PHASE I DIAGNOSTIC-FEASIBILITY STUDY OF SILVER LAKE, NEW YORK

DRAFT FINAL REPORT

September 1991

Presented to:

The Silver Lake Watershed Commission
Perry, New York 14530

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EXECUTIVE SUMMARY

The Silver Lake study was conducted as part of a New York State Department of Environmental Conservation grant to the Silver Lake Watershed Commission for a comprehensive management plan for Silver Lake and its watershed. This section of the management plan is a materials balance and watershed management action study, and was designed in accordance with procedures used in Phase I Diagnostic-Feasibility studies conducted under state and federal Clean Lakes Programs.

Silver Lake and its tributaries were monitored between January of 1990 and April of 1991. Watershed characteristics were analyzed in order to prepare a hydrologic and pollutant budget for Silver Lake. Specific restorative and management alternatives were considered based on lake and watershed analyses. A final management plan was drawn up, incorporating activities which were judged to be most cost-effective, efficient, and long-lasting. The conclusions and recommendations of this study are summarized below. A glossary of lake and watershed terms is provided in Appendix A and a Primer on Lake Ecology is provided in Appendix B as an aid to understanding the following discussion and the body of this report.

Conclusions

1. Silver Lake is a 825-acre lake in Wyoming County, New York. The mean lake depth is 27.3 feet and the maximum depth is 40.0 feet. The volume of Silver Lake is 6,375 million gallons and its hydraulic residence time is 1.2 years.

2. The Silver Lake watershed encompasses 10,987 acres. Land use consists primarily of agriculture activities (71 percent).

3. Silver Lake is used for swimming, boating, fishing, nature appreciation and education, and aesthetics. Nuisance growths of aquatic macrophytes (plants) and algae have hampered recreational use of the lake in recent years.

4. Along the northern shoreline, water depths are generally less than 2.5 feet. The loss of lake depth in the northern section of Silver Lake is primarily due to high suspended solid loadings to the lake by the Silver Lake Inlet.

5. Silver Lake is thermally stratified in the winter and the summer months. Winter stratification occurred in January through February in 1990 and 1991, and summer stratification occurred in late May through August in 1991. For the winter stratification periods, the greatest dissolved oxygen deficit occurred in January of 1990. In January of 1990, dissolved oxygen levels fell below 1 milligrams per liter at lake depths exceeding 20 feet. During the summer stratification period, the greatest dissolved oxygen deficit occurred during early August of 1990. In early August, dissolved oxygen concentrations fell below 1 milligram per liter at lake depths exceeding 25 feet. The lake bottom waters were essentially without oxygen in January and February 1990 and from May through mid-September 1990.

6. The average pH level in Silver Lake was 8.0 standard units and the average alkalinity was 105 milligrams per liter as calcium carbonate. Total suspended solids averaged 1.53 milligrams per liter for surface waters and 2.58 milligrams per liter for bottom waters. Lake transparency, measured with a Secchi disk, averaged 9.2 feet.

7. Total phosphorus concentrations in Silver Lake remained above the EPA eutrophic criterion of 0.02 milligrams per liter throughout the sampling period. The mean in-lake concentration of phosphorus was 0.036 milligrams per liter. Total phosphorus concentrations in the surface and bottom waters of Silver Lake peaked during the months of June, July, August and September.

8. In Silver Lake, the nutrient whose low supply limits algal growth appears to be phosphorus, except in the summer when either phosphorus or nitrogen may be limiting. During the summer, high pH, high temperature, low dissolved nutrient levels, and nitrogen limitation may set the stage for growth of nitrogen-fixing blue-green algae which fare well under these conditions.

9. Phytoplankton (microscopic free-floating algae) densities were low to moderate during most of the sampling period, punctuated by blooms in July and August. In July and August, the highest phytoplankton densities ranged from 3000-8000 cells per milliliter and coincided with the highest total phosphorus concentrations in Silver Lake.

10. Major dominant phytoplankton genera were the cryptophyte *Cryptomonas* during the winter and the diatom *Fragileria* during the spring when the phytoplankton population was low, and the blue-greens *Anabaena* and *Aphanizomenon* during the summer.

11. The Carlson Trophic State Index and EPA criteria applied to total phosphorus and transparency data indicate that Silver Lake is slightly eutrophic.

12. Heavy growth of an aquatic plant, *Vallisineria* (tape grass), *Myriophyllum* (milfoil) and several species of *Potamegeton* (pond weed) were observed during the summer of 1990. The most dense stands of aquatic plants occurred along the northern, western and southern shorelines in Silver Lake.

13. Based on the hydrologic budget for Silver Lake, the Silver Lake Inlet contributes the majority of flow to Silver Lake. It was determined that on an annual average, the Silver Lake Inlet contributes 46 percent of the flow to Silver Lake, while the remaining eight tributaries accounted for 54 percent of the flow to the lake.

14. There are no known point sources of pollution to Silver Lake.

15. Nonpoint sources contribute nutrients and sediments to Silver Lake. The pollutant budget based on land use indicated that most of the phosphorus (91 percent), nitrogen (85 percent), and sediment (88 percent) loads came from active agricultural lands. In the Silver Lake watershed, agricultural lands account for nearly 71 percent of the entire drainage basin.

Recommendations

Institutional

1. The Silver Lake Watershed Commission should oversee all activity in the Silver Lake watershed which affects water quality. Members should include all appropriate government representatives and other people who can offer valuable technical and planning expertise. The functions of the Silver Lake Watershed Commission should be as follows: 1) provision of technical and advisory assistance to local government, homeowners, businesses, developers, and farmers, 2) development of model programs and ordinances, including erosion and sedimentation ordinances for new construction and a stormwater runoff ordinance to control water quality and flooding, 3) prioritization and coordination of watershed and lake management activities, including implementation projects and further studies, and 4) financial management of lake and watershed programs, including seeking funds for implementation.

2. The Silver Lake Watershed Commission should develop educational materials and conduct educational programs for regulatory people, school children, and the public at large. One important activity which should be part of the educational program is a "Watershed Watch" program, where volunteers perform stream monitoring and keep an eye out for potential pollution problems. Educational fact sheets should be developed and distributed. The fact sheets should describes potential pollutant sources (eroding land, gasoline, oil, or chemical spills, etc.), present a primer on lake ecology and give a telephone number to contact if someone sees a possible problem.

3. The Silver Lake Watershed Commission should also be involved in land use planning activities which would protect or improve the water quality in Silver Lake. Such activities might include land acquisition, conservation easements, and land trusts.

<u>In-lake Restoration</u>

1. In Silver Lake, approximately 62,000 cubic yards of sediment should be hydraulically dredged along the northern shoreline, thereby creating an in-lake channel that will enhance the short circuiting effect between the Silver Lake Inlet and the lake's outlet. This management technique will only be cost-effective, however, if an adequate disposal site is located in the vicinity of the north end of Silver Lake. When a major inlet is in close proximity to a lake's outlet, inflowing waters may not thoroughly mix with the lake and simply short circuit through the lake's outlet. The short circuiting of the Silver Lake Inlet and the outlet in Silver Lake has been documented by Englert and Kenton (1983). In the case of the Silver Lake Inlet, this tributary drains approximately 59 percent of the watershed and carries high loadings of both nutrients and suspended solids. By enhancing the short circuiting of the Silver Lake Inlet, less nutrients and sediments will be allowed to enter the lake. Enhanced short-circuiting would also mean that watershed management practices could be targeted for the watershed that is not drained by the Silver Lake Inlet, effectively reducing the watershed to lake area ration from 13:1 to approximately 5½:1.

   Besides enhancing the short circuiting of the Silver Lake Inlet, hydraulic dredging will improve boat access by increasing the lake's depth along the northern shoreline and reducing the densities of nuisance aquatic plants near the lake's inlet and outlet.

2. Benthic plant barriers, such as nylon screening, should be installed in the vicinity of private and public docks where small areas of nuisance aquatic weeds impair current uses in Silver Lake.

3. For large lake areas that are infested with nuisance stands of aquatic weeds, mechanical weed harvesting is recommended. Harvested material must be removed from the lake and disposed off away from any surface waters that drain to the lake.

4. Reevaluate nutrient inactivation and hypolimnetic aeration after implementing all possible agricultural best management practices.

Watershed Best Management Practices

1. The construction of a sedimentation basin within the Silver Lake Inlet should be further investigated. Preliminary evaluation indicates that a minimum size of 21 acres is necessary in order to remove an acceptable amount of total suspended solids and total phosphorus from the inlet stream. In conjunction with in-lake dredging, the water quality of Silver Lake is expected to significantly improve by reducing the suspended solid and nutrient loadings from the Silver Lake Inlet.

2. The Silver Lake Watershed Commission should develop erosion and sedimentation ordinances and stormwater runoff ordinances for the watershed.

3. The Silver Lake Watershed Commission should work closely with the County Soil and Water Conservation District, the Soil Conservation Service, and the Agricultural Stabilization and Conservation Service to prioritize specific parcels of land for implementation of agricultural best management practices. Priority should be based on benefit to water quality, cost of implementation, funds available, and participation interest of land owner. Low-cost activities which could be addressed immediately include stabilization of known eroding areas, keeping animals out of rivulets and streams, controlling fertilizer application dosage and timing to maximize infiltration and minimize runoff, and creating buffer areas between agricultural fields and streams.

4. The Silver Lake Watershed Commission should work closely with the County Health Department in order to locate and remediate failing septic systems.

5. The Silver Lake Watershed Commission should identify areas of streambank erosion and classify these areas as slight, moderate, or severe problems and implement stabilization procedures.

6. The Silver Lake Watershed Commission should identify areas of roadway erosion and classify these areas as slight, moderate, or severe problems and implement stabilization procedures.

Implementation

1. Application for federal funding through the EPA Clean Lakes Program and Nonpoint Source Program should be made. Additional funding sources may also be appropriate.

   EPA Clean Lakes Phase II grants provide 50 percent of the total project costs at the federal level, and the remaining 50 percent would require a local match.

   EPA non-point source program (Section 319 of the Federal Water Pollution Control Act) . Historically, the program has stressed agricultural non-point sources. County Soil and Water Conservation Districts have been active participants in this program.

   Several other programs are available to help defray the costs of implementing agricultural best management practices. The Agricultural Conservation Program available through the U.S. Department of Agriculture Soil Conservation Service is a cost-sharing program funding 75% of costs for a particular management practice up to $3,500 per year per farm. Several cost-sharing programs are available to individual land owners through the ASCS.

1.0 Introduction

1.1 Project Objectives

Silver Lake is a glacially formed, 825 acre lake located in the towns of Castile and Perry, Wyoming County, New York (Figure 1.1). Maximum lake depth is 40 feet (12.2 meters) and mean depth is 23.7 feet (7.2 meters). Silver Lake is similar in shape to the eleven Finger Lakes which lie to the east. It is situated with its 3 mile length running northeast to southwest, and is approximately one-half mile wide. There are eight inlets into the lake, the largest of which is Silver Lake Inlet, located at the northeast end of the lake near the outlet. Water level is controlled by dam at the outlet. Approximately 300 shorefront homes have been built along 75% of the shoreline. Many of these cottages are vacation homes used only in the summer. Wetland areas at the north and south ends of the lake are still largely undeveloped. Nearly seventy-one percent of the 10,987 acre Silver Lake watershed is used for agricultural activities.

Silver Lake is a multi-use water resource, providing potable water to six townships, water for agricultural use, and recreational opportunities for local residents and visitors. Public access is readily available via beach, road, and state boat launch sites. Silver Lake State Park, located at the southern end of the lake, is an undeveloped park used for recreation. Park visitors and lakeside cottage owners use the lake for swimming, boating, fishing, and aesthetic enjoyment.

Problems with Silver Lake water quality began to surface in the late 1960's as algal blooms became more frequent and intense, and the yearly crop of water plants (macrophytes) gradually increased. Taste and odor problems in the Village of Perry's drinking water, possibly associated with nuisance algal growth, were reported during August and September of 1987. Weed-choked areas and algal scums near shore have curtailed swimming and boating activities in recent years. Fecal bacterial contamination has necessitated the periodic closing of the public swimming beach by the Wyoming County Health Department.

Concern about deteriorating lake conditions prompted local residents to search for effective remedial action. In an attempt to control the growth of aquatic plants (primarily the tape grass *Valisneria*), the Village of Perry operated a weed harvester in an 80 acre area in the northeastern section of the lake. This operation was abandoned when the odor of decomposing cut weeds which had washed up on shore resulted in complaints by lakefront property owners.

Studies conducted throughout the 1970's and 80's have characterized Silver Lake water quality parameters, flow patterns, and watershed interactions. As a result, a wastewater plan was developed, sewer districts were formed, and sewers were

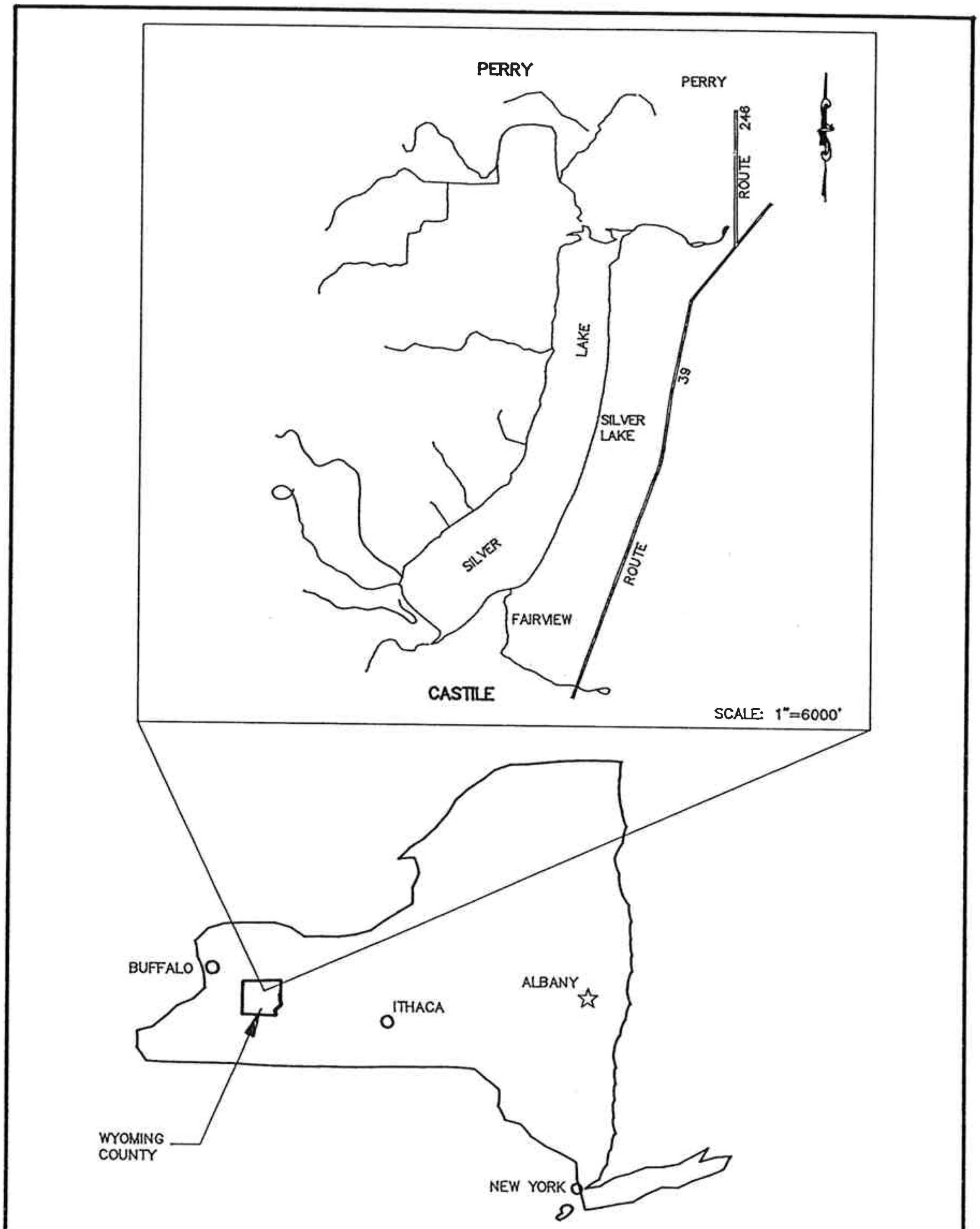

Figure 1.1	Location map of Silver Lake in Wyoming County, New York

installed during the 1980's. Most residences near the lake are now hooked into the sewer line. However, recent studies (Kishbaugh, 1988 and Tatakis, 1988) indicate that serious water quality problems still exist, and further remedial action is necessary.

The Silver Lake Watershed Commission, with representatives from the Village of Perry, Town of Perry, Village of Castile, Town of Castile, Village of Mount Morris, Village of Leroy, and the Silver Lake Cottage Owners Association, is developing a comprehensive water quality management plan based on a watershed hydrologic and nutrient budget, economic considerations, interpretation of limnological interactions indicated by historical data and an ongoing sampling program.

1.2 Project Objectives

This study was conducted as part of a New York State Department of Environmental Conservation grant to the Silver Lake Watershed Commission for a comprehensive management plan for Silver Lake and its watershed. This section of the management plan is a materials balance and watershed management action study, and was designed in accordance with procedures used in Phase I Diagnostic-Feasibility studies conducted under state and federal Clean Lakes Programs. A diagnostic-feasibility study is typically conducted in two stages. The diagnostic portion of the study is conducted to determine water quality conditions in the lake, identify existing problems, and determine the pollutant sources that are responsible for the observed problems. The feasibility aspect of the study involves the development of alternative restoration programs based on the results of the diagnostic study. These alternatives can include watershed management practices and in-lake restoration methods.

The primary objectives Phase I Diagnostic-Feasibility Study for Silver Lake were:

1. To identify the sources and magnitude of pollutants entering Silver Lake and recommend specific management controls,

2. To evaluate the potentially feasible control alternatives recommended in previous reports (Forest, 1984, Tatakis, 1988) and to evaluate any additional alternatives which may improve the condition of the lake and promote expanded recreational uses,

3. To develop and recommend a lake and watershed management program that is cost-effective, environmentally sound, and acceptable to the public,

4. To develop conceptual design information for the recommended management plan, and

5. To provide sufficient information for the implementation of the recommended lake and watershed management plan.

1.3 Project Funding

The Phase I Diagnostic-Feasibility Study of Silver Lake was funded by the New York Department of Environmental Conservation, Bureau of Construction Grants Administration to the Silver Lake Watershed Commission to develop a comprehensive management plan for Silver Lake and its watershed. The Silver Lake Watershed Commission contracted F.X. Browne Associates, Inc. to conduct the diagnostic-feasibility study of Silver Lake.

2.0 Lake and Watershed Characteristics

2.1 Lake Morphology

Silver Lake is a glacially formed, 825 acre lake located in the towns of Castile and Perry, Wyoming County, New York. Maximum lake depth is 40 feet (12.2 meters) and the mean depth is 24 feet (7.2 meters). Silver Lake is similar in shape to the eleven Finger Lakes which lie to the east. It is situated with its 3 mile length running northeast-southwest, and is approximately one-half mile wide. Lakefront development is most concentrated along the eastern shore in the Villages of Perry, Silver Lake, and Fairview. There is a large wetland at the southern end of the lake in Silver Lake State Park and a smaller wetland at the north end of the lake between Perry and West Perry along Silver Lake Inlet.

There are eight inlets into the lake, the largest of which is Silver Lake Inlet, located at the northeast end of the lake within approximately 500 feet of the outlet, where there is a controllable outlet dam. There are also many small inlet streams along the western and eastern shores which drain directly to the lake. Water exits Silver Lake either over the dam spillway or through a water supply line. Spillway water becomes Silver Lake Outlet which flows into the Genesee River and on into Lake Ontario. The water supply line carries water north past Lake LaGrange where it intersects with a water line carrying water from Lake LaGrange, and empties into Lake LeRoy in Genesee County (see Figure 2.1).

Physical characteristics of Silver Lake are listed in Table 2.1. Some values in Table 2.1 differ from previous reports as a result of information developed during the current study. A surface area of 825 acres was determined by planimetry using the 1972 USGS 7.5 minute series quadrangle and aerial photographs from the Agricultural Stabilization and Conservation Service. This value was more than surface areas reported in some of the earlier reports (Dunkleburg, 1971, 761 acres; Kisbaugh, NYS DEC, 1988, 812.4 acres) and less than that reported by Englert and Stewart, 1983, 865 acres). Seasonal changes in water level, shoreline visibility in aerial photos, and shoreline alteration affect the determination of lake area.

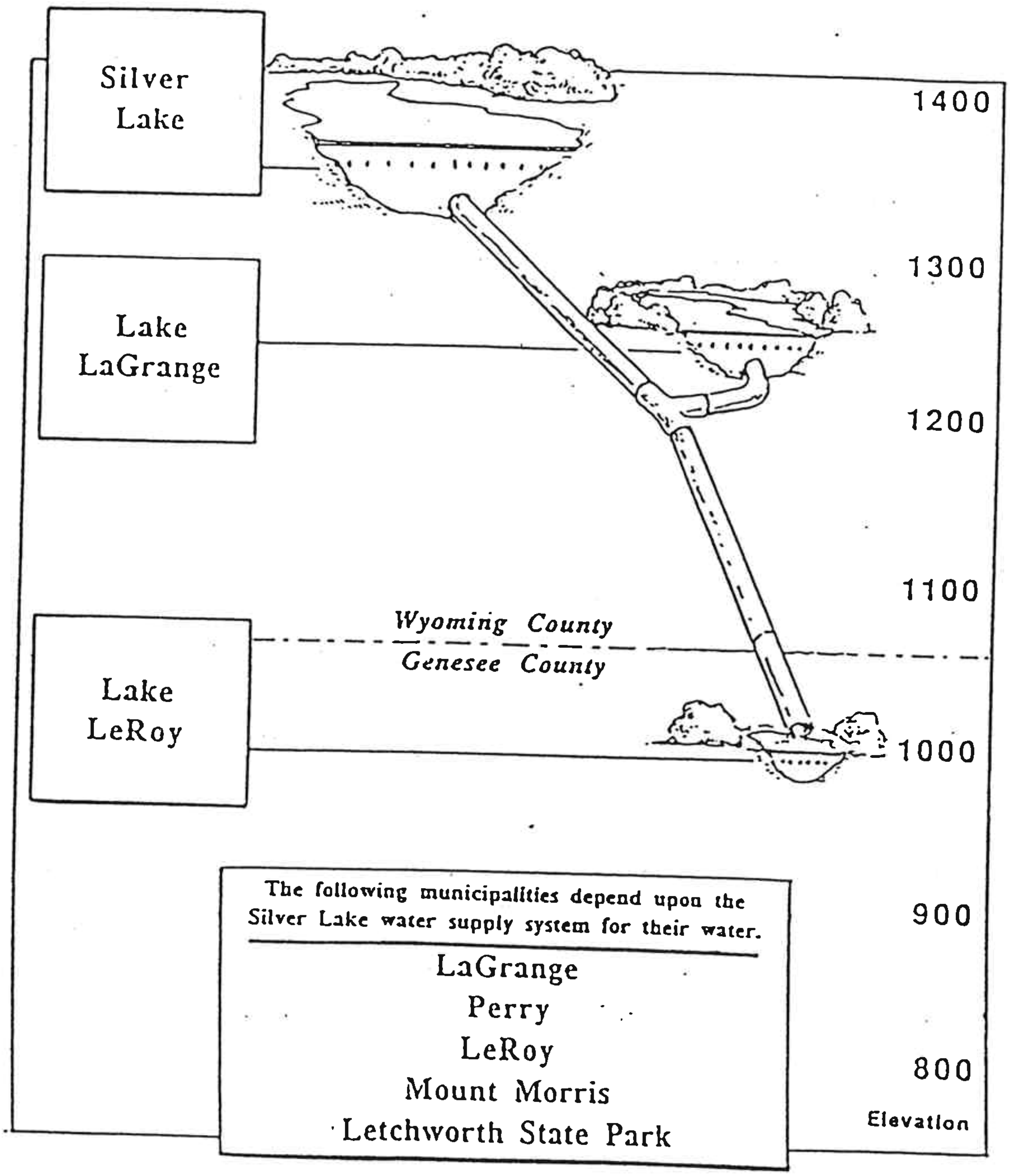

Figure 2.1	Schematic of Silver Lake Water Supply System

Table 2.1 Existing Physical Characteristics of Silver Lake	
Surface Area	825 acres (334 hectares)
Mean Depth	23.7 feet (7.2 meters)
Maximum Depth	40.0 feet (12.2 meters)
Lake Volume	6,375 million gallons (MG)
Mean Hydraulic Residence Time	448 days (1.2 years)
Drainage Basin Area	10,987 acres (4,446 hectares)
Mean Discharge	22.02 cubic feet per second (cfs)

The watershed boundaries were determined by visual topographic analysis, and were drawn on the Castile and Wyoming 7.5 minute USGS quadrangles. Boundary locations were checked against a watershed map prepared by the Wyoming County Soil and Water Conservation District and minor adjustments were made. The watershed area of 10,987 acres (including lake surface area) measured by planimetry was less than that reported by Kisbaugh, NYS DEC (12,920 acres); but very close to the area reported by Englert and Stewart, 1983 (land drainage of 10,600 acres plus 865 lake acres = 11,465 total acres). The ratio of drainage basin to lake surface area is 13 to 1.

