WARINANCO PARK LAKE PHASE II RESTORATION PROJECT

GRANT APPLICATION

FEBRUARY 4, 1998

Submitted to:

New Jersey Department of Environmental Protection
Division of Science and Research
Bureau of Freshwater and Biological Monitoring
35 Arctic Parkway
PO Box 427
Trenton, New Jersey 08625

Submitted by:

County of Union
Division of Parks and Recreation
Union County Administration Bldg., 5th Floor
Elizabeth, New Jersey 07207

I. General Information

1. Applicant: County of Union, Division of Parks and Recreation
2.

Address: Union County Administration Building, 5th Floor, Elizabeth, NJ 07207

Contact Person and Phone #: Dan Bernier, Bureau of Park Operations (908) 527-4911

3. Lake Name: Warinanco Park Lake
County: Union County

4. Please indicate type of lake and type of funding.

☒ Public Lake/Grant
☐ Private Lake/Loan
☐ State-owned/Grant

4. Total Project Cost

State share (grant/loan): $244,000

Local share: $101,000 ($86,000 cash and $15,000 in-kind)

Total cost: $345,000

5. Project time frame (months): 18 months
(Project start date is subject to award date of grant or loan)

II PRIORITY RANKING INFORMATION

The following information must be provided to the Department so that applications can be prioritized for funding. If the spaces provided do not permit enough space for responses, please use additional sheets and attach to the application package.

1. In the space provided below please document any recreational activities the applicant's lake supports which are listed in N.J. A.C. 7:9-2.5 (a)1. (Lake use and recreational potential). Please also describe recreational usage as it pertains to specific point totals.

According to N.J. A. C. (7:9-2.5) lake *recreational value* is defined as *those lakes having four major uses including boating, fishing, swimming, and aesthetics.* Warinanco Park Lake has three of the four major use categories defined by this program. It is a very popular park in a very densely populated area.

Warinanco Park Lake is a recreational focal point for Warinanco Park. The lake is presently used by the public for boating, fishing, and passive recreation including picnicking and hiking. The lake is an especially popular spot for boating. Paddle boats and rowboats are rented from the boating concession stand. Park visitors are able to use a drive up boat ramp for canoes and motorboats. Additional park amenities include two snack shops, bathroom facilities, and eleven athletic fields (e.g., baseball, soccer, football, and basketball). Shoreline fishing is also popular at the lake. Once a year there is a trout fishing tournament. The lake also contains catfish and sunfish.

Warinanco Park was designed by Frederick Olmstead and created by the Union County Park Commission in 1929. The park was designed to be visually pleasing and to accommodate high use. The active recreational areas are surrounded by wooded and grassy open space areas. A nature center is planned for the park. The center will be located in a historic building (circa 1924) previously used by the Park Commission. The Park Commission Administration building is listed on the National Register.

In summary, Warinanco Park lake has significant access for sail boats and power boats (3 points). It has a high quality fishery (3 points), and it has significant contact use (3 points). It has no designated swimming (0 points).

2. In the space provided below, please list any cities, boroughs, towns or townships and any counties contiguous to the lake [N.J. A.C. 7:9-2.5 (a)1]. Please also provide populations for each based on Federal 1990 Census Data.

Warinanco Park Lake is a 7.5 acre impoundment located in the eastern portion of Union County in Warinanco Park, in the Borough of Roselle and the City of Elizabeth, New Jersey. The population information is provided in the following sections.

Cities Contiguous to Warinanco Lake

- The City of Elizabeth ~ The City of Elizabeth has a population of 110,002 (1990, Federal Census Data).

Municipalities Contiguous to Warinanco Lake

- Borough of Roselle ~ Warinanco Park Lake is located in the Borough of Roselle. The population of the Borough was 20,314 in 1990 (190, Federal Census Data).

- Cranford Township ~ Cranford Township is a contiguous municipality. The population in 1990 for this Township was 22,633 (1990, Federal Census Data). The remaining municipalities are contiguous to the Borough of Roselle.

- Borough of Kenilworth ~ The population in 1990 for this Borough was 7,574 (1990, Federal Census Data).

- Borough of Roselle Park ~ The population in 1990 for this Borough was 12,805 (1990, Federal Census Data).

- Union Township ~ The population in 1990 for this Township was 50,024 (1990, Federal Census Data).

Counties Contiguous to Warinanco Lake

- Lily Lake is located in Union County. The population for Union County was 493,819 in 1990 (Federal Census Data). The following counties are contiguous to Union County.

- Essex County ~ The population for Essex County was 777,964 in 1990 (Federal Census Data).

- Morris County ~ The population for Morris County was Morris County was 421,361 in 1990 (Federal Census Data).

- Somerset County ~ The population for Somersett County was 240, 245 in 1990 (Federal Census Data).

- Middlesex County ~ The population for Essex County was 671,811 in 1990 (Federal Census Data).

The local population served by the lake exceeds 50,000 (10 points) and the county population is 493,819 (4 points).

3. In the space provided below, please detail local interest and involvement as defined in N.J. A.C. 7:9-2.5 (a)3. In order to justify points awarded for this category, please provide documentation of local involvement.

Local interest and involvement are imperative for a successful lake restoration project. We feel that local entities are *very involved* in restoration and management efforts in this watershed. If funded, there is great potential for additional interest and involvement. Actively involved entities include: The Union County Division of Parks and Recreation, the Union County Board of Chosen Freeholders, and The Union County Department of Operational Services.

Water Quality and Aquatic Studies

Warinanco Park Lake was one of eleven lakes investigated as part of the Union County Eleven Lakes Phase I Diagnostic-Feasibility Study. The Warinanco Park Lake Phase I study includes water quality data, pollutant budgets, an identification of problem areas, and a recommended management plan. The Phase I study (draft final, 1997) was funded *entirely* by the County of Union. This shows an appreciable amount of interest and involvement on the part of the County. The study is described in greater detail in the response to question 6.

Lake Management and Restoration Efforts

The lake was dredged once in 1960, however information on this particular dredging project is unavailable. In addition, the Union County Division of Parks and Recreation chemically treats the lake annually to control algae and aquatic plants. This effort is also funded entirely by Union County.

Union County has budgeted $500,000 per year to conduct "engineering and construction on activities needed for the restoration of lakes within the Union County Park System".

Union County is very interested in implementing the watershed and in-lake management recommendations included in the Phase I Diagnostic-Feasibility Study. Successful implementation of the Warinanco Park Lake Watershed Management Plan is expected with the help of local, state, and federal funding. All restoration efforts will include a public involvement and public education program. With funding, it is expected that increased citizen interest and involvement will be the logical result.

In summary, Union County has been very involved in management/restoration support as evidenced by the County commitment of funds to perform a totally locally-funded Phase I Diagnostic-Feasibility Study, the adoption of a watershed management plan, and the budgeting of $500,000/year for lake restoration and water quality management activities (20 points).

4. In the space provided below, indicate if the lake is located within a Center or an Environmentally Sensitive Area (Planning Area 4B, Planning Area 5 or the jurisdiction of Pinelands Protection Act) as designated by the State Development and Redevelopment Plan [N.J. A.C. 7:9-2.5 (a) 4].

According to information obtained from the Union County Department of Planning and Economic Development, Warinanco Park Lake is not located within the listed *critical* planning areas included in the State Development and Redevelopment Plan. The planning designation given to this portion of Union County is Metropolitan Planning Area (PA1).

5. In the space below, please indicate if this lake restoration project will be coordinated with other pollution control or watershed activities specified in N.J.A.C. 7:9-2.5 (a)5.

This particular lake restoration project will be directly coordinated with the management recommendations included in the Phase I Diagnostic Feasibility Study. At the present time there are no current dam safety restoration or wastewater treatment facility projects in progress in the Warinanco Park Lake watershed. Municipalities in the watershed include Roselle Borough, Roselle Park Borough, and the City of Elizabeth. They were all contacted for confirmation.

6. If this is a Phase II Application, please indicate below if the applicant has completed a Phase I Diagnostic-Feasibility Study [N.J. A.C. 7:9-2.5 (a)6.]. If a Phase I Study has been completed please include a copy with this application.

The Phase I Diagnostic-Feasibility Study and Watershed Management Plan for Warinanco Park Lake (Draft Final, 1997) is included in Appendix A of this application. As previously mentioned, the study includes water quality data, pollutant budgets, identification of problem areas, and a recommended management plan. The study concluded that the lake is hyper-eutrophic. The study also concluded that implementing specific watershed management practices should have a positive impact on the water quality in Warinanco Park Lake. The lake and watershed management plan focuses on increasing the water depth in the lake, increasing the circulation of the lake, and reducing nonpoint sources of pollution from the surrounding watershed.

In summary, the applicant has completed a Phase I Diagnostic-Feasibility Study (5 points).

III. PHASE II DETAILED INFORMATION

1.0 Introduction

Warinanco Park Lake is a 7.5 acre impoundment located in Warinanco Park in the Borough of Roselle, New Jersey. A small portion of the park and most of the watershed of the lake is located in the City of Elizabeth. The lake was designed by Frederick Olmstead and was created by the Union County Park Commission in 1929. The park provides bicycle paths, boating, fishing, ice skating, fitness trails, and picnicking.

In 1997, a Phase I Diagnostic Feasibility Study of Warinanco Park Lake was completed. The recommendations of the study included:

- A dredging feasibility study,
- Lake dredging,
- Construction of a created wetland,
- Shoreline stabilization using a combination of vegetative and structural methods,
- Lake aeration,
- Addition of a water colorant (Aquashade),
- Dilution and flushing,
- Environmental education (including homeowner practices),
- Water quality monitoring,
- Waterfowl Control, and
- Urban Stormwater Management.

This Phase II Grant Restoration Project will incorporate many of the recommendations of the Phase I Study and will focus on reducing nonpoint sources of pollution to the lake. In addition, a dredging feasibility study will be conducted to determine the feasibility of dredging the lake in the near future. The Phase II Restoration Project will include:

- Preparation of a dredging feasibility study,
- Testing of lake sediments to meet NJDEP testing requirements for dredging,
- Design and Construction of a created wetland,
- Design and Construction of shoreline stabilization measures,
- Dilution and flushing of the lake using wells as a water source,
- Development of an environmental education program, including homeowner practices, and
- Development and implementation of a waterfowl control program.

The scope of work for the Warinanco Park Lake Phase II Restoration Project is described in Section 2.0, and a detailed budget and milestone schedule are provided in Sections 3.0 and 4.0, respectively. The total project cost for the Warinanco Park Lake Phase II Restoration Project is $345,000.

2.0 Scope of Work

The scope of work for the Phase II Restoration of Warinanco Park Lake will include a dredging feasibility study, detailed sediment testing, shoreline stabilization, constructed wetlands, dilution and flushing of the lake, an environmental education program, a waterfowl control program, and project management and documentation. The tasks that will be conducted to implement the Warinanco Park Lake Restoration Project are listed below:

Task	Description
1	Dredging Feasibility Study
2	Sediment Testing to Meet NJDEP Requirements
3	Shoreline Stabilization
4	Created Wetlands
5	Dilution and Flushing
6	Environmental Education Program
7	Waterfowl Control Program
8	Project Management and Administration
9	Project Documentation

Each of the above tasks is described in the following sections. Union County has budgeted $500,000 per year to conduct "engineering and construction on activities needed for the restoration of lakes within the Union County Park System".

2.1 Dredging Feasibility Study

A detailed dredging feasibility study will be conducted to determine how much sediment is in the lake, the quality of the sediment in the lake, the most feasible type of dredging for Warinanco Park Lake, and the ultimate disposal area for the dewatered sediments. The first step in the dredging feasibility study will be to arrange and attend a pre-application meeting with the New Jersey Land Use Regulation Program (LURP). At the meeting, the project will be discussed. The required permits for the project and the required sediment sampling will be determined.

A detailed bathymetric survey will be conducted to determine the existing volume of sediment in the lake. The detailed bathymetric survey will be used as a base plan for future dredging design. Up to three separate sediment disposal areas will be evaluated as part of the dredging feasibility study to determine the ultimate sediment disposal area. Dredging methods, including mechanical and hydraulic, will be evaluated to determine the most cost effective method of dredging. Sediments will be collected and analyzed for compliance with NJDEP soil cleanup criteria. Information regarding the sediment testing is provided in Section 2.2.

Based on sediment data collected as part of the Phase I project, sediments in Warinanco Park Lake have high concentrations of arsenic, lead, benzo(a)anthracene, and benzo(a)pyrene and may require special methods of disposal. The quality of the sediments will be verified during the detailed sediment testing that is required for all dredging projects. During the pre-application meeting, various options for disposal will be discussed including using adjacent parkland. If parkland is used, the sediment may be able to be buried and capped with clean fill.

A dredging feasibility report will be prepared for the project. The report will include recommendations for the type of dredging, the locations for ultimate disposal, the ultimate volume of sediment to be dredged, dredging and disposal costs, and a listing of all permits that will be required for the dredging project.

The dredging feasibility study and sediment testing (Section 2.2) will be important considering the County's budgeted lake restoration funds of $500,000 per year.

2.2 Sediment Testing to Meet NJDEP Requirements

Based on past experience and the NJDEP Guidelines entitled "The Management and Regulation of Dredging Activities and Dredged Material in New Jersey's Tidal Waters" significant sediment testing is required for dredging projects. Although Warinanco Park Lake is not a tidal water, New Jersey has no other published guidelines for testing sediments for dredging projects. The total number of sediment tests and the exact parameters that will be analyzed will be determined at the pre-application meeting with the LURP. The costs presented in this grant application have been developed assuming that the following tests will be required for 7 discrete samples.

Laboratory Tests for 7 Discrete Samples

Grain Size
Percent Moisture
Total Organic Carbon
Pesticides
Inorganics (heavy metals)
Volatile Halogenated Organics
Volatile Aromatic Organics
Volatile Nonpurgeable Organics
Water Soluble Organics
Phenols
Phthalate Esters
n-nitrosamines
Polynuclear Aromatic Hydrocarbons
Haloethers
Chloronated Hydrocarbons
Nitrosaromatics
Isophorone

In addition to the 7 discrete samples, 2 composited samples will be collected for analysis using the Sequential Batch Leaching Test to ensure that no contaminants will leach into the groundwater at the final disposal site.

If additional tests (number of tests or additional parameters) are required by the DEP, the cost of the sediment testing will increase.

2.3 Shoreline Stabilization

The shoreline surrounding Warinanco Park Lake is eroding and requires stabilization. Approximately 2,000 linear feet of shoreline will be stabilized using bioengineering techniques including coir fiber bundles with vegetation and vegetative erosion control matting. All vegetative measure will be designed to enhance the natural beauty of the lake and will include grassy varieties of vegetation mixed with blue flag iris and cardinal flower. In addition to the vegetative stabilization techniques, structural methods or a combination of structural methods with vegetation will be required for an additional 1,375 linear feet of shoreline. The use of structural methods will be limited to high traffic areas and will provide park users the opportunity to walk close to the lake without walking in the tall grasses in the vegetative control areas.

2.4 Created Wetland

The existing lagoon that drains into Warinanco Park Lake will be converted into a created wetland that will be designed to trap sediments and nutrients. This will provide for an area to routinely "dredge" accumulated sediments in the forebay of the created wetland without obtaining a specific permit for dredging. In addition, the created wetland will be designed to reduce the nutrient loading to Warinanco Park Lake.

2.5 Dilution and Flushing

Dilution and flushing is a method of reducing the overall phosphorus concentration in a lake. Warinanco Park Lake is fed only by springs and stormwater runoff. One of the recommendations of the Phase I study was to drill one, or possibly two, well(s) in the vicinity of the lake to serve as a water source for the lake. A 10 gpm well pump will be installed in the well(s) and will pump water into the lake. As part of this task, groundwater quality will be evaluated to determine if this option should be implemented. If phosphorus concentrations in the groundwater are low, then this task will continue into the design and construction stage. If the groundwater contains high levels of phosphorus or nitrogen, then this task will not be completed and money will be distributed to other tasks, as necessary.

2.6 Environmental Education Program

Union County is currently working on a County-wide environmental education program using local funds and EPA-DEP 319 funds. The grant money that is being requested for this project will be used for preparing specific fact sheets for Warinanco Park Lake and its watershed. In addition, a kiosk will be developed and installed at Warinanco Park that includes a summary of the Phase I and Phase II work that has occurred at the lake and a primer on lake ecology and watershed management.

Also as part of the environmental education program, Union County will develop a fact sheet on the importance of proper lawn fertilization. The fact sheet will be distributed to homeowners in the watershed. The homeowner fact sheets will be posted at the park.

The County will develop stencils for storm drains to educate people that anything that goes down the storm sewer eventually drains to the lake. The stencil will be designed and will be painted adjacent to storm drains by County personnel.

In addition to storm drain stenciling, Union County will work internally to examine their leaf collection program. The existing leaf management program will be evaluated to determine if there are ways to improve the program so that leaves do not end up in the street for a long period of time. If leaves are left in the street too long, nutrients leach from the leaves and are carried into the storm sewers and eventually into the lake with stormwater runoff. Bagging leaves in biodegradable bags is one possibility for improving the leaf management program.

2.7 Waterfowl Control Program

Waterfowl are a problem for many New Jersey lakes and Warinanco Park Lake is no exception. Using grant money, Union County will develop a plan for controlling waterfowl at the lake. Likely control strategies will include landscaping, chemical deterrents, scare tactics, and egg inactivation. Once an acceptable plan has been developed for controlling waterfowl at the lake, the plan will be implemented with remaining funds. Signs will be designed, constructed, and posted at strategic locations in the park to inform people about not feeding the waterfowl.

2.8 Project Management and Administration

Union County will provide project management and administration activities to ensure that the project stays on schedule and on budget.

2.9 Project Documentation

Quarterly progress reports will be prepared and submitted to the DEP for the duration of the project. The progress reports will include a description of work completed during the quarter, a description of work to be conducted during the next quarter, and a description of any problems. In addition, a final report will be prepared at the end of the project and submitted to the DEP. The final report will include a description of all activities that occurred during the project.

3.0 Project Budget

The total cost to implement the Warinanco Park Lake Phase II Restoration Project is $345,000. Union County is requesting $244,000 which is 71% of the total project cost. The County will be providing $86,000 in cash and $15,000 in in-kind services for the project. The project budget, showing a breakdown of projects costs, is provided in Table 1.

Table 1
Warinanco Park Lake Project Budget

Description	DEP Funding (Cash)	Union County (in-Kind)	Union County (Cash)	Total Costs
Dredging Feasibility Study	$10,000	$0	$5,000	$15,000
Sediment Testing	$16,000	$0	$7,000	$23,000
Shoreline Stabilization*	$135,000	$0	$30,000	$165,000
Created Wetland*	$30,000	$0	$25,000	$55,000
Dilution/Flushing*	$30,000	$0	$10,000	$40,000
Environmental Education Program	$8,000	$7,000	$4,000	$19,000
Waterfowl Control	$5,000	$2,000	$3,000	$10,000
Project Management and Administration	$3,000	$6,000	$0	$9,000
Documentation	$7,000	$0	$2,000	$9,000
Totals	$244,000	$15,000	$86,000	$345,000

*Includes design, permitting, construction, and construction observation.

