a sewer to a receiving body of water.

Overturn, turnovers: The complete mixing of a previously thermally stratified lake. This occurs in the spring and fall when water temperatures in the lake are uniform.

Oxygen deficit: The difference between observed oxygen concentrations and the amount that would be present at 100 percent saturation at a specific temperature.

Peak discharge: The maximum instantaneous flow from a given storm condition at a specific location.

Percolation test: A test used to determine the rate of percolation or seepage of water through natural soils. The percolation rate is expresaed as time in minutes for a 1-inch fall of water in a test hold and is used to determine the acceptability of a site for treatment of domestic wastes by a septic system.

Perennial stream: A stream that maintains water in its channel throughout the year.

Periphyton: Microorganisms that are attached to or growing on submerged surfaces in a waterway.

Phosphorus, available: Phosphorus which is readily available for plant growth. Usually in the form of soluble orthophosphates.

Phosphorus, total (TP): All of the phosphorus present in a sample regardless of form. Usually measured by the persulfate digestion procedure.

Photic zone: The upper layer in a lake where sufficient light is available for photosynthesis.

Photosynthesis: The process occurring in green plants in which light energy is used to convert inorganic compounds to carbohydrates. In this process, carbon dioxide is consumed and oxygen is released.

Phytoplankton: Plant microorganisms, such as algae, living unattached in the water.

Plankton: Unattached aquatic microorganisms which drift passively through water.

Point source: A discreet pollutant discharge such as a pipe, ditch, channel, or concentrated animal feeding operation.

Population equivalent: An expression of the amount of a given waste load in terms of the size of human population that would contribute the same amount of biochemical oxygen demand (BOD) per day. A common base is 0.17 pounds (7.72 grams) of 5-day BOD per capita per day.

Primary production: The production of organic matter from light energy and inorganic materials, by autotrophic organisms.

Protozoa: Unicellular animals, including the ciliates and nonchlorophyllous flagellates.

Rainfall intensity: The rate at which rain falls, usually expressed in centimeters per hour.

Rational method: A means of computing peak storm drainage runoff (Q) by use of the formula Q = CIA, where C is a coefficient describing the physical drainage area, I is the average rainfall intensity, and A is the size of the drainage area.

Raw water: A water supply which is available for use but which has not yet been treated or purified.

Recurrence interval: The anticipated period in years that will elapse, based on average probability of storms in the design region, before a storm of a given intensity and/or total volume will recur; thus, a 10-year storm can be expected to occur on the average once every 10 years. Sewers are generally designed for a specific design storm frequency.

Riprap: Broken rock, cobbles, or boulders placed on earth surfaces, such as the face of a dam or the bank of a stream, for protection against the action of water (waves).

Saprophytic: Pertaining to those organisms that live on dead or decaying organic matter.

Scouring: The clearing and digging action of flowing water, especially the downward erosion caused by stream water in sweeping away mud and silt, usually during a flood.

Secchi depth: A measure of optical water clarity as determined by lowering a weighted Secchi disk into a water body to the point where it is no longer visible.

Sediment basin: A structure designed to slow the velocity of runoff water and facilitate the settling and retention of sediment and debris.

Sediment delivery ratio: The fraction of soil eroded from upland sources that reaches a continuous stream channel or storage reservoir.

Sediment discharge: The quantity of sediment, expressed as a dry weight or volume, transported through a stream cross-section in a given time. Sediment discharge consists of both suspended load and bedload.

Septic: A putrefactive condition produced by anaerobic decomposition of organic wastes, usually accompanied by production of malodorous gases.

Standing crop: The biomass present in a body of water at a particular time.

Sub-basin: A physical division of a larger basin, associated with one reach of the storm drainage system.

Substrate: The substance or base upon which an organism grows.

Suspended solids: Refers to the particulate matter in a sample, including the material that settles readily as well as the material that remains dispersed.

Swale: An elongated depression in the land surface that is at least seasonally wet, is usually heavily vegetated, end is normally without flowing water. Swales conduct stormwater into primary drainage channels and provide some groundwater recharge.

Terrace: An embankment or combination of an embankment and channel built across a slope to control erosion by diverting or storing surface runoff instead of permitting it to flow uninterrupted down the slope.

Thermal stratification: The layering of water bodies due to temperature-induced density differences.

Thermocline: See metalimnion.

Tile drainage: Land drainage by means of a series of tile lines laid at a specified depth and grade.

Total solids: The solids in water, sewage, or other liquids, including the dissolved, filterable, and nonfilterable solids. The residue left when a sample is evaporated and dried at a specified temperature.

Trace elements: Those elements which are needed in low concentrations for the growth of an organism.

Trophic condition: A relative description of a lake's biological productivity. The range of trophic conditions is characterized by the terms oligotrophic for the least biologically productive, to eutrophic for the most biologically productive.

Turbidity: A measure of the cloudiness of a liquid. Turbidity provides an indirect measure of the suspended solids concentration in water.

Urban runoff: Surface runoff from an urban drainage area.

Volatile solids: The quantity of solids in water, sewage, or other liquid, which is lost upon ignition at 600° C.

Waste load allocation: The assignment of target pollutant loads to point sources so as to achieve water quality standards in a stream segment in the most effective manner.

Water quality: A term used to describe the chemical, physical, and biological characteristics of water, usually with respect to its suitability for a particular purpose.

Water quality standards: State-enforced standards describing the required physical and chemical properties of water according to its designated uses.

Watershed: See drainage basin.

Weir: Device for measuring or regulating the flow of water.

Zooplankton: Protozoa and other animal microorganisms living unattached in water.

APPENDIX 1

WATER QUALITY DATA

The water quality data collected during this Phase I study of Lake Hopatcong has been logged in the STORET system and is available through NJDEP, Division of Water Resources.

APPENDIX 2

HISTORICAL WATER QUALITY IS PROVIDED IN
A SEPARATE VOLUME

Princeton Aqua Science. 1980. Application for Federal Assistance to Perform a Phase I Diagnostic and Feasiblity Study in Compliance with Federal Grant Regulation 35.1620-4P.P. under Section 314 of the Federal Clean Water Act of 1977 (P.L. 95-217). Lake Hopatcong Restoration Project.

LIFFY ISLAND AREA:
AN Evaluation of LIFFY ISLAND & Adjacent Areas

LAKE HOPATCONG RESTORATION PROJECT

For: LAKE HOPATCONG REGIONAL PLANNING BOARD
State Park Administration Building, Landing, New Jersey

JULY 10, 1982

pas PRINCETON AQUA SCIENCE

789 Jersey Avenue • P.O. Box 151 • New Brunswick, New Jersey 08902 • (201) 846-8800

July 10, 1982

Mr. Eric Grove, Chairman
Lake Hopatcong Regional Planning Board
State Park Administration Building
Landing, New Jersey 07850

Dear Mr. Grove:

Princeton Aqua Science (PAS) is pleased to submit the following report to the Lake Hopatcong Regional Planning Board (LHRPB), Green Acres Subcommittee, concerning the Liffy Island Area in Woodport Bay.

This evaluation has shown conclusively that, as part of the overall management and restoration program currently being developed for Lake Hopatcong, the aquisition of this area as a natural park is vital to maintaining Lake Hopatcong as a viable recreational resource.

If you have any questions concerning this report, please give me a call.

Sincerely,

PRINCETON AQUA SCIENCE

John Koppen, Ph.D.
Director
Aqua Science Program

JK/cm

Encl.
#1368

EXECUTIVE SUMMARY

The Lake Hopatcong Regional Planning Board (LHRPB) is recommending that Liffy Island and the contiguous shoreline area of Lake Hopatcong adjacent to Liffy Island, be acquired and incorporated as a "natural park".

This recommendation is based on information that has been developed as the result of the current lake management and restoration study that the LHRPB is currently undertaking. This recommendation is consistent with the preliminary findings of this study. As part of an overall management program this aquisition is important and will prevent irreparable damage to the viability of Lake Hopatcong as a recreational resource.

It is highly probable that due to development pressures this one of two last-remaining lakeside natural area will undoubtedly be destroyed. By maintaining it as a natural area of the following objectives will be achieved:

1) Further degradation of water quality in Woodport Bay will be prevented.

2) The most viable fish spawning area within the lake will be preserved.

3) Viable habitat for wildlife will be maintained and wildlife diversity will be assured.

4) A valuable passive recreational area for nature study at other passive pursuits will be preserved.

5) One of the most pleasing shoreline vista along the lake shore will be maintained.

Failure to preserve this area will contribute to the continued degradation of Lake Hopatcong as a viable recreation resource and will have far reaching economic effects on the recreational industry associated with Lake Hopatcong.

This report details some of the data and rational behind this recommendation.

EVALUATION OF LIFFY ISLAND AND ITS'

IMPORTANCE TO LAKE HOPATCONG AND SURROUNDING AREA.

INTRODUCTION

The Lake Hopatcong Regional Planning Board is conducting a Lake Management and Restoration Study in Lake Hopatcong, New Jersey. Though that study is not complete, the one salient feature of the basin that stands out is that the area immediately adjacent to the lake is heavily over developed with high-density residential development. Due to this over development significant pollutant loads are contributed to the lake.

The one large tract of land that has escaped development is Liffy Island and the shoreline immediately adjacent to it. This large forested tract is one of two "natural" areas remaining on the immediate lake-shore and its natural aesthetic features contribute considerably to the lake-users enjoyment. Associated with the tract is a tossock bog that is unique to the lake and rare in northern New Jersey. Also, an embayment (Stump Cove) that is a viable fish spawning area is located at this site adjacent to the Island.

DESCRIPTION OF LIFFY ISLAND

The Liffy Island area is located on the Jefferson Township shoreline of Lake Hopatcong in Woodport Bay (Figure 1). The island and the immediate shoreline make up a tract of approximately 100 acres of forested natural area. This 100 acres in part of a subwatershed basin of 168 acres that drains directly into Woodport Bay on Lake Hopatcong. The configuration of the shoreline in this area creates a small shallow enbayment (Stump Cove) that contains a tussock marsh along the shore.

There are three basic plant communities at Liffy Island and the adjacent mainland: Oak-birch forest, tussock marsh, and Nuphar. The forest stand on the island is surprisingly homogeneous in composition and structure. *Betula lenta*, *Quercus alba*, *Q. prinus*, *Fagus grandifolia*, and *Carya ovalis* dominate the canopy layer. There is a slight increase in the number of oaks with increase in altitude toward the center of the island. In addition to *Quercus alba* and *Q. prinus*, *Q. velutina* and *Q. rubra* are present. Individuals of *Liriodendron tulipifera*, *Fraxinus americanus*, and *Betula allegheniensis* are scattered throughout the island.

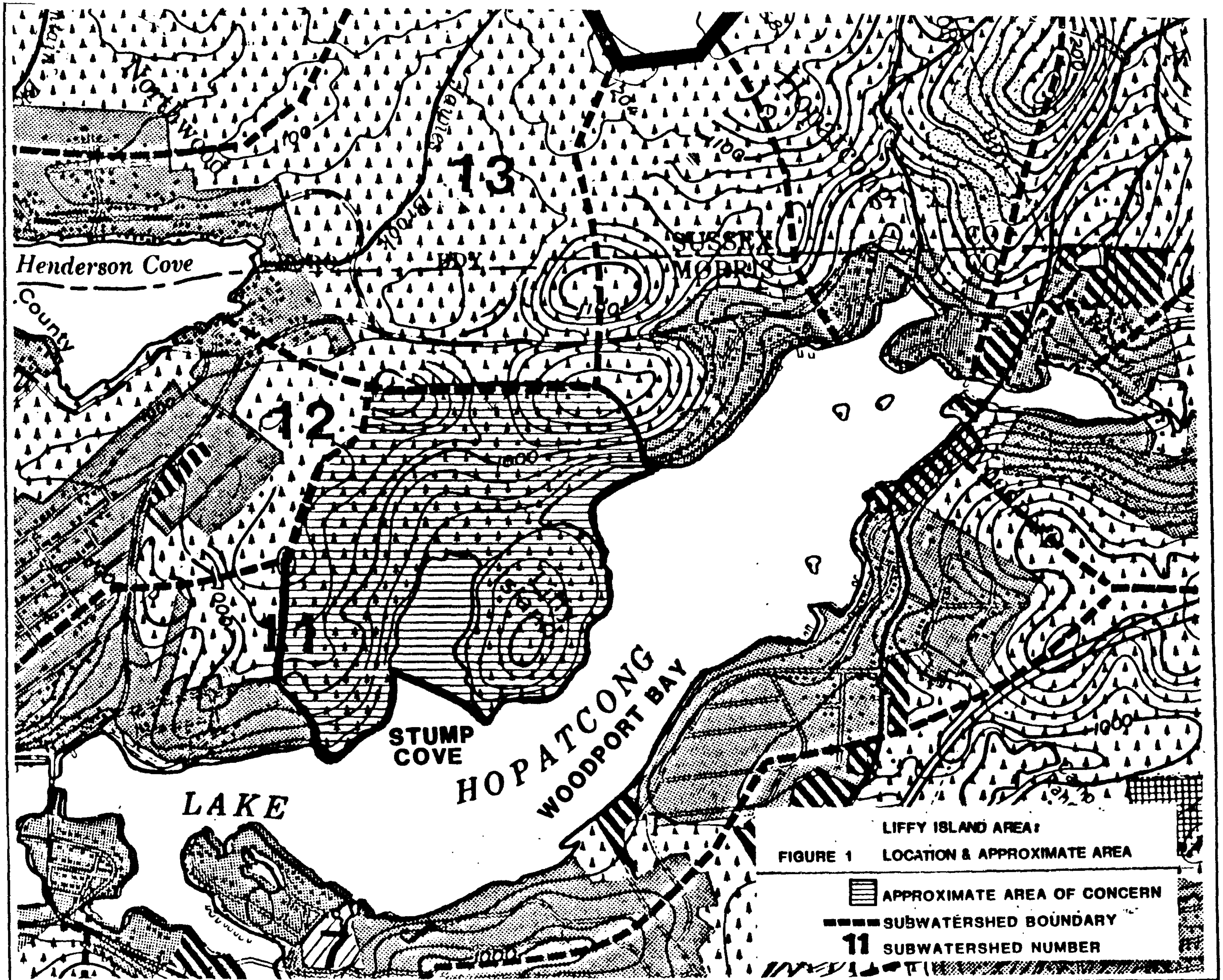

FIGURE 1 LIFFY ISLAND AREA: LOCATION & APPROXIMATE AREA

The dense shrub layer contains Kalmia latifolia, Rhododendron viscossum, Vaccinium corymbosum, and Gaylusaccium baccata. There are also many individuals of Castanea dentata and Fraxinus saplings. The herbaceous layer is very diverse; the most abundant herb is Maianthemum canadense. Several areas on the island have no shrubs or trees and appear to have been past as well as current campsites. These areas are covered with Juncus bufonis, Oxalis stricta, Rubus hispidus, and Stellaria media.

A core of one of the larger red oaks indicates it to be approximately 60-75 years old. The size (61 in diameter breast height) and architecture of this tree indicate it may have been in an open area at one time.

The mainland forest community is almost identical to that of the island. The understory is dominated by stump sprouts of Castanea dentata, indicating a past importance of this tree in the canopy. Because of the rocky nature of the slope the herbaceous layer is not as dense or rich in species as Liffy Island.

The soils of the Highlands physiographic region in which Liffy Island is located, are derived from gneissic rock and glacial till. These soils tend to be acid, shallow, and leached of nutrients, physical factors which probably account for the abundance of Ericaceous shrubs and evergreen herbs.

The remaining communities are in a wetland area between the island and mainland. The deeper waters along the southern edge of the island and the tussock marsh are vegetated with Nuphar advena. The larger shallow water community is a tussock-floating mat dominated by two species of Carex. The northern half of the marsh is composed of floating tussocks of Carex stricta and C. aquatilis ranging from 0.25 to 2 m in diameter. The larger mushroom-shaped tussocks have been colonized by several species of shrubs and small trees including Clethra alnifolia, Cephalanthus occidentalis, Spiraea tomentosa, Rhododendron viscossum, and Acer rubrum. Several species of herbs such as Bidens sp., Hypericum virginicum, and Lysimachia terrestris are very common the tussocks as well. In the open water between the floating tussocks Nuphar advena, Elatine americana, and Sagittaria rigida are found.

