Stantec

FOX LAKE ADAPTIVE MANAGEMENT PLAN

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Prepared for:
Cannon River Watershed Joint Powers Organization

Prepared by:
Stantec

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227704802

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Executive Summary

Fox Lake is a 330-acre deep lake located in the Upper Cannon River watershed in south central Minnesota. Aquatic recreation is impaired in Fox Lake due to excessive phosphorus which has resulted in frequent algal blooms. Consequently, Fox Lake is not meeting the designated water quality standards and is listed on the State's impaired waters list. The primary issues in Fox Lake are excessive phosphorus, nuisance algal blooms and the presence of Eurasian watermilfoil, an aquatic invasive species that is common in Minnesota lakes. Fox Lake has been included in several studies in the last 10 years which includes a draft lake response modeling report, total maximum daily load (TMDL) study, and a paleolimnological study among others. However, due to limited data and resources, some uncertainty remains in the determination of the relative magnitude of sources of phosphorus to the lake. In 2021, a robust suite of water quality data was collected from Fox Lake and the inflow to the Lake. Using this data, the lake response model (BATHTUB) was updated, and indicated that roughly 25% of the total load to the lake originates from within the lake (internal loading) while 75% of the load is derived from the watershed. Consequently, management actions to reduce nutrient loading from the watershed will be needed and may also require in-lake actions to reduce internal loading as well. Surface measurements of total phosphorus collected in 2021 indicate that the lake is close to meeting the standard so reductions in watershed loading may achieve the target goal of 40 µg/L within the next few years depending on available resources. Lake restoration and management is usually a labor- and cost-intensive process that may take several years to realize improvements in water quality with ongoing efforts required to sustain those improvements. Thus, taking an adaptive management approach to the management of Fox Lake will provide an iterative and flexible framework for improving water quality over time. This document lays out management goals and objectives to achieve water quality improvement in Fox Lake. For each goal, a set of management actions are recommended for implementation in the next 0-3 years along with a list of activities for future consideration depending on progress towards goal attainment. A key component to the success of this plan will be to monitor progress through routine data collection, and then updating the implementation plan every three years planned activities are completed and as new knowledge is gained.

1 Introduction

Fox Lake is a 330-acre deep lake located in the Upper Cannon River watershed in south central Minnesota. Aquatic recreation is impaired in Fox Lake due to excessive phosphorus which has resulted in frequent algal blooms. Consequently, Fox Lake is not meeting the designated water quality standards and was listed on the State's 303(d) list in 2010 (LimnoTech, 2016)

The primary issues in Fox Lake are excessive phosphorus, nuisance algal blooms and the presence of Eurasian watermilfoil, an aquatic invasive species that is common in Minnesota lakes. Fox Lake was identified as a Tier One impaired lake in the Cannon River Comprehensive Watershed Management Plan (Cannon River watershed 1W1P) which means that the issues need to be addressed within the 10-year timeframe of that plan (2020-2029) (1W1P, 2020). As part of that effort, the 10-year plan calls for development of a lake management plan by 2024 that will identify strategies to reduce phosphorus loading. Thus, the purpose of this Fox Lake Management Plan is to document the known sources of phosphorus loading (external vs internal), evaluate the load reduction goals and identify strategies for ongoing management to improve water quality in Fox Lake.

1.1 Adaptive Lake Management Planning Process

While several studies have been completed for the Upper Cannon River watershed which includes information about Fox Lake, observed data for the lake and tributary inputs are limited. Consequently, uncertainty remains regarding the relative magnitude of phosphorus loads to the lake as well as the extent of internal loading from the lake sediments. A fundamental outcome of the Fox Lake management plan will include recommendations for collection of additional data to refine phosphorus loads (sources and magnitude) in order to most effectively target management efforts with the limited resources available. Lakes are dynamic living ecosystems that may not always respond immediately or fully to management actions as predicted. In addition, lake restoration is usually a labor- and cost-intensive process that may take several years to realize improvements in water quality with ongoing efforts required to sustain those improvements. Thus, taking an adaptive management approach to the management of Fox Lake will provide an iterative and flexible framework for improving water quality over time.

Figure 1-1 illustrates the key steps of the adaptive management framework, which is a cyclical and iterative process to be implemented over time as resources allow. The steps of the framework include a condition analysis, goal setting, the evaluation of actions, prioritization and development of planned timelines, implementation, monitoring and evaluation of progress towards goal attainment then revisiting any component of the process as needed in order to meet management goals. One of the most important pieces of the adaptive management process is establishment of a schedule with predetermined milestones for implementation and progress evaluation which is discussed in more detail in Section XYZ.

Lake management and restoration to a desired condition is most effective when driven by data. Whether in the early stages of diagnosing lake condition or monitoring the effectiveness of implemented management actions, quality data is critically important component.

Figure 1-1. Adaptive lake management planning process.

1.2 Completed Studies

Several watershed studies have been completed in the Cannon River Watershed in the last ten years, which are listed below and can be readily accessed online.

- Cannon River Watershed Monitoring and Assessment Report- June 2014
- Cannon River Watershed Stressor Identification Report- October 2015
- Cannon River Watershed HSPF Model Development Project- November 2015
- Cannon River Watershed Restoration and Protection Strategies Report- October 2016
- Cannon River Watershed Total Maximum Daily Load - October 2016
- Cannon River One Watershed One Plan- March 2020
- BATHTUB Modeling to Support Watershed Protection and Restoration Strategy Development: Lakes of the Upper Cannon River Watershed *Working Paper.* Minnesota Pollution Control Agency. 2015.
- Paleolimnological Study of Phosphorus-Impaired Lakes in the Cannon River Watershed. Prepared by the St. Croix Research Station for the Minnesota Pollution Control Agency. 2019.

2 Watershed and Lake Characterization

Characteristics of the Cannon River watershed and Fox Lake have been described in many of the reports documented above and are briefly summarized in the following sections.

2.1 Watershed Description

Fox Lake lies in the Cannon River Watershed (CRW), which covers about 934,440 acres in southern Minnesota. The Fox Lake drainage area covers approximately 8,350 acres resulting in a watershed area: lake area ratio of 25:1 indicating that the watershed exerts a strong influence on the water quality of Fox Lake. Detailed descriptions of the CRW can be found in the reports listed in Section 1.2 and are briefly discussed below.

2.1.1 Land Use

The CRW is dominated by agricultural land use with 75% of the watershed comprised of cropland, pasture and forage acreage. Cropland is primarily used for corn and soybean agriculture. The remaining 25% of the land use in the CRW is comprised of forested, wetlands, and developed lands (WRAPS, 2016). Figure 2-1 was presented in the WRAPS and shows the distribution of land uses in the CRW.

