Prepared by: Emmons and Olivier Resources, Inc. (EOR)

For the Prior Lake-Spring Lake Watershed District

Adopted by the Prior Lake-Spring Lake Board of Managers December 12, 2023

FISH LAKE MANAGEMENT PLAN

Funding provided by the Clean Water Fund and Spring Lake Township. Minnesota BWSR as a sponsoring agency.

December 7, 2023

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Introduction

This Fish Lake Management Plan update was developed using funding provided by the Clean Water Fund, with Minnesota BWSR as a sponsoring agency through the Watershed Based Implementation Funding grant, and Spring Lake Township. The main driver for updating the plan was to determine the appropriate course of action to improve the water quality of Fish Lake. Past studies have reached conflicting conclusions as to the primary source of phosphorus loading in Fish Lake: watershed contribution versus internal loading (refer to Sections 2.D.i and 2.D.ii). Fish Lake was added to the MPCA impaired waters list in 2002 for aquatic recreation due to excessive nutrients. While Fish Lake is close to meeting state standards for recreational use, elevated levels of phosphorus are driving the presence of seasonal nuisance algae blooms.

To assist in developing this plan, meetings were held with a stakeholders group made up of residents and local officials. A Technical Advisory Committee (TAC) of state and local agency representatives was also established early in the planning process. Members representing the Minnesota Pollution Control Agency (MPCA), Minnesota Board of Soil and Water Resources (BWSR), Minnesota Department of Natural Resources (DNR), Metropolitan Council, Scott County, Spring Lake Township, and Scott Soil and Water Conservation District (SWCD) were invited to participate.

Fish Lake Assessment

The Fish Lake watershed, encompassing 699 acres in Scott County, Minnesota, has undergone significant land use changes since European settlement, transitioning from natural woodlands to predominantly agricultural and residential areas.

Overall, the Fish Lake watershed faces challenges related to land use changes, that have led to shifts in the water balance, resulting in elevated surface water runoff and increased phosphorus accumulation in Fish Lake. The current land cover distribution within the watershed includes 22% development, 21% agricultural use, 19% grasslands, 25% open water, 6% wetlands, and 7% forested/wooded areas. A historical sediment analysis indicates a notable increase in phosphorus accumulation from 1910 to 1950, attributed to intensified agriculture and fertilizer use. While there was a decline from 1980 to 1995, phosphorus levels have since increased.

Fish Lake's ecosystem shows a balance of diverse fish populations, stable aquatic plant communities, and a healthy riparian zone. Phytoplankton (algae) blooms commonly occur throughout the summer but are most pronounced in the early spring and late fall, corresponding to lake turnover. While phytoplankton supports the lake food web, excessive amounts during blooms restrict recreational use of the lake and can degrade water quality.

Fish Lake was originally assessed by the MPCA in 2001, at which time it was determined to be impaired for its designated use, Aquatic Recreation. This was due to excessive algae caused by the presence of nutrients such as phosphorus in the water. Fish Lake was included on the state's impaired waters list. The most recent MPCA assessment, completed in 2020, showed continued impairment of Fish Lake by phosphorus. The total phosphorus impairment threshold for North Central Hardwood Forest – Aquatic Recreational Use lakes (2B), like Fish Lake, is 40 µg/L. The 10-year average total phosphorus for Fish Lake is 42 µg/L.

The average nitrogen to total phosphorus (N:P ratio) for Fish Lake indicates that the lake is likely phosphorus limited. N:P Ratios in Fish Lake are lowest following mixing events, specifically during spring and fall turnover when surface phosphorus concentrations are highest. Fish Lake experiences episodic releases of highly bioavailable phosphorus from its sediments with subsequent algal blooms.

Past attempts to determine the phosphorus loading dynamics in Fish Lake have varied considerably, from suggesting watershed loading is the primary source of phosphorus to the lake to pointing towards internal phosphorus loading as the primary driver. As part of this assessment, a lake response model was created for Fish Lake that accounts for water and phosphorus inputs from tributaries, watershed runoff, the atmosphere, sources internal to the lake, and groundwater, as well as outputs through the lake outlet, water loss via evaporation, and phosphorus sedimentation and retention in the lake sediments. The model shows that internal loading varies considerably. For relatively normal precipitation value years, internal loading contributes a disproportionate amount of phosphorus to the overall lake load. In very wet years, where the watershed would be expected to contribute most of the loads, internal loading is still contributing almost a third of the overall load.

Overall, the watershed loading, while seemingly improving, is still contributing a large portion of load to Fish Lake, this along with the large input from internal loading is causing the impaired status of the lake. Due to past land uses, phosphorus laden sediment has accumulated within the lake and continues to be available for plant and algae growth.

Goals

Goals for the future of Fish Lake were established with input from the stakeholder group. The primary water quality goals for Fish Lake are based on standards the State of Minnesota established for recreational use of deep lakes in the ecoregion based on the presence of nuisance algae blooms. Fishery goals established for Fish Lake are aimed at maintaining health of the community, both from an ecological and human consumption perspective. The aquatic plant goals for Fish Lake focus on maintaining the benefits provided by a healthy, diverse population of native aquatic plants while minimizing the deleterious effects non-native invasives can have.

Water Quality Goals

- Meet the Minnesota standards (growing season averages) for deep lakesin order to remove Fish Lake from the impaired waters list:
    - Total Phosphorus <=40 µg/l
    - Secchi Depth Transparency >= 1.4 m
    - Chlorophyll-A <=14 µg/l
- Reduce frequency and severity of early and late season algal blooms.
- Reduce conditions that lead to blue-green algal blooms which are a health concern.
- Reduce watershed phosphorus loading.
- Control internal recycling of phosphorus.

Fishery Goals

- Maintain a healthy (edible, i.e. mindful of mercury contamination) game fish population with management emphasis on walleye.
- Manage carp and other species that may contribute to bottom-sediment release of nutrients.

Aquatic Plant Goals

- Maintain healthy population of diverse native aquatic plants.
- Manage infestations of Curlyleaf Pondweed past 150′ of shoreline.

Implementation Strategies

A holistic management of Fish Lake will employ both an internal load treatment and external load treatment to reduce seasonal algal blooms and slow the accumulation of TP rich sediment which contributes to internal loading in the future. In short, the internal load reduction will restore Fish Lake to a clear water state and the watershed load reduction will maintain the clear water status.

Watershed load management options are separated into three categories, regional watershed improvement projects, residential stormwater BMPs & lakeshore improvements, and agricultural conservation management.

Regional watershed improvement projects are large-scale infrastructure projects designed to manage stormwater runoff over a broad area, generally greater than a single parcel of land. They involve multiple components like detention basins, green infrastructure, and conveyance systems to handle significant volumes of stormwater. Due to their scale, they are typically cost-effective solutions that result in larger reductions in nutrient loading per dollar spent.

Residential stormwater best management practices treat runoff at a smaller scale throughout the watershed. The function of these practices is to capture and remove pollutants from runoff generated from impervious areas. Generally, these practices remove stormwater pollutants through settling of nutrient-laden sediment, biological uptake, or through infiltration into the ground. Lakeshore improvement practices entail planting of native vegetation along lakeshore and in emergent zone of the lake as a way of restoring the natural transition from lake to upland thereby trapping and filtering pollutants.

Agricultural conservation practices that promote soil health are recommended for the Fish Lake watershed. Soil health practices are a set of sustainable farming techniques and management strategies designed to protect and improve the overall health and quality of soil in agricultural ecosystems. These practices aim to enhance soil fertility, structure, and resilience, while minimizing erosion, nutrient depletion, and environmental degradation.

Several options for in-lake management have been evaluated including chemical treatments for phosphorus release from the sediment, physical management for removal or abatement of internal loading, and biological controls for removing in-lake phosphorus sources. The options were evaluated based on cost-benefit, feasibility, and ability to achieve lake management plan goals. Based on the evaluation, chemical management, i.e. alum treatment, was determined to be most feasible is recommended for internal loading control on Fish Lake because of its safety and effectiveness for permanent reduction of internal loading.

Monitoring and Adaptive Management

An adaptive management approach has been developed for attaining water quality and phosphorus reduction goals. The approach includes continued water quality monitoring and "course corrections" responding to results. Specific recommendations have been developed for effectiveness monitoring as water quality improvement projects are implemented. Additional in-lake monitoring protocols are also recommended to track progress to achieving lake management plan goals.

Implementation Plan

Implementing the recommendations of this management plan will involve a concerted effort from the many parties involved; the District, Spring Lake Township, Scott SWCD, the MnDNR, local sporting groups and the residents living on Fish Lake as well as those living and working within its watershed. Recommended management activities to meet the water quality goals established for the lake, have been developed and organized based on structure of the District's 2020 Water Resources Plan. The implementation table (Table 8) uses the format of the 2020 Water Resources Plan to facilitate incorporation of the Fish Lake Management Plan activities. The dollar amounts shown in Table 8 represent either the additional funding needed for Fish Lake management activities for the given budget category or an additional sub-category for the budget category to account for Fish Lake specific projects.

Capital Improvement Program

Specific in-lake and watershed improvement projects recommended to meet the water quality goals for Fish Lake have been developed and are proposed to be funded through use of the Districts Capital Improvement Program budget line item. The following Capital Improvement projects are being proposed (in order of priority).

1. In-lake Alum Treatments
2. Lake Ridge Estates Pond Retrofits Feasibility Study
3. Fish Lake West Wetland Restoration
4. Fairlawn Lane Lake Inlet Iron Enhanced Sand Filter
5. 200th Street Pond Improvements
6. 205th Street Pond Improvement
7. Malibu Ave Wetland Restoration

Operations and Maintenance Program

Additional recommended water quality improvement practices, specifically, residential stormwater management practices and lakeshore improvement are proposed to be funded through the District's existing Cost Share Program. The District's Farmer-Led Council Initiatives program is proposed to be utilized to fund recommended agricultural conservation practices Continued monitoring of Curly-leaf pondweed and other aquatic invasive species and continued monitoring of carp are also recommended. Funding for these activities is proposed to be funded using the District's Operations and Maintenance Program budget.

Planning and Program

The District's Water Resources Management Plan 2020-2030 will need to be updated to reflect the recommendations of this plan. The update is proposed to be funded by the District's Planning and Program budget.

Communications & Public Outreach

A public outreach campaign is being proposed to educate watershed residents about the Fish Lake Management Plan and specifically the recommendations for using alum for internal load management.

Monitoring Program

Additional monitoring of Fish Lake and the creek flowing into the lake is being recommended to assess trends in water quality and to evaluate progress toward achieving management plan goals. Project performance monitoring of specific projects is also recommended.

1. INTRODUCTION

The purpose of this Lake Management Plan (LMP) update is to determine the appropriate course of action to improve the water quality of Fish Lake. Fish Lake was added to the MPCA impaired waters list in 2002 for aquatic recreation due to excessive nutrients. However, it has been determined that Fish Lake is close to meeting state standards for recreational use and elevated levels of phosphorus are driving the presence of seasonal nuisance algae blooms. Past studies have reached conflicting conclusions as to the primary source of phosphorus loading in Fish Lake: watershed contribution versus internal loading (refer to Sections 2.D.i and 2.D.ii). The purpose of this LMP is to update the lake analysis using the most current data sources, determine the driver of phosphorus loading and make recommendations for management strategies.

To assist in developing this plan, two meetings were held with residents and local officials. Resident meetings were noticed through a series of four mailings to the 46 registered owners and residents of parcels surrounding Fish Lake. The first meeting was held on May 25, 2023, and had 20 residents in attendance. The meeting included an overview of the planning process, a review of past plans, and an introduction to watershed and lake science, which included preliminary findings from the assessment of Fish Lake. This meeting also included the setting of goals and objectives for the future management of Fish Lake through a facilitated discussion with residents. The second resident meeting was held on October 5, 2023, and had 11 residents in attendance. At this meeting, final assessment findings were presented to the group along with an overview of the implementation strategies to meet the goals of the plan.

A Technical Advisory Committee (TAC) made up of state and local agency representatives was established early in the planning process. Members representing the Minnesota Pollution Control Agency (MPCA), Minnesota Board of Soil and Water Resources (BWSR), Minnesota Department of Natural Resources (DNR), Metropolitan Council, Scott County, Spring Lake Township, and Scott Soil and Water Conservation District (SWCD) were invited to participate. Two TAC meetings were held, the first of which was on April 27, 2023. The objective of the first meeting was to review past modeling approaches and findings for Fish Lake and to solicit input into the proposed technical approach to be used for watershed and in-lake modeling. The condition of Fish Lake was also discussed. A follow-up TAC meeting was held on September 18, 2023, to review findings of the models and the implications for potential implementation strategies.

2. FISH LAKE ASSESSMENT

A. WATERSHED ASSESSMENT

i. General Setting

The Fish Lake watershed (699 acres) is located in Scott County, in southeastern Minnesota. It lies within the Prior Lake HUC-12 watershed, within the Minnesota River (HUC-10) basin. Water from Fish Lake (171 acres) flows north via an unnamed stream which feeds into Buck Lake. Buck Lake then eventually feeds into Spring Lake via an unnamed stream. The watershed to lake area ratio is 3:1.

ii. Historic Land Use

Prior to European settlement, the Fish Lake watershed would have contained a mosaic of aspen-oak woodlands, hardwoods, and various wet prairies (Figure 1). Post-European settlement the land use shifted to predominantly agricultural. Residential development in the watershed was primarily seen along the shore of Fish Lake and farmsteads along County Road 10 and Fairlawn Avenue until around 2000, when Lake Ridge Estates was completed northeast of the lake.

Figure 1. Fish Lake and surrounding areas 1992

As a result of conversion from woodlands and wet prairies to agricultural and residential land uses, the water balance of the Fish Lake watershed has changed from an evapotranspiration (ET) and infiltration dominated landscape to a landscape with elevated surface water runoff, increased shallow groundwater contributions via subsurface tile drainage, and volatile base flow conditions in receiving water bodies.

Past land uses, particularly agricultural, have resulted in sediment deposition in Fish Lake as documented in Phosphorus Release and Accumulation in the Sediments of Fish and Pike Lake, Scott County, Minnesota (Hermann and Hobbs n.d.). This study analyzed nine sediment cores sampled throughout Fish Lake for phosphorus in the upper six centimeters of sediment. The study found that phosphorus accumulation rapidly increased from 1910 to 1950, at which time it reached the highest level in the entirety of the collected record, 0.18 mgP/cm2/yr. The increase in phosphorus accumulation was attributed to increased agriculture following settlement of the area in the late 1800s, coupled with the increased usage of fertilizers towards the mid-1900s. A decrease in phosphorus accumulation rates occurred from 1980 to 1995, which is consistent with a decrease in agricultural production commonly referred to as the Farm Crisis. Since 1995, the phosphorus accumulation has increased to the current level of 0.14 mgP/cm2/yr.

iii. Current Land Use/Land Cover – Implications for Pollutant Sources

The types of land cover within a watershed, such as forests, urban areas, agricultural fields, and wetlands, greatly influence the quality of water that flows into the lake. A watershed is the area of land that drains into a particular lake, river, or other water body. Watershed land cover plays the following role in determining water quality in downstream resources:

- Runoff and Erosion: Different land covers affect how rainfall and runoff move across the landscape. Forests and wetlands tend to slow down and absorb water, reducing the amount of runoff and erosion. On the other hand, urban areas and agricultural fields can increase runoff and erosion due to impervious surfaces and soil disturbance.
- Sedimentation: Land cover influences the amount of sediment (soil particles) that washes into the lake. Excessive sedimentation can cloud the water, disrupting light penetration and harming aquatic plants and animals.
- Nutrient Loading: Agricultural areas can contribute to nutrient pollution through runoff of fertilizers and manure. Urban areas can also introduce pollutants like nitrogen and phosphorus through stormwater runoff. These nutrients can cause excessive algae growth (eutrophication), leading to oxygen depletion in the water and negative impacts on aquatic ecosystems.
- Pollutant Transport: Urban areas often produce various pollutants that can be transported into the lake through runoff. These pollutants might include chemicals, heavy metals, and toxins, which can harm aquatic life and human health.

- Buffering and Filtering: Natural land covers like forests and wetlands can act as buffers and filters. They can trap and absorb pollutants, nutrients, and sediment before they reach the lake, helping to improve water quality.
- Temperature Regulation: Vegetated areas provide shade, which can help regulate water temperature in the lake. Excessive warming due to lack of vegetation can stress aquatic organisms and disrupt the lake's ecological balance.
- Biodiversity and Habitat: Natural land cover types support diverse ecosystems, which in turn contribute to water quality. Diverse plant and animal communities can help maintain a balanced ecosystem that can better handle environmental changes and stressors.
- Resilience to Climate Change: Certain land covers, such as wetlands and riparian zones (areas along water bodies), can provide resilience against the impacts of climate change, such as flooding and drought. They can store water, reduce flood risks, and recharge groundwater.

The Fish Lake watershed is relatively small with a watershed to lake surface area ratio of 3:1. A watershed to lake ratio below 10:1 is considered small and is typically associated with a lake having good water quality.

Today, approximately 22% of the Fish Lake watershed is developed to some degree. Development within the watershed primarily consists of single-family residences on large lots and along the perimeter of the lake. Agricultural land use within the watershed has decreased over time and currently accounts for 21% of the land cover. Agricultural production in the watershed includes a mix of row-crops and pastureland. Grasslands account for 19% of the landcover within the watershed. Grasslands include a mix of lawns not associated with a building, natural prairie areas, parklands, and sometimes pastureland. Open water accounts for 25% of the watershed area (including Fish Lake itself) and wetland areas account for an additional 6% of the area. The remaining 7% of the watershed is forested/wooded (Figure 2).

The land cover within the watershed was used to develop a pollutant load model which is described in further detail in the pollutant source assessment section.

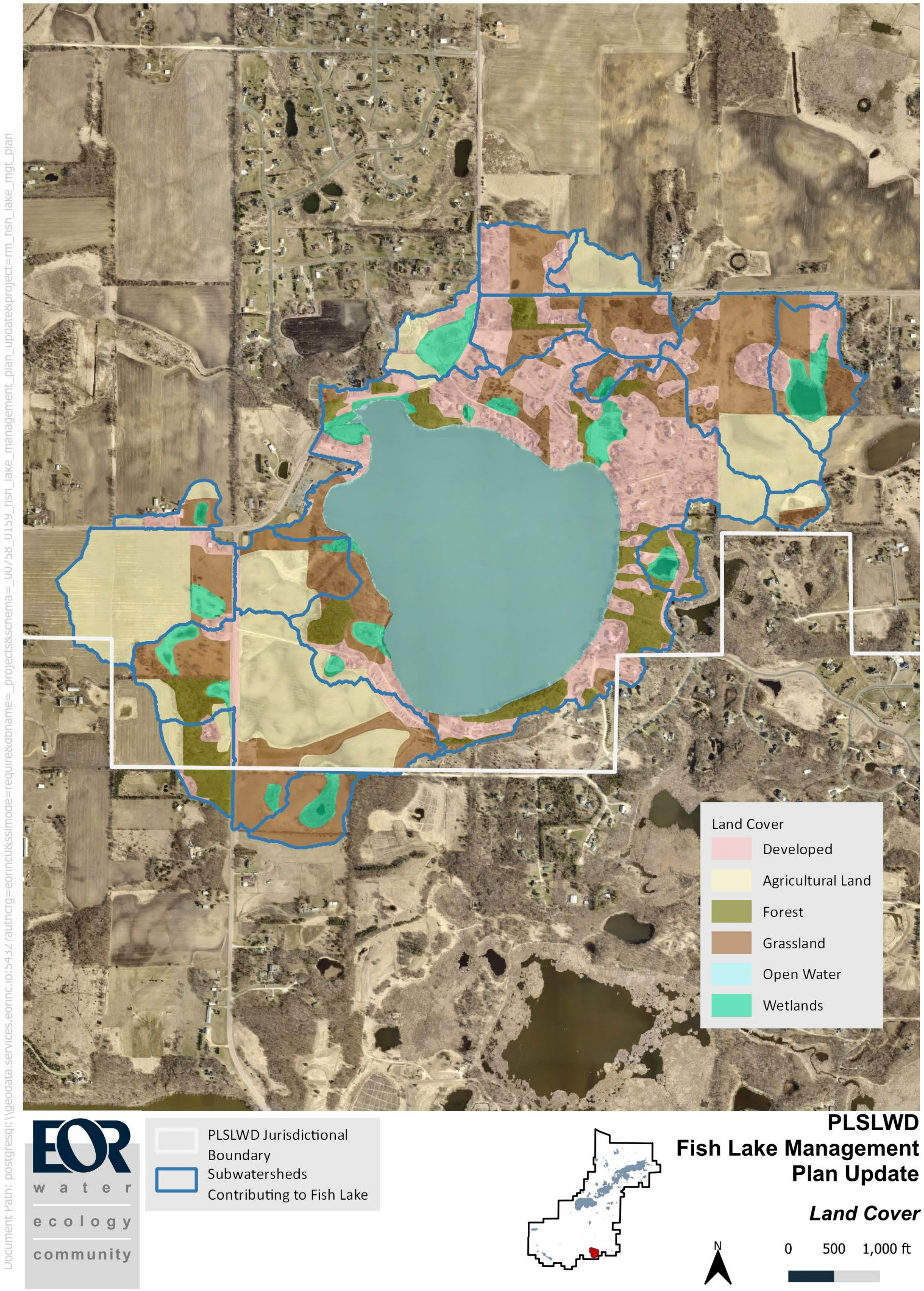

Figure 2. Fish Lake Watershed Land Cover.

iv. Soils

The Natural Resources Conservation Service’s Web Soil Survey Interactive Viewer was queried to develop a Custom Soil Resource Report for the Fish Lake watershed. Soils are predominately Hayden and Lester Loams and hydric soils make up 17% of the watershed (Figure 3). Hydric soils make up 28.5% of the watershed's agricultural land.

Hydric soils are soils saturated with water for extended periods of time, leading to low to no-oxygen environments. When oxygen levels go down, iron is reduced from the Fe3+ form to Fe2+, and the phosphate that was complexed with the Fe3+ is released and becomes mobile. Mobile phosphates can be transported by runoff into the lake. Hydric soils in agricultural land may release more phosphorous due to high historic accumulation and saturation during growing seasons.

In 2023, EOR sampled soil throughout the watershed to determine the amount of phosphorus in the soil that is available for uptake by plants. The average phosphorus concentration from across the watershed is below the concentration associated with nutrient runoff. However, there were some hot spots throughout the watershed. Section 2.D.iv comprehensively summarizes the soil sampling procedures and findings.

v. Feedlots

Feedlots are an animal farming operation consisting of an open air fenced-in field which houses farm cattle to feed them. Feedlots typically produce large amounts of manure, which is often spread on the neighboring or nearby fields. Precipitation on these feedlots and fields can be problematic due to runoff. Runoff can pick up organic matter, nutrients and pathogens from the animal waste and transport them to Fish Lake. While feedlots do not purposely discharge water pollutants, mismanagement of onsite runoff and uncontrolled runoff from the manure spreading locations can pollute local water resources. Historically, there were two feedlots within or immediately near the Fish Lake watershed. One site was located at the northwestern edge of the watershed at 205th Street near Malibu Avenue. This site ceased operations several years ago and is unlikely to restart operation. A second feedlot was in operation in the northeastern portion of the watershed near 200th Street. This site has been without cattle or had very few on pasture for the last 20 years. It is unlikely that any of the fields for either site will see manure spread in the near future. Past operation of these feedlots could have potentially loaded the soils with high levels of phosphorus if excessive amounts of manure were spread on adjacent fields. To assess whether watershed soils have high levels of phosphorus, a comprehensive soils analysis was conducted. See the 2023 Watershed Soils Analysis section for a summary of the soils analysis and findings.

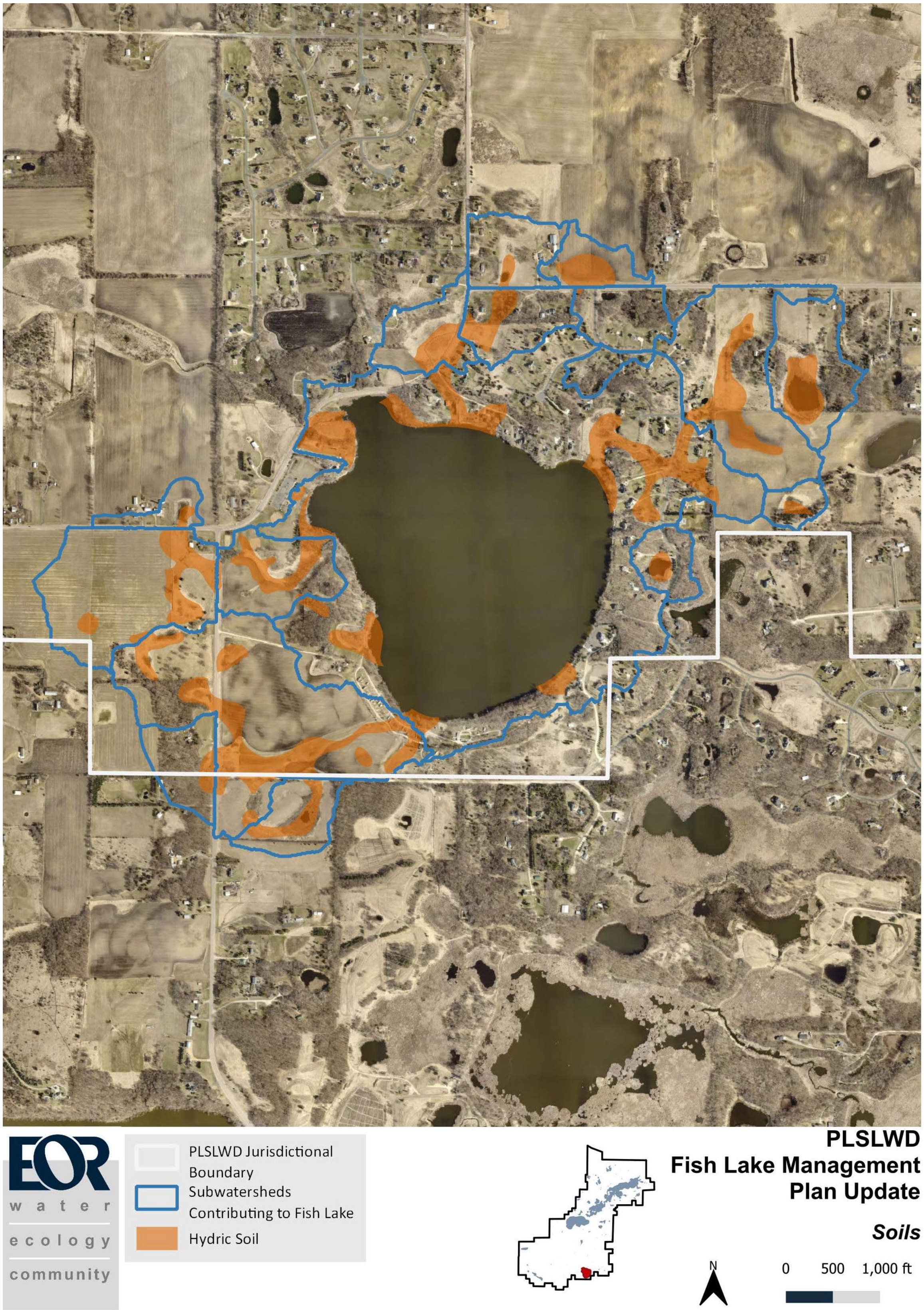

Figure 3. Hydric Soils in the Fish Lake Watershed

vi. Septic Systems

Septic systems are storage and treatment systems for wastewater. They are often used in more rural locations for residences that do not have access to a regional wastewater treatment facility. The system is made up of a septic tank, drain field, and pipes. The buried tank has a compartment which collects the wastewater from the residence, which sits until solids settle out to the bottom and fats, oils, and greases rise to the top. Microorganisms in the tank break apart the sludge and contaminants in the wastewater. Compartments in the tank keep the sludge and solids contained and treated water is allowed to flow out to the drainage field. The drainage field discharges water into the surrounding soil where it percolates down into the groundwater. This percolation through the soil filters the water until it reaches the groundwater.

Improper construction and maintenance of septic systems can prevent the system from treating wastewater correctly. This allows wastewater to be released from the system into the groundwater prematurely via the drainage field. This wastewater often carries pollutants and contaminants such as phosphorus, nitrogen, and bacteria. The groundwater can then carry the wastewater pollutants directly to Fish Lake.

