2018 Engineer's Report

Normandale Lake Water Quality Improvement Project

Petitioned by
City of Bloomington

Prepared for
Nine Mile Creek Watershed District

April 2018

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2018 Engineer's Report

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Certifications

I hereby certify that this Report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the State of Minnesota.

______________________________	April 13, 2018
Janna Kieffer	Date
Barr Engineering Co.	
PE Registration No: 43571	

Acronyms

Acronym	Description
cfs	cubic foot per second
FQI	Floristic Quality Index
LOx	bulk liquid oxygen
MDNR	Minnesota Department of Natural Resources
MPCA	Minnesota Pollution Control Agency
NMCWD	Nine Mile Creek Watershed District
SSS	side-stream saturation
UAA	Use Attainability Analysis
USACE	U.S. Army Corps of Engineers

1.0 Introduction and Project Background

1.1 Introduction

This report summarizes and assesses the feasibility of potential actions for improving the water quality of Normandale Lake. It is prepared in response to a petition from the City of Bloomington to the Board of Managers of the Nine Mile Creek Watershed District (NMCWD or District) (**Appendix A**) and to solicit feedback from stakeholders including the Department of Natural Resources and Board of Water and Soil Resources.

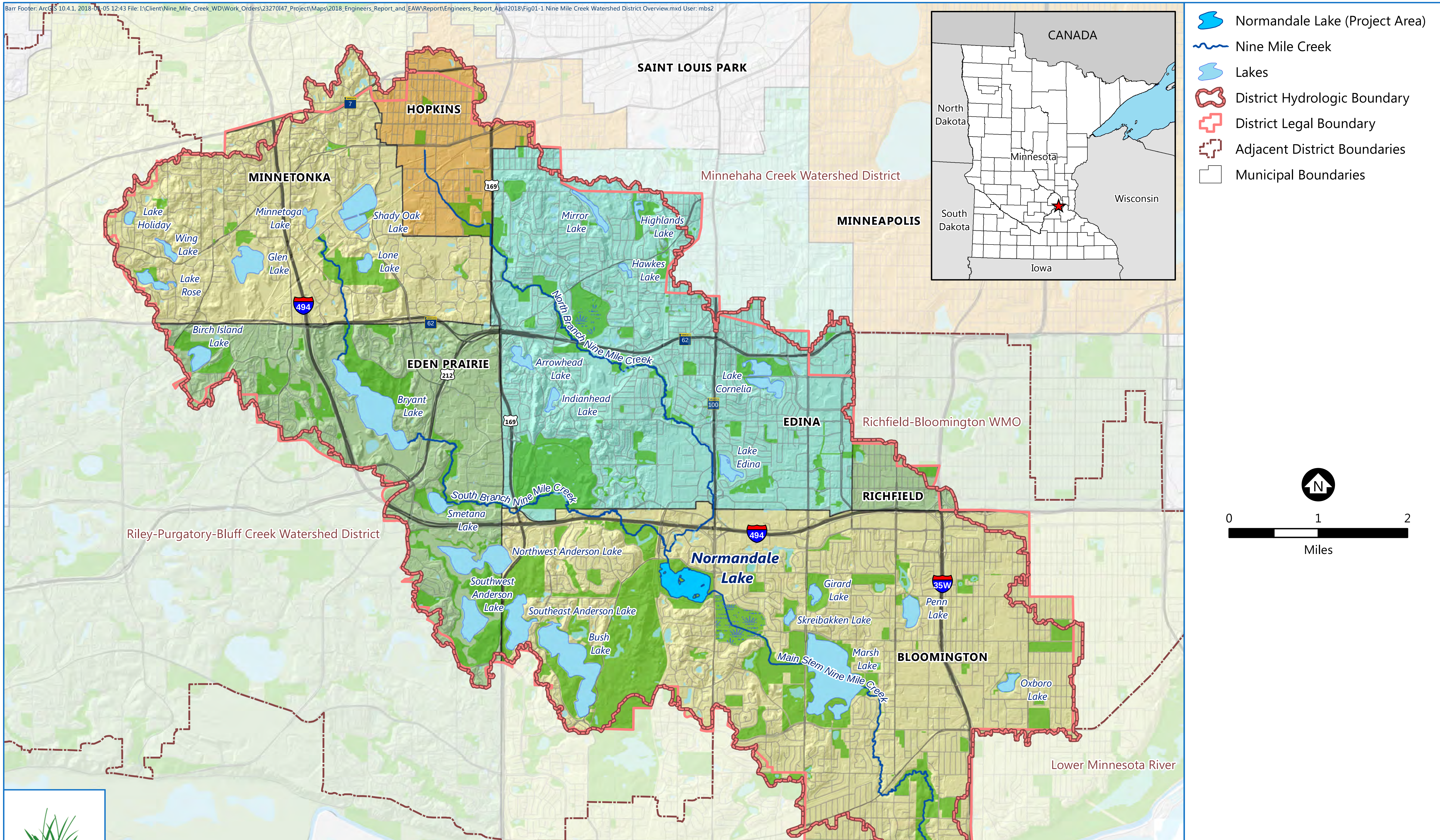
1.2 Project Background

The NMCWD was established by the Minnesota Water Resources Board in 1959 and consists of land that drains to Nine Mile Creek. The District encompasses approximately 50 square miles in southern Hennepin County and it includes portions of the cities of Bloomington, Edina, Eden Prairie, Hopkins, Minnetonka, and Richfield (**Figure 1-1**). Nine Mile Creek has two branches. The north branch is groundwater and stormwater fed, beginning in Hopkins. The south branch originates in Minnetoga Lake and surrounding wetlands in Minnetonka. The north and south branches join north of Normandale Lake and just south of Interstate 494 in Bloomington. The creek flows through Normandale Lake and continues southeast to the Minnesota River.

Stormwater management within the urbanized Nine Mile Creek watershed was guided initially by the District's *Overall Plan* dated March 1961. That plan was revised by the Watershed District in April 1973, as prescribed by the Minnesota Water Resources Board. The 1973 revised *Overall Plan* guided development in the District until it was further revised in May 1996, March 2007 and again in the 2017 *Nine Mile Creek Watershed District Water Management Plan*, in accordance with the Metropolitan Surface Water Management Act and Watershed Law: Minnesota Statutes Chapters 103B and 103D, respectively (NMCWD, 2017).

Normandale Lake was created as part of the Mount Normandale Lake flood-control project implemented by NMCWD in the mid-1970s, which included construction of a dam across Nine Mile Creek to the west of Normandale Boulevard. The U.S. Army Corp of Engineers (USACE) Section 404 permit that was issued in 1979 for construction of the dam contains several special conditions, including restrictions on vegetation control or dredging in the western portion of the lake. A copy of the permit is included as **Appendix B**.

Normandale Lake presently experiences high phosphorus concentrations in the summer (>60 µg/L) and occasional high phytoplankton amounts, both of which contribute to water quality concerns. The lake contains an abundance of curly-leaf pondweed, an aggressive invasive aquatic plant which contributes phosphorus to the water column following its early-summer die-off and can limited plant diversity. The low plant diversity in combination with low dissolved oxygen levels in the water column pose concerns for the lake's aquatic communities. Excessive aquatic plants and filamentous algae in Normandale Lake cause late summer algal blooms, resulting in an occasionally strong hydrogen sulfide odor and impediment of recreational use (boating, walking paths, etc.) of the lake.



PROJECT LOCATION
Normandale Lake Engineer's Report
Bloomington, Minnesota

Figure 1-1

Development of engineering solutions related to water quality in Normandale Lake has been ongoing since 2005, when the NMCWD completed a Use Attainability Analysis (UAA) for the lake. The Normandale Lake UAA (Barr, 2005) was a scientific assessment of the lake's physical, chemical, and biological condition and included both a water quality assessment and prescription of protective and/or remedial measures for Normandale Lake and the tributary watershed.

Following completion of the UAA, the City of Bloomington petitioned NMCWD to implement recommended water quality improvements for Normandale Lake. Since receiving this petition, the NMCWD has undertaken several rounds of additional analysis and consideration of lake management options. NMCWD has also worked with USACE to obtain a definitive interpretation of the 404 permit such as would clarify which lake-improvement projects could be undertaken without modification of the permit, and which would require temporary or permanent modifications to the permit. More recently, NMCWD has also worked closely with the USACE to identify shared management goals for the shallow lake (e.g., a more healthy and diverse native aquatic plant population) and develop a lake management plan that will help achieve these goals (**Appendix C**).

This Engineer's Report evaluates several water quality improvement approaches to address concerns associated with a prevalence of curly-leaf pondweed in Normandale Lake and the release of phosphorus from lake-bottom sediments (internal loading). Improvement approaches assessed in this report include lake-level drawdown, selective herbicide treatment, alum treatment, aquatic plant harvesting, and in-lake oxygenation.

2.0 Normandale Lake Overview

The characteristics of Normandale Lake and its watershed are described in the following sections.

2.1 Normandale Lake Characteristics

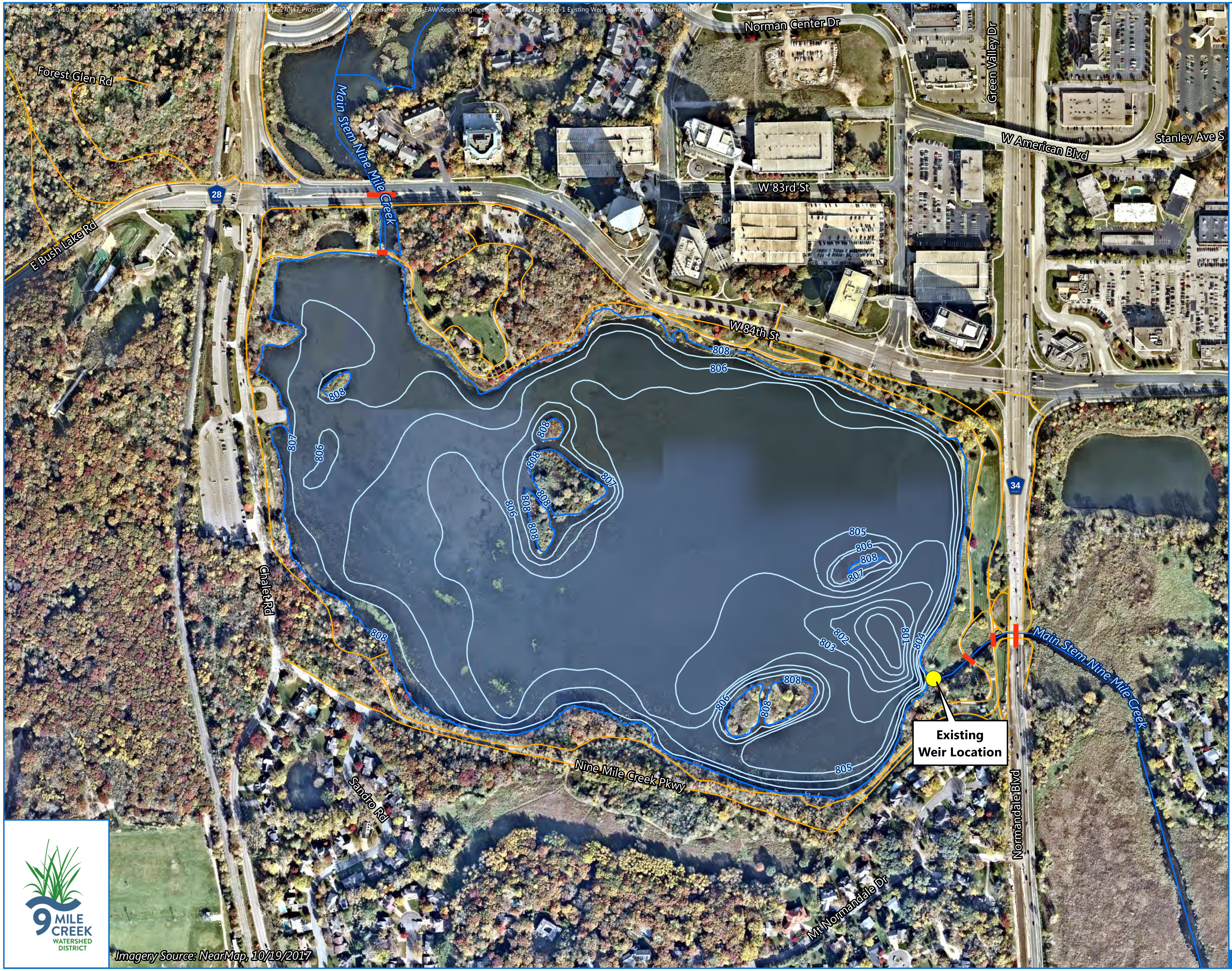
Normandale Lake is located in the northwestern portion of Bloomington. Normandale Lake was created as a direct result of the Mount Normandale Lake flood control project, implemented in the mid-1970's.

Prior to this project, Hennepin County Ditch #1, established in 1904, conveyed Nine Mile Creek flows downstream from where the north and south forks merged to roughly 300 feet south of 98th Street. As a result of the ditching, the flood storage potential of natural marsh areas, now known as Normandale Lake and Marsh Lake, was no longer being fully utilized to mitigate seasonal flood flows. The resulting flood control project that created Normandale Lake involved construction of a dam across Nine Mile Creek west of Normandale Boulevard, installation of a weir control structure, and construction of a low-flow bypass structure. The low-flow bypass structure consists of a 4-inch diameter opening cut through an 18-inch sluice gate at elevation 800.5. Flow through the bypass structure is influenced by tailwater elevations in the creek, which vary depending on flow conditions. A December 2003 survey indicates a tailwater elevation of approximately 802.25. Note that all elevations are in reference to mean sea level.

The main weir control structure **(Figure 2-1**) has an approximately 18-foot crest length at an elevation of 808.8 feet. The weir is covered with an artificial rock surface, and the low point along the weir was surveyed at elevation 807.9 in January 2005. The emergency overflow from Normandale Lake consists of an earthen embankment. Flow over the embankment discharges to the main stem of Nine Mile Creek, which continues to travel downstream of the lake before discharging into the Minnesota River.

The lake has a water surface of approximately 116 acres. Detailed bathymetry data has not been collected for Normandale Lake since the late-1980s (MnDNR, 1993). However, lake depths recorded during recent aquatic plant point-intercept surveys of the lake indicate a maximum depth of approximately 9 feet, and a mean depth of 3.0 feet at normal water surface elevation of approximately 808 feet (**Figure 2-1**). At this elevation, the lake volume is approximately 290 acre-feet, based on bathymetry developed from the point-intercept survey.

The lake is shallow enough for aquatic plants (i.e. marcophytes) to grow over the entire lake bed. The water level in the lake is controlled mainly by weather conditions (snowmelt, rainfall, and evaporation) and by the elevation of the outlet structure located at the east side of Normandale Lake.



- Existing Weir Location
- Existing Bridge or Culvert
- Paved Trails
- Bathymetric Elevation Contour
- Nine Mile Creek
- Normandale Lake (Project Area)

N

400 0 400

Feet

EXISTING WEIR AND BATHYMETRY
Normandale Lake Engineer's Report
Bloomington, Minnesota

Figure 2-1

2.2 Watershed Characteristics

Normandale Lake's 21,556-acre watershed, including the surface area of the lake and upstream landlocked areas (2,851 acres), encompasses portions of the cities of Bloomington, Edina, Eden Prairie, Hopkins, and Minnetonka. Runoff from the watershed enters the lake from Nine Mile Creek at the northwest corner of the lake, overland flow, and storm sewer outfalls at various points along the lakeshore.

The entire contributing watershed is developed, with the majority of the land use being low-density residential (34 percent), park/open space (22 percent), commercial (11 percent), industrial/office (8 percent), higher-density residential (7 percent), highway (6 percent), institutional (3 percent), and golf course (2 percent) uses.

2.3 Normandale Lake Water Quality

The water quality of a lake provides an indication of how a lake functions. A standardized lake rating system is often used to classify the ecological conditions of a lake. The rating system uses phosphorus, chlorophyll-*a*, and Secchi disc transparency values to classify lakes into four categories:

- Oligotrophic – clear, low productivity lakes with excellent water quality
- Mesotrophic – intermediate productivity lakes with good water quality
- Eutrophic – high productivity lakes with poor water quality
- Hypereutrophic – extremely productive lakes with poor water quality

Summer is the period of greatest interest to lake managers and the period of time in which the rating system is generally used to classify lakes. It is during the summer (June, July, and August, and September) that recreational-use of the parkland surrounding Normandale Lake is greatest, and it is during these times that algal blooms and odor problems are most common. For these reasons, the following water quality discussion is focused on summer water quality in Normandale Lake.

This section summarizes recently observed and predicted in-lake water quality conditions for Normandale Lake. Details of the analyses conducted to prepare these summaries and graphics are contained in the executive summary of the a 2017 report evaluating management measures to improve the water quality and ecology of Normandale Lake, which appears in **Appendix D** to this Engineer's Report (Barr, 2017).

2.3.1 Eutrophication Parameters (Total Phosphorus, Chlorophyll-*a*, Transparency)

The water quality in Normandale Lake has been monitored periodically since 1990 by the NMCWD and through the Metropolitan Council's Citizen-assisted Monitoring Program. **Figure 2-2, Figure 2-3**, and **Figure 2-4** show the historic summer average total phosphorus, chlorophyll-*a*, and Secchi disc depth, respectively. Normandale Lake has historically met the Minnesota shallow lake eutrophication standards for chlorophyll-*a* and Secchi disc depth, but not for total phosphorus. Summer average chlorophyll-*a* has ranged from 4 to 19 µg/L and Secchi disc depth has been quite good ranging from 1.1 to 2.4 meters (**Figure 2-3** and **Figure 2-4**, respectively). Summer average total phosphorus has ranged from 41 to

133 µg/L, with several years exceeding the Minnesota Pollution Control Agency's (MPCA's) shallow lake criteria of 60 µg/L (**Figure 2-2**).

The 2016 epilimnetic summer averages for total phosphorus, chlorophyll-*a*, and Secchi disc water transparency were 92 µg/L, 16.7 µg/L, and 1.2 meters, respectively (**Figure 2-5**). These 2016 summer averages generally place the lake in the eutrophic category. This characterization means that, by comparison to other lakes, Normandale Lake is extremely rich in algal nutrients, has the potential for algal blooms, and exhibits low water clarity.

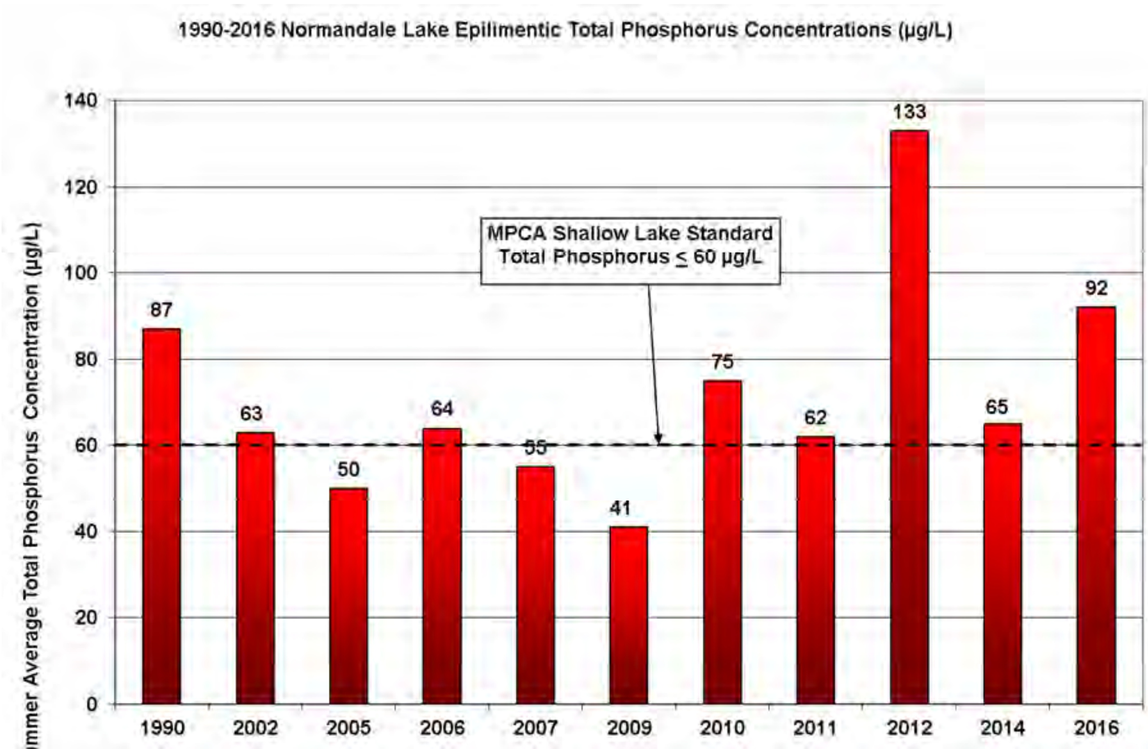


Figure 2-2 Historic summer-average total phosphorus concentrations in Normandale Lake

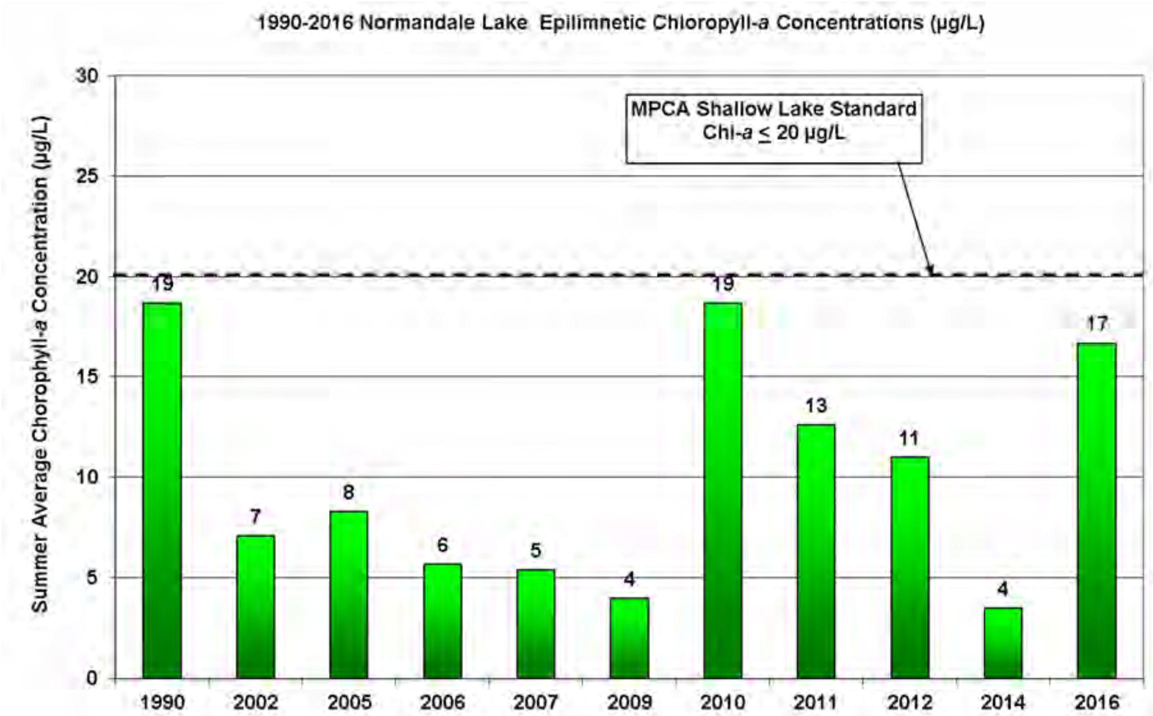


Figure 2-3 Historic summer-average chlorophyll-*a* concentrations in Normandale Lake

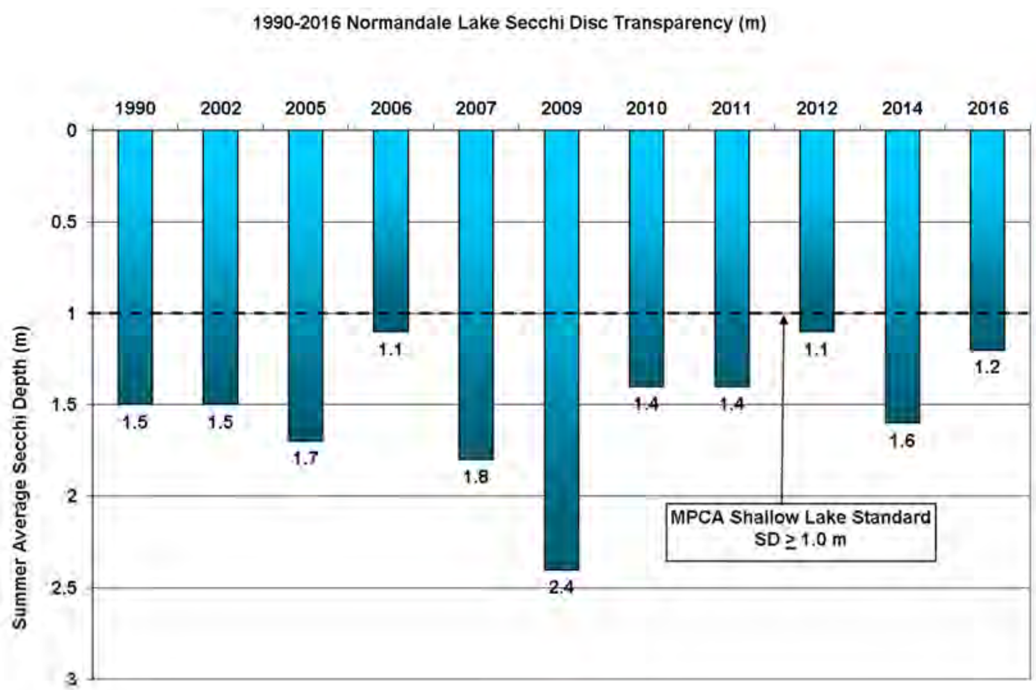


Figure 2-4 Historic summer-average Secchi disc transparency in Normandale Lake

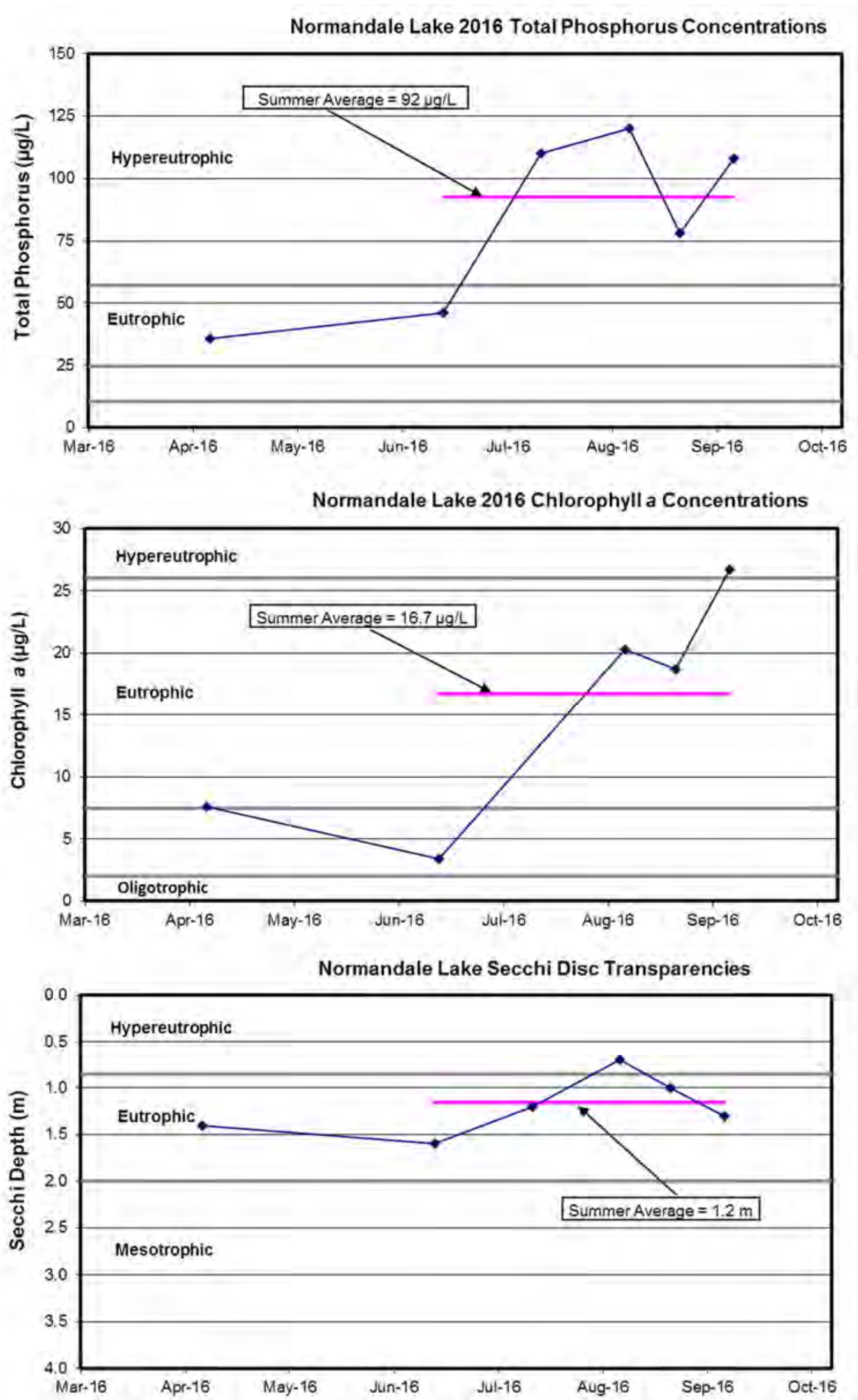


Figure 2-5 **Seasonal changes in concentrations of total phosphorus, Chlorophyll-*a*, and Secchi disc transparency in Normandale Lake, 2016**

2.3.2 Dissolved Oxygen

The water quality parameters included in the State's shallow lake standards (total phosphorus, chlorophyll-*a*, and Secchi depth transparency) provide an indication of the overall water quality and trophic state of the lake, however, the ecology (aquatic communities) and use of the lake are strongly affected by the dense and widespread growth of aquatic plants and filamentous algae in the lake. Normandale Lake has been experiencing increasing densities of invasive curly-leaf pondweed and excess filamentous algae, watermeal, and duckweed growths (**Figure 2-6**). Significant growths of watermeal and duckweed are typically associated with water bodies that have nutrient-rich environments, thus supporting the need for nutrient management in Normandale Lake.

Figure 2-6 Dense growth of filamentous algae, watermeal, and duckweed in early September

Dense surface growths of duckweed, watermeal, filamentous algae, and aquatic plants such as coontail in Normandale Lake can remove significant amounts of phosphorus from the water column. However, they also prevent the diffusion of oxygen from the air to the lake water column. **Figure 2-7** shows the average dissolved oxygen concentrations in the Normandale Lake water column in 2010 and 2016, in mg/L (note 1,000 µg/L is equivalent to 1 mg/L). As shown, the observed dissolved oxygen levels are low throughout much of the summer. Reduced oxygen levels place additional stress on certain fish species (e.g., northern pike) and increase phosphorus release from lake-bottom sediments.

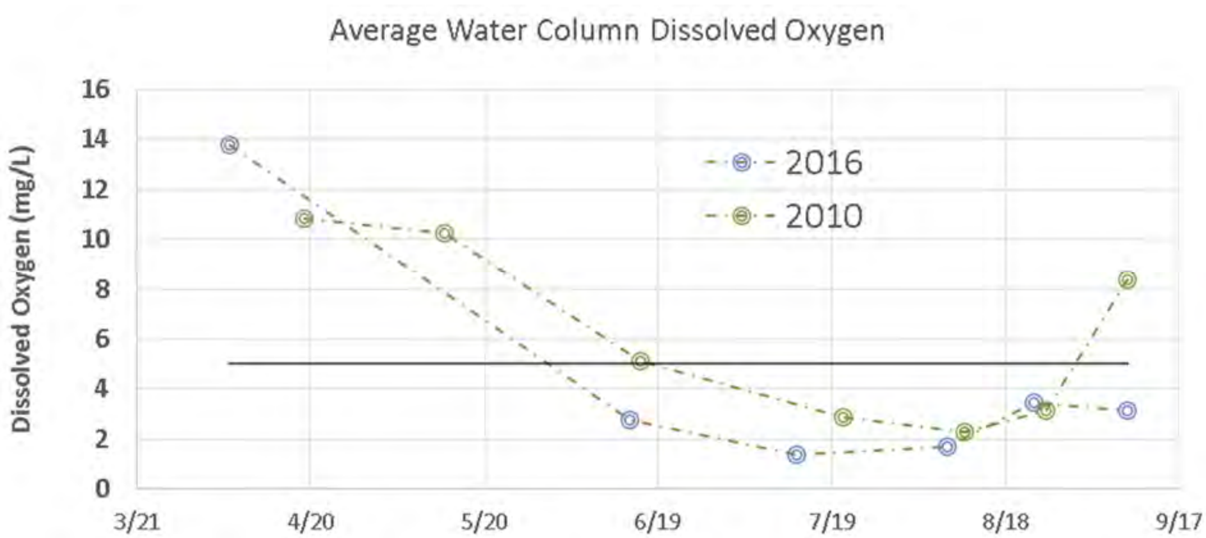


Figure 2-7 Average dissolved oxygen in the Normandale Lake water column in 2010 and 2016

2.3.3 Internal Phosphorus Loading

Based on observed temperature and dissolved oxygen profiles in Normandale Lake throughout the summer months, Normandale Lake mixes periodically; however, it mixes less than would be expected for a shallow lake. Dissolved oxygen profiles in 2016 (**Figure 2-8**) with low oxygen on the bottom and high oxygen on the surface provide an indication of the lack of mixing (i.e. the profile would be more uniform from the top to the bottom if there was more mixing) (Barr, 2017).

As a consequence of low oxygen, phosphorus is released from the sediments and builds up in lake-bottom waters (**Figure 2-9**). This internal load of phosphorus can be transported to the entire water column when wind causes lake circulation or as fall approaches and mixing typically begins to occur (Barr, 2017).

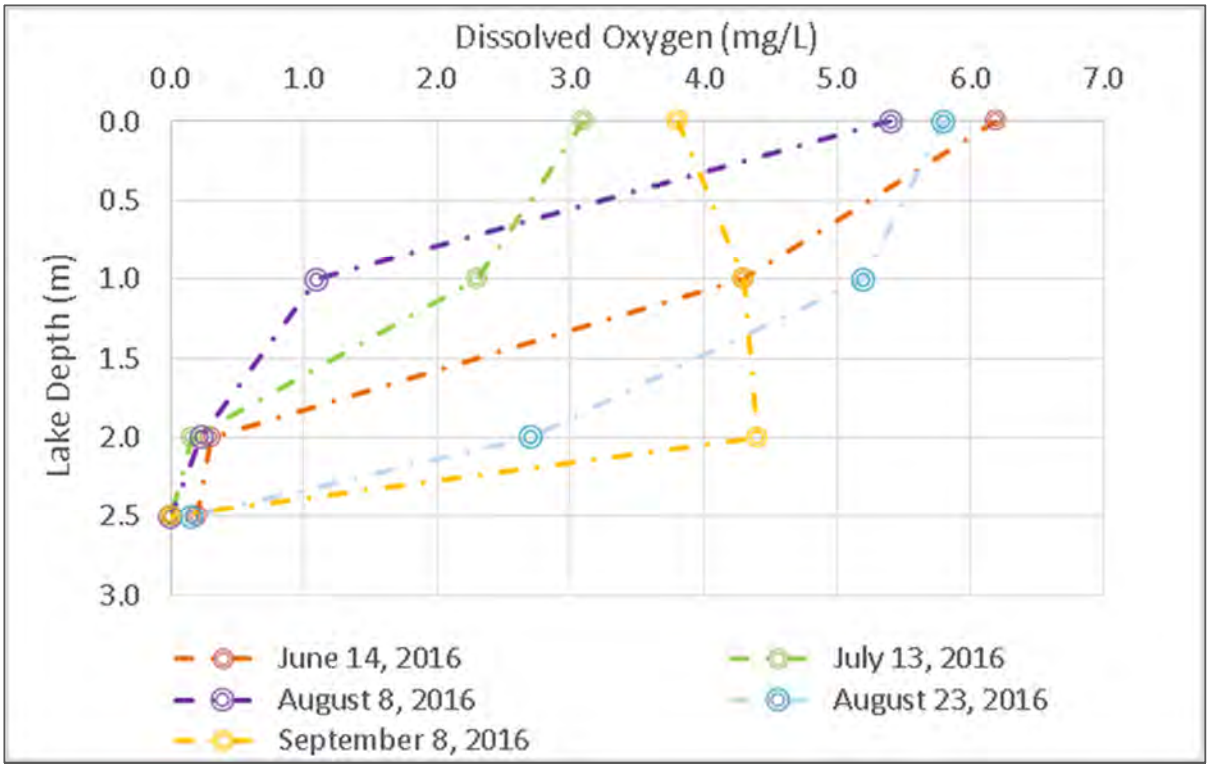


Figure 2-8 **Dissolved oxygen profiles show a lack of lake mixing in summer months**

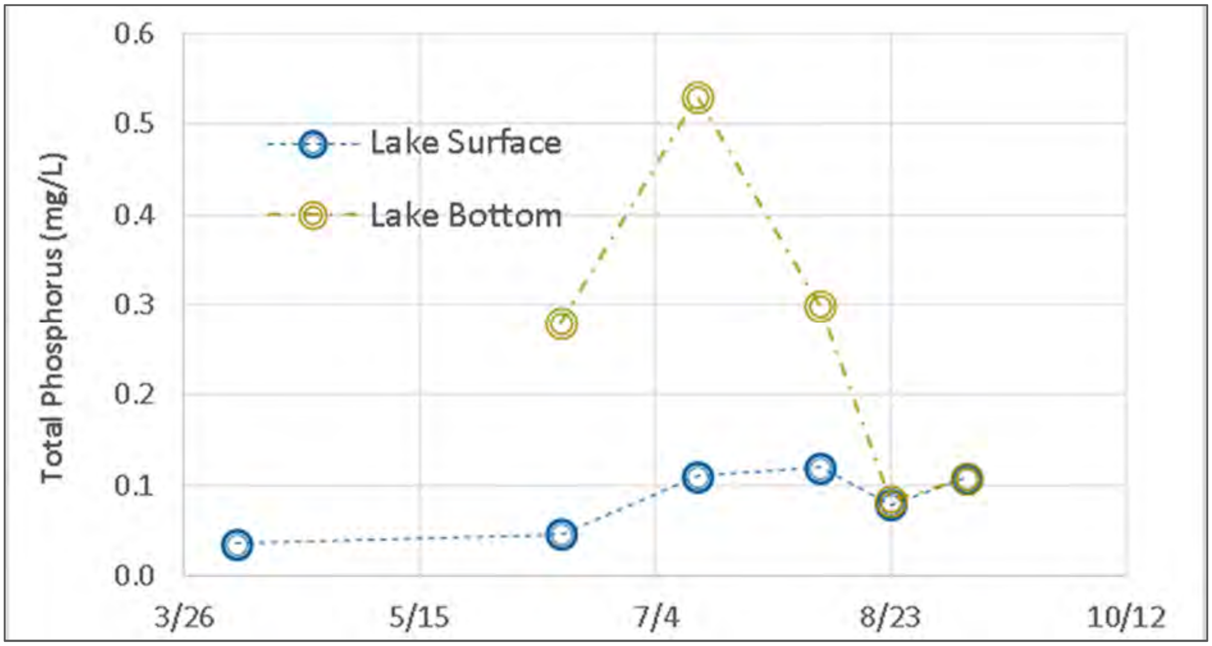


Figure 2-9 **Comparison of total phosphorus on the bottom and surface of Normandale Lake in 2016**

2.4 Normandale Lake Aquatic Communities

2.4.1 Aquatic Plants

Macrophytes, also called aquatic plants, grow in aquatic systems such as streams and lakes. There is a wide range of macrophytes, some attached to the lake bottom, some unattached and floating, some submerged and some, like cattails, grow in but emerge from the water column. Macrophytes are an important part of a 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 creates problems for a lake, including recreational use impairment, fluctuating water quality, and limitations of fisheries habitat. Results of a point-intercept survey conducted in June and August 2017 indicate that the extent of macrophyte and filamentous algae coverage in Normandale Lake is significant. In June, aquatic plants were found in all of the 125 pre-defined sampling locations. In August, only one sampling location did not contain plants (Barr, 2017). **Figure 2-10** below shows the relative abundance of aquatic plant species in the lake in 2017, with the dominant species including elodea, curly-leaf pondweed, coontail, and filamentous algae.

