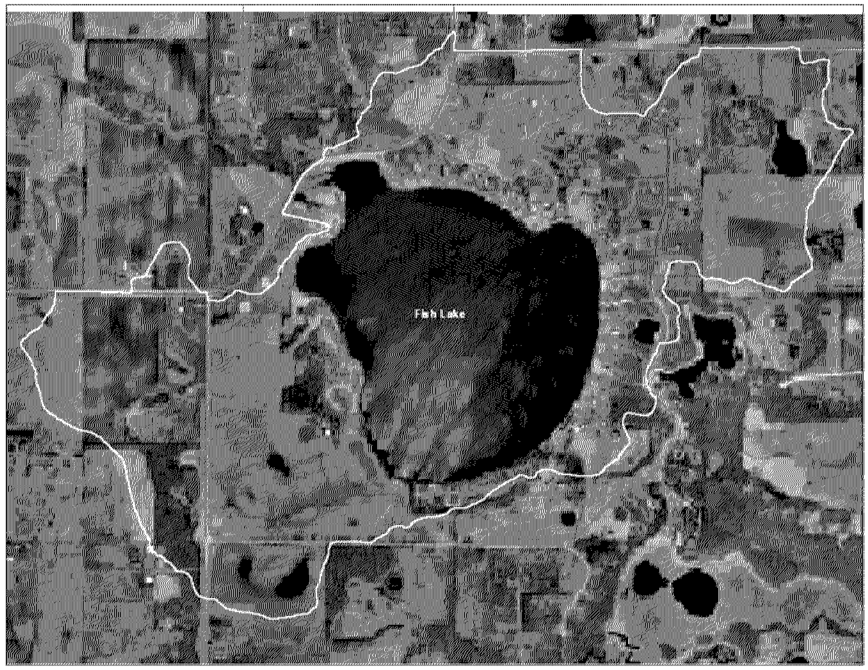

Sustainable Lake Management Plan for Fish Lake Scott County, MN

Prior Lake Spring Lake
WATERSHED DISTRICT

April 2006

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EXECUTIVE SUMMARY

Fish Lake is a relatively small recreational lake located in central Scott County, Minnesota. The lake is identified as a priority surface water resource in the Prior Lake-Spring Lake Watershed District's (PLSLWD's) Water Resources Management Plan. Since 1998, citizens have monitored Fish Lake through the Metropolitan Council's Citizen-Assisted Monitoring Program, with the help of the PLSLWD. While the lake supports and excellent fishery and is an important recreational resource for the residents of the District and Scott County, the monitoring data shows the lake is eutrophic and only partially supports swimming. Lakeshore residents have also observed increased curlyleaf growth, to the point of nuisance conditions.

In 2002, the PLSLWD began an overall sustainable lake management planning process for Fish, Spring and Prior Lakes, the main recreational lakes within the District. The *Sustainable Lake Management Plan for Spring and Prior Lakes* was completed in April 2004. In late 2003, the PLSLWD was awarded a Local Water Plan Challenge Grant by the Board of Water and Soil Resources to complete a Lake Management Plan for Fish Lake. Project activities included filling in monitoring gaps and providing watershed information to assist residents and resource managers in identifying goals, evaluating management options, and developing a sustainable lake management plan.

This report presents the results of the lake and watershed monitoring and data analysis, and lays out the process and results of the Fish Lake management planning effort. The result is an overall lake management plan that can help guide the PLSLWD, other agencies, community groups and citizens as we all strive to protect and improve this important water resource.

ACKNOWLEDGMENTS

A number of people and organizations participated in the development of this plan.

Organizations involved included:
Prior Lake-Spring Lake Watershed District (PLSLWD)
Spring Lake Township (SLT)
Minnesota Department of Natural Resources (MN DNR)
Scott County
Scott Soil and Water Conservation District (Scott SWCD)
Fish Lake Sportsman's Club
Minnesota Board of Water and Soil Resources

Individuals involved included:
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Chuck Bruzek, Fish Lake Sportsman's Club
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William Busacker
Daryl Ellison, MnDNR Fisheries
Craig Gontarek, PLSLWD
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David Shumate, Fish Lake Sportsman's Club
Roger Wahl, PLSLWD
Amal Djerrari, HMS, Inc. (volunteer watershed modeling)

INTRODUCTION AND PURPOSE

Fish Lake is a relatively small recreational lake located in central Scott County, Minnesota. The lake is identified as a priority surface water resource in the PLSLWD's Water Resources Management Plan. While the lake supports and excellent fishery and is an important recreational resource for the residents of the District and Scott County, the quality of the lake is impaired due to excess nutrients. These excessive nutrients lead to problems with nuisance algae blooms (i.e., microscopic plants) that turn the water green and scummy, limiting clarity of the water and detracting from recreational uses.

The PLSLWD has supported volunteer monitoring of Fish Lake through the Metropolitan Council's Citizen Assisted Monitoring Program (CAMP) since 1998. That data shows the lake is eutrophic and does not fully support swimming. Lakeshore residents have also observed increased curlyleaf growth, to the point of nuisance conditions.

In light of increased pressures from development and curlyleaf pondweed, the PLSLWD recognized the need to complete a lake management plan for Fish Lake to improve water quality and protect the lake's many recreational uses. Local residents, particularly members of the Fish Lake Sportsmen's Club, were also very interested in participating in the development of a management plan. In 2003, the PLSLWD applied for and was awarded a Local Water Management Challenge Grant from the Board of Water and Soil Resource, to engage local residents and agencies in the development of a management plan for Fish Lake.

The objectives of the lake management planning effort were as follows:

- Convene a group of citizens and agencies to develop a management plan for Fish Lake.
- Supplement existing monitoring data with more thorough monitoring (temperature and oxygen profiles, surface and near-bottom nutrient samples, water level) to develop a simple lake water-quality model.
- Review available plant community data and identify options for controlling curlyleaf pondweed and enhancing the native aquatic plant community.
- Evaluate current and future watershed conditions (land use, septic systems, etc.) to help predict water quality changes and identify management options.
- Collaboratively develop water quality, plant management and watershed management goals for the lake.
- Identify and evaluate management options.
- Collaboratively develop a management plan designed to achieve the identified goals.

This plan is the culmination of the planning effort that began in late 2003 with the establishment of the Fish Lake Planning Group. The plan summarizes the watershed, water quality and aquatic plant data available for Fish Lake, establishes lake management goals, and identifies a management plan to help achieve those goals. The plan is intended serve as a vehicle for a more organized approach to water quality management where the strengths and resources of various organizations are put to work toward common objectives. Appendix A presents letters and resolutions of support and commitment from several organizations that participated in the development of the plan and that will also participate in its implementation.

ABOUT THE PLANNING PROCESS

The planning process was completed using three phases of small-group workshops as indicated below. Following each workshop, summaries were compiled and distributed to participants and interested parties. Copies of the workshop summaries and materials are available for review at the Watershed District office.

- A ½-day **visioning session** was held in October 2002, where participants were invited to develop and express their understanding of the current and desired future conditions of the lakes.
- **Initial Planning Workshop (February 2003).** Reviewed the visioning session and current knowledge about the lake. Discussed data needed to continue the planning effort.
- **Data Gathering**. During 2003 through 2005, additional data was collected to help inform the planning process. Workshops were held to guide the data-gathering effort and review and discuss the information as it was generated.
- **Workshop 1: Initiate Planning Process (August 2004).** Participants discussed the planning process and the ongoing data-gathering effort, discussed the current understanding of the lake's water quality and reviewed the short and long-term visions developed during the visioning session and initial planning workshop.
- **Workshops 2 and 3: Aquatic Vegetation Management Plan (Fall/Winter 2004).** A series of workshops were held to develop an Aquatic Vegetation Management Plan for the lake.
- **Workshop 4: Fish Lake Data and Goals (Spring 2005).** At this workshop, participants reviewed the planning process and the latest information about the lake, including a map of the land uses in the watershed. The participants also reviewed and discussed goals identified for the lake to date, and discussed their views of the current and desired quality of the lake.
- **Workshop 5: Lake Goals and Objectives (Summer 2005).** Participants finalized specific goals and objectives for the management plan.
- **Workshop 6: Management Options and Draft Plan (Winter 2006).** Following the completion of the second year of detailed monitoring, the planning group met to discuss the latest data and lake management options and to review a draft of the management plan.

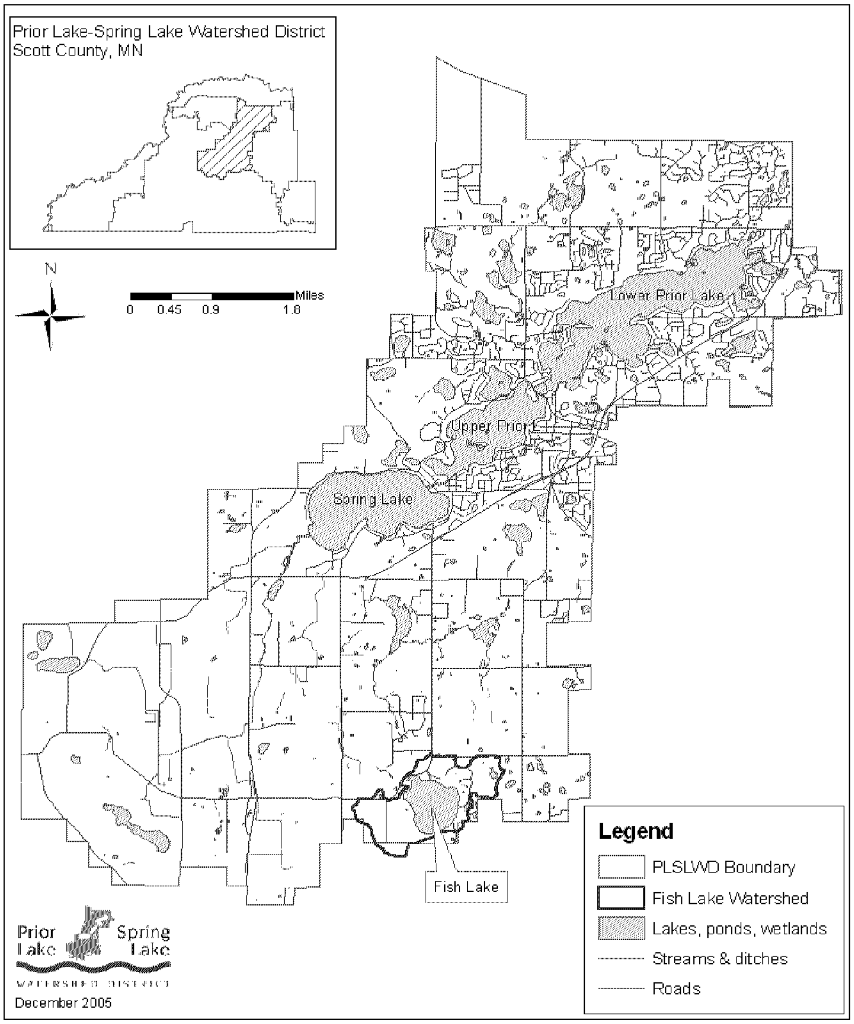
The final steps in this process involved sharing and discussing the final plan with various entities and community organizations interested and involved in the planning process.

ABOUT FISH LAKE

Physical Conditions

Fish Lake is located in Spring Lake Township in central Scott County, Minnesota (Figure 1).

Fish Lake Location



The lake has a surface area of 173 acres, a maximum depth of 28 feet and an average depth of 14 feet. According to the Minnesota Department of Natural Resources (DNR), 43 percent of the Fish Lake surface area is littoral area. The littoral area is the area of the lake that is less than 15 feet deep, which is the area where rooted aquatic plants may grow. Table 1 summarizes the physical characteristics of Fish Lake.

Table 1. Fish Lake physical characteristics.

Size (acres)	Average depth (feet)	Maximum depth (feet)	Littoral Area (acres)	Watershed size (acres)	Watershed:Lake Ratio (by area)
173.2	14	28	73 acres (43% of lake)	485.3 (excluding lake)	2.8

Watershed Setting
Fish Lake is situated within the North Central Hardwood Forest ecoregion (Figure 2), one of seven ecoregions in Minnesota. Ecoregions are areas of similar soil, land surface form, natural vegetation and current land use. Lakes within the same ecoregion often have similar characteristics, and it can be helpful to compare data for an individual lake to ecoregion averages.

Figure 2: Minnesota Ecoregions

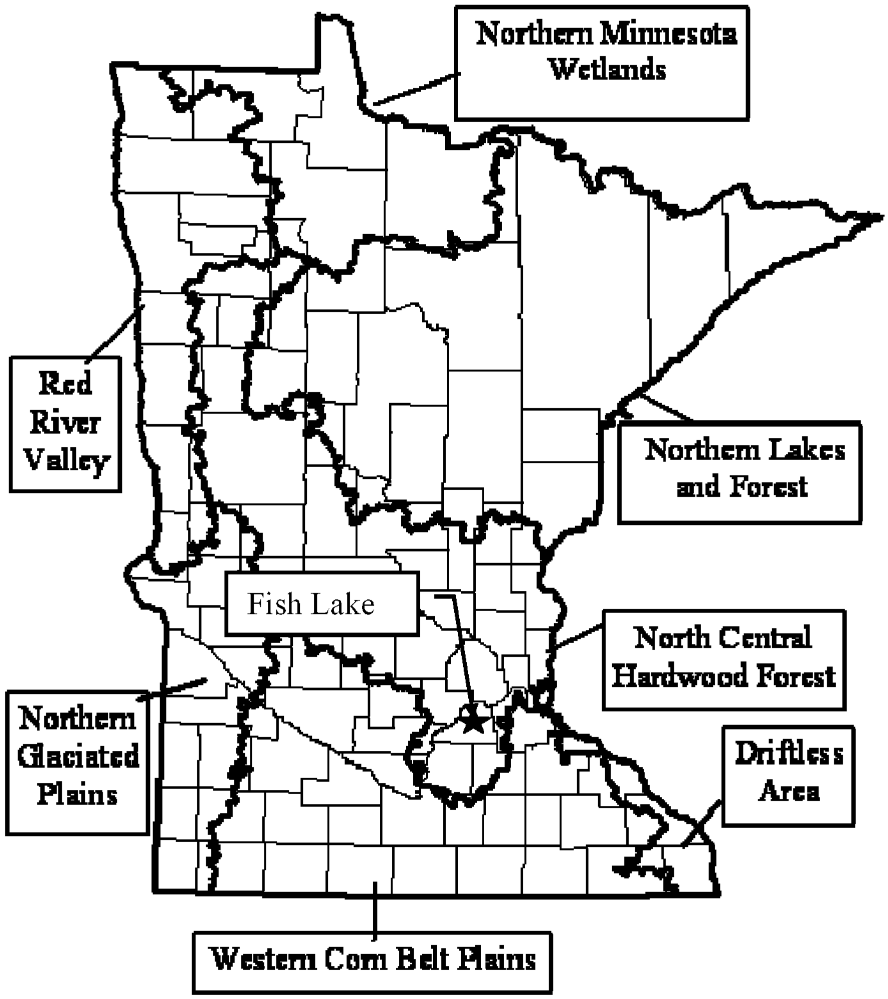
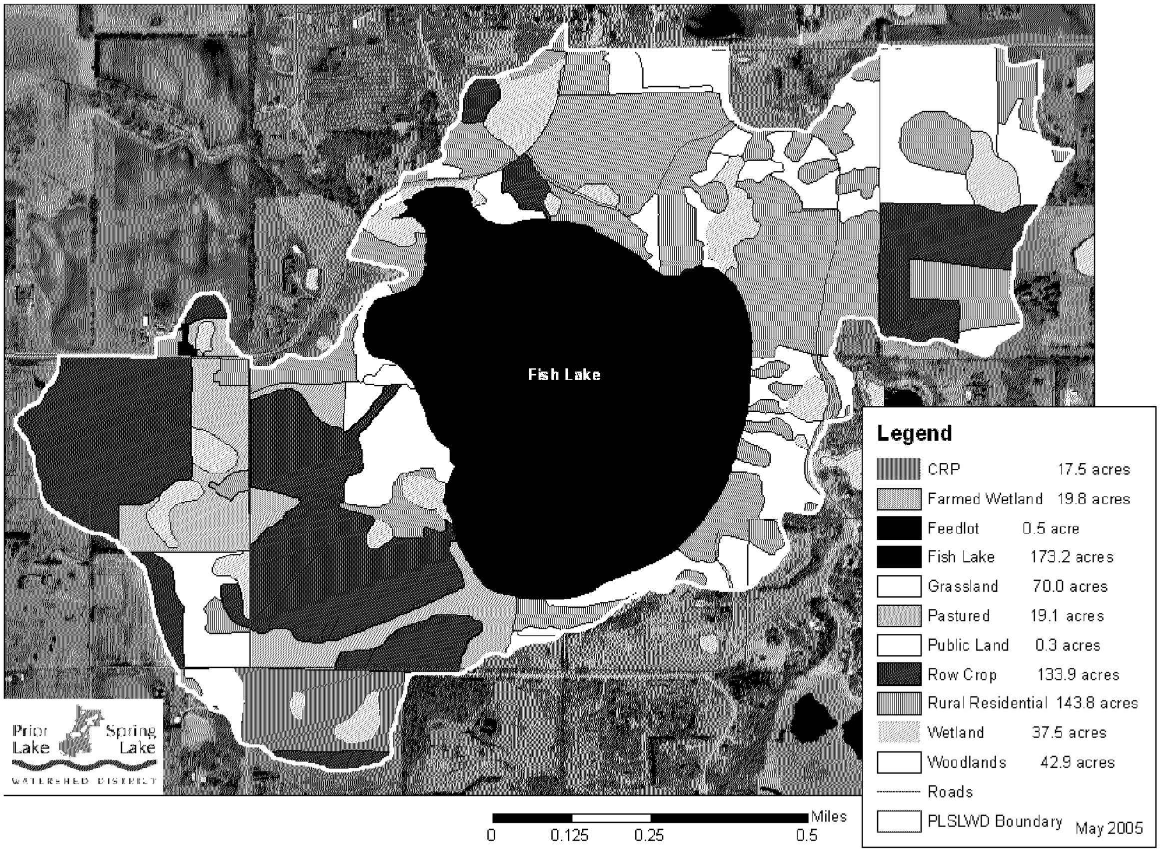
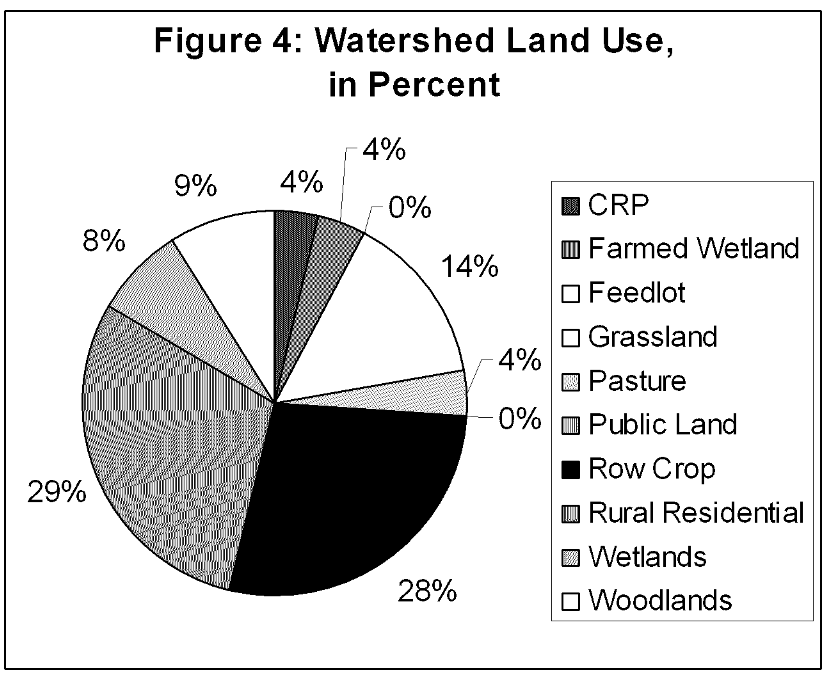


