SILVER LAKE
DIAGNOSTIC STUDY
Kosciusko County, Indiana

February 15, 2001

Prepared for:

Silver Lake Association
c/o Ronald Jones
3344 West Neher Road
Silver Lake, Indiana 46982

Prepared by:

J.F. New & Associates, Inc.
c/o Marianne Giolitto, Project Manager
708 Roosevelt Road
Walkerton, Indiana 46574
(219) 586-3400

SILVER LAKE DIAGNOSTIC STUDY
EXECUTIVE SUMMARY

Silver Lake is a 102-acre (41 ha), natural lake situated approximately 10 miles south of Warsaw, Indiana in the southern portion of Kosciusko County. The lake's watershed encompasses approximately 3,300 acres (1,336 ha) or 5.2 square miles (13.5 km^2). Nearly 80% of the land in the watershed is used for agricultural purposes, including cropland, pasture and agricultural woodlots. The remaining 20% of the watershed is divided almost equally among forested land, wetlands, open water, and urban land use. An analysis of hydric soils in the watershed suggests that only approximately 20.5 % of the original wetland acreage exists today. Only 20 acres of land in the watershed is mapped in a highly erodible soil unit; however, nearly 30% of the watershed is mapped in a potentially highly erodible soil unit.

Silver Lake has three main inlets: Funk Ditch, an unnamed ditch from the east, and an unnamed ditch from the south. Historical inlet stream sampling documented the heavy nutrient and bacterial loads Silver Lake received prior to installation of the sanitary sewer system. Current sampling showed Funk Ditch delivers the greatest amount of total Kjeldahl nitrogen, nitrate nitrogen, and total suspended solids during base and runoff flows. The unnamed ditch from the east delivered the greatest amount of phosphorus to the lake during runoff flows. The unnamed ditch from the south exhibited the highest concentration of fecal coliforms.

Silver Lake itself is best characterized as eutrophic lake. Bluegill and gizzard shad dominate the lake's fish community, while Eurasian water milfoil, coontail, curly leaf pondweed, and elodea dominate the lake's rooted plant community. Silver Lake generally has worse water quality than most other Indiana lakes. Phosphorus concentrations appear to be increasing over time, while the percentage of the water column containing oxygen appears to be decreasing over time. Other water quality parameters appear to be stable or show no trend. Volunteer lake monitoring data indicates that the Secchi disk transparency of Silver Lake is decreasing. When historical data is used to score the lake with the Indiana Trophic State Index (TSI), the lake falls in the eutorphic or hypereutrophic categories. Similar results were obtained using the Carlson TSI. Phosphorus modeling of the lake and their watershed suggests that a large portion of the phosphorus in the lake originates from internal sources.

The eutrophication of Silver Lake did not occur quickly and the lake's recovery from historical and current nutrient loading will take time. Lake residents and the town of Silver Lake have already taken a significant step toward improving water quality by installing a sanitary sewer system. Further improvement will be achieved by implementing a variety of management strategies. These include installing filter/buffer zones along the lake's inlets to filter sediment and nutrients from overland flow, restoring of wetlands in the watershed to increase water storage and alleviate flooding and erosion downstream, retrofitting storm drains with new filters to increase pollutant removal from stormwater, implementing of home owner best management practices to reduce pollutant release to the lake, and developing an aquatic plant management plan improve the lake's habitat potential. Specific locations for the implementation of these management techniques are outlined in the study.

ACKNOWLEDGMENTS

This Diagnostic Study was performed with funding from the Indiana Department of Natural Resources – Division of Soil Conservation and the Silver Lake Property owners Association. J.F. New and Associates, Inc. documented the historical information available, completed tributary stream sampling for nutrient and sediment loading, and modeled nutrient export to the lake. Significant contributors to this study included Samuel St. Clair and Julie Harrold of the Kosciusko County Soil and Water Conservation District. A special thank you is due Ron Jones and other Silver Lake board members for their initiative and assistance in getting this study completed. Phil Shalley, Gwen White, Jed Pearson, Carol Newhouse, and numerous others assisted with their comments and contributions on historic lake activities. Authors of this report include Marianne Giolitto, Cornelia Sawatzky, John Richardson, and Jason Thron.

TABLE OF CONTENTS

APPENDICES

TABLE OF FIGURES

TABLE OF TABLES

SILVER LAKE PRELIMINARY DIAGNOSTIC STUDY
KOSCIUSKO COUNTY, INDIANA

INTRODUCTION

Silver Lake is a 102-acre (41 ha), natural lake situated approximately 10 miles south of Warsaw, Indiana in the southern portion of Kosciusko County (Figure 1). The lake is located in Section 6, Township 30 North, Range 6 East; Latitude: N 41° 4' 51" and Longitude: W86° 54' 5". The lake's watershed encompasses approximately 3,300 acres (1,336 ha) or 5.2 square miles (13.5 km^2). The Silver Lake watershed lies within the larger Eel River watershed. Water from the lake discharges to Silver Creek. From there, water drains through the Eel River to the Wabash River, eventually reaching the Ohio River in southwestern Indiana.

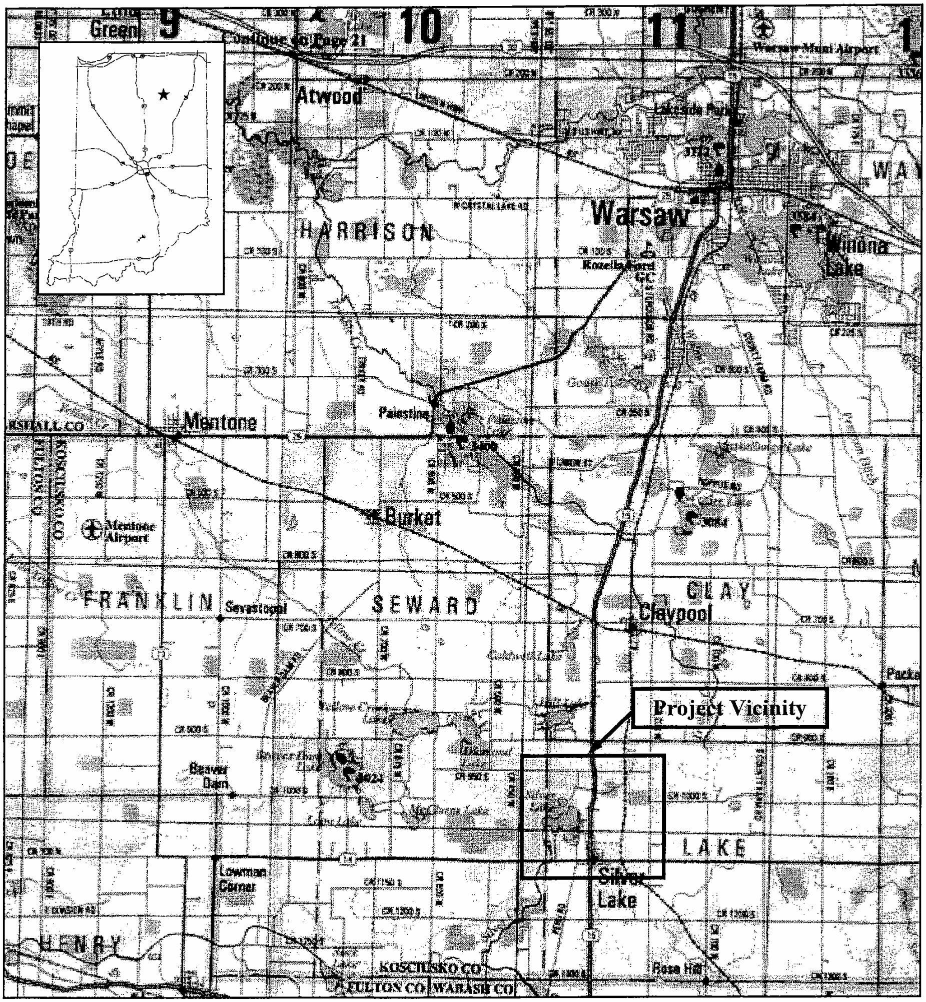
Silver Lake and its watershed were formed during the most recent glacial retreat of the Pleistocene era. The advance and retreat of the Saginaw Lobe of a later Wisconsian age glacier as well as the deposits left by the lobe shaped much of the landscape found in northeast Indiana (Homoya et al., 1985). In Kosciusko County, the receding glacier left a nearly level topography dotted with a network of lakes, wetlands, and drainages.

Silver Lake is located in the central portion of the Northern Lakes Natural Area (Homoya et al., 1985). The Northern Lakes Natural Area covers most of northeastern Indiana where the majority of the state's natural lakes are located. Natural communities found in the Northern Lakes Natural Area prior to European settlement included bogs, fens, marshes, prairies, sedge meadows, swamps, seep springs, lakes, and deciduous forests. Historically, swamps and oak-hickory mixed forests may have been the dominant communities in the Silver Lake watershed. Silver Lake itself was likely smaller in size without the existing dam. Shallow areas of the lake may have originally been wetlands. Dominant wetland vegetation may have included red and silver maple, American elm, and green and black ash in forested areas and cattails, swamp loosestrife, bulrush, marsh fern, and sedges in more open areas.

Like much of the landscape in Kosciusko County, a large portion of the Silver Lake watershed was converted to agricultural land. Today, approximately 80% of the Silver Lake watershed is utilized for agricultural purposes (row crop and pasture). The town of Silver Lake was established southeast of the lake, and residential land was developed along the lake's eastern and southern shores. These changes in land use have likely impacted Silver Lake's health.

Silver Lake has been plagued by a history of heavy nutrient loading. Early reports by the Indiana State Board of Health document the release of raw sewage to the lake via the lake's southern inlet. This inlet also conveyed laundromat wastes to the lake. Prior to the phosphate detergent ban implemented in the 1970's, these wastes were laden with phosphorus. These nutrient loads were in addition to the increased nutrient and sediment loads that occurred as forests and wetlands were converted to agricultural land.

Silver Lake's physical, chemical, and biological conditions reflected the heavy nutrient loading. According to Indiana Department of Natural Resources fisheries reports from the 1960's, a large,



Scale: 1" = 2.5 miles

JFNA# 99-09-24

Figure 1: **Location Map**
Silver Lake Diagnostic Study
Kosciusko County, Indiana

J.F. New & Associates, Inc.
708 Roosevelt Road
P.O. Box 243
Walkerton, IN 46574
Phone: 219-586-3400
FAX: 219-586-3446

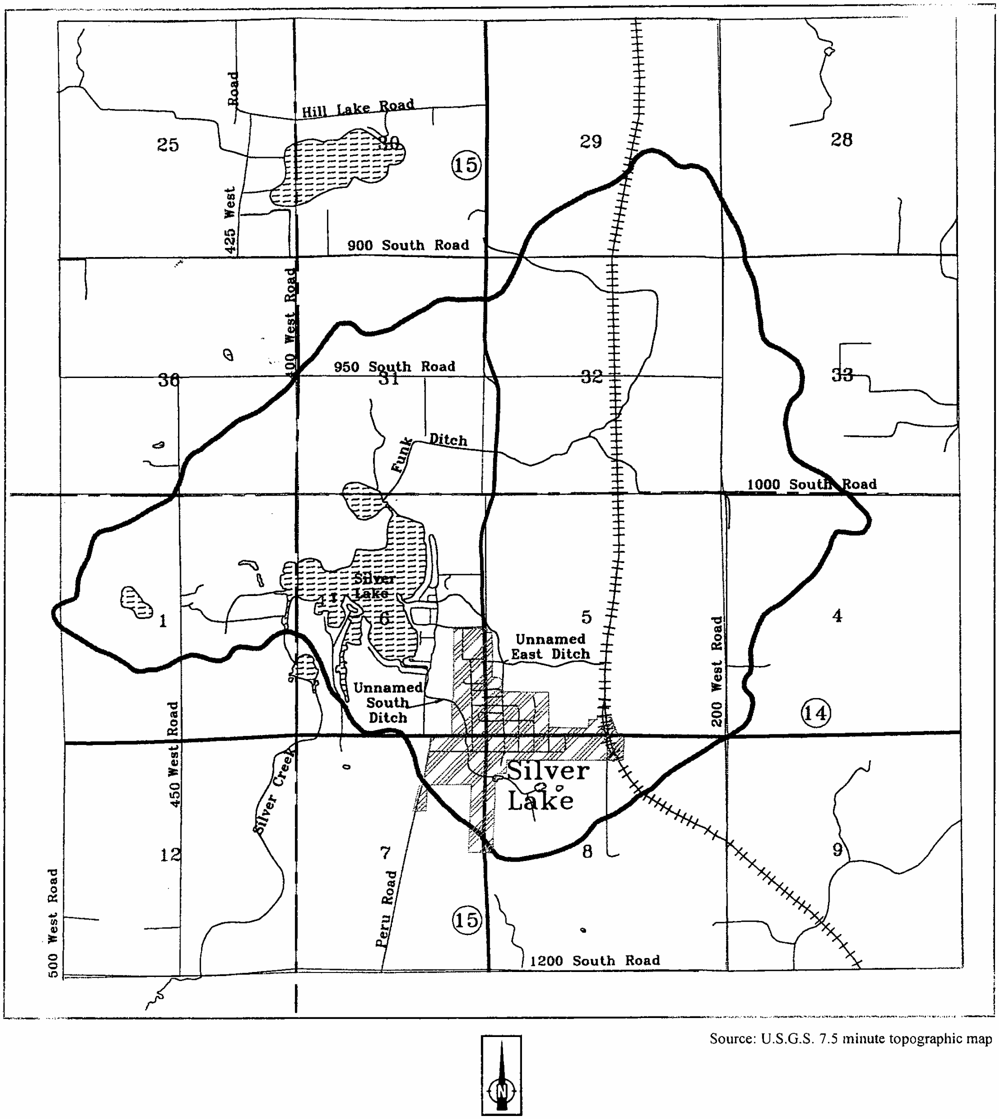
Permitting • Delineations • Mitigation Design • Biological Inventories
Wetland and Prairie Nursery • Lake and Stream Enhancement
Natural Systems for Wastewater Treatment

stunted bluegill population dominated the lake's fishery. Stunted bluegill populations are common in productive (eutrophic) lakes. A 1964 Indiana State Board of Health report noted the presence of a blue-green algae bloom. Blue-green algae are a nuisance species often associated with high nutrient concentrations. Further evidence of impairment was provided by a statewide lake survey conducted during the 1970's. Based on several water quality parameters, this survey placed Silver Lake in the IV Management Group, a group reserved for the lakes with the worst water quality. This data suggested that human-induced pressures were artificially accelerating the natural eutrophication process in Silver Lake.

The town of Silver Lake has taken measures to improve the lake's health. In 1990, the town installed a sanitary sewer system servicing the town and lake residences. (The treatment plant discharges effluent into Silver Creek downstream of the Silver Lake watershed.) While installation of the sewer system eliminated the discharge of nutrients from both functioning and failing septic systems, other sources of impairment exist. To assist in identifying these sources, the Silver Lake Property Owners Association applied for and received funding through the Indiana Department of Natural Resources Lake and River Enhancement Program for a preliminary lake and watershed diagnostic study. The purpose of the study was to describe the conditions and trends in Silver Lake and its watershed, identify potential problems, and make prioritized recommendations addressing these problems. Because this study was preliminary in nature, emphasis was placed on mapping current conditions and identifying trends in water quality. The study included a review of historical studies, interviews with lake residents and state/local regulatory agencies, the collection of stream water quality samples, an inventory of aquatic macrophytes (rooted plants), and field investigations identifying land use patterns. This report documents the results of the study.

WATERSHED PHYSICAL CHARACTERISTICS

Table 1 provides data concerning the physical size of the Silver Lake watershed and its subwatersheds. The Silver Lake watershed (Figure 2) encompasses approximately 3300 acres or 5.2 square miles (1,336 ha or 13.5 square km). Silver Lake has three main inlets. Funk Ditch is the largest source of discharge to Silver Lake draining approximately 1,450 acres (587 ha). The unnamed ditch from the east and the unnamed ditch from the south drain approximately 585 and 275 acres (237 and 111 ha) respectively. Approximately 965 acres (391 ha) of land drain directly to the lakes (including Little North Lake). Figure 3 shows each watershed's coverage. In total, Silver Lake possesses a watershed area to lake area ratio of approximately 33:1.

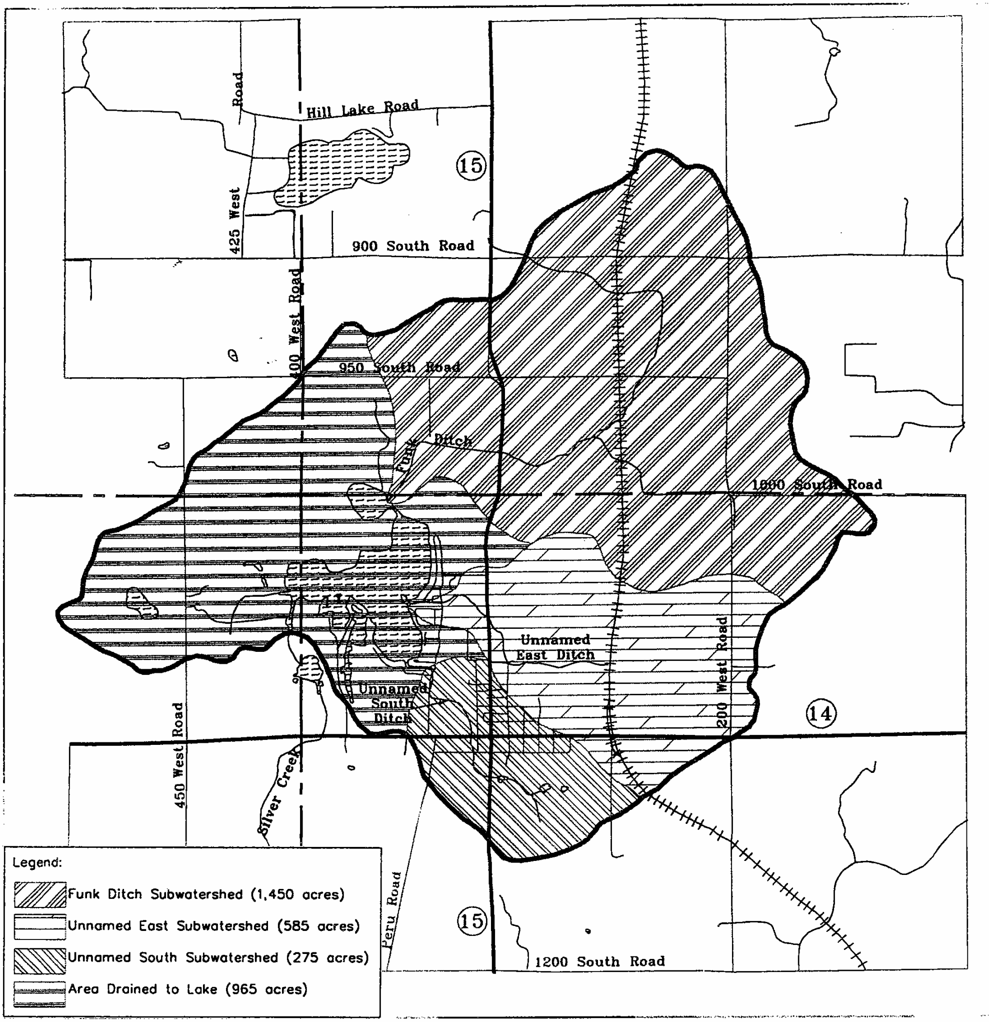


JFNA# 99-09-24

Figure 2: **Silver Lake Watershed**
Silver Lake Diagnostic Study
Kosciusko County, Indiana

J.F. New & Associates, Inc.
708 Roosevelt Road
P.O. Box 243
Walkerton, IN 46574
Phone: 219-586-3400
FAX: 219-586-3446

Permitting • Delineations • Mitigation Design • Biological Inventories
Wetland and Prairie Nursery • Lake and Stream Enhancement
Natural Systems for Wastewater Treatment



Source: U.S.G.S. 7.5 minute topographic map

Scale: 1" = 3,000 ft

JFNA# 99-09-24

**Figure 3: Silver Lake Subwatersheds
Silver Lake Diagnostic Study
Kosciusko County, Indiana**

J.F. New & Associates, Inc.
708 Roosevelt Road
P.O. Box 243
Walkerton, IN 46574
Phone: 219-586-3400
FAX: 219-586-3446

Permitting • Delineations • Mitigation Design • Biological Inventories
Wetland and Prairie Nursery • Lake and Stream Enhancement
Natural Systems for Wastewater Treatment

Table 1: Silver Lake Watershed and Subwatershed Sizes

	Area (acres)	Area (hectares)	Percent of watershed
Subwatershed			
Funk Ditch	1450	587	44%
Unnamed East	585	237	18%
Unnamed South	275	111	8%
Area adjacent to lake	965	391	30%
Total watershed	3275	1326	100%
Watershed to Lake Area Ratio	33:1		

Watershed size and watershed to lake area ratios can affect the chemical and biological characteristics of a lake. For example, lakes with large watersheds have the potential to receive greater quantities of pollutants (sediments, nutrients, pesticides, etc.) from runoff than lakes with smaller watersheds. For lakes with large watershed to lake ratios, watershed activities can potentially exert a greater influence on the health of the lake than lakes possessing small watershed to lake ratios. Conversely, for lakes with small watershed to lake ratios, shoreline activities may have a greater influence on the lake's health than lakes with large watershed to lake ratios.

For comparison, approximately 112 square miles (290 square km) of land drain to the 768-acre (311-ha) Lake Tippecanoe. This results in a watershed to lake area ratio of approximately 93:1. As a result, Lakes Tippecanoe's watershed can potentially exert a greater influence on the health of Lake Tippecanoe than Silver Lake's watershed can on Silver Lake. In contrast, Lawrence Lake, a 69-acre (28-ha) lake in Marshall County, has a watershed of approximately 355 acres (144 ha). Lawrence Lake's watershed to lake area ratio is approximately 5:1. This means shoreline activities along Lawrence Lake can potentially have a greater impact on the overall health of Lawrence Lake compared to the impact shoreline activities along Silver Lake have on the health of Silver Lake.

CLIMATE

The climate in Kosciusko County is characterized as cool and humid with winters that typically provide enough precipitation in the form of snow to supply the soil with sufficient moisture to minimize drought conditions when the hot summers begin. The average daily winter temperature is usually around 26 degrees Fahrenheit (-3 °C); the summer average is close to 70 degrees (21 °C). The highest temperature ever recorded was 103 degrees (39 °C) on July 17, 1976. Total annual precipitation averages 35 to 38 inches (89 to 97 cm). By October of 2000, approximately 35.4 inches (89.9 cm) of precipitation was recorded at the Warsaw recording station in Kosciusko County. This 9-month total meets the annual average for the county, highlighting the wetter than average weather conditions experienced to date for 2000. In contrast, 1999 was characterized by drought conditions. March, July, and October through December recorded precipitation levels well below the normal averages for those months in 1999.

SOILS

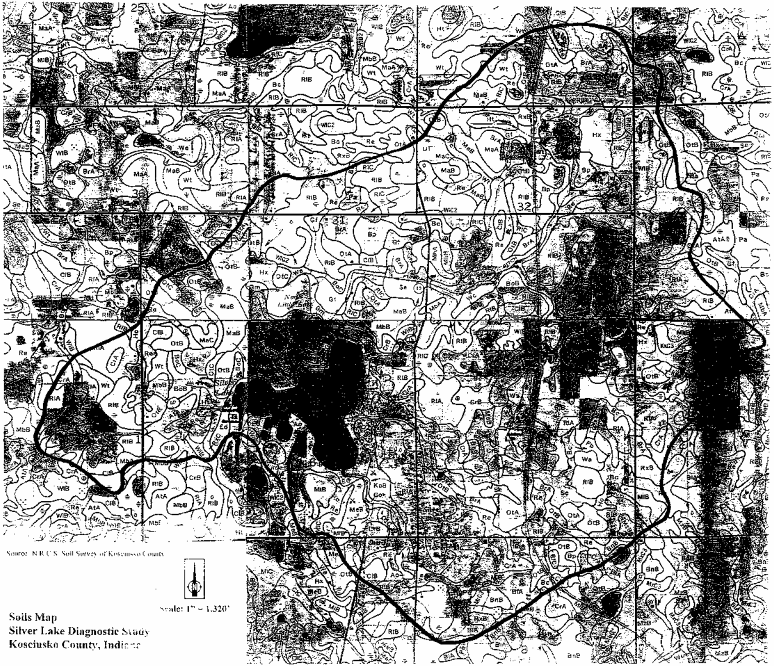
The soil types found in Kosciusko County are a product of the original parent materials deposited by the glaciers that covered this area 12,000 to 15,000 years ago. The main parent materials found in these two counties are glacial outwash and till, lacustrine material, alluvium, and organic materials that were left as the glaciers receded. The interaction of these parent materials with the physical, chemical, and biological variables found in the area (climate, plant and animal life, time, and the physical and mineralogical composition of the parent material) formed the soils of Kosciusko County today.

Specific soil types found in the Silver Lake watershed are mapped on Figure 4a. (Figure 4b displays the legend.) Soils in the watershed, and in particular their ability to erode or sustain certain land use practices, can impact the water quality of a lake. For example, highly erodible soils are, as their name suggests, easily erodible. Soils that erode from the landscape are transported to waterways or waterbodies where they impair water quality and often interfere with recreational uses by forming sediment deltas in the waterbodies. In addition, such soils carry attached nutrients, which further impair water quality by fertilizing macrophytes (rooted plants) and algae. Figure 5 maps the presence of highly erodible soils and potentially highly erodible soils in the Silver Lake watershed. It is important to note that this map is based on Natural Resources Conservation Service criteria for highly erodible soils and is not field checked.

Only 20 acres (8 ha) of land are mapped as highly erodible soils in the watershed. This acreage is concentrated in the upper reaches of the Funk Ditch and the unnamed southern inlet watersheds. However, almost 1000 acres (400 ha) of land in the watershed are mapped in potentially highly erodible units. By subwatershed, Funk Ditch and the unnamed southern inlet watersheds have the greatest percentage of land (34%) mapped as potentially highly erodible units. Approximately 31% of the unnamed east inlet's watershed and approximately 23% of the land draining directly to the lake is mapped in potentially highly erodible units.

LAND USE

Figure 6 and Table 2 present land use information for the Silver Lake watershed. Land use data was obtained from the Indiana Gap Analysis project. (Land use categories shown in Table 2 are general in nature; Appendix 1 breaks the data into more detailed categories.) Nearly 80% of the land in the watershed is used for agricultural purposes, including cropland, pasture and agricultural woodlots. The Silver Lake watershed is typical of Kosciusko County as a whole where 72% of the land in the county is used for agricultural purposes (U.S. Census of Agriculture, 1999). The remaining 20% of the watershed is divided almost equally among forested land, wetlands, open water, and urban land use.



