Lake Smetana Water Quality Study
Use Attainability Analysis (Updated from 2003)

Prepared for
Nine Mile Creek Watershed District

February 2020

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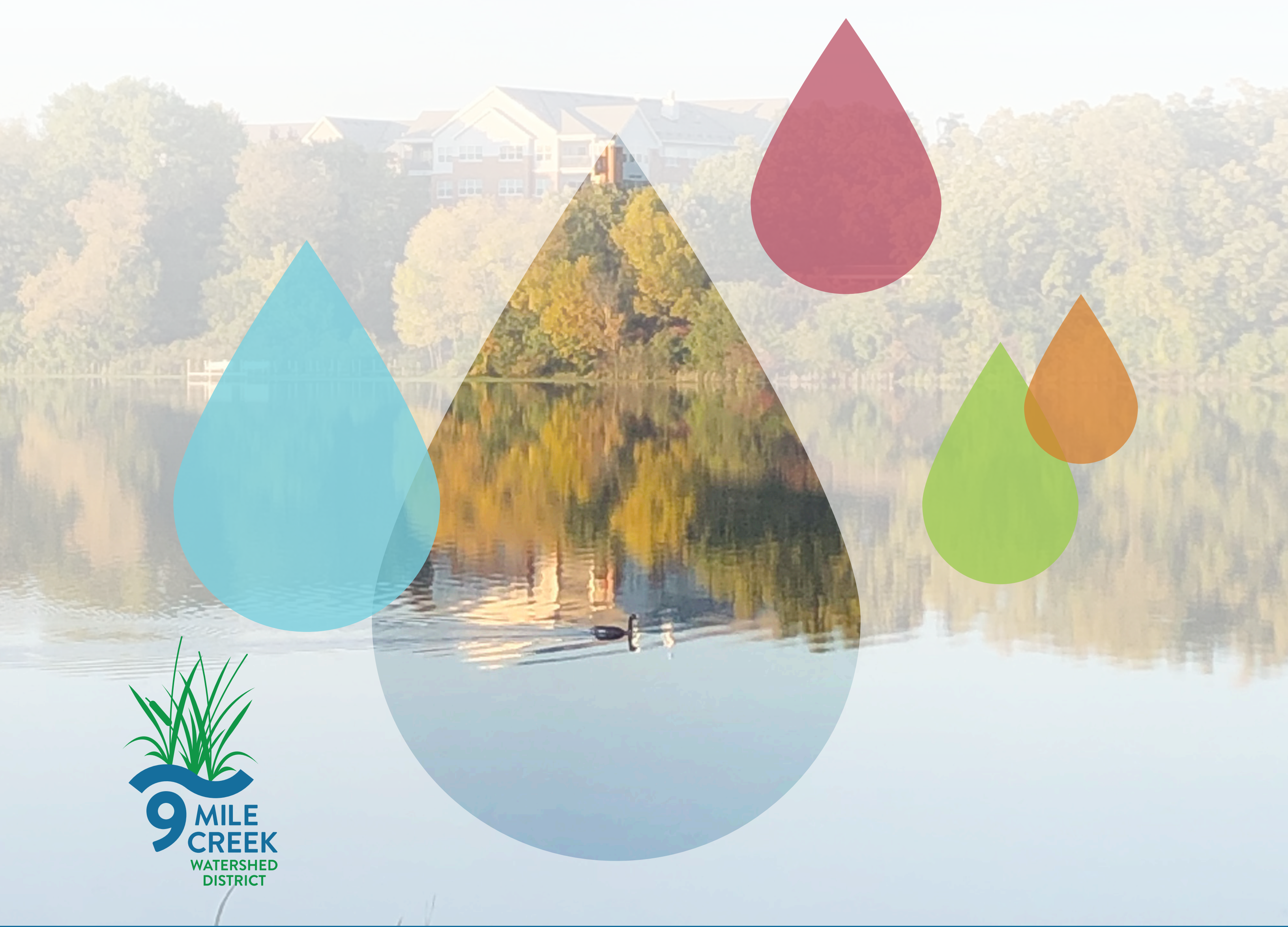
REPORT SUMMARY

Lake Smetana Water Quality Study

Use Attainability Analysis Update for Lake Smetana (2019)



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MANAGING LAKE SMETANA WATER QUALITY

WORKING TO MEET DISTRICT GOALS

Lake Smetana is a shallow, 56-acre lake within the "Golden Triangle" area of Eden Prairie, an industrial park surrounded by Interstate 494 and U.S. Highways 212 and 169. The lake is situated along the South Fork of Nine Mile Creek, approximately 1.3 stream miles downstream of Bryant Lake within the Nine Mile Creek watershed. With an average depth of 3 feet and maximum depth of 10 feet, the lake's shallow nature and urbanized watershed pose water quality challenges. Although improved in recent years, water quality in Lake Smetana has historically been moderate to poor. The Nine Mile Creek Watershed District (NMCWD), a local unit of government that works to solve and prevent water-related problems, conducted a study of Lake Smetana in 2019 to evaluate current water quality and identify protection and improvement strategies. Additional information on the current lake conditions, water quality challenges, and recommended management strategies are summarized in this project overview.

Protecting and enhancing the water quality of the lakes within the Nine Mile Creek watershed is one of the primary goals of the Nine Mile Creek Watershed District. The NMCWD's lake management program includes data collection (monitoring), assessment (e.g., studies), and implementation of projects and programs to protect and improve water quality and aquatic habitat. Utilizing monitoring data collected by NMCWD in recent years (2016 and 2018), the objectives of this study were to assess or "diagnose" the lake's water quality problems, understand the cause or sources of the problems, and recommend management strategies to improve the water quality and overall health of the lake.

LAKE MANAGEMENT GOALS

When assessing the ecological health of a lake, it is important to take a holistic approach, considering factors such as chemical water quality (e.g., phosphorus concentrations), the health and quality of the aquatic communities, and water quantity (see Figure 1). How recreation and wildlife habitat affect and are affected by overall lake health are also considered. Numerical goals exist for some of these factors (e.g., state water quality standards), however, other ecological lake health factors are assessed relative to narrative criteria (e.g., criteria that describe the desired condition) without strict numerical goals. For this study, the primary goals are to achieve the water quality standards for shallow lakes, maintain a diverse, native macrophyte (aquatic plant) population, and maintain a healthy, balanced fishery.

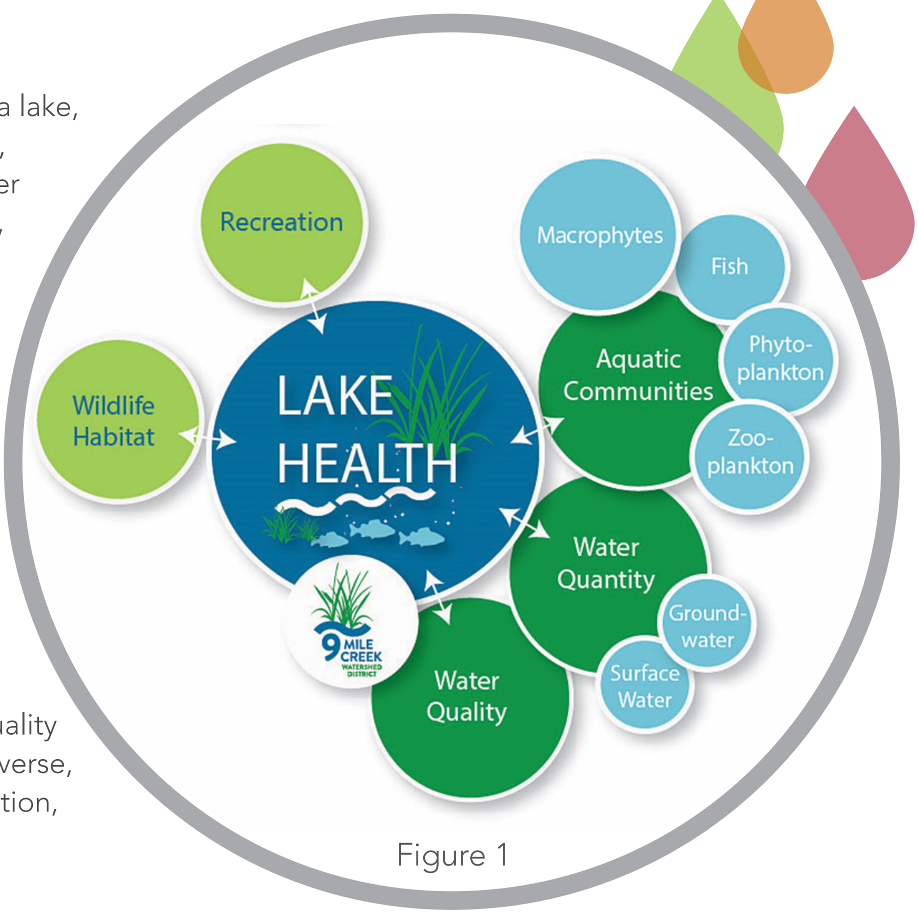


Figure 1

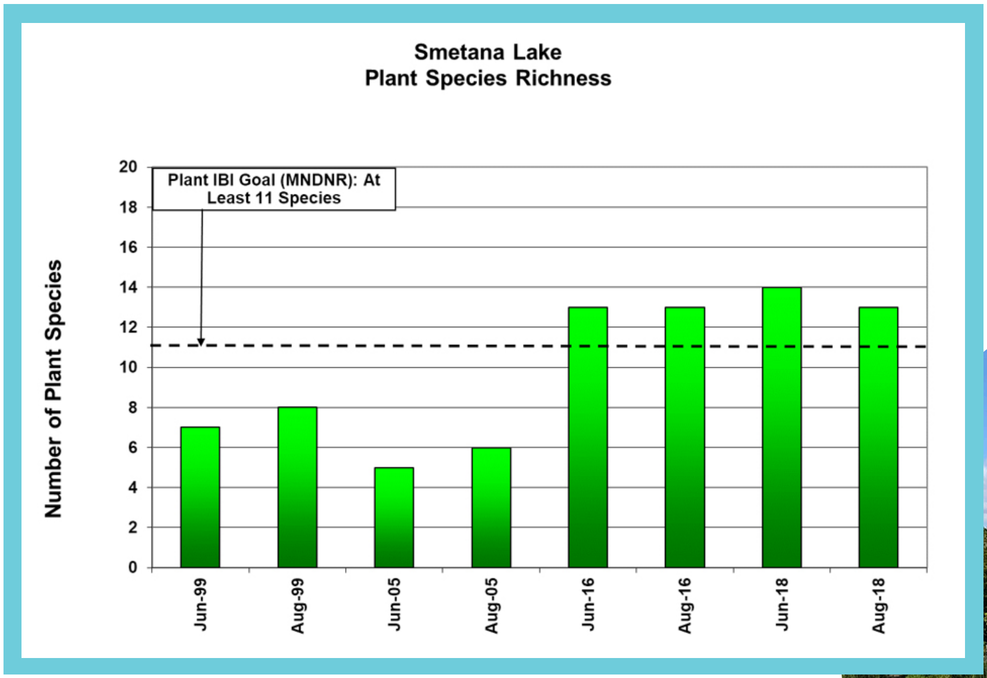
AN IN-DEPTH LOOK

HEALTHY SHALLOW LAKES

Lake Smetana can be classified as a shallow lake ecosystem. Shallow lakes have depths that allow for light to reach the lake bottom throughout most or all of the lake (often less than 10 feet deep). These lakes also tend to be more nutrient-rich than other deeper lakes, especially in an urban setting where they receive nutrients (e.g., phosphorus and nitrogen) from stormwater. A healthy shallow lake will have abundant aquatic plant growth due to the shallowness and nutrients. However, excess nutrients can lead to algal growth that creates turbid water and limits or prevents aquatic plant growth.

Aquatic plants are good for shallow lake ecosystems. Healthy shallow lakes have plants growing throughout the entire lake, with a variety of species such as coontail, native pondweed, and water lily. The plants take phosphorus and nitrogen from the lake water, reducing the amount of nutrients available for algae. Aquatic plants also provide excellent habitat for insects, zooplankton, fish, waterfowl and other wildlife.

One measure of a lake's health is the community of plants, fish and aquatic life it sustains. Certain species can't survive without clean water and a healthy habitat while other species are tolerant of degraded conditions. These species are considered "indicators" of the health of a lake. For aquatic plants, the Minnesota Department of Natural Resources has developed an index of biological integrity (IBI), which is a score that compares the types and numbers of plants observed in a lake to what is expected for a healthy lake. As shown below, the number of plant species in Lake Smetana in recent years exceeds the DNR's goal of at least 11 species for a healthy lake.



Smetana Lake has surpassed the MN DNR goal for number of plant species in the lake since 2016.

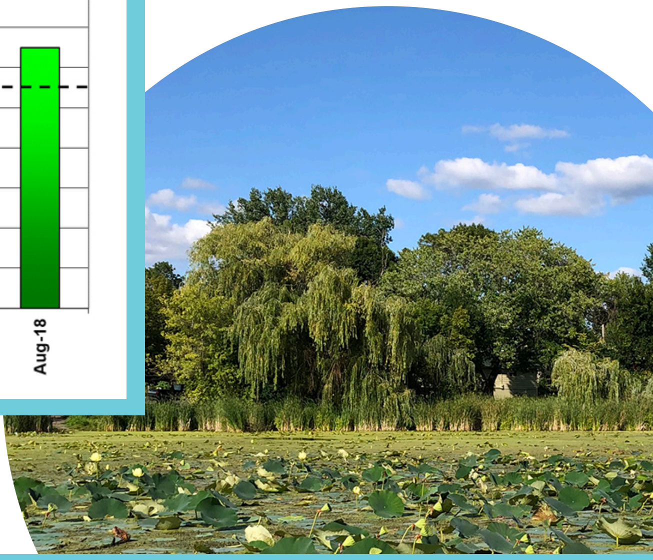
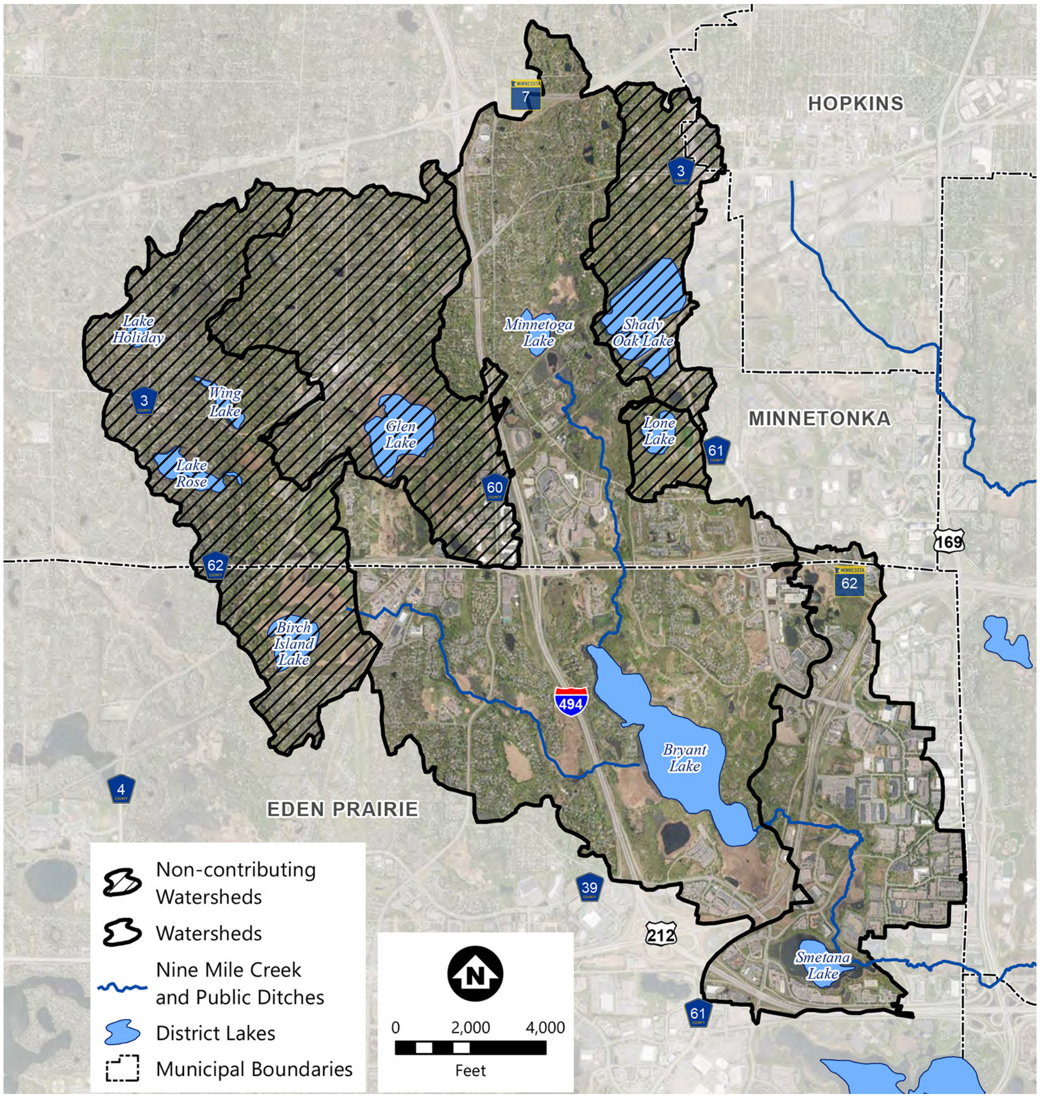


Photo source: Matthew Berg, Endangered Resource Services, LLC

LAKE SMETANA WATERSHED

Located along the South Fork of Nine Mile Creek, Lake Smetana receives inflows from a large contributing area. The watershed extends north of State Highway 7 in Minnetonka and includes both Minnetoga Lake (Minnetonka) and Bryant Lake in Eden Prairie (see figure below). The watershed tributary to Lake Smetana also includes approximately 1,000 acres downstream of Bryant Lake (see figure below). Runoff from the watershed enters Lake Smetana through overland flow, discharge from the South Fork of Nine Mile Creek, and from several storm sewer outfalls at various points along the lakeshore.

Land use practices within a lake's watershed impact the lake and its water quality by altering the amount of stormwater runoff, sediment load, and nutrient load (namely phosphorus) that reaches the lake from the lake's watershed. Each land use contributes a different amount of runoff and phosphorus to the lake, thereby impacting the lake's water quality differently. Land use within the highly developed Lake Smetana watershed is primarily industrial, highway, office/commercial, and public open space, with smaller areas of residential (low-density and high-density) and church/cemetery.

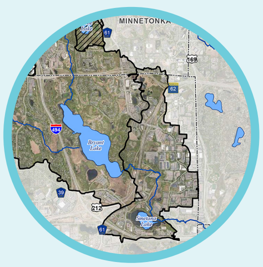


Watershed map showing the drainage area to Bryant Lake and the direct watershed to Lake Smetana. Hatched areas are watersheds that are generally land-locked or discharge infrequently.

SOURCES OF PHOSPHORUS TO LAKE SMETANA

An overabundance of nutrients (phosphorus and nitrogen) in a lake can result in nuisance algal blooms and threaten the health of the aquatic plant community. In Minnesota, phosphorus is most commonly the "limiting nutrient," meaning the available quantity of this nutrient tends to control the amount of algae and aquatic plants produced. As part of the 2019 water quality study, watershed and in-lake computer models were used to estimate the amount and sources of phosphorus to Lake Smetana during the evaluated years (2016 and 2018). The results of the analysis are summarized below.

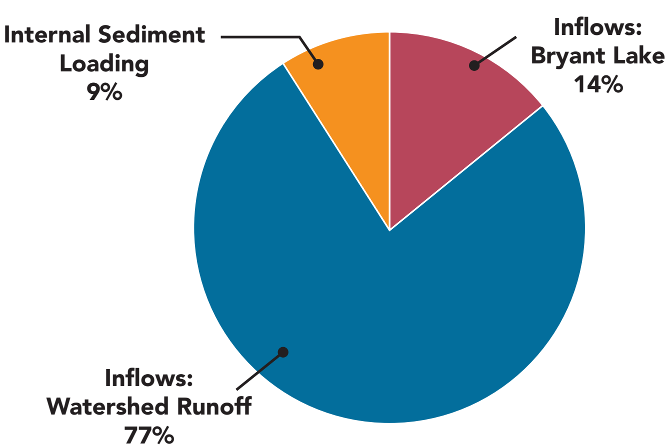
Phosphorus in stormwater runoff from the direct watershed — Stormwater runoff conveys phosphorus from streets, lawns, and parking lots within the direct watershed to Lake Smetana via a series of storm drain pipes or the South Fork of Nine Mile Creek. Computer models indicate that stormwater runoff is the major contributor of phosphorus to Lake Smetana, contributing 77% and 63% of the annual phosphorus load to the lake in 2016 and 2018, respectively.



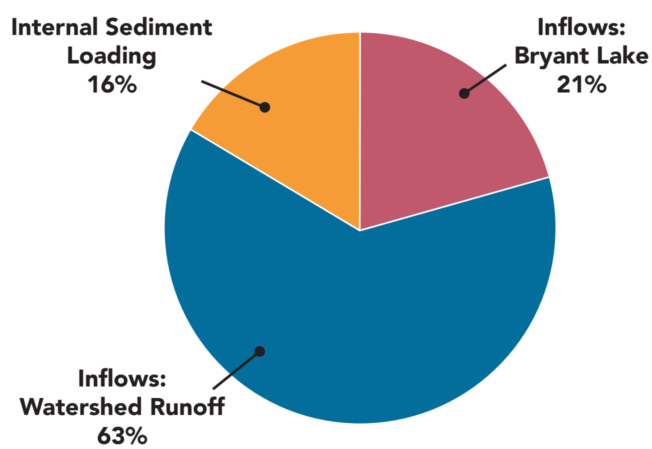
Phosphorus from Bryant Lake discharge — Lake Smetana is located along the South Fork of Nine Mile Creek, approximately 1.3 stream miles downstream of Bryant Lake. Modeling results indicate that flows from Bryant Lake accounted for approximately 14% and 21% of the annual phosphorus load to Lake Smetana in 2016 and 2018, respectively.

Nutrient-rich sediment — Phosphorus builds up over time in lake bottom sediments as a result of sedimentation and die-off of vegetation and algae. When oxygen levels are low at the lake bottom (typically periodically throughout the summer), some of the phosphorus is released from the sediment into the water column, contributing to poor water quality conditions. Modeling results indicate that phosphorus release from lake bottom sediments accounts for 9% and 16% of the annual phosphorus load to Lake Smetana in 2016 and 2018, respectively. While this represents a notable portion of the loading, other internal process in the lake are helping to balance the effects of loading from the sediments, including frequent and rapid flushing from high inflows and significant uptake of phosphorus from aquatic plant growth.

2016 TOTAL PHOSPHORUS SOURCES



2018 TOTAL PHOSPHORUS SOURCES

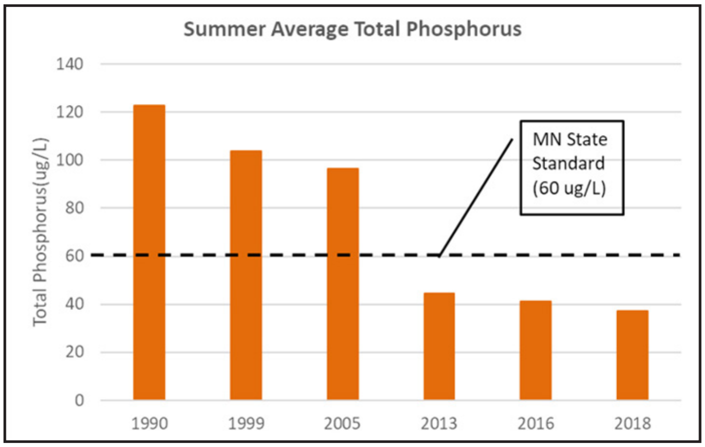


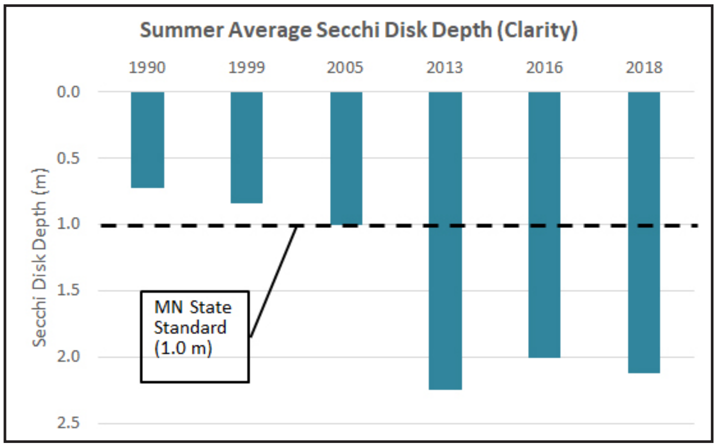
IMPROVED WATER QUALITY IN LAKE SMETANA

Water quality in Lake Smetana has seen a noticeable improvement in the past decade. Prior to 2009, water quality in the lake was moderate to poor, consistently failing to meet state standards for nutrients in shallow lakes, as measured by water clarity, total phosphorus and chlorophyll *a* (an indicator of algae). What caused the improvement in Lake Smetana water quality? While the marked improvement can be attributed to several management programs and activities implemented by the Nine Mile Creek Watershed District in recent decades, the alum treatment of upstream Bryant Lake in the fall of 2008 led to the most pronounced improvements in both Bryant Lake and downstream Lake Smetana. The alum, distributed throughout the lake by a barge (see photo at right), settles to the bottom of the lake, removing phosphorus from the water column and binding (or immobilizing) the phosphorus in lake bottom sediments, minimizing its release into the water column. Other management activities and programs that have helped to improve Lake Smetana water quality include a 2008 wetland restoration project upstream of Bryant Lake (just west of Interstate 494) and implementation of the NMCWD's permitting program that requires construction of stormwater best management practices when land is developed or re-developed.