Figure 3 depicts the location and size of the Fish Lake watershed, and the watershed land use. Figure 4 summarizes the watershed land uses on a percentage basis. The most common land uses in the watershed are rural residential development (29.6 percent) and row crop agriculture (27.6 percent). Approximately 12 percent of the watershed area either is or has historically been wetland. Some wetlands have been drained or filled for agricultural and residential purposes. Much of the remaining wetlands are impacted by ditching and/or stormwater runoff.

Figure 3. Fish Lake Watershed Land Use

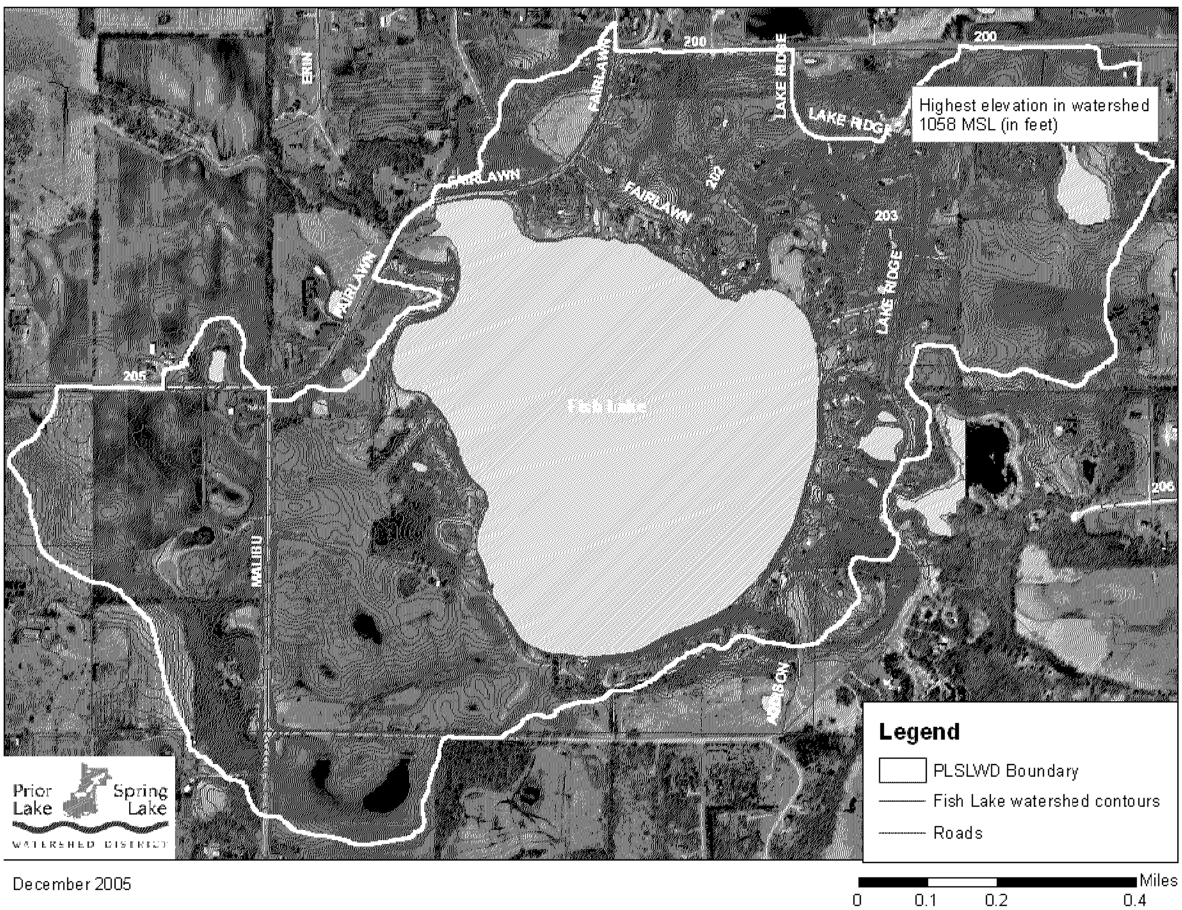




The Fish Lake shoreline itself exhibits a mix of land uses. About one-half to two-thirds of the lakeshore has been developed for residential housing. Most of the houses located along the northeast shoreline of the lake were built during the late 1940s to early 1960s on relatively small lots. Some of these houses were lakeshore cabins before they were converted to year-round residences, and at least one house still is used as a seasonal residence. About half of the residential areas in the watershed were built during the mid to late 1990's on larger lots, including those houses located on the east and southeast shoreline. The rest of the Fish Lake shoreline consists of a township park, DNR boat access, seasonal campground and agricultural land.

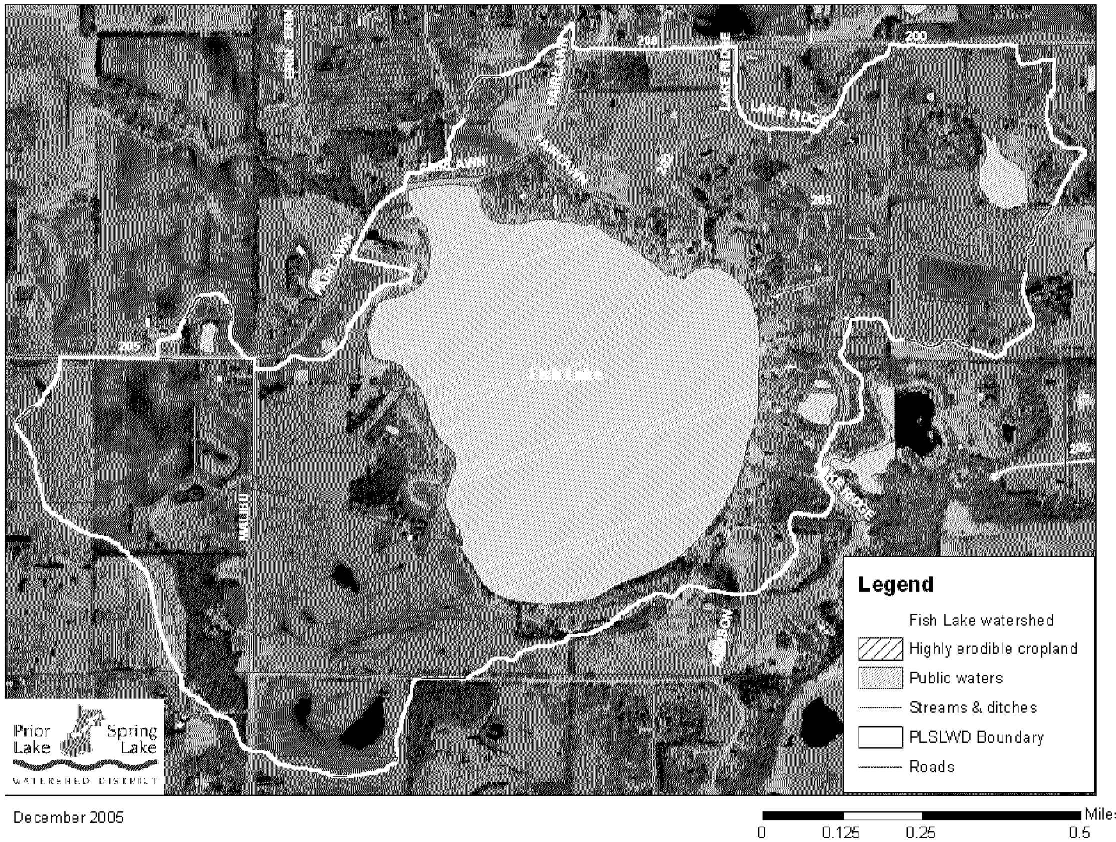
The topography of the Fish Lake watershed is rolling, with a significant amount of relief for such a small watershed. Watershed elevations range from 948 mean sea level (MSL, in feet) or less at the shoreline, to a height of 1058 MSL on the north/northeast edge of the watershed along Lake Ridge Drive (see Figure 5).

Figure 5. Fish Lake Topography



The soils found in the Fish lake watershed are primarily Lester or Hayden loams in hydrologic soil group B or B/D, and are generally rich in phosphorus and other nutrients. Several areas of cropland within the Fish Lake watershed have been classified by the Scott Soil and Water Conservation District (SWCD) as highly susceptible to erosion (Figure 6) based on an analysis of soil type and topography/slope. This does not mean that those areas are eroding, but that they have the potential for significant erosion if best management practices are not followed.

Figure 6. Highly Erodible Cropland



All of the residences within the watershed are served by individual sewage treatment systems (ISTS). The one exception is that eleven homes along the northeast shoreline of the lake are served by a small community treatment system. In 2002-2003, the community system was constructed to serve several homes that were in need of septic system upgrades or replacements but did not have enough space available on their lot to accommodate a new or upgraded system.

Although Scott County is one of the fastest growing counties in Minnesota, the Fish Lake watershed has experienced moderate growth and development in the last 20 years. About one-third to one-half of the shoreline and more than half of the total watershed land area remains undeveloped. The Fish Lake watershed is currently zoned for rural residential development (RR-1 or RR-2) in the Scott County Comprehensive Plan.

Lake Water Quality/Chemistry

Lake water quality is often described by "trophic" or nutrient status. Fish Lake is a nutrient rich lake. Like most lakes in this part of Minnesota, the growth of plants and algae in the lake are limited by the availability of phosphorus. Additions of phosphorus will enhance the growth of plants and algae, affecting the clarity of the water and the swimmability and aesthetics of the lake.

To track lake water quality, the PLSLWD has supported volunteer monitoring of Fish Lake through the Metropolitan Council's Citizen Assisted Monitoring Program (CAMP) since 1998. CAMP volunteers measure lake water clarity using a Secchi disk and collect water samples for laboratory analysis of nutrients (phosphorus and nitrogen) and chlorophyll-*a* (an indicator of how much algae are in the water). Volunteers also measure surface water temperature and rate the physical condition and recreational suitability of the lake during each visit.

In 2004 and 2005 the District also undertook a more detailed lake monitoring effort to further investigate the lake's water quality and identify the impact of internal phosphorus loading on the lake. Appendix B details the results of that monitoring effort.

Table 2 presents total phosphorus, chlorophyll-*a*, and Secchi disk transparency measurements for Fish Lake collected through the CAMP program and PLSLWD monitoring. The table compares this Fish Lake monitoring data to the typical range for all monitored and reference (i.e. un-impacted) lakes in the North Central Hardwood Forest (NCHF) ecoregion.

Table 2. Water quality data for Fish Lake as compared to assessed reference lakes in the North Central Hardwood Forest ecoregion (growing season data: May-September).

	Fish Lake			**MPCA Assessed Lakes[3] Interquartile Range (25-75th) and Median**	**MPCA Reference Lakes[3] Interquartile Range (25-75th) and Median**
Parameter	**2004[1]**	**2005[1]**	**5-Year Average[2]**		
Total Phosphorus (µg/L)	55	44	59	28 - 112 (51)	5 - 22
Chlorophyll-*a* (µg/L)	19	25	25	8 - 45 (21)	7 - 37
Secchi Depth (m)	1.6	1.2	1.8	1 - 2.6 (1.6)	1.5 - 3.2

[1] PLSLWD monitoring (sampling done by Three Rivers Park District for PLSLWD).
[2] 2001 through 2005 CAMP monitoring.
[3] All MPCA lake data is for the NCHF ecoregion. "Assessed lakes" are all NCHF lakes sampled by the MPCA; "reference lakes" are those NCHF lakes considered to be minimally impacted.

The monitoring data identify Fish Lake as a eutrophic (i.e. nutrient-rich) lake. Scientists use a tool called the Carlson Trophic State Index (TSI) to determine the trophic status of a lake. TSIs are calculated based on certain water quality indicators to determine where the lake fits on a nutrient enrichment continuum (see Table 3). The water quality indicators are total phosphorus concentration, chlorophyll-*a* concentration, and Secchi disk transparency. TSI values range from 0 (nutrient poor) to 100 (very nutrient rich). The average TSI for Fish Lake ranged from 56 to 64 during the years 2001 through 2005.

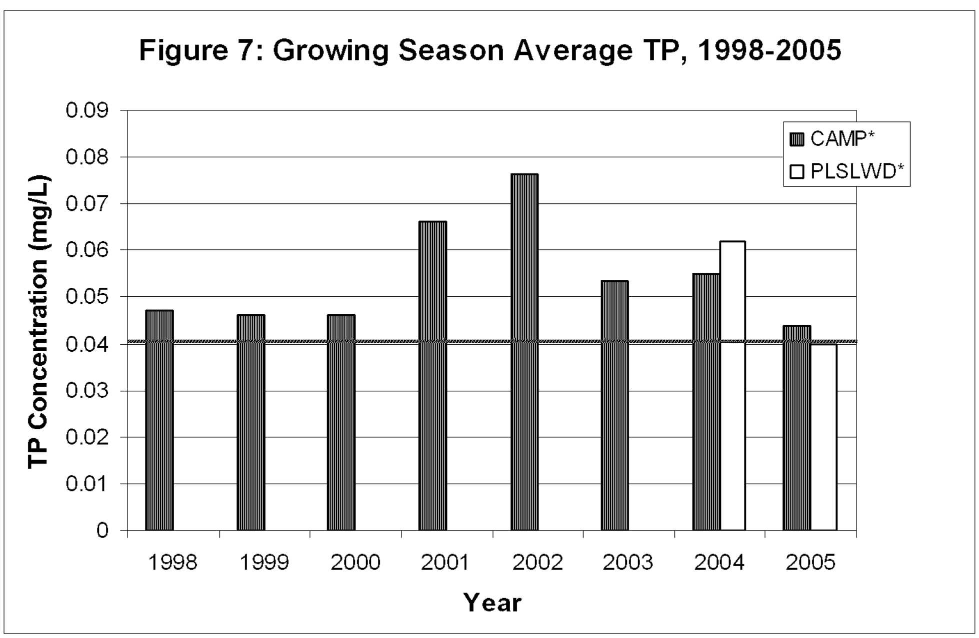
Table 3. Carlson's Trophic State Index (TSI) explanation. The observed TSI range for Fish Lake from 2001 through 2005 is highlighted.