Source: N.R.C.S. Soil Survey of Kosciusko County

Scale: 1" = 1,320'

Figure 4a: **Soils Map**
Silver Lake Diagnostic Study
Kosciusko County, Indiana

JFNA# 99-09-24

J.F. New & Associates, Inc.
708 Roosevelt Road
P.O. Box 243
Walkerton, IN 46574
Phone: 219-586-3400
FAX: 219-586-3446

Permitting • Delineations • Mitigation Design • Biological Inventories
Wetland and Prairie Nursery • Lake and Stream Enhancement
Natural Systems for Wastewater Treatment

Soils Legend:

Ao	Aquents-Urban land complex
AtA	Aubbeenaubbee fine sandy loam, 0-2% slope
Bc†	Barry loam
BnB*	Blount-Glynwood complex, 1-3% slope
BoC*	Boyer loamy sand, 6-12% slope
Bp	Brady sandy loam
BrA	Bronson sandy loam, 0-2% slope
ClB	Coloma loamy sand, 0-6% slope
CrA	Crosier loam, 0-1% slope
Ed†	Edwards muck, drained
Gf†	Gilford sandy loam
Gm†	Gilford mucky sandy loam
Go†	Gravelton loamy sand
He†	Histosols and Aquolls
Ho	Homer sandy loam
Ht†	Houghton muck
Hx†	Houghton muck, drained
KoB*	Kosciusko sandy loam, 2-6% slope
KxC3**	Kosciusko sandy clay loam, 8-15% slope, severely eroded
MaC*	Martinsville sandy loam, 6-12% slope
MbA	Metea loamy sand, 0-2% slope
MbB	Metea loamy sand, 2-6% slope
MeA	Metea loamy fine sand, 0-2% slope
MeB	Metea loamy fine sand, 2-6%
MlB*	Miami loam, 2-6% slope
MlC*	Miami loam, 6-12% slope
MrC3**	Miami clay loam, 6-12% slope, severely eroded
MvC**	Morley loam, 6-12% slope
MzB	Morley-Glynwood complex, 1-4% slope
OtA	Ormas loamy sand, 0-2% slope
OtB	Ormas loamy sand, 2-6% slope
OtC*	Ormas loamy sand, 6-12% slope
Pa†	Palms muck, drained
Pb†	Palms muck, gravelly substratum, drained
Pe†	Pewamo silty clay loam
Re†	Rensselaer loam
RlA	Riddles fine sandy, 0-2% slopes
RlB*	Riddles fine sandy, 2-6% slopes
RxB*	Riddles-Ormas-Kosciusko complex, 2-6% slope
RxC*	Riddles-Ormas-Kosciusko complex, 6-12% slope
Se†	Sebewa loam
To†	Toledo silty clay
Uf	Udorthents-Urban land complex
Wa†	Wallkill silt loam
Wc†	Washtenaw silt loam
We†	Washtenaw loam
WlB*	Wawasee fine sandy loam, 2-6% slope
WlC2*	Wawasee fine sandy loam, 6-12% slope, eroded
WlD2**	Wawasee fine sandy loam, 12-18% slope, eroded
Wt	Whitaker loam

† Hydric soils
* Potentially highly erodible soils
** Highly erodible soils

JFNA# 99-09-24

Figure 4b: Soils Map – Legend
Silver Lake Diagnostic Study
Kosciusko County, Indiana

J.F. New & Associates, Inc.
708 Roosevelt Road
P.O. Box 243
Walkerton, IN 46574
Phone: 219-586-3400
FAX: 219-586-3448

Permitting • Delineations • Mitigation Design • Biological Inventories
Wetland and Prairie Nursery • Lake and Stream Enhancement
Natural Systems for Wastewater Treatment

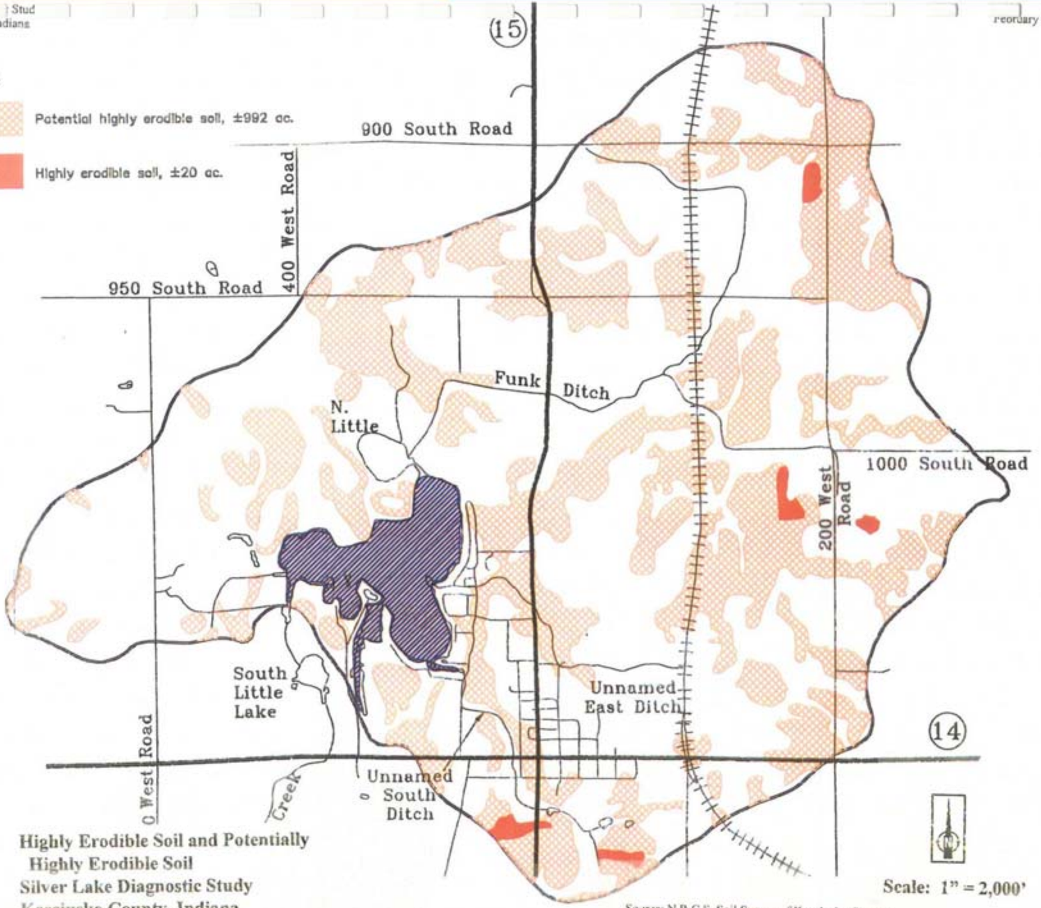


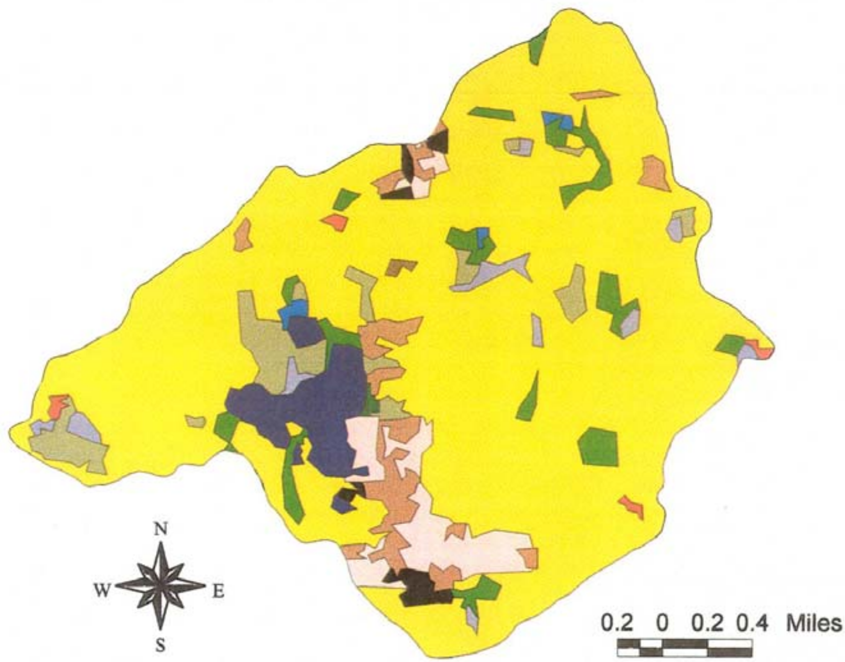
Figure 5: **Highly Erodible Soil and Potentially Highly Erodible Soil**
Silver Lake Diagnostic Study
Kosciusko County, Indiana

Scale: 1" = 2,000'

Source: N.R.C.S. Soil Survey of Kosciusko County

Figure 6: Land Use in the Silver Lake Watershed

*Source--Indiana GAP Analysis



Land Use

- Developed:Agriculture Pasture/Grassland=130 Acres
- Developed:Agriculture Row Crop=2478.245 Acres
- Developed:Urban High Density=17.167 Acres
- Developed:Urban Low Density=147.648 Acres
- Palustrine:Forest, Deciduous=50.923 Acres
- Palustrine:Herbaceous Deciduous=136.486 Acres
- Palustrine:Shrubland Deciduous=12.843 Acres
- Terrestrial:Forest Deciduous=142.488 Acres
- Terrestrial:Forest Evergreen=4.235 Acres
- Terrestrial:Shrubland Deciduous=.064 Acres
- Terrestrial:Woodland Deciduous=13.446 Acres
- Water=136.058 Acres

Table 2. Land Use in the Silver Lake Watershed

Land use	Area (acres)	Area (hectares)	Percent of watershed
Agricultural	2478.2	1003.3	75.8%
Wetland	200.3	81.1	6.1%
Residential/urban	164.8	66.7	5.0%
Forested	160.2	64.9	4.9%
Pasture	130.0	52.6	4.0%
Open water	136.1	55.1	4.2%
Total	**3269.6**	**1323.7**	**100%**

Source: Indiana Gap Analysis Project

As is common in much of Indiana, corn and soybeans are the major crops grown on agricultural land in Kosciusko County. In 1998, approximately 49% of the cropland in Kosciusko County was planted in corn and 39% in soybeans (U.S. Census of Agriculture, 1999). Conservation tillage practices are utilized throughout the county. In 1998, no-till was practiced on approximately 17% of the farmland planted in corn. Mulch tillage (a tillage method that leaves at least 30% of residue cover on the surface after planting) was practiced on approximately 13% of the farmland planted in corn. For fields planted in soybeans, the percentage of farmland utilizing conservation tillage methods was higher: 57% in no-till, 25% in mulch-till (Julie Harrold, Kosciusko County SWCD, personal communication).

Urban land use is largely residential in nature with a few commercial businesses and light industry along the main thoroughfares in town (State Roads 14 and 15). The town itself supports a relatively stable population. Census data (Table 3) indicate the town had a population low in 1930 with only 442 residents and a peak in 1970 with 588. Results from the 2000 census are not yet available, but STATS Indiana projects that Silver Lake will have a population of 578 by that time.

Table 3. Population of the Town of Silver Lake from 1900 to 1999.

Year	Population	Year	Population
1900	504	1960	514
1910	493	1970	588
1920	452	1980	576
1930	442	1990	528
1940	471	1999*	578
1950	472		

* projected
Source: Indiana State Library - STATS Indiana Census Data

WETLANDS

Because wetlands perform a variety of functions in a healthy ecosystem, they deserve special attention when examining watersheds. Functioning wetlands filter sediment and nutrients in runoff, store water for future release, provide an opportunity for groundwater recharge or discharge, and serve as nesting habitat for waterfowl and spawning sites for fish. By performing these roles, healthy, functioning wetlands often improve the water quality and biological health of streams and lakes located downstream of the wetlands. The land use table above (Table 2) indicates that wetlands account for approximately 6.1% of the Silver Lake watershed. Table 4 presents the acreage of wetlands by type. Figure 7 maps the wetlands in Silver Lake watershed by type.

Table 4. Acreage and Classification of Wetland Habitat in the Silver Lake Watershed.

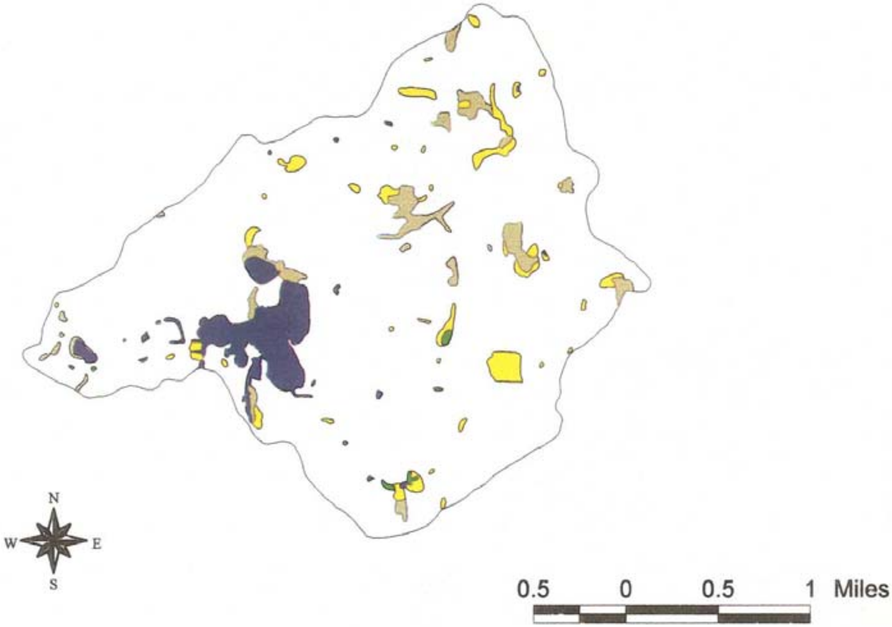
Wetland Type	Area (acres)	Area (hectares)	Percent of watershed
Forested	50.9	20.6	1.5%
Shrubland	12.8	5.2	0.4%
Herbaceous	136.5	55.3	4.2%
Total	**200.2**	**81.1**	**6.1%**

Source: Indiana Gap Analysis Project

The IDNR (Indiana Wetland Conservation Plan, 1996) estimates that approximately 85% of the state's wetlands have been filled. The greatest loss has occurred in the northern counties of the state such as Kosciusko County. The last glacial retreat in these northern counties left level landscapes dotted with wetland and lake complexes. Development of the land in these counties for agricultural purposes altered much of the natural hydrology, eliminating many of the wetlands. The 1978 census of agriculture found that drainage is artificially enhanced on 38% of the land in Kosciusko County (cited in Hudak, 1995). Some urban and residential development also resulted in the loss of wetland habitat. This is particularly true in low-lying areas bordering lakes. These marshy areas were filled to accommodate more lakeside homes once upland areas were completely developed.

To estimate the historical coverage of wetlands in the Silver Lake watershed, hydric soils in the watershed were mapped on Figure 8. (As noted for the highly erodible soils map, this map is based on the Natural Resources Conservation Service criteria for hydric soils and is not field checked.) Because hydric soils developed under wet conditions, they are a good indicator of the historical presence of wetlands. Comparing the total acreage of wetland (hydric) soils in the watershed (973 acres or 394 ha) to the acreage of existing wetlands (200 acres or 81 hectares) suggests that only approximately 20.5% of the original wetland acreage exists today. Table 5 examines wetland loss by subwatershed. The Funk Ditch subwatershed has experienced the greatest loss with only 19% of original wetland acreage existing today. Loss in wetland acreage

Figure 7: NWI Wetland Classes in the Silver Lake Watershed



Wetlands

- Lacustrine=123.529 Acres
- Palustrine emergent=91.656 Acres
- Palustrine forested=105.469 Acres
- Palustrine scrub/shrub=6.393 Acres
- Ponds=26.763 Acres
- Uplands=2938.331 Acres

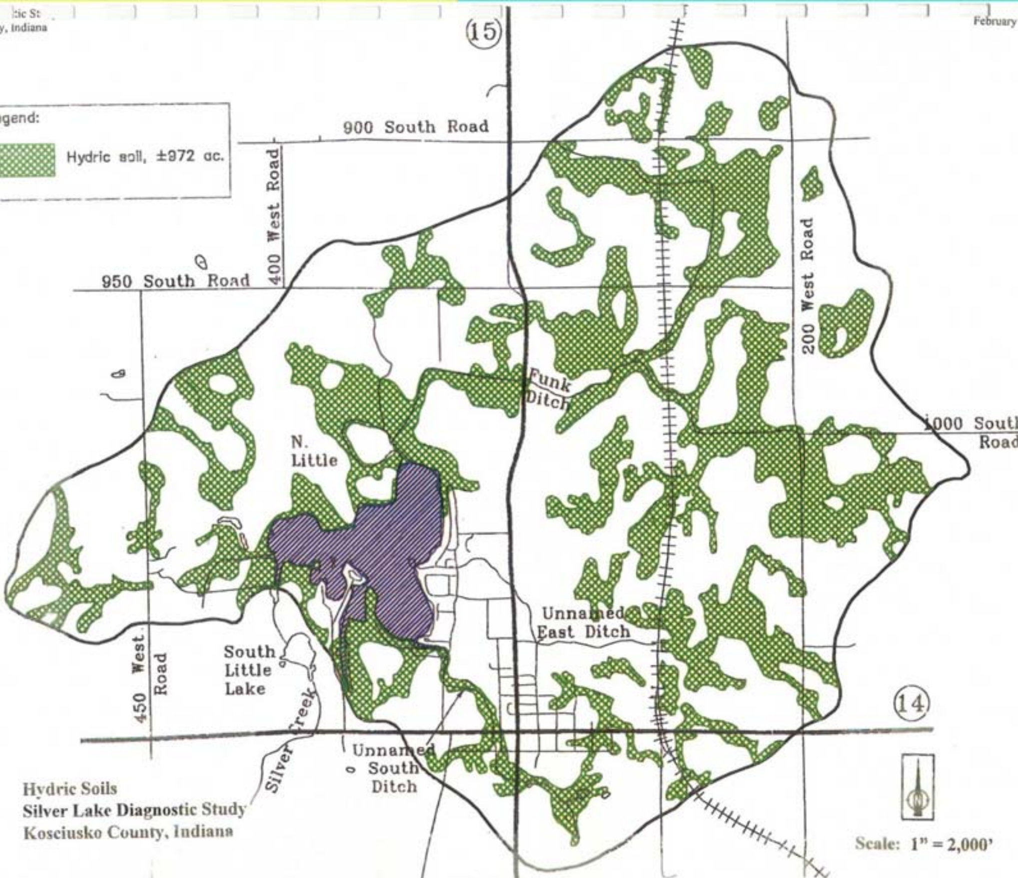


Figure 8: Hydric Soils
Silver Lake Diagnostic Study
Kosciusko County, Indiana

in the watershed results in a loss of wetland functions, many of which improve water quality. Restoration of at least some of the wetlands could restore some of these functions.

Table 5. Acreage of Wetland Habitat Loss in the Silver Lake Watershed.

Subwatershed	Hydric Soil in Acres (in hectares)	Wetland Area in Acres (in hectares)	Percent wetland remaining
Funk Ditch	507 (205)	87 (35)	17%
Unnamed East	154 (62)	30 (12)	19.5%
Unnamed South	49 (20)	19 (8)	39%
Lakeside	263 (106)	64 (26)	27.5%
Silver Lake watershed	**973 (394)**	**200 (81)**	**20.5%**

Because water storage is one of the many functions performed by wetland, wetland restoration in the Silver Lake watershed may alleviate periodic flooding of lake residential areas. The Silver Lake Property Owners Association (SLPOA) identified lakeside flooding as an issue of concern (personal communication). The SLPOA has investigated the possibility of increasing the drainage capacity of Silver Creek, the lake's outlet. Property owners along Silver Creek immediately downstream of the lake and some regulatory authorities have expressed opposition to the idea of snag removal and dredging to increase Silver Creek's drainage capacity. Because wetlands store water and often provide groundwater recharge, they reduce the volume of water flowing to the lake. Restoration of wetlands upstream of the lake may be a viable solution to reduce flooding in the lake.

NATURAL COMMUNITIES/ ENDANGERED, THREATENED AND RARE SPECIES

The Indiana Natural Heritage Data Center database provides information on the presence of endangered, threatened, or rare species, high quality natural communities, and natural areas in Indiana. The database was developed to assist in documenting the presence of special species and significant natural areas and to serve as a tool for setting management priorities in areas where special species or habitats exist. The database relies on observations from individuals rather than systematic field surveys by the Indiana Department of Natural Resources. Because of this, it does not document every occurrence of special species or habitat. At the same time, the listing of a species or natural area does not guarantee the presence of the listed species or that the listed natural area is in pristine condition. The database includes the date that the species or special habitat was last observed in a specific location.

Results from the database search for the Silver Lake watershed are presented in Appendix 2. (For additional reference, a listing of endangered, threatened and rare species documented in Kosciusko County is included in Appendix 3.) Two species, spotted turtle (*Clemmys guttata*) and the lytrosis moth (*Lytrosis permagnaria*), are listed in the database for the Silver Lake watershed. The state of Indiana lists the spotted turtle as endangered and the lytrosis moth as threatened. According to the database, the last recorded observation of the spotted turtle was in

1956 in the Silver Lake watershed. The last documented sighting of the lytrosis moth in the Silver Lake watershed occurred in 1979.

SHORELINE DEVELOPMENT

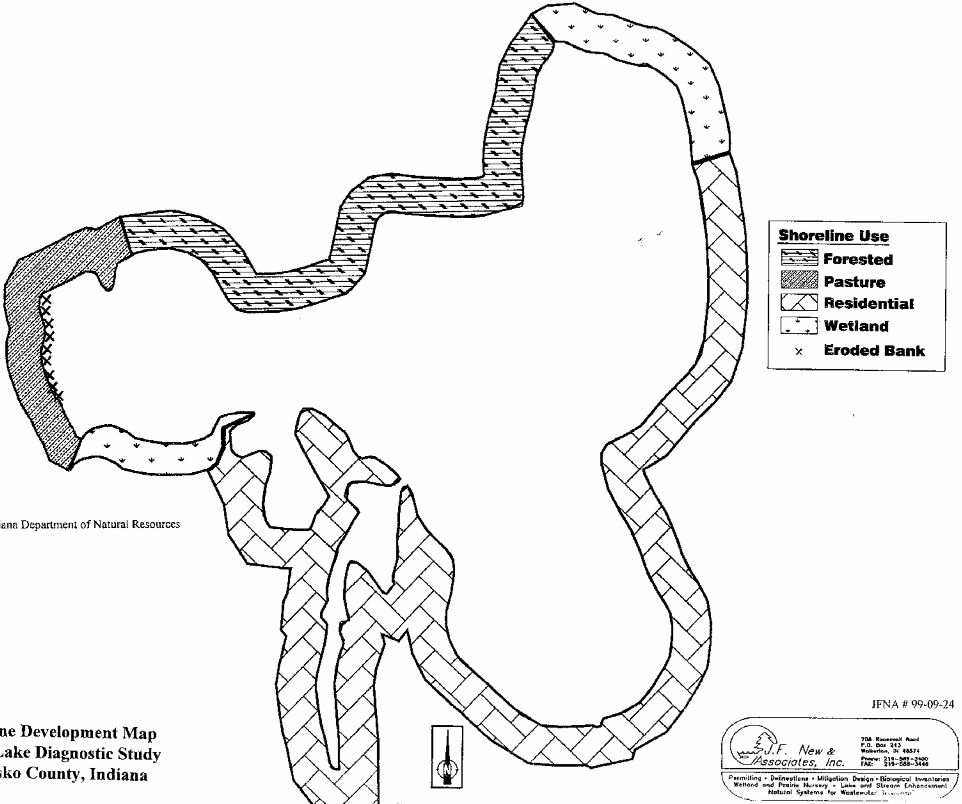
Modern development around Indiana lakes began in the 1940's and 1950's (Grant, 1999). It is likely that development of Silver Lake occurred at that time as well. A 1964 Indiana State Board of Health report noted that the town of Silver Lake had a population of 514 in 1960. The 1980 IDNR fisheries survey (Braun, 1980) estimated that approximately 50% of the lake's shoreline was developed for residential use. By the mid eighties, this percentage had increased to 60% (Braun, 1986). In his 1989 study, Hippensteel (1989) reported 205 homes bordering Silver Lake.

Little has changed since the late 1980's. Approximately 60% of Silver Lake's shoreline is developed for residential use. Homes are concentrated along the lake's eastern and southern shorelines as well as the along the channels on the southern shoreline. A manufactured home community lines the eastern shoreline. Permanent homes are more typical along the southern shoreline. Pasture borders the western edge of Silver Lake, while the northern shoreline is forested. Large wetland complexes exist in the northeast and southwest corners of the lake (Figure 9).

Seawalls line nearly all of the shoreline that is developed for residential use. These seawalls are composed of concrete, riprap, and/or wood. Concrete seawalls are the most common type on Silver Lake, accounting for approximately 65% of all seawalls. Riprap seawalls are the second most common type. Landscaped lawns exist along the large majority of the residentially developed portion of the shoreline; natural shoreline vegetation in the developed area is virtually non-existent.

While seawalls provide some temporary erosion control along shorelines, they cannot provide all the functions of a healthy shoreline plant community. Native shoreline communities filter nutrients, sediment, and pesticides from runoff water, protect the shore from wave action and erosion, release oxygen to the water column for use by aquatic biota, and provide food, cover, and spawning/nesting habitat for a variety of fish, waterfowl, insects, mammals, and amphibians. Removal of the native plant community eliminates many of these functions.

No areas of significant shoreline erosion were observed along the residentially developed portion of the shoreline. The existing seawalls provide sufficient protection from the erosive forces of wave action and water level fluctuation. Vertical, cut and sloughing banks were noted along the western portion of the shoreline. This erosion and instability is likely the result of livestock accessing the lake. Cows from the adjacent dairy operation have been observed in this area of the lake.



Base Map Source: Indiana Department of Natural Resources

igure 9: Shoreline Development Map
Silver Lake Diagnostic Study
Kosciusko County, Indiana

INLET STREAM SAMPLING

Historical sampling

Several studies have documented the water quality conditions in the Silver Lake inlets over the past four decades. Due to the sewage treatment issues that plagued the Silver Lake community in the past, fecal coliform concentrations in the inlets have been the focus of most of these studies. The earliest published report dates back to 1960. This Indiana State Board of Health (ISBH, 1960) report noted blue-green algae blooms and "black putrid sludge" in Silver Lake near the unnamed southern drainage inlet. The maximum coliform count in the lake was estimated at 230,000 organisms per 100 mL. (Coliform counts above a certain limit must be estimated using statistical means rather than enumerated directly.) As a reference, the state standard for waters designated for full body contact is 235 organisms per 100 mL. ISBH officials attributed the high coliform concentrations and algae blooms to septic tank and laundromat tiles that drained directly to the unnamed southeast drainage ditch.

Conditions had not improved four years after the 1960 study. In a 1964 study, the ISBH called the southern drainage a "sewage ditch" (ISBH, 1964). Black sludge, worm species associated with raw sewage, and sewage solids were all observed in the ditch during this survey. Maximum coliform counts as high as 110,000,000 organisms per/ 100mL were recorded in the ditch. (While the 1960 and 1967 reports do not indicate which type of coliform was collected in the earlier studies, it is most likely that fecal coliform was collected (Diana Ziamonne, ISBH Laboratory, personal communication).) In addition, the dissolved oxygen concentration was very low for running water, between 0 and 21%, suggesting a high biological oxygen demand (BOD). Organic material, including animal waste, requires oxygen to decompose. High inputs of sewage would increase the BOD of a ditch. The 1964 report recommended that the town immediately begin construction of sewage treatment facilities.

Funding difficulties prevented the town from constructing a sewage treatment facility in the 1970's. In 1979, the ISBH conducted a fecal coliform survey of several of the inlets to Silver Lake (ISBH, 1979). The 1979 sampling followed a storm event, so fecal coliform counts are likely higher than would be expected at base flow. Fecal coliform counts of 40,000 and 50,000 organisms per 100 mL were recorded for the unnamed southern drainage. In comparison, counts of 13,000 and 1,200 organisms per 100 mL were recorded for the unnamed eastern ditch and Funk Ditch respectively. This suggests that fecal coliform remained a problem in the unnamed southern ditch subwatershed in 1979.