Alum treatment of upstream Bryant Lake led to improvements in Lake Smetana water quality.

The graphs below show the historic summer-average concentrations of phosphorus and chlorophyll *a* in Lake Smetana for the years monitored by NMCWD. As can be seen in the graphs, water quality after the 2008 alum treatment in upstream Bryant Lake has consistently met the state standard for shallow lakes in this area of the state (60 ug/L).





Too much salt — Observed chloride concentrations in Lake Smetana in May and June of 2018 were high, exceeding the MPCA standard of 230 mg/L (244 mg/L on May 14, 2018 and 264 mg/L on June 12, 2018). While chloride occurs naturally in lakes and streams, too much chloride can be harmful to fish and other aquatic life. The primary source of chlorides in our lakes and streams is road salt, which is commonly used in the winter to minimize the amount of ice on our roadways, parking lots, and sidewalks. With Lake Smetana receiving stormwater runoff from several highways, local roadways and an area of densely-developed commercial, industrial, and residential properties, the lake is especially vulnerable to chloride pollution. NMCWD should continue periodic monitoring of chloride concentrations in Lake Smetana and seek opportunities to work with property owners, property management companies, and private applicators within the Lake Smetana watershed to reduce winter salt usage.

MANAGEMENT STRATEGIES TO PROTECT AND IMPROVE LAKE SMETANA

Water quality in Lake Smetana has improved in the past decade and the lake currently meets water quality and ecological health goals. Given this, future management efforts should be focused on protecting lake water quality, monitoring for changes, and improving water quality and ecosystem health as partnership opportunities arise. The recommended management and protection strategies for Lake Smetana are summarized below.

Maintain Bryant Lake Water Quality

The water quality improvements observed in Lake Smetana in the past decade are in large part due to the water quality projects implemented in upstream Bryant Lake, most markedly the 2008 alum treatment to reduce the release of phosphorus from the lake bottom sediments. The reduction in internal phosphorus loading to Bryant Lake resulted in significant improvements to Bryant Lake and Lake Smetana water quality, highlighting the importance of maintaining good water quality in upstream Bryant Lake. Although the longevity of alum treatments can vary widely depending on several lake and watershed characteristics, treatments typically have an effective life of 10 – 15 years. The NMCWD and partners will continue to monitor Bryant Lake nutrient and dissolved oxygen concentrations to identify changes in internal loading and assess the need for another alum treatment to avoid degrading water quality conditions in Lake Smetana.

Reduce Pollutant Loading from Stormwater Runoff

Study results indicate that the greatest source of phosphorus to Lake Smetana is stormwater runoff from the direct watershed. The following watershed management strategies are recommended to protect and improve Lake Smetana water quality.

Seek opportunities to improve water quality during development and redevelopment — NMCWD requires stormwater management and erosion control for development and redevelopment sites as part of its regulatory program. As portions of the Golden Triangle area redevelop in upcoming years with the construction of the Southwest Light Rail (SWLRT) transit system, the NMCWD will seek opportunities to partner with land owners to construct additional stormwater best management practices or expand existing practices.

Reduce erosion through partnership opportunities — Residents and lake users have noted areas of erosion along portions of the Lake Smetana shoreline and upstream slopes. NMCWD implements a cost-share grant program available to residents, associations, nonprofits, schools, businesses, and cities for projects that protect and improve water quality. NMCWD will partner with public and private entities through its cost share grant program as opportunities arise to address erosion issues that have the the potential to degrade Lake Smetana water quality.

Continue to Monitor Lake Smetana

NMCWD will continue periodic monitoring of water quality and the health of the aquatic communities in Lake Smetana to identify changes and plan for future management needs. NMCWD will also work with MDNR and other partners to collect additional fishery information.

Prepared by Barr Engineering Co.
February 2020

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Acronyms

Acronym	Description
AIS	Aquatic Invasive Species
BMP	Best Management Practice
CAMP	Metropolitan Council Citizen Assisted Monitoring Program
FQI	Floristic Quality Index
IBI	Index of Biological Integrity
MDNR	Minnesota Department of Natural Resources
MPCA	Minnesota Pollution Control Agency
MSL	Mean Sea Level
NCHF	North Central Hardwood Forests
NMCWD	Nine Mile Creek Watershed District
NOAA	National Oceanic and Atmospheric Administration
P8	Program for Predicting Polluting Particle Passage through Pits, Puddles and Ponds
RPBCWD	Riley Purgatory Bluff Creek Watershed District
TP	Total Phosphorus
TSS	Total Suspended Solids
UAA	Use Attainability Analysis

1.0 Introduction

This report describes the results of the Use Attainability Analysis (UAA) for Lake Smetana in Eden Prairie, Minnesota. A UAA provides the scientific foundation for a lake-specific management plan that will permit maintenance of, or attainment of, the intended beneficial uses of a waterbody. The UAA is a scientific assessment of a water body's physical, chemical, and biological condition. This study includes both a water quality assessment and prescription of protective and/or remedial measures for Lake Smetana and the lake's tributary watersheds. The work presented in this report follows analyses that were previously completed for a UAA developed by Nine Mile Creek Watershed District (NMCWD) for Lake Smetana in 2003.

The conclusions and recommendations presented in this report are based on historical water quality data, a fisheries survey conducted in 2005, several years of aquatic plant surveys, and the results of intensive lake water quality monitoring in 2016 and 2018. Lake models were developed and calibrated to the 2016 and 2018 data sets to gain a better understanding of the influence of various phosphorus sources on lake water quality.

1.1 Purpose and Process of the UAA

The Nine Mile Creek Watershed District (NMCWD) has historically used a process referred to as a Use Attainability Analysis (UAA) to assess the water quality condition of its lakes relative to the desired beneficial uses that can be reasonably achieved and maintained with implementation of management recommendations. The UAA process addresses a wide range of goals (e.g., water quantity, aquatic communities, recreational use, and wildlife), with the primary focus being achievement of water quality goals. As part of the *Nine Mile Creek Watershed District Water Management Plan* (Plan) adopted in 2017 and amended in 2018 and 2019 (NMCWD, 2017, amended 2019), the NMCWD has expanded its emphasis on the role of ecological indicators (aquatic plants, phytoplankton, fish, etc.) in overall lake health, as well as the feedback mechanisms between these indicators. A properly functioning ecosystem supports the attainment of good water quality. The NMCWD has also adopted the Minnesota eutrophication standards as part of their 2017 Plan.

The UAA employs a watershed runoff model and an in-lake water quality model to quantify pollutants from various sources and to quantify the benefits of management efforts. The in-lake water quality model predicts changes in lake water quality based on the results of the watershed runoff model (external inputs) as well as internal processes such as sediment phosphorus release due to anoxia and bioturbation (carp/goldfish), curly-leaf pondweed death and decay, and phosphorus settling to lake sediments. Using these models, various watershed and lake management strategies can be evaluated to determine their likely effects on lake water quality. The resulting lake water quality can then be compared with the water quality goals to see if the management strategies are able to produce the desired changes in the lake. Using the tools of the UAA, the cost-effectiveness of the management strategies can also be evaluated.

2.0 Shallow Lake Characteristics and Water Quality

Lake Smetana can be classified as a shallow lake ecosystem. Shallow lakes are lakes that generally have well mixed water columns throughout most of the year and have depths that allow for light penetration to reach the entire sediment surface (i.e., potential for macrophyte growth over the entire lake). Shallow lakes classically exist in two states: (1) clear water with submerged and emergent macrophytes; and (2) turbid water with phytoplankton (algae). The concentration of nutrients entering the shallow water system, the biovolumes of benthivorous fish per unit lake area, and the presence or absence of invasive species such as curly-leaf pondweed are primary drivers that determine the state of shallow lakes.

There are a number of concepts and terminology that are necessary to describe and evaluate a lake's water quality. This section is a brief discussion of those concepts.

2.1 Eutrophication

Eutrophication, or lake degradation, is the accumulation of sediments and nutrients in lakes. As a lake naturally becomes more fertile, biological production enhances and sediment inflow accumulates filling the lake's basin. Over a period of hundreds to thousands of years, a lake can successively become a pond, a marsh and, ultimately, a terrestrial site. This process of eutrophication is natural and results from the normal environmental forces that influence a lake. Cultural eutrophication, however, is an acceleration of the natural processes and is caused by human activities. Nutrient and sediment inputs from wastewater treatment plants, septic tanks, agriculture, and stormwater runoff can far exceed the natural inputs to a lake. Nutrient enrichment in lakes often intensifies primary production resulting in the manifestation of algal blooms. Enhanced sediment loadings can attenuate light and reduce lake transparency, which can limit macrophyte growth. Since macrophytes assist in creating a stable water state, especially in shallow lakes, high suspended sediment and enhanced nutrients can often lead to impaired water quality.

2.2 Nutrients

Biological production in an aquatic ecosystem is limited by the concentrations of essential nutrients. The "limiting nutrient" concept is a widely applied principle in ecology and in the study of eutrophication. It is based on the idea that phytoplankton and plants require many nutrients to grow, but the nutrient with the lowest availability, relative to the amount needed by the phytoplankton or plant, will limit growth. It follows then, that identifying the limiting nutrient will point the way to controlling aquatic plant and algal growth. Nitrogen (N) and phosphorus (P) are generally the two growth-limiting macronutrients in most natural waters. Thus, efforts to improve water quality typically focus on reducing the growth-limiting nutrient concentration in the waterbody; however, it is often difficult to identify and control all of the nutrient loadings to a specific waterbody.

Two primary sources, external and internal loads, are responsible for elevated nutrient concentrations in lakes. Nutrients that enter lakes through watershed runoff, groundwater inputs, or atmospheric deposition are considered external loads. As urbanization has occurred, more areas of impermeable surfaces have been developed causing increased stormwater runoff and pollutant transport during storm and spring thaw events. In urbanized areas, stormwater runoff typically flows through storm sewer systems to the downstream waterbody, which generally results in faster velocities than natural channel flow and can result in higher suspended loadings. Implementation of the NMCWD's stormwater management rules for new development and redevelopment and efforts to install retrofit best management practices (BMPs) are helping to reduce external loads to nearby waterbodies. However, for many shallow lakes, internal load reduction measures (e.g., alum treatment, aquatic plant management, fish management) are also required to meet water quality goals.

Once external nutrient loads enter a lake, over time, the nutrients accumulate in the sediment through the settling of particulates and through organism decay. Natural lake processes such as sediment resuspension, chemical dissolution, or microbial reduction can reintroduce these nutrients to the overlying water body resulting in internal loading. This is specifically common for phosphorus, which can be found bound to the sediment under oxidized conditions. The binding of phosphorus to iron in sediments allows the sediment to act as a sink or source depending on the lake's physical and chemical conditions. Therefore, understanding the chemical and physical conditions and the timing of these conditions will be important considerations when developing an internal loading management plan.

2.2.1 Stratification Impacts on Internal Loading

Lake stratification, the separating of an upper, well mixed warm layer (epilimnion) from a cool, bottom layer (hypolimnion) (Figure 2-1), can lead to low oxygen concentrations in lake bottom waters and trigger internal phosphorus loading. For shallow lakes like Lake Smetana, stratification is typically irregular and can happen on a daily, weekly, or longer timescale. Mixing likely occurs regularly in Lake Smetana and phosphorus released from sediments is then made available to phytoplankton during these frequent mixing events.

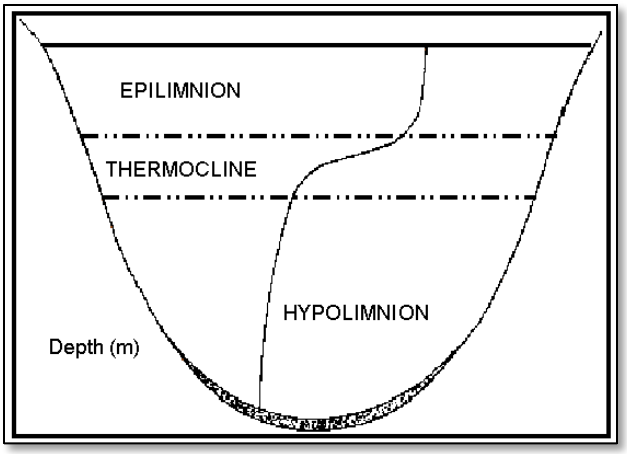


Figure 2-1 Generalized thermal lake stratification diagram

2.2.2 pH Impacts on Internal Loading

The pH of the water column can also play a vital role in affecting the phosphorus release rate under conditions when oxygen is present in the water column (oxic conditions). Photosynthesis by macrophytes (aquatic plants) and algae during the day tend to raise the pH in the water column, which can enhance the phosphorus release rate from the oxic sediment. Enhancement of phosphorus release at elevated pH (pH > 8.2) is thought to occur through replacement of the phosphate ion (PO_4^{-3}) with the excess hydroxyl ion (OH^-) on the oxidized iron compound (James, Barko, & Eakin, 2001). Large increases in pH are often the consequence of phytoplankton blooms.

2.2.3 Organism Impacts on Internal Loading

Benthivorous fish, such as carp, bullhead and goldfish, can have a direct influence on the phosphorus concentration in a lake (LaMarra, 1975). These fish typically feed on decaying plant and animal matter and other organic particulates found at the sediment surface. The fish digest the organic matter, and excrete soluble nutrients, thereby transforming sediment phosphorus into soluble phosphorus available for uptake by algae at the lake surface. Benthivorous (bottom-feeding) fish can also cause resuspension of sediments in shallow ponds and lakes, transporting phosphorus from sediment into the water column, causing reduced water clarity and poor aquatic plant growth, as well as high phosphorus concentrations (Cooke, Welch, Peterson, & Newroth, 1993). In some cases, the water quality impairment caused by benthivorous fish can negate the positive effects of BMPs and lake restoration.

The critical difference between biological (e.g., benthivorous fish feeding) and physical (e.g., wind and waves) sediment resuspension is the area and the frequency to which these components can induce impacts. The volume of sediment impacted by physical resuspension is largely influenced by the geometry of the lake (e.g., size, fetch, bathymetry) and wind events (e.g., direction, velocity). For example, a wind event may develop wave induced sediment resuspension along a portion of the shoreline. However, biological resuspension from feeding or mating activities can occur over a much larger area and is impacted by the number of organisms in the aquatic ecosystem. Additionally, while physical resuspension occurs in a periodic, episodic-based fashion, benthivorous fish resuspension can be more continuous.

2.2.4 Curly-leaf Pondweed Impacts on Internal Loading

Another potential source of internal phosphorus loading is the die-off of curly-leaf pondweed. Curly-leaf pondweed is an invasive (i.e., non-native) aquatic plant that is common in many of the lakes in the Twin Cities metropolitan area. Curly-leaf pondweed grows under the ice during the winter and gets an early start in the spring, crowding out native species. It releases a small reproductive pod that resembles a small pine cone in late-June, and then begins its die-back in late-June and early-July. The biomass sinks to the bottom of the lake and begins to decay, releasing phosphorus into the water column and causing oxygen depletion, exacerbating the internal sediment release of phosphorus. This cycle typically results in an increase in phosphorus concentrations in the lake in late-June or early-July in lakes with a higher percentage of invasive growth.

2.3 Climate Change Considerations

Considerable studies have been devoted to predicting the impacts of a warming climate on the hydrologic cycle. Of particular concern are the changes to atmospheric moisture content, evaporation, precipitation intensity, and the possibility of increased risk for drought and flooding extremes (Trenberth, 1999; Trenberth, Smith, Qian, Dai, & Fasullo, 2003; Giorgi, et al., 2011; Trenberth, 2011).

Alterations to the hydrologic cycle will consequently impact freshwater ecosystems. Observational records and climate model projections show evidence of freshwater vulnerability to a warming climate (Dokulil & Teubner, Eutrophication and climate change: Present situation and future scenarios, 2011). Freshwater characteristics such as lake stratification and mixing, ice coverage, and river flow could see discernable changes by the end of the 21st century (Dokulil & Teubner, 2011; Dokulil, 2013). Increases in nutrient loadings and water temperatures, changes to water levels, and amplified eutrophication could impact aquatic organisms and influence biodiversity.

2.3.1 Projected Changes to the Hydrologic Cycle

Larger concentrations of greenhouse gases in the atmosphere, such as carbon dioxide and methane, create an increased downwelling of longwave radiation to the earth's surface (Trenberth, 1999). This enhanced downwelling not only escalates surface temperature warming, but also induces changes to the atmospheric moisture content and evaporation. Higher atmospheric temperatures allow for an expanded water holding-capacity of the atmosphere and enhanced radiation causes elevated rates of evaporation. This results in increases to the atmospheric moisture content, which, consequently, will impact precipitation (Trenberth, 1999; Trenberth, Smith, Qian, Dai, & Fasullo, 2003; Kharin, Zwiers, Zhang, & Wehner, 2013).

While changes to precipitation amounts and intensity are expected on a global scale, the changes will be geographically disproportionate. Shifts in the natural modes of atmospheric circulation have been documented. The increase in evaporation and atmospheric moisture content causes more moisture to be transported from divergence regions (i.e., subtropics) to convergence zones (i.e., tropics and mid-latitudes). This causes wet areas to become wetter and dry areas to become drier (Trenberth, 1999). In recent decades annual average precipitation has risen in the Northeast, Great Plains, Pacific Northwest, and Alaska, while decreases have been observed for parts of the Southwest United States and in Hawaii (Cayan, 2013; Walsh, 2014; Dettinger, Udall, & Georgakakos, 2015).

According to the National Oceanic and Atmospheric Administration's (NOAA's) 2013 assessment of climate trends for the Midwest (NOAA, 2013), upward trends in annual and summer precipitation amounts have been observed. The frequency of higher intensity storms has also been noted. Specifically in Minnesota, climatologists have identified four significant climate trends (MDNR, 2017):

- Increasing annual precipitation
- Increasing frequency and size of extreme rainfall events
- Increasing temperatures, with winter temperatures warming the fastest
- Decline in severity and frequency of extreme cold weather

Overall, the changes to precipitation induced by atmospheric warming pose difficult challenges. The shift to more frequent, high intensity precipitation events in Minnesota indicates a risk for extreme flood events. Higher intensity precipitation events typically produce more runoff than lower intensity events with similar amounts of precipitation because higher intensity rainfall can overwhelm the capacity of the land surface to infiltrate and attenuate runoff.

Not only do these hydrologic changes pose challenges for agriculture, infrastructure, and human safety; but also has the potential to induce changes to aquatic environments. The subsequent section describes the anticipated impacts to aquatic ecosystems if atmospheric warming trends continue.

2.3.2 Projected Changes to Waterbodies (Physical and Chemical)

In freshwater lakes, one of the most important atmospheric variables influencing the lake's physical and chemical parameters is temperature. Due to enhanced air temperatures and the projected increasing trends, lake water temperature and the number of ice free days are projected to change in most inland waters globally. Increases in lake temperature will affect mixing regimes, the length and depth of summer stratification in deep lakes, and the oxygen concentration in the hypolimnion (Dokulil, 2013; Dokulil, 2014; Dokulil, 2016). As water temperature rises, lake stability enhances, which results in longer thermal stratification and shorter mixing periods (Dokulil, 2013). Resistance to mixing between the nutrient rich hypolimnion and nutrient poor epilimnion across the thermocline increases considerably at temperature gradients of only a few degrees Fahrenheit (Sahoo, et al., 2016).

Prolonged lake stability and a lower thermocline enhances the risk of oxygen depletion in the hypolimnion (Jeppesen, et al., 2009; Sahoo, et al., 2016). Anoxic conditions in the hypolimnion can cause nutrient release from the sediments raising the potential for algal blooms. Additionally, overall oxygen concentrations in the lake will be reduced as solubility decreases when the water temperature warms (Dokulil & Teubner, 2011).

In the tropics and mid-latitudes where precipitation is likely to increase, with the heighted chance for extreme events, other concerns are warranted. Intense rainfalls resulting in flooding could raise the loading of suspended sediments associated with larger areas experiencing soil erosion (Dokulil & Teubner, 2011; Dokulil, 2016). The combination of longer dry periods and extreme precipitation events could create episodic and intense pulse flows affecting aquatic habitats, bank stability, and species (Dokulil, 2016). Additionally, the increase in the number of extreme, high intensity rain events is likely to increase the runoff driven phosphorus transfers from the land to the water (Jeppesen, et al., 2009).

2.3.3 Projected Changes to Eutrophication

The potential for increased erosion and nutrient inputs from large runoff rates combined with higher water temperatures and prolonged lake stratification in summer could lead to widespread, climate-related eutrophication based on the results of existing studies (Dokulil & Teubner, 2011; Dokulil, 2013). Nutrient enrichment, whether through external or internal loading, stimulates the development of phytoplankton biomass. This resulting surface biomass absorbs light, can shade out benthic algae or macrophytes, and can produce negative lake aesthetics (Dokulil & Teubner, 2011). Unfortunately, not only has previous research projected larger biomasses of phytoplankton in a warmer climate, but research also predicts that a higher proportion of these phytoplankton biomasses will consist of potentially toxic cyanobacteria assemblages (Jeppesen, et al., 2009; Dokulil & Teubner, 2011; Jeppesen, et al., 2014; Dokulil, 2016). Multiple regression analyses on data from 250 Danish lakes sampled during the month of August indicated higher dominance of cyanobacteria with a warming climate. Studies during heat waves in the northern hemisphere also showed that higher percentages of cyanobacteria correlated with rises in temperature (Huisman, Matthijs, & Visser, 2005).

Changes in the seasonal pattern and dynamics of freshwater productivity could also be a consequence of a changing climate. With the earlier onset of warmer air temperatures in the spring, the timing of the phytoplankton peak is likely to shift forward. If the phytoplankton blooms contain a larger percentage of cyanobacteria species or if the timing of algal production falls out of synchrony with the food demands of zooplankton and fish, then upper levels of the food chain could be negatively impacted (Dokulil, 2016). Enhanced phytoplankton biomasses can also induce thermal feedback mechanisms for lakes. The thermal structure of lakes can be influenced by phytoplankton via light attenuation. The area of biomass at the surface of a lake affects vertical short-wave radiation. Thus, a large area of phytoplankton biomass can result in greater surface temperatures and stronger stratification by influencing the temperature gradient with depth (Dokulil, 2013). Additionally, increased light attenuation at the surface will reduce light availability at the lake bottom influencing macrophyte growth (Jeppesen, et al., 2014).

This UAA study did not directly assess potential impacts to lake responses due to a changing climate. However, any current and/or future management efforts for waterbodies will be affected by changing climate conditions. Continued monitoring of lake conditions will be important as management efforts are implemented and as changing climate conditions progress. Long-term studies of waterbodies will be essential in order to create the most effective plans to overcome climate-induced impacts.

3.0 Identification of Goals and Expectations

3.1 NMCWD Goals for Lake Management

The NMCWD's approach to assessing and improving lake health is illustrated in Figure 3-1. The primary factors identified as affecting lake ecological health include chemical water quality (e.g., nutrient concentrations), aquatic communities, and water quantity (groundwater and surface water). The effects of recreation and wildlife habitat on overall lake health are also considered.