Residences in the Fish Lake watershed are served by individual septic systems. A community septic system was built in 2002-2003 to serve several homes that needed system upgrades or replacements and did not have the available space onsite to accommodate the septic systems. The community septic field is located on land owned by Spring Lake Township on parcel number 110790110 at the address 20121 Fairlawn Avenue, Prior Lake, MN 55372. The location is southeast of the intersection of Fairlawn Avenue and 200th Street East and is the second parcel south of that intersection from 200th Street East.

A property owner adjacent to the Spring Lake Township septic system has expressed concern that drain tile in use prior to installation of the septic system may not have been appropriately disabled and may still be connected to the downstream tile system. Now that the outlet of the tile from the southeast has been disabled, that water has no place to flow and thus has generated a wet area where it intersected this tile historically. With no outlet, that water could potentially rise out of the ground, making a wet area which can flow into the road ditch and get to Fish Lake.

If the historical field tile drainage is still operating in some capacity near the septic field, the tile could potentially draw some leakage from the septic field and send it to the wet spot, which could then drain to Fish Lake via the ditch. Watershed and Scott Soil and Water Conservation District staff conducted further investigation, including a site visit and sampling of water in the downstream ditch, both of which suggested no presence of septic drainage getting into the ditch system. Water quality testing done on the ditch water samples did not show elevated concentrations of parameters that would be associated with human waste. Further investigation, including samples downstream of the system, should be conducted when there is flow coming out of the tile in order to verify that septic drainage is not occurring. While it is unlikely that there is a direct contribution of septic waste from this specific facility, failing septic systems could be a potential source of phosphorus to Fish Lake.

B. FISH LAKE ECOLOGY

i. Fisheries

The Minnesota DNR conducts periodic fisheries surveys on Fish Lake. The most recent survey was conducted in 2019. Fish Lake is primarily managed for Walleye, but includes catchable populations of Largemouth Bass, Bluegill, and Black Crappie. Other fish species sampled in 2019 include: Golden Shiner, Green Sunfish, Northern Pike, Pumpkinseed, White Crappie, White Sucker, Yellow Bullhead, and Yellow Perch.

The 2019 survey showed good numbers of Walleye with an average gill net catch rate of 4.3/net. Twenty-six Walleye were sampled in gill nets with an average length of 14.2 inches and maximum of 22.2 inches. Walleye growth in Fish Lake was modest compared to the statewide average and the MNDNR concluded that due to above average catch rates and sizes, Fish Lake provides Walleye angling potential.

The 2019 survey used nighttime boat electrofishing for Largemouth Bass for the first time and resulted in a high catch rate of 75.3 fish/hour. The average size was 13.0 inches (50% exceeded 13”) and the largest measured was 20.8 inches. The MNDNR concluded that despite high numbers, bass continue to reach large sizes desirable to anglers.

The 2019 survey found above average numbers of Bluegill (47.8/net), compared to similar lakes in the area with 430 total Bluegill sampled in trap nets. The average length of Bluegill trapped was 6.9 inches and the largest measured was 8.5 inches. The majority of sampled Bluegill (59%) were greater than 7 inches, providing excellent angling opportunity.

Black Crappies were found in high rates (10.0/net) in gill nets but very low rates (0.2/net) in trap nets during the 2019 survey, suggesting they may be using more offshore habitat in Fish Lake. Sixty-two Black Crappie were sampled with an average length of 7.8 inches and the largest measured was 9.9 inches.

Common Carp were not sampled in the 2019 MNDNR survey, but the Watershed District conducted catch per unit effort (CPUE) surveys for Carp in the fall of 2019 and 2023. CPUE is an indirect measure of the abundance of a target fish species that is commonly used for Carp. The surveys showed a low abundance of Carp in the lake (88.7 kg/ha in 2019 and 57 kg/ha in 2023). Stirring of lake-bottom sediments is not considered to be a concern with Carp at this level of abundance, therefore the District has not initiated Carp management on Fish Lake. However, the surveys also showed a decreased average size, indicating a reproduction event. It is recommended to continue to monitor the Carp population.

Fisheries management on Fish Lake includes scheduled Walleye fingerling stocking during odd-numbered years at a rate of 1 pounds per littoral acre (74 pounds), with other sizes/ages/amounts substituted if insufficient fingerlings are available.

In a 2005 assessment, elevated levels of mercury were found in tissue from fish within Fish Lake. As a result, Fish Lake has been determined to have an Aquatic Consumption Beneficial Use impairment. When consuming fish from Fish Lake, statewide fish consumption guidance developed by the Minnesota Department of Health (Fish Consumption Guidance - MN Dept. of Health (state.mn.us) should be followed.

ii. Aquatic Plants

Aquatic plants play an important role in the ecological health of lakes. Some of the key ecological benefits provided by these plants include:

- Oxygen production: Aquatic plants produce oxygen through photosynthesis, which helps maintain healthy oxygen levels in the water and supports aquatic life.
- Habitat creation: These plants provide important habitat and cover for fish, invertebrates, and other aquatic organisms, which can improve overall biodiversity in the lake.
- Nutrient cycling: Aquatic plants help regulate nutrient cycles by taking up and storing nutrients like nitrogen and phosphorus, which can help prevent excessive algal growth and reduce the risk of harmful algal blooms.
- Sediment stabilization: The root systems of aquatic plants help stabilize lake sediments, which can help reduce erosion and improve water clarity.
- Water filtration: These plants can help filter out pollutants and other contaminants from the water, improving water quality and reducing the risk of harmful effects on aquatic life and human health.

Overall, the presence of aquatic plants in lakes can help promote a healthy and balanced ecosystem. However, excessive growth of these plants can also negatively impact lake use, which may concern lake users.

Aquatic plant surveys have been conducted on Fish Lake by Blue Water Science in 2015, 2018, 2020 and August 1, 2022. The surveys are conducted using the point intercept method. Additionally, meander surveys are conducted in the spring and early summer to delineate and assess Curly-leaf pondweed in the lake to determine if treatment is needed.

The 2022 aquatic plant point intercept survey found a total of eight aquatic plant species, of which six were submerged species. Coontail was the most common plant. Other native species found were; Spatterdock, White water lilies, Flatstem pondweed, Sago pondweed, Water celery, and

Water stargrass. Curlyleaf pondweed was the only invasive species observed. The surveys conducted in 2015, 2018, and 2020 indicate a stable plant community.

One particularly interesting note within the 2022 aquatic plant survey is the finding that plants were generally only observed to a depth of 6 feet in Fish Lake, which is much shallower than the littoral (area of plant growth) depth of 15 feet typically seen in lakes in this region.

The 2022 Curlyleaf pondweed (CLP) meander surveys took place on April 26 and June 2. During the April survey, CLP was found at 5 of 65 sites and growth was classified as being light to moderate at all of the survey sites. No areas of heavy growth were identified. During the June survey, CLP was found in 20 of 154 sites with mostly light growth rates. Only one area of heavy growth was identified. The findings of the 2022 CLP survey resulted in a recommendation to not conduct any CLP management activities. Past CLP management activities have included application of a selective herbicide, Aquathol K. In 2005, 2006, 2007, and 2008, 15.5 acres were treated with early-season application of Aquathol K. There have been no CLP herbicide treatments in Fish Lake since 2008. A CLP survey was conducted in April 2023 and due to the scattered nature of CLP, treatment was not recommended.

iii. Riparian Area

The lake riparian area, which refers to the zone of land adjacent to a lake's shoreline, plays a crucial role in maintaining and influencing the quality of the lake ecosystem. Its impact is multifaceted:

- Water Quality Mitigation: The riparian area acts as a natural buffer zone, filtering and absorbing pollutants, sediments, and nutrients from runoff before they enter the lake. Plants in the riparian zone contribute to nutrient cycling by taking up excess nutrients like nitrogen and phosphorus from runoff. This can help prevent over-enrichment of the lake with nutrients, which can lead to issues like harmful algal blooms.
- Habitat and Biodiversity: Riparian zones provide important habitats for various plant and animal species. They offer food, shelter, and breeding sites for aquatic and terrestrial organisms, contributing to the overall biodiversity of the ecosystem.
- Bank Stabilization & Erosion Control: The roots of riparian plants help anchor the soil, preventing bank erosion and maintaining the structural integrity of the shoreline. This is particularly important during storms or high-water events. The vegetation in riparian areas, including trees, shrubs, and grasses, helps stabilize the soil along the shoreline. This prevents soil erosion and reduces sedimentation in the lake, which can negatively impact water quality and aquatic habitats.

Overall, the health and integrity of the lake riparian area are closely linked to the water quality and ecological balance of the lake itself. Proper management and conservation of these zones are essential for preserving the long-term health and sustainability of lake ecosystems.

To evaluate the current condition of Fish Lake's riparian area, a shoreland assessment was conducted in Summer 2023 using the Lake Shoreland & Shallows Habitat Monitoring Field Protocol (WIDNR, 2020). The protocol provides a standard methodology for surveying, assessing, and mapping habitat in lakeshore areas, including the Riparian Buffer, Bank, and Littoral Zones. Specific information collected in the process includes an assessment of vegetative cover within the riparian area, presence of man-made objects, impervious surfaces, 'manicured' lawns, bare soil, rip rap and boat ramps, among others. The assessment can be used to evaluate the overall health of a lake's riparian area and to identify areas where improvements can be made to reduce pollutant inputs to the lake. A rating system has been developed by Wisconsin DNR to classify lake shoreland areas as natural, moderate, or developed based on findings from the assessment protocols as shown in Table 1.

Table 1. Shoreland Rating

	Rating Criteria			
Shoreline Rating	Description	Tree Canopy	Manicured Lawn	Impervious Area
Tier 1 – Natural	Parcel with low potential for nutrient export to lake	80-100%	0-20%	0-5%
Tier 2 – Moderate	Parcel with medium potential for nutrient export to lake	40-80%	20-40%	5-20%
Tier 3 – Developed	Parcel with high potential for nutrient export to lake	0-40%	40-100%	20-100%

Overall, the shoreland of Fish Lake is in good condition. Tree canopy cover within the shoreland area is 67% and only 20% of the shoreland areas have manicured lawn. The findings of the shoreland assessment are shown in Figure 4.

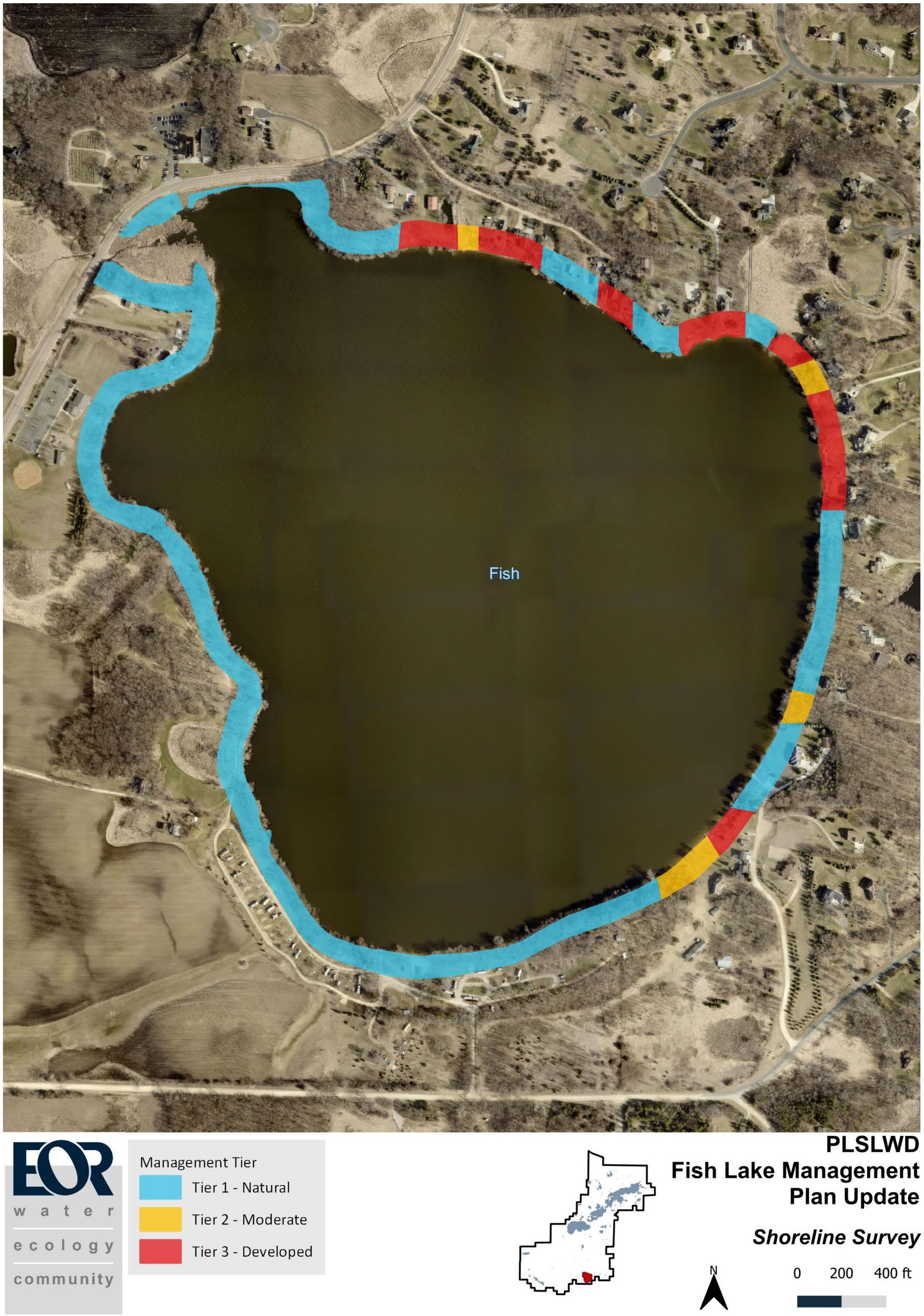

Figure 4. Fish Lake Shoreland Rating Summary

iv. Zooplankton

Zooplankton are tiny, free-floating animals that play an important role in the ecological health of lake ecosystems. Some of the key characteristics and roles of zooplankton in lakes include:

- Size and diversity: Zooplankton range in size from microscopic organisms to larger species visible to the naked eye, and include a wide range of animal groups, such as crustaceans, rotifers, and insect larvae.
- Food source: Zooplankton serve as a primary food source for many fish and other aquatic organisms and are an important link in the lake's food chain.
- Nutrient cycling: Zooplankton help regulate nutrient cycles in lakes by consuming algae and other small organisms, which can help prevent excessive algal growth and improve water quality.
- Indicator of lake health: The presence and diversity of zooplankton in a lake can be an indicator of overall lake health, as changes in their populations can reflect changes in water quality, nutrient levels, and other environmental factors.
- Susceptibility to environmental stressors: Zooplankton populations can be highly sensitive to changes in environmental conditions, such as temperature, pH, and nutrient levels, which can have cascading effects on the rest of the lake ecosystem.

Overall, zooplankton are an important component of lake ecosystems, providing key ecological functions and serving as an indicator of overall lake health.

No surveys or assessments of the zooplankton community within Fish Lake have been conducted to date. Anecdotal evidence, particularly the heath of the lake's fisheries, suggests that the lake has a healthy zooplankton community.

v. Phytoplankton & Algae

Phytoplankton are microscopic, free-floating plants that play a critical role in the ecological health of lakes. It is important to note that the terms "phytoplankton" and "algae" are often used interchangeably, but there is a distinction between the two. While all phytoplankton are algae, not all algae are phytoplankton. Algae can refer to any type of aquatic, photosynthetic organism, including those that are attached to surfaces or are large enough to be visible to the naked eye. Phytoplankton specifically refers to those algae that are small enough to float freely in the water column.

Some of the key characteristics and roles of phytoplankton in lakes include:

- Primary production: Phytoplankton are the primary producers in lake ecosystems, converting energy from the sun into organic matter through photosynthesis.

- Nutrient cycling: Phytoplankton help regulate nutrient cycles in lakes by taking up and storing nutrients like nitrogen and phosphorus, which can help prevent excessive algal growth and improve water quality.
- Food source: Phytoplankton serve as a primary food source for many zooplankton and other aquatic organisms, which in turn provide food for fish and other larger predators.

Algae are a diverse group of aquatic organisms found in Minnesota lakes, ranging from single-celled organisms to larger, multicellular forms. They are important in aquatic food webs and can also impact water quality and human health. Three main groups of algae are commonly found: green algae, blue-green algae, and diatoms. These groups can be distinguished by their growth form and pigmentation.

Green algae: These algae are typically green in color due to the presence of chlorophyll and can form a variety of growth forms, including unicellular, colonial, and filamentous. Some common green algae species found in Minnesota lakes include:

- Cladophora: a green algae that forms dense, tangled mats, and is commonly found in shallow areas of lakes and rivers.
- Cryptomonas: a common algae in freshwater habitats and brackish water worldwide often forming blooms in greater depths of lakes. Small counts of Cryptomonas were found in algae sampling conducted on Fish Lake (see May 2023 Algal Bloom summary below).
- Spirogyra: a green algae that forms long, unbranched filaments and is often found in stagnant or slow-moving waters.
- Chara: a macroscopic green algae that forms dense mats in shallow waters.

Blue-green algae: Also known as cyanobacteria, these algae can have a range of colors including blue-green, brown, and red. They can form colonies or mats and are often found in warm, nutrient-rich waters. Some common blue-green algae species found in Minnesota lakes include:

- Oscillatoria: a blue-green algae that forms dark green or black mats and is commonly found in nutrient-rich, shallow waters. Small counts of Oscillatoria were found in algae sampling conducted on Fish Lake (see May 2023 Algal Bloom summary below).
- Microcystis: a blue-green algae that can form toxic blooms and is often found in warm, nutrient-rich waters.
- Anabaena: a blue-green algae that forms long chains and is commonly found in nutrient-rich, stagnant waters.
- Aphanizomenon: a blue-green algae that can form toxic blooms and is often found in cooler, nutrient-rich waters.

Diatoms: These algae are single-celled and have a silica cell wall, which gives them a distinct shape. They are typically found in cool, clear waters and can form large blooms under the right conditions. Some common diatom species found in Minnesota lakes include:

- Fragilaria: a diatom that forms spring blooms and is often found in nutrient-rich waters. Significant counts of Fragilaria were found in algae sampling conducted on Fish Lake in May 2023 thus accounting for the visible bloom occurring at the time (see Section 2.B.vii summary below).
- Melosira: a diatom that forms long chains and is commonly found in cool, deep waters.
- Navicula: a diatom that can form large blooms and is often found in shallow, nutrient-rich waters.

vi. Harmful Algal Blooms (HABs)

Harmful algae blooms, or HABs, are a growing concern in Minnesota lakes. These blooms occur when cyanobacteria grow rapidly and produce toxins (cyanotoxins) that can harm people and animals. In Minnesota, HABs have been reported in several lakes, including Lake Minnetonka, Lake of the Woods, and Mille Lacs Lake. The Minnesota Department of Health issues warnings when HABs are detected in a lake, advising people to avoid contact with the water and to keep pets and livestock away.

The causes of HABs in Minnesota lakes are complex and can be influenced by several factors, including nutrient levels, water temperature, and weather patterns. However, human activities such as fertilizer runoff, sewage discharge, and urbanization can also contribute to the problem. It is important to monitor the health of lakes and act when HABs are detected, such as closing beaches or treating the water with chemicals to reduce the bloom.

Some of the most common cyanotoxins found in Minnesota lakes include:

- Microcystins: These are a type of cyanotoxin that are produced by certain species of blue-green algae, particularly during algae blooms, that are harmful to both humans and animals if ingested. They can cause a range of health effects including liver damage and gastrointestinal distress. They have been linked to deaths in pets and are also considered a potential carcinogen. Microcystins are known to persist in the environment, which means that they can accumulate in the food chain and have long-term impacts on aquatic ecosystems. Anatoxin-a: This toxin affects the nervous system and can cause paralysis and respiratory failure.
- Cylindrospermopsin: This toxin can cause liver damage and gastrointestinal problems.
- Saxitoxins: These toxins affect the nervous system and can cause paralysis and respiratory failure.

It is important to note that the presence of cyanobacteria does not always mean that toxins are present, and not all cyanotoxins have been identified in all Minnesota lakes. It is recommended to check with the Minnesota Department of Health or local authorities for any potential health advisories or warnings related to cyanobacteria or cyanotoxins in lakes before swimming or recreating in the water.

vii. May 2023 Algal Bloom

In early May 2023, a lake resident reported the presence of a reddish-brown, algae-type bloom on Fish Lake, as seen in Figure 5. District staff collected a sample of the bloom for analysis, and it was determined to be a diatom called Fragilaria. Fragilaria is a type of phytoplankton that is known to form large blooms in the spring months when water temperatures begin to rise. Spring blooms of Fragilaria are a phenomenon that has been observed in many lakes that experience multiple mixing events during the year. Refer to Section 2.D.vii for further description.

Figure 5. Fish Lake Bloom of May 2023 (photo credit: Matt Newman)

These blooms are important because they provide a food source for zooplankton, which in turn supports higher trophic levels, such as fish. However, excessive growth of Fragilaria can also lead to negative impacts on water quality, such as reduced clarity and oxygen depletion, which can harm aquatic organisms.

Research has shown that the timing and intensity of Fragilaria blooms can be influenced by a range of factors, including water temperature, nutrient availability, and light availability. Nutrient availability, especially phosphorus, is a key factor in promoting the growth of Fragilaria and other phytoplankton.

C. WATER QUALITY

i. Regulatory Setting

The Clean Water Act (CWA) is a federal law enacted in 1972 to regulate and improve the quality of the nation's waters, including lakes, rivers, streams, and wetlands. The CWA establishes a framework for setting water quality standards and implementing measures to achieve and maintain those standards. The CWA requires states to assess and identify impaired waters, i.e. those that fail to meet their designated uses, such as swimming, fishing, and maintaining a healthy aquatic ecosystem. States must then strive to restore impaired waters by developing a Total Maximum Daily Load (TMDL) which is a calculation of the maximum amount of a pollutant a water body can receive while still meeting water quality standards.

Minnesota’s impaired waters program is managed by the Minnesota Pollution Control Agency (MPCA) in collaboration with other state agencies, tribes, local governments, and citizens. Its main goal is to assess, monitor, and restore waters that do not meet water quality standards due to pollution or other factors. The MPCA compiles a list of impaired waters, known as the "Impaired Waters List," which is submitted to the U.S. (United States) Environmental Protection Agency (EPA) for approval.

Minnesota's impaired waters program incorporates the TMDL process, which involves identifying pollution sources, setting limits, and implementing strategies to reduce pollutant loads to improve water quality.

Fish Lake was originally assessed by the MPCA in 2001, at which time it was determined to be impaired for its designated use, Aquatic Recreation. This was due to excessive algae caused by the presence of nutrients such as phosphorus in the water. Fish Lake was included on the state’s impaired waters list. The most recent MPCA assessment, completed in 2020, showed continued impairment of Fish Lake by phosphorus. The total phosphorus impairment threshold for North Central Hardwood Forest – Aquatic Recreational Use lakes (2B), like Fish Lake, is 40 µg/L. The 10-year average total phosphorus for Fish Lake is 42 µg/L.

ii. Trophic State Index (TSI)

One method of evaluating the fertility/productivity of a lake is by computing water-quality indices such as the Trophic State Index (TSI), which considers Chlorophyll–a (CHL-A), Total Phosphorus (TP), and Secchi depth (water clarity) (Figure 6). The State of Minnesota uses a mathematical formula that produces a TSI score that ranges from 0 to 100, with lakes that are less productive having a low TSI.

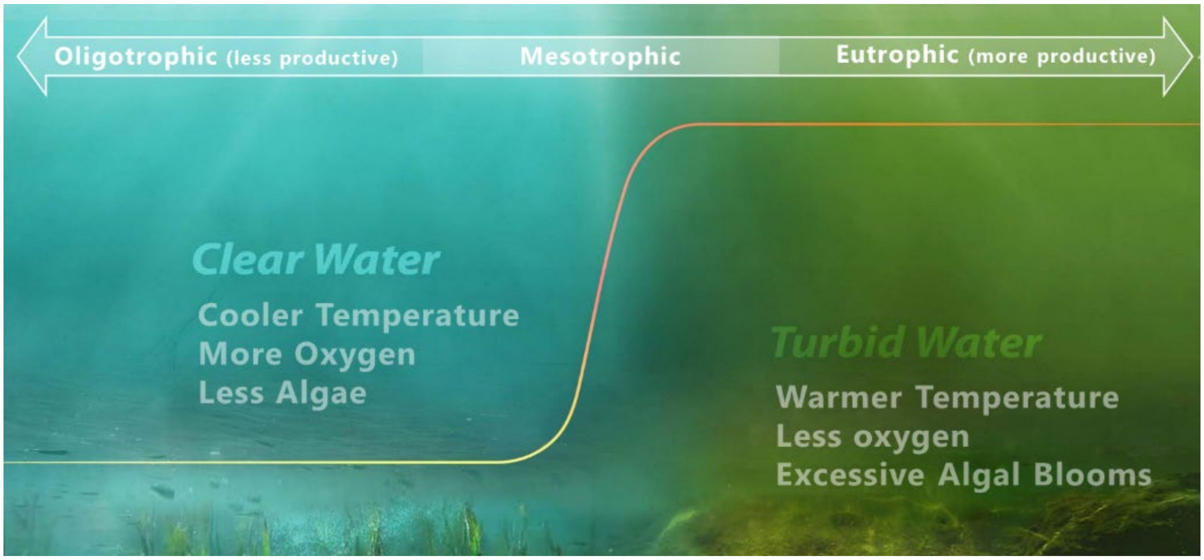

Figure 6. Trophic State Index Diagram – a measure of fertility/lake productivity.

Water quality data collected by the Three Rivers Park District from 2004-2022 suggests TSI scores in Fish Lake have remained consistent between 50 and 60 (refer to Figure 7). Lakes with TSI scores between 50 and 60 are best classified as eutrophic. These lakes have decreased clarity, fewer algal species, oxygen-depleted bottom waters during the summer, plant overgrowth evident, and primarily support warm-water fisheries (pike, perch, bass, etc.). TSI scores calculated based on observed CHL-A (TSI-CHL-A) concentrations were consistently greater than TSI scores calculated based on observed Secchi disk measurements. When TSI-Chl-A scores are higher than TSI-Secchi Disk scores, that indicates large particulates are dominating algal blooms, particularly blue-green algae species like aphanizemon.

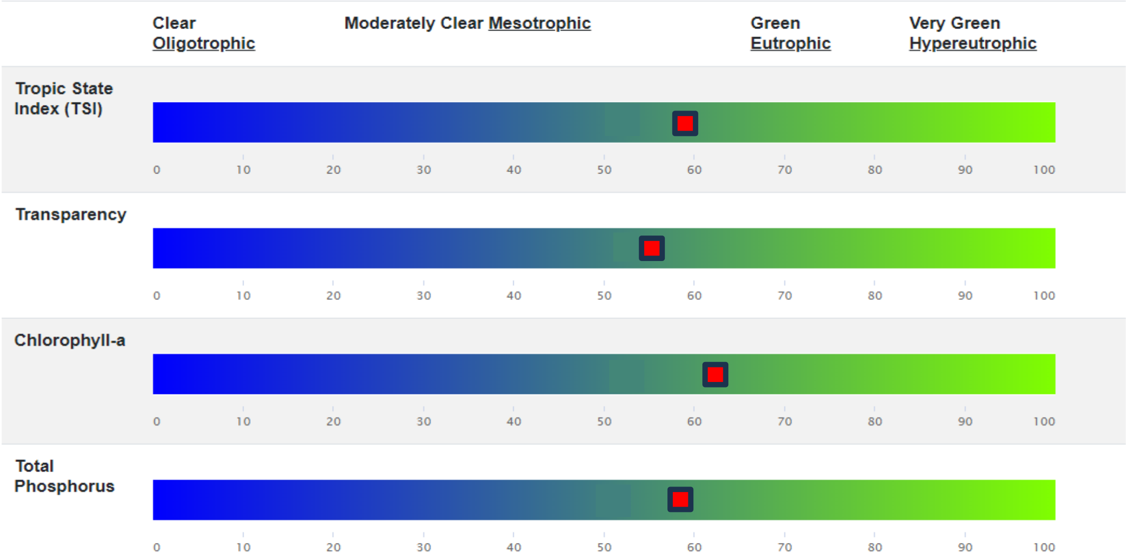

Figure 7. Fish Lake Trophic State Index 2004-2022

iii. Limiting Nutrients

The ratio of total nitrogen to total phosphorus (N:P ratio) in the lake can indicate which nutrient is likely to be limiting algal growth. When the N:P ratio is greater than 15:1, the lake is likely phosphorus limited, while a ratio of less than 10:1 indicates nitrogen is most likely the limiting nutrient. Ratios between 10:1 and 15:1 indicate periods in time in which either nutrient could be considered limiting. The average N:P ratio for Fish Lake from 2004-2022 was 26:1 but oscillated between 13 and 47 (Figure 8).