The Kosciusko County Health Department (KCHD) conducted several studies on the Silver Lake inlets in the 1980's and 1990's (KCHD, 1985, 1998). Table 6 details the results of these surveys and provides the results from the 1979 ISBH survey and the 2000 J.F. New & Associates sampling of the inlets for comparison. In the 1980's and 1990's, the fecal coliform concentrations in Funk Ditch ranged from 120 to 400 organisms per 100 mL. This range is well within the normal range for ditches in Indiana. In 1985, the fecal coliform concentration found in the unnamed east ditch also fell in the normal range. The fecal coliform concentration found in the unnamed southern ditch in 1985 is above the normal range but well below historical concentrations noted in the ditch. This data suggests an improvement in water quality in the unnamed southern ditch from 1960 to 1985.

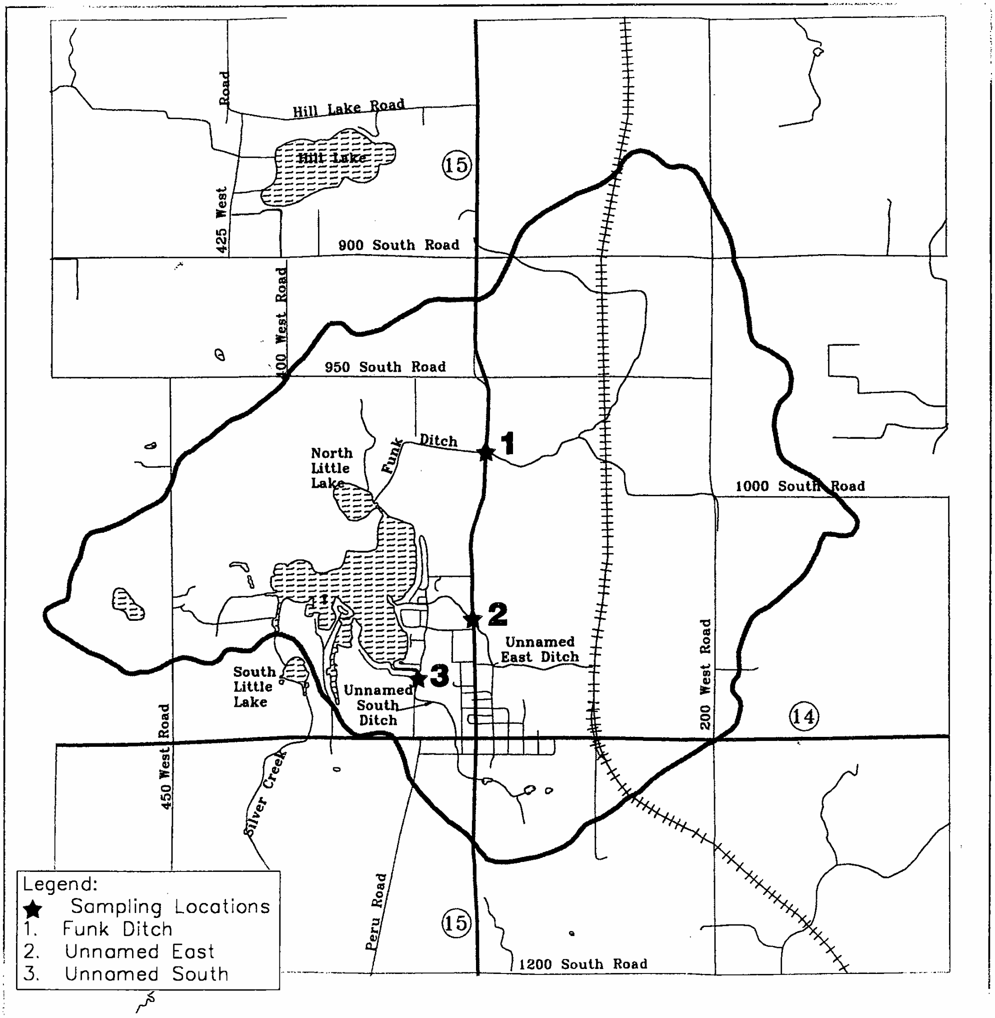
Table 6. Fecal Coliform Concentrations in Silver Lake Inlets

Date	Source	Fecal Coliform (col/100ml)
Funk Ditch		
05/03/79	IN State Board of Health	1200
06/24/85	Kosciusko Co. Health Dept.	260
11/15/96	Kosciusko Co. Health Dept.	310
05/14/97	Kosciusko Co. Health Dept.	130
01/06/97	Kosciusko Co. Health Dept.	400
05/19/98	Kosciusko Co. Health Dept.	120
08/29/00	J. F. New & Associates	2000
Unnamed East		
05/03/79	IN State Board of Health	13000
06/24/85	Kosciusko Co. Health Dept.	320
08/29/00	J. F. New & Associates	1400
Unnamed South		
05/03/79	IN State Board of Health	50000
06/24/85	Kosciusko Co. Health Dept.	2200
08/29/00	J. F. New & Associates	2200

Current sampling

J.F. New & Associates sampled each of the three inlets on two occasions in 2000. The first sampling was conducted on April 21, 2000 following a major storm event. Two to five inches (5 to 13 cm) of rain were reported for Kosciusko County from that storm event. The second sampling effort occurred on August 29, 2000. This sampling recorded inlet conditions during base flow. Parameters measured during each sampling effort included pH, conductivity, alkalinity, turbidity, total and ortho-phophorus (TP and OP), ammonium (NH_4^+), nitrate NO_3^-), and total Kjeldahl nitrogen (TKN), and total suspended solids (TSS). Fecal coliform bacteria samples were collected during the base flow sampling. Fecal coliform was measured rather than *E. coli* to provide a direct comparison to historical measurements. The sampling locations are shown in Figure 10. Laboratory data sheets are provided in Appendix 4.

There are two useful ways to report water quality data in flowing water. *Concentrations* describe the mass of a particular material contained in a unit of water, for example milligrams of phosphorus per liter (mg/L). *Mass loading,* on the other hand, describes the mass of a particular material being carried in the stream per unit of time. For example, a high concentration of phosphorus in a stream with very little flow can deliver a smaller total amount of phosphorus to the lake than will a stream with a low concentration of phosphorus but a high flow of water. It is the total amount (mass) of phosphorus, solids, and bacteria actually delivered to the lake that is



Source: U.S.G.S. 7.5 minute topographic map

Scale: 1" = 3,000 ft

JFNA# 99-09-24

Figure 10: **Storm Water Sampling Locations**
Silver Lake Diagnostic Study
Kosciusko County, Indiana

J.F. New & Associates, Inc.
708 Roosevelt Road
P.O. Box 243
Walkerton, IN 46574
Phone: 219-586-3400
FAX: 219-586-3446

Permitting • Delineations • Mitigation Design • Biological Inventories
Wetland and Prairie Nursery • Lake and Stream Enhancement
Natural Systems for Wastewater Treatment

most important when considering the effects of these materials on a lake. Tables 7 and 8 provide the inlet sampling results as concentrations and mass loadings respectively. Table 9 provides additional chemical data on each of the inlets.

Table 7. Nutrient and Sediment Concentration Data for Silver Lake Inlets

Date	Site	Flow (cfs)	Timing	TKN (mg/L)	NH_3 (mg/L)	NO_3^- (mg/L)	TP (mg/L)	OP (mg/L)	TSS (mg/L)	FC (col/100mL)
8/29/00	Funk	0.6	Base	0.88	<0.10	1.8	0.09	0.07	6.0	2000
04/21/00	Funk	9	Storm	14.6	<0.05	13.0	0.1	<0.05	18	-
8/29/00	Unnamed E	0.3	Base	0.50	<0.10	0.50	0.18	0.14	7.0	1400
04/21/00	Unnamed E	4.7	Storm	18.2	0.89	17.0	0.27	0.34	18	-
8/29/00	Unnamed S	0.1	Base	<0.40	<0.10	0.88	0.08	0.05	<1.0	2200
04/21/00	Unnamed S	2.1	Storm	3.08	<0.05	2.3	2.4	0.14	25	-

Table 8. Nutrient and Sediment Loading Data for Silver Lake Inlets

Date	Site	Flow (cfs)	Timing	TKN Load (mg/s)	NH_3 Load (mg/s)	NO_3^- Load (mg/s)	TP Load (mg/s)	OP Load (mg/s)	TSS Load (mg/s)
8/29/00	Funk	0.6	Base	15	-	30.6	1.5	1.2	102
04/21/00	Funk	9	Storm	3718.6	-	3311.1	25.5	-	4584.6
8/29/00	Unnamed E	0.3	Base	4.2	-	4.2	1.5	1.2	59
04/21/00	Unnamed E	4.7	Storm	2420.8	118.4	2261.2	35.9	45.25	2394.2
8/29/00	Unnamed S	0.1	Base	-	-	2.5	0.2	0.1	-
04/21/00	Unnamed S	2.1	Storm	183.1	-	136.69	14.2	8.3	1485.8

Table 9. Other Chemical Parameters for the Silver Lake Inlets

Date	Site	Flow (cfs)	Timing	pH	Conductivity (umhos)	Turbidity (NTU)	Fecal coliform (col/100mL)
8/29/00	Funk	0.6	Base	7.9	730	8.8	2000
04/21/00	Funk	9	Storm	7.1	700	18	-
8/29/00	Unnamed E	0.3	Base	7.7	720	4.8	1400
04/21/00	Unnamed E	4.7	Storm	7.6	610	64	-
8/29/00	Unnamed S	0.1	Base	7.9	920	1.3	2200
04/21/00	Unnamed S	2.1	Storm	7.5	750	46	-

In terms of *concentrations*, the unnamed ditch from the east exhibited the greatest concentration of phosphorus (total and ortho) and total suspended solids at base flow (Table 7). It also exhibited the highest concentrations of all nutrient parameters measured following the storm event. The water in Funk Ditch possessed the highest concentration of nitrate and total Kjeldahl nitrogen at base flow conditions.

In terms of *loading* to the lake, Funk Ditch delivered the greatest amount of total Kjeldahl and nitrate nitrogen and total suspended solids during base and runoff flows (Table 7). The unnamed ditch from the east delivered the greatest amount of phosphorus to the lake during runoff flows.

It is not surprising that Funk Ditch delivers the greatest amount of some pollutants to the lake given the fact that its watershed is nearly three times the size of the subwatershed drained by the unnamed ditch from the east. What is surprising is that the unnamed ditch from the east had the highest loading rate of phosphorus despite its size. To provide more perspective on the loading rates, the storm event loading rates for each inlet were divided by their respective subwatershed areas. This provides a loading rate per acre of subwatershed (Table 10). Per acre of subwatershed, the unnamed ditch from the east delivers the greatest amount of nutrients to the lake. Similarly, the unnamed ditch from the south delivers the greatest amount of total suspended solids per acre of subwatershed.

Table 10. Nutrient and Sediment Load in Inlet Streams Per Acre of Subwatershed

Inlet	TKN Load (mg/s-ac)	NO_3 Load (mg/s-ac)	TP Load (mg/s-ac)	TSS Load (mg/s-ac)
Funk Ditch	2.6	2.3	0.02	3.2
Unnamed east	4.1	3.9	0.06	4.1
Unnamed south	0.7	0.5	0.05	5.4

The information presented in Table 9 is useful for prioritizing management work in the subwatersheds. Because only limited funds are available for management, efforts to reduce sediment loading, for example, should focus on hot spots in the unnamed south subwatershed, which has the highest sediment loading rate on a per acre basis. The money allocated will likely provide more treatment (reduction of sediment load0 per dollar than money spent treating sediment issues in another subwatershed. This does not mean that information such as which inlet provides the greatest overall input of pollutants (Funk Ditch) should be ignored. Management efforts, such as education programs, designed to reach a large number of land owners for less money than typical on-site treatments (like ditch bank reconstruction) should be the focus in the Funk Ditch subwatershed. Both types of data (overall loading and loading on a per acre of subwatershed basis) are needed to develop a complete and feasible watershed management plan.

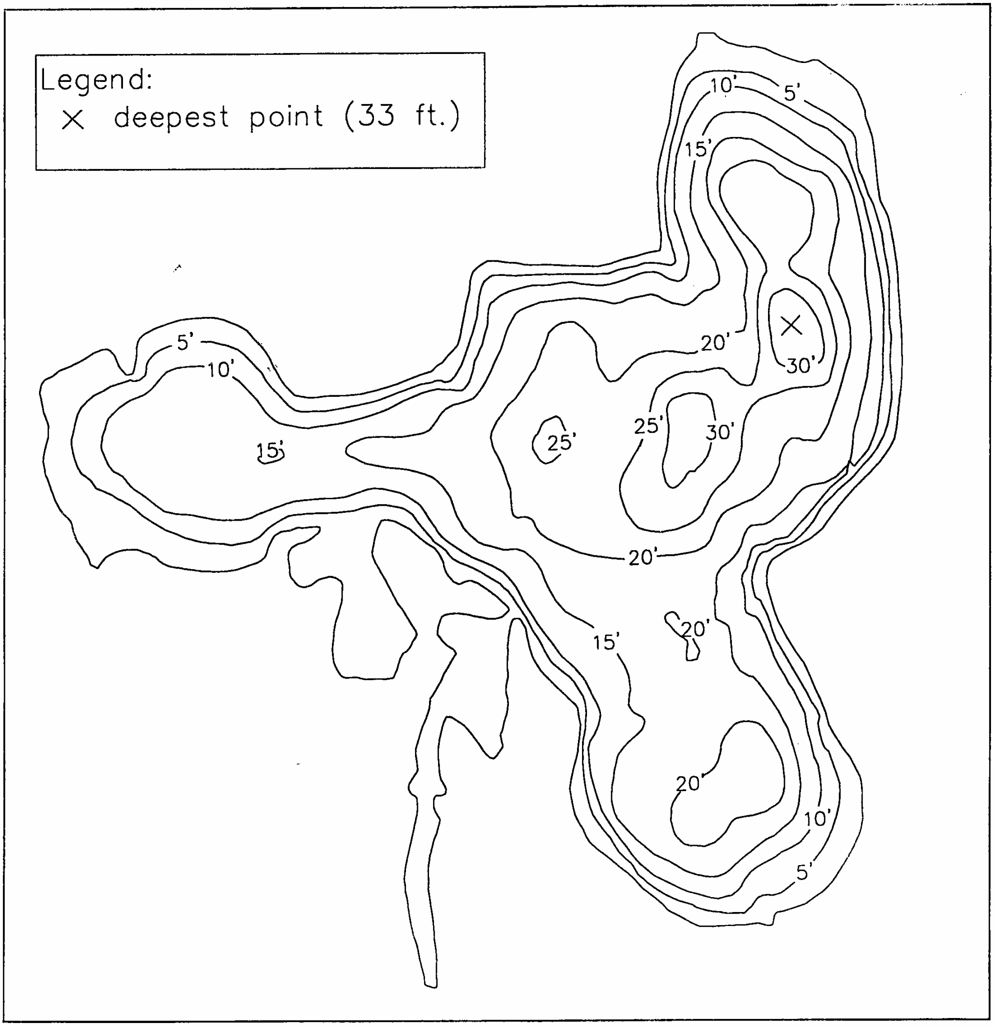
LAKE MORPHOMETRY

Table 11 summarizes Silver Lake's morphological characteristics. Silver Lake is a three-lobed basin covering approximately 102 acres (42 ha). Its greatest depth, 33 feet (10 m) is located off the central portion of the eastern shoreline (Figure 11). The shoreline development ratio is a measure of the development potential of a lake. It is calculated by dividing the shoreline length by the circumference of a circle that has the same area of the lake. A perfectly circular lake with the same area of Silver Lake (102 acres or 42 ha) would have a circumference of 7,470 feet (2,277 m). Dividing Silver Lake's shoreline length by 7470 feet yields a ratio of 2.3:1. Lakes with high shoreline development ratios have higher potential for development and this potential is often realized. Greater development around a lake has obvious impacts on the health of the lake.

Table 11. Morphological characteristics of Silver Lake.

Characteristic	Silver Lake
Surface Area	102 acres (42 ha)
Maximum Depth	33 feet (10 m)
Mean Depth	14.9 feet (4.5 m)
Shoreline Length	17,300 feet (5,275 m)
Shoreline Development Ratio	2.3

Depth-area and depth-volume curves (Figures 12 and 13) were developed from Silver Lake's bathymetric map (Figure 11). As Figure 11 shows, there is a fairly linear relationship between depth and area in Silver Lake. This contrasts with many of the lakes in Kosciusko County that have a greater percentage shallow areas relative to their lakes' surface areas. Volume increases uniformly with depth until approximately 20 ft (6.1 m) where there is a sharp increase in depth per unit of volume (Figure 12). The sharp increase in depth per unit of volume in the lake's deeper water suggests that very little of the lake's volume is contained in the lake's deeper water.



Base Map Source: Indiana Department of Natural Resources

Scale: 1" = 500 ft

JFNA# 99-09-24

Figure 11: **Bathymetric Map**
Silver Lake Diagnostic Study
Kosciusko County, Indiana

J.F. New & Associates, Inc.
708 Roosevelt Road
P.O. Box 243
Walkerton, IN 46574
Phone: 219-586-3400
FAX: 219-586-3446

Permitting • Delineations • Mitigation Design • Biological Inventories
Wetland and Prairie Nursery • Lake and Stream Enhancement
Natural Systems for Wastewater Treatment

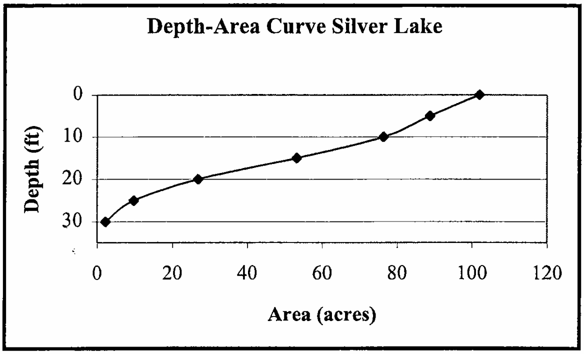


Figure 12. Depth-Area Curve for Silver Lake.

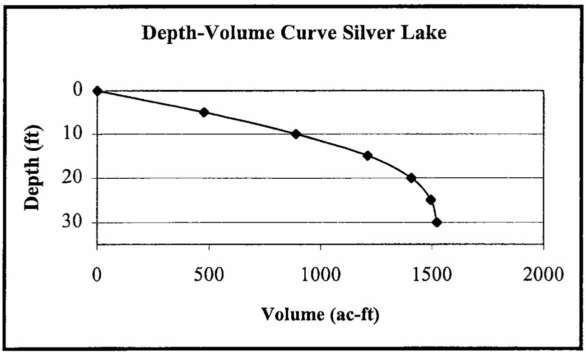


Figure 13. Depth-Volume Curve for Silver Lake.

These curves are extremely useful in illustrating important relationships between depth, volume, and area. For example, if a particular rooted aquatic plant can grow in water up to ten feet deep, the potential habitat for this plant is approximately 22 acres (8.9 ha) in Silver Lake. Knowing this, cost estimates for aquatic plant control or other treatments targeting at this particular plant can be easily calculated for a given area and water volume. A lake's physical morphometry impacts the fish community structure as well. Predator fish species often require deep holes for refuge. The presence and size (volume) of such holes determines the number of predator fish species the lake is capable of supporting. (More detailed explanations of how the lake's morphometry impacts the biota in the lake are provided in the following sections.)

WATER QUALITY

No in-lake water quality samples were collected during this preliminary study, however, several governmental agencies and other organizations have collected water quality data on Silver Lake over the past three decades. The Indiana State Board of Health, Kosciusko County Health Department, Indiana Department of Natural Resources, Indiana Department of Environmental Management, and Indiana Clean Lakes Program, including volunteer monitors, have all conducted studies on Silver Lake. The Indiana Clean Lakes Program has conducted the two most recent assessments of the lake. The results of their assessments are displayed in Tables 12 and 13.

Table 12. Results from the 7/6/95 Clean Lakes Program Sampling.

Parameter	Epilimnetic Sample	Hypolimnetic Sample	Average
pH	7.66	6.83	
Alkalinity	179 (mg/L)	266 (mg/L)	
Conductivity	395 (µmhos)	500 (µmhos)	
Secchi Disk Transp.	0.8 (m)		
Light Transmission @ 3 ft.	14 %		
1% Light Level	7 (ft)		
Total Phosphorus	0.102 (mg/L)	0.66 (mg/L)	0.381 (mg/L)
Soluble Reactive Phos.	0.018 (mg/L)	0.928 (mg/L)	0.473 (mg/L)
Nitrate-Nitrogen	0.754 (mg/L)	0.028 (mg/L)	0.391 (mg/L)
Ammonium-Nitrogen	0.17 (mg/L)	3.003 (mg/L)	1.587 (mg/L)
Total Kjeldahl Nitrogen	1.517 (mg/L)	4.191 (mg/L)	2.854 (mg/L)
Organic Nitrogen	1.347 (mg/L)	1.191 (mg/L)	
Oxygen Saturation @ 5 ft.	92 %		
% Water Column Oxic	67 %		
Plankton Density	103290 (#/L)		
Blue-Green Dominance	Yes - 92%		
Chlorophyll *a*	22.37 (µg/L)		

Table 13. Results from the 7/20/98 Clean Lakes Program Sampling.

Parameter	Epilimnetic Sample	Hypolimnetic Sample	Average
pH	8.8	7.41	
Alkalinity	130.1 (mg/L)	245.4 (mg/L)	
Conductivity	388 (µmhos)	427.4 (µmhos)	
Secchi Disk Transp.	0.7 (m)		
Light Transmission @ 3 ft.	13 %		
1% Light Level	0.75 (ft.)		
Total Phosphorus	0.0675 (mg/L)	1.33 (mg/L)	0.699 (mg/L)
Soluble Reactive Phos.	0.003 (mg/L)	1.12 (mg/L)	0.562 (mg/L)
Nitrate-Nitrogen	0.248 (mg/L)	0.022 (mg/L)	0.135 (mg/L)
Ammonium-Nitrogen	0.018 (mg/L)	3.379 (mg/L)	1.699 (mg/L)
Total Kjeldahl Nitrogen	1.07 (mg/L)	3.743 (mg/L)	2.407 (mg/L)
Organic Nitrogen	1.052 (mg/L)	0.364 (mg/L)	
Oxygen Saturation @ 5 ft.	152 %		
% Water Column Oxic	37.5 %		
Plankton Density	35650 (#/L)		
Blue-Green Dominance	Yes – 61.3 %		
Chlorophyll *a*	48.31 (µg/L)		

To put these numbers into context, it is useful to compare the results of the 1998 sampling to results from other Indiana Lakes. Table 14 shows the median, maximum, and minimum values of selected water quality parameters for 355 Indiana lakes sampled from 1994 to 1998 by the Indiana Clean Lakes Program. The values for each parameter are a mean of the eplimnetic and hypolimnetic samples.

Table 14. Comparison of Clean Lakes Program Sampling to Silver Lake

	Secchi disk (m)	Nitrate-N (mg/L)	Ammonium-N (mg/L)	Total Kjedahl-N (mg/L)	Total Phos. (mg/L)	Soluble Phos. (mg/L)	Chl. *a* (μg/L)
Median	1.8	0.025	0.472	1.161	0.097	0.033	5.33
Maximum	9.2	9.303	11.248	13.794	4.894	0.782	230.9
Minimum	0.1	0.022	0.018	0.230	0.001	0.001	0
Silver Lake	**0.7**	**0.135**	**1.7**	**2.41**	**0.7**	**0.56**	**48.31**

Silver Lake exceeds the median value for each of the water quality parameters except Secchi disk which is a negative parameter. In other words, Silver Lake has higher nutrient concentrations and worse transparency than most Indiana Lakes. Based on this data, Silver Lake has poorer water quality than most Indiana Lakes.

The 1995 and 1998 data illustrates two snapshots of the lake's water quality. While these snapshots provide useful information on conditions at the time the data was collected, examination of the trends in these water quality parameters over time may be more meaningful in evaluating the lake's water quality. Table 15 compares the data collected from various sampling efforts on Silver Lake. Indiana State Board of Health, the entity originally responsible for lake water quality measurements, recorded the 1975 and 1977 data. The Indiana Department of Environmental Management was responsible for the 1988 sampling, while the Clean Lakes Program collected the 1995 and 1998 measurements. Concentrations in the table reflect averages of epilimnetic and hypolimnetic samples.

Table 15. Comparison of water quality parameters from 1975 to 1998.

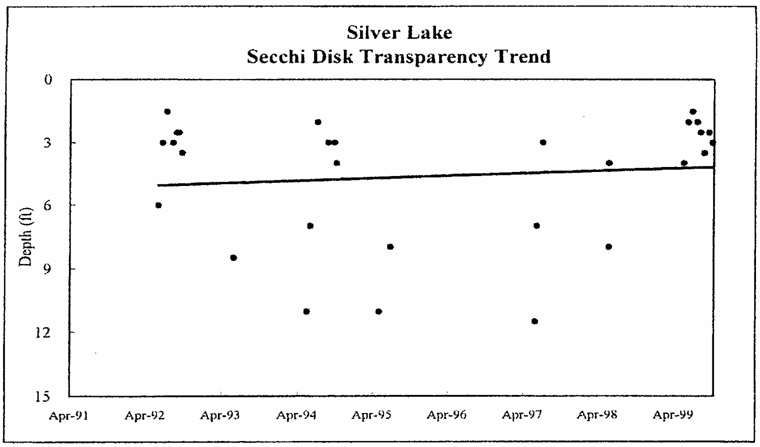
Parameter	**7/9/75**	**8/9/77**	**7/28/88**	**7/6/95**	**7/20/98**
Ammonium-Nitrogen (mg/l)	1.1	0.25	3.36	1.59	1.7
Nitrate-Nitrogen (mg/l)	< 0.1	< 0.1	< 0.1	0.39	0.14
Total Kjeldahl-Nitrogen (mg/l)	2.2	2.3	4.66	2.85	2.4
Total Phosphorus (mg/l)	0.19	0.34	0.646	0.38	0.70
Light Transmission @ 3 ft.	18%	-	12%	14%	13%
% Water Column Oxic	70%	52%*	69%	67%	37.5%
Secchi Disk Transparency	3 ft	2.5 ft	1.7 ft	7 ft	2.3 ft

*estimation

From 1975 to 1998, nitrate-nitrogen and total phosphorus show a trend toward increasing concentrations in Silver Lake, suggesting a worsening of water quality conditions. The percentage of the water column containing oxygen decreases from 1975 to 1998. A decrease in oxygen is also indicative of worsening water quality conditions since this limits aquatic biota habitat. Secchi disk transparency, total Kjedahl-nitrogen, and light transmission appear to be relatively stable in this time period. The ammonium-nitrogen concentrations do not show any trend from 1975 to 1998. In general this data suggests that the water quality in Silver Lake is stable or slightly decreasing.

A slight decrease in water quality is further supported by data collected by the volunteer Secchi disk transparency monitor for Silver Lake. A volunteer water quality monitor has been collecting data for the Indiana Clean Lakes Program on Silver Lake since 1992. Because of seasonal changes in algae populations and other factors that affect the transparency of a lake, Secchi disk transparency measurements are typically variable. Placing a best-fit line through the data collected from 1992 to 1999, however, suggests that Secchi disk transparency is decreasing in Silver Lake (Figure 14). The 7-ft Secchi disk transparency recorded by J.F. New & Associates during the June 1, 2000 sampling trip falls slightly below the best-fit line, but is within the typical range observed for Silver Lake.