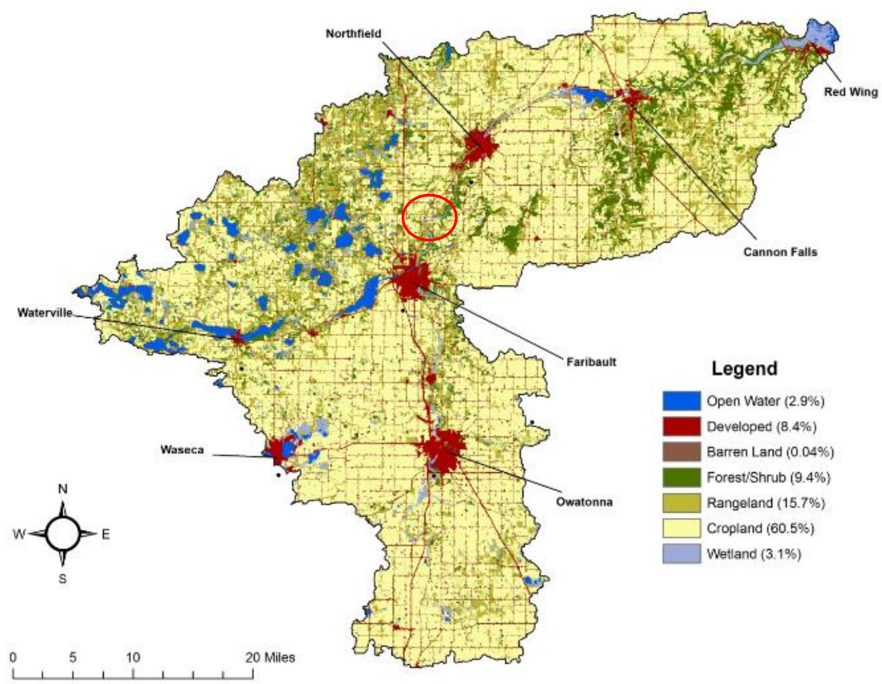

Figure 2-1. Land Use in the Cannon River Watershed Fox Lake is circled in red for reference. Source: (WRAPS, 2016).

2.1.2 Hydrology

Fox Lake lies in the Upper Cannon River Watershed which is a lake-rich portion of the watershed and is hydrologically connected to Mazaska and Circle Lakes (Figure 2-2). The Mazaska flows into Fox Lake which drains into Circle Lake through Wolf Creek and ultimately drains into the Cannon River to the east (Heiskary and Martin 2015).

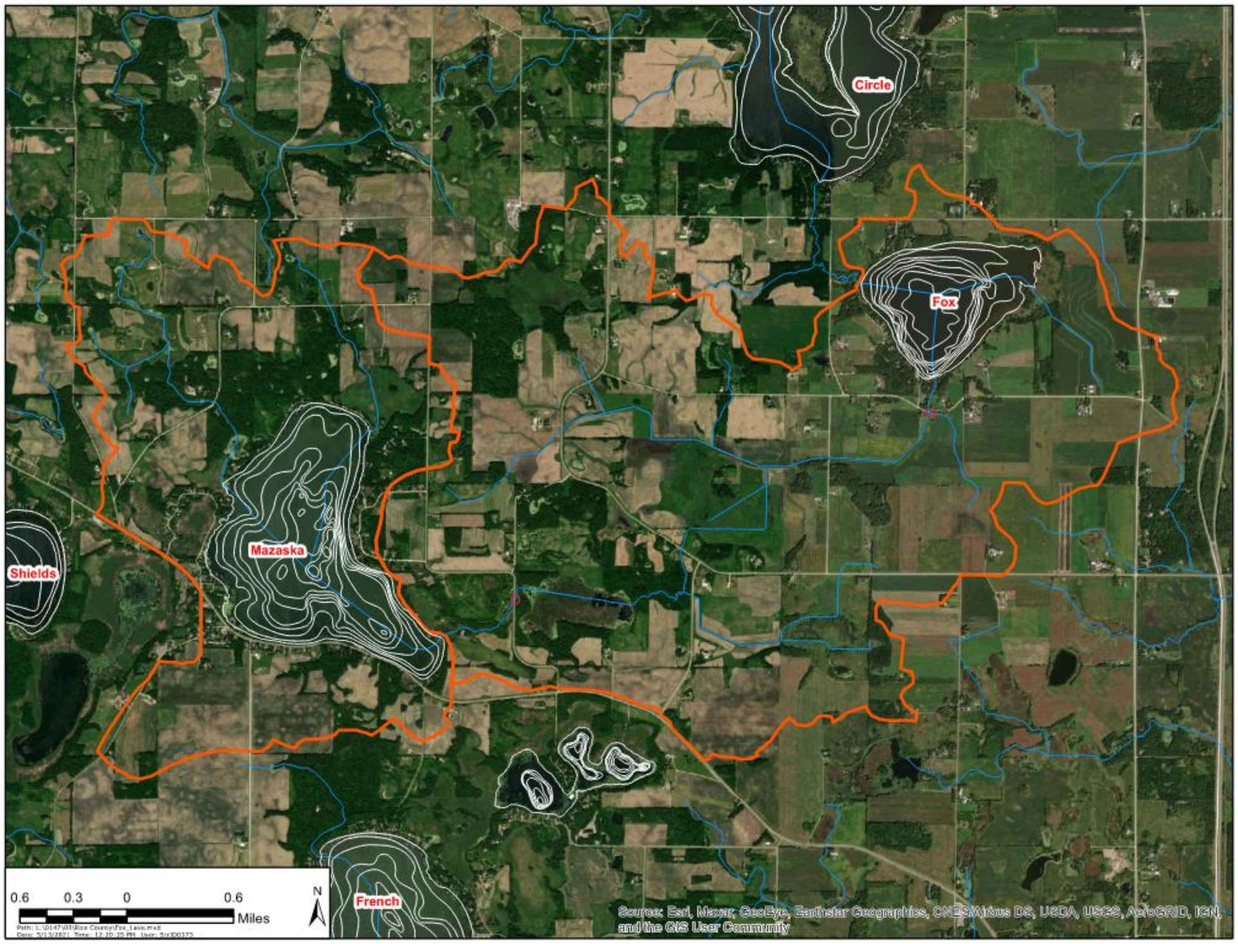

Figure 2-2. Hydrologic connectivity between Fox and Mazaska Lakes. Fox Lake receives flows from Mazaska Lake which then drains into Circle Lake.