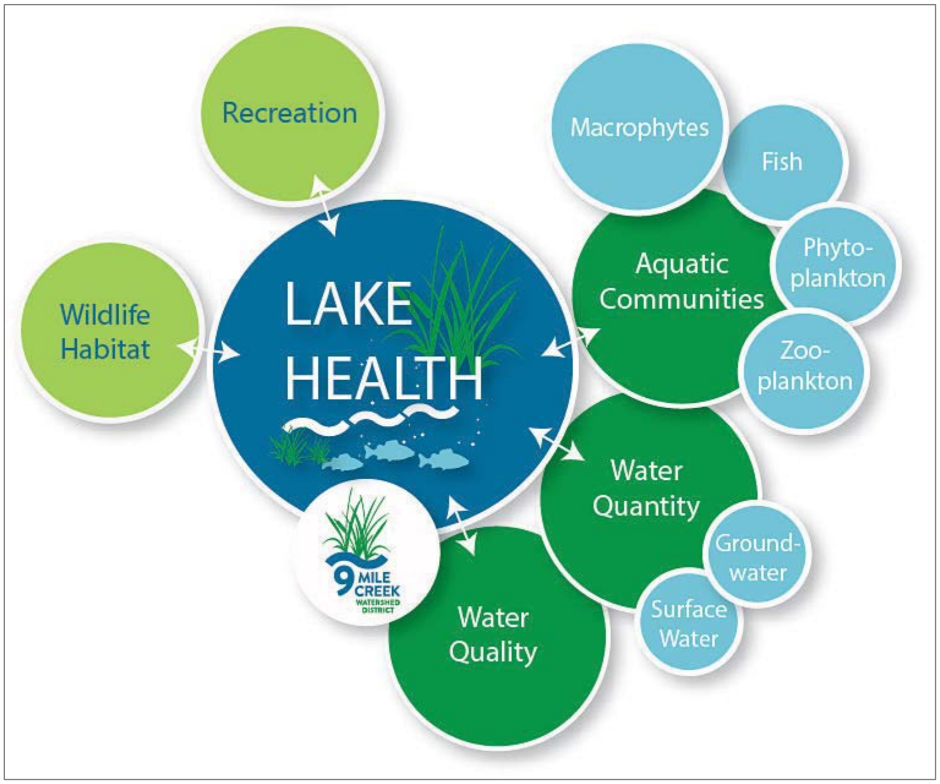


Figure 3-1 NMCWD Holistic Lake Health Assessment Factors (NMCWD, 2017, amended 2019)

3.1.1 Water Quality Goals

One of the primary goals of the District is to "ensure the water quality of the lakes and streams of the NMCWD is protected and enhanced." In 1996, the NMCWD established lake water quality management goals based on designated uses for a waterbody (i.e., full-contact recreational activities such as swimming; non-full body contact recreational activities such as boating, canoeing, or water skiing; fishing and aesthetic viewing; runoff management). In 2008, the Minnesota Pollution Control Agency (MPCA) adopted eutrophication water quality standards for Minnesota lakes, which vary by ecoregion and include criteria for both shallow and deep lakes. The MPCA defines "shallow" lakes as having a maximum depth of 15 feet or less or having at least 80% of the lake area shallow enough to support aquatic plants (referred to as "littoral area").

In their 2017 Plan, the NMCWD adopted the state's lake eutrophication standards as their lake water quality goals, as well as the state water quality standards for Escherichia coli and chloride. The water quality goals for shallow lakes (including Lake Cornelia and Lake Edina) are presented in Table 3-1.

Table 3-1 NMCWD water quality goals for shallow lakes

Water Quality Parameter	Water Quality Standard for Shallow Lakes[1, 2]
Total Phosphorus (summer average, µg/L)	60
Chlorophyll *a* (summer average, µg/L)	20
Secchi Disk Transparency (summer average, m)	1.0
Total Suspended Solids (mg/L)	NA
Daily Dissolved Oxygen Flux (mg/L)	NA
Biological Oxygen Demand (5 day) (mg/L)	NA
Escherichia coli (# per 100 mL)	126 [3]
Chloride (mg/L)	230

[1] NMCWD goals are based on MPCA standards included in MN Rules 7050. Revisions to MN Rules 7050 will supersede NMCWD standards. Note that MN Rule 7050.0220 includes standards for additional parameters that are enforced by the MPCA.
[2] Shallow lakes have a maximum depth less than 15 feet or littoral area greater than 80% of the total lake surface area.
[3] 126 organisms per 100 mL as a geometric mean of not less than five samples within any month, nor shall more than 10% of all samples within a month exceed 1,260 organisms per 100 mL.

3.1.2 Other Lake Health Goals

In addition to the water quality goals presented in Table 3-1, the NMCWD's 2017 Plan expresses the desire to establish holistic lake health targets for District-managed lakes. The holistic lake health targets consider a wide range of factors, with an increased emphasis on the role of ecological factors in overall lake health and the interrelated nature of these factors.

Table 3-2 lists the evaluation factors used by the NMCWD to holistically assess lake health. Numerical goals exist for some of the factors presented in this table (e.g., MPCA water quality standards), while other holistic health factors are assessed qualitatively by comparing to narrative criteria. The NMCWD collaborates with stakeholders and regulatory agencies (MPCA, Minnesota Department of Natural Resources (MDNR)) to develop lake-specific numerical goals for ecological indicators where appropriate.

Table 3-2 NMCWD holistic lake health assessment evaluation factors

Lake Health Assessment Factors	Evaluation Factors
Chemical Water Quality	• Nutrients • Sediment • Clarity • Chlorophyll *a* • Chloride
Aquatic Communities	• Aquatic Plant IBI[1]- species richness and floristic quality • Invasive Species Presence • Phytoplankton Populations • Blue-green Algae Presence • Zooplankton Populations
Water Quantity	• Water Levels • Water Level Bounce • Groundwater Levels
Recreation	• Shore Access • Navigation Potential • Aesthetics • Use Metrics
Wildlife	• Upland biodiversity • Buffer extent/width

[1] Lake plant eutrophication Index of Biotic Integrity (IBI) methodology developed by the MDNR and MPCA

3.2 NMCWD Adaptive Management Approach

The NMCWD implements an adaptive management approach to improve lake health based on water quality and assessment of the other holistic lake health factors. While striving to achieve the state standards for shallow lakes, the NMCWD recognizes that achieving the water quality goals may not be feasible for some lakes or may require a timeframe that extends several decades. For these situations, the NMCWD's objective it to make reasonable and measurable progress towards meeting the water quality goals and other holistic lake health targets.

The NMCWD reviews lake monitoring data annually to assess progress toward lake management goals. For lakes that are meeting the goals, the NMCWD continues periodic monitoring to track variations in water quality and potential trends. If water quality declines or if water quality does not meet NMCWD goals, a lake-specific Use Attainability Analysis is developed or updated to identify additional protection and improvement measures, as is being completed in this report for Lake Smetana.

4.0 Lake Basin and Watershed Characteristics

The following sections describe the unique characteristics of the Lake Smetana basin and watershed.

4.1 Lake Smetana Basin Characteristics

Lake Smetana is located in the northeast portion of the city of Eden Prairie. The lake was a natural marsh area prior to the 1999 when a 70-foot long weir structure was installed by the Nine Mile Creek Watershed District on the east end of the lake (approximate elevation 835.0 feet MSL). Prior to the installation of this control structure, the flow out of Smetana was controlled by a combination of the South Fork of the Nine Mile Creek channel configuration and the 60-inch RCP under Triangle Drive.

Lake Smetana has a water surface area of approximately 56 acres, a maximum depth of 11 feet, and a mean depth of approximately 3.2 feet at a normal water surface elevation of 835.0. At this elevation the lake volume is approximately 176 acre-feet (Figure 4-1. The water level in the lake is controlled mainly by weather conditions (snowmelt, rainfall, and evaporation) and by the outlet capacity of the control weir. The stage-storage-discharge relationship that was used in this study for Lake Smetana is shown in Table 4-1.

Since Lake Smetana is shallow, the lake is prone to frequent wind-driven mixing of the lake's shallow waters during the summer. Therefore, one would expect Lake Smetana to be *polymictic* (mixing many times per year) as opposed to lakes with deep, steep-sided basins that are usually *dimictic* (mixing only twice per year). Daily monitoring of the lake would be necessary to precisely characterize the mixing dynamics of a lake, but the limited data gathered from Lake Smetana strongly suggests that the lake is polymictic.

Table 4-1 Stage-storage-discharge relationships for Lake Smetana

Elevation	Area (acres)	Cumulative Storage (ac-ft)	Discharge (cfs)	Comment
825	0.3	0	0	Wet Detention Storage Volume
826	1.3	0.8	0	
827.1	2.5	2.6	0	
828	4	5.8	0	
829	6.2	10.9	0	
830	10.3	19.2	0	
831	14.1	31.4	0	
832	26.2	51.5	0	
833	32.5	80.9	0	
834	50.8	122.5	0	
835.05	55.6	175.7	0	Weir Elevation
835.15	55.9	181.3	6.6	Available Live Storage for Flood Control
835.25	56.2	186.3	18.8	
835.35	56.5	192.6	34.5	
835.45	56.7	198.2	53.1	
836	58.2	232.6	194.4	
838	66	356.9	1064	
840	68.3	491.1	2312.7	

1-ft Bathymetric Contours*

* Source: DNR, 2014

N

0 200 400

Feet

LAKE SMETANA BATHYMETRY

FIGURE 4-1

4.2 Watershed Characteristics

Lake Smetana's direct watershed is approximately 1,022 acres, including the surface area of the lake (56 acres). Runoff from the watershed enters Lake Smetana through overland flow, discharge from the South Fork of Nine Mile Creek, and from several storm sewer outfalls at various points along the lakeshore. Locations of the major stormwater conveyance features are shown on Figure 4-2.

Lake Smetana also receives flow from Bryant Lake, located approximately 1.3 stream miles upstream of Lake Smetana. Figure 4-3 shows Lake Smetana's direct watershed, as well as the watershed tributary to Bryant Lake. Past studies have shown that the water quality of Bryant Lake impacts the water quality of Lake Smetana. Therefore, understanding the interconnection of the two lakes will be important for understanding management effectiveness.

4.2.1 Land Use

Land use practices within a lake's watershed impact the lake and its water quality by altering the volume of stormwater runoff, sediment load, and nutrient load (namely phosphorus) that reaches the lake from the lake's watershed. Each land use contributes a different amount of runoff and phosphorus to the lake, thereby impacting the lake's water quality differently. As land use changes over time, changes can be expected in downstream water bodies as a result.

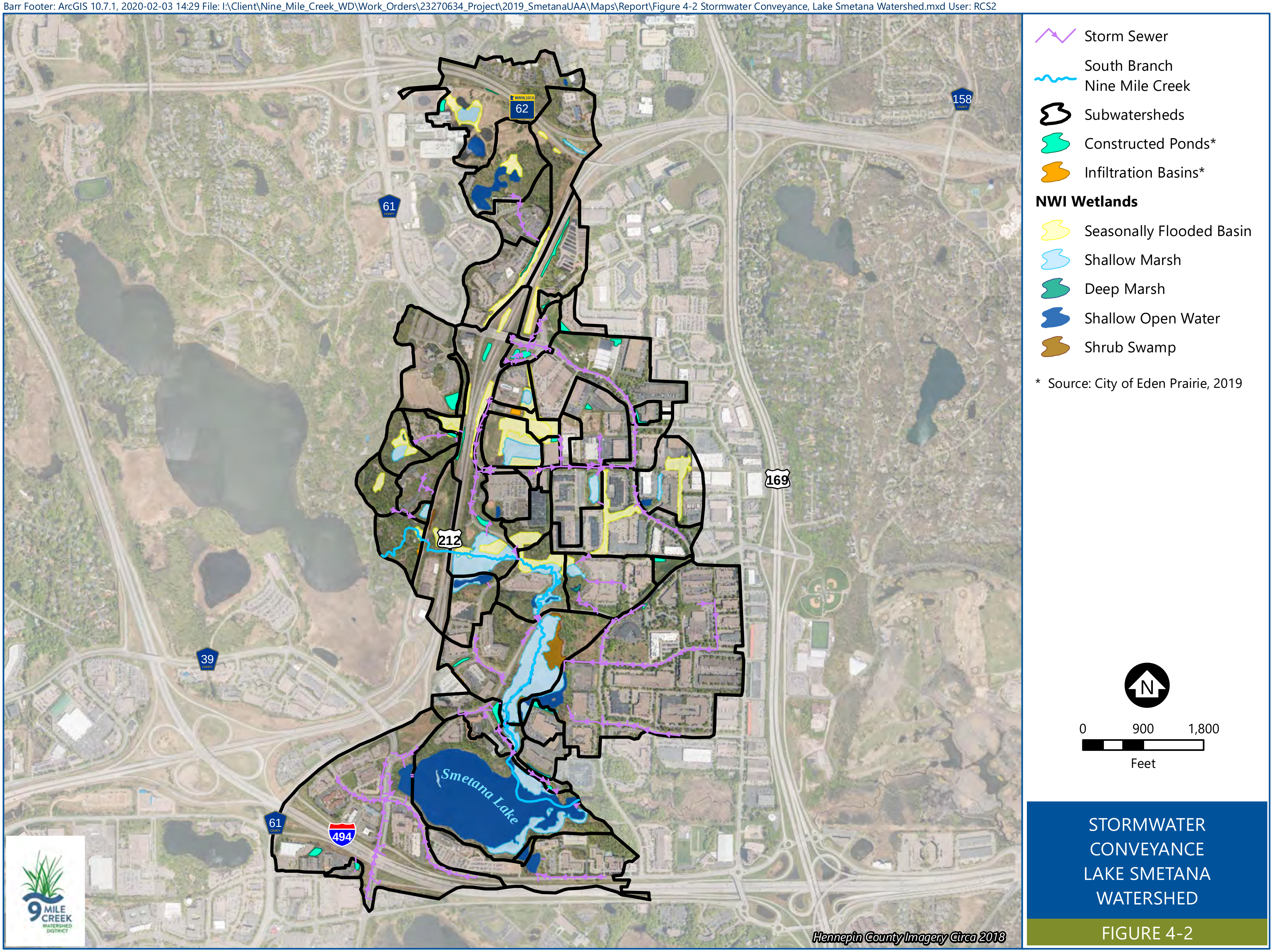
Historically, the Lake Smetana watershed was primarily comprised of basswood, sugar maple, and oak forests. There were also numerous wetlands located throughout the watershed. The terrain varies from relatively flat to rolling.

Based on the 2019 Land Use Inventory Dataset provided by the City of Eden Prairie, the watershed of Lake Smetana is near fully-developed. Table 4-2 provides a summary of the land use classifications within the watershed. The major land use classification in the Lake Smetana watershed is industrial. The watershed also includes some proportions of state highway, office/commercial, and public open space. To a lesser extent, the land use consists of low density residential (single family homes), high density residential, rural/vacant land, and church/cemetery. Figure 4-4 shows a map of the land use classifications within the Lake Smetana watershed.

Table 4-2 Land use classifications in the Lake Smetana watershed

Land Use Classification	Percent of Watershed
Industrial	34%
State Highway	21%
Office/Commercial	18%
Public/Open Space	13%
Low Density Residential	5%
Rural/Vacant	4%
High Density Residential	3%
Church/Cemetery	3%
Total Watershed Area (ac)	1,022

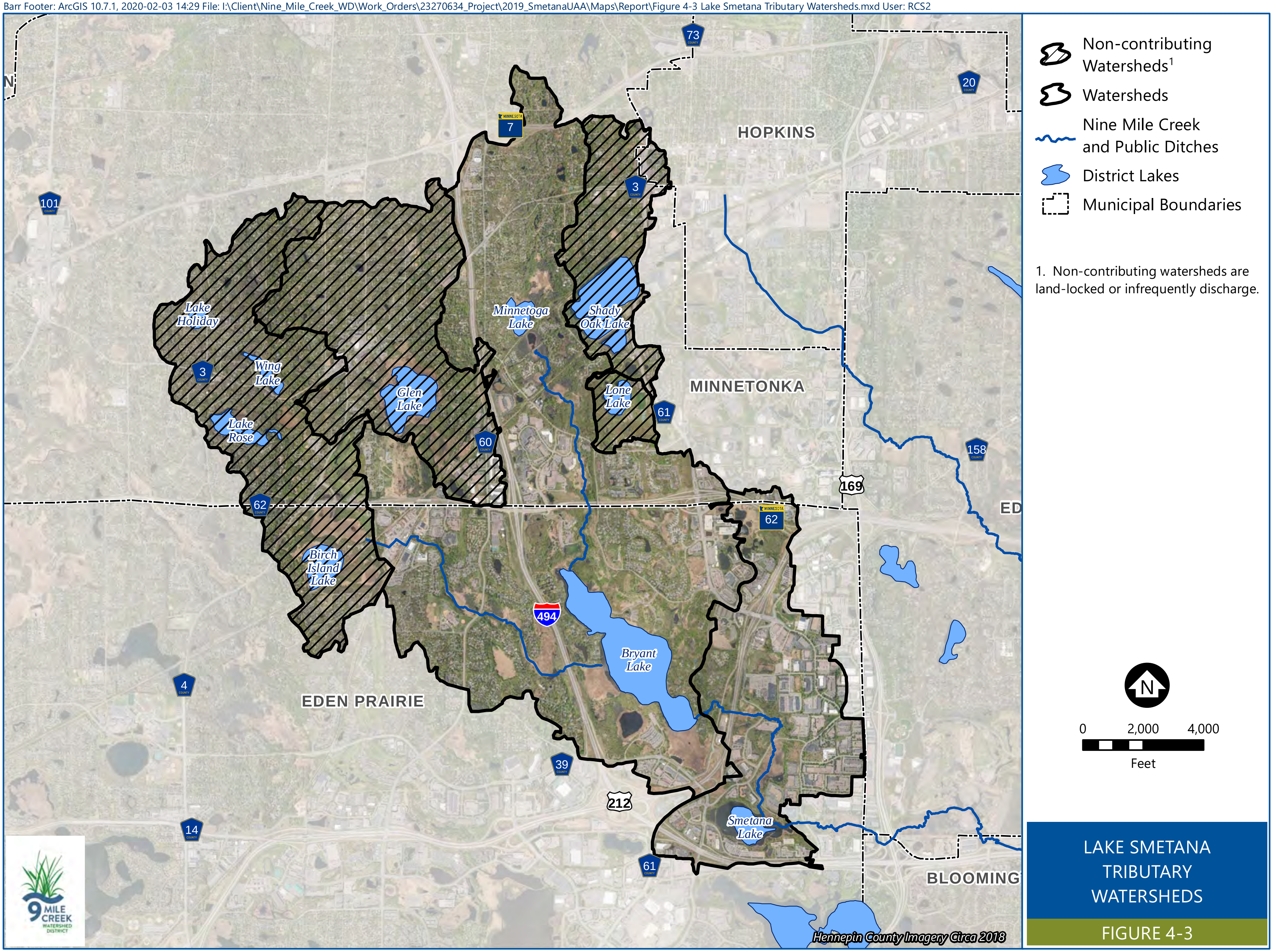
Barr Footer: ArcGIS 10.7.1, 2020-02-03 14:29 File: I:\Client\Nine_Mile_Creek_WD\Work_Orders\23270634_Project\2019_SmetanaUAA\Maps\Report\Figure 4-2 Stormwater Conveyance, Lake Smetana Watershed.mxd User: RCS2



STORMWATER CONVEYANCE LAKE SMETANA WATERSHED

FIGURE 4-2

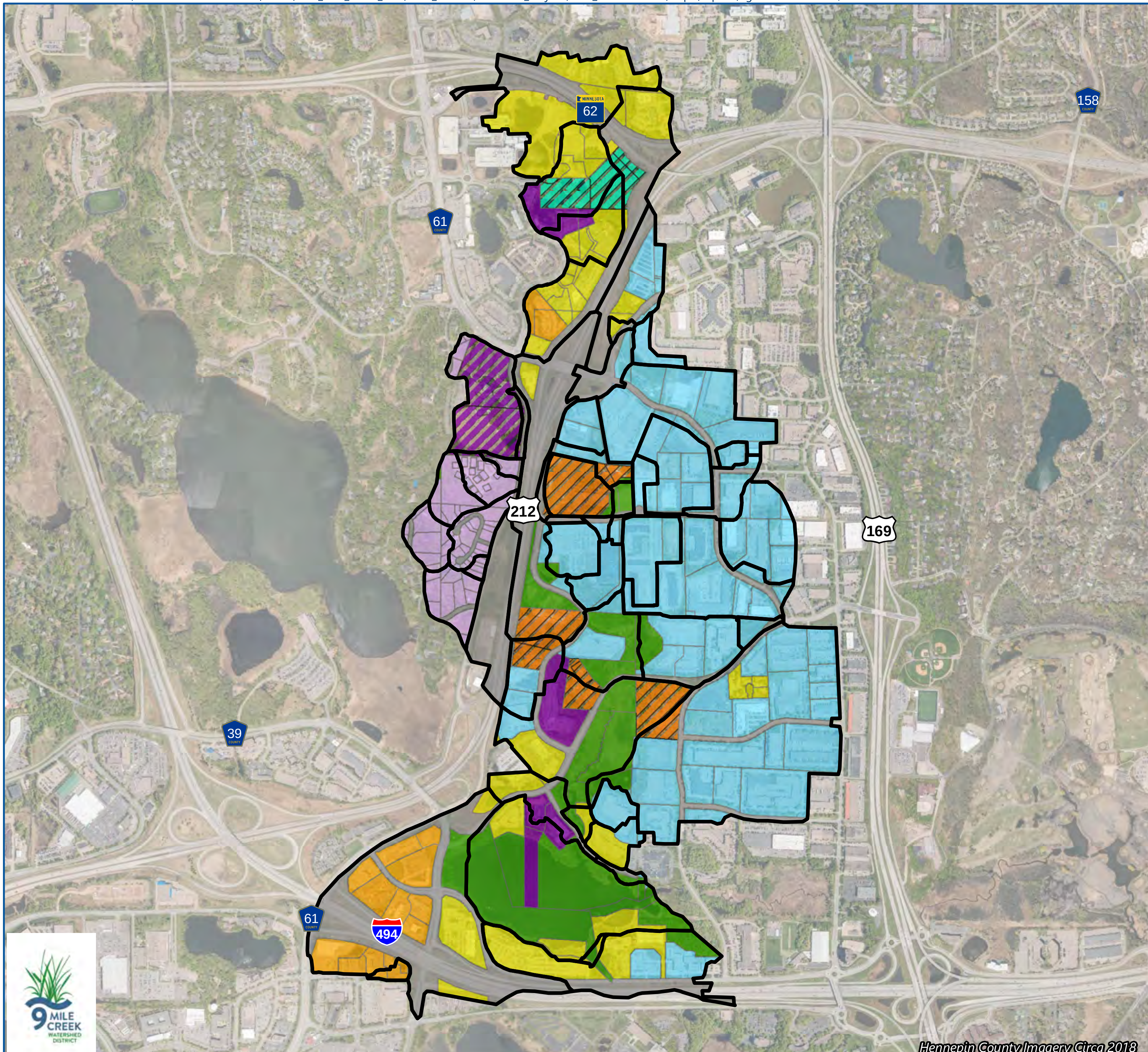
Barr Footer: ArcGIS 10.7.1, 2020-02-03 14:29 File: I:\Client\Nine_Mile_Creek_WD\Work_Orders\23270634_Project\2019_SmetanaUAA\Maps\Report\Figure 4-3 Lake Smetana Tributary Watersheds.mxd User: RCS2



LAKE SMETANA TRIBUTARY WATERSHEDS

FIGURE 4-3

Barr Footer: ArcGIS 10.7.1, 2020-02-03 14:30 File: I:\Client\Nine_Mile_Creek_WD\Work_Orders\23270634_Project\2019_SmetanaUAA\Maps\Report\Figure 4-4 Land Use, Lake Smetana Watershed.mxd User: RCS2



Subwatersheds

Land Use (2019 Eden Prairie)

- Industrial
- High Density Residential
- Low Density Residential
- Highway/ROW
- Commercial
- Office
- Park/Open Space
- Public/Semi-Public
- Church/Cemetery
- Rural/Vacant

0 900 1,800
Feet

LAND USE
LAKE SMETANA
WATERSHED

FIGURE 4-4

5.0 Existing Water Quality

5.1 Water Quality

The NMCWD conducted intensive water quality monitoring in Lake Smetana in 2016 and 2018 in support of this UAA. The NMCWD also collected data in 1990, 1999, and 2005. Furthermore, monitoring data was collected through the Metropolitan Council Citizen Assisted Monitoring Program (CAMP) in 2013.

5.1.1 Phosphorus, Chlorophyll *a*, and Clarity

The NMCWD intensive monitoring included the lake eutrophication parameters of total phosphorus (TP), chlorophyll *a*, and Secchi disk depth to assess water clarity. Data are presented using box plots. The box plots show averages (red cross), median values (straight horizontal line), maximum and minimum values (blue dots), as well as the region where 50 percent of the data lie (the area within the boxes). Box plots shown on

Figure 5-1 displays the summer-average TP and chlorophyll *a* concentrations from 1990 through 2018. Figure 5-2 shows the summer-average Secchi disk transparency depths from 1990 through 2018.