Figure 14. Secchi Disk Transparency Trend from 1992-1999



Source: Indiana Clean Lakes Volunteer Monitoring Program

Qualitative Evaluation

When considering a lake's water quality, lake residents are often more familiar with the terms *oligotrophic, mesotrophic, eutophic,* and *hypereutrophic* than many of the water quality parameters listed above. The terms are applied to lakes in an effort to categorize lakes with respect to productivity and water quality. The terms are broadly defined and lack rigid dividing lines separating individual categories. The terms are qualitative in nature, however, different researchers have placed different quantitative definitions on the terms. The following paragraphs briefly describe each of the terms.

Oligotrophic lakes are those lakes with the highest water quality. These lakes possess low nutrient (phosphorus and nitrogen) concentrations and, as a consequence, do not typically support algae blooms or extensive rooted plant populations. Oligotrophic lakes have clear water transparency. They support less tolerant organisms such as cold-water fish which have higher oxygen requirements than warm water fish.

Mesotrophic lakes are characterized by intermediate nutrient concentrations and intermediate productivity. These lakes can support algae but the severe blooms associated with eutrophic and hypereutrophic lakes are not common in mesotrophic lakes. Similarly, mesotrophic lakes support some rooted plants but not at nuisance levels.

Eutrophic lakes are productive lakes. They possess high nutrient concentrations and are able to support algae blooms and extensive rooted plant populations. Eutrophic lakes often exhibit a lack of oxygen in the bottom waters during summer stratification. This lack of oxygen limits the habitat potential of the lake.

Hypereutrophic lakes are highly productive lakes. These lakes possess very high concentrations of nutrients and support nuisance populations of rooted plants and have severe algae blooms. Algal blooms are so severe that the term "pea-soup" is often used to characterize hypereutrophic lakes. Transparency is poor in these lakes. Oxygen levels are low in hypereutrophic lakes; fish kills associated with low oxygen are common in hypereutrophic lakes.

Using these definitions, Silver Lake is best described as a eutrophic lake. Silver Lake has high concentrations of nutrients, particularly compared to other Indiana lakes. It also possesses an extensive rooted plant community. Transparency is less than that found in other Indiana lakes. Fisheries surveys from the IDNR and other lake assessments report a lack of oxygen in the bottom water of the lake during summer stratification. Finally, as noted in the fisheries surveys, Silver Lake supports only warm water fish, not the less tolerant, cold-water species.

Trophic State Indices

A Trophic State Index (TSI) evaluates several water quality parameters by condensing the parameters into a single number. Many TSI's translate the numerical score obtained from the index to one of the four productivity categories described above. Having a single numerical value for the lake allows for comparison between lakes and helps track trends within a given lake. TSI's may also be used to measure the success (or lack of success) of lake restoration treatments (Olem and Flock, 1990). Two of the more common TSI's used to assess Indiana lakes are the Indiana TSI and the Carlson TSI.

Indiana TSI

The Indiana TSI (ITSI) was developed by the Indiana Stream Pollution Control Board and published in 1986 (IDEM, 1986). The original ITSI differed slightly from the one in use today. Today's ITSI uses ten different water quality parameters to calculate a score. The following table shows the point values assigned for each parameter.

Table 16. The Indiana Trophic State Index

Parameter and Range			Eutrophy Points
I.	Total Phosphorus (ppm)		
	A.	At least 0.03	1
	B.	0.04 to 0.05	2
	C.	0.06 to 0.19	3
	D.	0.2 to 0.99	4
	E.	1.0 or more	5
II.	Soluble Phosphorus (ppm)		
	A.	At least 0.03	1
	B.	0.04 to 0.05	2
	C.	0.06 to 0.19	3
	D.	0.2 to 0.99	4
	E.	1.0 or more	5
III.	Organic Nitrogen (ppm)		
	A.	At least 0.5	1
	B.	0.6 to 0.8	2
	C.	0.9 to 1.9	3
	D.	2.0 or more	4
IV.	Nitrate (ppm)		
	A.	At least 0.3	1
	B.	0.4 to 0.8	2
	C.	0.9 to 1.9	3
	D.	2.0 or more	4
V.	Ammonia (ppm)		
	A.	At least 0.3	1
	B.	0.4 to 0.5	2
	C.	0.6 to 0.9	3

	D. 1.0 or more	4
VI.	Dissolved Oxygen: Percent Saturation at 5 feet from surface	
	A. 114% or less	0
	B. 115% 50 119%	1
	C. 120% to 129%	2
	D. 130% to 149%	3
	E. 150% or more	4
VII.	Dissolved Oxygen: Percent of measured water column with at least 0.1 ppm dissolved oxygen	
	A. 28% or less	4
	B. 29% to 49%	3
	C. 50% to 65%	2
	D. 66% to 75%	1
	E. 76% 100%	0
VIII.	Light Penetration (Secchi Disk)	
	A. Five feet or under	6
IX.	Light Transmission (Photocell) : Percent of light transmission at a depth of 3 feet	
	A. 0 to 30%	4
	B. 31% to 50%	3
	C. 51% to 70%	2
	D. 71% and up	0
X.	Total Plankton per liter of water sampled from a single vertical tow between the 1% light level and the surface:	
	A. less than 3,000 organisms/L	0
	B. 3,000 - 6,000 organisms/L	1
	C. 6,001 - 16,000 organisms/L	2
	D. 16,001 - 26,000 organisms/L	3
	E. 26,001 - 36,000 organisms/L	4
	F. 36,001 - 60,000 organisms/L	5
	G. 60,001 - 95,000 organisms/L	10
	H. 95,001 - 150,000 organisms/L	15
	I. 150,001 - 5000,000 organisms/L	20
	J. greater than 500,000 organisms/L	25
	K. Blue-Green Dominance: additional points	10

Values for each water quality parameter are totaled to obtain an ITSI score. Based on this score, lakes are then placed into one of five categories (Table 17). Four of these categories correspond to the qualitative lake productivity categories. The fifth category, dystrophic, is for lakes that possess high nutrient concentrations but have limited rooted plant and algal productivity (IDEM, 2000). In these lakes, plant productivity is controlled by a factor other than nutrient availability.

Table 17. Indiana Trophic State Index Score related to Water Quality

TSI score	Water Quality (Productivity)
0-15	Oligotrophic
16-31	Mesotrophic
32-46	Eutrophic
47-75	Hypereutrophic
*	Dystophic

* See explanation above.

Table 18 records the ITSI score calculated from the lake sampling efforts in 1975, 1988, 1995, and 1998. Silver Lake ITSI scores fell between the eutophic and hypereutophic categories each sampling year. The scores suggest that the water quality in Silver Lake has remained fairly constant over the past 25 years as no trend toward increasing or decreasing water quality is evident from the data. A statistical trend analysis conducted by IDEM on this data confirms that, based on the lake's TSI scores, water quality is neither improving nor deteriorating in Silver Lake (IDEM, 2000).

Table 18. Summary of Indiana TSI scores for Silver Lake

Year	**Indiana TSI Score**	**Productivity Category**
1975	51	Hypereutrophic
1988	46	Eutrophic
1995	52	Hypereutrophic
1998	45	Eutrophic

Using the ITSI, Silver Lake rates poorly when compared to other lakes in the region. Using data collected by the Clean Lakes Program 1998 assessment, approximately 12% of the lakes in the Upper Wabash Basin (which includes most of Kosciusko County) were classified as oligotrophic (IDEM, 2000). Another 35% rated as mesotrophic. Forty five percent fell in the eutrophic category, while 8% fell in the hypereutrophic category. Based on this, it is likely that Silver Lake falls within the lower ten to twenty percent of lakes in the region in terms of water quality.

Carlson Trophic State Index

Another commonly used TSI is the Carlson TSI. Carlson (1977) examined several Wisconsin lakes to understand the relationship between Secchi disk transparency, phosphorus concentration, and chlorophyll *a* concentration (chlorophyll *a* is a pigment found in algae; it is typically used as an algae indicator.), and lake productivity. From this study, he derived three equations that form the basis of the Carlson TSI:

$$TSI = 10\,(6 - \log_2 SD)$$

$$TSI = 10\,(6 - \log_2 7.7/\text{chlorophyll } a^{0.68})$$

$$TSI = 10\,(6 - \log_2 48/TP)$$

where SD stands for Secchi disk transparency and TP stands for total phosphorus. As the equations indicate, a TSI score can be calculated using only one water quality parameter. That TSI score can then be used to predict the values of the other two parameters. For example, if the Secchi disk transparency of a lake is known, the lake's total phosphorus and chlorophyll *a* concentrations can be predicted using Carlson's equations.

Although Carlson may not have intended to correlate qualitative water quality categories to the TSI scores from his index (Cooke et al., 1993), a correlation has been developed. Using the data from historical surveys of Silver Lake, Table 19 relates the Carlson TSI score to qualitative lake productivity categories. Regardless of the criteria used (transparency, phosphorus, chlorophyll *a*), Silver Lake consistently scores in the eutrophic or hypereutrophic ranges. There does not appear to be any trend toward increasing or decreasing water quality over the past 25 years.

Table 19. Carlson Trophic State Index Score Related to Silver Lake Productivity

Year	Secchi disk transparency	Total phosphorus	Chlorophyll *a*
1977	Eutophic	Eutrophic	-
1988	Hypereutrophic	Hypereutrophic	-
1995	Eutophic/hypereutrophic	Eutrophic	Eutrophic
1998	Eutophic	Eutophic/hypereutrophic	Hypereutrophic

This index has been applied to lakes across the Midwest. Like the Indiana TSI, it does have its limitations and should be used with caution under certain lake conditions. The Carlson TSI is most applicable in lakes that are similar to those used to develop the TSI. In general, it should be applied to lakes that have low non-algal turbidity and lack extensive rooted plant populations (Cooke et al., 1993).

__Summary of water quality section__

Comparing the most recent data collected for Silver Lake to other Indiana lakes suggests that Silver Lake possesses poorer water quality than other Indiana lakes. Nutrient and chlorophyll *a* concentrations are higher than found in most other Indiana lakes, while Secchi disk transparency is less than that observed for most other lakes. Applying this recent data, the Indiana TSI places

Silver Lake on the border between eutrophic or hypereutrophic categories. Similarly, Silver Lake falls into the eutrophic (poor) or hypereutrophic (poorest) categories using the Carlson TSI.

Examining the data for long-term trends reveals that the Silver Lake water quality is largely stable; it is neither improving nor deteriorating. The raw values for nitrate-nitrogen and total phosphorus show a slight trend toward increasing concentrations in Silver Lake, suggesting a worsening of water quality conditions. The percentage of the water column containing oxygen also decreased from 1975 to 1998. A decrease in oxygen is also indicative of worsening water quality conditions. Secchi disk transparency shows a slight trend toward worsening conditions. Other parameters do not suggest a specific trend.

No trend is established in a review of TSI scores. From 1977 to 1998, the Indiana TSI scores fluctuated between 45 and 52. This seven-point spread does not suggest any significant changes in lake health. Jones (1996) stated that changes of ten points or less can often be accounted for by climatic and other natural variations. Statistical analysis of the TSI scores confirms the lack of a trend in the scores. No trends are apparent when the lake is evaluating using the Carlson TSI. From 1977 to 1998, the lake's trophic status rated as either eutrophic or hypereutrophic for each parameter.

WATER BUDGET

Using data available from existing sources a water budget was calculated for Silver Lake. Water enters Silver Lake from four sources: drainage from the three main inlets (Funk Ditch and the two unnamed drainages), drainage from land immediately adjacent to the lake, direct precipitation to the lake, and groundwater inputs. Water leaves Silver Lake through: drainage to Silver Creek, evaporation from the lake, and groundwater discharge. Because groundwater records were not available, groundwater recharge and discharge were assumed to be negligible in comparison to surface water movements and omitted from the calculations.

As part of the water budget, the flushing rate and hydraulic residence time were calculated for Silver Lake. To simplify the calculation of Silver Lake's flushing rate and hydraulic residence time, North Little Lake was combined with Silver Lake. Flushing rate refers to rate at which water in a lake basin is completely replaced by new water draining from the watershed. A lake's hydraulic residence time is the inverse of its flushing rate. Hydraulic residence time refers to the length of time water resides in a lake before it is replaced by new drainage from the watershed.

A lake's hydraulic residence time is calculated by dividing a lake's volume by the discharge to the lake. Combining Little North Lake and Silver Lake results in a total volume of 1686 acre-ft (2.1×10^6 m^3). Discharge to the lake was estimated by adding the direct precipitation inputs to inputs from surface runoff. Using the 17-year average annual watershed runoff rate of 12.42 in/yr for the Eel River at North Manchester (Stewart et al., 1999) and average rainfall estimate of 35.52 in/yr for Kosciusko County (Staley, 1962), surface runoff in the Silver lake watershed is approximately 3,297 acre-ft (4.1×10^6 m^3) per year. Together, with direct precipitation inputs, approximately 3,635 acre-ft (4.5×10^6 m^3) of water discharges to Silver Lake per year. Dividing by the lake's volume (Silver and North Little combined) results in hydraulic residence time of 0.46 years or 169 days (approximately 5.5 months).

Based on these calculations, water from the watershed is stored in Silver Lake for approximately five and a half months before it flows into Silver Creek. Alternatively, Silver Lake's flushing rate is approximately 2.2 times per year. In other words, the entire lake volume replaces itself 2.2 times each year. This may be an underestimation of the lake's flushing rate since groundwater impacts were not included in the water budget calculation. The presence of marl suggests groundwater inputs to the lake are likely. If groundwater discharge exceeds recharge, the lake would have a greater flushing rate than the 2.2 times per year.

PHOSPHORUS BUDGET

Of the two nutrients commonly examined during lake investigations, phosphorus is usually the one of most concern. Phosphorus is often the "limiting nutrient" in aquatic ecosystems, meaning that aquatic plant growth is limited by the amount of phosphorus available to the plants (including algae). Thus, lake managers focus on reducing phosphorus inputs to their lakes in an attempt to reduce algae blooms.

Based on data collected during the 1998 Clean Lakes Program sampling, it is likely that phosphorus is the limiting nutrient in Silver Lake. Plant tissue typically has a nitrogen to phosphorus ratio of approximately 7:1 by weight. The ratio of total nitrogen to total phosphorus in the surface water of Silver Lake is approximately 19.5:1. (Because algae growth occurs largely in surface waters where there is sufficient light, only surface nutrient concentrations are considered in determining the nutrient ratio.) This suggests that much more nitrogen is available to algae compared to phosphorus, and it is likely that reducing the phosphorus concentrations will reduce the potential for algae blooms.

External Phosphorus Loading

A phosphorus budget was developed for Silver Lake to assist in understanding the sources of phosphorus to the lake. The limited scope of this LARE study did not allow for field measurements of phosphorus inputs to the lake. External phosphorus inputs were estimated using runoff coefficients developed for various land types. For the purposes of this budget calculation, the coefficients compiled in an EPA guidance manual by Reckow et al. (1980) were used. Reckhow et al. (1980) list of range of runoff coefficients for each land use. Conservative estimates were used in this calculation model.

Table 20 calculates the phosphorus inputs from various types of land use in the watershed. In total, approximately 685.7 kg (1,512 lb) of phosphorus is exported from the Silver Lake watershed per year. Phosphorus input to the lake by direct precipitation was estimated by multiplying the average yearly rainfall rate by a typical concentration of phosphorus in rainwater (0.03 mg/L) and the surface acre of the lake. This yields a direct deposition rate of 11.15 kg (24.6 lb) per year. Because a sanitary sewer system services the homes around Silver Lake, phosphorus inputs from septic fields were not included in this calculation. In total, it is estimated that approximately 697 kg (1,537 lb) of phosphorus are delivered to Silver Lake from external sources (Table 21).

Table 20. Estimated External Phosphorus Loading from Land Use.

LAND USE	P-export (kg/ha-yr)	Land Area (ha)	P-export (kg/yr)	Percent of Total
Row Crop	0.6	1003.34	602.0	87.8 %
Pasture	0.3	52.63	21.1	3.1 %
Forest	0.2	85.46	17.1	2.5 %
Shrubland	0.2	60.42	12.1	1.7 %
Urban	0.5	66.73	33.4	4.9 %
Total		1268.58	**685.7**	**100 %**

Table 21. Estimated External Phosphorus Loading by Source.

SOURCE	PHOSPHORUS LOAD
Phosphorus from Land Use Activities	685.7 kg/yr
Precipitation Phosphorus	11.15 kg/yr
Total External Phosphorus Load	**696.85 kg/yr**

0.540526 kg/ha/yr

Internal Phosphorus Loading

Phosphorus is also released to the lake's water column from the lake's bottom sediments. Several sources contribute to the phosphorus in the lake's bottom sediments. Some of these sources include dead algae, rooted plants, fish, and other biota, sediments deposited from the watershed, and lawn waste and/or other organic materials that are directly deposited in the lake or enter the lake via its inlets. Decomposition of the lake's organic material adds phosphorus to the water column. Under certain conditions, phosphorus tied to inorganic materials may be released from the bottom sediments as well. These internal sources of phosphorus may significantly contribute to the lake's total phosphorus loading rate.

An empirical model developed by Vollenweider (1975) was used to estimate the internal phosphorus loading to Silver Lake. Vollenweider's model states that the concentration of phosphorus in a lake ([P]) is directly related to the areal loading to a lake (L) and inversely related to the lake's average depth ($\bar{z}$) and flushing rate (ρ). The following equation describes this relationship:

$$[P] = \frac{L}{10+\bar{z}\rho} \qquad (1)$$

The areal loading (L) is the sum of the external areal loading rate and the internal areal loading rate. Dividing the total external load calculated above (695.85 kg/yr) by the lake surface area yields the external areal loading rate. Once equation 1 is solved for L, the total areal loading rate, the external areal loading rate can be subtracted from the total areal loading rate to determine the lake's internal areal loading rate.

Silver Lake's flushing rate, ρ, is 2.2 times per year; its average depth, $\bar{z}$, is approximately 4.5 m (14.8 ft). The lake's phosphorus concentration [P] was calculated by taking a volume-weighted average of the epilimnetic and hypolimnetic total phosphorus concentrations obtained during the 1998 Clean Lakes Program sampling effort. Using 15 feet (4.6 m) as the thermocline, the total phosphorus volume-weighted average concentration is 0.32 mg/L. Using these values in equation 1 and solving for L yields a total areal loading rate of 6.368 $g/m^2/yr$.

To determine the internal areal loading rate, the external areal loading rate of 1.687 $g/m^2/yr$ was subtracted from total areal loading rate of 6.368 $g/m^2/yr$. This calculation results in an internal areal loading rate of 4.681 $g/m^2/yr$. In other words, the internal loading of phosphorus accounts for 74% of the total phosphorus load; external sources account for only 26% of the total load.

Acceptable Phosphorus Loading

In his examination of lakes, Vollenweider found 0.03 mg/L to be the maximum acceptable concentration of phosphorus in a lake. Lakes that exceeded this concentration tended to suffer from high productivity and low water quality. Using this concentration and Silver Lake's flushing rate and mean depth in Vollenweider's model, the acceptable areal loading rate for Silver Lake is 0.597 $g/m^2/yr$. (The line on Figure 15 divides the areal phosphorus loading rates into acceptable or unacceptable loading rates depending upon the lake's mean depth and flushing rate.) Multiplying 0.597 g/m^2 yr by the lake's area yields a loading rate of 247 kg/yr. Thus, in order to achieve a total phosphorus concentration of 0.03 mg/L in Silver Lake, total inputs of phosphorus would have to be reduced from 2,541 kg/yr to 247 kg/yr. This significant reduction in phosphorus inputs would be nearly impossible to achieve, but it does highlight the need to control internal as well as external inputs of phosphorus.

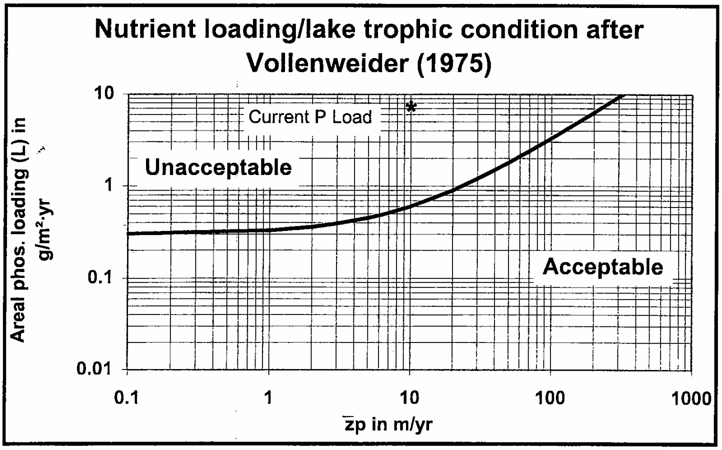


Figure 15. Phosphorus loading rate for Silver Lake based on 1998 CLP data. The line represents the loading rate for a given mean depth ($\bar{z}$) and flushing rate (ρ) that would achieve a total phosphorus concentration of 0.03 mg/L.

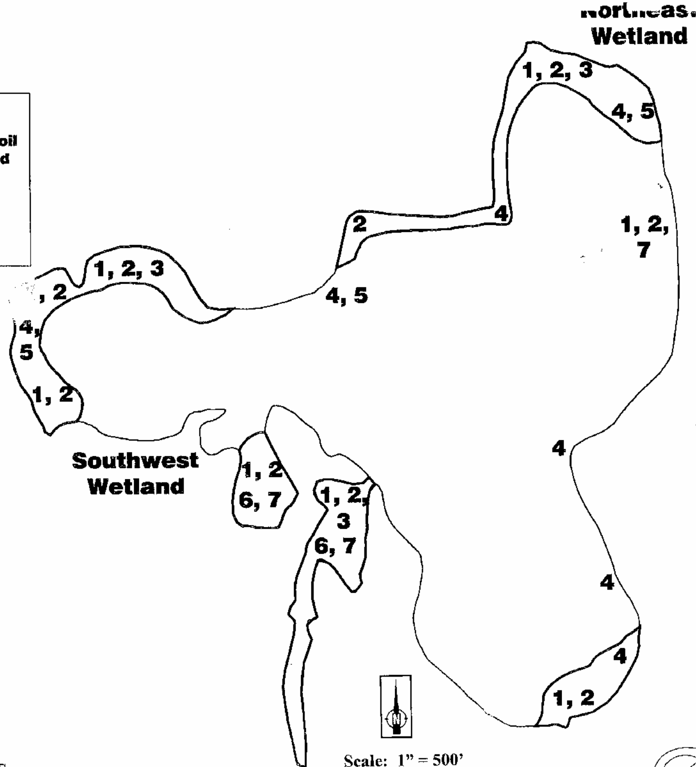
AQUATIC PLANT SURVEY

A general macrophyte (rooted plant) survey of Silver Lake was conducted on June 1, 2000. The survey located areas with a high density of submerged and emergent aquatic vegetation in the lake. Due to the limited scope of this LARE study, the survey consisted of a general reconnaissance in shallow areas of the lakes. In areas possessing the greatest density of rooted plant growth (based on visual observation), random rake grabs were performed to determine the species present. No quantitative measures of species abundance or percent cover were recorded. While this methodology has some shortcomings, it provides good information on the dominant species present and extent of coverage in the lake from which general management recommendations can be made.

Beds mapped on Figure 16 reflect areas with high density and high diversity (relative to Silver Lake). A complete list of plants found in Silver Lake during this survey as well as historical surveys is presented in Appendix 4. Before detailing the results of the macrophyte survey, it may be useful to understand the conditions under which lakes may support macrophyte growth and the roles macrophytes plan in a healthy, functioning lake ecosystem.

Conditions for Growth

Like terrestrial vegetation, aquatic vegetation has several habitat requirements that need to be satisfied in order for the plants to grow or thrive. Aquatic plants depend on sunlight as an energy



JFNA # 99-09-24

igure 16: Aquatic Plant Survey
Silver Lake Diagnostic Study
Kosciusko County, Indiana

source. The amount of sunlight available to plants decreases with depth of water as algae, sediment, and other suspended particles block light penetration. Consequently, most aquatic plants are limited to maximum water depths of 5 or 6 feet (1.5 to 1.8 m), but lakes with greater water clarity have a greater potential for plant growth. In addition, some species, such as Eurasian water milfoil, have a greater tolerance for lower light levels and can grow in up to 12 feet (3 m) of water. Refer to the depth-area curve for Silver Lake (Figure 12), aquatic plant growth may be light-limited to approximately 25.6 acres of the lake.

Aquatic plants also require a steady source of nutrients for survival. Aquatic macrophytes differ from microscopic algae (which are also plants) in their uptake of nutrients. Aquatic macrophytes receive most of their nutrients from the sediments via their root systems rather than directly utilizing nutrients in the surrounding water column. Some competition with algae for nutrients in the water column does occur. The amount of nutrients taken from the water column varies for each macrophyte species. Because most nutrients are obtained from the sediments, it does not necessarily follow that lakes with a high input of nutrients from the waterbody's watershed to the water column will automatically have aquatic macrophyte problems. Other factors, such as those listed above, play a role in limiting or promoting the growth of aquatic macrophytes.

The type of substrate present and the forces acting on the substrate affect a lake's ability to support aquatic vegetation. Lakes that have mucky, organic, nutrient-rich substrates have an increased potential for plant growth compared to lakes with gravelly, rocky substrates. The IDNR fisheries reports characterize the Silver Lake substrate as a combination of sand, muck and marl which should provide sufficient nutrients for rooted plant growth. In addition, lakes that have significant wave action that disturb the bottom sediments have decreased ability to support plants. Disturbance of bottom sediment may decrease water clarity, limiting light penetration or affect the availability of nutrients for the macrophytes. Wave action may also create significant shearing forces prohibiting plant growth altogether. Boating activity may also affect macrophyte growth by disturbing bottom sediments.

Ecosystem Roles

Aquatic plants are a beneficial and necessary part of healthy lakes. Plants stabilize shorelines holding bank soil with their roots. The vegetation also serves to dissipate wave energy further protecting shorelines from erosion. Plants play a role in a lake's nutrient cycle by uptaking nutrients from the sediments. Like their terrestrial counterparts, aquatic macrophytes produce oxygen which is utilized by the lake's fauna. Plants also produce flowers and unique leaf patterns that are aesthetically attractive.

Emergent and submerged plants provide important habitat for fish, insects, reptiles, amphibians, waterfowl, shorebirds, and small mammals. Fish utilize aquatic vegetation for cover from predators and for spawning and rearing grounds. Aquatic vegetation serves as substrate for aquatic insects, the primary diet of insectivorous fish. Waterfowl and shorebirds depend on aquatic vegetation for nesting and brooding areas. Aquatic plants such as pondweed, coontail, duckweed, water milfoil, and arrowhead, also provide a food source to waterfowl. Turtles and snakes utilize emergent vegetation as basking sites. Amphibians rely on the emergent vegetation zones as primary habitat.

Use of aquatic vegetation by waterfowl and other animals was noted during the plant survey of Silver Lake. Several painted turtles utilized spatterdock leaves as basking sites. Great blue herons fished in the shallow water off the undeveloped northern shore. A female mallard with ducklings and a pair of swans with three goslings were observed during the survey as well.