2.2 Benefits and Uses of Silver Lake

2.2.1 Present Lake Uses

Silver Lake is a multi-use water resource. The lake provides potable water to the Village of Perry, the Town of Perry, the Town of Castile, the Villages of Mount Morris, Leicester, and LeRoy, and Letchworth State Park. Water from Silver Lake flows through an eleven-mile water supply line to Lake Leroy where it is used to augment supplies in Lake LeRoy in case of drought (Noble, et al., 1990). In addition, Silver Lake water is used for agricultural irrigation. Silver Lake provides recreational opportunities for local residents and visitors. Silver Lake State Park, located at the southern end of the lake, is an undeveloped park used for recreation. Silver Lake is the primary feature which has attracted summer visitors to the area for years and provides an ideal location for lakeside vacation cottages. Park visitors and cottage owners use the lake for swimming, boating, fishing, and aesthetic enjoyment.

2.2.2 Impairment of Uses

Recreational use of Silver Lake has been curtailed in recent years by nuisance blooms of algae and the growth of aquatic macrophytes. Problems with Silver Lake water quality began to surface in the late 1960's as algal blooms became more frequent and intense, and the yearly crop of water plants (macrophytes) gradually increased. In late August of 1969, an algal bloom made swimming undesirable and resulted in the premature emptying of campsites on the eastern shore (Dunkleberg, 1971). Taste and odor problems in the Village of Perry's drinking water, possibly associated with nuisance algal growth, were reported during August and September of 1987 (Tatakis, 1988). Organic matter originating from plant and algal growth may form potentially harmful substances (trihalomethanes) in the chlorination process during water treatment. Weed-choked areas and algal scums near shore have interfered with swimming and boating activities in recent years. During the summer there are also aesthetic problems and odor from plant growth and rotting debris on beach. All of the above problems are restricting lake use and limiting the recreational potential of the lake, which appears to be considerable.

2.3 Bathymetric Survey

A bathymetric survey was conducted by Phil Cowie, Superintendent of Public Works, Village of Perry, on May 18, 1989 using a boat and fathometer. The fathometer recorded both water depth and depth of depth of sediments along predetermined transects. Based on this survey, a bathymetric map of Silver Lake was constructed and is include in Appendix C. From this map, the volume of Silver Lake was determined by planimetry.

2.4 Watershed Characteristics

The drainage basin for Silver Lake has an area of 10,987 acres (4,446 hectares) and lies within the Appalachian Uplands physiographic province. The boundaries of the Silver Lake watershed and the locations of major tributaries are shown in Figure 2.2. The Appalachian Uplands is a plateau that is moderately dissected by streams. To the northwest of the Silver Lake watershed are ravines leading to Oatka Creek and the Wyoming Valley which are the result of postglacial stream cutting. Streams within the Silver Lake watershed do not occupy deep, narrow valleys, but flow at levels closer to the plateau summit. The Silver Lake watershed is part of Hydrologic Unit 04130002-160/010 which includes parts of Allegany, Wyoming, Livingston, and Genessee Counties. Discussions of the topography, geology, and soils in the following sections are largely based on information contained in the <u>Soil Survey of Wyoming County, New York</u> by Wulforst et al. (1974).

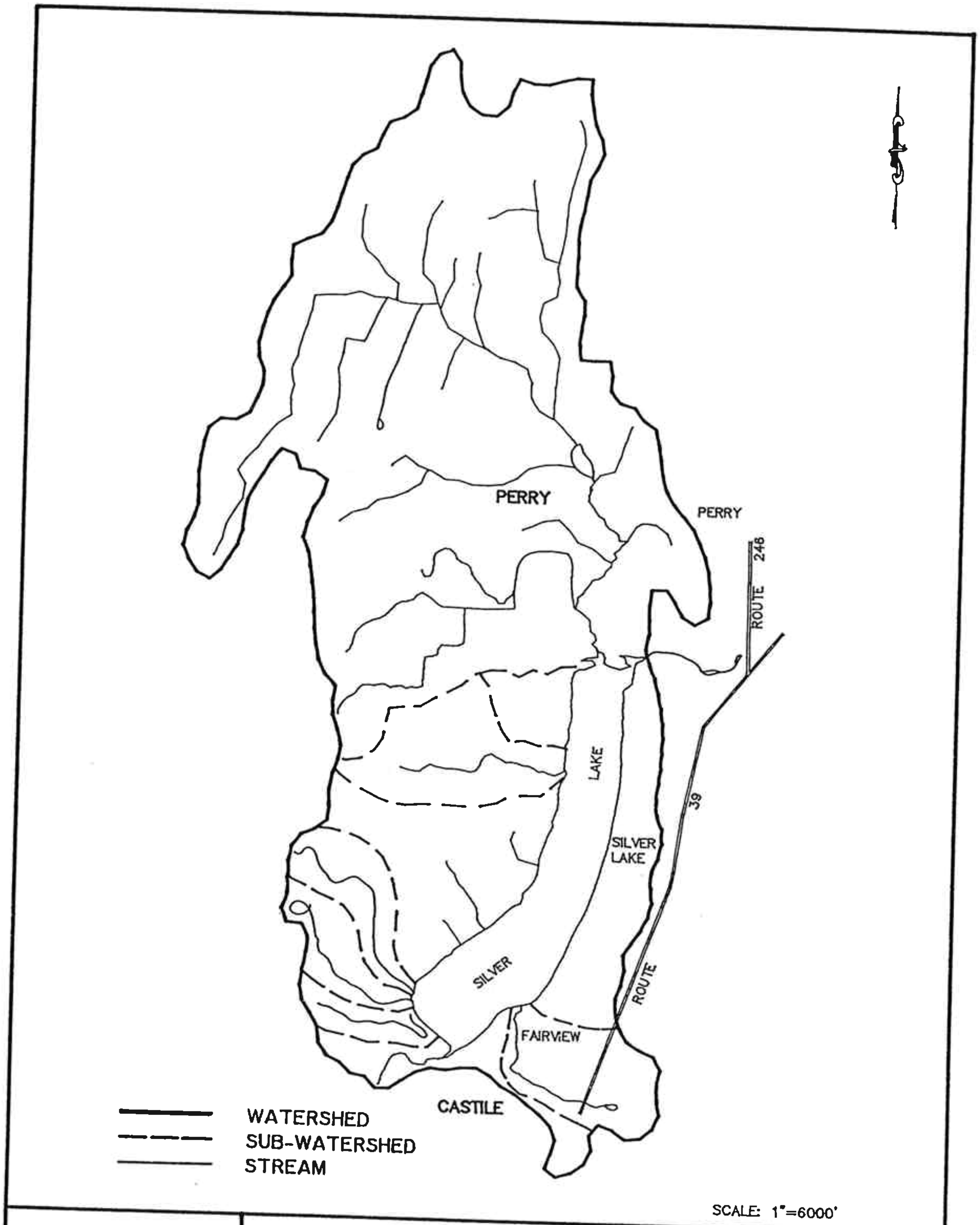

Figure 2.2 Silver Lake Watershed

2.4.1 Topography

The Silver Lake watershed lies in an area between valleys which consists of rolling uplands and flat-topped hills. Landforms are the result of the action of the ice that entirely covered the county during the last continental glaciation and to postglacial stream cutting. The long, narrow, configuration of many upland hills (drumlins) across the northeastern part of the county is the result of molding by glacial ice. The highest elevation in the watershed is 1,700 feet at Oak Hill, near Silver Lake State Park on the southwest edge of the watershed. The lowest elevation is 1,350 feet at the outlet of Silver Lake.

2.4.2 Geology

The Silver Lake watershed is underlain by bedrock of the Upper Devonian age. The stratum of bedrock is almost horizontal with a slight dip to the south of approximately 60 feet per mile. Major rock formations in the watershed are the Java Group, consisting of sandstone and shales, and the West Falls Group, made up of sandstone, shales, and some siltstone.

Wyoming County was completely covered by ice during the Wisconsin glacial stage of the Pleistocene epoch. Two substages can be recognized in Wyoming County: the Binghamton drift sheet and the Valley Heads drift sheet. Glacial till associated with the Valley Heads drift sheet is evident in the Silver Lake watershed. Till is an unsorted mixture of clay, silt, sand, and stones transported and deposited by glacial ice. The glacial till ranges in color from brown to gray with olive hues, reflecting the influence of material that came from glacial scouring of middle and upper Devonian rock strata. Glacial drift includes till, but also consists of the sorted and unsorted materials deposited by streams flowing from glaciers. Glacial drift in Wyoming County is variable in thickness. It is thick in drumlin-type landforms in the northeastern part of the county and is thin on many exposed slopes on the plateau.

2.4.3 Soils

The soil associations in the Silver Lake Waterside are illustrated in Figure 2.3. Most of the soils in the Silver Lake watershed are formed in glacial till, and most of the glacial till soils in the watershed belong to the Bath-Mardin association, with smaller areas of the Conesus-Lansing association and Lordstown-Tuller-Arnot association. Areas immediately north and south of Silver Lake belong to soils formed in glacial outwash kames, terraces, and flood plains. Most of this area belongs to the Halsey-Palms-Papakating association, except for a small section near Oak Hill which is part of the Howard-Chernango association.

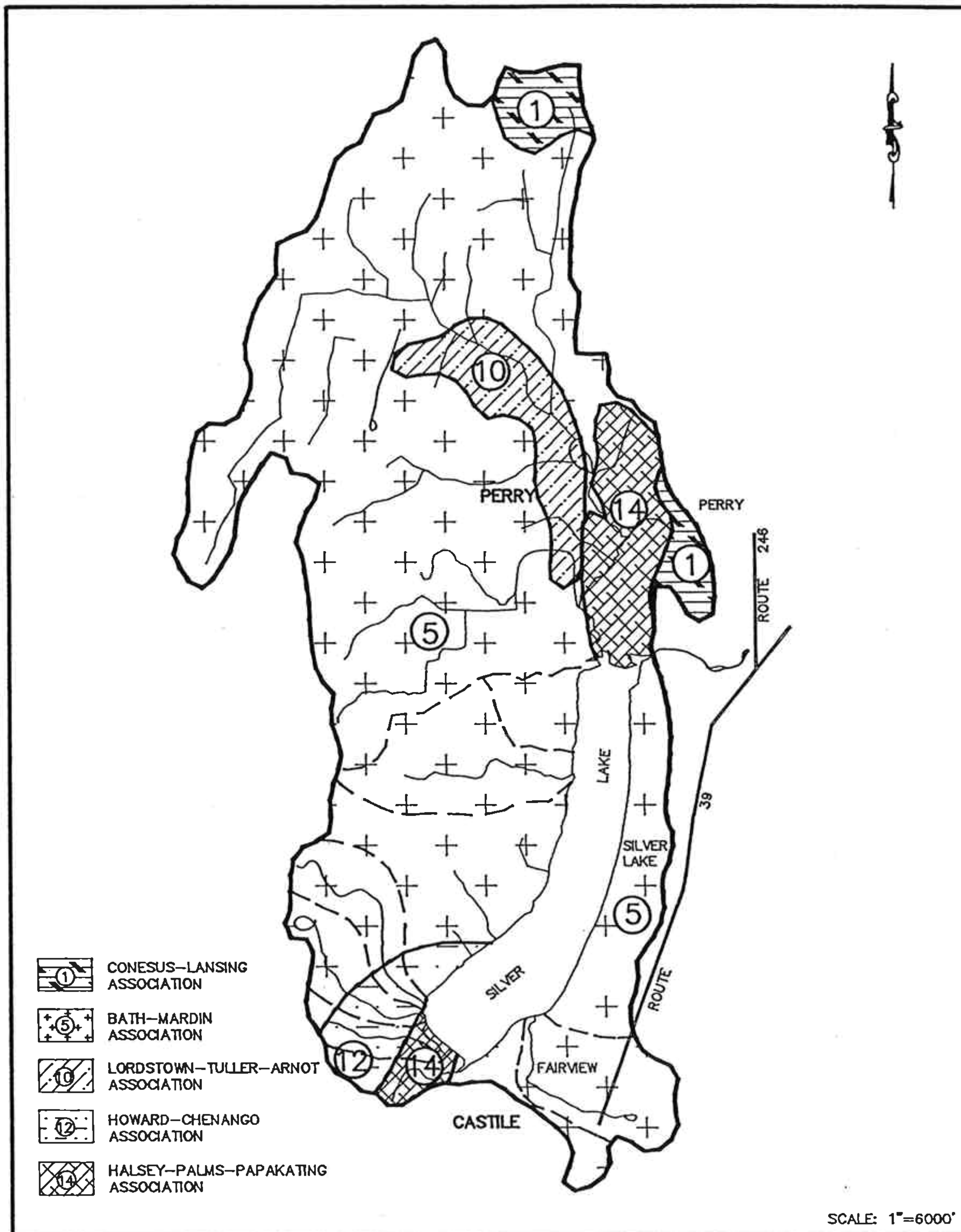

Figure 2.3	Soil Associations in the Silver Lake Watershed

The dominant soil association in the Silver Lake watershed is the Bath-Mardin association, formed in deep glacial till derived mainly from sandstone and shale. A typical soil pattern is shown in Figure 2.4 The soils are deep, well drained and moderately well drained, and have a medium-textured subsoil. This association is on undulating to rolling hilltops in the north-central and east-central sections of the county. The northern fringes of this association have drumlin-like landforms. The major soils of this association have a very low content of lime. Many flat fragments of sandstone are throughout the profile. They have a fragipan that restricts rooting and air and water movement. Bath soils make up about 35 percent of the association; Mardin soils, about 25 percent; and minor soils, the remaining 40 percent.

The well drained Bath soils are nearly level to steep and have convex slopes where water does not accumulate. They have a fragipan at a depth of 18 to 34 inches. The moderately well drained Mardin soils are intermingled with Bath soils. They are nearly level to moderately steep and have slopes where runoff is not rapid or where small amounts of water accumulate. They have a fragipan at a depth of 14 to 25 inches. The more extensive minor soils are the somewhat poorly drained Volusia soils that are on foot slopes and in areas where runoff is slow or water accumulates, and the poorly drained Ellery soils; also, the very poorly drained Alden soils that are in concave areas and depressions where large amounts of water accumulate. Other minor soils include Canaserage, Erie, Langford, Lordstown, and Valois soils, and various mixtures of soils that formed in alluvium along the narrow stream valleys that cross the association. Most areas of this association are cleared and used for cash crops and dairy farming. Some potatoes are grown. The response of crops to high levels of management is good. Most farms require some artificial drainage. Lime needs are high if legume crops are grown.

The next most common association in the Silver Lake watershed is the Halsey-Palms-Papakating association, formed on glacial outwash terraces and flood plains. The soils are deep, very poorly drained and poorly drained, contain a medium amount of lime, and have a moderately coarse textured to moderately fine textured mineral subsoil or an organic layer. This association is in depressional pockets of the higher valleys and includes mucky areas adjacent to Silver Lake. Wet soils are dominant, but mounds and bars of gravelly drier soils are common. Some areas of this association have been developed for wetland wildlife habitat and conservation areas. Few areas of this association can be drained enough to be used for any other purpose because of the lack of suitable outlets.

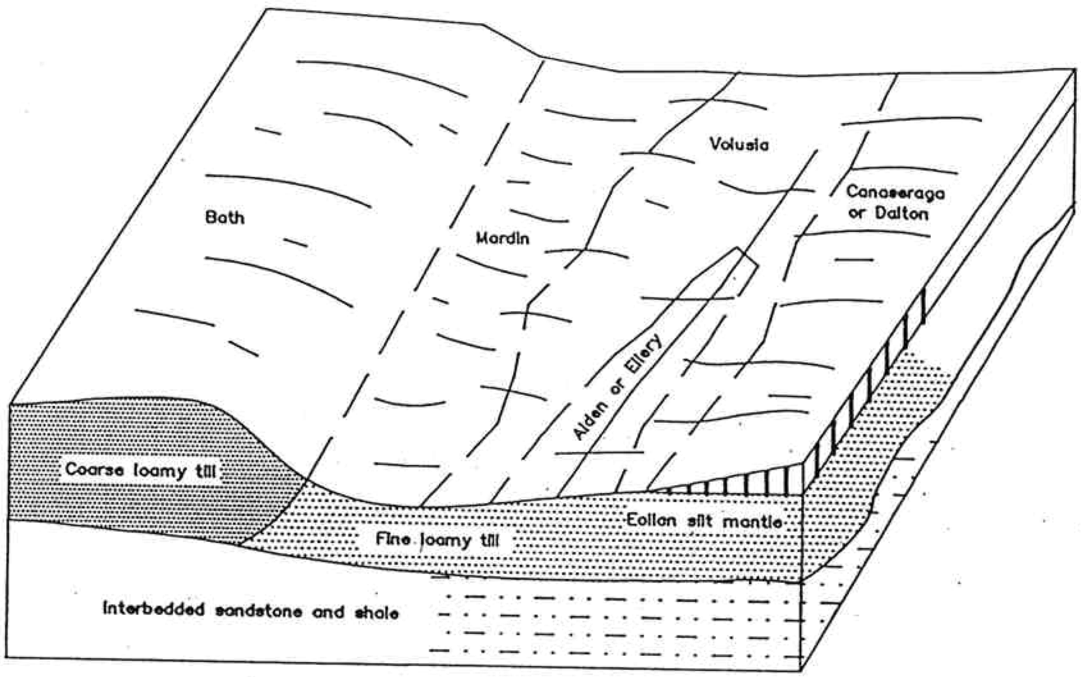

Figure 2.4	Typical pattern of soils in the Bath-Mardin Soil Association

Many soils in the Silver Lake watershed are in need of special management techniques to control erosion or deal with excess water. Conesus, Madrid, Bath, Mardin, Lordstown, and Fremont/Hornell soils on steeper slopes are subject to erosion, and need erosion control management techniques. Soils which exhibit wetness, poor drainage, and excess runoff include Mardin, Langford, Appleton, Volusia, Tuller, Halsey, Ellery, Sun, Lyons, Wayland, Wallkill, Alden, and Palms soils.

Almost all soils in the Silver Lake watershed are severely limited for use as septic tank absorption fields. The few soils in the watershed which have slight to moderate limitations for this use can exhibit seasonally high water tables or show potential hazard of pollution.

2.4.4 Groundwater

Throughout western New York, the concentration of dissolved solids in ground water increases with depth, and all water below some depth is too salty for most uses (Randall, 1979). In some parts of Wyoming County, such as the Dale Valley, salt is mined by pumping fresh water through brine wells to salt beds at depths of about 1,300 feet. Salt dissolves in the water and the resulting brine is forced back to the land surface under pressure.

Most of the Silver Lake watershed is underlain by till or by lacustrine very fine sand, silt, or clay, or by bedrock. Small patches of unconsolidated aquifers less than 0.5 square miles may underlie the area. Dug wells in till or lacustrine deposits may be capable of yielding one to five gallons per minute (Miller, 1988, and Kammerer and Hobba, 1986). The bedrock that underlies Wyoming County to depths of several hundred feet is arranged in nearly horizontal layers and is generally capable of yielding only small amounts of water (Randall, 1979). It is not expected that groundwater in these small aquifers contribute significantly to Silver Lake. However, there is significant concern about the quality of water in these small aquifers, for groundwater from some wells in the Perry and Castile area contain very high nitrate levels which exceed the drinking water standard of 10 milligrams per liter (Hurd, 1989). Two of the high nitrate wells participating in this study are within the Silver Lake watershed.

A very large unconfined aquifer of sand and gravel with high transmissivity and a saturated thickness of greater than ten feet underlies the southwestern section of the watershed, adjacent to Silver Lake, and continues southwestward, through Silver Springs and Castile to Eagle, Freedom, and Franklinville. This aquifer has potential well yields of greater than 100 gallons per minute (Miller, 1988). This type of aquifer is recharged rapidly by water that infiltrates through the permeable overlying material to the zone of saturation. Because Silver Lake is immediately adjacent to this aquifer, groundwater and lake water are free to mix. USGS water quality data taken in 1964 from wells in this aquifer show moderate hardness levels (130 to 180 milligrams per liter as calcium carbonate), pH values between 7.5 and 8.1, low nitrate levels (0.05 milligrams per liter), and moderate iron content (0.5 to 2.9 milligrams per liter).

2.4.5 Land Use

Land use in the Silver Lake watershed is primarily agricultural. Most of the agricultural operations are related to the dairy industry. Wyoming County is the largest producer of milk in New York State, with the 1989 milk production estimated at 569 pounds for an estimated value of 72 million dollars (Noble et al., 1990). Based on data from Englert and Stewart (1971), land uses is summarized in Table 2.2. Using the percentages listed Table 2.2 and the Silver Lake watershed area (10,987 acres), land use areas were determined and are included in Table 2.2.

Table 2.2
Land Use in the Silver Lake Watershed

Land Use	Percent in 1971*	Area (in acres)
Agriculture (active)	64.8	7,119
Agriculture (inactive)	5.9	648
Forest	13.3	1,461
Outdoor Recreation	5.6	615
Residential	2.8	308
Commercial	0.1	11
Lake	7.5	825

* Calculated from values in Englert and Stewart, 1983.

2.5 Population and Socio-Economic Structure

Silver Lake provides recreational opportunities for residents of Perry and Castile (combined population approximately 8,750), and other residents in Wyoming County and nearby Livingston and Genesee Counties. Some of the lakeside cottages are owned by people in New York and Pennsylvania who travel quite a distance to use Silver Lake in the summertime. Public access is readily available at Silver Lake State Park and at public boat launch sites.

All demographic data presented in this section was supplied by the Wyoming County Department of Economic Development. Resource material was prepared by the Center for Governmental Research Inc., using U.S. Bureau of Census, New York State Department of Commerce, New York State Department of Labor, and Genesee/Finger Lakes Regional Planning Council data as sources.

Population data for Perry Town, Castile Town, and Wyoming County is presented in Table 2.3. Wyoming County has a steadily increasing rate of population growth, with a 5.9 percent increase between 1970 and 1980, a 6.2 percent increase between 1980 and 1990, and a projected increase of 8.1 percent between 1990 and 2000. Perry Town has the highest population density in Wyoming County, with 149 people per square mile (1980 Census). There are 74 people per square mile in Castile Town and 67 people per square mile in Wyoming County as a whole.

Table 2.3
Population Data for the Towns of Perry, Castile, and Wyoming County, New York

Year	1980	1988	1990	2000
Population				
Perry	5,437	5,350	5,700	6,150
Castile	2,865	3,030	3,050	3,300
Wyoming County	39,895	41,900	42,379	45,795

Figure 2.5 presents the age distribution of the inhabitants of Wyoming County in 1980 and 1990. Median incomes in 1980 were $14,276 for Perry, $15,556 for Castile, and $16,019 for Wyoming County. Between 1979 and 1987, per capita incomes rose 56 percent in Perry, 62 percent in Castile, and 60 percent in Wyoming County.

Occupational data for Oswego County is presented in Figure 2.6. Data from the 1980 census indicate that the majority of workers in Wyoming County are employed in manufacturing, services, retail trade, and agriculture.

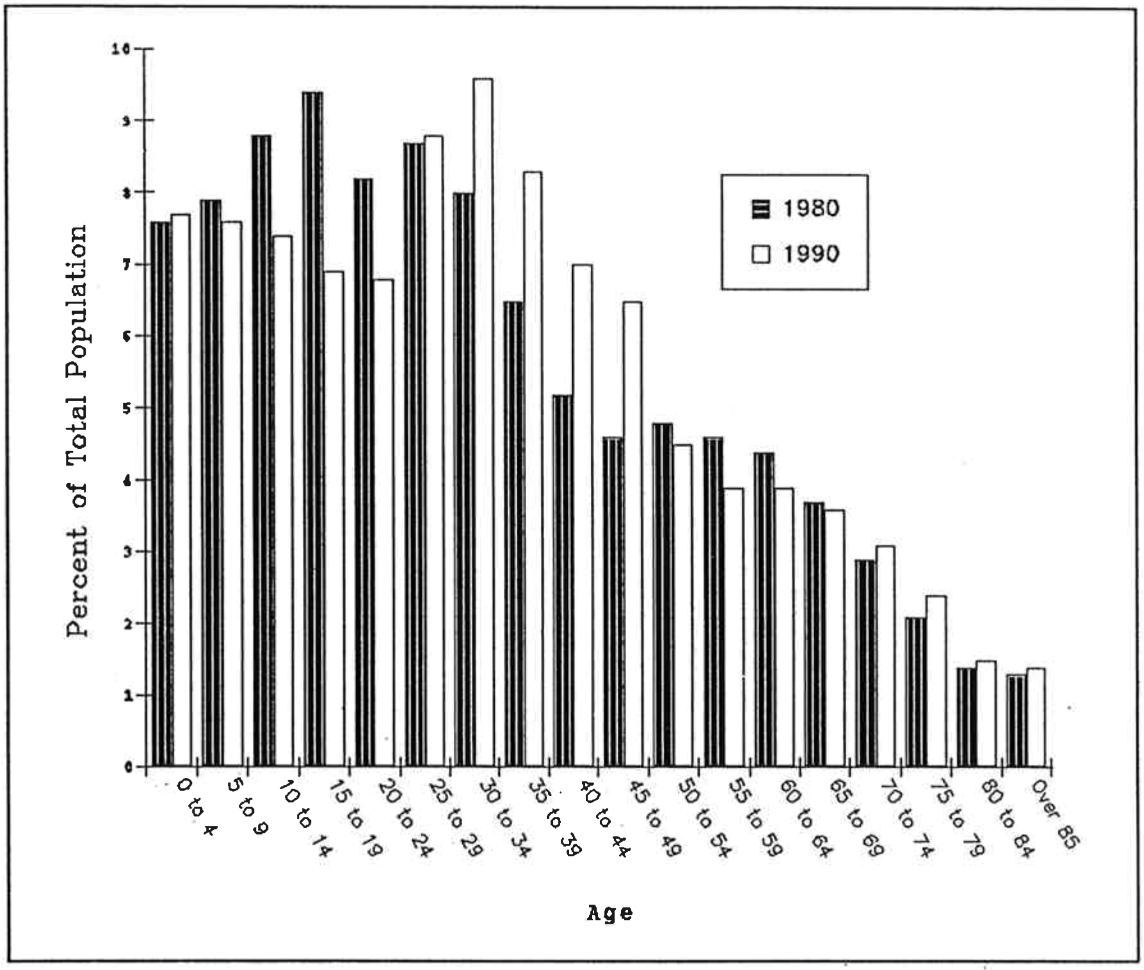

Figure 2.5 Age Distribution of Wyoming County Residents in 1980 and 1990.

