Nine Mile Creek Watershed District Summary of 2019 Water Monitoring Program

Prepared for
Nine Mile Creek Watershed District

April 2020

4300 MarketPointe Drive, Suite 200
Minneapolis, MN 55435
952.832.2600
www.barr.com

Nine Mile Creek Watershed District Summary of 2020 Water Monitoring Program

April 2020

Contents

1 Introduction 1-1

2 Lake Water Quality Monitoring—Conclusions and Recommendations 2-1

2.1 Arrowhead Lake 2-2

2.2 Indianhead Lake 2-2

2.3 Mirror Lake 2-2

2.4 Normandale Lake 2-3

2.5 Lake Edina 2-4

2.6 Lake Smetana 2-4

2.7 Southeast Anderson Lake 2-5

3 Arrowhead Lake 3-1

3.1 Chlorides 3-1

3.2 Total Phosphorus and Chlorophyll *a* Levels and Water Clarity (Secchi Depth) 3-2

3.3 Phytoplankton and Zooplankton 3-3

3.4 Aquatic Plants 3-6

3.5 Conclusions and Recommendations 3-7

4 Indianhead Lake 4-1

4.1 Chlorides 4-1

4.2 Total Phosphorus and Chlorophyll *a* Levels and Water Clarity (Secchi Depth) 4-2

4.3 Phytoplankton and Zooplankton 4-3

4.4 Aquatic Plants 4-7

4.5 Conclusions and Recommendations 4-8

5 Mirror Lake 5-1

5.1 Chlorides 5-1

5.2 Total Phosphorus and Chlorophyll *a* Levels and Water Clarity (Secchi Depth) 5-2

5.3 Phytoplankton and Zooplankton 5-3

5.4 Aquatic Plants 5-7

5.5 Conclusions and Recommendations 5-8

6 Normandale Lake 6-1
6.1 Chlorides 6-1
6.2 Total Phosphorus and Chlorophyll *a* Levels and Water Clarity (Secchi Depth) 6-2
6.3 Aquatic Plants 6-4
6.4 Conclusions and Recommendations 6-7
7 Lake Edina 7-1
7.1 Aquatic Plants 7-1
7.2 Conclusions and Recommendations 7-3
8 Lake Smetana 8-1
8.1 Aquatic Plants 8-2
8.2 Conclusions and Recommendations 8-4
9 Southeast Anderson Lake 9-1
9.1 Aquatic Plants 9-2
9.2 Conclusions and Recommendations 9-4
10 Nine Mile Creek Stream Monitoring 10-5
10.1 Nine Mile Creek Water Quality 10-5
10.2 Ecological Use 10-7
10.3 Fish IBI 10-9
10.4 Macroinvertebrates 10-11
10.5 Stream Monitoring Conclusions and Recommendations 10-15
11 Lake Level Monitoring 11-1
11.1 Lake Level Observations 11-1
12 Groundwater Well Monitoring 12-1
12.1 Groundwater Well Observations 12-1

List of Tables

Table 10-1 Nine Mile Creek 2019 Water Quality and Biological Data Summary 10-19

Table 11-1 Summary of 2019 Monthly Observed Lake Levels 11-3

Table 12-1 Summary of 2019 Monthly Observed Groundwater Levels 12-2

List of Figures

Figure 1-1 2019 Lake and Groundwater Level Monitoring Locations 1-2

Figure 1-2 2019 Lake and Stream Monitoring Locations 1-3

Figure 3-1 Arrowhead Lake 2004 , 2011, 2014, and 2019 summer average values 3-2

Figure 3-2 Arrowhead Lake 3-4

Figure 3-3 Arrowhead Lake 2004, 2011, 2014, and 2019 phytoplankton 3-4

Figure 3-4 2004, 2011, 2014, and 2019 Arrowhead Lake zooplankton summer average 3-5

Figure 3-5 2004, 2011, 2014, and 2019 Arrowhead Lake Plant Index of Biotic Integrity (IBI) Values compared with Plant IBI Thresholds 3-6

Figure 4-1 Indianhead Lake 2004, 2011, 2014, and 2019 summer average values 4-2

Figure 4-2 Indianhead Lake 4-4

Figure 4-3 Indianhead Lake 2004, 2011, 2014, and 2019 summer average phytoplankton 4-5