2.1.3 Hydrogeology

Geology in the CRW is characterized by karst features, which can create additional connections between surface water and groundwater. Karst features tend to occur where limestone is slowly dissolved by infiltrating rainwater and can also create hidden pathways from pollution sources to surface water, groundwater and/or drinking water wells (WRAPS, 2016).

2.2 Lake Characterization

The following subsections provide a description of the physical characteristics and water quality conditions in Fox Lake.

2.2.1 Physical Description

Fox Lake is 330-acre lake located in the NCHF ecoregion, near the town of Faribault, in Rice County, MN. The near circular lake has a deep central basin, surrounded by shallow littoral waters, with a max depth of 46 feet and a mean depth of 19 feet. The estimated residence time for the lake is 1.29 years (Martin, 2015). The deep, flow through lake has 3.08 miles of shoreline, with residential homes located along the western side of the lake. Land use is dominated by agricultural cropland and forest land (Figure 2-1).

2.2.2 Fisheries

Fox Lake is a recreational fishery, with a large population of black crappie. Additionally, the lake is home to northern pike, largemouth bass, walleye, bluegill, hybrid sunfish, white bass, yellow perch, as well as multiple non-game species fishes. The lake is primarily managed for Black Crappie, Walleye, and Northern Pike and secondarily for bluegill. Walleye fry are stocked ever other year (years ending in even numbers) at a rate of 1,000 fish per a littoral acre. Northern Pike fry are stocked every two out of three years to maintain the population.

The most recent fish survey data was collected in 2017 by the Minnesota Department of Natural Resources (MNDNR). Non-game species surveyed include bigmouth buffalo, black bullheaded, bowfin, freshwater drum, white sucker, and yellow bullhead. Of these, freshwater drum were the most abundant, and were the second most abundant when game fish are included. 64 freshwater drum were caught in total, which is just over half the number of most populous fish, black crappies, caught at 112. Catch rates of the other rough fish listed remained relatively low. Historic DNR survey data shows that black bullhead populations have declined substantially since surveys done in the early 1990’s. Based on the 2017 surveys, common carp and bullhead species appear to be at fairly low density. CRWJPO should continue to monitor the fish population in partnership with the MNDNR to evaluate any changes in density that might warrant management actions in the future.

2.2.3 Aquatic Vegetation

The presence of invasive aquatic macrophytes was first documented in Fox Lake in 2009, when Eurasian water-milfoil (EWM) was found. EWM forms thick dense mats on the water surface throughout the summer, impacting recreational activities and the displacing native plants.

2.2.4 Water Quality and Nutrient Loads

Fox Lake is listed on the State’s 303(d) list of impaired waterbodies due to excessive nutrients impacting aquatic recreational uses. It was also identified a tier one impaired lake in the 1W1P which puts Fox Lake on the priority list for phosphorus reduction activities within the 10-year plan duration. Table 2-1 below is excerpted from the Cannon 1W1P which shows the average observed water quality conditions resulting from a MNLEAP model conducted in 2014 for Fox Lake as well as the water quality standards for deep lakes in the North Central Hardwood Forest Ecoregion (NCHF) (1W1P, 2020).

Table 2-1. Observed water quality conditions and applicable water quality standards for Fox Lake (Source: 1W1P). The NCHF deep lake standard applies to Fox Lake.

Impaired Lake	Observed Water Quality Conditions		
	Total Phosphorus (ug/L)	Chlorophyll-a (ug/L)	Secchi Depth (m)
NCHF Deep Lake Standard	**<40**	**<14**	**>1.4**
Cedar (66-0052-00)	56	28	1.0
Fox (66-0029-00)	88	31	1.3
NCHF Shallow Lake Standard	**<60**	**<20**	**>2.0**
Hunt (66-0047-00)	91	61	1.0

The Clean Water Act requires that a total maximum daily load (TMDL) be calculated for waterbodies with impairments. The TMDL determines the maximum load to the lake that will allow it to meet water quality criteria. In 2016, LimnoTech completed a watershed-wide TMDL for impaired waterbodies in the Cannon River watershed, which included Fox Lake. The TMDL was approved by EPA on February 16, 2017 The TMDL for Fox Lake was determined through BATHTUB modeling (Heiskary and Martin, 2015), which is discussed in more detail in Section 2.3.

Table 2-2. Fox Lake TMDL Table.

Table 42. MIDDLE CANNON RIVER HUC-10: Fox Lake – 66-0029-00

Fox Lake 66-0029-00 TMDL Summary		Existing TP Load		Allowable TP Load		Estimated Load Reduction	
		kg/yr	kg/day	kg/yr	kg/day	kg/yr	%
Phosphorus Loading Capacity (TMDL)		1779.25	4.87	742.10	2.03	1037.15	58.29
Wasteload Allocation (WLA) Components	Permitted Municipal and Industrial Wastewater Facilities*	NA	NA	NA	NA	NA	NA
	Permitted Industrial Stormwater Facilities**	NA	NA	NA	NA	NA	NA
	Construction and Industrial Stormwater	1.48	0.00	1.48	0.00	0.00	0.00
	MS4***	NA	NA	NA	NA	NA	NA
	Total WLA	1.48	0.00	1.48	0.00	NA	NA
Total LA		1777.77	4.87	740.62	2.03	1037.15	58.34
10% Margin of Safety^		NA	NA	NA	NA	NA	NA

* No permitted wastewater facilities within lake drainage area

** No permitted individual stormwater facilities in the CRW

*** No current MS4 communities within reach drainage area

^ 10% MOS was taken off of WQ target concentration and is implicit in the TMDL loading capacity

To meet the established TMDL goals for total phosphorus concentrations Fox Lake will need to reduce its TP load by approximately 58%, from 1779.25 kg/yr to 742.10 kg/yr (LimnoTech, 2016).

2.2.4.1 2021 Water Quality Data

Cannon River Watershed Joint Powers Organization (CRWJPO) collected additional data from Fox Lake in 2021 along with some tributary flow and nutrient data. Figure 2-2 below shows a series of vertical dissolved oxygen (DO) profiles measured throughout the water column in Fox Lake on various occasions. Each panel represents a single sampling event where DO was measured in vertical increments. The bottom panel shows data from 2021 which indicate that Fox Lake experiences anoxia in the deep waters for most of the summer. Available historical DO data were included for reference. The data show that Fox Lake has experienced anoxic conditions in the deeper water layers for several decades. Depletion of DO in lakes is indicative of elevated nutrients and organic matter which increase the biological and chemical demand of oxygen in the sediments and overlying hypolimnetic waters.