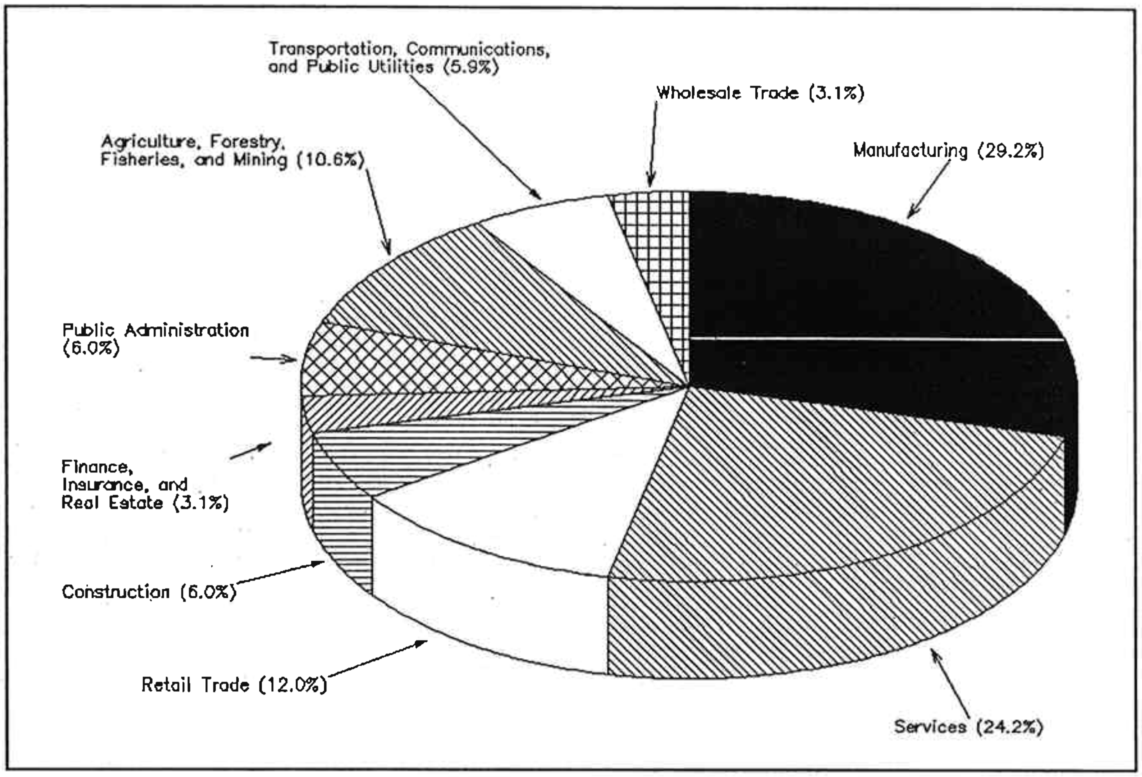

Figure 2.6 Occupation of Wyoming County Residents, By Industry

2.6 History

The first towns to be settled in Wyoming County were the villages of Wyoming and Warsaw in the early 1800's. At that time nearly all of the county was wooded with open stands of white pine, hard maple, beech, basswood, ash, hickory, and oak. The wetter areas also had red maple and American elm. Between 1800 and 1850 people moved into the area from primarily from New England and eastern New York. Wyoming County was formed in 1841 from lands west of the Genessee river which were originally part of the Holland Land Grant. The population has risen slowly and steadily since the mid-1800's except for a period between World War I and 1935, when the number of inhabitants decreased slightly (Wulforst, 1974).

3.0 Lake Water Quality

Water quality is determined by a complex system of chemical, physical and biological interactions. Lake water quality is dependent upon the interactions occurring within the lake itself, the chemical nature of soils and rocks within the watershed, direct discharges into tributaries and the lake, and upon land use and land management in the drainage basin upstream of the lake. A glossary of lake and watershed terms is provided in Appendix A and a Primer on Lake Ecology is provided in Appendix B as an aid to understanding the following discussion.

All lakes undergo a natural ageing process during which two types of long-term changes occur: (1) The lake gradually fills with soil from upstream and surrounding land areas; and (2) the additional materials carried to the lake area usually stimulate increased plant production. The lake fills with both sediments and the remains of plants and animals. The number of dead plants and animals increases as the production of organisms increases. These processes usually cause lakes to become shallower. The lake gradually tends to fill completely. As this process, called succession, continues, the types of animals and plants also begin to change. Desirable game fish, such as bass, pike and pan fish may be replaced by rough species such as carp, suckers, and bullheads. Rough fish are better adapted to live in a lake which is relatively old on the time scale of succession. Eventually the lake or pond becomes a bog or swamp. In turn the swamp tends to continue to fill in and, if conditions are right, a forest becomes established.

Depending on natural environmental conditions, the process of natural succession may take hundreds or even thousands of years. The actions of man, however, can considerably accelerate this ageing process. It can be said, therefore, that lakes have both a chronological age and an ecological age. The chronological age is simply the number of years a lake has existed. The ecological age, on the other hand, is a measure of the physical, chemical, and biological condition of a lake.

Relative to ecological age, most lakes can be classified as being oligotrophic, mesotrophic, or eutrophic. An oligotrophic lake is an ecologically "young" lake that usually has low nutrient levels and low plant and animal productivity. A mesotrophic lake can be considered to be a "middle-aged" lake that contains average amounts of nutrients and has average plant and animal productivity. A eutrophic ("old") lake is one that has a high nutrient content and high plant and animal productivity. During the spring, summer, and fall, a eutrophic lake is likely to experience algal blooms or excessive growth of aquatic plants.

3.1 Chemical and Biological Interactions

Nutrients (nitrogen and phosphorus) and suspended solids enter Silver Lake from upstream tributaries, direct runoff, and from storm sewers that collect runoff from the urban areas adjacent to the lake. As water enters the lake its velocity decreases, resulting in sedimentation of suspended solids. A portion of the phosphorus entering the lake is bound to sediment particles (referred to as particulate phosphorus), and this portion gradually settles. Very small sediment particles, such as clays, resist sedimentation and may pass through the lake without settling.

Phytoplankton (algae) and rooted plants adsorb available nutrients and convert them into plant material. The most readily available form of phosphorus, used by plants and algae is dissolved orthophosphate. Dissolved orthophosphate is analytically determined as dissolved reactive phosphorus (DRP), which can also include hydrolyzable particulate and organic phosphorus. 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. Concentrations of dissolved orthophosphate and inorganic nitrogen are usually low in lakes since they are quickly taken up by plants and algae.

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, resulting 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 larger organic waste products of the food web organisms, together with their remains after death, comprise detritus, which settles to the bottom of the lake and becomes part of the sediment. Bacteria and fungi (decomposers) utilize the energy in this material, converting organic molecules 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

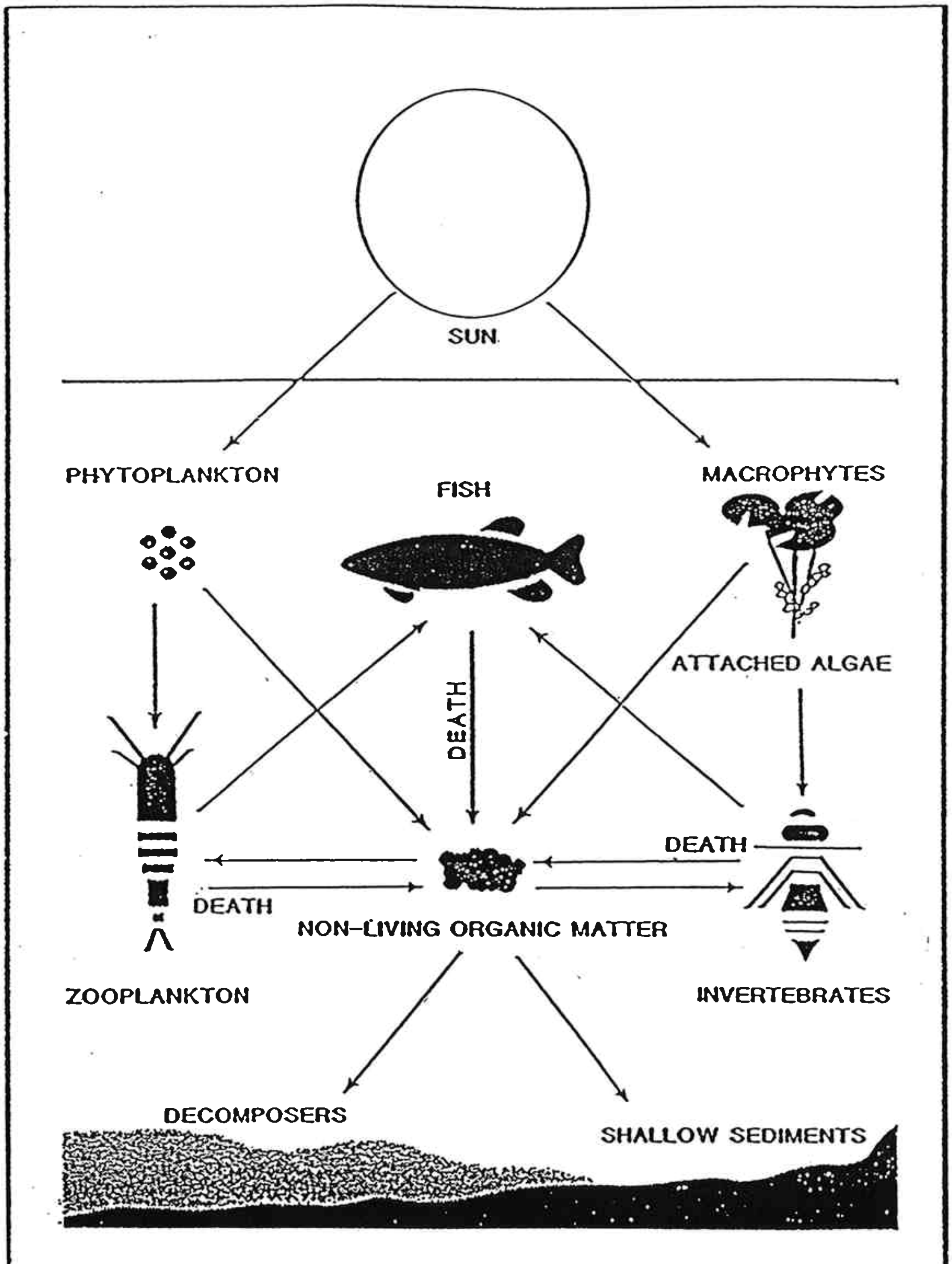

Figure 3.1	The Aquatic Food Web

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 Silver Lake Monitoring Program

A sampling program was designed to assess existing water quality in Silver Lake. Samples for water quality analyses were collected from two stations within the lake, one from the middle of the lake and one from the northern portion of the lake (Figure 3.2).

Water samples for chemical and biological analyses were collected from the lake on eight different occasions between January, 1990 and April, 1991; once in January 1990, April 1990, June 1990, July 1990, September 1990, November 1990, January 1991, and April 1991. Temperature and dissolved oxygen profiles and Secchi disk transparency were measured in the field on each sampling date. Temperature and dissolved oxygen readings were taken at one meter or half-meter intervals from the water surface to the bottom at each lake station throughout the sampling period.

Water samples for chlorophyll a and algae (phytoplankton) analysis were composited from the top and middle of the water column. All other chemical parameters were analyzed in samples taken at three depths (top, middle, and bottom) at each station. Samples for water quality analyses were stored in a cooler at 4°C, and transported to the laboratory for analysis. Water quality parameters analyzed in the laboratory included pH, alkalinity, total suspended solids, total phosphorus, dissolved reactive phosphorus, nitrate + nitrite-nitrogen, ammonia-nitrogen, total Kjeldahl nitrogen, specific conductivity, chlorophyll a, and phytoplankton.

Samples for phytoplankton analyses were preserved in the field with 7.0 mL of Lugol's solution per liter. Another 3 mL of Lugol's solution was added before storage in a refrigerator. Algal cells were identified and counted using a Sedgewick-Rafter counting chamber and a microscope equipped with a Whipple Grid.

Personnel from F. X. Browne Associates, Inc. and staff at SUNY College of Environmental Science and Forestry at Syracuse were responsible for collection and analyses of lake samples. Complete results of the chemical analyses performed are included in Appendix D, while complete phytoplankton results are included in Appendix E.

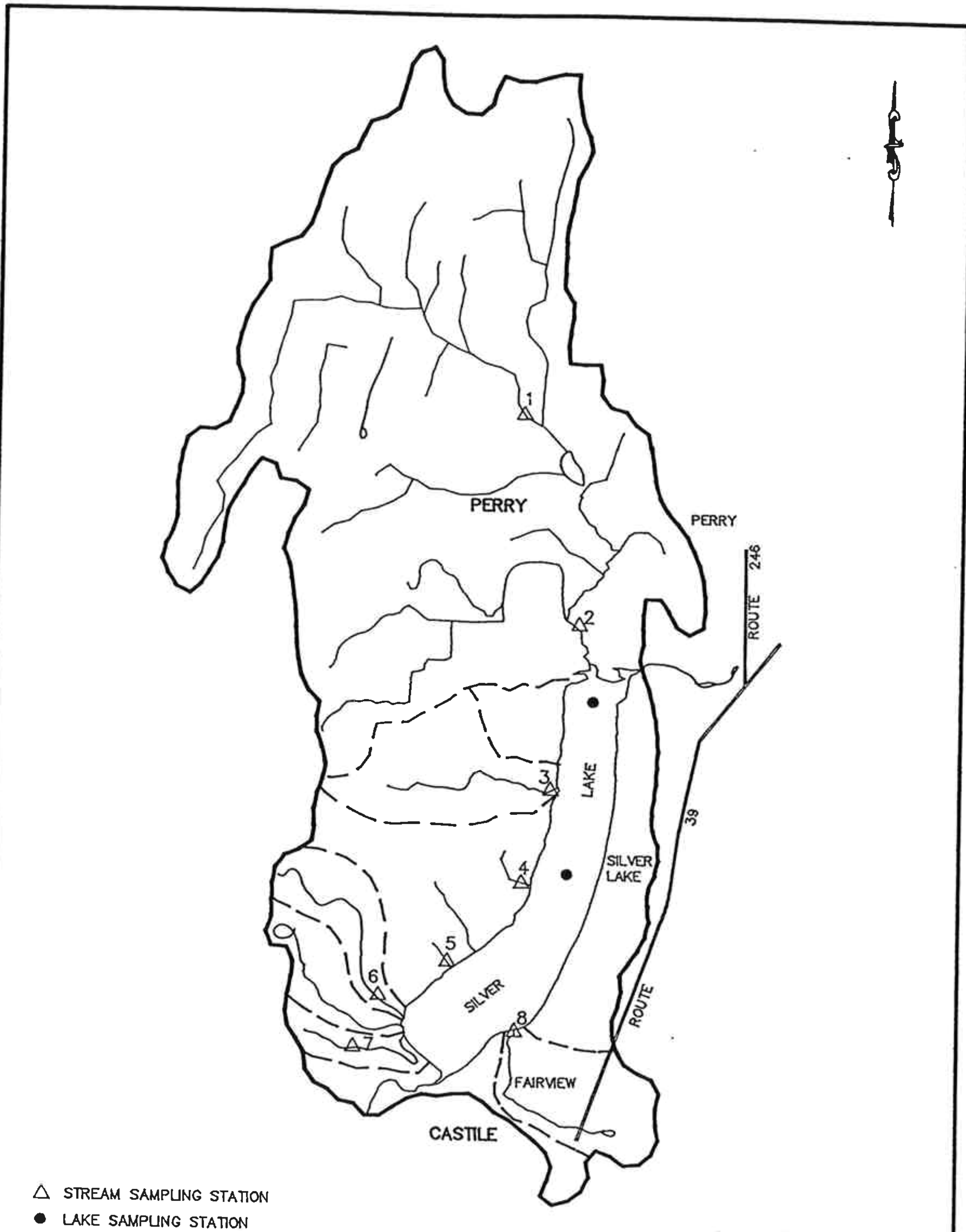

Figure 3.2	Water Quality sampling locations for Silver Lake

Sediment samples were collected with a KB 2-inch diameter core sampler on June 20, 1990 and from two locations by personnel from F. X. Browne Associates. Sediment samples were composited and analyzed for percent solids, percent volatile solids, total nitrogen and total phosphorous. Interstitial water samples were also collected with the KB corer on June 20, 1990 and September 19, 1990 and analyzed for soluble orthophosphorus and ammonia. Results from the sediment sampling program are included in Appendix F.

3.3 Silver Lake Water Quality Data

Results of chemical and biological analyses of Silver Lake are described in the following sections. The information presented in these sections will tell us much about the overall condition of Silver Lake.

3.3.1 Temperature and Dissolved Oxygen

Usually in late spring or the beginning of summer, 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 temperature differences become greater between these two water layers, the resistance to mixing will also increase. Under these circumstances, the epilimnion is usually oxygen rich due to photosynthesis and direct inputs from the atmosphere, while the hypolimnion may become depleted of oxygen due to the decomposition of organic matter.

Temperature and dissolved oxygen profiles were measured at both lake stations on each of the sampling dates. At Stations 1 and 2, temperature and dissolved oxygen profiles for selected sampling dates are shown in Figures 3.3 through 3.6. In Silver Lake, the lake's water column was completely mixed in April and September, 1990. A completely mixed water column is noted when surface, mid-depth, and bottom waters are similar in temperature as shown in Figures 3.3 and 3.5. Lake mixing occurs when differences between surface and bottom water temperatures are small, thereby allowing surface waters to be mixed with bottom waters by the wind. Under these circumstances, the bottom waters usually contain higher dissolved oxygen levels than during lake stratification (thermal stratification). As shown in Figures 3.4 and 3.6, the highest dissolved oxygen concentrations for bottom waters in Silver Lake occurred in April and September, 1990.

In January and July, 1990, Silver Lake was thermally stratified at both stations as shown in Figures 3.3 and 3.5. When a lake becomes thermally stratified, oxygen-rich surface waters are less likely to mix with the bottom waters. As presented Figures 3.4 and 3.6, Silver Lake recorded the lowest dissolved oxygen levels in January and July, 1990, where dissolved oxygen levels were below 1 milligram per liter (mg/L) at depths ranging from 5 to 11 meters.