N:P Ratios in Fish Lake are lowest following mixing events, specifically during spring and fall turnover (April/October), when surface phosphorus concentrations are highest. N:P ratios are highest during the summer, when surface water phosphorus concentrations are lowest. The low N:P ratios in the spring and fall are caused by the presence of iron-poor sediments in Fish Lake. When these sediments are exposed to anoxic conditions during summer and winter stratification, followed by spring and fall mixing events, Fish Lake experiences episodic releases of highly bioavailable phosphorus from its sediments. This seasonal change lowers the N:P ratios in the euphotic zone (the top of the water column, which sunlight can penetrate) of Fish Lake in the spring and fall (refer to Figure 9). Algal blooms are often observed early in the growing season in Fish Lake, usually within two weeks of ice-off. The release of highly bioavailable phosphorus from iron-poor sediments and subsequent algal blooms is a well-documented phenomenon in eutrophic lakes (Orihel et., al, 2015).

Average monthly lake surface water total phosphorus (TP) concentrations are highest during the spring and fall, during mixing events. Average lake surface water TP concentrations are lowest during the summer during periods of stratification where dissolved oxygen concentrations are near zero in the portions of the lake that are deeper than 11.5 feet (Figure 10). Hypolimnetic (lake bottom) phosphorus concentrations are highest during these periods of stratification.

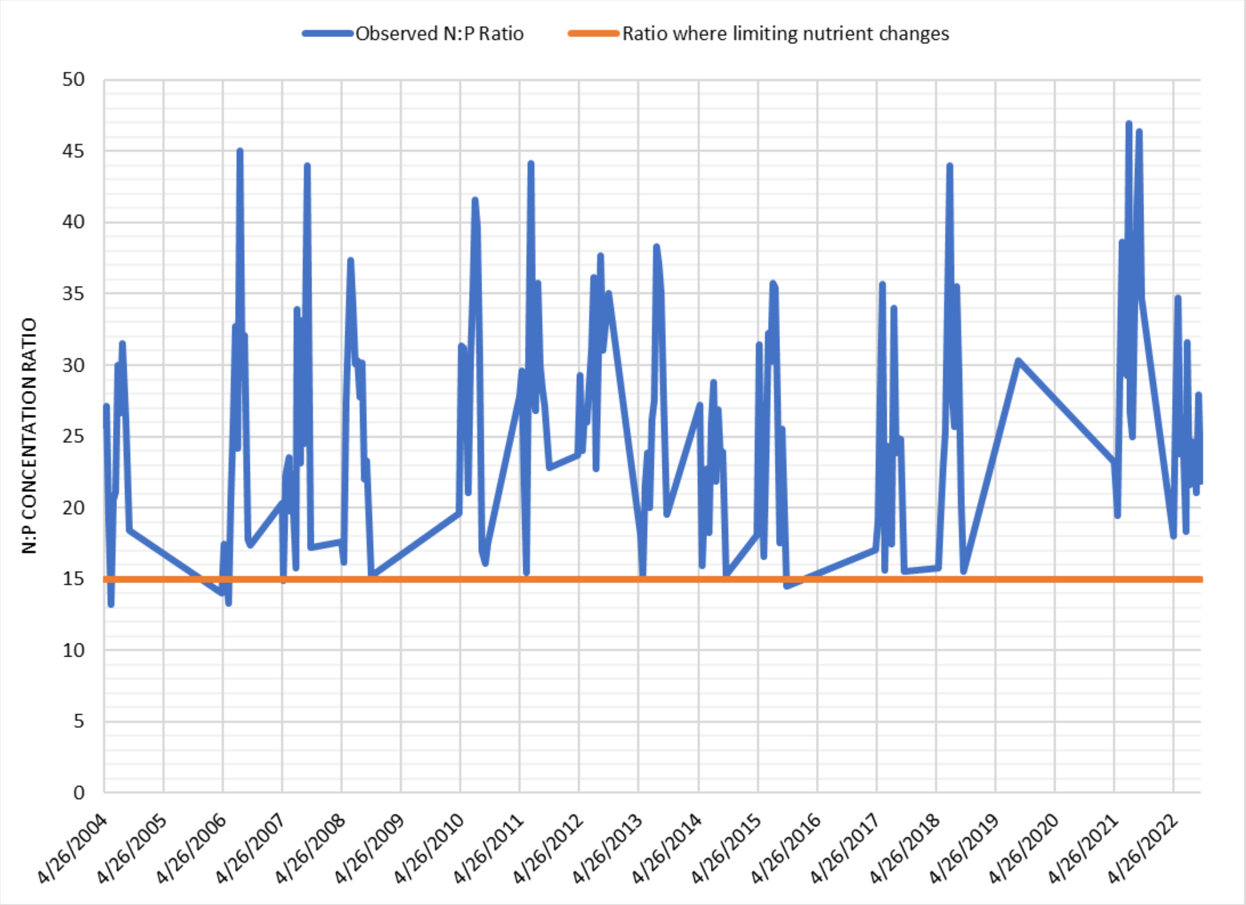

Figure 8. Total Nitrogen to Total Phosphorus Ratios

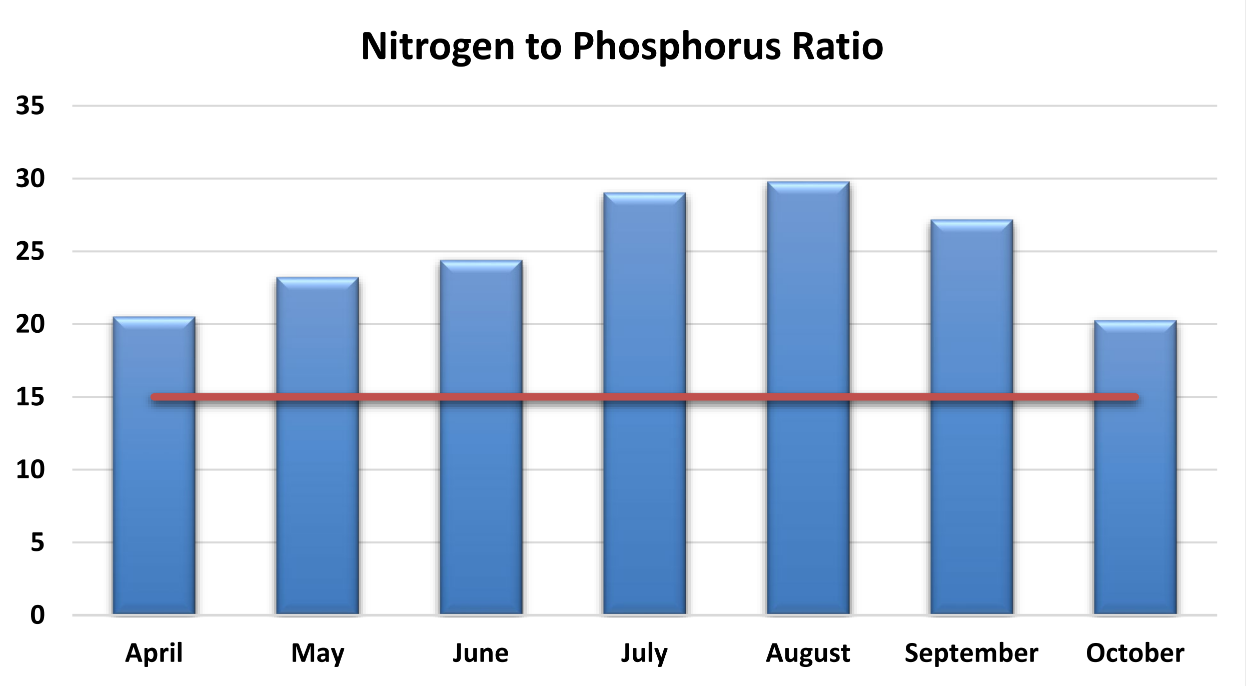

Figure 9. Nitrogen to Phosphorus ratios by month in Fish Lake, 2000-2023.

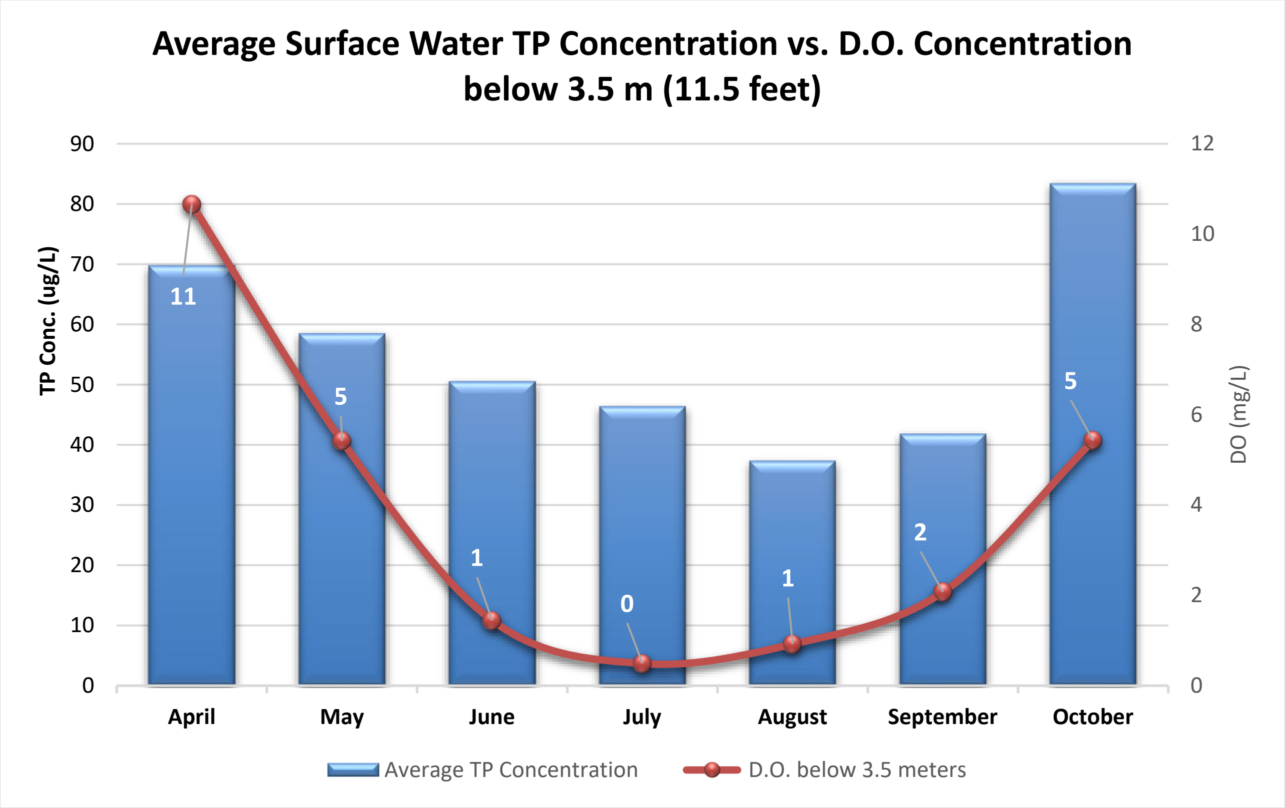

Figure 10. Average monthly surface water TP concentration versus observed dissolved oxygen concentrations below 3.5 meters (11.5 feet) for 2012-2022.

D. POLLUTANT SOURCE ASSESSMENT

To date, several assessments have been conducted to determine the phosphorus loading dynamics in Fish Lake. These efforts have been conducted in an effort to determine the relative contribution of phosphorus to the lake in order to inform management strategies. The findings of these assessments have varied considerably, from suggesting watershed loading is the primary source of phosphorus to the lake to pointing towards internal phosphorus loading as the primary driver (see Table 2).

i. Previous Assessment – Sustainable Lake Management Plan for Fish Lake, PLSLWD, April 2006

In 2006, a SWAT watershed model was developed for the Fish Lake watershed as part of a lake management planning effort led by Prior Lake-Spring Lake Watershed District. The modeling suggested an average annual watershed load of 205 pounds per year with a range between 100-440 pounds per year. An inverted Canfield Bachmann model was used to estimate the total load (external plus internal) for the summer growing season averages in Fish Lake. Several calculations were developed to quantify the internal phosphorus load in Fish Lake. Internal load estimates ranged from 245-1,075 pounds per year. Using the midpoint of these two ranges and assuming that half of the internal load is available for algal production, internal loading was predicted to account for a median of 73 percent of the total phosphorus load to Fish Lake.

ii. Previous Assessment – Lower Minnesota River Watershed Total Maximum Daily Load Report, Part I - Southern and Western Watersheds, MPCA, February 2020.

A TMDL Report, the Lower Minnesota River Watershed Total Maximum Daily Load Report, Part I - Southern and Western Watersheds, was adopted by the Minnesota Pollution Control Agency in February 2020. According to the TMDL report, a 14% reduction from non-point sources (generalized watershed runoff) was needed in the Fish Lake watershed to meet the phosphorus reduction goals of the TMDL. The total predicted existing phosphorus load for the Fish Lake watershed is 580 pounds per year and the required TMDL load is 500 pounds per year. Internal loading was not quantified for Fish Lake in the TMDL.

Section 3.6.1 of the TMDL report describes the methodology used to quantify loading from both permitted sources (e.g., wastewater and regulated stormwater) and non-permitted sources (e.g., unregulated stormwater, septic systems, and internal loading).

The phosphorus sources assessed included watershed runoff (regulated and unregulated), septic systems, and atmospheric deposition. The existing loads were calibrated to match observed average water quality over the range of years (2005 through 2014). Watershed (external) loading was predicted to be approximately 514 pounds per year in the 2020 TMDL report (refer to Figure 11).

An additional internal phosphorus load was not needed to calibrate the TMDL Fish Lake model, and internal load was not quantified in Fish Lake in this study. However, phosphorus monitoring data analyzed as part of the TMDL study indicated lake stratification and high phosphorus concentrations in the hypolimnion.

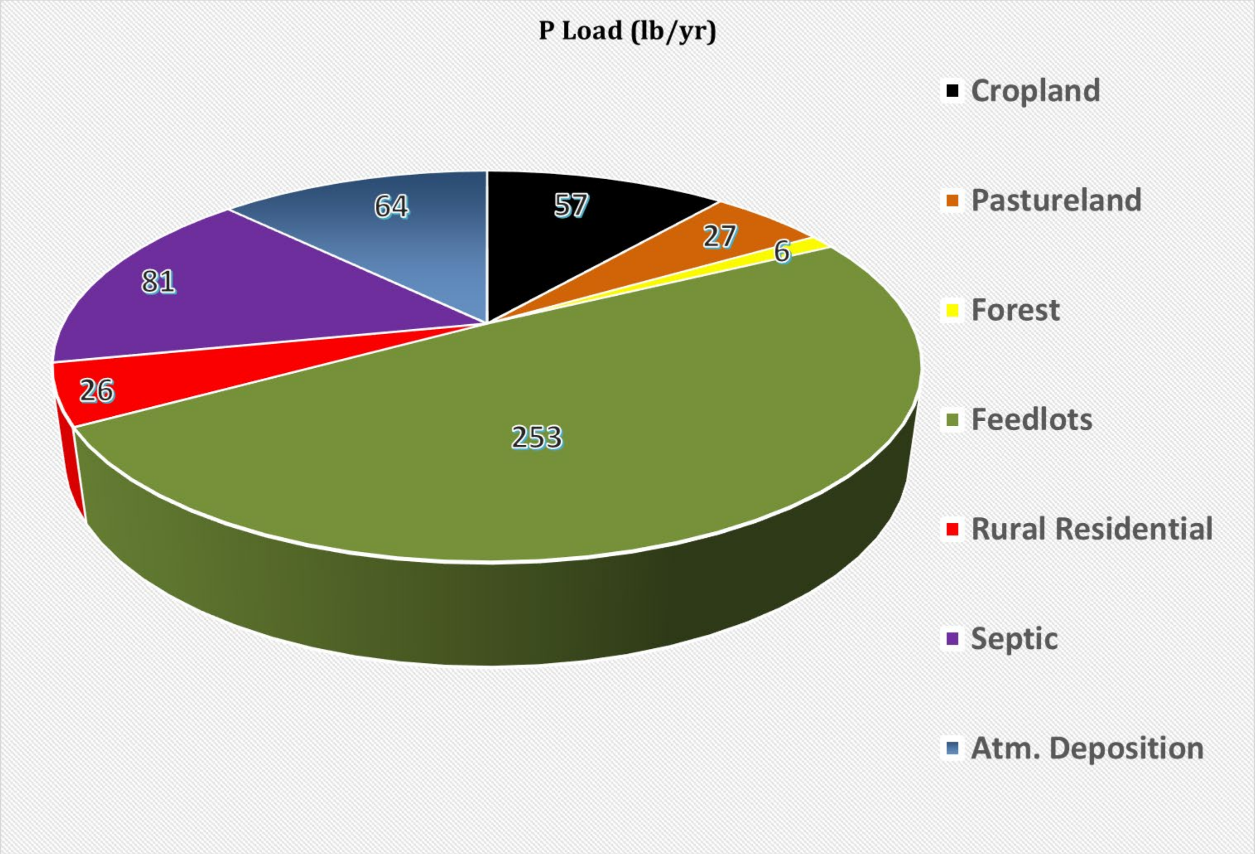

Figure 11. External Phosphorus (P) Load from the Fish Lake Watershed was predicted to be approximately 514 pounds per year. Source - Lower Minnesota River Watershed Total Maximum Daily Load Report, Part I - Southern and Western Watersheds, MPCA, February 2020.

The assumptions used in the Lower Minnesota River TMDL analysis for land uses within the Fish Lake watershed were reviewed as a part of the current LMP update and were determined to be inaccurate. Specifically, the TMDL study assumed that two large animal feeding operations were active within the watershed, which would add considerable phosphorus loading to the lake. With input from Soil and Water Conservation District staff, it was determined that there were no active animal feedlots within the Fish Lake watershed. To determine whether the watershed soils had elevated phosphorus levels, an analysis was conducted, which is described in Section 2.D.iv.

iii. Previous Assessment - 2016 MPCA HSPF Model

Note: while this report predates the 2020 Lower Minnesota River Watershed TMDL, the analysis was not available for use in the development of the TMDL.

In 2016, the MPCA developed a Hydrologic Simulation Program – Fortran (HSPF) model to simulate water quality and surface hydrology to help the MPCA better understand and predict how land use and land management practices impact nutrient and sediment delivery. This model uses real-world observed meteorological data (temperature, precipitation, etc.) to properly mimic the interconnected dynamics between land use, land management, climate, and resulting nutrient and sediment delivery.

After confirming the model's accuracy with a process called calibration, the MPCA and project partners can model different scenarios of land-use change and how those changes might affect water quality. The model can also be used to calculate Total Maximum Daily Loads (TMDLs). The Fish Lake watershed was explicitly modeled as its own HSPF subwatershed (532) and reach (lake/stream). Simulated flows and pollutant delivery to each modeled reach were extracted from the HSPF model to evaluate the relative contribution of external loading to Fish Lake from each land use present within the Fish Lake watershed. External loading from HSPF Reach 532 was used as the input to a phosphorus mass balance lake response model. The total external load predicted by the HSPF model was approximately 200 pounds/year (Figure 12).

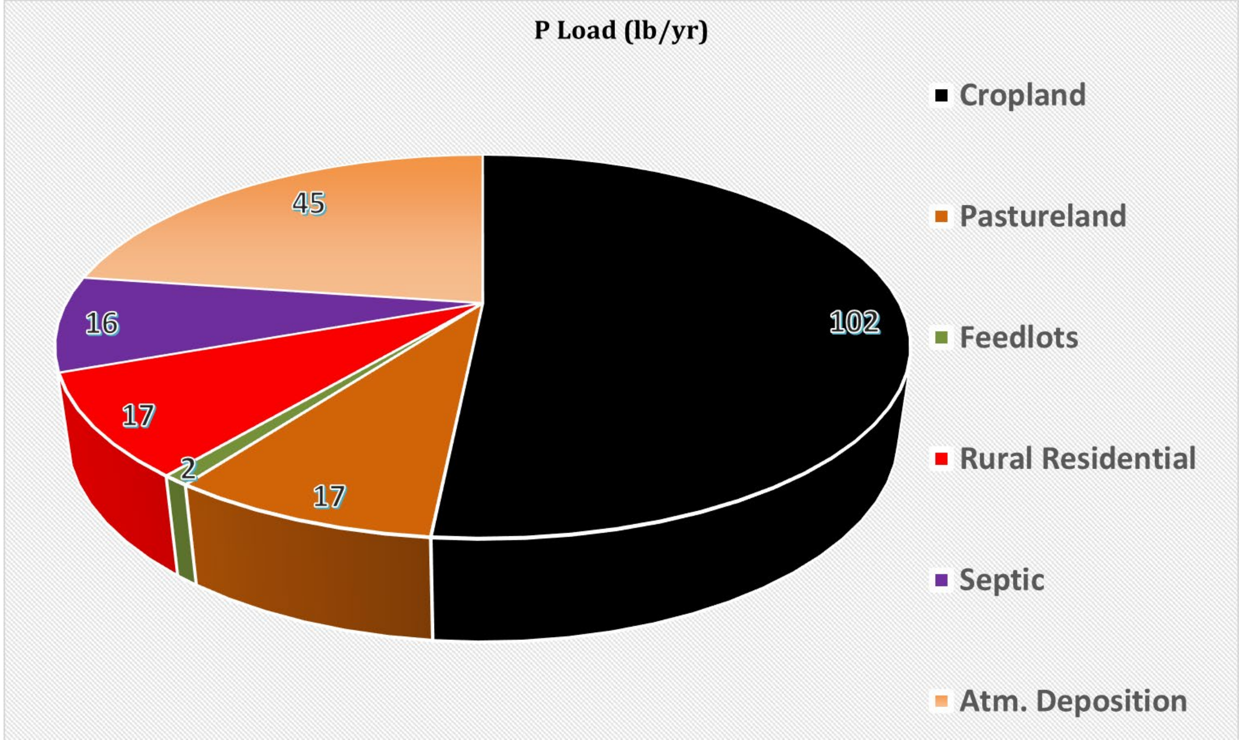

Figure 12. External Phosphorus (P) Load from the Fish Lake Watershed was predicted to be approximately 200 pounds per year. Source - Minnesota River HSPF Model.

Table 2. Summary of Fish Lake Watershed Loading Assessments

Fish Lake Assessment	Watershed Loading Average Annual TP (lbs/year)
Fish Lake Management Plan, 2006	205; range 100-440
Lower Minnesota River TMDL, 2020	514
Minnesota River HSPF Model, 2016	200

iv. 2023 Watershed Soils Analysis

Soils throughout the Fish Lake watershed were sampled and tested to determine a) if phosphorus concentrations were higher across the watershed than typical, which would warrant lake response model adjustments, and/or b) if there were potential ‘hot-spots’, such as the historic feedlot locations, with abnormally high phosphorus concentrations that should be addressed via watershed load reduction implementation strategies (such as nutrient management plans and water quality BMPs).

In June 2023, soil samples were taken from twenty-three (23) locations throughout the Fish Lake watershed. Sampling sites were chosen to represent the dominant land cover types within the watershed: agricultural, residential, and non-developed areas consisting of woodlands, wetlands, and grasslands. Soil samples from the top 6” of soil were collected at all sampling locations. Soil samples were analyzed by the University of Minnesota Research Analytical Laboratory for extractable phosphorus (P) using the Bray-1 method. Extractable P is a measure of the particle-bound phosphorus in the soil. Bray-1 phosphorus testing is used to determine the amount of phosphorus in the soil that is available for uptake by plants. The soil P levels are not directly translatable to watershed P loading (i.e., they are not directly used to quantify the load of phosphorus that is transported to downstream resources).

Current research suggests that when Bray-1 P levels are below 30 ppm there is enough phosphorus to support plant growth without exporting phosphorus from a soil matrix. At levels above 30 ppm there is a potential for phosphorus to leach from a soil matrix and become available for transport downstream through runoff. The average Bray-1 P concentration of samples in the Fish Lake watershed was 23 ppm, with very little variation across land cover types (Table 3) These levels were determined to be typical of watersheds in similar settings.

Table 3. Average Bray-1 P Concentrations by Land Cover

Land Cover	Average Bray-1 P Soil Concentration (ppm)	Number of Samples
Cropland	24	12
Developed	24	5
Grassland	25	2
Wetland	26	2
Farmed Wetland	10	2

Specific areas with high Bray-1 P soils were identified in the watershed. Five (5) of the twenty-three (23) samples had concentrations above 30 ppm. Areas with above average Bray-1 P levels, shown in Figure 13, represent locations to be evaluated for potential phosphorus reduction efforts. These efforts could include farmer-led changes in nutrient management practices, referred to as the 4Rs of Nutrient Management (right source, right rate, right place, and right time), or could involve installation of runoff control practices designed to remove phosphorus.

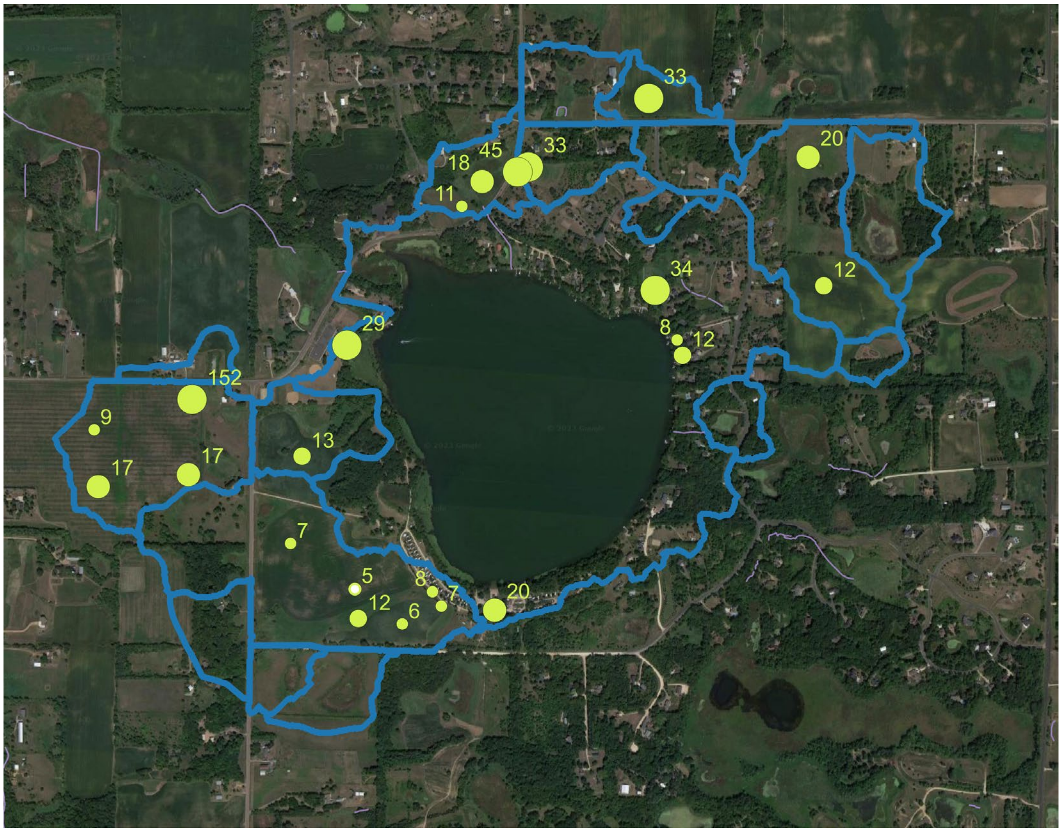

Figure 13. Soil Bray-1 P Concentrations

v. Tributary Monitoring

The District collected water quality samples at the tributary ditch located at the southeast corner of Fairlawn Avenue and Fairlawn Lane (Figure 14). This tributary accounts for approximately 14% of the total watershed to Fish Lake, and the land cover that drains to the tributary is representative of the land cover within the Fish Lake watershed as a whole. Average total phosphorus (TP) concentrations from samples collected from May to September (growing season) are shown in Figure 15. Phosphorus concentrations are highest in the summer months of July and August which does not correlate with the times of year that algae blooms typically are observed in Fish Lake. This finding suggests that while the watershed is a source of phosphorus to the lake, it is not the primary driver of algae blooms in Fish Lake.