Figure 4-4 2004, 2011, 2014, and 2019 Indianhead Lake zooplankton 4-6

Figure 4-5 2004, 2011, 2014, and 2019 Indianhead Lake Plant Index of Biotic Integrity (IBI) Values compared with Plant IBI Thresholds: Number of Plant Species (top) and Floristic Quality Index (FQI) Values (bottom) 4-7

Figure 5-1 Mirror Lake summer average total phosphorus (top), chlorophyll *a* (middle), and Secchi disc (bottom) values during 1990-2019. 5-2

Figure 5-2 Mirror Lake 1990-2019 summer average phytoplankton 5-4

Figure 5-3 Mirror Lake 2019 blue-green algae numbers compared with World Health Organization thresholds for health impacts 5-5

Figure 5-4 1990-2019 Mirror Lake zooplankton 5-6

Figure 5-5 2001, 2004, 2012, and 2019 Mirror Lake Plant Index of Biotic Integrity (IBI) Values compared with Plant IBI Thresholds: Number of Plant Species (top) and Floristic Quality Index (FQI) Values (bottom) 5-7

Figure 6-1 Normandale Lake summer average total phosphorus (top), chlorophyll *a* (middle), and Secchi disc (bottom) values during 1990-2019. 6-2

Figure 6-2 Normandale Lake 6-3

Figure 6-3 2002-2019 Normandale Lake Plant Index of Biotic Integrity (IBI) Threshold Values compared with Plant IBI Thresholds: Number of Plant Species (top) and Floristic Quality Index (FQI) Values (bottom) 6-4

Figure 6-4 2016-2019 Curly-leaf Pondweed Frequency of Occurrence (FOO) 6-5

Figure 6-5 2017-2019 Curly-leaf Pondweed Biomass (Average Wet Weight Per Sample Location) 6-6
Figure 7-1 Lake Edina 7-1
Figure 7-2 2008-2019 Lake Edina Plant Index of Biotic Integrity (IBI) Values compared with Plant IBI Thresholds: Number of Plant Species (top) and Floristic Quality Index (FQI) Values (bottom). 7-2
Figure 8-1 Lake Smetana 8-1
Figure 8-2 1999-2019 Lake Smetana Plant Index of Biotic Integrity (IBI) Values compared with Plant IBI Thresholds: Number of Plant Species (top) and Floristic Quality Index (FQI) Values (bottom). 8-2
Figure 9-1 A healthy plant community was found in Southeast Anderson Lake, pictured above in 2019, but several aquatic invasive species were also present in the lake. (Photo Credit: Endangered Resource Services, LLC.) 9-1
Figure 9-2 1991-2019 Southeast Anderson Lake Plant Index of Biotic Integrity (IBI) Values compared with Plant IBI Thresholds: Number of Plant Species (top) and Floristic Quality Index (FQI) Values (bottom) 9-2
Figure 10-1 Downstream Main Stem Location ECU-7C (Shorthead Redhorse Fish) 10-5
Figure 10-2 Downstream North Fork Location ECU-2A 10-6
Figure 10-3 Downstream South Fork Location ECU-5A 10-6
Figure 10-4 Downstream Main Stem Location ECU-7C 10-7
Figure 10-5 Upstream Main Stem Location ECU-7A 10-8
Figure 10-6 1974-2019 Main Stem ECU 7A Ecological Use (Type of Fish Community) 10-8
Figure 10-7 1997-2019 South Fork ECU 5A Ecological Use (Type of Fish Community) 10-9
Figure 10-8 Middle Main Stem Location ECU-7B 10-10
Figure 10-9 2003-2019 Nine Mile Creek MRAP Fish IBI Scores 10-11
Figure 10-10 1976 2019 Nine Mile Creek HBI: Middle North Fork Location, ECU 2 10-12
Figure 10-11 2019 Nine Mile Creek ICI: Middle North Fork Location, ECU 2 10-12
Figure 10-12 1975 2019 Nine Mile Creek Caddisfly Numbers: Middle North Fork Location, ECU 2 10-13
Figure 10-13 1997 - 2019 Nine Mile Creek HBI: Downstream South Fork Location, ECU 5A 10-13
Figure 10-14 1997 - 2019 Nine Mile Creek ICI: Downstream South Fork Location, ECU 5A 10-14
Figure 10-15 1976 - 2019 Nine Mile Creek HBI: Upstream Main Stem Location, ECU-7A 10-14
Figure 10-16 1997 2019 Nine Mile Creek ICI: Upstream Main Stem Location, ECU-7A 10-15
Figure 10-17 Middle North Fork Location ECU-2 10-16
Figure 10-18 Upstream South Fork Location ECU-3A 10-17