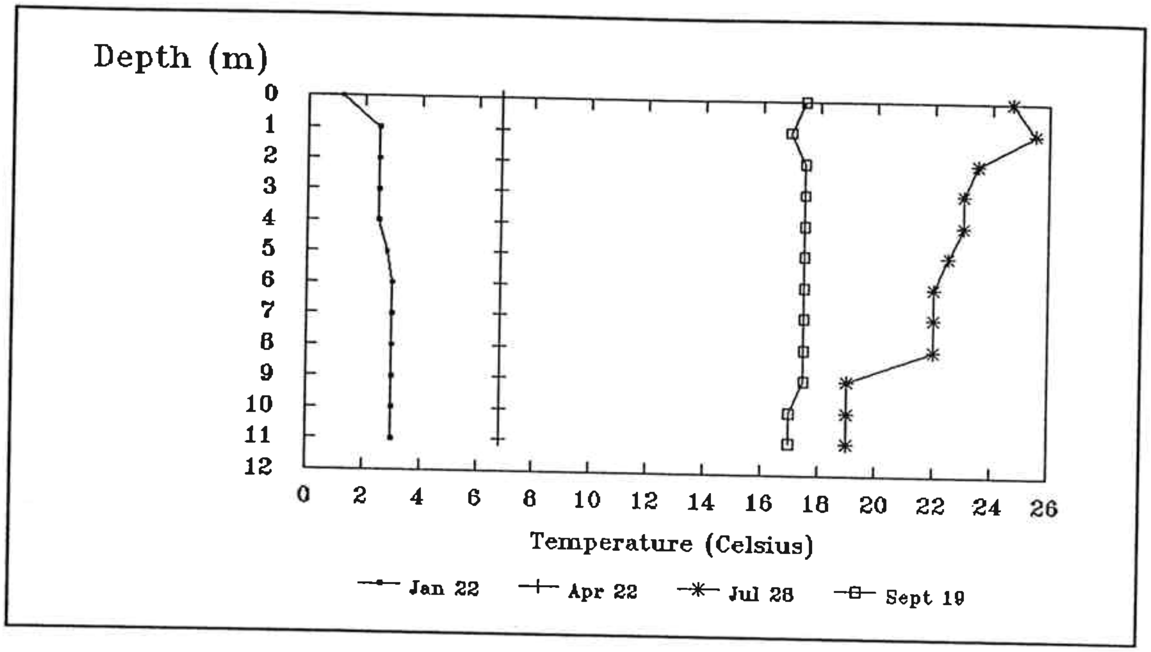

Figure 3.3 Temperature profiles at Station 1

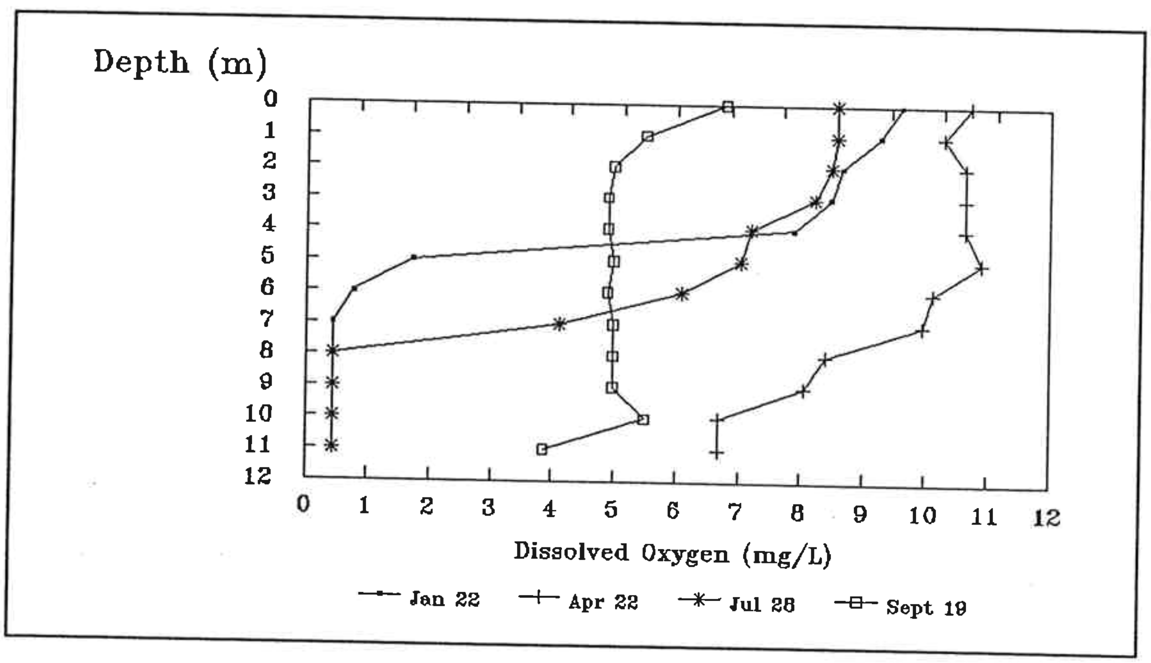

Figure 3.4 Dissolved oxygen profiles at Station 1

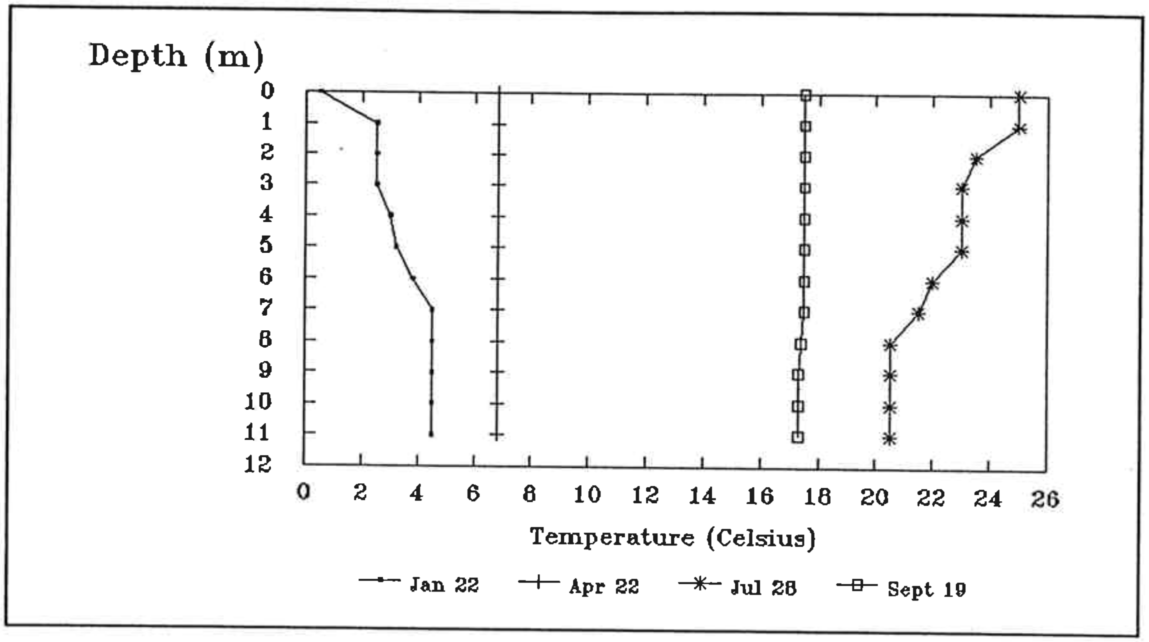

Figure 3.5 Temperature profiles at Station 2

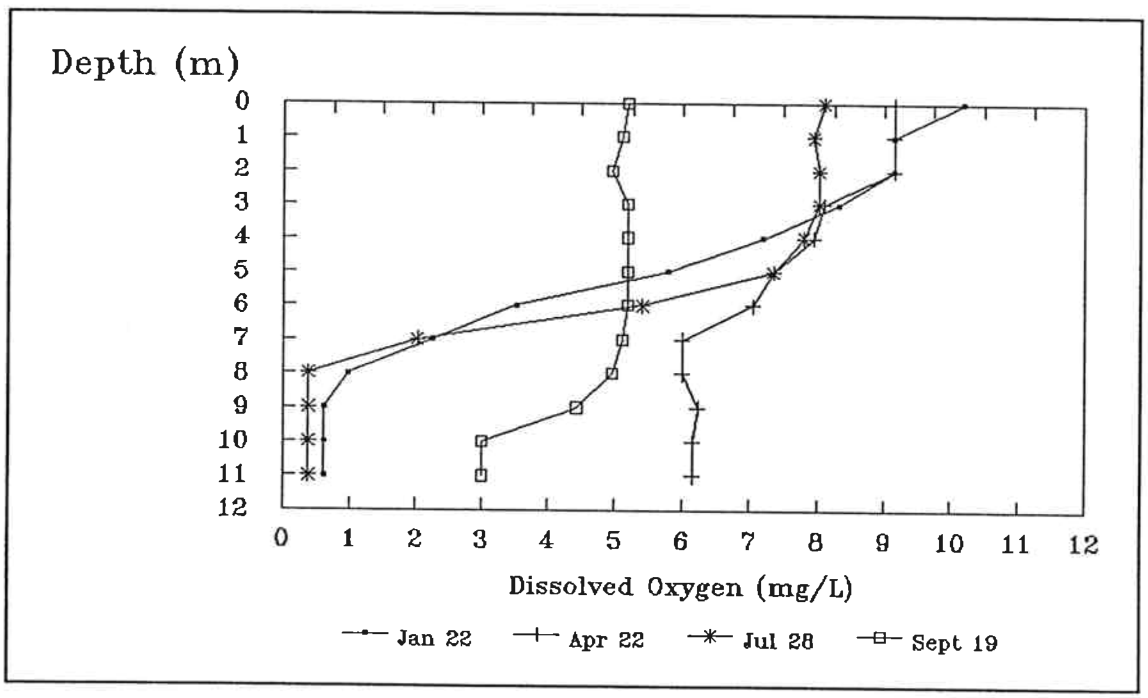

Figure 3.6 Dissolved oxygen profiles at Station 2

Contours showing the distribution of temperature from the lake surface to the bottom at Station 1 throughout the sampling period is shown in Figure 3.7. Horizontal lines in these figures indicate separation of water layers during periods of stratification. Vertical lines indicate uniform conditions throughout the water column, and mixing during these periods is more likely. To visualize conditions from the top of the lake to the bottom on any given day, choose a spot along the horizontal axis. Follow a straight vertical line and note changes in temperature or dissolved oxygen as you descend through the water column. It can be seen in this figure that the bottom waters of Silver Lake were essentially without oxygen during January and February 1990 and from June through mid-September 1990.

Game fish usually require oxygen concentrations above 5 milligrams per liter, although warm water fish often survive at lower levels. The minimum daily average concentration which can support warm water fish is 3.0 milligrams per liter, but the 30 day average should be above 5.5 milligrams per liter (Thomann and Mueller, 1987). Since dissolved oxygen in most of the water column remained at 5 milligrams per liter or above throughout the year, there is little stress on the fish due to low oxygen.

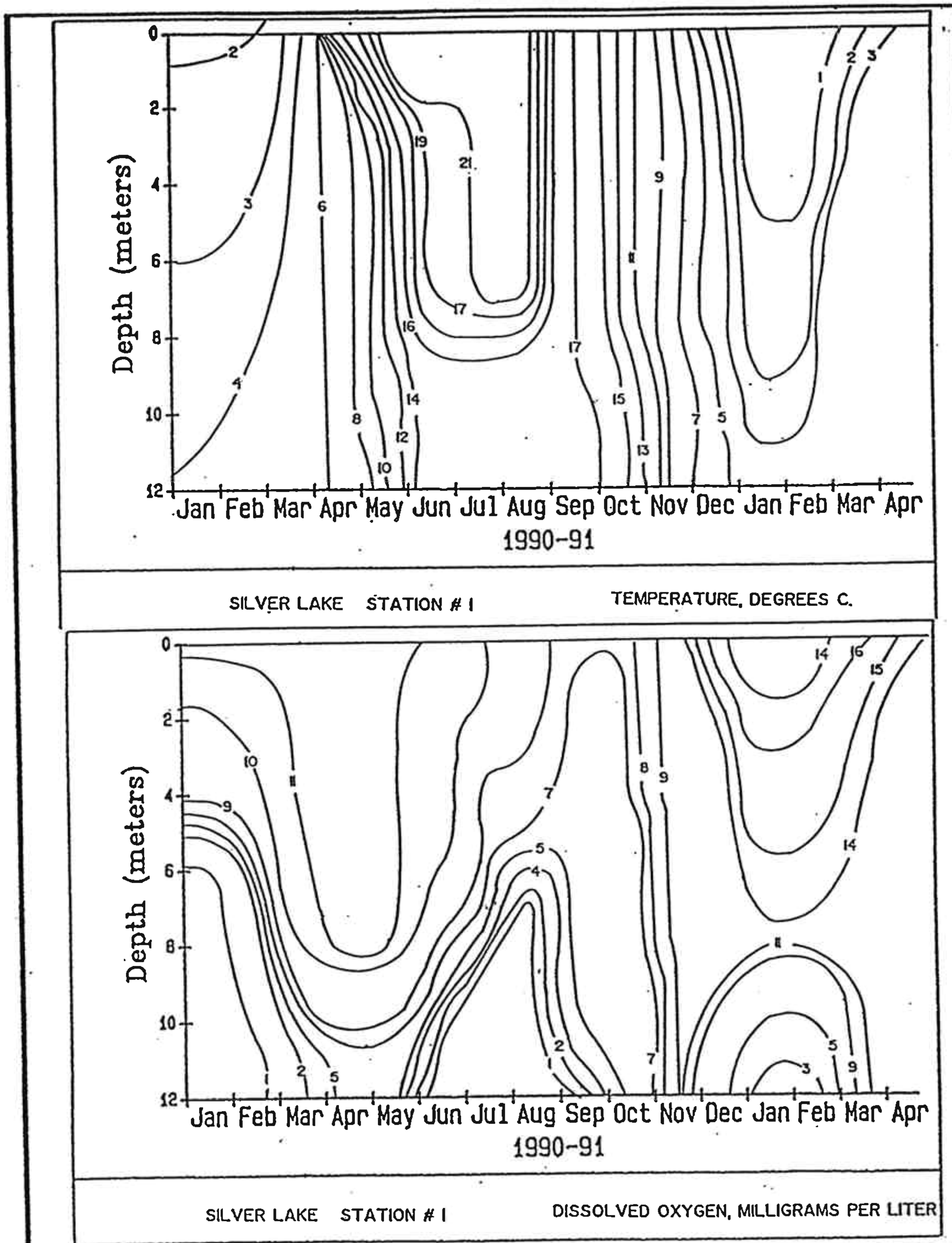

Figure 3.7	Temperature and dissolved oxygen isopleths at Station 1 in Silver Lake

3.3.2 Alkalinity, pH and Specific Conductivity

The pH and alkalinity of water are interrelated. The intensity of the acid and base reactions in water is usually expressed as pH, which is the negative logarithm of the hydrogen ion concentration. The hydrogen ion concentration in water is determined by a number of complex interactions, and the pH observed is an overall measure of the intensity of the various acid/base interactions which are occurring. The pH of water ranges from 1 to 14 standard units. A pH of 7 is neutral, while pH values less than 7 are acidic and pH values greater than 7 are basic. Since pH is expressed on a logarithmic scale, each 1 unit change in pH represents a ten-fold increase or decrease in hydrogen ion concentration. Therefore, a pH of 6 would be 10 times more acidic than a pH of 7 and 100 times more acidic than a pH of 8. The pH of normal rainwater (containing no pollutants) is about 5.0 to 5.6. As the rainwater travels over and through rocks and soil, chemical reactions with minerals affect the pH and buffering capacity of the water. The pH of water is important because most chemical and biological reactions are controlled or affected by pH.

Alkalinity is a measure of buffer capacity and provides an indication of the capacity of water to neutralize acids. The salts of weak acids, such as bicarbonates, carbonates, borates, silicates and phosphates, are the major source of alkalinity in most waters. In most cases, the bicarbonate ion represents the major form of alkalinity in natural waters at neutral pH levels.

In lake ecosystems, interactions between pH and alkalinity occur when phytoplankton use carbon dioxide in their photosynthetic activity. The pH of the water increases as dissolved carbon dioxide in the water column is used as a carbon source for algal growth. As carbon dioxide is removed, calcium carbonate precipitates to maintain chemical equilibrium. Calcium carbonate will dissolve when pH decreases to maintain carbon dioxide and bicarbonate concentrations in the water column. As a result of the above interactions, the carbonate system is one of the most important factors affecting the composition of natural waters.

In Silver Lake, alkalinity and pH concentrations were quite similar at both Stations 1 and 2. The average pH and alkalinity concentrations for surface and bottom waters at Stations 1 and 2 are shown in Table 3.1. For both Stations 1 and 2, the average pH concentrations were approximately 8.00 standard units for surface and bottom waters. For most temperate lakes, pH concentrations typically range from 6.0 to 9.0 standard units. At Stations 1 and 2, the average alkalinity concentrations were approximately 105 mg/L as calcium carbonate for both surface and bottom waters. Alkalinity concentrations at these lake stations may be classified as moderate, thereby providing a sufficient buffering capacity to neutralize acidic inputs, such as "acid rain".

Table 3.1
Average pH and Alkalinity Concentrations plus Specific Conductance Measurements at Stations 1 and 2

Station No.	Sample Depth	pH (Standard Units)	Specific Conductance (micromhos/cm)	Alkalinity (mg/L as $CaCO_3$)
1	Surface	8.00	337.5	109.91
	Bottom	7.94	339.0	107.37
2	Surface	8.02	333.8	103.82
	Bottom	7.97	341.7	107.97

Specific conductance or specific conductivity is the ability of water to convey an electric current. Specific conductivity is directly related to the ionic strength of the water sample. Ionic strength is defined as the sum of all ions or compounds that carry a negative or positive charge. Some examples of charged ions are calcium, magnesium, sodium, potassium, iron, carbonate, bicarbonate, nitrate, sulfate and chloride. The specific conductivity values for surface and bottom waters at Stations 1 and 2 are presented in Table 3.1. For both stations, the specific conductivities were quite similar with bottom waters recording slightly higher values than surface waters.

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, such as algae, and inorganic material, including soil particles and clay minerals.

The total suspended solid concentrations for surface and bottom waters at Stations 1 and 2 are presented in Table 3.2. For surface waters in Silver Lake, the mean total suspended solid concentrations at Stations 1 and 2 were 1.48 and 2.36 mg/L, respectively. For bottom waters, the mean total suspended solid concentrations at Stations 1 and 2 were 1.59 and 2.79 mg/L.

3.3.4 Lake 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 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 disk 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.

Secchi disk transparency or lake transparency for both Stations 1 and 2 are shown in Table 3.2. Lake transparency in Silver Lake ranged from 4.9 feet (1.4 meters) in April 1991 to 17.2 feet (5.25 meters) in June 1990. Average Secchi disk transparency was 9.9 feet (3.01 meters) at Station 1 and 8.6 feet (2.62 meters) at Station 2. Secchi depths of less than 6.6 feet (2.0 meters) are usually considered undesirable for recreational uses.

As observed in Table 3.2, Station 1 recorded an average lake transparency greater than Station 2. Lake transparency is inversely related to total suspended solid concentrations, therefore an increase in total suspended solids will result in a decrease in lake transparency as observed in Table 3.2. The lower lake transparency for Station 2 is probably due to high suspended solid loadings from the lake's main inlet.

Table 3.2
Average Lake Transparency Measurements and Total Suspended Solid Concentrations at Stations 1 and 2

Station No.	Lake Transparency (meters)	Total Suspended Solids (mg/L)	
		Surface	Bottom
1	3.01	1.48	1.59
2	2.62	2.36	2.79

3.3.5 Nutrient Concentrations

Phosphorus and nitrogen compounds are major nutrients required for the growth of algae and macrophytes in lakes. The lake monitoring program that was developed for Silver Lake included the analysis of lake samples for both total and dissolved inorganic forms of both nutrients. The dissolved inorganic nutrients, dissolved reactive phosphorus and nitrate and ammonia nitrogen, are regarded as the forms readily available to support aquatic growth, while the total nutrient amounts provide an indication of the maximum growth which could be achieved. Average nutrient concentrations at Stations 1 and 2 in Silver Lake are summarized in Table 3.3.

Table 3.3
Average Nutrient Concentrations at Stations 1 and 2*

Station No.	Sample Depth	Ortho-Phosphorus	Total Phosphorus	Ammonia	Nitrate + Nitrite	Total Kjeldahl Nitrogen
1	Surface	0.012	0.035	0.08	0.67	0.56
	Bottom	0.018	0.037	0.14	0.59	0.53
2	Surface	0.016	0.031	0.05	0.48	0.56
	Bottom	0.017	0.045	0.15	0.45	0.59

*All concentrations in mg/L

Phosphorus

Total phosphorus represents the sum of all phosphorus forms, including 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 (DRP) 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. Variations in total phosphorus concentrations in Silver Lake are shown graphically in Figure 3.8 and 3.9.

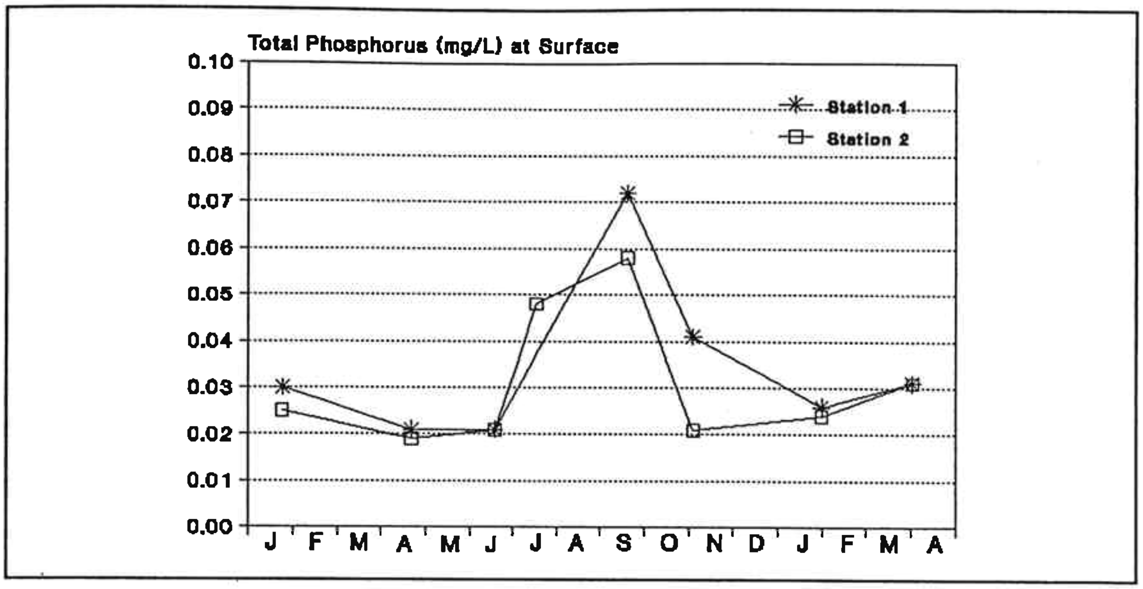

Figure 3.8 Total phosphorus concentrations for surface waters at Stations 1 and 2.

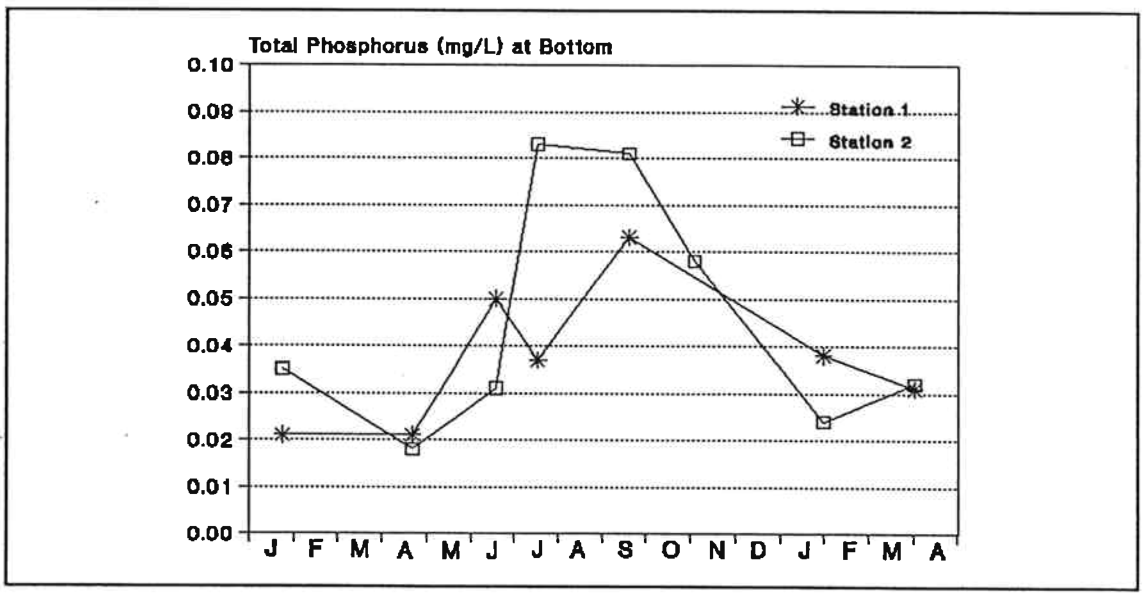

Figure 3.9 Total phosphorus concentrations for bottom waters at Stations 1 and 2.

The mean total phosphorus concentration in Silver Lake was 0.036 milligrams per liter. Total phosphorus concentrations were at or above the EPA total phosphorus eutrophic criterion of 0.02 to 0.03 mg/L (U.S. EPA, 1980) at all depths of both stations throughout the sampling period. The mean dissolved reactive phosphorus concentration was 0.017 milligrams per liter.

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 oxygen concentrations. Nitrate is the form usually found in surface waters, while ammonia is stable under anaerobic conditions often found in deeper water in the summertime. Nitrite is an intermediate form which is unstable in surface waters. Nitrate and nitrite 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, organic nitrogen, and particulate organic nitrogen. Total nitrogen, then, is the sum of total Kjeldahl nitrogen and nitrate plus nitrite nitrogen.

Average levels of total Kjeldahl nitrogen ammonia and nitrate-nitrite were similar between stations. Most of the nitrogen was in organic forms during winter and early spring while during the early summer much of the nitrogen was inorganic.

Limiting Nutrient

Phytoplankton growth depends on a variety of nutrients, including macronutrients such as phosphorus, nitrogen, and carbon, and trace nutrients, such as iron, manganese, and other trace minerals. According to the 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 milligrams of nitrogen per 1 milligram 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- and nitrate plus nitrite-nitrogen) to dissolved reactive phosphorus (DRP) greater than 12 are indicative of phosphorus limitation, ratios of TIN:DRP less than 7 are indicative of nitrogen limitation, and TIN:DRP ratios between 7 and 12 indicate either nutrient can be limiting. It is assumed that when the concentration of dissolved reactive phosphorus is below detectable levels, phosphorus is limiting.

Ratios of TN:TP and TIN:DRP were calculated from Silver Lake nutrient data. Ratios of TN:TP and TIN:DRP clearly indicate that during the winter, spring and fall phosphorus is limiting while during the summer either phosphorus or nitrogen is limiting. During the summer, high pH, high temperature, low dissolved nutrient levels, and nitrogen limitation may set the stage for growth of nitrogen-fixing blue-green algae which fare well under these conditions.

3.4 Trophic State Index

Eutrophication is a natural process whereby 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 are usually comprised of relatively few species. In contrast, an oligotrophic lake is one containing relatively small populations of many diverse organisms. Mesotrophic lakes have conditions intermediate 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. Carlson's TSI is actually composed of three separate indices based on observations of total phosphorus concentrations, chlorophyll a concentrations, and Secchi depths from a variety of lakes. Total phosphorus was chosen for the index because phosphorus is often the nutrient limiting 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 depth, as discussed previously, is a common measure of the transparency of lake water.

Mean summer values of total phosphorus, chlorophyll a, and Secchi depth for an individual lake 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, with indices of 40, 50, and 60. TSI values between 35 to 50 generally indicate mesotrophic conditions. TSI values below 35 are indicative of oligotrophic lake conditions, while values exceeding 50 are typical of eutrophic lake systems.

Trophic State Index (TSI) values for Stations 1 and 2 are presented in Table 3.4. TSI values were determined for average total phosphorus and secchi disk transparency readings during the summer (June through September). For both stations, TSI values for total phosphorus indicate that Silver Lake is eutrophic, while the TSI values based on secchi disk readings indicate that the lake is mesotrophic. The average TSI value for both total phosphorus and secchi disk readings is 50.3 for Station 1 and 51.9 for Station 2. Therefore, Silver Lake is likely classified as a slightly eutrophic lake system.

Table 3.4
Trophic State Indices for Silver Lake

Location	Carlson's Trophic State Index		
	Total P	Secchi Depth	Average
Station 1	57.7	42.9	50.3
Station 2	58.1	45.7	51.9

Lake trophic state can also be assessed by comparing monitoring data to trophic state criteria, such as those developed by the U.S EPA (1980) as presented in Table 3.5.

Table 3.5
Comparison of Silver Lake Monitoring Data to Trophic State Criteria*

Characteristic	Oligotrophy	Eutrophy	Silver Lake
Total P (micrograms/Liter)	$\leq$ 10-15	$\geq$ 20-30	36
Secchi Depth (meters)	$\geq$ 3-5	$\leq$ 1.5-2	2.8

*Source: U.S. EPA, 1980

In Silver Lake, the summer average total phosphorus concentration was 0.042 mg/L or 42 micrograms/L and the summer average Secchi depth (lake transparency) was 3.0 meters. With regard to the trophic status of Silver Lake, the summer average total phosphorus concentration and Secchi depth give similar results as compared to the Carlson's TSI values, indicating that Silver Lake is slightly eutrophic. Other visible signs of Silver Lake's classification as an eutrophic system is the excessive growth of aquatic weeds and algae.

3.5 Sediment Analyses

Sediment analyses were conducted on a sample collected on June 20, 1990. Sediment samples were taken at two locations and combined into one composite. Information on solids and nutrients in the Silver Lake sediments is summarized in Table 3.6. These preliminary testing results indicate Silver Lake sediments may be a significant source of nutrients to the internal pollutant loading budget of Silver Lake. If dredging is a selected restoration alternative, additional testing will be required to determine suitability of disposal.