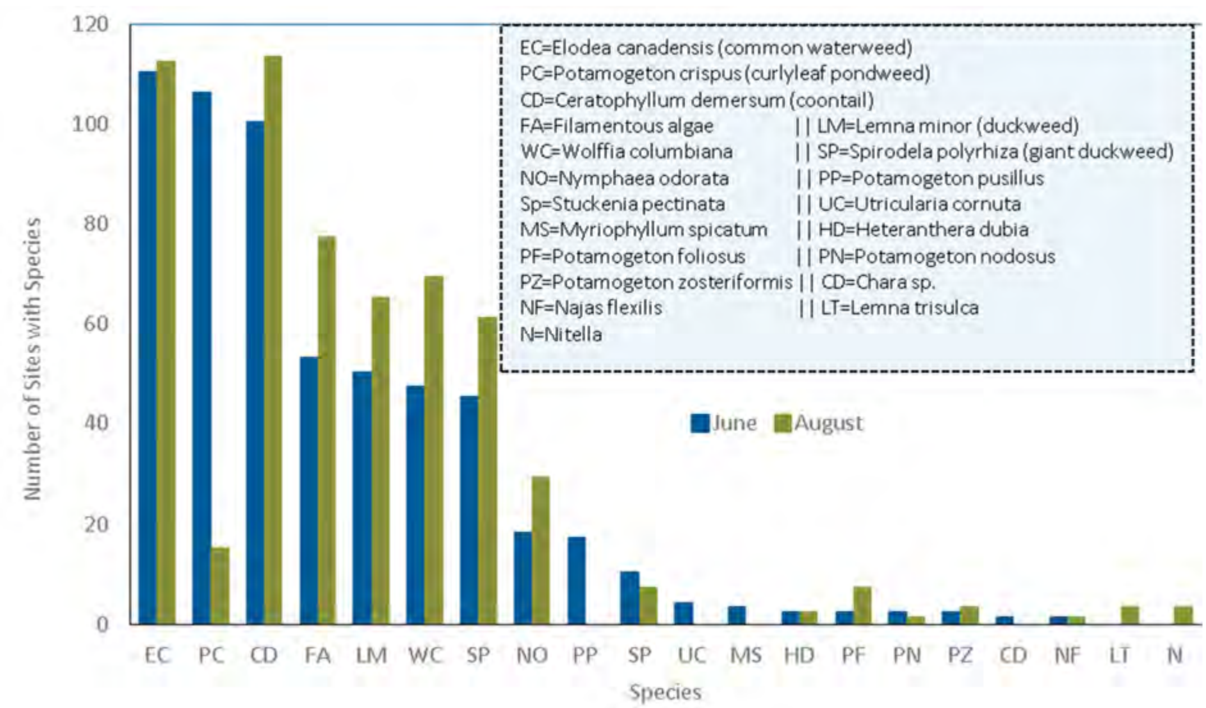
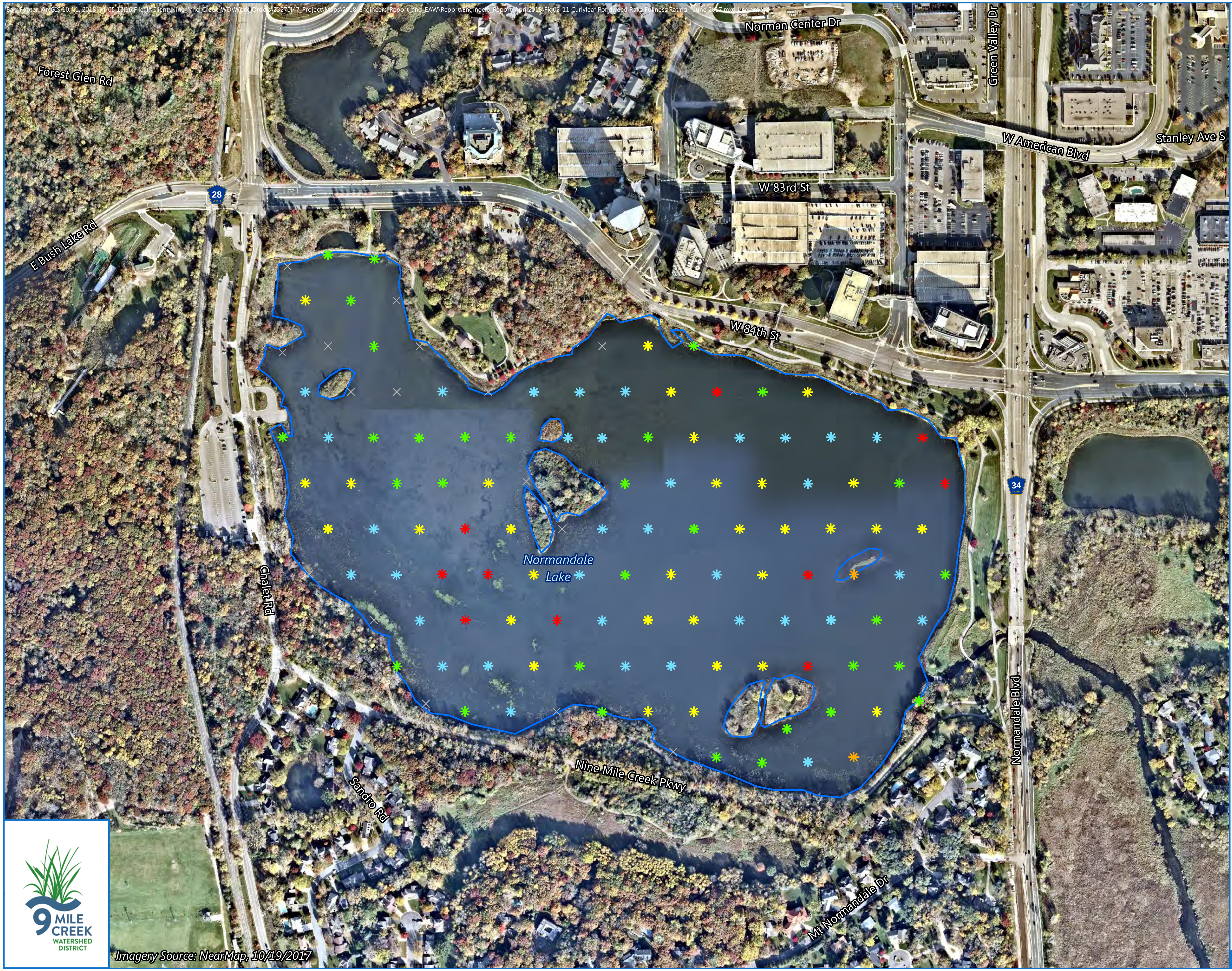


Figure 2-10 Relative abundance of aquatic plants in Normandale Lake, 2017

Two non-native aquatic invasive species (AIS) were observed in Normandale Lake in 2017, curly-leaf pondweed (*Potamogeton crispus*) and Eurasian watermilfoil (*Myriophyllum spicatum*). These non-native species are undesirable because they displace native species and create nuisance conditions in the lake. In 2017, curly-leaf pondweed grew abundantly and was extensive (**Figure 2-11**) in the lake. Curly-leaf pondweed comprised 29 percent of the lake's total aquatic plant biomass in the lake in June 2017. By August, the curly-leaf pondweed population was notably reduced, with the die-off and decomposition in June and July likely contributing to the low in-lake dissolved oxygen observed during these months.

Eurasian watermilfoil, a second non-native AIS, was observed at low levels in the lake during 2017. In June, it was observed at 2 percent of the monitoring locations. Eurasian watermilfoil currently grows abundantly in the South Fork of Nine Mile Creek immediately upstream from the lake. Because fragments of the plant naturally break off and are added to Nine Mile Creek multiple times each year and each fragment has the ability to grow into a new plant, the stream is the likely source of the current Eurasian watermilfoil infestation of the lake. Unless managed in the stream and lake, Eurasian watermilfoil could rapidly increase in abundance and extent in the lake creating nuisance conditions. Several metro area lakes have recently observed rapid increases in Eurasian watermilfoil resulting in nuisance conditions. For example, Lake Jane (Washington County, MN), observed an increase in Eurasian watermilfoil extent from 0.1 acres in 2012 to 69 acres in 2016 (VBWD 2017).



Curlyleaf Pondweek Rake Fullness Rating, June 2017

- Visual
- 1
- 2
- 3
- 4
- None Found
- Normandale Lake (Project Area)

N

400 0 400

Feet

CURLYLEAF PONDWEED RAKE FULLNESS RATING, JUNE 2017
Normandale Lake Engineer's Report
Bloomington, Minnesota

Figure 2-11

Figure 2-12a shows the lifecycle of curly-leaf pondweed, depicting growth of the plant before ice-out and die-off of the plant during early- to mid-summer. **Figure 2-12b** shows the dense growth of curly-leaf pondweed in Normandale Lake.

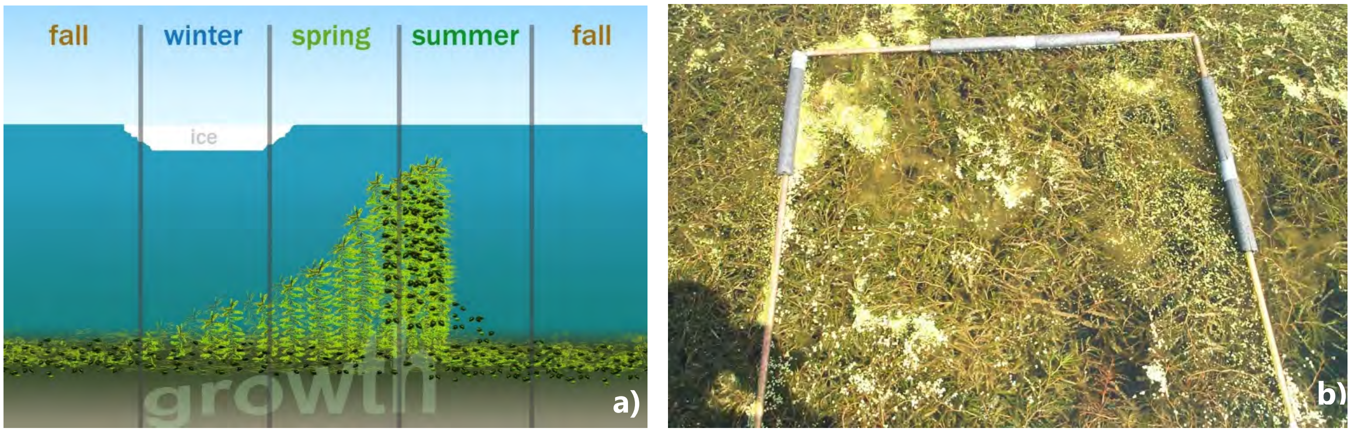


Figure 2-12 a) Curly-leaf pondweed life cycle, and b) dense growth of curly-leaf pondweed in Normandale Lake

Based on the 2017 plant survey, it is estimated that the total aquatic plant and filamentous algae wet biomass was 2.3 million pounds (1.03 million kilograms) in June and 1.7 million pounds (800,000 kilograms) in August (Barr, 2017). With the curyleaf pondweed die-off, other species such as filamentous algae and the non-attached floating species duckweed (*Lemna minor* and *Spirodela polyrhiza*) and common watermeal (*Wolfia columbiana*), filled the void left by curly-leaf pondweed.

The quality of aquatic plants in Normandale Lake has been steady since 2009 and has largely exceeded the Minnesota Department of Natural Resources (MDNR) Floristic Quality Index (FQI) goal (**Figure 2-13**). This suggests that there is a reasonably diverse population of native aquatic plants in the lake. However, the aquatic plant biomass survey conducted in 2017 demonstrates that most of the lake's biomass resides in coontail, elodea, curly-leaf pondweed, white water lily, and duckweed. For example, in August 2017 99.6 percent of the total lake mass could be accounted for by just four species. The relative percent mass of those four dominant species was: (1) coontail-38%, (2) elodea-41%, (3) white water lilly-17%, and (4) duckweed-3.6%. A more even distribution along with a diverse population of aquatic plants would benefit Normandale Lake. Note that curly-leaf pondweed was not one of the four most predominant species in August 2017 due to its early season die-off.

The abundance of coontail in Normandale Lake may provide a water quality benefit for the lake. Coontail releases allelochemicals which are substances that inhibit algae growth in the lake's water column—particularly blue-green algae (Korner et al. 2002, Gross et al. 2003, Wium-Anderson 1983). As noted previously, the lake's chlorophyll-*a* concentrations, a measure of the quantity of algae in the lake's water column, have generally been low relative to the amount of phosphorus in the lake. There are likely several factors that limit phytoplankton growth (measured as chlorophyll-*a*) including light limitation due to shading by the abundant aquatic plant population, nitrogen and phosphorus limitation. However, allelochemicals emitted by coontail may also inhibit algal growth in the lake, reducing chlorophyll concentrations and, therefore, improving its water quality.

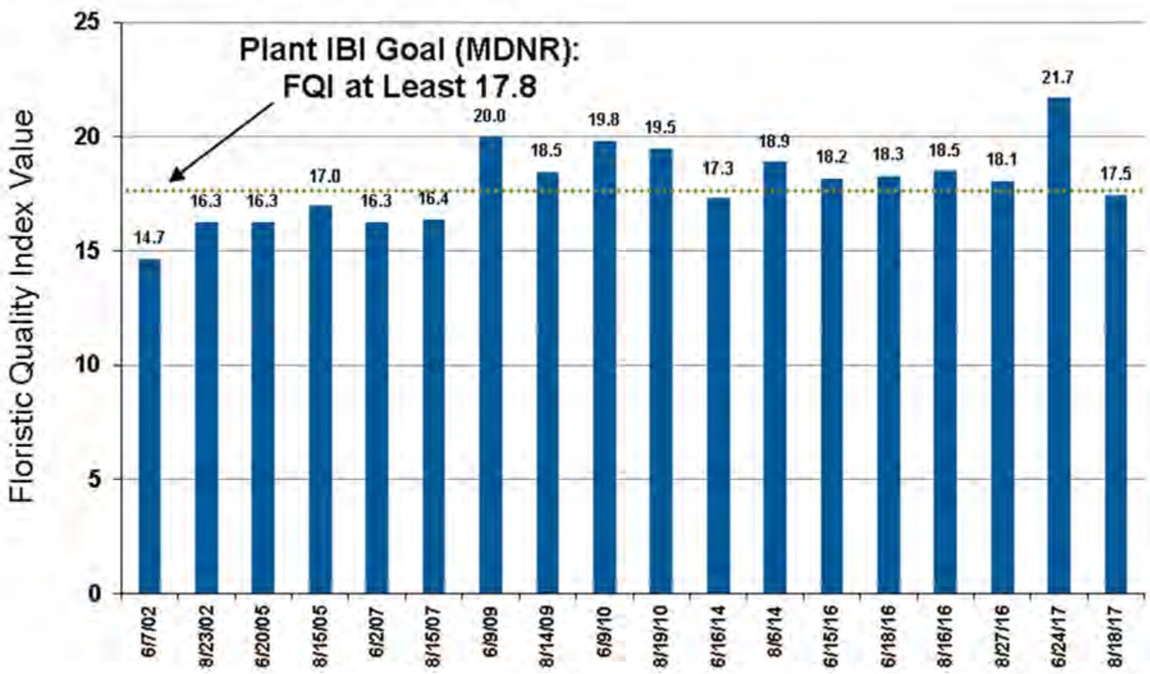


Figure 2-13 Floristic Quality Index values for Normandale Lake since 2002

2.4.2 Filamentous Algae

Filamentous algae are also present in Normandale Lake. Filamentous algae at the beginning of the open water season often begin growing on the bottom of lakes and move upward either with the growth of aquatic plants or by floating facilitated by gas bubble production. These species are often visible to residents as they float on the water surface or are attached to aquatic plants during the summer months. Three species of filamentous algae, *Pithophora (*horsehair algae), *Rhizoclonium hieroglyphicum* (filamentous green algae), and *Spirogyra* (filamentous green algae) were collected and identified in 2017. Additional information regarding the observed filamentous algae species is included in **Appendix E**.

2.4.3 Phytoplankton and Zooplankton

Phytoplankton, also called algae, are small aquatic plants naturally present in lakes, including Normandale Lake. Phytoplankton derive energy from the sun through photosynthesis and provide food for several types of aquatic organisms, including zooplankton, which are in turn eaten by fish. An inadequate phytoplankton population limits a lake's zooplankton population, and indirectly limit fish production in a lake. Excess phytoplankton can reduce water clarity, which can then make recreational use of a lake less desirable.

Depending upon the year and the month that sampling is conducted, the blue-green algae population in Normandale Lake can be a significant fraction of the total algae population. Blue-green algae are considered a nuisance algae because they are generally inedible for other aquatic organisms, generate expansive algal blooms, may be toxic to animals during large blooms, and can interfere with recreational uses of the lake. Excess phosphorus loads such as those seen in Normandale Lake stimulate blue-green and green algal growth. The warm growing conditions and release of dissolved phosphorus from the die-back of curly-leaf pondweed or anoxic sediment during July and August are particularly favorable to blue-green algae, and blue-green algae have a competitive advantage over the other algal species during this time. To date, monitored blue-green algae levels in Normandale Lake have remained below the World Health Organization's threshold for moderate health risk. In 2016, blue-green algae levels remained relatively low throughout the growing season and the algal community was generally dominated by green algae (Nine Mile Creek Watershed District, 2016).

Zooplankton are vital to the health of a lake ecosystem because they feed on the phytoplankton and are food themselves for many fish species. Zooplankton is also important to lake water quality. If present in abundance, certain groups of zooplankton (cladocera) can decrease the number of algae and improve water transparency within a lake. Between monitoring performed in 1990 and 2002, cladocera type zooplankton had nearly disappeared from Normandale Lake. One type of cladocera zooplankton in particular, Daphnia, is preferred by planktivorous fish (i.e. fish that eat zooplankton) and is considered especially desirable in lakes because of their large size and ability to consume large quantities of algae. Normandale Lake's population of Daphnia in particular was low during the monitoring period described in the UAA (Barr, 2005). In 2016, Daphnia was not observed in the lake and the cladocera observed in the lake were generally species that are small in size (Nine Mile Creek Watershed District, 2016).

2.4.4 Fishery

Based MDNR's lake classification system, Normandale Lake is classified as a Class 43 lake. Lakes in this category are not expected to be premier fishing lakes and are prone to winterkill (i.e. when below-ice dissolved oxygen becomes too low to support game fish). Eutrophic lakes, such as Normandale Lake, produce relatively large quantities of algae during summer months. After the algae die and settle to the bottom of the lake, their decomposition uses oxygen that would otherwise be available to the fish population. This problem becomes especially severe in the winter when ice cover on the lake prevents transfer of oxygen from the atmosphere to the water.

Fish species that are especially sensitive to low oxygen conditions are bluegills, sunfish, and largemouth bass. More tolerant species include bullheads, northern pike, and crappies. The last known fishery survey of Normandale Lake was conducted by the MDNR in 1992 (Schupp, 1992). At that time, northern pike, bluegill, and largemouth bass appeared to dominate the lake's fish population, indicating adequate dissolved oxygen in the water column. An updated survey of Normandale Lake's fishery, including carp, is planned for summer 2018.

3.0 Project Goals and Problem Assessment

3.1 Project Goals

As part of the 2017 *Nine Mile Creek Watershed District Water Management Plan*, NMCWD adopted the Minnesota lake eutrophication standards. These numeric standards for Minnesota Lakes (shown below) were adopted by the Minnesota Pollution Control Citizens' Board on December 18, 2007 and approved by the U.S. Environmental Protection Agency on June 16, 2008:

- Total Phosphorus $\leq$60 µg/L
- Chlorophyll-*a* $\leq$20 µg/L
- Secchi Disc $\geq$1.0 m

In addition to adopting the State lake eutrophication standards, as part of the 2017 *Nine Mile Creek Watershed District Water Management Plan* (2017 Plan), the NMCWD also 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 (NMCWD, 2017). While the District's UAA process has historically addressed a wide range of goals (e.g., water quantity, aquatic communities, recreational use, wildlife), the primary focus has been achievement of the water quality goals. With the 2017 Plan, the District emphasized several evaluation factors for holistic assessment of lake health, including water quality, aquatic communities, water quantity, wildlife habitat, and recreation (**Figure 3-1**). While numerical goals exist for some of these factors (e.g., MPCA water quality standards), other ecological lake health factors will be assessed without strict numerical goals (e.g., health of the aquatic plant communities).

Figure 3-1 NMCWD Holistic Lake Health Assessment Factors

3.2 Problem Assessment

Table 3-1 summarizes the issues in Normandale Lake, in relation to several of NMCWD's holistic lake health assessment factors. The table also describes the cause(s) of the issues and potential management options for consideration to improve lake health. The issues and their causes are described in further detail below. The lake management practices considered as part of this project are discussed further in Section 4.0.

Table 3-1 Summary of Issues and Potential Management Options

NMCWD Holistic Lake Health Assessment Factors	Issues	Causes	Potential Management Options
Water Quality	High phosphorus (>60 µg/L average summer concentration)	External and internal phosphorus loading	Whole lake alum treatment, upstream watershed BMP and lake management implementation.
	Potentially high phytoplankton	External and internal phosphorus loading	
Aquatic Communities	Invasive aquatic plants and limited plant diversity	Curly-leaf pondweed growth	Lake drawdown and chemical treatment of curly-leaf pondweed with Endothall
	Low dissolved oxygen	Coverage of the lake surface by aquatic plants, curly-leaf pondweed die-off	Aquatic plant harvesting, aeration (direct oxygen injection)
Recreational Use[1]	Smell—hydrogen sulfide	Coverage of the lake surface by aquatic plants, curly-leaf pondweed die-off	Aquatic plant harvesting, aeration (direct oxygen injection)
	Excessive aquatic plants and filamentous algae	External and internal phosphorus loading	Whole lake alum treatment, BMP implementation in upstream watershed.

[1] The NMCWD considers water quality, aquatic communities, and water quantity to be the three primary factors in assessing the ecological health of a lake. The NMCWD also considers how recreation and wildlife habitat affect and are affected by overall lake health.

3.3 External Phosphorus Loading

Stormwater from the large watershed tributary to Normandale Lake, much of which is untreated prior to reaching Nine Mile Creek, contributes significant phosphorus loading to the lake. Because summer average phosphorus concentrations in the lake often exceed the State's shallow lake standard, additional reductions in phosphorus loading to the lake from external (upstream) sources are desired. Reductions in external loading to Normandale Lake will be achieved through stream bank stabilization (e.g., Hopkins Stream Stabilization project and the ongoing Edina Stream Stabilization project), continued implementation of the NMCWD regulatory standards (through its permitting program), implementation of management strategies for upstream lakes, and construction of stormwater best management practices in the watershed tributary to Normandale Lake. Because existing external and internal phosphorus loads to Normandale Lake are currently very large, ongoing external phosphorus reduction efforts need to be combined with other measures to concurrently meet the NMCWD goals of improved water quality and health of the aquatic community.

Modeling conducted as part of NMCWD's 2016-2017 lake analysis concluded that Normandale Lake already acts as a significant sink for phosphorus, meaning, phosphorus is removed by aquatic plants, phytoplankton growth and settling, and by solids settling, and disturbance of these phosphorus removal mechanisms can lead to higher phosphorus concentrations in the lake (Barr, 2017). While reduced phosphorus loading will likely have the effect of reducing macrophyte growth, this also means less phosphorus removal by plants. The outcome is that phosphorus concentrations in the water column of Normandale Lake are reduced minimally with external phosphorus load reduction.

3.4 Internal Sediment Phosphorus Loading

Review of observed data and modeling results from NMCWD's 2016-2017 lake analysis confirm that internal phosphorus loading can be a significant source of phosphorus to Normandale Lake during summer months (Barr, 2017). Observed temperature and dissolved oxygen profiles in Normandale Lake throughout the summer months indicate that the lake mixes periodically, but less than would be expected for a shallow lake. And dissolved oxygen levels at the lake bottom are often low. As a consequence of low oxygen, phosphorus is released from the sediments and builds up in lake-bottom waters until transported to the entire water column when wind causes lake circulation or as fall approaches and mixing begins to occur. Controlling or reducing the release of phosphorus from lake sediments will reduce the phosphorus available for aquatic plants, filamentous algae, and other phytoplankton.

3.5 Curly-leaf Pondweed Growth

Normandale Lake has been experiencing increasing densities of invasive curly-leaf pondweed. As a result of the plant's lifecycle, the plant can be a source of internal phosphorus loading during summer months and it can cause severe dissolved oxygen depletion when it dies off and decays in June and July. Curly-leaf pondweed turions— dormant vegetative propagules that function as seeds—germinate in autumn. By May, the plants are well-established, making it difficult for native plants to compete effectively. In mid- to late-June, the dense mass of pondweed dies, and its decay releases phosphorus into the lakes system.

Curly-leaf pondweed can also be detrimental to a lake's native aquatic plant community, fish habitat and can hinder overall recreational enjoyment. Due to its early germination, the plants are often well-established by early-spring, making it difficult for native plants to compete effectively. A dense curly-leaf population can hinder gamefish growth, with small fish hiding in the dense aquatic plant growth, making it difficult for larger fish, such as bass, to locate and prey upon the small fish they need for food. Curly-leaf pondweed can also diminish recreational opportunities by restricting boat or canoe movement, reducing aesthetics, and fueling algal blooms.

3.6 Low Dissolved Oxygen

Review of observed data and modeling results from NMCWD's 2016-2017 lake analysis indicate that Normandale Lake suffers from low dissolved oxygen concentrations during the summer months. The total average water column dissolved oxygen concentration in the summer in 2010 was 4.7 mg/L and in 2016 it was 2.3 mg/L. The State of Minnesota standard for dissolved oxygen is 5.0 mg/L.

While there is some uncertainty as to why the dissolved oxygen concentrations are so low in Normandale Lake, it is theorized that the abundant filamentous algae, coontail, and curly-leaf pondweed floating on the lake surface throughout much of the summer inhibit the oxygen transfer at the lake surface during summer months. The die-off of curly-leaf pondweed in mid-summer can create a significant oxygen demand, also lowering oxygen concentrations throughout the water column.

Low dissolved oxygen levels place additional stress on certain fish species (e.g., northern pike) and increase phosphorus release from lake-bottom sediments.

3.7 Recreational Use

Information gathered from interested residents and park users indicates that recent conditions in Normandale Lake have hindered recreational opportunities. The dense aquatic plant and filamentous algae populations can restrict boat or canoe access and movement. The abundant filamentous algae, coontail, and curly-leaf pondweed floating on the lake surface can inhibit oxygen exchange and generate hydrogen sulfide— causing an unpleasant odor for park users. The filamentous algae can also significantly deteriorate the aesthetic appeal for lake users and nearby residents and businesses.

4.0 Evaluated Lake Management Practices

The lake management practices considered as part of this project are part of a holistic approach to improving the water quality and ecological health of Normandale Lake. The practices are intended to reduce internal phosphorus loading, improve the native aquatic plant community, and increase the concentrations of dissolved oxygen in the water column, helping the lake's fishery, reduce foul odors often produced during the summer months, and improve recreational use of the lake.

As identified in **Table 3-1**, the lake management practices considered as part of this project include:

- Lake Drawdown
- Chemical Treatment of Curly-leaf Pondweed
- In-lake Alum Treatment
- Aquatic Plant Harvesting (2-3 year test)
- Aeration (direct oxygen injection)

These lake management practices are discussed in further detail in the following sections.

4.1 Lake Drawdown

One way to control curly-leaf pondweed, and to a lesser extent internal phosphorus release from sediment, is to draw down Normandale Lake to allow the lake-bed to freeze over the winter. Curly-leaf pondweed primarily propagates through production of dormant vegetative propagules called turions. Turions are produced in late spring, remain dormant in sediment through the summer, and germinate under cooler water conditions in the fall. However, a winter freeze can kill the turions, thus disrupting curly-leaf pondweed's reproductive cycle. As such, a drawdown of Normandale Lake is being considered as the first of a phased process to reduce the lake's curly-leaf pondweed population.

Several other waterbodies in the region have used drawdown as a means to achieve water quality objectives. A successful shallow lake restoration was conducted in Big Muskego Lake in southeast Wisconsin using a combination of several in-lake treatments, including an 18-month drawdown period. This drawdown resulted in the consolidation of sediments in addition to allowing for the removal of rough fish populations and reestablishment of native aquatic plant species. Sediment consolidation was desired for the reduction of future sediment resuspension, although the extent of consolidation was limited by rain and flood events during the drawdown period (James and Barko, 1997).

The NMCWD completed a drawdown on Southwest and Northwest Anderson Lakes in Eden Prairie in fall 2008. The drawdown was conducted using electrical pumps to dewater a significant portion of each lake in an effort to significantly reduce and potentially eliminate curly-leaf pondweed from the two lakes. The goal of the project was to expose as much of the lake sediment as possible to freezing conditions during the 2008-2009 winter season and chemically treat any remaining open water areas. Freezing the lake sediment was expected to effectively kill the young curly-leaf pondweed plants and the curly-leaf pondweed turions. Monitoring conducted in 2015 found several floating fragments of curly-leaf pondweed in Southwest Anderson Lake, but rooted curly-leaf pondweed plants were not. In Northwest

Anderson Lake, curly-leaf pondweed was present but rare in the east end of the lake and was not found in the west portion of the lake. Overall the drawdown effort has remained successful in controlling curly-leaf pondweed.

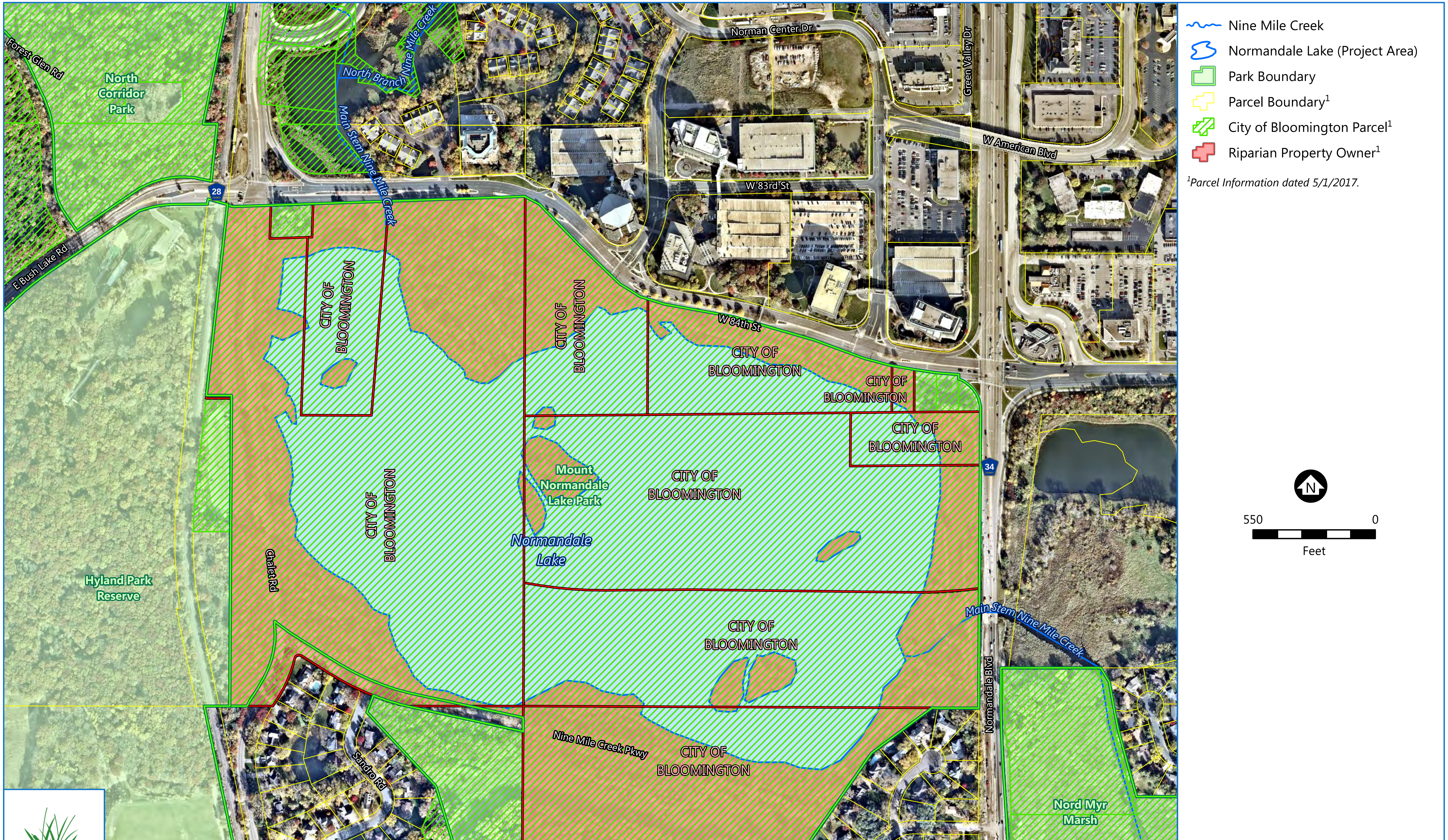
Three Rivers Park District also performed a successful lake level drawdown on Cleary Lake in Scott County, Minnesota to control curly-leaf pondweed (personal communications with John Barton). The initial Cleary Lake drawdown was not a complete drawdown because of a restriction in the outlet channel which limited the volume of water that would flow out of the lake by gravity. As a result, the initial drawdown was only effective at controlling curly-leaf pondweed over the portions of the lake bed exposed to freezing conditions. Therefore, the Park District did a complete drawdown the following year by modifying the outlet channel and installing temporary pumps to completely dewater the lake. The Park District has indicated the drawdown was extremely effective at controlling curly-leaf pondweed.

4.1.1 Drawdown Permitting

Conducting a lake drawdown will require approval from the MDNR through a Work in Public Waters Permit. Under Minnesota Statute section 103G.408, 75 percent of the riparian landowners must authorize a drawdown. The City of Bloomington owns all the property directly around Normandale Lake and has indicated it is supportive of the lake drawdown for curly-leaf pondweed control. **Figure 4-1** identifies the property owners riparian to Normandale Lake. Water levels in the wetland area between West 84th Street and Interstate 494 are also controlled by the Normandale Lake outlet. A temporary water control structure will be installed between the wetland area north of West 84th Street and the lake to prevent lowering of the water levels in this wetland area during the lake drawdown.

NMCWD will obtain the necessary rights to use property owned by the City of Bloomington in a cooperative agreement between the two entities for the project. No other acquisition of land-use rights or fee ownership of property will be necessary for the project.

Permits/approvals for the drawdown will also be required from the City of Bloomington, and may be required from the MPCA and the NMCWD (depending on dewatering method). The USACE has indicated that the lake drawdown itself can be complete without modification to the existing permit (see correspondence in Appendix C). However, installation of a larger bypass pipe would be considered placement of new fill in Normandale Lake and would likely require USACE permitting, either under the nationwide general permit or through the existing Section 404 permit for Normandale Lake.



RIPARIAN PROPERTY OWNERS
Normandale Lake Engineer's Report
Bloomington, Minnesota

Figure 4-1

Barr Footer: ArcGIS 10.6, 2018-04-12 10:01 File: I:\Client\Nine_Mile_Creek_WD\Work_Orders\23270I47_Project\Maps\2018_Engineers_Report_and_EAW\Report\Engineers_Report_April2018\Fig04-1 Riparian Property Owners.mxd User: mbs2

4.1.2 Lake Drawdown Analysis

A predictive spreadsheet water balance model was created to evaluate several drawdown options in terms of how quickly Normandale Lake can be drawn down in the fall, how likely the lake will remain drawn down over winter, and how quickly lake levels can rebound in the spring. Estimating the drawdown time for Normandale Lake is challenging due to baseflow and stormwater runoff contributions of Nine Mile Creek that vary based on season and precipitation events. Daily inflows to the lake were estimated based on correlations between measured precipitation and observed flows at the automated stream monitoring stations upstream of the lake and P8 model estimates for the runoff from the watershed area between the WOMP stations and the lake. Daily outflows from the lake were calculated using a rating curve that accounts for the existing outlet structure and tailwater impacts from the creek downstream of the outlet. The water balance model was calibrated and validated using water surface elevations observed in 2015 and 2016. Once the model was calibrated and validated, 50 years of precipitation data (1966-2016) were input into the model to predict the water surface elevations in the lake over a wide range of actual climatic conditions. The model was also set-up to predict the lake responses to the various drawdown options by allowing the user to vary the size of drawdown pipe or pump as well as the dates that the pipe is open or pump is turned on.

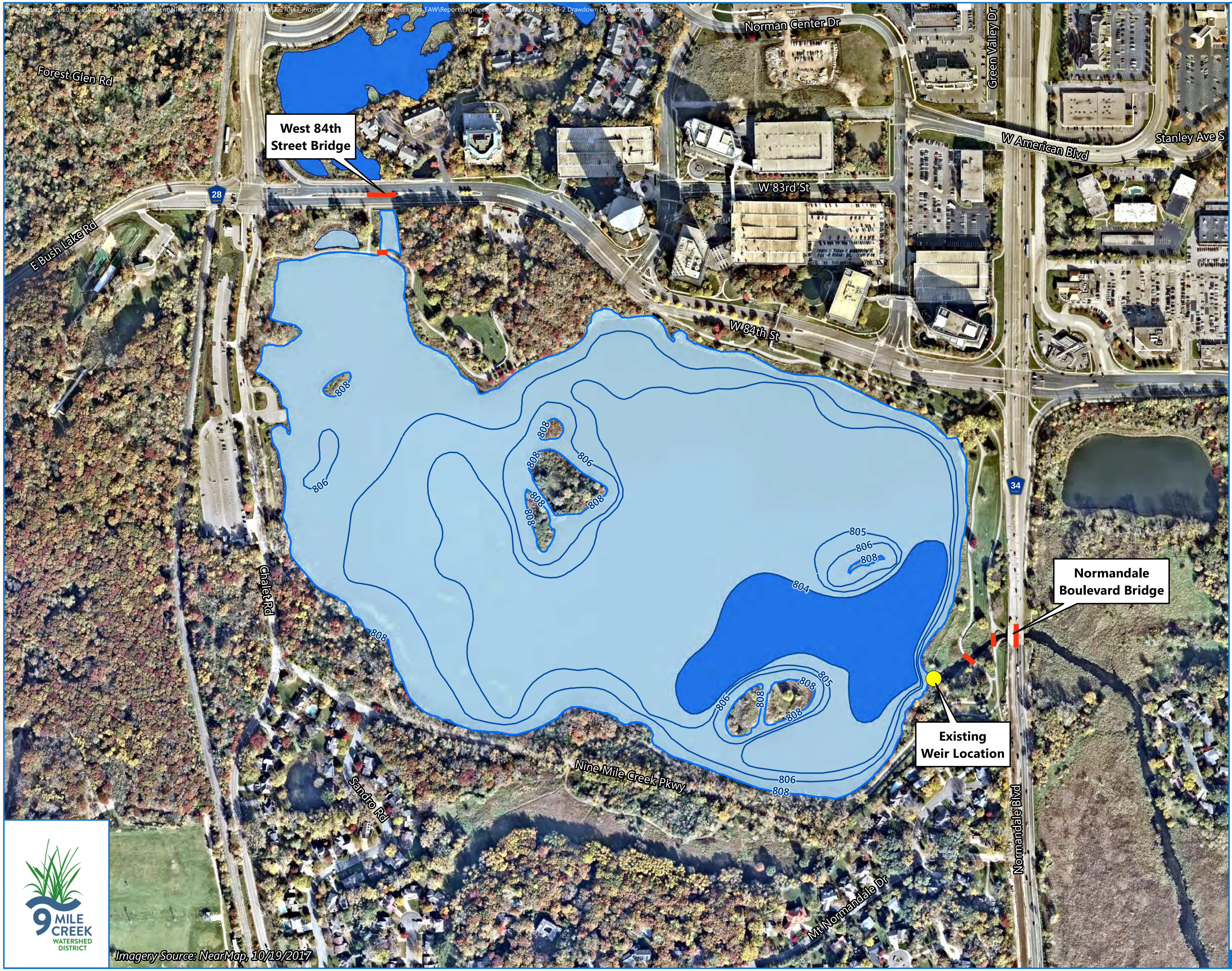
A lake level drawdown goal of 804 feet was used for the drawdown feasibility analysis. **Figure 4-2** shows the approximate lake bathymetry, as well as the extent of open water within the lake at a drawdown elevation of 804 feet.

4.1.2.1 Drawdown Methods

Four dewatering options were ultimately evaluated for the lake drawdown: 1) use the existing 18-inch gravity bypass outlet; 2) increase the discharge capacity of the bypass outlet pipe to that equivalent to a 30-inch pipe; 3) use the existing 18-inch bypass outlet in combination with supplemental pumping, and 4) use a temporary pump and the existing bypass to draw the lake down in late-summer, then install a larger bypass outlet to maintain the lake drawdown (**Figure 4-3**). These options are described in further detail in the following sections.

Drawdown Option 1 – Use Existing Bypass Outlet

The existing outlet for Normandale Lake includes an 18-inch bypass pipe that was installed when the lake was originally constructed. Drawdown Option 1 would involve opening a sluice gate to utilize the existing 18-inch bypass. The original 18-inch sluice gate appears to be in poor condition and may need significant repair and possibly replacement. The existing 18-inch outlet pipe has the potential to dewater Normandale Lake to an elevation of roughly 803.4 feet; the lake will not drawdown all the way to the bypass pipe invert elevation (800.5) due to the downstream tailwater impacts. Under baseflow conditions (no precipitation or snowmelt events) approximately 690 acre feet (224.8 million gallons) will be discharged during the drawdown at an average rate of 4,000 gallons per minute (approximately 9 cubic feet per second) over approximately 38 days.