4.0 Project Schedule

The Warinanco Park Lake Restoration Project will be completed within an 18 month period. The dredging feasibility study will be complete immediately upon receiving the grant from the DEP. If dredging is determined to be feasible, Union County will submit a grant application for dredging the lake for the next funding cycle. A milestone schedule is provided in Table 2.

Table 2
Warinanco Park Lake Phase II Project
Milestone Schedule

Task	1998						1999											
	1*	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Dredging Feasibility Study	■	■	■	■														
Sediment Testing		■	■															
Shoreline Stabilization																		
Engineering/Permitting	■	■	■	■	■													
Construction									■	■	■							
Created Wetlands																		
Engineering/Permitting	■	■	■	■	■	■	■											
Construction									■	■	■							
Dilution/Flushing																		
Engineering/Permitting					■	■	■	■	■									
Construction												■	■	■				
Environmental Education Program		■	■	■	■	■	■	■	■	■	■	■	■	■				
Waterfowl Control																		
Design					■	■	■	■										
Implementation											■	■	■	■	■	■		
Project Management/Administration	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
Documentation			■			■			■			■			■	■	■	■

*Schedule assumes project begins 7/1/98.

APPENDIX A

SUPPORTING INFORMATION

DIAGNOSTIC-FEASIBILITY STUDY AND WATERSHED MANAGEMENT PLAN FOR WARINANCO PARK LAKE

Draft Final Report
August 1997

Presented to:
Union County
Bureau of Parks and Recreation

Prepared by:
F. X. Browne, Inc.
1101 South Broad Street
Lansdale, Pennsylvania 19446

DIAGNOSTIC-FEASIBILITY STUDY

OF

Warinanco Park Lake

DRAFT FINAL REPORT

August 1997

Presented to:

Union County
Bureau of Parks and Recreation

Prepared by:

F. X. Browne, Inc.
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Lansdale, Pennsylvania 19446
(800) 220-2022

File No. 1289-03

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Acknowledgments

Warinanco Park Lake was one of eleven lakes that was investigated as part of the Union County Eleven Lakes Phase I Diagnostic-Feasibility Study. The Union County Eleven Lakes Phase I Study was funded entirely by the County of Union. Appreciation is extended to all members of the Board of Chosen Freeholders for their dedication and commitment toward preserving the water quality of county-owned lakes.

Thanks is extended to all County employees who assisted in this study. Special gratitude is extended to Mr. Daniel Bernier for his invaluable perspective on all eleven study lakes and their surrounding watersheds and his diligent assistance throughout the entire length of this study.

Ann M. Baran, County Manager

Armand A. Fiorletti, Director
Department of Operational Services

Charles Sigmund, Jr., Director
Division of Parks and Recreation

Daniel Bernier, Chief, Bureau of Park Operations
Division of Parks and Recreation

Board of Chosen Freeholders

Linda DiGiovanni, Chairman
Edwin H. Force, Vice-Chairman
Elmer M. Ertl
Linda-Lee Kelly
Henry W. Kurz
Frank H. Lehr
Walter McLeod
Linda Stender
Daniel P. Sullivan

Executive Summary

Overview

Warinanco Park Lake is a 7.5 acre impoundment located in Warinanco Park in the Borough of Roselle, New Jersey. A small portion of the park and most of the watershed of the lake is located in the City of Elizabeth. The lake was designed by Frederick Olmstead and was created by the Union County Park Commission in 1929. The park provides bicycle paths, boating, fishing, ice skating, fitness trails, and picnicking.

Several problems are common to the county's waterways including degraded lake water quality, sedimentation, eroding shorelines, proliferation of nuisance weed growth and waterfowl, and inadequate public accessibility. Union County established a team to prioritize over 30 county waterways within the county park system. Out of the 30 waterways, the County prioritized the top eleven lakes. Of the 11 priority lakes, Warinanco Park Lake was given a high priority rating of # 5. The lake is in danger of losing a variety of uses due to excessive siltation, algae blooms and an overabundance of aquatic plants and waterfowl. The lake was dredged once in about 1960.

In April 1996, Union County commissioned F. X. Browne, Inc. to perform a Phase I Diagnostic - Feasibility Study of Warinanco Park Lake. The Diagnostic-Feasibility Study was conducted in two stages. The diagnostic portion of the study was conducted to determine current water quality conditions, identify existing problems, and determine the pollutant sources that are responsible for the observed problems. The feasibility aspect of the study evaluated a variety of lake and watershed management alternatives based on the results of the diagnostic study. The product of this study is a Diagnostic Feasibility Report that provides a recommended management plan for the restoration of Warinanco Park Lake.

Conclusions

As part of the Warinanco Park Lake Phase I Study, a lake water quality monitoring program was conducted from May through August 1996. Conclusions of the study are based on the diagnostic portion of the project.

Water Quality

- During most of the year, Warinanco Park Lake is generally *well mixed and oxygenated at all water depths.*

- Under windless conditions in the summer months, the dissolved oxygen levels in the lake*can be depleted and may have an adverse impact on the aquatic biota. Anoxic (zero oxygen) conditions in the bottom waters* of the lake can cause phosphorus to be released from the sediments into the water column, becoming available for algal growth.

- Nitrogen appears to be the "limiting" nutrient in Warinanco Park Lake that causes the excessive algae and aquatic weed growth.

- The average total phosphorus concentration was 0.403 milligrams per liter (mg/L), and the average Secchi disk transparency measurement was 0.34 meters (1.1 feet). The average chlorophyll a concentration in the lake was 95.9 micrograms per liter (μg/L). Based on these values, Warinanco Park Lake is classified as a highly productive or hyper- eutrophic lake.

- Warinanco Park Lake has a *slow* flushing rate. It is estimated that the lake flushes *24 times* per year or every *15 days*. This estimate may be high since it is based on nearby gaging data.

Bathymetry and Sediment Chemistry

- The average water depth in Warinanco Park Lake is 2.93 feet. The maximum water depth is 3.7 feet.

- Warinanco Park Lake contains approximately *15,523 cubic yards* of unconsolidated sediments. The average sediment thickness in the lake is 1.35 feet, and the maximum sediment thickness in the lake is 3.3 feet.

- Sediments in Warinanco Park Lake contain arsenic and benzo(a)pyrene in concentrations that exceed the acceptable level for residential and non-residential sediment disposal. Lead and benzo(a)anthracene concentrations exceed the acceptable level for residential sediment disposal. Therefore, the sediments in

Warinanco Park Lake are contaminated and disposal of these sediments will be difficult.

Macrophytes

- During the summer months, Warinanco Park Lake is treated for macrophytes. During the macrophyte survey, the only major type of macrophyte noted were rushes. Large mats of filamentous algae were noted.

Watershed Characteristics

- The ratio of the watershed area to lake surface area is 50.7:1. Implementing watershed management practices should have a positive impact on the water quality in Warinanco Park Lake.
- The most dominant land use within the watershed area is high density residential and commercial areas.
- Most of the land immediately adjacent to Warinanco Park Lake is parkland consisting of grassed, open space area.

Recommendations

Based on the diagnostic portion of the Warinanco Park Lake Phase I Study, the following recommendations were developed as part of a Comprehensive Lake and Watershed Management Plan. The lake and watershed management plan focuses on increasing the water depth in the lake, increasing the circulation of the lake, and reducing nonpoint sources of pollution from the surrounding watershed.

Each element of the recommended Lake and Watershed Management Plan for Warinanco Park Lake is described below.

- The dredging feasibility study should also include an evaluation of beneficial soil reuse and reclamation of the contaminated sediments.

Lake Aeration

- Lake aeration is recommended for Warinanco Park Lake to increase lake circulation. Before implementing this recommendation, Union County must consider whether it wants aerators in a lake that allows boating. These two activities may conflict with each other, and the County must make the final decision.

Shoreline Stabilization

- Severely eroded areas along the lake shoreline should be stabilized with a combination of structural and vegetative shoreline stabilization measures.

Created Wetlands

- The existing lagoon that drains into Warinanco Park Lake should be converted into a created wetland that is designed to trap sediments and nutrients. This will provide for an area to routinely "dredge" accumulated sediments in the forebay of the created wetland without obtaining a specific permit for dredging. In addition, the created wetland will be designed to reduce the nutrient loading to Warinanco Park Lake.

Dilution/Flushing

- One, or possibly two, well(s) should be drilled in the vicinity of the lake to serve as a water source for the lake. A 10 gpm well pump should be installed in the well(s) and should pump water into the lake. Groundwater quality should be verified before this option is finalized. Water should be pumped into the lake for 8 hours per day from the beginning of April through the end of September.

Water Colorant

- Aquashade, an EPA-registered non-toxic blue dye should be added to the lake to block sunlight which will inhibit algae and aquatic plant growth. In addition, this blue dye will greatly improve the aesthetic quality of the lake.

Waterfowl Control

- Canada geese and gull populations at Warinanco Park Lake are excessive and should be controlled. Geese droppings are a significant and direct source of phosphorus, nitrogen and bacteria to Warinanco Park Lake.

- Geese populations should be controlled by landscaping, egg inactivation, chemical deterrents, and scare tactics.

- Park visitors should be discouraged from feeding the geese and other waterfowl. Signs should be posted at strategic locations in the park to inform people about not feeding the waterfowl.

Urban Stormwater Management

- Union County and local municipalities should evaluate street sweeping schedules. Increased street sweeping is recommended, especially in the spring and summer months.

- Stormwater catch basins should be cleaned after major storm events or at least once every three months. Cooperation between Union County and the local municipalities is recommended for this task.

- Although most of the watershed is developed, every opportunity to improve stormwater quality should be taken. For example, if a commercial establishment changes ownership, and the new owner needs approvals from the local municipality, local ordinances should be in place to require improving stormwater runoff quality from the site before approvals are granted. Possible stormwater quality treatment systems that could be installed on a developed property include sand filters, peat filters, or bioretention systems. The purpose of these systems is to treat stormwater runoff from roads and parking lots. These systems are installed to treat the first 0.5 inches of stormwater runoff.

- Existing homeowners and business owners should be encouraged to direct roof runoff to dry pits or rain barrels to reduce the amount of stormwater that enters the storm sewer system. Using a rain barrel or cistern gives the homeowner the advantage of water use reduction by storing rain water to water gardens or lawns during dry periods.

Homeowner Practices

Homeowner practices can be implemented as part of the public education program described in the following section.

- Lawn fertilizer can be a significant source of nutrients to lakes, especially in suburban areas where nice green lawns are desirable. A fact sheet on the importance of proper lawn fertilization should be prepared and distributed to homeowners in the watershed. This task could be facilitated through the public education program described below or by an "extra" in the local newspaper. Fact sheets could be posted at the park and possibly at local businesses.

- Leaf management is also important in reducing nonpoint source pollution in a developed watershed. The existing leaf management program should be evaluated to determine if there are ways to improve the program so that leaves do not end up in the street for a long period of time. If leaves are left in the street too long, nutrients leach from the leaves and are carried into the storm sewers and eventually into the lake with stormwater runoff. Bagging leaves in biodegradable bags is one possibility for improving the leaf management program.

- Homeowners should be informed that if they dump household chemicals and other substances into storm sewers, these substances will end up in the lake. Stenciling should be painted on storm inlets to educate homeowners that anything that goes down the storm sewer eventually drains to the lake.

- Homeowners should be encouraged to wash cars and trucks on grassy areas, if possible. This practice will reduce the amount of phosphorus and detergents that runs down the driveway, into a nearby storm sewer, and eventually into Warinanco Park Lake.

Public Education Program

Union County has developed and is continuing to implement an extensive environmental education program throughout the County. The County's environmental education program should be integrated into the Warinanco Park Lake watershed project. The environmental education program for Warinanco Park Lake should include the following elements:

1. Develop and distribute nonpoint source brochure
2. Develop a watershed management program for presentation to local schools,
3. Develop and install a kiosk at Warinanco Park Lake, and
4. Write a fact sheet on watershed management for distribution at the kiosk and at park events.

Water Quality Monitoring Program

- A limited water quality monitoring program should be implemented, after dredging has been completed, to document water quality improvements. Yearly monitoring of selected parameters (i.e. total phosphorus, chlorophyll a and Secchi disk depth) should be conducted to document water quality changes in the lake.

Institutional Approaches

- The Union County Waterways Team should work closely with municipal officials to improve the water quality in Warinanco Park Lake and to implement this Watershed Management Plan.

- The Union County Waterways Team and local municipalities should evaluate existing subdivision ordinances, erosion and sedimentation control ordinances, stormwater management ordinances, and other existing ordinances to look for way to strengthen these ordinances to protect the water quality in Warinanco Park Lake.

1.0 Project Description

1.1 Background

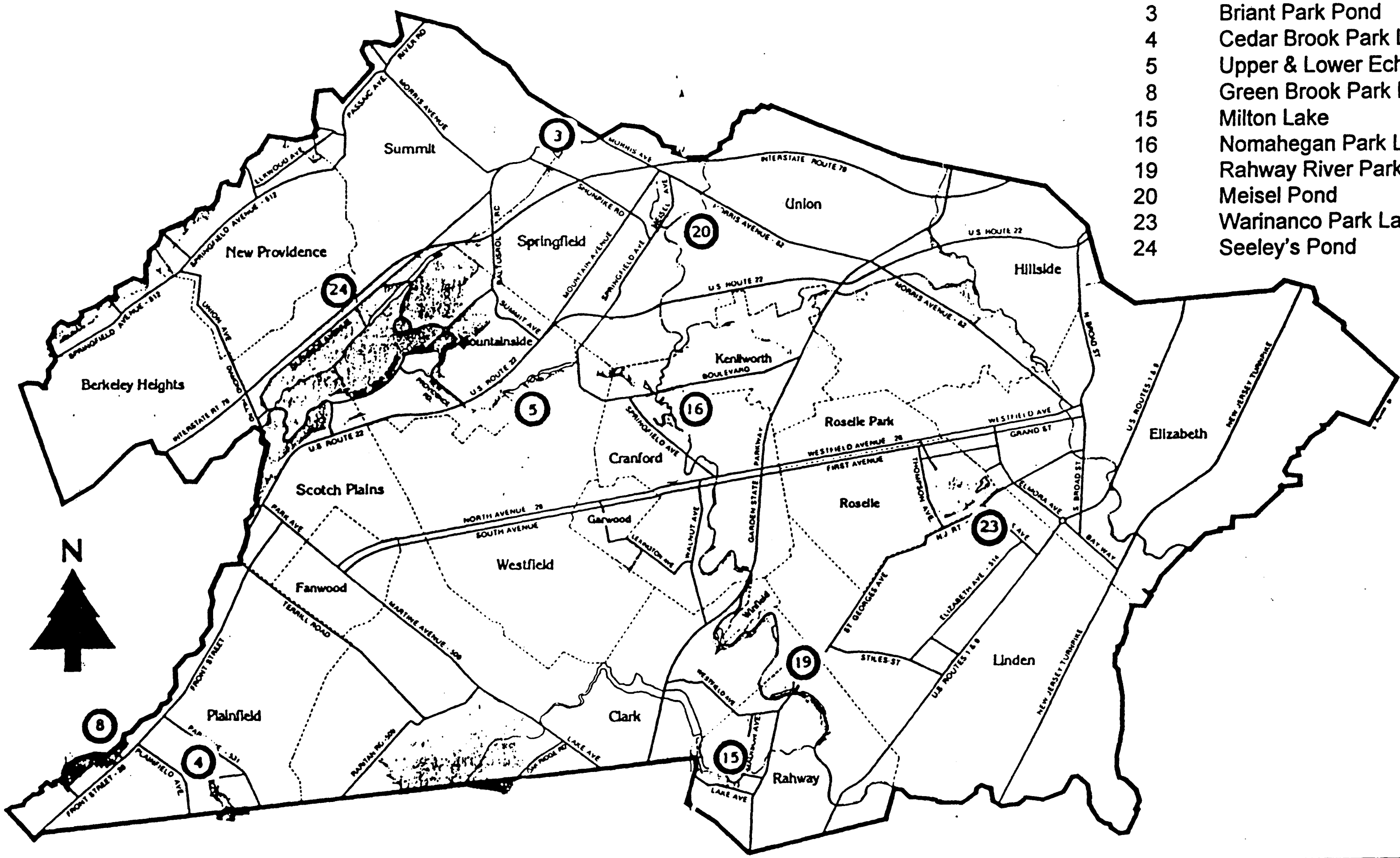
Union County recently established a "Waterways Team" which has the primary objective of developing a strategic plan to improve the County's waterways. The Waterways Team, consisting of ten County staff employees, has set its sights on dealing with 30 or more lakes, ponds, and lagoons that are County-owned and located in the County's vast park system.

The most common lake problems noted by the Waterways Team are degraded water quality, accumulation of litter, debris, and sediments, eroding shorelines, proliferation of nuisance weed growth, overabundance of waterfowl, degraded dam structures, and poor accessibility for the public.

The Waterways Team has determined the 12 most critical lakes in the Union County Park System. The team used a priority ranking system to evaluate the overall degradation of County-owned lakes. One of these lakes, Lake Surprise, was studied by F. X. Browne, Inc. (1995). The Lake Surprise Phase I Diagnostic-Feasibility Study was conducted in accordance with CFR, Part 35, Subpart H entitled "Cooperative Agreements for Protecting and Restoring Publicly Owned Freshwater Lakes" which pertains to the federal Clean Lakes Program. Based on qualifications and the success of the Lake Surprise Phase I Study, Union County also retained F. X. Browne, Inc. to implement the Lake Surprise Phase II Restoration Project. The major components of the Lake Surprise Phase II Restoration Project are the removal of excessive accumulated sediments in the lake, the design and implementation of watershed best management practices, the development of an environmental educational curriculum, and the implementation of a post-dredging water quality monitoring program.

The eleven remaining critical lakes, as ranked by the Waterways Team from worst to least bad, are Green Brook Lagoon, Upper Echo Lake. Seeley's Pond, Rahway River Park Lake, Warinanco Park Lake, Milton Lake, Meisel Pond. Lower Echo Lake, Nomahegan Lake, Briant Pond, and Cedar Brook Lake. The locations of the above eleven lakes are shown in Figure 1.1.

In order to restore these lakes as natural, recreational, and aesthetic resources, Union County, Department of Operations, Division of Parks and Recreation, retained F. X. Browne, Inc. to perform Diagnostic-Feasibility Studies for these remaining eleven critical lakes. The Phase I Diagnostic-Feasibility Studies have been performed by using a modified monitoring program that generally meets the requirements in 40 CFR, Part 35, Subpart H entitled "Cooperative Agreements for Protecting and Restoring Publicly Owned Freshwater Lakes."