Table 3.6
Concentrations of Solids and Nutrients in Silver Lake Sediments

Parameter	Amount (Units)
Solids	
Total Solids	16.0 (%)
Volatile Solids	17.8 (% of Total Solids)
Nutrients	
Total Phosphorus	984 (mg/kg)
Total Nitrogen	5511 (mg/kg)

3.6 Biological Interactions

The size of algal and plant populations in water, are primary biological indicators of lake trophic conditions. Identification of species within producer and consumer food web levels is also important in understanding dynamics causing lake conditions. Eutrophic lakes often support unbalanced communities characterized by large numbers of relatively few species.

3.6.1 Phytoplankton

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

A healthy lake should support a diverse assemblage of phytoplankton, in which many algal species are represented. Excessive growth of a few species is usually undesirable. Such growths can cause oxygen depletion in the water at night, when the algae are respiring but not photosynthesizing. 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.

Phytoplankton samples were collected from Silver Lake on seven different occasions between January 1990 and April 1991. Cells were identified to genus and counted. Biomass (in micrograms per liter) was determined for each genus, based on cell volume. Phytoplankton populations levels were low to moderate during most of the sampling period, punctuated by blooms in July and August at both stations (3000-8000 cells per mL and 1000 to 3000 micrograms per liter). The blooms (in term of cell number per mL) coincide with peak total phosphorus concentrations at both Station 1 and Station 2. Some of the blooms may be associated with phosphorus brought in by stormwater runoff.

Major dominant genera were the cryptophyte *Cryptomonas* during the winter and the diatom *Fragileria* during the spring when the phytoplankton population was low, and the blue-greens *Anabaena* and *Aphanisomenon* during the summer. The blue-greens are capable of fixing atmospheric nitrogen and thus is not dependent on dissolved nitrogen forms. They commonly grow to bloom proportions in eutrophic lakes and do particularly well when pH levels and temperatures are high.

3.7 Silver Lake Stream Water Quality

Inflowing tributaries to Silver Lake and the lake's outlet were sampled for nutrient and suspended solids during base flow (low flow) on 4/21/90, 6/19/90 and 1/31/91, and storm flow (high flow) conditions on 6/22/90, 7/5/90, 7/28/90, 8/5/90, 8/18/90, and 4/23/91. These stream sampling sites are shown in Figure 3.2. In addition to nutrient and suspended solid analyses, water samples were analyzed for fecal coliform and fecal streptococcus bacteria on 8/7/90, 8/28/90, 1/30/91 and 4/22/91.

Both fecal coliform and fecal streptococcus are groups of bacteria, which are indicators of fecal pollution from both human and other animal sources. Indicator groups of bacteria reflect the potential presence of pathogenic organisms (Thomann and Mueller, 1987). As the number of the above bacteria increase, the chance of encountering a pathogenic organism also increases. In general, testing procedures for "...pathogenic bacteria are difficult to perform and generally are not reproducible" (Hammer, 1986). Therefore, test procedures for nonpathogenic indicator bacteria is more desirable than for specific pathogenic organisms.

In the Silver Lake drainage basin, stream water quality under both base flow and storm flow conditions is discussed in the following paragraphs. It is important to remember that the stream samples represent a single "snapshot" of water quality in the stream at a particular time. Concentrations of water quality parameters in streams can fluctuate widely, depending on runoff and flow conditions, as well as land management activities upstream. For a brief discussion of total phosphorus, orthophosphorus, total nitrogen, nitrate plus nitrite, ammonia, and total Kjeldahl nitrogen, refer to Section 3.3.5, Water Quality Data.

As expected, average non-storm event total suspended solids, total phosphorus, fecal coliform, and fecal streptococcus concentrations were significantly lower than during storm events. During storm events when runoff is greatest, generally more nutrients, bacteria, and suspended solids are conveyed from adjacent lands to nearby watercourses. Though water quality data is important when expressed as a mass to volume ratio (concentration, i.e. milligrams per liter, mg/L), the actual amount or mass (i.e. kilograms, kg) of nutrients and suspended solids that a stream delivers is more important and is addressed in Section 5.0, Pollution Budget for Silver Lake.

3.7.1 Stream Water Quality During Base flow Conditions

During base flow conditions, the average total suspended solid, total phosphorus and total nitrogen concentrations for streams in the Silver Lake watershed are presented in Table 3.7. For all stations, the average total suspended solid concentrations ranged from 0.2 to 20.6 mg/L. The highest average suspended solid concentrations were observed at Stations Nos. 5 and 10 (Private Road #3 and lake outlet). For all stations, the average total phosphorus concentrations ranged from 0.01 to 0.926 mg/L as phosphorus and the average total nitrogen concentrations ranged from 1.72 to 16.79 mg/L as nitrogen. The highest average total phosphorus and total nitrogen concentrations were recorded at Station No. 5 (Private Road #3).

3.7.2 Stream Water Quality During Storm Events

During storm events, the average total suspended solid, total phosphorus and total nitrogen concentrations for streams in the Silver Lake watershed are presented in Table 3.8. For all stations, the average total suspended solid concentrations ranged from 14.8 to 269.1 mg/L. The highest average suspended solid concentrations were observed at Stations Nos. 6 and 10 (DEC Access and lake outlet). For all stations, the average total phosphorus concentrations ranged from 0.074 to 1.574 mg/L as phosphorus and the average total nitrogen concentrations ranged from 1.72 to 19.10 mg/L as nitrogen. The highest average total phosphorus and total nitrogen concentrations were recorded at Station No. 5 (Private Road #3).

3.7.3 Fecal Bacteria Concentrations

For the four sampling dates, fecal coliform and fecal streptococcus counts ranged from less than 10 to 18,200 cells per 100 mL and less than 10 to 114,000 cells per 100 mL, respectively. For most stations, the highest bacteria counts were measured during a storm flow conditions on 4/22/91 as shown in Table 3.9.

Table 3.7

Stream Water Quality During Base flow Conditions

Station No.	Mean Total Suspended Solids (mg/L)	Mean Total Phosphorus (mg/L as P)	Mean Total Nitrogen (mg/L as N)
1	3.5	0.043	3.24
2	4.5	0.048	3.43
3	9.3	0.048	4.40
4	8.0	0.305	5.73
5	20.6	0.929	16.79
6	7.0	0.032	2.82
7	0.2	0.044	2.55
8	3.4	0.025	10.29
9	7.2	0.034	2.11
10	19.7	0.073	1.72
11	1.2	0.010	1.90

Station 1 - Sucker Brook, east of airport
Station 3 - Country Club
Station 5 - Private Road #3
Station 7 - West Lake Road
Station 9 - West Lake Road #2
Station 11 - Sucker Brook #3
Station 2 - Sucker Brook, Lake St.
Station 4 - Private Road #1
Station 6 - DEC Access
Station 8 - Boat ramp/Fairview
Station 10 - outlet

Table 3.8

Stream Water Quality During Storm Events

Station No.	Mean Total Suspended Solids (mg/L)	Mean Total Phosphorus (mg/L as P)	Mean Total Nitrogen (mg/L as N)
1	41.5	0.403	2.87
2	17.5	0.317	1.87
3	14.8	0.142	2.50
4	43.7	0.300	5.55
5	57.8	1.574	19.10
6	269.1	0.307	4.10
7	32.4	0.074	2.24
8	22.5	0.165	9.63
9	----	----	----
10	171.2	0.220	4.38
11	77.6	0.334	1.72

Station 1 - Sucker Brook, east of airport
Station 2 - Sucker Brook, Lake St.
Station 3 - Country Club
Station 4 - Private Road #1
Station 5 - Private Road #3
Station 6 - DEC Access
Station 7 - West Lake Road
Station 8 - Boat ramp/Fairview
Station 9 - West Lake Road #2
Station 10 - outlet
Station 11 - Sucker Brook #3

Table 3.9

Stream Water Quality

Station No.	Fecal Coliform (FC) (cells/100 mL)				Fecal Streptococcus (FS) (cells/100 mL)			
	8/7/90	8/28/90	1/30/91	4/22/91	8/7/90	8/28/90	1/30/91	4/22/91
1	610	590	250	9,000	230	300	210	114,000
2	50	10	20	1,900	230	140	10	23,000
3	200	1,130	10	1,800	510	2,800	50	12,400
4	2,500	3,000	30	3,000	630	5,300	110	9,000
5	18,200	----	1,600	8,000	7,400	----	3,400	20,000
6	120	5,000	10	1,600	90	3,300	< 10	6,000
7	----	----	10	160	----	----	< 10	330
8	1,500	4,800	< 10	3,000	500	5,900	30	63,000
9	----	20	10	----	----	----	10	----
10	250	----	< 10	2,300	260	90	< 10	17,000
11	150	8,800	----	----	450	2,400	----	----

Station 1 - Sucker Brook, east of airport
Station 3 - Country Club
Station 5 - Private Road #3
Station 7 - West Lake Road
Station 9 - West Lake Road #2
Station 11 - Sucker Brook #3

Station 2 - Sucker Brook, Lake St.
Station 4 - Private Road #1
Station 6 - DEC Access
Station 8 - Boat ramp/Fairview
Station 10 - outlet

4.0 Pollutant Sources

Pollutants can enter a lake from both point and nonpoint sources. Point sources are defined as all permitted 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, internal loading from lake sediments, leaching from septic tanks, and groundwater inputs. Both natural events, such as precipitation and runoff, and human activities, including agriculture, silviculture, and construction, can contribute pollutants from nonpoint sources. Nonpoint sources can be difficult to quantify but are important because they often constitute the major source of pollutants to a lake.

Calculations of pollutant loads require information on the water quality of influent streams, knowledge of lake and watershed interactions, and hydrology, and also require data analysis, modeling, and engineering assumptions. Many sources of error can be incorporated into the results because of the number of water quality samples which must be analyzed, the data analysis required, and the number of assumptions which must be made.

Errors resulting from the water quality analyses can be minimized through a good laboratory quality assurance/quality control program, but the other errors involved can only be reduced through the collection of large amounts of chemical and hydrologic data from the entire watershed. This approach would be technically impractical and economically infeasible and was beyond the scope of this project. As a result, the pollutant loads presented in this report should be considered as best estimates rather than absolute values of the actual pollutant loads.

4.1 Hydrologic Budget

Estimates of lake discharge were derived from readings at five USGS gaging stations as shown in Table 4.1. For each of the five gaging stations listed in Table 4.1, the annual discharge to its drainage area was determined and based on these values, the average annual discharge to drainage area was computed. The average annual discharge for the five stations is 1.28 cubic feet per second (cfs) per square mile (mi^2) and this value should provide a good basis for estimating annual flows in the Silver Lake drainage basin.

The estimated annual discharge for Silver Lake was calculated by multiplying the average annual discharge to drainage area ratio of 1.28 cfs/mi^2 by the Silver Lake watershed area (10,987 acres or 17.2 square miles). Therefore, the estimated average annual discharge was 22.02 cubic feet per second (cfs).

Within the Silver Lake drainage basin, the main inlet has the largest direct watershed, which is approximately 6,497 acres or 59 percent of the entire Silver Lake watershed. Using the approach outlined above, the estimated average annual discharge for the main inlet is 10.15 cubic feet per second.

Table 4.1
Discharge to Drainage Area Ratio

Station	Years of Record	Discharge (cfs)	Drainage Area (mi^2)	Discharge to Drainage Area Ratio (cfs/mi^2)
Little Towanda Creek at Linden, NY	66	27.5	22.1	1.24
Towanda Creek at Attica, NY	11	116	76.9	1.51
Townada Creek at Batavia, NY	44	211	171	1.23
Oatha Creek at Warsaw, NY	24	53.5	39.1	1.37
Oatha Creek at Garbutt, NY	43	214	200	1.07
Average				**1.28**

4.2 Nonpoint Source Pollutant Loads

Nonpoint source pollutant loadings for lakes can be assessed through an extensive lake and stream monitoring program or through the use of the unit areal loading (UAL) approach (U.S. EPA, 1980). The monitoring approach requires that influent streams be analyzed for flow and pollutant concentrations during both wet and dry weather to determine average pollutant loadings. The unit areal loading approach is based on the premise that different types of land use contribute different quantities of pollutants through runoff. Both methods were used to develop pollutant budgets for Silver Lake.

4.2.1 Unit Areal Loadings

The unit areal loading (UAL) approach for the estimation of pollutant inputs from nonpoint sources has been widely-accepted for watersheds where extensive stream monitoring data is not available. Unit areal loadings were used in this report for the calculation of nonpoint source nutrient and total suspended solids budgets for Silver Lake.

Nutrient export coefficients compiled by Uttormark et al. (1974), Reckhow et al.(1980), and the U.S. EPA (1980) were evaluated and specific coefficients were selected based on their applicability to the Silver Lake watershed. The export coefficients describe the mass of pollutant loss per unit area and are usually given in the metric units of kilograms/hectare (kg/ha), which are approximately 10 percent greater than the corresponding English units of pounds/acre. Suspended solids coefficients compiled by US EPA (1980) and Betz (1977) were evaluated.

4.2.2 Septic Tank Leachate

Pollutants originating as septic tank leachate are considered to be nonpoint source loadings, but they are not included in the pollutant budgets calculated using the UAL approach. Loadings from septic tanks are potentially important in areas where on-lot septic systems are located near lake, streams, or other watercourses.

In the vicinity of Silver Lake, all homes are serviced by community wastewater treatment facilities, therefore nutrient loadings from on-lot septic systems were not determined as part of this study.

4.3 Point Source Pollutant Loads

Point sources are defined as all wastewater effluent discharges within a watershed. All point source dischargers of municipal and industrial waste are required to operate under a permit and are assigned a specific discharge number by the National Pollutant Discharge Elimination System (NPDES). The permit specifies effluent limitations for pollutants of concern. There are no known point source discharges in the Silver Lake watershed.

4.4 Pollutant Budgets for Silver Lake

The selected nutrient and sediment export coefficients and resulting annual loadings for each land use in the Silver Lake watershed are summarized in Table 4.2. Based on the unit areal loading approach, the average phosphorus, nitrogen and suspended solid loadings from nonpoint sources to Silver Lake is 6,472, 39,188, and 3,265,445 kilograms per year (kg/year), respectively.

As presented in Table 4.3, active agriculture accounts for the majority of the nutrient and suspended solid loadings to Silver Lake. Even though forested lands are estimated at 13.3 percent of the total Silver Lake watershed area, both nutrient and suspended solid loadings to lake are minimal.

Table 4.2
Nonpoint Source Pollutant Loadings for the Silver Lake Drainage Basin

Loadings from Runoff

Category	Area (hectares)	Parameter	Export Coefficient (kg/ha/yr)	Annual Load (kg/yr)
Agriculture (active)	2881	Total Phosphorus	2.04	5,877.24
	2881	Total Nitrogen	11.62	33,477.22
	2881	Total Suspended Solids	1000	2,881,000
Agriculture (inactive)	262	Total Phosphorus	0.50	131.00
	262	Total Nitrogen	4.50	1,179.00
	262	Total Suspended Solids	500	131,000
Forest	591	Total Phosphorus	0.06	35.46
	591	Total Nitrogen	2.82	1,666.62
	591	Total Suspended Solids	250	147,750
Outdoor Recreation (open space)	249	Total Phosphorus	0.91	226.59
	249	Total Nitrogen	5.94	1,479.06
	249	Total Suspended Solids	305	75,945
Residential	125	Total Phosphorus	0.71	88.75
	125	Total Nitrogen	4.11	513.75
	125	Total Suspended Solids	174	21,750
Commercial	4	Total Phosphorus	0.77	3.08
	4	Total Nitrogen	4.27	17.08
	4	Total Suspended Solids	2,000	8,000
Water (Lake Surface)	334	Total Phosphorus	0.33	110.22
	334	Total Nitrogen	2.56	855.04
	334	Total Suspended Solids	-----	----
Total Watershed Area	4446	Runoff Phosphorus Load		6,472
	4446	Runoff Nitrogen Load		39,188
	4446	Runoff Suspended Solids Load		3,265,445

Table 4.3
Nonpoint Pollutant Loadings to Silver Lake from Different Sources

Land Use	Percent of Watershed	Percent of Phosphorus Load	Percent of Nitrogen Load	Percent of Suspended Solids Load
Agriculture (active)	64.8	90.8	85.4	88.2
Agriculture (inactive)	5.9	2.0	3.0	4.0
Forest	13.3	0.5	4.3	4.5
Outdoor Recreation (open space)	5.6	3.5	3.8	2.3
Residential	2.8	1.4	1.3	0.7
Commercial	0.1	0.1	0.0	0.3
Lake Surface	7.5	1.7	2.2	----
Total	100.0	100.0	100.0	100.0

4.5 Phosphorus Modeling

The phosphorus budgets for Silver Lake determined from unit areal loadings (Table 4.1) and from monitoring data has been used in conjunction with the physical characteristics of Silver Lake (Table 3.1) to determine the effectiveness of several phosphorus loading models for predicting the response of Silver Lake to phosphorus inputs. Phosphorus has been chosen for modeling efforts because phosphorus is the nutrient limiting algal growth in Silver Lake and because the use of phosphorus loading models for predictive purposes has been widely documented.

The empirical model developed by Reckhow (1980) was used in predicting the phosphorus concentrations in Silver Lake. The model has the form:

$$TP = L/[11.6 + 1.2 (q_s)] \quad (1)$$

where TP = annual average phosphorus concentration (g/m^3),

L = areal phosphorus loading ($g/m^2/yr$),

q_s = areal water load (m/yr) = z/Tw,

z = average depth (m), and

Tw = average hydraulic residence time (yr).

The value for L calculated from Unit Area Loading data was 1.94 $g/m^2/yr$ for Silver Lake. This value and Equation 1 was used to calculate a average value for the annual total phosphorus concentration in Silver Lake of 0.10 mg/L. The predicted total phosphorus concentrations of 0.10 mg/L for the lake is much larger than the observed annual average concentration of 0.04 mg/L. One plausible explanation for the disagreement between the predicted and the observed phosphorus concentrations may be due to short-circuiting of the main inlet to Silver Lake. The main inlet to Silver Lake is in close proximity to the lake's outlet, therefore a substantial portion of the nutrient and solid loadings from this inlet may simply by-pass the lake and directly flow into the lake's outlet. The main inlet to Silver Lake drains about 60 percent of the entire Silver Lake watershed. Therefore it is expected that if short circuiting is occurring at the main inlet, a large portion the nutrient and suspended solid loadings may not ever enter Silver Lake.

By setting equation 1 equal to the observed in-lake phosphorus concentration of 0.04 mg/L, the phosphorus loading to the lake is estimated at 0.75 $g/m^2/year$. For Silver Lake to be classified as a mesotrophic system, the average in-lake phosphorus concentration for Silver Lake would have to be equal to or less than 0.02 mg/L or 0.02 g/m^3 (Vollenweider, 1977). By setting equation 1 equal to 0.02 mg/l as phosphorus, the predicted phosphorus loading of 0.38 $g/m^2/year$ would allow Silver Lake to obtain a mesotrophic status. From the above calculations, the total phosphorus loading to Silver Lake would have to reduced by 50 percent, thereby allowing the water quality of the lake to improve from an eutrophic to a mesotrophic status.

4.6 Pollutant Loadings Calculated from Monitoring Data

Nutrient and suspended solid loadings to and from a lake can be calculated from streamflow and water quality data. Streamflow data is obtained by measuring the discharge (or streamflow) for inflowing tributaries to the lake and at the lake's outlet. In addition to measuring discharges, the depth of the stream is also recorded during discharge measurements and through entire study period. By statistically analyzing both stream discharge and stream depth data, an equation is developed for the monitored stream. With this regression equation, one is able to measure the depth of a stream and predict its discharge. If a good regression equation between flow and water depth is developed for all watercourses entering and exiting the lake plus the depths of these watercourses are recorded frequently throughout the month, the average monthly discharge for each watercourse can be estimated. With average monthly discharges and pollutant concentrations, the average monthly pollutant loading can be estimated.

The above methodology for estimating a pollution budget for a lake is labor intensive, quite expensive, and was beyond the scope of this study. The approach used in this study is similar to the above method, but instead of developing a regression equation, the discharge for the watercourses are indirectly determined using USGS flow data from nearby stations, together with data from a limited monitoring program. At this time, the USGS flow data for water year 1990 has not been received. Once we receive this flow data, a pollution budget using stream water quality monitoring data in Section 3.7 will be determined for Silver Lake.

5.0 Evaluation of Lake Restoration Alternatives

Management alternatives for Silver Lake were divided into two categories: watershed management alternatives and in-lake management alternatives. 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 loading to Silver Lake, it is critical that lake restoration focuses on watershed controls. If watershed controls are not implemented, then the recommended in-lake restoration will have little effect towards improving water quality.

The following is a list of the in-lake and watershed restoration alternatives that were considered for the Silver Lake.

A. In-lake Management Alternatives
   1. Lake Aeration
      a. Aeration
      b. Mechanical Circulation

   2. Lake Deepening
      a. Dredging
      b. Drawdown and Sediment Consolidation
      c. Raise Lake Surface Elevation

   3. Other Physical Controls
      a. Harvesting of Nuisance Biomass
      b. Water Level Fluctuation
      c. Habitat Manipulation
      d. Covering Bottom Sediments to Control Macrophytes

   4. Chemical Controls
      a. Algicides
      b. Herbicides
      c. Pesticides

   5. Biological Controls
      a. Predator-prey relationships
      b. Intra- and inter-specific manipulation
      c. Pathologic reactions

6. In-lake Schemes to Accelerate Nutrient Outflow or Prevent Recycling
    a. Dredging for nutrient control
    b. Nutrient Inactivation/Precipitation
    c. Dilution/flushing
    d. Biotic harvesting for nutrient removal
    e. Selective discharge from impoundments
    f. Sediment exposure and desiccation
    g. Lake bottom sealing

B. Watershed Management Alternatives
1. Wastewater Treatment
2. Diversion of Wastewater
3. Watershed Management Practices
4. Homeowner Management Practices
5. Septic System Management Practices
6. Development of Model Ordinances

The following criteria were used in the evaluation of 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

Based on the above criterion, only those in-lake and watershed management strategies that are appropriate for the restoration of Silver Lake are discussed in the following paragraphs.

5.1 In-Lake Restoration Methods

In-lake management practices can be implemented to reverse the impacts of eutrophication. Watershed management practices should be considered along with in-lake restoration techniques because it is important to eliminate or reduce problems in the watershed so that in-lake practices are cost-effective.

5.1.1 Dredging

The physical removal of lake sediments can be used to achieve one or more objectives, including macrophyte removal, lake deepening, and nutrient removal. The most obvious advantage of dredging is the immediate removal of virtually all plants from the lake bottom. Therefore, all of the nutrient compounds and organic matter which comprise the existing vegetative biomass are permanently removed from the lake system. The entire macrophyte mass would be eliminated, including the seeds and roots, thereby preventing a quick recurrence of nuisance growths.

Lake sediments may be removed by mechanical or hydraulic methods. In mechanical dredging, lake sediments are excavated by using bulldozers after sediment are sufficiently dewatered or by using cranes equipped with buckets. Once the sediment is removed, this material must be loaded into trucks and hauled to the disposal site. In hydraulic dredging, a dredging barge is unloaded from a trailer into the lake. The barge is equipped with a cutterhead, which dislodges in-lake sediments. Once the sediments are dislodged by the cutterhead, the sediment is directly pumped from the barge to the disposal site via pipeline.

Problems associated with in-lake dredging are the resuspension of sediments and nutrients, the disturbance of the benthic community, and the disturbance of both fishery nesting and refuge areas. During the dredging operation, sediments and nutrients are often resuspended, which may result in algal blooms, increased turbidity, and decreased dissolved oxygen concentrations. By removing in-lake sediments, many of the residing aquatic organisms will be physically removed or smothered by the settling sediments in areas adjacent to the actual operation. In addition to the benthic community, both fish nesting (breeding) areas and refuge areas for juvenile fishes may also be removed or silted in by sediment. However, the continued improvement of hydraulic dredging equipment and dredging methods have helped to minimize these adverse impacts.

Silver Lake has a surface area of 825 acres, a mean depth of 23.7 feet and a maximum depth of 40.0 feet. A bathymetric map of Silver Lake is presented in Appendix B. The only area in Silver Lake that may require dredging is along the northern shoreline in the vicinity of the Silver Lake inlet and the lake's outlet. By removing sediments between the main inlet and the outlet, thereby enhancing the short circuiting of flow from the main inlet. The reason for enhancing the short circuiting of the Silver Lake inlet is because this main inlet drains approximately 60 percent of the watershed and contributes substantial nutrient and suspended solid loadings to Silver Lake. Enhanced short-circuiting would mean that watershed management practices can be concentrated in the smaller portion of the watershed not drained by Silver Lake Inlet.

The amount of lake sediments required to enhance the short circuiting effect of the Silver Lake Inlet is estimated 62,000 cubic yards. The cost to remove 62,000 cubic yards of sediment by hydraulic dredging is $850,000. This cost includes the cost for disposal site preparation, construction costs, design and permit preparation. The above dredging cost assumes that a suitable disposal site can be located in close proximity to the northern shoreline (within 1,000 feet of the site) and does not include permit application fees.