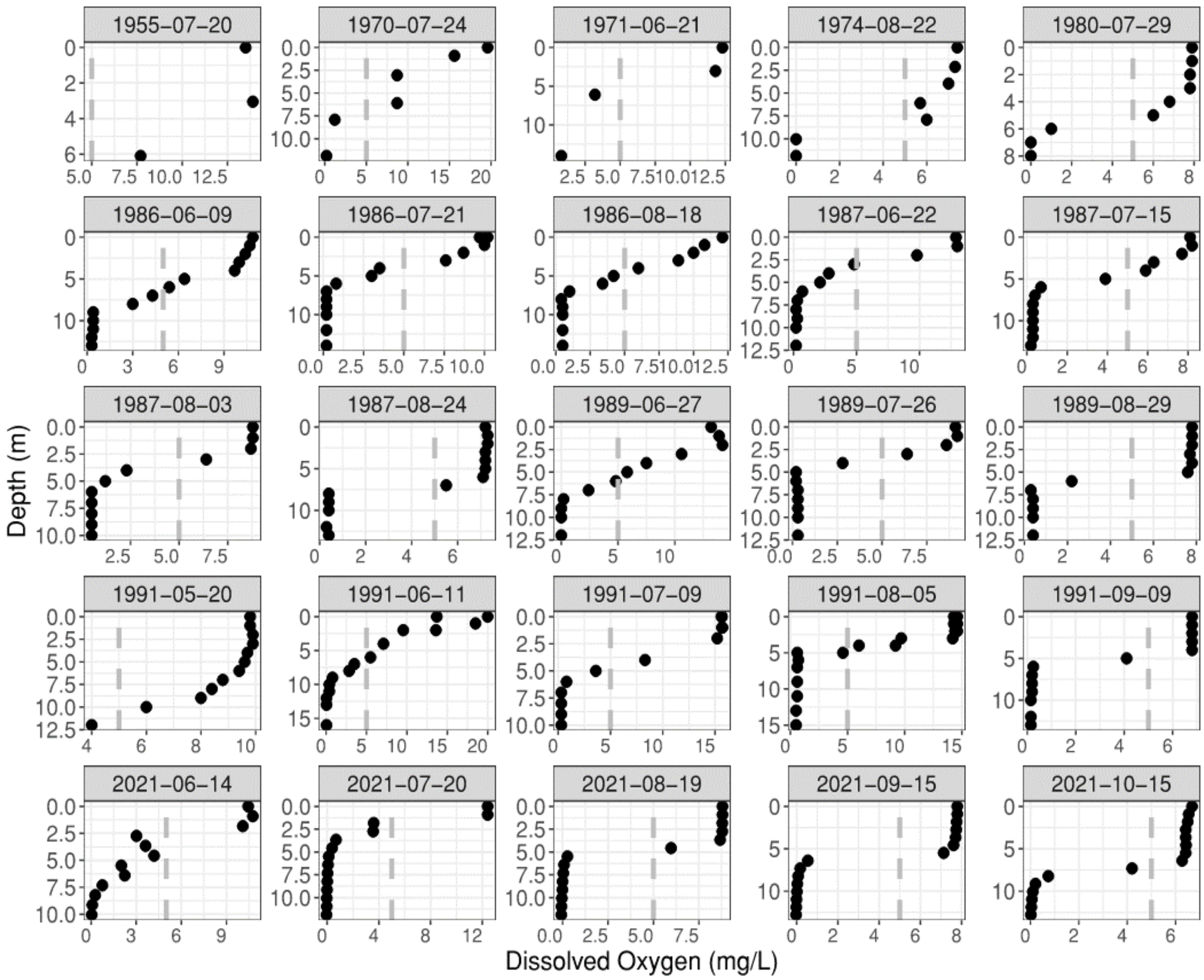

Figure 2-2. Vertical dissolved oxygen (DO) profiles for 2021 (bottom row) and available historical DO profiles for reference.

The following figures show total phosphorus (TP), orthophosphate and chlorophyll-a data that were collected in 2021 from surface and near maximum depth (12 meters) of Fox Lake. When flow was present, samples were also collected from the inlet to Fox Lake and near the outlet of Mazaska Lake. As noted above, 2021 was an extreme drought year so measurements from the inlet and outlet are not representative of typical conditions.

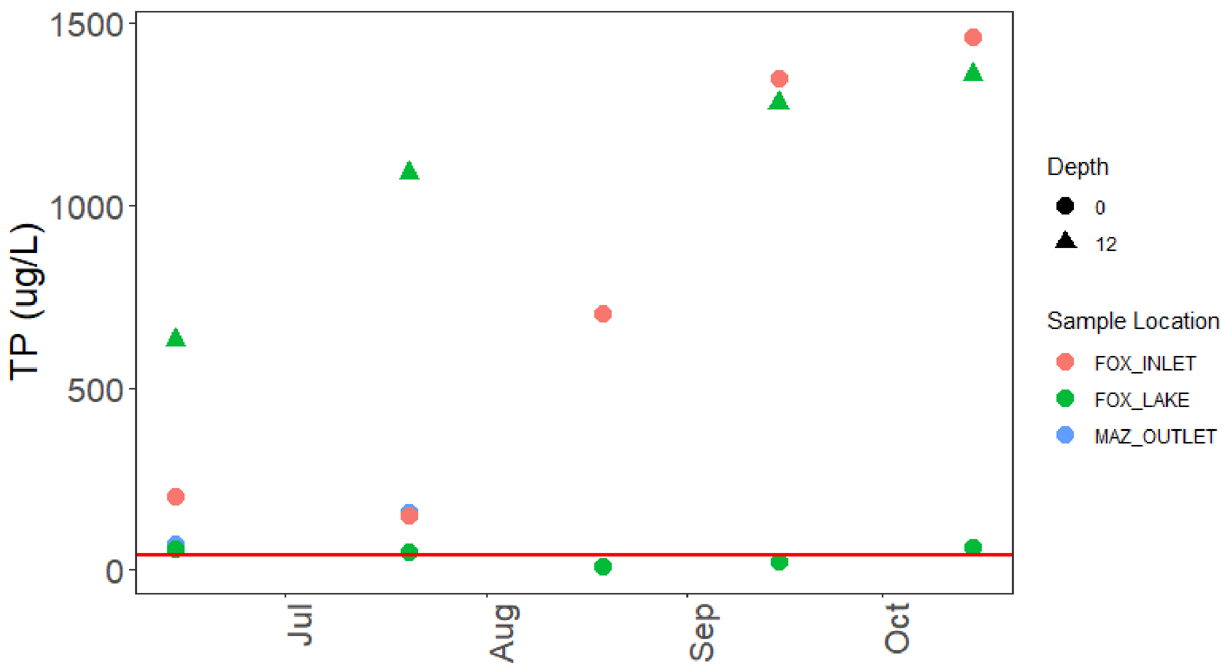

Figure 2-3. Total phosphorus (TP) collected in 2021 from the surface, hypolimnion (12-m depth), Fox Lake inlet and Mazaska Lake outlet. The red horizontal line represents the TP standard for deep lakes in the NCHF Ecoregion.