Legend

No.	Lake Name
3	Briant Park Pond
4	Cedar Brook Park Lake
5	Upper & Lower Echo Lake
8	Green Brook Park Lake
15	Milton Lake
16	Nomahegan Park Lake
19	Rahway River Parkway Lake
20	Meisel Pond
23	Warinanco Park Lake
24	Seeley's Pond

Figure 1.1 — Location of the Eleven Study Lakes in Union County, New Jersey

Based on the recommended comprehensive management plans offered as part of the Phase I Diagnostic-Feasibility Studies, Union County will then implement the recommended lake and watershed restoration strategies as capital appropriations and operations funds become available. Union County also will use these studies to apply for various sources of state and federal funding.

Individual reports were prepared for each of the eleven Union County study lakes. This document represents the Phase I Diagnostic - Feasibility Report for Warinanco Park Lake. Warinanco Park Lake is located in Warinanco Park. This county-owned park is located in the eastern portion of Union County as shown in Figure 1.1.

1.2 Project Objectives

Due to the lack of sufficient federal funding, Union County took it upon itself to perform a Phase I Diagnostic - Feasibility Study for eleven County-owned lakes. Undertaking such a study demonstrates the county's strong commitment in preserving and restoring its water resources for the public.

Union County selected F. X. Browne, Inc. to simultaneously conduct Phase I Diagnostic - Feasibility Studies for eleven County-owned lakes as discussed in Section 1.1. The Phase I Diagnostic - Feasibility Studies of all eleven lakes were designed and conducted using a modified approach in generally agreement with Title 40 CFR Part 35, Subpart H entitled "Cooperative Agreements for Protecting and Restoring Publicly Owned Freshwater Lakes" (U.S. Environmental Protection Agency, 1980).

The Diagnostic-Feasibility Studies for all eleven study lakes were conducted in two stages. The diagnostic portion of the studies was conducted to determine current water quality conditions, identify existing problems, and determine the pollutant sources that are responsible for the observed problems. The feasibility aspect of the studies evaluated a variety of lake and watershed restoration alternatives based on the results of the diagnostic study. These alternatives included watershed management practices and in-lake restoration methods. The management plan resulting from the feasibility study includes a description of identified lake and watershed problems, proposed solutions, and a suggested implementation program.

The primary objectives of the Phase I Diagnostic-Feasibility Studies for all eleven County-owned study lakes were:

1. To evaluate the existing water quality conditions in eleven study lakes and to determine impacts on the recreational uses of these lakes and their surrounding areas,

2. To identify the sources and magnitude of pollutants entering the eleven study lakes,

3. To evaluate feasible control alternatives and restoration methods, and

4. To develop and recommend conceptual lake and watershed management plans that are cost-effective, environmentally sound, acceptable to the public, and can be used as the basis for a Phase II Implementation Grant Applications for submission to the U.S. Environmental Protection Agency (U.S. EPA) and other government agencies.

2.0 Lake and Watershed Characteristics

2.1 Lake Morphology

Warinanco Park Lake is a 7.5 acre impoundment located in the eastern portion of Union County in Warinanco Park, in the Borough of Roselle and the City of Elizabeth, New Jersey. Warinanco Park Lake has no inlet tributaries and is fed by springs and stormwater runoff. The watershed of Warinanco Park Lake is 388 acres, including the area of the lake. The watershed boundary is shown in Figure 2.1 and includes the Warinanco Park area, high density residential areas, and commercial areas.

A complete listing of morphometric and hydrologic characteristics of Warinanco Park Lake are summarized in Table 2.1.

Table 2.1
Morphometric and Hydrologic Characteristics of Warinanco Park Lake

Lake Surface Area	7.5 acres
Lake Volume	5.96 Million Gallons
Average Depth	2.93 feet
Maximum Depth	3.7 feet
Hydraulic Retention Time	15 days*
Average Discharge	0.7 cfs
Drainage Basin Area (excluding lake area)	380.5 acres

* This retention time may be high and is based on stream gaging station data from nearby streams.

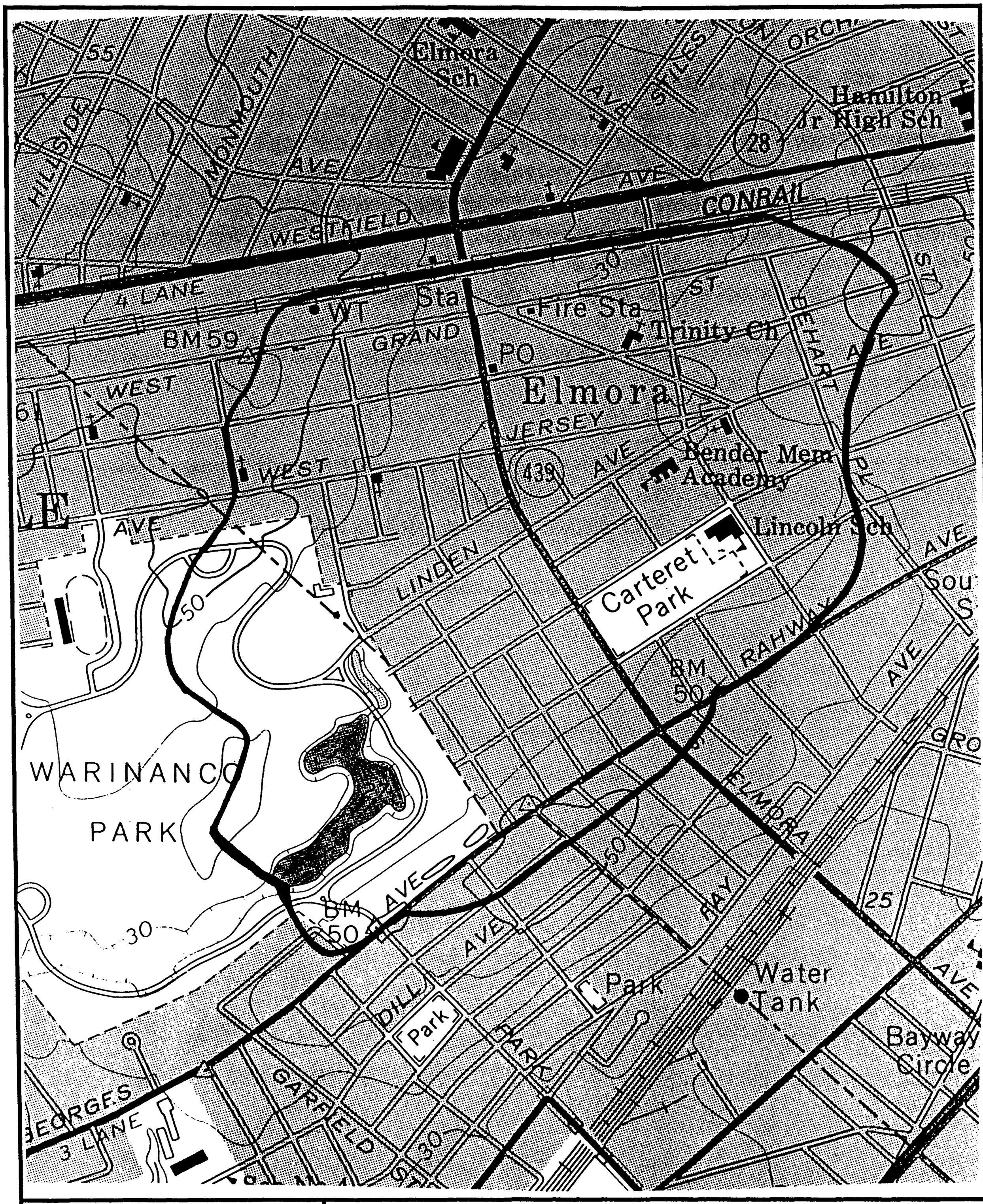


Figure 2.1	Warinanco Park Lake Watershed Elizabeth, NJ-NY USGS Quadrangle Scale: 1" = 1000'

2.2 Benefits and Recreational Uses of Warinanco Park Lake

2.2.1 Present Uses

Warinanco Lake is located in Warinanco Park, in Union County, New Jersey. The lake is a recreational focal point for the park. The park is owned and maintained by Union County and is open to the public. The lake is presently used by the public for boating, fishing, and passive recreation including picnicking and walking trails.

In addition to Warinanco Park Lake, there are other parks in the area offering a variety of recreational activities to the general public. The park is a very enjoyable place to recreate, and has a variety of offerings. Considering the population density of the area, this is an important recreational, economic and ecologic resource.

2.2.2 Public Access

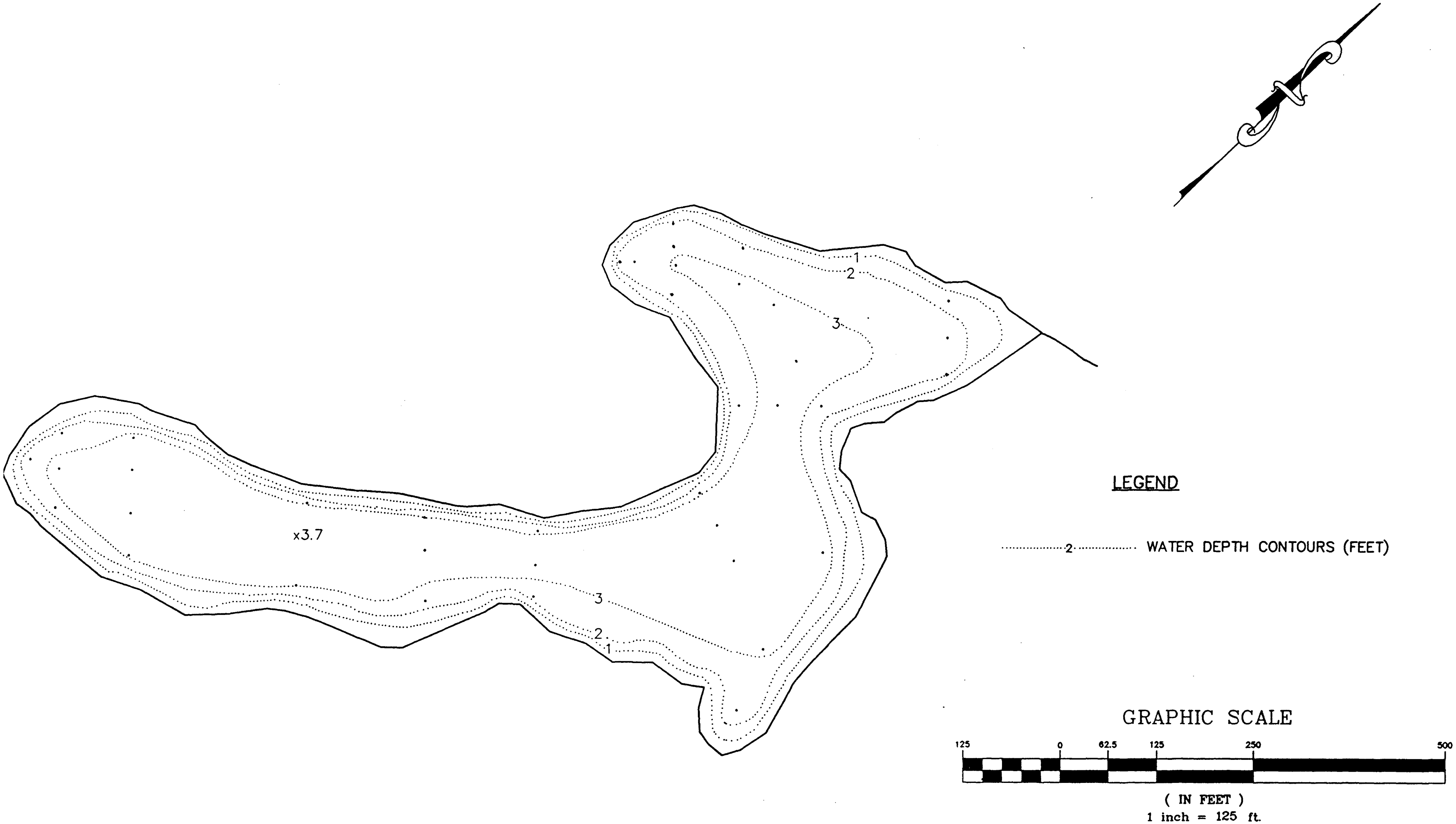
Warinanco Park is accessible via Interstate 95, New Jersey Transit, and the Garden state Parkway. Via I 95, take the 278 Interchange, to Bay Way east toward Roselle Borough. After passing the Bayway Circle, stay on Bay Way to South Elmora Avenue. Make a left on Rahway Avenue. Park Drive is 4-5 blocks on your right.

2.2.3 Impairment of Recreational Uses

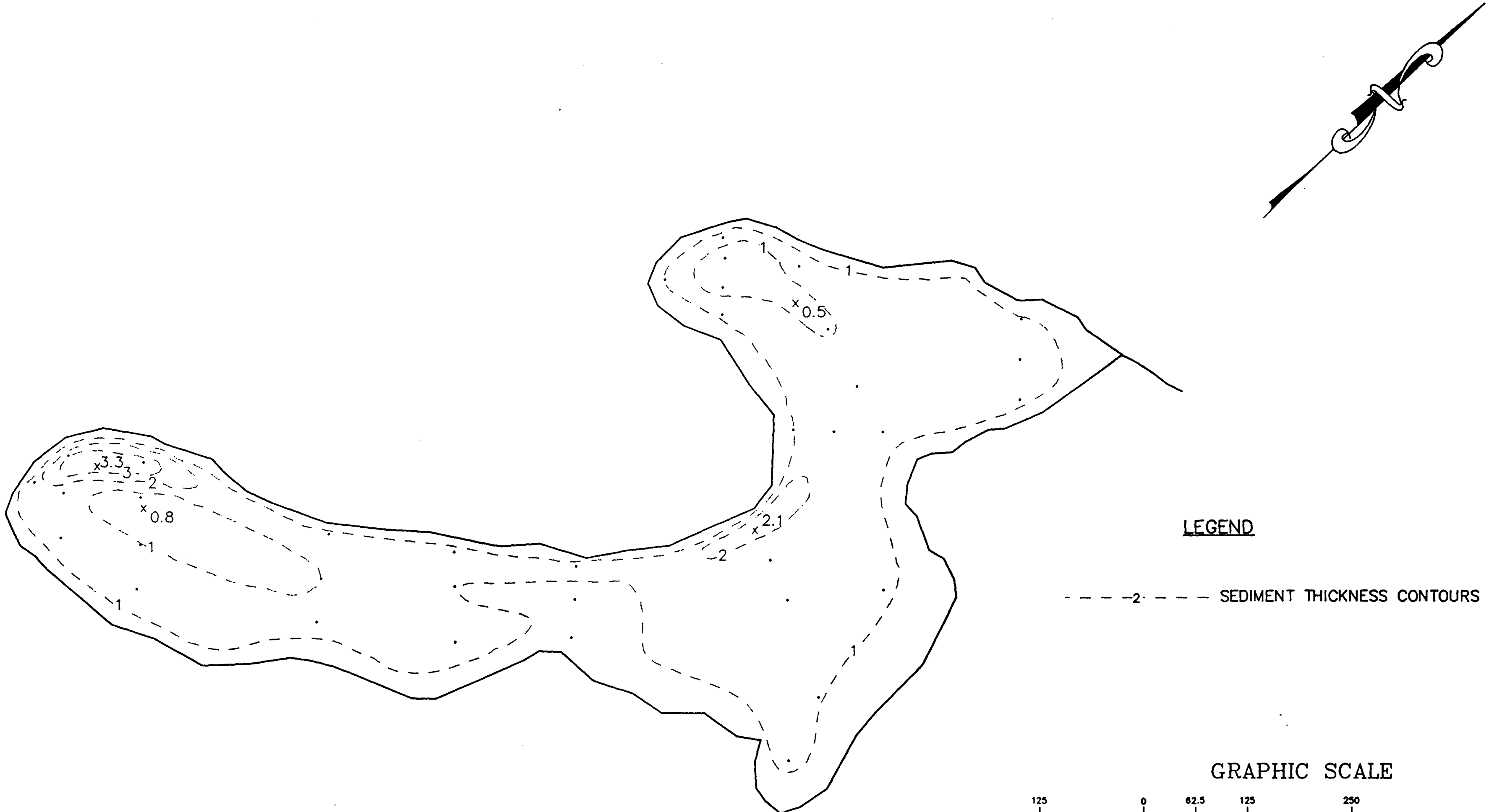
Over the years, the water quality in Warinanco Park Lake has deteriorated. The poor water quality conditions decrease the aesthetic value of the lake and the park. The lake is treated with chemicals to control algae and aquatic plants; however, a large portion of the lake was covered with mats of filamentous algae which can make boating and fishing difficult. The lake has lost some of its recreational value due to shoreline erosion, excessive algae, aquatic plants, and avian (Canada Geese, gulls) populations.

2.3 Lake Bathymetry

A bathymetric survey was conducted by F. X. Browne, Inc. in September 1996. Water and sediment depth measurements were collected along 14 transects. From these measurements, a water depth and sediment thickness map were prepared and are shown as Figures 2.2 and 2.3, respectively. The water depth map was used to determine the lake's volume, average depth, maximum depth and hydraulic retention time as presented in Table 2.1. Based on the sediment thickness mapping, Warinanco Park Lake contains 15,523 cubic yards of unconsolidated sediments. The average sediment thickness is 1.35 feet, and the maximum sediment thickness is 3.30 feet.



FXB F. X. BROWNE, INC. ENGINEERS • PLANNERS • SCIENTISTS LANSDALE, PA MARSHALLS CREEK, PA SARANAC LAKE, NY COPYRIGHT © 1997	FIGURE 2.2 BATHYMETRIC MAP OF WARINANCO PARK LAKE



LEGEND

- - - -2- - - - SEDIMENT THICKNESS CONTOURS (FEET)

GRAPHIC SCALE

125 0 62.5 125 250 500

(IN FEET)
1 inch = 125 ft.

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LANSDALE, PA MARSHALLS CREEK, PA SARANAC LAKE, NY

FIGURE 2.3
SEDIMENT THICKNESS MAP OF
WARINANCO PARK LAKE

2.4 Watershed Characteristics

The Warinanco Park Lake watershed covers 380.5 acres (not including the lake). Therefore, the ratio of the watershed area to the lake surface area is 50.7:1. This ratio indicates that watershed management via erosion control and stormwater management should effectively reduce the sediments and nutrients entering Warinanco Park Lake. Approximately 22 percent of the Warinanco Park Lake watershed lies within Warinanco Park Lake.

Union County lies entirely in the Peidmont Plains sub-province of Northern New Jersey, so Warinanco Park Lake watershed lies within it as well. Comprising about one-fifth of the total area of New Jersey, the Piedmont Plains sub-providence extends southwestward from the Hudson River, between the Coastal Providence and Highlands sub-providence, with an extension continuing further south (into Alabama and Georgia), between the Blue Ridge Mountains and the older Appalachians.

Topographically, the Piedmont Plains sub-providence includes ridges, hills, and higher elevations rising as much as 400 feet above adjoining lands. This sub-providence is primarily a lowland of smooth, rounded hills separated by wide valleys sloping gently down to the Coastal Plain with no clear topographic distinction between these two divisions.