As one moves south, the two Carex species are gradually replaced by the mat forming Typha latifolia and Eleocharis fallax. This floating mat is extensive at the southern end and has been colonized in areas by several species of Ericaceous shrubs.

The transition between the marshland and the uplands is very sharp and the only indicator species of this area is Rhododendron viscossum, the swamp azalea. Figure 2 shows the distribution of the plant communities. A list of the plant species found during this investigation is preceded as Appendix 1.

According to Dr. David Fairbrothers (Personal Communicaton to Gary Wein), the tussock marsh area is rare for northern New Jersey. In his experience, the only other marsh of its kind in northern part of the State is in Newfoundland, New Jersey.

Fish: Wildlife

During the survey of the island and adjacent area in June 1982 various species of wildlife, and evidence of wildlife were seen. Evidence that deer inhabit the area is abundant even though none were seen during the survey. However, woodchucks, squirrels, and many bird species were seen. Most notable among these observed were two great blue herons and four territorial redwing blackbirds in the wetland.

A survey of the fishery resources of the Liffy Island Stump Cove area of Lake Hopatcong was conducted by means of haul seine. The data collected from Stump Cove were compared with fishereies data collected by the same means for the River Styx-Crescent Cove section of the lake (Table 1).

The fish sample collected from Stump Cove was well represented by game fish and pan fish of desirable type and size. A healthy forage fish population, dominated by Alosa psuedoharengus, alewives, was also found to occur in the area. By comparison, the River Styx-Crescent Cove sample was dominated by Pumpkinseed, Lepomis gibbosus and bluegill, L. macrochirus, sunfish. Most of these fish were stunted.

Diversity measurements calculated for both areas (Table 2) indicate a much more diverse and rich fish community to exist in the Stump Cove area as opposed to Crescent Cove.

The differences observed in the fish communities sampled at both locations is in part a result of the habitat available at either location. Both game fish and forage fish require aquatic weeds for use in spawning, foraging, and predator avoidance. However, as the density of the vegetation increases,

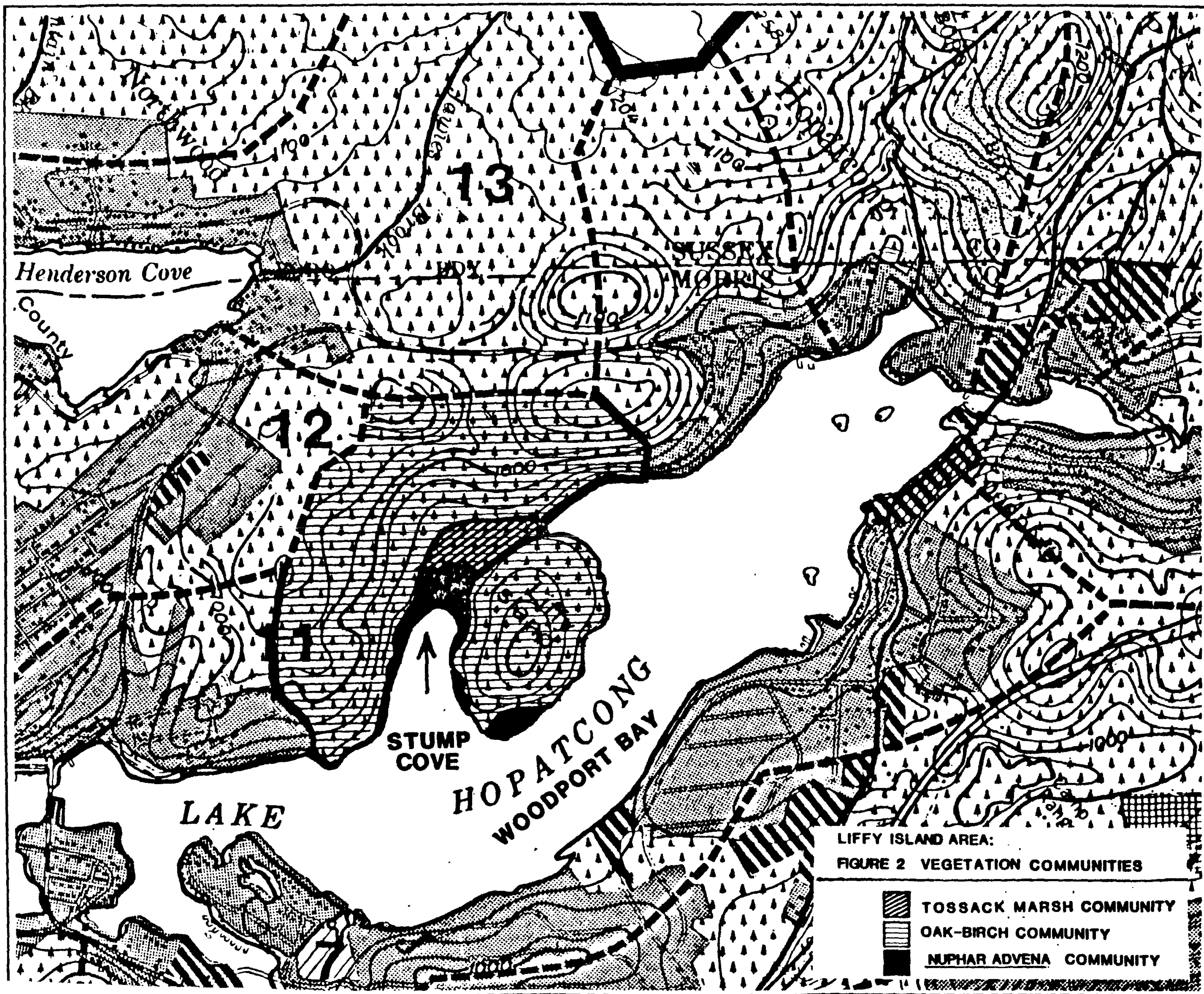
LIFFY ISLAND AREA:
FIGURE 2 VEGETATION COMMUNITIES
TOSSACK MARSH COMMUNITY
OAK-BIRCH COMMUNITY
NUPHAR ADVENA COMMUNITY
Henderson Cove
County
SUSSEX
MORRIS
Northwood
13
12
11
STUMP
COVE
LAKE
HOPATCONG
WOODPORT BAY

TABLE 1

HAUL SCEINE FISHERY DATA

FOR LIFFY ISLAND AND CRESCENT COVE

LIFFY ISLAND (STUMP COVE)

SPECIES	COMMON NAME	NUMBER
Lepomis gibbosus	Pumpkin Seed	1
L. macrochirus	Bluegill	2
L. auritus	Yellowbelly Sunfish	1
Pomoxis nigromaculatus	Black Crappie	2
Notemigonus crysoleucas	Golden Shiner	13
Perca flavescens	Yellow Perch	4
Alosa pseudoharengus	Alewife	71
Notropis sp	Shiner	5
Total---		102

RIVER STYX (CRESCENT COVE)

SPECIES	COMMON NAME	NUMBER
Lepomis gibbosus	Pumpkin Seed	22
L. macrochirus	Bluegill	10
L. auritus	Yellowbelly Sunfish	2
Esox niger	Chain Pickerel	1
Total---		35

TABLE 2

DIVERSITY, RICHNESS, AND EVENNESS
VALUES FOR LIFFY ISLAND & RIVER STYX
FISH COMMUNITIES

Location	Number of Species	Number of Individuals	Diversity* D	Richness* R	Evenness* E
Liffy Island-Stump Cove	8	102	5.062	1.51	2.43
River Styx - Crescent Cove	4	35	.109	.84	.079

* Calculated by Following Equations

$$D = 3.3219\ (\log_{10}N - \frac{1}{N}\Sigma n_i\ \log_{10}n_i)$$

$$R = \frac{S-1}{\log N}$$

$$E = D/\log S$$

Where

N = Total Individuals

N_i = Individuals in species i

S = Number of species

3.3219 = Conversion factor for $\log_{10}$ to $\log_e$

piscivorous game species such as perch, bass, and crappie become less successful in preying upon forage fish. It has also been found that in very dense macrophyte stands that sunfish fry can outcompete bass fry for both prey and habitat. In Crescent Cove aquatic macrophyte stands, composed primarily of Myriophyllum sp, occur in nuisance densities. The occurrence of these nuisance species in Crescent Cove and River Styx is directly attributable to the development around the cove. Although aquatic weeds are prevalent in Stump Cove, they do not reach the proportions observed in Crescent Cove and there is greater diversity. In addition, emergent plants, such as Nuphar dominate Stump Cove as opposed to the dense submergent plants found in Crescent Cove. Another habitat dimension is added by the vegetation comprising the floating tussock marsh located at the northwestern section of Stump Cove. This marsh area provides a habitat well suited for piscivorous fish which ambush their prey. This difference in habitat also makes the Stump Cove area more suitable for the spawning of perch and bass, than for the reproduction of sunfish.

IMPORTANCE OF AREA TO LAKE

As time goes on, the pressures to develop the remaining vacant land around Lake Hopatcong increases. As indicated earlier, this is one of two remaining natural areas along the lake. In its present "natural condition" its importance to the lake and the lake ecosystem is great and development of the area to any extent would produce considerable adverse environmental impacts to both the natural lake and ecosystem, and the socioeconomic well being of the area.

Water Quality Impacts

One of the findings of the current lake study is that pollution of the lake from nonpoint sources is substantial and possibly accounts for the greatest pollutant load to Lake Hopatcong. Nonpoint sources include surface runoff from the area adjacent to a watershed. In the case of Lake Hopatcong, the pollutants of most concern are phosphorus, nitrogen, and suspended sediment. The phosphorus and nitrogen contributed to the lake support nuisance growth of algae and aquatic plants. Suspended solids (eroding soil) tend to fill in water bodies. In the nonpoint source calculations presented here contributions from septic systems to the pollution of the lake are not included and the soils in much of the area are unsuitable for septic systems.

The subwatershed area that the Liffy Island and adjacent shoreline is located in is Number 11 as described in Lake Hopatcong Regional Planning Board Study (See Figure 2 and figure at end of report). This subwatershed is 168 acres of which approximately 100 acres represents the subject property.

Woodport Bay is separated from the rest of the lake and responds to pollutants as if it were a separate body of water. The development of the Liffy Island tract would have a substantial impact on the water quality of Woodport Bay, especially Stump Cove.

For example: if the load of pollutants entering Woodport Bay from watersheds 1-4 that come in through Lake Shawnee are disregarded because they tend to flow directly out of under the causeway into the main lake, the total remaining phosphorus load to Woodport Bay is 628.9 Kg/P/Yr. The following table illustrates the proportions of this load that can be attributed to this sub-watershed under existing and developed conditions.

PHOSPHORUS LOADING

Condition of Subbasin 11	Total Load Woodport Bay	% Increase	Phosphorus Load from Subbasin 11	% of total from Subbasin 11
Existing	628.90	0	89.79	14.3
50/50 High Low Density Residential	707.85	12	168.74	23.8
100% High Density Residential	792.05	25	252.94	31.9

In terms of phosphorus loading, development this subbasin would increase the phosphorus pollution to Woodport Bay by 12-25% depending upon development and density. This increased phosphorus load would further stimulate algae and weed growth even more than it is now. There would be comparable increases in nitrogen and suspended sediment loads with development also.

Impacts on Marsh

As indicated earlier, the tussock marsh located along the shoreline of Stump Cove is an unusual (rare) habitat in New Jersey. Much of the area on the shoreline and up from the lake drains directly into the cove near the marsh. Nonpoint source pollution that would come from this area if it were developed, would severly impact this marsh, and in fact, could destroy it as a viable habitat for wildlife. The major effect would be from increased suspended solids and phosphorus entering this area.

Fisheries Impacts

Also, the increased loading to Stump Cove would affect this area as a viable fishery. The comparison between the fishing investigations of Crescent Cove and those in Stump Cove indicates what could happen if development in this subwatershed were allowed. Due to construction activities at first, and increased loadings of phosphorus and suspended solids over the long term after development, the entire nature of this area would change both in depth and composition of the community.

For example: a game fish habitat and spawning area would be lost. The sedimentation of Stump Cove, resulting from development of the area, would affect bass spawning, as males commonly desert their nests if the egg becomes silt covered.

Thus, in respect to the existing fishery resource of Liffy Island - Stump Cove, it appears that noticable changes in the community structure would result if the surrounding area was to be developed.

Impacts To Terrestrial Fauna

Also, as far as terrestrial fauna is concerned, evidence of considerable faunal activity was observed. The relative inaccessability of the island proper, prevents a large influx of people which would normally take its toll on the biota. Preservation of the tracts vegetation will help insure faunal diversity in the area and will serve as habitat for species of animals that are less tolerant of human disturbance. This area should remain in its present condition to insure this diversity.

Recreation Impacts

In terms of recreational potential, the loss of this site to development would destroy an aesthetically pleasing location. It represents the most pleasing natural vista on the lake and is a valuable area for natural history study and other types of passive recreation. This is almost the last area on the lake where this type of activity can occur. For active recreation, the lake, State Park and Bertrand Island Amusement Park are available. The best use for this site is passive recreation such as bird watching, hiking, etc.

Recommendations

As part of a comprehensive watershed management plan for Lake Hopatcong, we recommend that this natural area be acquired to preserve its natural character and protect Lake Hopatcong.

The basis for making this recommendation includes the following:

1) There are only two remaining "natural" areas along the shoreline of Lake Hopatcong. Thus, its aesthetic value is great for passive recreational purposes.

2) The small floating tussock marsh located along the northwest shore of Stump Cove is unique to the lake and rare in New Jersey.

3) The area provides habitat for many animal species and this helps maintain wildlife diversity in the region.

4) One of the major problems associated with Lake Hopatcong is nonpoint loading of nutrients (phosphorus and nitrogen) to the lake. If this area were developed for residential or commercial use the loading rates for phosphorus would increase 2 to 5 times its current level and nitrogen loading could double.

5) Development of this area would threaten the most viable fish spawning area on the lake.

Thus, in our advisory capacity, the Lake Hopatcong Regional Planning Board is recommending that this tract of land be acquired and maintained in its current condition.

APPENDIX 3

LIFFY ISLAND AREA: AN EVALUATION OF
LIFFY ISLAND AND ADJACENT AREAS

LIFFY ISLAND AREA:
AN Evaluation of LIFFY ISLAND & Adjacent Areas

LAKE HOPATCONG RESTORATION PROJECT

For: LAKE HOPATCONG REGIONAL PLANNING BOARD
State Park Administration Building, Landing, New Jersey

JULY 10, 1982

PAS PRINCETON AQUA SCIENCE

789 Jersey Avenue • P.O. Box 151 • New Brunswick, New Jersey 08902 • (201) 846-8800

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Lake Hopatcong Regional Planning Board
State Park Administration Building
Landing, New Jersey 07850

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If you have any questions concerning this report, please give me a call.

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John Koppen,Ph.D.
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EXECUTIVE SUMMARY

The Lake Hopatcong Regional Planning Board (LHRPB) is recommending that Liffy Island and the contiguous shoreline area of Lake Hopatcong adjacent to Liffy Island, be acquired and incorporated as a "natural park".

This recommendation is based on information that has been developed as the result of the current lake management and restoration study that the LHRPB is currently undertaking. This recommendation is consistent with the preliminary findings of this study. As part of an overall management program this aquisition is important and will prevent irreparable damage to the viability of Lake Hopatcong as a recreational resource.

It is highly probable that due to development pressures this one of two last-remaining lakeside natural area will undoubtedly be destroyed. By maintaining it as a natural area of the following objectives will be achieved:

1) Further degradation of water quality in Woodport Bay will be prevented.

2) The most viable fish spawning area within the lake will be preserved.

3) Viable habitat for wildlife will be maintained and wildlife diversity will be assured.

4) A valuable passive recreational area for nature study at other passive pursuits will be preserved.