Existing Weir Location

Existing Bridge or Culvert

Normandale Lake (Project Area)

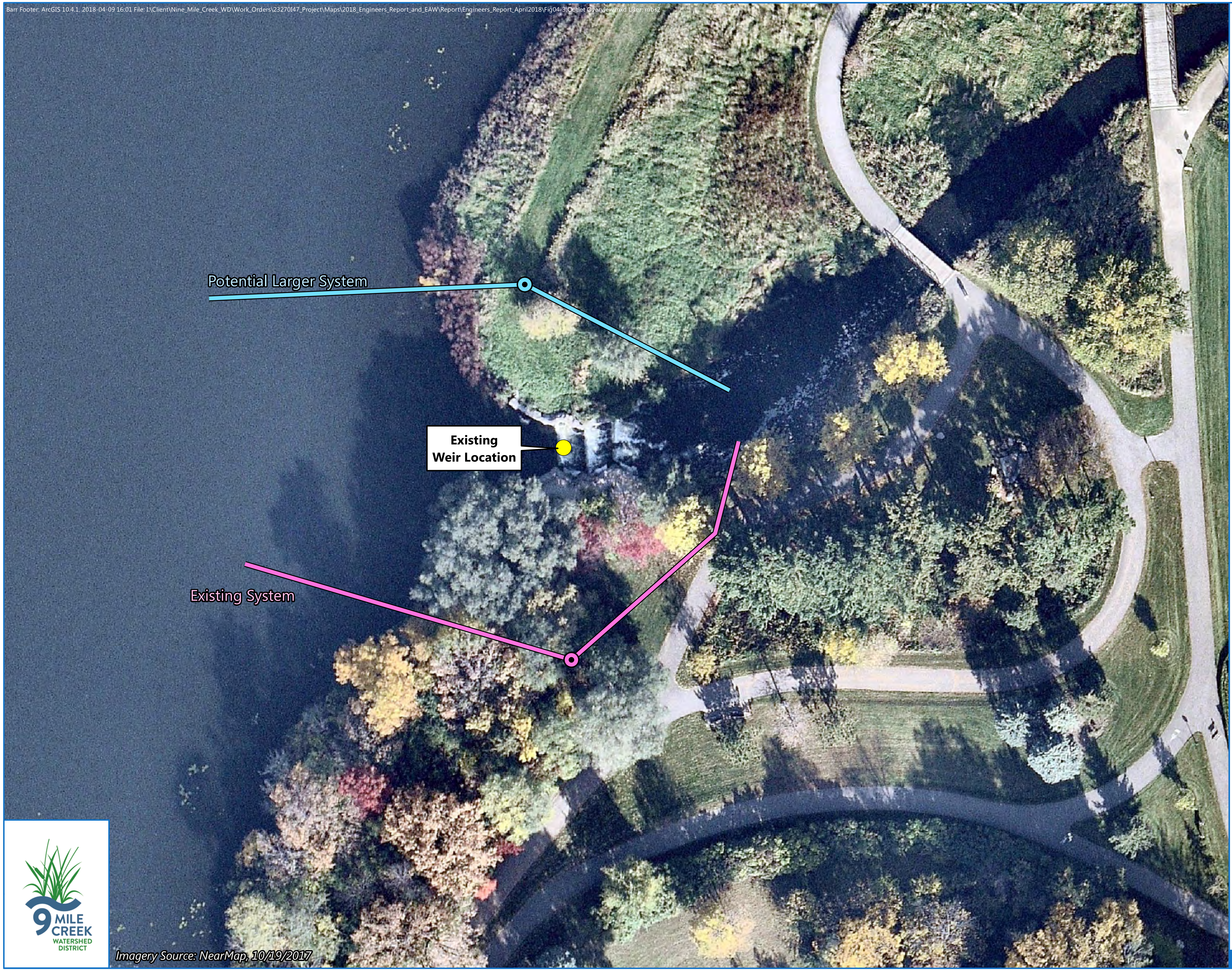
Open Water Extents to Existing Controlling Elevation*

Open Water Extents after Proposed Draw Down*

*Note:
Existing controlling elevation at weir is 808.0 Feet.
Proposed drawdown elevation is 804.0 to 805.0 feet.
Elevations provided in NAVD88 vertical datum.

DRAWDOWN OVERVIEW
Normandale Lake Engineer's Report
Bloomington, Minnesota

Figure 4-2



Existing Weir Location

Location of Existing Bypass System

Manhole

Pipe

Potential Location of New Bypass System

Manhole

Pipe

N

40 0 40

Feet

OUTLET OVERVIEW
Normandale Lake Engineer's Report
Bloomington, Minnesota

Figure 4-3

Drawdown Option 2- Replace Existing Bypass Outlet with Larger Bypass Outlet

Drawdown Option 2 consists of increasing the discharge capacity of the bypass outlet pipe to that equivalent to a 30-inch pipe to reduce the amount of time needed to draw down Normandale Lake and decrease potential impacts of rainfall or snowmelt events during the drawdown period. The existing 18-inch diameter pipe and sluice gate would be replaced with a 30-inch pipe and sluice gate. The pipe would extend into the deepest spot in Normandale Lake and convey water from the lake, under the embankment and directly into Nine Mile Creek downstream of the existing outlet weir. In addition to drawing the lake down much more rapidly in the fall and limiting the impact of precipitation or snowmelt events during winter months, this option offers the potential to draw the lake down to an elevation lower than the existing bypass pipe due to reduced energy losses due to friction (802.4 versus 803.4). Under baseflow conditions (no precipitation or snowmelt events) approximately 400 acre-feet (130.3 million gallons) will be discharged during the drawdown at an average rate of 15,100 gallons per minute (approximately 34 cubic feet per second) over approximately 6 days.

Installation of a larger bypass pipe would provide permanent infrastructure for future drawdowns, if this practice is deemed effective in managing and improving the aquatic plant community in Normandale Lake. A drawback to Option 2 is that it would trigger additional permitting that could impact the feasibility of a fall-2018 lake drawdown. Option 2 is expected to require USACE permitting, either under the nationwide general permit or through the existing Section 404 permit, to place the new pipe into Normandale Lake. This introduces an approximately two-month permit review into the schedule (assuming coverage under the nationwide general permit) as the USACE permit would be required prior to construction of the larger bypass.

Drawdown Option 3 – Use Existing Bypass Outlet with Supplemental Pumping

Drawdown Option 3 consists of increasing the discharge capacity by using a temporary pump to reduce the amount of time needed to draw down Normandale Lake and decrease potential impacts of rainfall or snowmelt events during the drawdown period. A diesel-powered pump with approximately 5,000 gallons per minute (10 cubic feet per second) capacity would be temporarily installed on the east side of the lake. The inlet pipe to the pump would extend into the deepest spot in Normandale Lake, conveying lake water over the embankment and discharging it directly into Nine Mile Creek downstream of the existing outlet weir. A temporary structure would be constructed to secure and protect the pump while it is on site. This option assumes that the existing 18-inch bypass would also be utilized. This option has the potential to draw the lake down to an elevation of 802.3 feet, an elevation lower than using the existing bypass (803.4).

There would be a considerable amount of operation cost with this option as the pump would likely need to be checked several times a week to make sure it is running properly and has enough fuel. The supplemental pumping provides capacity to draw the lake down much more quickly in the fall and limit the impact of precipitation or snowmelt events during the freezing period. Under baseflow conditions (no precipitation or snowmelt events) approximately 455 acre-feet (148.3 million gallons) will be discharged during the drawdown at an average rate of 8,600 gallons per minute (approximately 19 cubic feet per second) over approximately 12 days.

Drawdown Option 4 – Install Larger Bypass Outlet with Initial Temporary Pumping and Existing Bypass

A drawback to installing a larger bypass pipe is expected to require a USACE permit to place the pipe into Normandale Lake, introducing a permit review that would likely impact the timing of a late-summer 2018 drawdown. Drawdown Option 4 consists of using a temporary pump and the existing bypass to draw the lake down in late-summer, then installing a larger bypass outlet upon USACE permit approval to maintain the lake drawdown and decrease potential impacts of rainfall or snowmelt events during the drawdown period. A new 30-inch pipe and sluice gate would be installed on the north side of the existing outlet structure. The pipe would extend into the deepest spot in Normandale Lake and convey water from the lake, under the embankment and directly into Nine Mile Creek downstream of the existing outlet weir. The existing 18-inch bypass pipe would be abandoned following installation of the new pipe.

Option 4 would provide permanent infrastructure for potential future drawdowns, while also allowing the drawdown to begin in late-summer (with the temporary pump) to minimize impacts to the turtle population (see Section 4.1.2.2 below). Upon receiving the necessary USACE permit (or permit modification), installation of the 30-inch pipe would proceed (the lake drawdown is covered under the existing USACE permit). Preliminary estimates indicate that one to three months of temporary pumping would be necessary, depending on the timing of USACE permitting and installation of the larger bypass pipe.

4.1.2.2 Drawdown Timing

The amount of time for Normandale Lake to draw down to its target elevation of 804 feet is dependent on several factors, including inflows from Nine Mile Creek and discharge capacity of the dewatering system. Under baseflow conditions (no precipitation or snowmelt events), the existing 18-inch bypass pipe (Option 1) will draw down the lake in approximately 38 days, whereas, increasing the bypass pipe discharge capacity (Option 2) will draw down the lake in approximately 6 days, and adding a 10-cfs pump (Option 3) will draw down the lake in approximately 12 days. Following precipitation or snowmelt events, lake levels may rebound under each of the options, but Options 2 and 3 will draw the lake back down to the target elevation much more rapidly than Option 1. Option 4 would perform similarly to Option 3 with regard to drawdown timing.

The MDNR has indicated a preference for the lake to be drawn down by September 15 to minimize impacts to the area's turtle community as it prepares for winter hibernation. The predictive spreadsheet water balance model was used to evaluate the drawdown options (Options 1 – 3), assessing the likelihood of meeting the DNR's September 15 drawdown guideline if the drawdown begins on August 15, based on a 50 year time period representing a wide range of climate conditions. Starting the drawdown earlier than August 15 had minimal impact on meeting the September 15 drawdown guideline or the overall effectiveness of a fall drawdown since summer precipitation events tend to fill the lake back up.

Figure 4-4 shows the likelihood (% of years modeled) of drawing the lake down to an elevation of 804 feet on a given date for each of the drawdown options, based on the predictive water balance model. The modeling shows that the existing 18-inch bypass does not draw the lake down to the elevation of

804 feet by September 15 in any of the 50 modeled years and draws the lake down by December in only 50 percent of the years modeled. On the other hand, increasing the bypass pipe discharge capacity to that of a 30-inch pipe or adding a 10 cfs pump greatly improves the likelihood of drawing the lake down by September 15. Both of these options draw the lake down by September 15 in approximately 70 percent of the modeled years and draw the lake down by early-December in every modeled year. Under all three options, lake levels occasionally bounce back up during the fall in response to rainfall events. However, increasing the bypass pipe discharge capacity to that of a 30-inch pipe or adding a 10 cfs pump greatly decreases the amount of time it takes for the lake to draw back down.

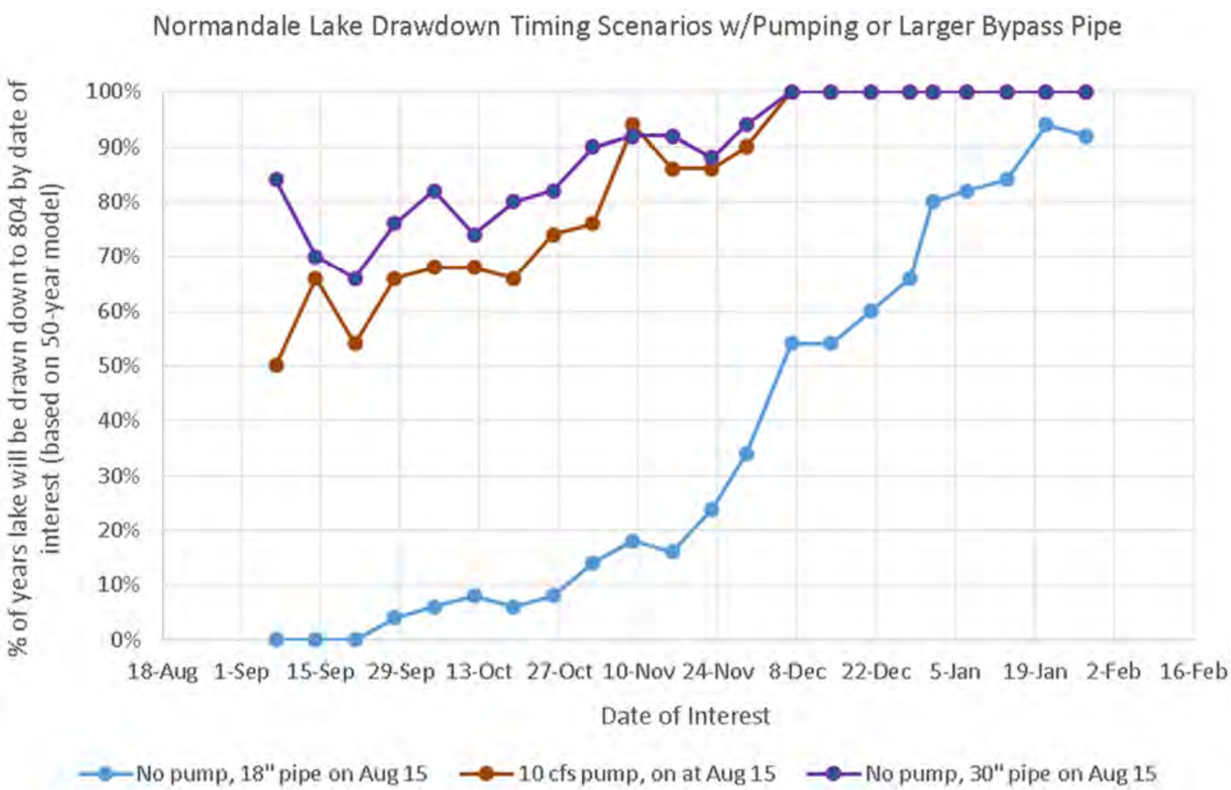


Figure 4-4 Fall Drawdown Effectiveness Based on August 15 Start Date

4.1.2.3 Maintaining Winter Drawdown Conditions

The lake drawdown will allow much of the lake-bed to freeze over the winter. Maintaining the drawdown over the winter months is important to maximize the extent to which and amount of time the sediments are frozen. Rainfall or snowmelt events do occasionally happen during the winter months and the resulting increased inflows from Nine Mile Creek can cause the lake level to quickly bounce up. The predictive water balance model was used to evaluate the likelihood of maintaining low lake levels during the months of December through February for each of the evaluated drawdown options, based on a 50-year time period representing a wide range of climate conditions. **Figure 4-5** shows the percentage of years that the drawdown target elevation of 804 feet was exceeded at least once during a given month due to a rainfall or snowmelt event. Model results indicate that lake levels are highly likely to rebound above the target elevation of 804 feet using the existing bypass (Option 1), whereas lake levels are much more likely remain below the target elevation with increasing the bypass pipe discharge capacity to that of a 30-inch pipe (Option 2) or adding a 10 cfs pump (Option 3). The pumping option performed the best since it is not tailwater dependent and can remove water from the lake at a faster rate at low water elevations than either of the two gravity flow options.

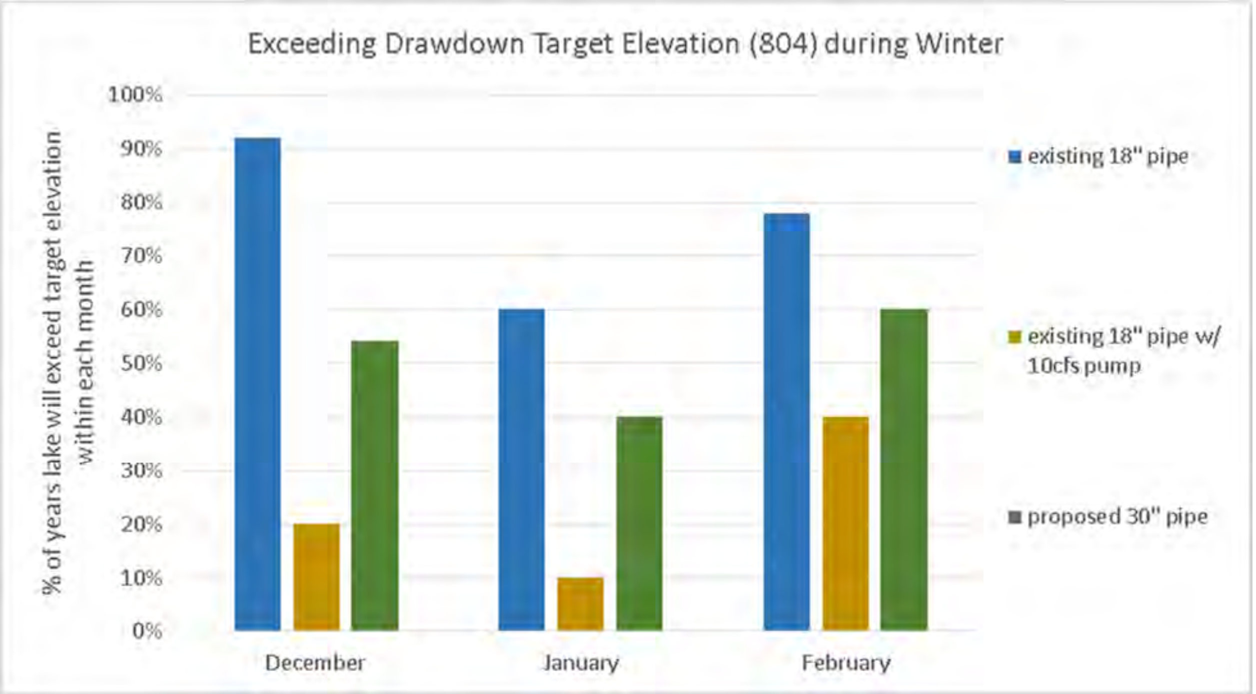


Figure 4-5 Effectiveness of maintaining drawdown conditions during winter months

4.1.2.4 Spring Lake Level Rebound

The predictive water balance model was used to evaluate the amount of time to refill the lake once the pumping and/or bypass are ceased, based on data from a 50-year time period representing a wide range of climate conditions. In general, the lake will refill relatively quickly (30 days under baseflow conditions and 21 days on average) in the spring from snowmelt and rainfall events because the lake has a large tributary watershed area that is nearly fully developed. **Figure 4-6** shows the likelihood of the lake rebounding to elevation 808 by a given date depending on when the drawdown operation ceases. These scenarios were evaluated to ensure enough time is provided for the lake to refill in order to conduct early-spring herbicide treatments (discussed below) while the water temperature is between 55-60°F (see Section 4.2). Based on the 50 years modeled, the lake will refill in less than 4 weeks regardless of when the drawdown operation stops.

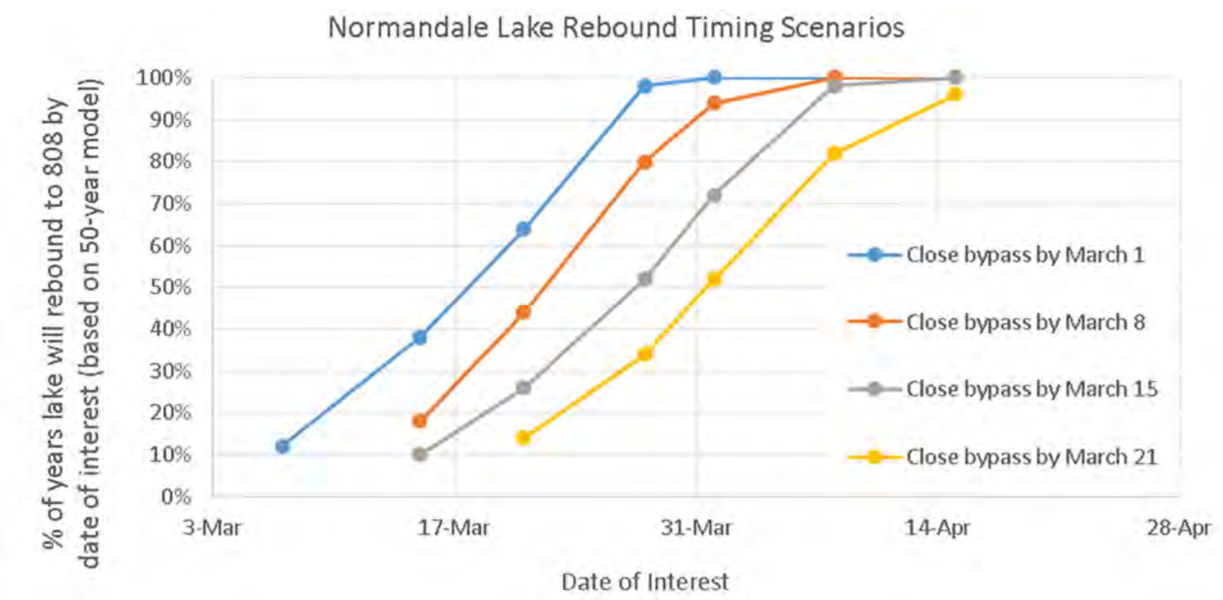


Figure 4-6 Likelihood of the lake refilling depending on when drawdown operation ceases

4.1.3 Drawdown Cost Comparison

Planning-level opinions of construction cost have been developed for the evaluated drawdown methods. The estimated costs are summarized in Table 4-1. More detailed cost estimates for the four improvement alternatives are provided in **Appendix F**. The opinions of cost for the lake drawdown options include an expected accuracy range (-20 percent to +40 percent), based on the current extent of project definition, wide-scale use of parametric models to calculate estimated costs (i.e., making extensive use of order-of-magnitude costs from similar projects or proposals), and project uncertainty.

4.1.4 Other Drawdown Considerations

With either the installing larger bypass pipe (Option 2) or the use of supplemental pumping (Option 3) for drawdown, additional factors must be considered. As discussed, Option 2 is expected to require a USACE permit to place the new pipe into Normandale Lake, introducing an approximately 2-month (or longer) permit review into the schedule as the USACE permit would be required prior to construction. In addition, Option 2 requires active construction activity as opposed to Option 3. Given the permitting timeline followed by time needed for pipe installation, Option 2 may hinder the ability for the project to begin drawdown in advance of the September 15, 2018 turtle hibernation date. Options 2 and 4 would require periodic maintenance to maintain integrity of the new bypass structure after completion of the project (active drawdown); presumably by the City of Bloomington. Details of post-project maintenance will be determined as the project develops.

Supplemental pumping (Option 3) will require construction of a temporary enclosure to store the pump, minimizing the potential for vandalism. Pumping over winter months introduces the potential for complications related to flash freezing, frazil ice, etc. The pump would need to be checked daily in times of extreme cold to ensure it is functioning properly. The pump would operate on diesel fuel and would need to be refueled several times a week. It is expected that diesel fuel would be stored on-site to assist in pump refueling efforts and that the storage tank would also need to be refueled periodically and secured.

Table 4-1 Summary of estimated costs for lake drawdown options

	Option 1 Existing Bypass	Option 2 Replace Existing Bypass with Larger Bypass	Option 3 Existing Bypass with Supplemental Pumping	Option 4 Install Larger Outlet with Initial Temporary Pumping and Existing Bypass[1]
Mobilization/Demobilization	$7,500	$19,000	$27,500	$28,000
Temporary Water Level Control (wetland area north of W 84th Street)	$20,000	$20,000	$20,000	$20,000
Maintenance (repair existing bypass, as needed)	$25,000	-	$25,000	$25,000
Pipe Installation	-	$137,000	-	$131,000
Restoration	-	$9,000	-	$9,000
Pump Rental/Set-up	-	-	$63,000	$18,000
Pump Operation	-	-	$49,000	$14,000
Pump Fuel	-	-	$77,500	$22,000
Temporary Structure	-	-	$10,000	$10,000
Turtle Fencing	$30,000	$30,000	$30,000	$30,000
Subtotal	**$82,500**	**$215,000**	**$302,000**	**$307,000**
Engineering Design and Construction Administration (30%)	$25,000	$64,000	$61,000[2]	$77,000[3]
Legal (5%)	$4,000	$11,000	$15,000	$15,000
Permitting (5%)	$4,000	$11,000	$15,000	$15,000
Total	**$115,500**	**$301,000**	**$393,000**	**$414,000**
Low Range (-20%)	$92,000	$241,000	$314,000	$331,000
High Range (+40%)	$162,000	$421,000	$550,000	$579,000

[1] Preliminary estimates indicate that one to three months of temporary pumping would be necessary, depending on the timing of USACE permitting. Cost estimate assumes two months of pumping (August 15 through October 15). The total estimated project cost ranges from $374,000 to $454,000 based on a range of one to three months of pumping.

[2] Engineering design (10%) and construction administration (10%) costs were assumed to be a total of 20% of the subtotal, versus 30%, due to a reduced level of design and construction observation effort required for the temporary supplemental pumping scenario.

[3] Engineering design (10%) and construction administration (15%) costs were assumed to be a total of 25% of the subtotal, versus 30%, due to a reduced level of design effort required for the temporary supplemental pumping portion of the project.

4.2 Herbicide Treatment

While drawdown controls curly-leaf pondweed through destroying turions, herbicide treatment is a management method that targets actively-growing curly-leaf pondweed. Once the lake has refilled after the drawdown, herbicide treatment with Endothall, a curly-leaf pondweed-selective herbicide, was considered to control the remaining curly-leaf pondweed. Research has shown that Endothall is most effective when applied in the spring when the water temperature is approximately 55-60ºF, and when a dose of 1mg/L is sustained for at least 3 days (Poovey et al. 2002). Since curly-leaf pondweed's life cycle primarily occurs during winter, applying Endothall in early spring removes curly-leaf pondweed during a time in which native plant species are seasonally suppressed. Endothall would be applied from a treatment boat or barge and, therefore, would require the lake to be restored back to its normal elevation of 808 feet prior to treatment.

Due to the influence of inflow from Nine Mile Creek, maintaining the appropriate concentration of Endothall in the lake for long enough to kill curly-leaf pondweed (3 days) is challenging – the creek deposits untreated water into the lake, and then carries some level of treated water with it as it leaves the lake. To mitigate this effect, the western third of Normandale Lake would be treated at a higher dose than the remainder of the lake (from 1.5 mg/L to 5 mg/L, depending on rate of inflow, rather than 1 mg/L). Normandale Lake would be treated when Nine Mile Creek inflows are approximately 5 to 13.5 cfs. Modeling indicates that applying this dosage at the given flow rates allows the concentration of Endothall across Normandale Lake to remain at 1 mg/L for at least 3 days following the treatment, long enough for curly-leaf pondweed to be controlled. To insure that the herbicide is applied prior to the start of the native plant growing season, the temperature of Normandale Lake will be measured daily from shortly after ice-out until and including the day of herbicide treatment. The Endothall will be applied before the average water column temperature reaches 60 °F.

The NMCWD Anderson Lakes water quality improvement projects showed that two to five years of annual Endothall treatment were required to effectively control curly-leaf pondweed. As such, Endothall treatment of Normandale Lake is expected to be performed annually for two to five years.

A planning-level opinion of cost for herbicide treatment at Normandale Lake estimates that the treatment would cost approximately $510,000, for a total of five annual whole-lake treatments and associated monitoring activities. Five successive years of treatment may not be necessary, and will be determined based on monitoring results. A detailed cost estimate for this lake management practice is provided in **Appendix F**.

After the successive lake-wide Endothall treatments, it is possible that some small areas of curly-leaf pondweed may be observed in the lake. If untreated, curly-leaf pondweed could rapidly increase in abundance and extent and attain pre-treatment growth conditions. Hence, ongoing lake maintenance may be needed, by treating any remaining areas of curly-leaf pondweed, to prevent a resurgence of curly-leaf pondweed in the lake.

4.2.1 Herbicide Treatment Permitting

Conducting an Endothall treatment will require modification of the existing USACE permit to allow for whole-lake treatment as the existing permit condition excludes vegetation control in the western half of the lake. Herbicide treatment would also require approval from the City of Bloomington.

The MDNR will require an Invasive Aquatic Plant Management Permit and a letter of variance to allow treatment of more than 15 percent of the lake with herbicide. To obtain the letter of variance, the NMCWD could either ask the sole riparian owner for Normandale Lake, the City of Bloomington, to sign a permission form or request a waiver from the permission form requirement from the MDNR. The City of Bloomington has indicated it is supportive of curly-leaf pondweed control. However, if NMCWD chooses to request a waiver from the riparian owner permission requirement and the MDNR were to grant the waiver, NMCWD would be required to notify the City of Bloomington of:

1. The proposed date for treatment and the name of the herbicide applicator
2. The target species for the treatment: curly-leaf pondweed
3. The method of control or product being used: chemical treatment using Endothall
4. Opt-out measures: The City of Bloomington would be provided with instructions for opting out of the herbicide treatment. The City of Bloomington could request that control not occur adjacent to the landowner's property – within 150 feet of shore in area adjacent to landowner's property. If the City of Bloomington desired that the treatment of the aquatic invasive plant NOT occur adjacent to City property (i.e., within 150 feet of shore adjacent to City property), the City would contact the NMCWD administrator and request to opt out of the treatment.

A Lake Vegetation Management Plan, including baseline assessment, would be required as part of the Invasive Aquatic Plant Management Permit. The MDNR's Invasive Aquatic Plant Management Permit would require monitoring to determine treatment effectiveness. The monitoring would evaluate the coverage of curly-leaf pondweed and native plants in the lake before and after treatment. The MDNR requires collection of turion samples in early fall, typically October, to determine the potential for new curly-leaf pondweed growth the next year. Herbicide residue monitoring for 30 days after treatment is also recommended to confirm that sufficient herbicide was applied to control curly-leaf pondweed. To determine whether a lethal Endothall concentration was sustained for at least 3 days after treatment, herbicide residual samples from multiple locations would be collected and analyzed for Endothall on 1, 2, and 3 days after treatment. Because Endothall is expected to degrade into carbon dioxide and water within 30 days after treatment, monitoring confirms that the herbicide is degrading on schedule for the native plants to grow.

The permit also requires monitoring data be analyzed and reported annually to the MDNR. The analysis and report would determine the degree of curly-leaf pondweed control attained and confirm the positive or neutral effect of the herbicide treatment on the native plant community. The data analysis to be performed and the content and format of the report will be specified by the MDNR. Herbicide residual monitoring data would be analyzed to confirm the correct application of the herbicide and to evaluate the herbicide degradation rate to confirm that the herbicide caused no harm to the native plant community.

The data analysis and report would be submitted to the Minnesota DNR annually to confirm compliance with permit requirements.

4.3 In-lake Alum Treatment

When aluminum is applied to a lake as a solution of alum (aluminum sulfate), it forms an insoluble aluminum hydroxide floc that settles to the lake bottom. The aluminum binds with phosphorus in the sediment to prevent it from recycling back into the water column. Sodium aluminate is often used in combination with alum to prevent a significant change in the lake's pH (alum is acidic, sodium aluminate is basic). The alum application would be conducted in spring 2019 following the winter drawdown, at approximately the same time as Endothall treatment. Alum would be applied from a treatment boat or barge, and therefore would require Normandale Lake to refill before alum could be applied. Conducting the alum treatment before aquatic plants are reestablished in the lake will allow the aluminum floc to reach the sediment more uniformly.

A sediment phosphorus study was conducted in Normandale Lake in 2016. Sediment samples were collected from several locations in the lake and analyzed for various phosphorus fractions, including iron-bound phosphorus and organic phosphorus. The results of the sediment phosphorus study were used to determine an appropriate alum dose.

The estimated cost to conduct an alum treatment of Normandale Lake is $141,000. This cost assumes an aluminum dose applied as 470 gallons alum equivalent per acre (note that the aluminum will be applied as a mixture of alum and sodium aluminate) and includes project administration; observation and documentation of the alum application; and monitoring of lake pH during the alum application. A detailed cost estimate for this lake management practice is provided in **Appendix F**.

The characteristics of the sediment are likely to change significantly following the drawdown, as is the aquatic plant community. Few if any studies have been conducted of lakes receiving alum treatments after a drawdown, and it may be beneficial to conduct a sediment study after the alum treatment to determine if the applied alum is having the desired effect on sediment phosphorus internal loading.

It should be expected that there will be a need to repeat the alum treatment. Given the large watershed and significant annual accumulation of phosphorus in the lake bottom sediments, it may be expected that the treatment will need to be repeated in 5 to 10 years. In-lake monitoring will be used to assess whether internal phosphorus loading has returned and whether additional treatment will be needed.

Eurasian watermilfoil, a non-native aquatic invasive species, is currently present in Normandale Lake at low levels. Improved light conditions in the lake following the alum treatment could facilitate the rapid expansion and increased growth of Eurasian watermilfoil in the lake. Herbicide treatment of Eurasian watermilfoil may be needed after the alum treatment if the results of point-intercept surveys conducted post alum treatment indicate that Eurasian watermilfoil is expanding. The herbicide treatment would prevent this non-native species from becoming detrimental to the lake's native aquatic plant community and fish habitat and from hindering overall recreational use.

4.3.1 Alum Treatment Permitting

Permits/approvals for alum treatment will be required by the City of Bloomington. The USACE has indicated that alum treatment can be covered under the existing permit issued when Normandale Lake was constructed, and will not require a permit modification. A letter of notification is typically sent to the Minnesota Pollution Control Agency (MPCA) and MDNR prior to conducting alum treatments.

4.4 Aquatic Macrophyte Harvesting

Depending on the success of the drawdown, Endothall treatment, and alum treatment, selective macrophyte harvesting may be considered to achieve the following potential benefits for Normandale Lake:

- Improved recreational access, including sport fishing and boating;
- Removal of plant biomass, which also includes the removal of phosphorus contained in the plant tissue;
- Removal of organic matter which decays upon senescence and reduces dissolved oxygen in the water column;
- Potentially increased longevity of the whole lake alum treatment as less plant matter and hence phosphorus from the plants would be deposited on the lake bottom;
- With the removal of aquatic plants that float on the surface of the lake there would be increased oxygen transfer from the air to the lake water column;
- Improved sunlight penetration which would promote more even growth of phytoplankton throughout the water column and potentially improve dissolved oxygen conditions throughout the lake.

In accordance with the 1979 USACE Permit for Normandale Lake, macrophyte harvesting is limited to the eastern half of the lake (**Figure 4-7**). Because harvesting boats can conduct harvesting activities to a lake water depth of 2 to 2.5 feet, the total harvesting area is expected to be approximately 40 acres. The cutting depth would be set to approximately 1-2 feet deep in the water column. Two harvesting events are proposed, with each event expected to take about 10 days to complete. The estimated annual total cost to conduct harvesting and dispose of the plant material is approximately $78,000 per year for the three-year test period ($234,000 total), which includes harvesting, transport of harvested material, and disposal of the material at a compositing facility within a distance of 20 miles of Normandale Lake. This cost also includes conducting aquatic plant surveys to assess the plant community prior to the start of the project, during each year of the three-year test period, and for one year after the project (approximately $3,000 per year for a total cost of $15,000). A detailed cost estimate for this lake management practice is provided in **Appendix F**.

The selective macrophyte harvesting would be conducted as a three-year test, with its effectiveness being measured by increased dissolved oxygen concentrations throughout the water column. However, one of the drawbacks to mechanical harvesting is the ongoing nature of the management activity and associated annual costs because plants continually grow and may attain pre-harvesting growth conditions. Studies to determine growth rates after harvesting indicate the plants in Normandale Lake may attain pre-harvesting conditions about a month after harvesting (Xu et al. 2015, Bianchini 2017, and Engel, 1990). A greenhouse study conducted in China using an elodea species (*Elodea nuttallii)* indicated harvesting increases plant growth rate enabling the plant to rapidly reach the water surface after harvesting (Xu et al. 2015). It should also be noted, however, that the biomass of the unharvested plots in this study was lower that the harvested plots in three of the four water depths studied. Hence, harvesting should be not too aggressive that it significantly hinders the aquatic plant population.

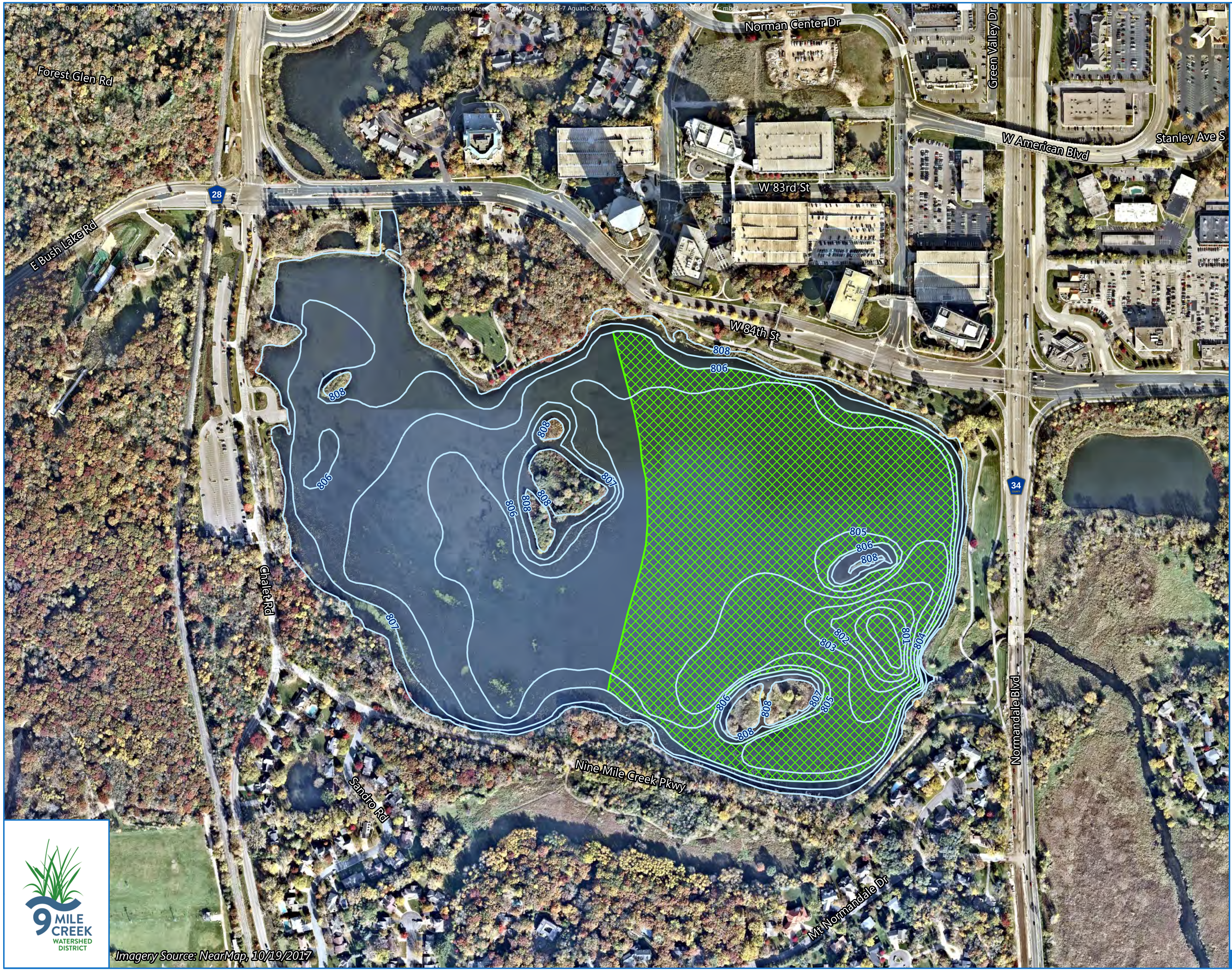
Another potential consideration related to the selective macrophyte harvesting is that mechanical harvesting has the potential to cause an increase in the extent and density of the coontail, elodea, and Eurasian watermilfoil communities in Normandale Lake. Mechanical harvesting creates thousands of plant fragments and deposits them in the lake (Nichols 1999 and MDNR). Coontail and elodea are native plant species that are able to reproduce from plant fragments. It should be noted also that coontail and elodea are already widespread in Normandale Lake and were 78 percent of the total biomass of the lake in August, 2017.

Close attention should be paid to changes in Eurasian watermilfoil following the management activities at Normandale Lake as the Eurasian watermilfoil population is not currently widespread. Eurasian watermilfoil is a non-native aquatic invasive species that is able to reproduce from plant fragments (Li et al 2015 and MDNR). Eurasian watermilfoil has a rapid growth rate and spreads quickly in a lake, displacing native species that provide a more desirable habitat. Mechanical harvesting could have the unintended consequence of increasing density and extent of Eurasian watermilfoil at the expense of more valuable native species (Engel 1990 and Xu et al. 2015). Because MDNR restricts management of native species, including coontail and elodea, to 15 percent of the lake each growing season, the changes in these communities from harvesting would likely be long-term and not reversible. MDNR would allow whole lake management of Eurasian watermilfoil because it is an aquatic invasive species. Hence, potential changes in the Eurasian watermilfoil community may be reversible, but would add additional cost to the project.

4.4.1 Aquatic Macrophyte Harvesting Permitting

Since aquatic macrophyte harvesting would be limited to the east half of the lake, as specified in the existing USACE permit, a permit modification will not be required.

Similar to the herbicide and in-lake alum treatment approaches described above, an Invasive Aquatic Plant Management Permit would be required from the MDNR, along with approval from the City of Bloomington. The MDNR is not expected to approve a permit for harvesting to occur during years in which the whole lake is treated with Endothall. Hence, the three years of aquatic macrophyte harvesting could likely not occur until completion of the Endothall treatments of the lake.