Survey Results

Figure 16 maps the areas of heaviest plant coverage. There is little difference in species dominance between these areas. Eurasian water milfoil and curly leaf pondweed dominate each of these areas. Coontail and elodea were present, often to lesser extents, in each of these areas as well. Filamentous algae coated much of the submerged vegetation in the protected coves. Algae coverage was heaviest in the two coves along the southern shoreline. Chara beds excluded other submerged vegetation growth in portions of the southern cove that was once excavated for marl. Spatterdock patches exist in many of the areas mapped on Figure 16. Arrow arum dominated the emergent zone immediately adjacent to the lake's shoreline. Dominant vegetation along the undeveloped northern shoreline includes maples, American elm, and eastern cottonwood. Appendix 5 provides a listing of all species found in Silver Lake during this survey and historical surveys of the lake.

Wetlands border the lake in its northeast and southwest corners. Reed canary grass dominates the wetland plant community in the northeast corner of the lake. The southwest wetland exhibits a more diverse community. Swamp loosestrife, American elm, green ash, sycamore, burreed, climbing nightshade, swamp dock, arrow arum, and reed canary grass vegetate the wetland's emergent edge. Submerged beds of Eurasian water milfoil, curly leaf pondweed, and coontail dominate the deeper water bordering both wetlands. Purple loosestrife was observed in both wetlands.

Areas not marked on Figure 16 are not devoid of vegetation. Submerged vegetation, predominantly Eurasian water milfoil and curly leaf pondweed but also coontail and elodea, was observed up to 50 feet from the shoreline for much of the lake.

Discussion and Summary

In general, Silver Lake suffers from a lack of species diversity. Like many of the lakes in northeastern Indiana, the Eurasian water milfoil and curly leaf pondweed have established large beds in the lakes. Coontail and elodea beds were also present in the lakes. Noticeably missing however, are native pondweeds.

Both Eurasian water milfoil and curly leaf pondweed are aggressive, exotic species. They often grow in dense mats excluding the establishment of other plants. For example, once Eurasian water milfoil plants reach the water's surface, the plant will continue growing horizontally across the water's surface. This growth pattern has the potential to shade other emergents preventing their growth and establishment. In addition, these exotic species do not provide the same habitat potential for aquatic fauna as many native pondweeds. Eurasian water milfoil leaflets serve as poor substrate for aquatic insect larva, the primary food source of many panfish.

It is important to note that the presence of curly leaf pondweed and Eurasian water milfoil is typical for northern Indiana lakes. These species were observed in every lake in Kosciusko County in 1997 (White, 1998a). Moreover, their absence was only documented in seven lakes in the 15 northern counties in Indiana. These 15 counties include all of the counties in northeastern Indiana where most of Indiana's natural lakes are located. Of the northern lakes receiving permission to treat aquatic plants in 1998, Eurasian water milfoil was listed as the primary target in those permits (White, 1998b).

In contrast to Silver Lake, however, healthy beds of native pondweeds and other species survive in many of these same lakes. For example, large leave pondweed is the dominant macrophyte species in Sechrist Lake. Big Chapman Lake supports large mixed beds of Sago, Illinois, and large leaf pondweed. Emergent stands of bulrush are scattered along shallow areas in Big Chapman Lake. These species and other including spatterdock, white water lilies, eel grass, pickerel weed, arrow arum, coontail and pondweeds are typical natives in lakes in the Northern Lakes Natural Region (Homoya et al., 1985). The poor water quality conditions in Silver Lake may produce an environment that favors exotics and heartier natives such as coontail and elodea. Improvement of the water quality in turn may allow the establishment of more natives.

FISHERIES

Silver Lake's water quality and macrophyte community described in the preceding sections have shaped the lake's fish community structure. The dense plant growth in the lake coupled with poor water clarity has created excellent conditions for large, stunted panfish populations. The rooted plants provide cover and food for young panfish trying to escape foraging predators. This leads to a crowded and competitive panfish population and ultimately to depressed growth rates. Predators' ability to locate prey is further hampered by poor water clarity.

In response to angler frustration with the large, stunted panfish populations in the Silver Lake fishery, the Indiana Department of Natural Resources began conducting fisheries surveys on the lake in the early 1960's. Surveys were performed in 1962, 1969, 1972, 1973, 1974, 1975, 1980, 1986, 1987, and 1989. These surveys documented the changes in the Silver Lake fish community over the years. The surveys also tracked fish community response to management techniques employed in the lake. These management techniques included a total eradication effort in 1970 and several years of northern pike stocking. The following summarizes the available IDNR fisheries studies.

1962

IDNR conducted its initial fish population survey in 1962 (McGinty, 1963) in response to angler reports that bluegill numbers in the lake had been declining and small crappies were abundant. IDNR biologists found that bluegill and black crappie dominated the catch in their survey

(71.3% of the sample). Only 8.5% of the black crappies were of catchable size according to IDNR standards (8.0+ inches or 20 cm), but 93.4% were at least 7 inches (18 cm) indicating a strong III+ year-class. Almost 25% of the bluegills in the survey were of catchable size (6.0+ inches or 15.2 cm). Largemouth bass comprised 4.6% of the catch, but over 50% of these were 14 inches (35.6 cm) or larger. White sucker, carp, and bullhead were the major non-sport fish found during this survey. Gizzard shad were not collected in this survey. Most of the problems within the fishery were attributed to the large population of small black crappies (McGinty, 1962).

In the 1962 survey, older bluegills showed below average growth rates while young bluegills had average growth rates indicating a stunted population. This may have been a result of ineffective predation or angler over-harvest of larger bluegills. Stunting in some bluegill populations has been attributed to harvest of large male bluegills. When large males are removed from the population, younger bluegills will direct energy towards reproductive development instead of growth resulting in a stunted population (Beard et al., 1997).

1969

A second fishery survey was conducted in 1969 (Hudson, 1969). Bluegill and black crappie dominated the fish community accounting for 82.6% of the catch. Fewer bluegills were of catchable size compared to the 1962 survey (8.1% to 25%). As in the 1962 survey, most of the largemouth bass (90%) were larger than 14 inches (36 cm). According to IDNR records, the catch per unit effort of largemouth bass had declined since the 1962 survey indicating a population decrease. Other notable observations in the 1969 survey were the decrease in the number of white suckers collected and the increase in the number of gizzard shad captured.

1970 Fishery Renovation

Comparing the results of the 1969 survey to those from the 1962 survey, the IDNR determined that the Silver Lake fishery had declined in quality. Factors contributing to this assessment included the stunted crappie population, large carp and shad populations, and an "unhealthy" bass size distribution (Hudson, 1969). Anglers' unhappiness with the fishery provided more incentive for the IDNR to take management steps. In September of 1970, the IDNR attempted complete fish eradication in Silver Lake using the common piscicide rotenone. The treatment resulted in the death of thousands of small crappie and shad, as well as many carp and bullheads, species that are typically tolerant of rotenone treatments (Hudson, 1970).

1972

In order to assess the fishery renovation, IDNR biologists conducted another fish population survey in 1972 (Taylor, 1972). The survey showed an increase in bluegill and bass populations and a decrease in the crappie population. Suckers and bullheads were present in the abundances similar to pre-treatment levels. The Age I bluegills collected exhibited growth rates nearly three times the northern Indiana average. This was likely the result of effective utilization of abundant food resources coupled with little competition. However, no young-of-the-year bluegills were captured during this survey.

Age I+ largemouth bass also demonstrated high growth rates following the eradication. Smaller individuals were observed in very poor condition. Like the bluegills, no young-of-the-year largemouth bass were observed. Based on the survey results, the IDNR recommended a follow-up survey in 1973.

1973

Bluegills dominated the 1973 survey (Taylor, 1973). In contrast to the 1972 survey, young-of-the-year fish were collected during sampling. The largemouth bass abundance decreased from the 1972 level. This finding confirmed anecdotal evidence from anglers regarding poor bass fishing in the lake. Non-sport fish such as gizzard shad, suckers, bullheads, and carp either increased in abundance or maintained numbers comparable to previous surveys. Gizzard shad ranked second in abundance behind bluegills. Strong recruitment was also noted for the gizzard shad and sucker populations. IDNR biologists speculated that the gizzard shad and suckers had migrated to the lake from Silver Creek and subsequently established naturally reproducing populations. The IDNR again recommended follow-up surveys for the next few years.

1976

Surveys conducted in 1974 and 1975 saw little change in the fishery with the exception of a small improvement in bluegill recruitment. By 1976, gizzard shad had replaced bluegill as the most abundant species present in Silver Lake accounting for over 71% of the survey catch by number (Pearson, 1977). Most (83%) of the shad recovered were young-of-the-year, an indication of continued strong recruitment. The abundance of gizzard shad is not surprising given the health of Silver Lake in the mid 1970's. The town of Silver Lake had discharged raw sewage into one of the lake's inlets for many years. This nutrient influx likely increased the lake's plankton populations providing ample food resources for planktivorous species such as gizzard shad.

Bluegill ranked second in abundance in the 1976 survey comprising 15.1% of the catch. Over 50% of these were of catchable size, and most of these were from the 1971-year class that was stocked following the 1970 eradication. Growth for most of the bluegill year classes in 1976 was average. The IDNR believed that the bluegill population had begun to stabilize, providing a satisfactory fishery to anglers.

The largemouth bass population showed some improvement over previous years in 1976. Over 63% of the bass sampled were young-of-the-year. Over 23% of the bass sampled were of catchable size. Bullhead were recovered in greater numbers than any previous survey conducted at Silver Lake. The catch rate for suckers was also very high in 1976. Only one carp was collected during the 1976 survey.

1980

In an effort to monitor the success of the 1978 northern pike stocking, a general fisheries survey was conducted in 1980 (Braun, 1980). The survey consisted of 216 hours of gill netting, 216 hours of trapping, and 1.29 hours of electrofishing. The effort resulted in the collection of 1,633 individuals representing 18 species. Gizzard shad dominated the catch accounting for 23.6% of the number of individuals collected, followed by bluegills (22%), white suckers (16.2%), black crappie (10.5%), yellow perch (9.0%), and largemouth bass (6.4%). White suckers and gizzard shad dominated the catch by weight. Only one northern pike was collected in the effort.

Despite this dominance by weight of non-game species, the results from the 1980 survey suggested that Silver Lake offered a fairly good fishery. Almost 72% of the bluegills collected were of harvestable size. Forty-four percent of the black crappies and 63% of the yellow perch captured were of harvestable size. The largemouth bass population was labeled "healthy" by IDNR biologists. IDNR biologists attribute the relative lack of northern pike to the low survival rate of 2-inch fingerlings. To improve survival of stocked northern pike, the report recommended increasing the size of stocked pike to 8-inch fingerlings.

1986

Five hundred ten 8-inch northern pike fingerlings were released into Silver Lake in 1985. A general fisheries survey (Braun, 1986) was conducted the following year to monitor northern pike survival. The survey methods included one hour of electrofishing and approximately 120 hours of trapping and 168 hours of gill netting. Both the traps and gill nets were disturbed during the survey. As a consequence, exact effort hours could not be determined.

The results of the survey were similar to those obtained during the 1980 survey. 1,561 individuals from 19 species were collected in the effort. Gizzard shad dominated the catch in terms of number of individuals and weight accounting for 28.6% and 32.9%, respectively, of the catch. Bluegills, white sucker, and yellow perch followed gizzard shad in dominance by number of individuals. White suckers ranked second in weight of individuals collected. White bass were collected for the first time at Silver Lake in 1986. Survival of the stocked northern pike was poor with only four representatives of the 1985 stocking being collected. No individuals from the 1978 stocking were collected.

IDNR biologists expressed concern regarding the dominance of non-game fish in the Silver Lake fishery. In the 1986 survey, gizzard shad and white suckers accounted for almost 40% of the number of individuals and over 60% of the weight of the catch. Carp, another non-game species, was the third most dominant of the fishery by weight (10.7%). This large biomass suggests these fish were tying up much of the lake's forage, perhaps limiting the amount available to other, more desirable fish such as bluegill. IDNR biologists had hoped to establish a reproducing northern pike population to control the larger non-game fish. The 1986 report recommended another 8-inch northern pike stocking attempt.

1987

Eight-inch northern pike fingerlings were stocked again in 1986 at a rate of 5 individuals per acre. The IDNR conducted a general fisheries survey in 1987 (Braun, 1987) to track the survival of this and other northern pike stocking efforts. The 1987 survey consisted of 96 hours of trapping, 144 hours of gill netting, and one hour of electrofishing. Results from the 1987 were consistent with other surveys conducted in the 1980's. 1,362 fish representing 16 species were collected in the effort. Gizzard shad and bluegills dominated the catch accounting for 29.7% and 17. 3% of the individuals collected, respectively. Gizzard shad dominated the catch by weight. None of the northern pike stocked in 1986 were collected in the survey; however, seven from the 1985 stocking effort were captured. Non-game fish continued to account for a large portion of the fishery biomass, but the IDNR states that game fishing in Silver Lake is "decent".

1989

The 1989 fish population survey was the most recent survey conducted at Silver Lake by IDNR. Gizzard shad were still the most abundant species found in the lake in the 1989 survey mainly because of the high number of young-of-the-year shad. Bluegill and largemouth bass were second and third respectively in terms of numbers of fish. Yellow perch were collected in large numbers compared to the 1970's when perch were virtually non-existent in the surveys. Only a few carp were recovered in the survey, but the individuals were very large according to IDNR reports.

Stocking efforts

In an effort to re-establish a stable fishery following the eradication of 1970, the IDNR stocked Silver Lake and other interconnected lakes with a variety of species (Pearson, 1977). Stocking occurred in October and November of 1970 and April of 1971. 6,808 large mouth bass were released into Silver Lake. Of these bass, 110 were adults, 310 were sub-adults, and the remaining 6,388 were fingerlings. This provided the fishery with an immediate variety in age class. In addition to the bass, 600 adult bluegills, 100 adult redears, 140 sub-adult black crappie, and 1,500 sub-adult channel catfish were released into Silver Lake. The IDNR also stocked South Little Lake and two ponds with 300 largemouth bass fingerlings and 45 sub-adults.

IDNR stocked the lake with northern pike in 1978, 1985, 1986, and 1988 in an attempt to control the stunted panfish population. In 1978, the IDNR stocked pellet-reared northern pike 2-inch fingerlings at a rate of approximately 70 fish per acre. Only one of these fish was collected during the 1980 survey. With the hope of increasing survival of the stocked fish, the IDNR switched to stocking 8-inch fingerlings in 1985, 1986, and 1988. Survival was poor with few to no individuals being collected during subsequent surveys. Those that did survive did not appear to have any impact on the forage fish. In each subsequent survey, gizzard shad ranked first in terms of numbers of individuals and often in weight of the catch.

Silver Lake's water quality may have played a role in limiting the survival of northern pike. The 1989 survey noted complete oxygen deficiency below fifteen feet. The temperature at this depth was fairly warm (25°C). In general, northern pike are less tolerant of low dissolved oxygen and warm temperatures than the other fish in the lake. 29°C is the maximum limit at which northern pike are able to grow and function normally in most lakes. Under thermal stress, the pike will likely enter a period of inactivity. Fingerlings, however, have limited body reserves from which they can draw energy during this period of inactivity adding to the stress and ultimately limiting their survival potential.

Summary

Table 22 and Figure 17 summarize the changes in the relative abundance of the dominant species in the Silver Lake fish community from 1962 to 1989. Appendix 6 provides a listing of all species found in Silver Lake during the IDNR fisheries surveys. Prior to the eradication, bluegill and black crappie dominated the fish community. Post-eradication dominance shifted to bluegills and gizzard shad. From 1980 to the most recent survey, the black crappie population more closely resembles black crappie populations found in other northern Indiana lakes; the population is cyclic in nature and usually accounts for 1 to 10% of the total fish community. The large mouth bass population has remained fairly stable over the years surveyed, typically accounting for between 3 and 9% of the total fish community. In the 1980's, yellow perch and golden shiners established large populations within the fish community. Prior to this, these species accounted for an insignificant proportion of the community.

Table 22. Summary of Fish Community Composition in Silver Lake. Percentages represent relative abundance by number.

Fish	1962	1969	1972*	1973	1976	1980	1986	1987	1989
Bluegill	24.3%	34%	83.6%	61.4%	15.0%	22.0%	27.0%	17.3%	22.6%
Black crappie	47.0%	48.6%	1.6%	<1%	<1%	10.5%	5.1%	7.7%	1.4%
Largemouth bass	4.5%	3.4%	8.5%	1.0%	4.2%	6.4%	3.9%	8.4%	17.0%
Gizzard shad	0%	5.3%	<1%	33.0%	71.3%	23.6%	28.6%	29.7%	26.3%
White sucker	16.3%	2.6%	4.1%	2.5%	<1%	16.2%	11.0%	8.3%	1.7%
Yellow perch	<1%	0%	0%	0%	<1%	9.0%	7.6%	8.4%	10.8%
Golden shiner	<1%	<1%	<1%	0%	<1%	1.2%	5.5%	6.7%	7.3%

*** indicates the year of the first post-eradication survey.**

One of the main problems faced by the Silver Lake fishery is that of stunted panfish populations Current literature (Drake et al. 1997, Ehlinger 1997, Jennings et al. 1997, Beard et al. 1997) points to a variety of factors that contribute to stunted panfish populations. These factors include, but are not limited to, competition within a species for available food or habitat, temperature, ineffective predation, turbidity, and excessive angler harvest of large male sunfishes. Several of these factors may contribute to the stunted panfish in Silver Lake.

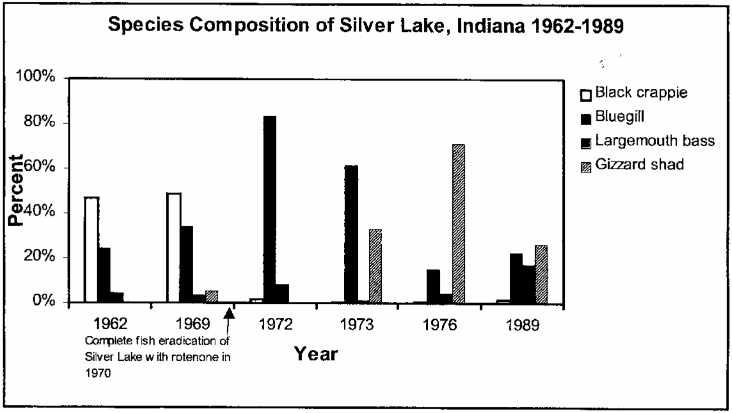


Figure 17. Historical Fish Community Composition of Silver Lake. Data Source: IDNR Fisheries Survey Reports.

High nutrient concentrations in Silver Lake have resulted in a biologically productive lake with hearty rooted plant and algae populations. Dense aquatic plant growth provides excellent cover and food sources for young panfish (i.e. bluegills) trying to escape foraging predators (i.e. bass and northern pike). This, in turn, leads to a crowded and competitive panfish population and ultimately to depressed growth rates. Below average growth rates observed for many of the age classes of bluegill in Silver Lake suggests this may be occurring in Silver Lake. Predators' ability to control panfish populations is further limited by large algae populations. Algae blooms decrease water clarity hampering the efforts of foraging predators to locate prey.

Algae populations may also play a role in determining species dominance in a lake. Large algae populations provide an excellent food base for planktivorus species such as gizzard shad. Surface plankton tows in the 1977 and 1988 lake assessments place algae abundance in the top category of the ITSI. This algal abundance may be responsible, at least in part, for the dominance of gizzard shad observed in Silver Lake from 1976 to 1989.

Despite these problems, Silver Lake still offers a fair to good fishery. To support this claim, the 1989 IDNR report (Braun, 1989) points to the strong numbers of largemouth bass, bluegills and yellow perch. Improvement in the lake's water quality, specifically a reduction in nutrient loading and thinning of rooted plant populations, would likely provide better habitat for the fish and improve the fishery further. A new IDNR fishery survey documenting the current status of the lake's fishery would assist in making other fisheries management decisions.

WATERSHED AND LAKE MANAGEMENT

The following paragraphs summarize the primary problems faced by each subwatershed or location and describe management techniques that might be utilized to treat the problems. Figure 18 provides a map of locations and areas that can be targeted for management.

Watershed

Funk Ditch subwatershed

Much of the Funk Ditch subwatershed is utilized for agricultural purposes. This land use can have an impact on water quality downstream. Runoff from farm fields can contain a variety of pollutants including nutrients (nitrogen and phosphorus), pesticides, sediment, and bacteria (fecal coliforms). Inlet sampling results showed that Funk Ditch delivered the greatest amount of total Kjeldahl nitrogen, nitrate nitrogen, and total suspended solids to Silver Lake during both base flow and storm flow conditions. The Funk Ditch subwatershed also possesses the greatest percentage of potentially highly erodible land (34% - tied with the unnamed southern ditch subwatershed). Farming practices on highly erodible lands may exacerbate non-point source pollution.

One way to reduce nutrient and sediment runoff associated with agricultural practices is to remove land from agricultural production. The Conservation Reserve Program (CRP), run by the U.S. Department of Agriculture, is a voluntary, competitive program designed to encourage farmers to establish vegetation on their property in an effort to decrease erosion, improve water

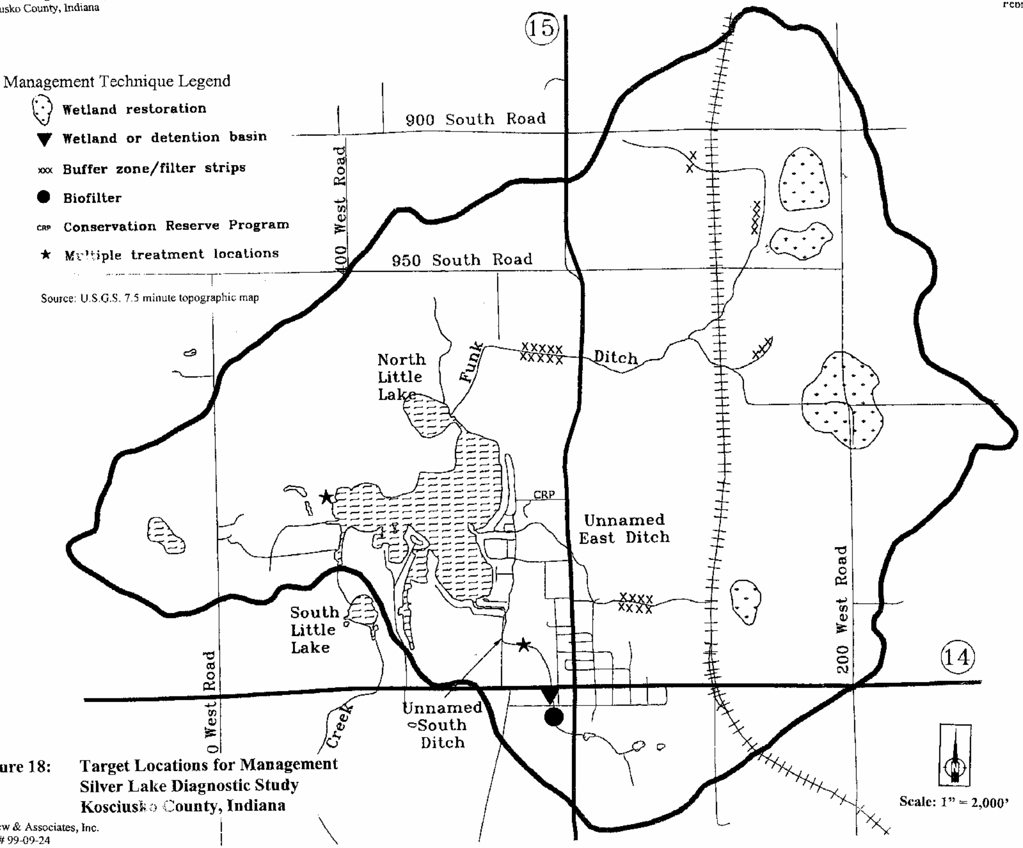


Figure 18: Target Locations for Management Silver Lake Diagnostic Study Kosciusko County, Indiana

quality, or enhance wildlife habitat. Ideal areas for this program include highly erodible lands, riparian zones, and farmed wetlands. In exchange for the plantings, farmers receive cost share assistance for the plantings and annual payments for their land. (See the Appendix 7: Additional Funding for more details on the Conservation Reserve Program.)

Removing land from production and planting it with vegetation has a positive impact on the water quality of lakes in the watershed. In a review of Indiana lakes sampled from 1989 to 1993 for the Indiana Clean Lakes Program, Jones (1996) showed that ecoregions reporting higher percentages of cropland in CRP had lower mean trophic state index (TSI) scores for their lakes. (As described in the Water Quality Section, a TSI is an indicator of lake productivity or health. Lower TSI scores indicate lower productivity or generally better water quality.)

Removal of land from agricultural production may not be economically feasible in some cases. Conservation tillage offers the potential for reducing erosion without removing the land from production. Conservation tillage requires leaving some portion of the crop on the land after its harvest rather than completely tilling the soil under as is done in conventional tillage. No till is a type of conservation tillage. Depending upon the type of conservation tillage used, reported decreases in sediment loading to waterways have ranged from 60 to 98 percent and reductions in phosphorus input range from 40 to 95 percent. Reductions of pesticide loadings have also been reported (Olem and Flock, 1990). In the review of Indiana lakes referred to above (Jones, 1996), lower TSI scores were observed in ecoregions with higher percentages of conservation tillage.

Buffer or filter strips and grassed waterways along drainages and riparian zones are also effective Best Management Practices (BMPs) to reduce pollutant input to waterways. Filter strips slow overland flows from adjacent agricultural areas and reduce flow volume by increasing infiltration of the runoff. Slower runoff velocities and reduced flow volumes will lead to decreased erosion downstream. Buffers also help stabilize stream banks. Vegetative strips filter sediments, nutrients, and pesticides from the runoff preventing them from reaching the lakes and streams. Buffer strips can reduce up to 80% of the sediment, 50% of the phosphorus, and 60% of the pathogens in runoff (Conservation Technology Information Center, 2000). Specific areas targeted for the establishment of buffer strips include: 1) a portion of the ditch located immediately south of County Road 900 South, east of the rail line, and west of an existing wetland, 2) a portion of the ditch downstream of this area, east of the rail line and north of County Road 1000 South, and 3) along a tributary of Funk Ditch between the rail line and County Road 200 West. Although some vegetative strips protect Funk Ditch immediately downstream of State Road 15, buffer strips in this area may be increased in size to achieve greater reductions in sediment and nutrient inputs. Figure 18 maps each of the locations described above.

A reduction in sediment delivery to Silver Lake via Funk Ditch may also be achieved by restoring wetlands in the subwatershed. Based on an analysis of hydric soil in the subwatershed, Funk Ditch has suffered the greatest loss in wetland acreage compared to other subwatersheds (Table 5). This loss of wetland acreage has decreased the storage capacity of the land and increased peak flows of water in Funk Ditch. An increase in peak flows typically leads to increases in channel erosion of both streambed and bank, and ultimately increases in sediment loads to the lakes. Wetlands also operate as nutrient sinks at times, which may decrease nutrient inputs to Funk Ditch. Specific locations where wetland restoration may be explored include: 1. near the intersection of County Road 1000 South and County Road 400 West, 2. a ditched tributary to Funk Ditch west of County Road 400 West and north of County Road 950 South, and 3. agricultural land south of County Road 900 South, between the rail line and County Road 400 West (Figure 18).