5) One of the most pleasing shoreline vista along the lake shore will be maintained.

Failure to preserve this area will contribute to the continued degradation of Lake Hopatcong as a viable recreation resource and will have far reaching economic effects on the recreational industry associated with Lake Hopatcong.

This report details some of the data and rational behind this recommendation.

EVALUATION OF LIFFY ISLAND AND ITS'

IMPORTANCE TO LAKE HOPATCONG AND SURROUNDING AREA.

INTRODUCTION

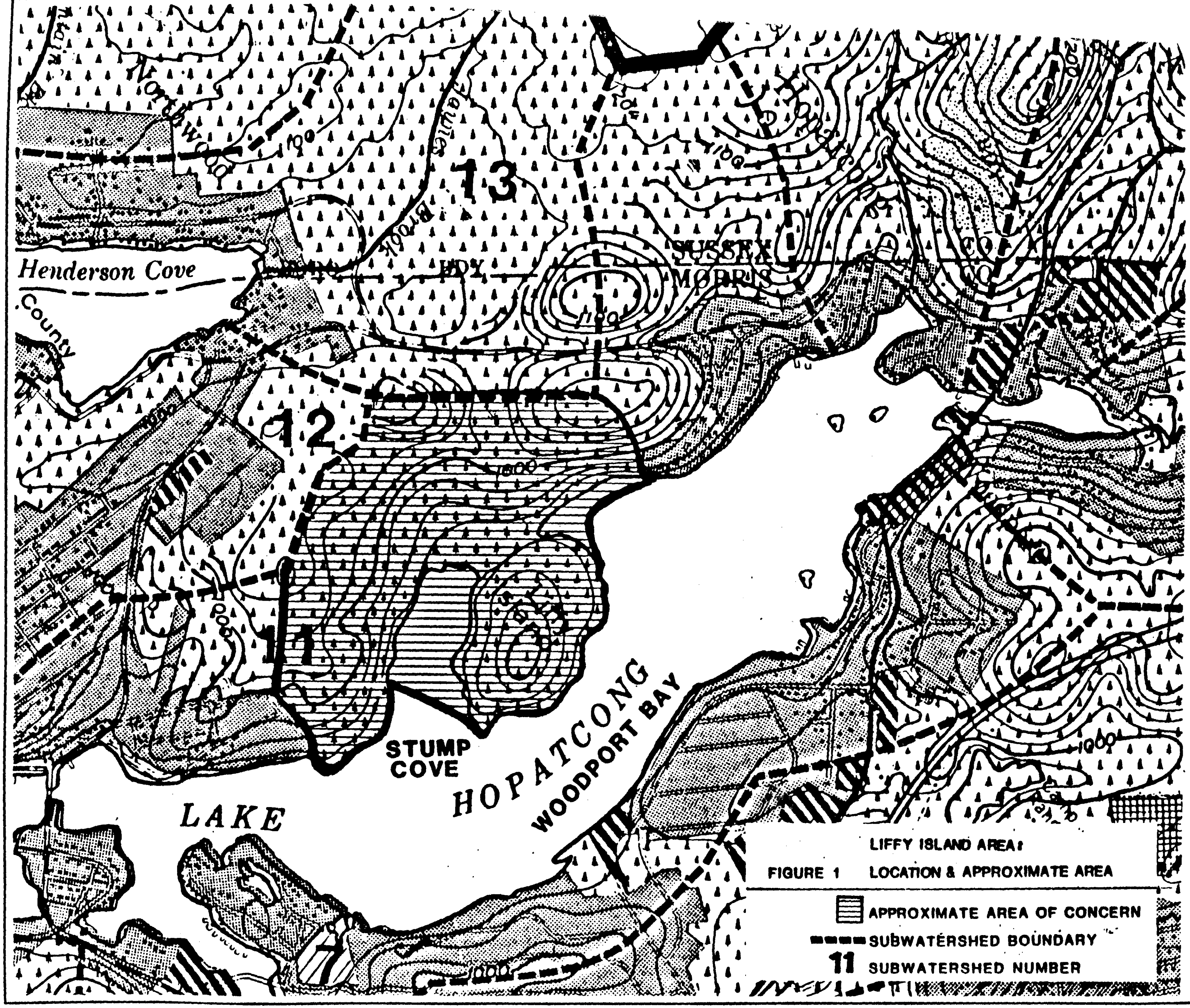
The Lake Hopatcong Regional Planning Board is conducting a Lake Management and Restoration Study in Lake Hopatcong, New Jersey. Though that study is not complete, the one salient feature of the basin that stands out is that the area immediately adjacent to the lake is heavily over developed with high-density residential development. Due to this over development significant pollutant loads are contributed to the lake.

The one large tract of land that has escaped development is Liffy Island and the shoreline immediately adjacent to it. This large forested tract is one of two "natural" areas remaining on the immediate lake-shore and its natural aesthetic features contribute considerably to the lake-users enjoyment. Associated with the tract is a tossock bog that is unique to the lake and rare in northern New Jersey. Also, an embayment (Stump Cove) that is a viable fish spawning area is located at this site adjacent to the Island.

DESCRIPTION OF LIFFY ISLAND

The Liffy Island area is located on the Jefferson Township shoreline of Lake Hopatcong in Woodport Bay (Figure 1). The island and the immediate shoreline make up a tract of approximately 100 acres of forested natural area. This 100 acres in part of a subwatershed basin of 168 acres that drains directly into Woodport Bay on Lake Hopatcong. The configuration of the shoreline in this area creates a small shallow enbayment (Stump Cove) that contains a tussock marsh along the shore.

There are three basic plant communities at Liffy Island and the adjacent mainland: Oak-birch forest, tussock marsh, and Nuphar. The forest stand on the island is surprisingly homogeneous in composition and structure. Betula lenta, Quercus alba, Q. prinus, Fagus grandifolia, and Carya ovalis dominate the canopy layer. There is a slight increase in the number of oaks with increase in altitude toward the center of the island. In addition to Quercus alba and Q. prinus, Q. velutina and Q. rubra are present. Individuals of Liriodendron tulipifera, Fraxinus americanus, and Betula allegheniensis are scattered throughout the island.



Henderson Cove
County
Brook
13
12
11
SUSSEX
MORRIS
BDY
STUMP
COVE
LAKE
HOPATCONG
WOODPORT BAY
1000
1100
LIFFY ISLAND AREA:
FIGURE 1 LOCATION & APPROXIMATE AREA
APPROXIMATE AREA OF CONCERN
SUBWATERSHED BOUNDARY
11 SUBWATERSHED NUMBER

The dense shrub layer contains Kalmia latifolia, Rhododendron viscossum, Vaccinium corymbosum, and Gaylusaccium baccata. There are also many individuals of Castanea dentata and Fraxinus saplings. The herbaceous layer is very diverse; the most abundant herb is Maianthemum canadense. Several areas on the island have no shrubs or trees and appear to have been past as well as current campsites. These areas are covered with Juncus bufonis, Oxalis stricta, Rubus hispidus, and Stellaria media.

A core of one of the larger red oaks indicates it to be approximately 60-75 years old. The size (61 in diameter breast height) and architecture of this tree indicate it may have been in an open area at one time.

The mainland forest community is almost identical to that of the island. The understory is dominated by stump sprouts of Castanea dentata, indicating a past importance of this tree in the canopy. Because of the rocky nature of the slope the herbaceous layer is not as dense or rich in species as Liffy Island.

The soils of the Highlands physiographic region in which Liffy Island is located, are derived from gneissic rock and glacial till. These soils tend to be acid, shallow, and leached of nutrients, physical factors which probably account for the abundance of Ericaceous shrubs and evergreen herbs.

The remaining communities are in a wetland area between the island and mainland. The deeper waters along the southern edge of the island and the tussock marsh are vegetated with Nuphar advena. The larger shallow water community is a tussock-floating mat dominated by two species of Carex. The northern half of the marsh is composed of floating tussocks of Carex stricta and C. aquatilis ranging from 0.25 to 2 m in diameter. The larger mushroom-shaped tussocks have been colonized by several species of shrubs and small trees including Clethra alnifolia, Cephalanthus occidentalis, Spiraea tomentosa, Rhododendron viscossum, and Acer rubrum. Several species of herbs such as Bidens sp., Hypericum virginicum, and Lysimachia terrestris are very common the tussocks as well. In the open water between the floating tussocks Nuphar advena, Elatine americana, and Sagittaria rigida are found.

As one moves south, the two Carex species are gradually replaced by the mat forming Typha latifolia and Eleocharis fallax. This floating mat is extensive at the southern end and has been colonized in areas by several species of Ericaceous shrubs.

The transition between the marshland and the uplands is very sharp and the only indicator species of this area is Rhododendron viscossum, the swamp azalea. Figure 2 shows the distribution of the plant communities. A list of the plant species found during this investigation is preceded as Appendix 1.

According to Dr. David Fairbrothers (Personal Communicaton to Gary Wein), the tussock marsh area is rare for northern New Jersey. In his experience, the only other marsh of its kind in northern part of the State is in Newfoundland, New Jersey.

Fish: Wildlife

During the survey of the island and adjacent area in June 1982 various species of wildlife, and evidence of wildlife were seen. Evidence that deer inhabit the area is abundant even though none were seen during the survey. However, woodchucks, squirrels, and many bird species were seen. Most notable among these observed were two great blue herons and four territorial redwing blackbirds in the wetland.

A survey of the fishery resources of the Liffy Island Stump Cove area of Lake Hopatcong was conducted by means of haul seine. The data collected from Stump Cove were compared with fishereies data collected by the same means for the River Styx-Crescent Cove section of the lake (Table 1).

The fish sample collected from Stump Cove was well represented by game fish and pan fish of desirable type and size. A healthy forage fish population, dominated by Alosa psuedoharengus, alewives, was also found to occur in the area. By comparison, the River Styx-Crescent Cove sample was dominated by Pumpkinseed, Lepomis gibbosus and bluegill, L. macrochirus, sunfish. Most of these fish were stunted.

Diversity measurements calculated for both areas (Table 2) indicate a much more diverse and rich fish community to exist in the Stump Cove area as opposed to Crescent Cove.

The differences observed in the fish communities sampled at both locations is in part a result of the habitat available at either location. Both game fish and forage fish require aquatic weeds for use in spawning, foraging, and predator avoidance. However, as the density of the vegetation increases,

TABLE 1

HAUL SCEINE FISHERY DATA

FOR LIFFY ISLAND AND CRESCENT COVE

LIFFY ISLAND (STUMP COVE)

SPECIES	COMMON NAME	NUMBER
Lepomis gibbosus	Pumpkin Seed	1
L. macrochirus	Bluegill	2
L. auritus	Yellowbelly Sunfish	1
Pomoxis nigromaculatus	Black Crappie	2
Notemigonus crysoleucas	Golden Shiner	13
Perca flavescens	Yellow Perch	4
Alosa pseudoharengus	Alewife	71
Notropis sp	Shiner	5
Total		102

RIVER STYX (CRESCENT COVE)

SPECIES	COMMON NAME	NUMBER
Lepomis gibbosus	Pumpkin Seed	22
L. macrochirus	Bluegill	10
L. auritus	Yellowbelly Sunfish	2
Esox niger	Chain Pickerel	1
Total		35

TABLE 2

DIVERSITY, RICHNESS, AND EVENNESS
VALUES FOR LIFFY ISLAND & RIVER STYX
FISH COMMUNITIES

Location	Number of Species	Number of Individuals	Diversity* D	Richness* R	Evenness* E
Liffy Island-Stump Cove	8	102	5.062	1.51	2.43
River Styx - Crescent Cove	4	35	.109	.84	.079

* Calculated by Following Equations

$$D = 3.3219\ (\log_{10} N - \frac{1}{N} \Sigma n_i \log_{10} n_i)$$

$$R = \frac{S-1}{\log N}$$

$$E = D/\log S$$

Where

N = Total Individuals

N_i = Individuals in species i

S = Number of species

3.3219 = Conversion factor for $\log_{10}$ to $\log_e$

piscivorous game species such as perch, bass, and crappie become less successful in preying upon forage fish. It has also been found that in very dense macrophyte stands that sunfish fry can outcompete bass fry for both prey and habitat. In Crescent Cove aquatic macrophyte stands, composed primarily of Myriophyllum sp, occur in nuisance densities. The occurrence of these nuisance species in Crescent Cove and River Styx is directly attributable to the development around the cove. Although aquatic weeds are prevalent in Stump Cove, they do not reach the proportions observed in Crescent Cove and there is greater diversity. In addition, emergent plants, such as Nuphar dominate Stump Cove as opposed to the dense submergent plants found in Crescent Cove. Another habitat dimension is added by the vegetation comprising the floating tussock marsh located at the northwestern section of Stump Cove. This marsh area provides a habitat well suited for piscivorous fish which ambush their prey. This difference in habitat also makes the Stump Cove area more suitable for the spawning of perch and bass, than for the reproduction of sunfish.

IMPORTANCE OF AREA TO LAKE

As time goes on, the pressures to develop the remaining vacant land around Lake Hopatcong increases. As indicated earlier, this is one of two remaining natural areas along the lake. In its present "natural condition" its importance to the lake and the lake ecosystem is great and development of the area to any extent would produce considerable adverse environmental impacts to both the natural lake and ecosystem, and the socioeconomic well being of the area.

Water Quality Impacts

One of the findings of the current lake study is that pollution of the lake from nonpoint sources is substantial and possibly accounts for the greatest pollutant load to Lake Hopatcong. Nonpoint sources include surface runoff from the area adjacent to a watershed. In the case of Lake Hopatcong, the pollutants of most concern are phosphorus, nitrogen, and suspended sediment. The phosphorus and nitrogen contributed to the lake support nuisance growth of algae and aquatic plants. Suspended solids (eroding soil) tend to fill in water bodies. In the nonpoint source calculations presented here contributions from septic systems to the pollution of the lake are not included and the soils in much of the area are unsuitable for septic systems.

The subwatershed area that the Liffy Island and adjacent shoreline is located in is Number 11 as described in Lake Hopatcong Regional Planning Board Study (See Figure 2 and figure at end of report). This subwatershed is 168 acres of which approximately 100 acres represents the subject property.

Woodport Bay is separated from the rest of the lake and responds to pollutants as if it were a separate body of water. The development of the Liffy Island tract would have a substantial impact on the water quality of Woodport Bay, especially Stump Cove.

For example: if the load of pollutants entering Woodport Bay from watersheds 1-4 that come in through Lake Shawnee are disregarded because they tend to flow directly out of under the causeway into the main lake, the total remaining phosphorus load to Woodport Bay is 628.9 Kg/P/Yr. The following table illustrates the proportions of this load that can be attributed to this subwatershed under existing and developed conditions.

PHOSPHORUS LOADING

Condition of Subbasin 11	Total Load Woodport Bay	% Increase	Phosphorus Load from Subbasin 11	% of total from Subbasin 11
Existing	628.90	0	89.79	14.3
50/50 High Low Density Residential	707.85	12	168.74	23.8
100% High Density Residential	792.05	25	252.94	31.9

In terms of phosphorus loading, development this subbasin would increase the phosphorus pollution to Woodport Bay by 12-25% depending upon development and density. This increased phosphorus load would further stimulate algae and weed growth even more than it is now. There would be comparable increases in nitrogen and suspended sediment loads with development also.

Impacts on Marsh

As indicated earlier, the tussock marsh located along the shoreline of Stump Cove is an unusual (rare) habitat in New Jersey. Much of the area on the shoreline and up from the lake drains directly into the cove near the marsh. Nonpoint source pollution that would come from this area if it were developed, would severly impact this marsh, and in fact, could destroy it as a viable habitat for wildlife. The major effect would be from increased suspended solids and phosphorus entering this area.

Fisheries Impacts

Also, the increased loading to Stump Cove would affect this area as a viable fishery. The comparison between the fishing investigations of Crescent Cove and those in Stump Cove indicates what could happen if development in this subwatershed were allowed. Due to construction activities at first, and increased loadings of phosphorus and suspended solids over the long term after development, the entire nature of this area would change both in depth and composition of the community.