Bathymetric Elevation Contour

Aquatic Macrophyte Harvesting Boundary

N

400 0 400

Feet

AQUATIC MACROPHYTE HARVESTING BOUNDARIES
Normandale Lake Engineer's Report
Bloomington, Minnesota

Figure 4-7

9 MILE CREEK WATERSHED DISTRICT

4.5 Oxygenation System

Addressing low dissolved oxygen concentrations in Normandale Lake is recommended for several reasons, including: (1) to prevent the generation of foul smelling hydrogen sulfide, (2) to help keep the lake sediments aerated and prevent internal loading as new, incoming phosphorus is deposited onto the lake bottom, and (3) to provide oxygen to fish species that cannot survive at low oxygen concentrations (e.g., 2-3 mg/L) that persist in the lake during the summer and to prevent winter fish kill. Depending on the success of the drawdown, Endothall treatment (two to five successive years), and alum treatment, addressing low dissolved oxygen through installation of an oxygenation system may be considered.

There are two common methods to manage low oxygen levels in bottom waters of a lake, destratification and oxygenation. Destratification involves the continuous mixing of the water column to promote atmospheric re-aeration of surface and mixing them to the bottom. Oxygenation involves the injection of pure oxygen locally to the bottom waters to supplement the oxygen deficiency. For Normandale Lake, destratification would require a significant amount of in-lake infrastructure that would be problematic given the shallow depth of 90% of the lake. Therefore, the recommended approach to mitigate low oxygen conditions in Normandale Lake is a hypolimnetic oxygenation system employing side-stream saturation (SSS) technology.

Side-stream saturation (SSS) systems withdraw water from the bottom of the lake, inject pure oxygen into the water flow upstream of a contact chamber that allows the oxygen gas to dissolve into the water, and then return the oxygenated water to the bottom of the lake via distribution piping. Oxygenation systems are commonly installed in the deepest part of lakes and reservoirs. In so doing, dissolved oxygen input is focused over the deepest sediments that are commonly most affected by low oxygen levels. **Figure 4-8** shows an approximate layout for the side-stream saturation system, with a 250 foot in-lake distribution header positioned within the elevation contour of 800 feet. The oxygen supply can either be stored onshore as bulk liquid oxygen (LOx) or can be generated on-site by a compressor supplying air to a pressure swing adsorption molecular sieve. Although LOx is a reliable oxygen source, due to the large footprint required to store the oxygen coupled with the undesirable obstruction it would have on the view and setting of Normandale Lake, onsite oxygen generation would be a better option for oxygen supply at Normandale Lake. Additional information on the SSS system is included as **Appendix G**.

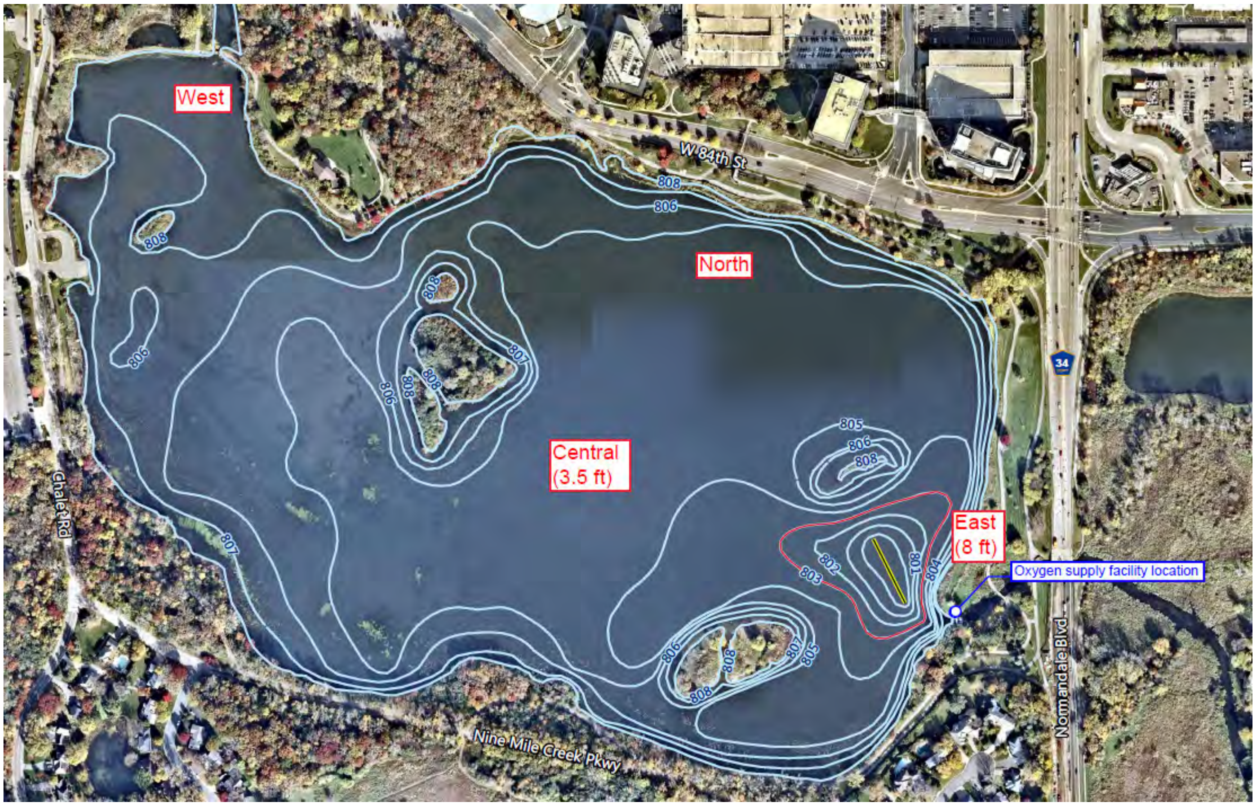


Figure 4-8 Normandale Lake side-stream saturation system proposed layout

Another benefit of a SSS system is the ability of the distribution header to also provide an injection means of geochemical augmentation, such as ferric or alum. Geochemical augmentation would be an additional method to mitigate internal phosphorus loading that would complement the in-lake alum treatment. With active circulation of the bottom water via the SSS system, ferric or alum injection can be added with the addition of a small feed header pipe.

A planning-level opinion of cost for the SSS oxygenation system at Normandale Lake estimates that the system would cost approximately $216,000, with annual maintenance of $8,000 per year. A detailed cost estimate for this lake management practice is provided in **Appendix F**.

4.5.1 Oxygenation System Permitting

The USACE has indicated that installation of an oxygenation system can be covered under the existing permit issued when Normandale Lake was constructed, and will not require a permit modification.

4.6 Cost Estimate Summary

Planning-level opinions of cost have been developed for the lake management practices described above. These opinions of cost are intended to provide assistance in evaluating and comparing alternatives and should not be assumed as absolute values. The estimated costs are summarized in **Table 4-2**. Detailed cost estimates are included as **Appendix F**.

Table 4-2 Summary of Estimated Costs for Lake Management Approaches

Management Approach	Estimated Cost	Estimated Cost Range[1]
Drawdown Options		
Drawdown Option 1 – Use Existing Outlet	$115,500	$92,000 - $162,000
Drawdown Option 2 – Replace Existing Bypass Outlet with Larger Bypass	$301,000	$241,000 - $421,000
Drawdown Option 3 – Use Existing Bypass Outlet with Supplemental Pumping	$393,000	$314,000 - $550,000
Drawdown Option 4 – Install Larger Bypass Outlet with Initial Temporary Pumping and Existing Bypass	$414,000	$331,000 - $579,000
Herbicide Treatment (two to five successive years)[2, 3]	$510,000	
In-Lake Alum Treatment[2]	$141,000	
Aquatic Macrophyte Harvesting[2]	$234,000	
Oxygenation System[4]	$216,000	

[1] The reported opinions of cost for the lake drawdown options include an expected accuracy range (-20 percent to +40 percent), which is based on the current extent of project definition, wide-scale use of parametric models to calculate estimated costs (i.e., making extensive use of order-of-magnitude costs from similar projects or proposals), and project uncertainty.

[2] The reported opinions of cost include a 10% contingency, based on the current extent of project definition and uncertainty.

[3] Cost for herbicide treatment assumes five successive years of treatment.

[4] The report opinions of cost include a 25% contingency, based on the current extent of project definition and uncertainty.

5.0 Recommended Lake Management Practices

The lake management practices proposed as part of this project are part of a holistic approach to improve the water quality and ecological health of Normandale Lake. The proposed lake draw down, Endothall herbicide treatments (two to five successive years), and alum treatment are intended to improve the native aquatic plant community and reduce internal phosphorus loading. Aquatic macrophyte harvesting and installation of an oxygenation system may also be considered following the completion of the herbicide treatments, as warranted by monitoring. The proposed lake management approach, proposed timing, and estimated cost of each are summarized in **Table 5-1**.

Four drawdown options were evaluated: Option 1 (Use Existing Outlet), Option 2 (Replace Existing Outlet with Larger Outlet), Option 3 (Use Existing Outlet with Supplemental Pumping), and Option 4 (Install Larger Bypass Outlet with Temporary Pumping). The benefits and challenges of each method are described in Section 4.1. Option 4 (Install Larger Bypass Outlet with Temporary Pumping) is recommended as it will increase the feasibility of drawing down the lake prior to the September 15 turtle hibernation guideline, while also maintaining drawdown levels over winter and providing permanent infrastructure for potential future drawdowns.

Table 5-1 Summary of Recommended Lake Management Practices and Schedule

Recommended Management Practice	Proposed Timing	Estimated Cost
Lake Drawdown – Option 4 (Install Larger Bypass Outlet with Initial Temporary Pumping and Existing Bypass)[1]	Fall 2018	$414,000
Herbicide Treatments with Endothall (two to five successive years)[2, 3]	Spring 2019, immediately after drawdown is complete and lake refills; Recurring for two to five years	$510,000
In-Lake Alum Treatment[2]	Spring 2019, immediately after drawdown is complete, lake refills, and herbicide treatment is complete	$141,000
	Subtotal	**$1,065,000**
Aquatic Macrophyte Harvesting[2, 4]	June and August potentially beginning following two to five successive years of herbicide treatments, as appropriate based on monitoring results	$234,000
Oxygenation System[4, 5]	Potentially beginning following two to five successive years of herbicide treatments, as appropriate based on monitoring results	$216,000

[1] The reported opinion of cost for the lake drawdown option does not include the expected accuracy range (-20 percent to +40 percent), which is based on the current extent of project definition, wide-scale use of parametric models to calculate estimated costs (i.e., making extensive use of order-of-magnitude costs from similar projects or proposals), and project uncertainty. See Table 4-2 for additional information.

[2] The reported opinion of cost includes a 10% contingency, based on the current extent of project definition and uncertainty.

[3] Cost for herbicide treatment assumes five successive years of treatment.

[4] Management practice may be considered, depending on the success of the drawdown, Endothall treatments (two to five successive years), and alum treatment.

[5] The report opinions of cost include a 25% contingency, based on the current extent of project definition and uncertainty.

The Normandale Lake Water Quality Improvement Project is a necessary and feasible part of the Overall Water Management Plan of the Nine Mile Creek Watershed District. The city of Bloomington has petitioned the Nine Mile Creek Watershed District to undertake this work on a cooperative basis with the City (**Appendix A**). Because the project meets the management goals of the District, it is recommended that the recommended lake management practices described in this Engineers Report and summarized in **Table 5-1** be implemented.

5.1 Monitoring

As part of the 2017 *Nine Mile Creek Watershed District Water Management Plan*, the District discussed implementing an adaptive management approach to managing its lakes. Adaptive management is an ongoing, systematic approach for natural resource management, with an emphasis on identifying and predicting the outcome of management alternatives, implementing alternatives, monitoring the outcome(s), and incorporating what is learned into ongoing or future management decisions. As such, the District intends to implement a comprehensive targeted monitoring program to assess the effectiveness of the lake management practices as they are implemented and evaluate the ongoing need for additional or repeat management activities. Several of the lake management activities also will require frequent or ongoing monitoring as part of permit compliance. **Table 5-2** summarizes the anticipated monitoring activities pre-, during- and post-implementation.

Several of the lake management activities also have long-term maintenance needs or may need to be periodically repeated to maintain effectiveness.

Table 5-2 Anticipated Monitoring Activities

Recommended Management Practice	Proposed Implementation Timing	Anticipated Monitoring
Lake Drawdown	Fall 2018	***During implementation***- lake level monitoring ***Post-implementation***- curly-leaf turion monitoring, fishery survey (year 3-5)
Herbicide Treatment with Endothall	Spring 2019, immediately after drawdown is complete and lake refills. Recurring for two to five successive years.	***Pre-implementation-*** water quality monitoring*, aquatic plant survey (point intercept)*, biomass plant survey ***During implementation-*** temperature monitoring (2-5 years) , flow monitoring (2-5 years), herbicide residual monitoring (2-5 years) ***Post-implementation***- turion sampling (2-5 years)*, water quality monitoring (2-5 years)*, point-intercept aquatic plant survey (2-5 years)*, biomass plant survey
In-Lake Alum Treatment	Spring 2019, immediately after drawdown is complete and lake refills	***Pre-implementation-*** water quality monitoring ***During implementation-*** pH monitoring, ***Post-implementation***- water quality monitoring (as desired)
Aquatic Macrophyte Harvesting	June and August potentially beginning following two to five successive years of herbicide treatments, as appropriate based on monitoring results	***Pre-implementation-*** dissolved oxygen monitoring, point-intercept aquatic plant survey ***During implementation-*** dissolved oxygen monitoring and point-intercept aquatic plant survey (3 years) ***Post-implementation***- dissolved oxygen monitoring and point-intercept aquatic plant survey (3 years)
Oxygenation System	Potentially beginning following two to five successive years of herbicide treatments, as appropriate based on monitoring results	***Pre-implementation-*** dissolved oxygen and total iron monitoring ***During implementation-*** dissolved oxygen and total iron monitoring ***Post-implementation***- dissolved oxygen and total iron monitoring
* Anticipated requirement of permitting		

5.2 Permitting Requirements

Permitting requirements for completing the recommended lake management practices described above are summarized in **Table 5-3**.

Table 5-3 Summary of Permits/Approvals Required for Recommended Lake Management Practices

Unit of Government	Type of Permit or Approval	Possibly Applicable Lake Management Practice
U.S. Army Corps of Engineers	Modification of existing Section 404 Permit	Lake Drawdown[1], Herbicide Treatment
U.S. Army Corps of Engineers	Coverage under a nationwide Section 404 general permit	Lake Drawdown[1]
Minnesota Department of Natural Resources	Public Waters Work Permit	Lake Drawdown, Herbicide Treatment, Alum Treatment, Aquatic Macrophyte Harvesting, Oxygenation System
Minnesota Department of Natural Resources	Invasive Aquatic Plant Management Permit (includes Lake Vegetation Management Plan)	Herbicide Treatment, Alum Treatment, Aquatic Macrophyte Harvesting
Minnesota Department of Natural Resources	Variance Letter for Whole-Lake Herbicide Treatment	Herbicide Treatment
City of Bloomington	Project Approval	Lake Drawdown, Herbicide Treatment, Alum Treatment, Aquatic Macrophyte Harvesting
City of Bloomington	Building Permit	Oxygenation System (structure)
Nine Mile Creek Watershed District	District Permit	Lake Drawdown

[1] Installation of a larger bypass pipe would be considered placement of new fill and would require USACE Section 404 permitting, either under the nationwide general permit or through the existing Section 404 permit for Normandale Lake.

6.0 Affected Property Owners

Affected property owners are those located immediately adjacent to the project. These owners are the same as the riparian owners identified on **Figure 4-1** above. A list of applicable owners is included in **Appendix H**.

7.0 Key Project Impacts

The lake management practices recommended by this Engineer's Report largely result in beneficial impacts. However, there is potential for adverse environmental affects as described in the April 2018 Environmental Assessment Worksheet completed for the project and summarized below.

7.1 Surface Waters (Wetlands)

The drawdown of Normandale Lake would temporarily affect water levels in the wetland area north of West 84th Street, along Nine Mile Creek. Water flows from this area of Nine Mile Creek into Normandale Lake. However, this wetland area is at similar elevation as Normandale Lake (808), allowing backwater from the lake to pool in the wetland. During the drawdown, Nine Mine Creek baseflow would continue to travel through the wetland; however, due to its hydraulic connection with the lake, this wetland area would also experience lower than normal hydrology conditions for the duration of the drawdown.

7.2 Fish, Wildlife, and Plant Communities

Fish, mussels, and other aquatic organisms inhabiting the lake may be impacted during drawdown due to loss of habitat. It is expected that fish and other mobile aquatic organisms would generally relocate to adjacent habitats during draw down of the lake. It is possible that mortality of more sessile aquatic organisms will occur if they reside within the lake once water levels have significantly lowered. Once complete, the proposed Project would likely enhance habitat for fish and other aquatic organisms by improving water quality and habitat diversity.

The project may have minor temporary adverse effects on terrestrial wildlife in the vicinity of Normandale Lake. Temporary impacts to terrestrial wildlife may include increased noise and human activity during Project activities. Many species, even those accustomed to human proximity, could temporarily abandon habitats near the proposed Project area until the work is completed and the water level in Normandale Lake has returned to normal conditions. These temporary impacts are not expected to irreparably harm terrestrial wildlife individuals or populations.

Turtles may be present in Normandale Lake and could be impacted by the project if drawdown of the lake occurs after September 15. If drawdown occurs after September 15, turtles may hibernate in Normandale Lake and ultimately not have enough water above them to survive the winter. If drawdown occurs before September 15, turtles would likely choose another adjacent habitat for hibernation.

The Project involves the use of the herbicide Endothall to control curly-leaf pondweed. Application of Endothall would be used within the parameters of the label's recommended dosage and is not expected to harm terrestrial or aquatic wildlife in the vicinity of the Normandale Lake. Although Endothall is a curly-leaf-selective herbicide, it does have the potential to stunt growth of other native plant species, especially other species of pondweeds. However, the herbicide will be applied prior to the start of the growing season. Hence, native plants are not expected to be impacted by the treatment. The potential changes in aquatic plant communities with harvesting were discussed in Section 4.4.

Aquatic plant harvesting would be expected to result in some fish mortality.   One study of fish mortality from aquatic plant harvesting found a mortality rate of 36 fish per hectare and found bluegills to be most impacted (Unmuth et al., 1998). Applying this mortality rate to Normandale Lake, the aquatic plant harvesting of 40 acres per year would be expected to result in the death of approximately 583 fish per year or a total of 1,749 fish during the project.

7.3 Visual

The project would occur within Normandale Lake, which can be seen from residences, trails, and roadways adjacent to the lake. The drawdown would be visible for approximately 7 months until the lake fills again. This visual impact would be temporary in nature and would not affect the permanent viewshed of the lake.

7.4 Benefits

Although there are several temporary and minor adverse effects, including potential adverse outcomes that will require ongoing evaluation (e.g., potential changes Eurasian watermilfoil population) and a response if warranted the overall project impacts are beneficial to the Normandale Lake ecosystem. The purpose of the project is to improve water quality of Normandale Lake by addressing concerns associated with a prevalence of curly-leaf pondweed in the lake and release of phosphorus from lake-bottom sediments (internal loading). Beneficiaries of the Normandale Lake Water Quality Improvement Project include users of recreational trails surrounding the lake, Normandale Lake boaters/fishermen, and downstream waters in the Nine Mile Creek watershed.

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Appendix A

City of Bloomington Petition

CITY OF
BLOOMINGTON
MINNESOTA

July 26, 2007

Kevin Bigalke
District Administrator
Nine Mile Creek Watershed District
7710 Computer Avenue
Suite 135
Edina, MN 55435

RE: Petition for Basic Water Management Project

Dear Mr. Bigalke,

Enclosed please find a petition to undertake a basic water management project to improve the water quality of Normandale Lake.

The Bloomington City Council passed a resolution on July 23, 2007 authorizing signature of the petition. The City has recognized the need for water quality improvements to Normandale Lake to maintain existing identified uses and goals.

The City asks that the Board of Managers consider this petition at their next available regular meeting. If you have any questions or need any additional information, please contact me at 952-563-4867. Thank you.

Sincerely,

Scott M. Anderson

Scott M. Anderson
Engineering Division

PUBLIC WORKS DEPARTMENT
1700 WEST 98TH STREET, BLOOMINGTON MN 55431-2501
PH 952-563-4581 FAX 952-563-4868 TTY 952-563-8740

PETITION OF THE CITY OF BLOOMINGTON TO THE NINE MILE CREEK WATERSHED DISTRICT TO UNDERTAKE A BASIC WATER MANAGEMENT PROJECT TO IMPROVE THE WATER QUALITY OF NORMANDALE LAKE

I. AUTHORITY

This petition, submitted by the City of Bloomington pursuant to the provisions of the Minnesota Statutes Sections 103D.605, 103D.705, and 103D.905 requests that the Nine Mile Creek Watershed District (District) undertake a basic water management project to improve the water quality in Normandale Lake.

II. PURPOSE

The public benefits and objectives of improving the water quality of Normandale Lake include enhancement of the diversity and quality of the aquatic vegetation in the lake, improvement of the habitat for wildlife surrounding and using the lake, and preservation of existing public recreational opportunities.

On Normandale Lake, the project would include control of Curleyleaf pondweed as well as other identified non-native invasive vegetative species. Other in-lake or watershed management approaches identified in the 2005 Use Attainability Analysis, or otherwise, for the purposes of improving lake water quality and/or meeting District water quality and recreational use goals would be included.

III. GENERAL DESCRIPTION OF WORK PROPOSED AND PURPOSES

The proposed work at Normandale Lake includes the engineering and construction of all appurtences necessary to control Curleyleaf pondweed in the lake to reduce summer in-lake total phosphorus concentrations and improve water quality.

Other in-lake or watershed management best management practices as identified in the UAA or in an Engineer's Report or feasibility study resulting in improvements to water quality should also be considered. The purpose or goal of all work is to improve water quality to meet the District identified classification for the lake and to ultimately support the water quantity, water quality, aquatic communities, recreational use, and wildlife goals for Normandale Lake.

IV. JURISDICTION OF THE LANDS OVER WHICH THE IMPROVEMENTS ARE LOCATED

Normandale Lake is wholly located within the City of Bloomington. The entire lakeshore is owned or under the jurisdiction of the City of Bloomington. Other watershed improvements identified in the UAA are located in whole or parts of other municipalities including the cities of Edina, Minnetonka, Hopkins, and Eden Prairie.

V. DESCRIPTION OF THE PART OF THE DISTRICT AFFECTED

The area to be served is entirely comprised of District lands ultimately tributary to Normandale Lake and Nine Mile Creek. The area immediately surrounding Normandale Lake is a mix of parkland, residential, office, commercial, and highway uses.

VI. NEED AND NECESSITY FOR THE PROPOSED IMPROVEMENT

Petitioner recognizes the need for water quality improvements to Normandale Lake to maintain existing identified uses and goals for the lake as well being consistent with the preservation of flood control along Nine Mile Creek. The Petitioner recognizes the necessity of recreational assets within Bloomington and the value of Normandale Lake and Nine Mile Creek. The project is necessary to address hydrological impacts from urban development of the tributary drainage area, to enhance the ecology of the lake and overall creek system, and improve the quality of the existing recreational opportunities.

VII. THE PROPOSED IMPROVEMENTS WILL INCREASE FUNCTIONALITY, ENHANCE RECREATION, AND PROMOTE PUBLIC WELFARE.

Petitioner proposes that these improvements be based upon its intention to increase functionality, enhance recreation, and promote public welfare. Improvements to Normandale Lake identified in the UAA will reduce in-lake nutrient concentrations resulting in better water quality and enhanced lake ecology more capable of supporting existing identified uses.

VIII. FINANCING OF THE PROPOSED IMPROVEMENT

The project is of common benefit to the District and is subject to Minnesota Statutes Section 103D.906, Subdivision 3, providing for the financing of the basic water management features.

IX. ABANDONMENT OF PROJECT

The Petitioner hereby states that it will pay all costs and expenses which may be incurred should the project be dismissed, no contract for the construction is let, or the project petition is withdrawn by the City of Bloomington.

Dated: 7/23, 2007

CITY OF BLOOMINGTON

By [signature]
Mayor

By [signature]
City Manager

Reviewed and approved by the City Attorney.

[signature]
City Attorney

Appendix B

1979 USACE Permit

Application No. 79-444-0[illegible]

Name of Applicant City of Bloomington

Issuance ~~Effective~~ Date

Expiration Date (If applicable) 31 December 1979

DEPARTMENT OF THE ARMY
PERMIT

Referring to written request dated 2 July 1979 for a permit to:

~~( ) Perform work in or affecting navigable waters of the United States, upon the recommendation of the Chief of Engineers, pursuant to Section 10 of the Rivers and Harbors Act of March 3, 1899 (33 U.S.C. 403);~~

(X) Discharge dredged or fill material into waters of the United States upon the issuance of a permit from the Secretary of the Army acting through the Chief of Engineers pursuant to Section 404 of the Federal Water Pollution Control Act (86 Stat. 816, P.L. 92-500);

~~( ) Transport dredged material for the purpose of dumping it into ocean waters upon the issuance of a permit from the Secretary of the Army acting through the Chief of Engineers pursuant to Section 103 of the Marine Protection, Research and Sanctuaries Act of 1972 (86 Stat. 1052; P.L. 92-532);~~

City of Bloomington
2215 West Old Shakopee Road
Bloomington, Minnesota 55431

is hereby authorized by the Secretary of the Army:

to retain fill material placed in conjunction with construction of a water impoundment structure, creation of waterfowl habitat islands, placement of a boat ramp, and shoreline protection. The work was part of the development of a multi-purpose facility named Mt. Normandale Lake

in wetlands adjacent to Nine Mile Creek

at secs. 16, 17, 20 and 21, T. 116 N., R. 21 W., Hennepin County, Bloomington, Minnesota

in accordance with the plans and drawings attached hereto which are incorporated in and made a part of this permit (on drawings: give file number or other definite identification marks.)

5 pages designated 79-444-09, page 1 of 5, 2 of 5, 3 of 5, 4 of 5, and 5 of 5.

subject to the following conditions:

I. General Conditions:

a. That all activities identified and authorized herein shall be consistent with the terms and conditions of this permit; and that any activities not specifically identified and authorized herein shall constitute a violation of the terms and conditions of this permit which may result in the modification, suspension or revocation of this permit, in whole or in part, as set forth more specifically in General Conditions j or k hereto, and in the institution of such legal proceedings as the United States Government may consider appropriate, whether or not this permit has been previously modified, suspended or revoked in whole or in part.

b. That all activities authorized herein shall, if they involve, during their construction or operation, any discharge of pollutants into waters of the United States or ocean waters, be at all times consistent with applicable water quality standards, effluent limitations and standards of performance, prohibitions, pretreatment standards and management practices established pursuant to the Federal Water Pollution Control Act of 1972 (P.L. 92-500; 86 Stat. 816), the Marine Protection, Research and Sanctuaries Act of 1972 (P.L. 92-532, 86 Stat. 1052), or pursuant to applicable State and local law.

c. That when the activity authorized herein involves a discharge during its construction or operation, of any pollutant (including dredged or fill material), into waters of the United States, the authorized activity shall, if applicable water quality standards are revised or modified during the term of this permit, be modified, if necessary, to conform with such revised or modified water quality standards within 6 months of the effective date of any revision or modification of water quality standards, or as directed by an implementation plan contained in such revised or modified standards, or within such longer period of time as the District Engineer, in consultation with the Regional Administrator of the Environmental Protection Agency, may determine to be reasonable under the circumstances.

d. That the discharge will not destroy a threatened or endangered species as identified under the Endangered Species Act, or endanger the critical habitat of such species.

e. That the permittee agrees to make every reasonable effort to prosecute the construction or operation of the work authorized herein in a manner so as to minimize any adverse impact on fish, wildlife, and natural environmental values.

f. That the permittee agrees that he will prosecute the construction or work authorized herein in a manner so as to minimize any degradation of water quality.

g. That the permittee shall permit the District Engineer or his authorized representative(s) or designee(s) to make periodic inspections at any time deemed necessary in order to assure that the activity being performed under authority of this permit is in accordance with the terms and conditions prescribed herein.

h. That the permittee shall maintain the structure or work authorized herein in good condition and in accordance with the plans and drawings attached hereto.

i. That this permit does not convey any property rights, either in real estate or material, or any exclusive privileges; and that it does not authorize any injury to property or invasion of rights or any infringement of Federal, State, or local laws or regulations nor does it obviate the requirement to obtain State or local assent required by law for the activity authorized herein.

j. That this permit may be summarily suspended, in whole or in part, upon a finding by the District Engineer that immediate suspension of the activity authorized herein would be in the general public interest. Such suspension shall be effective upon receipt by the permittee of a written notice thereof which shall indicate (1) the extent of the suspension, (2) the reasons for this action, and (3) any corrective or preventative measures to be taken by the permittee which are deemed necessary by the District Engineer to abate imminent hazards to the general public interest. The permittee shall take immediate action to comply with the provisions of this notice. Within ten days following receipt of this notice of suspension, the permittee may request a hearing in order to present information relevant to a decision as to whether his permit should be reinstated, modified or revoked. If a hearing is requested, it shall be conducted pursuant to procedures prescribed by the Chief of Engineers. After completion of the hearing, or within a reasonable time after issuance of the suspension notice to the permittee if no hearing is requested, the permit will either be reinstated, modified or revoked.

k. That this permit may be either modified, suspended or revoked in whole or in part if the Secretary of the Army or his authorized representative determines that there has been a violation of any of the terms or conditions of this permit or that such action would otherwise be in the public interest. Any such modification, suspension, or revocation shall become effective 30 days after receipt by the permittee of written notice of such action which shall specify the facts or conduct warranting same unless (1) within the 30-day period the permittee is able to satisfactorily demonstrate that (a) the alleged violation of the terms and the conditions of this permit did not, in fact, occur or (b) the alleged violation was accidental, and the permittee has been operating in compliance with the terms and conditions of the permit and is able to provide satisfactory assurances that future operations shall be in full compliance with the terms and conditions of this permit; or (2) within the aforesaid 30-day period, the permittee requests that a public hearing be held to present oral and written evidence concerning the proposed modification, suspension or revocation. The conduct of this hearing and the procedures for making a final decision either to modify, suspend or revoke this permit in whole or in part shall be pursuant to procedures prescribed by the Chief of Engineers.

l. That in issuing this permit, the Government has relied on the information and data which the permittee has provided in connection with his permit application. If, subsequent to the issuance of this permit, such information and data prove to be false, incomplete or inaccurate, this permit may be modified, suspended or revoked, in whole or in part, and/or the Government may, in addition, institute appropriate legal proceedings.

m. That any modification, suspension, or revocation of this permit shall not be the basis for any claim for damages against the United States.

n. That the permittee shall notify the District Engineer at what time the activity authorized herein will be commenced, as far in advance of the time of commencement as the District Engineer may specify, and of any suspension of work, if for a period of more than one week, resumption of work and its completion.

o. That if the activity authorized herein is not started on or before 31st day of December, 19 82, (one year from the date of issuance of this permit unless otherwise specified) and is not completed on or before 31st day of December, 19 84. (three years from the date of issuance of this permit unless otherwise specified) this permit, if not previously revoked or specifically extended, shall automatically expire.

p. That this permit does not authorize or approve the construction of particular structures, the authorization or approval of which may require authorization by the Congress or other agencies of the Federal Government.

q. That if and when the permittee desires to abandon the activity authorized herein, unless such abandonment is part of a transfer procedure by which the permittee is transferring his interests herein to a third party pursuant to General Condition t hereof, he must restore the area to a condition satisfactory to the District Engineer.

r. That if the recording of this permit is possible under applicable State or local law, the permittee shall take such action as may be necessary to record this permit with the Register of Deeds or other appropriate official charged with the responsibility for maintaining records of title to and interests in real property.

s. That there shall be no unreasonable interference with navigation by the existence or use of the activity authorized herein.

t. That this permit may not be transferred to a third party without prior written notice to the District Engineer, either by the transferee's written agreement to comply with all terms and conditions of this permit or by the transferee subscribing to this permit in the space provided below and thereby agreeing to comply with all terms and conditions of this permit. In addition, if the permittee transfers the interests authorized herein by conveyance of realty, the deed shall reference this permit and the terms and conditions specified herein and this permit shall be recorded along with the deed with the Register of Deeds or other appropriate official.

II. Special Conditions: (Here list conditions relating specifically to the proposed structure or work authorized by this permit):

1. The permittee shall use slopes no steeper than 10:1 below the ordinary lake level except in the area of the dam and in limited areas of critical shore protection where 6:1 and 5:1 slopes, respectively, are anticipated.

2. The permittee shall encourage and protect the growth of emergent aquatic macrophytes within the proposed lake's shallow fringe.

3. No vegetation control or dredging will be done in the area delineated on Figure 1. If needed, minimum dredging to maintain a boat access may be done.

4. The man-made islands are to be planted in a manner to provide a dense nesting cover. For example, a 3:2:1 ratio of alfalfa; reed canary grass or intermediate wheat grass; and yellow or white blossom sweet clover.

5. A minimum of 18 wood duck boxes will be placed in the general locations indicated on Figure 2. Each wood duck box will have a starling box placed 3 feet above it (see the attached study). It is recommended that the wood duck boxes be placed at a height of between 15 and 20 feet.

6. Refer to the Standard Conditions Attachment.

The following Special Conditions will be applicable when appropriate:

STRUCTURES IN OR AFFECTING VIGABLE WATERS OF THE UNITED STATES:

a. That this permit does not authorize the interference with any existing or proposed Federal project and that the permittee shall not be entitled to compensation for damage or injury to the structures or work authorized herein which may be caused by or result from existing or future operations undertaken by the United States in the public interest.

b. That no attempt shall be made by the permittee to prevent the full and free use by the public of all navigable waters at or adjacent to the activity authorized by this permit.

c. That if the display of lights and signals on any structure or work authorized herein is not otherwise provided for by law, such lights and signals as may be prescribed by the United States Coast Guard shall be installed and maintained by and at the expense of the permittee.

d. That the permittee, upon receipt of a notice of revocation of this permit or upon its expiration before completion of the authorized structure or work, shall, without expense to the United States and in such time and manner as the Secretary of the Army or his authorized representative may direct, restore the waterway to its former conditions. If the permittee fails to comply with the direction of the Secretary of the Army or his authorized representative, the Secretary or his designee may restore the waterway to its former condition, by contract or otherwise, and recover the cost thereof from the permittee.

e. Structures for Small Boats: That permittee hereby recognizes the possibility that the structure permitted herein may be subject to damage by wave wash from passing vessels. The issuance of this permit does not relieve the permittee from taking all proper steps to insure the integrity of the structure permitted herein and the safety of boats moored thereto from damage by wave wash and the permittee shall not hold the United States liable for any such damage.

MAINTENANCE DREDGING:

a. That when the work authorized herein includes periodic maintenance dredging, it may be performed under this permit for N/A years from the date of issuance of this permit (ten years unless otherwise indicated);

b. That the permittee will advise the District Engineer in writing at least two weeks before he intends to undertake any maintenance dredging.

DISCHARGES OF DREDGED OR FILL MATERIAL INTO WATERS OF THE UNITED STATES:

a. That the discharge will be carried out in conformity with the goals and objectives of the EPA Guidelines established pursuant to Section 404(b) of the FWPCA and published in 40 CFR 230;

b. That the discharge will consist of suitable material free from toxic pollutants in other than trace quantities;

c. That the fill created by the discharge will be properly maintained to prevent erosion and other non-point sources of pollution; and

d. That the discharge will not occur in a component of the National Wild and Scenic River System or in a component of a State wild and scenic river system.

DUMPING OF DREDGED MATERIAL INTO OCEAN WATERS:

a. That the dumping will be carried out in conformity with the goals, objectives, and requirements of the EPA criteria established pursuant to Section 102 of the Marine Protection, Research and Sanctuaries Act of 1972, published in 40 CFR 220-228.

b. That the permittee shall place a copy of this permit in a conspicuous place in the vessel to be used for the transportation and/or dumping of the dredged material as authorized herein.

This permit shall become effective on the date of the District Engineer's signature.

Permittee hereby accepts and agrees to comply with the terms and conditions of this permit.

Russell L Langseth ______ May 19, 1981 ______

PERMITTEE DATE

BY AUTHORITY OF THE SECRETARY OF THE ARMY:

______ ______

DATE

WILLIAM W. BADGER
Colonel, Corps of Engineers

DISTRICT ENGINEER,
U.S. ARMY, CORPS OF ENGINEERS

Transferee hereby agrees to comply with the terms and conditions of this permit.

______ ______

TRANSFEREE DATE

☆ U. S. GOVERNMENT PRINTING OFFICE: 1980—624-404 3-1

In addition to general and special conditions, this permit is subject to the following standard conditions, as applicable:

1. All work or discharges to a watercourse resulting from permitted construction activities, particularly hydraulic dredging, must meet applicable Federal, State and local water quality and effluent standards on a continuing basis.

2. Measures must be adopted to prevent potential pollutants from entering the watercourse. Construction materials and debris, including fuels, oil and other liquid substances, will not be stored in the construction area in a manner that would allow them to enter the watercourse as a result of spillage, natural runoff, or flooding.

3. If dredged or excavated material is placed on an upland disposal site (above the ordinary high watermark), the site must be securely diked or contained by some other acceptable method that prevents the return of potentially polluting materials to the watercourse by surface runoff or by leaching. The containment area, whether bulkhead or upland disposal site, must be fully completed prior to placement of any fill material.

4. Upon completion of earthwork operations all exposed slopes, fills and distrurbed areas must be given sufficient protection by appropriate means such as landscaping, or planting and maintaining vegetative cover to prevent subsequent erosion.

5. All fill (including riprap), if authorized under this permit, must consist of suitable material free from toxic pollutants in other than trace quantities. In addition, rock or fill material used for activities dependent upon this permit and obtained by excavation must either be obtained from existing quarries or the source borrow site must be identified and approved by the District Engineer.

6. If cultural, archaeological or historical resources are unearthed during activities authorized by this permit, work will immediately halt and the St. Paul District's Regulatory Functions Branch contacted at 612-725-7557 for further instruction.

7. An investigation must be made to identify water intakes or other activities which may be affected by suspended solids and turbidity increases caused by work in the watercourse, and sufficient notice must be given to the owners of affected activities to allow them to prepare for any changes in water quality.

8. A contingency plan must be formulated which would be effective in the event of a spill. This requirement is particularly applicable in operations involving the handling of petroleum products. If a spill of any potential pollutant should occur, it is the responsibility of the applicant to remove such material, to minimize any contamination resulting from this spill, and to immediately notify the U.S. Coast Guard at telephone number 800-424-8802, and the Minnesota Pollution Control Agency at (612) 296-7373.