TSI <30	Classic oligotrophy; clear water, oxygen through the year in the hypolimnion, salmonid fisheries in deep lakes.
TSI 30-40	Deeper lakes still exhibit classical oligotrophy, but some shallower lakes will become anoxic in the hypolimnion during the summer.
TS 40-50	Water moderately clear, but increasing probability of anoxia in hypolimnion during summer.
TS 50-60	Lower boundary of classical eutrophy: Decreased transparency, anoxic hypolimnion during the summer, macrophyte problems evident, warm-water fisheries only.
TSI 60-70	Dominance of blue-green algae, algal scums probable, extensive macrophyte problems.
TSI 70-80	Heavy algal blooms possible throughout the summer, dense macrophyte beds, but extent limited by light penetration. Often would be classified as hypereutrophic.
TSI > 80	Algal scums, summer fish kills, few macrophytes, dominance of rough fish.

Fish Lake (TSI 56 – 64)

Source: Minnesota Pollution Control Agency Lake data web site.

The nutrient-enrichment of Fish Lake affects the ability of lake users to enjoy the lake. In 2002, Fish Lake was included on the State of Minnesota's list of impaired waters due to excess nutrients. The Minnesota Pollution Control Agency (MPCA) has identified a phosphorus goal of 40 µg/L or less as the criterion for meeting aquatic recreation uses in the NCHF ecoregion; this corresponds to a TSI value of 57 or less. Figure 7 depicts the average growing season total phosphorus concentration for Fish Lake since 1998 compared to the ecoregion goal.



*CAMP = data collected through Met Council's Citizen Assisted Monitoring Program; PLSLWD = data collected by Three Rivers Park District staff for PLSLWD monitoring.

One important consideration in developing a management plan to protect and improve Fish Lake is the source of the excess phosphorus found in the lake. There are four general sources of phosphorus in lakes:

- Runoff from the watershed,
- Recycling from phosphorus-rich lake sediments,
- Groundwater inflow, and
- Atmospheric deposition (through precipitation or direct deposition).

For most lakes in this part of Minnesota, watershed runoff and internal recycling are the largest sources of phosphorus (i.e. phosphorus "loading") to the lake. This is also true for Fish Lake.

To get a sense for the relative importance of watershed runoff and internal loading as Fish Lake phosphorus sources, the monitoring data were analyzed for evidence of phosphorus loading and some simple models were used to estimate the external (i.e. watershed) and internal (i.e. sediment recycling) phosphorus loading to the lake.

In 2004 and 2005, samples were collected from the bottom waters of Fish Lake and analyzed for total phosphorus (TP) concentration. Appendix B presents the results of that monitoring effort. In both 2004 and 2005, phosphorus concentrations increased dramatically in the bottom water of the lake during the summer. This increased is one indicator of significant internal phosphorus loading in a lake.

Estimates were also made of the annual watershed and internal phosphorus loading to Fish Lake. A SWAT model was developed for the Fish Lake watershed by Dr. Amal Djerrari of Hydrogeological & Modeling Services, Inc. Because there was no inflow monitoring data available for the watershed, the model is based on assumed values of phosphorus runoff by land use (based on scientific literature values). Therefore, the model can only provide an approximate estimate of watershed loading. With that said, it can still be a useful tool for comparing internal and external phosphorus loads. The SWAT model results showed an estimated average annual watershed TP loading rate of 93 kilograms per year. Over an eight-year period, the modeled watershed loads ranged from approximately 45 kilograms to slightly over 200 kilograms (Appendix C).

Estimates were also made by Joe Bischoff of Wenck Associates, Inc. of the internal loading rate for Fish Lake. Using three different methods, the annual internal TP loading estimates ranged from 111 to 488 kilograms phosphorus (Appendix D). Although not all of the phosphorus released from the sediments are available for algal uptake during the growing season, approximately half was estimated to migrate across the thermocline from turbulent diffusion (Appendix D).

The Canfield Bachmann model was also used to develop an estimated total TP load to Fish Lake of 111 to 488 kg/yr (Appendix D). Using the midpoint of the internal and total loading ranges and assuming that half of the internal load is available for algal production resulted in an estimate that internal phosphorus load accounts for a median of 73% of the phosphorus load. It is likely that some external load is contributing to the phosphorus budget of Fish Lake; however, it is probably relatively small compared to the internal load in Fish Lake.

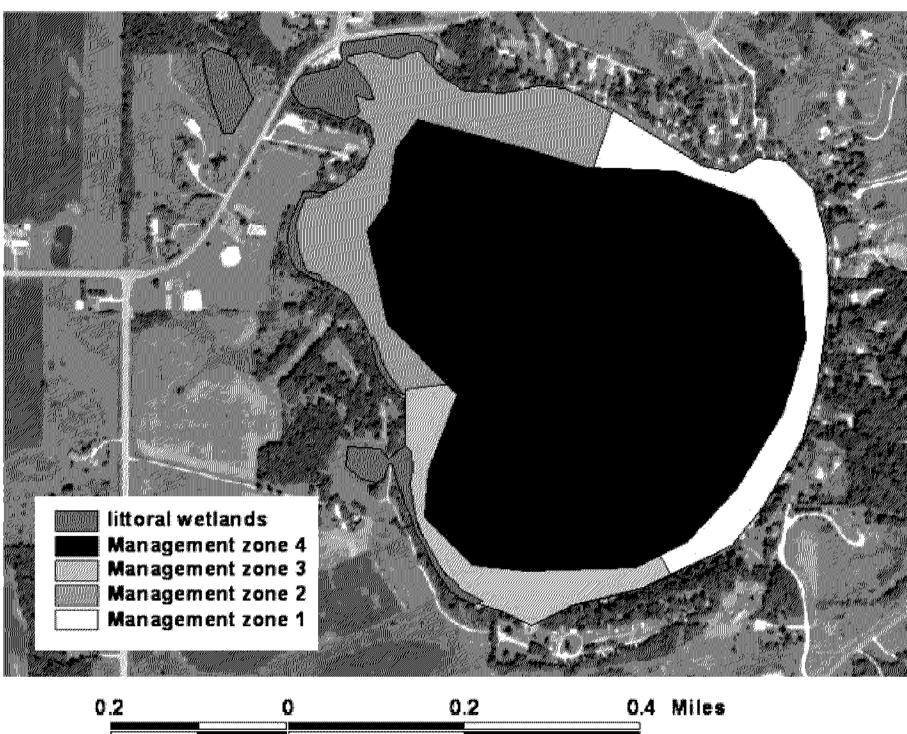
Lake Biology

Fish Lake is described by the Minnesota Department of Natural Resources (DNR) as a quality walleye fishery, particularly for a metro-region lake. Every other year the DNR stocks the lake with walleye fry and fingerlings. The lake does not appear to have an excessive carp population. This conclusion is supported by the diverse community of native plants found in the lake, and by the observations of the Fish Lake Sportsman's Club. The Sportsman's Club has attempted a carp seining operation in the past and has not found a significant carp population, nor have the club members observed carp spawning activity along the shoreline during the spring. In addition, the DNR installed a fish barrier downstream of the lake outlet to prevent upstream migration of carp.

Fish Lake also supports a relatively diverse community of rooted, floating and emergent plants. Plant surveys completed in 2003 and 2005 found as many as 13 species of emergent and rooted aquatic plants growing in the lake.

During the planning process, an Aquatic Vegetation Management Plan was developed for Fish Lake that included an assessment of the plant community, plant management goals, and recommended management actions designed to meet those goals. Figure 8 illustrates the plant management zones and management objectives identified for the lake. The aquatic vegetation management goals and management actions are incorporated into this overall Lake Management Plan. The entire Fish Lake Aquatic Vegetation Management Plan is available for review at the Watershed District office.

Figure 8: Fish Lake Aquatic Vegetation Management Zones (From *Fish Lake Aquatic Vegetation Management Plan, January 2005*)



Zone 1: Protect and restore native aquatic plants

Zone 2: Reduce growth of invasive curlyleaf pondweed, increase natives

Zone 3: Reduce curlyleaf, increase/maintain natives

Zone 4: Reduce algae blooms

Protect and restore littoral wetlands

About half of the Fish Lake shoreline has not yet been developed (on the west side of the lake in management zones 2 and 3). This shoreline will likely be developed as residential home sites some time in the future. The establishment of the above vegetation management zones is not intended to prohibit development from occurring along that shoreline in accordance with state and local ordinances and rules. Rather, the aquatic vegetation management zones are meant as a tool to educate current and future lakeshore owners about the importance of protecting and restoring native plants, and to encourage the use of best management practices in shoreland management.

State laws address the protection and removal of native aquatic plants in Minnesota. Under Minnesota law aquatic plants growing in public waters are the property of the state. The Department of Natural Resources oversees an Aquatic Plant Management Program that protects native vegetation and the aquatic environment from unnecessary harm while allowing lakeshore homeowners to control some aquatic vegetation for water access.

GOALS

An important purpose of this planning process was the development of strategies, goals and objectives for Fish Lake. The first step in this goal-setting process involved discussing the current status of the lake and developing preliminary goals. At a Visioning Workshop in 2002 and the start of the planning process in 2004, participants shared their view of the lake's current condition. The individual comments on the lake conditions were summarized as follows:

- Fish Lake is a small headwaters lake that is sensitive to water quality impacts. While the lake's watershed is less developed than some other lakes in the area, the land use is changing and the lake is in need of protection and restoration to reduce summer algae blooms and address excessive growth of invasive aquatic plants. These issues can be addressed by increased awareness, attention, funding, and citizen involvement.

The group developed the following short- and long-term goals for the lake at that time:

- Short-term:
    - Educate regarding headwater lake and its value
    - Establish clearly understood, measurable goals for the lake
    - Identify specific funding options
    - Address planning
    - Fill data gaps
    - Identify potential sources of excess nutrients
    - Investigate lake level/outlet concerns
- Long-term:
    - Improve water quality by reducing nutrient inputs
    - Maintain and restore natural shoreline as much as possible
    - County park
    - Preserve natural environment
    - Development conducted in a manner that protects lake
    - Lake association or similar information/education/management group

Water Quality, Plant Management and Education Strategies and Goals

After sharing perceptions of the current conditions of the lake and their vision for the future, the participants in the planning process then learned about the current status of the lakes through the workshops described previously under the planning process. Additional data was collected during 2004 and 2005 to fill in some of the data gaps, and that information was summarized and discussed with the planning process participants. The participants also developed an Aquatic Vegetation Management Plan for Fish Lake. This led to the development of the goals presented in Table 2.

Table 4. Fish Lake Management Goals.

Category	Goal
Education and Awareness	• Increase community understanding of lake quality issues and lake management efforts. • Inform community about the dangers posed by exotic species, and how to prevent the introduction of exotic species in area lakes and streams. • Improve resident's knowledge of and use of shoreline and lawn maintenance best management practices (BMPs). • Increase use of BMPs for low-impact development and storm water management before, during and after construction • Promote environmentally sustainable land management and development.
Water Quality	Reduce the number of days that the physical condition is "definite algae present" and increase the frequency of "some algae present" conditions. Improve the recreational suitability to a "beautiful" or "minor aesthetic problem" rating for most of the summer.
	• Achieve average growing season transparency of 1.2 meters or greater (3.9 feet).
	• Reduce average growing season phosphorous concentration to 40 µg/L or less.
	• Reduce watershed phosphorus loading (from current annual average estimate of 94 kg per year).
	• Control internal recycling of phosphorous (currently estimated at 111 to 488 kg per year, or approximately 70% of annual TP load).
Aquatic Plant Management	Reduce severe nuisance growth of curlyleaf pondweed and preserve native aquatic plant growth.
	• Reduce nuisance curlyleaf pondweed coverage to <4 acres (from 16).
	• Increase native plant diversity in spring/early summer by 50%, from 6 species to a minimum of 9 species.
	• Maintain late-summer native plant species diversity at 10 species or more.
	• Increase late summer native aquatic plant coverage to 32% of the lake area.
	• Increase stands of bulrush and other desirable emergent vegetation and maintain current stands of floating-leaf vegetation.
	• Reduce frequency of nuisance algae blooms in summer
Fisheries	Maintain game fish populations and habitat (walleye, pike, bass), and watch for and (as necessary) try to reduce any impacts from carp.
	• Encourage/request an updated fisheries survey by the Department of Natural Resources.

ACTION PLAN

Following the establishment of general and specific goals for the lakes, the discussions turned to how to reach those goals. A number of alternatives were discussed. Particular emphasis was given to options for controlling internal phosphorus cycling (i.e. reducing phosphorus inputs from the lake sediments), as this is likely a significant source of the phosphorus in Fish Lake. The need for additional lake and watershed monitoring to pinpoint phosphorus sources and further investigate internal loading control options was also discussed. Actions to reduce phosphorus and sediment loading from the watershed were also identified and evaluated.

For each of the management goal areas (water quality, aquatic plant management, fisheries and education/information), specific implementation actions were identified and evaluated based on their feasibility and effectiveness in achieving the management lake goals. Numerous activities were considered, ranging from carp removal, to alum treatment, to continued education efforts.

Some potential actions have greater uncertainty associated with them, and others are undesirable due to cost, potential adverse impacts, or stakeholder/citizen concerns. Still others, such as "nondegradation and sustainable development," are concepts and approaches that should be incorporated into all of the actions that move forward. The most feasible options – those with the greatest likelihood of implementation and the greatest expected progress towards the sustainable lake goals – were identified in Table 5 below as management actions for Fish Lake. Although some of the actions overlap somewhat, since they are important BMPs they were included as separate items. It is also important to note that many of these ideas will require additional discussion and exploration prior to implementation.

The information in Table 5 focuses primarily on the roles and responsibilities of local government, volunteer groups and individuals. It is important to note that there are also many resources available from non-local sources, particularly state and federal agencies. These include the Department of Natural Resources, Pollution Control Agency, Board of Water and Soil Resources, Metropolitan Council, and federal Environmental Protection Agency. Local governments, volunteer organizations and citizens in the watershed rely on these federal and (especially) state sources for technical assistance, educational materials, and financial support. The following abbreviations are used in Table 5:

Organization/Term	Abbreviation
Fish Lake watershed residents	FL
Prior Lake-Spring Lake Watershed District	WD
Spring Lake Township	SLT
Scott Soil & Water Conservation District	SWCD
Scott County	County
Minnesota Department of Natural Resources	DNR
Minnesota Pollution Control Agency	PCA
Metropolitan Council	Met. Council
Citizen Assisted Monitoring Program	CAMP
Water Quality	WQ
Phosphorus	P

Table 5. Implementation Actions.

Action	Description	Outcome	Cost	Time-frame	Lead Entity	Notes
Education/Behavior—Change behaviors to reduce nutrient loading and help achieve water quality goals						
Homeowner, landowner and lake user Best Management Practices (BMPs)	Encourage homeowners and watershed landowners to adopt practices that protect WQ.	Increased use of P-free fertilizer, increased buffers and other lakeshore and watershed BMPs, increased awareness of impacts on lake WQ, reduced P loading.	Incorporated in other actions.	Ongoing	WD, SWCD, County, SLT, residents	*Prior Lake American, Scott County Scene*, community meetings are all avenues for conveying message.
Increase visibility of water quality protection efforts	Include information on web sites, City Council open forum, newsletters, etc.	Increased awareness of lake water quality issues and efforts to improve water quality.	Staff time, cost of web programming	Ongoing	All	
Student projects and community meetings	Share WQ messages & BMPs by supporting student projects and attending community meetings.	Increased awareness of lake WQ issues, changes in behavior to reduce runoff of sediment & nutrients to lake.	Staff time, costs for displays or brochures	Ongoing	All	
Communicate successes	Share success stories in protecting and improving water quality.	Increased awareness; greater enthusiasm and support for projects.	Staff time	Ongoing	All	Should become a component of all the management actions.
Monitoring/Information-gathering – Direct management actions and measure progress towards goals						
Volunteer lake level monitoring	Citizens measure lake levels weekly after ice-out.	Better information on lake level fluctuations.	Minimal	Ongoing since '05	DNR, Volunteers	This data will help with lake outlet evaluation
Volunteer lake water quality monitoring	Citizens provide water quality (WQ) information through CAMP.	Better understanding of lake quality, more involved and informed citizens.	CAMPs: $550/ lake	Annual	WD, Volunteers	
Detailed water quality monitoring	Detailed monitoring of surface and bottom conditions of lake.	Info. needed to track overall WQ and internal loading.	$1,500-$2,000/ year + staff time	Every 3rd yr?	WD	May not need every year.
Watershed inflow/ outflow monitoring	Measure inflow and outflow of water, phosphorus, sediment.	Develop/refine water and P budgets and track changes in watershed loading.	~$1,000/ station + staff time & equip.	As needed	WD	Would help verify model estimates and focus actions.
Aquatic plant monitoring	Survey of composition of plant community and species abundance.	Info. needed to manage aquatic plants, evaluate control measures, plan for future.	$1,500 per survey (2/yr)	Annual when treating	WD	
Total Maximum Daily Load Study	Complete TMDL study and implementation plan.	Established load reduction goals; long-term: removal of lake from impaired waters list.	Approx. $25,000	2008	WD	Included in WD Capital Improvement Plan for 2008.