For example: a game fish habitat and spawning area would be lost. The sedimentation of Stump Cove, resulting from development of the area, would affect bass spawning, as males commonly desert their nests if the egg becomes silt covered.

Thus, in respect to the existing fishery resource of Liffy Island - Stump Cove, it appears that noticable changes in the community structure would result if the surrounding area was to be developed.

Impacts To Terrestrial Fauna

Also, as far as terrestrial fauna is concerned, evidence of considerable faunal activity was observed. The relative inaccessability of the island proper, prevents a large influx of people which would normally take its toll on the biota. Preservation of the tracts vegetation will help insure faunal diversity in the area and will serve as habitat for species of animals that are less tolerant of human disturbance. This area should remain in its present condition to insure this diversity.

Recreation Impacts

In terms of recreational potential, the loss of this site to development would destroy an aesthetically pleasing location. It represents the most pleasing natural vista on the lake and is a valuable area for natural history study and other types of passive recreation. This is almost the last area on the lake where this type of activity can occur. For active recreation, the lake, State Park and Bertrand Island Amusement Park are available. The best use for this site is passive recreation such as bird watching, hiking, etc.

Recommendations

As part of a comprehensive watershed management plan for Lake Hopatcong, we recommend that this natural area be acquired to preserve its natural character and protect Lake Hopatcong.

The basis for making this recommendation includes the following:

1) There are only two remaining "natural" areas along the shoreline of Lake Hopatcong. Thus, its aesthetic value is great for passive recreational purposes.

2) The small floating tussock marsh located along the northwest shore of Stump Cove is unique to the lake and rare in New Jersey.

3) The area provides habitat for many animal species and this helps maintain wildlife diversity in the region.

4) One of the major problems associated with Lake Hopatcong is nonpoint loading of nutrients (phosphorus and nitrogen) to the lake. If this area were developed for residential or commercial use the loading rates for phosphorus would increase 2 to 5 times its current level and nitrogen loading could double.

5) Development of this area would threaten the most viable fish spawning area on the lake.

Thus, in our advisory capacity, the Lake Hopatcong Regional Planning Board is recommending that this tract of land be acquired and maintained in its current condition.

d - dominant

SPECIES	COMMON NAME	COMMUNITY: Marsh	Nuphar	Mainland	Liffy Isl.
*Musaceae					
Sphagnum sp.					
Lycopodiaceae					
Lycopodium obscurum	Ground pine				c
L. complanatum	Ground cedar				c
Osmundaceae					
Osmunda regalis	Royal fern	r			
Polypodiaceae					
Adiantum pedatum	Maidenhair fern			r	
Pteridium aquilinum	Bracken fern			r	
Thelypteris palustris	Marsh fern	c			
Dryopteris marginalis	Shield fern				c
Pinaceae					
Pinus strobus	White pine				r
Typhaceae					
Typha angustifolia (latifolia x angustifolia ?)	Cattail	d			
Sparganiaceae					
Sparganium sp.	Bur-reed	r			
Najacaceae					
Potamogeton confervides	Pondweed	c			
Alismataceae					
Sagittaria rigida	Arrow-head	c			
Hydrochoritaceae					
Vallisneria americana	Tape-grass		c		
Gramineae					
Panicum sp.	Panic-grass				r
Cyperaceae					
Eleocharis fallax	Spike rush	d			
Carex aquatilis	Sedge	c			
C. stricta	Sedge	d			
Araceae					
Arisaema triphyllum	Jack in the Pulpit			c	c
Lemnaceae					
Lemna sp.	Duckweed	c			
Juncaceae					
Juncus bufonis	Toad rush				c
Liliaceae					
Smilacina racemosa	False solomon's seal			c	c
Maianthemum canadense	Lily of the valley			c	c
Uvularia perfoliata	Bellwort				c
Polygonatum biflorum	Solomon's seal			c	c
Medeola virginiana	Indian cucumber root			c	
Iridaceae					
Iris sp.	Blue flag				r
Orchidaceae					
Goodyera pubescens	Downy rattlesnake plantain				
Salicaceae					
Salix discolor	Pussy-willow	c			
Populos grandidentata	Large-toothed aspen			r	
Juglandaceae					
Carya ovata	Shagbark hickory			r	c
C. ovalis	Pignut hickory			c	c
Betulaceae					
Ostrya caroliniana	Hop-bornbeam			c	c
Betula lenta	Sweet birch			d	d
B. populifolia	Grey birch			r	
B. alleghaniensis	Yellow birch			c	c
Fagaceae					
Fagus grandifolia	Beech			c	c
Castanea dentata	Chestnut			c	c
Quercus alba	White oak			d	d
Q. prinus	Chestnut oak			d	d
Q. valutina	Black oak			c	c
Q. palustris	Pin oak			c	c
Polygonaceae					
Rumex orbiculatus	Great water dock	c			
Polygonum persicaria	Smartweed			c	
Caryophyllaceae					
Stellaria media	Chickweed				c
Nymphaeaceae					
Nuphar advena	Water lily		d		
Magnoliaceae					
Liriodendron tulipifera	Yellow poplar			c	c
Ranunculaceae					
Actea pachypoda	Baneberry			c	c
Aquilegia canadensis	Columbine			r	
Ranunculus abortivus	Small flowered crowfoot				c
Hepatica americana	Hepatica				c
Anemonella thalictroides	Rue anemone				r

*Nomenclature from Gleason & Cronquist (1963)

SPECIES	COMMON NAME	Marsh	Nuphar	Mainland	Liffy Isl.
Lauraceae					
Sassafras albidum	Sassafras			r	
Lindera benzoin	Spice bush			r	
Hamamelidaceae					
Hamamelis virginiana	Witch hazel			c	c
Rosaceae					
Spiraea tomentosa	Steeplebush	d			
Potentilla simplex	Cinquefoil			c	c
Rubus hispidus	Dewberry				c
Agrimonea sp.	Agrimony				c
Rosa palustris	Swamp rose	c			
Amelanchier sp.	Shad bush			c	c
Fabaceae					
Desmodium nudeflorum	Tick trefoil			c	c
Oxalidaceae					
Oxalis stricta	Sheepsorrel				c
Geraniaceae					
Geranium maculatum	Geranium			c	c
Anacardiaceae					
Toxicondendron radicans	Poison ivy			r	r
Aceraceae					
Acer saccharum	Sugar maple			c	r
A. rubrum	Red maple	d		c	c
A. saccharinum	Silver maple				c
Balsaminaceae					
Impatiens biflora	Touch me not	c			
Vitaceae					
Vitis sp.	Grape				r
Parthenocissus quinquifolia	Virginia creeper			c	c
Treadenum virginicum	Marsh St. John's wort	c			
Elatinaceae					
Elatine americana	Waterwort	c			
Violaceae					
Viola spp.	Violets			c	c
Araliaceae					
Aralia nudicaulus	Wild sarsaparilla			c	c
Umbelliferae					
Sanicula trifoliata	Black snakeroot			c	r
Cornaceae					
Cornus florida	Flowering dogwood			c	c
					r

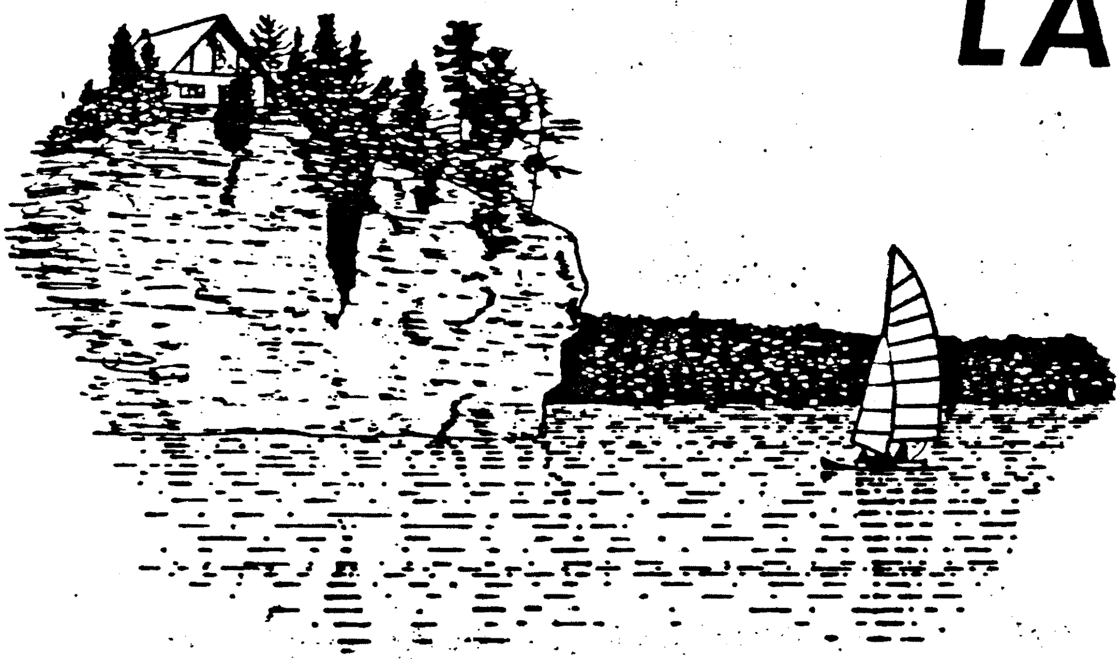
SPECIES	COMMON NAME	Marsh	Nuphar	Mainland	Liffy Isl.
Clethraceae					
Clethra alnifolia	Sweet pepper bush	d			
Ericaceae					
Monotropa uniflora	Indian pipe				r
Chimophilia maculata	Spotted wintergreen				r
Pyrola elliptica	Shinleaf				r
Rhodendron viscosum	Swamp azalea	c		c	c
Kalmia latifolia	Mountain laurel				c
Gaultheria procumbens	Wintergreen			c	c
Gaylussacia baccata	Black huckleberry			c	c
Vaccinium corymbosum	Highbush blueberry			c	c
V. vacillans	Lowbush blueberry			c	c
Prinulaceae					
Lysimachia quadrifolia	Loosestrife				c
L. terrestris	Loosestrife	r			c
L. thyrsiflora	Loosestrife	c			
Oleaceae					
Fraxinus americana	White ash			c	c
Polemoniaceae					
Phlox paniculata	Phlox	r			
Labiatae					
Scutellaria epilobilifolia	Marsh skullcap	c			
Lycopus uniflorus	Bugle weed	c			
L. americanus	Horehound	c			
Hedeoma pulegioides	Hedeoma				r
Collinsonia canadensis	Horse balm			r	
Scrophulariaceae					
Verbascum thapsus	Mullein			r	
Rubiaceae					
Mitchella repens	Partridge berry			c	
Cephalanthus occidentalis	Buttonbush	c			
Galium palustre	Marsh bedstraw	c			
G. aparine	Whoreled loosestrife				
Caprifoliaceae					
Viburnum acerifolium	Maple leaf vidurnum			c	
Compositae					
Bidens sp.	Beggar ticks	c			
Erechtitis hieracifolia	Fireweed				
Solidago spp.	Goldenrod			r	
Aster divaricatus	Woodland aster			c	
Eupatorium rugosum	White snakeroot			c	
Prenanthes spp.	White lettuce			c	

APPENDIX 4

WISCONSIN LAKE MANAGEMENT PROGRAM

FIFTH EDITION

A GUIDE TO WISCONSIN'S LAKE MANAGEMENT LAW



This guide provides practical information on how Chapter 33, Wisconsin Statutes, can be implemented in your community. However, a legally binding interpretation of the law can only be made by the courts or the attorney general.

Prepared by
UNIVERSITY OF WISCONSIN EXTENSION
and
WISCONSIN DEPARTMENT OF NATURAL RESOURCES

1982

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I. INTRODUCTION

A. Preface to the Fifth Edition

Substantial changes were made in Chapter 33 during the 1982 legislative session. These changes were primarily the result of the 1981 audit of the program. The main thrust of the changes is to encourage efforts to keep nutrients and soil in the watershed and out of the lake. Dredging is discouraged.

The new amendments, as well as the results of the statewide referendum in 1980, are incorporated in this edition. Passage of the referendum guaranteed property owners who live outside of lake districts the right to vote in lake district affairs.

B. The Need for the Law

A program of lake protection and rehabilitation for Wisconsin was established by Chapter 33, Wisconsin Statutes, in 1974. Increasing use of our lakes and shorelines has caused problems on some Wisconsin lakes. Among the major problems of declining water quality are nuisance weed and algae growth, sedimentation and water levels, and fish kills. Dealing with lake problems can be complicated, time-consuming, and expensive. It will take dedicated effort at both the local and state level. The law authorizes a joint state-local partnership whereby local lakeshore property owners can organize a special purpose district to protect or improve a lake. The local effort is to be supported by technical and financial assistance from the Department of Natural Resources (DNR) with additional assistance from the University of Wisconsin Extension. The following language from the law describes the legislative intent.

> The legislature finds that a state effort of research, analysis, planning and financing, and a local effort undertaken by lake rehabilitation and protection districts of planning and plan implementation is necessary and desirable and that the local districts should be formed by persons directly affected by the deteriorated condition of inland waters and willing to assist financially, or through other means, in remedying lake problems. The legislature further finds that state efforts are needed to aid and assist local efforts, to ensure that projects are undertaken only if they promote the public rights in navigable waters, environmental values, and the public welfare, and to administer a program of financial aids to support rehabilitation projects with benefits to all state citizens (Sec. 33.001).

Although Chapter 33 provides technical and financial assistance from the state, lake protection and rehabilitation must be initiated and carried out at the local level. People working through voluntary lake property owners associations have done many worthwhile things. But in many cases they have been frustrated in their efforts because voluntary associations lack sufficient legal and fiscal powers to undertake lake management. The law provides for special purpose units of government called lake protection and rehabilitation districts which can be formed at the local level to do the job. More than 130 lake communities have organized official lake districts.

C. A General Overview of the Law

Lake districts may be created in several ways as discussed later. Once formed, a district holds annual meetings to elect commissioners, adopt a budget, and vote a tax for the cost of operation for the coming year. The district board of commissioners is authorized to plan, adopt, and carry out lake protection and rehabilitation projects. Under certain conditions, the district may also provide sanitary services to the lake community. The district has the power to issue contracts, hold property, and do other things to carry out a program of lake protection and rehabilitation. It may raise money through taxation, special assessment, user charges, bonds, or loans.

Some lakes may not need a district because the people around the lake are happy with their present situation and are confident it will not change. Other groups may want to form a district to implement a purely preventative management program. In other instances, local people may want to consider forming a district even though state cost-sharing is not available for the particular activity they have in mind. An example of this situation would be repair of a dam.

State funding will not normally be available for this type of activity because it is not directly related to water quality. Nevertheless, formation of a district may facilitate such an undertaking by improving the ability of a lake group to raise and administer funds by assessing costs according to the benefits received.

In many cases, local districts do engage in activities which are eligible for state financial assistance. The DNR assists local lake districts seeking technical aid in lake rehabilitation and administers a program of financial assistance to local districts. A local lake management program involving state aids will typically utilize the following general approach: (1) gathering information to define the existing or potential problems on a lake and to identify their causes; (2) considering the various protective or remedial measures to deal with these problems and alternative courses of action; (3) selecting the most feasible rehabilitation and protection measures; and (4) implementing the project.

What follows is a more detailed look at Wisconsin's Inland Lake Management Law. There is a discussion of the powers of lake districts, how they are organized, their governing body, their financial powers, state aids available to them, and district boundaries. In many cases, parts of the law are quoted or reference is made to the relevant section. By reading this booklet and then reviewing the law and other materials such as the Model Bylaws, people interested in lakes will have a better idea of how Chapter 33 can help in the job of protecting and restoring Wisconsin's lakes.