FIGURE 1

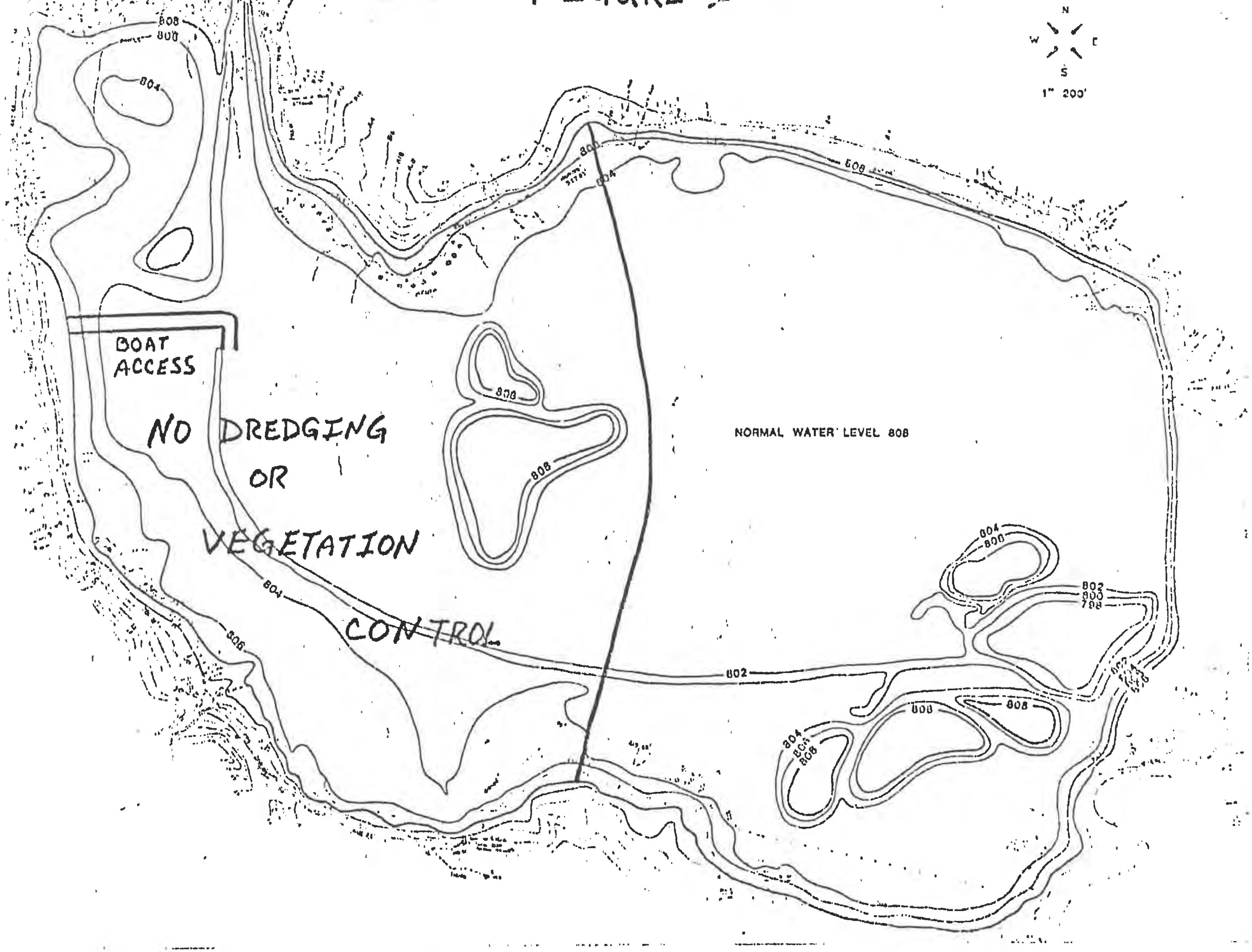
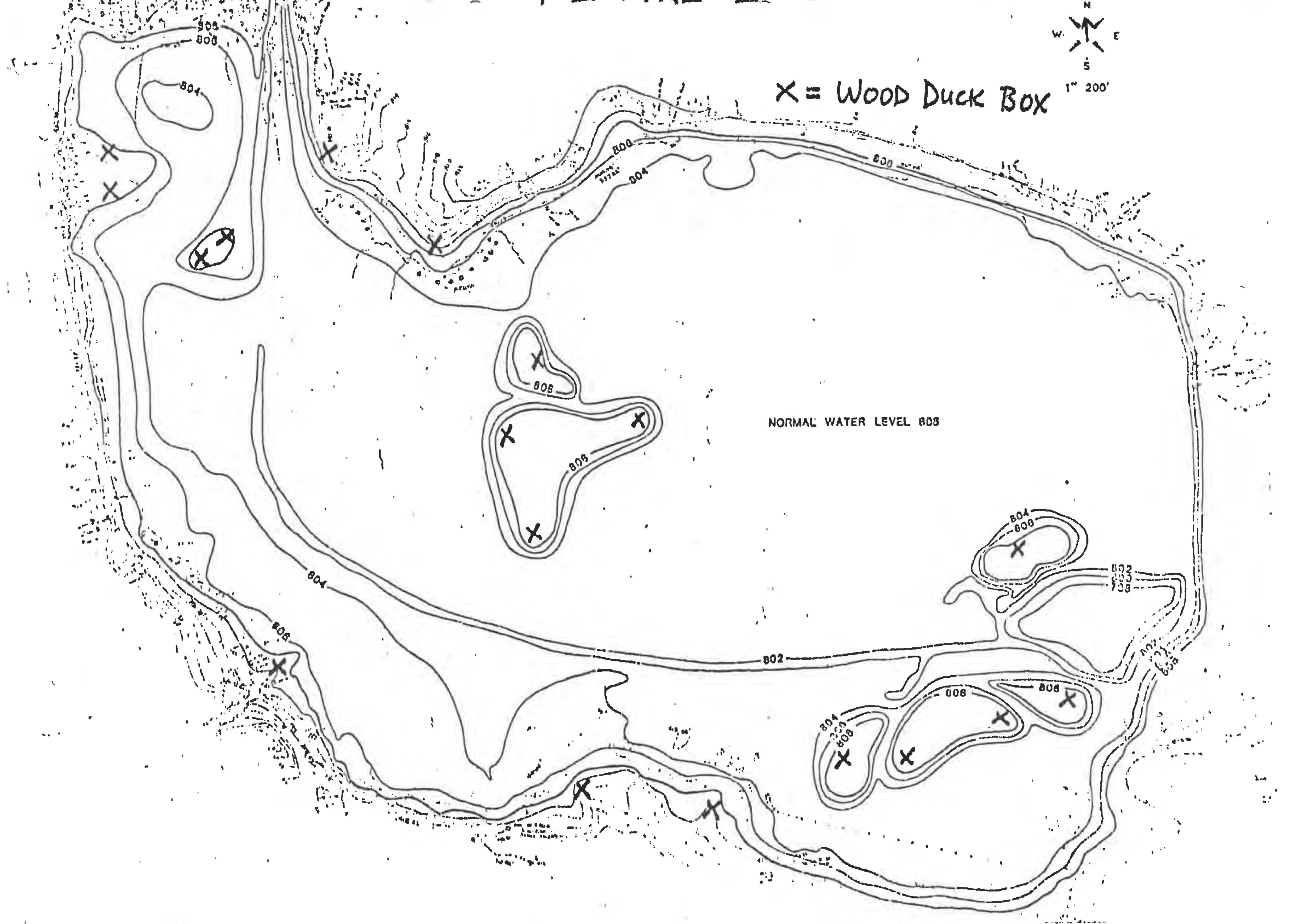

N
W
E
S
1" 200'
BOAT ACCESS
NO DREDGING OR VEGETATION CONTROL
NORMAL WATER LEVEL 808
808
806
804
802
800
798

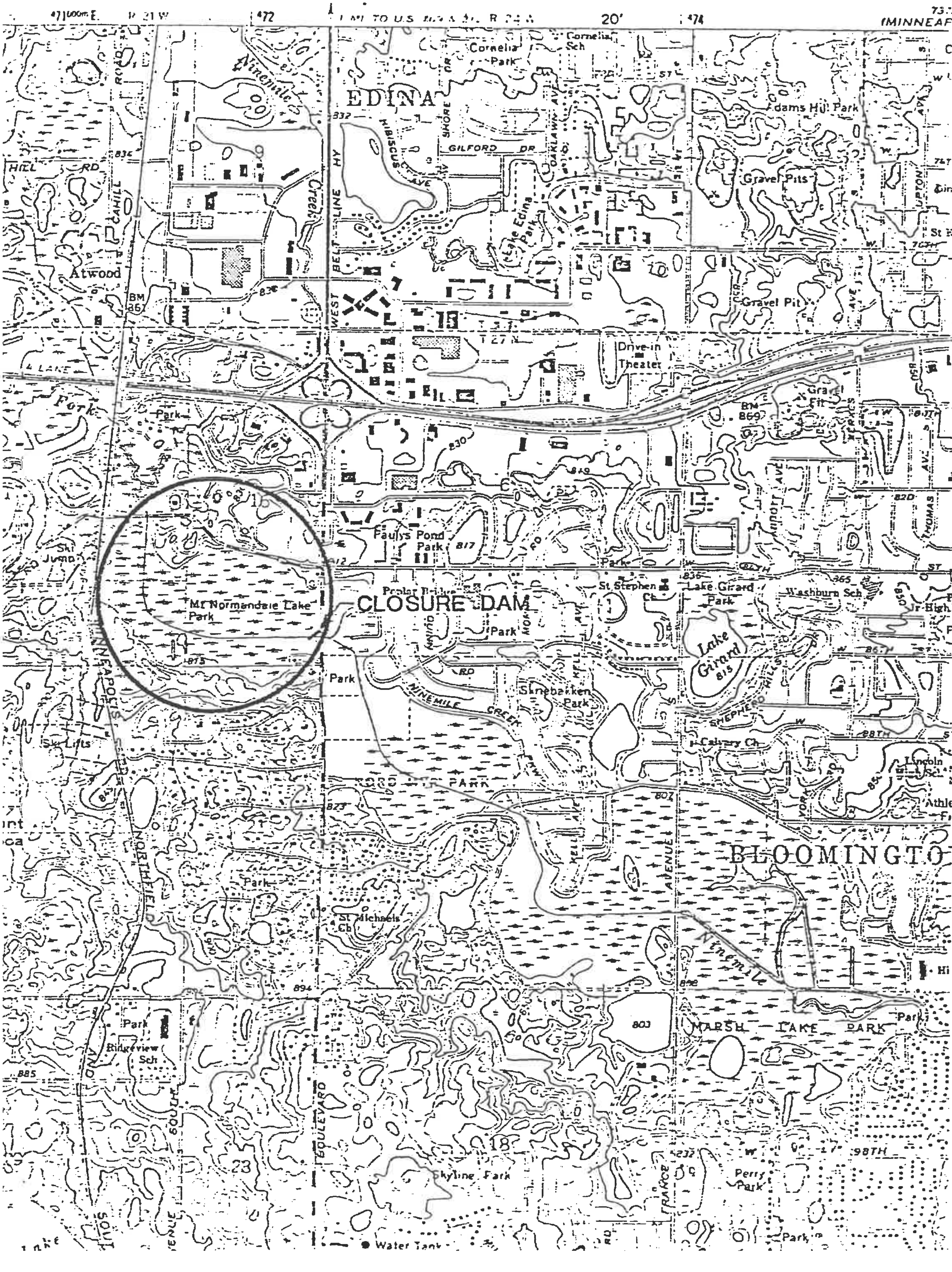
FIGURE 2

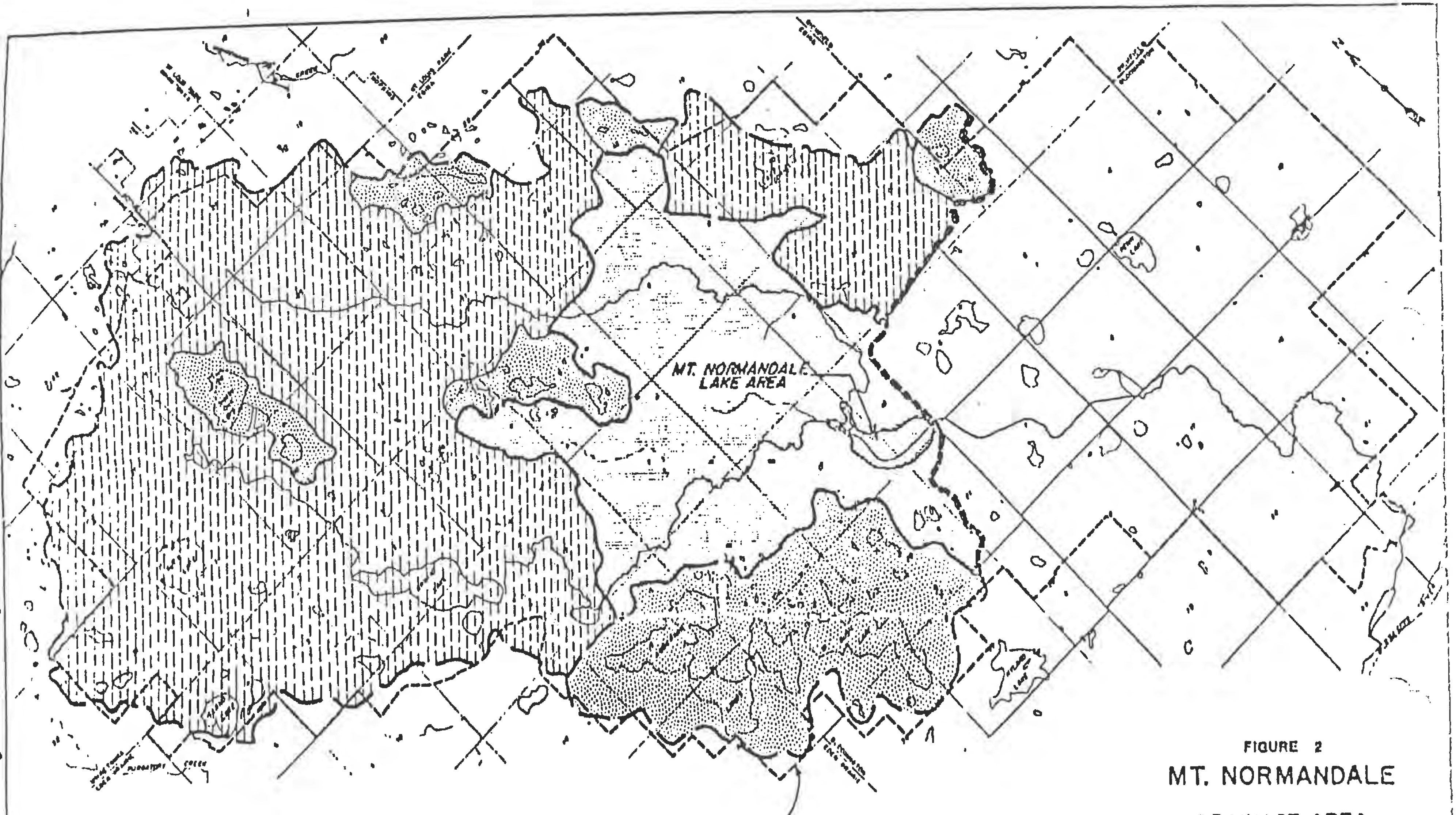


X = WOOD DUCK BOX
N
W
E
S
1" 200'
NORMAL WATER LEVEL 808
804
805
806
808
802

MENT OF THE INTERIOR
OLOGICAL SURVEY

LOCATION MAI





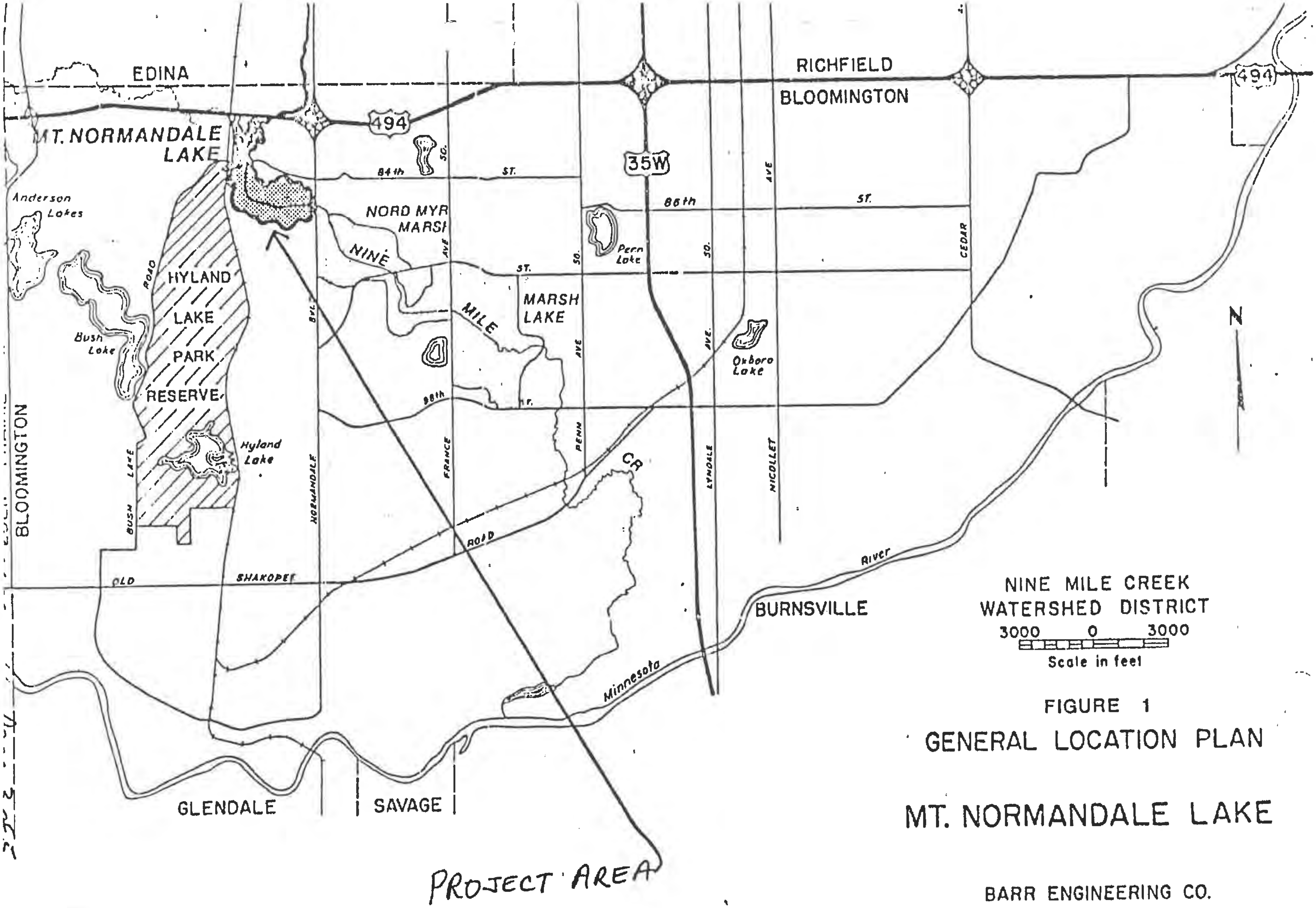
NINE MILE CREEK
WATERSHED DISTRICT
HENNEPIN COUNTY

SCALE

DIRECT DRAINAGE AREA
INDIRECT DRAINAGE AREA
LAND-LOCKED AREA

FIGURE 2
MT. NORMANDALE
DRAINAGE AREA

BARR ENGINEERING CO.



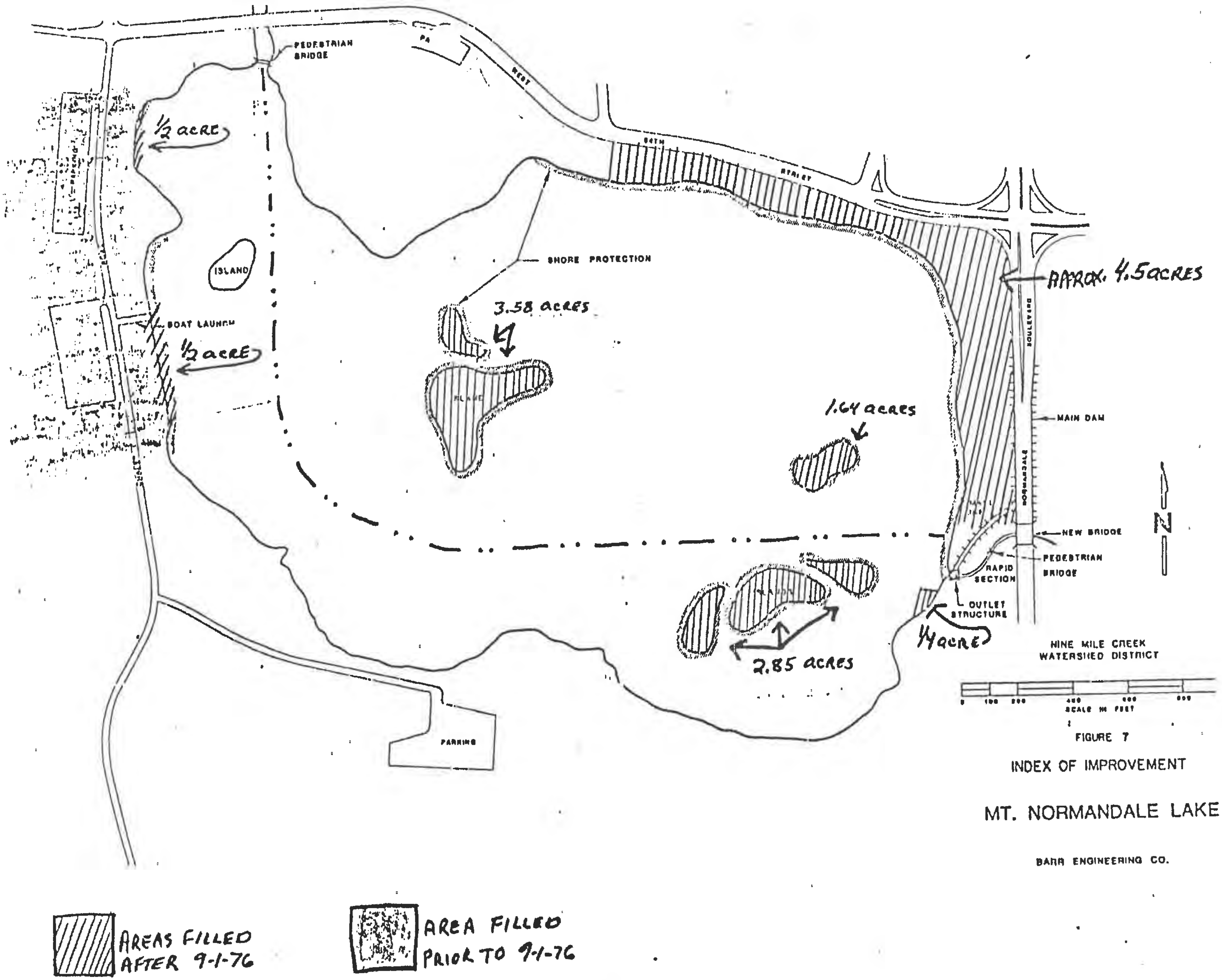
NINE MILE CREEK
WATERSHED DISTRICT

3000 0 3000
Scale in feet

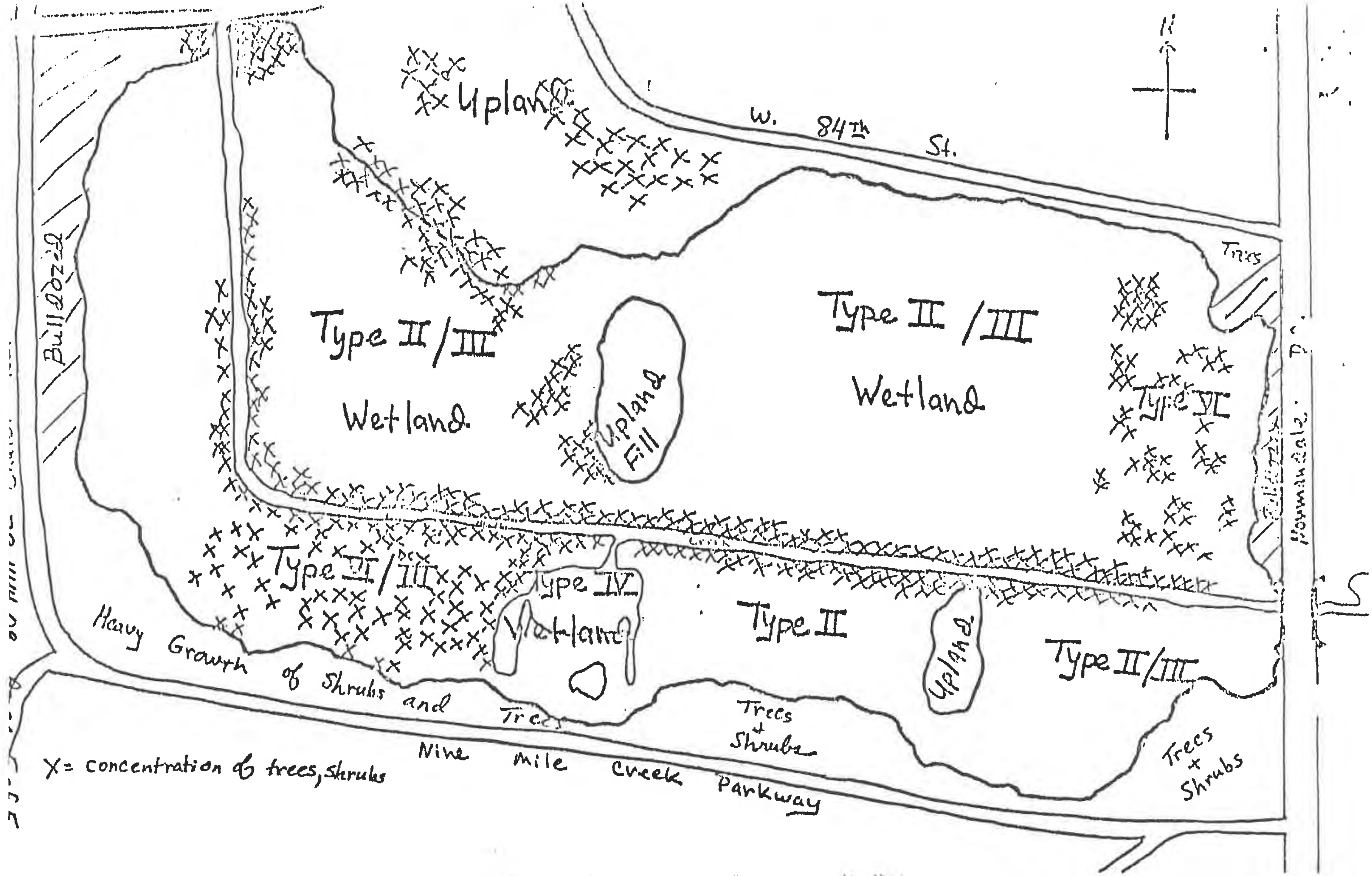
FIGURE 1
GENERAL LOCATION PLAN

MT. NORMANDALE LAKE

BARR ENGINEERING CO.



PEDESTRIAN BRIDGE
PA
WEST
84TH
STREET
SHORE PROTECTION
ISLAND
BOAT LAUNCH
1/2 acre
1/2 acre
3.58 acres
1.64 acres
2.85 acres
1/4 acre
APPROX. 4.5 acres
MAIN DAM
NORMANDALE
BOULEVARD
NEW BRIDGE
PEDESTRIAN BRIDGE
RAPID SECTION
OUTLET STRUCTURE
PARKING
N
NINE MILE CREEK WATERSHED DISTRICT
SCALE IN FEET
FIGURE 7
INDEX OF IMPROVEMENT
MT. NORMANDALE LAKE
BARR ENGINEERING CO.
AREAS FILLED AFTER 9-1-76
AREA FILLED PRIOR TO 9-1-76


N
W. 84th St.
Upland
Trees
Type II /III
Wetland
Upland Fill
Type VI
Bulldozed
Type II/III
Type IV
Wetland
Type II
Upland
Type II/III
Heavy Growth of Shrubs and Trees
Trees + Shrubs
Nine Mile Creek Parkway
X= concentration of trees, shrubs

city of
bloomington, minnesota
Municipal Building • 2215 West Old Shakopee Road • Bloomington, Minnesota 55431

July 2, 1987

William Goetz
Chief, Construction-Operations Division
U.S. Army Corps of Engineers, St. Paul
1135 U.S. Post Office & Customs House
St. Paul, MN. 55101-1479

Subject: Normandale Lake Application 79-444-0

Dear Mr. Goetz:

As we discussed by telephone today, we would appreciate your review of our permit for Normandale Lake and suggestions on actions we can take to alleviate concerns expressed by residents. A copy of the permit and associated information is enclosed for your use.

We have been receiving frequent contacts from users of the lake area about the appearance of the west end of the lake. Recently a stronger concern has been expressed about the strong odors. People who reside close to the lake have been most adamant in their complaints. I personally noticed that the smell was real bad on the northwest side when the wind was from the southeast.

My specific request is to review the permit and determine what would need to be done to allow the remainder of the lake to be harvested.

You suggested having some of your people view the site. We would appreciate any recommendations that would alleviate the problem.

We would be pleased to discuss this with your personnel at their convenience.

Yours Truly,

Ronald L. Rudrud

Ronald L. Rudrud
City Engineer

RLL:gb
Encl.

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
1135 U.S. POST OFFICE & CUSTOM HOUSE
ST. PAUL, MINNESOTA 55101-1479

August 4, 1987

REPLY TO
ATTENTION OF

Construction-Operations
Regulatory Functions (79-444-09)

Mr. Ronald L. Rudrud
City Engineer
City of Bloomington
2215 West Old Shakopee Road
Bloomington, Minnesota 55431

Dear Mr. Rudrud:

This is in response to your letter of July 2, 1987, regarding Normandale Lake and complaints you have received. Specifically, you asked whether the permit issued to the city could be modified to allow harvesting of aquatic weeds in the west half of the lake. Presently, a special condition on the permit (Number 3) only allows for aquatic weed harvesting within the east half of the lake.

A staff ecologist inspected the west half of Normandale Lake on July 12, 1987, and also in September 1986. An abundant growth of algae, coontail and duckweeds was observed on both occasions.

The growth and abundance of algae and aquatic vascular plants is an expected result of creating a shallow impoundment. Impoundments in general act as settling basins, and in urban areas tend to be especially eutrophic (because of runoff containing lawn fertilizers, etc.). The relatively large population of Canada geese, in combination with other waterfowl, is contributing further to the nutrient-rich condition of Normandale Lake. This condition and the shallow water depths have created an ideal situation for what may be considered excessive growth of algae and aquatic vascular plants. The strong odor reported is apparently the result of decomposition of these plants. Whereas the pre-impoundment emergent wet meadows and marshes of the site probably improved water quality through sediment trapping and nutrient assimilation, the man-made impoundment has created a solar-heated pool of shallow, stagnant, nutrient-rich water.

Alternatives for alleviating the problem include:

1. Chemical Control: This would not be desirable from an ecological standpoint, and could worsen the problem by resulting in a mass die-off of plants.

2. Dredging: Dredging would be expensive, would present the problem of where to dispose of the dredged material, and would reduce the waterfowl habitat value of the lake. This is not an acceptable alternative because of the loss of waterfowl habitat and because it would prevent reestablishment of shallow and deep marsh vegetation as discussed in a following paragraph. Furthermore, dredging may not be an economically viable alternative.

3. Mechanical Harvesting: The city has a mechanical harvester on the lake. Modification of the permit could allow harvesting in the west half of the lake. To be effective, periodic harvesting throughout the growing season would be required. For the reasons stated below, we would not endorse mechanical harvesting as an acceptable alternative.

4. Watershed Planning: Reducing the nutrient inflow to the lake could be examined. Restricting use of lawn fertilizers and correcting failing septic systems are two examples.

5. Removal of the Water Control Structure: A permanent drawdown of the impoundment would allow for the reestablishment of emergent wet meadow and marsh vegetation. The short-term, adverse aesthetic impact (mudflats) would be followed by a long-term benefit in water quality. The shallow open water conducive to algae blooms and excessive growth of aquatic vascular plants would be replaced by emergent wet meadow and marsh vegetation and its associated sediment-trapping and nutrient assimilation functions.

A primary consideration in the Corps decision to issue the permit was that, eventually, a deep to shallow marsh should develop in the west half of the lake as organic material accumulates and as Nine Mile Creek enters the impoundment and drops its sediment load. This succession to a marsh was viewed as being desirable and constituting partial compensation for the loss of high-quality emergent wetlands due to establishment of the impoundment. The current condition of the lake is a developmental stage in succession to the desired establishment of a marsh. Allowing mechanical harvesting in the west half of the lake would be contrary to this goal. Furthermore, the effectiveness of mechanical harvesting as a means to correct the odor problem may not be significant, given the nutrient-rich condition of the lake.

In summary, the city has committed itself to the current situation by flooding an emergent wetland and creating a shallow impoundment with its attendant water stagnation and aquatic vegetation features. This could be reversed by removal of the water control structure. Whether the current situation or removal of the water control structure would be the most acceptable alternative to its citizens is for the city to decide.

In view of the above, we do not believe a modification of the permit to allow mechanical harvesting of the west half of the lake is warranted.

Sincerely,

Wm. L. Goetz

Wm. L. Goetz
Chief, Construction-Operations Division

Appendix C

USACE Correspondence re: Lake Management

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
180 FIFTH STREET EAST, SUITE 700
ST. PAUL, MN 55101-1678

REPLY TO ATTENTION OF
REGULATORY BRANCH

March 22, 2018

Regulatory File No. 79-00444-IP

Nine Mile Creek Watershed District
c/o Randy Anhorn
Discovery Point
12800 Gerard Drive
Eden Prairie, MN 55346

City of Bloomington
c/o Shelly Hanson
1800 West Old Shakopee Road
Bloomington, MN 55431-3027

Dear Mr. Anhorn and Ms. Hanson:

This is in response to your recent correspondence regarding Normandale Lake. We issued a permit to the City of Bloomington authorizing wetland impacts associated with the Normandale Lake project on July 29, 1979. This permit authorized the City to retain fill material placed in conjunction with construction of a water impoundment structure, waterfowl habitat islands, a boat ramp, and shoreline protection around the lake.

We have reviewed your recent submittal entitled "Evaluation of Management Measures to Improve the Water Quality and Ecology of Normandale Lake," which discusses actions being considered by the Nine Mile Creek Watershed District (NMCWD) and the City of Bloomington to address problems associated with Normandale Lake. These actions were discussed during a meeting between the NMCWD, City and Corps of Engineers staff on July 17, 2017. The primary question is whether the management proposals presented in this recent submittal would be in compliance with the Section 404 permit that we issued in 1979, or if a permit modification would be necessary. The permit modification question is specific to permit special condition #3, which states that "no vegetation control or dredging is authorized in the west half of Normandale Lake, with the exception of that necessary for maintenance of a boat access channel." The proposed management actions discussed in the above-mentioned submittal are summarized below, followed by Corps comments regarding each proposed action, and a determination regarding if a permit modification would be required for each proposal.

a. Drawdown of the Lake. Periodic drawdown of shallow lakes and impoundments is a well-accepted practice for reinvigorating aquatic vegetation. Drawdown would consolidate sediments and provide an opportunity to remove carp and other rough fish. The Corps has determined that the proposed drawdown of the lake is in concert with the special condition of the Section 404 permit. No permit modification is necessary.

b. Curlyleaf Pondweed Treatment. Control of this non-native, invasive species is desirable provided the method applied targets this specific species thereby minimizing collateral damage to native species. Curlyleaf pondweed has a different active growing period compared to native pondweeds and other native aquatics thereby offering the opportunity to apply an appropriate herbicide with minimal collateral damage. A permit for the proposed lake-wide aquatic herbicide treatment would need to be obtained from the Minnesota Department of Natural Resources and we can rely on their expertise for review and approval of the proposed spring application of endothall. The Corps has determined that the proposed herbicide treatment for the invasive curlyleaf pondweed would enhance the lake's aquatic vascular plant bed – with the caveat stated in the first sentence of this paragraph. A permit modification is necessary as the existing permit condition excludes herbicide applications in the western half of the lake.

c. In-Lake Alum Treatment. This proposal would be beneficial in reducing the availability of phosphorus that fuels excessive algal blooms. The Corps has determined that the in-lake alum treatment is in concert with the special condition of the Section 404 permit, and no permit modification is necessary for this management action.

d. Aeration (Direct Oxygen Injection). Increasing levels of dissolved oxygen would be beneficial to the aquatic habitat provided by the lake. The Corps has determined that the aeration proposal is in concert with the permit, and no permit modification is necessary for this management action.

e. Limited Plant Harvesting (2-3 Year Test). Lake-wide harvesting via mechanical cutting of aquatic vegetation within the upper one-foot of the water column would be conducted for two or three growing seasons. Floating-leaved aquatics (e.g., white water-lily, long-leaf pondweed) would lose floating leaves, flowers and fruit, and any submerged leaves within the upper one foot of the water column. Free floating aquatics such as coontail and bladderwort tend to be concentrated within the upper one-foot of the water column and would be substantially reduced by the proposed action. All would grow back once mechanical cutting ceased, but during the 2- to 3-year test period mechanical cutting would be detrimental in view of the objective to protect the aquatic vascular plant bed in the western half of the lake. Longer-term mechanical cutting—i.e., beyond the 2- to 3-year test period—would be even more detrimental. In sum, the potential benefits of removing the upper one-foot of aquatic vegetation are speculative and are not likely to outweigh known adverse impacts. The Corps has determined that his proposal would not be in compliance with the special condition of the Section 404 permit specifying no vegetation control within the western half of Normandale Lake. Control of aquatic vegetation in the eastern half of the lake could be conducted as this action is not restricted by the Section 404 permit.

The Corps acknowledges the extent and expense of monitoring, modeling and analyses conducted by the NMCWD and City to address issues and inform stakeholders regarding potential actions to improve Normandale Lake. We recommend that the City and NMCWD pursue the management activities described in activities a. through d. above, and request a permit modification as necessary. Our determination is that the fifth option, as proposed in your recent report, would not be in compliance with the permit that we issued for this project. Compensatory mitigation for this project included maintaining an aquatic vascular plant bed in the western half of Normandale Lake. Therefore, based on the current proposal and available information, we would not be inclined to modify the permit to allow for plant harvesting activities in the western portion of the lake.

If you have any questions, please contact me in our St. Paul office at (651) 290-5363 or Melissa.m.jenny@usace.army.mil. In any correspondence or inquiries, please refer to the Regulatory file number shown above.

Sincerely,

Melissa Jenny
Project Manager

Ccs:
Bryan Gruidl, City of Bloomington
Erica Sniegowski, NMCWD
Bob Obermeyer, Barr
Janna Kieffer, Barr
Michael Welch, Smith Partners

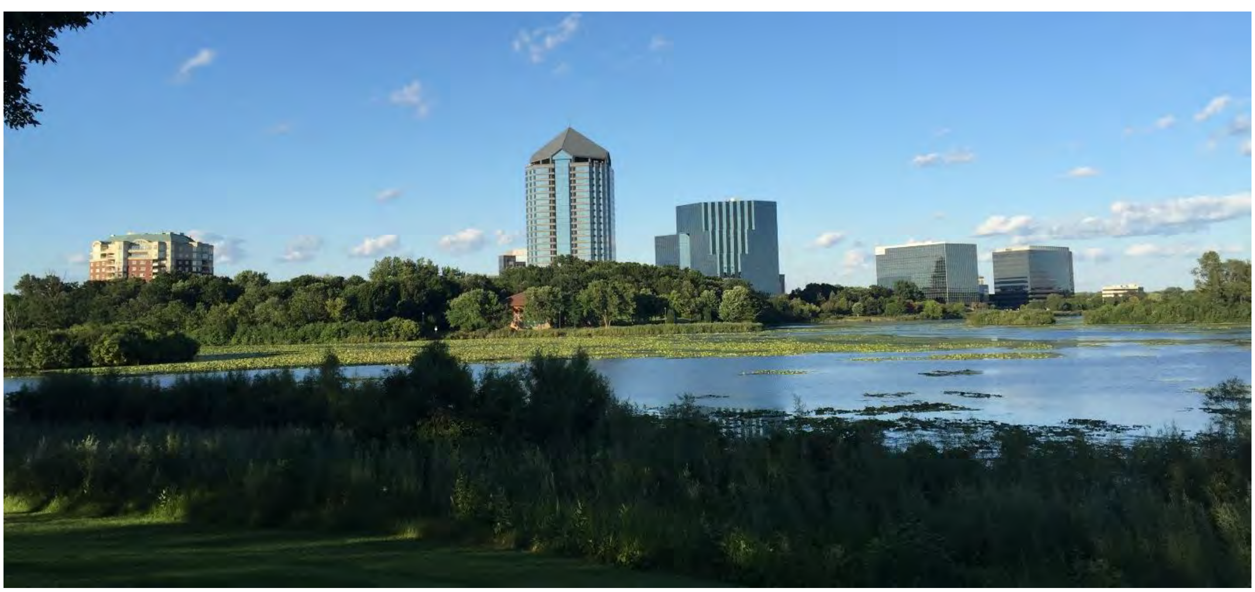
Appendix D

Evaluation of Management Measures to Improve the Water Quality and Ecology of Normandale Lake

Evaluation of Management Measures to Improve the Water Quality and Ecology of Normandale Lake

Prepared for
Nine Mile Creek Watershed District

October 2017



BARR

Evaluation of Management Measures to Improve the Water Quality and Ecology of Normandale Lake

Prepared for
Nine Mile Creek Watershed District

October 2017

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Evaluation of Management Measures to Improve the Water Quality and Ecology of Normandale Lake

October 2017

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Executive Summary

With nearly 100 percent surface coverage, aquatic plants are a dominant feature of Normandale Lake. Interpretation of monitoring data and modeling results demonstrate the importance of the aquatic plant population in the control of phosphorus concentrations in Normandale Lake and prevention of phytoplankton blooms by limiting light availability and competing for nutrients. However, the aquatic plant and filamentous algae population has become excessive (a maximum of approximately 2 million wet pounds in 2017) and is threatening attainment of Nine Mile Creek Watershed District water quality and aquatic community goals by causing very low dissolved oxygen (which is detrimental to fish and other aquatic life). The excessive aquatic plant and filamentous algae population is also hindering lake usage by creating unpleasant odors and physically inhibiting lake access due to plant density. The aquatic plant population included a large population of curlyleaf pondweed in 2017 and the overall population appears to be dominated by a few species.

The root cause of the abundant aquatic plant community is excessive nutrients. These nutrients come from external sources, which are currently being addressed with the ongoing implementation of upstream watershed management practices, and internal sources which can be controlled by inactivating phosphorus in the lake bottom sediment with the application of alum. The aquatic plant and filamentous algae community itself can also be directly managed. This may include mechanical harvesting to physically remove plants and reduce plant coverage, lake drawdown, and/or chemical treatment to control invasive species such as curlyleaf pondweed. The low oxygen concentrations in the lake can be addressed by constructing a system that directly injects oxygen in the water column of Normandale Lake. These management approaches are summarized in Section 1.0 of this report.

1.0 Introduction and Study Objectives

Normandale Lake is located in the northwestern part of Bloomington. The existence of the lake is the direct result of the Mount Normandale Lake flood control project implemented in the late-1970s, which included construction of a dam across Nine Mile Creek to the west of Normandale Boulevard, with a weir control structure and a low flow bypass structure. The lake has a water surface of approximately 112 acres, a maximum depth of approximately 10 feet, and a mean depth of 4.2 feet at normal water surface elevation of 808.0.