Figure 14. Tributary Monitoring Location and Drainage Area

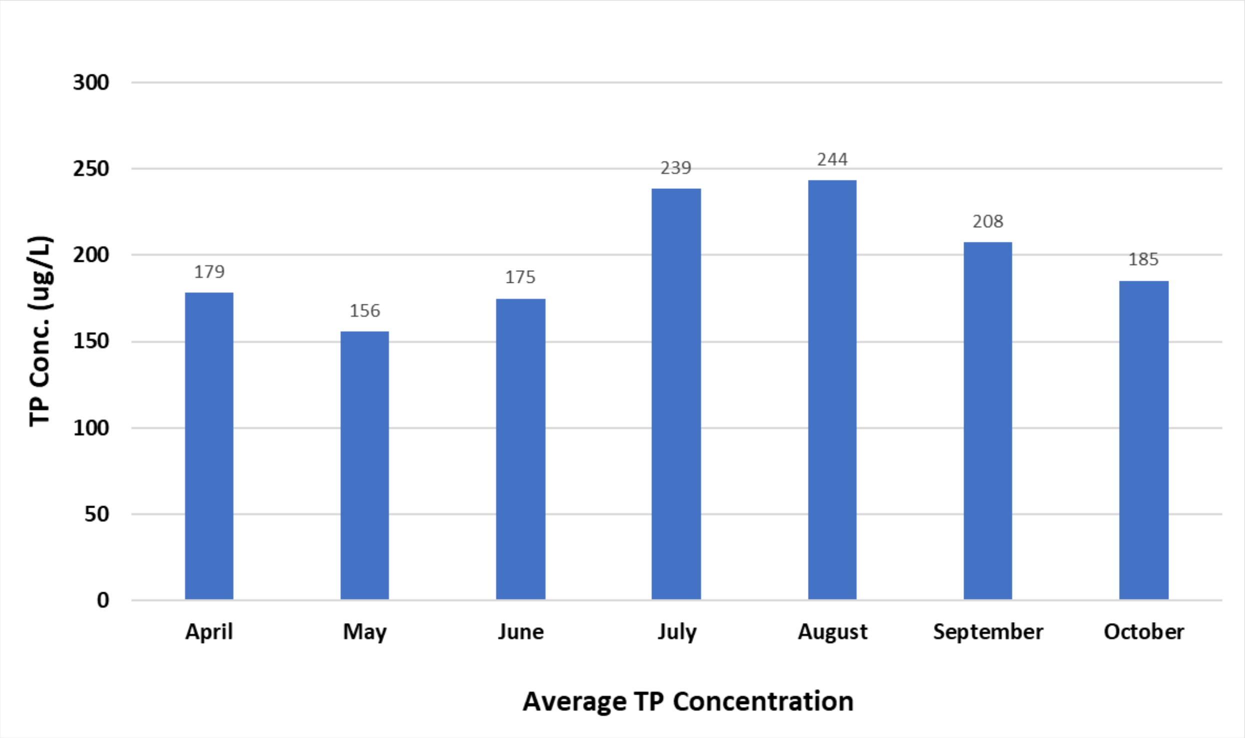

Figure 15. Average TP concentrations by month, tributary at the SE corner of Fairlawn Avenue and Fairlawn Lane. Data was collected from 2015-2021 by Scott SWCD and PLSLWD. Sample Size – 60 samples.

vi. Internal Phosphorus Conditions

Phosphorus release from lake sediments is influenced by various conditions. The following are key factors that can contribute to phosphorus release:

Anoxic Conditions: Phosphorus release is commonly observed in sediments that lack oxygen (anoxic conditions). When oxygen is depleted, certain microorganisms in the sediments start carrying out anaerobic processes that release phosphorus. Under anoxic conditions, phosphorus bound to iron and manganese oxides is released and becomes available in the water column. Anoxic conditions result through two primary mechanisms:

1. **Thermal Stratification:** Lakes often undergo a process called thermal stratification, where the water column separates into distinct layers based on temperature. During the warmer months, the upper layer (epilimnion) receives sunlight and becomes heated, while the lower layer (hypolimnion) remains cooler. This temperature difference prevents mixing between the layers, limiting oxygen transfer to the hypolimnion and promoting anoxia.
2. **Nutrient Enrichment:** Excessive nutrient inputs, particularly nitrogen and phosphorus from human activities such as agriculture or wastewater discharge, can cause excessive algal growth in lakes. This leads to the development of algal blooms. When these algae die and sink to the bottom, their decomposition consumes oxygen, depleting it in the bottom waters and creating anoxic conditions.

Sediment Disturbance: Human activities and natural processes can disturb lake sediments, which can lead to phosphorus release. When sediments are resuspended, phosphorus that was previously bound to particles becomes available in the water column. In shallow areas of the lake, wind and wave action can disturb the bottom sediments. Rough fish, like Carp, can cause significant resuspension of bottom sediments, although Carp populations in Fish Lake are thought to be below the level at which they would be considered a significant threat for resuspension. Boating activity can also disturb lake sediment, which can release phosphorus into the water column. Boating impacts to lake sediment are based on the boat speed and boat make in relation to the water depth where the boat is operating. Select boats can disturb sediments as deep as 16 feet (Marr, 2022). Impacts of boating to lake health is a topic receiving current research attention. The District does not regulate boat activity on Fish Lake. However, the 2023 District Board has been supportive of educational materials on the impacts of boat operations on lake health.

Redox Potential: The redox potential, which indicates the oxidation-reduction conditions, affects phosphorus release. High redox potential (more oxidizing conditions) tends to keep phosphorus bound to sediments, while low redox potential (more oxygen-reducing conditions) favors phosphorus release.

pH and Alkalinity: The pH (the concentration of hydrogen ions or the acidity of water) and alkalinity (the ability of the water to neutralize or buffer changes in acidity) of the lake water also influence phosphorus release. Lower pH and alkalinity can increase the solubility of phosphorus, leading to its release from sediments.

The potential internal loading rate in Fish Lake was reported in "Phosphorus release and accumulation in the sediments of Fish and Pike Lake, Scott County, Minnesota" (Hermann and Hobbs n.d.). Average potential phosphorus release rates from anoxic sediments in Fish Lake were determined to be 4.26 mg P/m2-day, which corresponds to approximately 271 pounds of phosphorus per year. The standard deviation in potential phosphorus release rate of sediment samples taken across the lake (nine total samples) was 2.74 mg P/m2-day. Despite being based on sediment samples collected in 2013, the estimated phosphorus release rate was determined to still be valid by reviewing the measured phosphorus accumulation rates reported in the Hermann and Hobbs report and applying the linear relationship of Pilgrim et al. (2007) for phosphorus release against mobile P concentrations in sediment. Applying the highest rates of phosphorus accumulation ever measured to the ten-year time period since 2013 resulted in a minor increase in phosphorus release rate and was well within the standard deviation.

vii. Lake Mixing

In cold climates, lake mixing is an important process that affects the nutrient cycling and water quality of lakes. During the winter months, surface waters of the lake cool and become denser, causing them to sink to the bottom and mix with deeper waters. This process, known as winter mixing or turnover, redistributes nutrients and oxygen throughout the lake, replenishing oxygen in deeper waters and bringing nutrient rich water to the surface.

A dimictic lake is a type of lake that undergoes two complete mixing events each year, one in the spring and one in the fall. In the spring and fall, temperature and density differences between the upper and lower layers of the lake cause them to mix, resulting in a uniform temperature and nutrient distribution throughout the lake.

In some cases, lake mixing can redistribute phosphorus released during internal nutrient loading, which can lead to harmful algal blooms and low oxygen levels. This occurs when nutrients, such as phosphorus and nitrogen, are released from the bottom sediments during mixing events and become available for uptake by algae and other aquatic organisms.

Fish Lake is periodically in a turbid, algae-dominated state. Algal growth restricts light penetration, which leads to periodic thermal stratification and the formation of anoxic conditions in the bottom waters (hypolimnion) of Fish Lake. Figure 16 shows multiple dissolved oxygen profiles from 2020. The April and October profiles are evidence of lake mixing with uniform dissolved oxygen concentrations throughout the water column. The July profile shows the varied dissolved oxygen concentrations throughout the water column during the period when Fish Lake is stratified.

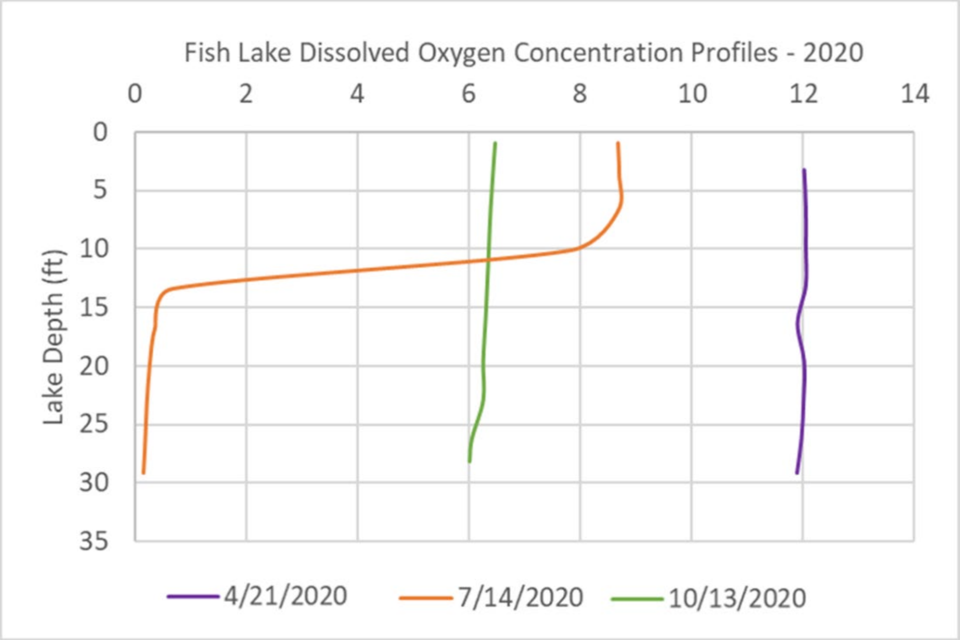

Figure 16. 2022 Fish Lake Dissolved Oxygen Concentrations profiles.

During periods of stratification, phosphorus is released from anoxic lake sediments into the overlying hypolimnion. Water and nutrient exchanges can occur as stratification breaks down seasonally due to the cooling/warming of surface waters (Figure 17). During these mixing (de-stratification) events, phosphorus that has built up in the hypolimnion is redistributed throughout the water column, ultimately fueling algae blooms.

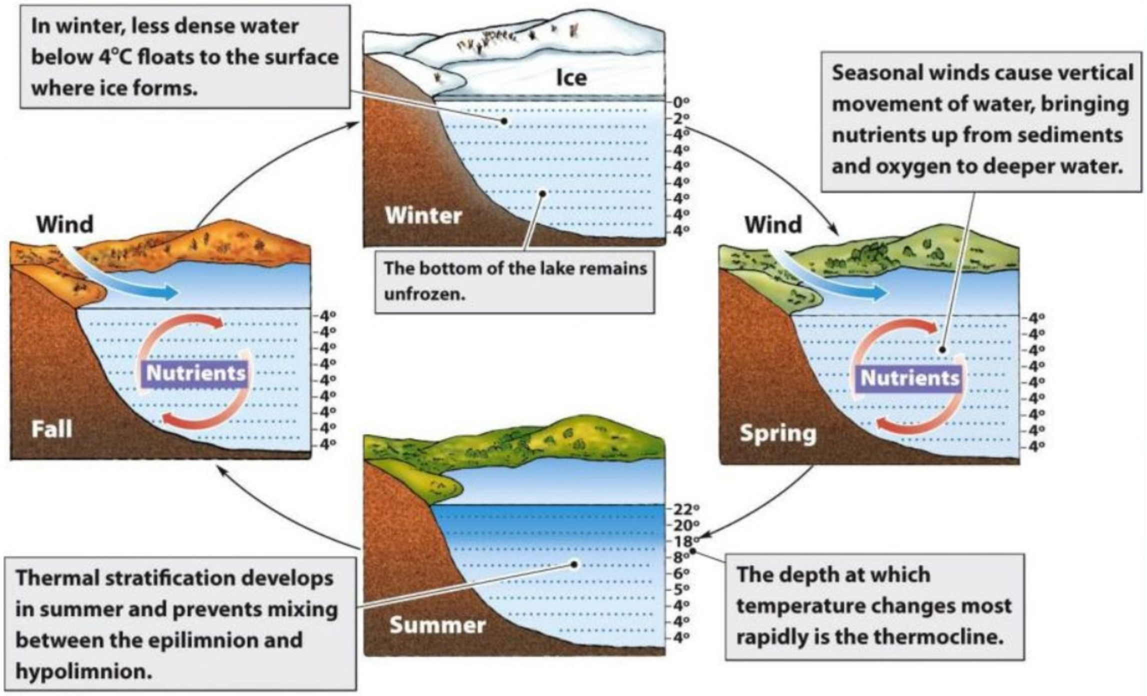

Figure 17. Seasonal stratification dynamics can lead to periods of stratification followed by mixing. (The Economy of Nature, Sixth Edition)

viii. Lake Response Model

Based on the conflicting findings of the 2006 and 2020 studies (2.D.i and 2.D.ii), an alternative and comprehensive approach was needed to determine the watershed and internal loading dynamics for Fish Lake.

A lake response model was created for Fish Lake. A lake response model is a mass-balance phosphorus model that accounts for water and phosphorus inputs from tributaries, watershed runoff, the atmosphere, sources internal to the lake, and groundwater, as well as outputs through the lake outlet, water loss via evaporation, and phosphorus sedimentation and retention in the lake sediments. Data inputs into the Fish Lake-lake response model included lake bathymetry data, phosphorus loading and water balance data from the Minnesota River HSPF model (2016), and tributary water monitoring data.

With the various data sources and models, a proportional approach was used for the modelling. Using tributary monitoring data in combination with HSPF model outputs, four models were built for the years 2017, 2018, 2019, and 2021. Running a model for four years ensures that results encompass the variation that occurs along the spectrum of drier and wetter years. Using each of the four model year precipitation totals, a proportion value was developed comparing the respective year's precipitation total to the precipitation average for the area over the last 30 years. These proportional values were then used to adjust the "average year" loads for each year, which were taken from the HSPF modelling. In addition, year specific tributary monitoring data was used for each year. This sampling data was entered into FLUX-32 to produce yearly loading values; these values then were applied to the tributary's watershed area. Due to the lack of monitoring data for the rest of Fish Lake's watershed, the HSPF proportional loading values were applied to the rest of the watershed. The models were then calibrated to match the observed average in-lake phosphorus concentration for the specific year from the Three Rivers Park District's in-lake monitoring location.

The calibrated excess internal load represents the internal load that is above what is expected for a normal lake at a certain trophic state. All lakes have a natural, background level of internal loading (sediment phosphorus release), this background internal load is implicitly included in the BATHTUB model. Therefore, internal loading rates added to the BATHTUB model during calibration represent the excess sediment release rate beyond the average background release rate accounted for by the model development lake dataset.

Phosphorus sedimentation in the lake response model was described using the Canfield & Bachmann (1981), Natural Lakes equation which is a commonly used phosphorus sedimentation equation for Upper Midwest lakes. The phosphorus sedimentation equation was calibrated to match observed conditions in Fish Lake.

Figure 18 shows the loading results for the various years modelled. At first glance it appears the loading to Fish Lake is decreasing with each year. This is consistent with the findings of the tributary monitoring data at the southeast corner of Fairlawn Avenue and Fairlawn Lane. The water quality and quantity seem to be improving from this watershed over the last few years. Phosphorus concentration and overall average flows from this tributary into Fish Lake are decreasing. This appears to be helping decrease the overall yearly loading to Fish Lake.

The internal loading varies overall during the last few years from 159-396 pounds of phosphorus per year. This range fits in with the predicted 271 pounds of phosphorus per year from *Phosphorus release and accumulation in the sediments of Fish and Pike Lake, Scott County, Minnesota* (Hermann and Hobbs n.d.). Figure 19 shows the phosphorus loading broken into percentages. For relatively normal precipitation value years (2017 and 2018), internal loading contributes a disproportionate amount of phosphorus to the overall lake load. While during very wet years (2019) where the watershed would be expected to contribute most of the loads, internal loading is still contributing almost a third of the overall lake load.

Overall, the watershed loading, while seemingly improving, is still contributing a large portion of load to Fish Lake, this along with the large input from internal loading is causing the impaired status of the lake. Due to past land uses, phosphorus laden sediment has accumulated within the lake and continues to be available for plant and algae growth. Other conditions that typically contribute to internal loading do not appear to be an issue at this time. These factors include the presence of large populations of bottom-stirring fish species such as carp, large populations of curly-leaf pondweed that can release phosphorus as they senesce, or large-wave producing watercraft that can stir bottom sediments.

A combination of watershed-based improvements and in-lake treatment will be needed to improve water quality. Strategically targeted BMPs aimed at reducing external load from the monitored tributary, coupled with an aluminum sulfate treatment designed to target internal loading will result in improved water quality and ultimately the de-listing of Fish Lake from the impaired waters list.

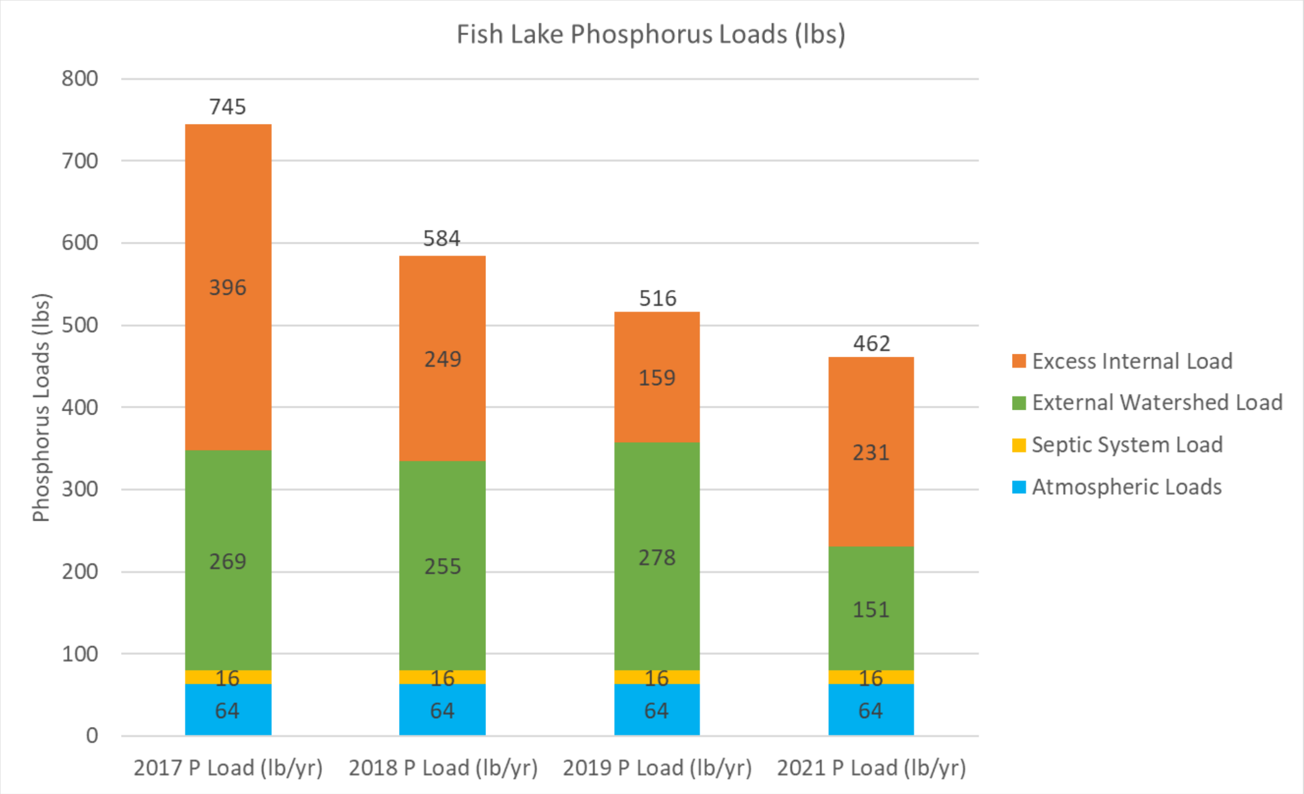

Figure 18. BATHTUB modeling loading results for Fish Lake.

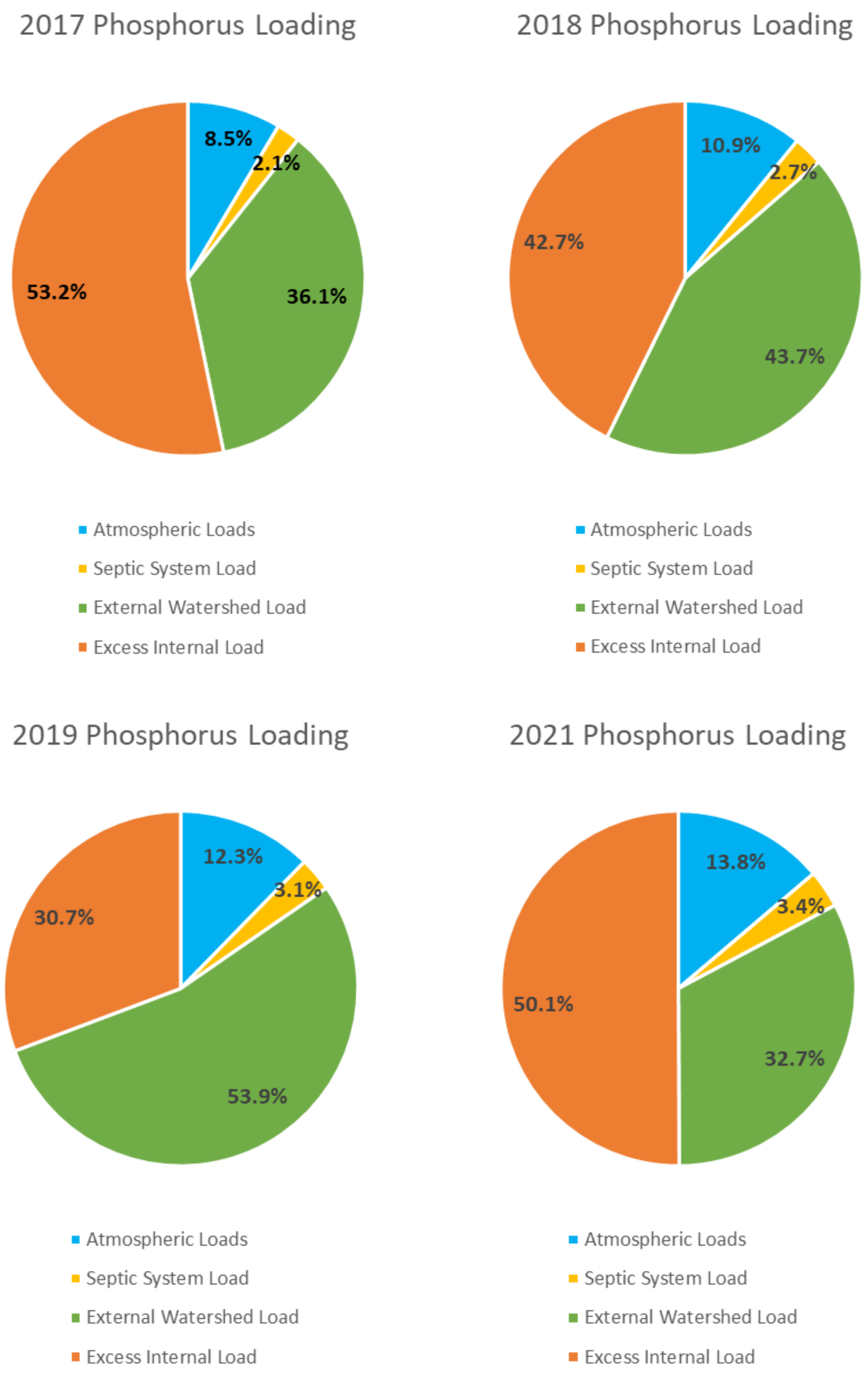

Figure 19. Phosphorous loading percentages for 2017, 2018, 2019, and 2021

3. FISH LAKE MANAGEMENT GOALS

Goals for the future of Fish Lake were established with input from the stakeholder group. An initial draft was developed based on the 2006 Sustainable Lake Management Plan for Fish Lake and discussed with the stakeholder group at their May 25, 2023, and October 5, 2023, meetings. Input from the stakeholders was incorporated into the final version of goals as stated below.

A. WATER QUALITY GOALS

The primary water quality goals for Fish Lake are based on standards the State of Minnesota established for recreational use of deep lakes in the North Central Hardwood Forest Ecoregions. The presence of nuisance algae blooms is the primary basis for Minnesota recreational-use standards. The numeric criteria provided in the state standard are essentially proxies for the presence of algae or the conditions which lead to algal blooms. It is important to note that these standards apply to growing season measurements. As described in the watershed assessment section, Fish Lake frequently experiences algal blooms outside of the growing season. Additional goals are included to address the primary sources of nutrient loading to the lake as described in the Pollutant Source Assessment section. The water quality goals are bolded below:

- **Meet the Minnesota standards (growing season averages) for deep lakes in order to remove Fish Lake from the impaired waters list:**
    - ***Total Phosphorus <=40 µg/l***
    - ***Secchi Depth Transparency >= 1.4 m***
    - ***Chlorophyll-A <=14 µg/l***
- **Reduce frequency and severity of early and late season algal blooms.**
- **Reduce conditions that lead to blue-green algal blooms which are a health concern.**
- **Reduce watershed phosphorus loading.**
- **Control internal recycling of phosphorus.**

The total phosphorus concentrations within the growing season have been meeting or close to meeting the standard for the past five years of monitoring data. However, the TP concentrations are the highest in April and October, when the high concentration of TP in the hypolimnion is mixed into the water column and is more available to phytoplankton, Figure 20. Unfortunately, internal load and lake mixing is causing seasonal algal blooms and must be reduced to control seasonal algal blooms.

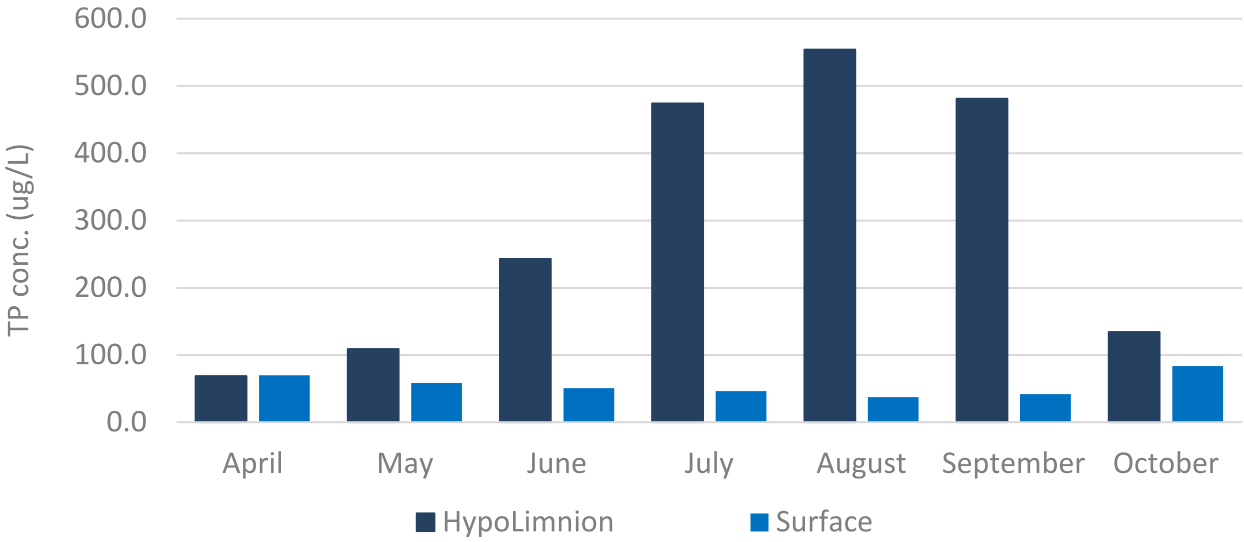

Figure 20. Comparison of surface and hypolimnetic total phosphorus (monthly averages of 2017, 2018, 2019, and 2021)

The target reduction goals are established to reduce the frequency and occurrence of these seasonal algal blooms by meeting the water quality standard during April and October, 40 µg/L. To calculate the load reductions, the lake response model was updated to focus on the April and October loads specifically.