List of Appendices

Appendix A	2019 Water Quality Data: Arrowhead Lake, Indianhead Lake, Mirror Lake, and Normandale Lake
Appendix B	Aquatic Plant Survey Maps: Arrowhead Lake, Indianhead Lake, and Mirror Lake
Appendix C	2019 Phytoplankton Data: Mirror Lake
Appendix D	Aquatic Plant Survey Maps: Normandale Lake
Appendix E	Aquatic Plant Survey Maps: Lake Edina
Appendix F	Aquatic Plant Survey Maps: Lake Smetana
Appendix G	Aquatic Plant Survey Maps: Southeast Anderson Lake
Appendix H	Lake Level Graphs
Appendix I	Groundwater Level Graphs

1 Introduction

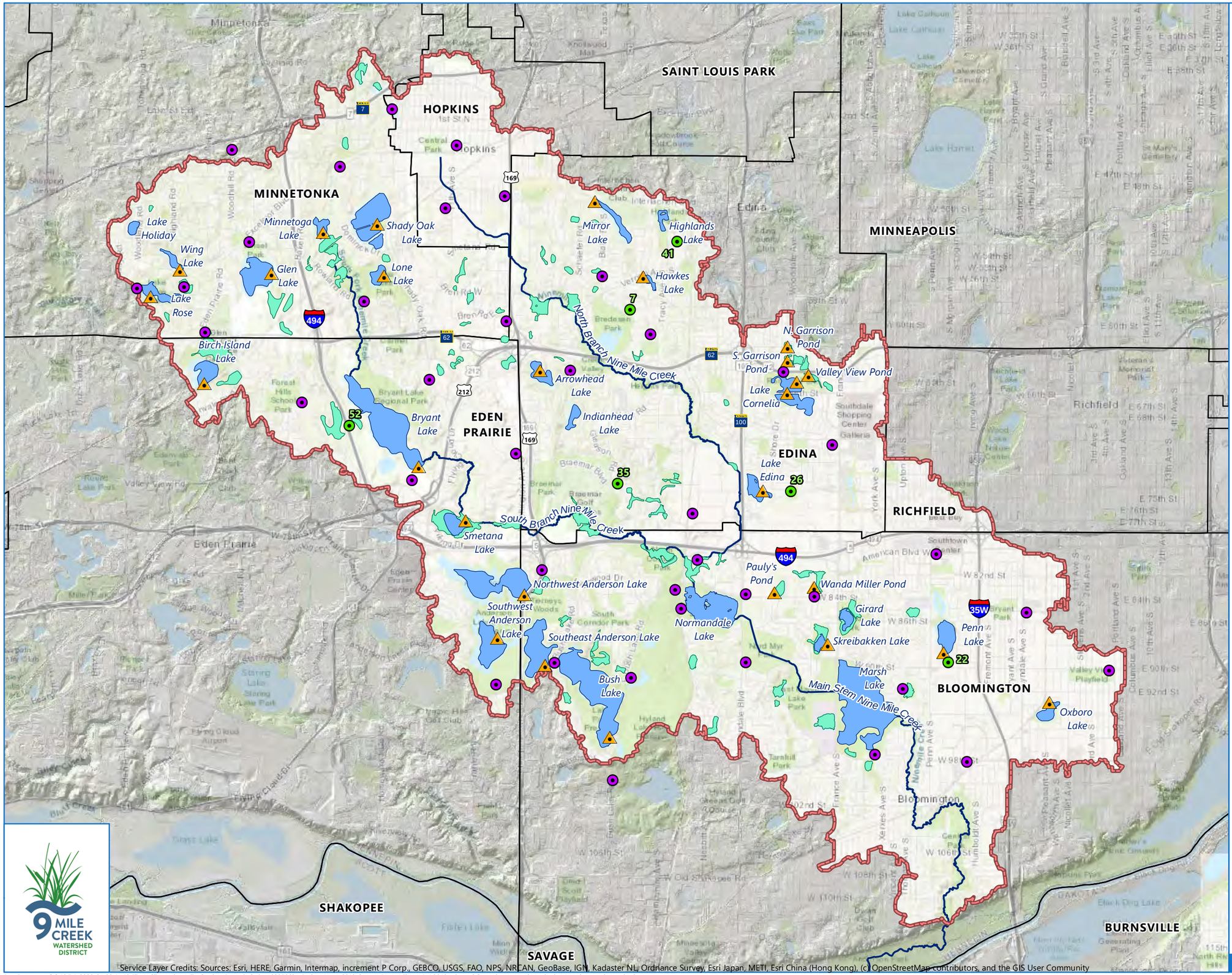
Monitoring of waterbodies in the Nine Mile Creek watershed is essential to developing an understanding of past and present conditions within the watershed and determining the need for action by the Nine Mile Creek Watershed District (District) or other entities. The District annually implements a lake, groundwater, and stream monitoring program designed to establish baseline conditions, track changes, inform additional studies (e.g., feasibility studies, lake management plans), and measure the effectiveness of past and/or ongoing improvement projects. The following report summarizes the lake, groundwater, and stream monitoring data collected by the District in 2019.