There is significant variability in total phosphorus and chlorophyll *a* concentrations in Lake Smetana from year to year, as well as within a given year. The variability can be a reflection of numerous factors, including climatic variability, changing aquatic plant populations, periodic winter fish kills, and changes in external pollutant loadings from the direct watershed and upstream water bodies.

Water quality monitoring that occurred in 2005 and prior showed that the summer-average (June through September) total phosphorus and chlorophyll a concentrations were well above the 60 µg/L and 20 µg/L shallow lake criteria, respectively. However, water quality measurements taken after 2013 showed improved water quality in Lake Smetana, with summer-average total phosphorus and chlorophyll a concentrations below the Minnesota state standards for shallow lakes.

While the marked improvements in lake water quality can be attributed to several management programs and activities implemented by the Nine Mile Creek Watershed District in recent decades, the fall 2008 alum treatment of upstream Bryant Lake led to the most pronounced improvements in both Bryant Lake and downstream Lake Smetana. The alum, distributed throughout the lake by a barge, settles to the bottom of the lake, removing phosphorus from the water column and binding (or immobilizing) the phosphorus in lake bottom sediments, minimizing its release into the water column. Other management activities and programs that have helped to improve Lake Smetana water quality include a 2008 wetland restoration project upstream of Bryant Lake (just west of Interstate 494) and implementation of the NMCWD's permitting program that requires construction of stormwater best management practices when land is developed or re-developed.

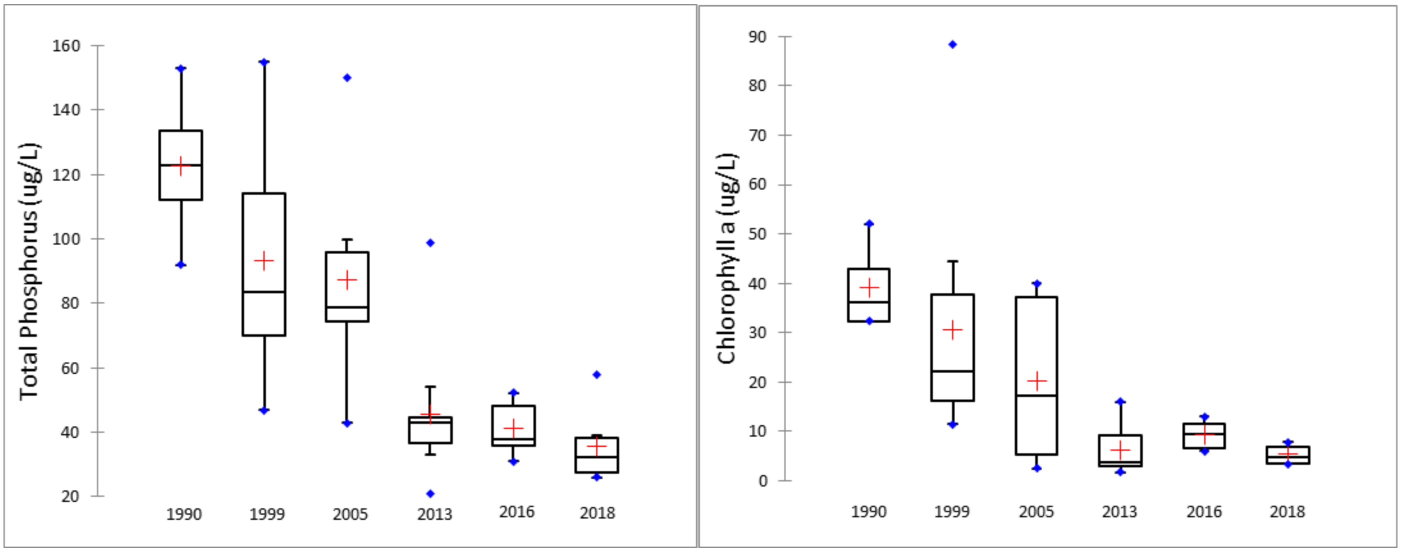


Figure 5-1 **Total phosphorus and chlorophyll *a* concentrations in Lake Smetana from 1990 through 2018. The red crosses indicate the summer-average (June through September) concentrations.**

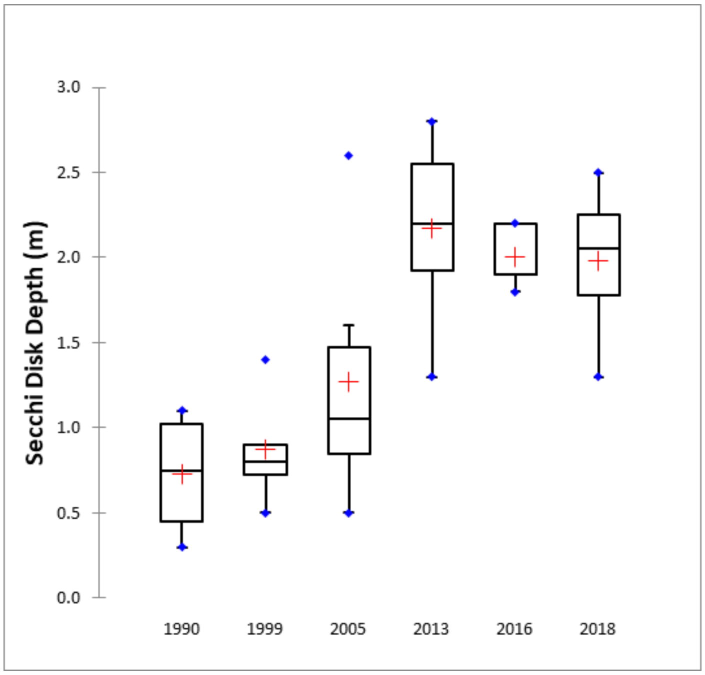


Figure 5-2 **Secchi disk measurements in Lake Smetana from 1990 through 2018. The red crosses indicate the summer-average (June through September) concentrations.**

5.1.2 Chlorides

Chloride concentrations in area lakes have increased since the early 1990s when many government agencies switched from sand or sand/salt mixtures to salt for winter road maintenance. When snow and ice melts, the salt goes with it, washing into lakes, streams, wetlands, and groundwater. It only takes 1 teaspoon of road salt to permanently pollute 5 gallons of water. And, once in the water, there is no way to remove chloride without extensive financial implications.

Because high concentrations of chloride can harm fish and plant life, MPCA has established a chronic exposure chloride standard of 230 mg/L or less and considers two or more exceedances of the chronic standard in 3 years to be an impairment. In May and June of 2018, chloride concentrations in Lake Smetana exceeded the MPCA standard of 230 mg/L (244 mg/L on May 14, 2018 and 264 mg/L on June 12, 2018). Following the high concentrations recorded in late spring and early summer 2018, chloride concentrations in Lake Smetana decreased to below the standard throughout the summer months. Spring chloride concentrations were not recorded in 2019.

5.2 Sediment Quality

Phosphorus in lake bottom sediments is often bound to a range of different elements such as iron and manganese (often referred to as mobile phosphorus), aluminum, or calcium. Phosphorus can also be found incorporated into organic matter (organically-bound phosphorus). It is the mobile phosphorus fraction that releases from sediment during low oxygen conditions (this is often called internal loading). Organically-bound phosphorus also releases phosphorus from lake sediment but at a slow rate.

Phosphorus composition data from cores taken from lake-bottom sediments in 2019 were used to estimate the maximum potential phosphorus release rate (internal loading) in Lake Smetana. The average mobile phosphorus in the top 6 centimeters of five sediment cores was 8.7 µg P/cm^3. Table 5-1 provides the maximum potential internal loading rate (0.7 mg/m^2-d) for Lake Smetana and compares this value with other lakes in the metro area. This release rate is low, but it is similar to other shallow lakes in the Twin Cities Metro Area. Because Lake Smetana is shallow and has a small water volume, even a low internal phosphorus loading rate can significantly increase phosphorus concentration in the lake water column.

Table 5-1 Maximum potential internal loading rate for Lake Smetana compared to other Twin Cities Metro Area lakes.

Lake	Maximum Potential Internal Phosphorus Load ($mg/m^2/d$)
Kohlman[1]	17.0
Isles (pre-alum, deep hole)[2]	14.1
Harriett (pre-alum, deep hole) [2]	11.1
Calhoun/Bde Maka Ska (pre-alum, deep) [2]	10.8
Fish E[3]	10.5
Cedar (pre-alum) [2]	9.3
Fish W[3]	8.1
Como[3]	7.6
North Cornelia[4]	7.6
Calhoun/Bde Maka Ska (pre-alum, shallow) [3]	5.6
Keller[1]	3.5
Parkers[3]	3.5
Phalen[3]	2.3
McCarrons[3]	2.0
Bryant[3]	1.5
South Cornelia[4]	1.3
Nokomis[3]	1.0
Smetana	**0.7**
Minnewashta[3]	0.2
Edina[4]	0.0
Christmas[3]	0.0

Sources:
[1] (Barr Engineering Co., 2007)
[2] (Huser & Pilgrim, 2014)
[3] (Pilgrim, Huser, & Brezonik, 2007)
[4] (Barr Engineering Co., 2018)

5.3 Aquatic Communities

The fish, zooplankton, phytoplankton, and aquatic plants residing in Lake Smetana are all linked and the composition and abundance of biota observed in the lake provides indication of lake health and if biological management should be considered to improve water quality.

5.3.1 Aquatic Plants

Macrophytes, also called aquatic plants, grow in aquatic systems such as streams and lakes. There is a wide range of macrophytes including species attached to the lake bottom, species unattached and floating, submerged species, and emergent species (e.g., cattails). Macrophytes are an important part of a shallow lake ecosystem and provide critical habitat for aquatic insects and fish. A healthy native plant community contributes to the overall health of the lake. However, a dense non-native plant community can create problems, including recreational use impairment, fluctuating water quality, and a less than ideal fisheries habitat, which has adverse impacts on the fish community. The dense growth makes it difficult for invertebrates and other organisms that fish eat to survive. So, with less to eat and less open water, fish populations decrease (MPCA, Eurasian Water Milfoil, 2019). The dense growth makes it hard for fish to catch food. When fish are less effective at controlling prey species, an unbalanced fishery results (Indiana Department of Natural Resources, 2019)

The Minnesota Department of Natural Resources (MDNR) developed the Lake Plant Eutrophication IBI in recent years to assist the MPCA in assessing lake impairment based on the plant community. The Lake Plant Eutrophication IBI includes two metrics to measure the response of a lake plant community to eutrophication. The first metric is species richness—the estimated number of species in a lake. The second metric is floristic quality index (FQI), which distinguishes the quality of the plant community and can be a reflection of the quantity of nutrients in the lake.

The MDNR's Lake Plant Eutrophication Index of Biological Integrity (IBI) was used to assess the health of the Lake Smetana plant communities. Aquatic plant data collected by NMCWD from 1999 through 2018 was used to determine species richness and Floristic Quality Index (FQI) scores. The scores were then compared with MDNR Lake Plant Eutrophication IBI impairment thresholds (a minimum of 11 species and an FQI score of at least 17.8) to determine whether the Lake Smetana plant community would be considered impaired.

The Lake Smetana plant community failed to meet the MDNR Lake Plant Eutrophication IBI criteria for measurements taken in 1999 and 2005, which reflects the lake's poor water quality during that time period (i.e., total phosphorus and chlorophyll *a* concentrations above Minnesota State shallow lake water quality standards). The number of species observed in Lake Smetana in 1999 and 2005 ranged from 5 to 8 species, which was less than the plant IBI impairment threshold of at least 11 species (Figure 5-3). However, in 2016 and 2018, the Lake Smetana plant community improved. The number of species observed in Lake Smetana in 2016 and 2018 ranged from 13 to 14 species, which is greater than the plant IBI impairment threshold of at least 11 species (Figure 5-3). The increase in observed species is reflective of improved water quality.

The FQI values follow a similar trend to the number of plant species observed in Lake Smetana over time. FQI values ranged from 9.4 to 13.2 from 1999 to 2005, which is less than the plant IBI impairment threshold for FQI of at least 17.8 (Figure 5-4). FQI values from 2016 to 2018 increased, ranging from 19.4 to 20.8, which is greater than the plant IBI impairment threshold for FQI of at least 17.8 (Figure 5-4).

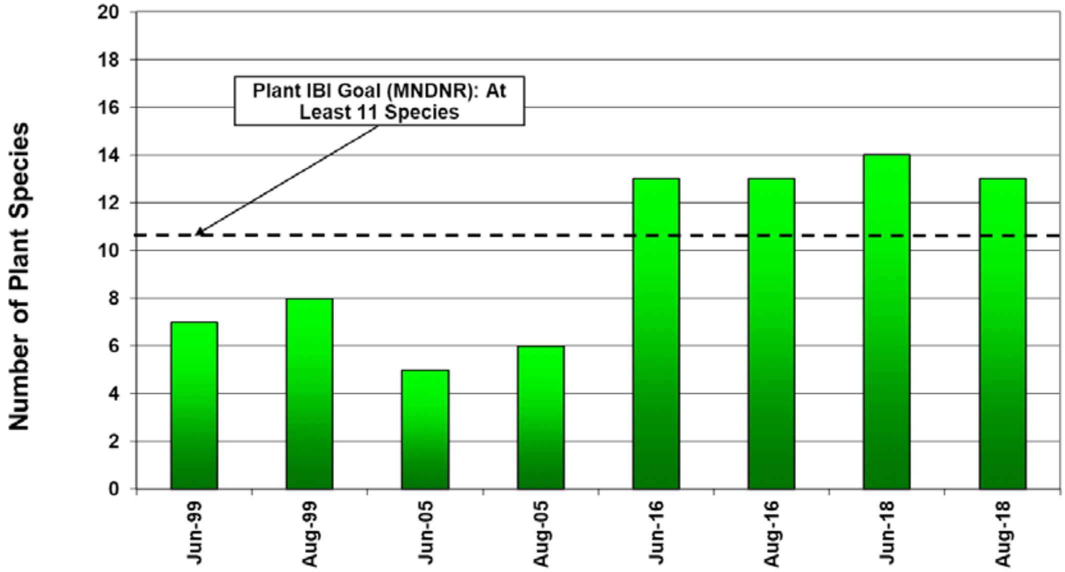


Figure 5-3 Macrophyte Species Richness Compared with Plant IBI Threshold for Species Richness

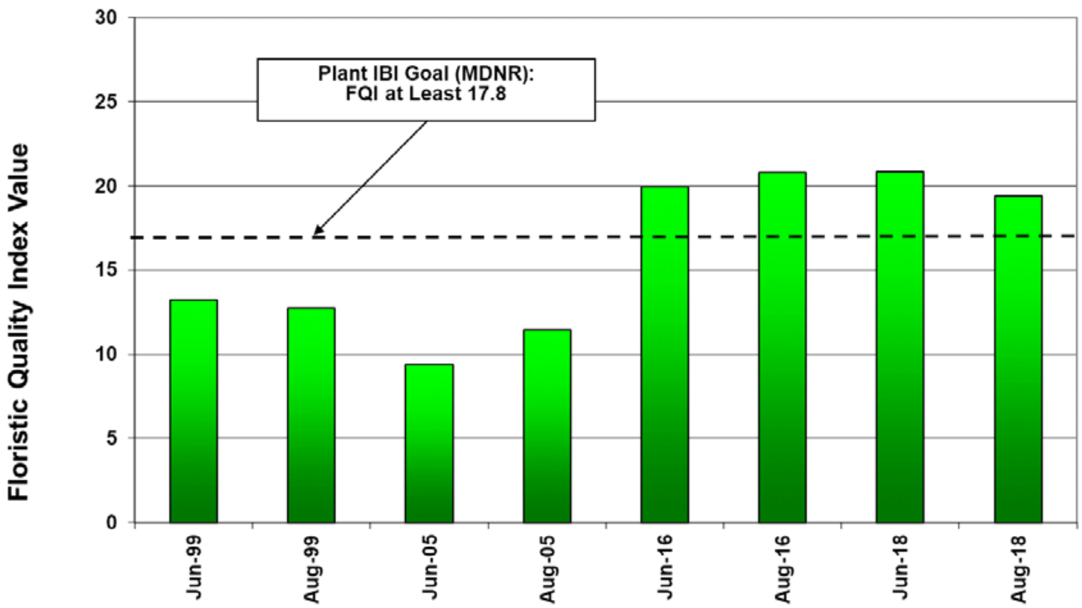


Figure 5-4 Macrophyte Species Richness Compared with Plant IBI Threshold for Floristic Quality Index (FQI)

Two non-native aquatic invasive species (AIS) are present in Lake Smetana: Purple loosestrife and curly-leaf pondweed.

Purple loosestrife has been observed in Lake Smetana since the first recorded survey in 1999. Purple loosestrife was observed along the northwest and southeast shorelines during 1999, 2005, 2016 and 2018. Curly-leaf pondweed was observed in Lake Smetana during the 1999, 2016, and 2018 surveys. It is unclear why no curly-leaf pondweed was observed during the 2005 survey. In 1999, curly-leaf pondweed was found in southern and eastern portions of the lake. In 2016, curly-leaf pondweed was more widespread with observations not only in the southern and eastern portions of the lake, but also in the central and northern portions. In 2018, curly-leaf growth continued to expand with additional observations in the north and center of the lake. No treatments have been applied in Lake Smetana for purple loosestrife or curly-leaf pondweed to date, and while both species are prevalent, they have been co-existing with native plants at relatively low densities. Neither species have been considered problematic. The NMCWD will continue to track the plants' growth.

Aquatic plant maps from 1999 through 2018 are provided in Appendix A.

5.3.2 Phytoplankton

Samples of phytoplankton, microscopic aquatic plants, were collected from Lake Smetana to evaluate water quality and the quality of food available to zooplankton (microscopic animals). Phytoplankton numbers during the monitoring period of 1990 through 2018 followed a pattern similar to that of the water quality parameters (e.g., total phosphorus, chlorophyll *a*, Secchi disk depth), both reflecting the improvement in water quality of Lake Smetana. For the period prior to the start of the water quality improvement projects (1990-2005), the summer-average phytoplankton number was 14,573 per milliliter. For the period after the completion of the water quality improvement projects (2013-2018), the summer-average phytoplankton number was 5,541 per milliliter. Blue-green algae numbers were much lower after the completion of the water quality improvement projects – pre-project average blue-green numbers were 6,938 units per milliliter compared with post-project average blue-green numbers of 747 units per milliliter (Figure 5-5).

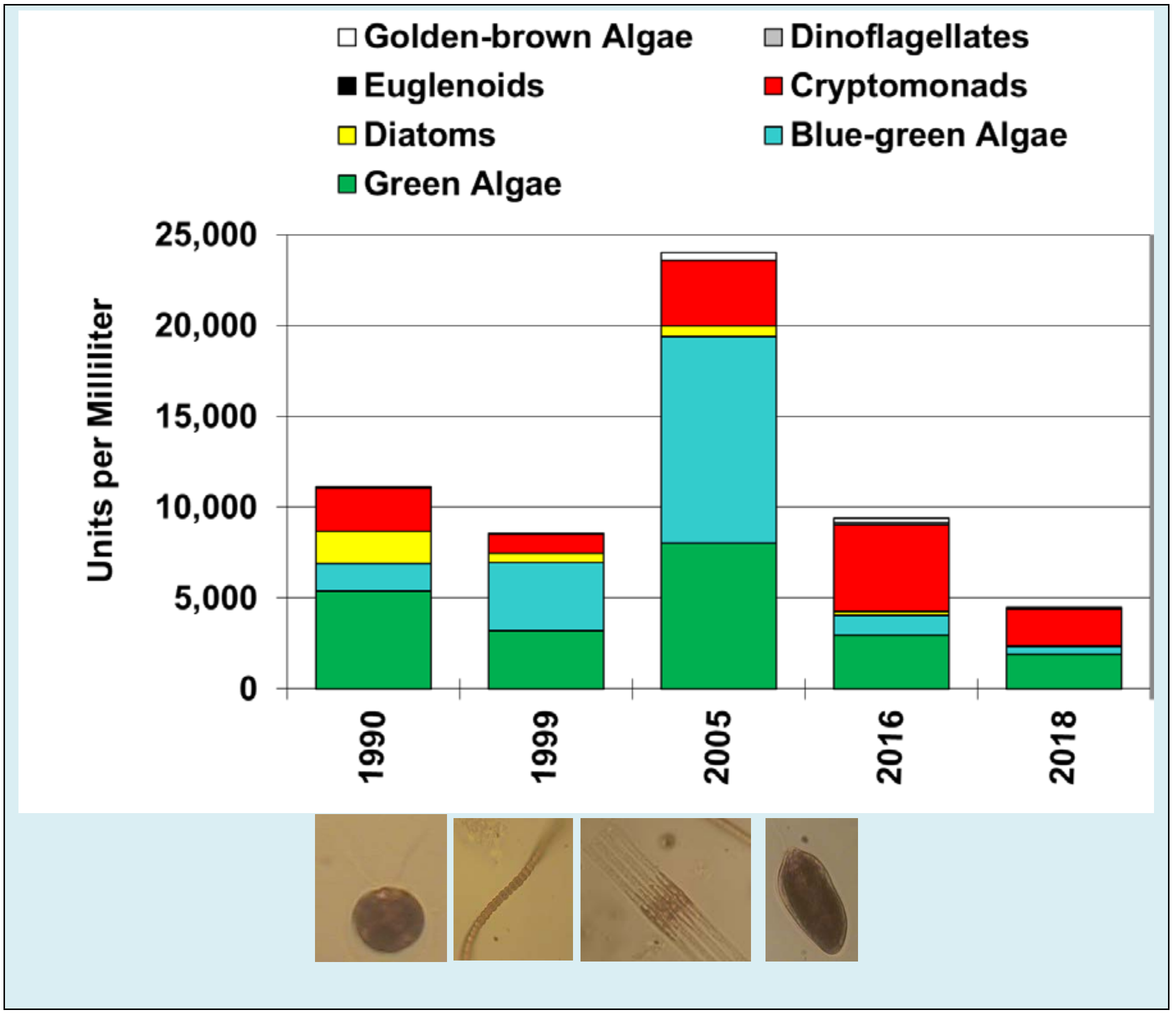


Figure 5-5 **Top, Lake Smetana 1990-2018 summer average phytoplankton numbers and bottom, microscopic pictures of phytoplankton species from the lake , from left to right, Chlamydomonas globosa (green algae) Dolichospermum affine (blue-green algae), Fragilaria crotonensis (diatom), and Cryptomonas erosa (cryptomonad).**

5.3.3 Zooplankton

Zooplankton are microscopic animals that are a source of food for fish (e.g., bluegills, crappies). The composition of the 2018 zooplankton community was consistent with recent years, with all three groups of zooplankton (rotifers, copepods, and cladocerans) represented (Figure 5-6). During the period of record, small rotifers, copepods, and small cladocerans have generally dominated the community. Because small rotifers, copepods, and small cladocerans do not graze as heavily on algae as the larger cladocerans, they generally have limited impact on the lake's water quality.