Action	Description	Outcome	Cost	Time-frame	Lead Entity	Notes
Aquatic Plant Management – Manage invasive species and protect and restore native plants to achieve water quality goals						
Curlyleaf treatment with endothall	Targeted, early-season treatment of nuisance curlyleaf growth.	Annual control. If done in successive years, can reduce re-growth.	$10,000 (open water), + staff time	3-5 yrs of annual treatmt.	WD, FL residents	Effectiveness studies are ongoing; results to date are encouraging.
Shoreland restoration	Restore upland and in-lake native plants along residential shoreline.	Improved coverage of native aquatic plants, erosion protection, reduced P loading.	Varies depending on project.	Ongoing	Residents, WD, SWCD	
Carp management	Monitor effects of carp and consider carp exclusion or removal efforts if problems develop.	Increased native plant growth and reduced phosphorus loading due to carp.	?	?	DNR, WD	Current indication is carp are not significantly harming native plants.
In-Lake Phosphorus (P) Controls – Reduce phosphorus loading to achieve water quality goals						
Evaluate options	Evaluate options and costs for sediment P inactivation.	Plan and budget for reducing sediment recycling in lake.	$5,000-$10,000	2007 or 2008	WD; need funding	
Alum treatment or other P inactivation effort.	Add aluminum sulfate to bind P in lake sediments, or use other method to keep P in sediment.	Decreased sediment P loading, decreased algae growth, increased clarity (note: clarity may stimulate aquatic plants).	$?? Need to determine dosing first	After 2008	WD; need funding	Nuisance curlyleaf growth may reduce long-term alum effectiveness.
Watershed Management – Reduce phosphorus loading from watershed to achieve water quality goals						
Wetland restoration	Restoration of drained or impacted wetlands to increase storage and WQ treatment.	Decrease in water, P and sediment loading to lakes.	Varies based on land & construction costs	Ongoing	WD, SWCD, land-owners	Currently supported by PLSLWD and Scott SWCD with ongoing funding.
Filter strip installation	Planting native grasses along waterways to provide a buffer.	Decreased transport of P and sediment from fields to ditches/ streams and lakes; increased water storage.	$200/acre/yr. incentive	Ongoing	WD, SWCD, ag. operators	Currently supported by PLSLWD and Scott SWCD with ongoing funding.
Reduce sheet and rill erosion on agricultural land	Install agronomic and structural best management practices on cropland acres.	Reduce sediment and nutrients leaving cropland and entering receiving waters.	$10,000/yr to add to state and federal cost-share	Ongoing	WD, SWCD NRCS, Met. Council, landowners	Funding to provide further incentive for existing cost-share efforts.
Shoreline restoration and erosion control	Return of native plants to shoreline areas.	Decreased erosion; less impact to lake from lawns, stormwater runoff.	Variable depending on project	Ongoing	WD, DNR, SWCD, landowners	PLSLWD has cost-share funding; includes some landowner cost-share.
Rain gardens, buffers	Incorporate rain gardens and buffer areas into existing homes, new and re-development.	Increased infiltration; decreased runoff of water, sediment and nutrients; increased wildlife habitat	Depends on scale, purpose, etc.	Ongoing	WD, SWCD, land-owners	PLSLWD has cost-share funding. Opportunity to enhance existing neighborhoods.

Action	Description	Outcome	Cost	Time-frame	Lead Entity	Notes
Homeowner & business runoff management	Various efforts to increase awareness and foster BMP adoption by homeowners and businesses.	Increased awareness; changes in behavior; decreased runoff, TP and sediment loading from homes & businesses	Variable depending on project	Ongoing	Land-owners, WD	PLSLWD has cost-share. This action overlaps with several others.
Rules for new development	Implement PLSLWD and Scott County rules that require WQ treatment, rate and volume control on new and re-development.	Runoff maintained at pre-development rates, volume increases mitigated somewhat, sediment runoff and associated P captured/minimized.	Staff and outreach costs to City/County	Ongoing	WD, County	Most costs of treatment/ meeting the rules and ordinances are borne by developers.
Retrofit ponds and sediment traps (catch basins)	Retrofit existing neighbor-hoods to include WQ ponds, or sediment traps catch basins.	Decreased nutrient and sediment loading to the lakes.	Variable	Ongoing	SLT, County	An assessment of current stormwater ponds is necessary as a first step.
Soil management on new lots	Education to reduce soil compaction during construction and to raise awareness of soil mgmt. options & benefits.	Increased infiltration and turf establishment on new lots due to less compaction. Decreased erosion and fertilizer runoff.	Variable depending on effort	Getting started with develop-ers	WD, County, SWCD, SLT, residents	Costs would depend on "delivery" option for information (Workshops? Web info.? Rules?)
Manure management on hobby farms	Education of hobby farm owners on options for manure management and disposal.	Decreased nutrients and bacteria in runoff, better awareness of WQ concerns associated with manure mgmt.	~$500-$1,000 to develop (plus staff time)	?	SWCD, WD, SLT	
Non-degradation and sustainable development; Low-Impact & Open Space Development	Encourage land mgmt. (including development, shoreline mgmt., agriculture) that maintain or improve WQ and preserve resources for the future.	Increased infiltration and storage; decreased runoff of water, sediment & nutrients; greater understanding of connections between WQ, recreation, quality of life.	Variable	Ongoing	WD, County, SLT, residents	Should be included in some way in all the implementation actions.

It is important to note that each of the actions identified above will require additional discussion and refinement, and the development of a detailed plan for implementation. To ensure that the details around each action item are explored and developed, an Implementation Team made up of volunteers from the original planning group will meet at least annually to develop a work plan for the upcoming year (see "Implementation Process" below). This will help ensure the ongoing implementation of this plan, and, therefore, the ultimate success of these efforts.

IMPLEMENTATION SCHEDULE

The actions listed in Table 5 present a detailed approach for moving forward to improve and protect the water quality of Fish Lake. However, not all of the actions can be accomplished at once. As discussed earlier, some will need to be sequenced to enhance the potential for success, while the timing for others will reflect budgeting and staff time needs and constraints. Table 6 presents a five-year schedule for implementing each of the action items.

It is difficult to predict the expected response of the lake over the five-year implementation timeline. A successful alum treatment on Fish Lake will result in a dramatic, and immediate, improvement in water quality, but it is hard to know how long the improvement will last. Controlling Curlyleaf Pondweed will help ensure the long-term effectiveness of an alum treatment; that is why it is important to address this problem before an alum treatment. The completion of studies currently in progress on other metro-area lakes will also provide more information to help predict future responses in Fish Lake. It will also be important to continually evaluate the effects of various implementation actions on Fish Lake, and to continually refine the management plan to reflect the current status of the lake and the knowledge we gain as the plan is implemented.

Annual Reporting

It is important that this Lake Management Plan be a “living” plan that can be refined and updated as we learn more about the responses of Fish Lake to management actions, and as new tools and new information about existing management tools becomes available. To ensure that implementation of the Plan is continuing and that progress is being made towards the sustainable lake goals, an annual update will be completed each year that includes the following:

1. A discussion of the actions initiated and completed during the past year, including what worked well and what didn’t work as well.
2. Analysis of progress made towards the sustainable lake goals.
3. A discussion of any changes needed to the plan to ensure continued implementation and success.
4. A description of the actions planned for the next year, including lead organizations/ individuals, funding source(s), and a more detailed timeline (i.e. an annual work plan).

Note that as indicated in the previous section, for each action item a number of steps will be needed for implementation. This will require the ongoing involvement of the various individuals and groups that participated in developing this Lake Management Plan.

Future Revisions to the Sustainable Lakes Management Plan

It is important that this Sustainable Water Quality Management Plan be a “living” plan that can be refined and updated as we learn more about the responses of Fish Lake to management actions, and as new tools and new information about existing management tools becomes available. At a minimum, the Plan will be re-visited and updated every five years.

Table 6: General Implementation Schedule (details to be added through annual work planning).

Year	2006				2007				2008				2009				2010			
Quarter	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Education/Behavior																				
Homeowner/Landowner BMPs	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Increase visibility of water quality protection issues	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Student projects, commun. mtgs.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Communicate successes	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Monitoring/Information-gathering																				
Volunteer lake level monitoring		—	—			—	—			—	—			—	—			—	—	
Volunteer lake WQ monitoring		—	—			—	—			—	—			—	—			—	—	
Detailed water quality monitoring	—	—	—	—					—	—	—	—					—	—	—	—
Watershed inflow/outflow monit.					—	—	—	—	—	—	—	—								
Aquatic plant monitoring		▲	▲			▲	▲			▲	▲			▲	▲					
Total Maximum Daily Load Study									—	—	—	—	—	—						
Aquatic Plant/Invasive Species Management																				
Chemical treatment of curlyleaf		—				—				—				—	-?					
Shoreland Restoration	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Carp Monitoring/Management	-- As Needed --																			
In-Lake Phosphorus Controls																				
Evaluate options					—	—	—	—	—	—	—	—								
Alum treatment or other P control																▲ -?				

Year	2006				2007				2008				2009				2010			
Quarter	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Watershed Management																				
Wetland restoration																				
Filter strip installation																				
Reduce sheet and rill erosion																				
Shoreline restoration and erosion control																				
Rain gardens, buffers																				
Homeowner & business runoff management																				
Rules for new development																				
Retrofit ponds and sediment traps																				
Soil management on new lots	-- As residential development occurs --																			
Manure mgmt. on hobby farms						Develop			Implement											
Non-degradation and sustainable development	-- Ongoing, as development occurs --																			
Annual Reporting & Planning				▲				▲				▲				▲				▲

Appendix A

Letters/Resolutions of Support/Commitment

Resolution 06-204

A Resolution Adopting A Sustainable Lake Management Plan For Fish Lake

WHEREAS, The Prior Lake-Spring Lake Watershed District (PLSLWD) is established and authorized under Minnesota Statute 103D; and

WHEREAS, the mission of the PLSLWD is to manage and preserve the water resources within the watershed district; and

WHEREAS, the PLSLWD has an approved management plan under Minnesota Statute 103B.231 that includes a policy developing water quality improvement plans for priority water bodies with public access, such as Spring and Prior Lakes; and

WHEREAS, the PLSLWD led the development of a Sustainable Lake Management Plan for Fish Lake that involved more than 30 members of the community representing lakeshore owners, lake associations, local government, regional and state agencies, and watershed residents; and

WHEREAS, the purpose was to engage stakeholders to develop a plan that summarizes the watershed, water quality and aquatic plant data available for Fish Lake; establishes lake management goals, and identifies a management plan to help achieve those goals, improve water quality and protect the lake's many recreational uses.

NOW, THEREFORE, BE IT RESOLVED that the Prior Lake-Spring Lake Watershed District does hereby adopt the Sustainable Lake Management Plan for Fish Lake, dated April 2006.

Adopted this 11th day of April 2006, upon motion by WILLIAM KALLBERG and second by LARRY MUELLER by the following vote:

Craig Gontarek CEG
William Kallberg
Larry Mueller

William Schmokel
Roger Wahl

President

Attest to:

I, Craig Gontarek, Secretary of the Prior Lake-Spring Lake Watershed District , do hereby certify that the above resolution 06-204 was duly passed by the Board of Managers at a duly called meeting on the 11th day of April, 2004.

Craig Gontarek, Secretary

RESOLUTION #06-018

Spring Lake Township, Scott County, Minnesota

A RESOLUTION ADOPTING THE SUSTAINABLE LAKES MANAGEMENT PLAN FOR FISH LAKE AS PREPARED BY THE PRIOR LAKE SPRING LAKE WATERSHED DISTRICT

WHEREAS, the Spring Lake Township Board recognizes the importance of managing the water quality of Fish Lake; and

WHEREAS, the Spring Lake Township Board participated in the development of the Sustainable Lakes Management Plan for Fish Lake; and

WHEREAS, the purpose was to develop a plan that 1) sets common goals and objectives, 2) blends the skills of all the groups involved in lake management, 3) identifies roles and responsibilities, and 4) develops support networks and integrates the various types of community resources.

NOW, THEREFORE, BE IT RESOLVED, that the Town Board of Spring Lake Township, Scott County, Minnesota does hereby adopt the Sustainable Lakes Management Plan for Fish Lake dated April, 2006.

		Yes	No	Other
Chairman	Eugene Berens	X		
Supervisor	John Henschel	X		
Supervisor	Michael Borka	X		

Adopted by Spring Lake Township this 13 day of July, 2006.

Eugene Berens
Eugene Berens, Town Chair

Kathy Nielsen
Kathy Nielsen, Town Clerk

Appendix B
Water Quality Monitoring and Modeling Report

Report on 2004 – 2005 Lake Monitoring and Modeling

of

Fish Lake Scott County, Minnesota

March 2005

Prior Lake Spring Lake WATERSHED DISTRICT

Introduction

Fish Lake is a relatively small lake located in the central part of Scott County, Minnesota. The Prior Lake-Spring Lake Watershed District (PLSLWD or District) has been supporting volunteer monitoring of Fish Lake through the Metropolitan Council's Citizen Assisted Monitoring Program (CAMPs) since 1998. In 2004, the District undertook a more detailed lake monitoring effort to further investigate the lake's water quality and identify the role of internal phosphorus loading on the quality of Fish Lake. This monitoring effort was intended to help inform the development of a Lake Management Plan for protecting and improving Fish Lake.

Methods

In 2004 and 2005, the PLSLWD contracted with the Three Rivers Park District to monitor Fish Lake from spring through fall of each year. The District also continued to support CAMPs monitoring of the lake, and also collected a few grab samples from inflows to the lake in an attempt to get a sense for potential watershed "hotspots."

Every two weeks beginning in April of each year, Three Rivers Park District staff sampled the lake. During each sampling trip temperature, dissolved oxygen, conductivity and pH profile data were collected and a secchi disk transparency measurement was recorded. Grab samples were taken at the lake surface, thermocline, and just above the lake bottom and the samples were transported on ice to the Three Rivers Park District laboratory for analysis of total phosphorus, soluble reactive phosphorus, total nitrogen (surface grab only), and chlorophyll-a (surface grab only). Standard sampling and laboratory protocols and quality assurance/quality control (QA/QC) measures were followed. Details about the protocols and QA/QC measures are available from the PLSLWD.

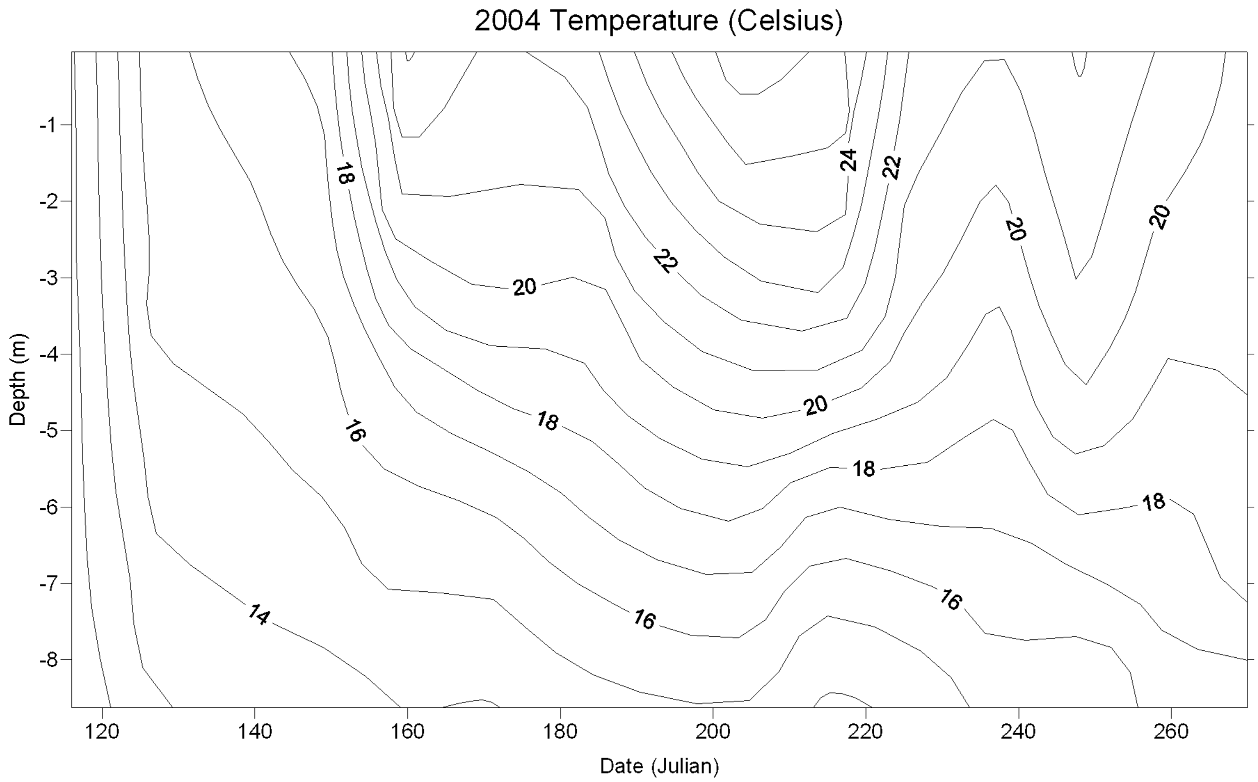
Monitoring Results

Precipitation

In 2004, precipitation within the PLSLWD was nearly 5 inches greater than the long-term average for Scott County. This was driven by large amounts of rainfall in May and September, compared to the long-term average. In 2005, precipitation totaled 32 inches, 4 inches above normal. The majority of rainfall occurred in June and September, with September totals almost 4 times the annual average.