2.4.1 Topography

The Warinanco Park Lake watershed area is shown in Figure 2.1. The lake itself is located east of the Watchung Mountains, which are generally oriented in a northeast to southwest direction. Lands in Union County east of the mountains are gently sloping plains that eventually become areas of tidal marsh land bordering the Arthur Kill and Newark Bay. Warinanco Park Lake is located on sloping plains. Portions of the park and watershed have slopes ranging from less than 2 percent to 7 percent. The slope of the land immediately surrounding the lake is in the 2 percent to 5 percent range.

2.4.2 Geology

Glacial activity has influenced the majority of the subsurface geology in Northern Jersey. Though influenced by glaciers, no significant glacial surface deposits, such as stratified drift, ground moraine, or terminal moraine, are found within the Warinanco Park Lake watershed.

Most of the Warinanco Park Lake watershed consists of shale and sandstone of the Brunswick Formation, and much of the area is a glacial "outwash plain" covered to varying depths with sand, silt, gravel, and cobbles in well-defined layers or beds deposited by water from melting glaciers.

2.4.3 Soils

The majority of the soils in Union County belong to the major Gray-Brown Podzolic soil grouping indigenous to the northeastern United States. These soils developed beneath the hardwood forest are common along the eastern coast. Soils derived from soft red shale and sandstone (Brunswick Formation) make up most of Union County. The major soil series of the watershed area is the Boonton soils series.

2.4.4 Land Use

Land uses in the Warinanco Park Lake watershed are presented in Table 2.2. Land use data were determined from topographic maps by planimetry. Field investigations were used to verify existing land uses delineated from topographic maps.

Table 2.2
Land Use in the Warinanco Park Lake Watershed

Land Use Category	Area (acres)	Percent (%)
Open Space (parkland)	86	22
High Density Residential and Commercial	294	76
Warinanco Park Lake	7.5	1.9
Other Lakes	0.5	0.1
Total (including Warinanco Park Lake)	**388**	**100**

2.5 Population and Socio-Economic Structure

Warinanco Park Lake is located within Warinanco Park, which is one of 26 parks operated by the Union County, Division of Parks and Recreation. Warinanco Park Lake, along with lands within the park, provide a variety of recreational opportunities for the residents of Union County and other nearby counties. The park is located within the New York City Metropolitan Region. In addition to Warinanco Park Lake and its watershed, many people visit several other county parks and other attractions that are located in the area.

Union County is one of twenty-one counties in the State of New Jersey. Union County comprises an area of 103.4 square miles which makes it the smallest county in the state. The county consists of 21 municipalities, 5 cities, 8 townships, 7 boroughs and 1 town.

Population data for Union County are presented in Table 2.3. The population of Union County was 504,094 and 493,819 residents in 1980 and 1990, respectively. The population reduction is attributed to the lack of available vacant land for development and a decline in birth rate. The greatest growth rate in Union County occurred in the decades following World War I and II. The projected population estimate for Union County in the year 2000 is 505,300 residents as listed in Table 2.3.

Table 2.3
Population Data for Union County, New Jersey

County	Population		
	1980	1990	2000†
Union County	504,094	493,819	505,300

Source: Union County Data Book, 1991.
† Projected population estimates.

The distribution of people by race in 1990 in Union County was 74.4 percent white, 18.8 percent black, and 6.8 percent for other minorities. People of Spanish origin comprised 13.7 percent of the county's population in 1990.

Union County ranks as one of the more affluent counties in the State of New Jersey. According to the 1980 census, the 1980 median family income was $25,266 compared to $22,907 for the state. In 1989, the per capita income in Union County was $25,328 compared to $5,526 in 1970. Based on 1990 census data, only 5.8 percent of the county reported incomes below the poverty level as compared to 7.6 percent for the state (Union County, 1991).

3.0 Monitoring Program

3.1 Primer on Lake Ecology

[*Refer to Appendix A for a comprehensive list of Lake and Watershed Management Terms*]

Lake water quality is a direct "reflection" of the water quality of the watershed area. The term "watershed" is defined as all lands that eventually drain or flow into a lake (..."all waters that are shed to a lake"). Potential sources of water to lakes are streams (tributaries), surface runoff (overland flow from lakeside properties), groundwater (interflow), and precipitation. The water quality of these water sources are greatly influenced by watershed characteristics including soils, geology, vegetation, topography, climate, and land use. Typical land uses encountered in watershed areas are wetlands, forests, agriculture, residential, commercial, and industrial. With regards to water quantity, larger watershed areas contribute larger volumes of water to lakes and vice versa.

Nutrients (nitrogen and phosphorus) and suspended solids enter a lake from upstream tributaries, direct overland flow (runoff from adjacent lands) and storm drains that collect runoff from the roadside areas adjacent to the lake. Nutrients can also enter a lake as shallow groundwater flow and direct precipitation. As surface waters enter a lake, water velocity decreases and allows for suspended solids to settle to the bottom of the lake (i.e. "sedimentation"). Very small sediment particles, such as clays, resist sedimentation and may pass through the lake without settling. Suspended solids generally contain attached phosphorus which is commonly referred to as "particulate phosphorus". Consequently, lakes provide an excellent environment for the sedimentation of suspended solids along with attached forms of phosphorus.

Within a lake, water quality is largely affected by a complex system of chemical, physical and biological interactions. Phytoplankton (suspended microscopic algae) and attached aquatic plants adsorb available nutrients and convert them into plant material. The most readily-available form of phosphorus is dissolved orthophosphate, analytically determined as dissolved reactive phosphorus (DRP). DRP can include other forms of phosphorus such as hydrolyzable particulate and organic phosphorus, but these concentrations are generally considered negligible in lakes. The inorganic forms of nitrogen, ammonia (NH_3-N) and nitrate (NO_3-N), are the forms most available to support the growth of aquatic life. Aquatic plants, or macrophytes, and algae can also affect concentrations of other chemical species in water. For example, in the photosynthetic process, carbon dioxide, a weak acid, is removed from the water and oxygen is produced. This process results in increased pH and dissolved oxygen levels.

Interactions among biological communities (the food web) greatly affect levels and cycling of nutrients, such as phosphorus, nitrogen and carbon in lakes. Energy from the sun is captured and converted to chemical energy via photosynthesis in aquatic plants, which forms the base of the food web as shown in Figure 3.1. Energy and nutrients, now tied up in organic molecules, travel through the different levels of the food web. Small aquatic animals (zooplankton and invertebrates) graze upon algae and plants. Larger invertebrates and fish then consume the grazers. Energy at upper levels of the food web is derived from the breakdown of organic molecules in the process known as respiration. Respiration and decomposition processes consume oxygen in the water column and in lake sediments.

The organic waste products of these aquatic organisms along with their remains after death are called "detritus". Detritus settles to the bottom of the lake and becomes part of the sediment. Bacteria and fungi (decomposers) use the energy in the detritus thereby converting organic materials into to inorganic nutrients which are once again available for use by plants and algae. Unused organic material accumulates in the sediments. Energy can become blocked in lower levels of the food web instead of flowing smoothly through it, because many of the algae and aquatic plants found in highly eutrophic lakes are also the ones least favored by grazers.

3.2 Study Design and Data Acquisition

In order to assess the ecological health of the study lakes, lake water quality samples were collected monthly from May through August 1996. In general, lake studies are performed over an entire year or if funding is limited, only during the growing season (May through August). The growing season is typically the critical period for most lake systems. During the summer months, lake usage by the public sharply increases and lake problems (if any) are most prevalent (algae blooms, floating mats of algae, dense plant growth, noxious odors, and fish kills).

All major streams to the study lakes were monitored during baseflow (low flow) and stormflow (high flow) conditions. Discrete baseflow stream samples were collected once per month from May through August 1996 and sample collection coincided with lake monitoring activities. Major streams were monitored during three different storm events. Periodically, stream discharge data were collected in the field during both baseflow and stormflow conditions.

Stream water quality and discharge data is used to assess the overall impacts that major streams have on the study lakes. Stream water quality and discharge data also will be used in determining nutrient and sediment budgets for the study lakes. Of the eleven study lakes, only five lakes have major tributaries. Milton Lake, Seeley's Pond, and Nomahegan Lake are fed by a single tributary, while Briant Pond and Upper Echo Lake are fed by two major streams. The remainder of the study lakes are primarily fed by surface runoff and groundwater sources.

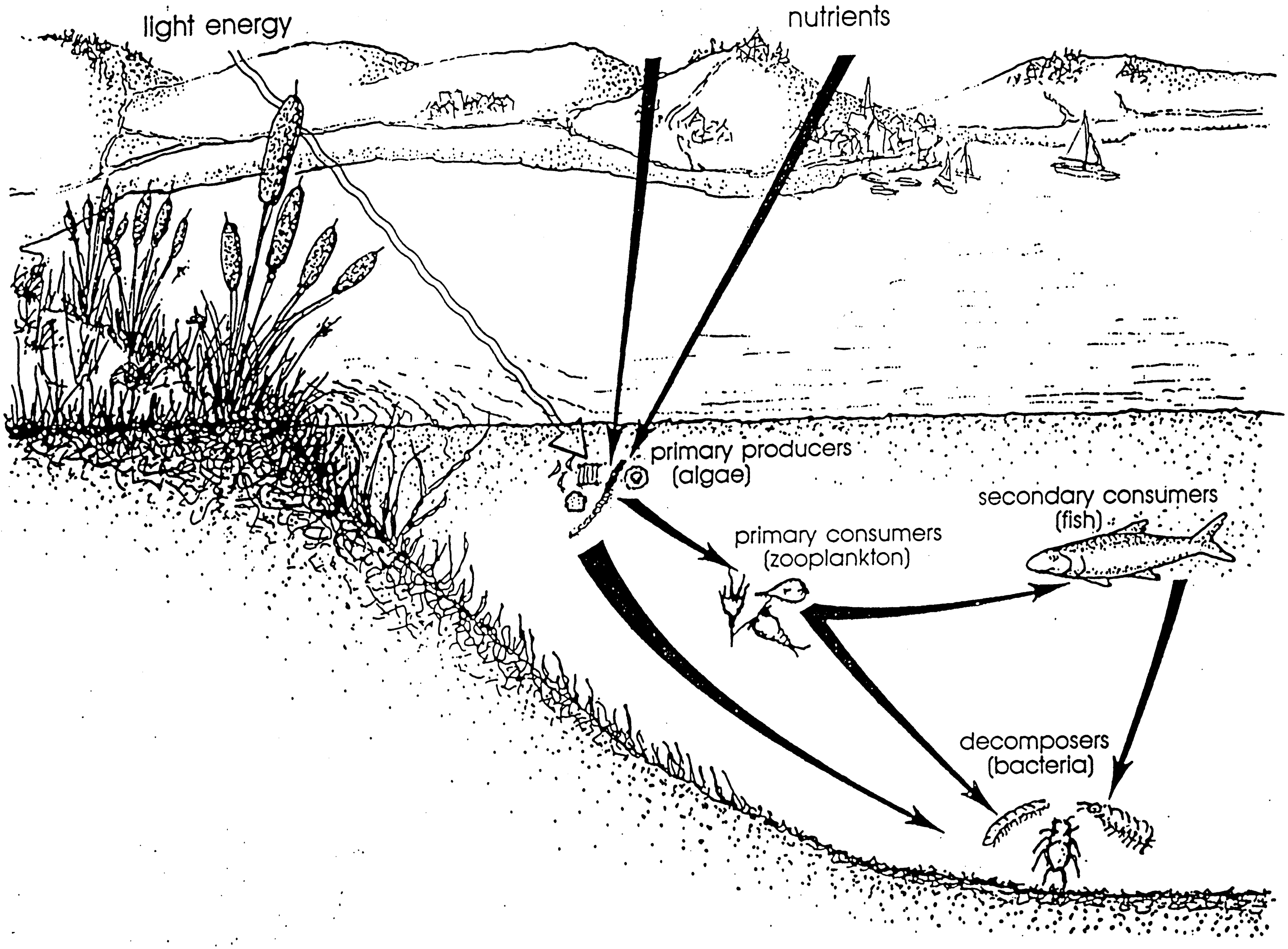


Figure 3.1 Aquatic Food Web

In addition to the lake and stream samples, F. X. Browne, Inc. collected sediment samples from the study lakes for further physical and chemical analysis. F. X. Browne, Inc. also performed bathymetric and macrophytic surveys of all eleven study lakes as discussed in Section 2.3 and 3.10 of this report.

The results of the water quality monitoring program for Warinanco Park Lake are summarized below. For more detailed information about these monitoring programs, refer to the "Union County Eleven Lakes Quality Assurance/Quality Control Work Plan" that was prepared by F. X. Browne, Inc. (1996).

Lake Water Quality Monitoring

One lake water quality monitoring station was established at the deepest portion of Warinanco Park Lake. The deepest portion of Warinanco Park Lake was located near the dam. During this study, lake water samples were collected monthly from May through August 1996 at the lake monitoring station.

On each study date, lake water samples were collected using a vertical Kemmerer sampler (Model 1290, Wildlife Supply Company) at depths of 0.5 meters below the lake's surface and 0.5 meters above the lake's bottom. Discrete lake water samples were subsequently composited together and analyzed for nutrients (total phosphorus, dissolved reactive phosphorus, total Kjeldahl nitrogen, nitrate plus nitrite nitrogen, and ammonia nitrogen), and total suspended solids. The pH of the composited sample was measured in the field using a portable pH meter (Model pHep3, Hanna Instruments).

On each study date, temperature and dissolved oxygen profiles were measured every 0.5 meters using a dissolved oxygen and temperature meter. The Secchi disk transparency was also measured using an 8-inch diameter black and white Secchi disk.

Additional lake samples were collected monthly for chlorophyll a analysis and both phytoplankton and zooplankton identification and enumeration (to genus). At a minimum, two discrete lake water samples were collected from the photic zone using a vertical Kemmerer water sampler. The photic zone was defined in this study as a water depth equal to two times the Secchi disk depth. Photic zone discrete samples were then composited together and analyzed for chlorophyll a and used for phytoplankton identification and enumeration. Zooplankton samples were collected by vertically towing a plankton net (80 μm mesh size with a 8-inch orifice) at least five times through the water column. Both phytoplankton and zooplankton identification and enumeration were performed in the laboratory using a Sedgewick-Rafter counting chamber and a microscope equipped with a Whipple Grid. All phytoplanton and zooplankton cell densities (number per volume) were expressed as biomass based on mean cell size.

Sediments

In Warinanco Park Lake, three discrete sediment core samples were collected using a Ogeechee lake sediment sampler (Model 2427, Wildlife Supply Company) equipped with 20 inch corer tubes. Discrete sediment samples were collected along the center line of the lake near the middle and at both ends. Discrete sediment samples were subsequently composited together in the field and submitted to the laboratory for analysis.

The composited lake sediment sample was analyzed for particle size distribution, solids, total phosphorus, total nitrogen, polychlorinated biphenyls (PCBs), pesticides, heavy metals, organic compounds, chlorides, pH, and reactivity for sulfur and cyanide (total concentrations only).

Bathymetric and Macrophyte Surveys

A bathymetric survey and macrophyte (aquatic plant) survey of Warinanco Park Lake were conducted in September 1996. The bathymetric survey included taking measurements of water depth and sediment depth along pre-determined transects in the lake. As part of the macrophyte survey, plants were collected, identified, and delineated in order to show the distribution of aquatic plants within the lake.

Based on the above information, a bathymetric map, an unconsolidated sediment depth map, and a macrophyte map were prepared by F. X. Browne, Inc.

3.3 Lake Water Quality

Lake water samples were collected from Warinanco Park Lake during the months of May through August 1996. Lake water quality samples were analyzed for a variety of chemical, physical and biological parameters. The results of these analyses are discussed in detail in the following sections of this report and water quality data is presented in Appendix B of this report.

3.3.1 Temperature and Dissolved Oxygen

In late spring or the beginning of summer, deep temperate lakes develop stratified layers of water, where warmer and colder waters are near the lake's surface (epilimnion) and the lake's bottom (hypolimnion), respectively. As the temperature difference becomes greater between these two water layers, the resistance to mixing increases. Under these circumstances, the epilimnion (top water) is usually oxygen-rich due to photosynthesis and direct inputs from the atmosphere, while the hypolimnion (bottom water) may become depleted of oxygen due to oxygen being consumed by organisms decomposing organic matter at the lake bottom.

Conversely, shallow temperate lakes may never develop stratified layers of water. For these shallow lake systems, wave action caused by the wind may be sufficient to keep the entire lake completely mixed for most of the year. In shallow lakes, low dissolved oxygen levels may occur above the lake sediments even though most of the water in the lake is completely mixed.

Therefore, both shallow and deep temperate lakes can have low dissolved oxygen concentrations near the surface of the lake sediments. If low dissolved oxygen levels occur near the lake bottom, sediments may release significant amounts of nutrients (primarily orthophosphorus and ammonium) back into the lake, thereby allowing for more nutrients for algae and aquatic plant growth.

The dissolved oxygen and temperature profiles in Warinanco Park Lake in August 1996 are listed in Table 3.1. The maximum depth at the monitoring station was 1.0 meters (m) or 3.3 feet. The lake was completely mixed, and the water temperature throughout the water column was 25.0 degrees Celsius (° C) at the surface and at the bottom of the lake. Dissolved oxygen concentrations ranged from 7.0 milligrams per liter (mg/L) at a depth of 1 meter to 8.0 mg/L near the surface of the lake. Dissolved oxygen and temperature profiles for the May, June and July sampling events were similar to profiles measured in August. During all sampling events, the dissolved oxygen concentration remained well above zero in the bottom waters.

Table 3.1
Dissolved Oxygen and Temperature Profile Data
Warinanco Park Lake - August 1996

Depth (meters)	Temperature (Celsius)	Dissolved Oxygen (mg/L)
0.0	25.0	7.0
0.5	25.0	8.0
1.0	25.0	8.0

In general, the optimal water temperature for trout is 55 to 60 °F (12.8 to 15.6 °C). Trout may withstand water temperatures above 80 °F (26.7 °C) for several hours, but if water temperatures exceed 75 °F (23.9 °C) for extended periods, trout mortality is expected (Pennsylvania State University). A safe minimum dissolved oxygen concentration for trout is 5 mg/L. Warmwater species (i.e. golden shiners, bass, bluegill) grow well when water temperatures exceed 80 °F (26.7 °C). For many warm water fish species, a safe minimum dissolved concentration is considered 3 mg/L.

During the study period, Warinanco Park Lake was not thermally stratified and is considered a completely mixed lake system during the summer months.

3.3.2 pH and Alkalinity

In lake ecosystems, changes in pH and alkalinity occur when phytoplankton use carbon dioxide during photosynthesis. Dissolved carbon dioxide reacts with water to form carbonic acid (H_2CO_3). When phytoplankton take up the carbon dioxide dissolved in the lake water during photosynthesis, it results in a decrease in the carbonic acid concentration and a consequent increase in pH. For this reason, the pH of surface waters are higher during an algal bloom than the pH of deeper waters where phytoplankton (suspended microscopic plants) numbers are much lower.