Unnamed East Ditch subwatershed

Agricultural land use dominates this subwatershed as well. The impact of this land use is observed in the nutrient runoff to the unnamed ditch from the east. Based on the study's sampling, this ditch delivered the most total phosphorus to Silver Lake during runoff flow events (Tables 7 and 8). Total phosphorus delivery at base flow equaled that of Funk Ditch at base flows even though the Funk Ditch subwatershed is nearly 2.5 times the size of the subwatershed draining to the unnamed ditch from the east. When delivery rate is compared on a per acre basis (Table 10), the unnamed ditch from the east delivers the greatest amount of all nutrient parameters measured.

Aerial photography suggests that a portion of the unnamed ditch from the east upstream of State Road 15 lacks a vegetative buffer. Crops are grown immediately adjacent to the ditch. Fertilizer runoff from the agricultural land may be a significant source of nutrient inputs to this ditch. The establishment of buffer strips on each side of this ditch in this area may help reduce any nutrient runoff. Nutrient and sediment runoff may also be reduced by setting aside land in the CRP or encouraging farmers that do not already do so to utilize conservation tillage methods. The benefits to the ditch and Silver Lake from these management techniques were outlined above.

This subwatershed may also benefit from the restoration of wetlands at the ditch's headwaters. The hydric soils map (Figure 8) suggests that wetlands may have historically covered much of the ditch's headwaters. While some wetland acreage still exists in the subwatershed, much has been converted to agricultural land. As described above, this land change leads eventually to increased bank and streambed erosion. This is of particular concern in the lower reaches of the ditch, immediately upstream and downstream of State Road 15. This area is mapped in a potentially highly erodible soil unit (Figure 5). Reducing peak flows upstream of this area may alleviate erosive pressure in this area.

Unnamed South Ditch subwatershed

The unnamed ditch from the south does not deliver high amounts of nutrients compared to the other subwatersheds. The low nutrient runoff may be a factor of land use in the subwatershed. Agricultural land use dominates the Funk Ditch and unnamed east ditch subwatersheds, whereas urban land use balances agricultural land use in the unnamed south ditch subwatershed. Inlet sampling indicated that the ditch possesses the highest fecal coliform concentration and delivers the greatest amount of total suspended solids on per acre of watershed (Tables 7 and 10).

Urban land use likely contributes to the total suspended solids load in this ditch. Several tiles connect storm water drains in the town to this ditch. In contrast to vegetated landscapes, the impervious surface associated with urban land use prevents infiltration of rainwater. This increases the peak flows in the southern inlet leading to channel erosion. Downstream of where storm water discharges to the southern inlet, the inlet's cut banks and deep sediment deposition bars provide evidence of erosion and heavy sediment transport. These characteristics are typical of a increase in peak flows in a stream.

Roadside runoff also carries sediments and other pollutants directly to the ditch. In vegetated areas, some of this pollutant load would be filtered. Impervious surfaces provide little opportunity for filtering of pollutants. To address this problem, storm drains are often equipped with catch basins to drop coarse sediment particles out of runoff water. All of the town's drains are equipped with catch basins. To ensure these catch basins are operating as designed, they must be cleaned on a regular basis. Seventy percent of the town's urban runoff drains to state maintained drains. These are cleaned twice a year. The remaining 30% of the town's urban runoff drains to city maintained drains, which are cleaned on an "as-needed" basis (Phil Schaley, Town of Silver Lake superintendent, personal communication).

Several management techniques have been developed to assist city planners in reducing storm water flows and the pollutants associated with those flows. The amount of impervious surface area may be reduced by replacing parking areas and pedestrian walkways with porous materials. A number of different porous surfaces have been designed for use as parking areas. These surfaces usually consist of a network of hard, impervious surfaces such as cement or plastic interspersed with open areas where vegetation growth is possible. Despite the open spaces, the networks are strong enough to support vehicular travel. Such surfaces will increase infiltration of storm water as well as provide some pollutant filtering capacity. At a minimum, use of porous surfaces should be considered when new impervious surfaces are proposed in the town.

Storm drain filters are also available to remove sediment and pollutants. These filters often remove many of the finer textured sediments and dissolved pollutants that are not captured by traditional catch basins. Removal of fine textured silts and clays is important since nutrients and toxics bind to these particles more readily than they do to coarser sands.

Two specific drains were identified where additional detention or filtration may be possible. One of these drains is located in a limestone gravel parking lot; the other is located in an open grassy area along State Road 14. Drainage from the gravel parking lot may be directed to a storm water sand bed biofilter constructed adjacent to the parking lot. This bio-filter would increase infiltration to the ground and filter the milky limestone storm water, preventing it from reaching the southern inlet and ultimately Silver Lake. A detention pond or wetland could be constructed to store water prior to outletting to the storm drain in the grassy open area. Either structure would decrease peak flows by storing storm water until it infiltrates into the ground or evaporates. A wetland may also serve as a sink to pollutants in storm water.

In addition to storm water drains and impervious surfaces, the pasture located along Neer Road and State Road 14 is of concern in this subwatershed (Figure 18). Livestock heavily graze this pasture as evidenced by the shortly cropped grass in the field. As Figure 5 indicates, a large portion of this pasture is mapped in a potentially highly erodible soil unit. Removal of vegetation through grazing only increases the erosion potential of the pasture. The livestock also have free access to the unnamed southern inlet. The livestock traveling through the channel contributes to bank erosion and resuspends bed sediments which are then transported to the lake. Livestock waste may be one of the sources of fecal coliform to the inlet.

Several actions may be taken to address these problems. First, livestock should be excluded from the channel. The channel should also be stabilized with grade controls. This will alleviate erosion caused by downcutting. The channel banks should be resloped and planted with a variety of native grasses to create a buffer zone around the ditch. As noted in the management section for the Funk Ditch subwatershed, buffer zones are effective in reducing sediments and nutrient agricultural runoff. The effect of buffer strips in reducing pollutant runoff from feedlot or pasture areas has also been examined. Olem and Flock (1990) report that buffer strips remove nearly 80% of the sediment, 84% of the nitrogen and approximately 67% of the phosphorus from runoff from feedlots. They also found a 67% reduction in runoff volume.

Shoreline/Near shore

The near shore area possesses the lowest percentage of potentially highly erodible land. It also has the second greatest percentage of wetlands remaining. Direct runoff from land immediately adjacent to the lake was not measured as part of this study. Consequently, a determination of nutrient input from this area cannot be made. Land use immediately adjacent to the lake does have an impact on lake water quality. Three areas of concern were noted in the area immediately adjacent to the lake: the lakeshore residential land, the dairy operation on the west side of the lake, and a field located at the corner of Dixie Drive and State Road 15 (Figure 18). These areas and management techniques to address concerns in the areas are described below.

Many of the shoreline residences on Silver Lake have maintained turf grass lawns. Fertilizers and pesticides are one source of nutrients and toxics to the lake. Lakeshore landowners should reduce or eliminate the use of lawn fertilizers. Landowners typically apply more fertilizer to lawns and landscaped areas than necessary to achieve the desired results. Plants can only utilize a given amount of nutrients. Nutrients not absorbed by the plants or soil will run into the lake, providing a nutrient base for rooted plants and algae in the lake. At the very minimum, landowners should follow dosing recommendations on product labels. Landowners should also avoid depositing lawn waste such as leaves and grass clippings in the lake as this adds to the nutrient base in the lakes. This includes disposal of animal waste in the lake. It is not uncommon for lake residents to dispose of goose droppings by tossing them into the lake. Unfortunately, this action contributes further nutrients to the water, fertilizing the submerged plants immediately adjacent to the shore.

In addition to reducing the amount of fertilizer used, landowners should apply phosphorus-free fertilizers. Most fertilizers contain both nitrogen and phosphorus. However, the soil usually contains enough natural phosphorus to allow for plant growth. As a consequence, fertilizers with only nitrogen work as well as those with both nutrients. The excess phosphorus that cannot be absorbed by the grass or plants will run off into the lake. Landowners can have their soil tested to ensure that their property does indeed have sufficient phosphorus and no additional phosphorus needs to be added. The local Soil and Water Conservation District or the NRCS can usually provide information on soil testing.

Lake residents should also consider replacing maintained lawns with native vegetation. In those areas that do not have seawalls, rushes (*Juncus* spp.), sedges (*Carex* spp.), pickerel weed (*Pontederia cordata*), arrowhead (*Sagittaria latifolia*) and lizard's tail (*Saururus cernua*) offer an aesthetically attractive, low profile community in wet areas. Behind existing seawalls, a variety of upland forbs and grasses that do not have the same fertilizer/pesticide maintenance requirements as turf grass may be planted in its place. Plantings can even occur in front of existing seawalls. Bulrushes (*Scirpus spp.*) and taller emergent plants are recommended for this. While not providing all the functions of a native shoreline, plantings in front of seawalls provide fish and invertebrate habitat. In addition, the restoration of native shoreline or the planting of emergents in front of seawalls also discourages Canadian geese. The geese prefer maintained lawns because any predators are clearly visible in lawn areas. Native vegetation is higher in profile than maintained lawns and has the potential to hide predators, increasing the risk for the geese. Partial or full restoration of the native shoreline community with these measures would provide shoreline erosion control and filter runoff to the lakes, thus improving the lake's overall health, without interfering with recreational uses of the lake.

Several local drains were noted in the residentially developed portion of the lake. These drains may also contribute to sediment and nutrient loading and thermal pollution of the lake. Each lake property owner should investigate local drains, roads, parking area, driveways, and rooftops. Where possible, alternatives to piping the water directly to the lake should be considered. Alternatives include French drains (gravel filled trenches), wetland filters, catch basins, and native plant overland swales.

Shoreline erosion problems on the west side of the lake were identified in the Shoreline Development Section of this document. To address the erosion problems along the lake's western shoreline, fencing should be installed to prevent livestock access to the lake. Lake residents can work with the landowner and the local NRCS office to build a livestock watering pond, eliminating the need for access to the lake. In addition to erosion problems, these livestock contribute nutrients and bacteria through waste products to the lake. Fencing should be located at a distance from the lake to create a buffer zone between the livestock pasture and the lake. Once fencing is installed, the lake's shoreline should be stabilized with erosion control blankets and planted with an appropriate native seed mix. Planting the buffer zone with a mix of prairie species would speed recovery of the area.

The dense beds of aquatic vegetation at the mouth of the channels extending from the dairy operation on the west side of the lake to the lake suggest the channels are contributing sediment and nutrients to the lake. Sediment accumulation is sufficient to allow the establishment of spatterdock and some emergent vegetation. While these channels outlet near the lake outlet minimizing the impact to the lake as a whole, management steps should be taken to reduce sediment and nutrient loading from these channels.

To alleviate the sediment and nutrient loading, livestock should be restricted from the channels. Buffer zones should be established and planted with native vegetation. (The benefits of buffer strips in filtering pasture runoff pollutants were described above.) The channels themselves could be planted with aquatic vegetation to facilitate sediment deposition and nutrient removal from the runoff water.

Another area of concern in the near lake subwatershed is the field located in the northwest corner of the Dixie Drive/State Road 15 intersection. This field is currently in agricultural production. A local drain channels runoff from this field directly to the lake. The field is mapped in a potentially highly erodible soil unit (Figure 5). Combining the highly erodible nature of the field with an agricultural land use likely results in nutrient and sediment release from the field to the lake via the local drain. Lake residents should work with the property owner to remove this field from production. If removal of the land from agricultural production is not possible, conservation tillage methods should be encouraged or filter strips should be installed along the lower edge of this field.

Lake

Two areas of concern were identified within Silver Lake itself. The first is the internal phosphorus loading. Results from the Vollenweider model (1975) suggest that approximately 74% of the total phosphorus load to Silver Lake originates from internal sources. The second area of concern is the aquatic macrophyte community. The community lacks diversity, is dominated by exotics, and, according to lake residents, interferes with recreational uses of the lake. The following paragraphs briefly describe management techniques available to treat these two issues.

Phosphorus inactivation and precipitation

Phosphorus precipitation and inactivation is a common management technique used to treat internal phosphorus loading. The technique involves adding an aluminum salt, typically alum, to the lake. The aluminum salt reacts with phosphorus in the water column to form a flocculent precipitate. This ties up existing phosphorus in the water column, making it unavailable for algae or rooted plant growth. The flocculent precipitate then sinks to the lake's sediment layer where it forms a seal over the sediments. This seal prevents the release of phosphorus in the lake's sediments that is common under anoxic conditions.

An alum treatment was recently conducted on Lake Shakamak in southern Indiana. Initial results following the treatment show a decrease in water column phosphorus as expected (Bill

Jones, unpublished data presented at the 2000 Indiana Lake Management Society meeting). Long-term monitoring will determine the effectiveness of any sediment seal formed by the precipitate.

Phosphorus precipitation and inactivation is most effective in lakes with long hydraulic residence times and low watershed phosphorus loading (Olem and Flock, 1990). In lakes with short residence times, new water from the watershed is continually replacing the water in a lake basin. If this water contains a high phosphorus load, the new phosphorus immediately replaces the phosphorus that was precipitated out of the water column. This new phosphorus also promotes the growth of algae and rooted plants. When these organisms die and sink to the lake's sediment, they form a new sediment layer over the alum treatment's seal. The seal is not able to prevent release of phosphorus from the dead organisms over it.

Regardless of the lake hydraulic residence time, decomposition of aquatic organisms and sedimentation will naturally occur within a lake. This limits the alum treatment's effectiveness to approximately five to ten years (Olem and Flock, 1990). The treatment's expected length of effectiveness should always be weighed against its cost. Costs vary depending upon the location and size of lake, type of applicator barge utilized for treatment, and other factors. Cooke et al. (1993) reports a cost of approximately $1,600 per acre ($640/ha) using a newer (faster) barge applicator.

An alum treatment should always be performed by an experienced applicator. An experienced applicator will test chemical conditions in the lake to ensure parameters are within ranges necessary to attempt a treatment (i.e. sufficient buffering capacity and water hardness). In addition, an experienced applicator will monitor the lake during treatment to ensure that the pH of the lake does not fall below 5.5-6.0. Below this pH range, conditions are appropriate for the formation of Al^{3+}, which is toxic to many organisms.

Cooke et al. (1993) outlines several of the potential drawbacks to alum treatments. These include the potential for increased rooted plant growth. As phosphorus that was once available for algae growth is removed from the water column, algae growth is reduced. This may increase water transparency. Increased water clarity allows for greater light penetration which could enhance rooted plant growth. Food chain impacts from the immediate reduction of algae could also affect a lake's fishery. Finally, the toxicity of aluminum even in neutral or basic conditions (pH >7) is of some concern to researchers.

Aquatic plant control

Silver Lake's rooted plant community is the second in-lake area of concern. In the past, lake residents have managed the rooted plant community with spotty chemical herbicide applications. These applications have achieved limited control and may be contributing to the internal phosphorus loading problem. To help guide better management of the lake's rooted plant community, development of an aquatic plant management plan is strongly recommended. Such a plan would identify long term goals for plant management while considering the varied needs of all lake users and how plants in the lakes affect these needs.

Several aquatic plant management techniques are available to assist lake residents in managing rooted plant populations. To provide lake residents with a better understanding of the range of techniques available, several of these are listed below. Not all of these techniques are recommended or even feasible on Silver Lake. A good plant management plan often utilizes different techniques in different parts of a lake to adjust for specific lake characteristics as well as lake users' needs. For example, because Silver Lake has a high internal phosphorus loading rate, management techniques that remove plant material from the lake should be given preference over techniques that allow dead plant material to remain in place. Regardless of which techniques are utilized to manage the rooted plant community, it is important to remember that rooted plants are a vital part of a healthy functioning lake ecosystem. Complete eradication of rooted plants is neither desirable nor feasible. A good plant management plan will reflect these facts.

Chemical control

Herbicides are the most traditional means of controlling aquatic vegetation. Herbicides vary in their specificity to given plants, method of application, residence time in the water and the use restrictions for the water during and after treatments. Herbicides (and algalcides; chara is an algae) that are non-specific and require whole lake applications to work are generally not recommended. Such herbicides can kill non-target plant and sometimes even fish species in a lake. Costs of an herbicide treatment vary from lake to lake depending upon the type of plant species present in the lake, the size of the lake, access availability to the lake, the water chemistry of the lake, and other factors. Typically, in northern Indiana costs for treatment range from \$275 to \$300 per acre (\$680 to \$750 per hectare, Jim Donahoe, Aquatic Weed Control, personal communication).

While providing a short-term fix to the nuisances caused by aquatic vegetation, chemical control is not a lake restoration technique. Herbicide and algalcide treatments do not address the reasons why there is an aquatic plant problem, and treatments need to be repeated each year to obtain the desired control. In addition, some studies have shown that long-term use of copper sulfate (algalcide) has negatively impacted some lake ecosystems. Such impacts include an increase in sediment toxicity, increased tolerance of some algae species, including some blue-green (nuisance) species, to copper sulfate, increased internal cycling of nutrients and some negative impacts on fish and other members of the food chain (Hanson and Stefan, 1984 cited in Olem and Flock, 1990).

Past use on the Silver Lake. Chemical control on Silver Lake has been sporadic. In 1995, the Silver Lake Association obtained a permit to treat 12 acres of milfoil, coontail, and pondweed along the eastern and southern shorelines with Aquathol. According to the lake association (personal communication), lake residents have treated their own frontages on an as-needed basis since then. Based on comments from lake residents, these treatments have not been successful in providing the amount of control desired by the residents.

Effectiveness. Table 23 is a guide for common herbicides and their effectiveness in treating the dominant macrophytes found in Indiana lakes. This table is general in nature. While the table rates the chemical as effective vs. non-effective, some chemicals are obviously more effective than others. The effectiveness of any chemical often depends upon the water chemistry of the lake to which it is applied. Any chemical herbicide treatment program should always be developed with the help of a certified applicator who is familiar with the water chemistry of a targeted lake. In addition, application of a chemical herbicide may require a permit from the Indiana Department of Natural Resources, depending on the size and location of the treatment area. Information on permit requirements is available from the DNR Division of Fish and Wildlife or conservation officers.

Table 23: Common Herbicides and Their Effectiveness

Species	Diquat	Endothal	2,4 D	Fluridone
Eurasian water milfoil	M	M	E	E
Curly leaf pondweed	E	E	N	E
Other pondweeds	E	E	-	E*
Coontail	E	E	E	E
Elodea	E	M	N	E
Naiads	E	E*	E*	M

* Depends on species
E = effective
N = non effective
M = mixed results
Table based on information from Olem and Flock, 1990, Westerdahl and Getsinger, 1988, Pullman, 1992 and SePro, 1999.

<u>Mechanical Harvesting</u>

Harvesting involves the physical removal of vegetation from lakes. Harvesting should be viewed as a short-term management strategy. Like chemical control, harvesting needs to be repeated yearly and sometimes several times within the same year. (Some carry-over from the previous year has occurred in certain lakes.) Despite this, harvesting is often an attractive management technique because it can provide lake users with immediate access to areas and activities that have been affected by excessive plant growth. Mechanical harvesting is also beneficial in situation where removal of plant biomass will improve a lake's water chemistry. (Chemical control leaves dead plant biomass in the lake to decay and use up valuable oxygen.)

Macrophyte response to harvesting often depends upon the species of plant and particular way in which the management technique is performed. Pondweeds, which rely on sexual reproduction for propagation, are managed well through harvesting. However many harvested plants, especially milfoil, can re-root or reproduce vegetatively from the cut pieces left in the water.

Plants harvested several times during the growing season, especially late in the season, often grow more slowly the following season (Cooke et al., 1993). Harvesting plants at their roots is usually more effective than harvesting higher up on their stems (Olem and Flock, 1990). This is especially true with Eurasian water milfoil and curly leaf pondweed. Benefits are also derived if the cut plants and the nutrients they contain are removed from the lake. Harvested vegetation that is cut and left in the lake ultimately decomposes, contributing nutrients and consuming oxygen.

The cost of the harvester is typically the largest single outlay of money. Depending upon the capacity of the harvester, costs can range from $3,500 to over $100,000 (Cooke et al., 1993). Other costs associated with harvesting include labor, disposal site availability and proximity, amortization rate, size of lake, density of plants, reliability of the harvester, and other factors. Depending upon the specific situation, harvesting costs can range up to $650 per acre ($1,600 per hectare, Prodan, 1983; Adams, 1983). Estimated costs of the mechanical harvesting program at Lake Lemon in Bloomington, Indiana averaged $267 per acre ($659 per hectare, Zogorski et al., 1986). In general, however, excluding the cost of the machine, the cost of harvesting is comparable to that for chemical control (Cooke et al., 1993, Olem and Flock, 1990). Hand harvesting equipment is also available for smaller areas around piers at a cost of $50-$1,500 (McComas, 1993).

Drawdown

Lake level drawdown can be used as a macrophyte control technique or as an aid to other lake improvement techniques. This technique requires the ability to discharge water from a lake through an outlet structure or dam. Drawdown can be used to provide access to dams, docks, and shoreline stabilizing structures for repairs; to allow dredging with conventional earthmoving equipment; and to facilitate placement of sediment covers.

As a macrophyte control technique, drawdown is recommended in situations where prolonged (one month or more) dewatering of sediments is possible under conditions of severe heat or cold and where susceptible species are the major nuisances. Eurasian watermilfoil control for example, apparently requires three weeks or longer of dewatering prior to a one-month freezing period (Cooke, 1980). Cooke (1980) classifies 63 macrophyte species as decreased, increased, or unchanged after drawdown. One must note the presence of resistant species as well as susceptible species, since resistant species can experience a growth surge after a successful drawdown operation.

Macrophyte control during drawdown is achieved by destroying seeds and vegetative reproductive structures (e.g., tubers, rhizomes) via exposure to drying or freezing conditions. To do so, complete dewatering and consolidation of sediments is necessary. Dewatering may not be possible in seepage lakes.

There are a number of other benefits to lakes and reservoirs from drawdown. Game fishing often improves after a drawdown because it forces smaller fish (bluegill) out of the shallow areas and concentrates them with the predators (bass). This decreases the probability of stunted fish and increases the winter growth of the larger game fish. Drawdown has also been used to consolidate loose, flocculent sediments that can be a source of turbidity in lakes. Dewatering compacts the sediments, and they remain compacted after re-flooding (Born et al. 1973 and Fox et al. 1977).

A final consideration in implementation of lake level drawdown is season; winter or summer are usually chosen because they are most severe. According to Cooke (1980), "it is not clear whether drawdown and exposure of lake sediments to dry, hot conditions is more effective than exposure to dry, freezing conditions." One factor to consider is which season is most rigorous. Advantages of winter drawdown include less interference with recreation, ease of spring versus autumn refill, and no invasion of terrestrial plants. Sediment dewatering is easier in summer. Additionally, summer drawdown may also create opportunities for establishing *native* shoreline communities.

In Murphy Flowage, a 180-acre (73 ha) reservoir in Wisconsin, a five-foot drawdown from mid-October to March greatly reduced the presence of aquatic macrophytes the following growing season. Milfoil was reduced from 20 to <2.5 acres (8 ha to <1 ha), spatterdock was reduced from 42 to 12.5 acres (17 ha to 5 ha), and pondweeds were reduced from 114 to 7.5 acres (46 ha to 3 ha) (Beard 1973).

Drawdowns are not possible on all lakes. In lakes and reservoirs that do not have legal lake levels, manipulation of water level is possible without obtaining permission from regulatory agencies. Any effort to raise or lower the lake level requires that the legal level be changed. This process can be quite time consuming taking up to a year for a decision to be made. In addition, drawdowns are not physically practical on lakes that lack water control structures. On lakes where drawdowns are feasible, however, they offer a low cost management technique that does not require the introduction of chemicals or machinery.

<u>*Biological Control*</u>

Grass carp. Grass carp are the most well known species used for biological control of aquatic plants. Grass carp are an exotic fish species brought to this country from Malaysia. These carp feast on a wide range of aquatic plants; *Elodea* spp. and pondweeds are among their favorites. Unfortunately, grass carp do not like milfoil and will only eat milfoil when their favorite foods are depleted. Over the course of time, grass carp typically will devour all the plants in a lake, leaving none for fish habitat or bank/substrate stabilization. In addition, grass carp may negatively alter resident fish communities, increase nutrient release from sediments promoting algal blooms and increase the turbidity of lakes. For these reasons, the use of grass carp in public waters is banned in 18 states including Indiana. Carp stocked in private ponds must be certified as genetically triploid and must have no possible access to other waterways.

Insects. The use of specific insect species in controlling aquatic plant growth has been investigated as well. Much of this research has concentrated on aquatic plants that are common in southern lakes such as alligator weed, hydrilla and water hycinth. Cooke et al. (1993) also points to four different species that may reduce Eurasian water milfoil infestations: *Triaenodes tarda*, a caddisfly, *Cricotopus myriophylii*, a midge, *Acentria nivea*, a moth and *Litodactylus leucogaster*, a weevil.

Eurasian water milfoil
Recent research suggests another alternative: *Euhrychiopsis lecontei*, a weevil. *E. lecontei* has been implicated in a reduction of Eurasian water milfoil in several Northeastern and Midwestern lakes (EPA, 1997). *E. lecontei* weevils reduce milfoil biomass by two means: one, both adult and larval stages of the weevil eat different portions of the plant and two, tunneling by weevil larvae cause the plant to lose buoyancy and collapse, limiting its ability to reach sunlight. Techniques for rearing and releasing the weevil in lakes have been developed and under appropriate conditions, use of the weevil has produced good results in reducing Eurasian water milfoil.

Cost effectiveness and environmental safety are among the advantages to using the weevil rather than traditional herbicides in controlling Eurasian water milfoil (Christina Brant, EnviroScience, personal communication). Cost advantages include the weevil's low maintenance and long-term effectiveness versus the annual application of an herbicide. In addition, use of the weevil does not have use restrictions that are required with some chemical herbicides. Use of the weevil has a few drawbacks. The most important one to note is that reductions in Eurasian water milfoil are seen over the course of several years in contrast to the immediate response seen with traditional herbicides. Therefore, lake residents need to be patient. Because Silver Lake possesses large stretches of natural shoreline, which the weevils require for over-wintering, Silver Lake may be a good candidate for weevil release.

Purple loosestrife
Biological control may also be possible for controlling the growth and spread of the emergent purple loosestrife. Like Eurasian water milfoil, purple loosestrife is an aggressive non-native species. Once purple loosestrife becomes established in an area, the species will readily spread and take over the habitat, excluding many of the native species which are more valuable to wildlife. Conventional control methods including mowing, herbicide applications, and prescribed burning have been unsuccessful in controlling purple loosestrife.

Some control has been achieved through the use of several insects. A pilot project in Ontario, Canada reported a decrease of 95% of the purple loosestrife population from the pretreatment population (Cornell Cooperative Extension, 1996). Four different insects were utilized to achieve this control. These insects have been identified as natural predators of purple loosestrife in its native habitat. Two of the insects specialize on the leaves defoliating a plant (*Gallerucella calmariensis* and *G. pusilla*), one specializes on the flower, while one eats the roots of the plant (*Hylobius transversovittatus*). Insect releases in Indiana to date have had mixed results. At Fish Lake, LaPorte County, after six years the loosestrife is showing signs of deterioration.

Like biological control of Eurasian water milfoil, use of purple loosestrife predators offers a cost-effective means for achieving long-term control of the plant. Complete eradication of the plant cannot be achieved through use of a biological control. Insect (predator) populations will follow the plant (prey) populations. As the population of the plant decreases, so will the population of the insect since their food source is decreasing.