Recent TP measurements collected in 2021 at the Fox Lake inlet, Mazaska Lake outlet, and directly from Fox Lake at depths of 0 and 12 meters show elevated levels of phosphorus. Some of the lake surface samples that phosphorus levels often exceed the NCHF deep lake standard of 40 µg/L (red horizontal line on Figure 2-3) with an average concentration of 41 µg/L.TP measurements collected from at a depth of 12 feet show highly elevated levels in the hypolimnion averaging 2.1 µg/L which shows patterns indicative of internal loading from the bottom sediments.

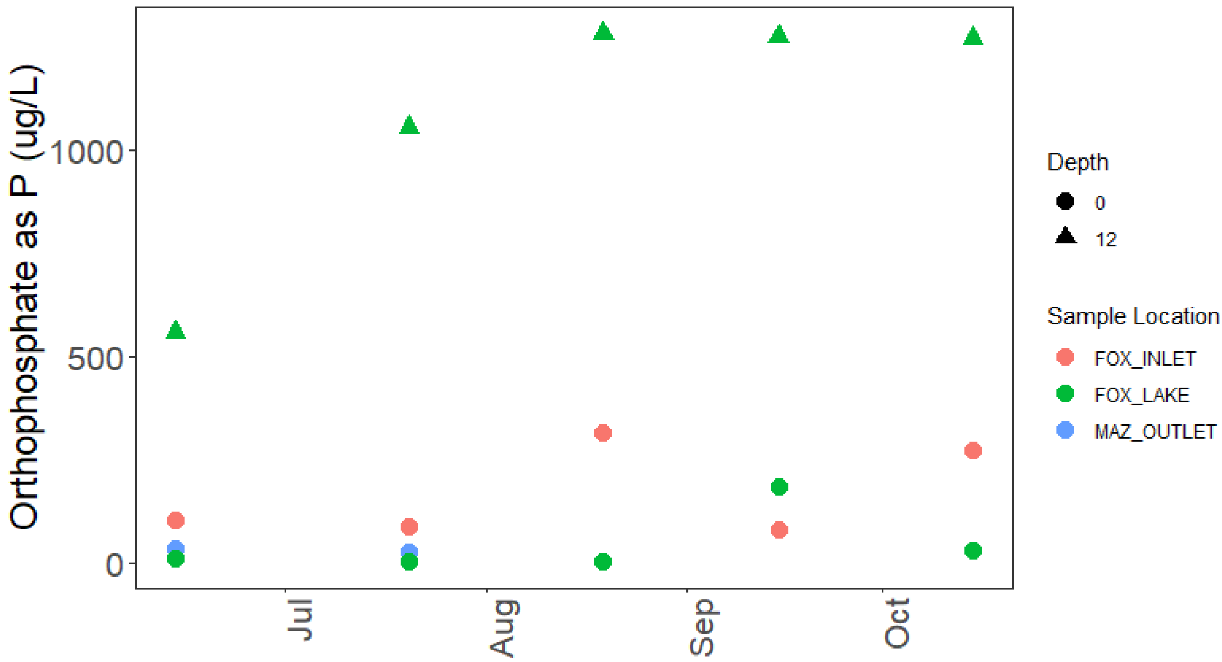

Figure 2-4. Orthophosphate collected in 2021 from the surface, hypolimnion (12-m depth), the inlet of Fox Lake and the outlet of Mazaska Lake.

High levels of orthophosphate in the hypolimnion, as shown in Figure 2-4, provide additional evidence of internal phosphorus loading from the sediments. The accumulation of orthophosphate in hypolimnion during the summer months, combined with low dissolved oxygen levels (shown in Figure 2-2), are clear indicators that internal loading is likely occurring. Orthophosphate, being the most bioavailable form of phosphorus, is readily taken up by algae, increasing the possibility of algal blooms and subsequent anoxic conditions. When the stratified layers mix, elevated TP in the hypolimnion becomes available to surface algae which can lead to an algal bloom. Many lakes in the Upper Midwest mix two times a year, once in spring and again in fall while some lakes may mix only once a year. The mixing regime of Fox Lake is not currently known but could be determined with bi-weekly to monthly vertical sonde measurements of DO and temperature.

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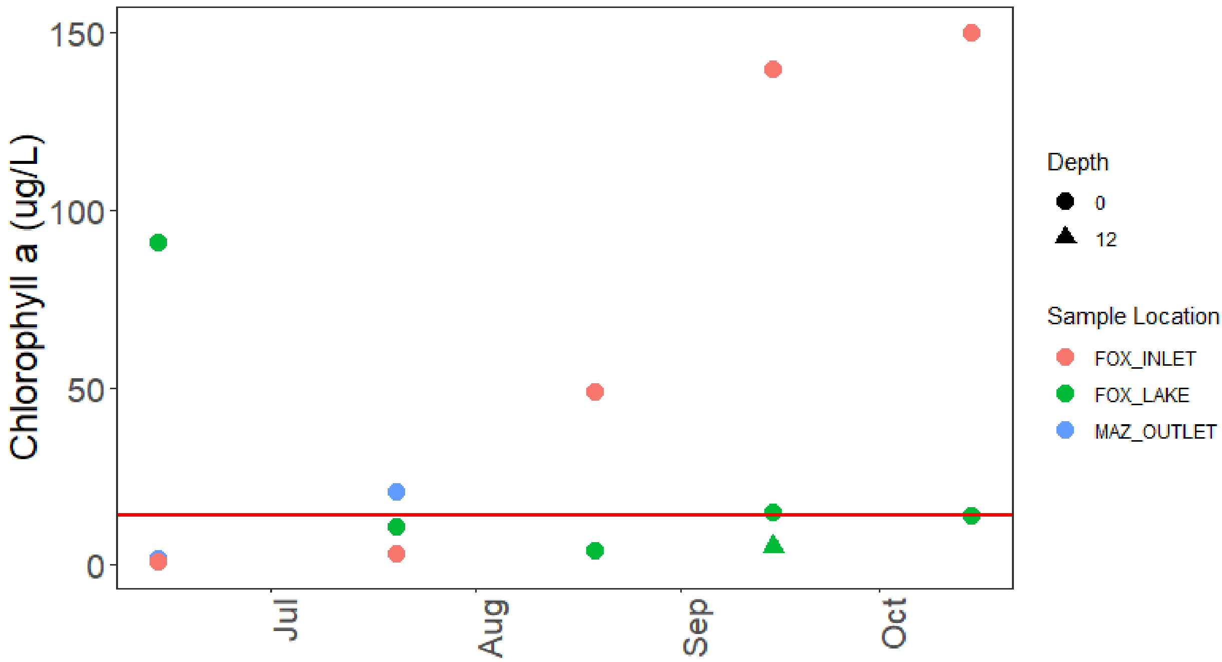