Alkalinity refers to the ability of water to neutralize acids. Acidic water contains a relatively high concentration of hydrogen ions, and the higher the concentration of hydrogen ions, the lower the pH. Several anionic salts such as bicarbonates, carbonates, phosphates, silicates, and borates, can bind with hydrogen ions, thereby reducing the acidity of water. When these salts bind with the hydrogen ions, the pH increases and the water is said to be "buffered". Alkalinity, or this ability of salts in the water to bind with hydrogen ions and increase the pH of water, is also referred to as the acid buffering capacity of water.

The forms of alkalinity most commonly found in lakes are those salts which comprise the carbonate system. Bicarbonate (HCO_3^-) is the most common of the carbonate salts at pH values ranging from 6 to 9. At higher pH values, carbonate ($CO_3^=$) plays a more important role in the buffering capacity of the water. Bicarbonate and carbonate salts enter a lake through the natural dissolution of carbon dioxide in water, the reaction of carbon dioxide and water to form carbonic acid, and the subsequent loss of hydrogen ions from the carbonic acid molecule to form bicarbonate and carbonate. Carbonate salts also enter a lake as a result of the weathering of rocks containing limestone (calcium carbonate), when water flowing over the limestone-rich rocks in the watershed carries dissolved carbonate into the lake.

The mean pH concentration in Warinanco Park Lake was 8.0 standard unit (su) and pH concentrations ranged from 7.5 to 8.6 standard units. The water in Warinanco Park Lake is considered basic (0.5 to 1.6 standard units above neutral conditions). Under most circumstances, pH concentrations for lakes in the United States generally range between 6.0 and 9.0 standard units.

3.3.3 Total Suspended Solids

The concentration of total suspended solids in a lake is a measure of the amount of particulate matter in the water column. Suspended solids are comprised of both organic matter (i.e. algae) and inorganic materials (i.e. soils and clay particles).

The mean total suspended solids concentration in Warinanco Park Lake was 22.3 mg/L and concentrations ranged from 17.0 to 31.7 mg/L. The mean total suspended solids concentration in the lake is considered high for most lake and reservoir systems.

3.3.4 Transparency

The transparency, or clarity, of water is most often reported in lakes as the Secchi disk depth. This measurement is taken by lowering a circular white or black-and-white disk, 20 cm (8 inches) in diameter, into the water until it is no longer visible. Observed Secchi disk depths range from a few centimeters in very turbid lakes to over 40 meters in the clearest known lakes (Wetzel, 1975). Although somewhat simplistic and subjective, this testing method probably best represents the conditions which are most readily visible to the common lake user.

Secchi disk transparency is related to the transmission of light in water and depends on both the absorption and scattering of light. The absorption of light in dark-colored waters reduces light transmission. Light scattering is usually a more important factor than absorption in determining Secchi depths. Scattering can be caused by color, by particulate organic matter, including algal cells, and by inorganic materials such as suspended clay particles in water.

In Warinanco Park Lake, the mean Secchi disk measurement was 0.34 meters (1.1 feet). Secchi disk readings in the lake ranged from 0.3 to 0.4 meters (1.0 to 1.3 feet). Based on criteria established by the United States Environmental Protection Agency (U.S. EPA 1980), Secchi disk readings that are less than 1.5 meters indicate eutrophic (highly productive) lake conditions. Warinanco Park Lake is highly eutrophic (hyper-eutrophic) based on the EPA criterion for Secchi Disk depth.

3.3.5 Phosphorus Concentrations

Phosphorus and nitrogen compounds are major nutrients required for the growth of algae and macrophytes in lakes. The dissolved inorganic nutrients, dissolved reactive phosphorus, nitrate nitrogen, and ammonia nitrogen are regarded as the forms most readily available to support aquatic growth, while the total nutrient amounts provide an indication of the maximum growth which could be achieved in the lake. In most lake system, phosphorus is the limiting nutrient and therefore is the nutrient which controls the amount of aquatic plant growth (vascular plants and algae).

Total phosphorus represents the sum of all phosphorus forms, and includes dissolved and particulate organic phosphates from algae and other organisms, inorganic particulate phosphorus from soil particles and other solids, polyphosphates from detergents, and dissolved orthophosphates. Soluble orthophosphate is the phosphorus form that is most readily available for algal uptake and is usually reported as dissolved reactive phosphorus, because the analysis takes place under acid conditions which can result in some hydrolysis of other phosphorus forms. Total phosphorus levels are strongly affected by the daily phosphorus loads that enter the lake. Soluble orthophosphate levels, however, are affected by algal consumption during the growing season.

The mean dissolved reactive phosphorus and mean total phosphorus concentrations in Warinanco Park Lake were 0.106 and 0.403 mg/L as phosphorus (P), respectively, as shown in Table 3.2. During the months of May through August 1996, dissolved reactive phosphorus concentrations ranged from 0.027 to 0.117 mg/L as P, while total phosphorus concentrations ranged from 0. 185 to 0.520 mg/L as P.

Table 3.2
Mean Phosphorus Concentrations in Warinanco Park Lake

Total Phosphorus (mg/L as P)	Dissolved Reactive Phosphorus (mg/L as P)
0.403 [0.185 - 0.520]	0.106 [0.027 - 0.177]

Note: Range of concentrations present inside of brackets [ ].

The mean dissolved reactive phosphorus in Warinanco Park Lake is considered the phosphorus that is readily available for algae and macrophytes to use. In many lake systems during the summer months, dissolved reactive phosphorus concentrations are very low (less than 0.001 mg/L) since it is readily used by plants and algae as soon as it becomes available. The mean total phosphorus concentration in the lake was 0.403 mg/L and is typical of eutrophic lake conditions. Based on criteria set forth by the U.S. EPA, a lake system is classified as eutrophic when total phosphorus concentrations exceed 0.03 mg/L as P.

3.3.6 Nitrogen

Nitrogen compounds are also important for algae and aquatic macrophyte growth. The common inorganic forms of nitrogen in water are nitrate (NO_3^-), nitrite (NO_2^-), and ammonia (NH_3). The form of inorganic nitrogen present depends largely on dissolved oxygen concentrations. Nitrate is the form usually found in surface waters, while ammonia is only stable under anaerobic (low oxygen) conditions. Nitrite is an intermediate form of nitrogen which is unstable in surface waters. Nitrate and nitrite (total oxidized nitrogen) are often analyzed together and reported as NO_3+NO_2-N, although nitrite concentrations are usually insignificant. Total Kjeldahl nitrogen (TKN) concentrations include ammonia and organic nitrogen (both soluble and particulate forms). Organic nitrogen is easily determined by subtracting ammonia nitrogen from total Kjeldahl nitrogen. Total nitrogen is easily calculated by summing the nitrate-nitrite, ammonia, and organic nitrogen fractions together.

The mean total Kjeldahl nitrogen concentration, nitrate plus nitrite nitrogen concentration, and ammonia nitrogen concentration, along with ranges of concentrations in Warinanco Park Lake, are presented in Table 3.3.

Table 3.3
Mean Nitrogen Concentrations in Warinanco Park Lake

Total Kjeldahl Nitrogen (mg/L as N)	Nitrate/Nitrite (mg/L as N)	Ammonia (mg/L as N)
2.07 [0.848 - 3.30]	0.09 [0.01 - 0.31]	0.10 [0.10 - 0.10]

Note: Range of concentrations present inside of brackets [ ].

The total nitrogen concentration in the lake is considered to be the sum of the Total Kjeldahl nitrogen and the nitrate+nitrite nitrogen (2.16 mg/L). Of this total nitrogen concentration, most of nitrogen occurs in the organic form. Nitrate plus nitrite and ammonia concentrations (inorganic nitrogen compounds) in the lake are 0.19 mg/L, which indicate high uptake rates by aquatic plants and algae for growth and reproduction.

3.3.7 Limiting Nutrient

Algal growth depends on a variety of nutrients including macronutrients such as phosphorus, nitrogen, carbon, and trace nutrients such as iron, manganese, and other minerals. According to Liebig's law of the minimum, biological growth is limited by the substance that is present in the minimum quantity with respect to the needs of the organism. Nitrogen and phosphorus are usually the nutrients limiting algal growth in most natural waters.

Depending on the species, algae require approximately 15 to 26 atoms of nitrogen for every atom of phosphorus. This ratio converts to 7 to 12 mg of nitrogen per 1 mg of phosphorus on a mass basis. A ratio of total nitrogen to total phosphorus of 15:1 is generally regarded as the dividing point between nitrogen and phosphorus limitation (U.S. EPA, 1980). Identification of the limiting nutrient becomes more certain as the total nitrogen to total phosphorus ratio moves farther away from the dividing point, with ratios of 10:1 or less providing a strong indication of nitrogen limitation and ratios of 20:1 or more strongly indicating phosphorus limitation.

Inorganic nutrient concentrations may provide a better indication of the limiting nutrient because the inorganic nutrients are the forms directly available for algal growth. Ratios of total inorganic nitrogen (TIN = ammonia, nitrate, and nitrite) to dissolved reactive phosphorus (DRP) greater than 12 are indicative of phosphorus limitation, ratios of TIN:DRP less than 8 are indicative of nitrogen limitation, and TIN:DRP ratios between 8 and 12 indicate either nutrient can be limiting (Weiss, 1976).

The total nitrogen to total phosphorus ratio (TN:TP) and the total inorganic nitrogen to dissolved reactive phosphorus ratio (TIN:DRP) in Warinanco Park Lake were 5.2:1 and 2.4:1, respectively. Based on these nutrient ratios, the limiting nutrient in the lake is nitrogen.

3.3.8 Chlorophyll a

Chlorophyll a is a pigment which gives plants their green color. Its function is to convert sunlight to chemical energy in the process known as photosynthesis. Because chlorophyll a constitutes about 1 to 2 percent of the dry weight of planktonic algae, the amount of chlorophyll a in a water sample is an indicator of phytoplankton biomass.

The mean chlorophyll a concentration in Warinanco Park Lake was 95.9 micrograms per liter (μg/L) and concentrations ranged from 50.1 to 150.3 μg/L. Based on USEPA criteria, a lake is classified as eutrophic when chlorophyll a concentrations exceed 6.0 to 10.0 μg/L. Therefore, Warinanco Park Lake is highly eutrophic based on chlorophyll a concentrations.

3.3.9 Phytoplankton

Phytoplankton are microscopic algae that have little or no resistance to currents and live free floating and suspended in open water. Their forms may be unicellular, colonial, or filamentous. As photosynthetic organisms (primary producers), phytoplankton form the foundation of aquatic food web and are grazed upon by zooplankton (microscopic animals) and herbivorous fish (plant-eating fish).

A healthy lake should support a diverse assemblage of phytoplankton represented by a variety of algal species. Excessive phytoplanktonic growth, which typically consists of a few dominant species, is undesirable. Excessive growth can result in severe oxygen depletion in the water at night, when the algae are respiring (using up oxygen) and not photosynthesizing (producing oxygen). Oxygen depletion can also occur after an algal bloom when bacteria, using dead algal cells as a food source, grow, and multiply. Excessive growths of some species of algae, particularly members of the blue-green group, may cause taste and odor problems, release toxic substances to the water, or give the water an unattractive green soupy or scummy appearance.

Planktonic productivity is commonly expressed by enumeration and biomass. Enumeration of phytoplankton is expressed as cells per milliliter (cells/mL). Biomass is expressed on a mass per volume basis as micrograms per liter (mg/L). Of the two, biomass provides a better estimate of the actual standing crop of phytoplankton in lakes.

During the months of May through August 1996, six taxa (groups) of phytoplankton were identified in Warinanco Park Lake including Bacillariophyta (diatoms), Chlorophyta (green algae), Cryptophyta (cryptomonads), Cyanophyta (blue-green algae), Euglenophyta (euglenids) and Pyrrhophyta (dinoflagellates). The mean phytoplanktonic total biomass was 16,306 micrograms per liter (ug/L) and ranged from 6,741 to 19,927 ug/L. The lowest and highest total biomass levels were observed in the months of June and August, respectively. Another indication of eutrophication is the dominance of blue-green algae (Cyanophyta) lakes; however, since algicides were applied to Warinanco Park Lake, blue-green algae populations in the lake were sporadic.

3.3.10 Zooplankton

Zooplankton are microscopic animals whose movements in a lake are primarily dependent upon water currents. Zooplankton remain suspended in open water. Major groups of zooplankton include protozoa, rotifers and crustaceans. Crustaceans are further divided into copepods and cladocerans (i.e. water fleas). Zooplanktons are generally smaller than 2 millimeters (one-tenth of an inch) in size and primarily feed on algae, other zooplankton, and plant and animal particles. Zooplankton grazing can have a significant impact on phytoplankton species composition and productivity (i.e. biomass) through selective grazing (e.g. size of zooplankton influences what size phytoplankton are consumed) and nutrient recycling. Zooplankton, in turn, are consumed by fish, waterfowl, aquatic insects, and others, thereby playing a vital role in the transfer of energy from phytoplankton to higher trophic levels.

In Warinanco Park Lake, the mean zooplankton biomass was 762 μg/L and ranged from 437 to 1035 μg/L. The lowest and highest zooplankton biomass levels were observed in August and June, respectively. In general, the zooplankton biomass order of dominance in Warinanco Park Lake was cladocera followed by copedoda, rotifera, and protozoa.

Zooplankton data is often used in conjunction with fishery surveys to assess a lake's fishery. In particular, the mean length of crustacean zooplankters collected during the spring and mid-summer is compared to one another and the results can be used to assess a lake's fishery (Mills and Green, 1987). In Warinanco Park Lake, the mean length of crustacean zooplankton ranged from 0.32 millimeters (mm) in May and June to 0.40 mm in August.

These mean zooplankton lengths in early-spring and summer are quite small and are typical of lakes with low predator to prey ratios. Under such circumstances, a lake's fishery can consist of many undersized planktivorous fish (i.e. blue gill, white perch, yellow perch, pumpkinseed). With too many undersized planktivorous fish and too few piscivorous fish (i.e. bass, pickerel) to control them, overgrazing of large-bodied zooplankters is inevitable. If the zooplankton population is low, the algae population is high because there are not enough zooplankton to eat and control the algae population.

Based on the zooplankton data, Warinanco Park Lake most likely contains an unbalanced fishery. An unbalance fishery may be caused by the over harvesting of larger gamefish by anglers or indirectly related to poor lake water quality. Poor lake water quality may severely impair reproductive success rates, growth rates, and survival rates of some gamefish.

3.3.11 Trophic State Index

Eutrophication is a natural process where sediments and nutrients from the watershed accumulate in the lake. The eutrophication process is often accelerated by the activities of man. Contrary to the popular opinion that a eutrophic lake is "dead," it is actually suffering from an over-abundance of living organisms. The organisms in a eutrophic lake are abundant in number, but usually represent relatively few species. In contrast, an oligotrophic lake is one containing relatively small numbers of organisms representing many species. Mesotrophic lakes have intermediate conditions between eutrophic and oligotrophic lakes.

The Trophic State Index (TSI) developed by Carlson (1977) is among the most commonly used indicators of lake trophic state. This index is actually composed of three separate indices based on measurements of total phosphorus concentrations, chlorophyll a concentrations, and Secchi disk depths for a variety of lakes. Total phosphorus was chosen for the index because phosphorus is often the limiting nutrient for algal growth in lakes. Chlorophyll a is a plant pigment present in all algae and is used to provide an indication of the biomass of algae in a lake. Secchi disk depth, as discussed previously, is a common measure of the transparency of the water in a lake.

Most commonly, summer average values for total phosphorus, chlorophyll a, and Secchi depth are logarithmically converted to a scale of relative trophic state ranging from 1 to

100. Increasing values for the Trophic State Index are indicative of increasing trophic state in a lake. In general, index values less than 40 are indicative of oligotrophic conditions, while index values greater than 50 are indicative of eutrophic lake conditions.

The mean Carlson Trophic State Index (TSI) values for total phosphorus, chlorophyll-a, and Secchi disk transparency for Warinanco Park Lake were 91, 76, and 75, respectively. The above TSI values were based on the mean total phosphorus, chlorophyll-a, and transparency values recorded in Warinanco Park Lake. Based on the mean TSI values for total phosphorus, chlorophyll a, and transparency, Warinanco Park Lake is classified as a highly productive or hyper-eutrophic lake.

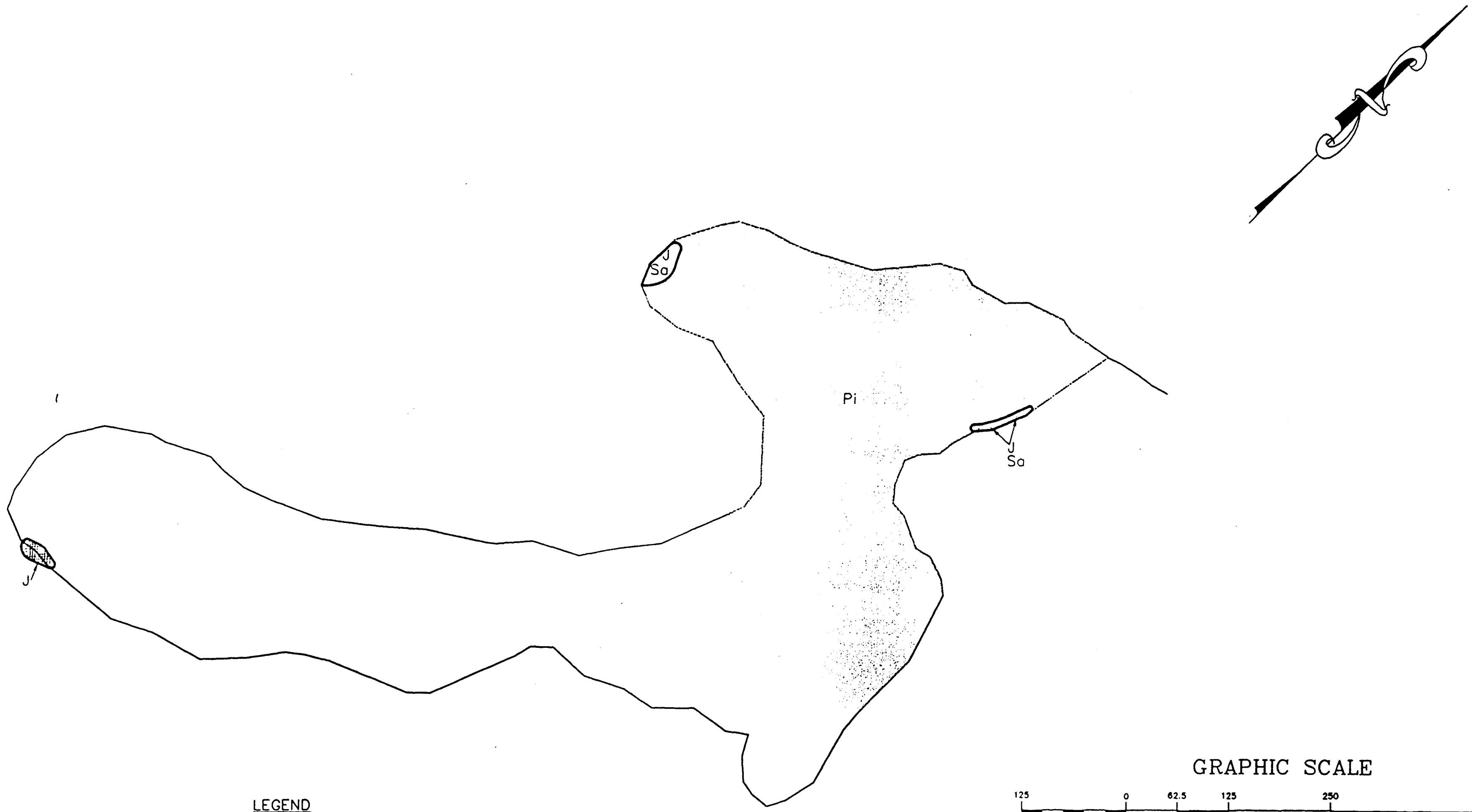
3.4 Macrophytes

Aquatic vegetation ranges from tiny microscopic algae or phytoplankton to large vascular aquatic plants which are called macrophytes. Macrophytes can be either rooted to the lake bottom or float on the lake's surface. Based on growth and habitat characteristics, macrophytes generally can be classified in one of three categories: submerged aquatic vegetation, floating aquatic vegetation, and emergent aquatic vegetation. Submerged aquatic plants live and grow completely underwater or just up to the surface of the water. A few species, when in flower, protrude just above the water surface. Floating aquatic plants refers to those plants where their leaves float above the water. These plants may or may not be anchored to the bottom of the lake via stems or roots. Emergent aquatic plants have their upper stems and leaves protruding above and out of the water. These plants are always attached directly to the lake bottom via roots.