The total target load reduction is 762 lbs/yr to reduce algal blooms. A combination of both internal loading reductions and watershed load reductions is required to meet this goal, Table 4. We calculated the internal load for the entire anoxic period (April-October) which extends longer than the previous modeling period presented in Figure 18. The average internal load (2017, 2018, 2019, 2021) during the entire anoxic period was estimated at 878 lbs/yr. The internal load reduction is based on conservatively reducing the internal load by 75%, 659 lbs/yr.

The watershed load reduction of 103 lbs/yr, 30% is based on further reductions necessary to meet the goals during the period of algal bloom. Additionally, reducing the watershed load increases the longevity of the internal load treatment. See Appendix A for more details about the internal load management longevity calculation.

Table 4. Target Load Reduction Goals

Load	Load Reduction (lbs/yr)	Load Reduction (%)
Internal Load	659	75
Watershed Load	103	30

B. FISHERY GOALS

Fishery goals established for Fish Lake are aimed at maintaining health of the community, both from an ecological and human consumption perspective. As described in the Water Quality section, elevated levels of mercury found in fish tissue from Fish Lake in 2005 resulted in the lake having an Aquatic Consumption Beneficial Use impairment designation. The State of Minnesota developed a Statewide Mercury Total Maximum Daily Load (TMDL) in 2007 that included Fish Lake. As mercury is an air pollution issue, the focus of the TMDL was to limit mercury emissions. The fishery goals are bolded below:

- **Maintain a healthy (edible, i.e. mindful of mercury contamination) game fish population with management emphasis on walleye.**
- **Manage carp and other species that may contribute to bottom-sediment release of nutrients.**

Management of mercury in Minnesota is the responsibility of the MPCA. At the 2021 Statewide Mercury TMDL Oversight Committee Meeting, the MPCA reported that as of 2020, mercury emissions in Minnesota have been reduced by 64% compared to 2005 levels. However, mercury pollution from outside the state affects Minnesota, and mercury concentrations in fish haven't significantly declined despite emissions reductions in North America. As a result, the continued recommendation when consuming fish from Fish Lake is to follow the statewide fish consumption guidance developed by the Minnesota Department of Health (Fish Consumption Guidance - MN Dept. of Health (state.mn.us).

Fish Lake is primarily managed for walleye. The Minnesota DNR and private sporting groups stock walleye into Fish Lake approximately every other year at an approximate rate of 1 pounds per littoral acre, with other sizes/ages/amounts substituted if insufficient fingerlings are available.

The District currently monitors Fish Lake for carp on a periodic basis. Size structure recorded between the surveys conducted in 2019 and 2023 show that average length of carp captured had decreased. Smaller and more uniform lengths suggests that a successful reproduction event likely occurred in the last 4 years. While the most recent survey, conducted in 2023, indicated that that carp population was not at a level of concern in terms of sediment disturbing, continued monitoring of the lake is recommended. The Carp Management Program is identified as IV.C.2.2 in the District’s 2020 Water Resources Plan.

C. AQUATIC PLANTS GOALS

The aquatic plants (underwater plant) goals for Fish Lake focus on maintaining the benefits provided by a healthy, diverse population of native aquatic plants while minimizing the deleterious effects non-native invasives can have. The aquatic plants goals are bolded below:

- **Maintain healthy population of diverse native aquatic plants.**
- **Manage infestations of Curlyleaf Pondweed past 150′ of shoreline.**

The District conducts annual aquatic plant surveys on Fish Lake to determine the health of the community and to monitor the growth of Curly-leaf pondweed (CLP). The District uses the findings of the annual CLP survey to determine whether management practices are warranted. There have been no CLP herbicide treatments in Fish Lake since 2008. This management is identified as IV.C.2.1AIS Prevention & Management in the District's 2020 Water Resources Plan.

Figure 21. Aquatic Plant Community from Fish Lake Western Shoreline

4. IMPLEMENTATION STRATEGIES

A holistic management of Fish Lake will employ both an internal load treatment and external load treatment to reduce seasonal algal blooms and slow the accumulation of TP rich sediment which contributes to internal loading in the future. In short, the internal load reduction will restore Fish Lake to a clear water state and the watershed load reduction will maintain the clear water status. A summary of the recommended best management practices (BMPs), anticipated benefits, implementation costs, funding sources, and schedule is provided in the sections below.

A. WATERSHED LOAD MANAGEMENT

A target watershed load reduction is 103 lbs/yr to meet the management goals, in conjunction with internal load reductions. The watershed load management options are separated into three categories, regional watershed improvement projects, residential stormwater BMPs & lakeshore improvements, and agricultural conservation management. The regional watershed improvement project discussions include planning level cost benefit analysis. The following cost estimates are based on engineer's opinion of probable cost estimates. The annual TP load removal is based on an average watershed load/acre and estimated TP removal rates reported in the Minnesota Pollution Control Agency's Minimal Impact Design Standards (MIDS). MIDS is a project that offers guidelines, recommendations, and tools to help implement low impact development (LID) more uniformly across Minnesota. Additional in-depth analysis of life cycle cost benefit will be required during the feasibility phases of each project. Individual project feasibility studies would include modeling to improve loading and removal estimates specific to project locations. This plan does not quantify the cost or phosphorus reduction that would be achieved by residential stormwater management practices, lakeshore improvements or agricultural conservation practices. The cost and load reduction of these types of practices would be very site specific and require further analysis to estimate.

i. Regional Watershed Improvement Projects

Included in this category of watershed load management options are large-scale infrastructure projects designed to manage stormwater runoff over a broad area, generally greater than a single parcel of land. They involve multiple components like detention basins, green infrastructure, and conveyance systems to handle significant volumes of stormwater. Due to their scale, they are typically cost-effective solutions that result in larger reductions in nutrient loading per dollar spent. Regional watershed improvement projects are designed to provide additional ecosystem services such as pollinator habitat and flood retention. Several potential regional watershed improvement projects have been identified in the Fish Lake watershed. The following describes each of the potential projects along with an engineer's opinion of probable cost and anticipated pollutant removal performance. These projects are shown in Figure 22 and summarized in Table 5 below. The phosphorus removals were based on the BMP specific removal efficiencies from the Minnesota Stormwater Manual applied to the estimated average aerial load from each contributing drainage area. The 205th St pond was assigned a higher aerial load based on the results of the sediment core analysis. The Lake Ridge Estates pond retrofits require additional feasibility to determine possible removal rates and cost benefit analysis. The combined removal from all the regional watershed improvement projects is 128.3 lb/yr which exceeds the watershed load goal.

Figure 22. Regional Watershed Improvement Projects

Table 5. Regional Watershed Improvement Project Summary

Project	Load Reduction (lbs/yr)	Cost ($)*	Operation and Maintenance Costs over 15-yr Life Cycle	Cost/Load Reduction ($/lb) over 15-yr Life Cycle**
Lake Ridge Estates Pond Retrofits	$50,000 for feasibility study, cost benefit analysis TBD			
Fish Lake West Wetland Restoration in-line IESF	26.6	$231,000	$13,000	$612
Fairlawn Lane Lake Inlet Iron Enhanced Sand Filter	32.7	$321,000	$19,000	$693
Fish Lake West Wetland Restoration After Banking Credits	18.8	$716,000	$123,000	$2,211
Fish Lake West Wetland Restoration	18.8	$716,000	$76,000	$2,809
200th Street Pond Improvements	4	$17,000	$0	$283
205th Street Pond Improvement	2.1	$84,000	$0	$2,667
Malibu Ave Wetland Restoration After Banking Credits	31.1	$1,519,000	$223,000	$997
Malibu Ave Wetland Restoration	31.1	$1,519,000	$152,000	$3,582
Residential Stormwater Best Management Practices	4	***		
Lakeshore Improvements	2	***		
Agricultural Conservation Practices	7	***		
Total	128.3			

*[Cost including land acquisition. Estimated value per Scott GIS 2023 Land EMV $/acre.]

**[Cost per load reduction when land acquisition costs, monitoring costs, and wetland banking revenue are included in the overall calculation.]

***[Cost to be funded through existing Cost Share and Farmer Led Council Initiative Programs]

Lake Ridge Estates Pond Retrofits Feasibility Study

Lake Ridge Estates is a subdivision development constructed in the 1980s at the northern end of Fish Lake (Figure 23). Scattered throughout the development are four stormwater ponds. One is southeast of the intersection of 200th St. E. and Lake Ridge Drive. The other three appear to be connected through a surface water connection. A second basin is west of Lake Ridge Drive south of 203rd Court E. and flows into a basin on the eastern edge of wetland. The third basin then outlets into a large wetland that discharges to the lake. Based on a review of construction plans, a fourth basin should be located on the southern edge of the wetland near the northern edge of Fish Lake. The fourth basin was not observed in the field and historical aerial imagery from 2008 to 2022 is inconclusive on whether the feature was actually constructed, as planned.

The stormwater ponds were constructed in the 1980s when the current technical standards recommended wet ponds, nicknamed NURP ponds after EPA's Nationwide Urban Runoff Program, to reduce sediment and nutrients. NURP pond design standards are considered out of date by today's stormwater management standards. There is little information available about the proposed design and actual function of the NURP ponds in Lake Ridge Estates, which makes assessing the effectiveness difficult.

It is recommended that the Lake Ridge Estates subwatershed is studied further to estimate the potential phosphorus loading from the watershed and monitor the outlets of the NURP ponds to determine if water quality results indicate a need to reduce phosphorus. The NURP ponds were designed and constructed in locations such as depressions in or adjacent to wetlands or without outlet structures that limit the opportunity to apply standard retrofit solutions that could improve effectiveness. If it is determined that retrofitting the ponds may be necessary to achieve a desired load reduction, a feasibility study will likely be required to investigate novel approaches to each individual basin. Spring Lake Township as a MS4 (Municipal Separate Storm Sewer System) permit holder is likely the entity responsible for the maintenance of the Lake Ridge Estates NURP ponds. District leadership and funding may be required to assist the Township in the evaluation/retrofit of this system. As part of any modification/performance enhancement, it is recommended that a long-term maintenance plan agreement be established.

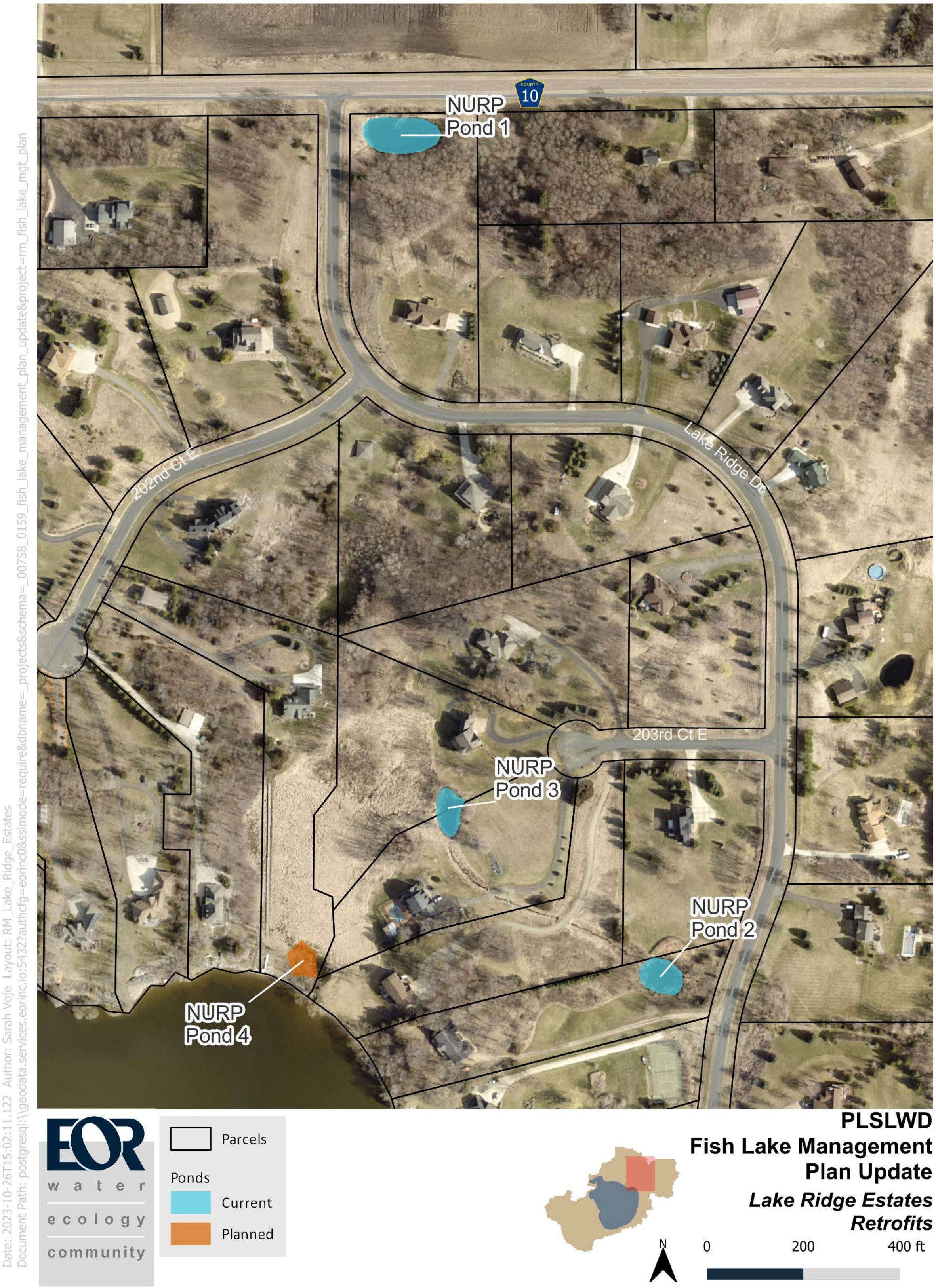

Figure 23. Lake Ridge Estates Pond Retrofits

Fish Lake West Wetland Restoration

The Fish Lake West Wetland Restoration was identified as a potential water quality project. The project area is located on the west side of Fish Lake directly south of Fish Lake Park (Figure 24). An ephemeral/intermittent unnamed drainage flows through hydric soils for approximately 1,300 feet through the northern half of the property from Malibu Avenue to the Fish Lake. The drainage is located in a combination of a wooded corridor and hydric soils dominated by reed canary grass. The potential project has three main components: an in-line stormwater treatment feature downstream of the Malibu Avenue culvert, wetland restoration within hydric soil units on the property, and upland native buffer restoration. The project location has the strategic advantage of being currently listed for sale, as well as being immediately downstream of the most phosphorus dense soil sample site.

An in-line stormwater feature is proposed downstream of the Malibu Avenue crossing. The in-line feature would be a shallow, depressional basin that allows sediments to drop out of the water column and nutrients to be removed with an iron-enhanced sand filter. Treated stormwater would then proceed through the proposed restored wetland, further providing additional stormwater treatment. Locating the in-line feature near the Malibu Avenue culvert allows for easy access to monitoring and regular maintenance to keep the feature functioning properly.

An iron enhanced sand filter (IESF) has been proposed for this location. An IESF is a commonly used flow-through system designed to improve stormwater by slowly filtering runoff through two treatment basins. The first basin, a sedimentation basin, captures untreated stormwater and detains it long enough for large particles to settle out. Stormwater then proceeds to the second basin, a filtration basin, where iron enhanced sand media filters stormwater that collects in an underdrain system before being discharged downstream. The iron enhanced sand media is effective at removal dissolved phosphorous and other pollutants through adsorption.

Approximately 5.9 acres of mapped hydric soils are present within the Fish Lake West parcel including areas that are currently being cropped or are degraded because they are dominated by invasive reed canary grass with altered hydrology. Wetland restoration would include improving wetland hydrology by filling at least a portion of the channel draining through the hydric soils. Filling the channel would restore hydrologic function of the wetland by spreading water out through the site, which can increase groundwater elevation closer to the surface, thus increasing the rate at which water passes through the wetland. Historically, wetlands similar to the one present on the Fish Lake West parcel would likely have had multiple shallow, poorly defined channels that concentrated flow, but didn’t drain the site with the same efficiency as the channel.

A 50-foot upland buffer around the perimeter of the restored wetlands would be established per Wetland Conservation Act (WCA) rules. These areas are currently being cropped or are poor quality non-native perennial vegetation, primarily cool season grasses and would be converted to native vegetation. Native vegetation would act as a buffer, filtering stormwater to remove sediment and nutrients before it entered the restored wetland, and the buffer would provide slope stabilization through perennial vegetation cover.

Further investigation would be needed to determine the location and extent of filling. Reed canary grass would be removed through a combination of chemical and mechanical means and native vegetation would be planted in both the cropped areas and where reed canary grass was removed. At least three years of maintenance would be required to get native vegetation established. Long-term maintenance and monitoring would be required. Appendix B provides a cost breakdown for individual cost components including long-term maintenance and monitoring costs. Wetland restoration and associated upland buffer would provide additional ecosystem services in increased flood attenuation through stormwater storage and increase pollinator habitat through flowering native forbs for feeding and increased egg-laying and overwintering habitat in the thatch layer.

Establishing the Fish Lake West parcel as a wetland mitigation site can provide some additional cost advantages to completing the project. At a minimum, wetland credit sales should pay for the costs related to the restoration work. The estimated credit yield from wetland and upland buffer restoration could generate approximately 4.66 wetland credits, which has an estimated value of approximately $214,000 in credit sales based on the current wetland credit transaction cost in the Bank Service Area. There are additional costs associated with project implementation when the site involves wetland mitigation because there are increased permitting, monitoring, and maintenance costs due to meeting or exceeding performance standards to get credits released for sale. If a wetland mitigation bank site was considered, the next step should be to develop a prospectus that evaluates the potential cost and revenue in greater detail, including determining if there are opportunities to maximize credit yield.

Any of the proposed restoration projects on the Fish Lake West property could be completed independent of each other. The individual project elements could be accomplished through purchase or with easement agreements with the landowner. In addition to these projects, the District should encourage (through use of Farmer-Led Council Initiative) the farmer on the phosphorus dense fields immediately upstream (West of Malibu Ave) to implement agricultural conservation practices that will reduce phosphorus export. Appropriate practices would focus on nutrient management, essentially drawing down phosphorus reserves in the soil.

Figure 24. Fish Lake West Wetland Restoration

Fairlawn Lane Lake Inlet Iron Enhanced Sand Filter

The Fairlawn Lane Lake Inlet site, within the FL-007 subwatershed area was identified as a potential water quality improvement project. The site is located downstream of the intersection of Fairlawn Ave and Fairlawn Lane and consists of a narrow drainage that flows for approximately 620 feet before discharging to the northern end of Fish Lake (Figure 25). The total subwatershed area is 96 acres. The drainage flows through a scattered, narrow wooded corridor and then through a reed canary grass-dominated wetland. An existing monitoring station is near this location which will help facilitate performance monitoring in the future.

The type of filter (basin vs. bench) and the specific geometry that would provide the most cost-effective treatment will be defined in the preliminary design phase. A generalized design based on the site size and contributing area has been used to develop the cost and effectiveness information included in this plan. The filter could be a bench that is developed along the length or a portion of the length of the tributary. The filter could also be a stormwater basin-type of feature that treats a volume of stormwater before discharging into the tributary and then into the lake. A feasibility study should also include consideration for whether the road necessary to access the site is private or has public right of way.

Figure 25. Fairlawn Lane Inlet

200th Street Pond Improvements

The 200th Street Pond, located in subwatershed FL-009 was identified as a potential water quality improvement project. The site is in the northern portion of the Fish Lake watershed northeast of the intersection of Fairlawn Avenue and 200th St. E. (Figure 26). The site consists of two small ponds/wetlands that are directly downstream of a former feedlot operation. Aerial imagery analysis indicates that sometime between 1980 and 1990, the basin features became more pronounced, likely resulting from an action such as a road expansion or transportation project. Additional research with the county transportation or local township would be required to understand the full history and any opportunities for cost share. Since 2008, aerial imagery analysis indicates that the northernmost pond has decreased in size from 0.1 acres of open water to 0.1 acres of emergent wetland likely due to sediment and nutrients accumulation. The second pond to the south is 0.2 acres and has been reduced to 0.1 acres of open water. One to two feet of sediment removed from 0.1 to 0.2 acres combined from both ponds would restore the original footprints of the ponds and provide additional sediment storage. The outlet structure of the south pond is unknown at this time so additional flood attenuation potential is unknown.

205th Street Pond Improvement

The 205th Street Pond, located in subwatershed FL-024 was identified as a potential water quality improvement project. The site is in the northwest portion of the Fish Lake watershed northwest of the intersection of Fairlawn Avenue and Malibu Avenue (Figure 27). The site consists of a small pond/wetland that is directly downstream of a feedlot operation. Aerial imagery analysis indicates that the pond is a natural feature but has likely been modified over time to increase the amount of open water habitat. Since 2008, aerial imagery analysis indicates that the pond has decreased in size from 0.8 acres of open water to 0.3 acres of open water and sediment and nutrients have accumulated. It is assumed that the phosphorus removal effectiveness of this pond has been greatly diminished as a result of this significant level of accumulation. Monitoring of the pond’s outlet could be conducted to confirm this assumption.

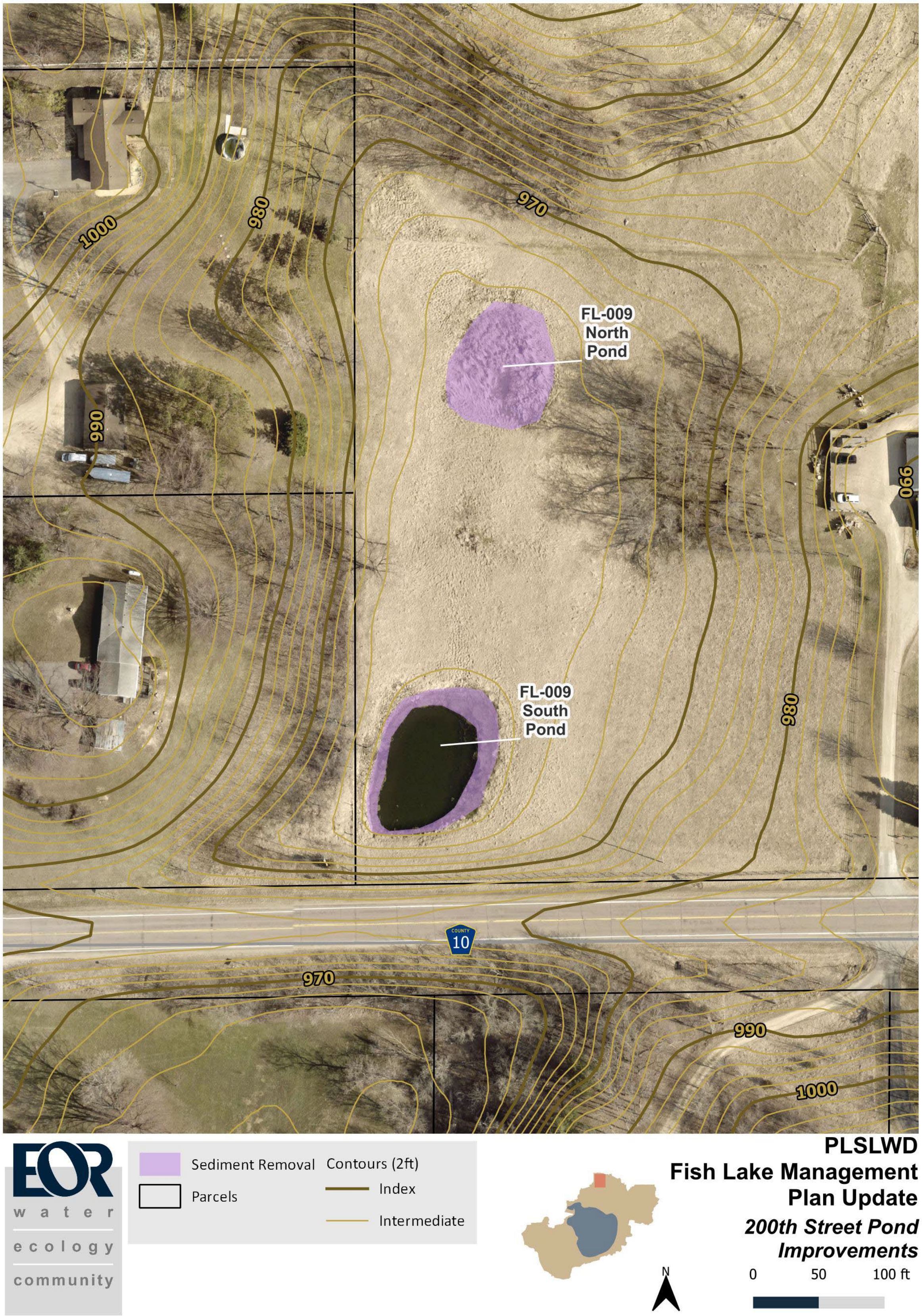

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Figure 26. 200th Street Pond Improvements

Figure 27. 205th Street Pond Improvements

Malibu Avenue Wetland Restoration & Enhancement

The Malibu Avenue Wetland Restoration was identified as a potential wetland restoration project. The project area is located on the west side of Fish Lake, east of Malibu Avenue and north of 210th St. E. (Figure 28). The proposed project area is located on two parcels directly south of Fish Lake Park. There do not appear to be defined channels draining through the property. One or more culverts must outlet on the property and surface flow through the site. A grassed waterway is present along the southern half of the site and crosses between the two parcels. The site represents a potential wetland restoration project that could be completed as a standalone project for minor water quality benefits, but more for the ecosystem services that wetlands provide or done as a wetland mitigation site to fund additional work within the watershed through credit sales. Wetland restoration would include restoring wetlands in areas currently being cropped and enhancing wetlands that have perennial non-native vegetation. A 50-ft upland native buffer within the project area would be created adjacent to the wetland restoration areas.

The proposed site contains significant areas of mapped hydric soil and National Wetland Inventory wetlands. Additionally, signatures of conditions that would potentially support wetland vegetation and hydrology can be seen in aerial photographs. It appears that there could be up to 31 acres of wetland restoration, which would include 20.8 acres that are currently being cropped and 10.2 acres that do not have a recent cropping history. Reed canary grass and other cool season grasses would be removed from the grassed waterway and other perennial vegetation areas through a combination of chemical and mechanical means. Native vegetation would be planted in both the cropped areas and where reed canary grass was removed. At least three years of maintenance would be required to get native vegetation established. Wetland restoration for mitigation credit requires demonstration of improving hydrologic function of wetlands. In many cases, this is filling ditches or breaking drainage tile. At this point, it is uncertain if or what hydrologic restoration actions would be required as part of the overall wetland restoration. The site does not appear to be ditched. Aerial imagery signatures could be investigated for the presence of drain tiles.

Establishing a wetland mitigation site can provide some additional cost advantages to completing the project. At a minimum, wetland credit sales should pay for the costs related to the restoration work. The estimated credit yield from wetland and upland buffer restoration could generate approximately 27.75 wetland credits, which has an estimated value of approximately $1.3 million in credit sales based on the current wetland credit transaction cost in the Bank Service Area. There are additional costs associated with project implementation when the site involves wetland mitigation because there are increased permitting, monitoring, and maintenance costs due to meeting or exceeding performance standards to get credits released for sale. If a wetland mitigation bank site was considered, the next step should be to develop a prospectus that evaluates the potential cost and revenue in greater detail, including determining if there are opportunities to maximize credit yield.