The District has been collecting lake levels and groundwater levels since 1960 and 1962, respectively. This information has been used by the District to monitor fluctuations in lake and groundwater levels, helping to understand the connections between groundwater and surface water throughout the watershed and providing important information during times of flooding and drought. In 2019, the District collected monthly levels at 29 lakes and six ground monitoring wells. Figure 1-1 shows the lake level and groundwater monitoring locations.

The District has been conducting its water quality monitoring program since the late-1960s. Protecting and enhancing the surface water quality of Nine Mile Creek and the lakes within the watershed has been an important goal of the District for many decades. To help accomplish this goal, the District operates an extensive lake and stream management program. Generally, the program includes:

- Data collection (monitoring)
- Assessment (e.g., studies)
- Implementation of projects and programs

The 2019 District water quality monitoring program included monitoring seven lakes (Arrowhead, Indianhead, Mirror, Normandale, Edina, Smetana, and Southeast Anderson) and Nine Mile Creek (Figure 1-2).



Level Monitoring Location

Inactive Groundwater Observation Wells

Active Groundwater Observation Wells

Nine Mile Creek

Lakes

Public Water Wetland

District Hydrologic Boundary

Municipal Boundaries

N

0 1 2

Miles

9 MILE CREEK WATERSHED DISTRICT

2019 LAKE AND GROUNDWATER LEVEL MONITORING LOCATIONS
Nine Mile Creek Watershed District
Hennepin County, Minnesota

Figure 1-1

Barr Footer: ArcGIS 10.7.1, 2020-04-02 14:10 File: I:\Client\Nine_Mile_Creek_WD\Work_Orders\23270634_Project\Maps\2019_Stream_Report\Figure 1-1 2019 Lake and Groundwater Level Monitoring Locations.mxd User: kac2

WOMP (Watershed Outlet Monitoring Point) Stream Monitoring Station

Stream Monitoring Locations

Lake

Monitored Lake

Nine Mile Creek

District Legal Boundary

Municipal Boundaries

0 1 2

Miles

2019 LAKE AND STREAM MONITORING LOCATIONS
Nine Mile Creek Watershed District
Hennepin County, Minnesota

Figure 1-2

Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

2 Lake Water Quality Monitoring—Conclusions and Recommendations

The Nine Mile Creek Watershed District (District) monitors the water quality of its lakes on a rotating basis. The District's full lake monitoring program consists of water quality monitoring on six occasions (ice-out and five events during June through September), analysis of zooplankton and phytoplankton on five occasions (June through September), and qualitative aquatic plant (macrophyte) surveys during June and August. The water quality monitoring includes the following parameters: total phosphorus (TP), soluble reactive phosphorus (ortho phosphorus), total nitrogen, total Kjeldahl nitrogen, nitrate plus nitrite nitrogen, pH, chlorophyll *a*, chloride, dissolved oxygen, temperature, specific conductance, turbidity, and oxidation reduction potential (ORP). In 2019, the full lake water quality monitoring program was conducted for three lakes: **Arrowhead Lake**, **Indianhead Lake**, and **Mirror Lake** (Figure 1-2).