A macrophyte (aquatic plant) survey of Warinanco Park Lake was conducted in September 1996. Plants were collected, identified to genus, and mapped in order to show the aquatic plant distribution within the lake. The distribution of macrophytes in Warinanco Park Lake is illustrated in Figure 3.3. During the macrophyte survey, large amounts of filamentous algae was observed in the lake. The areal coverage of the filamentous algae is also shown on the macrophyte map.

The aquatic plant community in Warinanco Park Lake primarily consisted of rush (*Juncas sp.)*, Spike-rush (*Eleocharis sp.)*, and Chearmakers bulrush (*Scirpus americanus)*. The lake is chemically treated to control algae, duckweed, curly leaf pondweed, and fine leaf pondweed.

In general, the density of macrophytes in Warinanco Park Lake is considered light, most likely due to the fact that the lake is chemically treated for macrophytes.



GRAPHIC SCALE

125 0 62.5 125 250 500

(IN FEET)
1 inch = 125 ft.

LEGEND

J RUSH (*Juncus sp.*)
SPIKE-RUSH (*Eleocharis sp.*)
Pi FILAMENTOUS ALGAE (*Pithophora Sp.*)
Sa CHIRMAKER'S BULRUSH (*Scirpus americanus*)

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LANSDALE, PA MARSHALLS CREEK, PA SARANAC LAKE, NY

FIGURE 3.3
MACROPHYTE DISTRIBUTION MAP OF WARINANCO PARK LAKE

3.5 Water Quality Data Comparisons

Lake water quality comparisons for the eleven study lakes were based on a trophic state ranking system as shown in Table 3.4. This ranking system was designed to assign point values to the Carlson's Trophic State Index (TSI) values for total phosphorus, chlorophyll a, and Secchi disk lake transparency for each study lake. Next, the point values for the three parameters were added together for each lake and these total point values provided the basis for lake water quality data comparisons as described below.

For all three parameters (total phosphorus, chlorophyll-a, and Secchi disk transparency), lake TSI values received scores ranging from 1 to 11 points. For example, the lake with the highest TSI value for phosphorus (worst water quality) received 1 point, while the lake with the lowest TSI value for phosphorus (best water quality) received 11 points as shown in Table 3.4. This scoring procedure was also performed for both chlorophyll-a and Secchi disk transparency TSI values. Next, for each study lake, the "Individual TSI Ranked Scores" for all three parameters were summed, thereby resulting in a "Total TSI Ranked Score". Based on this scoring procedure, the "Total TSI Ranked Scores" could theoretically range from 3 to 33 points. Using the "Total TSI Scores", the eleven study lakes were subsequently ranked relative to one another (Relative Ranking) from lowest (worst water quality) to highest (best water quality) as shown in Table 3.4.

In Table 3.4, the Total TSI Ranked Scores for the eleven study lakes ranged from 7 to 33 points. Of these County lakes, Warinanco Park Lake and Seeley's Pond recorded the worst and best lake water quality, respectively. It should be noted that the majority of the study lakes were treated with algicides throughout the study period, therefore the TSI values for Secchi disk transparency and chlorophyll-a data and subsequently their Total TSI Ranked Scores are likely "artificially" lower than expected. Of the study lakes, only Briant Park Pond and Seeley's Pond were not chemically treated with algicides during the study period.

Based on the data presented in Table 3.4, Warinanco Park Lake was ranked with the worst water quality of all eleven lakes. As stated above, Warinanco Park Lake was treated with algicides during the study period, therefore the TSI values for phosphorus, Secchi disk, and chlorophyll a may be even higher than presented in Table 3.4.

Table 3.4
Lake Water Quality Data Comparisons Using Carlson's Trophic State Index Values

Lake Name	TSI Values			Algicides Used	Total TSI Ranked Score	Relative Ranking
	Total P	Secchi Disk	Chlorophyll-a			
Warinanco Park Lake (WPL)	91 [2]	76 [2]	75 [3]	Yes	7	1
Cedar Brook Park Lake (CBPL)	80 [7]	76 [1]	77 [2]	Yes	10	2
Briant Park Pond (BPP)	82 [6]	73 [4]	81 [1]	No	11	3
Green Brook Park Lake (GBPL)	97 [1]	74 [3]	66 [9]	Yes	13	4
Nomahegan Park Lake (NPL)	87 [4]	71 [6]	74 [6]	Yes	16	5
Lower Echo Lake (LEL)	90 [3]	61 [10]	75 [4]	Yes	17	6
Meisel Pond (MP)	83 [5]	73 [5]	71 [8]	Yes	18	7
Rahway River Parkway Lake (RRPL)	76 [10]	69 [7]	74 [5]	Yes	22	8
Upper Echo Lake (UEL)	77 [9]	66 [8]	73 [7]	Yes	24	9
Milton Lake (ML)	79 [8]	62 [9]	63 [10]	Yes	27	10
Seeley's Pond (SP)	61 [11]	59 [11]	49 [11]	No	33	11

Note: Values in brackets [ ] are the "Individual TSI Ranked Scores" for total phosphorus, Secchi disk transparency, and chlorophyll-a for each lake.

3.6 Lake Water Quality Summary

Based upon the results of the lake monitoring program, Warinanco Park Lake is classified as a completely mixed eutrophic lake system. The mean total phosphorus and mean chlorophyll a concentrations in the lake were 0.403 mg/L as phosphorus and 95.9 μg/L, respectively. Based on the U.S. EPA trophic state criteria, lakes are classified as eutrophic when total phosphorus and chlorophyll a concentrations exceed 0.030 mg/L as P and 10.0 µg/L, respectively. The mean Secchi disk lake transparency value was 0.34 meters. Based on the U.S. EPA trophic state criteria, lakes are defined as eutrophic when Secchi disk depths are less than 1.5 meters. The Carlson's Trophic State Index values for the mean total phosphorus concentration, the mean chlorophyll a concentration, and the Secchi disk transparency value were 91, 76, and 75, respectively. Trophic state values exceeding 50 are generally an indication of eutrophic lake conditions.

The limiting nutrient in the lake is nitrogen. The total nitrogen to total phosphorus ratio (TN:TP) and the total inorganic nitrogen to dissolved reactive phosphorus ratio (TIN:DRP) were 5.2:1 and 2.4:1, respectively. In general, TN:TP and TIN:DRP ratios exceeding 20:1 and 12:1, respectively, are a strong indication that phosphorus is the limiting nutrient with regards to plant growth in the lake.

3.7 Lake Sediment Analyses

As part of a lake study, lake sediments are often collected and analyzed for nutrients, texture, and accumulated pollutants, such as pesticides, herbicides, and metals. Sediment test results are often used in order to assess the potential impacts of any accumulated pollutants on the aquatic community, the internal release of nutrients by in-lake sediments, and how to properly dispose of lake sediments during a lake dredging project.

In September 1996, one composited lake sediment sample was collected and analyzed for particle size distribution, solids (total, volatile and percent composition), nutrients (total phosphorus, total nitrogen), heavy metals, pesticides, polychlorinated biphenyl compounds, pesticides, herbicides, volatile organic compounds, and semi-volatile compounds. With the exception of particle size and solids data, the above data were analyzed as total (bulk) concentrations and are presented on a dry weight basis.

The physical characteristics of the sediments in Warinanco Park Lake are presented in Table 3.5. Based on weight, the sediments in Warinanco Park Lake contain 59 percent water and 41 percent solids. Of these solids, the lake sediments are primarily composed of inorganic materials. Based on particle size, most of the solids are classified as silt as shown in Table 3.5.

Table 3.5 Physical Characteristics of Sediments in Warinanco Park Lake	
Parameters	**Results**
Composition:	
Percent Solids	41
Particle Size Distribution:	
Percent Gravel	12
Percent Sand	20
Percent Silt	44
Percent Clay	24
Total	100

With regard to sediment disposal and sediment reuse, the sediment analyses should meet the Soil Cleanup Criteria proposed by the New Jersey Department of Environmental Protection (NJDEP). Sediment reuse, such as fill material, is obviously the least expensive manner in which to dispose of dredged lake sediments. Under the Soil Cleanup Criteria, one set of criteria applies to the disposal of sediments at residential type lands, while the second set of criteria applies to the disposal of sediments at non-residential type lands. Of the two sets of criteria, the residential criteria are more stringent.

Both sets of criteria, which are proposed by NJDEP, list a variety of pollutants along with their corresponding proposed state regulatory levels. These pollutants are classified as heavy metals, polychlorinated biphenyl compounds (PCBs), pesticides, herbicides, volatile organic compounds (VOCs), and semi-volatile organic compounds (SOVs). The proposed regulatory levels are based on total concentrations and are expressed on a dry weight basis.

The total concentrations of heavy metals, polychlorinated biphenyl compounds (PCBs), pesticides, herbicides, volatile organic compounds (VOCs), and semi-volatile organic compounds (SOVs) for the composited sediment sample collected from Warinanco Park Lake were compared to the NJDEP proposed Soil Cleanup Criteria for both residential and non-residential land classifications. The total concentrations of the above parameters that exceeded the residential or both the residential and non-residential Soil Cleanup Criteria proposed by NJDEP are presented in Table 3.6. All sediment quality data is presented in Appendix C.

Table 3.6
Total Concentrations of Various Constituents Exceeding the Proposed NJDEP Soil Cleanup Criteria

Parameter	Concentration (mg/Kg)	Residential (mg/Kg)	Non-Residential (mg/Kg)
Metals			
Arsenic	95.2	20	20
Lead	242	100	600
Semi-volatile Compounds			
Benzo(a)anthracene	1.1	0.9	4
Benzo(a)pyrene	1.3	0.66	0.66

In Warinanco Park Lake, arsenic, lead, benzo(a)anthracene and benzo(a)pyrene exceeded the Soil Cleanup Criteria proposed by the NJDEP as shown in Table 3.6. Lead and benzo(a)anthracene exceed the residential criteria, while arsenic and benzo(a)pyrene exceed both the residential and non-residential criteria. The total concentration for these parameters indicates that the lake sediments cannot be applied to any lands for reuse unless a "Declaration of Environmental Restriction" is applied to the land parcel that is used as the disposal site. Another alternative for sediment disposal is to transport the sediments to a hazardous waste landfill.

Each proposed lake dredging project is reviewed by the NJDEP on a case-by-case basis. As stated previously, the NJDEP Soil Cleanup Criteria are informal guidelines that have not been promulgated by the State of New Jersey as formal regulatory levels.

4.0 Pollutant Budgets

Overview

Pollutants can enter a lake from both point and nonpoint sources. Point sources are defined as all wastewater effluent discharges within a watershed. All other pollutant sources within a watershed are classified as nonpoint sources. Nonpoint sources can contribute pollutants to a lake through inflow from tributaries, direct runoff, direct precipitation on the lake surface, or through internal loading via lake sediments and groundwater inputs. Both natural events, such as precipitation and runoff, and human activities, including agriculture, silviculture, septic systems, and construction, can contribute pollutants to the lake system. Nonpoint sources can be difficult to quantify but are important because they often constitute the major source of pollutants to lakes.

Nonpoint source pollutant loadings for lakes (including reservoirs) can be assessed through a lake and stream monitoring program, through the use of the Unit Areal Loading (UAL) approach (U.S. EPA, 1980), or through the use of desktop models, such as the Simple Method (Schueler, 1987). The monitoring approach requires the acquisition of both streamflow and water quality data for inlet (inflowing) streams during dry and wet weather periods. The UAL approach is based on the fact that different land use types contribute different quantities of pollutants through runoff.

The Simple Method is an empirical method for estimating pollutant loads from urban development sites. The Simple Method uses the extensive database obtained from the Nationwide Urban Runoff Program. The Simple Method is versatile because it predicts pollutant loadings under a variety of planning conditions. It is primarily intended for use in developed sites that are less than one square mile in size. The Simple Method is considered precise enough to make reasonable and reliable nonpoint source pollution management decisions. The Simple Method was used to develop pollutant loadings for total phosphorus, total nitrogen, and total suspended solids for the Green Brook Park Lagoon.

Warinanco Park Lake

Warinanco Park Lake has a surface area of 7.5 acres. The watershed of Warinanco Park Lake is 0.60 square miles (380.5 acres) as shown in Figure 2.1. The pollutant budget to Warinanco Park Lake was calculated based on the Simple Method. The Simple Method consists of the following empirical formula:

$$L = [(P) (Pj) (Rv)/12] (C) (A) (2.72)$$

where:

L =	the load in pounds,
P =	the rainfall depth in inches over the desired time period,
Pj =	a correction factor for P for storms that produce no runoff,
Rv=	the runoff coefficient which expresses the fraction of rainfall that is converted to runoff,
C =	the flow-weighted mean concentration of the pollutant (mg/L), and
A =	area of the development site (acres).

Based on NOAA rainfall data, the average yearly rainfall for the Newark, New Jersey station is 43 inches per year. Therefore, P equals 43. Pj is 0.9 based on Schueler, 1987. Rv equals 0.05+0.009(I), where I is the percent impervious area in the watershed. The estimated percent impervious area in the Green Brook Park Lagoon watershed is 65 percent. Therefore, Rv equals 0.635. The area of the watershed is 380.5 acres. The flow-weighted mean concentration is 1.08 mg/L for total phosphorus and 13.6 mg/L for total nitrogen. The mean concentration for total suspended solids is 325 mg/L based on graphs presented in *Controlling Urban Runoff: A Practical Manual for Planning and Designing BMPs* (Schueler, 1987).

By incorporating these numbers into the Simple Method empirical formula, the following annual pollutant loads are generated:

Pollutant	**Annual Pollutant Load (lb/yr)**
Total Phosphorus	204
Total Nitrogen	28,825
Total Suspended Solids	688,827

5.0 Identification of Problem Areas

As part of the Warinanco Park Lake Study, a watershed evaluation was performed to identify nonpoint source pollution problem areas within the Warinanco Park Lake Watershed. Several types of nonpoint source pollution problems were observed in the watershed including shoreline erosion, excessive waterfowl populations, and urban stormwater management problems. In addition, based on the results of the bathymetric survey and on observations during the watershed evaluation, excessive sedimentation has occurred in Warinanco Park Lake resulting in excessive amounts of sediment in the lake.

5.1 Shoreline Erosion

Portions of the shoreline of Warinanco Park Lake are experiencing excessive erosion problems. Shoreline erosion problem areas are shown in Figure 5.1. The shoreline erosion problem areas are aggravated by the waterfowl populations that walk up and down the banks to enter and exit the lake.

5.2 Waterfowl

Excessive numbers of waterfowl can create major water quality problems for lakes. The large numbers of waterfowl, mainly Canada geese and gulls, aggravate shoreline erosion problems by walking up and down the lake banks. The waterfowl droppings are also a problem and are a direct source of phosphorus, nitrogen, and bacteria to the lake. The large amount of waterfowl droppings around the lake are a significant problem at Warinanco Park Lake.

5.3 Urban Stormwater Management

Based on our field investigations, it is apparent that stormwater runoff from impervious areas, such as parking lots and roads, enters the storm sewers and streams untreated. This untreated urban stormwater is a significant source of nutrients and sediments to Warinanco Park Lake.

5.4 Lake Sedimentation

Excessive amounts of sediments have accumulated in Warinanco Park Lake. Based on field observations, it is evident that the lake is filling up with sediments.