The cost for mechanical dredging of 62,000 cubic yards of sediment would be approximately $990,000. This cost includes design, construction, dredging, and permit preparation. Permit application fees are not included. If the removed sediments must be trucked to another location, then hauling costs must also be considered. Hauling costs vary with location and with the size of truck used. A typical one mile round trip cost for hauling sediment is $2.50 per cubic yard. If the disposal site was located one half mile from the site, then the trucking costs for 62,000 cubic yards of sediment would be approximately $155,000.

5.1.2 Flow Diversion

Lake water quality may be improved by diverting a stream or river that delivers high nutrient and suspended solid loadings to a lake. Flow diversion of a stream or river is accomplished by constructing an earth berm or dam across the watercourse to be diverted and excavating a channel to transfer the flow from the diverted stream to the receiving watercourse. For flow diversion to be cost-effective, the diverted and the receiving watercourses should be in close proximity to one another.

Based on the hydrologic and pollution budgets for Silver Lake, the main inlet drains 60 percent of the entire watershed and has the potential to deliver high loadings of nutrient and suspended solid to the lake. The close proximity of the inlet to the lake's outlet makes a partial diversion of the Silver Lake Inlet feasible. A diversion of flow would achieve some of the same goals as the sediment dredging outlined above. A small concrete dam, located approximately 500 feet above the inlet, would be constructed across the Silver Lake Inlet. During stormflow conditions, the majority of the flow from the Silver Lake Inlet would be diverted into the northeast bay of Silver Lake via a newly constructed revegetated channel. This channel would be constructed in a wetland area near the lake's northern shoreline. Under base flow conditions, a culvert installed through the concrete dam would transfer the entire flow of the Silver Lake Inlet directly into the northeastern bay of Silver Lake.

The estimated cost to design and construct a concrete diversion dam across the Silver Lake Inlet and a channel extending from the inlet to the northeastern bay of Silver Lake is $375,000. Depending the results of the required geotechnical study and additional hydrologic studies, the above cost may significantly increase.

The above cost does not include costs for additional hydrologic studies, permit preparation, surveying, and permit application fees. Furthermore, it should be noted that the U.S. Corps of Engineers may require that the disturbed wetland area be replaced with the same type wetlands present prior to construction. If this is the case, wetland mitigation (wetland creation) may be in order and can increase the total cost of the project. This alternative may not be acceptable to waterfront property owners who use the Silver Lake Inlet to access the lake.

5.1.3 Macrophyte Harvesting

Aquatic weed harvesting is used for two lake restoration purposes: (1) to physically remove nuisance vegetation, and (2) to remove nutrients and organic matter from the lake ecosystem. Harvesting is a direct way to accomplish the first goal with minimal negative impacts. The actual harvesting does not interfere with the use of a lake, improves recreational usage and does not introduce foreign substances (algicides or herbicides) to the ecosystem. Weed harvesting is used primarily to restore the recreational uses of a lake. However, the technique presents a maintenance problem since the equipment seldom removes the entire plant. Most lakes usually require two to three cuttings per year in order to maintain the weeds at a non-nuisance level. The frequency of cutting, however, may be reduced after several years of harvesting.

The advantages of weed harvesting versus chemical application were evaluated for a small lake in Ohio (Conyers and Cooke, 1982). It was concluded that harvesting is much more effective than the recommended doses of Cutrine-Plus and Diquat in controlling the biomass, and harvesting would be less costly over a two-year period than chemical treatment for the same period.

In addition to removing nuisance plant growth, harvesting can result in water quality improvements. Removing intact plants reduces the oxygen demand associated with decaying plants and improves fish habitat. Since up to 50 percent of dead plant tissue deposited on a lake bottom does not decompose, sediment and detrital accumulation rates would decrease with harvesting. The benefit in harvesting macrophytes to remove nutrients is less certain. When possible, plants absorb nutrients in excess of their needs. As much as 0.05 to 0.4 grams per square meter of phosphorus per year can be removed from a lake by mechanical harvesting (Burton, et al., 1979). In order to have a net effect, removal of phosphorus by harvesting would have to exceed the annual phosphorus accumulation rate. Phosphorus removal is affected by the type of harvesting operation, the amount of phosphorus stored in the sediments and taken up by vegetation, and whether nutrient inputs are controlled. Net nutrient removal is likely only in limited instances where nutrient inputs are reduced to low levels. It would most likely take years to deplete the supply of phosphorus stored in the upper layers of the sediment.

Compared to other restoration techniques, the cost of aquatic weed harvesting is moderate. The size and type of harvesting operation determines the type of machinery that should be used and the cost-effectiveness of purchasing equipment versus contracting a harvester. In general, those harvesters that cut the macrophytes and immediately remove them by means of a conveyor are most effective.

The potential negative environmental impacts of harvesting include:

1. A change in the dominant plant species,
2. A change in the composition of benthic and aquatic organisms,
3. Short-term suspension of sediments and detritus,
4. Dissolved oxygen depletion due to plant decomposition,
5. Nutrient release to the water column from decaying plants and ruptured stems, and
6. An increase in algae populations.

The extent and likelihood of these effects depend in part on the completeness of macrophyte removal and on the magnitude of sediment release of nutrients and nonpoint sources of nutrients.

There are several ways to establish a weed harvesting program. They are 1) purchase and run your own harvester, 2) share a harvester with other lakes or establish a county-wide harvesting program, or 3) contract the harvesting to an outside service. Purchasing and running your own harvester is initially the most expensive way to establish a harvesting program. Over the long-term, the initial expense will be offset by the cost of contracting out, but annual operational and maintenance costs will continue. The cost to an individual lake association can be reduced by sharing ownership among several lakes or by establishing a county-wide macrophyte harvesting program.

The cost for equipment depends on the size of the harvester and ranges between $50,000 and $120,000 for the mechanical weed harvester, shore conveyor and trailer. Weed harvesters can cut approximately one acre of weeds in 4 to 8 hours and typically cost about $200 per acre to operate not including the disposal of cut vegetation (New York Department of Environmental Conservation, 1990). The actual time and operational cost will be highly dependent on the harvester unit selected and the density of the macrophytes. The harvester should be able to cut a swath ranging from six to ten feet in width and to a depth of six to eight feet. The use of mechanical harvesters is generally limited to lake depths greater than 2.0 feet and beyond docks due to poor maneuverability. It should be noted the above cost does not include weed disposal.

Instead of a lake association or a county purchasing its own weed harvesting equipment, a lake association may choose to contract out its weed harvesting duties. Typically, contractor rates for weed harvesting are quite variable and greatly depend on the geographic location of the lake and local market prices. Weed harvesting fees are typically $250 to $350 per acre.

After harvesting, the weeds are usually unloaded from the harvester to trucks via shore conveyor units. Prior to the commencement of any weed harvesting activities, several weed disposal sites should be identified. Aquatic weeds compost well, thereby producing a good mulching material. In many instances, the agricultural community will generally accept harvested weeds. In any of the above approaches to weed harvesting, it is important to find a close disposal site, thereby reducing hauling costs for weed disposal.

In Silver Lake, nuisance stands of weeds have been a common complaint from lakeside residents. With the assistance of a lake consultant, the watershed commission should identify lake areas, where stands of aquatic plants interfere with desired lake uses. After these areas are identified, the commission should receive bids from local weed harvesting contractors and compare these bids to the purchase of their own weed harvesting unit.

5.1.4 Physical Barriers

Physical sediment covering is another method which has been used to control aquatic and sediment nutrient release. Researchers have experimented with various cover materials including sand, clay, synthetic sheeting and fly ash.

The primary advantages of sand is its lower material and application costs. However, sand has not been shown to provide either an effective physical or chemical barrier when used as a solitary treatment approach. Both macrophytes and nutrients are usually able to break through sand coverings. One apparently successful application of sand occurred in a lake where the nutrient-rich sediments were first excavated from the lake bottom.

A more promising candidate for a natural sealant might be clay. Although a full scale treatment with clay has not been reported, laboratory experiments indicated that a two inch layer of kalinite was effective in retarding phosphorus release for up to 140 days. However, the seal was eventually disrupted by gas formation in the sediments. In addition, it might be necessary to add a precipitant such as alum to remove colloidal clay particles from the water column. Also, the effect of rooted macrophytes on a clay layer has not been adequately tested. Overall, the use of clay or sand are not considered to be applicable to Silver Lake since these methods involve decreasing the depth of the lake.

The use of fly ash (a waste product from coal combustion) to control phosphorus release from sediments has also been tested. However, besides being susceptible to plants and gases in the same manner as sand and clay, the use of fly ash may cause adverse effects such as high pH, dissolved oxygen depletion, biological reduction of sulfate to sulfide, heavy metal accumulation and toxicity, and the physical clogging and crushing of organisms.

One of the more successful approaches for covering lake sediments to control aquatic plants has involved the use of synthetic sheeting (benthic barriers). Sheeting can be installed by first lowering the water level, installing cover on ice surface and allowing it to sink during ice-out, or by wading out and installing it directly under water.

There have been several problems with the use of this material, including:

1. holes have to be placed in the sheeting to avoid the formation of gas pockets.

2. The sheeting was easily dislodged by currents.

3. The sand which is often used as an anchor can become enriched with new sediments and tends to again support weed growth after two to three years.

4. Polyethylene degrades rapidly in sunlight.

5. The sheeting may have severe impacts on the benthic community.

The most effective benthic covers are gas permeable screens, which are constructed of fiberglass, polypropylene, or nylon as opposed to those gas impermeable covers constructed of polyethylene or synthetic rubber materials. For the above screen materials, both fiberglass and polypropylene materials are generally the easiest to install and the most effective in controlling macrophytic growth (EPA, 1990).

The installation of benthic covers over large areas has only been successful demonstrated for several years. Once in place, sediments may accumulated on the barrier, thereby allow plant fragments to re-establish. Therefore, screens must removed and periodically cleaned, possibly every 2 to 3 years. For localized control, such as around docks, benthic barriers are routinely installed in early spring and removed in the fall. While this introduces a winter storage problem, it prevents the re-establishment of macrophytes.

Where plant growth is dense, benthic barriers could be installed from individual docks to the edge of the littoral zone (the region extending from the lake's shoreline to open water), thereby increasing boat access to the open water and reducing the use of aquatic herbicides. Of the wide-variety of materials on the market, fiberglass or polypropylene materials should be used over other barriers because these materials are gas permeable and are easier to install.

Assuming an individual dock requires 400 square feet (20 by 20 feet) of lake bottom to be covered, fiberglass netting would cost approximately $120. The above cost does not include shipping and installation, and any additional materials, such as benthic anchors.

In Silver Lake, the installation of benthic barriers around docks to control aquatic weed growth is recommended. For large stands of nuisance aquatic weeds that impair current lake uses, mechanical weed harvesting is recommended.

5.1.5 Nutrient Inactivation

Since phosphorus-rich sediments will release phosphorus in the water column under low oxygen conditions, water quality problems can continue in a lake long after watershed controls are implemented. By applying aluminum salts (commonly refer to as alum) to lake sediments, a chemical barrier is established which can provide continuous control of phosphorus. Nutrient inactivation usually consists of adding aluminum salts (aluminum sulfate and/or sodium aluminate) to produce an aluminum hydroxide floc which forms a chemical bond with phosphorus. Under the appropriate lake conditions, this method has been known to reduce internal phosphorus loadings for periods of 5 to 15 or more years. Alum treatments are most effective in deep lakes with a surface area greater than 50 acres in size and a low flushing rate, and where watershed inputs of phosphorus have been minimized.

Connor and Martin (1989) and Cooke, et al. (1986) provide an excellent summary of the effects and costs of using aluminum salts (alum) to inactivate sediment phosphorus. Assuming that watershed phosphorus loading has been minimized, this management technique can provide long-term improvements in water quality with minimal negative environmental impacts. Based on the treatment costs for six New England lakes, the average cost was approximately $1,372 per hectare at a mean aluminum dosage of 28 grams of aluminum per cubic meter (Connor and Martin, 1989). In recent years, the trend has been towards using higher application dosages ranging from 40 to 45 grams of aluminum per cubic meter. Due to advancements in application technologies, alum treatment costs in the mid-1980's have been further reduced to $1,306 per hectare at a dosage of 40-45 grams of aluminum per cubic meter. At an annual inflation rate of five percent, this would be equivalent to $1,838 per hectare in 1992.

The actual aluminum dosage is lake specific and largely depends on the results from jar tests, which are performed in the laboratory. For the Silver Lake study, jar tests were beyond the scope of this project. Therefore, the costs for hypolimnetic alum treatments are only intended as "estimated" values and are based on the above cost of $1,838 per hectare at a dosage of 40-45 grams of aluminum per cubic meter.

For in-lake alum treatment to be cost-effective, a lake should have a long hydraulic residence time (generally greater than 0.5 years), high sediment phosphorus concentrations, high hypolimnetic phosphorus concentrations, high summer phytoplankton levels, and low total suspended and phosphorus loadings from its surrounding watershed.

For Silver Lake, the area of the hypolimnion is approximately 478.7 acres (193.7 hectares). Assuming an average alum cost of $1,838 per hectare (in 1992 dollars) at a dosage of 40-45 grams of aluminum per cubic meter, the estimated cost to treat Silver Lake with alum is $356,000.

Based on the criterion listed above, Silver Lake is a possible candidate for alum treatment once suspended solid loadings from nonpoint sources are reduced. At this time, alum treatment is not recommended for Silver Lake. Once the suspended solid loadings to Silver Lake are reduced, alum treatment should be reevaluated.

5.1.6 Artificial Circulation

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 (mix) 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.

Some studies have shown that algae levels may be controlled by destratifying a lake, though most recent works on larger lakes indicate that this effect is only temporary. After a few seasons, algae concentrations may actually increase and bluegreen algae can continue to dominate. Aeration by destratification works by bubbling air from the lake bottom, causing the water column to circulate.

Hypolimnetic aerators, which do not destratify a lake, work by lifting and aerating bottom water in a closed chamber and circulating the aerated water back into the hypolimnion.

Based on the morphology and the water quality characteristics of Silver Lake, hypolimnetic aeration was selected over destratifying systems because as stated above, these systems would provide a coldwater habitat for coldwater fish species, reduce internal phosphorus loadings from lake sediments, and greatly reduce the risk of nutrient recirculation. For Silver Lake, the anoxic volume of water was calculated from the prepared bathymetric map by F. X. Browne Associates, Inc. and dissolved oxygen profiles obtained in the field.

In sizing hypolimnetic aeration systems, an oxygen deficit rate (ODR in $mg/m^2/day$) is usually determined from multiple dissolved oxygen profiles recorded throughout the spring and summer months (Cooke et. al, 1986). After the ODR is determined, this value is converted to $kg/m^2/day$ and multiplied by the hypolimnetic area, thereby providing the oxygen demand (kg/day) in Silver Lake. For Silver Lake, the oxygen deficit rate was determined to be 0.4236 $mg/m^2/day$. The hypolimnetic area of Silver Lake is 478.7 acres (1,937,197 m^2), therefore oxygen demand was determined to be --821 kg/day.

Based on six projects as reported by R.S. Geney, the average installed cost per kilogram of oxygen delivered per day ranged from $138 to $570 with a mean of $354. The operating cost per kilogram of oxygen delivered per day ranged from $0.036 to $0.076 with a mean $0.056 (Cooke et. al, 1986). Assuming an inflation rate of 0.05 percent, the estimated average cost to install a hypolimnetic aeration system in Silver Lake is $390,000. Annual operating costs for this system over a six month period is $11,100 in 1992 dollars.

For Silver Lake, hypolimnetic aeration is not recommended until nutrient and suspended solid loadings from the watershed are reduced. After suspended solid and nutrient loadings to Silver Lake are significantly reduced, hypolimnetic aeration for Silver Lake should be reevaluated at this time.

5.2 Watershed Management Methods

The pollutant budget indicates that most of the load comes from nonpoint sources. Any long-term improvement in water quality will require watershed management practices to control the quantities of nutrients and sediments entering Silver Lake. Watershed management practices are also important because they help eliminate or reduce problems in the watershed and make in-lake practices more cost-effective. The Silver Lake Watershed Commission would take the initiative in prioritizing projects aimed at improving water quality within the watershed.

5.2.1 Development and Enforcement of Ordinances

The New York Department of Environmental Conservation (DEC), the Soil Conservation Service (SCS) and local Soil and Water Conservation District (SWCD) are interested in helping localities develop stormwater runoff ordinances and erosion and sedimentation ordinances in order to control flooding and erosion as well as protect water quality. One of the key functions of the Silver Lake Watershed Commission would be to develop model ordinances which would be supported by the public in order to protect and improve water quality in Silver Lake. There are technical manuals published by DEC and SCS designed to give guidance to localities in these areas.

Erosion Control Ordinance

The Watershed Commission should develop a model erosion and sediment control ordinance to control erosion from construction sites. The ordinance should include technical guidelines and typical details for the installation of erosion and control measures. These guidelines should discuss and recommend methods for controlling soil erosion and sedimentation, including the drainage area and velocity required for silt fences, straw bales, diversions, channel lining and other erosion control measures, and design specifications. Details for the installation of silt fence, straw bales, construction entrances and other standard methods should be included. Procedures for review of erosion control plans and inspections of construction sites should also be included.

Runoff Control Ordinance

The Silver Lake Watershed Commission should develop a model runoff control ordinance which can be adopted and implemented communities within the watershed. Unlike the proposed erosion and sediment control ordinance which is designed to control erosion and runoff during construction activity, the runoff control ordinance is designed to control erosion and runoff after construction activities are complete, for the life of the project.

The runoff control ordinance should be developed on the basis of the environmental performance standards that the peak stormwater runoff and the pollutant loads from a new development or facility shall not exceed the pre-development levels.

The runoff control ordinance should include methods for calculating runoff flows and velocity, design storm requirements, rate of runoff control requirements and water quality standards. If detention or retention facilities are required, the ordinance should include design standards for these facilities for freeboard, emergency spillways, bottom slope and other technical or safety requirements. The ordinance should also include procedures for an engineering review of the plan and inspections during construction.

5.2.2. Agricultural Best Management Practices

Nonpoint source pollution from agricultural runoff is a significant source of phosphorus, nitrogen, and sediment in the Silver Lake watershed. Approximately 91 percent of the phosphorus load, 88 percent of the nitrogen load, and 88 percent of the sediment load originates with agricultural runoff. A number of agricultural best management practices (BMP's) are designed to reduce erosion from highly erodible land. These practices include conservation tillage, cover cropping, critical area planting, terraces, filter strips, and grassed waterways. Some of these practices are presently being used by farmers in the Silver Lake watershed in conjunction with the Soil and Water Conservation District. Other agricultural practices which would benefit water quality in Silver Lake are keeping animals out of the streams and managing manure and fertilizer in order to reduce their contribution to bacterial and nutrient loading. Farmland management, fencing, and agricultural waste storage structures are practices which can achieve these ends. The Soil Conservation Service, the Agricultural Stabilization and Conservation Service, and the Soil and Water Conservation District are excellent sources of information regarding technical questions and funding opportunities associated with agricultural land management.

For dairy operations, key items to address are barnyard runoff, manure spreading and storage, and milkhouse waste disposal. Methods which divert clean runoff around the barnyard keep the barnyard dry, thereby not only improving the quality of stormwater runoff, but improving herd health, reducing hoof disease, and reducing sediment in milk. Long or short-term manure storage would provide options for spreading methods. Filter strips or storage lagoons could be used to treat milkhouse wastes.

In the following paragraphs, agricultural best management practices that are applicable within the Silver Lake drainage basin are presented.

Conservation Tillage

Conservation tillage applies to crop tillage methods used to control the amount of erosion from crop fields. Stormwater runoff can be reduced by retaining water on the fields and infiltration can be increased due to slower runoff velocities.

The most common conservation tillage practice is no-tillage or zero tillage. No-till farming involves soil preparation and planting that are accomplished in one operation with specialized farm equipment. This results in limited soil disturbance and leaves most crop residues on the soil surface. Planting is normally done in narrow slots opened by a fluted coulter or double-disk opener. Soil infiltration rates of the area are increased by maintaining a plant canopy or a mulch of plant residues on the surface for the entire year. However, soil compaction and reduction of evaporation from the surface due to the residues may lead to increases in runoff.

Other conservation tillage practices such as ridge planting, strip tillage, and plow planting are less common than no-tillage. Typically these methods require specialized soil and cropping conditions to be practical. Some of the conservation tillage methods may also decrease runoff volume by allowing significant amounts of runoff to infiltrate into the soil. The infiltration capacity is dependent on the amount of soil compaction in the undisturbed areas of the field and the amount of crop residues that are left exposed. High soil compaction inhibits infiltration whereas exposed crop residues absorb the water and retain it on site until it evaporates.

Additional benefits of conservation tillage include less labor per acre, lower equipment costs, and reduced fuel costs. Disadvantages of conservation tillage include increased use of herbicides, soil compaction, increased management requirements, and lower soil temperatures in spring caused by heavy mulch residue. Concentrations of nitrate in runoff water from conservation tilled fields are typically higher than concentrations from conventionally tilled fields. This is not necessarily a disadvantage since less runoff occurs from conservation tilled fields. The concentration of available phosphorus in eroded soils is higher with conservation tillage than with conventional tillage. Again, this is not necessarily a disadvantage since less soil erosion occurs when conservation tillage practices are employed.

The effectiveness of no-till farming is considerable. A comprehensive study performed in Georgia indicated that runoff can be reduced by 47 percent with the use of no-till farming. Soil loss can be reduced by 91 to 98 percent with the use of no-till farming compared to convention tillage (North Carolina Agricultural Extension Service, 1982).

Cover Cropping

Cover cropping involves planting and growing cover and green manure crops. Cover and green manure crops are crops of close-growing grasses, legumes (clover), or small grain planted in a fallow field and plowed into the ground before the next row crop is planted. This technique is used to control erosion during periods when the major crops do not furnish cover. In addition to erosion control, residual nitrogen from legume cover crops enhances the soil for the major commercial crops and should be considered when calculating the nitrogen requirements of these crops planted later.

The cover crop can be seeded after harvesting the major crop by light plowing or it can be seeded prior to cultivation of the major crop without additional seedbed preparation. The cover crop should be protected from grazing until it is well established and from weeds by chemical or mechanical methods as needed. Cover crops are most beneficial to farm practices that leave bare soil following harvesting.

Critical Area Planting

Critical area planting involves planting vegetation on critical areas to stabilize the soil and promote stormwater infiltration, thereby reducing damage from sediment erosion and excessive runoff to downstream areas. Critical areas can be sediment-producing, highly erodible, or severely eroded areas where vegetation is difficult to establish with usual seeding or planting methods.

The selection of vegetation and the use of mulching materials immediately after seeding is of special concern. Jute and excelsior matting and mulching can be used to protect soil from erosion during the period of vegetative establishment when plants are most sensitive to environmental conditions. To reinforce areas designated for planting, bank stabilization structures can be used.

Maintenance of critical area planting includes periodic inspection of seeded areas for failures. Repairs should be made as needed. If the stand is more than sixty percent damaged, the planting area should be re-established using the original planting criteria.

Terraces

A terrace is an earth embankment, ridge or channel constructed across a slope at a suitable location to intercept runoff water and control erosion. Generally, terraces are considered supporting practices to use in conjunction with contouring, stripcropping and reduced tillage methods. Terracing has been shown to be highly effective in trapping sediment and reducing erosion. The effectiveness of terracing is not as good for reducing the loss of nutrients and soil from surface runoff. Subsurface nitrogen losses may increase.

A terrace can be constructed across a slope with a supporting ridge on the lower side. The use of terraces is usually not applicable below high sediment producing areas without supplementary control measures. Any sediment build-up that does occur should be removed on an as-needed basis. The effectiveness of terraces for reducing sediment loss ranges from 50 to 98 percent.

Grassed Waterways

Grassed waterways are designed to facilitate the disposal and transmission of surface runoff. Grassed waterways apply to both natural and constructed drainage channels. The effectiveness of grassed waterways to remove sediments from runoff has not been well documented. Grassed waterways should be used in conjunction with other BMP's such as conservation tillage and terraces.

Constructed grassed waterways are generally shaped or graded by heavy equipment and are usually over ten feet wide at the top of the channel. Vegetation cover is usually a variety of grass or legume compatible with existing species in the area. These channels should be protected from grazing, fire and insects and should not be used as farm roads. Maintenance consists of mowing the grass and spraying if weed control is needed. If necessary, cuttings should be removed to prevent transport to nearby streams during storm events. All seeded areas should be inspected occasionally for needed repairs. Also, any sediment build-up that significantly reduces the capacity of the channel should be removed.

Grade Stabilization Structures

Soil in areas subject to heavy erosional forces, such as the outlet of a grassed waterway or a steep area which will not support vegetative cover, can be stabilized with a structure such as riprap. This is an effective method for treating small problem areas unsuitable for other stabilization methods. Construction cost for grade stabilization is approximately $500 per structure.