Any purple loosetrife control at Silver Lake should focus first on the southwest habitat. This wetland has the greatest plant diversity and therefore the greatest potential loss of functionality due to a decline in native species (i.e., fewer food resources, reduced physical habitat complexity, etc.). The reed canary grass, another exotic, already infests the northeast wetland. The density of reed canary grass may actually help limit the growth potential of purple loosetrife in the northeast wetland.

Bottom covers

Bottom shading by covering bottom sediments with fiberglass or plastic sheeting materials provides a physical barrier to macrophyte growth. Buoyancy and permeability are key characteristics of the various sheeting materials. Buoyant materials (polyethylene and polypropylene) are generally more difficult to apply and must be weighted down. Sand or gravel anchors can act as substrate for new macrophyte growth, however. Materials must be permeable to allow gases to escape from the sediments; gas escape holes must be cut in impermeable liners. Commercially available sheets made of fiberglass-coated screen, coated polypropylene, and synthetic rubber are non-buoyant and allow gases to escape, but cost more (up to $66,000 per acre or $163,000 per hectare for materials, Cooke and Kennedy, 1989). Indiana regulations specifically prohibit the use of bottom covering material as a base for beaches.

Due to the prohibitive cost of the sheeting materials, sediment covering is recommended for only small portions of lakes, such as around docks, beaches, or boat mooring areas. This technique may be ineffective in areas of high sedimentation, since sediment accumulated on the sheeting material provides a substrate for macrophyte growth. The IDNR requires a permit for any permanent structure on the lake bottom, including anchored sheeting.

Dredging

Dredging is occasionally used as a means to control aquatic plant growth. Dredging may control aquatic vegetation by two means. First, it removes aquatic vegetation. Second, it may prevent the re-establishment of vegetation by removing the substrate in which vegetation flourished and deepening the lake to a depth at which the sunlight penetration may be too limited or water pressure may be too great to allow for plant growth. Any dredging activities in a fresh water public lake will require permits from the Corps of Engineers, the Indiana Department of Environmental Management (IDEM), and IDNR. Dredging operations are fairly costly with prices ranging from $15,000 to $20,000 per acre ($37,000 to $49,400 per hectare, Jeff Krevda, Dredging Technologies, personal communication). This estimate excludes the cost of transportation to a disposal site and purchasing the disposal site if one is not available for free.

Dredging has several negative ecological impacts associated with it. For example, habitat for many aquatic insects (the macrophytes and top portion of the lake sediment) is removed along with the insects. These insects serve as an important food source to fish, and their removal may harm a lake's fishery. In addition, mechanical dredging resuspends nutrient rich sediments causing algae blooms. Because of these reasons and given the amount of material that would have to be removed in order to achieve the desired effect in Silver Lake, dredging is not recommended as a cost effective means of aquatic plant control.

RECOMMENDATIONS

The preceding management discussion provides a wish list of possible management options available to improve the health of Silver Lake and its watershed. Financial, time, manpower, and other restraints make it impossible to implement all of these management techniques all at once. Thus, it is necessary to prioritize these recommendations.

Vollenweider's model suggests that approximately 74% of the total phosphorus load originates from internal sources in the lake. Based on this, giving an in-lake alum treatment a high priority appears to be a logical decision. However, alum treatments are more effective in lakes that have controlled external phosphorus inputs. Modeling calculations show that phosphorus inputs from the watershed alone would result in an in-lake concentration of phosphorus above the acceptable 0.03 mg/L level. An alum treatment in Silver Lake would likely be less effective because of this high phosphorus input. Reduction of watershed phosphorus input should be achieved before any alum treatment is attempted.

Focusing on the watershed, priority should be given to work in the unnamed ditch from the east and Funk Ditch subwatersheds first. The unnamed ditch from the east delivers the greatest amount of phosphorus to the lake during storm flows. In addition, this ditch contributes the greatest amount of all nutrients on a per acre of watershed basis. Funk Ditch delivers the greatest amount of total suspended solids and total nitrogen. Both subwatersheds also exhibited large percentages of potentially erodible soils and wetland loss. Reduction in nutrient loading to the lake will ultimately reduce algae and rooted plant populations improving over all water quality and enhancing recreational opportunities on the lake. Similarly, reduction in sediment loading may decrease rooted plant populations by limiting additional substrate and improve recreational uses of the lake.

Secondary priority should be given to the subwatershed drained by the unnamed ditch from the south and areas immediately adjacent to the lake. These areas do contribute to the sediment and nutrient loading of the lake, but not to the level of the other two subwatersheds. Despite this, suggested projects in these areas should not be ignored. Some may actually be easier to implement than projects suggested for the other two subwatersheds. For example, shoreline residents may immediately implement the suggested best management practices. Ultimately, recommendations may be prioritized by landowner willingness and regulatory approval, where needed. Thus, it is important to keep all of the recommendations as open options.

Based on the above rationale, the following is a list of prioritized management recommendations.

1. Work with the SWCD office in Warsaw, the Kosciusko County Surveyors Office, and landowners to implement buffer or filter strip installation along the unnamed ditch from the east upstream of State Road 15 where crops appear to be grown immediately adjacent to the ditch. Work with SWCD to place agricultural land along the ditch in CRP where possible or utilize conservation tillage methods.

2. Similarly, work with the SWCD office, the surveyors office, and landowners to implement buffer or filter strip installation or enhance existing buffer zones along the Funk Ditch. (Specific locations are shown on Figure 18.) Work with SWCD to place agricultural land along the ditch in CRP where possible or utilize conservation tillage methods.

3. Initiate a feasibility study to examine potential wetland restoration projects in the headwaters of the unnamed east ditch and Funk Ditch.

4. Retrofit storm water drains with new filters to trap sediment and remove pollutants from runoff. Work with town officials to determine the possibility of constructing biofilters or wetlands to provide greater storage and treatment of urban runoff. Encourage town planners to consider porous surfaces when expanding or creating new impervious surfaces.

5. Work with the SWCD and landowner to install Best Management Practices such as fencing and filter strips on the property at the corner of State Road 14 and Neer Road. Consider a feasibility study to reslope the ditch banks and add grade controls on this property as well.

6. Develop a plant management plan that comprehensively addresses control of invasive species, the issue of phosphorus created by decomposing plants, and the importance of preserving and promoting native plants for water quality, fish and aquatic invertebrate habitat. Emphasis should be placed on management techniques that remove plant material from the water column to prevent additional internal loading of phosphorus.

7. Home Owner Recommendations:

a) use only phosphorus-free fertilizers.
b) consider natural stone or aquatic vegetation to protect shoreline from erosion instead of concrete seawalls; consider planting native vegetation in front of existing seawalls.
c) examine all drains that lead from roads, driveways or rooftops to the lake; consider alternate routes for these drains that would filter pollutants before they reach the lake.
d) keep organic debris such as lawn clippings, leaves or animal waste out of the water.

e) use idle speeds in shallow water to limit prop wash and mark those areas with buoys.

8. Work with the SWCD and landowner to install Best Management Practices (BMPs) such as fencing, filter strips, and native plantings in the channels located on the property along the west side of Silver Lake.

9. Encourage the landowner to remove the field along Dixie Drive east of State Road 15 from agricultural production and plant with tree and grass cover or work with the SWCD and the landowner to implement alternative BMPs if removal from production is not possible.

10. Once phosphorus loading from the watershed has been controlled, consider an alum treatment to reduce internal phosphorus loading.

It is important to remember that the eutrophication of Silver Lake did not occur overnight. Recovery of the lake from historical and current nutrient loading will also take time. Lake residents and the town of Silver Lake have already taken a significant step toward improving water quality by installing a sanitary sewer system. Few lakes in Kosciusko County are fortunate enough to have a sewer system. Over the years, the lake will benefit from the sewer system. Implementation of many of these suggested management techniques will also provide long-term improvement in the lake's water quality.

LITERATURE CITED

Adams, R.W. 1983. Guidelines for use of the Herbicide 2, 4-D to Control Eurasian Water Milfoil in British Columbia. Lake Restoration, Protection and Management Proceedings of the Second Annual Conference of the North American Lake Management Society. EPA 440/5-83-00. U.S. Environmental Protection Agency, Washington, D.C.

Beard, T. Douglas, Jr., Melissa T. Drake, James E. Breck, Nancy A. Nate. 1997. Effects of simulated angling regulations on stunting in bluegill populations. North American Journal of Fisheries Management, 17:525-532.

Born, S.M., T.L. Wirth, E.M. Brick, and J.P. Peterson. 1973. Restoring the recreational potential of small impoundments. Tech. Bull. No. 70. Wisconsin Department of Natural Resources, Madison, Wisconsin.

Braun, Edward R. 1980. Silver Lake, Kosciusko County, Fish Management Report. December 19, 1980.

Braun, Edward R. 1986. Silver Lake, Kosciusko County, Fish Management Report. November 26, 1986.

Braun, Edward R. 1987. Silver Lake, Kosciusko County, Fish Management Report. December 29, 1987.

Braun, Edward R. 1989. Silver Lake, Kosciusko County, Fish Management Report. January 3, 1990.

Carlson, R.E. 1977. A trophic state index for lakes. Limnology and Oceanography, 22(2):361-369.

CLP. 1994. Indiana Clean Lakes Program files. School of Public and Environmental Affairs, Indiana University, Bloomington, IN.

CLP. 1998. Indiana Clean Lakes Program files. School of Public and Environmental Affairs, Indiana University, Bloomington, IN.

Conservation Technology Information Center. Conservation Buffer Facts. [web page] No date. http://www.ctic.purdue.edu/core4/buffer/bufferfact.html. [Accessed March 3, 2000]

Cooke, G.D. 1980. "Lake level drawdown as a macrophyte control technique." Water Resources Bulletin, 16:317-322.

Cooke, G.D., and Kennedy, R.H. 1989. Water Quality Mangement for Reservoirs and Tailwaters. Report 1. In-lake Reservoir Water Quality Mangement Techniques. Tech. Rep. E-89-1. U.S. Army Corps of Engineers. Vicksburg, Mississippi.

Cooke, G.D., E.B. Welch, S.A. Peterson, and P.R. Newroth. 1993. Restoration and management of lakes and reservoirs. Second edition. Lewis Publishers, Boca Raton, Florida.

Cornell Cooperative Extension. 1996. Video- "Restoring the Balance: Biological Control of Purple Loosestrife". Cornell University Media Services, Ithica, New York.

Drake, J.T., J.E. Claussen, D.P. Philipp, and D.L. Pereira. 1997. A comparison of bluegill reproductive strategies and growth among lakes with different fishing intensities. North American Journal of Fisheries Management, 17:496-507.

Ehlinger, T.J. 1997. Male reproductive competition and sex-specific growth patters in bluegill. North American Journal of Fisheries Management, 17:508-515.

EPA Office of Water, 1997. Watershed protection: Clean lakes case study. "Use of aquatic weevils to control a nuisance weed in Lake Bomoseen, Vermont". EPA841-F-97-002.

Fox, J.L., P.L. Brezonick, and M.A. Keirn. 1977. Lake drawdown as a method of improving water equality. EPA-600/3-77-005.

Grant, W. 1999. A survey for septic system effects on Barbee Lake Chain, Indiana.

Hanson, M.J., and Stefan, H.G. 1984. Side Effects of 58 Years of Copper Sulfate Treatment of the Fairmont Lakes, Minnesota.

Hippensteel, P. 1989. Preliminary Investigation of the Lakes of Kosciusko County. Tri-State University, Angola, Indiana.

Homoya, M.A., Abrell, B.D., Aldrich, J.R., and Post, T.W. 1985. The natural regions of Indiana. Indiana Academy of Science. Vol. 94. Indiana Natural Heritage Program. Indiana Department of Natural Resources, Indianapolis, Indiana

Hudak, D.C. 1995. U. S. Fish and Wildlife Service response to U. S. Army Corps of Engineers letter requesting "a reconnaissance level planning aid letter for the proposed flood control project in the Upper Tippecanoe River Basin." Citeds in U. S. Army Corps of Engineers 1995 study.

Hudson, G.E. 1969. Fish management report of Silver Lake. Indiana Department of Natural Resources.

Hudson, G.E. 1970. Post-fish population control report. Indiana Department of Natural Resources.

IDEM. 1986. Indiana Lake Classification System and Management Plan. Department of Environmental Management, Indianapolis, Indiana.

IDEM. 2000. Indiana 305 (b) Water Quality Report. Department of Environmental Management, Office of Water Management. Indianapolis, Indiana.

IDNR. 1996. Indiana Wetlands Conservation Plan. Indianapolis, Indiana.

Indiana State Board of Health. 1960. Report of Survey, Silver Lake and Vicinity. September 1-2, 1960, August 4, 1960.

Indiana State Board of Health. 1964. Report of Survey, Silver Lake and Vicinity. July 30 & 31, 1964. Division of Sanitary Engineering.

Indiana State Board of Health. 1979. Report of Survey, Silver Lake and Vicinity. May 3, 1979.

Indiana Volunteer Lake Monitoring Program. Undated. Data files. School of Public and Environmental Affairs, Indiana University, Bloomington, IN.

Jennings, J.J., J.E. Claussen, and D.P. Philipp. 1997. Effects of population size structure on reproductive investment of male bluegill. North American Journal of Fisheries Management, 17:516-524.

Jones, William. 1996. Indiana Lake Water Quality Update for 1989-1993. Indiana Department of Environmental Management. Clean Lakes Program. Indianapolis, Indiana.

Kosciusko County Health Department. 1985. Lake and Stream Report, Silver Lake. June 24, 1985.

Kosciusko County Health Department. 1998. Kosciusko County Stream Monitoring Watershed Study. Two years, four events, Fall of 1996 – Spring of 1998.

McComas, S. 1993. Lake smarts. The Terrene Institute, Washington, D. C. 215 pp.

McGinty. D.J. 1962. Fish management report of Silver Lake. Indiana Department of Natural Resources.

McGinty, D.J. 1963. Fish management report of Silver Lake. Indiana Department of Natural Resources.

Olem, H. and G. Flock, eds. 1990. Lake and reservoir restoration guidance manual. 2nd edition. EPA 440/4-90-006. Prepared by North American Lake Management Society for U.S. Environmental Protection Agency, Washington, DC.

Pearson, Jed. 1997. A summary of fish management at Silver Lake, Indiana. Indiana Department of Natural Resources, Division of Fish and Wildlife. January, 1997.

Prodan, W.T. 1983. Milfoil Control in Seattle and the King County Region: Metro's Harvesting Program. Cited in Lake Restoration, Protection and Management. Proceedings of the Second Annual Conference of the North American Lake Management Society. EPA 440/5-83-00. U.S. Environmental Protection Agency, Washington, D.C.

Pullman, PhD., G. Douglas. 1992. Aquatic Vegetation Management Guidance Manual, Version 1. The Midwest Aquatic Plant Management Society, Flint, Michigan.

Reckhow, K.H., M.N. Beaulac, and J. T. Simpson. 1980. Modeling phosphorus loading and lake response under uncertainty: A manual and compilation of export coefficients. EPA 440/5-80-11. U.S. Environmental Protection Agency, Washington, D. C.

Staley, L.R. 1989. Soil Survey of Kosciusko County, Indiana. United States Department of Agriculture, Indianapolis, Indiana.

Stewart, J.A., C.R. Keeton, B.L., L.E. Hammil, Hieu T. Nguyen and D.K. Majors. 1999. Water Resources Data - Indiana Water Year 1998. Data Report IN-98-1. U.S. Geological Survey, Indianapolis, IN.

Taylor, M. 1972. Fish management report of Silver Lake. Indiana Department of Natural Resources.

Taylor, M. 1973. Fish management report of Silver Lake. Indiana Department of Natural Resources.

Vollenweider, R.A. 1975. Input-output models with special reference to the phosphorus loading concept in limnology. Schweiz Z. Hydrol, 37(1):53-84.

Westerdahl, H.E., and K.D. Getsinger. 1988. Efficacy of Sediment-applied Herbicides Following Drawdown in Lake Ocklawaha, Florida. Information Exchange Bulletin, A-88-1. U.S. Army Corps of Engineers, Vicksburg, Mississippi.

White, G.M. 1998a. Exotic plant species in Indiana Lakes. Report prepared for the Nonindigenous Aquatic Species Database, USGS, Gainesville, Florida. Indiana Department of Natural Resources, Division of Soil Conservation.

White, G.M. 1998b. Factors affecting and estimated cost of aquatic plant control in Indiana Lakes. Indiana Department of Natural Resources, Division of Soil Conservation.

Zygorski, J.S., W.W. Jones and others. 1986. Lake Lemon diagnostic/feasibility study. ESAC-86-02. School of Public and Environmental Affairs, Indiana University, Bloomington, Indiana.

APPENDICES

APPENDIX 1:

Detailed Land Use for
Silver Lake

Land use in the Silver Lake Watershed

Land Cover	Area (ac)	Area (ha)	Percent
High Density Urban	17.17	6.95	0.5%
Low Density Urban	147.65	59.78	4.5%
Row Crop	2478.25	1003.34	75.8%
Pasture/Grassland	130.00	52.63	4.0%
Shrubland	0.06	0.03	0.0%
Woodland	13.45	5.44	0.4%
Deciduous Forest	142.49	57.69	4.4%
Evergreen Forest	4.24	1.71	0.1%
Palustrine Forest	50.92	20.62	1.6%
Palustrine Shrubland	12.84	5.20	0.4%
Palustrine Herbaceous	136.49	55.26	4.2%
Water	136.06	55.08	4.2%
TOTAL	**3269.60**	**1323.73**	**100.0%**

APPENDIX 2:

Indiana Natural Heritage Database Results for Silver Lake Watershed

February 7, 2000

ENDANGERED, THREATENED, AND RARE SPECIES
AND HIGH QUALITY NATURAL COMMUNITIES AND NATURAL AREAS DOCUMENTED FROM
THE SILVER LAKE WATERSHED, KOSCIUSKO COUNTY, INDIANA

Type.........	Element Name................	Common Name...............	State	Fed..	Townrang	Sec................	Date	Comments
SILVER LAKE QUADRANGLE								
Reptile	CLEMMYS GUTTATA	SPOTTED TURTLE	SE	**	030N006E	06	1956	
Insect	LYTROSIS PERMAGNARIA	A LYTROSIS MOTH	ST	**	030N006E	06	1979	

STATE: SX=extirpated, SE=endangered, ST=threatened, SR=rare, SSC=special concern, WL=watch list, SG=significant, SRE=state reintroduced

FEDERAL: LE=endangered, LT=threatened, LELT=different listings for specific ranges of species, PE=proposed endangered, PT=proposed threatened, E/SA=appearance similar to LE species, **=not listed

APPENDIX 3:

Indiana Natural Heritage Database Results for Kosciusko County

November 12, 1999

ENDANGERED, THREATENED AND RARE SPECIES DOCUMENTED FROM KOSCIUSKO COUNTY, INDIANA

SPECIES NAME	COMMON NAME	STATE	FED	SRANK	GRANK
VASCULAR PLANT					
ACTAEA RUBRA	RED BANEBERRY	SR	**	S2	G5
ANDROMEDA GLAUCOPHYLLA	BOG ROSEMARY	SR	**	S2	G5
ARETHUSA BULBOSA	SWAMP-PINK	SX	**	SX	G4
ASTER BOREALIS	RUSHLIKE ASTER	SR	**	S2	G5
BIDENS BECKII	BECK WATER-MARIGOLD	SE	**	S1	G4G5T4
CAREX AUREA	GOLDEN-FRUITED SEDGE	SR	**	S2	G5
CAREX BEBBII	BEBB'S SEDGE	ST	**	S2	G5
CAREX CHORDORRHIZA	CREEPING SEDGE	SE	**	S1	G5
CAREX DISPERMA	SOFTLEAF SEDGE	SE	**	S1	G5
CAREX ECHINATA	LITTLE PRICKLY SEDGE	SE	**	S1	G5
CAREX FLAVA	YELLOW SEDGE	ST	**	S2	G5
CAREX PSEUDOCYPERUS	CYPERUS-LIKE SEDGE	SE	**	S1	G5
CORNUS AMOMUM SSP AMOMUM	SILKY DOGWOOD	SE	**	S1	G5T?
CORNUS CANADENSIS	BUNCHBERRY	SE	**	S1	G5
CYPRIPEDIUM CALCEOLUS VAR PARVIFLORUM	SMALL YELLOW LADY'S-SLIPPER	SR	**	S2	G5
CYPRIPEDIUM CANDIDUM	SMALL WHITE LADY'S-SLIPPER	SR	**	S2	G4
DROSERA INTERMEDIA	SPOON-LEAVED SUNDEW	SR	**	S2	G5
ELEOCHARIS GENICULATA	CAPITATE SPIKE-RUSH	ST	**	S2	G5
ERIOPHORUM ANGUSTIFOLIUM	NARROW-LEAVED COTTON-GRASS	SR	**	S2	G5
ERIOPHORUM GRACILE	SLENDER COTTON-GRASS	ST	**	S2	G5
ERIOPHORUM VIRIDICARINATUM	GREEN-KEELED COTTON-GRASS	SR	**	S2	G5
GERANIUM ROBERTIANUM	HERB-ROBERT	ST	**	S2	G5
JUGLANS CINEREA	BUTTERNUT	WL	**	S3	G3G4
LATHYRUS OCHROLEUCUS	PALE VETCHLING PEAVINE	SE	**	S1	G4G5
LEMNA PERPUSILLA	MINUTE DUCKWEED	SX	**	SX	G5
MALAXIS UNIFOLIA	GREEN ADDER'S-MOUTH	SE	**	S1	G5
MATTEUCCIA STRUTHIOPTERIS	OSTRICH FERN	SR	**	S2	G5
MYRIOPHYLLUM VERTICILLATUM	WHORLED WATER-MILFOIL	ST	**	S2	G5
PANICUM BOREALE	NORTHERN WITCHGRASS	SR	**	S2	G5
PLATANTHERA PSYCODES	SMALL PURPLE-FRINGE ORCHIS	SR	**	S2	G5
POTAMOGETON EPIHYDRUS	NUTTALL PONDWEED	SE	**	S1	G5
POTAMOGETON FRIESII	FRIES' PONDWEED	SE	**	S1	G4
POTAMOGETON OAKESIANUS	OAKES PONDWEED	SE	**	S1	G4
POTAMOGETON RICHARDSONII	REDHEADGRASS	ST	**	S2	G5
POTAMOGETON STRICTIFOLIUS	STRAIGHT-LEAF PONDWEED	SE	**	S1	G5
PRUNUS PENSYLVANICA	FIRE CHERRY	SR	**	S2	G5
SCIRPUS SUBTERMINALIS	WATER BULRUSH	SR	**	S2	G4G5
SELAGINELLA APODA	MEADOW SPIKE-MOSS	SE	**	S1	G5
SPARGANIUM ANDROCLADUM	BRANCHING BUR-REED	ST	**	S2	G4G5
SPIRANTHES LUCIDA	SHINING LADIES'-TRESSES	SR	**	S2	G5
STENANTHIUM GRAMINEUM	EASTERN FEATHERBELLS	SE	**	S1	G4G5
TOFIELDIA GLUTINOSA	FALSE ASPHODEL	SR	**	S2	G5

STATE: SX=extirpated, SE=endangered, ST=threatened, SR=rare, SSC=special concern, WL=watch list, SG=significant,** no status but rarity warrants concern

FEDERAL: LE=endangered, LT=threatened, LELT=different listings for specific ranges of species, PE=proposed endangered, PT=proposed threatened, E/SA=appearance similar to LE species, **=not listed

November 12, 1999

ENDANGERED, THREATENED AND RARE SPECIES DOCUMENTED FROM KOSCIUSKO COUNTY, INDIANA

SPECIES NAME	COMMON NAME	STATE	FED	SRANK	GRANK
UTRICULARIA RESUPINATA	NORTHEASTERN BLADDERWORT	SX	**	SX	G4
VACCINIUM OXYCOCCOS	SMALL CRANBERRY	ST	**	S2	G5
WOLFFIELLA FLORIDANA	SWORD BOGMAT	SX	**	SX	G5
ZANNICHELLIA PALUSTRIS	HORNED PONDWEED	SE	**	S1	G5
ZIGADENUS ELEGANS VAR GLAUCUS	WHITE CAMAS	SR	**	S2	G5T4T5
MOLLUSCA: BIVALVIA (MUSSELS)					
ALASMIDONTA VIRIDIS	SLIPPERSHELL MUSSEL	**	**	S2	G4G5
EPIOBLASMA OBLIQUATA PEROBLIQUA	WHITE CAT'S PAW PEARLYMUSSEL	SE	LE	S1	G1T1
EPIOBLASMA TORULOSA RANGIANA	NORTHERN RIFFLESHELL	SE	LE	S1	G2T2
LAMPSILIS FASCIOLA	WAVY-RAYED LAMPMUSSEL	SSC	**	S2	G4
LAMPSILIS OVATA	POCKETBOOK	**	**	S2	G5
LIGUMIA RECTA	BLACK SANDSHELL	**	**	S2	G5
PLEUROBEMA CLAVA	CLUBSHELL	SE	LE	S1	G2
PTYCHOBRANCHUS FASCIOLARIS	KIDNEYSHELL	SSC	**	S2	G4G5
QUADRULA CYLINDRICA CYLINDRICA	RABBITSFOOT	SE	**	S1	G3T3
TOXOLASMA LIVIDUS	PURPLE LILLIPUT	SSC	**	S2	G2
TOXOLASMA PARVUM	LILLIPUT	**	**	S2	G5
VILLOSA FABALIS	RAYED BEAN	SSC	**	S1	G1G2
VILLOSA LIENOSA	LITTLE SPECTACLECASE	SSC	**	S2	G5
ARTHROPODA: INSECTA: LEPIDOPTERA (BUTTERFLIES; SKIPPERS)					
EUPHYDRYAS PHAETON	BALTIMORE	**	**	S2S4	G4
EUPHYES BIMACULA	TWO-SPOTTED SKIPPER	SR	**	S2	G4
EURISTRYMON ONTARIO	NORTHERN HAIRSTREAK	WL	**	S2S4	G4
HESPERIA LEONARDUS	LEONARDUS SKIPPER	SR	**	S2	G4
LYCAENA HELLOIDES	PURPLISH COPPER	**	**	S2S4	G5
PIERIS OLERACEA	VEINED WHITE	SE	**	S1	G5T4
ARTHROPODA: INSECTA: LEPIDOPTERA (MOTHS)					
HEMILEUCA SP 3	MIDWESTERN FEN BUCKMOTH	**	**	S1?	G3G4
LYTROSIS PERMAGNARIA	A LYTROSIS MOTH	ST	**	S2	GU
FISH					
ACIPENSER FULVESCENS	LAKE STURGEON	SE	**	S1	G3
COREGONUS ARTEDI	CISCO	SSC	**	S2	G5
HYBOPSIS AMBLOPS	BIGEYE CHUB	**	**	S2	G5
NOTROPIS HETEROLEPIS	BLACKNOSE SHINER	**	**	S2	G5
PERCINA EVIDES	GILT DARTER	SE	**	S1	G4
AMPHIBIANS					
AMBYSTOMA LATERALE	BLUE-SPOTTED SALAMANDER	SSC	**	S2	G5
HEMIDACTYLIUM SCUTATUM	FOUR-TOED SALAMANDER	SE	**	S2	G5

STATE: SX=extirpated, SE=endangered, ST=threatened, SR=rare, SSC=special concern, WL=watch list, SG=significant,** no status but rarity warrants concern

FEDERAL: LE=endangered, LT=threatened, LELT=different listings for specific ranges of species, PE=proposed endangered, PT=proposed threatened, E/SA=appearance similar to LE species, **=not listed