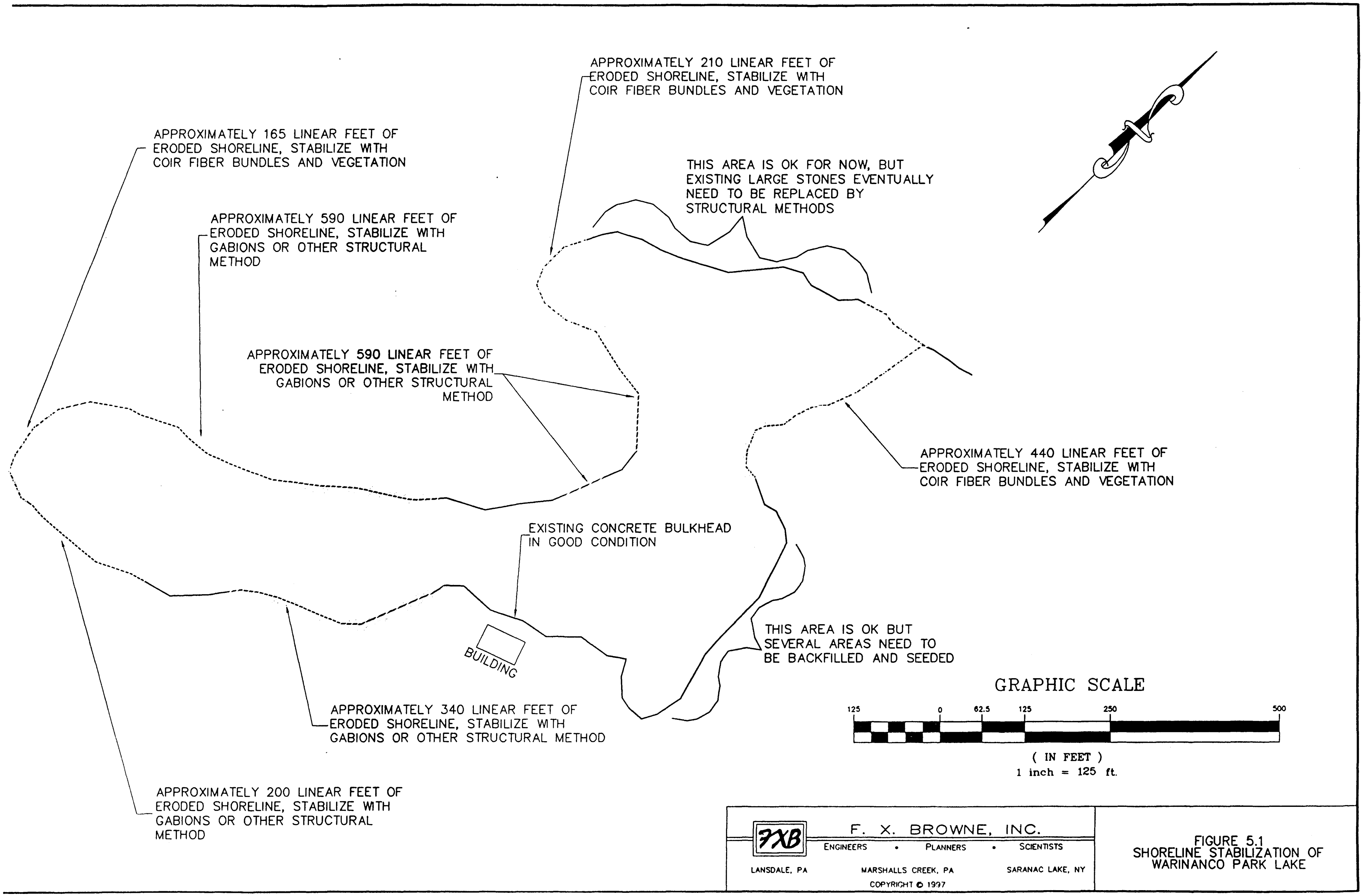

FIGURE 5.1
SHORELINE STABILIZATION OF WARINANCO PARK LAKE

6.0 Recommended Management Plan

In developing a recommended management plan for Warinanco Park Lake, both in-lake management alternatives and watershed management alternatives were evaluated. The first priority in all management programs is to determine whether watershed management practices can be implemented to reduce the pollutants entering the lake. Because nonpoint source pollutants account for a high percentage of the nutrient and sediment loadings to Warinanco Park Lake, it is critical that lake restoration focuses on watershed controls in addition to in-lake restoration techniques.

In-lake restoration alternatives that are recommended for Warinanco Park Lake include lake dredging, dilution with well water, and addition of a water colorant. Watershed management practices that are recommended for Warinanco Park Lake include shoreline stabilization, waterfowl control, urban stormwater management, construction of a created wetland in the area of the existing lagoon, and homeowner practices. In addition, a public education program, water quality monitoring program, and institutional approaches are recommended.

During the development of the watershed management plan, the following criteria were used to evaluate the potential management alternatives:

Effectiveness:	how well a specific management practice meets its goal
Longevity:	reflects the duration of treatment effectiveness
Confidence:	refers to the number and quality of reports and studies supporting the effectiveness rating given to a specific treatment
Applicability:	refers to whether or not the treatment directly affects the cause of the problem and whether it is suitable for the region in which it is considered for application
Potential for Negative Impacts:	an evaluation should be made to insure that a proposed management practice does not cause a negative impact on the lake ecosystem
Capital Costs:	standard approaches should be used to evaluate the cost-effectiveness of various alternatives
Operation and Maintenance Costs:	these costs should be evaluated to help determine the cost-effectiveness of each management alternative

The recommended management plan for Warinanco Park Lake is based upon the following: (1) lake water quality data, (2) watershed tours, (3) estimated pollutant budgets, and (4) the goals as established by the Union County Waterways Team.

6.1 In-Lake Treatment

6.1.1 Lake Dredging

The physical removal of lake sediments can be used to achieve one or more objectives and is often referred to as the "ultimate face-lift". Overall, the costs for dredging are high, but the benefits are long-term, as long as control measures are implemented to minimize the amount of sediment entering the lake. Warinanco Park Lake was created in 1929 and has never been dredged. The inlet lagoon to the lake was dredged once in 1960+/-.

Warinanco Park Lake contains approximately 15,523 cubic yards of unconsolidated sediment that should be removed by dredging. Warinanco Park Lake should be either mechanically dredged or hydraulically dredged and pumped into on-site sediment dewatering equipment. In either case, the sediment must be disposed of at an approved disposal site.

Potential disposal areas for contaminated sediments include hazardous waste landfills and available non-residential land. County owned parkland may be acceptable for sediment disposal, but site remediation techniques such as capping and/or covering the sediments may be required. The DEP has indicated that they will consider disposal sites for contaminated sediments on a case by case basis. Currently, they have no specific guidelines for the disposal of contaminated sediments. Finding an acceptable disposal site for the sediments may be difficult, but according to DEP personnel, it is not impossible. Parkland adjacent to the lake could be used for sediment disposal, depending upon review by the NJDEP. Sufficient parkland is available for sediment disposal.

A dredging feasibility study should be performed before detailed dredging design and permitting begins. The main work elements of the dredging feasibility study should include the following:

1. Attend a pre-application meeting with the DEP to discuss the project, to determine what permits will be required for this specific project, and to discuss potential disposal areas. A pre-application meeting is required by the DEP for dredging projects.

2. Determine if additional sediment samples must be collected and analyzed based on the pre-application meeting with the DEP. If additional sediment samples are required, they should be conducted as part of the dredging feasibility study.

3. Identify a suitable disposal area for the contaminated sediments. Suitable areas may include non-residential properties, including County property or hazardous waste landfills.

4. Prepare a dredging feasibility report for submission to the County. Based on information provided in this report, Union County can determine if dredging Warinanco Park Lake is feasible.

The dredging feasibility study should also include an evaluation of beneficial soil reuse and reclamation of the contaminated sediments.

6.1.2 Lake Aeration

Aeration has been widely-used as a restoration measure for lakes where summer hypolimnetic oxygen depletion and/or winter-kill are of major concern. Aeration can be divided into two categories: those methods which destratify the lake water column and circulate the entire lake and those methods which aerate the hypolimnion (deep water layer) without destratifying the lake. Both methods are based on the principle that if you increase the dissolved oxygen concentration in a lake, you will provide additional habitat for fish while decreasing the release of phosphorus from the sediments that occurs under anoxic (low dissolved oxygen) conditions.

Since the lake is well oxygenated except for a very small area near the bottom of the lake, a hypolimnetic aeration system would not be appropriate for Warinanco Park Lake. A destratification aeration system would keep all the water aerated and cause the water column to circulate. This type of aeration system may be appropriate for Warinanco Park Lake to help improve the circulation in the lake. However, aeration should only be considered for Warinanco Park Lake after dredging occurs.

6.1.3 Dilution/Flushing

Dilution and flushing can improve water quality in eutrophic lakes by diluting the amount of phosphorus in the lake while increasing the flushing of algae from the lake. This technique works best in small eutrophic lakes that have low flushing rates and is most cost effective whin a large quantity of low-nutrient water is available. In most cases, the water supply for dilution and flushing is obtained by diversion of water from a nearby river, although the use of wells may also be used.

Dilution and flushing of Warinanco Park Lake is recommended with the use of groundwater wells as a water source. First, however, any nearby wells should be tested to ensure that phosphorus and nitrogen concentrations are relatively low compared to the phosphorus and nitrogen concentrations in the lagoon. One well pumping for an 8 hour period each day at a rate of 10 gallons per minute would decrease the phosphorus concentration by approximately 0.005 mg/l per day. Pumping should start in April each year and continue through the end of September. Based on estimated pumping rates and efficiencies and on local electrical costs, the annual cost to operate the pump would be approximately $720. Based on conversations with the DEP, no permits should be required for a well to dilute Warinanco Park Lake since the volume of water pumped will be less than 100,000 gpd.

6.1.4 Water Colorant

Since the detention time in Warinanco Park Lake is relatively long, is an excellent candidate for a water colorant such as Aquashade. Aquashade is an EPA -registered non-toxic organic water dye for algae and weed control that filters sunlight to reduce the growth of aquatic weeds and algae. It is also useful for coloring controlled waterways an attractive blue to enhance their aesthetic quality. The typical application rate of Aquashade is one gallon per 1,000,000 gallons of pond water and applications should begin in the spring before aquatic plants begin to grow. One application lasts for approximately 4 weeks. A one gallon jug of Aquashade costs approximately $45. Approximately 6 gallons would be required for Warinanco Park Lake for each application period. If application begins in April and continues through September, approximately six applications would be required per year. Therefore, the total cost of Aquashade per year for Green Brook Park Lagoon would be $1600.

Use of Aquashade can begin at any time; however, it will be most effective and will make the lake the most aesthetically pleasing once the lake is dredged and an aeration system is installed.

6.2 Watershed Controls

6.2.1 Shoreline Stabilization

Soil erosion occurring along steep slopes, streambanks, and lake shoreline areas can contribute large quantities of nutrient-laden sediments to lakes. Land areas exhibiting high levels of soil erosion are commonly referred to as critical areas. Generally, soil erosion from critical areas will continue to occur at accelerated rates until these areas are properly stabilized. Excessive loadings of nutrient-laden sediments to lakes will result in increased levels of lake eutrophication.

Critical areas in a watershed may be stabilized using conventional methods, bioengineering methods, or a combination of both. Conventional methods such as, rip-rap and gabions, are very effective in controlling soil erosion, but they can be expensive to implement and do not always fit into the natural environment. Bioengineering methods consist of planted vegetation used separately or in conjunction with conventional methods to control soil erosion. Some highly effective bioengineering methods are live stakes, live fascine, brush layering, branch packing, live gully repair, live cribwalls, vegetated rock gabions, vegetated rock walls, and vegetated rip-rap.

In the Warinanco Park Lake watershed, high levels of soil erosion are occurring along lake shoreline areas as shown in Figure 5.1. Severely eroded areas along the lake shoreline should be stabilized with a combination of vegetation and structural measures.

6.2.2 Waterfowl Control

Canada geese populations at Warinanco Park Lake are excessive and should be controlled. Geese droppings are a significant and direct source of phosphorus, nitrogen and bacteria to Warinanco Park Lake. Geese populations should be controlled by landscaping, egg inactivation, chemical deterrents, and scare tactics. Park visitors should be discouraged from feeding the geese and other waterfowl. Signs should be posted at strategic locations in the park to inform people about not feeding the waterfowl.

6.2.3 Urban Stormwater Management

Over the past ten years, a number of stormwater best management practices have been developed in order to reduce the adverse water quality impacts associated with urbanization. Overall, stormwater control measures serve two distinct functions: (1) reproduce pre-development hydrologic conditions, and (2) provide pollutant removal capabilities. Historically, stormwater management has focused on reducing the frequency and severity of downstream flooding by reducing the peak discharge from post-developed sites. More recently, stormwater management has been redefined to include for the removal of pollutants, thereby improving and protecting the quality of downstream waters.

Below is a list of stormwater management practices that were evaluated for urban areas in the Warinanco Park Lake watershed. In developed areas, stormwater management should primarily focus on urban stormwater controls such as, sand filters, water quality inlets, and infiltration structures. These stormwater controls do not require vast areas of land, and therefore can be integrated into existing urban settings.

Urban Stormwater Controls

1. Sand Filters
2. Water Quality Inlets
3. Infiltration Trenches
4. Bioretention Systems
5. Buffer Strips (Filter Strips)

In areas of future development or redevelopment, stormwater management controls such as, infiltration basins, extended detention basins, constructed wetlands, and buffer strips, should be constructed or implemented. These stormwater control measures typically require larger tracts of land and therefore should be incorporated or designed as part of the land development planning process.

Other options for improving the water quality of stormwater runoff include:

1. Union County and local municipalities should evaluate street sweeping schedules. Increased street sweeping is recommended, especially in the spring and summer months.

2. Stormwater catch basins should be cleaned after major storm events or at least once every three months. Cooperation between Union County and the local municipalities is recommended for this task.

3. Although most of the watershed is developed, every opportunity to improve stormwater quality should be taken. For example, if a commercial establishment changes ownership, and the new owner needs approvals from the local municipality, local ordinances should be in place to require improving stormwater runoff quality from the site before approvals are granted. Possible stormwater quality treatment systems that could be installed on a developed property include sand filters, peat filters, or bioretention systems. The purpose of these systems is to treat stormwater runoff from parking lots and roads. These systems are installed to treat the first 0.5 inches of stormwater runoff.

4. Existing homeowners and business owners should be encouraged to direct roof runoff to dry pits or rain barrels to reduce the amount of

stormwater that enters the storm sewer system. Using a rain barrel or cistern gives the homeowner the advantage of water use reduction by storing rain water to water gardens or lawns during dry periods.

6.2.4 Created Wetlands

The existing lagoon should be converted to a created wetland system to help treat stormwater runoff. The created wetland should include a forebay area where larger sediment settles out. The forebay will require continual maintenance; however, this maintenance will be routine. Since the created wetland will be permitted as a stormwater treatment system, dredging the forebay on a regular schedule can be done without obtaining any permits from the NJDEP. After the forebay, the water will be directed through a wetland system containing a variety of wetland plants. The water will then be directed to a micropool and then discharged to Warinanco Park Lake. The entire lagoon area will be used along with additional park land. An example of a typical created wetland is presented in Figure 6.1.

6.2.5 Homeowner Practices

Homeowner practices are important since most of the nutrients and sediments that enter Warinanco Park Lake originate from residential and commercial land within the watershed. Several homeowner practices are listed below. These practices can be implemented as part of a public education program.

1. Lawn fertilizer can be a significant source of nutrients to lakes, especially in suburban areas where nice green lawns are desirable. A fact sheet on the importance of proper lawn fertilization should be prepared and distributed to homeowners in the watershed. This task could be facilitated through the public education program described below or by an "extra" in the local newspaper. Fact sheets could be posted at the park and possibly at local businesses.

2. Leaf management is also important in reducing nonpoint source pollution in a developed watershed. The existing leaf management program should be evaluated to determine if there are ways to improve the program so that leaves do not end up in the street for a long period of time. If leaves are left in the street too long, nutrients leach from the leaves and are carried into the storm sewers and eventually into the lake with stormwater runoff. Bagging leaves in biodegradable bags is one possibility for improving the leaf management program.

3. Homeowners should be informed that if they dump household chemicals and other substances into storm sewers, these substances will end up in

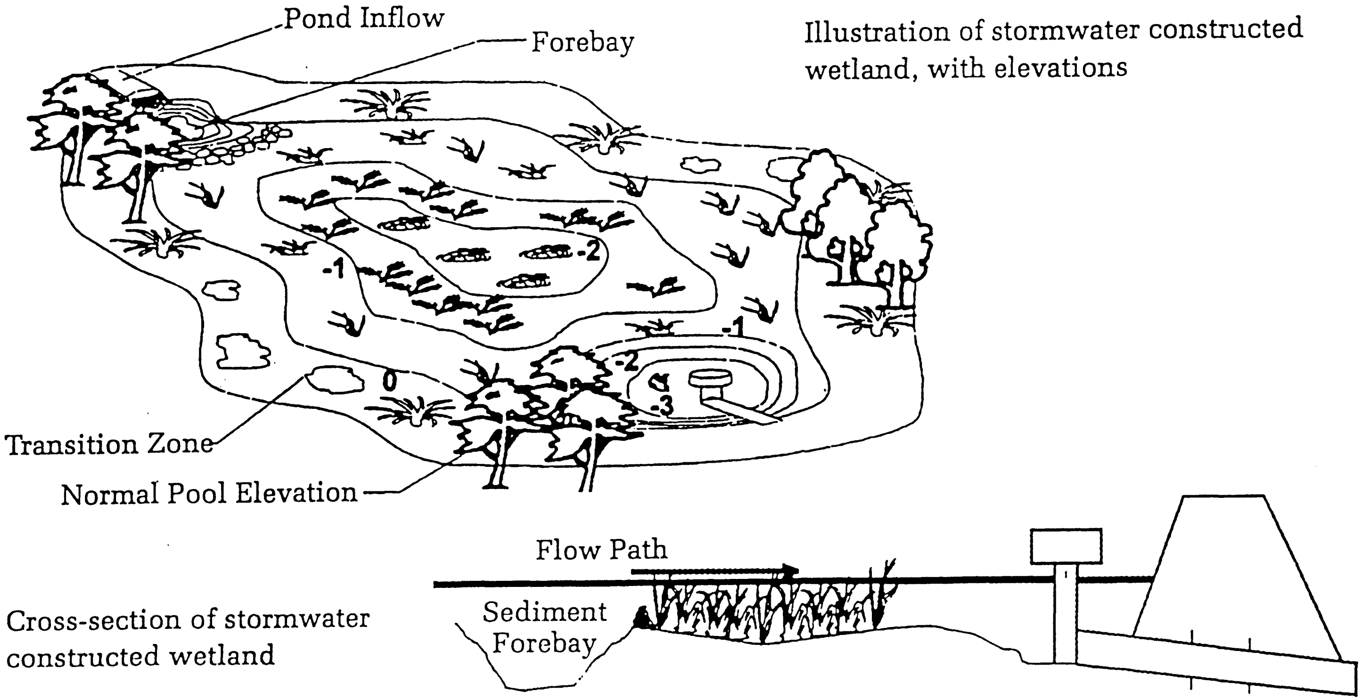

Figure 6.1

Typical Forebay Constructed Wetland System (from Shaver and Maxted 1994)

the lake. Stenciling should be painted on storm inlets to educate homeowners that anything that goes down the storm sewer eventually drains to the lake.

4. Homeowners should be encouraged to wash cars and trucks on grassy areas, if possible. This practice will reduce the amount of phosphorus and detergents that runs down the driveway, into a nearby storm sewer, and eventually into Warinanco Park Lake.

6.3 Other Lake and Watershed Management Recommendations

Other recommendations to help improve the water quality of Warinanco Park Lake include a public education program, a water quality monitoring program, and institutional approaches.

6.3.1 Public Education Program

The U.S. Environmental Protection Agency (EPA) actively encourages the development of environmental education programs by providing helpful literature, suggestions and funding sources. The U.S. EPA has funded education programs, such as the program developed for Lake Wallenpaupack (F. X. Browne, Inc., 1994), through its 314 Clean Lakes Program, its 319 Nonpoint Source Program and its Environmental Education Program.

Union County has developed and is continuing to implement an extensive environmental education program throughout the County. The County's environmental education program should be integrated into the Warinanco Park Lake watershed. The environmental education program for Warinanco Park Lake should include the following elements:

1. Develop and distribute nonpoint source brochure,
2. Develop a watershed management program for presentation to local schools,
3. Develop and install a kiosk at Warinanco Park Lake, and
4. Write a fact sheet on watershed management for distribution at the kiosk and at park events.

6.3.2 Water Quality Monitoring Program

A limited water quality monitoring program should be implemented, after dredging has been completed, to document water quality improvements. Yearly monitoring of selected parameters (i.e. total phosphorus, chlorophyll a, and Secchi disk depth) should be conducted to document water quality changes in the lake.