Farmland Management

Farmland management incorporates several practices which discourage accelerated erosion at the farm site. The first farmland management practice is commonly referred to as pasture and hayland planting. Pasture and hayland planting involves the proper planting techniques to establish long-term stands of adapted species of perennial and biennial forage plants. The primary purpose of pasture and hayland planting is erosion control. An additional benefit could be the production of a high quality forage crop. Proper planting measures involve the adequacy and timing of lime and fertilizer application; determination of a particular area's seedbed preparation needs, seed mixtures, seeding rates, and weed control.

In addition to special planting techniques there are also general pasture and hayland management techniques. Pasture and hayland management involves the proper treatment and use of pasture and hayland. Proper management involves the use of adapted species of grasses, time of harvest, state of plant growth and height to which plants are cut of grazed, and the control of weeds, diseases and insects. Of particular importance is establishment of grazing plans. Grazing plans should be developed to include schedules for moving animals into and out of the pasture as well as for maintenance of the pasture. Uniform, complete cover, and vigorous pasture growth are essential for control of erosion and subsequent nutrient loss. Adequate pasture facilities should be provided, including waters, shade and mineral feeders. These facilities should be periodically moved to prevent overuse in any one area. Streams, ponds, and lakes should be fenced to limit animal access.

Another farmland management practice is the control of livestock watering facilities. The development and protection of springs can be used as water supply sources of farms. Spring development involves excavation, cleaning, and capping of waterways to convey and distribute water to livestock at several locations in the farmyard and pastures. This technique distributes grazing to several points rather than concentrating it in one area. Concentrated grazing can result in overgrazing which in turn leads to accelerated erosion. Developments should be confined to springs or seepage areas that are capable of providing a dependable supply of suitable water during the planned period of use. Maintenance includes the periodic removal of sediment from spring boxes.

Fencing

Fencing involves enclosing and dividing an area of land with a permanent structure that serves as a barrier to animals and people. The primary purpose of fencing is to control erosion by protecting sensitive areas, particularly watercourses, from the disturbance of grazing or public access, by subdividing designated grazing areas for a planned grazing system and by protecting new seedlings and plantings from grazing until they are well established. Fencing may also be a source pollution control by preventing livestock from depositing their wastes in natural watercourses.

Fencing controls streambank erosion by preventing both the physical destruction of the bank and the denuding of streambank vegetation from grazing animals. The use of filter strips between fences and the watercourses can increase the effectiveness of fencing. Fences for this purpose are not to be temporary such as electric fences. Depending on the type of animal to be restricted, the permanent fence can be woven wire, barbed wire, or high tension wire. Fences should be periodically inspected to check for broken or disconnected wire, loose staples and loose or deteriorated post or brace members.

Agricultural Waste Storage Structures

An agricultural waste storage structure can be either an above-ground fabricated structure or an excavated pond. The above-ground fabricated structure can be either a holding tank or a manure stacking facility designed to temporarily store nontoxic agricultural and animal wastes. The primary purpose of agricultural waste storage structures is to reduce contamination of natural watercourses by source pollution control of liquid and solid wastes. Wastes can be disposed of by controlled application to cropland. Animal wastes supply soils with nutrients and soil tilth. Runoff rates are reduced and soil infiltration rates are increased with the application of animal wastes. Manure should not be applied when the ground is frozen or there is snow on the ground.

Manure stacking facilities that are used for solid waste may be open or roofed. Manure stacking facilities can be made of reinforced concrete, reinforced concrete block, precast panels, or treated tongue and groove lumber. Holding tank facilities for liquid and slurry wastes may be open or covered. Holding tanks may be located indoors, beneath slotted floors. Holding tanks can be made of cast-in-place reinforced concrete or fabricated steel with fused glass or plastic coatings.

Both holding tanks and stacking facilities should be emptied in accordance with the overall waste management plan for land application. If the holding tanks are located outdoors and are not covered, a grass waterway should be constructed downslope of the tanks to prevent surface runoff from reaching a stream or drainage channel.

A waste storage pond is an impoundment constructed by excavation or earthfill for temporary storage of nontoxic agricultural and animal wastes. When polluted runoff is stored, accumulated liquids are removed from the pond promptly after settling to ensure that sufficient capacity is available to store runoff from subsequent storms. Extraneous surface runoff should be prevented from entering the pond. The pond should be located as near to the source of waste or polluted runoff as possible. Soils under the pond should be of low to moderate permeability. Where self-sealing is not probable, the pond should be sealed by mechanical treatment or by using an impermeable membrane. Accumulated wastes should be properly disposed of as discussed above for fabricated structures. Waste storage ponds should be properly maintained including periodic inspection and clearing of inlets.

Agricultural waste storage structures can result in significant nutrient reductions because the wastes treated by these structures contains nutrients in mobile forms. In the Silver Lake watershed there are a number of dairy operations which could benefit from some type of waste storage structure. Dairy cattle produce 0.37 lbs of nitrogen and 0.069 lbs of phosphorus/1000 pounds of cattle/day (Ralph Timmons, personal communication). Construction costs can run from $5,000.00 to $15,000 depending on volume and treatment requirements.

Agricultural Waste Management

Manure is a resource that should be used and managed wisely to increase crop yields and control pollution. In normal farming operation manure application provides nutrients for plant growth, improves soil tilth, and helps develop beneficial soil organisms. The use of manure as a fertilizer also decreases the erosion potential of the soil and promotes infiltration and retention of water in soil. The use of manure can reduce soil loss from sloping land by 58 to 80 percent. (North Carolina Agricultural Extension Service, 1982)

Care must be taken to spread manure at rates appropriate to soils and weather conditions in order to maximize infiltration and minimize manure loss in runoff. A manure management plan should be adopted for individual farms. The plan should include methods to conserve nutrients in the manure while it is being stored, to determine appropriate application rates, to determine appropriate time of application, and to determine the method of application. Methods of application typically include daily spreading, storage and periodic spreading, and subsurface injection.

Filter Strips

Filter strips are vegetated areas which intercept storm runoff, reduce runoff velocities, and filter out runoff contaminants. Although filter strips are similar to grassed waterways, they are primarily used for urban developments, agricultural fields, and logging areas.

Successful application of filter strips to urban developments and agricultural fields requires consideration of natural drainage patterns, steepness of slopes, soil conditions, selection of proper grass cover, filter width, sediment size distribution, and proper maintenance. All of these factors affect pollutant removals, which can range from 30 to over 95 percent, depending on local conditions.

Water tolerant species of vegetative cover (reed canary grass, tall fescue, Kentucky bluegrass, and white clover) should be used to maintain high infiltration rates. The type of filter strip depends upon land capability, uses of the strip, types of adjacent land use, kinds of wildlife desired, personal preferences of the landowner, and availability of planting stock or seed. Filter strips should be established at the perimeter of disturbed or impervious areas to intercept sheet flows of surface runoff. These grass buffer strips will slow runoff flow to settle particulate contaminants and encourage infiltration. Periodic inspections are necessary and thatch should be periodically removed.

In the Silver Lake watershed, filter strips would be an effective method to use in agricultural areas suffering from turn row erosion. Runoff in a field can travel along individual rows, concentrating in the areas at the ends of the rows where the plow made a sharp turn. Cost of implementation is approximately $400 per acre.

5.2.3. Septic System Alternatives

In the Silver Lake watershed, many of the soils classified as "severely limited" for proper function of septic tank leach fields. Malfunctioning septic systems leach nutrients and bacteria to nearby surface and ground waters which can eventually end up in Silver Lake. Suspect septic systems, particularly those near drainage streams, should be inspected with the aid of the County Health Department.

5.2.4. Streambank and Roadway Stabilization

Most of the streambanks and road shoulders in the Silver Lake watershed are gently sloped and vegetated. However there are particular sites along streams and near some bridges where uncovered soil is exposed to the erosive action of stormwater runoff and streams.

Streambank Erosion Control

Although it was beyond the scope of this study to identify specific streambank erosion problems, streambank erosion is often a significant source of the sediments and nutrients that enter a lake. The Watershed Commission District should identify areas of streambank erosion and classify these areas as slight, moderate, or severe problems.

Streambank erosion can be corrected in various ways: (1) by reducing the amount and velocity of water in the stream; (2) by relatively high cost structural controls such as rip-rap and gabions; and (3) by relatively low-cost vegetative controls such as willow twigs.

Reducing the amount and velocity of water in the stream is not usually practical since existing upstream conditions dictate the present storm flow regime. However, controls can keep the existing amount and velocity of water from increasing. Creation and implementation of a Runoff Control Ordinance will minimize the increase in the amount and velocity of storm flow, resulting in little or no increase in streambank erosion.

Structural streambank erosion controls such as rip-rap or gabions should only be implemented in severe problem areas where low-cost vegetation controls cannot be used.

Low-cost vegetative controls, such as the planting of willow twigs, should be used wherever practical to control moderate and severe streambank erosion. Vegetative controls can often be planted by volunteers such as Boy Scouts and Girl Scouts. Use of volunteers enhances the benefits by adding educational and publicity aspects to the program.

Roadway Erosion Control

The roads in the watershed cross many streams and drainage ways that are tributary to Silver Lake. Stormwater runoff from the roads and from the lands adjacent to the roads travel down the road shoulders and discharge sediments and nutrients into the waterways and eventually into the lake.

The road shoulders are maintained by the transportation department usually to cut down extraneous weeds and grass. This often results in increased stormwater runoff with increased water velocity, increased erosion, and increased pollutant loading to the waterbodies.

The Watershed Commission should identify roadway and stream crossing problem areas and classify them as slight, moderate, or severe problems. Both structural and vegetative controls can be used to reduce the sediment and nutrient entering the waterways.

5.3 Institutional

The Silver Lake Watershed Commission must be instrumental in addressing the needs of the entire Silver Lake watershed. This organization should have sufficient authority to assume management responsibility for the lake and its watershed, arranging and overseeing outside technical and financial assistance as needed, but would not levy taxes or enforce regulations. Major functions of the Silver Lake Watershed Commission should conduct lake and watershed monitoring programs, provide technical assistance, review, and advisory service, develop model programs and ordinances, coordinate watershed management activities, and apply for state and federal funding for various projects within the watershed.

Another important function of the commission should be to develop educational materials and conduct educational programs for regulatory people, school children, and the public at large. One important activity which should be part of the educational program is a "Watershed Watch" program. An educational fact sheet could be distributed which describes potential pollutant sources (eroding land, gasoline, oil, or chemical spills, etc.), and gives a telephone number to contact if someone sees a possible problem.

The Silver Lake Watershed Commission should also be involved in land use planning activities which would protect or improve the water quality in Silver Lake. Such activities might include land acquisition, conservation easements, and land trusts.

5.4 Sedimentation Basins

Depending on their size and the associated drainage area, sedimentation basins can remove a significant amount of sediment, phosphorus and nitrogen from the stream that it serves. The use of a sedimentation basin along the Silver Lake Inlet, together with other best management practices to control of the amount of nutrients and sediment, is recommended. Basin efficiency was determined using the results of the Nationwide Urban Runoff Program summary by Driscoll (1983).

To remove 75 percent of the total suspended solids, 45 percent of the total phosphorus and 32 percent of the total Kjeldahl nitrogen, biological oxygen demand, chemical oxygen demand and metals, a sedimentation basin of 21 acres (mean depth 3.5 feet) would have to be constructed. A larger, more efficient basin of 64 acres (mean depth 3.5 feet), would remove 95 percent of the total suspended solids, 62 percent of the total phosphorus and 45 percent of the total Kjeldahl nitrogen, biological oxygen demand, chemical oxygen demand and metals. Two methods of constructing the sedimentation basins are possible. The first method involves the construction of a berm and some excavation of land behind the berm. The second alternative is to create a basin by excavation alone. The construction costs for the berm and excavation are less, although more land is required. The second method has higher construction costs but requires less land. Costs for the installation of each of the alternative sedimentation basins were determined from previous sedimentation design projects.

The estimated cost for creating a 21 acre basin by the berm and excavation method is $930,000. To create a 64 acre basin the cost would be approximately $2.8 million. Costs include design and construction, but do not include land acquisition or permit application fees. These costs are based on similar estimates for smaller basins multiplied by the increased area of these basins.

The construction of the 21 acre and 64 acre sedimentation basins by excavation alone would require the removal of 102,000 cubic yards and 310,000 cubic yards of sediment respectively. Dredging by mechanical methods is required in wetland areas. If the area to be excavated was composed entirely of wetlands, then the cost to create the 21 acre basin would be $1.6 million. The cost for the 64 acre basin would be $4.9 million. The most cost efficient way to excavate the site of the proposed sedimentation basin is with bulldozers. Costs would be significantly reduced if bulldozers could be used for large portions of the basin area. These cost estimates include the design and construction of the basins. The costs for land acquisition and permit application fees are not included.

Based on the above costs and removal effiencies, it is recommended that a sedimentation basin with a minimum surface area of 21 acres be constructed in the Silver Lake Inlet. It is presumed that this basin could be constructed by the combination berm and excavation method. In conjunction with in-lake dredging, the water quality of Silver Lake should is expected to significantly improve by reducing the suspended solid and nutrient loadings from the Silver Lake Inlet.

6.0 Recommended Management Plan for Silver Lake

Based on the data collected during the diagnostic portion of this study and the research into the feasibility of various lake and watershed management techniques presented in Sections 4 and 5 of this report, a recommended program to address the water quality problems in Silver Lake has been developed. Since most of the pollutant load originates from nonpoint sources in the drainage basin, significant improvement in lake water quality will come about slowly, but because the ratio of watershed area to lake surface area is relatively small, watershed management practices have a real chance to improve water quality in Silver Lake. The following management plan is recommended to achieve these ends.

6.1 Institutional

The Silver Lake Watershed Commission should oversee all activity in the Silver Lake watershed which affects water quality. Members should include all appropriate government representatives and other people who can offer valuable technical and planning expertise. The functions of the Silver Lake Watershed Commission should be as follows: 1) provision of technical and advisory assistance to local government, homeowners, businesses, developers, and farmers, 2) development of model programs and ordinances, including erosion and sedimentation ordinances for new construction and a stormwater runoff ordinance to control water quality and flooding, 3) prioritization of watershed and lake management activities, including implementation projects and further studies, and 4) financial management of lake and watershed programs, including seeking funds for implementation.

The Silver Lake Watershed Commission has no taxation or enforcement powers, therefore these activities are accomplished through the existing power base. Enforcement and taxation bodies should look to the watershed Commission for guidance on watershed-related activities. A formal organization plan for the Silver Lake Watershed Commission should be drawn up immediately so that action can begin on Silver Lake management activities.

Public Education

Another important function of the commission should be to develop educational materials and conduct educational programs for regulatory people, school children, and the public at large. One important activity which should be part of the educational program is a "Watershed Watch" program. An educational fact sheet could be distributed which describes potential pollutant sources (eroding land, gasoline, oil, or chemical spills, etc.), and gives a telephone number to contact if someone sees a possible problem.

Land Use Planning

The Silver Lake Watershed Commission should also be involved in land use planning activities which would protect or improve the water quality in Silver Lake. Such activities might include land acquisition, conservation easements, and land trusts.

6.2 In-Lake Restoration Methods

The management plan for Silver Lake primarily focuses on enhancing the short circuiting of Silver Lake Inlet and controlling nuisance growth of aquatic weeds. In the following paragraphs, in-lake restoration recommendations for Silver Lake are discussed.

6.2.1 Lake Dredging

The Silver Lake Inlet drains approximately 59 percent of the watershed and delivers substantial suspended solid and nutrient loadings to Silver Lake. Since the lake's main inlet and outlet are in close proximity to one another, it is recommended that the short circuiting of the Silver Lake Inlet be enhanced by in-lake sediment dredging between the inlet and outlet. For lake dredging, approximately 62,000 cubic yards of sediments must be removed to enhance short circuiting. The proposed maximum depth of water is 6 feet.

In comparing mechanical and hydraulic dredging costs, the hydraulic dredging option is more economically feasible if a sediment disposal site can be located near the northern shoreline. The estimated cost to hydraulically dredge 62,000 cubic yards of sediments is $850,000. This cost includes the cost for disposal site preparation, construction costs, design and permit preparation. The above dredging cost assumes that a suitable disposal site can be located in close proximity to the northern shoreline (within 100,000 feet of the site) and does not include permit application fees.

Another benefit associated with the dredging of sediments is by improving boat access in both the Silver Lake Inlet and Outlet areas. This is accomplished by increasing the water depth plus reducing the density of aquatic plants.

6.2.2 Physical Barriers

In the vicinity of docks, nuisance stands of aquatic weeds should be controlled by installing benthic barriers. Benthic barriers, such as fiberglass netting, provide a cost-effective means of controlling nuisance aquatic weed growth in an environmental sound manner. Benthic barriers are best suited for smaller areas and become quite expensive for controlling weed growth over large lake areas.

The estimated cost to cover an area of 400 square feet with fiberglass netting is approximately $120. The above cost does not include shipping and installation, and any additional materials, such as benthic anchors.

6.2.3 Macrophyte Harvesting

For large open lake areas where aquatic weed growth impairs desired lake uses, mechanical weed harvesting is recommended. The removal of macrophytes (or aquatic weeds) from Silver Lake by mechanical harvesting accomplishes several management objectives. Removal of plant material removes nutrients from the lake and reduces the size of the nutrient pool available to support future plant growth. Clearing macrophytes from shallow areas increases the amount of lake surface available for recreational activities, particularly boating and swimming. Care must be taken to leave sufficient plant growth for fish cover; bass and young fish thrive with good plant cover which is also suitable habitat for their food sources.

Harvesting macrophytes is preferable to chemical treatment for a number of reasons. When plants are killed by chemicals, they die and sink to the bottom of the lake. As they rot, bacteria use dissolved oxygen, and the resultant low dissolved oxygen in the water stresses fish. Low dissolved oxygen in deeper waters also creates chemical conditions which increase the rate of nutrient transfer from the sediments. Thirdly, the plant material itself becomes a nutrient source as decay proceeds. Harvesting has little effect on the dissolved oxygen content of the water, other than slightly increasing it because of increased turbulence, and a potential nutrient source (the plant material) is removed from the lake.

The Silver Lake Watershed Commission should identify areas where aquatic plant growth impairs desired lake uses. Once these areas are delineated, the watershed commission should accept bids from contractors with expertise in mechanical weed harvesting. At this time, the watershed commission should also receive cost for purchasing their own weed harvesting unit. The weed harvester unit should be able to cut a swath ranging from six to ten feet in width and to a depth of six to eight feet.

After comparing the above the costs, the watershed commission must decide on whether to contract out the weed harvesting program or establish their own program by purchasing their own harvesting unit.

6.2.4 Nutrient Inactivation and/or Hypolimnetic Aeration

While nutrient inactivation and hypolimnetic aeration are not recommended at this time, these in-lake restoration techniques would work well in Silver Lake, once the watershed loadings have been controlled. These techniques should be reevaluated at that time.

6.3 Watershed Management Methods

Development of stormwater runoff and erosion control ordinances, implementation of agricultural best management practices, evaluation of septic system alternatives, streambank stabilization, and evaluation of stormwater diversion are recommended to control nonpoint source pollution in the Silver Lake watershed. The Silver Lake Watershed Commission would take the lead in prioritization, procurement of funds, and implementation of these projects.

6.3.1 Development of Erosion Control and Stormwater Runoff

Ordinances

The Silver Lake Watershed Commission should develop erosion and sedimentation ordinances and stormwater runoff ordinances for the watershed. Model ordinances which have been developed by the New York Department of Environmental Conservation. There are technical manuals published by DEC and SCS designed to give guidance to localities in these areas.

Erosion Control Ordinance

The Watershed Commission should develop a model erosion and sediment control ordinance to control erosion from construction sites. The ordinance should include technical guidelines and typical details for the installation of erosion and control measures. These guidelines should discuss and recommend methods for controlling soil erosion and sedimentation, including the drainage area and velocity required for silt fences, straw bales, diversions, channel lining and other erosion control measures, and design specifications. Details for the installation of silt fence, straw bales, construction entrances and other standard methods should be included. Procedures for review of erosion control plans and inspections of construction sites should also be included.

Runoff Control Ordinance

The Silver Lake Watershed Commission should develop a model runoff control ordinance for regions within the Silver Lake watershed. Unlike the proposed erosion and sediment control ordinance which is designed to control erosion and runoff during construction activity, the runoff control ordinance is designed to control erosion and runoff after construction activities are complete, for the life of the project.

The runoff control ordinance should be developed on the basis of the environmental performance standards that the peak stormwater runoff and the pollutant loads from a new development or facility shall not exceed the pre-development levels.

The runoff control ordinance should include methods for calculating runoff flows and velocity, design storm requirements, rate of runoff control requirements and water quality standards. If detention or retention facilities are required, the ordinance should include design standards for these facilities for freeboard, emergency spillways, bottom slope and other technical or safety requirements. The ordinance should also include procedures for an engineering review of the plan and inspections during construction.

6.3.2 Agricultural Best Management Practices

The Silver Lake Watershed Commission should work closely with the Soil and Water Conservation District, the Soil Conservation Service, and the Agricultural Stabilization and Conservation Service to prioritize specific parcels of land for agricultural BMP implementation. Priority should be based on benefit to water quality, cost of implementation, funds available, and participation interest of land owner. Low-cost activities which could be addressed immediately include stabilization of known eroding areas, keeping animals out of rivulets and streams, controlling fertilizer application dosage and timing to maximize infiltration and minimize runoff, creating buffer areas between agricultural fields and streams.

For dairy operations, key items to address are barnyard runoff, manure spreading and storage, and milkhouse waste disposal. Methods which divert clean runoff around the barnyard keep the barnyard dry, thereby not only improving the quality of stormwater runoff, but improving herd health, reducing hoof disease, and reducing sediment in milk. Long or short-term manure storage would provide options for spreading methods. Filter strips or storage lagoons could be used to treat milkhouse wastes.

6.3.3 Septic System Alternatives

The Silver Lake Watershed Commission should work closely with the County Health Department in order to locate and remediate failing septic systems. Systems which are old and are near streams merit high priority for inspection. An educational program followed by a voluntary inspection program could be implemented by the district. A "Do you know your septic system?" questionnaire could be developed and sent out to watershed residents not serviced by the community wastewater treatment facility. After working through the questionnaire, people may elect to have their system inspected and evaluated if it can be done without penalty and at low cost. A shallow groundwater monitoring project could be conducted by the Watershed Commission in order to ascertain the extent of septic failure and the resultant nutrient and bacterial loading within the watershed.

6.3.4 Streambank Stabilization

The Watershed Commission should identify areas of streambank erosion and classify these areas as slight, moderate, or severe problems. Streambank erosion can be corrected by: (1) reducing the amount and velocity of water in the stream; (2) installing relatively high cost structural controls such as rip-rap and gabions; and (3) installing relatively low-cost vegetative controls such as willow twigs, shrubs or grasses. Low-cost vegetative controls should be used wherever practical to control moderate and severe streambank erosion. Trees, grasses, and shrubs which can withstand both desiccation and submersion are recommended. The SWCD can provide technical assistance. Vegetative controls can often be planted by volunteers such as Boy Scouts and Girl Scouts. Use of volunteers enhances the benefits by adding educational and publicity aspects to the program.

6.3.5 Roadway Erosion Control

The Watershed Commission should identify roadway and stream crossing problem areas and classify them as slight, moderate, or severe problems. Both structural and vegetative controls should be used to reduce the sediment and nutrient entering the waterways.

6.3.6 Sedimentation Basin

Within the Silver Lake Inlet, it is recommended that a 21 acre sedimentation basin be constructed. The estimated cost for design and construction is $930,000. A smaller basin would obviously cost less, but the pollutant removal efficiency of a smaller basin would not be sufficient to improve lake water quality. In conjunction with in-lake dredging, the water quality of Silver Lake should is expected to significantly improve by reducing the suspended solid and nutrient loadings from the Silver Lake Inlet.

6.4 Benefits Expected From Management Plan Implementation

The benefits to be realized from implementation of the proposed management plan will be reduced pollutant loadings to Silver Lake and subsequent improvement in recreational opportunities for the Silver Lake State Park. The general public would benefit from improved water quality by increased use of Silver Lake for fishing, swimming, and boating. Wildlife would benefit from protection in refuge areas and an increase in potential cover and spawning areas. Farmers in the area would benefit by a reduction in soil loss preserving an important natural resource and lower chemical costs through the implementation of various BMP's.

It is difficult to assign a numerical value to the benefits expected from implementation of the management program as various levels of pollutant loading reduction to Silver Lake are attainable depending on the level of BMP implementation in the watershed. While the reductions in nutrient loadings would probably not result in mesotrophic conditions in Silver Lake, the lake should become considerably less eutrophic, aquatic plants should be less troublesome, and the severity and number of algal blooms should noticeably diminish. Significant reductions in bacterial loadings are also expected but cannot be quantified from the available information.

6.5 Environmental Evaluation

Since socio-economic and environmental impacts are part of the cost-effectiveness analysis for the restoration of Silver 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?

   Possibly. If a septic sewer system is expanded or installed, developmental pressures could increase. Improving agricultural lands through the installation of BMP's may actually enhance the desirability of the land for continued agricultural usage.

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

   No. The recommended Best Management Practices (BMP's) will reduce sediment and nutrient losses from cropland and pastureland and should benefit agricultural activities.