II. POWERS OF LAKE DISTRICTS

A. General Lake Management Powers

Districts may be formed under the law for the purpose of undertaking programs for the protection and rehabilitation of public inland lakes. "Public inland lakes" which are covered by the act and eligible for state financial assistance are defined as those lakes, reservoirs, or flowages within the boundaries of the state which have public access. In order to be eligible to form a lake district, the access need not be developed with docking, launching, or parking facilities. If a public user can reach the lake without trespassing on private land, the lake is a public inland lake (Sec. 33.01(8)).

When organized, a lake protection and rehabilitation district is a body corporate for the purpose of carrying out its special governmental functions (Sec. 33.22(1)):

> Any district organized under this chapter may sue and be sued, make contracts, accept gifts, purchase, lease, devise or otherwise acquire, hold or dispose of real or personal property, disburse money, contract debts and do such other acts as are necessary to carry out a program of lake protection and rehabilitation.

These general powers are designed to enable the district to conduct "any work in the lake or its watershed which will protect or enhance the opportunities for public enjoyment of the lake." Lake protection and rehabilitation programs include but are not limited to the following:

1. Study of the sources of lake problems,
2. Treatment of aquatic weeds,
3. Treatment of algae,
4. Treatment of swimmer's itch,
5. Aeration,

6. Nutrient diversion,
7. Erosion control,
8. Dredging,
9. Bottom treatment,
10. Construction and operation of water level control structures.

The district does not have zoning power on either the land or the water, but may ask counties, towns, cities, and villages to enact needed ordinances or any other measures necessary to improve and protect the conditions of public inland lakes.

Certain projects are subject to the provisions of Subchapter III of the act which are discussed later in relation to state aids. Basically, this means that before state money can be granted for implementation, a feasibility study must be made and a plan developed which is approved by both the lake district and by the DNR.

B. Assumption of Sanitary District Powers

A lake district can assume some or all of the powers of sanitary districts (Sec. 60.30, 60.306, and 60.307, other than Sec. 60.306(3)), including:

1. Storm water sewer system,
2. Drainage improvements,
3. Sanitary sewer systems,
4. Waterworks,
5. Garbage or refuse disposal,
6. Require installation of private sewage systems,
7. Make rules, regulations, and issue orders to promote and preserve public sanitation.

A lake district can assume these powers only if the annual meeting votes to merge with a sanitary district or if the annual meeting requests these powers or if a sanitary district is converted to a lake district. All such assumptions of sanitary district powers require town board approval (Sec. 33.22(3) and 33.235).

III. ORGANIZING LAKE DISTRICTS

Lake protection and rehabilitation districts may be organized either by landowners petitioning the county board or town board, or by resolution of the governing body of a village or city. The following discussion is intended to explain when and how each of these methods may be utilized. The question of boundaries is addressed later.

A. Petitioning the County Board

The petition: Districts may be formed by a county board upon petition of landowners. The petition requires the signatures of at least (1) 50% of the owners of land in the proposed district, or (2) persons owning 51% of the land within the proposed district. However, before part or all of a city or village may be included within a district, the city council or village board must first approve inclusion (Sec. 33.24). The petition to the county board must be used if more than one municipality is involved; it may be used even if another method is available. The specific statutory requirements regarding the petition are shown below (Sec. 33.25):

1. WHO TO MAKE. Before a county board may establish a district under s. 33.24, a petition requesting establishment shall be filed with the county clerk, addressed to the board and signed by persons constituting 51% of the landowners or the owners of 51% of the lands within the proposed district. Governmental subdivisions, other than the state or federal governments, owning lands within the proposed district are eligible to sign such petition. A city council or village board may by resolution represent persons owning lands within the proposed district who are within its jurisdiction, and sign for all such landowners.

2. CONTENTS. The petition shall set forth:

   (a) The proposed name of the district;

   (b) The necessity for the proposed district;

   (c) That the public health, comfort, convenience, necessity, or public welfare will be promoted by the establishment of the district and that the lands to be included therein will be benefited by such establishment; and

   (d) The boundaries of the territory to be included in the proposed district.

3. VERIFICATION, PLAT. The petition shall be verified by one of the petitioners, and shall be accompanied by a plat or sketch indicating the approximate area and boundaries of the district.

4. PRESUMPTION. Every petition is presumed to have been signed by the persons whose signatures appear thereon, until proved otherwise.

Fifty-one percent of the landowners or owners of 51% of the land within the district is the statutory minimum number of signatures. County boards may as a matter of political reality and in the interest of community unity expect much higher percentages of landowners to sign the petition. A referendum on forming a district cannot substitute for a petition. With regard to qualifications for signing the petition, a landowner is a person whose name appears on the assessment roll prepared for purposes of real property taxation (Sec. 33.01(9)). Ownership of more than one parcel of real estate within the proposed district does not entitle the individual to sign more than once. A partnership, corporation, or local unit of government is normally considered to be equivalent to a single individual.

In addition to signing for its own land, a city council or village board can also sign the petition for the other landowners in the city or village. Each and every landowner whose name appears on the assessment roll prepared for purposes of real property taxation would count toward the 51% minimun if the city council or village board voted to sign up all landowners in the proposed district. The town board cannot sign for rural landowners.

The lands to be included in the proposed district must be described and be clearly shown on a map or sketch which is part of the petition as it is being circulated. Boundaries should follow normal government survey division lines whenever possible. The use of roads for boundaries is less advisable. Do not refer to distances from the lake in the boundary.

Finally, the petition must be verified by one of the signers to the effect that the petition and the signatures thereon are true and correct to the best of his knowledge.

Notice and hearing: Upon receipt of the petition, the county board must schedule a public hearing to be held not more than 30 days from the date the petition is filed with the county clerk, appoint a committee to conduct the hearing, and notify DNR. Notice of the hearing must also be sent by the county board to each person whose name appears on the assessment role prepared for purposes of real property taxation within the district and must be published once in a paper of general circulation in the county.

At the hearing, the committee shall hear all interested persons who wish to offer objections, criticisms or suggestions regarding the necessity of the district or the benefit to specific property in the proposed district. Written comments may also be filed with the county clerk prior to the date of hearing and must be considered by the committee (Sec. 33.26(1)(2)(5)).

Decision to establish the district: The county board must decide, based on the report of the committee, whether to approve or disapprove formation of a lake management district. The board is directed to create the district if it makes certain findings (Sec. 33.26(3)):

1. That the petition was signed by at least 51% of the landowners or owners of at least 51% of the land in the proposed district.

2. That the district is necessary.

3. That the district will promote the public health, comfort, convenience, necessity, or public welfare.

4. That the district will not cause or contribute to long-range environmental pollution.

5. That the property included in the district will be benefited.

In determining benefit to land within the proposed district, the board needs to find that the land within the district as a whole will be benefited and need not examine parcels individually. Parcels of land need not be excluded because the owner objects to inclusion. This construction follows from a Wisconsin Supreme Court decision which interpreted a similar provision relating to the establishment of town sanitary districts. (Fort Howard Paper Co. v. Fox River Heights Sanitary District (1947), 250 Wis. 145, 152.)

However, the county board may change the boundaries from those originally proposed. The size of the district can be reduced, but new lands may not be included until another public hearing is held (Sec. 33.26(6)).

The county board must file copies of its order creating the district with DNR, the Department of Revenue, and with the register of deeds in each county in which the district is located. If the county board rejects the petition, it must state in writing the reasons for disapproval (Sec. 33.26(4)(8)). Persons have 30 days within which to petition in circuit court for review of the board's decision (Sec. 33.26(7)).

B. Petitioning the Town Board

This method can be used only if all the frontage of a lake and all the land within the proposed district lies within a single town. If a city or village or another town is involved, the petition must be addressed to the county board.

The same procedure is required to petition the town board as is required to petition the county board. The petitions are filed with the town clerk. The town board holds the hearing and makes the decision according to the same five criteria listed above (Sec. 33.23). The decision is filed with the county register of deeds, the Department of Revenue, and DNR.

C. Creation by City Council or Village Board

Villages or cities can establish public inland lake protection and rehabilitation districts by simple resolution (Sec. 33.23). While the law requires no petition, notice, or hearing in connection with establishment by such resolution, general principles of fairness and due process would suggest reasonable notice to persons whose land is included in a district as well as provision for hearing objections to inclusion. Nevertheless, this method allows a fast and easy way to establish a district. This power can be exercised only if the invorporated municipality encompasses all the frontage of a lake or all the frontage that is within the boundaries of the state. A court ruling has nullified the creation of a district around a lake with a small tip outside the city limits. All such districts must be created through the county board.

D. Conversion of a Town Sanitary District

A special provision of the law allows creation of a lake district where a sanitary district already exists which encompasses all the frontage of a lake. The town board which created the sanitary district may, by resolution, convert the sanitary district to a lake district with the same boundaries. If more than one town is involved, the conversion can be made by the town in which the largest part of the district, based on equalized valuation, lies. The lake district automatically assumes all the rights and liabilities of the sanitary district (Sec. 33.325(1)).

Sanitary districts which do not encompass all the frontage of a lake may be converted by the county board. Commissioners of such a sanitary district may, with approval of the town board, petition the county board and sign for each and every landowner wihtin the sanitary district. The granting of this petition would include an automatic conversion of the sanitary district into the lake district, but the method of apportioning the rights and liabilities of the sanitary district within the new lake district must be set out in the county board order creating the district (Sec. 33.235(2)).

E. Organizing Districts Across County Lines

Where the proposed district lies in more than one county, the law gives jurisdiction to the county with the highest equalized valuation within the proposed district. While it is still possible to form separate districts and merge them (Sec. 33.33 and Sec. 60.30), the procedure can be streamlined to a single petition to the county board with jurisdiction (Sec. 33.37).

IV. THE GOVERNING BODY

Public inland lake protection and rehabilitation districts are governed on a day-to-day basis by a district board of commissioners. The commissioners, however, manage the district affairs subject to the powers of the annual meeting which include budget approval, tax levy, and approval of projects costing the district more than $5,000.

A. Initial Board of Commissioners

If a district is formed by the county board, five initial commissioners are appointed at the time of establishment of a district. The county board appoints three persons owning property within the district to serve until the first annual meeting. An official representative of an organization that owns property may serve as a commissioner (Sec. 33.285). At least one of the appointees must be a resident of the district. The county board, which created the district, shall also appoint a person who is a member of the county land conservation committee or who has been nominated by the committee (Sec. 33.27(1) and 33.285). Within 30 days following the order establishing the district, the governing body of the municipality (town, city, or village) having the largest portion of property by valuation with the district shall appoint one of its members to serve as the fifth commissioner (Sec. 33.27(2)).

Between 30 and 90 days after establishment of the district or following the final judgment in any appeal, the board shall hold an organizational meeting, select officers and begin conducting affairs of the district (Sec. 33.27(3)).

The town board, village board, or city council itself becomes the commission of lake districts each may establish. However, if a sanitary district is converted to a lake district by a town board, the sanitary district commissioners become the initial lake district commissioners (Sec. 33.23 and Sec. 33.235(1)).

The initial commission may make an initial assessment on all taxable property in the district in order to pay organizational costs and operate the district until a tax is voted by the first annual meeting (Sec. 33.27(4)). The commissioners, however, may not undertake any project costing the district more than $5,000 without approval of the annual meeting.

B. Permanent Board of Commissioners

Except where the town board, village board, or city council serves as the commissioners, the five member lake district board consists of:

- 3 - elected commissioners, one of whom is a resident and two of whom are either residents or property owners within the district.
- 1 - commissioner appointed by the county board from the land conservation committee or nominated by the committee.
- 1 - commissioner appointed by the town, village, or city governing body representing the largest portion (by valuation) of the district.

At the first annual meeting of districts established by the county board, the three property owners appointed to the initial board of commissioners shall be replaced or re-elected at the meeting. The new commissioners can be either residents or property owners in the district or an official representative of an organization which owns property in the district. At least one must be a resident of the

district. These three elected members shall serve staggered three-year terms. The remaining two members appointed to the initial board of commissioners by the county and by the municipality with the highest equalized valuation continue to serve until replaced by the governing body that appointed them (Sec. 33.28(2) and 33.285).

At the first annual meeting of a lake district converted from a sanitary district, three commissioners are elected and the county and town board each appoints a representative. Thereafter, the district functions the same as a district created by the county board.

Where a district is formed by resolution, the city council, town board, or village board serves as the commissioners and cannot delegate these functions. However, such districts can adopt the same form of governance as districts established by county boards. Upon presentation of a petition requesting such change and signed by at least 20% of the property owners within the district, the present governing body shall direct that such change shall become effective at the time of the next annual meeting, and shall provide for the necessary election of commissioners at that time (Sec. 33.23).

Any lake district that results from the conversion or merger of a sanitary district shall at the next annual meeting automatically assume the same form of governance as districts established by county boards (Sec. 33.235).

The board shall meet at least quarterly and at other times at the call of the chairman or any three commissioners. Three commissioners constitute a quorum (Sec. 33.28(3)(6)).

The board shall select from its membership a chairman, secretary, and treasurer. Commissioners shall be paid actual and necessary expenses plus such compensation as may be established by the annual meeting (Sec. 33.28(4)(5)).

C. Powers and Duties of Commissioners

Subject to the directives of the annual meeting, Section 33.29 specifically lists the powers and duties of commissioners:

1. The board shall be responsible for:

   a. Initiating and coordinating research and surveys for the purpose of gathering data on the lake, related shorelands and the drainage basin;

   b. Planning lake rehabilitation projects;

   c. Contacting and attempting to secure the cooperation of officials of general purpose units of government in the area for the purpose of enacting ordinances deemed necessary by the board to further the objectives of the district;

d. Adopting and carrying out lake protection and rehabilitation plans and obtaining any necessary permits therefor; and

e. Maintaining liaison with those officials of state government involved in lake protection and rehabilitation.

2. The board shall have control over the fiscal matters of the district, subject to the directives of the annual meeting. The board shall annually, at the close of the fiscal year, cause an audit to be made of the financial transactions of the district, which shall be submitted to the annual meeting.

3. The board, immediately after each annual meeting, shall elect a chairman, secretary, and treasurer, whose duties shall be as follows:

a. The chairman shall preside at the annual meeting, all meetings of the board, and all public hearings held by the board.

b. The secretary shall keep minutes of all meetings of the board and hearings held by it, and shall annually notify the department of the continued existence of the district.

c. The treasurer shall receive and take charge of all moneys of the district, and pay out the same only on order of the board.

D. The Annual Meeting and Budget Hearing

Every public inland lake renewal district, regardless of method of formation, is directed to hold an annual meeting. The first annual meeting must be held between May 22 and September 8. Notice of the meeting must be mailed to all nonresident property owners whose name appears on the assessment roll prepared for purposes of real property taxation, and to DNR. Residents may be notified by mail or by two publications of the notice and budget summary in a local paper (Sec. 33.30(1)(2)). Notice must be sent at least ten days before the date scheduled for the meeting.

At the meeting, all residents and U.S. citizens over the age of 18 owning land in the district are eligible to vote. All persons (whether or not they own property) who are eligible to vote in other elections by virtue of the fact that they reside within the district

can vote at the annual meeting. In addition, owners of property who do not reside within the district can also vote. The annual meeting must adopt rules relating to how nonresident property owners can vote (Sec. 33.30(3)(g)). Ownership of more than one parcel of real estate within the district does not entitle the individual to more than one vote. Corporations, partnerships, and local units of government are normally treated as one ownership with one vote by an official representative. Typically, other multi-ownerships, such as joint tenants or tenants in common, are allowed two votes per property in order that both husband and wife can vote if both own the property. Model by-laws which address this issue and many other issues are available upon request.

The major actions of the annual meeting include election of commissioners (except for districts governed by a city council, village board, or town board), approval of a budget for the coming year, voting a tax on taxable property in the district, and approval of major district projects. The functions of the annual meeting are specifically listed in Section 33.30:

1. Every public inland lake protection and rehabilitation district shall have an annual meeting. The first annual meeting shall be scheduled during the time period between May 22 and September 8, and shall be held annually thereafter unless changed by vote of the previous annual meeting.

2. The annual meeting shall be preceded by written notice, mailed at least 10 days in advance of the meeting, to all electors within the district and persons owning lands within the district whose address is known or can be ascertained with reasonable diligence, and to the department. The district board of commissioners may substitute a class 2 notice, under ch. 985, in lieu of sending written notice to electors residing within the district.