Figure 28. Malibu Avenue Wetland Restoration & Enhancement

ii. Residential Stormwater Best Management Practices

In addition to the larger scale, regional watershed improvement projects, there are opportunities to treat residential stormwater runoff at a smaller scale throughout the watershed. Collectively known as residential stormwater best management practices, the function of these practices is to capture and remove pollutants from runoff generated from impervious areas. Generally, these practices remove stormwater pollutants through settling of nutrient-laden sediment, biological uptake, or through infiltration into the ground.

While residential stormwater best management practices are typically initiated and paid for by property owners, certain practices are eligible for funding from the District. The District implements a Cost Share program with the Scott Soil and Water Conservation District (SWCD). The program is a results-focused cost share program that engages rural, urban, shoreline and business landowners. The program is prioritized around a "pay-for-performance principle," which is primarily a "dollar per pound of phosphorus removed" for residential & agricultural water quality improvement projects.

The District and the Scott SWCD meet roughly quarterly throughout the calendar year to assess potential projects and prioritize project selection based on project funding, feasibility, and the following cost-benefits factors:

- Water quality benefits
- Food reduction benefits
- Cost-effectiveness
- Collaboration
- Long-term management

The District and SWCD maintain a list of eligible practices which is referred to as the Cost Share Docket. The current cost share docket, as of the writing of this plan, is documented in the 2023 Conservation Practice Financial Assistance Program Policy Manual. Bioretention Basins (Practice Code 3.1) are the primary practice on the 2023 docket that is aimed at residential stormwater management. Multiple types of practices are considered bioretention practices but are referred to with more specific names (raingardens and bioswales for example) that describe the particular landscape, scale, and vegetation settings where they are applied. These practices are currently being funded at a maximum rate of 75% of the total project cost.

Additional appropriate practices for treating residential stormwater in the Fish Lake watershed would currently fall under Practice Code 3.14 (Other Practices). This category includes innovative practices such as cutting-edge techniques and technologies that will have a high likelihood of success, but which have either never been used before or have not been used or are non-conventional stormwater practices. Recommended practices falling into this category include permeable pavement, rain-barrels, and conversion of residential turf-grass to native prairie. These practices are currently funded at a rate of 50% - 70%.

The reduction in total phosphorus loading to Fish Lake that could be achieved through implementation of residential stormwater management practices is estimated to be approximately 4 lbs/year. The estimated reduction is based on the acreage of residential land in the Fish Lake watershed that is not already treated by a stormwater management practice or part of the Lake Ridge Estates development. The estimate assumes that practices could be implemented to treat 25% of these non-treated areas and assumes an average practice effectiveness of 60%.

Bioretention Basins

Bioretention basins are shallow landscaped depressions filled with sandy amended soil, topped with a layer of mulch, and planted with suitable vegetation. Stormwater runoff flows into the depression, with some water stored in the soil profile and the remainder slowly percolates through the soil, or engineered filter media, (which acts as a filter) and into the groundwater at a rate dependent on the underlying soils. Some of the stored water is also taken up by the plants. This important technique uses soil, plants, and microbes to treat stormwater before it is infiltrated or discharged.

Bioretention areas are usually designed to allow ponded water 6 to 12 inches deep, with an overflow outlet to prevent flooding during heavy storms. Where soils are compacted or infiltration is otherwise limited, a perforated underdrain connected to the storm sewer or alternative discharge should be utilized to draw down water levels within an acceptable period of 24 to 48 hours. Practices with an underdrain are sometimes referred to as biofiltration practices since the main treatment mechanism will be filtration, not retention (infiltration). Maintaining the unsaturated soil zone above a perched underdrain system when needed can enhance the performance of bioretention practices, such as higher removal rates for nitrogen.

Bioretention areas provide comprehensive pollutant load reduction through physical, chemical, and biological mechanisms. Infiltration completely removes pollutants from stormwater runoff and should be encouraged where practical.

Rain Gardens

Rain gardens are small versions of bioretention basins. Due to their scale, rain gardens typically treat runoff from small contributing drainage areas such as rooftops, driveways, sidewalks, and portions of the adjacent road. Bump-out rain gardens include the extension of a road’s curb into the street so that the garden can be constructed in the space between the extended curb and the original curb line. Curb cuts are commonly used to direct drainage from the road into the depression. Rain gardens also typically include an overflow pathway designed to safely convey drainage beyond the rain garden’s capacity to exit or bypass the facility.

Residential rain gardens can look very similar to a conventional planting bed. The main difference between rain gardens and conventional gardens is that the rain gardens are designed with at least a depression and engineered soil layer to capture and treat rainwater.

Bioswales

Bioswales, also called vegetated swales, are a variation of bioretention basins that utilize slope and earthen dams to temporarily detain flows, which allows infiltration through the sandy soil layer. They are shallow, open vegetated channels designed to provide non-erosive conveyance with longer detention time and slower velocities than traditional curbs and gutter or ditch systems.

These practices are effective for pre-treatment of concentrated flows before discharge to a downstream low impact development (LID) practice. Although grass swales provide generally limited pollutant removal through gravity separation, they can be designed to enhance their stormwater pollutant removal effectiveness. High sediment load reductions have been observed in well-constructed swales.

Properly designed grass swales are ideal when used adjacent to roadways or parking lots, where runoff from the impervious surfaces can be directed to the swale via sheet flow. As the vegetative cover is an integral component to the function of grass swales, flow depth should not exceed the height of the vegetation on a regular basis (i.e., small storms). As routing meltwater over a pervious surface will yield some reduction in flow and improved water quality, these practices have been shown to be very effective in cold climate conditions. The effectiveness of the practice can be further enhanced by using engineered soil mix as the substrate and installing an underdrain. The presence of such designed under layers are the differentiating characteristic of bioswales in comparison to grass swales.

Permeable Pavement

Permeable pavement is a durable, load-bearing paved surface with small voids or aggregate-filled joints that allow water to drain through to an aggregate reservoir. Stormwater stored in the reservoir layer can then infiltrate underlying soils or drain at a controlled rate through underdrains to other downstream stormwater control systems. Permeable pavement allows streets, parking lots, sidewalks, and other typically impervious surfaces to retain the infiltration capacity of underlying soils while maintaining the structural and functional features of the materials they replace. When designed and installed properly, permeable pavement systems consistently reduce concentrations and loads of several stormwater pollutants, including heavy metals, oil and grease, sediment, and some nutrients (US EPA and Tetra Tech 2014). The aggregate sub-base improves water quality through filtering, but the primary pollutant removal mechanism is typically loading reduction by infiltration.

Permeable pavement can be developed using modular paving systems (e.g., permeable interlocking concrete pavers, concrete grid pavers, or plastic grid systems) or poured in place solutions (e.g., pervious concrete or porous asphalt). In many cases, especially where space is limited, permeable pavement is a cost-effective solution relative to other practices because it serves stormwater control and transportation purposes. Permeable pavement can be successful in cold climates when properly installed and maintained. To make sure permeable pavements function properly, it is particularly important to eliminate sand application in the winter.

Rain Barrels

Rain barrels are small scale rainwater/stormwater harvesting systems that typically direct rooftop runoff through a downspout into a barrel that holds less than 100 gallons. The water stored in the barrel can then be used for irrigating gardens or lawns. Drip irrigation outlet systems may also be installed to slowly draw down the water levels in the rain barrel between rainfall events.

Conversion of Residential Turf Grass to Native Prairie

Restoring native prairie in urban areas is a type of practice that is growing in popularity because of its cost savings and ecosystem benefits. Converting turf grass to native prairie reduces ongoing maintenance costs from frequent mowing to occasional maintenance of the prairie. Prairies also provide multiple ecosystem benefits, such as reduced runoff, cleaner runoff, increased bird habitat, increased pollinators, and educational opportunities, in addition to aesthetic benefits.

It should be noted that while use of native vegetation and native prairie is ideal and the preferred alternative in conversions, if the site conditions, social norms, or local ordinances make that difficult to accomplish, other natural plantings can still be employed and be very beneficial in many aspects. For instance, conversion to open space that contains deep rooted and larger canopy plants, such as tall grasses, forbs, shrubs, and trees, whether native or not, can provide many of the benefits desired with converting surface areas.

iii. Lakeshore Improvements

As described in the Watershed Assessment section, the zone of land adjacent to a lake's shoreline or lake riparian area plays a crucial role in maintaining and influencing the quality of the lake ecosystem. In particular, the riparian area acts as a natural buffer zone, filtering and absorbing pollutants, sediments, and nutrients from runoff before they enter the lake. Plants in the riparian zone contribute to nutrient cycling by taking up excess nutrients like nitrogen and phosphorus from runoff. While the assessment conducted on Fish Lake concluded that overall, the lake riparian area is healthy, it was determined that approximately 20% of the shoreland zone included some degree of manicured lawn extended to the lake edge. Improvements to these areas would result in a reduction of nutrient loading to Fish Lake. Lakeshore improvements entail planting of native vegetation along lakeshore and in emergent zone of the lake as a way of restoring the natural transition from lake to upland. The goal of a lakeshore improvement effort is a dense stand of vegetation growing throughout the riparian area to trap and filter pollutants as depicted in Figure 29. Beyond addressing water quality, lakeshore improvements provide additional ecosystem services such as habitat for birds, spawning and refuge for fish, wave-erosion protection, and pollinator habitat.

Lakeshore improvements are currently eligible for 70% cost-share through the District’s cost-share program under Project Code 3.16 (Riparian Buffer). Further armoring of lakeshore is a common trend on metro lakes and has already been seen on Fish Lake since the shoreline survey was conducted. Including an educational and outreach component may be a valuable effort to preserve and improve lakeshore conditions. The DNR has expressed support for educational elements, with potential to provide materials or other assistance.

The reduction in total phosphorus loading to Fish Lake that could be achieved through implementation of lakeshore improvements is estimated to be approximately 2 lbs/year. This estimate is based on implementing a 50 foot buffer on the areas around Fish Lake determined to be “developed shoreline” in the shoreline assessment. The estimate assumes a 68% total phosphorus reduction rate (Nieber 2011).

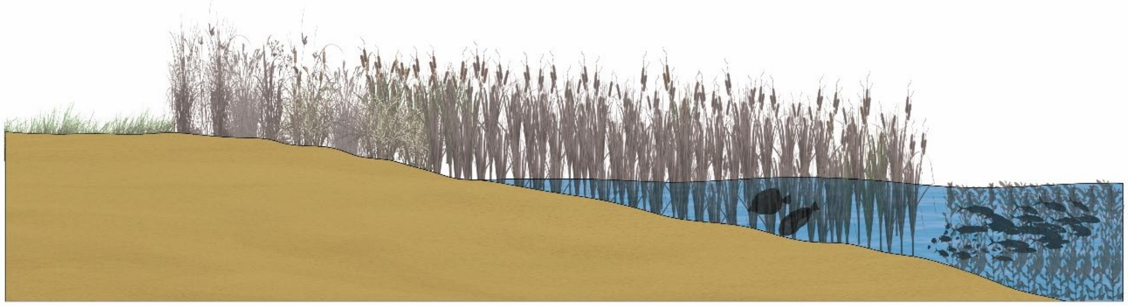


Figure 29. Desired Lake to Upland Transition of a Lakeshore Improvement Effort

iv. Agricultural Conservation Practices

A wide array of conservation practices is available to manage nutrient loading from agricultural land. Roughly 20% of the Fish Lake watershed is currently used for row crop production, forage for animals or pastureland. Agricultural conservation practices that promote soil health are recommended for the Fish Lake watershed. Soil health practices are a set of sustainable farming techniques and management strategies designed to protect and improve the overall health and quality of soil in agricultural ecosystems. These practices aim to enhance soil fertility, structure, and resilience, while minimizing erosion, nutrient depletion, and environmental degradation. They are critical for maintaining long-term agricultural productivity and sustainability. In many cases, these practices are cost-neutral (reduce expenses) or are eligible for funding through the District’s cost share program.

Cover Crops

Cover crop is a term to describe any crop grown primarily for the benefit of the soil rather than the crop yield. Cover crops are typically grasses or legumes (planted in the fall between harvest and planting of spring crops) but may be comprised of other green plants. Cover crops prevent erosion, improve the physical and biological properties of soil, supply nutrients, suppress weeds, improve the availability of soil water, and break pest cycles, in addition to a wide range of additional benefits. Cover crops are included as Practice Code 3.5 in the District’s 2023 Cost Share Docket and are currently being incentivized at a rate of $60/acre.

No-till

No-till is a way of growing crops or pasture from year to year without disturbing the soil through tillage. No-till increases the amount of water that infiltrates into the soil, the soil's retention of organic matter and its cycling of nutrients. It can also reduce soil erosion and increase the amount and variety of life in and on the soil. The most powerful benefit of no-tillage is improvement in soil biological fertility, making soils more resilient. No-till is included as Practice Code 3.15 in the District’s 2023 Cost Share Docket and is currently being funded at a rate of $30/acre.

4Rs of Nutrient Management

The 4Rs of nutrient management refer to fertilizer application techniques focused on minimizing the risk of nutrient loss from the field. The principles of the 4R framework include:

- Right Source – Ensure a balanced supply of essential nutrients, considering both naturally available sources and characteristics of specific products in plant available forms.
- Right Rate – Assess and make decisions based on soil nutrient supply and plant demand.
- Right Time – Assess and make decisions based on the dynamics of crop uptake, soil supply, nutrient loss risks, and field operation logistics.
- Right Place – Address root-soil dynamics and nutrient movement and manage spatial variability within the field to meet site-specific crop needs and limit potential losses from the field.

Nutrient management plans are tailored by farmers and/or crop consultants to maximize yields and minimize nutrient inputs. Nutrient management is included as Practice Code 3.13 in the District’s 2023 Cost Share Docket. The cost for manure testing is currently 100% reimbursed through the program, and the use of variable rate fertilizer application is currently being funded at a rate of $15/acre.

The reduction in total phosphorus loading to Fish Lake that could be achieved through implementation of agricultural conservation practices was estimated at approximately 7 lbs/year. The estimate was based on cover crop adoption on agricultural fields in the watershed and assumed an existing rate of adoption of 10% and an estimated total phosphorus removal rate of 29% (Iowa Nutrient Reduction Strategy, 2013).

B. IN-LAKE PRACTICES

This section outlines options for in-lake management, including chemical treatments for phosphorus release from the sediment, physical management for removal or abatement of internal loading, and biological controls for removing in-lake phosphorus sources. The annual internal load in Fish Lake is estimated to contribute 878 lbs/yr. The internal load should be reduced by 75%, 659 lbs/yr, to achieve the goal of reducing the seasonal algal blooms. In-lake practices to reduce internal loading can be categorized as: chemical, physical, or biological. Each practice is outlined below and summarized in Table 6 and Table 7.

i. Chemical (Sediment Inactivation Treatment)

Chemical treatments inactivate the phosphorus release from the sediments by permanently binding the phosphorus. Alum is the most common sediment inactivation strategy used in the Upper Midwest. Alum (aluminum sulfate) is a nontoxic liquid that is commonly used in water treatment plants to clarify drinking water. Alum is applied to lakes using specialized equipment that ensures the precise placement of material in the lake (see Appendix A). When added to lake water, alum removes phosphates through precipitation, forming a heavier than water particulate known as a floc. This floc then settles to the lake bottom to create a barrier that binds to the phosphorus released from the sediments. The floc permanently binds to the phosphorus, i.e. the existing internal load is inactivated, and no further alum treatments would be needed to meet the goals stated in this plan. The only consideration for future alum treatments would be from new sediment loads entering the lake from external sources, thus watershed load reduction strategies are recommended to prevent further accumulation. More background information can be found at: https://www.nalms.org/nalms-position-papers/the-use-of-alum-for-lake-management/. Although alum (chemical) treatment is the most feasible and cost-effective method of reducing internal load in Fish Lake, it is worth mentioning that some landowners present at the landowner meetings expressed a preference to not use chemical treatment.

Some common concerns that have been raised from landowners are summarized below:

1. Treatment is unnecessary because the lake can naturally reduce this load. Ideally the lake ecosystem would be in a stable clear water state in which the phosphorus load from both internal and external source would be in balance with a healthy lake ecosystem. Unfortunately, because changes in the watershed throughout history have increased the sediment load contributing to excess internal load, the lake is in a turbid state in which high phosphorus loads are promoting the proliferation of algal blooms. The goals in this plan are set to transition Fish Lake from a turbid to a clear water state by reducing excess loads from the sediments and the watershed.

2. Changes in pH can occur during alum treatments. Alum itself has a low pH, however, changes in pH can be avoided by adding a buffer solution of sodium aluminate which neutralizes the low pH of alum itself.
3. The risk of free aluminum release from the aluminum sulfate compound is a common concern. Free aluminum cannot be released from aluminum sulfate until the pH of the water is below 6, conservatively. As stated above a buffer is recommended to keep the pH of the lake water in a safe range. Additionally, the specification for the alum treatment includes onsite dose testing and pH monitoring during treatment to ensure the proper pH range is maintained.
4. The effect of alum on zooplankton and heterotrophic bacteria. Zooplankton are the base of the food chain and integral to lake health. Studies show zooplankton are not removed during alum treatments. Similarly heterotrophic bacteria are an integral part of the lake ecosystem and under oxic conditions digest nutrient rich sediments. However, in the treatment zone, heterotrophic bacteria are not present due to anoxic conditions.
5. The risk that the floc barrier created by the alum application would prevent growth of aquatic plants. The floc layer at the sediment water interface is thin and not dense enough to prevent light penetration to the sediment nor prevent plant growth through the floc. Additionally, the vegetation survey shows there is no plant growth in the proposed application area since it is outside of the littoral zone.

Surveys given to landowners at the meeting showed that support and non-support for chemical treatment was split roughly 50/50.

The alum treatment feasibility study is attached in Appendix A. The feasibility study evaluates the dose, cost, and longevity of an alum treatment in Fish Lake. The planning level cost estimate for the alum treatment is $619,000 for project implementation and $15,000 for monitoring for a total of $634,000, and a conservative estimated load reduction of 659 lbs/yr. We assumed a lifecycle cost of 15 years for the in-lake management practices. The cost per lb reduced is $64/lb over a 15-year lifecycle. The final alum dose and treatment area is determined based on lake bathymetry, sediment core, Releasable Phosphorous (RP) content, and Hypolimnion/ Epilimnion water quality sampling results. Note that lanthanum modified bentonite was investigated as another option for sediment inactivation. The dose of lanthanum modified bentonite for Fish Lake is included in Appendix A. Lanthanum enhanced clay applications are not common in the upper Midwest and would be considered a more experimental treatment in Fish Lake. Additionally, there are concerns about the release of free lanthanum into the water column during application. Unlike alum treatments in which the conditions for unintended free aluminum release are well documented and understood, the conditions and risk for free lanthanum release are still to be determined (Zhi et al, 2021, Hermann et al., 2016, and Spears et al. 2013). The North American Lake Management

Society has only published a position on the use of alum for safe and effective internal load management.

Figure 30. Alum being applied from a barge to a Minnesota lake.

ii. Physical

Physical options for reducing internal loading in Fish Lake include targeted dredging to permanently remove phosphorus laden sediments, and the addition of aerators to add air to bottom waters (hypolimnion) to prevent anoxia.

Dredging

Dredging is an uncommon strategy for managing internal load reduction in natural lakes and is most common to maintain specific and discrete areas of man-made reservoir function (i.e. navigation or removing excess sediment in formerly riverine systems with high upstream sediment loads).

Analysis of lake sediment RP concentrations identified high RP levels throughout approximately 100 acres of the lake. Excavation of nutrient rich sediment represents a practicable opportunity in environments where high concentrations of RP are relegated to confined areas. For example, during landowner meetings the lake users were concerned about sediment accumulation affecting navigation near the boat launch, especially during dry years. However, given the distribution of high RP concentration over a large area for internal load control, this option quickly became impractical from an environmental and cost-benefit for Fish Lake. The environmental impacts of dredging are complete disruption and removal of the benthic community. Given the large area, the removal of the entire benthic habitat can affect the lake ecosystem at all trophic levels, from removal of the seedbank to removal of the zooplankton community which over winter in the sediment.

Disposal of dredge sediment is a difficult/expensive effort due to the water content and weight of the material. Large, nearby drying areas are needed to reduce the water content of the sediment prior to disposal. There is also significant lake use disruption during dredging, from pausing lake and lakeshore activities to increases in lake turbidity. Dredging this large area would take several months, up to an entire season. During dredging there would be significant disturbance of the shoreline for staging of the equipment and removed materials. There would also be significant neighborhood traffic to transport the removed material. Within the lake itself, the removal of the sediment can cause resuspension which would lead to high turbidity throughout the season.

There are also some feasibility hurdles that have yet to be investigated, including, changes to lake level, RP content of the parent material, and permitting obstacles. Removal of the significant sediment volume would increase the capacity of the lake and may lead to changes in watershed hydrology, residence time and lake response to watershed loading. Additionally, an investigation of the parent material will be needed to determine the internal load potential after the proposed dredging. It could be that even after the accumulated sediment is removed, the underlying parent sediment may still have a high pool of phosphorus that can contribute to the internal load after the dredging is complete, thus further sediment cores would need to be collected to determine the release rate and the phosphorus content of the parent sediment. Finally, since this is an uncommon practice for natural Minnesota lakes on such a large scale, the permitting process will be quite significant, leading to additional time and engineering cost and the permit may not be approved.

The planning level cost estimate is based on the Interstate Technology Regulatory Council areal cost of Minnesota lake dredging projects. The cost estimate ranges from $18,000/acre-$140,000/acre. Additionally, an estimated $300,000-$500,000 for feasibility studies and dredging design. The estimated cost of the project would be around $2.1 million to $14.5 million, based on 100-acre treatment area. The estimated load reduction is conservatively estimated to be 75% of the total internal load, 659 lbs/yr. We assumed a lifecycle cost of 15 years for the in-lake management practices. The cost per lb TP removed over the 15-year lifecycle is $212-$1,466/lb.

Landowner feedback on dredging was mixed at the landowner meeting, with some in favor of a non-chemical method and some against, primarily for lake disruption and cost reasons.

Aeration

Hypolimnetic aeration is a phosphorus cycling control technique whereby P rich anoxic waters in the hypolimnion are oxygenated with a mechanical aeration system preventing an anaerobic condition that leads to release of P.

The aeration system would be designed to aerate the entire 100 acres which is a significant disruption of the benthic community. Hypolimnetic aeration has been proven successful in reducing contributions of phosphorus from lake sediments with sufficiently high iron to phosphorus concentrations such as Vadnais Lake which serves as a municipal drinking water source for the City of St. Paul. However, in many lakes, additions of iron are required to supplement hypolimnetic aeration to sufficiently bind phosphorus present within the sediment pool. Additional feasibility is recommended to determine if iron supplement is required. Aeration systems have a high-power demand and infrastructure which will require significant feasibility and design, especially on the scale required to oxygenate the anoxic area in Fish Lake (100 acres). These additional feasibility activities will add time and cost to the project.

Hypolimnetic aerators need to be run in perpetuity to control releases of loosely bound phosphorus within the hypolimnion. Unlike aeration, the alum plan presented permanently binds a mass of RP. Aeration systems also have high maintenance requirements and often have down time due to system errors/maintenance. The phosphorus control can be quickly lost when the aeration systems are down, and phosphorus begins to be released from the sediment once anoxic conditions return. Thus, aeration systems will need to be running during the winter months which will cause thin ice and impact recreation on the lake. Aeration would also require a DNR Aeration permit, which may or may not be approved.

While hypolimnetic aeration may have similar or less upfront costs in comparison to alum, the continued annual operation and maintenance cost are an expense that would be incurred in perpetuity as these systems are only effective so long as the aeration units are running. Therefore, hypolimnetic aeration is not recommended for Fish Lake. Landowner surveys suggest that landowners were primarily against aeration due to the impact on ice thickness and ongoing reliance on maintenance and operation.

The planning level cost estimate is based on the Interstate Technology Regulatory Council areal cost of hypolimnetic aeration system $2,000-$2,5000/acre with $100-765/acre for operation and maintenance cost. The cost of the additional design and feasibility would be $100,000-$150,000. The estimated cost is $300,000-$400,000, based on 100-acre treatment area, for the design and installation and $10,000-$76,500/yr for operation and maintenance. The estimated load abatement is conservatively estimated to be 75% of the total internal load, 659 lbs/yr. We assumed a lifecycle cost of 15 years for the in-lake management practices. The estimated cost per lb removed for the 15-year lifecycle is $30-40/lb plus $15-$120/lb of maintenance.

iii. Biological (fisheries and vegetation mgmt.)

The biological components of the lake are distributed throughout the lake, along the shoreline, and on the bottom sediments. These biological components can control the relationship between phosphorus and the lake response.

Vegetation Management

Vegetation management can remove phosphorus from the lake by harvesting the plants after they have absorbed phosphorus from the sediment in which they are rooted. Vegetation harvesting only provides a small load reduction per year and the removal of vegetation is not consistent with the goal of transitioning Fish Lake to a plant dominated clear water state since there is no guarantee that continual harvesting would not affect the future plant community. In fact, removing the plant population in Fish Lake, which is mostly native, will remove habitat for fish and aquatic organisms and, without plants, in fluxes of phosphorus even at low levels promote algae growth. Additionally, the reduction of phosphorus load from the plant harvesting would be 2-6 lbs/yr/acre depending on the density (EOR and Blue Water Science, 2020). The vegetation survey only showed plant growth in areas shallower than 6 ft at a light-moderate density and only a few sections of heavy vegetation. The District is only permitted to remove vegetation from areas greater than 150′ from shore. Thus, the available harvest area is 5 acres. Given the current conditions, if every plant that the District were permitted to harvest were harvested from the Fish Lake that would be an 20 lb/yr reduction (assuming uniform moderate density throughout the area shallower than 6 ft and 150 ft from shore). First, this process would have to be repeated annually and assume there is no diminishing of the plant population which is unlikely. Second, this activity is contrary to the goal of promoting a plant dominated clear water state. Finally, this reduction is not enough to meet the goal.

The estimated planning level cost is $300-$600 per acres. Thus, a total annual cost of $1,500-$3,000. The maximum load reduction is 20 lbs/yr, However, this practice is contrary to the goals of the lake management plan.

Despite low effectiveness, landowner surveys were largely in favor of vegetation harvesting. However, management of invasive species is important for the lake ecosystem, thus continued management of invasive species in Fish Lake is recommended.

Fisheries Management

Fisheries management does not directly address the internal load from the sediment. Management of rooting fishing, like carp, can resuspend sediment and disturb benthic plants.

However, the fish survey does not show a significant population of carp and other rooting species. Thus, the potential internal load reduction does not meet the goal. In fact, the fish population in Fish Lake is healthy. However, as stated in 2.B.i, the carp surveys showed a decreased average size, likely indicating a reproduction event. It is recommended to continue to monitor the carp population. Anecdotal data suggests that the Fairlawn tributary may be an opportunistic location for a carp barrier.

iv. Recommended Internal Load Management

The recommended internal load management is based on three criteria:

1. Cost-benefit analysis
2. Feasibility –Will this activity be appropriate for Fish Lake?
3. Goal Achievement – Does this activity meet the lake management plan goals?

The summary in Table 7 outlines the cost benefit analysis and each criterion for each of the physical, chemical, and biological options discussed above.

For physical management, i.e., dredging and aeration, both address internal loading and could meet reduction goals, however, neither is feasible for Fish Lake. Dredging is not feasible because of its disturbance to the benthic community, permitting issues, and possible implication of lake hydrology. Aeration is not feasible for Fish Lake because of its effect on ice conditions in the winter, the risk of downtime due to system failure/maintenance, and the effect of such a large aeration system on the benthic community. Neither biological management is recommended for Fish Lake as neither practice would achieve the required phosphorus reduction goal. Chemical management, i.e. alum treatment, is feasible and recommended for internal loading control on Fish Lake because of its safety and effectiveness for permanent reduction of internal loading.