Physical Characteristics

Figure 1 shows the temperature and dissolved oxygen (DO) patterns in the lake in 2004, and Figure 2 shows the same information for 2005. In both years the lake stratified thermally during the summer months, and also showed strong DO stratification. It appears that the lake is dimictic, with a spring and fall overturn. The monitoring program captured the spring overturn in 2004 and the start of fall overturn, and the start of the fall overturn in 2005. Also note that in both years the lake bottom was anoxic (i.e. oxygen concentration less than 2 mg/L) for much of the growing season.



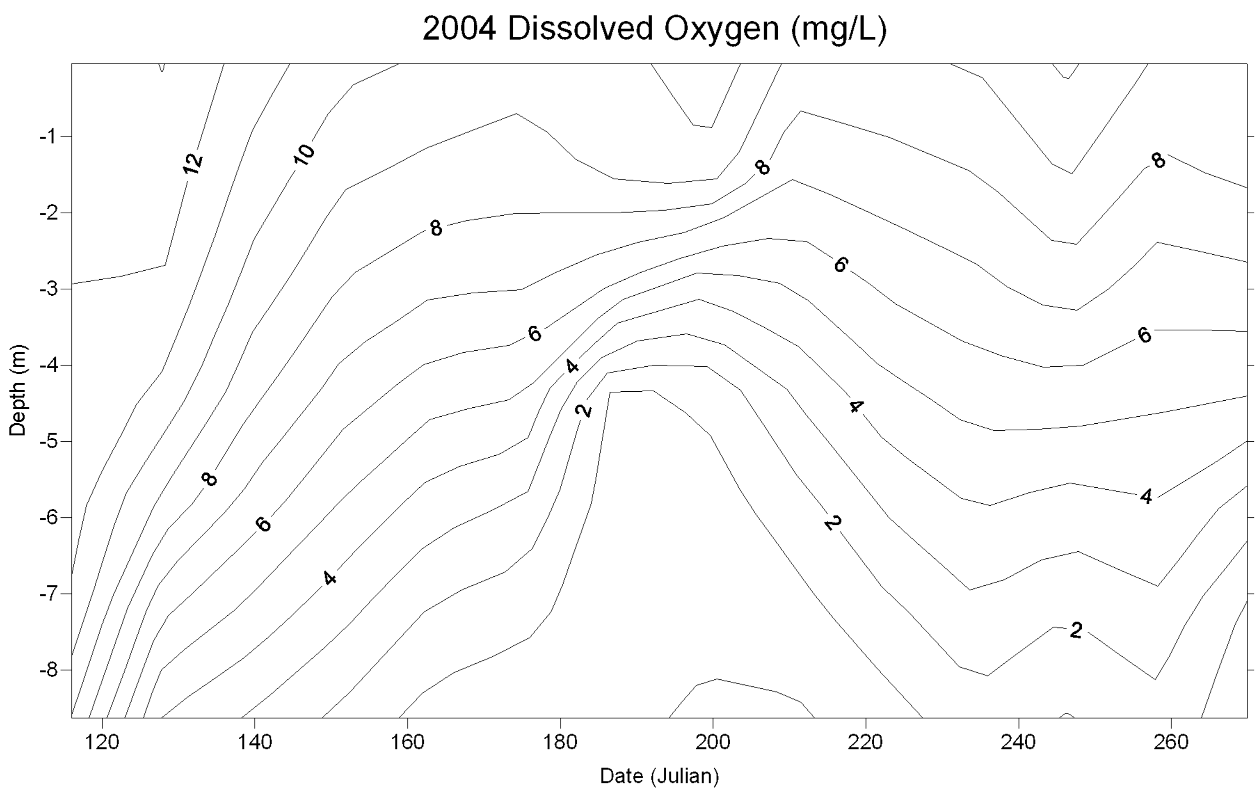


Figure 1. Isoplots for dissolved oxygen and temperature in Fish Lake for 2004.

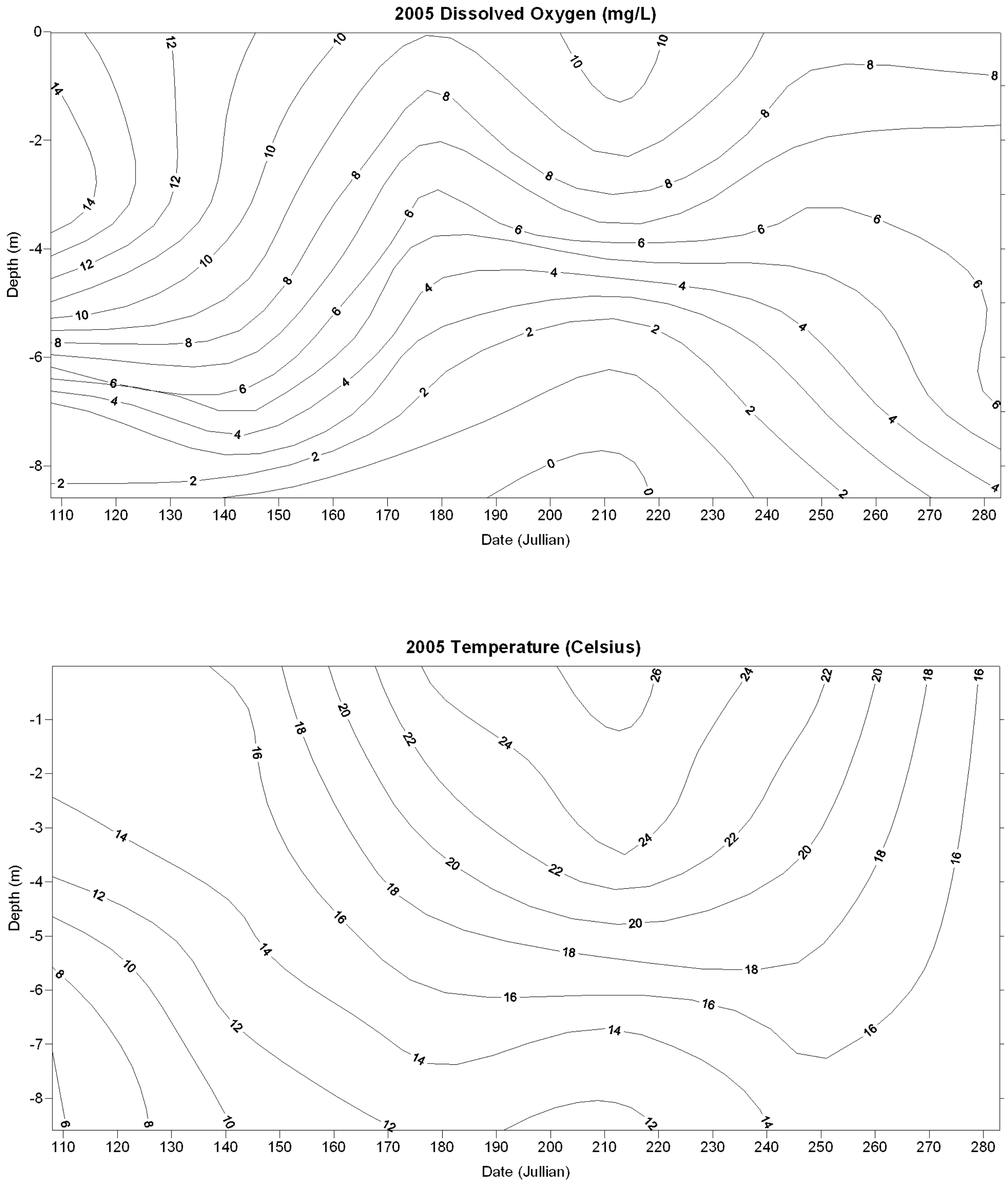


Figure 2. Isoplots for dissolved oxygen and temperature in Fish Lake for 2005.

Water Quality

Total Phosphorus: Phosphorus is an important nutrient for plant growth in Minnesota lakes. In 2004, total phosphorus (TP) concentrations at the lake surface ranged from 44.6 to 92.2 µg/L (ppb). The 2004 growing season average TP was 63.8 µg/L. In 2005 TP concentrations ranged from 31.4 µg/L to 133.9, with a growing season average of 43.8 µg/L. In general, TP concentrations were lower in 2005 than in 2004 (Figure 3).

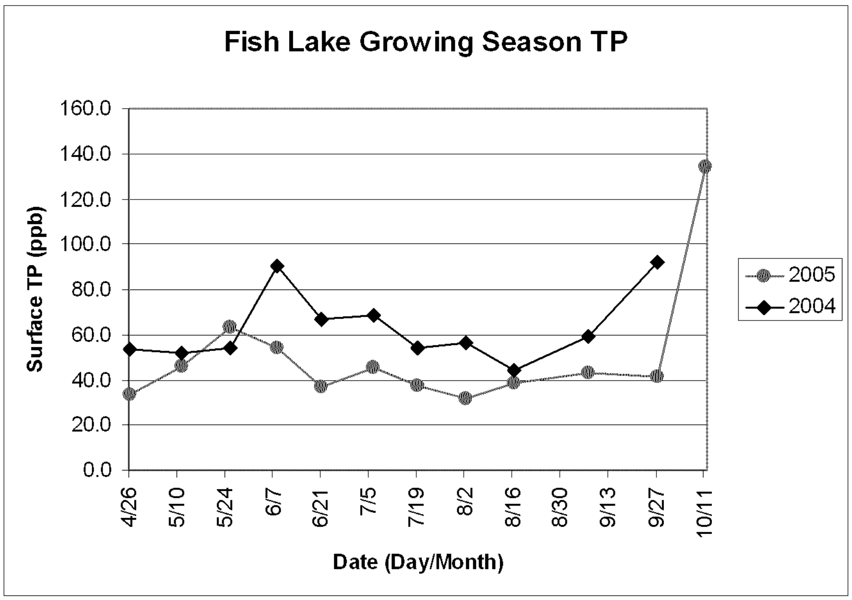


Figure 3. Fish Lake surface (epilimnion) total phosphorus concentrations, 2004 and 2005.

In both 2004 and 2005, TP concentrations near the bottom of the lake were generally much greater than the surface water concentrations (Figures 4 and 5). The increase in phosphorus concentration from surface to bottom waters is due to the release of phosphorus from the lake sediments under low DO conditions (less than 2 mg/L). The phosphorus concentration remains high in the bottom waters until the lake mixes, when the phosphorus is then distributed throughout the lake and available for plant and algae growth. This "phosphorus recycling" can be a significant source of phosphorus loading to lakes.

In Fish Lake, a "pulse" of phosphorus upon lake mixing is visible in the fall sampling data from both 2004 and 2005. Although plant and algae growth declines significantly in the fall and winter due to cooler cold water temperatures and reduced light availability, some of the phosphorus remains in the water column to fuel plant and algae growth in the spring. During the summer, some of the phosphorus released from the sediments can also diffuse across the lake thermocline (the zone of greatest temperature change) and become available for plant growth.

Partial wind mixing of the lake can also bring phosphorus from the bottom waters up towards the surface. For example, the temperature data from 2005 suggests that Fish Lake experience partial mixing around May 23. The surface TP measurement from May 23 was greater than both the previous measurement (May 10) and the following measurement on June 7.

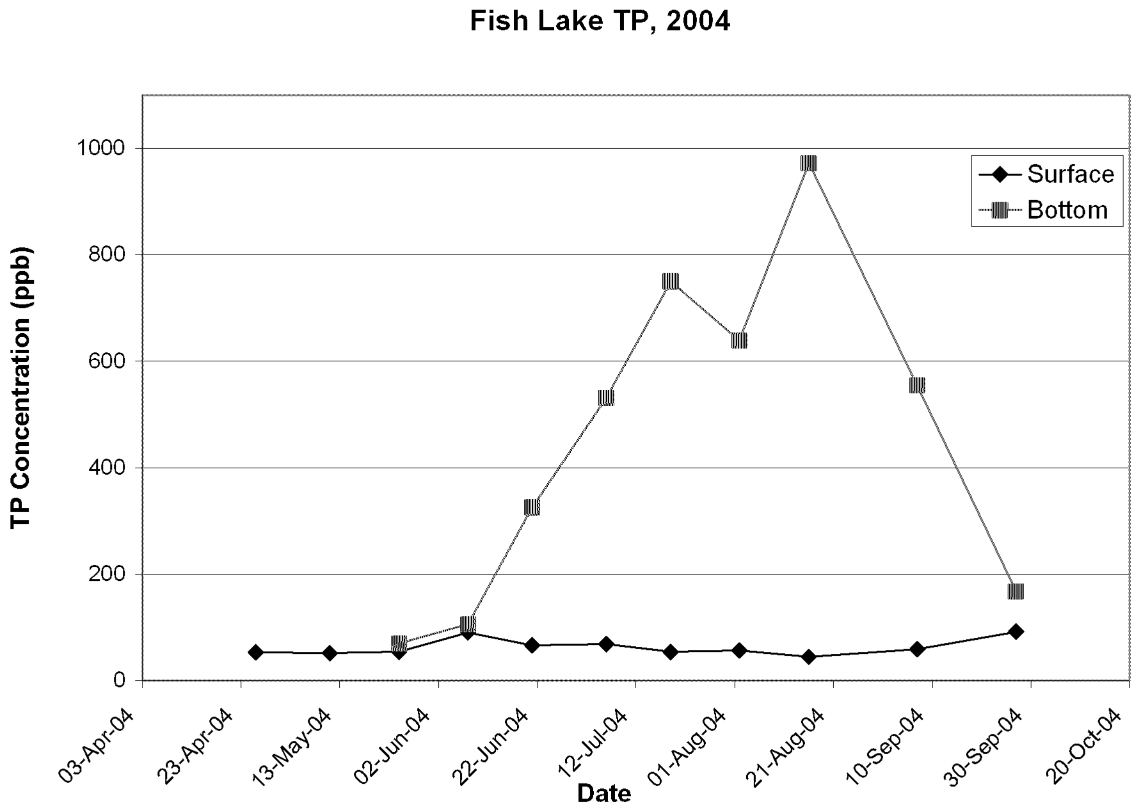


Figure 4. Fish Lake surface and bottom total phosphorus concentration for 2004.

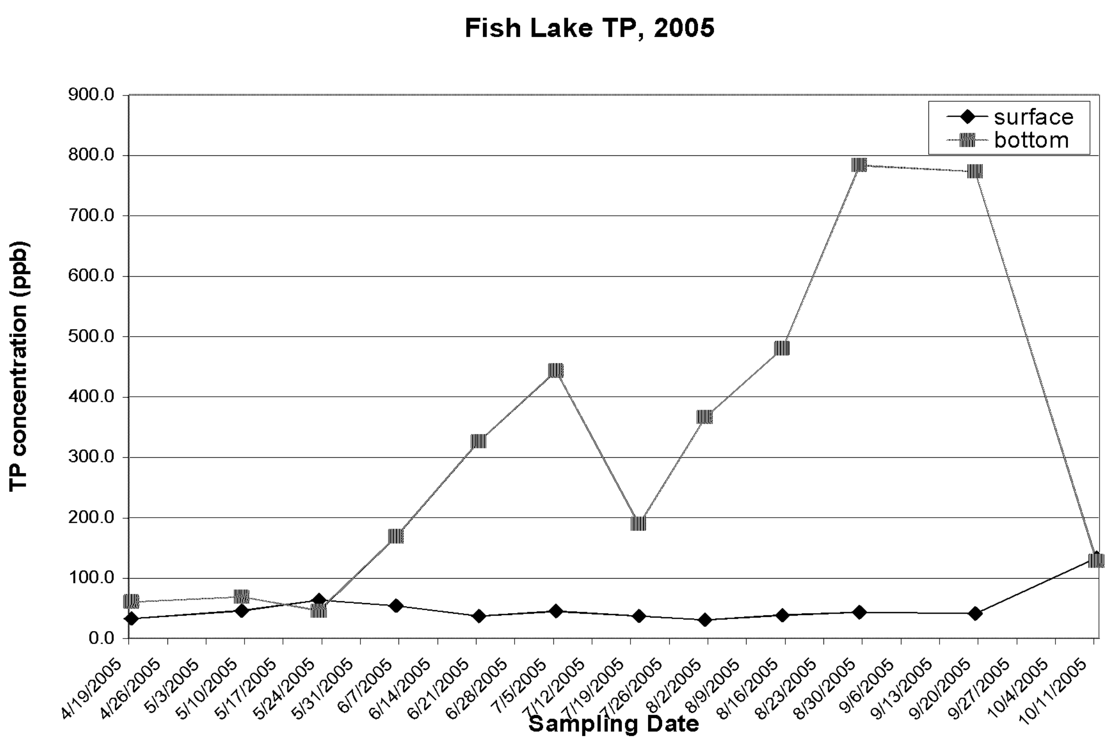


Figure 5. Fish Lake surface and bottom total phosphorus concentration for 2005.