The Nine Mile Creek Watershed District has historically used a process referred to as Use Attainability Analyses (UAA) to assess the water quality condition of its lakes relative to the desired beneficial uses that can be reasonably achieved and maintained and identify management recommendations. The UAA process addresses a wide range of goals (e.g., water quantity, aquatic communities, recreational use, wildlife), with the primary focus being achievement of the water quality goals. As part of the 2017 *Nine Mile Creek Watershed District Water Management Plan*, 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. The NMCWD has also adopted the Minnesota lake eutrophication standards as part of their 2017 Plan.

The Minnesota lake eutrophication standards include criteria for total phosphorus, chlorophyll *a*, and Secchi disc transparency for shallow and deep lakes. Historically (1990 to 2016) Normandale Lake has met the Minnesota shallow lake eutrophication standards for chlorophyll *a* and Secchi disc depth but not for total phosphorus. Summer average chlorophyll *a* has ranged from 4 to 19 µg/L and Secchi disc depth has been quite good ranging from 1.1 to 2.4 meters (Figure 1 and Figure 2, respectively). Summer average total phosphorus has ranged from 41 to 133 µg/L, with several years exceeding the MPCA's shallow lake criteria of 60 µg/L (Figure 3).

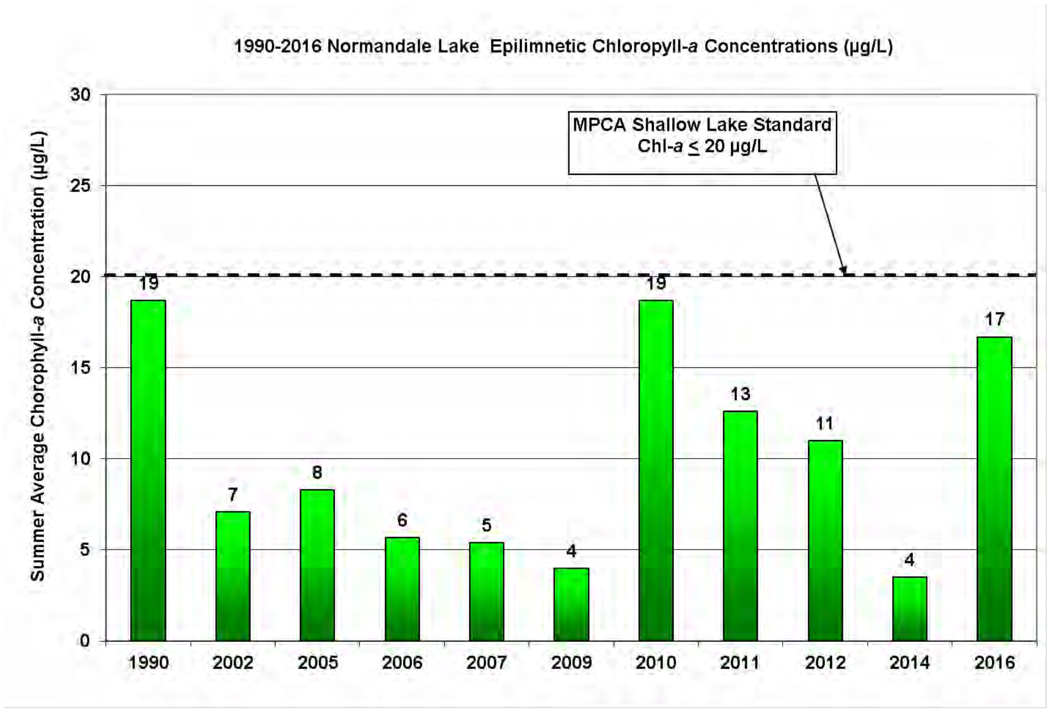

Figure 1 **Summary of historic chlorophyll-*a* concentrations in Normandale Lake**

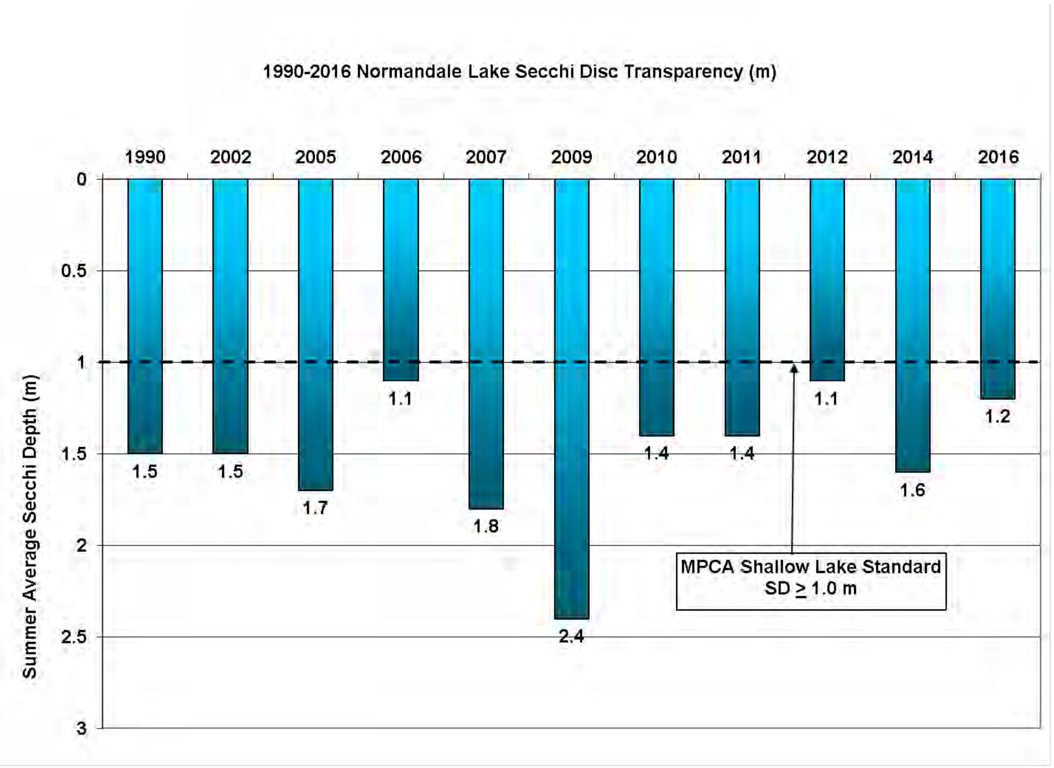

Figure 2 **Summary of historic Secchi depth transparency in Normandale Lake**

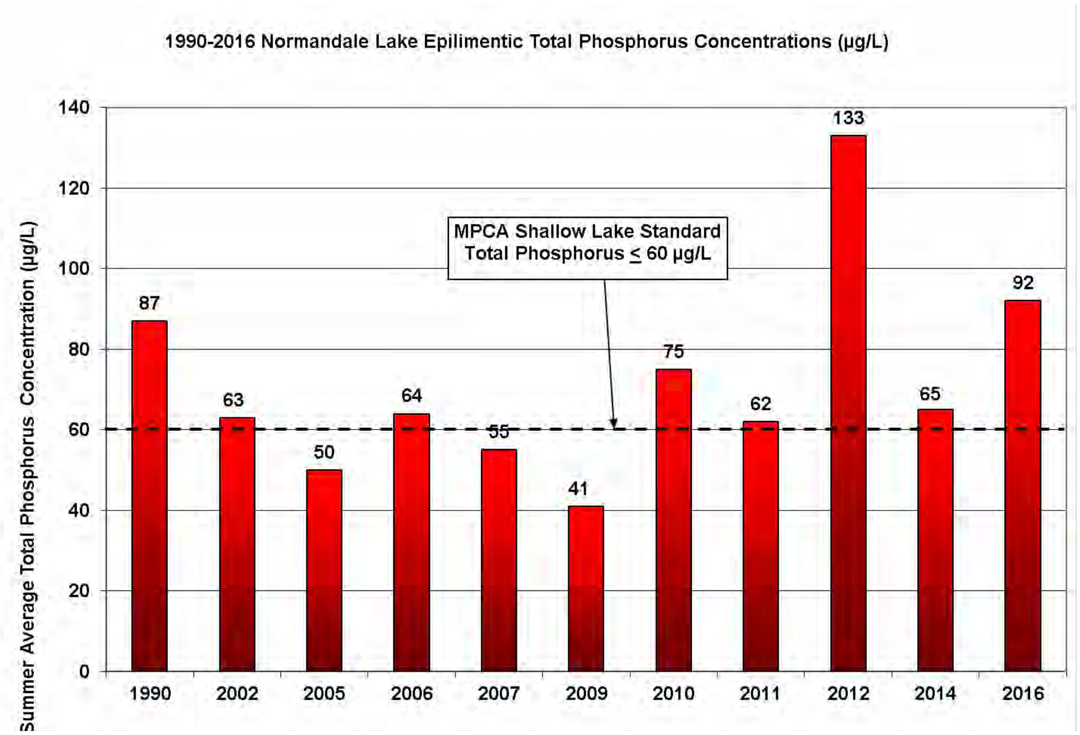

Figure 3 Summary of historic total phosphorus concentration in Normandale Lake

The water quality parameters included in the State's nutrient criteria (total phosphorus, chlorophyll *a*, and Secchi depth transparency) provide an indication of the overall water quality and trophic state of the lake, however, the ecology (aquatic communities) and use of the lake are strongly affected by the dense and widespread growth of aquatic plants and filamentous algae in the lake. For example, aquatic plants were found at 124 out of 125 points sampled during an August, 2017 point intercept survey. The total estimated wet mass of aquatic plants and filamentous algae in August 2017 was 1,754,831 pounds (795,974 kilograms). In addition to aquatic plants that are attached to the lake bottom, there is an abundant population of unattached floating species such as Wolfia, *Lemna minor* (common duckweed), and *Spirodela polyrhiza* (greater duckweed). Filamentous algae is also abundant and the aquatic plants coontail and curlyleaf pondweed also float on the lake surface. The result is that oxygen transfer is inhibited at the lake surface and the lake experiences very low oxygen during the summer months. The total average water column dissolved oxygen concentration in the summer in 2010 was 4.7 mg/L and in 2016 it was 2.3 mg/L. The State of Minnesota standard for dissolved oxygen is 5.0 mg/L.

The extensive coverage of aquatic plants has an effect on the general use of the lake and surrounding area inducing foul smells which are likely from hydrogen sulfide generated in the lake bottom sediments. Some management action is needed, however, the potential benefits of aquatic plant management have to be weighed against how management may affect in-lake phosphorus, clarity, and chlorophyll *a*. Management should not cause the lake to exceed the shallow lake nutrient criteria that are part of the Minnesota eutrophication standards. For example, in August 2017, the mass of phosphorus tied-up in aquatic plants and filamentous algae in Normandale Lake is estimated to be 579 pounds (this assumes water content of 90 percent and total phosphorus of 3,300 milligrams phosphorus per kilogram dry plant mass). Aquatic plants and filamentous algae are an important phosphorus control mechanism for the lake. Roughly half of the phosphorus that enters Normandale Lake is captured internally (e.g., removed by the lake). Modeling conducted as part of this study (discussed in detail below) suggest that aquatic plant growth accounts for approximately 15 to 19 percent of the phosphorus captured by the lake. Hence, it is important to recognize that any activity that may potentially reduce the aquatic plant population in the lake also has the potential to reduce phosphorus capture, resulting in an increase in phosphorus concentrations in the water column. Reductions of aquatic plants and filamentous algae may also lead to increases in phytoplankton.

Given the considerations discussed above, this study was designed to evaluate several lake management approaches applied separately or in concert to improve the overall lake health, with emphasis on achieving a healthy balance among aquatic communities.

A one dimensional hydrodynamic and ecological and water quality model (GOTM-FABM) was developed for Normandale Lake for several purposes, including:

- To better understand the overall ecological function of the lake.
- To quantify aquatic plant and filamentous algae growth and the effect of aquatic plants and filamentous algae on: (1) in-lake phosphorus concentrations in the lake, (2) phytoplankton growth, and (3) dissolved oxygen.
- Evaluate the effect of reducing <u>internal phosphorus loads</u> via whole lake alum treatment (designed to bind phosphorus and inhibit phosphorus release from lake-bottom sediments) on: (1) phosphorus concentrations in the water column of the lake, (2) phytoplankton growth (chlorophyll *a*) in Normandale Lake, and (3) aquatic plant growth in the lake
- Evaluate the effect of reducing <u>external phosphorus loads</u> (in this case, with the use of an inflow alum treatment system) on: (1) phosphorus concentrations in the water column of the lake, (2) phytoplankton growth (chlorophyll *a*) in the lake, and (3) aquatic plant growth in Normandale Lake.

Additional management approaches that were evaluated but could not be modeled included:

- Direct oxygen aeration of the lake water column.
- Aquatic plant and filamentous algae harvesting.
- Curlyleaf pondweed treatment.
- A lake drawdown to manage invasive aquatic plants and promote native aquatic plants.

2.0 Normandale Lake Water Quality and Biota

Recent monitoring data from Normandale Lake, both water quality and biological, are presented in this section to facilitate a better understanding of the current condition of the lake. Data presented are not exhaustive and are presented to facilitate discussion of this study's findings.

2.1 Normandale Lake and Nine Mile Creek Water Quality

This current study used the most recent two years of lake data (2010 and 2016), and associated tributary monitoring data. The primary tributary to Normandale Lake is Nine Mile Creek, and while there is a direct tributary watershed, the water quality of Nine Mile Creek can be considered characteristic of the stormwater inputs to Normandale Lake.

Table 1 Average Nine Mile Creek water quality for selected monitoring parameters

Year	Location	Parameter						
		Ortho-Phosphorus (mg/L)	Total Dissolved Phosphorus (mg/L)	Total Phosphorus (mg/L)	TKN (mg/L)	Nitrate + Nitrite (mg/L)	Total Suspended Solids (mg/L)	Volatile Suspended Solids (mg/L)
2010[1]	Nine Mile Creek-N2	0.032	0.044	0.157	1.58	0.14	32.3	12.5
	Nine Mile Creek-N3	0.055	0.068	0.254	1.66	0.50	26.0	11.3
	Composite N2 and N3[3]	0.046	0.058	0.214	1.63	0.35	28.6	11.8
2016[2]	Nine Mile Creek-N2	0.039	0.050	0.104	1.01	0.15	14.2	5.00
	Nine Mile Creek-N3	0.047	0.064	0.335	1.97	0.46	152	34.0
	Composite N2 and N3	0.045	0.061	0.281	1.74	0.39	119	27.1

1. Water quality monitoring period from March 17 to October 14, 2010

2. Water quality monitoring period from March 8 to November 3, 2016

3. Average Nine Mile Creek total flow (station N2 + station N3) and direct tributary inflow in 2010 averaged 13.9 cfs and in 2016 it averaged 12.6 cfs during the water quality monitoring period.

High concentrations of phosphorus, nitrogen, and solids in Nine Mile Creek have the potential to cause eutrophication of Normandale Lake. The residence time of Normandale Lake is fairly short (18 days in 2010 during the open water season) and there is not much time for phosphorus removal by settling. However, it can be seen in the figures below (Figure 4) that the phosphorus concentration in the lake water column is quite low given the concentration of phosphorus in Nine Mile Creek, indicating that other mechanisms (e.g., aquatic plant and filamentous algae growth, discussed below) are contributing to phosphorus capture. It is also notable that there is a steady increase in phosphorus in Normandale Lake beginning in early June of each year (Figure 4), and this steady increase in phosphorus is characteristic of internal phosphorus loading. The build-up of phosphorus in the lake bottom sediments, which can be seen in Figure 5, is also a clear indication of internal phosphorus loading in the lake.

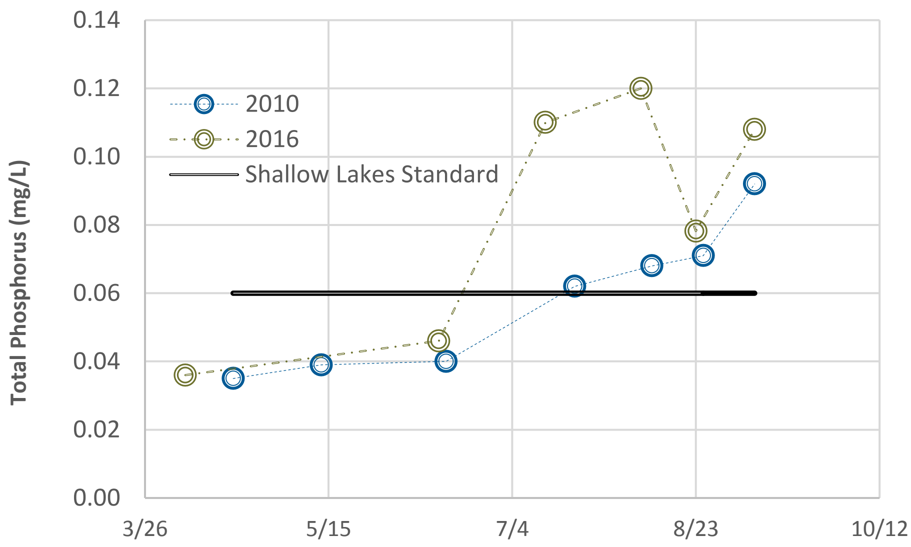

Figure 4 **Total phosphorus in the surface of Normandale Lake**

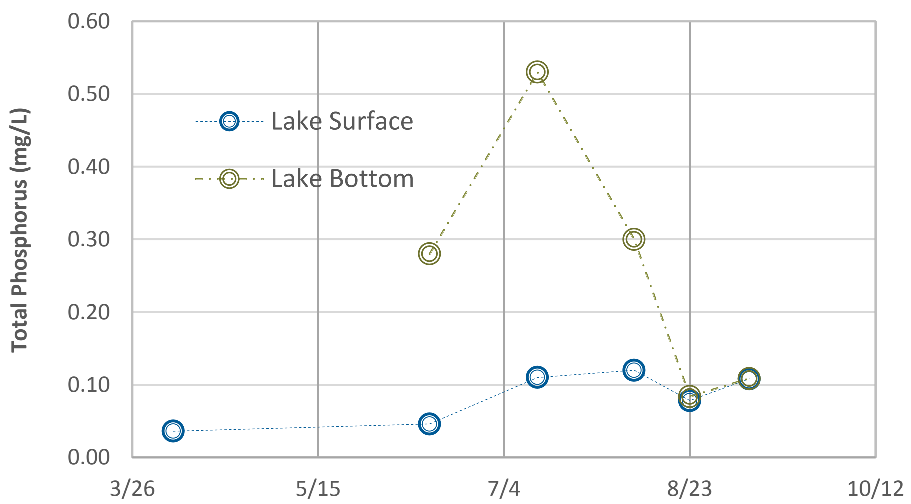

Figure 5 **Total phosphorus in the surface and bottom of Normandale Lake in 2016**

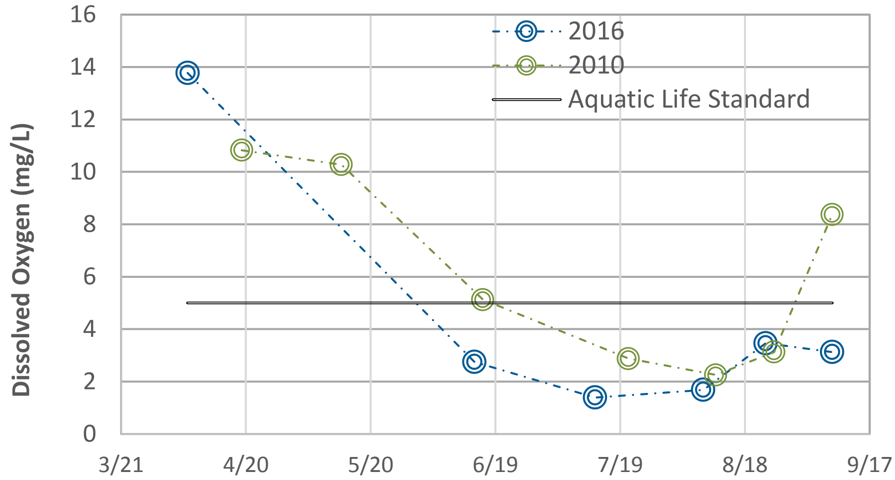

Figure 6 **Average total water column dissolved oxygen concentration in 2010 and 2016**

Increases in the lake's surface total phosphorus in both 2010 and 2016 corresponded with a significant decline in dissolved oxygen that began in June of each year (Figure 6). To a limited degree in 2016, phytoplankton populations (measured as chlorophyll *a*) increased with greater phosphorus in the water column, however, a similar response was not observed in 2010 (Figure 7).

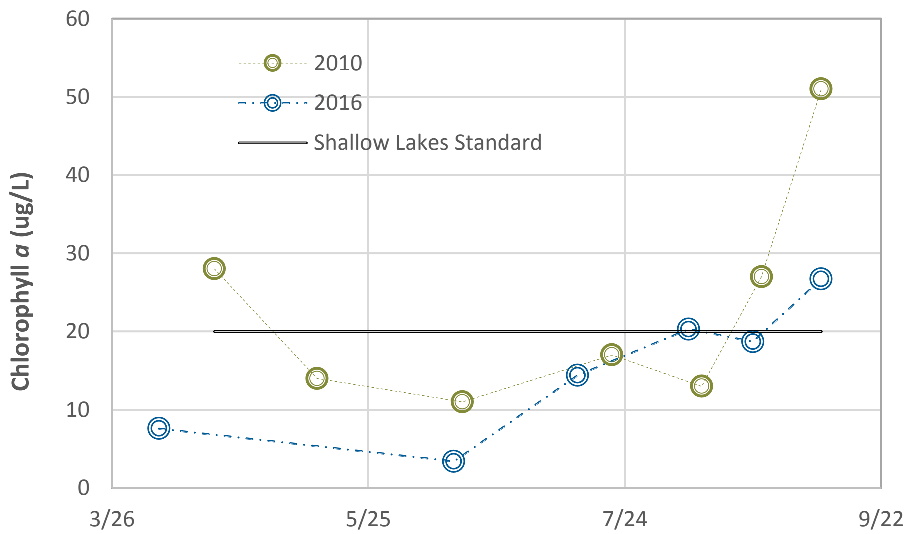

Figure 7 **Chlorophyll *a* concentrations in the surface of Normandale Lake**

2.2 Macrophytes and Filamentous Algae in Normandale Lake

Macrophytes, also called aquatic plants, are plants that grow in aquatic systems such as streams and lakes. There is a wide range of aquatic plants, some attached to the lake bottom, some unattached and floating, some submerged and some, like cattails, grow in but emerge from the water column. Macrophytes are an important part of a lake ecosystem and provide critical habitat for aquatic insects and fish.

Results of a point-intercept survey conducted in June and August 2017 indicate that the extent of macrophytes and filamentous algae coverage is significant. In June, aquatic plants were found in all of the 125 pre-defined sampling locations. In August, only one sampling location did not contain plants. Figure 8 below shows the dominate species in the lake, which include elodea (EC), curlyleaf pondweed (PC), coontail (CD), and filamentous algae (FA).

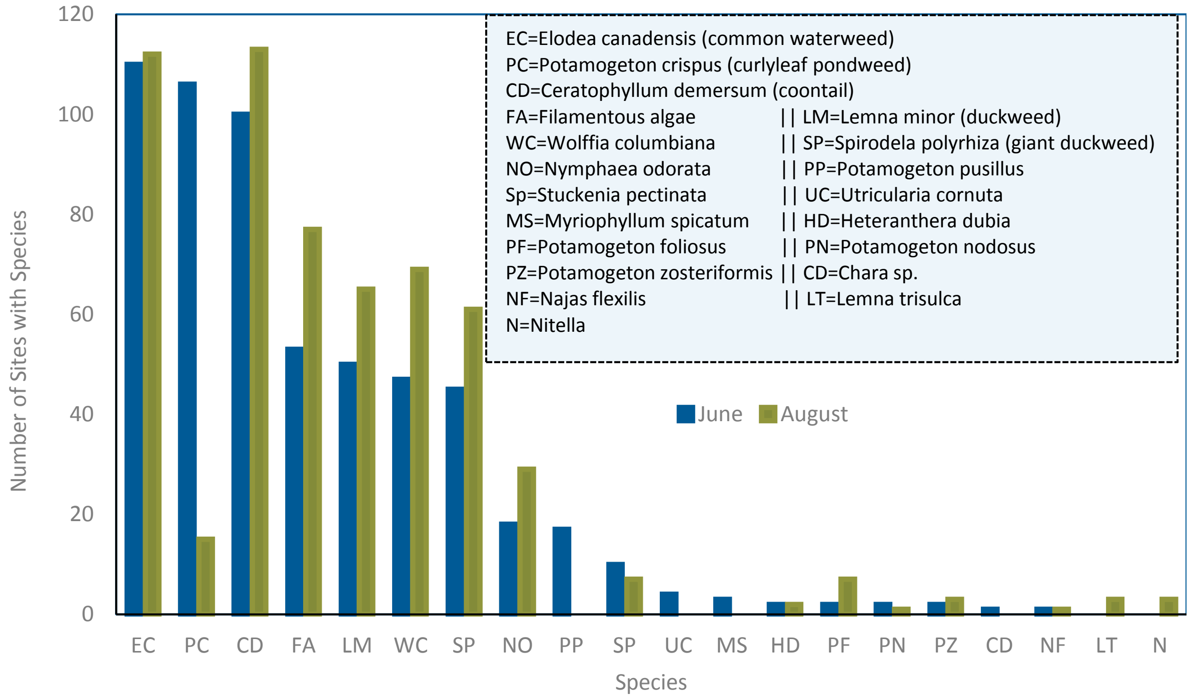

Figure 8 Relative abundance of aquatic plants in Normandale Lake in 2017

The curlyleaf pondweed population was extensive in 2017, comprising 29 percent of the lake's total aquatic plant and filamentous algae biomass in the lake in June. Increases in curlyleaf pondweed appear to have been a regional phenomenon, likely triggered by early ice-off and climate. By August, the curlyleaf pondweed population was significantly reduced, with the die-off and decomposition in June and July likely contributing to the low oxygen observed during these months. It is estimated that the total aquatic plant and filamentous algae wet biomass was 2,266,130 pounds (1,027,894 kilograms) in June and 1,754,831 pounds (795,974 kilograms) in August. With the curyleaf pondweed die-off, other species such as filamentous algae, and the non-attached floating species duckweed (*Lemna minor* and *Spirodela polyrhiza*) and wolfia filled the void left by curlyleaf pondweed.

The quality of aquatic plants in Normandale Lake has been steady since 2010 and has largely exceeded the Minnesota Department of Natural Resources Floristic Quality Index goal (see Figure 9). This suggests that there is a reasonably diverse population of native aquatic plants in the lake. However, the aquatic plant biomass survey conducted in 2017 demonstrates that most of the lake's biomass resides in coontail, elodea, curlyleaf pondweed, white water lily, and duckweed. For example, in August 2017 99.6 percent of the total lake mass could be accounted for by just four species. The relative percent mass of those four dominant species was: (1) coontail-38%, (2) elodea-41%, (3) white water lilly-17%, and (4) duckweed-3.6%. A more even distribution as well as diverse population aquatic plants would benefit Normandale Lake.

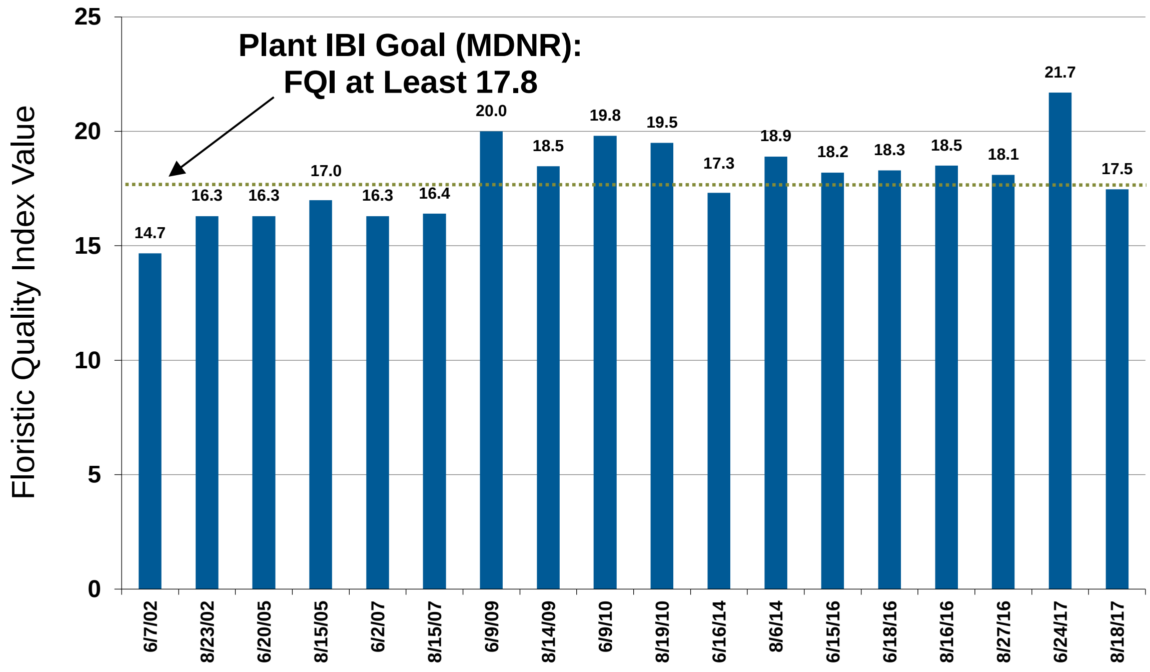

Figure 9 **Floristic Quality Index values for Normandale Lake since 2002**

Filamentous algae are also present in Normandale Lake with an average lake-wide rake fullness of 1 in August and 0.68 in June[1]. Biomass was not directly determined for filamentous algae but is included in the total biomass estimate for the lake. Three species of filamentous algae, *Pithophora (*horsehair algae), *Rhizoclonium hieroglyphicum* (filamentous green algae), and *Spirogyra* were collected and identified in 2017. These species are often visible to residents as they float on the water surface or are attached to aquatic plants during the summer months. Filamentous algae at the beginning of the open water season

[1] Aquatic plant surveys are conducted by throwing a rake into the lake and pulling it out to examine the plants that are pulled up with the rake. A rake fullness of 4 indicates that the rake is full of aquatic plants and 1 indicates that approximately 25 percent of the rake length contains aquatic plants (ranking of 2 and 3 imply 50 percent and 75 percent coverage). Zero is implicitly given to a condition when a rake has no plants. The total rake capture as well as each species is given a ranking from 1 to 4.

often begin growing on the bottom of lakes and move upward either with the growth of aquatic plants or by floating facilitated by gas bubble production. These species have similar nutrient requirements to aquatic plants and phytoplankton[2]. Hence, strategies to reduce aquatic plant and phytoplankton growth by nutrient reduction should also reduce filamentous algae growth.

[2] In Kohlman Lake (Ramsey Washington Metropolitan Watershed District) in 2015 the average concentration of phosphorus in dry filamentous algae was 2.5 grams per dry kilogram of material while aquatic plants had 3.3 grams of phosphorus per dry kilogram of plant material.

3.0 Water Quality Modeling of Management Options

3.1 Model Description

The GOTM-FABM model used for this study is a hydrodynamic and ecological (water quality) model, meaning it simulates lake temperature, stratification, water movement, nutrients, solids, phytoplankton growth, aquatic plant growth, dissolved oxygen, as well as several other chemical and biological parameters in lakes. It was developed by a consortium of European universities with staff at Arhus University in Denmark being lead developers.

This model was used to better understand and quantify several relationships, including:

- The effect of macrophytes on phytoplankton growth and overall population size (typically measured as chlorophyll *a*).
- The effect of phosphorus reduction (both external loads from stormwater and internal loads from lake-bottom sediment) on macrophyte and phytoplankton growth.
- The effect of phosphorus reduction (both external loads from stormwater and internal loads from lake-bottom sediment) on phosphorus concentrations in the water column of the lake.
- The relationship between light availability on macrophyte and phytoplankton growth.
- The deposition of phosphorus into lake-bottom sediments and the release of phosphorus from lake sediments.
- The cause of low oxygen in the lake.

3.2 Model Inputs and Set Up

Model inputs included climate (air temperature, relative humidity, percent cloud cover, wind speed), inflow and outflow rates, and inflow water chemistry (nutrients, solids, dissolved oxygen). The models were run for 2010 and 2016 starting at ice-off (approximately March 17, 2010, and March 8, 2016) and finishing at the end of October.

3.3 Calibration and Functional Observation

The process of model calibration involved changing a range of coefficients (e.g., "nobs") such that the model output is close to the measured data. For a model such as GOTM-FABM, the calibration parameters have to be based on reasonable literature-derived values in order for the mass balance of nutrients (in water, sediment, and in biota) and other key biological growth parameters to converge. Calibration is important such that predictions (e.g., for different management scenarios) are based upon a model with realistic calibration parameters. The results of the calibration process for select parameters are summarized in Table 2 below.

Table 2 Comparison of average model predictions and average monitoring results for selected model parameters

Year	Condition	Parameter (mg/L)		
		Dissolved Oxygen	Total Phosphorus	Chlorophyll *a*
2010[1]	Model	8.6	0.103	21.6
	Measured	5.8	0.120	18.5
2016[2]	Model	15.4	0.066	11.9
	Measured	4.4	0.083	15.2

1. Period of modeling results and monitoring data was from 4/19/2010 to 9/8/2010.
2. Period of modeling results and monitoring data was from 4/6/2016 to 9/8/2016.

Calibrated models should also be able to capture the seasonal changes in key parameters such as phosphorus. Capturing the seasonal change in total phosphorus (see calibration in Figure 9) indicates the model is correctly modeling the magnitude of internal phosphorus loading as well as the uptake and removal of phosphorus by biota such as phytoplankton and aquatic plants (see Figure 10).

A strength of the GOTM-FABM model is that it is capable of capturing the effect of other growth limiting factors such as light, in addition to nutrients (phosphorus as well as nitrogen limitation). The effect of shading by macrophytes, subsequent light limitation, as well as light inhibited phytoplankton growth can be seen in Figure 11, which shows the seasonal change in phytoplankton and macrophyte mass. The model results indicate that macrophyte growth (an increase in the population size) appears to inhibit phytoplankton growth (population size). Once the macrophytes stop growing (e.g., a stable population size), the phytoplankton begin growing. This demonstrates that the large macrophyte population in Normandale Lake is controlling phytoplankton and is likely preventing phytoplankton blooms during the summer months.

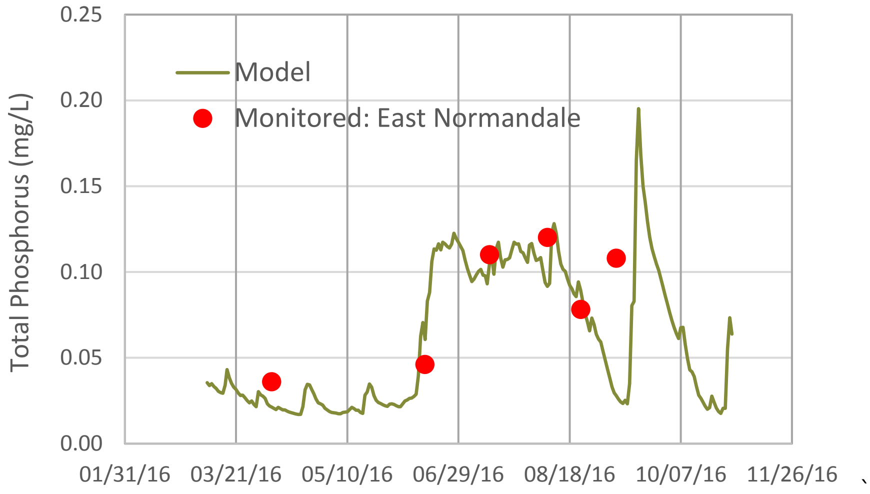

Figure 10 **Comparison of model predicted and measured total phosphorus in the surface water of Normandale Lake. Increase in phosphorus during late June through mid-August demonstrates the effect of internal loading on phosphorus concentrations in the water column of Normandale Lake (2016).**

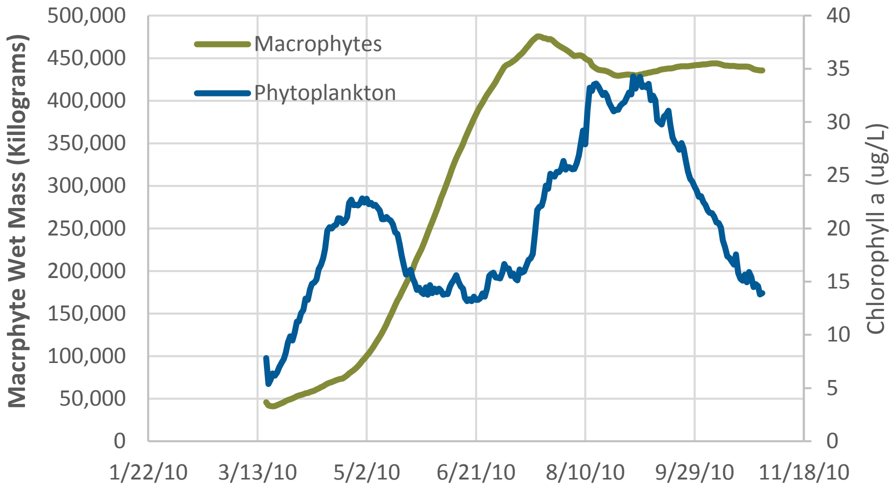

Figure 11 **Comparison of model predicted total wet mass of macrophytes in Normandale Lake and the concentration of phytoplankton (measured as chlorophyll a) in the surface waters of the lake (2010).**

3.4 Management Scenarios

Several modeling scenarios were conducted to better understand the effect of a range of phosphorus reduction strategies on: (1) phosphorus concentrations in the lake, (2) phytoplankton growth, and (3) macrophyte growth. Note that macrophytes in the model are representing any attached aquatic plant or filamentous algae or largely fixed plant that is not emergent. In essence, not phytoplankton. The modeled management scenarios included: (1) reduction of internal loading with a whole lake alum treatment, (2) reduction of external phosphorus loading (simulated as an inflow alum treatment facility that flocculates and removes phosphorus), and (3) a combination of internal and external loading control.

Reduction of internal loading by binding phosphorus in the lake sediments with alum (active component being aluminum) was simulated. The assumed alum dose was based upon the observed concentration of the phosphorus fraction in the lake sediment (e.g., the mobile phosphorus fraction), which is largely responsible for internal phosphorus loading. Alum dosing assumptions included: (1) a targeted aluminum to aluminum bound phosphorus ratio (Al:Al-P) of 75:1; (2) an 85 percent reduction in mobile phosphorus; (3) treatment of the upper 8 cm (3+ inches) of lake sediment with alum, i.e., aluminum; (4) total alum application of 23,024 gallons; and (5) total sodium aluminate application of 11,512 gallons. Sodium aluminate is similar to alum except it contains aluminum in a chemical with the formula $Na\mathbf{Al}(OH_4)$. Alum contains aluminum in the form $\mathbf{Al}_2(SO4)_3$. Aluminum is Al. Sodium aluminate is used in combination with alum to protect aquatic life from any potential pH effects of alum application.

The external load control scenario was simulated as an alum treatment facility located just upstream of Normandale Lake to treat Nine Mile Creek inflows. This modeling approach was taken due to strong interest expressed by local residents regarding the effects of an alum treatment facility on lake water quality. The simulation was based on an assumption that an alum treatment facility would remove 82 percent[3] of the total phosphorus that enters the treatment system. A range of treatment flows were simulated. Alum treatment systems are typically designed and sized to treat flows up to a targeted rate (see “Maximum Treated Flows” in Table 3). Flows above the targeted maximum flow rate are bypassed. Hence, there is greater overall efficiency from a capital cost standpoint when these systems are designed to treat lower maximum flows.

It should be noted that although the external load control scenario was simulated as an alum treatment facility, the phosphorus removals are largely analogous to implementation of stormwater Best Management Practices (BMPs) in the watershed, which will also lead to reduced phosphorus in Nine Mile Creek and ultimately reduced phosphorus loads to Normandale Lake. For example, the 5 cfs inflow alum treatment system that was simulated corresponds to a 25 percent reduction in total phosphorus from the watershed. The modeling results for the 5 cfs inflow alum system hence would be analogous to a 25 percent reduction in phosphorus with BMP implementation (based on 2010 data- see Table 3). Per the NMCWD’s 2017 Water Management Plan, reductions in external loading will be achieved through stream bank stabilization, implementation of the NMCWD permitting program, and implementation of stormwater best management practices and lake management strategies in the upstream watershed.

[3] The inflow alum treatment facility currently in operation at the Ramsey Washington Metro Watershed District has a treatment efficiency of 82 percent total phosphorus removal.