Table 6. Internal Load Management Information Summary

Management Strategy	Mechanism for reduction	Performance and Feasibility for Fish Lake	Landowner Disturbance	Operation and Maintenance
Sediment Inactivation Treatment	Inactivate the P-release from the sediments	-Proven treatment for internal P loading	-Several days of application while the lake is open for recreation -Small staging area with minor disruption of lake use	-Recommend dose split into two applications -Post implementation monitoring
Dredging	Remove P-rich sediments	-Proven treatment for removal of internal P loading and other nutrients in the sediments -Requires significant feasibility study	-Several months of lake and lakeshore disturbance while the lake is open -Requires large staging area near the lake -Short term turbidity increases in the lake	-Post implementation monitoring

Management Strategy	Mechanism for reduction	Performance and Feasibility for Fish Lake	Landowner Disturbance	Operation and Maintenance
Aeration	Prevents anoxia	-Locally effective, system must cover large areas in Fish Lake -Loses P-binding function as soon as aeration is ceased. -Requires significant feasibility study	-Thin ice in winter	-Continued operation required -Annual maintenance required -Post implementation monitoring
Vegetation Harvesting	Removes P rich plant material	-Vegetation survey does not show a significant invasive plant population thus removal would be focused on native species	-Several days of removal while the lake is open per year -Reduction of fish habitat	-Multiple removals may be required based on population response
Fisheries Management	Removes carp which resuspend sediment	-Fish survey does not show a significant carp population	-Several days of removal while the lake is open	-Multiple removals may be required based on population response

Table 7. Internal Load Management Summary

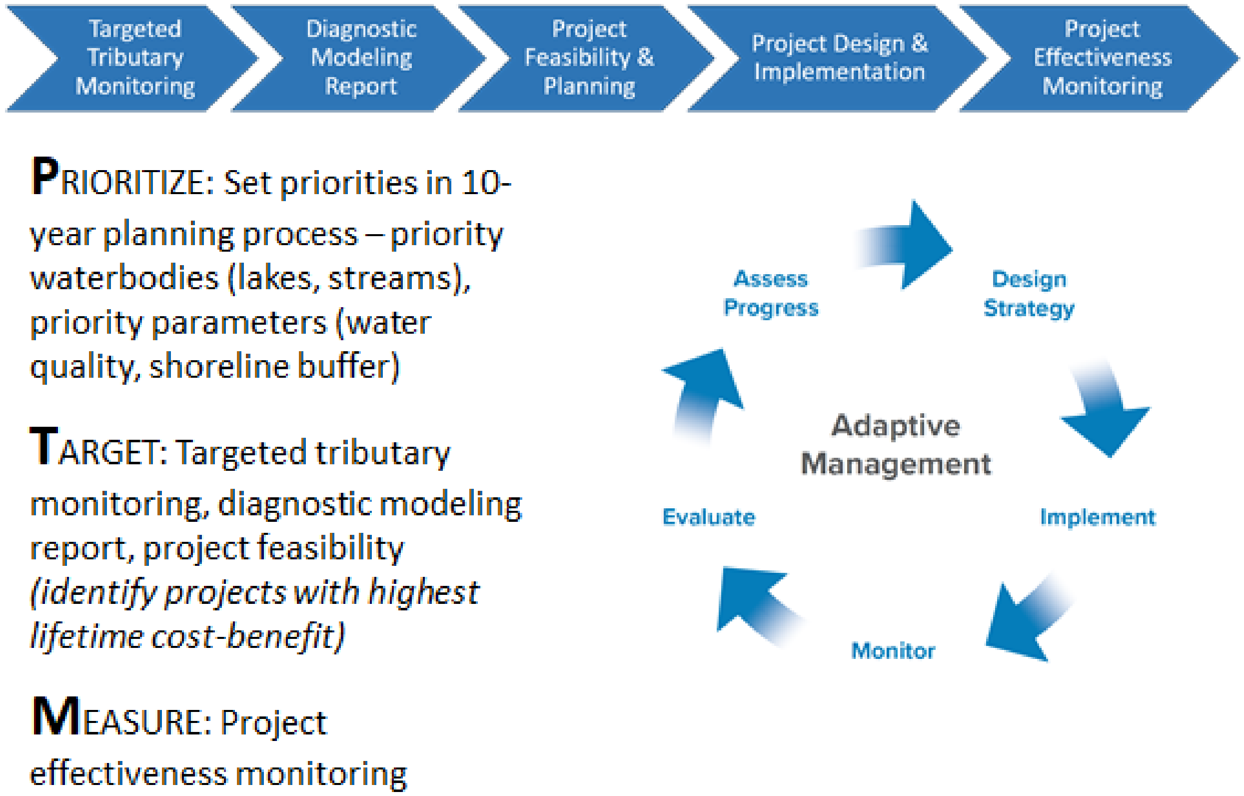
Internal Load Management	Cost Range over 15-year Lifecycle ($)	Removal (lbs/yr)	Cost Benefit over 15-year Lifecycle ($/lb)	Feasibility for Fish Lake	Meets Reduction Goals
Sediment Inactivation	$634,000	659	$64	✓	✓
Dredging	$2.1-$14.5 million	659	$212-$1,466	Requires Additional Feasibility	✓
Aeration	$300,000-$400,000 $10,000-$76,500 annual O&M	659*	$30-$40 $15-$120 O&M	Requires Additional Feasibility	✓
Vegetation Harvesting	$1,500-$3,000 annually	20	$75-$150	✗	✗
Fisheries Management**	-	-	-	✗	✗

*Phosphorus release is being abated; the pool of phosphorus is not being removed.

**The carp population is not currently high enough to contribute to phosphorus loading, thus there can be no load reduction attributed to this management strategy.

5. MONITORING & ADAPTIVE MANAGEMENT

An adaptive management approach, which includes continued water quality monitoring and "course corrections" responding to results, is the appropriate strategy for attaining water quality and phosphorus reduction goals at the watershed scale. Plan progress and success will be tracked by water quality improvement, progress of best management practice implementation, addressing legacy sources of phosphorus, and by participation rates in public awareness and education efforts using an adaptive management approach (Figure 31) to prioritize, target, and measure the plan's effectiveness towards reaching established water quality goals.



PRIORITIZE: Set priorities in 10-year planning process – priority waterbodies (lakes, streams), priority parameters (water quality, shoreline buffer)

TARGET: Targeted tributary monitoring, diagnostic modeling report, project feasibility *(identify projects with highest lifetime cost-benefit)*

MEASURE: Project effectiveness monitoring

Figure 31. Water Quality monitoring is a key component to an adaptive management approach.

A. RECOMMENDED MONITORING

i. Best Management Practice (BMP) Effectiveness Monitoring

As the regional stormwater management practices are implemented, it is vitally important that they are monitored to validate their effectiveness. In most cases, effectiveness monitoring is a requirement of grant programs likely to be used to implement the practices. The goal of effectiveness monitoring is to compare water quality upstream and below a given practice. It is typically accomplished by determining the load of pollutant (combination of volume of runoff and concentration of pollutant) over a given period (a full year or growing season) for runoff coming into the practice and again at the outlet of the practice. The difference in load is then attributed to the performance of the practice. Findings from effectiveness monitoring can be used to inform future management decisions.

ii. In-lake Monitoring

It is recommended that sediment cores be collected at least one year after the first sediment inactivation (alum) dose application and cores be collected at similar locations to this study and include the following parameters: anaerobic phosphorus release, moisture content-bulk density, loss-on ignition organic matter, total aluminum, aluminum bound phosphorus, and redox-sensitive phosphorus. Biweekly surface and hypolimnetic phosphorus monitoring following the treatment is also recommended to confirm water quality improvements in Fish Lake and assess if the second dose will need to expand to shallower regions of the lake.

6. IMPLEMENTATION PLAN

Implementing the recommendations of this management plan will involve a concerted effort from the many parties involved; the District, Spring Lake Township, Scott SWCD, the MnDNR, local sporting groups and the residents living on Fish Lake as well as those living and working within its watershed. The following description of recommended management activities has been developed based on the organizational structure of the District's 2020 Water Resources Plan. The implementation table (Table 8) uses the format of the 2020 Water Resources Plan to facilitate incorporation of the Fish Lake Management Plan activities. The dollar amounts shown in Table 8 represent either the additional funding needed for Fish Lake management activities for the given budget category or an additional sub-category for the budget category to account for Fish Lake specific projects.

A. CAPITAL IMPROVEMENT PROGRAM

The proposed in-lake treatments and the regional watershed improvement projects are included in the Capital Improvement Programs budget category IV.C.1. These are large scale, high initial investment projects.

i. In-Lake Alum Treatments

The recommended management for in-lake treatment is an alum treatment. The specific treatment design is outlined in Appendix A. The recommended implementation of the alum treatment on Fish Lake is a buffered alum treatment split between two doses with follow up sediment cores after the first dose to allow for adaptive management of the second dose.

The estimated probable cost of the application was estimated from previous bids in the last five years with an added 15% contingency on the second dose to adjust for unforeseen supply costs increases.

ii. Fish Lake Watershed Projects

The regional stormwater management projects described above are included in the existing budget category IV.C.1.5 Fish Lake Watershed Projects. The summary of each project estimated cost is outlined in Appendix B.

Lake Ridge Estates Pond Retrofits Feasibility Study

A feasibility study is needed to evaluate the current nutrient loading dynamics and treatment being provided by the stormwater management practices within the Lake Ridge Estates subwatershed. If it is determined that retrofitting the ponds may be necessary to achieve a desired load reduction, the feasibility study will investigate novel approaches to address each individual basin. The estimated cost for a subwatershed feasibility study is approximately $50,000. At this time, there are too many uncertainties surrounding this opportunity to accurately develop a cost estimate for implementation.

Fish Lake West Wetland Restoration: In-line Iron Enhanced Sand Filter

The second priority project is an in-line stormwater treatment feature downstream of the Malibu Avenue culvert. The estimated cost for design, permitting, and construction of the in-line stormwater treatment feature is $231,000 with operation and maintenance costs over a 15 year life cycle of $13,000.

Fairlawn Lane Lake Inlet Iron Enhanced Sand Filter

The design for an Iron Enhanced Sand Filter at the lake inlet near Fairlawn Lane will determine final size, shape, type (basin vs. bench), and cost. A planning level cost estimate for engineering, permitting, and construction of the Iron Enhanced Sand Filter is $321,000 with an estimated operation and maintenance cost over a 15 year life cycle of $19,000.

Fish Lake West Wetland Restoration

The estimated cost for land acquisition, design, permitting, and construction for the Fish Lake West Wetland Restoration is $716,000. The estimated cost to conduct the required wetland monitoring as well as operations and maintenance for the wetland restoration over a 15 year life cycle is $123,000.

200th Street Pond Improvements

Improvements to the 200th Street Pond are primarily focused on removal of nutrient laden sediments but could include retrofits to the pond that would increase detention time or infiltration rates, thus increasing the pond's ability to reduce phosphorus loading. The estimated cost to remove between 325 to 650 cubic yards of material, permitting, and engineering would be $17,000. No additional costs are anticipated for operation and maintenance of this project.

205th Street Pond Improvements

Improvements to the 205th Street Ponds also focus on removal of nutrient laden sediments but could include retrofits to the ponds that would increase detention time or infiltration rates, thus increasing the pond's ability to reduce phosphorus loading. The estimated cost to remove between 2,100 to 2,500 cubic yards of material, permitting, and engineering would be $84,000. No additional costs are anticipated for operation and maintenance of this project.

Malibu Avenue Wetland Restoration & Enhancement

The Malibu Avenue Wetland Restoration & Enhancement is included using the general wetland restoration and enhancement budget item of IV.C.1.12. The proposed project includes restoring wetlands in areas currently being cropped and enhancing wetlands in areas that have perennial non-native vegetation. An upland native buffer within the project area would also be created in areas not designated for wetland restoration. The estimated cost for design, permitting, and construction is $1,519,000. The estimated cost to conduct the required wetland monitoring as well as operations and maintenance for the wetland restoration over a 15 year life cycle is $152,000.

B. OPERATION & MAINTENANCE PROGRAM

Monitoring of aquatic invasive species, carp management efforts, and implementation water quality improvement through District cost share programs are proposed to be conducted using the Operations and Maintenance Program budget category IV.C.2.

i. AIS Prevention & Management

Continued monitoring of Curly-leaf pondweed and other aquatic invasive species on Fish Lake is recommended and is already accounted for in budget category IV.C.2.1.

ii. Carp Management Program

Continued monitoring of carp on Fish Lake is recommended and is already accounted for in budget category IV.C.2.2.

iii. Cost Share Program

Residential stormwater management practices and lakeshore improvements are proposed to be funded through use of the District's Cost Share Program and are included as budget category IV.C.2.3. The number of practices to be funded by the cost share program is based entirely on interest level/willingness of individual landowners in the watershed. A planning level estimate range of an additional $5,000 - $7,500 per year for Fish Lake specific cost share projects has been included.

A strategic informational campaign is proposed to encourage watershed residents to implement residential stormwater management practices and lakeshore improvements on properties. The campaign will also advertise the availably of financial assistance through use of the Districts Cost Share Program. A one-time additional expense of $2,500 has been included for this informational campaign.

iv. Farmer-Led Council Initiatives

Agricultural conservation practices are proposed to be funded through use of the District's Farmer-Led Council Initiatives and are included as budget category IV.C.2.4. The number of practices to be funded by the cost share program is based entirely on interest level/willingness of individual farmers within the watershed. A planning level estimate range of an additional $5,000 - $7,500 per year for Fish Lake specific conservation farming incentives has been included.

A strategic informational campaign is proposed to encourage watershed residents to implement agricultural conservation practices on properties. The campaign will also advertise the availably of financial assistance through use of the Districts Farmer-Led Council Initiative. A one-time additional expense of $2,500 has been included for this informational campaign.

v. Project Maintenance

Projects that receive funding through the Cost Share Program and Farmer-Led Council Initiatives may include a stipulation for on-going maintenance. Maintenance time frames are specific to each practice type. Scott SWCD performs project inspections to ensure that maintenance is conducted. No additional funding in the budget category IV.C.2.9 has been included for potential future Fish Lake projects. Operation and maintenance estimates for each of the proposed capital improvement projects are shown in Table 5. Annualized O & M costs are included in Table 8 beginning in the year following proposed project construction.

C. PLANNING PROGRAM

i. District Plan Updates

The specific projects included in the capital improvement program will require an amendment to the Districts Water Resources Management Plan. One comprehensive plan update is proposed to include these specific plans at an estimated cost of $10,000.

D. EDUCATION & OUTREACH PROGRAM

i. Communications & Public Outreach

A public outreach campaign is being proposed to educate watershed residents about the Fish Lake Management Plan and specifically the recommendations for using alum for internal load management. The estimated cost for conducting this targeted public outreach is $5,000/year.

E. MONITORING PROGRAM

i. Lake Monitoring

The recommended monitoring program for lake monitoring is outlined in Section 5. The cost for monitoring includes $15,000 for follow up sediment cores after each application. This cost is shown as an addition to the existing cost for lake monitoring accounted for in budget category IV.C.5.2.

ii. Stream & Ditch Monitoring

Continued monitoring of the stream/ditch near the Fairlawn Avenue / Fairlawn Lane intersection is recommended. The cost of this monitoring is already accounted for in budget category IV.C.5.3.

iii. Effectiveness / BMP Monitoring

Post-construction monitoring of the regional stormwater management practices to determine nutrient removal effectiveness is strongly recommended. A summary of the recommended monitoring approach is provided in Section 5. The cost for BMP effectiveness monitoring is assumed to be $10,000 in the first year following construction to account for equipment purchase and initial installation costs and then $5,000 a year for the following 2 years.

iv. Wetland Monitoring

Monitoring of the proposed wetland restoration & enhancement projects (Fish Lake West and Malibu Avenue) is a requirement of the banking process. Costs for the wetland monitoring for the proposed projects described above are totaled by year in Table 8.

F. ADMINISTRATION & PROJECT IMPLEMENTATION

i. Project Implementation (District Staff)

District staff involvement in the implementation of proposed regional stormwater management practices has been estimated as a percentage (5%) of the annual capital project cost, using budget category IV.C.7.2.

ii. Project Implementation (District Engineer)

Engineering costs for the proposed regional stormwater management practices are included in the overall project cost described above.

Table 8. Fish Lake Management Plan Implementation Table

			Schedule and Estimated Cost												Funding Options			
	Programs & Projects	***Total Project Cost***	2020	2021	2022	2023	2024	**2025**	**2026**	**2027**	**2028**	**2029**	**Watershed Plan Total**	**Post Plan Cost**	**Property tax levy**	**Grants** *(state, federal, local, private)*	**Government Partners** *(cities, townships, SWCD, county, state agencies and federal agencies)*	**Local & Non-Profit** *(lake associations, school district, landowners, businesses, community groups, volunteers, etc.)*
IV.C.1	**Capital Improvement Program**							**$586,000**	**$716,000**	**$321,000**	**$415,000**	**$1,519,000**	**$3,557,000**					
IV.C.1.1	In-Lake Alum Treatments	$619,000						$288,000			$331,000		**$619,000**		X	X	X	
IV.C.1.5	Fish Lake Watershed Projects																	
IV.C.1.5.a	Lake Ridge Estates Retrofits Feasibility Study	$50,000						$50,000					**$50,000**		X	X		
IV.C.1.5.b	Fish Lake West Wetland Restoration: In-line IESF	$231,000						$231,000					**$231,000**		X	X		
IV.C.1.5.c	Fairlawn Lane Inlet (FL- 007 Subwatershed)	$321,000								$321,000			**$321,000**		X	X		
IV.C.1.5.d	Fish Lake West Wetland Restoration: Wetland	$716,000							$716,000				**$716,000**		X	X		
IV.C.1.5.e	200th St Pond Improvements (FL-009 Subwatershed)	$17,000						$17,000					**$17,000**		X	X		
IV.C.1.5.f	205th Street Pond Improvements (FL-024 Subwatershed)	$84,000									$84,000		**$84,000**		X	X		
IV.C.1.12	Malibu Avenue Wetland Restoration & Enhancement Wetland	$1,519,000										$1,519,000	**$1,519,000**		X	X	X	
IV.C.2	**Operation & Maintenance Program**							**$20,000**	**$16,000**	**$22,000**	**$23,500**	**$23,500**	**$105,000**					
IV.C.2.1	AIS Prevention & Management	On-going District program													X	X	X	X
IV.C.2.2	Carp Management Program	On-going District program													X	X	X	X
IV.C.2.3	Cost Share Program	$5,000 - $7,500/year & $2,500 one-time						$10,000	$7,500	$7,500	$7,500	$7,500	**$40,000**	**$7,500/year**	X	X	X	X
IV.C.2.4	Farmer-Led Council Initiatives	$5,000 - $7,500/year & $2,500 one-time						$10,000	$7,500	$7,500	$7,500	$7,500	**$40,000**	**$7,500/year**	X		X	
IV.C.2.9	Project Maintenance								$1,000	$7,000	$8,500	$8,500	**$25,000**	**$282,500**	X			
IV.C.3	**Planning Program**							**$10,000**	**$0**	**$0**	**$0**	**$0**	**$10,000**					
IV.C.3.3	District Plan Updates	$10,000						$10,000					**$10,000**		X			
IV.C.4	**Education & Outreach Program**							**$5,000**	**$5,000**	**$5,000**	**$5,000**	**$5,000**	**$25,000**					
IV.C.4.2	Communications & Public Outreach	$5,000/year						$5,000	$5,000	$5,000	$5,000	$5,000	**$25,000**	**$5,000/year**	X			X
IV.C.5	**Monitoring Program**							**$0**	**$35,000**	**$20,000**	**$30,000**	**$25,000**	**$110,000**					
IV.C.5.2	Lake Monitoring	$15,000							$15,000				**$15,000**		X			X
IV.C.5.3	Stream & Ditch Monitoring	On-going District program													X			
IV.C.5.4	Effectiveness / BMP Monitoring	refer to Section 6							$20,000	$10,000	$20,000	$15,000	**$65,000**	**$15,000**	X		X	
IV.C.5.5	Wetland Monitoring	Wetland monitoring bank certification								$10,000	$10,000	$10,000	**$30,000**	**$99,000**	X			
IV.C.7	**Administration & Project Implementation**							**$30,000**	**$36,000**	**$17,000**	**$21,000**	**$76,000**	**$178,000**					
IV.C.7.2	Project Implementation (District Staff)							$30,000	$36,000	$17,000	$21,000	$76,000	$178,000	**$0**	X			
Annual Total								**$651,000**	**$808,000**	**$385,000**	**$494,500**	**$1,648,500**	**$3,985,000**					

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APPENDIX A. FISH LAKE SEDIMENT CORE AND ALUM DOSING ANALYSIS

1. SEDIMENT CHARACTERISTICS, CORING ANALYSIS, & RESULTS

1.1. Bottom Hardness

Identifying areas of the lake with sandy or gravel sediments is an important factor in identifying areas with low phosphorus release rates. Sandy/gravel (hard) sediments tend to have a much lower phosphorus release rate in comparison with muck (soft) sediments. A comparison of bottom hardness data from BioBase's social map identified soft bands of mucky sediment within the deepest portions of the lake that are greater than 15 feet (Figure 3). There is a small rock bar in the central portion of the lake, east of sediment core sampling location 1. This area likely has a lower releasable P concentration in comparison with the muck (lighter colored) sediments that surround the bar.

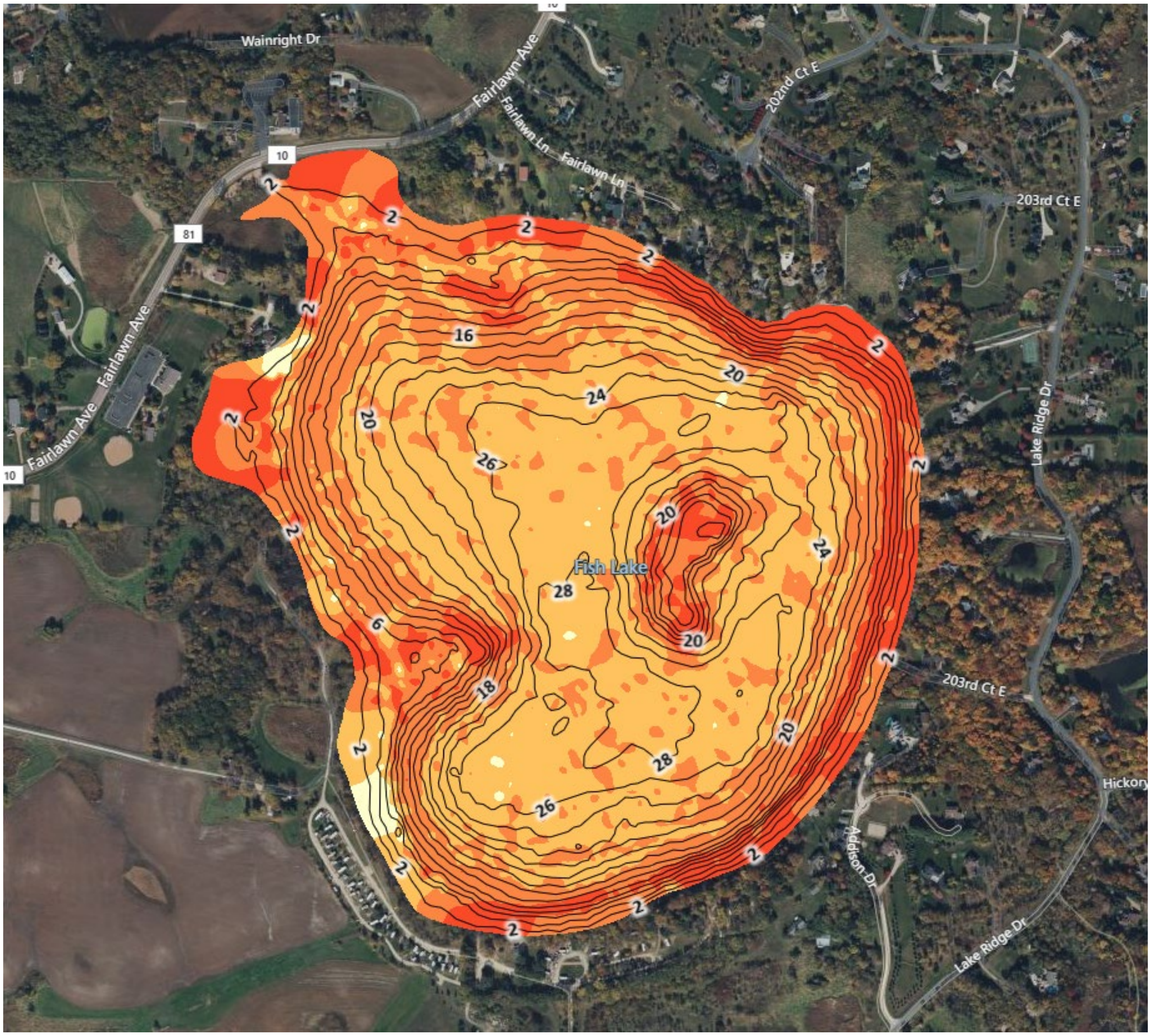

Figure 1. Fish Lake BioBase bottom hardness estimates. Sonar data has been voluntarily contributed by C-Map Genesis (Biobase) users.

1.2. Sediment Core Releasable Phosphorous (RP) Concentration and Bulk Density

Redox-Sensitive Phosphorus is the sum of Labile Phosphorus and Iron-bound Phosphorus fractions. Redox-Sensitive Phosphorus is controlled by stoichiometric redox chemistry and internal loading from this source generally occurs when the sediments and sediment porewater are anoxic. Biogenic Phosphorus (BP) represents the portion of Organic Phosphorous that is currently loosely bound in organic matter, but which is most readily available for dissolution into the water column and is often controlled by biological activity in the sediments.

These two sediment sources of phosphorous (Redox-Sensitive and Biogenic) were added to determine the amount of RP available during internal loading events. Sediment cores were only collected to a depth of 6 CM. The top 0-2 CM contained the highest RP concentrations, while the bottom 4-6 inches of the sediment core contained the least.

The sediment cores collected near the deeper central parts of the Fish Lake basin had a higher RP concentration, whereas the shallower sediments tend to have higher amounts of tightly bound phosphorus. This information, when compiled with bathymetry data, dissolved oxygen data, and bottom hardness data provided additional evidence to suggest that the internal load control measures should focus on the deeper portions of the lake, greater than 15 feet deep. The RP fractions observed in Fish Lake are shown in Table 1. Observed RP concentrations in Fish Lake were like other Wisconsin and Minnesota Lakes, specifically Lake Desair. However, the Al dosage required to bind RP in the upper 6-cm layer of Lake Desair sediment varied between 263 g/m^2 and 437 g/m^2 (Table 4). In contrast, most alum dosage estimates that resulted in successful sediment P control have ranged between 40 and 137 g/m^2. The reason for the higher alum dosage on Lake Desair is because of the relatively high sediment and bulk density of Lake Desair sediments (more dense), which means there is a greater mass of RP per unit area to be inactivated. By comparison, Fish Lake requires an alum dosage of 120 g/m2. Furthermore, Lake Desair had a higher proportion of iron-bound phosphorus in comparison with Fish Lake.

Table 2 shows the ranges in sediment physical-textural characteristics, Redox-Sensitive Phosphorus and Iron-bound Phosphorus concentrations, and the AL:P binding ration ranges in surface sediment (James and Bischoff, 2015).

1.3. Sediment Core RP Concentration with Lake Depth

In addition to differences in RP concentration within the sediment core, there are statistically significant differences (increasing trend) in RP concentrations with depth. The most significant differences in sediment RP content occur at depths greater than 15 feet (Figure 1). This trend of increasing RP concentration with depth justifies ensuring all deep zones within the lake receive alum treatment.