Additional targeted monitoring activities were conducted on several other lakes within the watershed to gather additional information needed for consideration of potential management activities or in preparation for proposed projects, or to measure the effectiveness of past and/or ongoing improvement projects. These targeted monitoring activities are briefly summarized below and discussed further in the following sections.

Normandale Lake- water quality was monitored on six occasions for selected parameters including: total phosphorus (TP), soluble reactive phosphorus (ortho phosphorus), total nitrogen, total Kjeldahl nitrogen, nitrate plus nitrite nitrogen, pH, chlorophyll *a*, chloride, dissolved oxygen, temperature, specific conductance, turbidity, and oxidation reduction potential (ORP). Point intercept and biomass aquatic plant (macrophyte) surveys were performed during June and August to assess plant species present and their density and biomass. A curly-leaf pondweed turion survey was completed during October to assess the number of turions remaining in the sediment.

Lake Edina- Point intercept aquatic plant (macrophyte) surveys were performed during June and August to assess plant species present and their density.

Lake Smetana- Point intercept and biomass aquatic plant (macrophyte) surveys were performed during June and August to assess plant species present and their biomass.

Southeast Anderson Lake- Point intercept aquatic plant (macrophyte) surveys were performed during June and August to assess plant species present and their density.

Results of the District's 2019 lake monitoring are summarized in detail by lake in Sections 3 through Section 9. Overall conclusions and recommendations from the 2019 lake monitoring are described below.

2.1 Arrowhead Lake

Monitoring results indicate Arrowhead Lake met the Minnesota Pollution Control Agency (MPCA) chloride standard, but failed to meet MPCA water quality standards for a shallow lake in 2019 due to excess phosphorus in the lake and poor water clarity. Aquatic plant data indicated the plant community had few species, was of poor quality, and failed to meet the Minnesota Department of Natural Resources (MDNR) proposed plant Index of Biological Integrity (IBI) impairment thresholds. The Arrowhead Lake Use Attainability Analysis (UAA) completed in 2006 identified phosphorus loading from the lake's watershed as the largest source of phosphorus to the lake and wet weather conditions as placing the greatest strain upon the lake's water quality. The National Weather Service documented that 2019 was the wettest water year on record for the Twin Cities Metro Area.

The District's Water Management Plan (2017) identifies updating the Arrowhead Lake UAA as an implementation item for 2021. As part of that UAA update, it is recommended that the District identify management measures to reduce watershed phosphorus loading to the lake. Continuation of water quality and biological monitoring is also recommended to periodically assess the condition of the lake's water quality and biological community and identify trends.

2.2 Indianhead Lake

Monitoring results indicate Indianhead Lake met the MPCA chloride standard, but failed to meet MPCA water quality standards for a shallow lake in 2019 due to excess phosphorus in the lake and poor water clarity. Aquatic plant data indicated the plant community had few species, was of poor quality, and failed to meet the MDNR proposed plant IBI impairment thresholds. The Indianhead UAA completed in 2006 identified phosphorus loading from the lake's watershed as the largest source of phosphorus to the lake and wet weather conditions as placing the greatest strain upon the lake's water quality. The National Weather Service documented that 2019 was the wettest water year on record for the Twin Cities Metro Area.

The District's Water Management Plan (2017) identifies updating the Indianhead Lake UAA as an implementation item for 2021. As part of that UAA update, it is recommended that the District identify management measures to reduce watershed phosphorus loading to the lake. Continuation of water quality and biological monitoring is also recommended to periodically assess the condition of the lake's water quality and biological community and identify trends.

2.3 Mirror Lake

2019 results indicate that Mirror Lake met the MPCA water quality standard for chlorides. Mirror Lake failed to meet MPCA water quality standards for shallow lakes in 2019 due to excess phosphorus in the lake and poor water clarity. In fact, Mirror Lake has not met the state standards during the entire period of record (2001, 2004, 2012, 2019). Since 2004, blue-green algae numbers have been within the moderate risk of adverse health impacts for lake users due to the potential for algal toxins in the water more than 80 percent of samples in 2004 and 40 percent of samples in 2012 and 2019. The number of plant species found in the lake and the quality of the plant community measured by Floristic Quality Index (FQI) did not meet the proposed minimum IBI thresholds that define impairment during the entire period examined.