6.3.3 Institutional Practices

Union County Waterways Team

The Union County Waterways Team should work closely with Borough and City officials to improve the water quality in Warinanco Park Lake. Recommended tasks that should be performed by the Waterways Team with the assistance of municipal officials are as follows:

1. To evaluate existing subdivision ordinances, erosion and sedimentation control ordinances, and others for their applicability to the Warinanco Park Lake watershed.

2. To determine if any of the above ordinances require revisions to further protect lake water quality.

3. To assist in the coordination of all lake and watershed management activities.

4. To establish a "Watershed Watch" program to ensure that erosion and sedimentation controls are properly installed and maintained during and after construction activities.

5. To communicate watershed problems including the lack of compliance with County-wide ordinances to the proper authorities

6. To assist in obtaining funds for the implementation of lake and watershed management best management practices.

Ordinances

The Union County Waterways Team, with the assistance of municipal officials, should evaluate the existing erosion and sedimentation control and stormwater control ordinances to ensure that these documents are effectively protecting the water quality in County streams and lakes.

The Waterways Team, with the assistance of municipal officials, should also evaluate the applicability of lawn fertilization and waterfowl feeding ordinances for the Warinanco Park Lake watershed. Lawn fertilizers, when over applied or applied during improper times of the year, can result in high nutrient loadings to streams and the lake. Excessive numbers of residential waterfowl can also contribute both high nutrient and fecal bacteria loadings to the lake. High nutrient loadings to lakes and streams can result in accelerated rates of eutrophication, while high levels of bacteria increase the incidence of potential health risks for lake users.

6.4 Implementation Costs

The proposed budget for the various elements of the Warinanco Park Lake Restoration Project are shown in Table 6.1 These costs include engineering design, permitting, construction and construction observation costs. The cost for dredging Warinanco Park Lake is difficult to estimate since the sediments are contaminated. However, assuming that land within the park can be used to dispose of the sediments, and assuming the capping or covering the sediment is required, the estimated cost to dredge Warinanco Park Lake could range from $440,000 to $516,000. This cost may increase if the sediment must be disposed of in a hazardous waste landfill. The estimated cost for dredging is not included in Table 6.1.

Table 6.1 Budget Summary for the Proposed Warinanco Park Restoration Project		
Task	**Description**	**Estimated Costs***
1	Dredging Feasibility Study	10,000**
2	Created Wetland	$50,000
3	Dilution/Flushing	$40,000
4	Shoreline Stabilization	$117,000
5	Lake Aeration	$20,000
6	Water Colorant	$1,200
5	Homeowner Practices	$5,000††
5	Environmental Education	$15,000
6	Water Quality Monitoring	$6,000
7	Project Administration	$5,000
8	Project Documentation and Final Report	$8,000
	Total	**$277,200**

* These costs are in 1997 dollars and are subject to change based on when and to what extent the management program is implemented.

** The construction cost for lake dredging is estimated at $440,000 - $516,000 as described in Section 6.4. This cost for the feasibility study does not include the cost of any additional sediment analysis since these costs cannot be determined until after the pre-application meeting with the DEP.

†† This cost includes consulting fees to prepare information and County administration fees to disseminate information.

6.5 Funding Sources

There are many state and federal programs that provide funding for lake and watershed management projects. The two primary funding sources for implementing the recommended management plan are the New Jersey Clean Lakes Program and the EPA's 319 Nonpoint Source Program. The Clean Lakes Program provides 50% funding to implement best management practices and public education programs. The 319 Nonpoint Source program provides funds for watershed management projects and public education programs.

7.0 Environmental Evaluation

Since socio-economic and environmental impacts are part of the cost-effectiveness analysis for the restoration of Warinanco Park Lake, many of these impacts were addressed during the evaluation of restoration alternatives. However, the impacts and their mitigative measures are formally documented below using the environmental evaluation checklist in the Clean Lakes Program Guidance Manual (U.S. EPA, 1980).

1. Will the project displace people?

   No.

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

   No. Residential areas are not affected by the proposed plan.

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

   No.

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

   No.

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

   Temporarily. During the lake sediment removal portion of this study, portions of the parkland will be disturbed. Upon completion of lake dredging, the parkland will be regraded and revegetated to its original appearance. Construction equipment will be necessary for the construction of the shoreline stabilization measures and construction of the created wetland.

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

   No.

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

   No.

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

No. The lake sediments are well oxygenated throughout the year and contain low levels of organic materials.

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

No.

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

No chemical treatments are proposed for Warinanco Park Lake as outlined in the Lake and Watershed Management Plan Section of this report. Aquashade, a non-toxic water colorant, is recommended.

11. Will the project be located in a floodplain?

Yes. Sediment removal activities will be temporarily employed in Warinanco Park Lake.

12. Will structures be constructed in the floodplain?

Yes. Gabions will be used for shoreline stabilization along areas of the shoreline that receive heavy pedestrian traffic.

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?

Yes. A portion of lake shoreline will be regraded and revegetated to reduce further soil erosion.

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

Yes. Sediment removal will have short-term adverse impacts on the aquatic biota. However, within 6 months after dredging is complete, the benthic community is expected to be back to normal.

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

Yes.

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

There are no possible mitigation measures known at the present time which have not been discussed.

8.0 Public Participation

9.0 Literature Cited

Baudo, R. and H. Muntau. 1990. Lesser known in-place pollutants and diffuse source problems in Sediments: Chemistry and Toxicity of In-Place Pollutants. Baudo, R., J. Giesy and H. Muntau, ed. Lewis Publishers, Inc. Chelsea, Michigan.

Carlson, R. E. 1977. A trophic state index for lakes. Limnol. Oceanogr. 22:361-369.

Conyers, D. L. and G. D. Cooke. 1982. Comparing Methods for Macrophyte Control, in Lake Line. North American Lakes Management Society, East Winthrop, ME.

Cooke, G. D., E. B. Welch, S. A. Peterson, and P. R. Newroth. 1993. Second Edition. Lake and Reservoir Restoration. Ann Arbor Science. Boston.

F. X. Browne, Inc. 1994. Lake Wallenpaupack: A Resource Worth Protecting. Prepared in cooperation Wallenpaupack Area School District, Lake Wallenpaupack Watershed Management District, and Pennsylvania Power and Light Company for the Wallenpaupack Area High School.

New York DEC. 1990. Diet for a Small Lake. New York Department of Conservation, Albany, NY.

The Pennsylvania State University. Pennsylvania Fish Ponds. The Pennsylvania State University, College of Agricultural Cooperative Extension Service. University Park, Pennsylvania.

Reckhow, K. H., M. N. Beaulac, and J. T. Simpson. 1980. Modeling phosphorus loading and lake response under uncertainty: A manual and compilation of export coefficients. Report No. EPA-440/5-80-011. U. S. EPA, Washington, D.C.

Union County Planning Board. January 1967. Report Number One: Physical Characteristics. Master Plan Program, Union County, New Jersey.

U.S. EPA. 1980. Clean lakes program guidance manual. Report No. EPA-440/5-81003. U.S. EPA, Washington, D.C.

U.S. EPA. 1990. The Lake and Reservoir Restoration Guidance Manual, Second Edition. Report No. EPA-440/4-90-006. U.S. EPA, Washington, D.C.

Weiss, C. M. 1976. Evaluation of the algal assay procedure. Ecol. Res. Ser. EPA-600/3-76-064. US EPA, Corvallis, OR.

Wetzel, R. G. 1975. Limnology. W.B. Saunders Company. Philadelphia.

APPENDIX A

GLOSSARY OF LAKE AND WATERSHED MANAGEMENT TERMS

Appendix A

GLOSSARY OF LAKE AND WATERSHED MANAGEMENT TERMS

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.

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 expressed 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, and 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 B

WARINANCO PARK LAKE WATER QUALITY DATA

UNION COUNTY: ELEVEN LAKES PHASE I STUDY
WARINANCO PARK LAKE CHEMISTRY WATER QUALITY DATA
FILE NO. NJ1289-03

Date	Station	Type	pH (su)		NO3/NO2 (mg/L)		NH3 (mg/L)	TKN (mg/L)	TP (mg/L)	DRP (mg/L)	TN* (mg/L)	TN/TP Ratio*	TIN/DRP Ratio*	TSS (mg/L)
05/21/96	WPL	composite	7.7	<	0.01	<	0.10	0.84	0.185	0.027	0.85	4.6	4.1	18.3
06/16/96	WPL	composite	7.5		0.31	<	0.10	1.73	0.470	0.101	2.04	4.3	4.1	17.0
07/21/96	WPL	composite	8.0	<	0.01	<	0.10	3.30	0.520	0.177	3.31	6.4	0.6	31.7
08/11/96	WPL	composite	8.6	<	0.01	<	0.10	2.39	0.435	0.120	2.40	5.5	0.9	22.0
WPL	**Min**		7.5		0.01		0.10	0.84	0.185	0.027	0.85	4.3	0.6	17.0
	Max		8.6		0.31		0.10	3.30	0.520	0.177	3.31	6.4	4.1	31.7
	Mean		8.0		0.09		0.10	2.07	0.403	0.106	2.15	5.2	2.4	22.3
	Med		7.9		0.01		0.10	2.06	0.453	0.111	2.22	5.1	2.5	20.2
	Stds		0.5		0.2		0.0	1.0	0.1	0.1	1.0	0.9	1.9	6.6
	Std		0.4		0.1		0.0	0.9	0.1	0.1	0.9	0.8	1.7	5.8
	Count		4		4		4	4	4	4	4	4	4	4

UNION COUNTY: ELEVEN LAKES PHASE I STUDY
WARINANCO PARK LAKE CHEMISTRY WATER QUALITY DATA
FILE NO. NJ1289-03

Date	Station	Type	SD (meters)	CHL a (ug/L)	PHEO (ug/L)
05/21/96	WPL	photic	0.30	57.7	24.8
06/16/96	WPL	photic	0.40	50.1	13.4
07/21/96	WPL	photic	0.35	150.3	22.3
08/11/96	WPL	photic	0.30	125.4	18.6
WPL	**Min**		0.30	50.1	13.4
	Max		0.40	150.3	24.8
	Mean		0.34	95.9	19.8
	Med		0.33	91.5	20.5
	Stds		0.05	49.6	4.9
	Std		0.04	43.0	4.3
	Count		4	4	4

APPENDIX C

WARINANCO PARK LAKE SEDIMENT RESULTS

Union County Eleven Lakes Phase I Study
Sediment Results
File No. NJ1289-03

		Concentration (2)											No. of Times	NJDEP Criteria (4)	
	Parameters (1)	**WPL** ↓	**RRPL**	**ML**	**CBPL**	**GBPL**	**SP**	**BPP**	**MP**	**UEL**	**LEL**	**NPL**	**Detected**	**Res**	**Non-Res**
pH		7.12	6.69	6.54	6.35	6.36	6.44	6.52	6.82	6.75	6.82	6.74	11	n/a	n/a
Reactivity	cyanide												0	n/a	n/a
	sulfide												0	n/a	n/a
Nutrients	ammonia	140	290	90	220	220	410	280	190	330	190	230	11	n/a	n/a
	nitrate	0.92	0.84	0.94 j	0.75 j	1 j		0.97 j	1.2 j	0.7 j	0.89 j	1.2 j	10	n/a	n/a
	TKN												11	n/a	n/a
	Total N (3)												11	n/a	n/a
	Total P	610	600	440	460	690	1100	830	610	850	870	810	11	n/a	n/a
Moisture		55.7	39.8	41.5	52.4	57.2	55.3	50.7	47.4	47.5	59.4	59	11	n/a	n/a
Chloride		180	57	30	17	18		450	25	69	92	30	10	n/a	n/a
Metals	Antimony (Sb)	8.6 j	3.6 j										2	14	340
	Arsenic (As)	95.2	11.3	3.5	32.4	67.2	10.6	7.8	10.8	6	11.1	11.7	11	20	20
	Beryllium (Be)	0.71 j	0.64 j	0.54 j	0.89 j	0.99 j	1.1	0.61 j	0.55 j	0.85 j	1.18 j	0.59 j	11	1	1
	Cadmium (Cd)				5.8								1	1	100
	Chromium (Cr)	21.4	25.1	15.5	39	46.8	87.5	38.2	29.8	24.3	34	23.1	11	n/a	n/a
	Copper (Cu)	196	154	35.9	190	191	236	109	97.1	92.8	226	194	11	600	600
	Lead (Pb)	242	170	36	200	213	166	308	267	162	156	125	11	100	600
	Mercury (Hg)	0.26	0.46	0.19	0.25	0.72	0.3	0.27	0.43	0.149 j	0.178 j	0.197 j	11	14	270
	Nickel (Ni)	24	16.7	10.5	25	24	27	23.2	21	18.2	25	16	11	250	2400
	Selenium (Se)	0.64 j	0.77 j		0.88 j	0.74 j		0.54 j	0.58 j		0.62 j	0.76 j	8	63	3100
	Silver (Ag)						1.9 j						1	110	4100
	Zinc (Zn)	229	233	78	200	200	188	270	202	167	181	178	11	1500	1500
VOCs	2-butanone		28			47	40	84			56		5	1000	1000
	Acetone	160	160	51	56	240	240	300	140	86	270	53	11	1000	1000
	chlorobenzene					26							1	37	680
	methylene chloride		7 j							4 j			2	49	210
	toluene									4 j			1	1000	1000
Pest/	DDD	0.03			0.04	0.11	0.15	0.23	0.63	0.14	0.21	0.04	9	3	12
PCBs	DDE	0.09	0.014 j		0.06	0.08	0.06	0.08	0.15	0.04	0.07	0.04	10	2	9
	DDT	0.015 j			0.02	0.15	0.12 j	0.04	0.03	0.08 j	0.16 j	0.01 j	9	2	9
	Endrin	0.006 j					0.012 j						2	17	310

Union County Eleven Lakes Phase I Study
Sediment Results
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		↓					Concentration (2)						No. of Times	NJDEP Criteria (4)	
	Parameters (1)	**WPL**	**RRPL**	**ML**	**CBPL**	**GBPL**	**SP**	**BPP**	**MP**	**UEL**	**LEL**	**NPL**	**Detected**	**Res**	**Non-Res**
	PCB-1254		0.3		0.39 j								2	0.49	2
	chlorodane			0.17			0.6	1.4	1.34	1.1	0.7	1.1	7	n/a	n/a
	delta BHC										0.011 j		1	n/a	n/a
	methoxychlor					0.013 j							1	280	5200
SVOCs	1,2,4-trichlorobenzene	0.19 j											1	68	1200
	1,3-dichlorobenzene	0.089 j				0.11 j							2	5100	10000
	1,4-dichlorobenzene	0.81	0.1 j		0.41 j	0.76 j				0.077 j		0.21 j	6	570	10000
	2-methylnaphthalene							0.11 j					1	n/a	n/a
	N-nitrosodiphenyamine							0.19 j					1	140	600
	acenaphthylene				0.16 j	0.19 j		0.11 j					3	n/a	n/a
	acenapthene				0.17 j	0.63 j	0.098 j	0.2 j	0.15 j	0.092 j			6	3400	10000
	anthracene	0.14 j	0.095 j		0.36 j	0.68 j	0.28 j	0.52 j	0.29 j	0.21 j	0.17 j	0.09 j	10	10000	10000
	benzo(a)anthracene	1.1	0.61	0.26 j	2.5	4.1	1.3	2.6	1.5	1.3	1.2	0.64 j	11	0.9	4
	benzo(a)pyrene	1.3	0.68	0.26 j	3	4.6	1.3	2.6	1.3	1.5	1.4	0.73 j	11	0.66	0.66
	benzo(b)fluoranthene	2	1.1	0.45 j	4.2	6.1	1.8	3.8	2.1	2.1	2.1	1.2	11	n/a	n/a
	benzo(ghi)perylene	0.81	0.44 j		1.9	3.8	0.76	2.3	0.9	1.2	1.3	0.64 j	10	n/a	n/a
	benzo(k)fluoranthene	0.69 j	0.31 j		1.5	2.2	0.55 j	1.2	0.64	0.74	0.77 j	0.41 j	10	0.9	4
	bis(2-ethylhexyl)phthalate	0.38 j	0.58	0.77	1.3	0.62 j	1.3	5.4	0.78	1.4	0.64 j	1.8	11	49	210
	butyl benzyl phthalate						0.19 j	0.34 j				0.19 j	3	1100	10000
	carbazole	0.083 j			0.15 j	0.16 j	0.11 j	0.21 j	0.19 j	0.095 j	0.11 j		8	n/a	n/a
	chrysene	1.6	0.88	0.36 j	3.6	5.2	1.7	3.3	2	1.9	1.7	0.95	11	9	40
	di-n-butyl phthalate							0.97 j					1	5700	10000
	di-n-octyl phthalate							0.21 j				0.16 j	2	1100	10000
	dibenz(a,h)anthracene	0.25 j			0.52 j	1.1	0.16 j	0.56 j	0.17 j		0.18 j		7	0.66	0.66
	dibenzofuran					0.12 j		0.11 j	0.073 j				3	n/a	n/a
	flouranthene	2.4	1.3	0.6	5	6.5	1.7	4.9	3.2	2.7	2.3	1.3	11	2300	10000
	flourene		0.13 j		0.27 j	0.64 j	0.21 j	0.28 j	0.22 j		0.18 j		7	2300	10000
	indeno(1,2,3-cd)pyrene	0.88	0.45 j	0.12 j	2.1	3.9	0.81	2.3	0.97	1.3	1.3	0.64 j	11	0.9	4
	naphthalene					0.094 j		0.08 j					2	230	4200
	phenanthrene	0.84	0.68	0.26 j	2.4	3.4	1.8	2.6	1.9	1.5	1.3	0.62 j	11	n/a	n/a
	pyrene	2.3	1.7	0.57	5.7 6	8.8	3.2	6.4	3.2	3.2	3	1.5	11	1700	10000

Union County Eleven Lakes Phase I Study
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Parameters (1)	WPL	RRPL	ML	CBPL	GBPL	SP	BPP	MP	UEL	LEL	NPL	No. of Times Detected	NJDEP Criteria (4) Res	Non-Res
	Concentration (2)													
No. of Parameters Detected per Lake (5)	32	29	19	33	37	33	39	31	30	31	29			

Note(s):

(1) Only includes metals, pest/PCBs, VOCs, and SVOCs that were detected at least once in all 11 study lakes
(2) Concentrations expressed on a dry weight basis as mg/Kg (ppm) for nutrients, metals, pest/PCBs, VOCs, & SVOCs. Moisture expressed as a percentage and pH expressed as standard units.
(3) Total nitrogen determined as TKN plus nitrate
(4) NJDEP criteria expressed on a dry weight basis as mg/Kg (ppm) NJDEP Soil Cleanup Criteria (Informal Guidelines, last revised 2/3/94)
(5) Only for metals, pest/PCBs, VOCs, and SVOCs listed in the above table for each study lake.

Also,

Letter "j" after a concentration indicates estimated value by the contract laboratory

"Blank" values indicate the parameter was not detected by the contract laboratory

One composited sediment sample was analyzed for each of the eleven study lakes.
Composited sediment sample = 3 discrete sediment cores (0-48 in) from center-line of lake.