Table 3 **Treatment volume and phosphorus removal with construction of an inflow alum treatment facility**

Maximum Treated Flows (cfs)	2010		2016	
	% of Total Stream Volume Treated	% Total Phosphorus Reduction	% of Total Stream Volume Treated	% Total Phosphorus Reduction
0	0%	0%	0%	0%
5	31%	25%	36%	29%
10	46%	38%	53%	43%
15	56%	46%	62%	51%
20	63%	52%	69%	56%

3.5 Results

The predicted outcomes of internal and external phosphorus load control on total phosphorus concentration, phytoplankton (measured as chlorophyll *a*), and the total wet mass of macrophytes in Normandale Lake are shown in Table 4 (for 2010) and Table 5 (for 2016). The challenge for Normandale Lake is that the lake already acts as a significant sink for phosphorus, meaning, phosphorus is removed by aquatic plants, phytoplankton growth and settling, and by solids settling (phosphorus is incorporated into the solids). Any disturbance of these phosphorus removal mechanisms can lead to higher phosphorus concentrations in the lake. Although reduced phosphorus loading does have the effect of reducing macrophyte growth (see Table 4 and Table 5), this also means less phosphorus removal by plants. The outcome is that phosphorus concentrations in the water column of Normandale Lake are reduced minimally or not at all with phosphorus load reduction.

Another somewhat counter intuitive outcome of external and internal phosphorus reduction in Normandale Lake is that phytoplankton growth increases with phosphorus reduction. This is largely a function of increased light availability with reduced shading by macrophytes. Hence, any activity that increases light availability in the lake may be accompanied by increased phytoplankton growth. Aquatic plant harvesting may be the exception to this as harvesting removes some of the plant mass, but the overall mass of phosphorus taken up by aquatic plants is not reduced as long as aquatic plant growth is not significantly hindered by harvesting. This is difficult to predict, however, and the benefit of harvesting would need to be determined by a limited harvesting test period (e.g., 1 to 3 years of harvesting conducted as a test).

Table 4 2010 total phosphorus concentration, phytoplankton (measured as chlorophyll *a*), and the total wet mass of macrophytes in Normandale Lake with internal and external phosphorus load control.

Phosphorus Management Approach	Phosphorus Management Target	Maximum Flows Treated	% of Total Flow Treated	*Management Outcome: In-Lake Condition: June 1 to September 30*		
				Average Total Phosphorus (mg/L)	Average Chlorophyll *a* (mg/L)	Maximum Macrophyte Wet Mass (kg) In Entire Lake
None	NA	NA	0%	0.107	24	421,618
Inflow Alum Treatment Facility	External P Loads	5 cfs	31%	0.095	27	404,693
		10 cfs	46%	0.098	33	375,351
		15 cfs	56%	0.103	39	347,803
		20 cfs	63%	0.106	44	325,264
Whole Lake Alum Treatment	Internal P Loads	Not Applicable	0%	0.110	25	391,623
Whole Lake and Inflow Alum Treatment	External and Internal P Loads	5 cfs	31%	0.102	30	356,047

Table 5 2016 total phosphorus concentration, phytoplankton (measured as chlorophyll a), and the total wet mass of macrophytes in Normandale Lake with internal and external phosphorus load control.

Phosphorus Management Approach	Phosphorus Management Target	Maximum Flows Treated	% of Total Flow Treated	*Management Outcome: In-Lake Condition from June 1 to September 30*		
				Average Total Phosphorus (mg/L)	Average Chlorophyll *a* (mg/L)	Maximum Macrophyte Wet Mass (kg) In Entire Lake
None	NA	NA	NA	0.089	12.9	631,150
Inflow Alum Treatment Facility	External P Loads	5 cfs	29%	0.072	14.7	629,585
		10 cfs	43%	0.066	15.8	609,778
		15 cfs	51%	0.062	16.3	597,087
		20 cfs	56%	0.059	16.7	587,013
Whole Lake Alum Treatment	Internal P Loads	NA	NA	0.074	13.6	511,213
Whole Lake and Inflow Alum Treatment	External and Internal P Loads	5 cfs	29%	0.060	16.2	432,352

4.0 Management Options, Schedule and Costs

Table 6 summarizes the issues in Normandale Lake, in relation to the NMCWD's holistic lake health assessment factors. The table also describes the cause(s) of the issues and potential management options for consideration to improve lake health.

Table 6 Summary of issues and potential management options

NMCWD Holistic Lake Health Assessment Factors	Issues	Causes	Potential Management Options
Water Quality	High phosphorus (>60 µg/L average summer)	External and internal phosphorus loading	Whole lake alum treatment, upstream watershed BMP and lake management implementation.
	Potentially high phytoplankton	External and internal phosphorus loading	
Aquatic Communities	Invasive aquatic plants	Curlyleaf pondweed growth	Lake drawdown and chemical treatment of curlyleaf pondweed with endothall
	Low dissolved oxygen	Coverage of the lake surface by aquatic plants, curlyleaf pondweed die-off	Aquatic plant harvesting, aeration (direct oxygen injection)
Recreational Use[1]	Smell—hydrogen sulfide	Coverage of the lake surface by aquatic plants, curlyleaf pondweed die-off	Aquatic plant harvesting, aeration (direct oxygen injection)
	Excessive aquatic plants and filamentous algae	External and internal phosphorus loading	Whole lake alum treatment, BMP implementation in upstream watershed.

[1] The NMCWD considers water quality, aquatic communities, and water quantity to be the three primary factors in assessing the ecological health of a lake. The NMCWD also considers how recreation and wildlife habitat affect and are affected by overall lake health.

As summarized in the NMCWD's 2017 Water Management Plan, reductions in external loading to Normandale Lake will be achieved through stream bank stabilization, implementation of the NMCWD permitting program, implementation of management strategies for upstream lakes, and construction of stormwater best management practices in the watershed tributary to Normandale Lake. Because existing external and internal phosphorus loads to Normandale Lake are currently very large, ongoing external phosphorus reduction efforts need to be combined with other measures to concurrently meet the NMCWD goals of improved water quality and health of the aquatic community.

To maintain a more moderate aquatic plant population it is recommended that a whole lake alum treatment be conducted in concert with aquatic plant harvesting. The whole lake alum treatment will reduce internal phosphorus loads and facilitate reduced aquatic plant and filamentous algae growth by limiting phosphorus availability. The aquatic plant harvesting will reduce the coverage of the aquatic plant population which will improve exchange of oxygen between the lake and the atmosphere. This improved exchange of oxygen should lead to increased oxygen in the water column and improved fisheries habitat.

A lake drawdown and whole lake treatment targeting curlyleaf pondweed (treatment would be conducted with endothall in the spring at a dose of 1 mg/L) is recommended to promote a more diverse and native aquatic plant community. The current outlet structure includes a low flow bypass consisting of a 4-inch diameter hole cut through an 18-inch sluice gate at elevation 802.25 feet. Because of the constant and periodically high flows into Normandale Lake from Nine Mile Creek and the discharge limitations of the low flow bypass, it can be expected that the drawdown will not cover the entire lake. As such, the curlyleaf pondweed treatment with endothall is recommended to control pondweed across the entire lake (including those areas of the lake that are and are not affected by the drawdown). The drawdown is also expected to consolidate and aerate sediments and provide an opportunity to remove carp and other rough fish and restock the lake with a more balanced fishery. Because there is an opportunity to remove carp and re-balance the fishery, a carp and fisheries survey is recommended to determine if the carp population is large enough to disturb the ecology of Normandale Lake.

Direct oxygen injection is also recommended to keep the lake aerated for several reasons: (1) to prevent the generation of foul smelling hydrogen sulfide, (2) to help keep the lake sediments aerated and prevent internal loading as new, incoming phosphorus is deposited onto the lake bottom, and (3) to provide oxygen to fish species that cannot survive at low oxygen concentrations (e.g., 2-3 mg/L) that persist in Normandale Lake during the summer and to prevent winter fish kill. This system would inject pure oxygen into the water column across approximately half of the lake. The bubbles that are generated are small and not readily visible by those viewing or recreating on the lake and hence from a lake use standpoint this approach has benefits over forced air injection.

Table 7 summarizes the recommended schedule, permitting, engineering and design tasks and considerations, and estimated costs for the management options discussed above. The costs included in Table 7 are planning-level opinions of probable costs, intended to provide assistance in evaluating and comparing options and should not be assumed as absolute values for given alternatives.

It is important to note that management of Normandale Lake must be in conformance with the Army Corp of Engineers Section 404 permit that was issued in 1979 for construction of the dam. The permit contains several special conditions, including restrictions on vegetation control or dredging in the western portion of the lake. For management options being considered that are not allowed under the current permit, the NMCWD and City of Bloomington may need to seek modification to the existing permit.

As discussed in Section 3.4, the modeling analysis included evaluation of an alum treatment facility located just upstream of Normandale Lake to treat Nine Mile Creek inflows, due to strong interest expressed by local residents. Modeling results showed only moderate reductions in in-lake phosphorus concentrations. Due to the moderate reductions, high estimated capital cost to construct and operate an alum treatment facility, and land requirements for a pond to capture alum floc (minimum size of 1-2 acres for the 5 cfs treatment system with proportionately larger ponds needed for the large systems), this management option is not recommended for Normandale Lake.

Table 7 Management options, potential timing for implementation, tasks that need to be completed in preparation for the management activity, and opinion of probable cost

Management Option	Potential Timing	Preparatory Tasks/ Considerations	Opinion of Cost
Upstream Watershed BMP and Lake Management Implementation	Ongoing	Ongoing implementation of NMCWD 2017 Water Management Plan (see Tables 6-2 and 6-3)	See NMCWD 2017 Water Management Plan (Tables 6-2 and 6-3)
Lake Drawdown	Conduct in fall 2018	Carp and fisheries survey (spring/summer 2018)	$12,000
		Design and permitting (fall 2017-summer 2018)	$20,000
		Outfall construction/drawdown	$100,000–$300,000
Curlyleaf Pondweed Treatment	Spring 2019	Curlyleaf pondweed treatment. Apply for DNR permit and request a variance to treat more than 15% of the littoral area.	$100,000
In-lake Alum Treatment	Conduct in 2019 immediately after drawdown is completed and lake refills	Design and permitting (summer 2018)	$140,000
Aeration (Direct Oxygen Injection)	After drawdown, with timing dependent upon: (1) outcome of design analysis in the Engineer's Report, and (2) DNR and Army Corps of Engineers approval to harvest more than 50% of the lake's littoral area.	Consider installing a dual system (aeration plus ferric chloride for maintenance of internal phosphorus loading control)	$230,000, $15,000/year operation
Limited Plant Harvesting (2-3 Year Test)	After drawdown, with timing dependent upon DNR and Army Corps of Engineers approval to harvest more than 50% of the lake's littoral area.	Apply for DNR permit to harvest more than 50% of the littoral area. Request for modification of Army Corps of Engineers permit.	$50,000/year

Appendix E

Filamentous Algae Memo

Memorandum

To: Bob Obermeyer and Janna Kieffer, Barr Engineering Co.
From: Meg Rattei, Barr Engineering Co.
Subject: Normandale Lake Filamentous Algae
Date: August 18, 2017
Project: 23270I47.00

On August 8, 2017, Barr staff collected a filamentous algae sample from Normandale Lake to determine algal species. During the August 17, 2017 point intercept plant survey of Normandale Lake, the plant surveyor observed three different species of filamentous algae in the lake and collected a sample of each. The filamentous algae samples collected on August 8 and August 17 were analyzed in the Barr microscope laboratory for algal species. For the analysis, a 1 milliliter aliquot from each sample was placed in a Sedgewick Rafter counting chamber and selected microscopic fields in each counting chamber were then analyzed at 100 times magnification using a compound microscope. Results are shown in Table 1 and discussed in the following paragraphs.

Table 1 2017 Normandale Lake Filamentous Algae

Sample Date	Algal Taxa
8/8/2017	*Rhizoclonium hieroglyphicum*
8/17/2017	*Pithophora, Rhizoclonium hieroglyphicum*, and *Spirogyra*

1.0 *Pithophora*

Pictures of *Pithophora* collected from Normandale Lake on August 17, 2017 are shown below.

Pithophora belongs to the family Cladophoraceae, a family of filamentous green algae. This common mat-forming species, often referred to as "horsehair algae," forms infestations of thick, free-floating mats in shallow lakes, small impoundments, and coves and channels of larger lakes and reservoirs throughout the Midwest and southeastern United States. *Pithophora* may range in color from lime green to a dark green or greenish brown. It is often described as resembling a tangled mass of steel-wool or wool-like growth which is very course to the touch. *Pithophora* consists of multinucleate cylindrical cells united end to end in branched filaments. It is free-floating throughout its life and found in lakes or ponds where water flow is not rapid enough to wash it away[1].

Pithophora begins its growth on the bottom, attached to the substratum by holdfasts, and sporadically surfaces. When it becomes dense enough, the plant produces gas bubbles that become trapped. In warmer water, it becomes buoyant and it floats to the surface. Disturbance of these mats by high wind or heavy rain events may cause them to temporarily sink to the bottom. This often gives a false impression that the growth has "disappeared", only to have it return to the surface within several days.[2]

Pithophora distribution is determined by nutrient availability, particularly nitrogen. An Indiana study indicated that nitrate nitrogen concentrations of at least 1.23 mg/L and phosphate phosphorus concentrations of at least 0.1 mg/L would support *Pithophora* growth.[1] The external nutrient concentrations capable of supporting *Pithophora* growth were related to its half saturation constants (K_s). The K_S value for nitrate limited growth was 88 μM and the K_S value for phosphorus limited growth was 3.2 μM. Using these half saturation constants in a ratio between nitrate (NO3) and phosphate (PO4), it can be concluded that *Pithophora* growth would be limited by both nitrate and phosphate when the NO_3:PO_4 ratio is 27.6. When the NO_3:PO_4 ratio is greater than 27.6, growth would be limited by phosphorus and when the ratio is less than 27.6, growth would be limited by nitrogen. In the Indiana study, the NO_3:PO_4 ratio indicated nitrogen would limit *Pithophora* growth and the study results indicated nitrogen was the nutrient limiting *Pithophora* growth in Surrey Lake.[1] Other laboratory studies have found that *Pithophora* grew best in a medium heavily supplemented with nitrogen[3].

Pithophora reproduces by forming akinetes which are borne either singly or in chains on the filaments. The akinetes provide a means of overwintering, surviving desiccation when mats are stranded above the shoreline, and surviving conditions of nutrient depletion. While akinetes have been found throughout the year, akinete numbers show a definite temporal periodicity with highest numbers observed in winter and lowest numbers in summer. Although akinetes appear to be viable throughout the year, the majority of

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[1] Lembi, C. A., N. L. Pearlmutter, and D. F. Spencer. 1980. Life Cycle, Ecology, and Management Considerations of the Green Filamentous Alga, Pithophora. IWRRC Technical Reports. Paper 130. http://docs.lib.purdue.edu/watertech/130.
[2] http://www.bioremediate.com/algae2.html
[3] Neal, E. JCJ. And W. R. Herndon. 1968. Germination in *Pithophora* akinetes. Trans. Am. Microsc. Soc. 87:525-527.

akinetes appear to germinate when the water temperature reaches 20° C.[1] Algal biomass is highest following germination of akinetes. Consequently, biomass is highest in summer and lower in winter and spring. *Pithophora* forms a thick layer on the lake bottom resulting in the presence of significant amounts under the ice during winter.[1]

The most promising management option for *Pithophora* is nutrient reduction to create nutrient limitation. Studies indicate nitrate reduction has resulted in greater reductions in *Pithophora* biomass than phosphorus reduction.[4]

Chemical treatment is unlikely to attain long-term control:

- This species is resistant to copper sulfate. Studies of chemical control indicate that akinetes are more resistant than filamentous cells to copper sulfate treatments, tolerating copper concentrations as high as 4 µg/mL.[5] The mode of resistance to copper is the binding of copper to the outer layers of the cell wall so that very little copper enters the living cytoplasm within the cell. The copper binding is reversible and it is likely that most of the cell wall-sorbed copper is released back into the water and replaced by calcium and magnesium as the concentration of copper in the water is lowered.

- The tight clumping of filaments prevents penetration of the copper to the interior of the algal mats.[6]

- A further complication occurs because this species occurs in mats floating at the surface and also in mats found on the lake bottom. Hence, good distribution of chemicals, including that to bottom-lying mats, would be essential to control both surface and bottom mats.

- Control of both surface and bottom-lying mats would not eliminate *Pithophora* since akinetes stored in the hydrosoil on the lake bottom could germinate and initiate a new growth of filaments.

- Combinations of chemicals such as copper and diquat or copper and Hydrothol have been used with some success to control mats, but repeat treatments every three to four weeks are generally needed to prevent new mats from floating to the surface. It is doubtful that any

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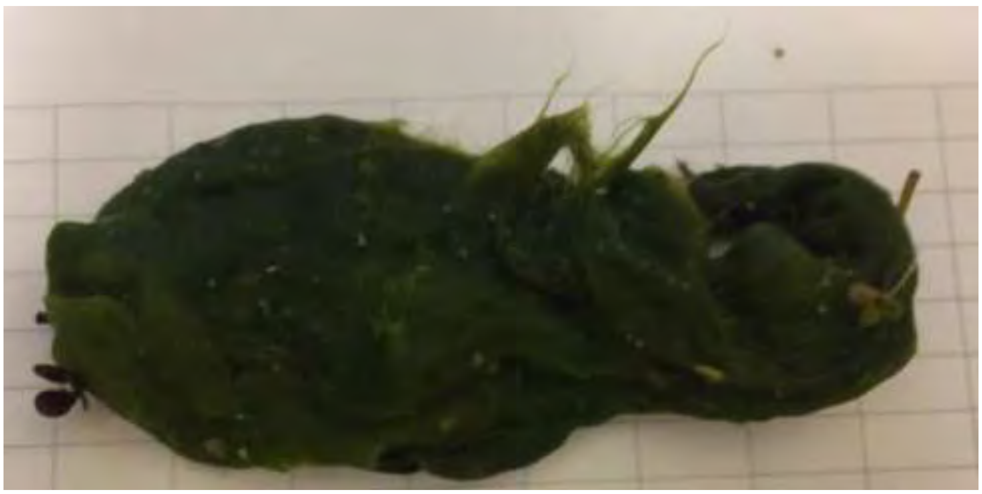
[4] Spencer, David F., Steven W. O'Neal, and Carole A. Lembi. 1987. A Model to Describe Growth of the Filamentous Alga Pithophora Oedogonia (Chlorophyta) in an Indiana Lake. J. Aquat. Plant Manage. 25:33-40.
[5] Pearlmutter, N. L. and C. A. Lembi. 1986. The Effect of Copper on the Green Alga *Pithophora* oedogonia. Weed Sci. 34:842-849.
[6] Lembi, Carole A., Steven W. O'Neal, and David F. Spencer. 1985. *Pithophora*. Aquatics, Volume 7, No. 4, pages 8-9 and 22.

chemical would provide long-term control since akinetes on the lake bottom can germinate and replenish the supply of *Pithophora* after treatment.[6]

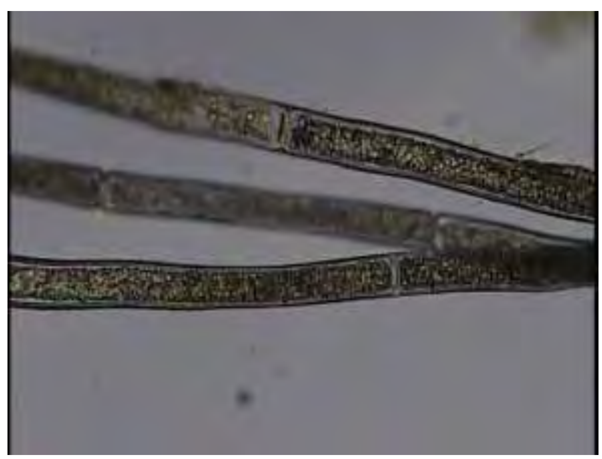
2.0 *Rhizoclonium hieroglyphicum*

Pictures of *Rhizoclonium hieroglyphicum* collected from Normandale Lake on August 8 and August 17 are shown below.



Rhizoclonium hieroglyphicum (August 17, 2017)

Rhizoclonium hieroglyphicum (August 8, 2017)



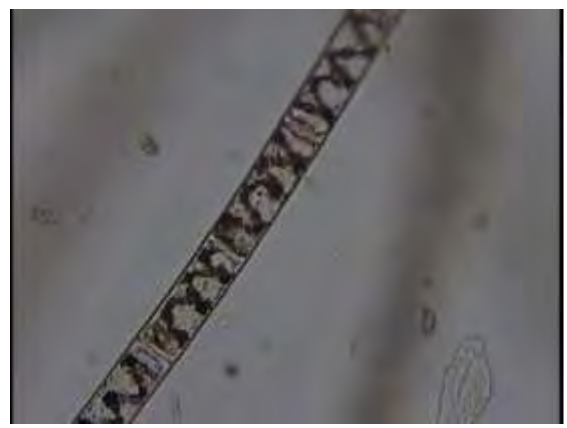
Rhizoclonium hieroglyphicum (August 17, 2017)

Rhizoclonium hieroglyphicum, a filamentous alga in the family Cladophoraceae, is commonly found in the algal mats of lakes and ponds. *Rhizoclonium* and *Pithophora* are members of the same family and share many characteristics, including the ability to survive unfavorable conditions by developing thick-walled akinetes

Similar to *Pithophora*, *Rhizoclonium* has a high tolerance to copper. In a study of tolerance of mat-forming algae to copper, *Rhizoclonium* had a similar tolerance to copper as *Pithophora* and was more than 15 times more tolerant to copper as *Spirogyra*.[7] The similarity in copper tolerances of *Rhizoclonium* and *Pithophora* is not unexpected since the two algae are in the same taxonomic family (Cladophoraceae) and are characterized by thick cell walls, which may reduce the penetration of copper into the cells.[1] As with *Pithophora*, nutrient reduction is the most promising long-term management option for *Rhizoclonium*.

3.0 *Spirogyra*

Pictures of *Spirogyra* collected from Normandale Lake on August 17 are shown below.



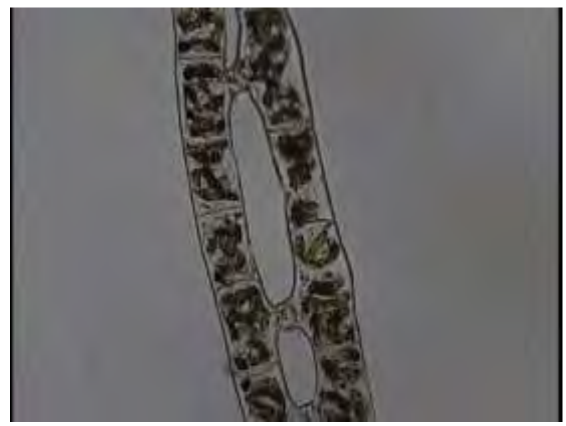
Spirogyra is a filamentous alga in the family Zygnematacea. The unbranched filaments consist of cells that are connected end. The cell wall has two layers: the outer wall is composed of pectin that dissolves in water to make the filament slimy to touch while the inner wall is of cellulose. The cytoplasm forms a thin lining between the cell wall and the large vacuole it surrounds. Chloroplasts are embedded in the peripheral cytoplasm; their numbers are variable (as few as one). The chloroplasts are ribbon shaped, serrated or scalloped, and spirally arranged, resulting in the prominent and characteristic green spiral on each filament. Each chloroplast contains several pyrenoids, centers for the production of starches, appearing as small round bodies.[8]

[7] Lembi, Carole A. Relative Tolerance of Mat-forming Algae to Copper. J. Aquat. Plant Manage. 38:68-70.
[8] *Spirogyra*. Wikipedia. http://en.wikipedia.org/wiki/*Spirogyra*

Spirogyra is very common in relatively clean eutrophic water, developing slimy filamentous green masses. *Spirogyra* begins its growth under the water in spring. When there is enough sunlight and warmth, they produce large amounts of oxygen, adhering as bubbles between the tangled filaments. The filamentous masses come to the surface and become visible as slimy green mats.[8]

Spirogyra can reproduce both sexually and rarely asexually. In vegetative reproduction, fragmentation takes place to form new filaments. Sexual reproduction is of two types:

1. **Scalariform conjugation occurs between two filaments** - Two different filaments line up side by side either partially or throughout their length. One cell each from opposite lined filaments emits tubular protuberances known as conjugation tubes, which elongate and fuse, to make a passage called the conjugation canal. The cytoplasm of the cell acting as the male travels through this tube and fuses with the female cytoplasm, and the gametes fuse to form a zygospore. This form of conjugation is shown in Figure 8.



Spirogyra reproducing by scalariform conjugation in Normandale Lake on August 17, 2017

2. **Lateral conjugation occurs between adjacent cells on the same filament** - Gametes are formed in a single filament. Two adjoining cells near the common transverse wall give out protuberances known as conjugation tubes, which further form the conjugation canal upon contact. The male cytoplasm migrates through the conjugation canal, fusing with the female. The rest of the process proceeds as in scalariform conjugation.[8]

Spirogyra is very sensitive to copper and, hence, a temporary control can be attained with copper sulfate. Copper is a compound required by plants and animals in very small amounts. However, application of copper at the recommended dose rates is very toxic to algae, inhibiting photosynthesis and preventing growth. In a study of tolerance of mat-forming algae to copper, the level of copper that resulted in a 50 percent reduction in dry weight biomass after 12 days of culture under laboratory conditions was <0.001 mg/L for *Spirogyra*. This compares with 0.046 mg/L for *Pithophora,* and 0.053 mg/L for *Rhizoclonium*.[6]

Despite its sensitivity to copper, long-term control of *Spirogyra* is unlikely because (1) the toxic action of copper upon algae is short-lived, (2) the supply of nutrients in the lake water is not reduced by an algaecide application, and (3) nutrients from the decaying algae are released back into the water. New algae growth begins soon after application and new mats of *Spirogyra* are formed as long as growing conditions for the algae are favorable. It is also believed algae"rebound" is aided by a lower abundance of algae-eating zooplankton following application (copper is toxic to *Daphnia* species, one of the most common and effective algae eaters). It's not surprising that algaecide control typically ranges from only a few days to a few weeks, and repeated applications are usually needed. It should be noted that it is necessary to wait 10 to 14 days between algaecide applications to protect fish and other aquatic life.[9]

4.0 Management Recommendations

Because the growth potential of filamentous algae is dependent upon nutrient and light conditions, the species of filamentous algae found in Normandale Lake (Table 1) have the potential to be present throughout the growing season. If drier conditions occur as the summer progresses and nutrients in the lakes diminish, the surface mats could disappear. However, the disappearance of the surface mats would not indicate the elimination of the algae from the lakes. The algae continuously reproduce, but increase the production of reproductive structures (e.g., akinetes) when conditions become unfavorable for growth. These reproductive structures fall to the lake bottom and wait for conditions to once again become favorable for growth of filamentous algae. When favorable conditions occur, the algae growth cycle resumes. Once filamentous algae are seen in a lake, they can be expected to grow during each growing season whenever light and nutrient conditions permit. The beginning of the growth season is generally triggered by the warming of the water to a threshold temperature (e.g., 15 to 20° C). The end of the growing season occurs when light, nutrient, or temperature conditions become unfavorable for growth of filamentous algae.

Management of filamentous algae is similar to the algae that float in the water column, termed planktonic algae. The most effective management option for both filamentous algae and planktonic algae is nutrient reduction to create a nutrient condition that is unfavorable for algal growth.

Management of nuisance mats of algae by chemical treatment is not recommended. Of the species listed in Table 1, only *Spirogyra* is easily controlled with a copper based algaecide. The other two species are resistant to copper and, hence, would require a relatively high dose of algaecide to attain control. A combination of herbicides (e.g., a copper based algaecide and an aquatic plant herbicide such as diquat or endotholl) is sometimes used on difficult to control species. Even when the algaecide dose is sufficient to remove existing plants from the water, the hardy reproductive structures would fall to the lake bottom, germinate, and replenish the supply of filamentous algae. Because filamentous algae can grow very rapidly, the benefit of a chemical treatment may only last a few days or a few weeks.

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[9] Hudson, Holly. 1997. Lake Notes: Aquatic Plant Management Options. Illinois Environmental Protection Agency and Northeast Planning Commission. 11 pages. http://www.epa.state.il.us/water/conservation/lake-notes/aquatic-plant-management/aquatic-plant-management.pdf

Harvesting of nuisance mats of algae is not recommended. Some literature studies have said harvesting was successful and some have said it was not successful at removing algal mats. A factor to be considered is whether or not filamentous algal species removed by harvesting would be prone to slip from the harvester and return to the lake. One of the three species listed in Table 1, *Spirogyra,* is slippery and could slip from the harvester and return to the lake. A second factor to be considered is whether harvesting could cause unintended negative changes to the aquatic plant community. While removing filamentous algae, the harvester would remove aquatic plants and deposit plant fragments. For species such as coontail that grow from plant fragments, depositing plant fragments can result in new plant growth in the lake. Coontail was found at 80 percent of plant survey points during June. Hence, harvesting filamentous algae could concurrently harvest coontail and deposit substantial numbers of coontail fragments. Populating the lake with coontail fragments while harvesting could increase both coontail extent and density in Normandale Lake.

Appendix F

Detailed Cost Estimates

ENGINEERS OPINION OF COST
DATED APRIL 13, 2018

DRAWDOWN OPTION 1: Open Existing 18-inch Bypass				
ITEM DESCRIPTION	**UNIT**	**ESTIMATED QUANTITY**	**UNIT COST**	**EXTENSION**
MOBILIZATION/DEMOBILIZATION (10%)	LS	1	$ 7,500.00	$ 7,500.00
Temporary sand bag weir to maintain water levels in wetland north of W 84th Street	LS	1	$ 20,000.00	$ 20,000.00
Repair/Replace Existing 18-inch Bypass	LS	1	$ 25,000.00	$ 25,000.00
Turtle Fencing	LF	10,000	$ 3.00	$ 30,000.00
			Subtotal=	**$ 82,500.00**
Engineering and Design (15%)				$ 12,375.00
Construction Management (15%)				$ 12,375.00
Legal (5%)				$ 4,125.00
Permitting (5%)				$ 4,125.00
			Total =	**$ 115,500.00**

Probable Cost Range: -20% to +40% ($92,400) to ($161,700)

ENGINEERS OPINION OF COST
DATED APRIL 13, 2018

DRAWDOWN OPTION 2: Replace Existing 18-inch Bypass with Larger 30-inch Bypass				
ITEM DESCRIPTION	**UNIT**	**ESTIMATED QUANTITY**	**UNIT COST**	**EXTENSION**
MOBILIZATION/DEMOBILIZATION (10%)	LS	1	$ 19,530.00	$ 19,530.00
Temporary sand bag weir to maintain water levels in wetland north of W 84th Street	LS	1	$ 20,000.00	$ 20,000.00
Clear and Grub (Light)	LS	1	$ 3,500.00	$ 3,500.00
Erosion Control Construction Entrance	Each	1	$ 2,500.00	$ 2,500.00
Site Access and Protect Existing Trails	LS	1	$ 4,500.00	$ 4,500.00
Silt Fence	LF	250	$ 3.50	$ 875.00
Turtle Fencing	LF	10,000	$ 3.00	$ 30,000.00
Sediment Log	LF	175	$ 5.50	$ 962.50
Floatation Silt Curtain	LF	320	$ 10.50	$ 3,360.00
Erosion Control Blanket Category 3, Type 2S	SY	650	$ 2.30	$ 1,495.00
Remove/Salvage Top Soil	CY	7	$ 4.50	$ 31.50
Remove Burrowing Animal Barrier Bank Protection	SY	66	$ 10.00	$ 660.00
Remove Storm Sewer Pipe, 18" DIP	LF	290	$ 15.00	$ 4,350.00
Remove 18" Sluice Gate	Each	1	$ 750.00	$ 750.00
Remove Existing Bituminous Trail	SY	56	$ 5.50	$ 308.00
Construct Coffer Dam and Removal	LF	350	$ 65.00	$ 22,750.00
Control of Water/Dewatering	LS	1	$ 25,000.00	$ 25,000.00
Install 30" RCP Class III	LF	290	$ 135.85	$ 39,396.50
Connect to Existing 72" Dia. Manhloe	Each	2	$ 750.00	$ 1,500.00
30" RCP Flared End Section and HD Trash Rack	Each	1	$ 2,694.00	$ 2,694.00
Class 3 Riprap with Filter/Fabric	TON	12	$ 94.00	$ 1,128.00
30" Sluice Gate	Each	1	$ 20,800.00	$ 20,800.00
Class 5 Aggregate Trail Base	CY	12	$ 35.00	$ 420.00
Replace Bituminous Trail	TON	10	$ 125.00	$ 1,250.00
Replace Burrowing Animal Barrier Bank Protection	SY	66	$ 15.00	$ 990.00
Replace Salvaged Topsoil	CY	7	$ 5.00	$ 35.00
Seed; (Native)	SY	650	$ 1.75	$ 1,137.50
Sod	SY	50	$ 7.50	$ 375.00
Misc. Erosion Control, (Street and Trail Sweeping)	LS	1	$ 3,000.00	$ 3,000.00
Pedestrian Traffic Control, Trail Signage	LS	1	$ 1,500.00	$ 1,500.00
			Subtotal =	**$ 214,798.00**
Engineering and Design (15%)				$ 32,220.00
Construction Management (15%)				$ 32,220.00
Legal (5%)				$ 10,740.00
Permitting (5%)				$ 10,740.00
			Total =	**$ 300,718.00**

Probable Cost Range: -20% to +40% ($240,575) to ($421,005)

ENGINEERS OPINION OF COST
DATED APRIL 13, 2018

DRAWDOWN OPTION 3: Open Existing 18-inch Bypass and Install Temporary 10-cfs Pump				
ITEM DESCRIPTION	**UNIT**	**ESTIMATED QUANTITY**	**UNIT COST**	**EXTENSION**
MOBILIZATION/DEMOBILIZATION (10%)	LS	1	$ 27,450.00	$ 27,450.00
Temporary sand bag weir to maintain water levels in wetland north of W 84th Street	LS	1	$ 20,000.00	$ 20,000.00
Repair/Replace Existing 18-inch Bypass	LS	1	$ 25,000.00	$ 25,000.00
Pumping Equipment Rental (28 day period)	LS	7	$ 8,975.00	$ 62,825.00
Temporary Structure	LS	1	$ 2,000.00	$ 2,000.00
Temporary Structure Construction and Modification	LS	1	$ 8,000.00	$ 8,000.00
Pump Maintenance and Operation (28 day period)	LS	7	$ 7,000.00	$ 49,000.00
Diesel Fuel (28 day period, maximum amount)[1]	LS	7	$ 11,100.00	$ 77,700.00
Turtle Fencing	LF	10,000	$ 3.00	$ 30,000.00
			Subtotal =	**$ 301,975.00**
Engineering and Design (10%)[2]				$ 30,198.00
Construction Management (10%)[2]				$ 30,198.00
Legal (5%)				$ 15,099.00
Permitting (5%)				$ 15,099.00
			Total =	**$ 392,569.00**

Probable Cost Range: -20% to +40% ($314,055) to ($549,595)

1. Assumes pump is running at full capacity consuming 6.6 gal/hr, 24 hr/day for 28 days at a fuel price of $2.50/gal.
2. Costs reduced from the usual 15% due to the lower design and construction administration costs associated with the tem

ENGINEERS OPINION OF COST
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DRAWDOWN OPTION 4: Open Existing 18-inch Bypass, Construct New 30-inch Bypass and Install Temporary 10-cfs Pump for Two Months				
ITEM DESCRIPTION	**UNIT**	**ESTIMATED QUANTITY**	**UNIT COST**	**EXTENSION**
MOBILIZATION/DEMOBILIZATION (10%)	LS	1	$ 27,870.00	$ 27,870.00
Temporary sand bag weir to maintain water levels in wetland north of W 84th Street	LS	1	$ 20,000.00	$ 20,000.00
Repair/Replace Existing 18-inch Bypass	LS	1	$ 25,000.00	$ 25,000.00
Pumping Equipment Rental (28 day period)	LS	2	$ 8,975.00	$ 17,950.00
Temporary Structure	LS	1	$ 2,000.00	$ 2,000.00
Temporary Structure Construction and Modification	LS	1	$ 8,000.00	$ 8,000.00
Pump Maintenance and Operation (28 day period)	LS	2	$ 7,000.00	$ 14,000.00
Diesel Fuel (28 day period, maximum amount)[1]	LS	2	$ 11,100.00	$ 22,200.00
Clear and Grub (Light)	LS	1	$ 3,000.00	$ 3,000.00
Erosion Control Construction Entrance	Each	1	$ 2,500.00	$ 2,500.00
Site Access and Protect Existing Trails	LS	1	$ 5,000.00	$ 5,000.00
Silt Fence	LF	220	$ 3.50	$ 770.00
Turtle Fencing	LF	10,000	$ 3.00	$ 30,000.00
Sediment Log	LF	160	$ 5.50	$ 880.00
Floatation Silt Curtain	LF	320	$ 10.50	$ 3,360.00
Erosion Control Blanket Category 3, Type 2S	SY	595	$ 2.30	$ 1,368.50
Remove/Salvage Top Soil	CY	8	$ 4.50	$ 36.00
Remove Burrowing Animal Barrier Bank Protection	SY	66	$ 10.00	$ 660.00
Construct Coffer Dam and Removal	LF	350	$ 65.00	$ 22,750.00
Control of Water/Dewatering	LS	1	$ 25,000.00	$ 25,000.00
Install 30" RCP Class III	LF	240	$ 135.85	$ 32,604.00
30" RCP Flared End Section	EACH	1	$ 2,694.00	$ 2,694.00
Class 3 Riprap with Filter/Fabric	TON	11	$ 94.00	$ 1,034.00
72" Dia. RC Manhole and Casting Assembly	Each	1	$ 10,452.00	$ 10,452.00
30" Sluice Gate	Each	1	$ 20,800.00	$ 20,800.00
Replace Burrowing Animal Barrier Bank Protection	SY	66	$ 15.00	$ 990.00
Replace Salvaged Topsoil	CY	8	$ 5.00	$ 40.00
Seed; (Native)	SY	620	$ 1.75	$ 1,085.00
Misc. Erosion Control, (Street and Trail Sweeping)	LS	1	$ 3,000.00	$ 3,000.00
Pedestrian Traffic Control, Trail Signage	LS	1	$ 1,500.00	$ 1,500.00
			Subtotal =	**$ 306,543.50**
Engineering and Design (10%)[2]				$ 30,654.00
Construction Management (15%)				$ 45,982.00
Legal (5%)				$ 15,327.00
Permitting (5%)				$ 15,327.00
			Total =	**$ 413,833.50**

Probable Cost Range: -20% to +40% ($331,065) to ($579,365)

1. Assumes pump is running at full capacity consuming 6.6 gal/hr, 24 hr/day for 28 days at a fuel price of $2.50/gal.
2. Costs reduced from the usual 15% due to the lower design costs associated with the temporary pump.

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ENDOTHALL TREATMENT FOR CURLYLEAF PONDWEED MANAGEMENT			
ITEM DESCRIPTION	**UNIT COST**	**COST PER YEAR**	**COST FOR 5 YEARS**
Lake Vegetation Management Plan (1)	$ 5,700.00	$ 5,700.00	$ 5,700.00
Prepare Bids/Specs (1)	$ 7,000.00	$ 7,000.00	$ 7,000.00
Management (5 years)	$ 4,200.00	$ 4,200.00	$ 21,000.00
Treatment Design (5 years)	$ 1,500.00	$ 1,500.00	$ 7,500.00
MnDNR Permitting/Variance (5 years)	$ 1,200.00	$ 1,200.00	$ 6,000.00
USACE Permit Amendment (1)	$ 5,000.00	$ 5,000.00	$ 5,000.00
Temperature Measurements (5 years)	$ 7,500.00	$ 7,500.00	$ 37,500.00
Flow Measurements (5 years)	$ 5,500.00	$ 5,500.00	$ 27,500.00
Aquatic Plant Monitoring (5 years)	$ 3,900.00	$ 3,900.00	$ 19,500.00
Turion Monitoring (5 years)	$ 3,600.00	$ 3,600.00	$ 18,000.00
Herbicide Residue Monitoring (5 years)	$ 2,300.00	$ 2,300.00	$ 11,500.00
Water Quality Monitoring (5 years)	$ 12,200.00	$ 12,200.00	$ 61,000.00
Data Processing/Reporting to MnDNR (5 years)	$ 4,200.00	$ 4,200.00	$ 21,000.00
Mobilization (5 years)	$ 3,000.00	$ 3,000.00	$ 15,000.00
Endothall Application (5 years)	$ 40,000.00	$ 40,000.00	$ 200,000.00
	Subtotal=	**$ 106,800.00**	**$ 463,200.00**
Contingency (10%)		$ 10,680.00	$ 46,320.00
	Total=	**$ 117,480.00**	**$ 509,520.00**

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ALUM TREATMENT				
ITEM DESCRIPTION	**UNIT**	**ESTIMATED QUANTITY**	**UNIT COST**	**EXTENSION**
MOBILIZATION/DEMOBILIZATION	LS	1	$ 15,000.00	$ 15,000.00
Alum + Sodium Aluminate	Gallon	34,500	$ 2.84	$ 97,980.00
			Subtotal =	**$ 112,980.00**
Bid and Contract Documents	lump sum	1	$ 10,000.00	$ 10,000.00
pH Monitoring and Oversight	lump sum	1	$ 5,000.00	$ 5,000.00
			Subtotal =	**$ 127,980.00**
Contingency (10%)				$ 12,798.00
			Total =	**$ 140,778.00**

Assumptions

- Assumes HAB Aquatic Solutions mob./demob. from Nebraska
- Dose equipment to 470 gal/acre alum only applied to entire 112 acres of lake.
- Tax exempt unit rate for alum/sodium aluminate assuming 2:1 volume ratio from LMRWMO April 2017 treatments
- Barr assistance with bid administration and contract documents
- Two Barr staff, 2 full days of observation of alum application and pH monitoring.