The *Mirror Lake Use Attainability Analysis* (UAA) completed by the District in 2004 concluded the cause of the lake's water quality problem is excess phosphorus loading from the lake's watershed (46 percent of annual load) and from internal sources (49 percent of the annual load). Internal sources include mid-season die-back of curly-leaf pondweed and lake sediments via release of phosphorus from lake bottom sediments. The Mirror Lake UAA recommended an alum treatment to reduce phosphorus loading from sediment. An alum treatment for Mirror Lake would improve water quality and reduce numbers of blue-green algae in the lake. Modeling completed for the UAA predicted the alum treatment alone would not improve the water quality enough to meet State water quality standards. However, reducing the numbers of blue-green algae in the lake would reduce risk of adverse health impacts for lake users. The UAA also recommended several potential best management practices (BMPs) to reduce the external watershed load to Mirror Lake. Modeling completed for the UAA predicted that watershed measures would not significantly improve lake water quality, but predicted that the reduction in watershed phosphorus loading would increase the longevity of in-lake management measures such as an alum treatment. The UAA also recommended herbicide treatment of curly-leaf pondweed if it began to dominate the submerged plant community and recommended management of purple loosestrife by either chemical treatment or biological means if it began to dominate the emergent plant community.

The District's Water Management Plan (2017) identifies updating the Mirror Lake UAA as an implementation item for 2022. As part of that UAA update, it is recommended that the District confirm the recommendation to conduct an alum treatment, and identify additional management measures to reduce watershed phosphorus loading to the lake. Continuation of water quality and biological monitoring is also recommended to periodically assess the condition of the lake's water quality and biological community and identify trends.

2.4 Normandale Lake

2019 results indicate that Normandale Lake met MPCA water quality standards for chlorides. Secchi disc (measure of clarity), and chlorophyll *a* concentrations met the state eutrophication criteria for shallow lakes. Summer-average total phosphorus concentrations exceeded the state standard, but the observed summer average value of 63 µg/L was close to the maximum impairment threshold of 60 µg/L. According to the MDNR proposed plant IBI, the lake's plant community is not impaired.

A comparison of pre- and post-project aquatic plant data to assess changes after completion of a drawdown and alum treatment to improve water quality in Normandale Lake documented an overall improvement in the plant community in 2019. Curly-leaf pondweed (CLP) frequency and biomass declined in 2019, frequency of three native species increased, and quality of the plant community, measured by FQI, improved.

In 2019, four aquatic invasive species (CLP, Eurasian watermilfoil, reed canary grass, and hybrid cattail) were present in the lake. As noted in the previous paragraph, the District's water quality improvement project reduced CLP frequency and biomass. Eurasian watermilfoil (EWM) was not observed in the lake during 2019, but a small cluster of EWM occurred just upstream of the lake in August. Reed canary grass and hybrid cattail extent have not changed since first observed in the lake in 2016 – reed canary grass was common along the shoreline and hybrid cattail was observed at one location.

In 2018, the District began implementation of a water quality improvement project for Normandale Lake. A drawdown of the lake was completed in fall of 2018 to expose the lake bed to a winter freeze and freeze out CLP. An alum treatment was completed in spring of 2019. Herbicide treatment of the remaining CLP is planned beginning in 2020 with additional herbicide treatments completed in subsequent years as needed to reduce CLP.

Continuation of water quality and biological monitoring is recommended in upcoming years to assess the impacts of the improvement project(s) on the condition of the lake's water quality and biological community.

2.5 Lake Edina

Aquatic plant surveys were conducted on Lake Edina in June and August 2019 to further assess the extent of curly-leaf pondweed (CLP) and Eurasian watermilfoil (EWM), two aquatic invasive species observed in previous plant surveys. Aquatic plant data from Lake Edina indicated the 2019 plant community had few species, was of poor quality, and failed to meet the MDNR proposed plant IBI impairment thresholds. Poor water quality is the cause of the lake's poor plant community. In 2019, severe algal blooms in August limited water clarity to just a couple of inches. Many plant species seen in June were not present or were in the process of dying back in August due to the poor water clarity.