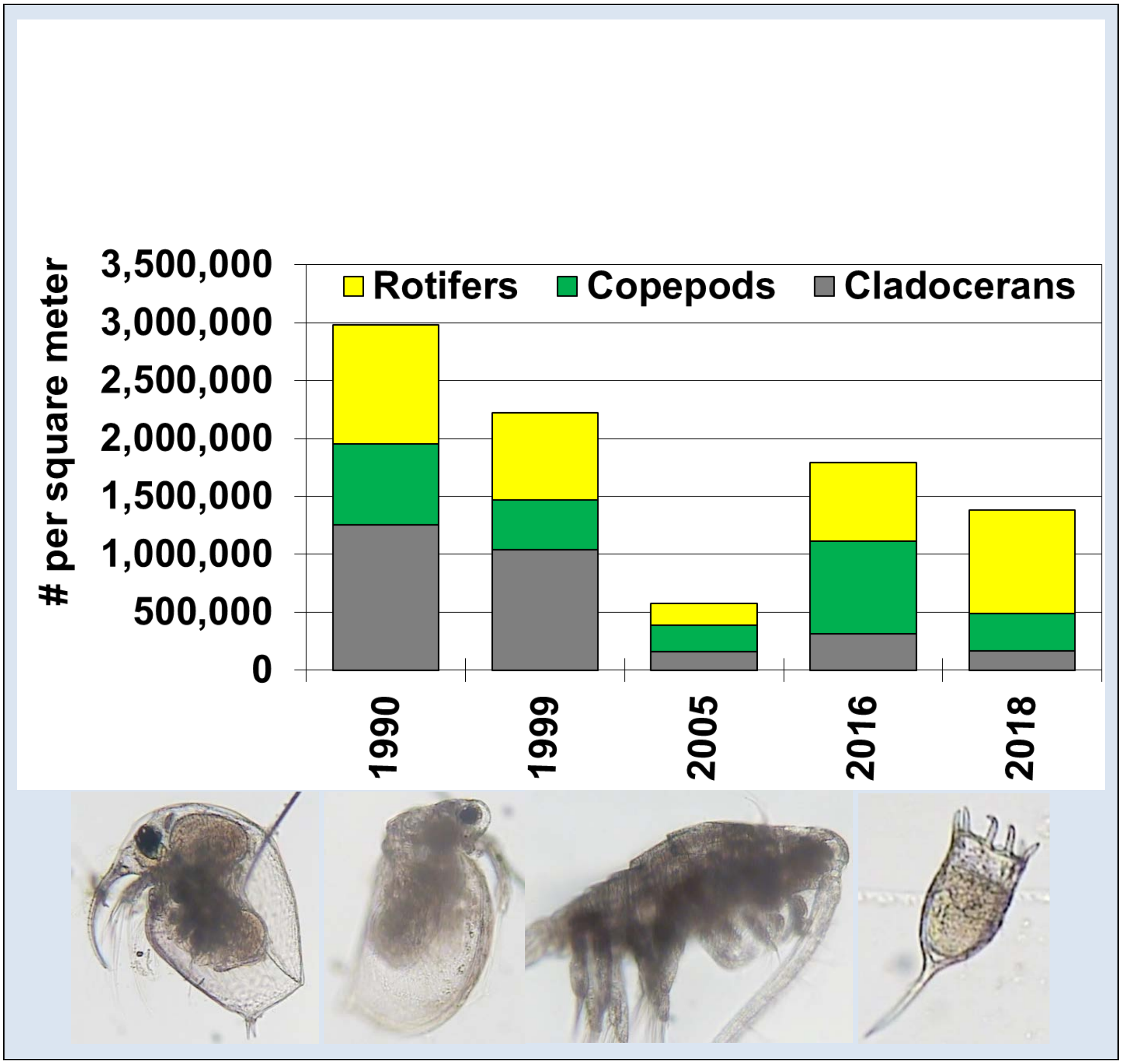


Figure 5-6 **Top, 1990-2018 zooplankton numbers and bottom, microscopic pictures of zooplankton species from the lake, from left to right, Bosmina longirostris. (cladoceran), Ceriodaphnia sp. (cladoceran), Diaptomus sp. (copepod), and Keratella cochlearis (rotifer).**

5.3.4 Fish

The MDNR completed a fisheries assessment of Lake Smetana in 2005. On August 1, 2005 the MDNR completed a standard lake survey of Lake Smetana using two gill nets and nine trap nets. On September 6, 2005, a special assessment of Lake Smetana was also conducted using electrofishing. This special assessment was conducted to sample a small selection of the species already present in the primary standard lake survey completed in August. The official survey reports from the MDNR can be found in Appendix B. No additional fish surveys have been conducted by MDNR since 2005.

During the standard lake survey in early August 2005, a variety of species were sampled, including black bullhead, black crappie, bluegill, brown bullhead, common carp, green sunfish, hybrid sunfish, largemouth bass, northern pike, pumpkinseed sunfish, yellow bullhead, and yellow perch. Northern pike was found to be the most prominent predator fish in the lake, but the average size was small. The majority of pike sampled were from the 2001- and 2002-year classes (3 to 4 years old) and growth was average until age 4 when it appeared to slow. The growth of bluegill in the lake was found to be above average and there were several classes sampled. In 2005, black bullhead, brown bullhead, and common carp populations appeared to be small. As these fish typically feed from the bottom lake sediments, low populations are positive for lake water quality. Lower bottom feeding species reduces the amount and frequency of sediment resuspension, which can lower sediment phosphorus release and increase lake clarity.

Recorded/reported winter fish kills are available from the MDNR starting in 1999. Lake Smetana has recorded/reported winter fish kills during winter 2007-2008 and winter 2010-2011. It should be noted that these reported years have not been officially verified and fish mortality has not been specifically quantified.

6.0 Water Quality Modeling for the UAA

For this UAA study, water and phosphorus loading to Lake Smetana was evaluated during two separate years (2016 and 2018). Modeling was used to link water and phosphorus loading to observed phosphorus concentrations in the water column of the lake. Modeling included the dynamics of internal lake processes such as phosphorus release from lake sediments (internal sediment loads), phytoplankton/macrophyte nutrient uptake, and phytoplankton/macrophyte death and decay. Model years 2016 and 2018 were typical of the variability that Lake Smetana may experience from a watershed loading, in-lake loading, and biological variability perspective.

6.1 P8 Model Runoff and Phosphorus Loading

Central to a lake water quality analysis is the use of a water quality model that has the capacity to predict the amount of runoff and pollutants that reach a lake via stormwater runoff (external loading). The P8 (Program for Predicting Polluting Particle Passage through Pits, Puddles and Ponds) modeling software was used to estimate watershed loads to the lake (I.E.P, Inc., 1990). The P8 model incorporates hourly precipitation and daily temperature data. The P8 model was used to calculate the daily water volume and phosphorus loads introduced from each tributary subwatershed in the Lake Smetana watershed. A P8 model was also used to calculate the daily water volume and phosphorus loads introduced from each tributary subwatershed in the Bryant Lake watershed. Since Bryant Lake is directly upstream of Lake Smetana, phosphorus discharge estimates from Bryant Lake are required to accurately represent the water quality conditions in Lake Smetana.

P8 model inputs included:

- **Climate Data:** hourly precipitation and daily temperature (source: National Weather Service gage at Minneapolis-St. Paul International Airport, MSP)
- **Watershed:** storm sewer network, tributary land areas (both pervious and impervious)
- **Best management practices:** ponds, including the water storage and solids and phosphorus settling functionalities

The P8 model was run for the Lake Smetana and Bryant Lake watersheds for water years 2016 and 2018.

Since no data has been collected regarding the inflow water quantity or quality for Lake Smetana or Bryant Lake on a subwatershed-scale, detailed calibration of the P8 models was not conducted. The P8 model outputs, used as inputs for the in-lake model (described below) is thought to be best-suited for considering relative changes in loading under varying watershed conditions.

6.1.1 Smetana P8 Model Updates

A P8 watershed model was developed for the previous Lake Smetana UAA that was based on land use information from 1999. Since then, over 40 permit applications were submitted to NMCWD for various projects within the Lake Smetana watershed. These projects ranged from stream restorations to parking lot expansions to roadway reconstructions to full site redevelopments. Not all of these permitted projects included the implementation of a BMP (mostly due to the area of disturbance). Of the permit applications that did include the construction of a BMP with the redevelopment, BMPs with treatment volumes greater than 1,000 cubic feet were added to the Lake Smetana P8 model. Eighteen permit applications were referenced to either update existing BMPs in the P8 model or to add new BMPs. The BMPs added to the model included infiltration basins, filtration basins, wet detention ponds, underground treatment facilities, and porous asphalt pavement.

6.2 Water Balance Calibration

6.2.1 Precipitation and Runoff

The annual water and watershed phosphorus loadings to Lake Smetana and Bryant Lake under existing land use conditions were estimated for two different water years, each having distinctly different in-lake phosphorus concentrations, water clarity, and biota (e.g., type of phytoplankton, zooplankton, and aquatic plants). The precipitation totals during the two modeled water years are summarized in Table 6-1.

Annually- and seasonally-varying climatic conditions affect watershed runoff and subsequently lake volume and hydraulic residence time (lake volume divided by flow through the lake). In some cases where phosphorus in stormwater is greater than phosphorus in the receiving lake, a shorter hydraulic residence time is associated with higher in-lake phosphorus. Hence, loading and flushing (e.g., hydraulic residence time) can have an effect on annual and seasonal phosphorus concentrations in the lake.

Table 6-1 Precipitation amounts for 2016 and 2018

Model Year	Water Year (Oct 1 through Sept 30) Precipitation (inches)	Growing Season (May 1 through Sept 30) Precipitation (inches)
2016	41.2	25.3
2018	32.7	20.8

6.2.2 Stormwater Volume Calibration (Water Balance)

Water balance models were developed for Bryant Lake and Lake Smetana. The changes in water volumes of the lake over time were calibrated by matching the modeled surface elevations to monitored data. To translate the water loadings into water surface elevations, a water balance model was utilized. The model uses estimated daily watershed runoff inflows (predicted by P8 models), daily precipitation, daily evaporation, daily discharge (estimated with outlet rating curves), estimated groundwater inflow or outflow, and observed lake levels to estimate changes in the water level of the lake. The Lake Smetana water balance model also included the daily discharge predicted by the Bryant Lake water balance model.

Figure 6-1 shows an example of the water balance calibration that was completed for Bryant Lake for water year 2018. The predicted water levels, shown by the green line on the plot, were calibrated to match as closely as possible to the observed monthly water levels, indicated by the blue diamonds. Groundwater inflow (red line) was used to calibrate the modeled water surface elevations to the observed data and was based on monthly observations of baseflow of the South Fork of Nine Mile Creek. The blue and dark purple lines in the plot represent the modeled evaporation and precipitation, respectively. The orange line represents the Bryant Lake watershed runoff from the P8 model and the periwinkle line represents the inflow from Lake Minnetoga. The Bryant Lake water balance models were used to develop daily discharge volumes to Lake Smetana in the in-lake model. The in-lake model used the assumption that outflows from Bryant Lake entered directly and immediately to Smetana Lake.

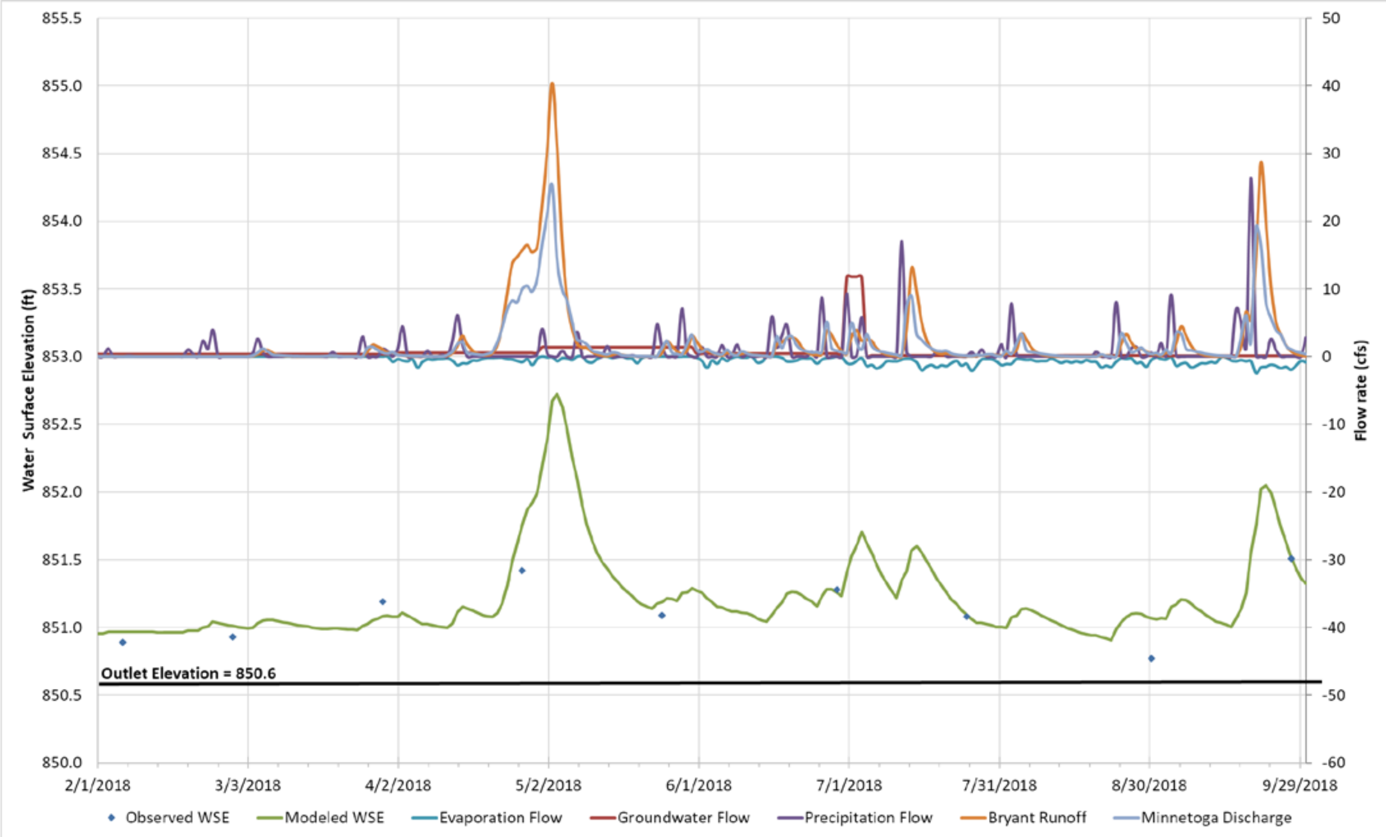


Figure 6-1 Bryant Lake (2018) Water Balance

Figure 6-2 shows an example of the water balance calibration that was completed for Lake Smetana for water year 2018. The predicted water levels, shown by the green line on the plot, were calibrated to match as closely as possible to the observed monthly water levels, indicated by the blue diamonds. The blue and dark purple lines in the plot represent the modeled evaporation and precipitation, respectively. The orange line represents the combined flow from the Bryant Lake outlet and flow from the watershed directly to the North of Smetana Lake.

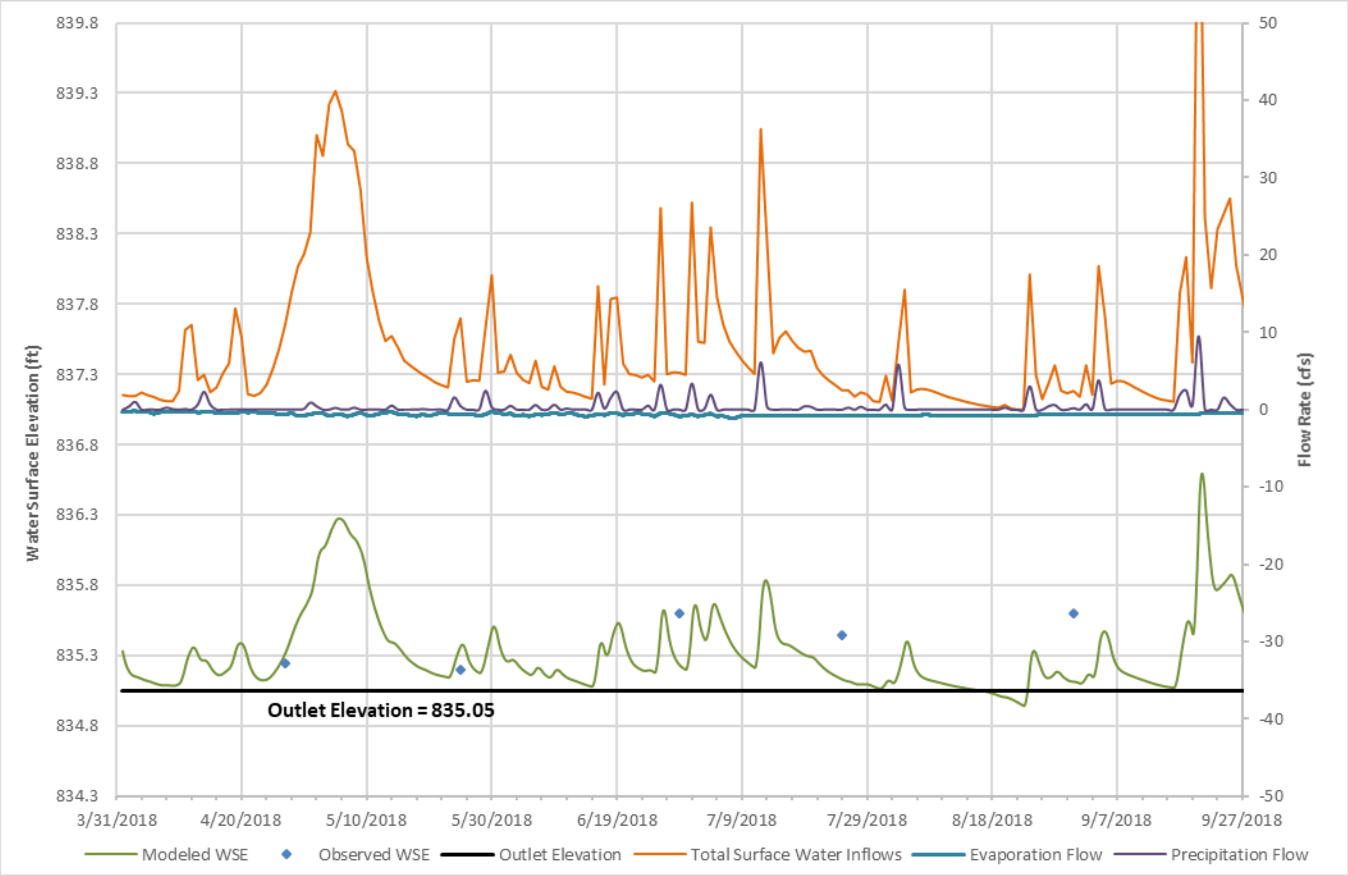


Figure 6-2 Lake Smetana (2018) Water Balance

Overall, the water balance calibrations for both Bryant Lake and Lake Smetana correlate well with the observed monitored data. Figure 6-3 provides a water balance volume comparison for Bryant Lake for 2016 and 2018. For 2016 and 2018, the proportions of inflows (direct watershed runoff, Lake Minnetoga discharge, creek baseflow) and outflows (evaporation, lake outflow) are very similar. The volume of water discharging from the direct watershed and from the upstream lake (Lake Minnetoga) are relatively equal (±3%).

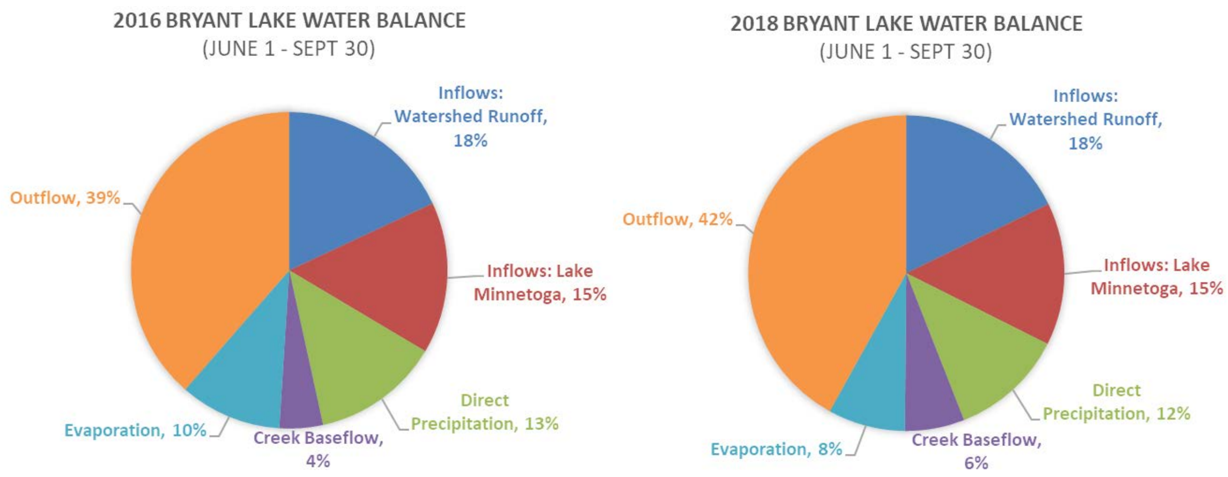


Figure 6-3 Bryant Lake water balance summaries for 2016 and 2018

Figure 6-4 provides a water balance volume comparison for Lake Smetana for 2016 and 2018. For 2016 and 2018, the proportions of inflows (direct watershed runoff, Bryant Lake discharge) and outflows (evaporation, lake outflow) are very similar. The volume of water discharging from the direct watershed and from the upstream lake (Bryant Lake) are relatively equal (±3%-7%). Water balance modeling showed that Lake Smetana has an average hydraulic residence time of 12-13 days, which indicates frequent and rapid flushing. This suggests that while in-lake processes are important in Lake Smetana, the lake's water quality is significantly influenced by the water quality of tributary watershed inflows.

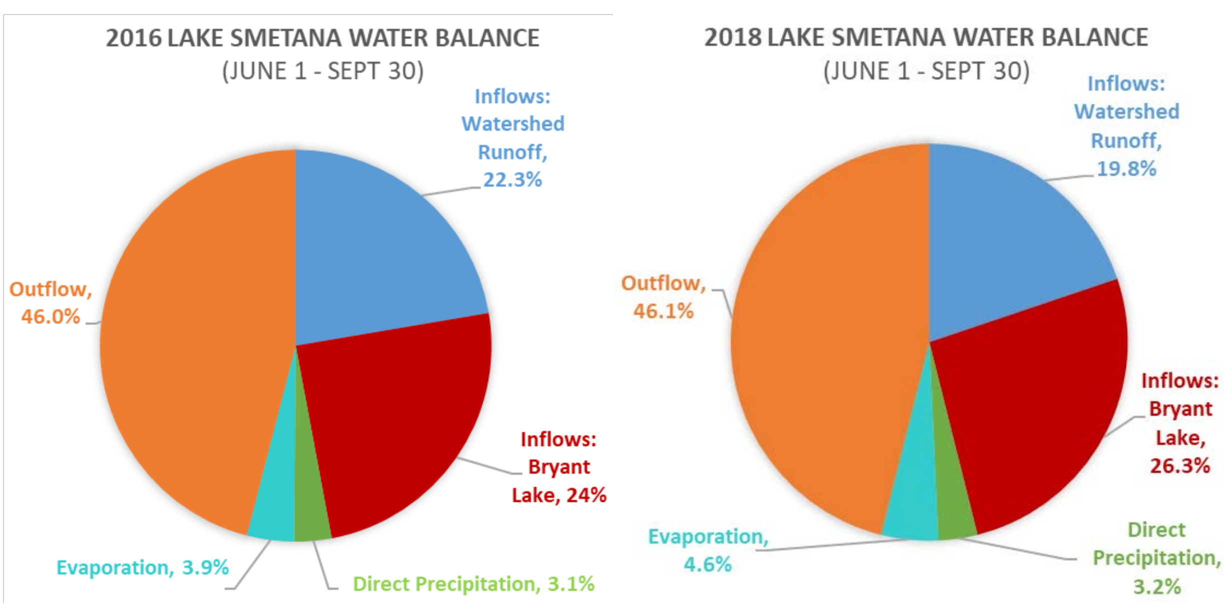


Figure 6-4 Lake Smetana water balance summaries for 2016 and 2018

6.3 In-Lake Modeling

The purpose of in-lake modeling is to establish a relationship between the amount of nutrients that enter a lake and the concentration of these nutrients that remain in a lake. Generally, for freshwater lakes, phosphorus is the main nutrient of concern and is reported on in greater detail in this report.

There are several processes that dynamically increase or reduce the concentration of phosphorus in the lake water column, including (the "-" or "+" indicates that the mechanism either reduces or increases phosphorus):

- **Watershed Runoff (+):** Phosphorus enters the lake through natural channels and discharge storm sewer pipes following precipitation or snow melt events.
- **Upstream Lakes (+):** Outflow from upstream lakes introduces phosphorus into the downstream lakes. For Lake Smetana, Bryant Lake is the upstream lake. Water originating at the Bryant Lake outlet were estimated from surface in-lake monitoring data collected for Bryant Lake.
- **Atmospheric Deposition (+):** Phosphorus deposits into the water body from the atmosphere
- **Settling (-)**: Phosphorus in phytoplankton and attached to particles settles out of the lake water column to the sediments.
- **Flushing (-)**: Phosphorus that leaves through a lake outlet.
- **Internal Sediment Loading (+)**: Phosphorus from lake bottom sediments may release into the water column during low oxygen conditions.
- **Phytoplankton and macrophyte growth (-):** Phosphorus will be removed from the water column and the sediment through uptake by phytoplankton and macrophyte during the growth phase.
- **Phytoplankton and macrophyte die-off and decay (+):** Phosphorus in the phytoplankton and plant tissues is released into the water column when the species die and decay.
- **Curly-leaf pondweed die-off and decay (+)**: Phosphorus in the plant tissue is released into the water column when curly-leaf pondweed dies and decays. Curly-leaf pondweed die-off and decay occurs much earlier than other native plant species (typically in late June and July), so this species is modeled separately.