Figure 2-5. Chlorophyll-a measurements collected in 2021 from the surface, hypolimnion (12-m depth), the inlet of Fox Lake and the outlet of Mazaska Lake. The red horizontal line represents the chlorophyll-a standard for deep lakes in the NCHF Ecoregion.

Some of the chlorophyll-a measurements collected in 2021 from the surface of Fox Lake (green circles in Figure 2-5) exceeded the water quality standard or were just below the standard. Some of the inlet samples near the inlet of the lake recorded values as high as 150 ug/L, indicating eutrophic conditions and a probable algal bloom in the inlet to Fox Lake.

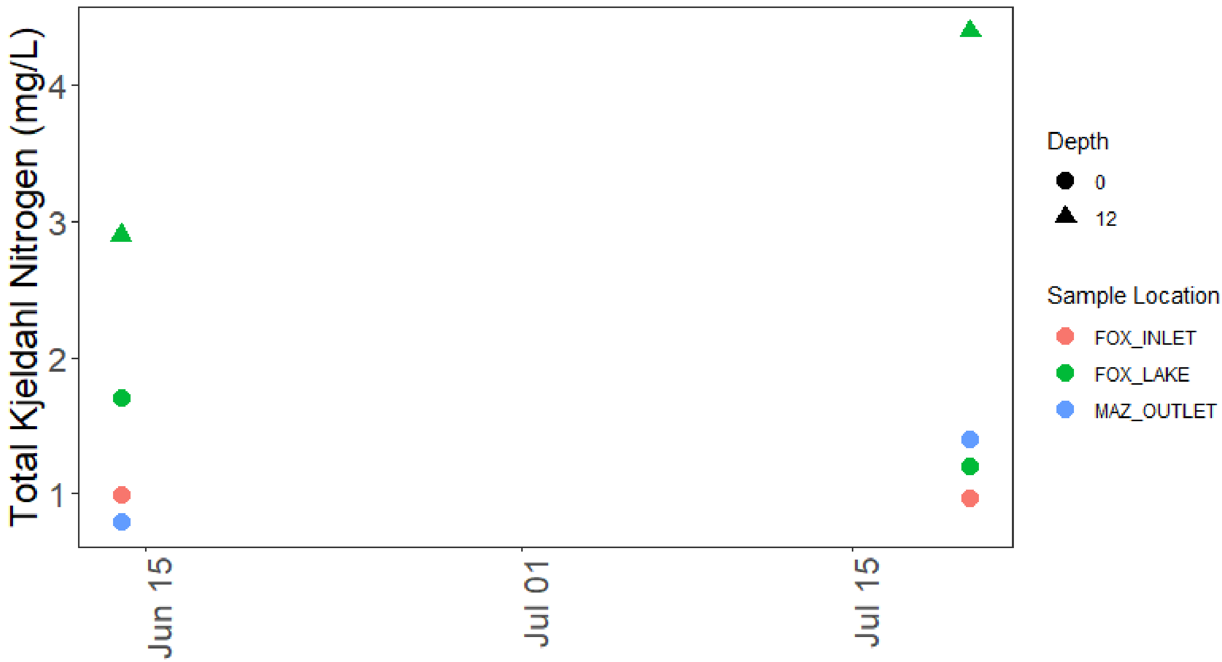

Figure 2-6. Total Kjeldahl nitrogen collected in 2021 from the surface, hypolimnion (12-m depth), the inlet of Fox Lake and the outlet of Mazaska Lake.

Nitrogen, like phosphorus, is a nutrient necessary for aquatic life to flourish. At high levels, however, it can lead to excess algae growth, low dissolved oxygen, and eutrophication in waterbodies. Total Kjeldahl nitrogen (TKN) is a measure of all organic nitrogen, ammonia, and ammonium in a waterbody. Sources of TKN include sewage, manure, organic matter, eroding soils, and fertilizers. Data from 2021 suggest that TKN is highest in the hypolimnion, which is natural as organic matter debris settles to the bottom of the lake (Figure 2-6). Hypolimnetic TKN samples can also be elevated due to ammonia/ammonium diffusing from the lake sediments under anoxic conditions, which is typically a function of microbially-driven decomposition of organic matter.

2.3 Nutrient Sources and Loading

Several studies on Fox Lake have estimated the nutrient loads and sources based on best available information at the time of assessment. Most of the studies have acknowledged considerable uncertainty in the relative magnitude of watershed and in-lake loads of phosphorus due to limited data.

In 2015, the Minnesota Pollution Control Agency developed a BATHTUB lake response model for Fox Lake to support protection and restoration strategies for the watershed (Heiskary and Martin 2015). Heiskary and Martin (2015) models estimated that the majority of the loads to Fox Lake are derived from the watershed either from direct drainage from the watershed (80%), flows from Mazaska (9%) and feedlots (8%). They did not find any unaccounted for loads in the model calibration and therefore did not assign any loads to internal sources. Heiskary and Martin (2015) identified the data limitations and likelihood of internal P loading but with an unknown magnitude due to limited available data

The TMDL for Fox Lake was informed by the HSPF modeled loads and the preliminary BATHTUB models developed by Heiskary and Martin (2015) for the entire watershed based on land use and some watershed monitoring data (LimnoTech 2016).