3. At the annual meeting, electors and property owners shall:

a. Elect one or more commissioners by secret ballot to fill vacancies in the district board;

b. Approve a budget for the coming year;

c. Vote a tax upon all taxable property within the district for the costs of operation for the coming year, which tax shall not exceed a rate of 2.5 mills of equalized valuation;

d. Approve or disapprove all proposed projects by the district having a cost to the district in excess of $5,000, by vote of the electors and property owners within the district. The annual meeting may also authorize the board of commissioners, during the succeeding year until the next annual meeting, to approve or disapprove projects having a cost to the district in excess of $5,000, and to enter into contracts accordingly;

e. Take up and consider such other business as comes before it;

f. Establish compensation, if any, to be paid the district board commissioners;

g. Adopt rules relating to voting at annual and special meetings (by-laws).

A hearing on the proposed budget, with 15 days prior published notice, is required by Section 65.90. This hearing can be held immediately prior to the annual meeting. See Sec. 65.90 for details.

V. FINANCIAL POWERS

A. General Property Tax

As indicated above, the annual meeting is authorized to vote a tax upon all taxable property within the district for the cost of operating the district during the following year. The general property tax is normally used for activities such as bookkeeping, postage, commission expenses, and feasibility studies that do not specifically impact individual properties. The tax may not exceed the rate of 2.5 mills of equalized valuation and must be uniformly applied across the entire district. It is apportioned among the municipalities on the basis of equalized value. All property normally subject to property tax is taxable by the district. Homes built by lessees are taxable. Public property is not subject to property tax.

The treasurer of the district must deliver a report containing the amount of tax to the clerk of each municipality in the district by the end of October. The municipality will then collect the tax for the district as an itemized part of the regular property tax bill. The district tax is not included when municipal levy limits are calculated.

B. User Charges

Special charges to pay for activities with temporary benefits to individual properties, such as weed harvesting, swimmer's itch and algae control, and garbage pickup are collected directly by the lake district commission. However, the charges must be identified in the annual budget submitted to the annual meeting. The annual meeting may also prescribe the manner of allocating the charges. The charge can vary from one category of property to another depending on the benefit or service received. Delinquent special charges may be entered on the tax roll (Sec. 33.32(5)).

C. Special Assessments*

While special assessments can be used for a variety of activities approved by the annual meeting, this tax is usually reserved for major projects. In order to fund such projects, districts may levy special assessments payable in up to 10 annual installments (Sec. 33.32(1)(2)).

After approval of a project by the membership at an annual meeting and by the DNR; and the receipt of state and/or federal grants, the commissioners determine the local share of the cost of the project. They then determine the benefits to accrue to each parcel of land. Tax-exempt property, including county and municipally-owned real estate in the district, is subject to special assessments. State-owned property may only be assessed with approval of the Public Lands Commission. Size, proximity to the lake, present and potential use of the land, including zoning regulations, and other factors may be considered in selecting a method of making assessments. The precise language concerning determination of benefits is found in Sec. 33.32(1)(b):

> The commissioners shall then examine each parcel within the district, other than state or federal lands, and determine the benefits to each from the project, considering such factors as size, proximity to the lake, and present and potential use of the parcel, including applicable zoning regulations. After benefits to each parcel are determined, assessments shall be made in an aggregate amount equal to the cost to the district of the project. Such assessments shall be made in accordance with s. 66.60, so far as it is applicable and not in conflict with this subchapter.

Notice of the assessment must be given to every person having an interest in an affected parcel within the district and also filed with the county clerk. The notice, which is published twice and sent to each person having an interest in an affected parcel, shall inform affected persons of a place where they may review the assessments. In addition, notice shall set a day, within three days after the expiration of the 30 day review period, on which the commissioners shall hear objections to the assessments (Sec. 33.32(1)(c)).

If, as the result of the hearing, an assessment is increased, a new hearing with notice must be provided. (Sec. 33.32(1)(d)).

After the hearing, the commissioners shall publish a final determination of assessments once in the local paper and send a notice to each person having an interest in an affected parcel. Affected persons have 40 days within which to appeal to the circuit court (Sec. 33.32 (1)(e)(f)). As a practical matter, notice is typically sent to the person(s) whose name appears on the tax roll.

D. Other Financial Powers*

A district may borrow money and use other financing methods prescribed by law (Sec. 33.32(1)). The commissioners must follow the procedures

*It is usually recommended that a district retain an attorney when arranging financing for large projects.

required by law of all municipalities under Sections 66.059, 66.066, 66.067, 66.078, 66.09, 66.54, and 67.04. Tax incremental financing cannot be used.

Bonding or borrowing may be used to acquire capital for large projects. The debt limit is 5% of the equalized valuation of the district.

Districts may also borrow when in temporary need according to the provisions and limitations applicable to cities under Section 67.12, Wisconsin Statutes. Temporary borrowing must be approved by a 3/4 vote of the commissioners, and a promissory note, payable with interest on August 30 following the next tax levy, must be given. The property tax levied to repay the loan is not includable in the 2.5 mill operations tax limit (Sec. 33.31(2)).

VI. STATE AIDS TO LAKE DISTRICTS

Chapter 33 enables local people to create a lake district and to undertake certain activities without any involvement by DNR. Other activities may simply require a permit from the Department of Natural Resources. However, if state aids are requested, both the district and the DNR must approve the activity. The procedure to apply for state aid and the steps by which the partners (district and DNR) arrive at a mutually acceptable plan of action is described in this section.

A. Policy Determination

The law provides that the Inland Lakes Protection and Rehabilitation Council serve as the policy advisory body for the program. The Council consists of:

--Four public members nominated by the Governor and confirmed by the Senate;
--Director of the University of Wisconsin-Madison Water Resources Center;
--Chairman of the Land Conservation Board;
--A representative of the Department of Natural Resources;
--A representative of the Department of Agriculture;
--A representative of the Department of Local Affairs and Development.

The major recommendations of the Council are passed on to the Natural Resources Board for a final decision. In addition, the law specifies that the administrative rules (N.R. 60) for the program must be reviewed by the Natural Resources and Agriculture Committees of the Assembly and the Senate (Sec. 15.347(8), 33.05, and 33.06(1)).

B. Procedure

Only legally constituted lake districts qualify for aids under this program. If a lake district decides to apply for state aids, the procedure can be found in Chapter N.R. 60 of the Wisconsin Administrative Code. The major parts of the procedure are discussed below.

Feasibility study: The general purposes of the feasibility study are defined in Section 33.13(1):

--Determine appropriate protection and/or rehabilitation techniques;
--Evaluate the potential for success of the project and the permanence of any improvement;
--Establish a base line or standard against which to measure future changes in lake quality.

State aids are available to conduct feasibility studies. Unless the department finds that adequate data are available, a feasibility study must be done before the district is eligible to apply for aid for other activities.

1. The first step in the process is an application by the lake district for technical assistance.

2. An interdisciplinary team of DNR specialists then evaluates existing information about the lake and prescribes a feasibility study design to collect any additional information needed.

3. The lake district, if it chooses to proceed, then applies for financial assistance to conduct the feasibility study.

4. If sufficient state funds are available, DNR then makes a grant offer to the district.

5. If the district accepts the grant or if it chooses to proceed without state money, it hires an appropriate firm or individual to carry out the study as prescribed. The district may contract with the lowest responsible bidder who submits a bid in the manner the district commissioners prescribe.* However, DNR must approve the contract and be made a party to it if grant funds are involved. The data collected are sent back to the interdisciplinary team for analysis.

Plan Development and Project Implementation: The second major part of the process is the action phase and follows logically from the study phase (Sec. 33.13(2)(3), 33.14, 33.15, and 33.22):

6. The interdisciplinary team will analyze the feasibility study results and formulate alternative methods for protecting or rehabilitating the lake.

7. The district commissioners may then develop a lake management plan based upon one or more of the alternatives provided, or other technically feasible options. Such a plan should include:

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*Since there is no certification of firms, the commission must judge responsibleness. If the lowest bidder is not accepted, the commission should clearly indicate the reason. A court has overturned a district decision where this was not done.

a. Specific objectives and anticipated benefits,

b. Description of the lake and watershed,

c. Nature of existing or potential problems,

d. Discussion of alternative corrective actions,

e. Proposed management approach
   1) Methodology (including appropriate maps)
   2) Participants
   3) Timetable
   4) Budget (by work element),

f. Monitoring strategy (DNR will provide guidance).

The plan must include an assessment of point or non-point pollution sources within the watershed. The lake district is responsible for including remedial actions in its project proposal, or obtaining firm commitments from other responsible parties for correction of sediment and/or nutrient pollution problems.

8. The district submits the plan, together with a request for financial assistance and any permits required from DNR, to the department for approval. Copies of the plan must also be submitted to the county land conservation committee and to the regional planning commission for comment. The department may, after a hearing or a published legal notice, approve, modify, or disapprove the plan.

9. Based upon actions taken by the department on the plan and financial assistance request and permits, the district decides whether to proceed with implementation of the plan. All contracts for the performance of any work or the purchase of any materials exceeding $2,500 shall be awarded by the commissioners to the lowest responsible bidder in such manner as they prescribe.

Monitoring and Future Management: While a feasibility study and implementation of a major project will typically occur only once, the implementation of the management scheme is a continuous responsibility.

10. DNR and the district monitor the condition of the lake.

11. With technical assistance from DNR, the district provides for long-term maintenance of lake quality.

C. Availability of State and Federal Money

The amount of funds available for grants to districts is dependent on a biennial appropriation by the Legislature. The law requires that

no project (feasibility study or implementation) can be awarded a grant for more than 25% of the grant funds available in a given biennium, and that a dredging project is limited to 10%. During the period from 1975-1983, about $2,000,000 have been available biennially for grants. In addition, at least 25% of the money must be available to districts north of Stevens Point (Sec. 33.16 (1)(6)). State funds have been augmented by some federal funds which are funneled through this program. Future availability of federal funds is uncertain.

To insure that funds are invested in the most worthy projects, the Inland Lake Council developed objectives for a priority system. The system is being re-evaluated following the 1981 audit. The specific factors adopted by the Council and used by DNR will become part of N.R. 60 of the Wisconsin Administrative Code.

D. Cost Sharing

Upon the recommendation of the Council, the rate of cost sharing for feasibility studies has been set at 60% state and 40% local. Management projects are cost-shared at different rates depending on type Part or all of the local share can be defrayed by non-monetary aids--voluntary work and materials provided by people in the district. The local share can be raised by the district through taxes, contributions, fishing contests, etc. The law and Council policy allow an adjustment of the state share under special circumstances or when the lake management technique being utilized is highly experimental.

VII. BOUNDARIES OF LAKE DISTRICTS

A. Initial Boundaries and General Regulations

The law does not provide any guidelines on boundaries for lake districts. Clearly, the district must have some relationship to a lake, but it may include only a part of a lake, the whole lake, or more than one lake. All parts of the district must be connected by land or water.

The decision on the boundaries is made locally, first by the organizers and then by county board or municipality which creates the district. A larger district means that more of the problems in the watershed are within the boundaries and a larger district means a larger tax base. But organizers of a petition drive must also consider whether a sufficient percentage of property owners' signatures can be obtained in the proposed district. While this decision is a purely local one, the following three guidelines may be helpful:

--Include all riparian property, since all property on the lake will be benefited by a better lake.

--Include property which isn't on the lake but which is being used as it is because the lake is very close by (subdivision, back-lot homes, recreationally-oriented businesses, etc.).
--Include as much of the source of the lake's problems (often in the watershed) as logistically and politically feasible.

The law prohibits the inclusion of any part of a city or a village in a lake district without approval by the city council or village board. When a city council or village board creates a district by resolution, it has discretion to include in the district the whole municipality or only that part of the municipality immediately around the lake (Sec. 33.24).

B. Attachment

Districts do not have powers of annexation. Contiguous territory may be attached in two ways:

1. A landowner may request attachment and may be accepted by majority vote of the commissioners (Sec. 33.33(2)(a)).
2. The commission initiates attachment proceedings by notifying owners and petitioning the county board. The county board proceeds with a notice, hearing, and decision in the manner used to establish the district. The same right of appeal would also apply (Sec. 33.33(2)(b)).

C. Merger

Any district may be merged with a contiguous district. The procedure follows:

1. Merger resolution is passed by four-fifths vote of all the members of each commission.
2. Merger is endorsed by a majority of electors and property owners present and voting at the next annual meeting.

Upon ratification, the board of commissioners shall be constituted in the following manner (Sec. 33.33(1)):

1. Upon merger, the commissioners of the former separate districts serve together until the first annual meeting of the new merged district.
2. At the first annual meeting of the merged district, three commissioners are elected for staggered three-year terms.
3. The representative of the county having the largest portion by valuation within the merged district shall remain on the board of the merged district.

4. The representative of the city, village, or town having the largest portion by valuation within the merged district shall remain on the board.
5. The by-laws of the larger of the merging districts apply to the newly created district, but may be amended by the combined membership.

To insure geographical representation, the district may require in the by-laws that at least one elected commissioner come from each of the major parts of the district. It is also possible to add non-voting members to the board or appoint active electors to committee chairships.

A lake district and a town sanitary district may also merge if their boundaries are identical or contiguous. The same procedures listed above would be followed. In addition, town board approval would be necessary. All the rights and liabilities of the sanitary district would be assumed by the lake district, but the method of discharging such rights and obligations shall be set out in the merger resolution (Sec. 33.235(3)).

D. Detachment

Upon petition of a landowner or motion of the commissioners, territory may be detached from a district. The commissioners may detach territory after finding that it is not benefited by continued inclusion in the district. The board's decision can be appealed (Sec. 33.33(3)).

E. Dissolution

An existing district may be dissolved. A two-thirds vote of the membership at the annual meeting to petition the county board for dissolution is the first step. The county board may order dissolution following receipt of the petition. However, the order shall be conditioned on petition to the circuit court for appointment of a receiver to conclude the affairs of the district under court supervision. The dissolution becomes complete upon the final order of the circuit court (Sec. 33.35).

F. Filing

When the boundaries of a district are altered, the secretary should file a copy of the authorizing document and legal description of changes with the register of deeds, Department of Revenue, and DNR.

VIII. SAMPLE FORMS AVAILABLE

The following forms are provided as a public service of University Extension. They are only samples, and are not the only forms that can be used to accomplish the purpose. Only a few are applicable to any one community.

They should not be used without further consultation with an attorney or someone familiar with Chapter 33:

A. Petitions

1. Petition to the town (county) board seeking creation of a lake district
2. Petition to the town board seeking self-governance of a district created by town board resolution
3. City council (or village board) resolution permitting the inclusion of the city (or village) in a lake district
4. City council (or village board) resolution petitioning the county board to create a lake district partially within the city (or village) limits

B. Notice

1. Notice of hearing on lake district creation by county board
2. Notice of hearing on lake district creation by town board

C. Creation Orders and Resolutions

1. County board order establishing a lake district
2. County board resolution appointing initial commissioners for a lake district
3. Town board resolution establishing a lake district
4. City council (or village board) resolution establishing a lake district
5. Town board resolution converting a sanitary district which surrounds an entire lake to a lake district
6. Town board resolution approving of petition to convert a sanitary district which does not surround an entire lake to a lake district

D. Resolutions Altering Powers and Boundaries

1. Lake district resolution requesting town board to grant sanitary district powers
2. Town board resolution granting sanitary district powers to a lake district
3. Town board resolution providing for self-governance of a lake district
4. Lake district board motion requesting county board to attach territory to a lake district
5. County board resolution ordering attachment to a lake district
6. Town board, sanitary district, and lake district resolution merging a sanitary district into a lake district
7. Lake district board resolution for merger of contiguous lake district (with annual meeting ratification)

E. Miscellaneous

1. Reference Handbook for Lake District Commissioners ($4.00)
2. Model By-laws

3. Certification of Taxes for a Lake District in a Single Municipality
4. Certification of Taxes for a Lake District in More Than One Municipality
5. Model Memorandum of Understanding Between Lake District and County Land Conservation Committee

The above materials relating to lake district organization can be obtained from:

Lowell L. Klessig
College of Natural Resources
University of Wisconsin
Stevens Point, WI 54481
715/346-3783

--Technical Assistance Application
--Financial Assistance Application
--Claim for Aids
--Chapter NR 60, Wisconsin Administrative Code
--Chapter 33, Wisconsin Statutes

The above materials relating to state aids to lake districts and procedures can be obtained from:

Oliver Williams, DNR
Inland Lake Renewal
Box 7921
Madison, WI 53707
608/266-3125

FOR OTHER EDUCATIONAL MATERIALS AND FURTHER ASSISTANCE, CONTACT YOUR LOCAL COUNTY EXTENSION OFFICE OR DNR DISTRICT OFFICE.