The model integrates these phosphorus loads and losses as part of an hourly time-step used in a finite difference lake model developed by Barr Engineering. This model is considered to be zero-dimensional, meaning, it is assumed that every input to the model is completely mixed both vertically and horizontally in the lake water column. Biological components, as discussed above, include phytoplankton and macrophytes (aquatic plants and attached filamentous algae) and growth is dependent upon phosphorus, nitrogen, light, and temperature. Macrophytes can derive nutrients from the sediment and the water column. Each of these processes occur at different levels during different periods and hence they are quantified (e.g., calibrated) by matching the in-lake phosphorus concentration with the field-measured phosphorus concentration.

6.3.1 In-Lake Water Quality (Phosphorus) Model Calibration

Calibration is a process in which model parameters and coefficients are reasonably adjusted such that the model predictions are similar to in-lake measurements. Example in-lake model calibrations for Lake Smetana are provided below. Figure 6-5 and Figure 6-6 show the 2016 calibrations for total phosphorus and chlorophyll *a* concentrations, respectively. The blue line represents the modeled in-lake concentrations and the orange circles represent the monitored concentrations. Figure 6-7 and Figure 6-8 show the total phosphorus and chlorophyll *a* in-lake model calibrations for Lake Smetana in 2018.

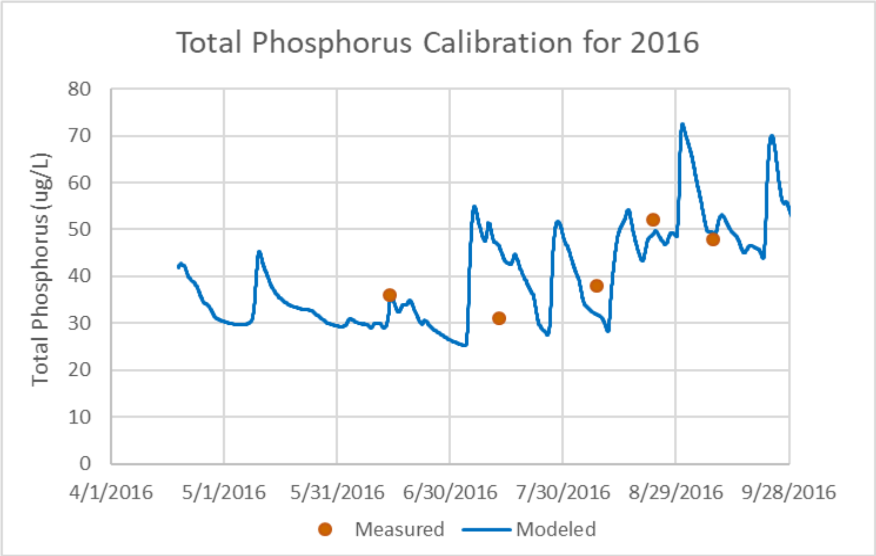


Figure 6-5 Lake Smetana In-Lake Total Phosphorus Calibration for 2016

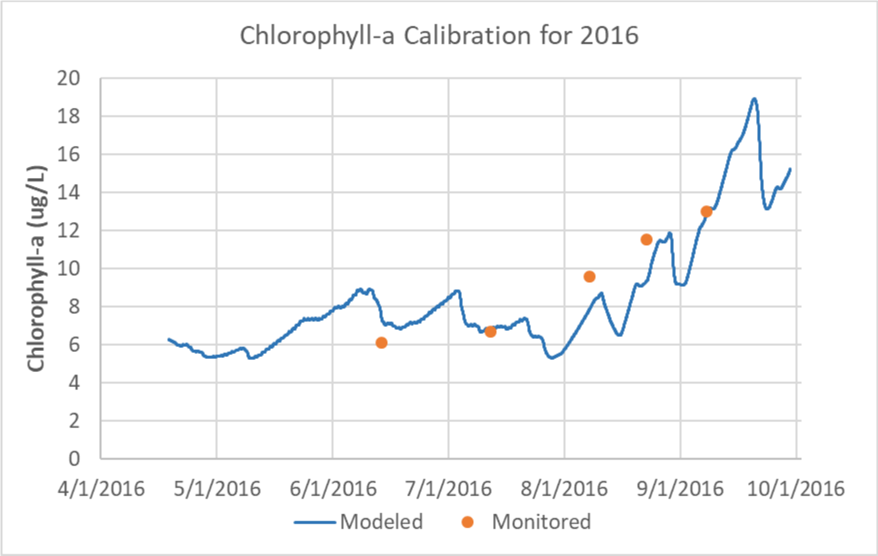


Figure 6-6 Lake Smetana In-Lake Chlorophyll *a* Calibration for 2016

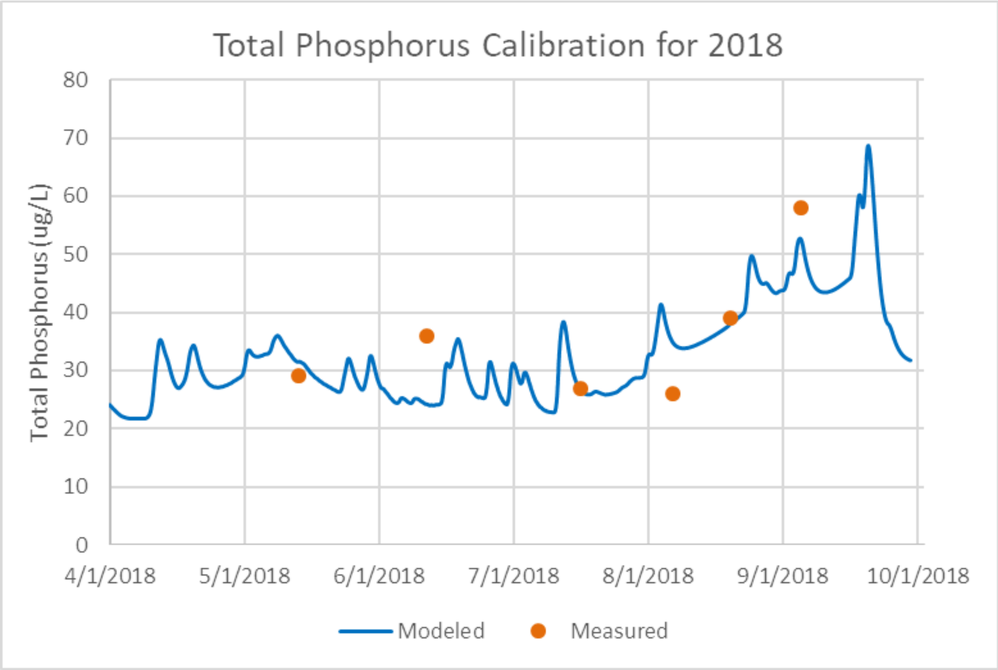


Figure 6-7 Lake Smetana In-Lake Total Phosphorus Calibration for 2018

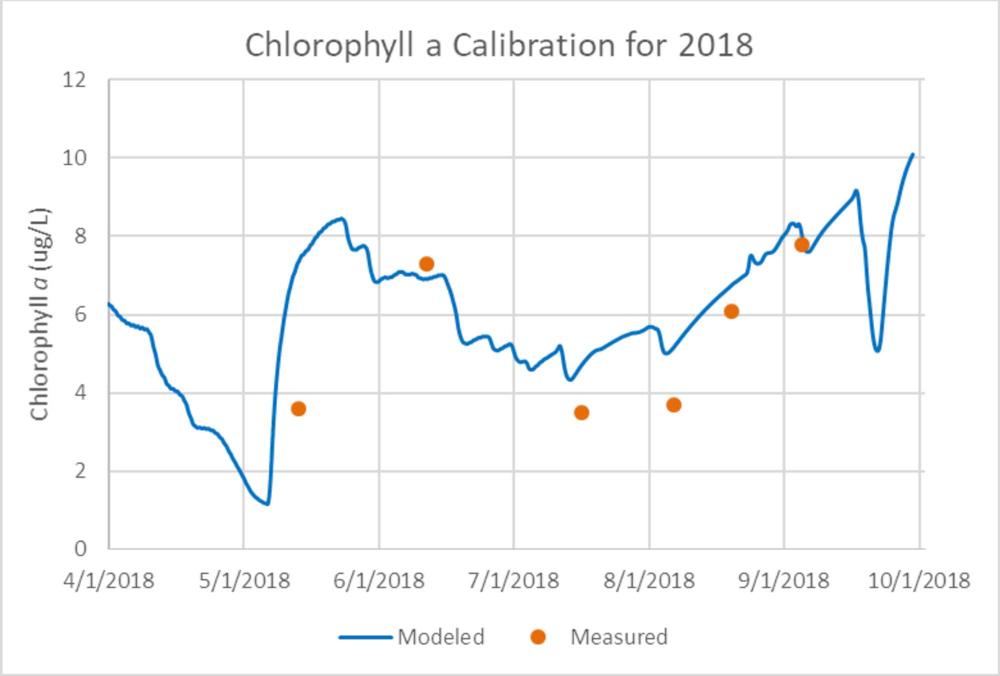


Figure 6-8 Lake Smetana In-Lake Chlorophyll *a* Calibration for 2018

6.3.2 In-Lake Water Quality (Phosphorus) Model Calibration Loading Summaries

After the in-lake water quality model calibrations were finalized for each calibration year, loading summaries were developed. Figure 6-9 shows the total phosphorus loading summaries for Lake Smetana for 2016 and 2018. While the water volume from Bryant Lake and from Lake Smetana's direct watershed were very similar (Figure 6-2), there was significantly greater total phosphorus loading from the Lake Smetana direct watershed compared to the load coming from Bryant Lake (Figure 6-9). Approximately 77% of the total phosphorus load in 2016 and 63% of the total phosphorus load in 2018 originated from Lake Smetana's direct watershed. Comparatively, approximately 14% of the phosphorus load in 2016 and 21% of the phosphorus load in 2018 originated from Bryant Lake. The reduction in phosphorus loading coming from Bryant Lake is largely the result of the alum treatment applied to Bryant Lake's sediments in fall 2008.

Dissolved oxygen concentration in Lake Smetana bottom waters are low enough to stimulate phosphorus release (internal phosphorus loading) during most of the summer (June through September). Profile monitoring data also show elevated phosphorus on the lake bottom (see Section 5.2). The lake model includes internal phosphorus loading and the maximum potential release rate was based upon sediment cores taken in June 2019. The actual rate of release is then adjusted based upon the dissolved oxygen concentration. As shown in Figure 6-9 internal loading accounted for about 9 to 16 percent of the total phosphorus inputs into Smetana Lake in 2016 and 2018, respectively.

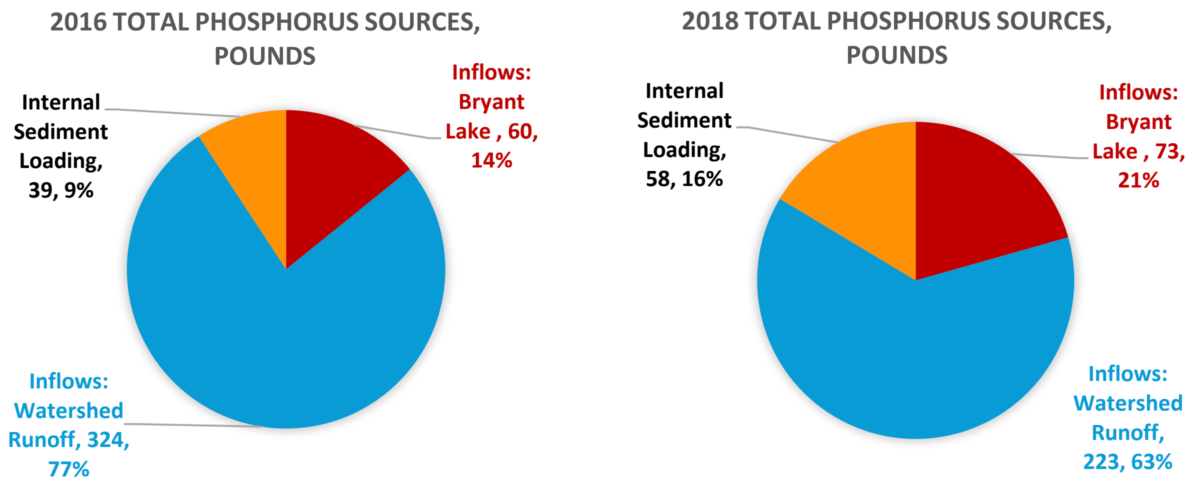


Figure 6-9 Total Phosphorus Loading Summaries from Lake Smetana In-Lake Calibration Models

Estimates of particulate phosphorus (inorganic and organic particulate phosphorus) were also developed from each source. For Lake Smetana's direct watershed, particulate phosphorus was 80 percent of the total phosphorus load while for Bryant Lake, particulate phosphorus was approximately 55 percent of the total phosphorus load. The average composite total phosphorus concentration entering Smetana Lake was 0.071 mg/L in 2016 and 0.061 mg/L in 2018 (June 1 to September 30). These are low input concentrations and they partially explain why in-lake phosphorus concentrations in Lake Smetana are below Minnesota state standards.

6.3.3 In-Lake Water Quality Additional Observations

6.3.3.1 Macrophyte Nutrient Uptake

Macrophytes provide many benefits to lake ecosystems, including the uptake of nutrients. Model results indicate that phosphorus uptake by aquatic plants ranged from 44 to 30 pounds during the summer period for 2016 and 2018, respectively. This is 11% to 10% of the total external phosphorus load. The load removed by aquatic plants is similar to the internal phosphorus load attributed by release from the sediments. In essence, aquatic plant growth in Lake Smetana mitigates the total phosphorus loading from internal sources (see Figure 6-10). This finding demonstrates the importance of aquatic plants in maintaining good water quality in Lake Smetana.

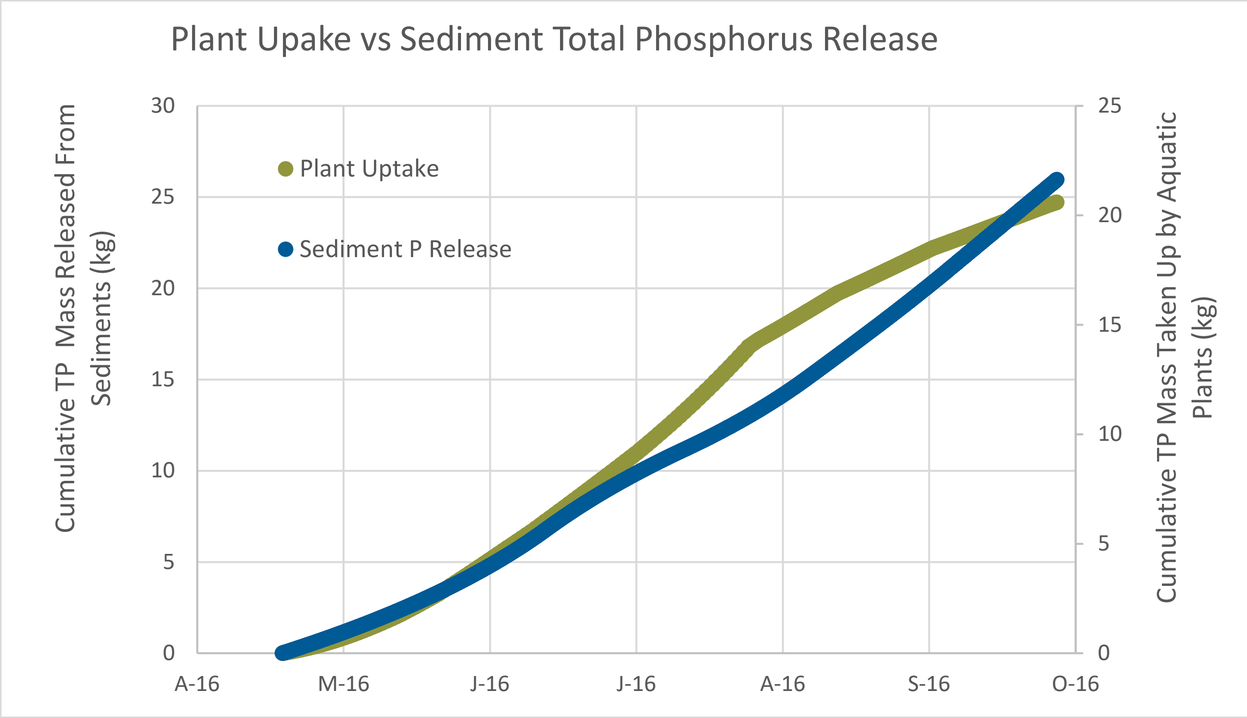


Figure 6-10 **Total phosphorus (TP) release from the sediments over time compared to uptake by aquatic plants in Lake Smetana**

6.3.3.2 Nitrogen Limitation

It should be noted that as part of the calibration process, it became evident that nitrogen was limiting phytoplankton growth during the end of the summer months. Hence, it can be concluded that low nitrogen concentrations in Lake Smetana limit phytoplankton growth at times. Aquatic plant growth in Lake Smetana appears to be contributing to the nitrogen limiting condition in Lake Smetana. This also demonstrates the importance of aquatic plants in maintaining good water quality in Lake Smetana.

6.3.3.3 Curly-leaf Pondweed as a Phosphorus Source

The presence of curly-leaf pondweed and its mid-summer die-off can negatively impact the water quality of a shallow lake. When lakes start to accumulate a prolific growth of curly-leaf pondweed, a spike in in-lake total phosphorus concentration is generally observed during the same period of curly-leaf pondweed die-off and decay. However, this total phosphorus spike was not observed in Lake Smetana during monthly monitoring or during in-lake modeling. As shown in Figure 6-11, in model year 2016, during the period of time when curly-leaf pondweed begins to die and decay (late-May into late-June) there is no associated spike in total phosphorus concentration outside what is attributed to storm events. Thus, model results indicate that the current curly-leaf pondweed population in Lake Smetana is not having a negative effect on the total phosphorus concentrations of Lake Smetana. The invasive species growth will continue to be tracked with periodic aquatic plant surveys.

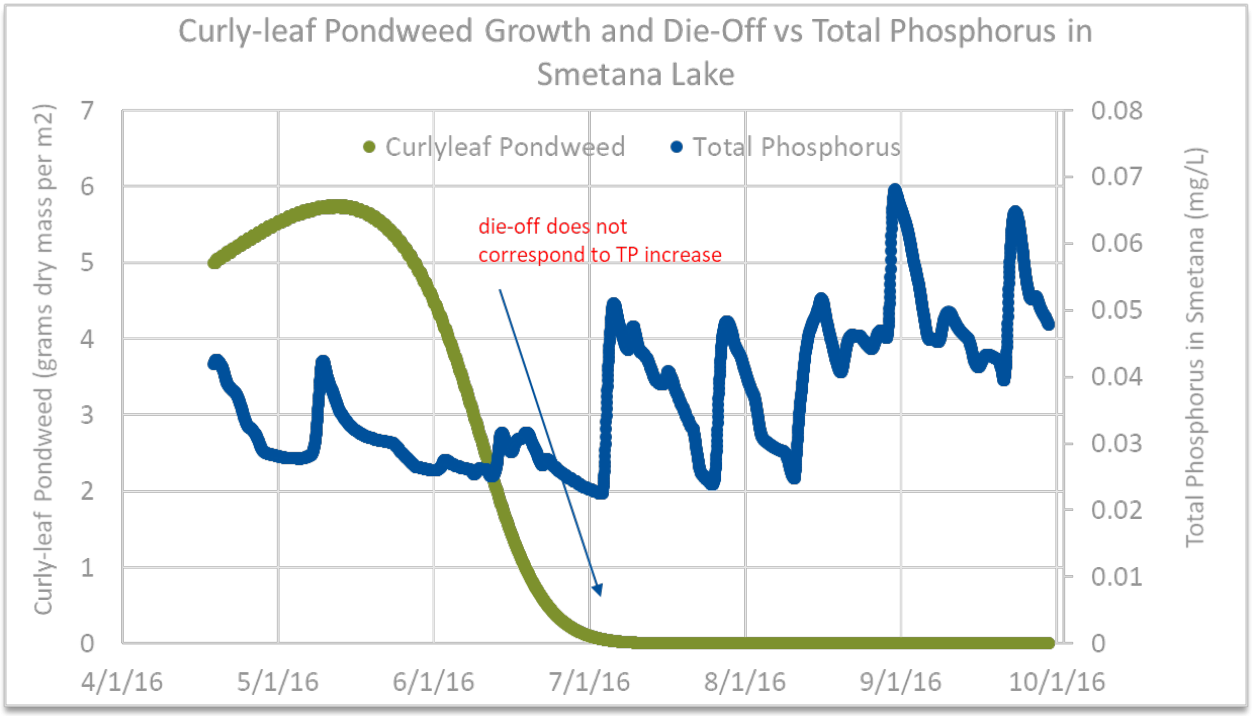


Figure 6-11 Curly-leaf pondweed die-off compared to in-lake total phosphorus concentrations over time.

7.0 Conclusions and Recommendations

7.1 Lake Smetana Water Quality Conclusions

Recent monitoring data indicates that Lake Smetana is meeting Minnesota's water quality standards for shallow lakes. The summer average (May 1-Sept 30) total phosphorus and chlorophyll *a* concentrations measured between 2013 and 2018 are below the shallow lake standards of 60 µg/L and 20 µg/L, respectively (Figure 7-1). The summer average Secchi disk depths measured between 2013 and 2018 are greater than the minimum 1.0 meter Secchi disk depth for shallow lakes based on Minnesota State standards (Figure 7-1). The plant surveys completed in Lake Smetana in 2016 and 2018 also indicate a healthy plant community. Increases in the number of species were observed in 2016 and 2018 as well as increases in the quality of the aquatic plants (e.g., increases in the floristic quality index). Furthermore, the mass of phytoplankton sampled in Lake Smetana has decreased in recent years and specifically, blue-green algae numbers were much lower in 2016 and 2018 compared to 2003.

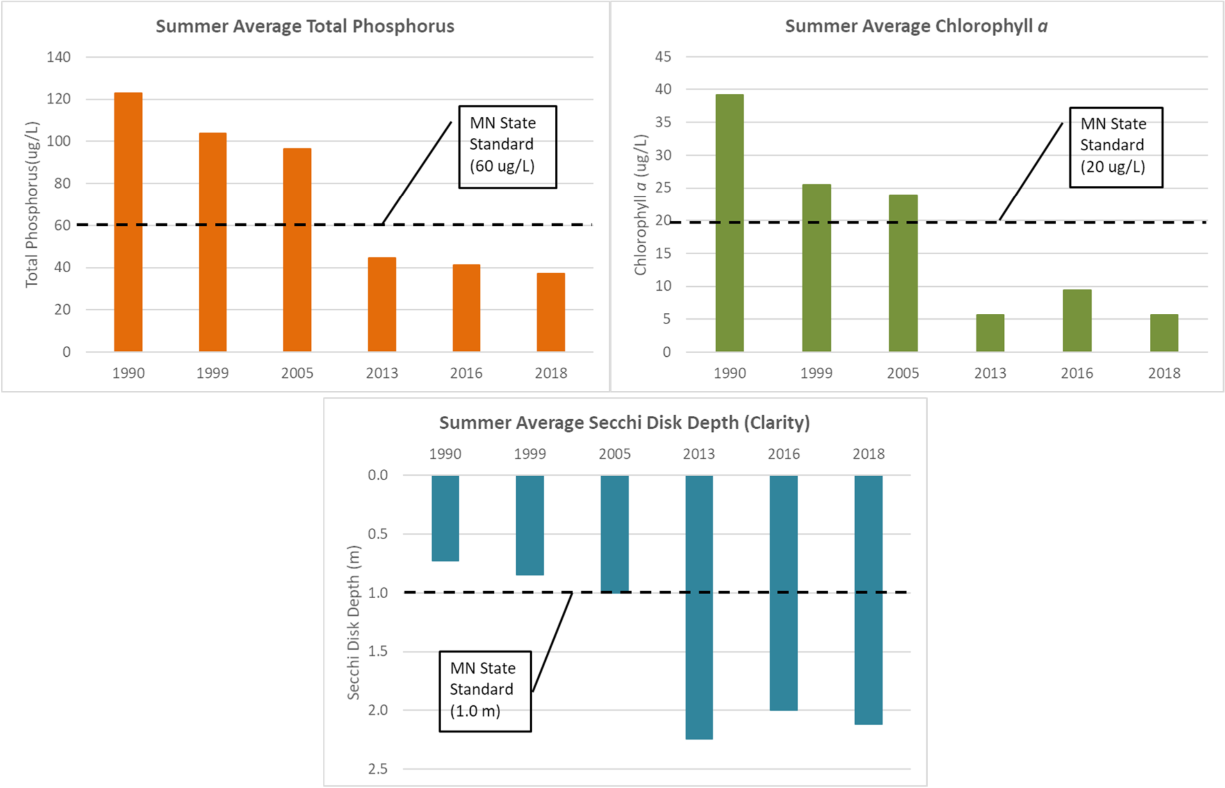


Figure 7-1 Summer average total phosphorus and chlorophyll *a* concentrations and Secchi disk depth measured in Lake Smetana between 1990 and 2018

7.2 Recommendations

Water quality in Lake Smetana has improved in the past decade and the lake currently meets water quality and ecological health goals. Given this, future management efforts should be focused on protecting lake water quality, monitoring for changes, and improving water quality and ecosystem health as partnership opportunities arise. The following sections summarize the recommended management and protection strategies for Lake Smetana.