The most recent study by the St. Croix Research Station in 2019 collected sediment cores for paleolimnological analyses aiming to determine the history of phosphorus deposition in Fox Lake sediments (Engstrom et al. 2019). In their modeling assessment, they found no unaccounted loads and thus estimated a single estimate of TP inputs from external sources. Internal phosphorus loads were not directly measured or quantified.

These studies acknowledged uncertainties in findings relative to the magnitude of internal versus external loads due to limited data. The CRWJPO and partners collected water quality data from Fox Lake and the inflows which we used to update the existing BATHTUB model developed by Heiskary and Martin (2015). As shown in Figure 2-7, Fox Lake showed strong evidence of internal phosphorus loading during the summer when anoxic conditions were persistent (Figure 2-2). Internal phosphorus loading in Fox Lake has not been directly quantified so we estimated the sediment phosphorus release rate based on established equations by Nürnberg (2004), which estimates the duration of anoxia in lake sediments based on observed dissolved oxygen profiles. The estimated duration of anoxia in Fox Lake in 2021 was 53 days, which is used with the observed changes in hypolimnetic orthophosphate data to estimate sediment phosphorus release rates. Our calculated sediment phosphorus release rates for Fox Lake were 9.3 mg/m2/day which was input into our BATHTUB to construct a new nutrient budget (Figure 2-7). Our model estimates indicate that roughly 25% of the total load is from internal sediment sources. These model updates and estimates of internal loading were made possible by the 2021 data collected in Fox Lake.

The results from the updated BATHTUB modeling indicate that 75% of the total load to Fox Lake is coming from the watershed. Consequently, nutrient load reduction should be focused on watershed activities to reduce loading. However, 25% of the total load is estimated to come from the sediments and may need to be addressed over the next few years as well in order to meet the TMDL goal of 58% load reduction from existing conditions (Table 2-2)

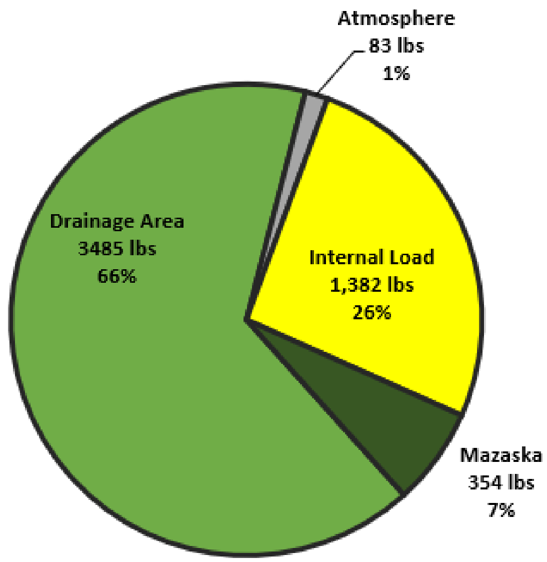

Figure 2-7. BATHTUB simulated phosphorus nutrient budget for Fox Lake

3 Identified Issues in Fox Lake

The primary water quality concern for Fox Lake is high phosphorus loading. As discussed in Section 2.3, the majority of this loading originates from the drainage area around the lake, which is dominated by agricultural land use. However, there is also evidence of internal phosphorus loading from bottom sediments. High phosphorus levels in Fox Lake have led to an increase in aquatic plant growth and a subsequent decrease in dissolved oxygen during the summer months relative to 1991 levels. This process, known as eutrophication, impairs the waterbody's ability to support life and limits its designated use.

High phosphorus values in Fox Lake have contributed to frequent algal blooms. These algal blooms have been a cause for concern in the community. Not only are algal blooms unsightly, but they can be harmful to human and environmental health.

Along with an increase in nuisance algal blooms, Fox Lake has also seen an increase in Eurasian Watermilfoil (EWM). This invasive aquatic plant, once introduced, can spread rapidly and outcompete native species for lake resources. EWM also forms dense beds of plant material that limit recreational uses of the lake. Due to its ability to reproduce through fragmentation, EWM is nearly impossible to eliminate from lakes and must be managed on an ongoing basis to limit its range and density.

4 Management Goals, Objectives and Actions

The goals and objectives outlined below are intended to align with the 10-year measurable goals outlined in the One Watershed, One Plan guidance for the Tier One impaired lakes. As shown in Table 4-1, the overarching goal for the priority impaired lakes in the Cannon River watershed are: "Achieve the 10-year total phosphorus reduction goals for the Tier One Impaired Lakes". The Fox Lake specific goals (discussed in more detail below) are designed to promote a healthy lake community capable of supporting a diverse aquatic ecosystem and supporting its designated uses, which are aquatic consumption, aquatic life and aquatic recreation.[1]

Table 4-1. 10-year total phosphorus reduction goals for the Tier One Impaired Lakes in the Cannon River Watershed. The table below is excerpted from the Cannon River Comprehensive Watershed Management Plan.

10-Year Measurable Goals

Goal 1: *Achieve the 10-year Total Phosphorus Reduction Goals (lb/yr) for the Tier One Impaired Lakes listed in Table 3-5.*

Table 3-5. Existing Total Phosphorus Loads and Load Reduction Goals for Tier One Impaired Lakes in the Cannon River Comprehensive Watershed Management Plan

	Total Phosphorus (TP) Existing Load and Load Reduction Goals					
Impaired Lake	TMDL Existing TP Load (includes watershed and internal sources)* [lb/yr]	TMDL TP Reduction needed to Meet Lake Aquatic Recreation Water Quality Standard (Long-term Future Condition) Measurable Goal* [lb/yr]	Estimated 5-year TP Reductions [lb/yr]	Estimated 10-year TP Reductions** (total from Table 3-6) [lb/yr]	10-year Progress Towards TMDL TP Reduction Measurable Goal** [%]	10-year TP Reduction from Existing Load** [%]
Cedar	2,476	930	96	341	37%	14%
Fox	3,922	2,286	221	534	23%	14%
Hunt	899	741	14	606	82%	67%

* *Based on the 2017 Cannon River Watershed TMDL.*
** *Lake management plans will be completed by 2024 to identify activities to achieve the remaining phosphorus reductions needed to achieve the measurable goal.3*

[1] Lakes and Streams Water Quality Dashboard, MPCA: https://webapp.pca.state.mn.us/wqd/surface-water/waterunit-details?wid=66-0029-00

Goal 1: Reduce frequency and duration of nuisance algal blooms

Objective 1a: Directly quantify internal sediment loading to develop accurate internal and external load reductions goals.