ENDANGERED, THREATENED AND RARE SPECIES DOCUMENTED FROM KOSCIUSKO COUNTY, INDIANA

SPECIES NAME	COMMON NAME	STATE	FED	SRANK	GRANK
NECTURUS MACULOSUS	MUDPUPPY	SSC	**	S2	G5
RANA PIPIENS	NORTHERN LEOPARD FROG	SSC	**	S2	G5
REPTILES					
CLEMMYS GUTTATA	SPOTTED TURTLE	SE	**	S2	G5
CLONOPHIS KIRTLANDII	KIRTLAND'S SNAKE	SE	**	S2	G2
EMYDOIDEA BLANDINGII	BLANDING'S TURTLE	SE	**	S2	G4
NERODIA ERYTHROGASTER NEGLECTA	COPPERBELLY WATER SNAKE	SE	**	S2	G5T2T3
SISTRURUS CATENATUS CATENATUS	EASTERN MASSASAUGA	SE	**	S2	G3G4T3T4
BIRDS					
ACCIPITER COOPERII	COOPER'S HAWK	**	**	S3B,SZN	G5
ARDEA HERODIAS	GREAT BLUE HERON	**	**	S4B,SZN	G5
BOTAURUS LENTIGINOSUS	AMERICAN BITTERN	SE	**	S2B	G4
CHLIDONIAS NIGER	BLACK TERN	SE	**	S1B,SZN	G4
CIRCUS CYANEUS	NORTHERN HARRIER	SE	**	S2	G5
CISTOTHORUS PALUSTRIS	MARSH WREN	SE	**	S3B,SZN	G5
CISTOTHORUS PLATENSIS	SEDGE WREN	SE	**	S3B,SZN	G5
DENDROICA CERULEA	CERULEAN WARBLER	SSC	**	S3B	G4
FALCO PEREGRINUS	PEREGRINE FALCON	SE	E(S/A)	S2B,SZN	G4
GRUS CANADENSIS	SANDHILL CRANE	SE	**	S2B,S1N	G5
IXOBRYCHUS EXILIS	LEAST BITTERN	SE	**	S3B	G5
MNIOTILTA VARIA	BLACK-AND-WHITE WARBLER	SSC	**	S1S2B	G5
NYCTICORAX NYCTICORAX	BLACK-CROWNED NIGHT-HERON	SE	**	S1B,SAN	G5
RALLUS ELEGANS	KING RAIL	SE	**	S1B,SZN	G4G5
RALLUS LIMICOLA	VIRGINIA RAIL	SSC	**	S3B,SZN	G5
VERMIVORA CHRYSOPTERA	GOLDEN-WINGED WARBLER	SE	**	S1B	G4
MAMMALS					
CONDYLURA CRISTATA	STAR-NOSED MOLE	SSC	**	S2?	G5
LUTRA CANADENSIS	NORTHERN RIVER OTTER	SE	**	S?	G5
MUSTELA NIVALIS	LEAST WEASEL	SSC	**	S2?	G5
MYOTIS SODALIS	INDIANA BAT OR SOCIAL MYOTIS	SE	LE	S1	G2
TAXIDEA TAXUS	AMERICAN BADGER	SE	**	S2	G5
HIGH QUALITY NATURAL COMMUNITY					
FOREST - UPLAND DRY-MESIC	DRY-MESIC UPLAND FOREST	SG	**	S4	G4
FOREST - UPLAND MESIC	MESIC UPLAND FOREST	SG	**	S3	G3?
LAKE - LAKE	LAKE	SG	**	S2	
WETLAND - BEACH MARL	MARL BEACH	SG	**	S2	G3
WETLAND - BOG ACID	ACID BOG	SG	**	S2	G3
WETLAND - BOG CIRCUMNEUTRAL	CIRCUMNEUTRAL BOG	SG	**	S3	G3
WETLAND - FEN	FEN	SG	**	S3	G3

STATE: SX=extirpated, SE=endangered, ST=threatened, SR=rare, SSC=special concern, WL=watch list, SG=significant,** no status but rarity warrants concern

FEDERAL: LE=endangered, LT=threatened, LELT=different listings for specific ranges of species, PE=proposed endangered, PT=proposed threatened, E/SA=appearance similar to LE species, **=not listed

ENDANGERED, THREATENED AND RARE SPECIES DOCUMENTED FROM KOSCIUSKO COUNTY, INDIANA

SPECIES NAME	COMMON NAME	STATE	FED	SRANK	GRANK
WETLAND - FEN FORESTED	FORESTED FEN	SG	**	S1	G3
WETLAND - MARSH	MARSH	SG	**	S4	GU
WETLAND - MEADOW SEDGE	SEDGE MEADOW	SG	**	S1	G3?
WETLAND - SWAMP SHRUB	SHRUB SWAMP	SG	**	S2	GU

STATE: SX=extirpated, SE=endangered, ST=threatened, SR=rare, SSC=special concern, WL=watch list, SG=significant,** no status but rarity warrants concern

FEDERAL: LE=endangered, LT=threatened, LELT=different listings for specific ranges of species, PE=proposed endangered, PT=proposed threatened, E/SA=appearance similar to LE species, **=not listed

APPENDIX 4:

Storm Water Laboratory Data Sheets

SAMPLE RESULTS

CLIENT SAMPLE ID: **Silver - Funk**
CLIENT PROJECT: **Barbee/Silver/Webster**
SAMPLE TYPE: **Water(Non DW)**
Date Sampled: 4/21/00

Report Date: 5/9/00
EIS Sample No: 067772
EIS Order No: 000400183
Date Received: 4/21/00

Parameter	Results	Units	SDL	MDL	Analyst	Test Date	Method
Nitrogen(Kjeldahl)Total	1.6	mg/L	0.1	0.1	SzkarlatM	5/2/00	351.2
Nitrogen(Ammonia)	<0.05	mg/L	0.05	0.05	SzkarlatM	4/24/00	350.1
Nitrogen(Nitrate+Nitrite)	13	mg/L	0.3	0.1	SzkarlatM	5/3/00	353.2
pH	7.1	SU			ClarkS	4/21/00	4500-H B
Phosphorus,ortho	<0.05	mg/L	0.05	0.05	SzkarlatM	5/2/00	4500-P F
Phosphorus,Total	0.10	mg/L	0.05	0.05	SzkarlatM	5/2/00	4500-P F
Solids,Total Suspended	18	mg/L	1	1	SzkarlatM	4/26/00	2540 D
Specific Conductance	700	umhos/cm	1	1	ClarkS	5/8/00	2510 B
Turbidity	18	NTU	1	1	ShaneD	4/27/00	180.1

SAMPLE RESULTS

CLIENT SAMPLE ID: **Silver - Unnamed E**
CLIENT PROJECT: **Barbee/Silver/Webster**
SAMPLE TYPE: **Water(Non DW)**
Date Sampled: 4/21/00

Report Date: 5/9/00
EIS Sample No: 067773
EIS Order No: 000400183
Date Received: 4/21/00

Parameter	Results	Units	SDL	MDL	Analyst	Test Date	Method
Nitrogen(Kjeldahl)Total	1.2	mg/L	0.1	0.1	SzkarlatM	5/2/00	351.2
Nitrogen(Ammonia)	0.89	mg/L	0.05	0.05	SzkarlatM	4/24/00	350.1
Nitrogen(Nitrate+Nitrite)	17	mg/L	0.6	0.1	SzkarlatM	5/3/00	353.2
pH	7.6	SU			ClarkS	4/21/00	4500-H B
Phosphorus,ortho	0.34	mg/L	0.05	0.05	SzkarlatM	5/2/00	4500-P F
Phosphorus,Total	0.47	mg/L	0.05	0.05	SzkarlatM	5/2/00	4500-P F
Solids,Total Suspended	18	mg/L	1	1	SzkarlatM	4/26/00	2540 D
Specific Conductance	610	umhos/cm	1	1	ClarkS	4/25/00	2510 B
Turbidity	64	NTU	1	1	ShaneD	4/27/00	180.1

SAMPLE RESULTS

CLIENT SAMPLE ID: Silver - Unnamed S
CLIENT PROJECT: Barbee/Silver/Webster
SAMPLE TYPE: Water(Non DW)
Date Sampled: 4/21/00

Report Date: 5/9/00
EIS Sample No: 067774
EIS Order No: 000400183
Date Received: 4/21/00

Parameter	Results	Units	SDL	MDL	Analyst	Test Date	Method
Nitrogen(Kjeldahl)Total	0.78	mg/L	0.1	0.1	SzkarlatM	5/2/00	351.2
Nitrogen(Ammonia)	<0.05	mg/L	0.05	0.05	SzkarlatM	4/24/00	350.1
Nitrogen(Nitrate+Nitrite)	2.3	mg/L	0.1	0.1	SzkarlatM	5/3/00	353.2
pH	7.5	SU			ClarkS	4/21/00	4500-H B
Phosphorus,ortho	0.14	mg/L	0.05	0.05	SzkarlatM	5/2/00	4500-P F
Phosphorus,Total	0.24	mg/L	0.05	0.05	SzkarlatM	5/2/00	4500-P F
Solids,Total Suspended	25	mg/L	1	1	SzkarlatM	4/26/00	2540 D
Specific Conductance	750	umhos/cm	1	1	ClarkS	4/25/00	2510 B
Turbidity	46	NTU	1	1	ShaneD	4/27/00	180.1

LABORATORY REPORT

Turner Technologies, Inc.

560 Zimmer Road - P.O. Box 1096
Warsaw, Indiana 46581-1096
Voice 219/267-3305 Fax 219/269-6569
Certified Public Health Laboratory #: MC-43-1
USDA Laboratory Code#: 3659

Customer: 471

J. F. New & Associates

708 Rossevelt Rd
Walkerton, IN 46574

Billing: J. F. New & Associates

708 Rossevelt Rd
Walkerton, IN 46574

Sample: 124959
Description: FUNK DITCH
Desc Code: SILVER
Sampled: 8/29/00 Time:
Received: 8/29/00
Reported: 9/07/00 3:59 pm
P.O. Number:

Test Description		RESULT	Units	Detection Limit	Our Lab's Method	Date Tested	Time	Run #	Analyst	QC Data	Comments
Turbidity		8.80	NTU	.50	180.1	8/30/00	16:20	59390	SB		
				Reference Method: 2130 B Nephelometric Method							
Conductivity		730.00	uMho		2510B	8/29/00	13:00	59358	JAS		
				Reference Method: 2510 B Conductivity Electrometric							
Suspended Solids		6.00	mg/L	1.00	2540D	8/30/00	10:30	59414	EM		
				Reference Method: 2540 D Total Suspended Solids Dried at 103 C							
Nitrate-Nitrite/N		1.80	mg/L		353.2	9/01/00	16:00	59480	SB		
				Reference Method: 4500 NO3 D Nitrate Nitrogen Electrode Method							
pH value		7.89	unit		4500HB	8/29/00	17:00	59360	EM		
				Reference Method: 4500 H B pH Electrometric Method							
Ammonia Nitrogen	<	.10	mg/L	.10	4500NH3F	8/29/00	15:00	59359	EM		None Detected
				Reference Method: 4500 NH3 F Ammonia Selective Electrode							
Kjeldahl Nitrogen		.88	mg/L	.05	4500NORGB	8/29/00	12:00	59505	EM		
				Reference Method: 4500 NORG B Nitrogen Macro-Kjeldahl Method							
Phosphorus Total		.09	mg/L	.01	4500PB5E	8/30/00	12:00	59361	JS		
				Reference Method: 4500 P B 5 E H2SO4-HNO3, Ascorbic Acid							
Phosphorus Ortho		.07	mg/L	.01	4500PE	8/30/00	13:00	59363	JS		
QC-Phosphorus Ortho		.07	mg/L	.01	4500PE	8/30/00	13:00	59363	JS	DUP	
QC-Phosphorus Ortho		2.50	mg/L	.01	4500PE	8/30/00	13:00	59363	JS	SPK 2.5	
				Reference Method: 4500 P E Ascorbic Acid							
E Coli Beaches		2,000.00	/100		9213D	8/29/00	15:00	59449	KK		
				Reference Method: 9213 D Natural Bathing Beach Escherichia coli							

1. For bacteriological results, "<" or "none detected" indicates negative.
2. Zeros to the right of the decimal point and/or to the right of a digit are not significant. IE: 10.00=10; 1.00=1; 1.10=1.1

All testing is conducted in accordance with Turner Technologies, Inc. "Quality Control / Quality Assurance Manual" and the the following regulations as applicable: 40 CFR Part 136, 40 CFR Part 261 or PL 91-597.

Approved by: David M Turner

LABORATORY REPORT

Turner Technologies, Inc.

560 Zimmer Road - P.O. Box 1096
Warsaw, Indiana 46581-1096
Voice 219/267-3305 Fax 219/269-6569
Certified Public Health Laboratory #: MC-43-1
USDA Laboratory Code#: 3659
Billing: J. F. New & Associates

708 Rossevelt Rd
Walkerton, IN 46574

Customer: 471

J. F. New & Associates

708 Rossevelt Rd
Walkerton, IN 46574

Sample: 124960
Description: UNNAMED EAST
Desc Code: SILVER
Sampled: 8/29/00 Time:
Received: 8/29/00
Reported: 9/07/00 3:59 pm
P.O. Number:

Test Description		RESULT	Units	Detection Limit	Our Lab's Method	Date Tested	Time	Run #	Analyst	QC Data	Comments
Turbidity		4.80	NTU	.50	180.1	8/30/00	16:20	59390	SB		
				Reference Method: 2130 B Nephelometric Method							
Conductivity		720.00	uMho		2510B	8/29/00	13:00	59358	JAS		
				Reference Method: 2510 B Conductivity Electrometric							
Suspended Solids		7.00	mg/L	1.00	2540D	8/30/00	10:30	59414	EM		
QC-Suspended Solids		7.00	mg/L	1.00	2540D	8/30/00	10:30	59414	EM	DUP	
				Reference Method: 2540 D Total Suspended Solids Dried at 103 C							
Nitrate-Nitrite/N		.50	mg/L		353.2	9/01/00	16:00	59480	SB		
				Reference Method: 4500 NO3 D Nitrate Nitrogen Electrode Method							
pH value		7.73	unit		4500HB	8/29/00	17:00	59360	EM		
				Reference Method: 4500 H B pH Electrometric Method							
Ammonia Nitrogen	<	.10	mg/L	.10	4500NH3F	8/29/00	15:00	59359	EM		None Detected
				Reference Method: 4500 NH3 F Ammonia Selective Electrode							
Kjeldahl Nitrogen		.50	mg/L	.05	4500NORGB	8/29/00	12:00	59505	EM		
				Reference Method: 4500 NORG B Nitrogen Macro-Kjeldahl Method							
Phosphorus Total		.18	mg/L	.01	4500PB5E	8/30/00	12:00	59361	JS		
				Reference Method: 4500 P B 5 E H2SO4-HNO3, Ascorbic Acid							
Phosphorus Ortho		.14	mg/L	.01	4500PE	8/30/00	13:00	59363	JS		
				Reference Method: 4500 P E Ascorbic Acid							
E Coli Beaches		1,400.00	/100		9213D	8/29/00	15:00	59449	KK		
				Reference Method: 9213 D Natural Bathing Beach Escherichia coli							

1. For bacteriological results, "<" or "none detected" indicates negative.
2. Zeros to the right of the decimal point and/or to the right of a digit are not significant. IE: 10.00=10; 1.00=1; 1.10=1.1

All testing is conducted in accordance with Turner Technologies, Inc. "Quality Control / Quality Assurance Manual" and the the following regulations as applicable: 40 CFR Part 136, 40 CFR Part 261 or PL 91-597.

Approved by: David M Turner

LABORATORY REPORT

Turner Technologies, Inc.

560 Zimmer Road - P.O. Box 1096
Warsaw, Indiana 46581-1096
Voice 219/267-3305 Fax 219/269-6569
Certified Public Health Laboratory #: MC-43-1
USDA Laboratory Code#: 3659

Billing: J. F. New & Associates
708 Rossevelt Rd
Walkerton, IN 46574

Customer: 471

J. F. New & Associates

708 Rossevelt Rd
Walkerton, IN 46574

Sample: 124961
Description: UNNAMED SOUTH
Desc Code: SILVER
Sampled: 8/29/00 Time:
Received: 8/29/00
Reported: 9/07/00 3:59 pm
P.O. Number:

Test Description		RESULT	Units	Detection Limit	Our Lab's Method	Date Tested	Time	Run #	Analyst	QC Data	Comments
Turbidity		1.30	NTU	.50	180.1	8/30/00	16:20	59390	SB		
				Reference Method: 2130 B Nephelometric Method							
Conductivity		920.00	uMho		2510B	8/29/00	13:00	59358	JAS		
QC-Conductivity		920.00	uMho		2510B	8/29/00	13:00	59358	JAS	DUP	
				Reference Method: 2510 B Conductivity Electrometric							
Suspended Solids	<	1.00	mg/L	1.00	2540D	8/30/00	10:30	59414	EM		None Detected
				Reference Method: 2540 D Total Suspended Solids Dried at 103 C							
Nitrate-Nitrite/N		.88	mg/L		353.2	9/01/00	16:00	59480	SB		
QC-Nitrate-Nitrite/N		.90	mg/L		353.2	9/01/00	16:00	59480	SB	DUP	
QC-Nitrate-Nitrite/N		2.70	mg/L		353.2	9/01/00	16:00	59480	SB	SPK 2.00	
				Reference Method: 4500 NO3 D Nitrate Nitrogen Electrode Method							
pH value		7.88	unit		4500HB	8/29/00	17:00	59360	EM		
				Reference Method: 4500 H B pH Electrometric Method							
Ammonia Nitrogen	<	.10	mg/L	.10	4500NH3F	8/29/00	15:00	59359	EM		None Detected
				Reference Method: 4500 NH3 F Ammonia Selective Electrode							
Kjeldahl Nitrogen	<	.40	mg/L	.05	4500NORGB	8/29/00	12:00	59505	EM		None Detected
				Reference Method: 4500 NORG B Nitrogen Macro-Kjeldahl Method							
Phosphorus Total		.08	mg/L	.01	4500PB5E	8/30/00	12:00	59361	JS		
				Reference Method: 4500 P B 5 E H2SO4-HNO3, Ascorbic Acid							
Phosphorus Ortho		.05	mg/L	.01	4500PE	8/30/00	13:00	59363	JS		
				Reference Method: 4500 P E Ascorbic Acid							
E Coli Beaches		2,200.00	/100		9213D	8/29/00	15:00	59449	KK		
				Reference Method: 9213 D Natural Bathing Beach Escherichia coli							

1. For bacteriological results, "<" or "none detected" indicates negative.
2. Zeros to the right of the decimal point and/or to the right of a digit are not significant. IE: 10.00=10; 1.00=1; 1.10=1.1

All testing is conducted in accordance with Turner Technologies, Inc. "Quality Control / Quality Assurance Manual" and the the following regulations as applicable: 40 CFR Part 136, 40 CFR Part 261 or PL 91-597.

Approved by: David M Turner

APPENDIX 5:

Macrophyte Species List

SILVER LAKE
PLANT COMMUNITY LIST

Common Name	Scientific Name
Submergent:	
Coontail	*Ceratophyllum demersum*
Elodea	*Elodea canadensis*
Eurasian watermilfoil	*Myriophyllum spicatum*
Curly pondweed	*Potamogeton crispus*
Eel grass	*Vallisneria americana*
Emergent:	
Sedge	*Carex* sp.
Hairy swamp-loosestrife	*Decodon verticillatus*
Purple loosestrife	*Lythrum salicaria*
Spatterdock	*Nuphar advena*
White water lily	*Nymphae odorata*
Arrow arum	*Peltandra virginica*
Reed canary grass	*Phalaris arundinacea*
Swampdock	*Rumus verticillatus*
Climbing nightshade	*Solanum dulcamara*
American burreed	*Sparganium americanum*
Giant burreed	*Sparganium eurycarpum*
Cattail	*Typha* sp.
American elm	*Ulmus americana*
Floating:	
Duckweed	*Lemna* sp.
Algae:	
Chara	*Chara* sp.
Filamentous algae	

APPENDIX 6:

Fish Species List

Fish community list for Silver Lake, Indiana. An **x** indicates the presence of the specified species as recorded in IDNR fish survey reports.

Common Name (Scientific Name)	**1962**	**1969**	**1972**	**1973**	**1974**	**1975**	**1976**	**1980**	**1986**	**1987**	**1989**
Bluegill (*Lepomis macrochirus*)	x	x	x	x	x	x	x	x	x	x	x
Redear sunfish (*Lepomis microlophus*)							x				
Pumpkinseed sunfish (*Lepomis gibbosus*)	x	x	x	x	x	x	x	x	x	x	x
Green sunfish (*Lepomis cyanellus*)								x			x
Hybrid sunfish (*Lepomis* sp.)					x				x		x
Warmouth (*Lepomis gulosus*)	x						x	x	x	x	x
Black crappie (*Pomoxis nigromaculatus*)	x	x	x	x	x		x	x	x	x	x
White bass (*Morone chrysops*)									x	x	x
Largemouth bass (*Micropterus salmoides*)	x	x	x	x	x	x	x	x	x	x	x
Rock bass (*Ambloplites rupestris*)											
Yellow perch (*Perca flavescens*)	x							x	x	x	x
Northern pike (*Esox lucius*)								x	x	x	x
Grass pickerel (*Esox americanus*)								x			
Bowfin (*Amia calva*)	x										
Black bullhead (*Ameiurus melas*)	x		x			x		x	x	x	x
Brown bullhead (*Ameiurus nebulosus*)	x	x	x	x			x	x	x	x	x
Yellow bullhead (*Ameiurus natalis*)	x	x	x	x			x	x	x	x	x
White sucker (*Catostomus commersoni*)	x	x	x	x	x	x	x	x	x	x	x
Spotted sucker (*Minytrema melanops*)	x	x		x	x		x	x	x	x	x
Lake chubsucker (*Erimyzon sucetta*)									x		x
Carp (*Cyprinus carpio*)	x	x	x	x	x	x	x	x	x	x	x
Gizzard shad (*Dorosoma cepedianum*)		x	x	x	x	x	x	x	x	x	x
Creek chub (*Semotilus atromaculatus*)									x		
Common shiner (*Luxilus cornutus*)			x								
Golden shiner (*Notemigonus crysoleucas*)	x	x	x				x	x	x	x	x

APPENDIX 7:

Additional Funding Sources

ADDITIONAL FUNDING

There are several cost-share grants available from both state and federal government agencies specific to watershed management. Lake associations and/or Soil and Water Conservation Districts can apply for the majority of these grants. The main goal of these grants and other funding sources is to improve water quality though specific BMPs (best management practices). As public awareness shifts towards watershed management these grants will become more and more competitive. Therefore, any association interested in improving water quality through the use of grants must become active soon. Once an association is recognized as a "watershed management activist" it will become easier to obtain these funds repeatedly. The following are some of the possible major funding sources available to lake associations for watershed management.

Lake and River Enhancement Program (L.A.R.E.)

This is the program that funded this diagnostic study. L.A.R.E. is administered by the Indiana Department of Natural Resources, Division of Soil Conservation. The program's main goals are to control sediment and nutrient inputs to lakes and streams and prevent or reverse degradation from these inputs through the implementation of corrective measures. Under present policy, the L.A.R.E. program may fund lake specific construction actions up to $100,000 for a specific project or $300,000 for all projects on a specific lake or stream. Cost-share approved projects require a 0-25% cash or in-kind match, depending on the project. L.A.R.E. also has a "watershed land treatment" component that can provide grants to SWCD's for multi-year projects. The funds are used on a cost-sharing basis with farmers who implement various BMP's.

Clean Water Act Section 319 Nonpoint Source Pollution Management Grant

The 319 Grant program is administered by the Indiana Department of Environmental Management (IDEM), Office of Water Management, Watershed Management Section. 319 is a federal grant made available by the Environmental Protection Agency (EPA). 319 grants fund projects that target nonpoint source water pollution. Nonpoint source pollution (NPS) refers to pollution originating from general sources rather than specific discharge points (Olem and Flock, 1990). Sediment, animal and human waste, nutrients, pesticides, and other chemicals resulting from land use activities such as mining, farming, logging, construction, and septic fields are considered NPS pollution. According to the EPA, NPS pollution is the number one contributor to water pollution in the United States. To qualify for funding, the water body must be listed in the state's 305(b) report as a high priority water body or be identified by a diagnostic study as being impacted by NPS pollution. Funds can be requested for up to $300,000 for individual projects. There is a 25% cash or in-kind match requirement.

Section 104(b)(3) Watershed Protection Grant

The Watershed Protection Grant program is funded by the EPA and is administered locally by IDEM. These grants provide funding for the reduction and elimination of pollution within a targeted watershed. Priorities for funding include wetland/watershed protection demonstration projects, river corridor and wetland restoration projects, wetland conservation plans, assessment and monitoring plans, and wetland assessment models. The awarded amount can vary by project and there is a required 25% match.

Watershed Protection and Flood Prevention Program

The Watershed Protection and Flood Prevention Program is funded by the U.S. Department of Agriculture (USDA) and is administered by the Natural Resources Conservation Service (NRCS). Funding targets a variety of watershed activities including watershed protection, flood prevention, erosion and sediment control, water supply, water quality, fish and wildlife habitat enhancement, wetlands creation and restoration, and public recreation in small watersheds (250,000 or fewer acres). The program covers 100% of flood prevention construction costs or 50% of construction costs for agricultural water management, recreational, or fish and wildlife projects.

Conservation Reserve Program

The Conservation Reserve Program (CRP) is funded by the USDA and administered by the Farm Service Agency. CRP is a voluntary, competitive program designed to encourage farmers to establish vegetation on their property in an effort to decrease erosion, improve water quality, or enhance wildlife habitat. The program targets farmed areas that have a high potential for degrading water quality under traditional agricultural practices or areas that might make good habitat if they were not farmed. Such areas include highly erodible land, riparian zones, and farmed wetlands. Participants in the program receive cost share assistance for any plantings or construction as well as annual payments for any land set aside.

Wetlands Reserve Program

The Wetlands Reserve Program (WRP) is funded by the USDA and is administered by the NRCS. WRP is a subsection of the Conservation Reserve Program. This voluntary program provides funding for the restoration of wetlands on agricultural land. To qualify for the program, land must be restorable and suitable for wildlife benefits. This includes farmed wetlands, prior converted cropland, farmed wet pasture, farmland that has become a wetland as a result of flooding, riparian areas which link protected wetlands, and the land adjacent to protected wetlands that contribute to wetland functions and values. Landowners may place permanent or 30-year easements on land in the program. Landowners receive payment for these easement agreements. Restoration cost-share funds are also available. No match is required.

North American Wetland Conservation Act Grant Program

The North American Wetland Conservation Act Grant Program (NAWCA) is funded and administered by the U.S. Department of Interior. This program provides support for projects that involve long-term conservation of wetland ecosystems and their inhabitants including waterfowl, migratory birds, fish and other wildlife. The match for this program is on a 1:1 basis.

Wildlife Habitat Incentive Program

The Wildlife Incentive Program (WHIP) is funded by the USDA and administered by the NRCS. This program provides support to landowners wanting to develop and improve wildlife habitat on private lands. Support includes technical assistance as well cost sharing payments. Those lands already enrolled in WRP are not eligible for WHIP. The match is 25%.

In addition to these federal and state funded grants there are several private organizations that provide grants to parties interested in maintaining or restoring the watershed where they live. For more information on private grant foundations visit the web site www.fdncenter.org.