Total Kjedahl Nitrogen (TKN): The TKN concentration averaged 1.43 mg/L during the 2004 growing season (May through September), and 1.37 mg/L in 2005. The ratio of total nitrogen (TN) to total phosphors (TP) can provide an indication as to which nutrient is limiting the production of algae in a lake. For Fish Lake, the TN:TP ratio was about 22 in 2004, and 31 in 2005. This indicates that nitrogen is much more abundant in the lake than phosphorus, making phosphorus the "limiting nutrient" for algae growth.

Chlorophyll-a and Secchi Disk Transparency: Chlorophyll-*a* (chl-*a*) concentration provides an estimate of the amount of algae growing in the lake. In Fish Lake, chl-*a* ranged from a low of 11.5 µg/L on June 21, 2005, to a high of 41.2 µg/L on October 11, 2005 (Figure 6). The average growing season chl-*a* concentrations were 27.6 µg/L in 2004, and 24.8 µg/L in 2005.

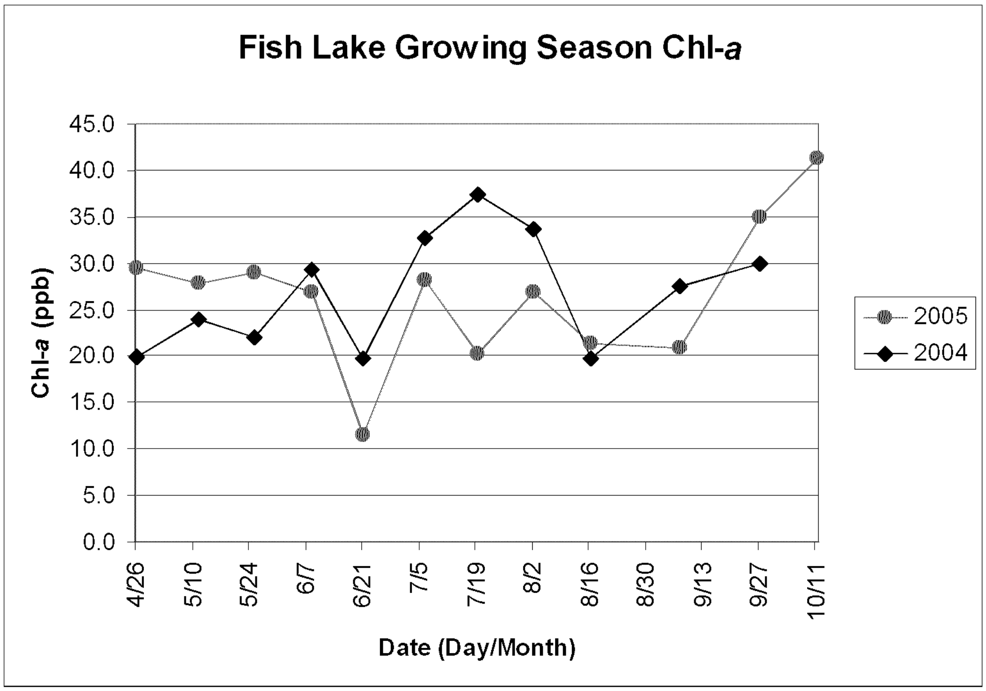


Figure 6. Fish Lake surface chlorophyll-*a* concentrations for 2004 and 2005.

The Minnesota Pollution Control Agency has found that chlorophyll-*a* concentrations between 10 and 20 µg/L are frequently perceived as a mild algae bloom, while concentrations greater than 30 µg/L may be perceived as a severe nuisance (Heiskary and Walker, 1988). The monitoring data suggest that the lake exhibited nuisance algae blooms in July 2004, and September and October 2005.

Chlorophyll-*a* concentrations are also very closely related to Secchi disk transparency measurements, as illustrated in Figures 7 and 8.

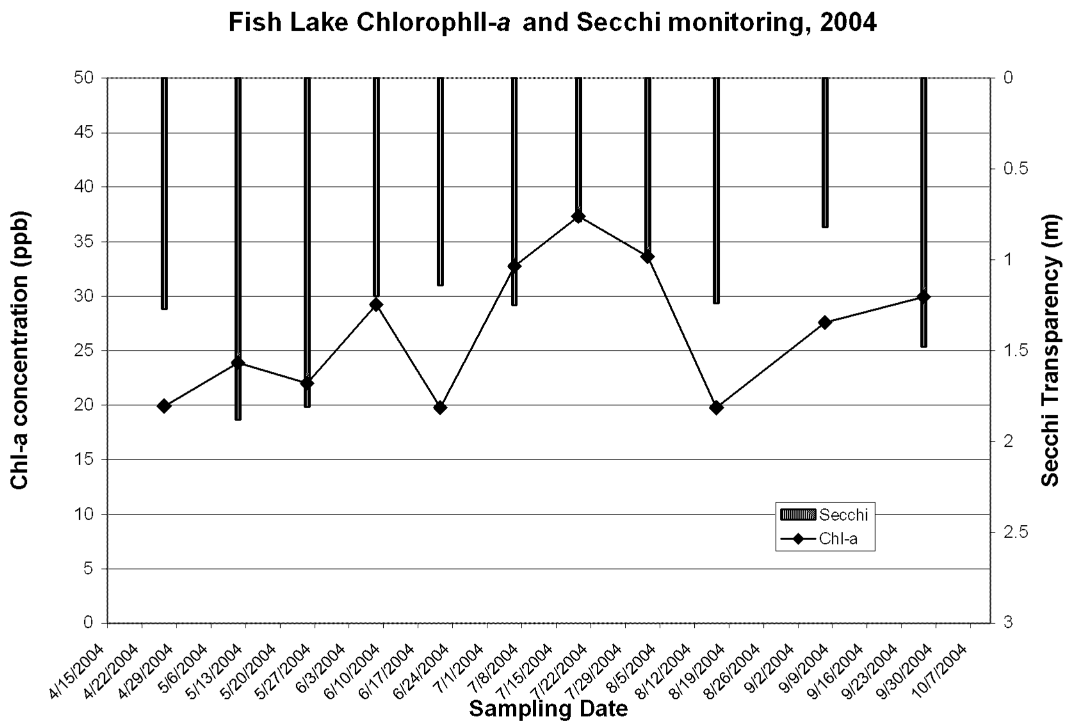


Figure 7. Fish Lake Chlorophyll-a concentrations and secchi depth for 2004.

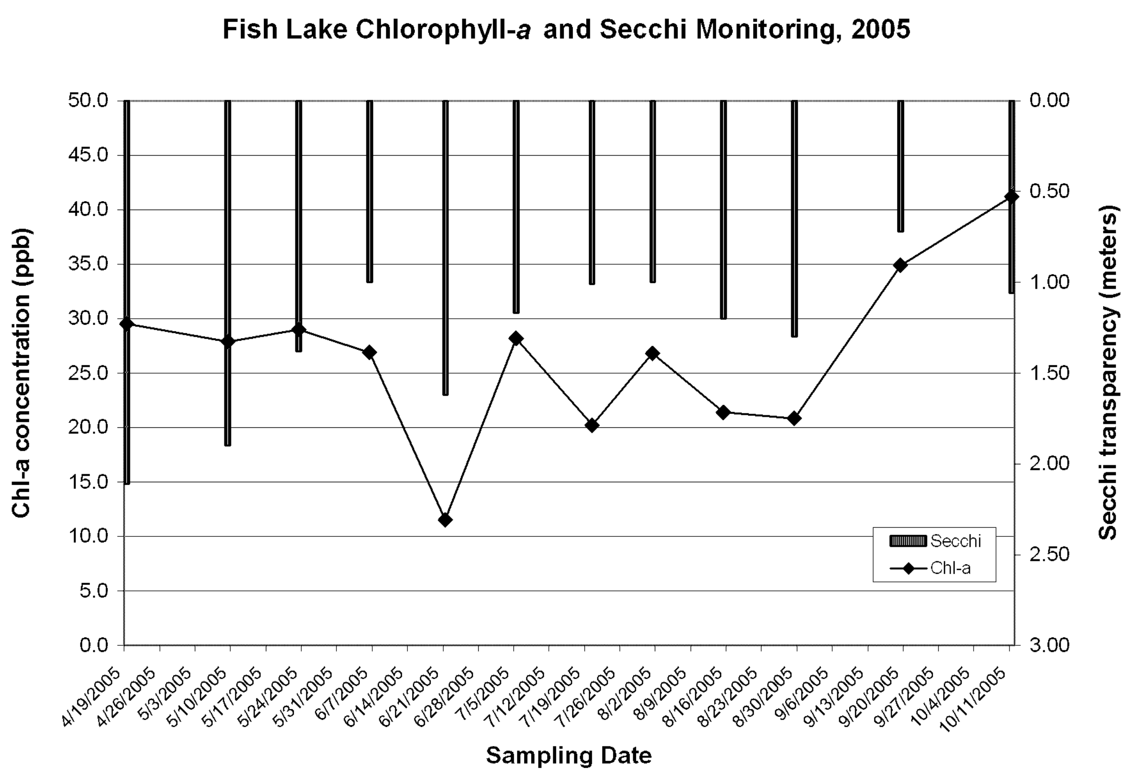


Figure 8. Fish Lake Chlorophyll-a concentrations and secchi depth for 2005.

Lake Trophic Status

One method used to characterize lakes is to identify the "trophic" or nutrient enrichment status of the lake. The Carlson Trophic State Index (TSI) is a tool used to interpret the relationship between total phosphorus, chlorophyll-*a* and Secchi disk measurements in a lake (Carlson 1977). TSI values are calculated as follows:

Total Phosphorus TSI = 14.42 ln (TP) + 4.15
Chlorophyll-*a* TSI = 9.81 ln (Chl-*a*) + 30.6
Secchi Disk TSI = 60 – 14.41 ln (secchi disk)

The individual TSI values for TP, Chl-*a* and Secchi disk transparency are then averaged to develop a composite TSI number for a lake. TSI values range from 0 (nutrient poor) to 100 (very nutrient rich). With this index, each increase of ten units represents a doubling of algal biomass.

TSI values for Fish Lake are presented in Table 1. The average TSI for Fish Lake over the past 10 years was 58. A TSI value of 58 suggests the lake is in an advanced state of eutrophy where blue-green algae dominate and the lake can demonstrate periods of severe algal blooms.

Table 1. TSI values for Fish Lake between 1980 and 2005.

Year	TP TSI	Chl-*a* TSI	Secchi TSI	Average TSI
2005	61	62	56	60
2004	62	59	54	58
2003	62	62	47	57
2002	67	65	60	64
2001	65	61	45	57
2000	59	NA	46	53
1999	59	NA	51	55
1998	60	NA	54	57
1997	62	NA	55	58
1995	63	NA	63	63
1990	53	NA	55	54
1987	NA	NA	57	57
1986	NA	NA	63	63
1985	NA	NA	65	65
1984	66	NA	57	61
1980	57	NA	59	58

It is useful to compare the water quality data from an individual lake with lakes from the same ecoregion. Table 2 presents the 2004, 2005 and five-year average water quality data for Fish Lake compared to the typical range for the North Central Hardwood Forest (NCHF) Ecoregion.

Table 2. Water quality data for Fish Lake as compared to assessed and reference lakes in the North Central Hardwood Forest Ecoregion.

Parameter	**Fish Lake**			**NCHF Ecoregion**	
	2004	**2005**	**5-Year Average**	**MPCA Assessed Lakes[1] Interquartile Range (25-75th) and Median**	**MPCA Reference Lakes[1] Interquartile Range (25-75th) and Median**
Total Phosphorus (μg/L)	55	52	61	28-112 (51)	5-22
Chlorophyll-a (μg/)	19	25	25	8-45 (21)	7-37
Secchi Depth (m)	1.6	1.3	1.8	1-2.6 (1.6)	1.5-3.2

[1]All lake data is for the NCHF Ecoregion. Assessed lakes are all lakes sampled in that ecoregion by the MPCA and reference lakes are those lakes in the ecoregion considered to be minimally impacted.

Fish Lake is well within the average lake conditions for the ecoregion; however, phosphorus concentrations are considerably higher than the reference lakes for the ecoregion (61 μg/L as compared to an interquartile range of 5-22 μg/L). Chlorophyll-*a* and secchi depth were in the range for reference lakes albeit closer to the poorer water quality ends of the range. The MPCA goals for assessing whether a lake is considered impaired are presented in Table 3. Goals for both the NCHF and the Western Cornbelt Plain (WCBP) are shown since land uses in the District are often more similar to the WCBP Ecoregion. Fish Lake is relatively close to the Western Cornbelt Plain standards for deep lakes suggesting that even in the impacted watershed conditions, water quality remains relatively good. Consequently, it is likely that the NCHF goals are achievable.

Table 3. Proposed MPCA goals for protecting Class 2B waters. Values are summer averages (June 1 through September 30).

	Ecoregions			
	North Central Hardwood Forest (NCHF)		**Western Corn Belt Plains (WCBP)**	
Parameters	**Shallow[1]**	**Deep**	**Shallow[1]**	**Deep**
Phosphorus Concentration (μg/L)	60	40	90	65
Chlorophyll-a Concentration (μg/L)	20	14	30	22
Secchi disk transparency (meters)	>1	>1.4	>0.7	>0.9

[1] Shallow lakes are defined as lakes with a maximum depth of 15 feet or less, or with 80% or more of the lake area shallow enough to support emergent and submerged rooted aquatic plants (littoral zone).

Modeling Results and In-Lake Dynamics

Watershed Loading

A MnLEAP model was constructed for Fish Lake to generate a rough estimate for external (primarily watershed) loading to Fish Lake. The model assumed an inflow concentration of 208 µg/L total phosphorus, which resulted in a watershed load of 59 kilograms of total phosphorus (TP) per year. However, this is likely an underestimate of the watershed load because phosphorus data from limited grab sampling conducted by the District suggests that inflow concentrations of total phosphorus may be higher than 208 µg/L (see Table 4).

Table 4. Grab sampling results for intermittent inflows to Fish Lake.

Date	Site (see below)	TSS (mg/L)	TP (mg/L)	Ortho-P (mg/L)	TKN (mg/L)	Total Rainfall	Notes
7/28/2004						0.33 in.	
	1	6	0.25	0.0089	1.3		
	2	--	--	--	--		No discharge observed
	3	--	--	--	--		No discharge observed
9/5/2004						0.77 in.	
	1	18	0.37	0.022	1.6		Samples not received on ice
	2	74	2.3	0.1	2		Samples not received on ice
	3	640	0.92	0.37	1.8		Samples not received on ice
6/27/2005						0.3 in.	
	1	--	--	--	--		No discharge observed
	2	<5.0	0.77	0.54	1.6		
	3	--	--	--	--		No discharge observed

Site 1: Outlet of wetland complex on northeast side of lake, just west/southwest of 203rd Court (drainage also comes from Lake Ridge Drive area, through two ponds and the wetland).

Site 2: Outlet of ditch/stream that runs under County Road 10 and along part of Fairlawn Lane on north side of lake (ditch comes from wetland north of CR 10).

Site 3: Pipe outlet from Addison Drive area drainage, southeast corner of the lake. Drainage appears to follow Addison Drive, then go under the road and down the slope to the lake.

A SWAT watershed model was also developed for the Fish Lake watershed by Dr. Amal Djerrari of Hydrogeological & Modeling Services, Inc. Because there was very little inflow monitoring data available for the watershed, the model inputs were determined from literature values of phosphorus runoff by land use. Therefore, the model can only provide an approximate estimate of watershed loading. With that said, it can still be a useful tool for comparing internal and external phosphorus loads. The modeling suggested an average annual watershed load of 93 kilograms per year. Over an eight-year period, the modeled watershed loads ranged from approximately 45 kilograms to slightly over 200 kilograms (see Appendix C).

Joe Bischoff of Wenck Associates, Inc. used an inverted Canfield-Bachmann model to estimate the total load (external plus internal) for the summer growing season averages in Fish Lake (see Appendix D). The model was run for average runoff conditions in each year, although precipitation varies from year to year. Annual runoff values were not available. The Canfield-

Bachmann model suggests that Fish Lake received loads ranging from 70 to 330 kilograms phosphorus from 1990 to 2005 (see Figure 9).