Actions: In order to target phosphorus load reduction activities, it's important to know the magnitude of internal vs external loading. The nutrient budget estimated by the BATHTUB model described above indicates that roughly 25% of the load is derived from the sediments. However, there is still uncertainty in this estimate because internal loads have not been directly quantified by collecting sediment cores and measuring rate of P flux in lab incubations. The results of this direct measurement would allow refinement of the existing BATHTUB model, which may change the relative proportion of external and internal phosphorus load reductions needed to achieve the TMDL target. For future management of internal loading options, refined estimates of internal loading will be needed for some grant opportunities.

Objective 1b. Reduce external loading by implementing best management practices throughout the Cannon River Watershed.

Actions: The Cannon River Comprehensive Watershed Plan (1W1P) puts forward a framework for reducing nutrient loadings throughout the watershed. The Plan has proposed a process for identifying BMPs that will be most effective at reducing nutrient loadings to Fox Lake and other impaired lakes in the watershed. BMPs identified through this process should be readily implemented in order to reduce external loading to Fox Lake.

Objective 1c. Assess shoreline and protect sensitive and erosional areas.

Actions: Eroding shorelines can increase nutrient inputs and turbidity in lakes. Therefore, the shoreline around Fox Lake should be assessed to identify sensitive and actively eroding areas, which should then be protected and/or stabilized to reduce erosion. Shoreline residents should also avoid mowing turf grass down to the water's edge and use of lawn fertilizers.

Objective 1d. Upgrade failing septic systems around Fox Lake.

Actions: Identify failing septic systems around Fox Lake that might be serving as sources of nutrients and bacteria to Fox Lake. Failing septic systems should be upgraded to prevent future failures.

Goal 2: Establish, implement and maintain baseline monitoring and assessment program.

Objective 2a. Develop a baseline water quality monitoring plan.

Actions: Given the limited data available for Fox Lake, a regular monitoring program should be established and implemented for baseline monitoring of conditions. Water quality should be monitored in the surface water and maximum depth at least monthly during the summer growing season (June through September). Parameters should include total phosphorus, dissolved phosphorus or orthophosphate, total nitrogen, and chlorophyll-a (surface only). In addition, monthly measurements of vertical profiles of dissolved oxygen, pH, and temperature will be an important component of a routine monitoring program to document changes in hypolimnetic anoxic conditions as part of ongoing nutrient reduction activities.

Objective 2b. Measure progress of implemented actions to meet goals.

Actions: Monitoring water quality will allow stakeholders to evaluate the success of their implemented actions and provide a means of reporting progress to stakeholders and regulatory agencies. With better data, the goals, objectives, and actions can be adaptively managed over the 10-year life of this management plan to increase the effectiveness of the overall strategy for improving lake health.

Goal 3: Assess shoreline and protect sensitive or erosional areas.

Objective 3a: Determine the spatial extent and density native and invasive plant communities throughout the lake.

Actions: To inform the management of aquatic invasive species, aquatic vegetation surveys should be conducted. These should be early- and late-season point intercept surveys. This will help lake managers determine the spatial distribution of invasives, particularly EWM, throughout the lake.

Objective 3b. Develop a long-term aquatic management plan to control EWM.

Actions: The spatial extent of EWM and other aquatic invasive species will allow lake managers to develop a plan to limit the spread of these invasives. Management actions could include harvesting, aquatic herbicide treatment, boat inspections, or manual pulling.

Objective 3c. Educate the public on how to limit the spread

Actions: Public awareness is crucial to preventing the spread of invasive species. Practices such as *Clean In, Clean Out* can limit spreading via watercraft and these practices and should be publicly promoted.

5 Implementation

Meeting TMDL goals and ultimately improving water quality in Fox Lake will take require significant efforts to reduce loading from the watershed and may also require in-lake management actions such as alum to address internal loads. Lake restoration is an expensive and labor-intensive effort and requires ongoing monitoring to evaluate the success of implemented actions over time. In addition, lakes do not always respond predictably to management actions which require changes in management direction as new knowledge is gained about the lake or restoration techniques. For these reasons, we recommend focusing on specific implementation activities in the next three years, monitoring progress through routine data collection, and then updating the implementation plan every three years planned activities are completed and as new knowledge is gained.

Table 5-1 below includes a set of recommended actions for years 0-3 of this plan along with a list of activities for future consideration depending on progress towards goal attainment.

Table 5-1. Fox Lake management goals and objectives along with recommended short-term actions.

Goal/Objective	Short-term Actions (0-3 years)	Potential Future Actions
Goal 1. Reduce frequency and duration of nuisance algal blooms.		
Objective 1a: Directly quantify internal sediment loading to develop accurate internal and external load reductions goals.	Quantify internal loading by collecting sediment cores and measure rate of P flux in lab incubations. Update existing BATHTUB model with refined internal loading estimates.	Aluminum sulfate (alum) treatment to mitigate sediment diffusion of phosphorus
Objective 1b. Reduce external loading by implementing best management practices throughout the Cannon River Watershed.	Implement agricultural BMPs identified in watershed studies per the 1W1P.	Monitor flow and nutrients in the inflow to Fox Lake to measure success of implemented actions.
Objective 1c. Enhance shoreline protection measures.	Assess shoreline to identify sensitive and active erosional areas.	Stabilize/protect erosional areas.
Objective 1d. Upgrade failing septic systems around Fox Lake.	Identify failing septic systems that may be sources of nutrients and bacteria.	Upgrade failing systems.
Goal 2: Establish, implement and maintain baseline monitoring and assessment program.		
Objective 2a. Develop a baseline water quality monitoring plan.	Develop and implement baseline monitoring plan at monthly intervals during growing season.	Continue monitoring until goals are attained and then frequency can be reduced to lower frequency such as every other year.
Objective 2b. Measure progress of implemented actions to meet goals.	Measure progress of implemented actions to meet goals through evaluation of monitoring data.	
Goal 3: Manage aquatic plant community in Fox Lake to reduce EWM and enhance native plant community.		
Objective 3a: Determine the spatial extent and density native and invasive plant communities throughout the lake.	Conduct early and late season point intercept surveys to ID community composition and density.	Additional surveys will likely be needed in parallel with management actions to reduce EWM density. Herbicide treatments to target dense areas of EWM to reduce density and limit spread.
Objective 3b. Develop an aquatic management plan to control EWM.	Conduct delineation of EWM. Seek aquatic plant management funding from MN DNR to treat/manage EWM.	
Objective 3c. Educate the public on how to limit the spread	Implement public education in Clean In, Clean Out practices	Continue public outreach efforts to educate public on spread of invasive species.

6 References

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