Table 1. Fish Lake Sediment Core Characteristics

Core ID	Sediment Characteristics						Sediment P concentration					Mass per volume of sediment (mg/cm3)					Redox-P	Releasable P
	Interval (cm)	dry bulk density (g/cm3)	%moisture	%organic matter	%carbonate	%mineral	Total	Loosely Bound	FE-Al Bound	Ca bound	Organic (residual)	Total	Loosely Bound	FE-Al Bound	Ca bound	Organic (residual)	(mg/g)	(mg/g)
S1	0-2	0.050	95.16	25.22	29.61	45.18	1.67	0.07	0.72	0.29	0.59	0.08	0.0035	0.036	0.014	0.029	0.791	1.081
	2-4	0.071	93.17	22.4	33.19	44.41	1.39	0.056	0.61	0.25	0.47	0.1	0.004	0.043	0.018	0.034	0.666	0.916
	4-6	0.083	92.03	21.14	34.39	44.48	1.27	0.033	0.6	0.27	0.37	0.11	0.0027	0.05	0.022	0.031	0.633	0.903
	mean						***1.44***	***0.05***	***0.64***	***0.27***	***0.48***	***0.1***	***0.0034***	***0.043***	***0.018***	***0.031***	0.690	0.960
S2	0-2	0.054	94.72	26.45	26.46	47.09	1.31	0.061	0.33	0.26	0.66	0.07	0.0033	0.018	0.014	0.036	0.391	0.651
	2-4	0.074	92.85	24.61	29.16	46.24	1.36	0.039	0.32	0.26	0.74	0.1	0.0029	0.024	0.019	0.055	0.359	0.619
	4-6	0.082	92.15	24.31	28.83	46.86	0.99	0.049	0.28	0.3	0.36	0.08	0.004	0.023	0.024	0.029	0.329	0.629
	mean						***1.22***	***0.05***	***0.31***	***0.27***	***0.59***	***0.08***	***0.0034***	***0.022***	***0.019***	***0.04***	0.360	0.630
S3	0-2	0.058	94.37	20.67	59.88	19.45	0.73	0.056	0.11	0.5	0.06	0.04	0.0032	0.006	0.029	0.003	0.166	0.666
	2-4	0.133	87.63	15.16	67.64	17.21	1.08	0.06	0.09	0.6	0.32	0.14	0.0079	0.012	0.08	0.043	0.150	0.750
	4-6	0.192	82.75	11.65	72.68	15.66	0.79	0.054	0.07	0.62	0.05	0.15	0.0103	0.013	0.119	0.01	0.124	0.744
	mean						***0.87***	***0.06***	***0.09***	***0.58***	***0.14***	***0.11***	***0.0072***	***0.011***	***0.076***	***0.019***	0.150	0.730
S4	0-2	0.059	94.31	22.69	19.78	57.53	1.10	0.043	0.29	0.31	0.45	0.06	0.0025	0.017	0.018	0.027	0.333	0.643
	2-4	0.115	89.18	20.69	19.98	59.33	1.12	0.038	0.22	0.57	0.29	0.13	0.0044	0.025	0.066	0.033	0.258	0.828
	4-6	0.129	87.97	20.32	20.17	59.51	1.08	0.031	0.23	0.32	0.49	0.14	0.004	0.03	0.041	0.063	0.261	0.581
	mean						***1.10***	***0.04***	***0.25***	***0.40***	***0.41***	***0.11***	***0.0037***	***0.024***	***0.042***	***0.041***	0.290	0.690
S6	0-2	0.053	94.81	25.1	30.02	44.87	1.94	0.079	1.08	0.27	0.52	0.1	0.0042	0.058	0.014	0.028	1.159	1.429
	2-4	0.075	92.81	23.47	32.09	44.45	1.75	0.076	1.26	0.28	0.14	0.13	0.0057	0.094	0.021	0.01	1.336	1.616
	4-6	0.080	92.31	22.51	31.66	45.84	1.53	0.049	0.8	0.31	0.37	0.12	0.0039	0.064	0.025	0.029	0.849	1.159
	mean						***1.74***	***0.07***	***1.05***	***0.29***	***0.34***	***0.12***	***0.0046***	***0.072***	***0.02***	***0.022***	1.120	1.410
S7	0-2	0.065	93.76	24.03	29.4	46.57	1.21	0.044	0.31	0.26	0.59	0.08	0.0028	0.02	0.017	0.038	0.354	0.614
	2-4	0.082	92.18	23.31	30.14	46.56	1.15	0.034	0.3	0.25	0.56	0.09	0.0028	0.025	0.021	0.045	0.334	0.584
	4-6	0.093	91.19	22.53	30.09	47.38	0.89	0.036	0.26	0.29	0.3	0.08	0.0033	0.024	0.027	0.028	0.296	0.586
	mean						***1.08***	***0.04***	***0.29***	***0.27***	***0.48***	***0.08***	***0.003***	***0.023***	***0.021***	***0.037***	0.330	0.600
S8	0-2	0.072	93.03	25.75	22.09	52.16	1.24	0.052	0.24	0.39	0.56	0.09	0.0038	0.017	0.028	0.04	0.292	0.682
	2-4	0.103	90.22	24.43	22.59	52.99	0.97	0.061	0.3	0.32	0.3	0.1	0.0063	0.031	0.033	0.031	0.361	0.681
	4-6	0.107	89.86	25.56	21.83	52.61	0.83	0.049	0.19	0.36	0.23	0.09	0.0052	0.02	0.038	0.025	0.239	0.599
	mean						***1.01***	***0.05***	***0.24***	***0.35***	***0.36***	***0.09***	***0.0051***	***0.023***	***0.033***	***0.032***	0.290	0.640
S9	0-2	0.066	93.59	27	20.47	52.53	1.06	0.052	0.27	0.24	0.5	0.07	0.0035	0.018	0.016	0.033	0.322	0.562
	2-4	0.088	91.62	26.28	20.47	53.24	1.20	0.055	0.23	0.19	0.71	0.1	0.0048	0.021	0.017	0.062	0.285	0.475
	4-6	0.100	90.47	26.48	20.56	52.96	1.30	0.057	0.18	0.25	0.82	0.13	0.0057	0.018	0.025	0.082	0.237	0.487
	mean						***1.19***	***0.05***	***0.23***	***0.23***	***0.68***	***0.1***	***0.0047***	***0.019***	***0.019***	***0.059***	0.280	0.510
S10	0-2	0.058	94.37	31.9	17.18	50.92	1.17	0.045	0.31	0.22	0.6	0.07	0.0026	0.018	0.013	0.035	0.355	0.575
	2-4	0.089	91.51	30.1	16.1	53.8	1.21	0.038	0.3	0.3	0.58	0.11	0.0034	0.026	0.026	0.051	0.338	0.638
	4-6	0.094	91.05	29.82	17.36	52.82	0.96	0.054	0.21	0.26	0.44	0.09	0.0051	0.02	0.024	0.041	0.264	0.524
	mean						***1.11***	***0.05***	***0.27***	***0.26***	***0.54***	***0.09***	***0.0037***	***0.021***	***0.021***	***0.042***	0.320	0.580

Fish Sediment Characteristics Greater Than 15 Feet Deep	Min	0.48
	Mean	**0.82**
	Max	1.62
Fish Sediment Characteristics Less Than 15 Feet Deep	Min	0.52
	Mean	**0.66**
	Max	0.83

Table 2. Ranges in Sediment Physical-textural Characteristics, Redox-Sensitive Phosphorus (P) and Iron (Fe)-bound Phosphorus Concentrations, and the AL:P Binding Ratio Ranges in Surface Sediment.

Lake	*n*	Surface Area (ha)	Mean Depth (m)	Stratification	Moisture Content (%)	Wet Density (g/cm³)	Dry Density (g/cm³)	Organic Content (%)	Redox-sensitive P (mg/g)	Fe-bound P (%)	Al:P Ratio
Ardmore, MN	1	4	2.88	Dimictic	94	1.028	0.071	31	0.52	95	48
Bald Eagle, MN[1]	6	513	0.00	Dimictic	94–96	1.017–1.025	0.042–0.069	35–40	0.10–1.08	88	168–24
Big Chetac, WI	3	363	4.89	Polymictic	95–96	1.015–1.020	0.043–0.052	37–40	1.52–2.46	92	20–17
Big Moon, WI	2	77	0.00	Dimictic	95–96	1.016–1.023	0.039–0.058	29–31	7.77–8.84	97	9
Burandt, MN[1]	1	37	0.00	Dimictic	90	1.045	0.108	27	0.40	14	20
Cedar, WI	4	452	0.00	Polymictic	93–94	1.025–1.033	0.067–0.088	27–33	0.24–0.32	84	72–59
Desair, WI	3	32	0.00	Dimictic	84–86	1.074–1.095	0.199–0.260	15–17	0.52–1.77	92	54–18
East Alaska, WI[1]	3	21	0.00	Dimictic	93–94	1.026–1.034	0.059–0.086	24–28	0.17–0.21	53	111–86
Fish, MN	2	96	6.07	Dimictic	89–93	1.033–1.055	0.084–0.134	23–29	0.38–0.39	85	44–43
Golden, MN	3	23	0.00	Dimictic	93–96	1.015–1.027	0.040–0.072	34–39	0.83–2.61	97	25–13
Half Moon, MN	1	12	4.08	Dimictic	96	1.011	0.041	54	0.84	96	37
Half Moon, WI[1]	7	62	0.00	Polymictic	86–92	1.040–1.077	0.104–0.201	15–34	0.15–4.96	98	170–12
Halsted's Bay, MN	3	227	0.00	Dimictic	89–91	1.045–1.054	0.103–0.119	23–26	0.28–0.41	66	46–40
Long, WI	1	110	3.15	Polymictic	92	1.039	0.087	24	0.545	95	55
Spurzem, MN	2	26	3.39	Dimictic	93-95	1.018–1.021	0.056–0.072	44–49	0.30 –2.23	93	62–19
Squaw, WI	5	52	0.00	Dimictic	86–97	1.009–1.073	0.030–0.146	18–53	0.13–0.60	83	155–42

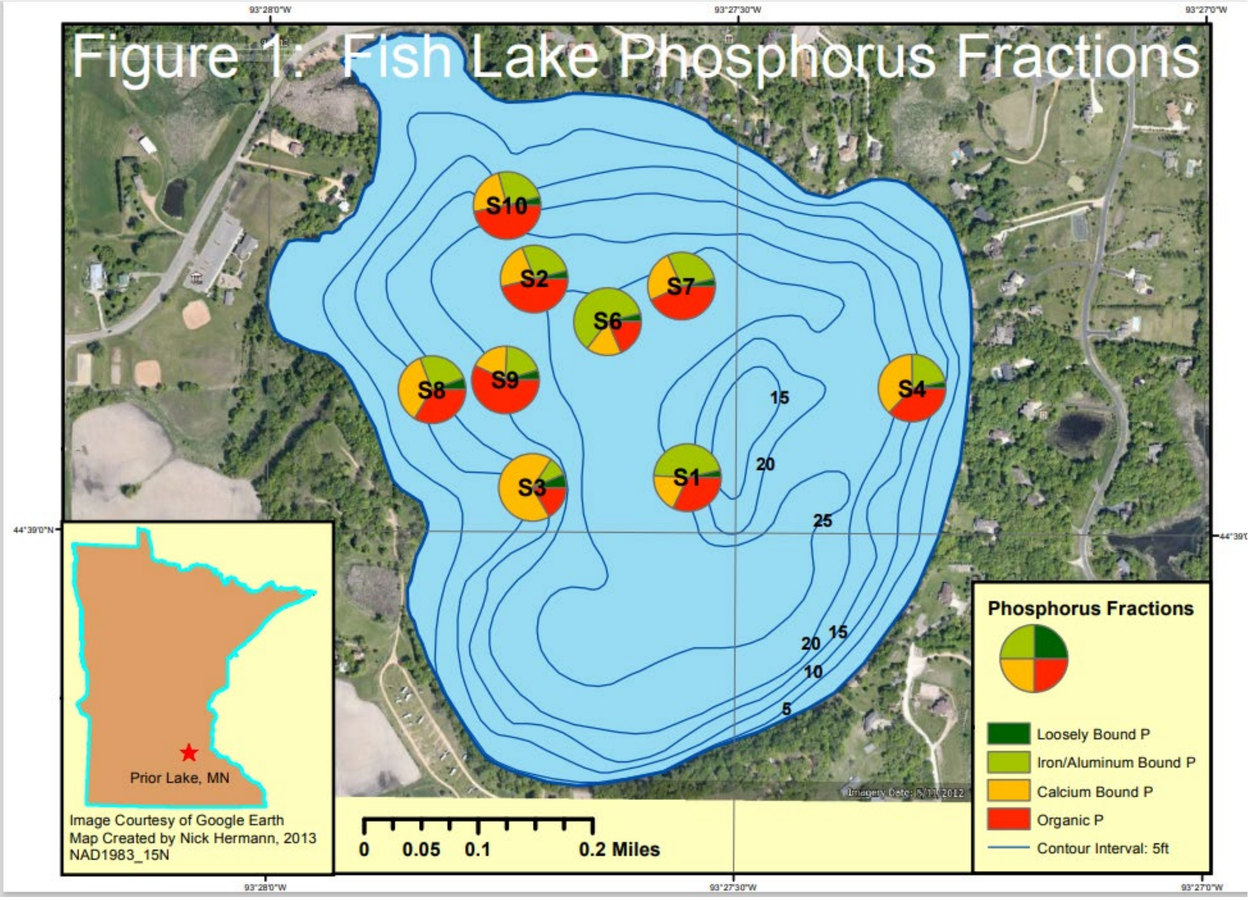

Figure 2. Releasable Phosphorus (RP) content within the first 6 cm of the sediment core increases significantly in the portions of the lake that are greater than 25 feet.

1.4. Determination of Sediment Phosphorus Release Rates

Results from the sediment incubation release rate analysis provided further evidence to suggest there are significant differences in sediment phosphorus release rates between the shallow areas of Fish Lake in comparison with the deeper areas of the lake (Table 3). Samples collected within the portions of Fish Lake that are deeper than 15 feet had an averaged anoxic release rate of about 5.26 mg/m^2 day which is considered to be a low to moderate release rate. By comparison, mean anoxic diffusive flux rates varied between 8.4 to 14.7 mg/m^2 day in Lake Desair. Another study completed by EOR on Forest Lake (Washington County, Minnesota) in 2022 and 2023 found anoxic release rates between 8.3 and 13.2 mg/m^2 day. Samples collected by EOR on Upper Whitefish Lake (Crow Wing County) in 2022 had lower phosphorus release rates (0.26-4.27 mg/m^2 day). Aerobic phosphorous release is approximately 12% of anaerobic release for all three basins. Estimated aerobic (oxic) phosphorous release rates are shown in Table 3.

Table 3. Phosphorus Release Rates by Basin

Core ID	Anoxic phosphorous Release Rate (mgP/m2/day)	Approximate Depth of Water at Sediment Sampling Location	Oxic phosphorous release (mg/m^2 day)
S1	6.29	Deep (20-25')	0.75
S2	3.08	Deep (15-20')	0.37
S3	1.99	Shallow (10-15')	0.24
S4	3.49	Shallow (10-15')	0.42
S6	10.87	Deep (20-25')	1.30
S7	3.23	Deep (20-25')	0.39
S8	3.5	Shallow (10-15')	0.42
S9	2.85	Deep (15-20')	0.34
S10	3.07	Shallow (10-15')	0.37
Average (Deep Samples)	**5.26**	**Deep (15-25')**	**0.63**
Average (Shallow Samples)	**3.01**	**Shallow (10-15')**	**0.36**

1.5. Phosphorus Budget

A review of dissolved oxygen data in Fish Lake provided evidence to suggest that lake sediments are anaerobic for an average of 154 days in the summer months, no data was collected in the winter, but it is assumed that the lake is dimictic and there is a symmetrical prolonged anoxic period in the winter contributing to release in spring. Annual anoxic phosphorous loading to Fish Lake was estimated by multiplying conservative anoxic release rate measured in the laboratory study (6.79 mg/m^2 day) by the surface area of Fish Lake by the anoxic factor (85 days). The anoxic factor is the ratio of temporal and spatial extent of anoxic sediments to the lake surface area. This yields an estimate of 878 lbs/yrs. for annual anoxic release. The anoxic area (100 acres) corresponds to the area of 15 feet or more depth.

2. ALUM DOSING RECOMMENDATIONS

A The weight of evidence approach provided the background information needed to identify a treatment zone which consisted of the portions of Fish Lake that are deeper than 15 feet, which equates to an area of approximately 100 acres. This portion of the lake is stratified during the majority of the growing season in most year.

2.1. Fish Lake

Treatment of Fish Lake requires targeting the top 6 cm of the sediment column within the portion of the Fish Lake that is deeper than 15 feet (100 acres) using an alum to phosphorus (AL:P) binding ratio of 34.4:1. The AL:P binding ratio was calculated using the average observed RP concentration of 0.82 mg/g. Observed RP concentrations for all sediment cores are shown in Table 1of this report.

The treatment requires the application of 95,988 gallons of alum at an average alum dosing rate of 960 gallons per acre and 47,994 gallons of sodium aluminate buffer at an average dosing rate of 480 gallons per acre. These are the application rates needed to bind at least 90%, 75% is more conservative, of the redox-sensitive P. The required Al dosage is 121 g Al/m^2. The dosage was determined based on the alum to phosphorus binding ratios by James and Bischoff (2015) using concentrations of redox-sensitive phosphorus to calculate this ratio. EOR recommends the buffered alum treatment be separated into two doses with follow up sediment and water quality monitoring. We recommend that the follow-up sediment cores be collected at least one year after the first dose application and cores be collected at similar locations to this study and include the following parameters: anaerobic phosphorus release, moisture content-bulk density, loss-on ignition organic matter, total aluminum, aluminum bound phosphorus, and redox-sensitive phosphorus. EOR also recommends surface and hypolimnetic water quality monitoring in years following each treatment to confirm water quality improvements in Fish Lake and assess if future applications will need to expand to shallower regions of the lake.

2.2. Longevity Analysis

Brian Huser of the Swedish University of Agricultural Sciences, Department of Aquatic Sciences conducted an analysis of 114 lakes treated with alum to identify factors driving the longevity of post-treatment water quality improvements. The following three variables: 1) Al dosage rate, 2) watershed to lake area ratio, and 3) lake morphology explained 82% of the variation in treatment longevity based on post-treatment changes in TP concentration (Huser et., al, 2011).

Due to the uncertainties in the alum longevity partition model presented above, an alternative analysis was performed to estimate how long it will take to bury the alum layer after the alum application. The important factor to consider for this analysis is how much P sedimentation is occurring and not just overall sedimentation. To do this, we focused on the estimated P sedimentation rate from the lake response model. The Canfield-Bachmann sedimentation equation (Canfield et al, 1981) was used to estimate how long it would take to replace inactivated phosphorus in the top 6 cm of sediment. It is important to note that this analysis should not be interpreted as the exact life of an alum treatment, but rather to assess whether a treatment will be quickly buried based on phosphorus settling and if additional watershed load should be reduced prior to an alum treatment.

This exercise suggests that burial of the alum layer to 6 cm is 81 years under current watershed loading and the additional watershed load reductions of 30% would improve estimated burial time by approximately 97 years.

2.3. Cost

The total estimated cost of the alum treatment includes the estimated probable cost of the alum treatment and the cost of the follow up sediment cores. The estimated probable cost of the application was estimated from previous bids in the last 5 years with an added 15% contingency to adjust for unforeseen supply costs increases for the final dose.

Activity	Year	Cost
First Dose Application 1	2025	$288,000
Follow up Sediment cores	2026	$15,000
Final Dose	2028	$331,000

3. LANTHANUM MODIFIED BENTONITE APPLICATION

Lanthanum (La) modified bentonite (LMB) was investigated as another option for sediment inactivation. LMB binds to phosphate released from sediments at a 1:1 molar ratio. Like alum, LMB is applied from a barge, as slurry. Once settled onto the bed, the product retains P released from the sediment in a form not available to phytoplankton and is stable within the pH range 5–9. LMB applications are not common in the upper Midwest and would be considered a more experimental treatment in Fish Lake. Additionally, there are concerns about the release of free lanthanum into the water column during application. Unlike alum treatments in which the conditions for unintended free aluminum release are well documented and understood, the conditions and risk for free La release are still to be determined (Zhi et al, 2021, Hermann et al., 2016, and Spears et al. 2013). The North American Lake Management Society has only published a position on the use of alum for safe and effective internal load management.

3.1. Lanthanum Modified Bentonite

EOR reached out to SePro Corporation to develop a dose for Fish Lake. SePro is the supplier of a lanthanum modified bentonite product, Eutrosorb G. The dosing rate is 50 lbs. of Eutrosorb G. to 1 lb. of phosphorus. Thus, the dose for 878 lbs. Of phosphorus is 43,900 lbs. To move forward with the dose, the District would have to reach out to a qualified applicator. SePro provided us the following contractors:

- Black Lagoon – Amy Kay (715-891-6798) amy.kay@blacklagoon.us
- Lake Management – Mike O’Connell (651-433-3283) mike@lakemanagementinc.com
- PLM Lake and Land Management – Patrick Selter (651-383-1150) patricks@plmcorp.net

APPENDIX B. EXPANDED COST ESTIMATES: REGIONAL WATERSHED IMPROVEMENTS

Fish Lake West - Wetland Restoration In-line IESF	
Project Rank	2
Initial Capital Investment	**Estimated Cost**
Construction Cost (2023)	$126,500
Permits and Legal Fees (10% Construction)	$12,650
Design and Construction Engineering (30% Construction)	$37,950
Contingency (20% of Construction, P&L, Design & Const. Eng.)	$35,420
Total Capital Investment	**$213,000**
Approximated Land Value Costs	
2023 Land Value (Scott GIS) ($/acre)	$70,000
BMP Area (acre)	0.25
Landowner Compensation	**$17,500**
O&M	
Annual Maintenance (15-years)	$1,000
Annual Maintenance Present Value	$13,000
Total O&M	**$13,000**
Summary	
Total Cost	$244,000
Annual Load Reduction (lbs TP)	26.6
Total Load Reduction (15 years)	399
Cost Effectiveness ($/lb TP)	**$612**

Fairlawn Lane Lake Inlet IESF	
Project Rank	3
Initial Capital Investment	**Estimated Cost**
Construction Cost (2023)	$160,000
Permits and Legal Fees (10% Construction)	$16,000
Design and Construction Engineering (30% Construction)	$48,000
Contingency (20% of Construction, P&L, Design & Const. Eng.)	$44,800
Total Capital Investment	**$269,000**
Approximated Land Value Costs	
2023 Land Value (Scott GIS) ($/acre)	$186,000

Fairlawn Lane Lake Inlet IESF	
BMP Area (acre)	0.28
Landowner Compensation	**$52,080**
O&M	
Annual Maintenance (15-years)	$1,500
Annual Maintenance Present Value	$19,000
Total O&M	**$19,000**
Summary	
Total Cost	$340,000
Annual Load Reduction (lbs TP)	32.7
Total Load Reduction (15 years)	490.5
Cost Effectiveness ($/lb TP)	**$693**

Fish Lake West - Wetland Restoration (Mitigation Banking)	
Project Rank	4
Initial Capital Investment	**Estimated Cost**
Construction Cost (2023)	$32,000
Permits and Legal Fees (10% Construction)	$3,200
Design and Construction Engineering (30% Construction)	$9,600
Contingency (20% of Construction, P&L, Design & Const. Eng.)	$8,960
Total Capital Investment	**$54,000**
Approximated Land Value Costs	
2023 Land Value (Scott GIS) ($/acre)	$70,000
BMP Area (acre)	9.45
Landowner Compensation	**$661,500**
O&M	
Annual Maintenance (15-years)	$6,000
Annual Maintenance Present Value	$76,000
Wetland Bank Monitoring (5-yr)	$10,000
Wetland Bank Monitoring Present Value	$47,000
Total O&M	**$123,000**
Wetland Banking Revenue	
Credit Sales	($215,000)
Total Wetland Banking Revenue	**($215,000)**
Summary	

Fish Lake West - Wetland Restoration (Mitigation Banking)	
Total Cost	$623,500
Annual Load Reduction (lbs TP)	18.8
Total Load Reduction (15 years)	282
Cost Effectiveness ($/lb TP)	**$2,211**

Fish Lake West - Wetland Restoration	
Project Rank	4
Initial Capital Investment	**Estimated Cost**
Construction Cost (2023)	$32,000
Permits and Legal Fees (10% Construction)	$3,200
Design and Construction Engineering (30% Construction)	$9,600
Contingency (20% of Construction, P&L, Design & Const. Eng.)	$8,960
Total Capital Investment	**$54,000**
Approximated Land Value Costs	
2023 Land Value (Scott GIS) ($/acre)	$70,000
BMP Area (acre)	9.45
Landowner Compensation	**$661,500**
O&M	
Annual Maintenance (15-years)	$6,000
Annual Maintenance Present Value	$76,000
Total O&M	**$76,000**
Summary	
Total Cost	$792,000
Annual Load Reduction (lbs TP)	18.8
Total Load Reduction (15 years)	282
Cost Effectiveness ($/lb TP)	**$2,809**

200th Street Pond Improvements	
Project Rank	5
Initial Capital Investment	**Estimated Cost**
Construction Cost (2023)	$8,000
Permits and Legal Fees (10% Construction)	$800
Design and Construction Engineering (30% Construction)	$2,400
Contingency (20% of Construction, P&L, Design & Const. Eng.)	$2,240
Total Capital Investment	**$14,000**

200th Street Pond Improvements	
Approximated Land Value Costs	
2023 Land Value (Scott GIS) ($/acre)	$10,000
BMP Area (acre)	0.3
Landowner Compensation	**$3,000**
O&M	
Annual Maintenance (15-years)	$0
Annual Maintenance Present Value	$0
Total O&M	**$0**
Summary	
Total Cost	$17,000
Annual Load Reduction (lbs TP)	4.0
Total Load Reduction (15 years)	60
Cost Effectiveness ($/lb TP)	**$283**

205th Street Pond Improvements	
Project Rank	6
Initial Capital Investment	**Estimated Cost**
Construction Cost (2023)	$42,000
Permits and Legal Fees (10% Construction)	$4,200
Design and Construction Engineering (30% Construction)	$12,600
Contingency (20% of Construction, P&L, Design & Const. Eng.)	$11,760
Total Capital Investment	**$71,000**
Approximated Land Value Costs	
2023 Land Value (Scott GIS) ($/acre)	$16,000
BMP Area (acre)	0.8
Landowner Compensation	**$12,800**
O&M	
Annual Maintenance (15-years)	$0
Annual Maintenance Present Value	$0
Total O&M	**$0**
Summary	
Total Cost	$84,000
Annual Load Reduction (lbs TP)	2.1
Total Load Reduction (15 years)	31.5
Cost Effectiveness ($/lb TP)	**$2,667**

Malibu Ave. Wetland Restoration (Mitigation Banking)	
Project Rank	7
Initial Capital Investment	**Estimated Cost**
Construction Cost (2023)	$58,000
Permits and Legal Fees (10% Construction)	$5,800
Design and Construction Engineering (30% Construction)	$17,400
Contingency (20% of Construction, P&L, Design & Const. Eng.)	$16,240
Total Capital Investment	**$98,000**
Approximated Land Value Costs	
2023 Land Value (Scott GIS) ($/acre)	$37,000
BMP Area (acre)	38.4
Landowner Compensation	**$1,421,000**
O&M	
Annual Maintenance (15-years)	$12,000
Annual Maintenance Present Value	$152,000
Wetland Bank Monitoring (5-yr)	$15,000
Wetland Bank Monitoring Present Value	$71,000
Total O&M	**$223,000**
Wetland Banking Revenue	
Credit Sales	($1,277,000)
Total Wetland Banking Revenue	**($1,277,000)**
Summary	
Total Cost	$465,000
Annual Load Reduction (lbs TP)	31.1
Total Load Reduction (15 years)	466.5
Cost Effectiveness ($/lb TP)	**$997**

Malibu Ave. Wetland Restoration	
Project Rank	7
Initial Capital Investment	**Estimated Cost**
Construction Cost (2023)	$58,000
Permits and Legal Fees (10% Construction)	$5,800
Design and Construction Engineering (30% Construction)	$17,400
Contingency (20% of Construction, P&L, Design & Const. Eng.)	$16,240
Total Capital Investment	**$98,000**

Malibu Ave. Wetland Restoration	
Approximated Land Value Costs	
2023 Land Value (Scott GIS) ($/acre)	$37,000
BMP Area (acre)	38.4
Landowner Compensation	**$1,421,000**
O&M	
Annual Maintenance (15-years)	$12,000
Annual Maintenance Present Value	$152,000
Total O&M	**$152,000**
Summary	
Total Cost	$1,671,000
Annual Load Reduction (lbs TP)	31.1
Total Load Reduction (15 years)	466.5
Cost Effectiveness ($/lb TP)	**$3,582**