7.2.1 Maintain Bryant Lake Water Quality

The improvement of water quality observed in Lake Smetana is in large part due to the water quality projects implemented for upstream lake, Bryant Lake. In fall 2008, Bryant Lake underwent a sediment alum treatment to reduce the sediment phosphorus load (internal load). The reduction in internal phosphorus loading to Bryant Lake had downstream trickle effects on Lake Smetana. The phosphorus loads to Lake Smetana from Bryant Lake were smaller after the alum treatment, helping to reduce in-lake phosphorus concentration in Lake Smetana. The watershed and in-lake modeling developed for this UAA showed this result as well. Although similar water volumes were entering Lake Smetana from the direct watershed and from Bryant Lake, the amount of phosphorus coming from the direct watershed was significantly higher than the proportion entering from Bryant Lake. This finding suggests that management strategies for Lake Smetana should include maintaining good water quality in Bryant Lake.

Continued water quality monitoring of Bryant Lake nutrient and dissolved oxygen concentrations is recommended in order to assess changes in internal loading potential and downstream impacts to Lake Smetana. Although it can vary widely depending on lake and watershed characteristics, alum treatments typically have an effective life of 10-15 years.

7.2.2 Reduce Pollutant Loading from Stormwater Runoff

Watershed and in-lake modeling for this UAA demonstrated that the highest percentage of phosphorus loading entered Lake Smetana from the direct watershed in 2016 and 2018 (63% and 77% of the total phosphorus load, respectively). This suggests that management strategies should also focus on reducing external loading within the direct watershed. NMCWD already has water quantity and quality rules in place for the development of existing parcels. As additional development occurs in the watershed, it is recommended that NMCWD seek to partner with land owners to add additional and/or enhanced BMPs, where feasible and cost effective. Additionally, close monitoring of construction projects within the watershed is recommended to ensure adequate erosion control practices are in place and maintained. This is especially important during construction of the Southwest Light Rail transit and associated redevelopment in the watershed.

Residents surrounding Lake Smetana have noted instances of enhanced erosion on nearby slopes, especially in areas with prevalent buckthorn growth and have indicated interest in partnering with NMCWD to help improve slope stability. NMCWD should consider partnering with public and private entities through its cost share grant program to address the erosion issues that have the potential to degrade Lake Smetana water quality.

Observed chloride concentrations in Lake Smetana in May and June of 2018 were high, exceeding the MPCA standard of 230 mg/L. Continued periodic water quality monitoring of Lake Smetana chloride concentrations is recommended. NMCWD should also consider seeking opportunities to work with property owners and/or management companies within the Lake Smetana watershed to reduce winter salt usage.

7.2.3 Continue to Monitor Impacts from Internal Sediment Loading

In-lake modeling for this UAA demonstrated that internal loading from bottom sediments in Lake Smetana play a role in influencing water quality. Internal sediment loading represented 9% and 16% of the total phosphorus load to Lake Smetana in 2016 and 2018, respectively. However, while this represents a notable proportion of the loading, other internal process in the lake are helping to balance the effects of loading from the sediments. First, water balance modeling showed that Lake Smetana has an average hydraulic residence time of 12-13 days, which indicates frequent and rapid flushing. This suggests that while in-lake processes are important in Lake Smetana, the lake's water quality is likely to be affected more strongly by the water quality of tributary watershed inflows rather than the sediment loading. Secondly, in-lake modeling showed that the load removed by aquatic plants is similar to the internal phosphorus load attributed by release from the sediments. In essence, aquatic plant growth in Lake Smetana mitigates the total phosphorus loading attributed by internal sources. Continued periodic monitoring of dissolved oxygen concentrations and nutrient concentrations should be continued for Lake Smetana, but sediment management is not recommended at this time.

7.2.4 Continue to Monitor Growth and Impacts from Curly-leaf Pondweed

The presence of curly-leaf pondweed and its mid-summer die-off can negatively impact water quality of a lake. Currently, for Lake Smetana, model results indicate that the current curly-leaf pondweed population is not having a negative effect on the total phosphorus concentrations of Lake Smetana. No treatments have been applied in Lake Smetana for curly-leaf pondweed to date, and while the species is prevalent, curly-leaf pondweed has been co-existing with native plants at relatively low densities. The invasive species growth should continue to be tracked with periodic aquatic surveys to assess if conditions are changing. However, curly-leaf pondweed management is not recommended at this time.

7.2.5 Update Fisheries Survey

The most recent fisheries assessment of Lake Smetana was completed by the MDNR in 2005. At that time, the lake had a healthy and diverse fishery. However, winter fish kills were reported for Lake Smetana during winter 2007-2008 and winter 2010-2011. It is recommended that an updated fishery survey be completed for Lake Smetana, conducted by MDNR or NMCWD.

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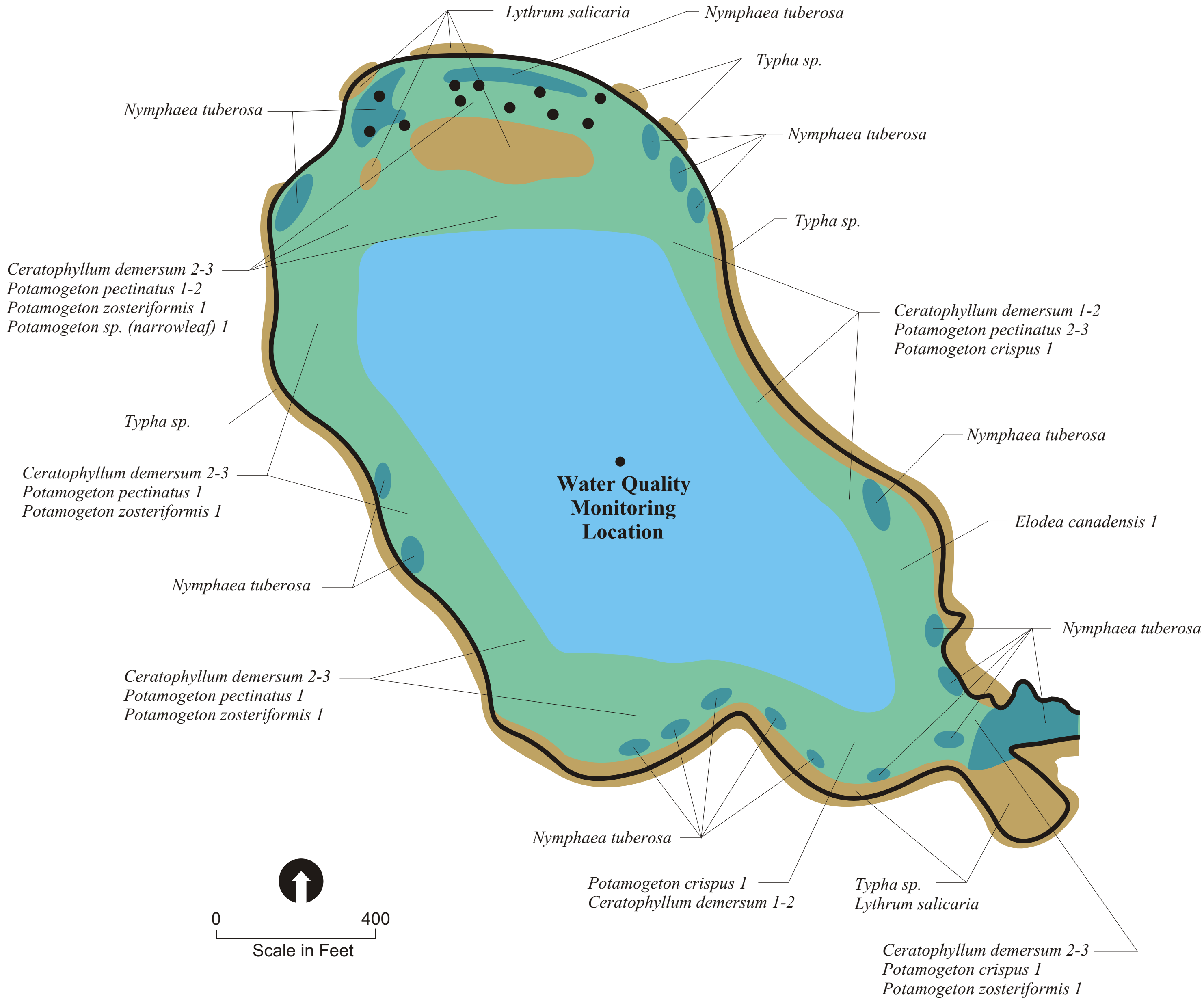
Appendices

Appendix A

Aquatic Plant Surveys



- No Macrophytes Found In Water > 5.0' to 6.0'
- Macrophyte Densities Estimated As Follows: 1 = light; 2 = moderate; 3 = heavy

	Common Name	Scientific Name
Submerged Aquatic Plants:	Narrowleaf pondweed	*Potamogeton sp. (narrowleaf)*
	Flatstem pondweed	*Potamogeton zosteriformis*
	Sago pondweed	*Potamogeton pectinatus*
	Curlyleaf pondweed	*Potamogeton crispus*
	Coontail	*Ceratophyllum demersum*
	Elodea	*Elodea canadensis*
Floating Leaf Plants:	White waterlily	*Nymphaea tuberosa*
Emergent Plants:	Cattail	*Typha sp.*
	Purple loosestrife	*Lythrum salicaria*
No Aquatic Vegetation Found:		
	Tree stumps	

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SMETANA LAKE
MACROPHYTE SURVEY
JUNE 24, 1999

- No Macrophytes Found In Water > 5.0' to 6.0'
- Macrophyte Densities Estimated As Follows: 1 = light; 2 = moderate; 3 = heavy

	Common Name	Scientific Name
Submerged Aquatic Plants:	Narrowleaf pondweed	*Potamogeton sp. (narrowleaf)*
	Flatstem pondweed	*Potamogeton zosteriformis*
	Sago pondweed	*Potamogeton pectinatus*
	Curlyleaf pondweed	*Potamogeton crispus*
	Coontail	*Ceratophyllum demersum*
	Elodea	*Elodea canadensis*
Floating Leaf Plants:	White waterlily	*Nymphaea tuberosa*
Emergent Plants:	Cattail	*Typha sp.*
	Purple loosestrife	*Lythrum salicaria*
	Giant bur-reed	*Sparganium eurycarpum*
No Aquatic Vegetation Found:		
	Tree stumps	

SMETANA LAKE
MACROPHYTE SURVEY
AUGUST 24, 1999

Appendix A: Page 2

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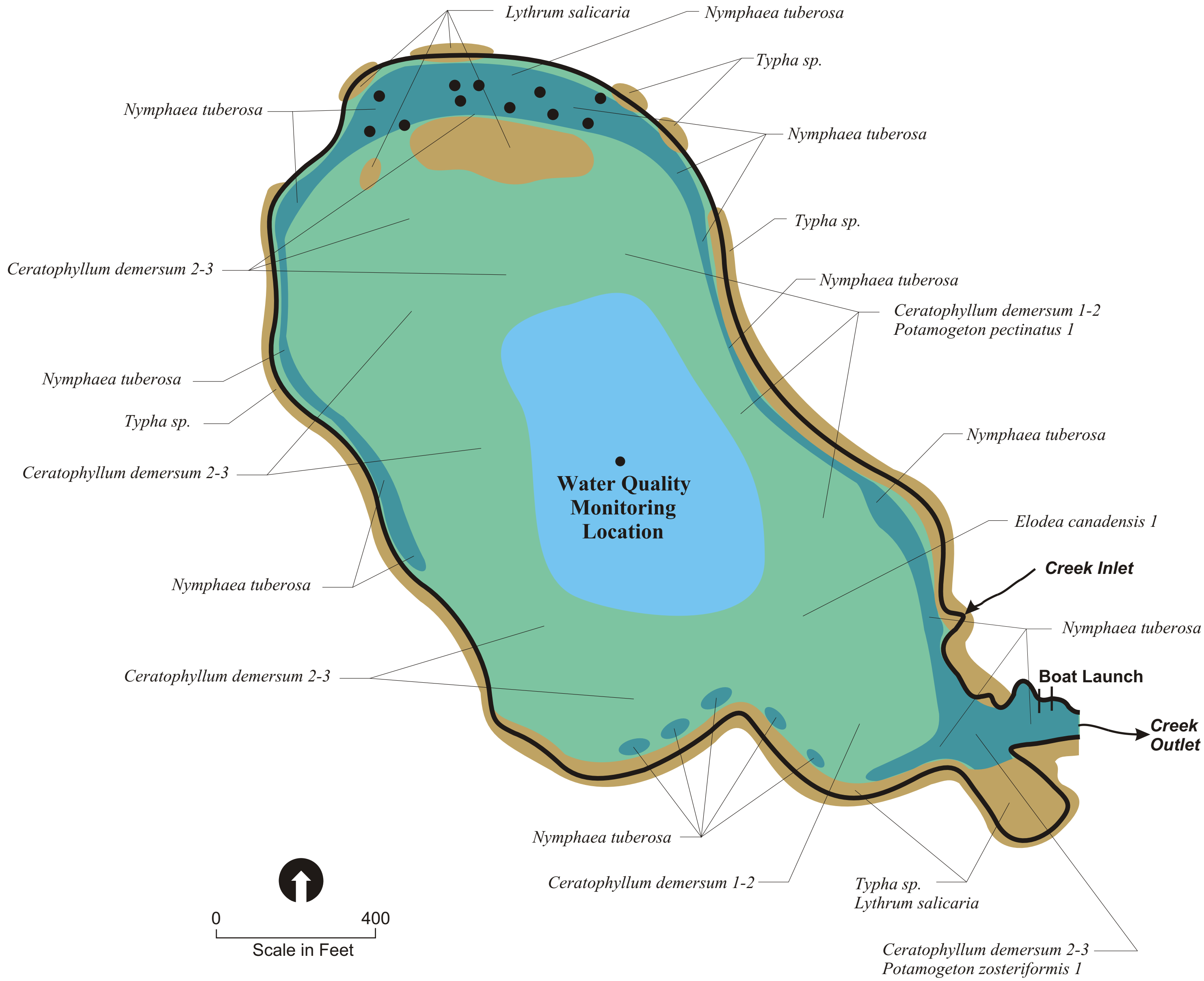

- No Macrophytes Found In Water > 8.0' to 10.0'
- Macrophyte Densities Estimated As Follows: 1 = light; 2 = moderate; 3 = heavy

	Common Name	Scientific Name
Submerged Aquatic Plants:	Flatstem pondweed Sago pondweed Coontail Elodea	*Potamogeton zosteriformis* *Potamogeton pectinatus* *Ceratophyllum demersum* *Elodea canadensis*
Floating Leaf Plants:	White waterlily	*Nymphaea tuberosa*
Emergent Plants:	Cattail Purple loosestrife	*Typha sp.* *Lythrum salicaria*
No Aquatic Vegetation Found:		
	Tree stumps	

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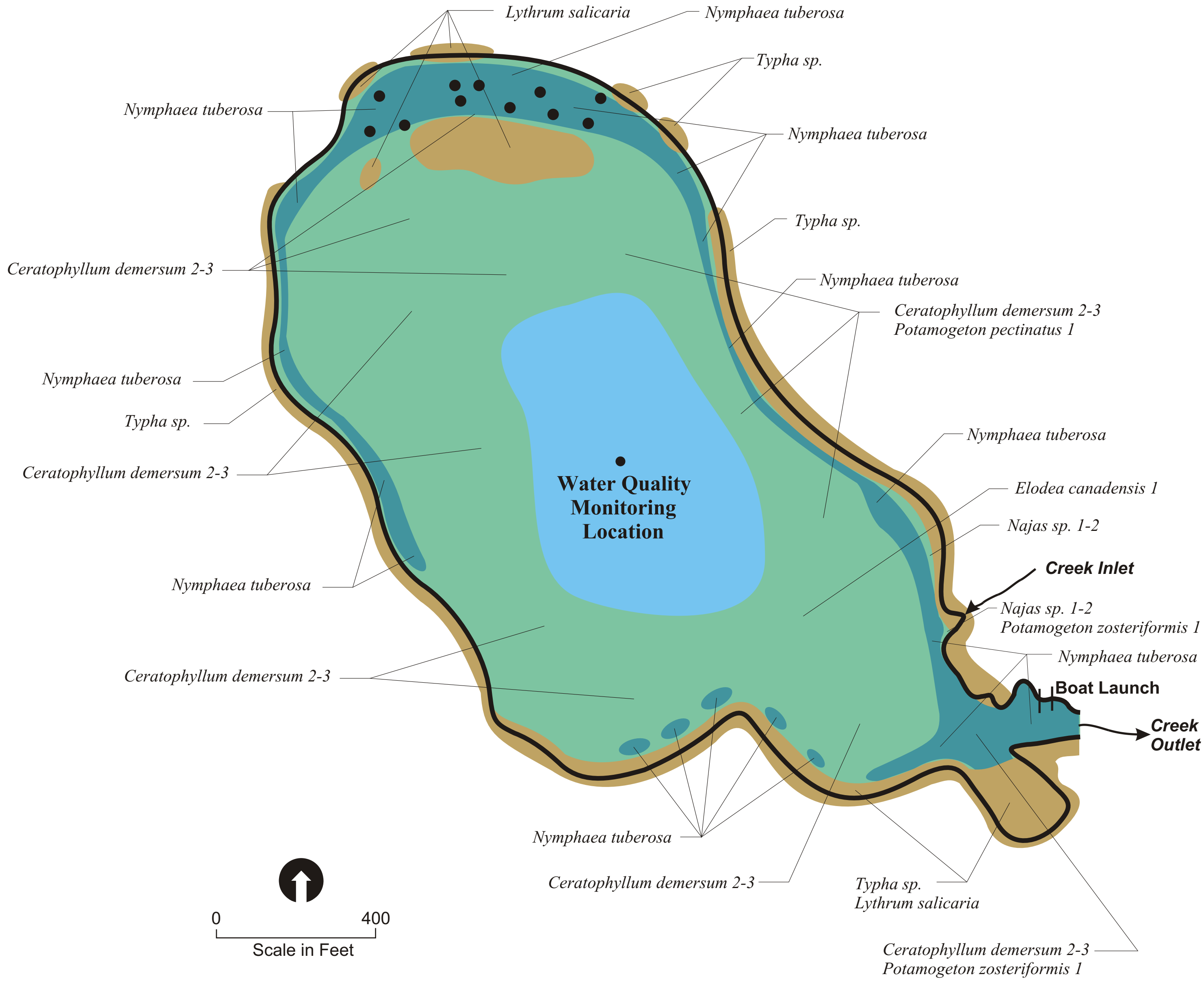
SMETANA LAKE MACROPHYTE SURVEY JUNE 20, 2005



- No Macrophytes Found In Water > 9.0' to 10.0'
- Macrophyte Densities Estimated As Follows: 1 = light; 2 = moderate; 3 = heavy

	Common Name	Scientific Name
Submerged Aquatic Plants:	Flatstem pondweed	*Potamogeton zosteriformis*
	Sago pondweed	*Potamogeton pectinatus*
	Coontail	*Ceratophyllum demersum*
	Elodea	*Elodea canadensis*
	Bushy pondweed and naiad	*Najas sp.*
Floating Leaf Plants:	White waterlily	*Nymphaea tuberosa*
Emergent Plants:	Cattail	*Typha sp.*
	Purple loosestrife	*Lythrum salicaria*
No Aquatic Vegetation Found:		
	Tree stumps	

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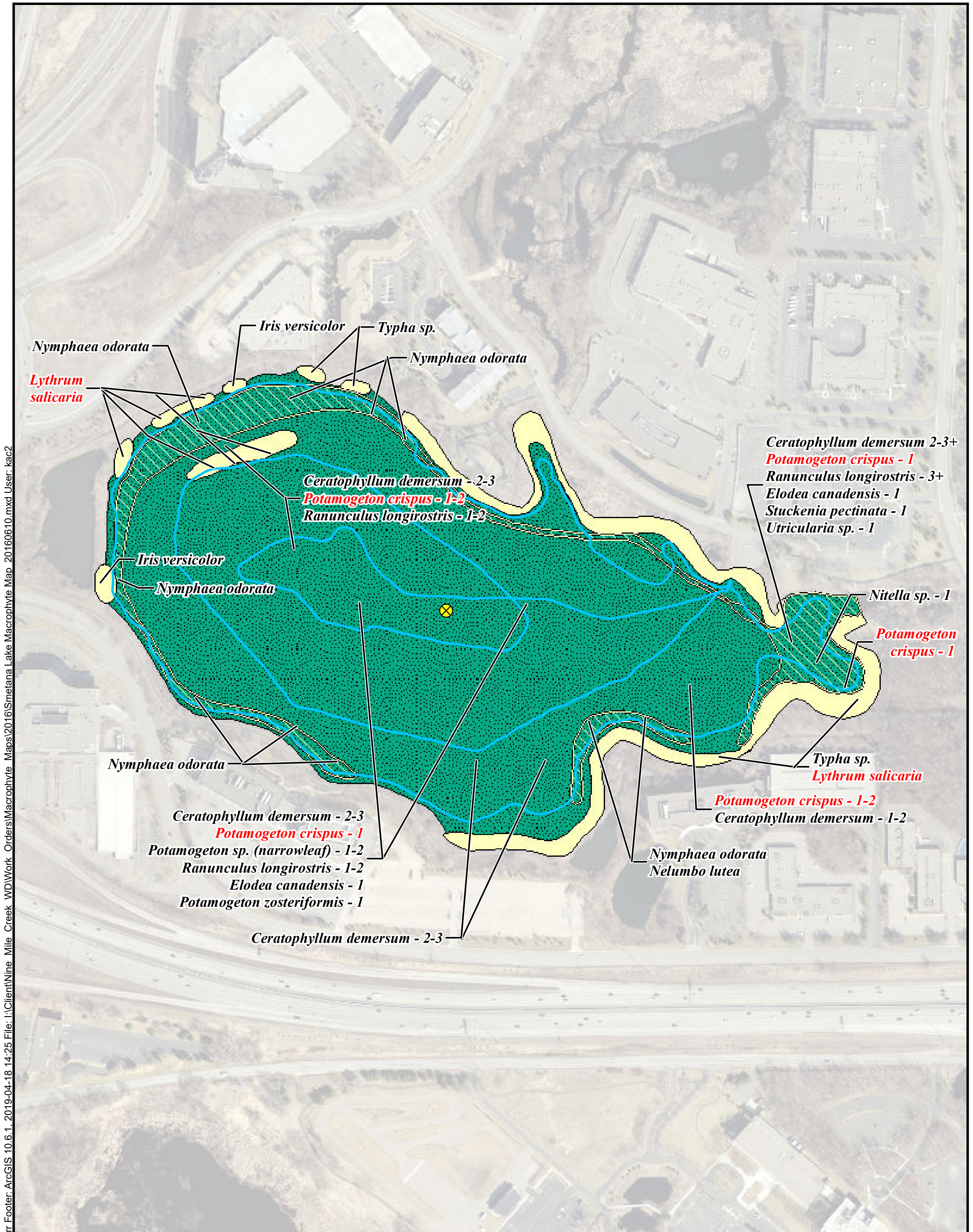
SMETANA LAKE MACROPHYTE SURVEY AUGUST 15, 2005



Submerged Aquatic Plants

Common Name	Scientific Name
Coontail	*Ceratophyllum demersum*
Elodea	*Elodea canadensis*
Stonewort	*Nitella sp.*
Curlyleaf Pondweed	***Potamogeton crispus***
Narrow-leaf pondweed	*Potamogeton sp. (narrow-leaf)*
Flat-stem pondweed	*Potamogeton zosteriformis*
White water buttercup	*Ranunculus longirostris*
Sago pondweed	*Stuckenia pectinata*
Bladderwort	*Utricularia sp.*

Floating Leaf Plants

Common Name	Scientific Name
Forked duckweed	*Lemna trisulca*
American lotus	*Nelumbo lutea*
White waterlily	*Nymphaea odorata*
Common waterweed	*Wolffia columbiana*

Emergent Plants

Common Name	Scientific Name
Blue flag iris	*Iris versicolor*
Purple loosestrife	***Lythrum salicaria***
Cattail	*Typha sp.*

*Note: Bold red name indicates extremely aggressive/invasive introduced species.