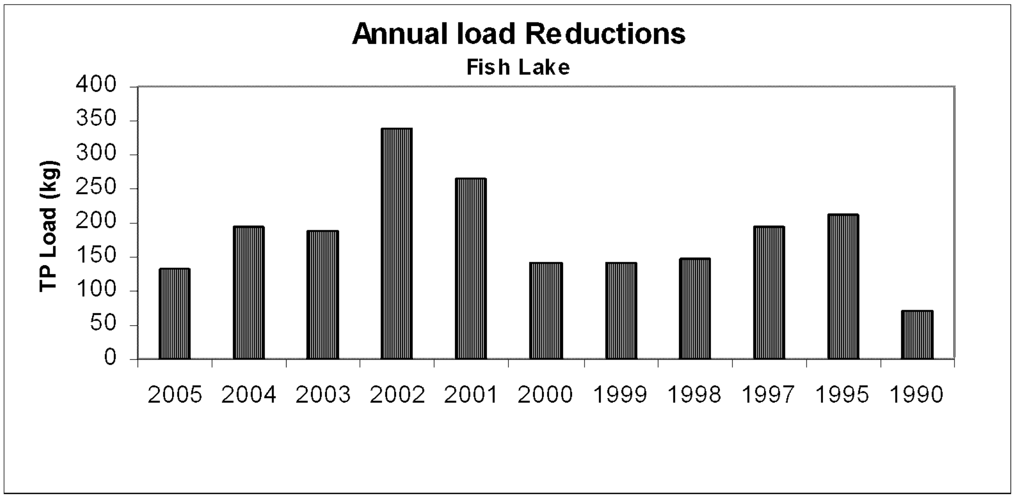


Figure 9. Estimated loads from the inverted Canfield-Bachmann model for Fish Lake.

Internal Loading

Several calculations were developed in an attempt to quantify the internal phosphorus load in Fish Lake. The three methods used were the calculation of an anoxic factor and sediment release rates, a hypolimnetic mass balance, and a fall turnover mass balance (see Appendix D). Table 5 summarizes the internal load estimates for Fish Lake.

Table 5. Summary of internal load estimates for Fish Lake.

Year	Method	Estimated Internal Load (kg)
2004	Anoxic Factor	392
2005	Anoxic Factor	420
2004	Hypolimnetic Mass Balance	Not Calculated
2005	Hypolimnetic Mass Balance	331-488
2004	Fall Turnover	313
2005	Fall Turnover	111

The internal phosphorus load estimates range from 111 to 488 kilograms phosphorus. When compared to the watershed load estimates of 45 to 200 kilograms phosphorus (SWAT model, Appendix C), it is clear that internal loading is very likely a significant component of the phosphorus load in Fish Lake.

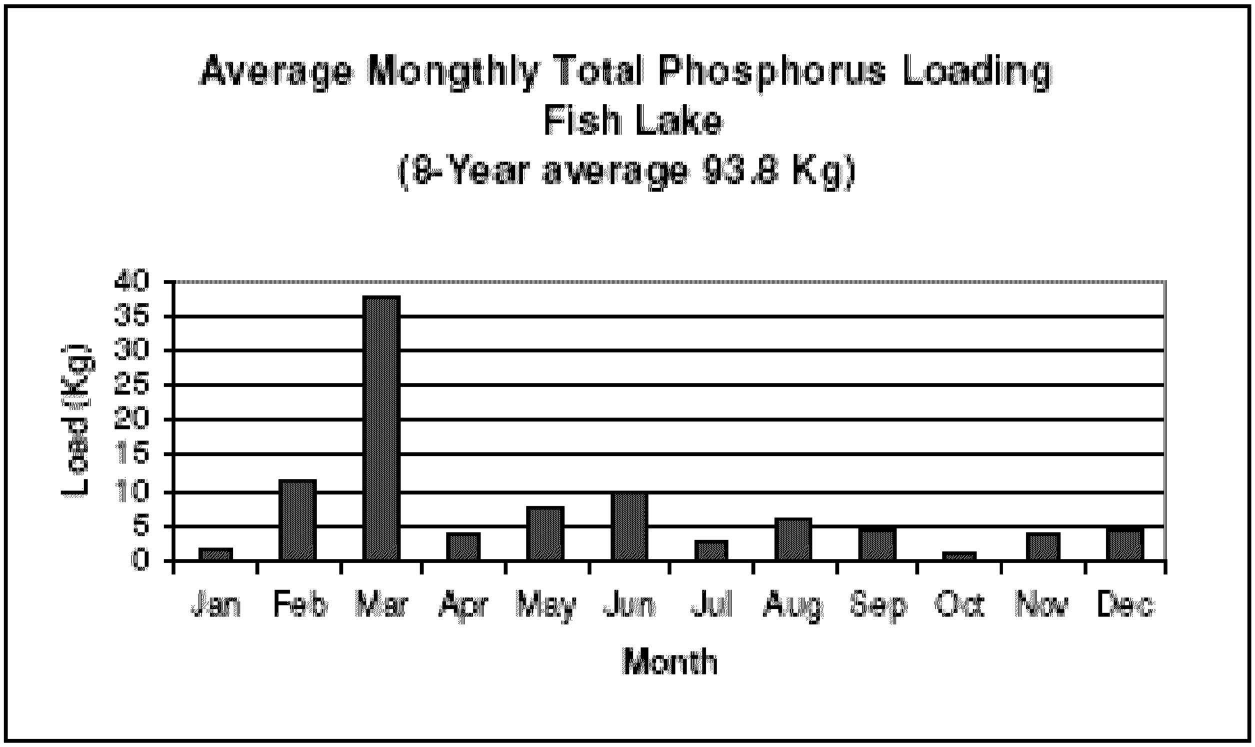
Late season algal blooms at fall turnover also suggest that internal loading of phosphorus is a significant problem in Fish Lake. Results of the internal load assessment (Appendix D) also found that phosphorus loading may be occurring in the winter due to anoxic sediments, albeit at a lower rate due to lower temperatures (2004 demonstrated anoxic sediments in April). This may be important at spring turnover by providing a large amount of phosphorus for early season algal blooms. When compared to the external loading estimates, the magnitude of the internal load is large enough to account for almost the entire phosphorus budget for Fish Lake.

Phosphorus Dynamics in Fish Lake

The internal load calculations suggest that almost all of the load to Fish Lake could be from the internal load. The inverted Canfield-Bachmann model predicted a total load range between 70 and 330 kg/year while internal loading was estimated at 111 to 488 kg/yr. Although not all of the phosphorus released from the sediments are available for algal uptake during the growing season, approximately half was estimated to migrate across the thermocline from turbulent diffusion (Appendix D). Using the midpoint of these two ranges and assuming that half of the internal load is available for algal production, internal phosphorus load accounts for a median of 73% of the phosphorus load. It is likely that some external load is contributing to the phosphorus budget of Fish Lake; however, that contribution is likely relatively small compared to the internal phosphorus load in Fish Lake.

Appendix C

Watershed Modeling Results: Fish Lake SWAT Model (Uncalibrated Model)


Average Mongthly Total Phosphorus Loading
Fish Lake
(8-Year average 93.8 Kg)
Load (Kg)
40
35
30
25
20
15
10
5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

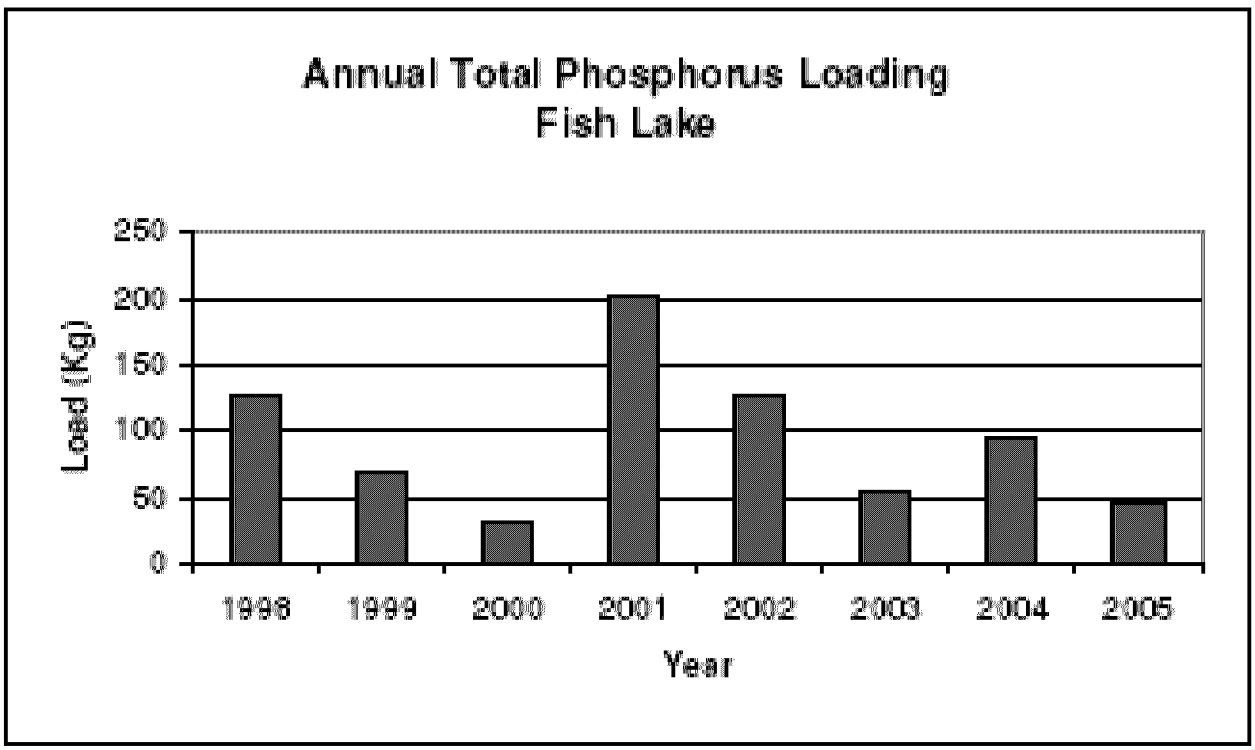
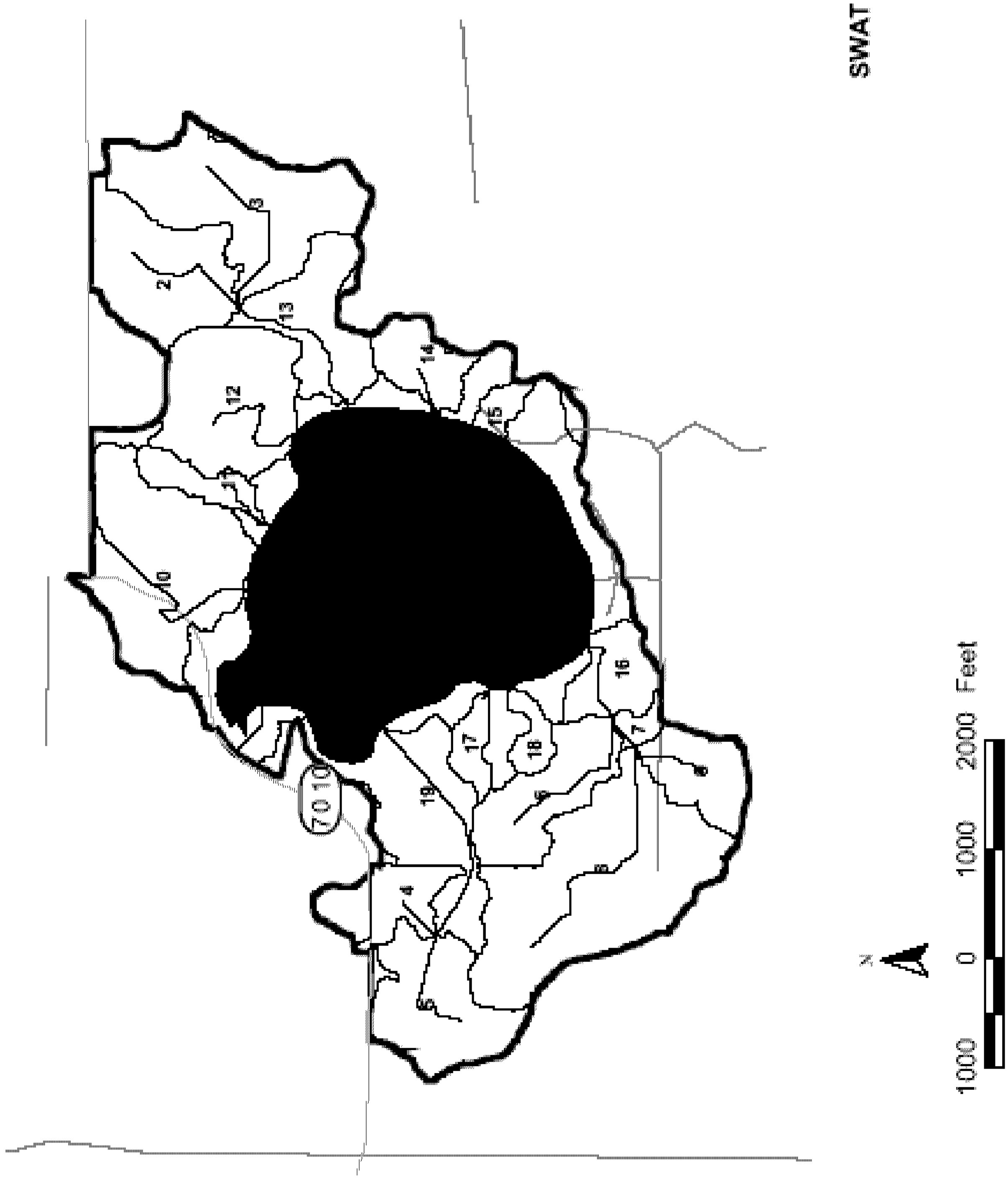

Annual Total Phosphorus Loading
Fish Lake
Load (Kg)
250
200
150
100
50
0
1998
1999
2000
2001
2002
2003
2004
2005
Year