ENGINEERS OPINION OF COST
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MACROPHYTE HARVESTING				
ITEM DESCRIPTION	UNIT	ESTIMATED QUANTITY	UNIT COST	EXTENSION
Harvest (assumed 40 acre area)- twice a year for 3 years.	LS	6	$ 25,000.00	$ 150,000.00
Harvested Material Removal (assumes 30 round trips per monitoring event)	round trips	180	$ 100.00	$ 18,000.00
Harvest Monitoring (assumes 10 days per monitoring event)	daily	60	$ 200.00	$ 12,000.00
Macrophyte Survey	each	5	$ 3,000.00	$ 15,000.00
			Subtotal =	**$ 195,000.00**
Contigency (10%)				$ 19,500.00
Coordination and permitting (10%)				$ 19,500.00
			Total =	**$ 234,000.00**

ENGINEERS OPINION OF COST
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OXYGENATION SYSTEM				
ITEM DESCRIPTION	**UNIT**	**ESTIMATED QUANTITY**	**UNIT COST**	**EXTENSION**
In-lake Apparatus	LS	1	$ 66,500.00	$ 66,500.00
On-shore Facilities (pre-cast concrete)	LS	1	$ 15,000.00	$ 15,000.00
Air Supply	LS	1	$ 12,050.00	$ 12,050.00
Oxygen Separator	LS	1	$ 7,575.00	$ 7,575.00
Pump and Oxygen Saturator	LS	1	$ 32,050.00	$ 32,050.00
			Subtotal =	**$ 133,175.00**
Engineering and Design (30%)				$ 39,952.50
Contingency (25%)				$ 43,281.88
			Total =	**$ 216,409.38**
Annual Operating Cost (10 Hp total)				**$ 8,000.00**

Appendix G

Side-stream Saturation Technology Documentation

Normandale Lake Oxygenation Summary Technical Report

PREPARED FOR: BARR Engineering Co.

PREPARED BY: Paul Gantzer (Gantzer Water Resources Engineering, GWRE)

CONTRACTED BY: Keith Pilgrim (BARR Engineering Co.)

DATE: April 8, 2018 ***DRAFT***

The following technical memorandum is provided with regards to evaluation of water quality management strategy for Normandale Lake related to anoxia.

Project objectives and deliverables:

- GWRE will evaluate available data to determine the required oxygen input to address oxygen demands contributing to anoxia during summer periods. Design will include evaluation of applicable water quality management strategies such as pure oxygen. Design recommendations will consider maintenance of thermal stratification during operation.
- Sizing and cost of the aeration system.
- Short memo describing the system design, sizing, and cost

1. Background

Water quality data were reviewed to evaluate anoxia (i.e., the lack of dissolved oxygen, DO). Anoxia in the lake's bottom waters results primarily from decomposition of organic matter where natural atmospheric aeration does not occur due to thermal stratification of the water column. Organic matter and nutrient loadings (both internal and external sources) fuel algal growth and DO demands, that in turn result in additional organic loading to the sediment as algae die and settle to the bottom. As organic material builds up and is incompletely oxidized due to insufficient DO supply, DO demand in near-bottom suspended sediment as well as in the sediment bed increases thereby creating "legacy" DO demand.

Under oxic conditions, phosphorus in the form of phosphate is chemically bound to iron as a precipitate ($FePO_4$) in the sediment. During thermal stratification, the water column is divided into three distinct layers, warm upper water (epilimnion), cold bottom water (hypolimnion), and the temperature gradient zone in the middle (metalimnion or thermocline) (Figure 1.1). Because of the density gradient in the thermocline, the hypolimnion is isolated from the well-oxygenated epilimnion. As DO is depleted in the hypolimnion, the bond between iron and phosphate is broken and results in the release of (soluble) ferrous iron (Fe^{+2}) and phosphate (PO_4^{-3}) from the sediment to the overlying waters. Iron thereby plays a vital role in binding phosphorus in the form of phosphate (PO_4^{-3}) in the sediments. It is also noted that phosphorus exists in both soluble and insoluble forms, but more importantly that insoluble phosphorus can be converted to soluble.

In the fall, when the surface and bottom temperatures align, the water column mixes releasing stored phosphorus in the hypolimnion to the surface where algae can increase. This is usually observed as a fall algae bloom. Algal blooms often can promote undesirable algal species. This is the case when surface waters warm and are not subject to mixing by normal wave action that, in turn, promotes blue-green algae (cyanobacteria) production. Cyanobacteria create a secondary water quality concern related to the cyanotoxins stored in their cell structure that are released to the water column as a result of cell lysis. Although cyanotoxins have not been identified as problematic prior to this investigation, it is something that should be considered.

Furthermore, as organic loading continues each year, compounded by incomplete oxidation between growing seasons, DO demand in the sediments perpetually increases. In summary, DO demands exceeding the DO stored in the water column, excessive latent and continuing organic buildup in the sediments, the inability to sequester and/or remove phosphorus in the water column, as well as conditions favorably promoting cyanobacteria growth all result in water quality degradation.

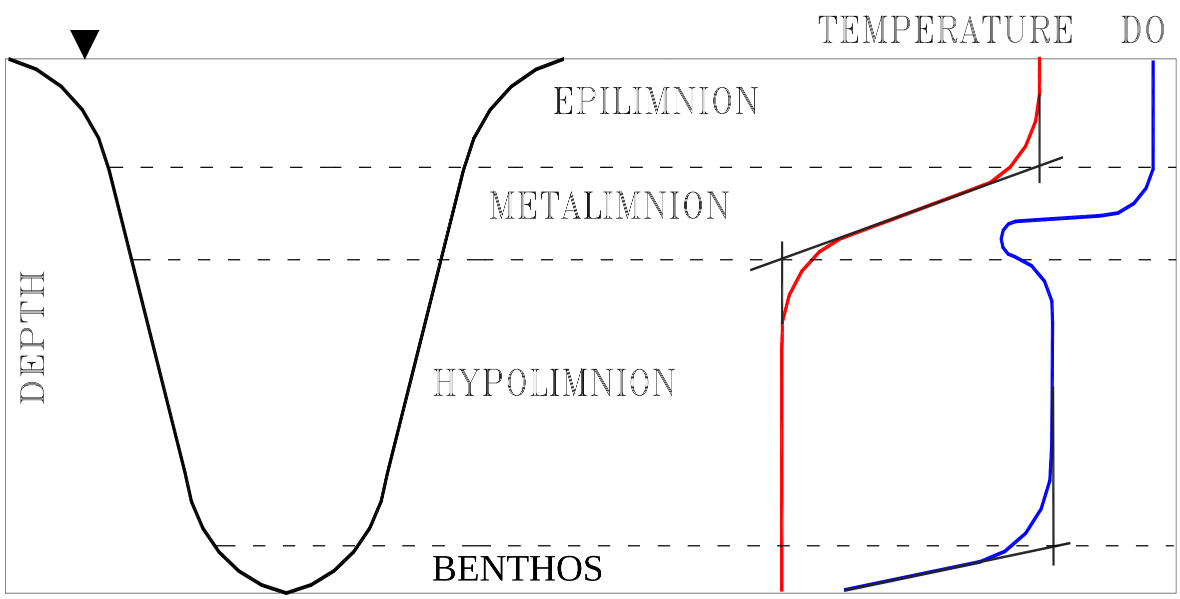

Figure 1.1: Graphical representation of different regions in the water column, using the temperature profile showing epilimnion, metalimnion, hypolimnion and benthos.

2. DO Demand

To properly size a hypolimnetic oxygenation system, the DO demand to be overcome needs to be calculated. There are several different methods used to determine DO demand, *in-situ* sediment oxygen demand (SOD) measurements, regression analysis of water column profiles, and empirical calculations. For the Normandale Lake oxygenation evaluation, the regression analysis was conducted using the provided 2010 water column data set. Oxygen depletion rates were determined for each strata based on depth DO data were collected (Table 2.1).

Table 2.1: Summary of DO data and calculated oxygen depletion rates.

Lake Depth (ft)	0	3.28	6.56	8.2	
Date	Dissolved Oxygen Concentration (mg/L)				
4/19/10	14.0	13.6	11.1	4.6	
5/13/10	10.8	10.4	10.2	9.7	
6/16/10	9.9	9.3	1.0	0.3	
7/21/10	5.4	5.2	0.6	0.3	
8/11/10	3.6	3.1	2.1	0.2	
8/25/10	4.3	4.2	3.7	0.3	
9/8/10	8.8	8.7	8.0	8.0	
Observed depletion rate (mg/l d)	-0.085	-0.084	-0.271	-0.276	
Observed depletion rate (kg/ d)		-3.41	-0.48	-0.06	-3.95
Corresponding Areal depletion rate (g/m^2 d)		-0.001	-0.048	-0.189	

Evaluation of the Areal depletion rate, using the available water column data revealed rates very low compared to other eutrophic systems. Other eutrophic systems often have measured areal depletions rates between 2.0 and 3.0 g/m^2 day, which is more than an order of magnitude higher than the calculated rates from the available data. As a result, the oxygenation system design was evaluated using the higher estimated rates.

3. Recommended Water Quality Management System

There are two common methods to manage water quality related to bottom water anoxia, destrtification and oxygenation. Destratification involves the continuous mixing of the water column to promote atmospheric re-aeration of surface and mixing them to the bottom. Oxygenation involves the injection of pure oxygen locally to the bottom waters to supplement the oxygen deficiency. For Normandale Lake, destratification would require a significant amount of in-lake infrastructure that would be problematic given the shallow depth of 90% of the lake. Therefore the recommended strategy to mitigate anoxia in Normandale Lake is an oxygen maintenance strategy employing side-stream saturation (SSS) technology.

A schematic of an SSS system is shown in Figure 3.1. SSS systems withdraw water from the bottom of the reservoir, inject pure oxygen into the water flow upstream of a contact chamber that allows the oxygen gas to dissolve into the water, and then return the oxygenated water to the bottom of the reservoir. A photo of an SSS system including in-lake distribution is shown in Figure 3.2. For optimal water circulation and oxygen distribution, nozzles are placed on opposite sides of the distribution header, which is shown in Figure 3.3.

Another benefit of a SSS system is the ability of the distribution header to provide an injection means of geochemical augmentation, such as ferric or alum. Geochemical augmentation would be an additional method to mitigate internal phosphorus loading identified in the Normandale Lake Report that would complement the full-lake Alum treatment. With active circulation of the bottom water via the SSS system, ferric or alum injection can be added with the addition of a small feed header pipe, which is shown in Figure 3.4.

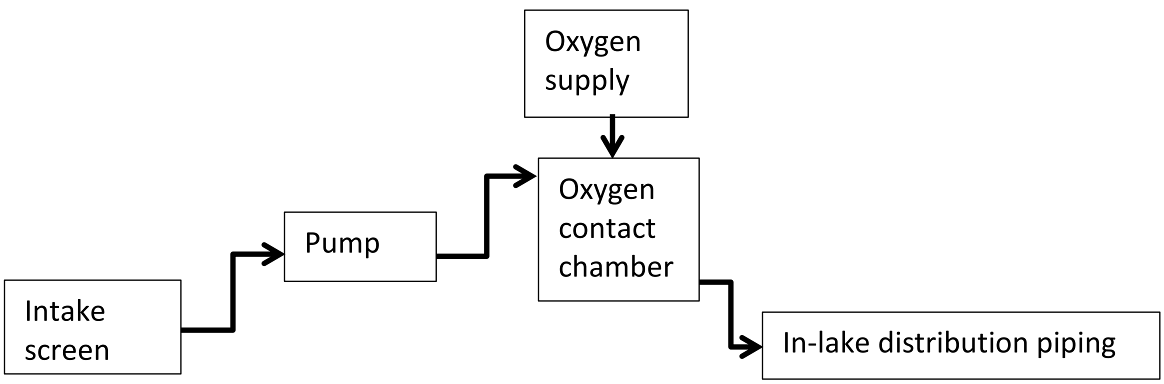

Figure 3.1: Flow diagram of SSS

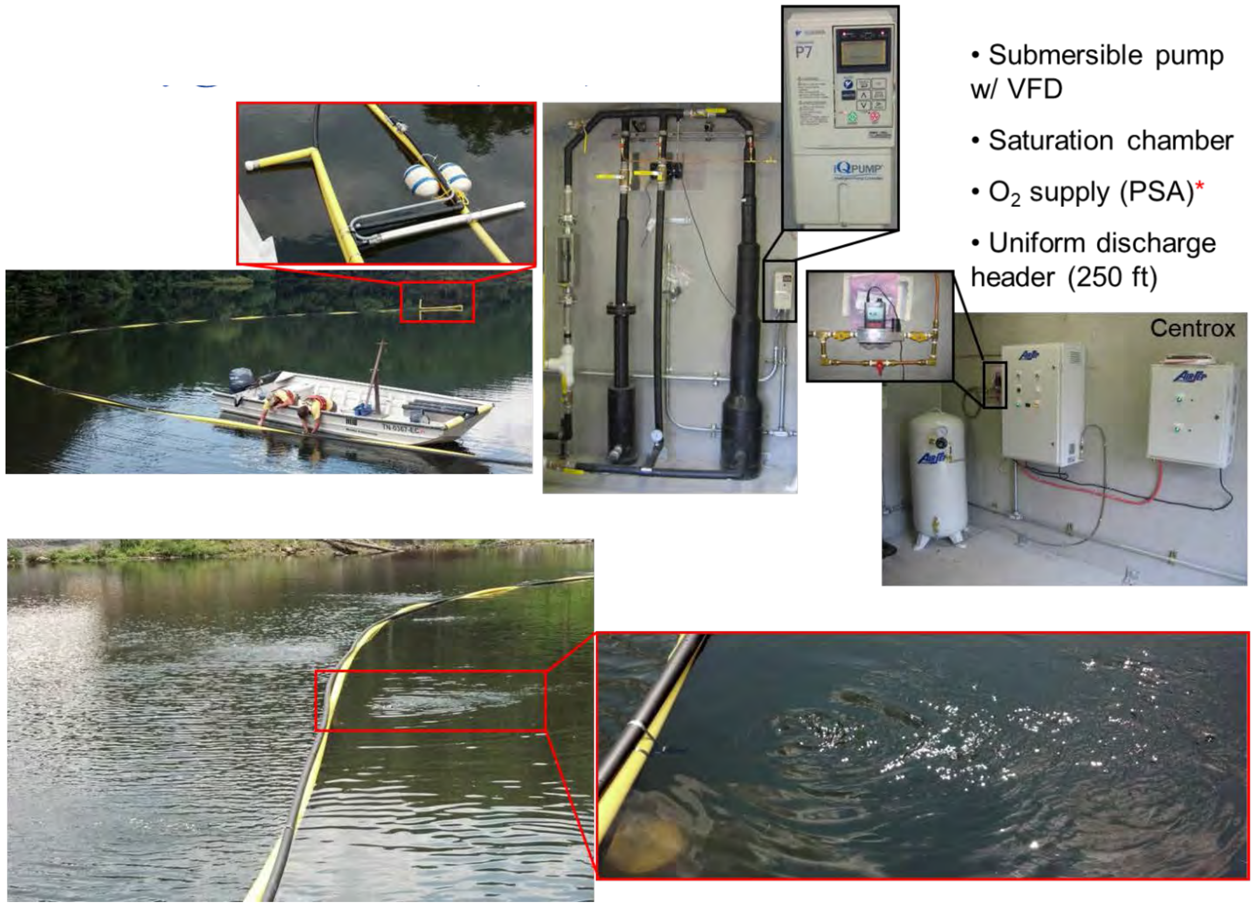

Figure 3.2: Example of an SSS layout showing in-lake distribution piping and corresponding components

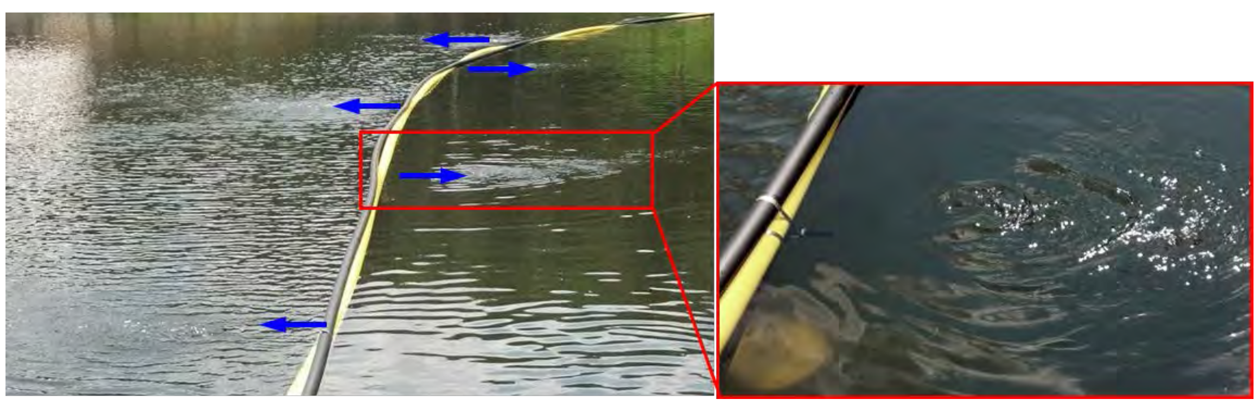

Figure 3.3: Close up of in-lake distribution header showing direction of nozzles on opposite sides of pipe.

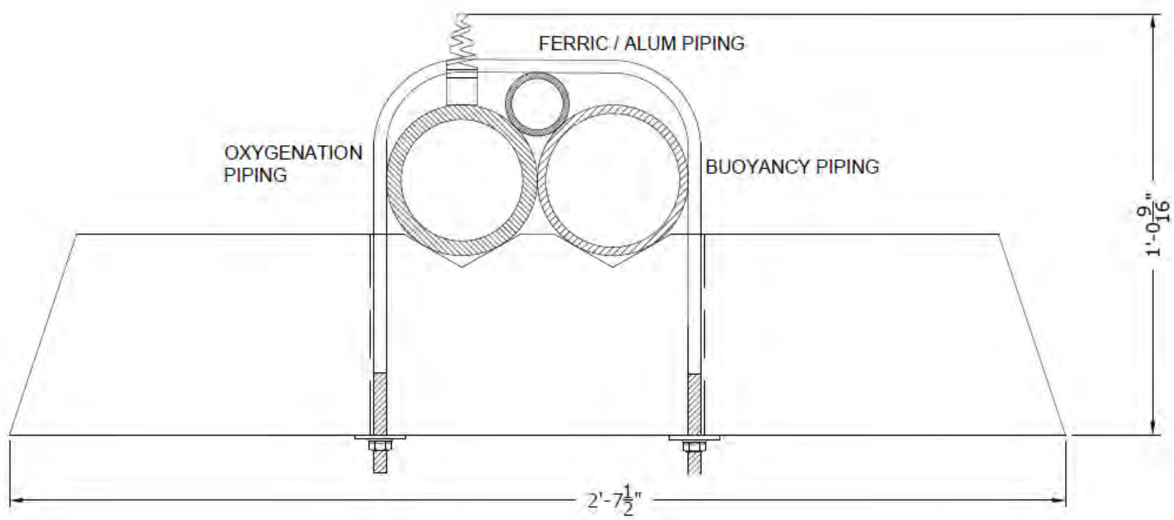

Figure 3.4: Example of SSS distribution piping/anchoring showing spiral nozzle on top and additional micro-floc piping.

3.1 Oxygenation System Sizing

As previously stated, the calculated DO depletion rate was significantly low; therefore, estimated rates observed for other eutrophic system of 2.0 and 3.0 g/m2 d were used to estimate oxygenation system sizing. Using the DO data collected in 2010 (Figure 3.5) and reviewing the topography (Figure 3.6), an oxygenation system was sized using the area below 803 ft msl contour. This corresponded to a depth of five feet and estimated a hypolimnion position between the three and six foot depth data points.

The surface area associated with the 803 ft msl contour is 3.26 acres (13180 m^2). By multiplying areal depletion rates of 2.0 and 3.0 g/m^2 d by this area, the estimated oxygen demand was calculated to be 26 and 40 kg/d respectively. Therefore, the SSS and corresponding oxygen supply should be capable of delivering at least 40 kg/d of pure oxygen to the volume of water below five foot depth (803 ft msl contour).

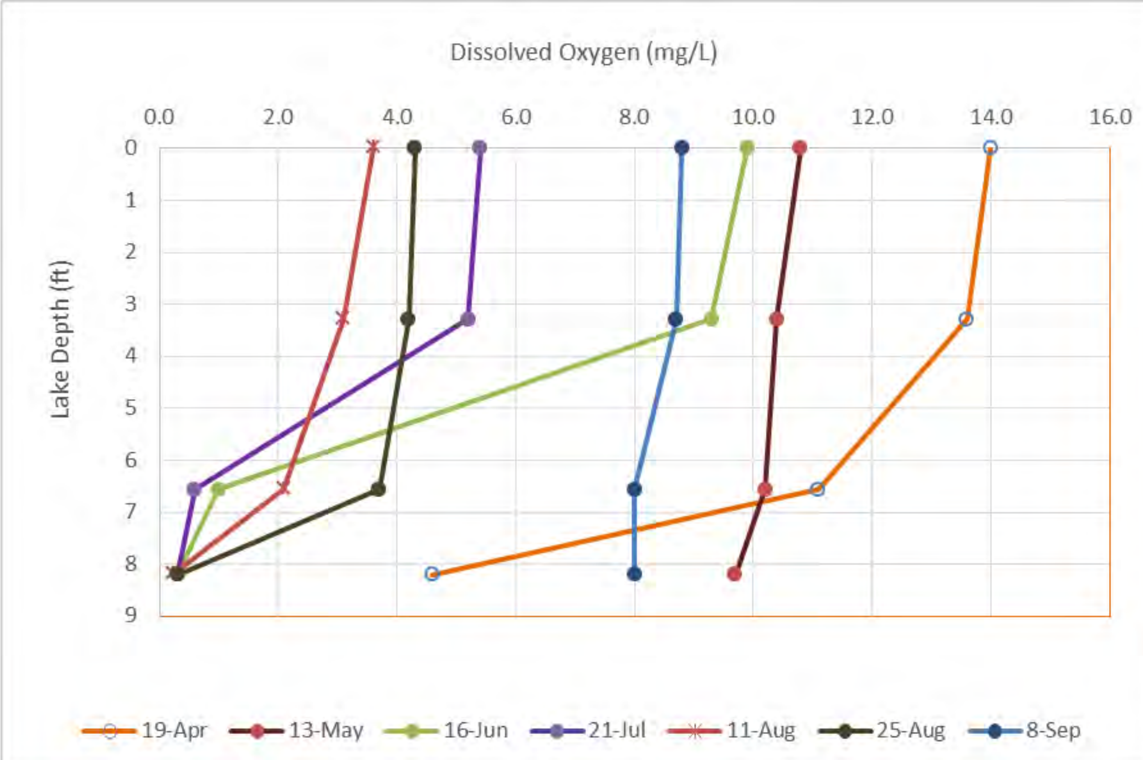

Figure 3.5: Dissolved Oxygen data collected in 2010

3.2 Oxygenation System Layout

Oxygenation systems are commonly installed in the deepest part of lakes and reservoirs. In so doing, DO input is focused over the deepest sediments that are commonly most affected by anoxia. The topographical map was used to estimate the deepest section of Normandale Lake (Figures 3.6). The schematic was scaled in Autocad and the distribution header drawn within the boundary of the 800 ft msl contour.

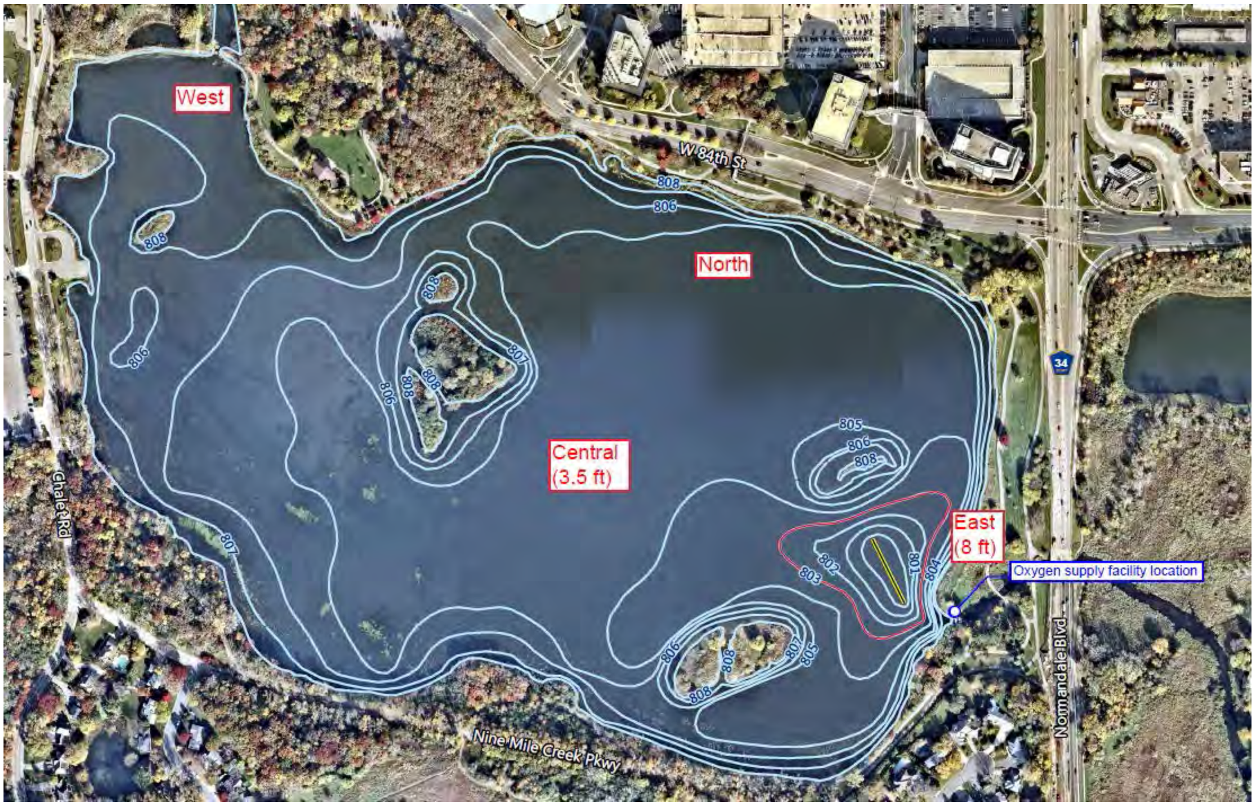

Figure 3.6: Normandale Lake SSS layout, showing a 250 ft in-lake distribution header positioned within the 800 ft msl contour.

3.3 Oxygen Supply

The oxygen supply can either be stored onshore as bulk liquid oxygen (LOx) or can be generated on-site by a compressor supplying air to a pressure swing adsorption (PSA) molecular sieve. Both options provide a reliable source of oxygen supply and are applied based on site-specific conditions and/or requirements.

3.3.1 Liquid Oxygen Tanks

LOx utilizes the evaporative nature of liquid oxygen to gaseous oxygen through a vaporizer to generate the driving pressure to move the gas to the line diffuser on the bottom of the reservoir. LOx systems consist of a tank, vaporizers, and respective concrete pads to support the equipment (Figure 3.7). There are no moving parts; therefore, electrical power requirements are minimal to support telemetry. Three LOx suppliers, Linde, Praxair, and Airgas/AirLiquide are the most common and largest suppliers of bulk liquid oxygen in the industry.

Figure 3.7: Example of a typical LOx system. Photo shows a 1500 gallon tank.

3.3.2 On-Site Oxygen Generation

On-site oxygen generation requires an air source, an air receiving tank, an oxygen separator, and an oxygen receiving tank (Figure 3.8). Air is typically supplied by a rotary screw compressor that supplies clean dry air to an air receiving tank before applying it to the PSA oxygen separator. The PSA consists of two zeolite sieves that alternately absorb nitrogen under pressure and vent nitrogen when exposed to atmospheric pressure. As the pressure swings from high to low, the zeolite bed strips nitrogen to allow 93 percent pure oxygen (nominal) to pass through to the oxygen receiving tank or vent nitrogen to the atmosphere. Three on-site oxygen generation manufacturers, AirSep, OGSI, and OXAIR are the most common and largest suppliers of on-site oxygen generators.

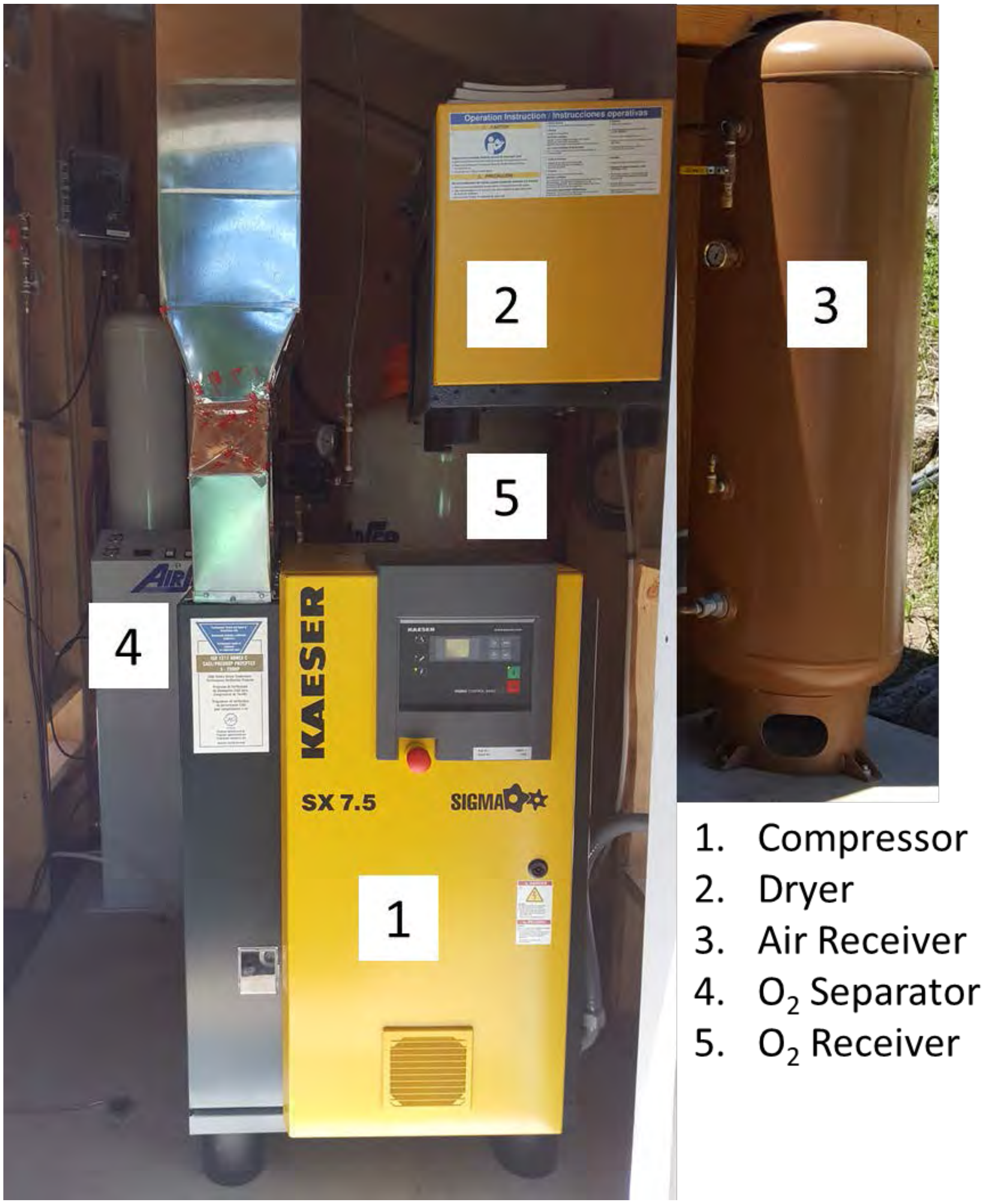

Figure 3.8: Photo of an on-site oxygen generation system installed for Lake Alpine Water Company used to provide pure oxygen to an oxygenation system installed in their water supply reservoir. Image shows the basic components for on-site generation: 1.air supply (7.5 Hp Kaeser air compressor), 2. dryer to remove moisture, 3. air receiving tank, 4. oxygen separator (AirSep AS-D, and 5. oxygen receiving tank.

3.4 Equipment Layout and Housing

An example footprint for a complete PSA system layout was configured using the installation data sheet for an AS-B and a Kaeser SX 5 Aircenter (Figure 3.9). Using the recommended offsets for the compressor and common spacing for the receiving tanks, the building footprint was estimated to be 8 ft x 8 ft. Photos of a similar sized SSS system are shown in Figure 3.10 in a precast concrete building (Figure 3.11).

For a bulk liquid oxygen system, the recommended tank size would be 1500 gallons. Typical site improvements would require a 14ft x 14ft x 14 in tank pad and a 12ft x 14ft x 8 in driveway pad for deliveries, similar to that shown in Figure 3.1.

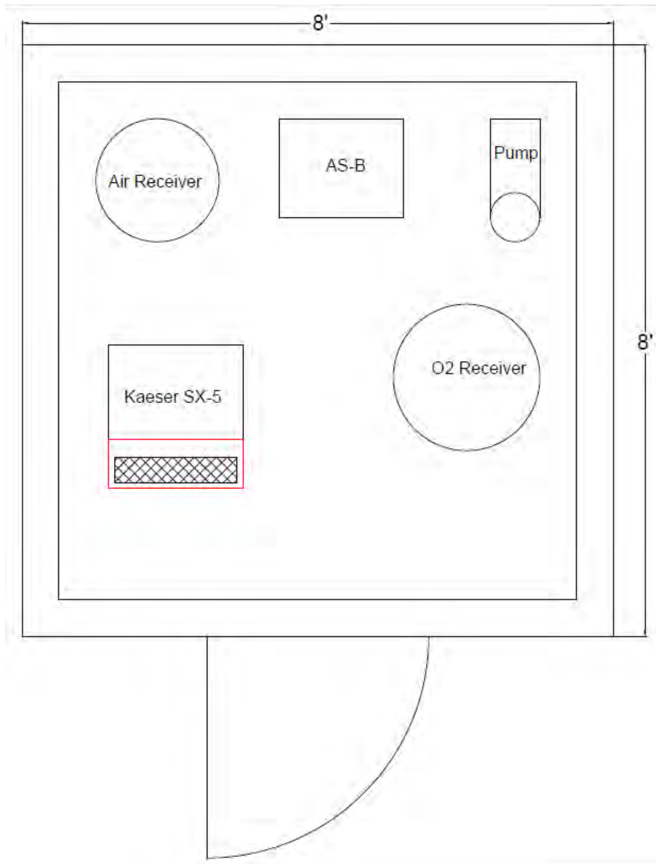

Figure 3.9: Example layout of PSA equipment.

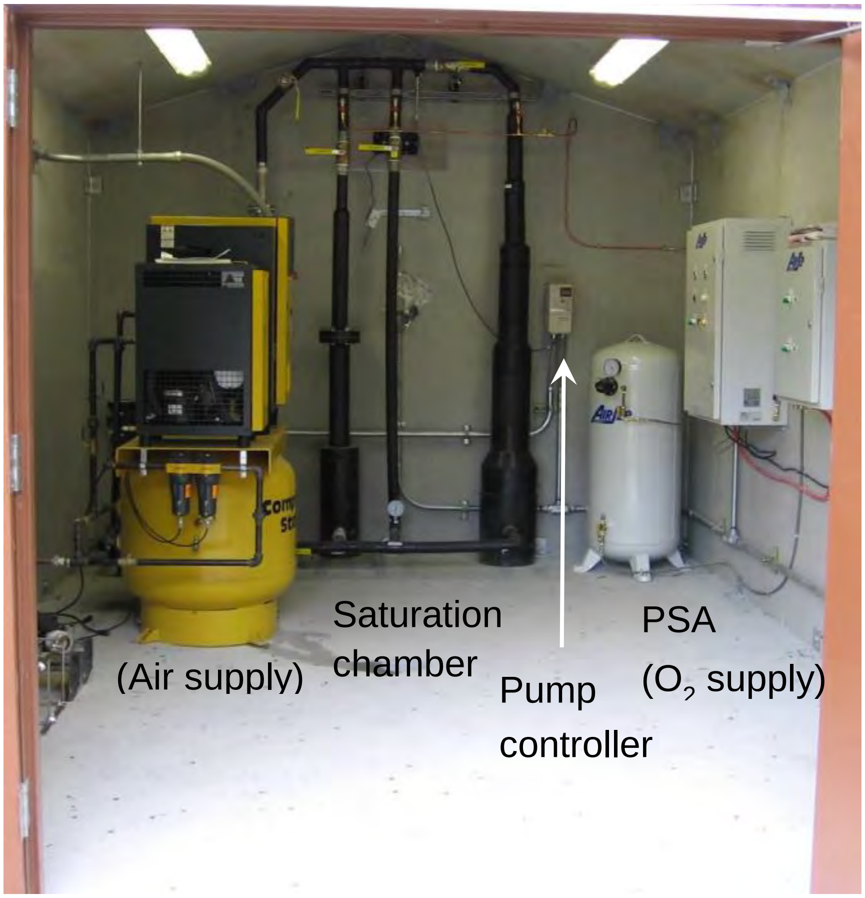

Figure 3.10: Photo of a precast concrete building used to house a Kaeser SX 7.5, a small Centrox oxygen generator and all piping for a small SSS oxygenation equipment.

Figure 3.11: Example of a pre-cast building to house oxygen supply equipment

4. Conceptual Cost Estimate

The cost to install and operate a hypolimnetic oxygenation system was compiled using the estimates for the main components of the system, including in-lake apparatus (line diffuser), on-shore facilities / site upgrade, and the oxygen supply.

Although LOx is a reliable oxygen source, it is believed that both the large foot print coupled with the undesirable obstruction it would have on the view and settings of Normandale Lake, it would not be a viable option for oxygen supply and thus not included. Therefore estimated pricing for an SSS system is as follows:

- in-lake apparatus — $66,500
- on-shore facilities (Pre-cast concrete) — $15,000
- oxygen supply
  - Air Supply — $12,050
  - Oxygen separator — $7,575
  - Pump and oxygen saturator — $32,050
- Mark up
  - General Conditions (7%) — $9,300
  - Overhead (21%) — $28,000
  - Contingency (25%) — $33,300

- Capital Investment — $203,775
- annual operating cost (10 Hp total) — $7,150

10 hp = 7.3 kW / Operated 9 mo per year 7/24.

7.3 kW x 24 hr/d x 30 d/m x 9 m = 47,520 kWhr x $0.15 /kWhr = $7150 yr or about $600/mo

Note: Pricing does not include geochemical augmentation (ferric or alum).

Appendix H

Affected Property Owners

Appendix H - Affected Property Owners

PID	HOUSE_NO	STREET_NM	MAILING__1	ZIP_CD	OWNER_NM	TAXPAYER_1	TAXPAYER_2
1611621310009	5401	84TH ST W	BLOOMINGTON	55437	CITY OF BLOOMINGTON	1800 OLD SHAKOPEE RD W	BLOOMINGTON MN 55431
1611621310010	5501	84TH ST W	BLOOMINGTON	55437	CITY OF BLOOMINGTON	1800 OLD SHAKOPEE RD W	BLOOMINGTON MN 55431
1611621320002	5801	84TH ST W	BLOOMINGTON	55437	CITY OF BLOOMINGTON	1800 OLD SHAKOPEE RD W	BLOOMINGTON MN 55431
1611621330001	8550	NORMANDALE BLVD	BLOOMINGTON	55437	CITY OF BLOOMINGTON	1800 OLD SHAKOPEE RD W	BLOOMINGTON MN 55431
1611621330002	8500	NORMANDALE BLVD	BLOOMINGTON	55437	CITY OF BLOOMINGTON	1800 OLD SHAKOPEE RD W	BLOOMINGTON MN 55431
1611621340001	8416	NORMANDALE BLVD	BLOOMINGTON	55437	CITY OF BLOOMINGTON	1800 OLD SHAKOPEE RD W	BLOOMINGTON MN 55431
1711621410002	6101	84TH ST W	BLOOMINGTON	55438	CITY OF BLOOMINGTON	1800 OLD SHAKOPEE RD W	BLOOMINGTON MN 55431
1711621440001	6251	84TH ST W	BLOOMINGTON	55438	CITY OF BLOOMINGTON	1800 OLD SHAKOPEE RD W	BLOOMINGTON MN 55431
2011621110006	5900	NINE MILE CREEK PKWY	BLOOMINGTON	55437	CITY OF BLOOMINGTON	1800 OLD SHAKOPEE RD W	BLOOMINGTON MN 55431
2111621220001	5600	NINE MILE CREEK PKWY	BLOOMINGTON	55437	CITY OF BLOOMINGTON	1800 OLD SHAKOPEE RD W	BLOOMINGTON MN 55431