Water Quality Monitoring Location
Emergent Plants
Floating Leaf Plants
Submerged Aquatic Plants
No Aquatic Vegetation
GPS Survey Location Path

Imagery Source: Hennepin County (2015)

N

0 400 800
Feet

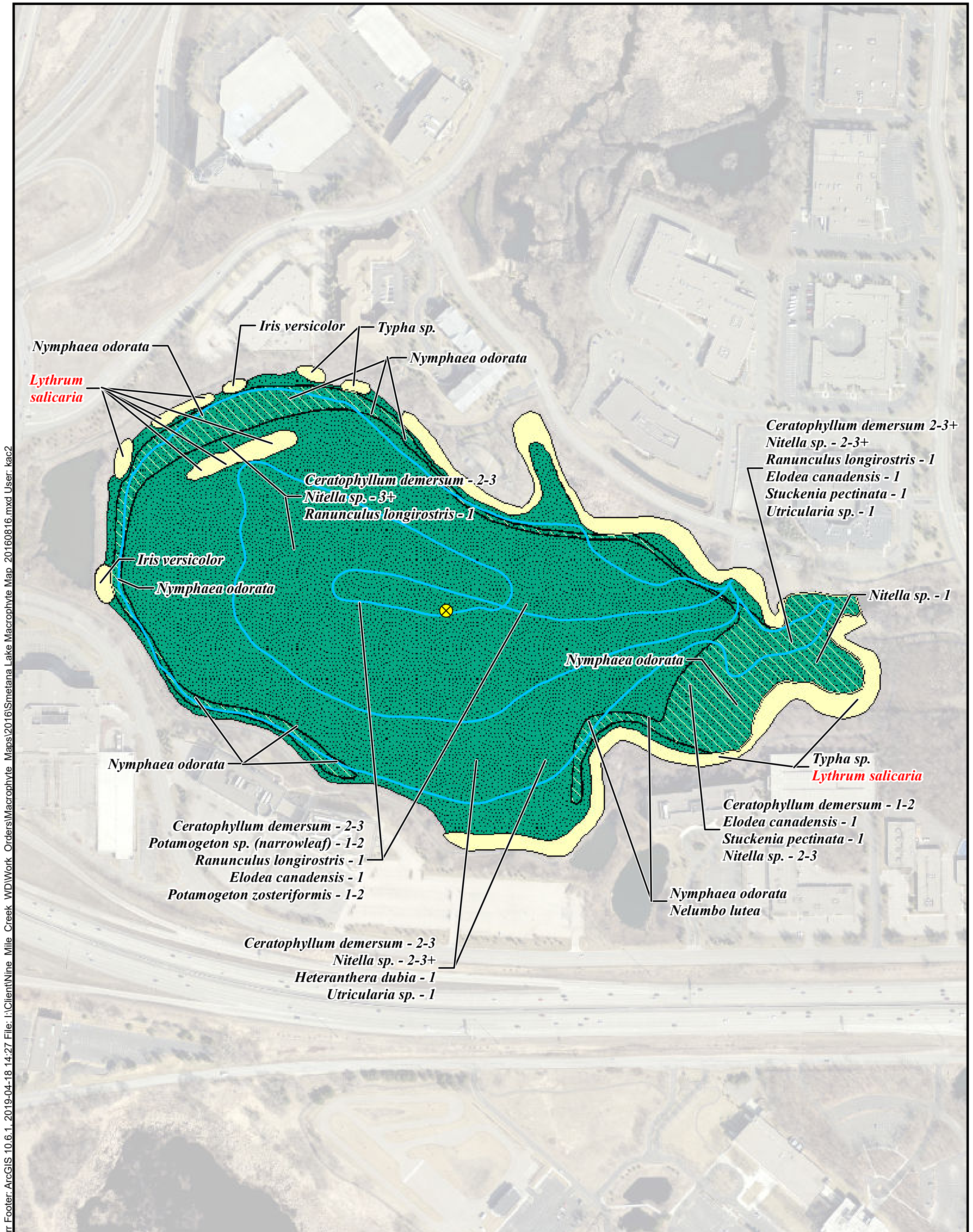
0 100 200
Meters

BARR

FIELD NOTES:
- ***Lythrum salicaria*** observed around entire lake perimeter (sporadically).
- Entire water body has macrophyte coverage.
- Macrophyte densities estimated as follows:
  1=light; 2=moderate; 3=heavy
- Algal mats, *Lemna trisulca* and *Wolffia columbiana* present.

SMETANA LAKE MACROPHYTE SURVEY

June 10, 2016
Nine Mile Creek Watershed District



Submerged Aquatic Plants

Common Name	Scientific Name
Coontail	*Ceratophyllum demersum*
Elodea	*Elodea canadensis*
Stonewort	*Nitella sp.*
Narrowleaf pondweed	*Potamogeton sp. (narrow-leaf)*
Flatstem pondweed	*Potamogeton zosteriformis*
White water buttercup	*Ranunculus longirostris*
Sago pondweed	*Stuckenia pectinata*
Bladderwort	*Utricularia sp.*
Bladderwort	*Utricularia sp.*
Water stargrass	*Zosterella dubia*

Floating Leaf Plants

Common Name	Scientific Name
Forked duckweed	*Lemna trisulca*
American lotus	*Nelumbo lutea*
White waterlily	*Nymphaea tuberosa*
Common waterweed	*Wolffia columbiana*

Emergent Plants

Common Name	Scientific Name
Blue flag iris	*Iris versicolor*
Purple loosestrife	***Lythrum salicaria***
Cattail	*Typha sp.*

*Note: Bold red name indicates extremely aggressive/invasive introduced species.

- Water Quality Monitoring Location
- Emergent Plants
- Floating Leaf Plants
- Submerged Aquatic Plants
- No Aquatic Vegetation
- GPS Survey Location Path

Imagery Source: Hennepin County (2015)

N

0 400 800
Feet

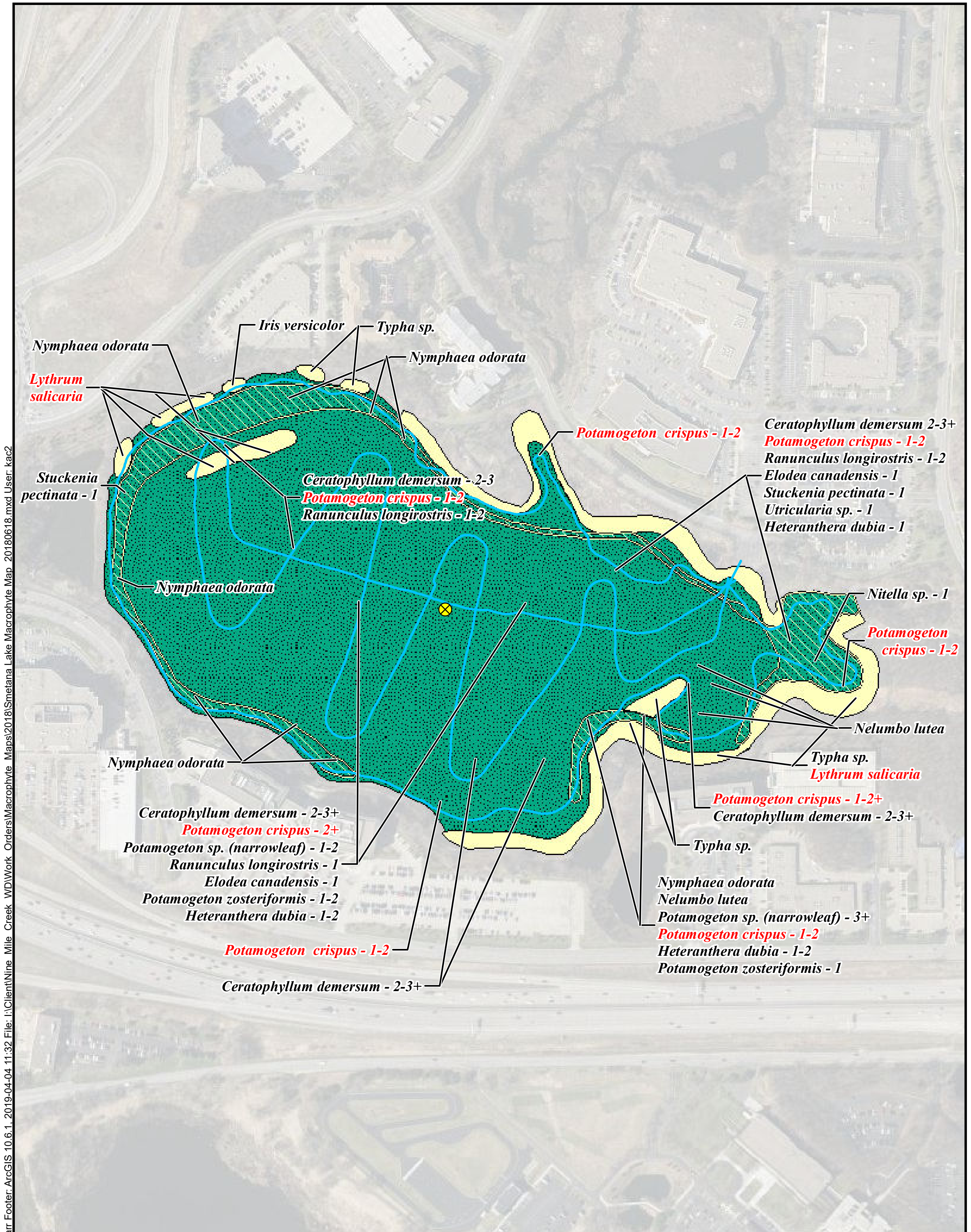
0 100 200
Meters

BARR

FIELD NOTES:
- ***Lythrum salicaria*** observed around entire lake perimeter (sporadically).
- Entire water body has macrophyte coverage.
- Macrophyte densities estimated as follows:
  1=light; 2=moderate; 3=heavy
- Algal mats, *Lemna trisulca* and *Wolffia columbiana* present.

SMETANA LAKE MACROPHYTE SURVEY

August 16, 2016
Nine Mile Creek Watershed District



Submerged Aquatic Plants

Common Name	Scientific Name
Bladderwort	*Utricularia sp.*
Coontail	*Ceratophyllum demersum*
Curly-leaf Pondweed	***Potamogeton crispus***
Elodea	*Elodea canadensis*
Flat-stem pondweed	*Potamogeton zosteriformis*
Narrow-leaf pondweed	*Potamogeton sp. (narrowleaf)*
Sago pondweed	*Stuckenia pectinata*
Stonewort	*Nitella sp.*
Water stargrass	*Heteranthera dubia*
White water buttercup	*Ranunculus longirostris*

Floating Leaf Plants

Common Name	Scientific Name
American lotus	*Nelumbo lutea*
Common waterweed	*Wolffia columbiana*
Forked duckweed	*Lemna trisulca*
White waterlily	*Nymphaea odorata*

Emergent Plants

Common Name	Scientific Name
Blue flag iris	*Iris versicolor*
Cattail	*Typha sp.*
Purple loosestrife	***Lythrum salicaria***

*Note: Bold red name indicates extremely aggressive/invasive introduced species.

Water Quality Monitoring Location
Emergent Plants
Floating Leaf Plants
Submerged Aquatic Plants
No Aquatic Vegetation
GPS Survey Location Path

Imagery Source: Twin Cities 2016 (MnGeo WMS)

N

0 400 800
Feet

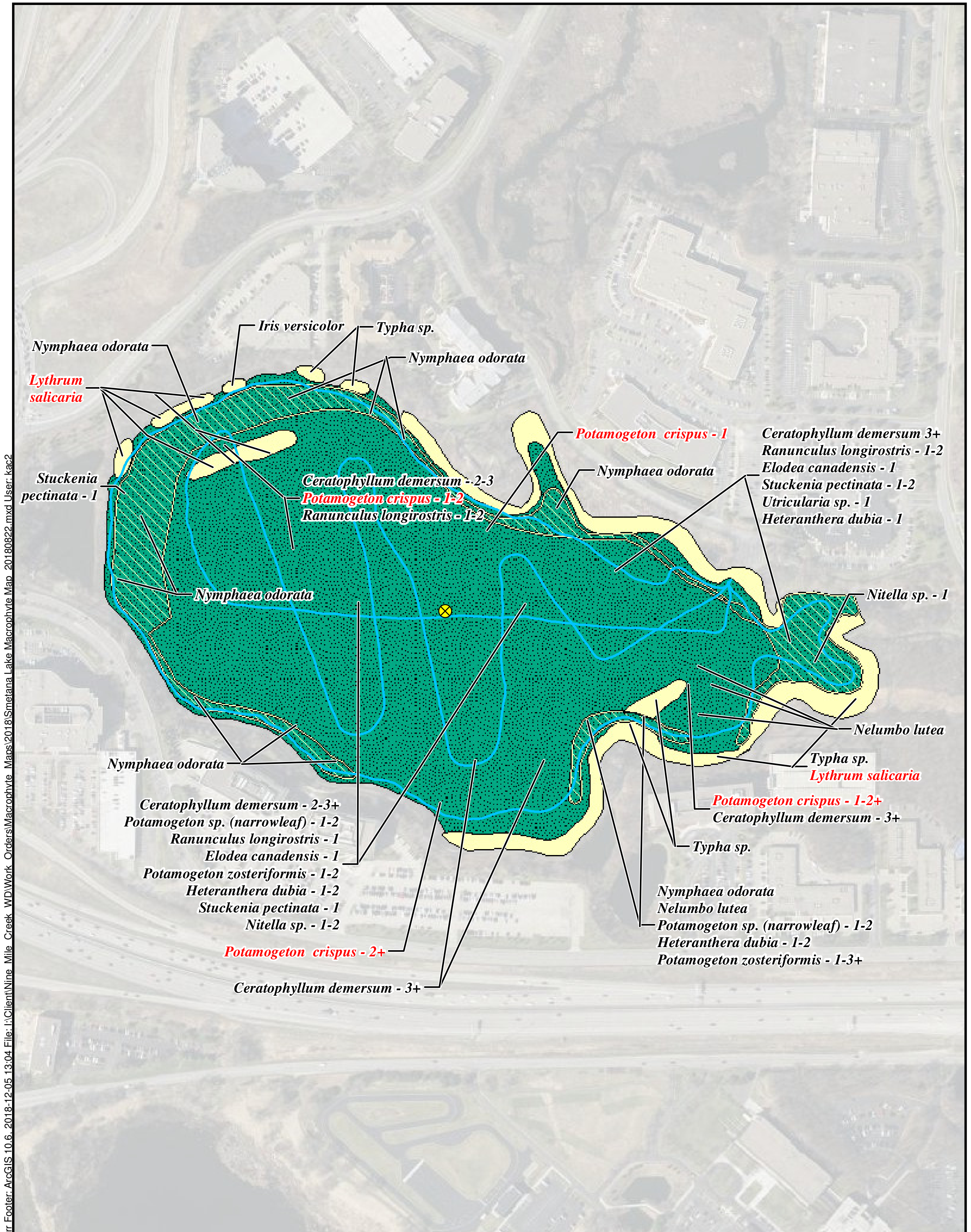
0 100 200
Meters

FIELD NOTES:
- ***Lythrum salicaria*** observed around entire lake perimeter (sporadically).
- Entire water body has macrophyte coverage.
- Macrophyte densities estimated as follows:
  1=light; 2=moderate; 3=heavy
- Algal mats, *Lemna trisulca* and *Wolffia columbiana* present.

BARR

SMETANA LAKE MACROPHYTE SURVEY

June 18, 2018
Nine Mile Creek Watershed District



Submerged Aquatic Plants

Common Name	Scientific Name
Bladderwort	*Utricularia sp.*
Coontail	*Ceratophyllum demersum*
Curly-leaf Pondweed	***Potamogeton crispus***
Elodea	*Elodea canadensis*
Flat-stem pondweed	*Potamogeton zosteriformis*
Narrow-leaf pondweed	*Potamogeton sp. (narrowleaf)*
Sago pondweed	*Stuckenia pectinata*
Stonewort	*Nitella sp.*
Water stargrass	*Heteranthera dubia*
White water buttercup	*Ranunculus longirostris*

Floating Leaf Plants

Common Name	Scientific Name
American lotus	*Nelumbo lutea*
Common waterweed	*Wolffia columbiana*
Forked duckweed	*Lemna trisulca*
White waterlily	*Nymphaea odorata*

Emergent Plants

Common Name	Scientific Name
Blue flag iris	*Iris versicolor*
Cattail	*Typha sp.*
Purple loosestrife	***Lythrum salicaria***

*Note: Bold red name indicates extremely aggressive/invasive introduced species.

Water Quality Monitoring Location
Emergent Plants
Floating Leaf Plants
Submerged Aquatic Plants
No Aquatic Vegetation
GPS Survey Location Path

Imagery Source: Twin Cities 2016 (MnGeo WMS)

N

0 400 800
Feet

0 100 200
Meters

FIELD NOTES:
- ***Lythrum salicaria*** observed around entire lake perimeter (sporadically).
- Entire water body has macrophyte coverage.
- Macrophyte densities estimated as follows:
  1=light; 2=moderate; 3=heavy
- Algal mats, *Lemna trisulca* and *Wolffia columbiana* dense around lake perimeter.

BARR

SMETANA LAKE MACROPHYTE SURVEY

August 22, 2018
Nine Mile Creek Watershed District

Appendix B

Fisheries Assessment (2005)

Minnesota Department of Natural Resources

Fisheries Management

STANDARD LAKE SURVEY REPORT

DRAFT VERSION - PRELIMINARY DATA (AS OF 05/19/2014)

Lake Name: Smetana | **Survey Type: Special Assessment**

DOW Number: 27-0073-00 | **Survey ID Date: 06/09/2005**

SPECIAL ASSESSMENT
Electrofishing

Lake Identification

Alternate Lake Name: N/A
Primary Lake Class ID: 40
DNR Sounding Map Number: N/A
Alternate Lake Class ID: N/A

Lake Location

Primary County: Hennepin
Nearest Town: Rowland

Legal Descriptions

Lake Center: Township - 116N Range - 22W Section - 12
PLS Section Lake Center: 11602212

All Legal Descriptions:
Hennepin County: Township - 116N Range - 22W Sections - 12, 13

Area Office

Area Name: Metro West
Region Name: Central
ORG Code: F314
Region Number: 3

Lake Characteristics

Lake Area (planimetered acres): 59.00
GIS Lake Area (acres): 52.23
DOW Lake Area (acres): 56.00
Littoral Area (acres): 52.23
Area in MN (acres): 52.23
Maximum Depth (feet): 12.0
Mean Depth (feet): 5.0

GIS Shoreline Length (miles): 1.60
Maximum Fetch (miles): 0.51
Fetch Orientation (degrees): 315
USGS Quad Map Number: S16c
USGS Quad 24K GIS Index: 3731

Watershed Characteristics

Major Watershed
Name: Lower Minnesota River
Watershed Number: 33
Watershed size (acres): 1,174,348

Minor Watershed
Name: S Fork Ninemile Cr
Watershed Number: 141
Watershed size (acres): 11,541

Surveys And Investigations

Initial Survey: 08/01/2005.
Special Assessment: 06/09/2005.

Electrofishing Catch Summary for EF

Standard electrofishing

Total run-time for all stations: 01:00:00
Total on-time for all stations: 00:40:32
First Sampling Date: 06/09/2005
Last Sampling Date: 06/09/2005
Daylight Sampling: No
Target Species: N/A

		Summary By Numbers			Summary By Weight (pounds)			
		Total	Number per Hour		Total	Lbs per Hour		Mean
Abbr	Species	Number	Run-Time	On-Time	Weight	Run-Time	On-Time	Weight
BLG	Bluegill	5	5.00	7.40	2.35	2.35	3.47	0.47
LMB	Largemouth Bass	4	4.00	5.92	6.53	6.53	9.67	1.63

Length Frequency Distribution For EF

Standard electrofishing
(Field work conducted on 06/09/2005)

	BLG	LMB
< 3.00	-	-
3.00 - 3.49	-	-
3.50 - 3.99	-	-
4.00 - 4.49	-	1
4.50 - 4.99	-	-
5.00 - 5.49	-	1
5.50 - 5.99	-	-
6.00 - 6.49	-	-
6.50 - 6.99	-	-
7.00 - 7.49	1	-
7.50 - 7.99	3	-
8.00 - 8.49	1	-
8.50 - 8.99	-	-
9.00 - 9.49	-	-
9.50 - 9.99	-	-
10.00 - 10.49	-	-
10.50 - 10.99	-	-
11.00 - 11.49	-	-
11.50 - 11.99	-	-
12.00 - 12.99	-	-
13.00 - 13.99	-	-
14.00 - 14.99	-	-
15.00 - 15.99	-	-
16.00 - 16.99	-	-
17.00 - 17.99	-	2
18.00 - 18.99	-	-
19.00 - 19.99	-	-
20.00 - 20.99	-	-
21.00 - 21.99	-	-
22.00 - 22.99	-	-
23.00 - 23.99	-	-
24.00 - 24.99	-	-
25.00 - 25.99	-	-
26.00 - 26.99	-	-
27.00 - 27.99	-	-
28.00 - 28.99	-	-
29.00 - 29.99	-	-
30.00 - 30.99	-	-
31.00 - 31.99	-	-
32.00 - 32.99	-	-
33.00 - 33.99	-	-
34.00 - 34.99	-	-
35.00 - 35.99	-	-
= > 36.00	-	-

	BLG	LMB
Total	5	4
Min. Length	7.48	4.21
Max. Length	8.07	17.87
Mean Length	7.83	11.13
# Measured	5	4
No Lengths for	0	0

Note: Unless all fish were measured in the catch, totals shown for some length-frequency distributions may differ from the total number of fish in the catch, due to rounding of fractions used in the estimation of length frequency from a subsample of measured fish

Approval Dates And Notices

Date Approved By Metro West Area Fisheries Supervisor: ______________

Date Approved By Central Region Fisheries Manager: ______________

This DRAFT VERSION of the Standard Lake Survey Report contains preliminary data (as of 05/19/2014), and is therefore subject to change at any time.

Minnesota Department of Natural Resources

REPORT OVERVIEW - FOR OFFICE USE ONLY

(This page is not part of the Standard Lake Survey Report and should be discarded)

Lake Name: Smetana **Survey Type: Special Assessment**

DOW Number: 27-0073-00 **Survey ID Date: 06/09/2005**

Electrofishing

Survey Status: Migrating

The following 26 (of 31) report components are not included in this report:

1. Lake Access
2. Current Water Level
3. Benchmark And Gauge Descriptions / Locations
4. Water Level History[1]
5. Water Level History - Readings*
6. Water Level History - Station Summary*
7. Lake Inlets
8. Additional Inlet Information
9. Lake Outlets
10. Additional Outlet Information
11. Water Control Structure (Dam)
12. Surrounding Watershed Characteristics, Shoreline Characteristics, and Riparian Landscape Observations[2]
13. Resorts And Campgrounds
14. Fish Spawning Conditions
15. Erosion And Pollution
16. Fish Diseases And Parasites
17. Aquatic Vegetation And Shoalwater Substrates
18. Dissolved Oxygen And Temperature Profile Of Lake Water
19. Field Measusrements Of Water Quality
20. Laboratory Analysis Of Water Chemistry
21. Length At Capture With Last Incremental Length*
22. Back-Calculated Lengths
23. Age Class Frequency Distributions
24. Status Of Fishery And Field Notes
25. Other Species (added to revision 03/24/2009)
26. Water Quality (Winter Observations) (added to revision 01/21/2010)

[1] Water Level History report: This data has not yet been migrated into the Fisheries LSM database. On 01/08/2009, two additional Water Level History report components (Readings and Station Summary) were added.

[2] Effective 03/25/2014, the Surrounding Watershed Characteristics, Shoreline Characteristics, and Riparian Landscape Observations report component was modified to be included in the Standard Lake Survey report if it did not include any Watershed and Shoreline characteristics and only consisted of Riparian Landscape Observations.

* Length At Capture With Last Incremental Length report: The following criteria must be met for a report to be generated:

1. The fish species must have an assigned body scale constant.
2. Fish must have an "official" age assigned.
3. Fish must have a digitized measurement marked for back calculation use.

Note: The data source for Length and Age Class Frequency Distribution tables is updated twice daily - once at noon and once overnight. Any changes to the data made after noon on 05/19/2014 may not be reflected in the Distribution tables until 05/20/2014.