Figure 1
SWAT Model Segmentation
Fish Lake



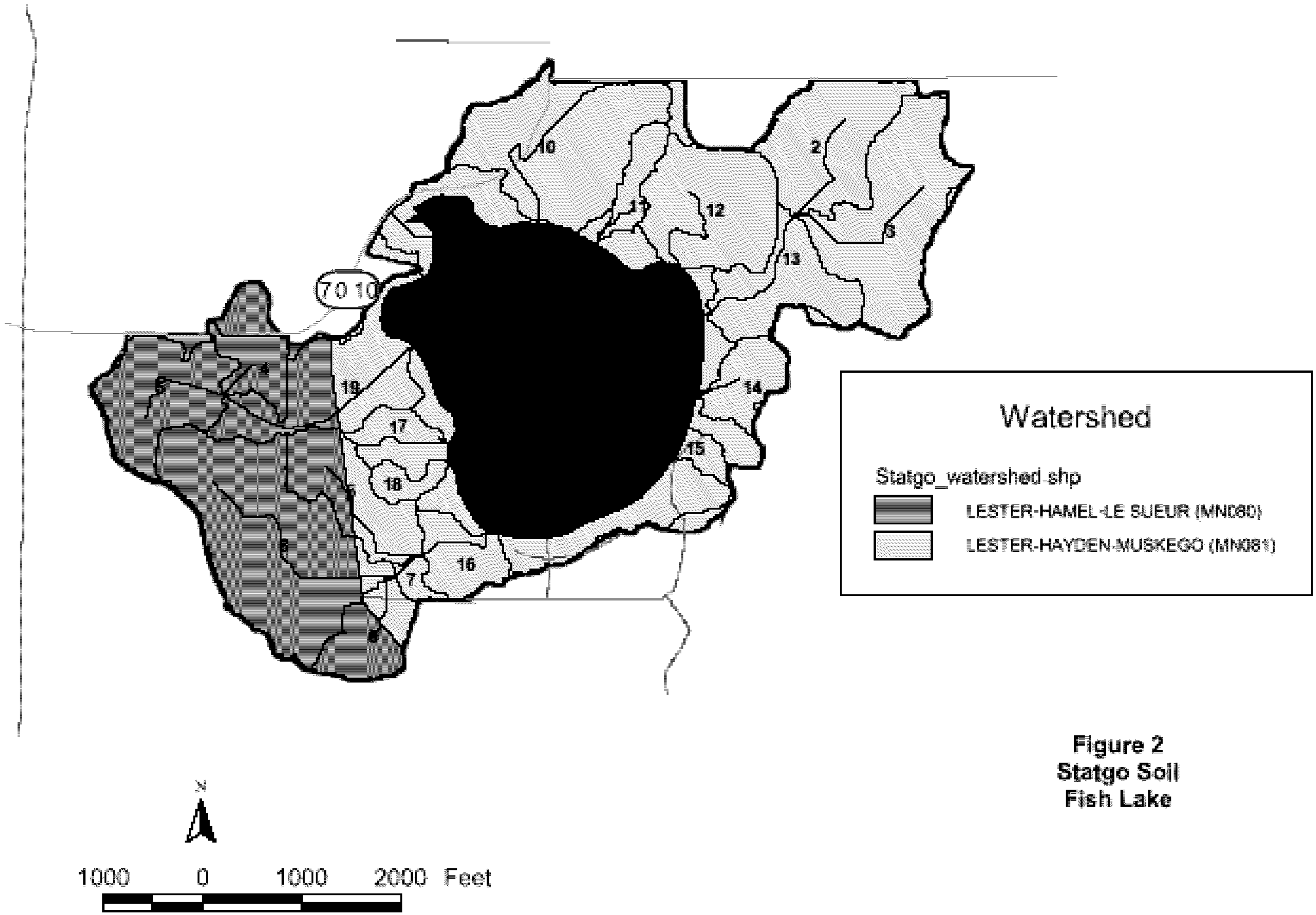


Figure 2
Statgo Soil
Fish Lake

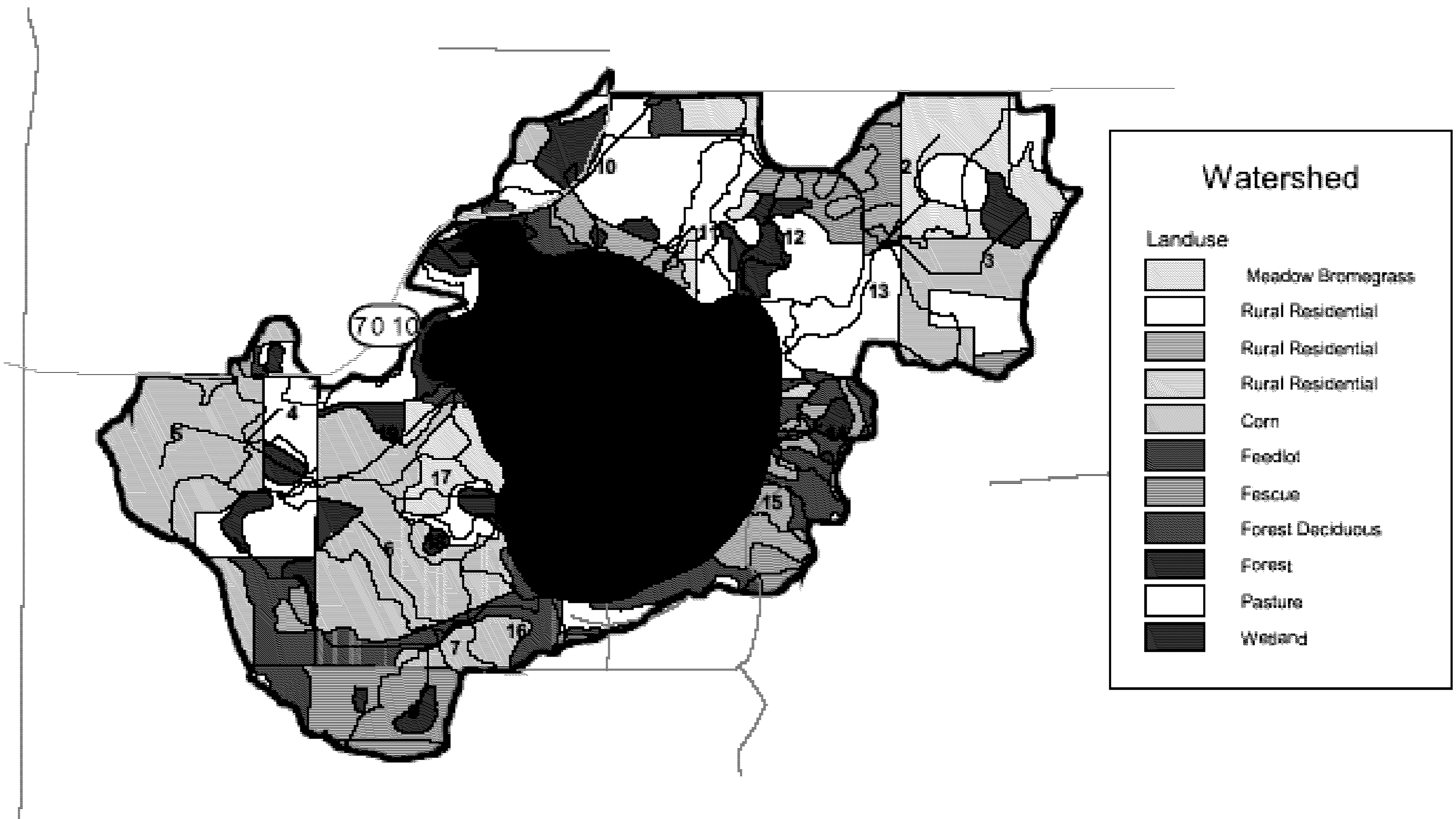


Figure 3
SWAT Model Landuse
Fish Lake

Table 1
Curve Numbers Used for Landuse in Fish Lake Watershed

	DESCRIPTION	LUKEY	SWAT Recommended Values	Recommended Cn			Cn Used
				Poor	Fair	Good	1
Fish Lake	Rural Residential	BLG1	65				62
	Rural Residential	BLG2	68				67
	Rural Residential	BLG3	70				69
	Kentucky Bluegrass	BLUG	71	80	71	62	71
	Smooth Bromegrass	BROM		80	71	62	79
	Corn	CORN	70 - 81	81		78	68
	Fescue	FESC	58 - 79	80	71	62	58
	Forest-Deciduous	FRSD	55 - 66	66	60	55	61
	Forest	FRST	58 - 73	73	65	58	65
	Summer Pasture	SPAS	61 - 79	79	69	61	70
	Water	WATR					92
	Wetlands-non Forested	WETF					78
	Precipitation Stations						Jordan/ Farmington

Table 2
Computed Runoff into the Lake (SWAT Model Results)

	Q cfs	Q m3/yr	Q acre-feet/year	Total Area (acres)	Runoff (inches/year)
1998	0.59	530120.2	430.08		
1999	0.46	410283.4	332.85		
2000	0.16	145507.1	118.05		
2001	0.41	366133.0	297.04		
2002	0.75	666986.4	541.11		
2003	0.23	207033.8	167.96		
2004	0.50	446865.1	362.53		
Average	0.44	396132.71	321.37	484.93	7.95

Appendix D
Internal Loading Analysis

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Maple Plain, MN 55359-0249

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Fax (763) 479-4242
E-mail: wenckmp@wenck.com

TECHNICAL MEMORANDUM

TO: Shannon Lotthammer

FROM: Joe Bischoff

DATE: December 13, 2005

SUBJECT: Internal Loading Analysis for Fish Lake

The purpose of this memo is to outline the results of the internal loading analysis for Fish Lake.

Internal Load Assessment

To assess the extent of internal phosphorus loading in Fish Lake, several calculations were developed in an attempt to quantify the internal phosphorus load. The first method utilized was to develop the anoxic factor for the lake and apply a sediment phosphorus release rate (Nurnburg 2004). The anoxic factor is expressed in days but is normalized over the area of the lake. For example, if the depth of oxygen depletion (<2 mg/L DO) was 6 meters, then the number of days was multiplied by the anoxic area at that depth and divided by the entire area of the lake. A release rate was then selected based upon the eutrophic state of the lake. The selected release rates were a range based on previous lake studies (Figure 1; Nurnburg 2002). The results of the analysis are provided in Table 1.

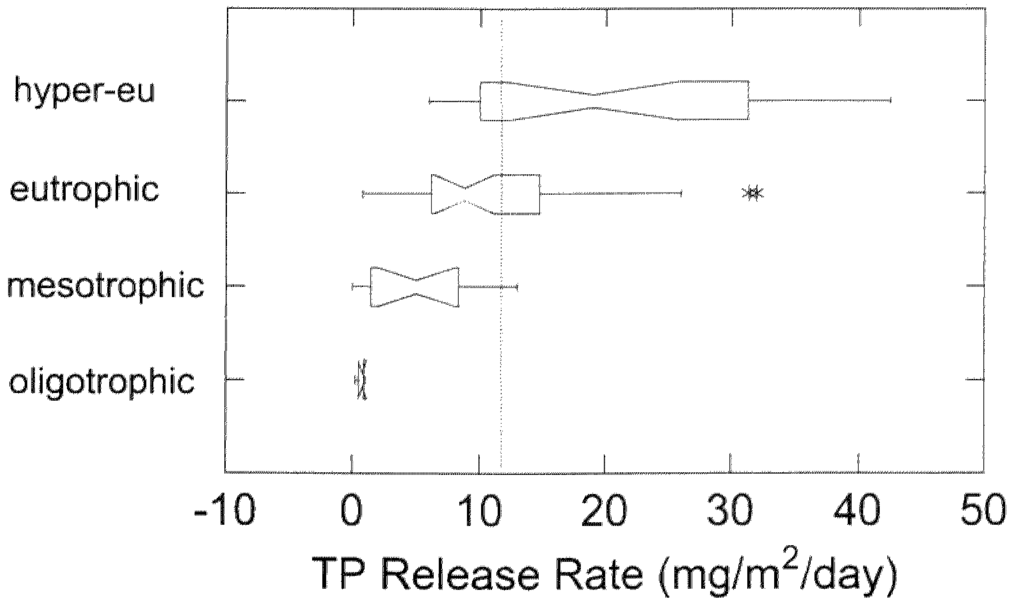

Figure 1. Sediment phosphorus release rates by eutrophic condition (Nurnburg 2002).

Table 1. Results of the internal load assessment using an anoxic factor and release rate for Fish Lake.

Year	Release Rate (mg/m2/day)	Anoxic Factor (days)	Gross Load (mg/m^2/summer)	Gross Load (kg)
	6	92	554	392
	9	92	831	589
2004	15	92	1385	981
	6	99	593	420
	9	99	890	630
2005	15	99	1483	1051

It is likely that Fish Lake is loading on the lower end of the range because the lake summer mean average concentration is on the lower end of eutrophic lakes. So the first estimate of internal loading suggests a rate of 393 to 420 kilograms per year.

The second method utilized in the internal load assessment was to develop a mass balance in the hypolimnion of Fish Lake. The assumption in this method is that the change in concentration in the hypolimnion is a result of phosphorus release from the sediments. The results of this analysis are presented in Table 2.

Table 2. Internal load mass balance for the hypolimnion of Fish Lake.

Date	Depth of Oxycline (m)	TP (μg/L)	OP (μg/L)	Volume (m^3)	TP Mass (KG)	OP Mass (KG)	TP Internal Load (kg)	OP Internal Load (kg)
20-Feb-05	7						NA	NA
19-Apr-05	8	61.0	26.96	313,409.5	19.1	8.4	NA	NA
9-May-05	7	68.8	15.36	523,074.5	36.0	8.0	NA	NA

23-May-05	6	45.8	6.55	661,571.0	30.3	4.3		
6-Jun-05	3	168.8	107.03	985,446.5	166.3	105.5		
21-Jun-05	4	326.0	154.30	816,057.7	266.0	125.9		
5-Jul-05	3	443.4	271.47	985,446.5	436.9	267.5		
20-Jul-05	4	189.3	103.00	816,057.7	154.5	84.1		
1-Aug-05	4	366.3	223.45	816,057.7	298.9	182.3		
15-Aug-05	4	480.3	302.96	816,057.7	392.0	247.2		
29-Aug-05	5	783.8	506.30	661,571.0	518.5	335.0	488	331
19-Sep-05	7	772.9	524.90	523,074.5	404.3	274.6	NA	NA
10/11/2005		128.3	32.16				NA	NA

The internal load was estimated by the mass change in hypolimnetic TP and OP from May 23rd through August 29th. Since TP concentrations in the hypolimnion can be affected by senesced and settling algae, it is likely that the OP mass is the better estimate. Consequently, the estimated internal load using method 2 is around 331 kg phosphorus.

The third method utilized to estimate the internal load for Fish Lake was a mass balance for the change in lake concentration at fall turnover. Results of this analysis are presented in Table 3.

Table 3. Results of the mass balance at fall turnover.

Date	TP (µg/L)	OP (µg/L)	Volume (m^3)	TP Mass (KG)	OP Mass (KG)	TP Internal Load (kg)	OP Internal Load (kg)
9/19/05	41.4	6.93	3,381,278	140.0	23.4		
10/11/05	133.9	27.59	3,381,278	452.8	93.3	313	70
9/07/04	59.3		3,381,278	200.5			
9/27/04	92.2		3,381,278	311.8		111.2	NA

Results of the mass balance at fall turnover suggest that internal loading is approximately 111 to 313 kilograms per summer.

Table 4 summarizes the internal load estimates for Fish Lake. Based on the three methods utilized for estimating the internal phosphorus load for Fish Lake, the internal load ranges from 111 to 488 kilograms phosphorus.

Table 4. Summary of internal load estimates for Fish Lake.

Year	Method	Estimated Internal Load (kg)
2004	Anoxic Factor	392
2005	Anoxic Factor	420
2004	Hypolimnetic	Not Calculated

	Mass Balance	
2005	Hypolimnetic Mass Balance	331-488
2004	Fall Turnover	313
2005	Fall Turnover	111

Turbulent Diffusion

To estimate the amount of phosphorus moving across the thermocline into the epilimnion from the hypolimnion during the stratified summer season, we utilized a turbulent diffusion coefficient that accounts for the thickness of the thermocline and the phosphorus gradient between the epilimnion and the hypolimnion. Based on this assessment, approximately 190 kg of phosphorus will move across the thermocline into the epilimnion and become available for algal uptake (more than 50% of the internal load). Although this estimate may be high, it does suggest that the internal load during stratification is an important source of phosphorus for algal growth. However, the internal load is most important in Fish Lake at turnover by providing a water column rich in phosphorus for early season growth and lake season algal blooms following fall turnover (as seen in 2005).

Canfield-Bachmann Assessment

To put the internal loads in perspective for the whole lake, we used an inverted Canfield-Bachmann model to estimate the load for the summer growing season averages in Fish Lake. The model was run for average runoff conditions in each year, although precipitation varies from year to year. However, annual runoff values were not available.

The Canfield-Bachmann model suggests that Fish Lake received loads ranging from 70 to 330 kilograms phosphorus from 1990 to 2005. The internal load calculations suggest that almost all of the load to Fish lake could be from the internal load. It is likely that some external load is contributing to the phosphorus budget of Fish Lake; however, it is likely relatively small compared to the internal load in Fish Lake.

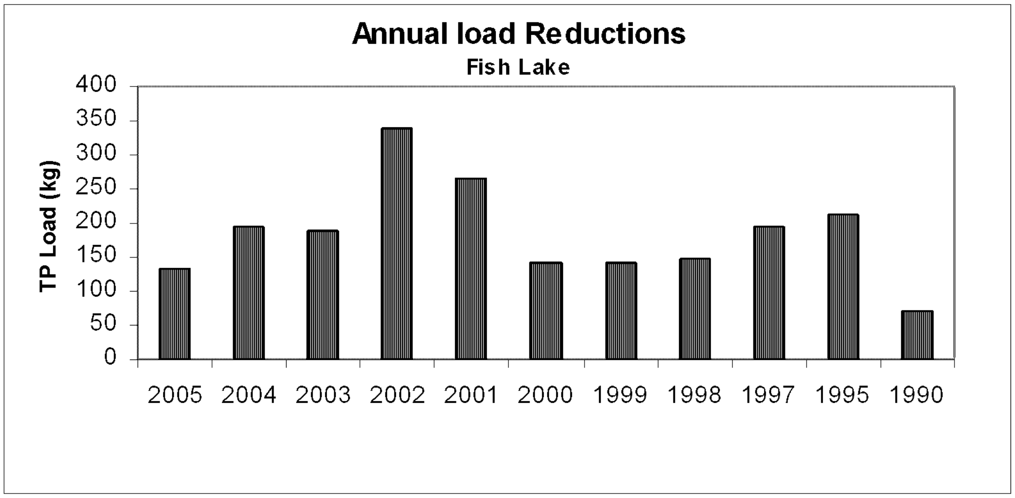

Figure 2. Estimated loads from the inverted Canfield-Bachmann model for Fish Lake.

Conclusions

Following are the conclusions from this analysis:

1. Phosphorus loading may be occurring in the winter, albeit at a lower rate due to lower temperatures, due to anoxic sediments (2004 demonstrated anoxic sediments in April). This may be important at spring turnover by providing a large amount of phosphorus for early season algal blooms.

2. Late season algal blooms at fall turnover suggest that internal loading of phosphorus is a significant problem in Fish Lake.

3. The magnitude of the internal load is large enough to account for almost the entire phosphorus budget for Fish Lake.

Since the internal load is such an important factor in Fish Lake, Alum should be considered as an appropriate BMP for controlling internal loading. The watershed is small compared to the lake resulting in a residence time of approximately 8.5 years. This suggests that an Alum treatment could have a lasting effect in Fish Lake since watershed loads are likely to be small compared to the lake volume. However, for long-term success, watershed loads should be monitored to develop a target for runoff loads.