COUNTY EXTENSION OFFICES

ADAMS 608-339-7811-50/51 Courthouse, Friendship 53934
ASHLAND 715-682-8137 Room 301 Courthouse, Ashland 54806
BARRON 715-537-3124 Courthouse, Barron 54812
BAYFIELD 715-373-2221 Courthouse, Washburn 54891
BROWN 414-497-3216 1150 Bellevue St., Green Bay 54302
BUFFALO 608-685-4560 Courthouse Annex, Alma 54610
BURNETT 715-866-4201 County Office Bldg., Webster 54893
CALUMET 414-849-2361 Courthouse, Chilton 53014
CHIPPEWA 715-723-9195 Box 310, Chippewa Falls 54729
CLARK 715-743-3118 Courthouse, Neillsville 54456
COLUMBIA 608-742-2191 County Administration Bldg., Portage 53901
CRAWFORD 608-326-6431 111 W. Dunn, Prairie du Chien 53821
DANE 608-266-4271 57 Fairgrounds Dr., Madison 53713
DODGE 414-386-4411-400 County Office Bldg., Juneau 53039
DOOR 414-743-5511 Courthouse, Sturgeon Bay 54235
DOUGLAS 715-394-0363 Courthouse, Superior 54880
DUNN 715-232-1536 Courthouse, Menomonie 54751
EAU CLAIRE 715-839-4712 Courthouse, Eau Claire 54701
FLORENCE 715-528-4480 County Hwy. Bldg., Rt. 1 Box 1, Florence 54121
FOND DU LAC 414-921-5600 UW Center-Campus Dr., 112 Classroom Bldg., Fond du Lac 54935
FOREST 715-478-2212 Courthouse, Crandon 54520
GRANT 608-723-2125 Youth and Agriculture Center—Fairgrounds Box 31, Lancaster 53813
GREEN 608-325-5181 Agricultural Bldg., Box 120, Monroe 53566
GREEN LAKE 414-294-6573 Courthouse, Green Lake 54941
IOWA 608-935-3354 Agricultural Center, Dodgeville 53533
IRON 715-561-2695 Courthouse, Hurley 54534
JACKSON 715-284-7441 Courthouse, Black River Falls 54615
JEFFERSON 414-674-2500 Courthouse, Jefferson 53549
JUNEAU 608-843-1341 Courthouse, Mauston 53948
KENOSHA 414-656-6793 714 52nd St., Kenosha 53140
KEWAUNEE 414-388-2542 Courthouse, Kewaunee 54216
LA CROSSE 608-785-9583 Courthouse, LaCrosse 54601
LAFAYETTE 608-776-4494 Courthouse, Darlington 53530
LANGLADE 715-623-4156 Fairgrounds, Box 460, Antigo 54409
LINCOLN 715-536-7151 Lincoln County Annex, 1106 E. 8th St., Merrill 54452
MANITOWOC 414-682-8877 County Offices Bldg., 1701 Michigan Ave., Manitowoc 54220
MARATHON 715-842-0471 Courthouse, Wausau 54401
MARINETTE 715-735-3371 Courthouse, Box 105, Marinette 54143
MARQUETTE 414-297-2141 Courthouse, Montello 53040
MENOMINEE 715-799-3641 Courthouse, Box 48, Keshena 54135
MILWAUKEE 414-257-5351 9722 W. Watertown Plank Rd., Wauwatosa 53226
MONROE 608-269-8718 Courthouse, Sparta 54656
OCONTO 414-834-5322 Courthouse, Box 19, Oconto 54153
ONEIDA 715-362-6314 Courthouse, Box 1208, Rhinelander 54501
OUTAGAMIE 414-735-5119 Courthouse-Room C103, Appleton 54911
OZAUKEE 414-284-9411 Courthouse—Room 21, Port Washington 53074
PEPIN 715-672-5214 Courthouse, Box 39, Durand 54736
PIERCE 715-273-4376 Courthouse, Ellsworth 54011
POLK 715-485-3136 Agricultural Center, Balsam Lake 54810
PORTAGE 715-346-3573 County-City Building, Stevens Point 54481
PRICE 715-339-2555 Normal Building, Phillips 54555
RACINE 414-886-2744 14200 Washington Ave., Sturtevant 53177
RICHLAND 608-647-6148 UW Center, Richland Center 53581
ROCK 608-755-2196 Courthouse, Janesville 53545
RUSK 715-532-5539 Courthouse, Ladysmith 54848
ST. CROIX 715-684-3301 Agricultural Center, Baldwin 54002
SAUK 608-356-5581 Box 46, Baraboo 53913
SAWYER 715-634-4839 Box 351, Hayward 54843
SHAWANO 715-526-6136 Courthouse, Shawano 54166
SHEBOYGAN 414-459-3141 UWEX Office, 650 Forest Ave., Sheboygan Falls 53085
TAYLOR 715-748-3327 Agricultural Center, Medford 54451
TREMPEALEAU 715-538-2311 Courthouse, Whitehall 54773
VERNON 608-637-2165 Courthouse Annex, Box 392, Viroqua 54665
VILAS 715-479-4797 Courthouse, Eagle River 54521
WALWORTH 414-723-3838 Courthouse, Elkhorn 53121
WASHBURN 715-635-3192/8725 County Hwy. Bldg., Spooner 54801
WASHINGTON 414-338-4479 Courthouse Annex 2, Box 537, West Bend 53095
WAUKESHA 414-544-8080 Courthouse, Waukesha 53186
WAUPACA 715-258-7681 Courthouse, Waupaca 54981
WAUSHARA 414-787-4631 Courthouse, Wautoma 54982
WINNEBAGO 414-424-0050 Sunnyview Complex, 500 E. Sunnyview Rd., Oshkosh 54901
WOOD 715-423-3000 Courthouse, Wisconsin Rapids 54494

DNR District Offices

Northwest/Spooner
Box 309, 54801
715/635-2101

North Central/Rhinelander
Box 818, 54501
715/362-7616

Lake Michigan/Green Bay
Box 3600, 54303
414/494-9601
497-4030

West Central/Eau Claire
1300 W. Clairemont, 54701
715/836-2951

Southern/Madison
3911 Fish Hatchery Rd.
53711
608/266-0752

Southeast/Waukesha
9722 W. Watertown Plank Rd.
Milwaukee, 53226
414/257-6515

ADDITIONAL COPIES OF THIS GUIDE ARE AVAILABLE FROM:

George Gibson
Dept. of Environmental Resources
University of Wisconsin-Extension
University of Wisconsin
Madison, WI 53706
or
Lowell Klessig
College of Natural Resources
University of Wisconsin
Stevens Point, WI 54481

APPENDIX 5

SECTION 314 APPENDIX A RESPONSES

APPENDIX A RESPONSES

The following are the responses to Appendix A ("Requirements for Diagnostic-Feasibility Studies and Environmental Evaluations") as it appears in 40 CFR Part 35.1600 FR. Vol. 45, No. 25, Tues., February 5, 1980, p. 7797-7800.

Given below is the page number in the body of the report where the answer to the various questions can be found. In some cases the actual response is given in this appendix.

QUESTION #[a][1] - pages 4; 8 (Table 1); 10-11.

[A][2] - pages 12-21

[a][3] - pages 48-50
Note: Public transportation to Lake includes regular bus routes to the municipalities in the basin from the Port Authority Terminal in New York and Newark. Also, charter services are used extensively to bring various groups to the lake for recreational purposes, especially at the state park. Also, the lake is easily accessible from the metropolitan area by private automobile (40 mi. from N.Y. City).

[a][4] - pages 28-40

[a][5] - pages 41-47 (See Section - Degradation of Fishery)

[a][6] - All segments of the lake user population have been affected by degradation. However, the activities that have been affected to the greatest extent are fishing, swimming and boating. (See text at various locations.)

[a][7] - pages 51-52.

[a][8] - pages 70-77. These point sources contribute only 3.9% of the total phosphorus load to the lake, however the 201 Facilities Plans for the basin indicate that those discharges would be removed when the 201 implementation takes place. We estimate approximately 10 years for implementation of the 201 Facilities Plans.

[a][9] - Figure 1; pages 23-27; pages 89-103.

[a][10] - See Sections VI, p. 53; VII, p. 70; VIII, p. 78; IX, p. 89; X, p. 99; XI, p. 105; XII, p. 184; XIII, p. 196.

[a][11] - Section XI, p. 129-171.

QUESTION [b][1] - See Section VIV, p. 212-241. We have presented the plan and have discussed water quality improvements throughout the entire report. In addition to Section XIV, a thorough discussion of justification is given in the Executive Summary and the letter of transmittal to NJDEP. Engineering drawing and specifications are inappropriate at this time.

[b][2] - Section XIV. The benefits to be derived from implementation of the plan are discussed in depth throughout Section XIV and are presented in the Executive Summary and letter of transmittal to NJDEP.

[b][3] - Phase II monitoring will be performed as described in this section, with the exception that 3 subbasins within the lake will be sampled. Also, given the nature of the in-lake proposals records of biomass harvested and removal of nutrients by the harvesting program, area harvested and rate of regrowth will be monitored.

[b][4] - See Appendix 8

[b][5] - Nonfederal funds will be obtained through the methods described in the letter of transmittal to NJDEP.

[b][6] - The plan as presented is consistent with the Sussex County 208 areawide wastewater management plan. Also, the Jefferson Township and Upper Musconetcong Sewerage Authority Step I Facilities Plans are incorporated by reference as part of this project.

[b][7] - Public Participation: There has been extensive publicity concerning the project through the newspapers and other media. Also, meetings were held with all of the governmental units in the basin where the plan was presented. A public hearing on the plan was held on October 27, 1983 at the Hopatcong Community center. Comments are presented in Appendix 7. Notification of the public hearing was published in the New Jersey Herald Newspaper. Reports on the progress of the study were given to the public monthly at the LHRPB meetings.

[b][8] - Through the auspices of the LHRPB, the State of New Jersey will oversee the operation and maintenance of the plan. NJDEP has one seat on the LHRPB so coordination between the State and Board will occur. As the specific maintenance plans are developed each year NJDEP will have a role in approving those plans.

QUESTION [b][8] (continued) - The financial arrangements for ongoing funding is being developed by the LHRPB and the State of New Jersey in cooperation with the counties and local municipalities.

[b][9] - No permits are required for those activities presented in the plan. If dredging does become a reality then a 404 permit would have to be acquired.

[c] - Environmental Evaluation: See Section XIV (D), p. 244.

APPENDIX 6

PUBLIC HEARING COMMENTS

PUBLIC HEARING OF LAKE HOPATCONG REGIONAL PLANNING BOARD
OCTOBER 27, 1983

Chairmman Eric Grove opened the meeting at 7:38 p.m. and introduced the members of the board and summarized the workings of the board. Grove then introduced Dr. John Koppen of Princeton Aqua Science, consultants for the LHRPB, who then took the floor.

Dr. Koppen explained the restoration and management plan for Lake Hopatcong. He presented (with the use of graphs and tables) the problems of Lake Hopatcong and possible causes and measures to attack causes.

After a brief recess the public was asked for comments. The following is that section of the meeting.

HARRY A. GOTIMER, Councilman from Hopatcong

He stated the Lake Hopatcong Regional Planning Board has settled for a modified program basically for cost. His question to the board was "has the board looked into resources or funding from the Army Corps of Engineers?" He stated that right now the Corps is completing a ten-year project in New York harbor clearing out driftwood and other projects of similar nature. Dr. Koppen stated the board has done so already.

SAL FIORENTINO, President, Terrace Beach Club, Ingram Cove, Hopatcong

He explained that his organization has just dredged their beach property at a cost of $4,000 for an area 120' by 50' deep. His question was if Ingram Cove was included in the dredging project. Dr. Koppen answered "Yes". He then asked for the location of the catch basin. Eric Grove stated it would be located underground at the end of Holiday Drive. Grove then explained the workings of a similar catch basin in operation in Lake Mohawk. His third question regarded the taxing of boats. "Why couldn't the boat-use taxes be used to offset the cost of projects designated for lake restoration?" Dr. Koppen stated that this was one of the recommendations of the Lake Hopatcong Regional Planning Board's study.

V. ARNOLD KUELLING, Hopatcong

He stated that he is an ex-member of the beach club and has been a resident of the area since 1925. He also stated that he had a few comments and continued to list them 1) why aren't we included in the Musconetcong Sewerage Authority plans?... 2) most of the stuff that goes into the lake is caused from the boats, there are too many too much racing and no consideration from the drivers;... 3) he questioned the harvesting of the lake and asked how it could be accomplished wth all the rocks at the bottom;... 4) what would be done with the solids that are removed from the lake when dredging (dry it out and haul it away)?... 5) why tax only shoreowners, most do not use the lake;... 6) if the state says they own the lake, why doesn't the state do something about it?

Dr. Koppen Responded:

1) We are included in the UMSA sewerage plans.

2) Boats are a problem as far as safety, however, most of the pollutants come from the watershed. There is, however, some problem with large boats discharging wastes into the lake. the LHRPB is currently requesting a change in NJ regulations concerning these discharges.

3) We have run some trial runs and the equipment has done extremely well around the rocky areas.

4) A spoils site would have to be designed, however, we do not see dredging occurring in the near future.

5) The state is in the process of trying to do something. That is why we are here tonight.

FRANCES KUELLING, Hopatcong
Mrs. Kuelling stated she had three points to express... 1) there would not be much success without boating on the lake but what could be done to restrict size, speed and number on the lake. Cliff Lundin (Board member from Hopatcong) stated that the board is in the process of reviewing boating regulations and hopes this problem can be eliminated. ...2) she had lived in the area for over 40 years and has noticed very few new residences on the lake and questioned the taxing of these few shore line owners. ...3) why should the residents around the lake pay for the upkeep of a state owned lake, shouldn't the state maintain it?

Dr. Koppen Responded:

1) Cliff Lundin responded (LHRPB).

2) There has been explosive growth in the basin, in the immediate vicinity of the lake.

3) It is the position of the LHRPB that all levels of government should assist in paying for the upkeep of the lake.

BOB HART, Hopatcong
He made a proposal to the board...that they look into a five to five and a half foot drawdown each year and then perhaps the weed problem would be eliminated. Dr. Koppen explained the pros and cons of drawing down the lake each year, he stated that if drawdown was to be successful, perhaps drawing down the lake for two years in a row and weed harvesting for three years would be effective but not every year. Dr. Koppen spoke of the monoculture weeds and how organisms would be detrimentally affected if the lake was drawn down each year.

JOAN SHEPPARD, co-chairman of Prospect Point Committee Against Pollution, Hopatcong.
She stated these comments are of her own and on behalf of her group. "The problems concerning the lake are evident and we should spread the burden of paying for it. I believe that local funds should be put into this project and that it is important that the local communities share the cost burden and not wait until the EPA or the state pays the bill. The local municipal officials should be willing to lend political support and should take part in informing the public of projects such as this. The local officials shouldn't have to wait until the public cries and then do something. I hope that the work done by the board is continued and that the local officials see the long term results not just the short term ones."

ROBERT RUNG, Hopatcong
His question was "has the board computed the household expenses for a year?" The board members replied that it would be approximately $8-10 a year for each household. Robert Rung stated "Not a high price to pay for a clean lake."