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

   No. Restoration activities will greatly enhance the recreational and aesthetic uses of the lake and adjacent park land.

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

   The project as planned involves no modifications to or activities which will impact existing structures. No lands which have not already been altered by agricultural or other development activities will be affected.

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

   The selected restoration alternatives will not cause any significant increases in energy demand over the long-term.

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

   Air quality may be affected over the short-term due to construction activities associated with agricultural BMP installation. All construction equipment should have proper emission controls and proper dust control practices should be used. Modern aquatic weed harvesters should not adversely affect air quality if properly maintained and operated.

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

   Noise levels may be temporarily affected by harvesting and construction activities. All construction vehicles and equipment should use noise control devices.

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

    No in-lake chemical treatments are recommended.

11. Will the project be located in a floodplain?

    Some of the proposed agricultural BMP's and stream bank stabilization activities may be located in floodplains, although no adverse effects are expected.

12. Will structures be constructed in the floodplain?

    The proposed sedimentation basin might be constructed within the floodplain. The impacts would be addressed during design prior to construction.

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?

    Shoreline stabilization activities might cause temporary increases in lake turbidity. Other construction activities could result in the transportation of nutrients, sediments or other pollutants to downstream waters. All earthmoving activities will be conducted in a way to minimize the erosion potential and minimize in-lake turbidity.

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

    No adverse effects are expected. The planting of buffer strips, streambank stabilization, and revegetation of exposed eroding areas will have secondary benefits and will expand habitat areas for birds and mammals.

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

All feasible alternatives for restoring Silver Lake have been thoroughly analyzed. The recommended plan has minimal negative environmental impacts, and implementation of BMP's will improve management of land resources and water quality. Because of the complexity of the problems encountered in Silver Lake and its watershed, the recommended approach using both in-lake and watershed management practices appears to be the most cost-effective method to improve fishing, boating, aesthetics, and other lakeside uses of Silver Lake.

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.

7.0 Public Participation

Members of F. X. Browne Associates, Inc. presented preliminary results at a public meeting in June 1991. A lake study fact sheet was distributed at that time. Conclusions and recommendations of the study were presented to the Silver Lake Watershed Commission and the public in September 1991. Their comments will be incorporated into the final report.

8.0 Implementation Program

In order to implement the recommended management plan for Silver Lake, a plan of action is needed, setting forth a schedule of target dates for specific activities estimated costs for each activity, and potential funding sources. The following sections describe potential federal and state funding programs, water quality monitoring and documentation necessary for assessment of the effect of restoration methods on water quality, and a summary and schedule of the management plan for Silver Lake.

8.1 Financial Assistance

Recent trends in state and federal funding indicate that implementation of the recommended management plan for Silver Lake may have to derive funds from a variety of sources. The original intent of the federal Clean Lakes Program, administered by the U.S. EPA was to fund Phase I studies to diagnose lake problems and develop feasible restoration alternatives, and then provide Phase II grants to implement lake restoration programs.

The money available for Clean Lakes Program funding has been variable in recent years and although there is no way to predict the availability of funding for the long term, 7 million dollars were appropriated for the program for fiscal 1991, $426,000 which were split among New Jersey, New York, and Puerto Rico. If a Phase II grant is awarded by the EPA, 50 percent of the total project costs would be funded at the federal level, and the remaining 50 percent would require a local match.

There is also a federally funded program administered by the EPA intended to reduce pollutant loading from non-point sources under Section 319 of the Federal Water Pollution Control Act. The program received 50 million dollars in fiscal 1991 for projects throughout the entire nation. Historically, the program has stressed agricultural non-point sources. County Soil and Water Conservation Districts have been active participants in this program.

Several other programs are available to help defray the costs of implementing agricultural best management practices. The Agricultural Conservation Program available through the U.S. Department of Agriculture Soil Conservation Service is a cost-sharing program funding 75% of costs for a particular management practice up to $3,500 per year per farm. Several cost-sharing programs are available to individual land owners through the ASCS.

New York State funds may be available for lake projects either through appropriations to DEC or through the local assistance budgets. Special funds may be secured by state legislators for lake restoration projects in their districts. Facilities development and land acquisition may be funded by bond acts approved by state referendum, such as the 1986 Environmental Quality Bond Act. Research projects and water quality studies conducted by non-profit organizations can obtain funding from the New York State Water Resources Institute at Cornell through the New York State Legislature and the NYS Department of Agriculture and Markets. Activities involving the protection and management of fish and game can be funded through the Conservation Fund, which receives revenue from fishing and hunting licenses.

Local funding can be arranged through special taxes (stormwater), donations, dues, developer option trade-off of funds for restoration and recreation rather than open space, and special fund raising events.

8.2 Future Monitoring

If EPA Phase II funding is obtained, a water quality monitoring program is required in order to detect changes occurring as a result of Phase II restoration programs. EPA regulations require that a limited monitoring program be conducted throughout the restoration project and for at least one additional year after all facets of the management program are in place.

A limited monitoring program is recommended even if EPA funding is not available for the restoration of Silver Lake. Monitoring shows the effects of project activities on water quality both during and after implementation. Project activities can be modified if water quality deteriorates beyond acceptable limits during the implementation stage.

8.3 Pollutant Budget Update and Detail

Fine tuning of the pollutant budget would aid in watershed management, particularly as restoration projects are implemented and land use changes. Detailed knowledge of acreage under specific land management practices, the number of animals per field or barnyard, etc., can pinpoint priority target areas. The Soil and Water Conservation District, the SCS, and the ASCS could work in conjunction with F. X. Browne Associates to use a computer model, such as "Agricultural Nonpoint Source" (AGNPS) to detail and monitor land use and management changes within the watershed. The model also allows the user to estimate effects of specific project implementation on water quality.

8.4 Documentation

Results of the Silver Lake Restoration Project should be fully documented to provide the Silver Lake Watershed Commission with a record of project activities. The final report should include a description and evaluation of all project activities, a listing of all water quality data collected, and an evaluation of the success of the project. If outside funding is obtained, the project should be documented in accordance with requirements of the funding agency.

8.5 Management Plan Schedule and Summary

The management plan for Silver Lake is summarized in Table 8.1, along with target dates for implementation.

Table 8.1
Action Plan for the Restoration of Silver Lake

Define the role of the Silver Lake Watershed Commission	Winter, 1991.
Public education	Spring, 1992. Ongoing.
Land use planning	Spring, 1992. Ongoing.
Installation of benthic barriers	Spring, 1992.
Weed Harvesting	Spring, 1992.
Apply and obtain funding	Fall 1991 through Summer 1992
Sediment dredging in Silver Lake	Design and permitting, Fall 1992. Construct, Spring/Summer 1993
Construction of sedimentation basin in the Silver Lake Inlet	Spring and Summer, 1993.
Investigate on-lot septic systems	Spring, 1992. Ongoing.
Development of erosion control ordinance	Summer, 1992.
Development of stormwater runoff ordinance	Summer, 1992.
Identify and implement agricultural best management practices	Summer, 1992. Ongoing.
Identify areas in need of streambank stabilization and implement stabilization	Summer, 1992. Ongoing.
Identify areas in need of roadway stabilization and implement stabilization	Summer, 1992. Ongoing.

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APPENDIX A

Glossary of Lake and Watershed Management Terms

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.

*From EPA Clean Lakes Manual, 1980.

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

Primer on Lake Ecology

Lake Ecology Primer

The ecological conditions of any lake is the summation of physical, chemical, and biological processes which occur in it. Temperature and dissolved oxygen measurements are usually reliable means of evaluating the ecological conditions of a lake. Life processes in the upper well lighted waters result in the uptake of nutrients and in the production of oxygen and organic material. At the bottom, the absence of light results in an environment which is colder than the surface and often devoid of dissolved oxygen. Photosynthetic production by green plants is the predominant life process at the surface while bacterial decomposition is the predominant process at the bottom. The supply of dissolved oxygen at the bottom may be depleted by bacterial decomposition and by various chemical processes associated with nutrient cycling.

Dissolved oxygen is necessary to support most forms of aquatic life. A minimum dissolved oxygen concentration of 5.0 milligrams per liter is usually required to support most fish. Warm water fish, such as bass and perch, often survive at lower oxygen levels. Oxygen levels in lakes are directly related to physical, chemical and biological activities occurring in the lake water. Measurement of dissolved oxygen is therefore an excellent indicator of the overall water quality of a lake.

Although lakes are usually in a balanced condition, two types of natural long-term changes are occurring: (1) The lake is gradually filling in with soil from upstream and surrounding land areas; and (2) the additional materials carried to the lake area usually stimulate increased plant production. The lake fills with both sediment and with the remains of plants and animals. The number of dead plants and animals increases as the production of organisms increases. These processes usually cause lakes to become shallower. The lake gradually tends to fill completely. As this process, called succession or aging, continues, the types of animals and plants also begin to change. Game fish such as bass, pike, and pan fish may be replaces by rough species such as carp, suckers, and bullheads. Rough fish are better adapted to live in a lake which is relatively old on the time scale of succession. Eventually the lake or pond becomes a bog or swamp. In turn the swamp tends to continue to fill in and, if conditions are right, a forest takes over.

Depending on the natural environmental conditions, the process of natural succession may take hundreds or even thousands of years. The actions of man, however, can considerably accelerate this aging process. It can be said, therefore, that lakes have both a chronological and ecological age. The chronological age is simply the number of years a lake has existed. The ecological age, on the other had, is a measure of the physical, chemical, and biological conditions of a lake.

Relative to ecological age, most lakes are classified as being either oligotrophic, mesotrophic or eutrophic. An oligotrophic lake is an ecologically "young" lake that usually has low nutrient levels and low plant and animal productivity. A mesotrophic lake can be considered to be a "middle-aged" lake that contains average amounts of nutrients and has an average plant and animal productivity. A eutrophic lake is one that has a high nutrient content and a high plant and animal productivity. During the spring, summer, and fall, a eutrophic lake usually has an algal bloom or an excessive growth of aquatic plants.

APPENDIX C

Bathymetric Map of Silver Lake

APPENDIX D

Water Quality Monitoring Data

Date	Sample Depth (m)	Integ. pH	Alkalinity (mg CaCO3)	Specific Conductivity	Ortho Phosphate	Total Suspended Solids	Total Phosphate	Nitrate/ Nitrite	Ammonia	Total Kehldahl Nitrogen	Integrated Chlorophyll a
1-23-90											
Station 1	0.5	7.9	116	337	0.01	1	0.03	0.39	-0.1	0.77	0.7
	3.5	7.9	112	344	0.01	1.5	0.021	0.25	-0.1	0.93	
	7	7.9	118	351	0.01	1.5	0.021	0.34	-0.1	0.95	
Station 2	0.5	8	110	333	-0.01	1.7	0.025	0.25	-0.1	0.86	0.6
	4.5	7.9	114	342	-0.01	1.5	0.016	0.21	-0.1	0.83	
	9	7.8	130	372	0.013	1.6	0.035	0.34	0.239	0.94	
4-22-90											
Station 1	0.5	8.1	108	339	-0.01	0.6	0.021	0.583	-0.1	0.465	0.6
	7	8	110	339	-0.01	0.6	0.019	0.583	-0.1	0.435	
	11	7.9	110	339	-0.01	1	0.02	0.576	-0.1	0.355	
Station 2	0.5	8	110	340	-0.01	1.4	0.019	0.596	-0.1	0.425	0.3
	5.5	8	108	340	-0.01	1	0.013	0.583	-0.1	0.475	
	10.5	7.9	112	340	-0.01	0.6	0.018	0.59	-0.1	0.355	
6-19-90											
Station 1	0.5			323.7	0.015	1.26	0.021	1.2	0.13		
	6.5			345.7	0.007	0.98	0.021	0.7	0.09		
	9			358.7	0.056	4.1	0.057	0.29	0.18		
	10.5			356.7	0.045	2.34	0.05	1.16	0.22		
Station 2	0.5			340.7	0.02	1.5	0.021	0.71	0.08		
	6.5			339.7	0.017	1.12	0.019	0.59	0.09		
	9			348.7	0.009	1.38	0.018	0.4	0.11		
	10.5			354.7	0.049	4.08	0.031	0.55	0.2		
7-18-90											
Station 1	0.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	6.5	NA	NA	293.8	NA	2	0.031	0.02	ND	0.35	
	10.5	NA	NA	303.4	NA	0.7	0.037	0.01	ND	0.26	
Station 2	0.5	NA	NA	292.1	NA	2.7	0.048	0.04	ND	0.53	
	6.5	NA	NA	290.4	NA	3.3	0.04	0.02	ND	0.37	
	10.5	NA	NA	313.8	NA	4.8	0.083	0.03	0.22	0.77	
9-19-90											
Station 1	0.5	8.1	99.4	325.7	0.03	NA	0.072	0.65	0.03	0.23	
	6.5	7.96	NA	307.1	0.032	NA	0.065	0.72	0.06	0.18	
	10.5	7.92	99.9	319.9	0.034	NA	0.063	0.24	0.09	0.25	
Station 2	0.5	8.01	90.8	326.7	0.041	2.7	0.058	0.4	0.016	0.32	
	6.5	8.01	95.5	319.9	0.035	2.3	0.077	0.57	0.03	0.18	
	10.5	8.01	95.6	322.8	0.033	2.5	0.081	0.23	0.03	0.23	
11-3-90											
Station 1	0.5	8	104.03	344.2	N.D.	2.8	0.041	0.5	N.D.	N.A.	
	6.5	8.02	101.7	346.1	N.D.	2.78	0.051	0.23	N.D.	N.A.	
	10.5	7.99	102.3	346.1	N.D.	64.88	0.5	0.35	N.D.	N.A.	

Station 2	0.5	8.1	102.1	345.2	N.D.	3	0.021	0.46	N.D.	N.A.	
	6.5	8.11	101.5	346.2	N.D.	2.94	0.029	0.75	N.D.	N.A.	
	10.5	8.09	102.2	345.2	N.D.	2.54	0.058	0.5	N.D.	N.A.	
1-30-91											
Station 1	0.5	7.9	130	353	0.007	1.2	0.026	0.57	-0.1	0.64	
	6.5	7.9	106	352	0.01	1.8	0.025	0.61	-0.1	0.65	
	10.5	7.9	110	356	0.022	1.2	0.038	0.69	-0.1	0.6	
Station 2	0.5	8	108	353	0.008	1.2	0.024	0.59	-0.1	0.57	
	6.5	8	106	347	0.007	1.2	0.024	0.58	-0.1	0.62	
	10.5	8	108	345	0.008	1.2	0.024	0.6	-0.1	0.6	
4-2-91											
Station 1	0.5	8	102	340	0.004	2	0.031	0.77	-0.1	0.68	4.8
	5.5	8	104	340	0.005	2.4	0.044	0.74	-0.1	0.75	
	11	8	104	340	0.005	2.8	0.031	0.76	-0.1	0.74	
Station 2	0.5	8	102	340	0.003	4	0.031	0.79	-0.1	0.66	5
	4.5	8	1	340	0.005	3.6	0.045	0.79	-0.1	0.52	
	8.5	8	100	340	0.003	3.8	0.032	0.78	-0.1	0.64	

APPENDIX E

Phytoplankton Data

SILVER LAKE #1 012490

TAXON	CELLS/ML
BACILLARIOPHYTA	
Asterionella	5.2
Eunotia	19.5
Tabellaria	5.2
CHLOROPHYTA	
Chlamydomonas	3.9
CRYPTOPHYTA	
Cryptomonas	65
CYANOPHYTA	
Chroococcus	20.8
TOTAL	119.6
BACILLARIOPHYTA	29.9
CHLOROPHYTA	3.9
CRYPTOPHYTA	65
CYANOPHYTA	20.8

TAXON	UG/L
BACILLARIOPHYTA	
Asterionella	1.0
Eunotia	15.6
Tabellaria	15.6
CHLOROPHYTA	
Chlamydomonas	1.5
CRYPTOPHYTA	
Cryptomonas	65
CYANOPHYTA	
Chroococcus	8.3
TOTAL	107.1
BACILLARIOPHYTA	32.2
CHLOROPHYTA	1.5
CRYPTOPHYTA	65
CYANOPHYTA	8.3

SILVER LAKE #1 042190

TAXON	CELLS/ML
BACILLARIOPHYTA	
Asterionella	43.2
Cyclotella	5.4
Eunotia	34.2
Fragilaria	136.8
CHRYSOPHYTA	
Dinobryon	57.6
CRYPTOPHYTA	
Cryptomonas	57.6
PYRRHOPHYTA	
Peridinium	5.4
TOTAL	340.2
BACILLARIOPHYTA	219.6
CHRYSOPHYTA	57.6
CRYPTOPHYTA	57.6
PYRRHOPHYTA	5.4

TAXON	UG/L
BACILLARIOPHYTA	
Asterionella	8.6
Cyclotella	27
Eunotia	136.8
Fragilaria	96.1
CHRYSOPHYTA	
Dinobryon	172.8
CRYPTOPHYTA	
Cryptomonas	57.6
PYRRHOPHYTA	
Peridinium	16.2
TOTAL	515.1
BACILLARIOPHYTA	268.5
CHRYSOPHYTA	172.8
CRYPTOPHYTA	57.6
PYRRHOPHYTA	16.2

SILVER #1 062290

TAXON	CELLS/ML
BACILLARIOPHYTA	
Cyclotella	7.8
Eunotia	31.2
Synedra	15.6
CHLOROPHYTA	
Coelastrum	31.2
Eudorina	62.4
Sphaerocystis	109.2
CHRYSOPHYTA	
Dinobryon	161.2
CRYPTOPHYTA	
Cryptomonas	10.4
CYANOPHYTA	
Anabaena	156
Merismopedia	156
TOTAL	741
BACILLARIOPHYTA	54.6
CHLOROPHYTA	202.8
CHRYSOPHYTA	161.2
CRYPTOPHYTA	10.4
CYANOPHYTA	312

TAXON	UG/L
BACILLARIOPHYTA	
Cyclotella	39
Eunotia	31.2
Synedra	12.4
CHLOROPHYTA	
Coelastrum	18.7
Eudorina	24.9
Sphaerocystis	10.9
CHRYSOPHYTA	
Dinobryon	483.6
CRYPTOPHYTA	
Cryptomonas	10.4
CYANOPHYTA	
Anabaena	62.4
Merismopedia	31.2
TOTAL	724.8
BACILLARIOPHYTA	82.6
CHLOROPHYTA	54.6
CHRYSOPHYTA	483.6
CRYPTOPHYTA	10.4
CYANOPHYTA	93.6

SILVER #1 072890

TAXON	CELLS/ML
CHLOROPHYTA	
Chlorella	992
Chlorococcum	682
Eudorina	49.6
Sphaerocystis	74.4
CRYPTOPHYTA	
Cryptomonas	40.3
CYANOPHYTA	
Anabaena	496
Aphanizomenon	744
Lyngbya	232.5
PYRRHOPHYTA	
Ceratium	3.1
TOTAL	3313.9
CHLOROPHYTA	1798
CRYPTOPHYTA	40.3
CYANOPHYTA	1472.5
PYRRHOPHYTA	3.1

TAXON	UG/L
CHLOROPHYTA	
Chlorella	99.2
Chlorococcum	68.2
Eudorina	19.8
Sphaerocystis	7.4
CRYPTOPHYTA	
Cryptomonas	40.3
CYANOPHYTA	
Anabaena	198.4
Aphanizomenon	7.4
Lyngbya	465
PYRRHOPHYTA	
Ceratium	124
TOTAL	1029.8
CHLOROPHYTA	194.6
CRYPTOPHYTA	40.3
CYANOPHYTA	670.8
PYRRHOPHYTA	124

SILVER #1 091990

TAXON	CELLS/ML
BACILLARIOPHYTA	
Asterionella	4.8
Cyclotella	36
Eunotia	2.4
Fragilaria	76.8
Melosira	288
CHLOROPHYTA	
Cosmarium	4.8
Staurastrum	4.8
CRYPTOPHYTA	
Cryptomonas	55.2
CYANOPHYTA	
Anabaena	1824
Aphanizomenon	480
Lyngbya	528
Microcystis	960
PYRRHOPHYTA	
Ceratium	4.8
TOTAL	4269.6
BACILLARIOPHYTA	408
CHLOROPHYTA	9.6
CRYPTOPHYTA	55.2
CYANOPHYTA	3792
PYRRHOPHYTA	4.8

TAXON	UG/L
BACILLARIOPHYTA	
Asterionella	.9
Cyclotella	180
Eunotia	9.6
Fragilaria	23.0
Melosira	86.4
CHLOROPHYTA	
Cosmarium	3.8
Staurastrum	57.6
CRYPTOPHYTA	
Cryptomonas	11.0
CYANOPHYTA	
Anabaena	729.6
Aphanizomenon	4.8
Lyngbya	1056
Microcystis	192
PYRRHOPHYTA	
Ceratium	192
TOTAL	2546.8
BACILLARIOPHYTA	300

SILVER #2 091990

TAXON	CELLS/ML
BACILLARIOPHYTA	
Cyclotella	33.6
Fragilaria	168
Melosira	228
CHLOROPHYTA	
Closterium	2.4
Oocystis	9.6
Staurastrum	4.8
CYANOPHYTA	
Anabaena	1200
Aphanizomenon	672
Lyngbya	336
Microcystis	1440
PYRRHOPHYTA	
Ceratium	2.4
TOTAL	4096.8
BACILLARIOPHYTA	429.6
CHLOROPHYTA	16.8
CYANOPHYTA	3648
PYRRHOPHYTA	2.4

TAXON	UG/L
BACILLARIOPHYTA	
Cyclotella	168
Fragilaria	50.4
Melosira	68.4
CHLOROPHYTA	
Closterium	240
Oocystis	28.8
Staurastrum	57.6
CYANOPHYTA	
Anabaena	480
Aphanizomenon	6.7
Lyngbya	672
Microcystis	288
PYRRHOPHYTA	
Ceratium	96
TOTAL	2155.9
BACILLARIOPHYTA	286.8
CHLOROPHYTA	326.4
CYANOPHYTA	1446.7
PYRRHOPHYTA	96

SILVER LAKE #2 013091

TAXON	CELLS/ML
BACILLARIOPHYTA	
Asterionella	76.8
Cyclotella	3.2
Synedra	1.6
CHLOROPHYTA	
Chlamydomonas	9.6
Elakatothrix	6.4
CRYPTOPHYTA	
Cryptomonas	46.4
TOTAL	144
BACILLARIOPHYTA	81.6
CHLOROPHYTA	16
CRYPTOPHYTA	46.4

TAXON	UG/L
BACILLARIOPHYTA	
Asterionella	15.3
Cyclotella	12
Synedra	12.8
CHLOROPHYTA	
Chlamydomonas	3.8
Elakatothrix	.6
CRYPTOPHYTA	
Cryptomonas	31.5
TOTAL	76.1
BACILLARIOPHYTA	40.1
CHLOROPHYTA	4.4
CRYPTOPHYTA	31.5

SILVER LAKE #2 040291

TAXON	CELLS/ML
BACILLARIOPHYTA	
Asterionella	81.6
Cyclotella	10.2
Fragilaria	64.6
Gyrosigma	3.4
Melosira	34
Navicula	5.1
CHLOROPHYTA	
Eudorina	217.6
CHRYSOPHYTA	
Dinobryon	71.4
CRYPTOPHYTA	
Cryptomonas	88.4
TOTAL	576.3
BACILLARIOPHYTA	198.9
CHLOROPHYTA	217.6
CHRYSOPHYTA	71.4
CRYPTOPHYTA	88.4

TAXON	UG/L
BACILLARIOPHYTA	
Asterionella	16.3
Cyclotella	51
Fragilaria	59.8
Gyrosigma	10.8
Melosira	10.2
Navicula	5.1
CHLOROPHYTA	
Eudorina	184.9
CHRYSOPHYTA	
Dinobryon	214.2
CRYPTOPHYTA	
Cryptomonas	42.1
TOTAL	594.6
BACILLARIOPHYTA	153.3
CHLOROPHYTA	184.9
CHRYSOPHYTA	214.2
CRYPTOPHYTA	42.1

APPENDIX F

Lake Sediment Data

RECEIVED APR 2 9 1991

Hess Environmental Laboratories
112 North Courtland Street
East Stroudsburg, Pennsylvania 18301

EPA Lab # 45-116

4/24/91

Job Number : 01105.00

F.X. BROWNE ASSOC.
P.O. BOX 1398
PO#1363
MARSHALLS CREEK, PA 18335

Sample Number : 2028

Date Sampled : 4/3/91
Time Sampled : 1100
Sampled By : CLIENT

Sample Type : LAKE SEDIMENT
Location : SILVER LAKE

Date Received : 4/4/91

Date Tested : -----

Test	Description	Result	EPA Method
0043	PHOSPHORUS TOTAL	984. MG/KG	------
0071	NITROGEN KJELDAHL	5510 MG/KG	------
1040	NITROGEN/NITRATE	1.20 MG/KG	------
0101	NITROGEN/NITRITE	<0.34 MG/KG	------
0082	SOLIDS PERCENT	16.0 %	------
0104	SOLIDS VOLATILE	17.8%	------

NOTE : All Results expressed in mg/l unless otherwise specified

Laboratory Director