TOM JERAMAZ, Hopatcong
He stated that he has been a resident of the area since 1929 and during the night had been jotting down suggestions and comments and they include: 1) everyone pays not just lake property owners, perhaps 1 cent per $100 of assessment. ...2) have the persons who use the state park pay 10 cents per person for the use of the lake (Henry Lieber, board member from Roxbury) stated that people already pay to enter the park; perhaps we want 50 cents of the money they already pay, not an additional sum. ...3) since the state says they own the lake, have the state pay for the maintenance. ...4) have boat marina owners pay an amount on the number of slips they have, the number of boats that use the lake and the volume of water they cover. ...5) lowering the lake also kills food for the fish, perhaps once in five years is enough. ...6) subject of boats, there are too many, too loud, too fast and not considerate and they do add to the pollution and something should be done about it.

STEVE GUERRIERO, President, Knee Deep Club
He thanked the board, Dr. Koppen and the area mayors for the studies already done and hoped that the state would now lend a helping hand. He explained the projects of the Knee Deep Club and stated that up to 1983 the club had spent $126,0000 for fish and other projects around the lake. He continued by stating that the club members were willing to help when called upon.

LEE PURCELL, Purcell Associates
He stated that the company has been involved in sewer utility development in the area for 20 plus years and that the presentation was very informative. He requested that the board consider endorsing the position of the ranking of the

LEE PURCELL, Purcell Associates (continued)

municipalities and MUA on the state's priority list with a letter to the state and stressed that sewer utility development is a must in this area. He also stated that in five to ten years there may be state funding of this type of project.

At this point, the chairman thanked the public for their presence and comments and again reminded all that the board meets every fourth Thursday of the month at the state park at 8 p.m.

APPENDIX 7

PROPOSED MILESTONE SCHEDULE AND ESTIMATED COSTS

MILESTONE SCHEDULE AND BUDGET

This budget and milestone schedule is based on the following assumptions:

1) Grant award date of June 1, 1984
2) Funding from the grant to cover 1984, 1985 and part of 1986.
3) Preaward notification in March or April to allow for writing of bid specifications.
4) Dredging is not anticipated in the plan for at least 5 years and costs are not projected here.

Activity	Milestone Dates
A. Weed Control	
1. Writing bid specifications	April - June 1984
2. Advertising for bids	June - July 1984
3. Purchase of equipment	July 1984
4. Delivery of equipment	August 1984
5. Start harvesting program (1984)	August 1984 - Sept. 30, 1984
6. 1985 harvesting	May 1985 - Sept. 1985
7. 1986 harvesting	May 1986 - Sept. 1986
8. 1987 harvesting	May 1987 - Sept. 1987
9. Lake drawdown	Sept. 1987 - Jan. 1988
10. 1988 harvesting	May 1988 - Sept. 1988, etc.
11. Lake drawdown	Sept. 1988 - Jan. 1988
12. 1989 harvesting	May 1989 - Sept. 1989

B. Phase II Monitoring - Start March 1984. Due to the nature of the plan and the importance of Lake Hopatcong it is anticipated that the monitoring program will be an ongoing part of the management program.

C. Lake Drawdown - The next regularly scheduled drawdown is 1987. We will anticipate drawing the lake down in both 1987 and 1988.

D. The public education program would begin at the award of the grant.

E. Pilot Project - Design of pilot project on Lakeside Boulevard would start in June 1984 and continue throughout the summer. Construction will begin and be completed in 1985.

F. Stormwater Management Planning - A request for funds will go to the State of New Jersey in 1985 (next budget cycle). Planning study would extend from 1985 through September 1986.

G. Implementation of Stormwater Management Plans - This would be a stepwise process making sure of opportunities that arise (See text of report).

H. Implementation of 201 Facilities Plans - As funds become available, hopefully can begin within 6 years.

PROJECTED COSTS

	1984	1985	1986	1987
1. Weed Control				
A. Capital	$208,000			
B. Expenses	8,000	$ 8,800	$ 9,680	$ 10,648
C. Maintenance	2,000	3,000	3,000	3,300
D. Labor	60,000	66,000	72,600	79,860
	$278,000	$ 77,800	$ 85,280	$ 93,808
2. Phase II Monitoring	$ 17,000	$ 16,500	$ 18,150	$ 19,965
3. Lake Draw-Down	--	--	--	--
4. Public Education	$ 10,000	$ 5,000	$ 5,000	$ 5,000
5. Design of Pilot Project Stormwater	$ 10,000	---	---	---
6. Administration				
DEP	$ 5,000	$ 5,000		
LHRPB In Kind	5,000	5,000		
	$ 10,000	$ 10,000		
Subtotal	$325,000	$109,300	$108,430	$118,773

ADDITIONAL PROJECT COSTS

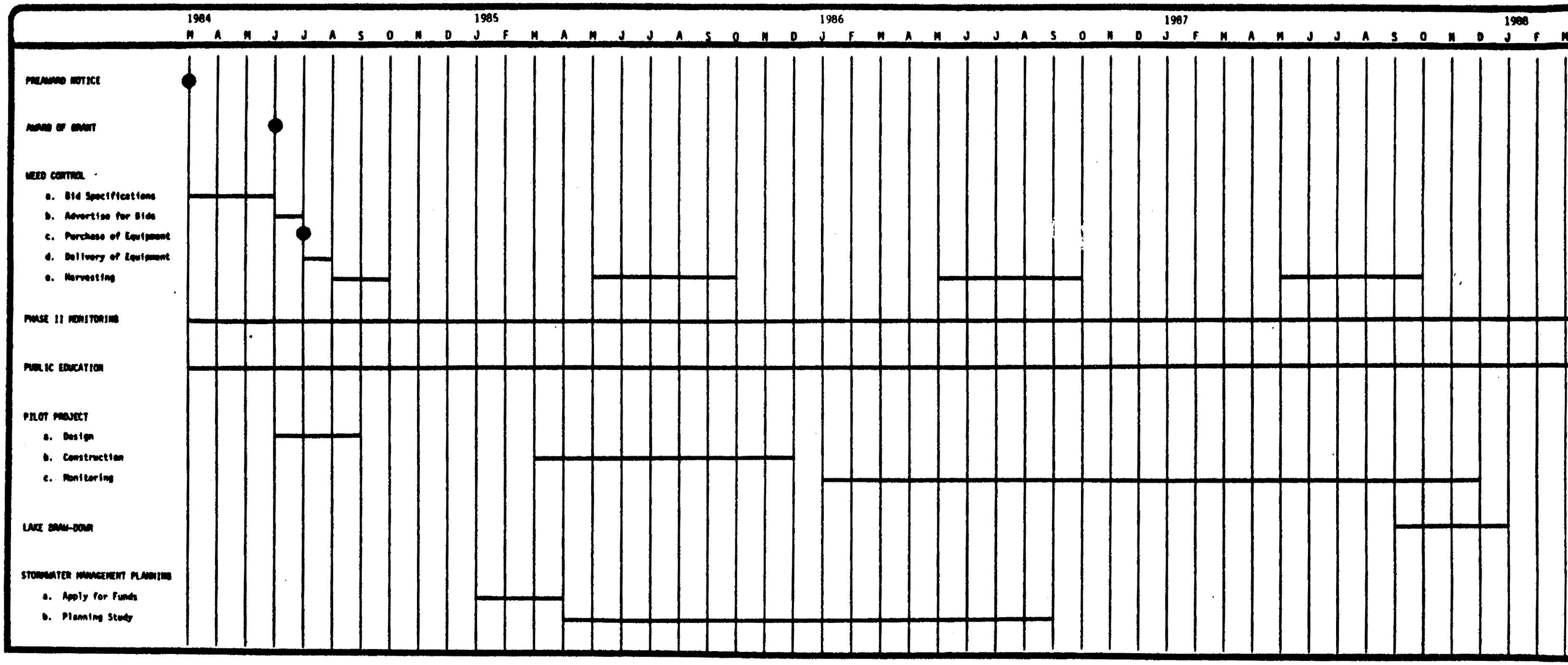
	1984	1985	1986	1987
6. Stormwater Management				
A. Planning		$100,000	$ 50,000	
B. Pilot Project Lakeside Dr.				
(1) Design	See #5 above			
(2) Construction[2]		$100,000		
(3) Project Monitoring			$ 10,000	$ 10,000
TOTAL WITHOUT DREDGING[3]	$325,000	$309,300	$168,430	$128,773

*Note: 1. Depending upon award date and delivery of equipment the actual expenditures in 1984 may be less in the Labor category. These excess funds, if realized, would be utilized for the 1986 Labor category.

2. Construction costs are to be born by Highway Construction funds.

3. It is estimated that 58 acres of Lake Hopatcong would benefit from dredging at a cost of C.a. $2,500,000. These funds are not part of this request.

PROPOSED MILESTONE SCHEDULE



APPENDIX 8

1979 AND 1980

EXPERIMENTAL WEED HARVESTING PROGRAM
ON
LAKE HOPATCONG

Experimental Harvest

Experimental aquatic weed harvests were performed on June 4, 1979 in the Weldon Brook area and the third week in June of 1980. The planned objectives of this experimental harvest were:

1) To acquaint local officials, legislators, and citizens with harvesting and provide a first-hand demonstration.

2) To determine the rate at which the weeks would grow back.

3) To determine the amount of nutrient removal that could be effected through harvesting.

In 1979, not all of these objectives were realized and this harvest did not prove to be a good measure of the effectiveness of harvesting in controlling aquatic macrophytes for several reasons.

1) The area harvested was too small (due to difficulty with equipment).

2) The depth of the cut was very shallow (2-3 feet) due to the shallowness of the water at test plot location.

3) The apparent dominant vegetation was *B. schreberi*. This taxon is probably the most difficult to effectively harvest, since it is coated with a clear, slippery mucilage. This made the plants very slippery, and the depth of the cutter was limited so the slope on the conveyor could be less, enabling the plants to be carried up onto the harvester.

Although this experimental harvest was not extensive, it did demonstrate some of the potential for this macrophyte control method.

The vegetation in the test plot was composed primarily of *B. schreberi, M. spicatum, P. amplifolius, E. nutalii, C. demersum, V. americana, and U.vulgaris*. At the time of harvest, *B. Schreberi, M. spicatum*, and *P. amplifolius* were the most abundant taxa. Their ratio by weight was 10:10:1 respectively. *B. schreberi* leaves covered the surface of the water (80-90%) at the test site. The few areas that were not occupied by *B. schreberi* were filled with *M. spicatum. P. amplifolius* was scattered throughout the site and extended up to several inches below the surface.

The depth to which the weeds were cut ranged between 2-3 feet below the water surface and the size of the harvested area was approximately 0.5 acres. Following the harvest, the test plot appeared cosmetically clean and motorboats were able to pass through with no problem.

One week after the harvest (6/15/79) the area was reexamined and, outside of a few scattered floating leaves of *B. schreberi*, that were probably missed by the harvester, the test plot appeared clean. At this time, some plants were measured so the rate of growth following the harvest could be measured. The average detph from the water surface to the cut plants ranged from 46 cm. to 61 cm. One week later (6/23/79) the observations were similar to the previous week. *B. schreberi* appeared to be slightly more abundant than the previous week.

On 6/30/79 large masses of floating filmentous algae (*Mougeotia sp.*) were noticed. The floating leaves of *B. schreberi* were more abundant compared to the previous week. It covered ≈10% of the surface with new leaves growing toward the surface. New shoots of *M. spicatum* were observed and *C. demersum* and *U. vulgaris* were becoming more abundant in the test plot. The appearance of substantial numbers of these two species is probably because they are normally late developing and more abundant later in the season. Some of the plants were cut and tneir heights measured. By 6/30/79 the cut plants were not doing well and their length actually seemed to be decreasing (i.e., their average length was shorter than previous measurements). Boats could still travel through the area with ease.

On 7/9/79 substantial grow-back was apparent. *B. schreberi* leaves covered ≈40% of the harvested area. *E. nutalii, M. spicatum* and *C. demersum* were abundant, but not to the extent that they were a nuisance. *P. amblifolia* appears to grow slower, since it still was not near the surface. The mass of the filamentous algae *Mougeotia sp.* still persisted but was not a problem to boats. At this time it was becoming difficult to distinguish between the cut and uncut plants; thus, additional measurements were not taken.

On 7/15/79 *B. schreberi* covered ≈70% of the surface. *C. demersum, V. americana, E. Nutalii* were becoming more abundant, but did not pose a problem. *M. spicatum* reached the surface, but the growth was not dense and *P. amplifolius* was still very slow to recover. The algae mats still persisted.

On 8/13/79 the site appeared almost as if it had not been harvested. *M. spicatum* or *P. amplifolius* filled areas where *B. schreberi* was absent. Over all the vegetation was not as heavy as before the harvest, but it did pose some difficult for boaters.

The period of time over which these observations were made was approximately 10 weeks. When one considers that the area was so small and the depth of the cut so shallow, the results were very satisfactory.

1980 Harvest

In the week of June 23, 1980 an experimental weed harvest was carried out in Lake Hopatcong using the Mud-Cat harvester. Approximately 20 acres was harvested of the 20 acres a 4 acre test plot was monitored closely.

The test site was located in Henderson Cove next to the east shore. The major aquatic macrophyte in this area was *Myriophyllum spicatum*. During the course of the harvest 20,000 lbs of wet weight of aquatic macrophyte was removed. This represents 1,800 lbs dry weight and a removal of 3.6 - 7.2 lbs of P or 0.9 to 1.8 lbs/P-Acre/Year. In terms of nitrogen the estimated removal would be 48.6 to 54 lbs of N or 12.2 to 13.5 lbs/N/Acre/Year.

Given a 400 acre harvest on Lake Hopatcong at this density a total of 360 to 720 lbs of P and 4,800 to 5,400 lbs of N could be removed annually by harvesting. It should be recognized that this estimate is based on a very small sample.

The weed harvesting demonstration site has been regularly monitored. One week after harvesting, the site was reexamined. Most of the cleared area appeared devoid of vegetation except for occasional patches of weeds that had been missed by the harvester. Recreational use of the area had been restored, with swimming and water skiing widespread.

The first incidence of regrowth was noted in early July (7-7-80). The macrophytes seen from the surface (primarily *Myriophyllum spicatum*) were widely scattered but had strong lateral branches forming. The average depth from the water surface to the cut plants ranged from 36-40 cm. depending on water depth. On 7-25-80 the plants in the shallowest areas of Henderson Cove were already reaching the surface. *M. spicatum* still dominated the community with scattered growth of *Vallisneria americana, Najas guadalupensis, Potamogeton ampifolius, Ceratophyllum demersum,* and filaments of *Lyngbya latissima* and *Mougiotia* sp. intertwined with the weeds.

By early August (8-12-80) the macrophytes were only 9-12 cm. below the surface. Occasional blossoms of *V. americana* were seen on the surface, with heavy blossoming of *M. spicatum* in the shallow waters along the shore. Boating and water skiing were still possible in the deeper waters but swimming was restricted. The rapid spurt of growth within this two week period was probably due to the extended period of hot weather experienced this summer. In addition, the drought conditions had begun to lower the water table.

By 8-30-80 the macrophytes were in full bloom throughout the cove. The weeds on the surface had intertwined to form a dense mat which prohibited most recreational use of the area. The actual number of plants per square meter might have been less than before harvesting, but the lateral growth of the macrophytes made the site appear more densely populated. An additional decrease in the water level continued through August causing overcrowding of the macrophytes and resulting in some decomposition. To allevaite the regrowth and subsequent seed dispersal of this type of site, a second harvest in August may be indicated.

Removal of Phosphorus by Harvesting

On the basis of our harvesting trials on Lake Hopatcong and analysis of plant tissues, a once-a-year harvest of 300 acres of weeds of similar composition and density to the trial site would, based on our loading rate of the annual 0.391 x m^{-2}/yr^{-1} phosphorus, remove approximately 9% of all phosphorus loading.

If a seond harvest could be accomplished within the course of a year, and an equivalent of 600 acres harvested, the amount of removal could be approximately doubled to Ca 18% of the normal annual load.

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