The District completed a Use Attainability Analysis (UAA) of Lake Cornelia and Lake Edina in July of 2019 to identify water quality improvement measures for both lakes. The UAA concluded that the poor water quality in Lake Edina is primarily due to excess phosphorus in the lake, which fuels algal production and decreases water clarity. Phosphorus in Lake Edina comes from runoff from the watershed (external sources) and flows from upstream Lake Cornelia. Modeling indicates that during 2017, flows from upstream Lake Cornelia comprised nearly two thirds of the annual phosphorus load to Lake Edina. Because the water quality of Lake Edina is highly influenced by the water quality of Lake Cornelia, the recommended management strategy to improve water quality in Lake Edina is to implement the recommendations for upstream Lake Cornelia. Opportunities to reduce phosphorus from the direct watershed to Lake Edina should also be considered.

EWM spread rapidly since first observed in the lake in 2017 and was found throughout Lake Edina during June 2019. It is recommended that treatment of invasive (EWM) in Lake Edina be considered to prevent it from further threatening the lake's aquatic plant community. Control of EWM would also minimize the likelihood of plant fragments being conveyed to Nine Mile Creek and downstream Normandale Lake.

CLP was not observed in Lake Edina during 2019 but had been consistently observed in the lake in one or two locations during the period of record (2008, 2012, 2015, and 2017). Continuation of water quality and biological monitoring is recommended to periodically assess the condition of the lake's water quality and biological community and identify trends.

2.6 Lake Smetana

Aquatic plant surveys were conducted on Lake Smetana in June and August 2019 to further assess the extent of curly-leaf pondweed in the lake, in support of the Use Attainability Analysis (UAA) update

underway in 2019-2020. Aquatic plant data indicated the plant community met the Minnesota Department of Natural Resources (MDNR) proposed plant Index of Biological Integrity (IBI) impairment thresholds (i.e., the lake's plant community is not impaired).

In 2019, three aquatic invasive species (CLP, Eurasian watermilfoil, and purple loosestrife) were present in the lake. Although CLP has expanded its extent in the lake since 2016 and EWM first appeared in the lake during 2019, neither species is currently causing problems in the lake. The *Lake Smetana Water Quality Study, Use Attainability Analysis* (draft, February 2020) concluded that CLP is not having a significant negative effect on the total phosphorus concentrations of Lake Smetana. However, the growth of CLP and EWM and the effects of CLP on lake quality should continue to be tracked with periodic monitoring and aquatic plant surveys. Introduction of additional purple loosestrife eating beetles could be considered to increase biological control of purple loosestrife.

2.7 Southeast Anderson Lake

Point-intercept aquatic plant surveys were conducted on Southeast Anderson Lake in June and August 2019 to further assess the extent of curly-leaf pondweed and Eurasian watermilfoil in the lake and provide information required for permitting if the District decided to pursue curly-leaf pondweed treatment in 2020 or subsequent years. Similar to the 2018 aquatic plant data, 2019 data indicated the plant community in Southeast Anderson Lake met the Minnesota Department of Natural Resources (MDNR) proposed plant Index of Biological Integrity (IBI) impairment thresholds (i.e., the lake's plant community is not impaired). However, the appearance and expansion of CLP in the lake during the past five years and appearance and expansion of EWM during the past 2 years is unfavorable for the Southeast Anderson Lake native plant community. The addition of phosphorus from decaying CLP after its annual die-off in late June is unfavorable for the lake's water quality. Further consideration of management of CLP and EWM to protect, and if possible improve, the health of the native plant community and the lake's water quality is recommended.

The *Nine Mile Creek Watershed District Water Management Plan* (2017, amended 2018) identifies implementation of improvement recommendations in Southeast Anderson Lake in 2020, including alum treatment of phosphorus-rich lake sediments and additional curly-leaf pondweed management as needed, based on recommendations from the *Southeast, Southwest, and Northwest Anderson Lakes Use Attainability Analyses* (2005). In the summer of 2019, Barr and District staff reviewed the 2018 and historical water quality monitoring data from Southeast Anderson Lake in detail to evaluate pursuit of an alum treatment and/or additional CLP management in 2020. The 2018 summer average phosphorus concentration was one of the best years on record in Southeast Anderson Lake. Because of the good water quality exhibited in 2018, and associated uncertainty regarding necessity of conducting an alum treatment or additional herbicide treatment, District staff decided to delay implementation of additional improvement measures until additional water quality data is collected.

Continuation of water quality and biological monitoring is recommended to periodically assess the condition of the lake's water quality and biological community and identify trends.

3 Arrowhead Lake

Arrowhead Lake is a small lake located in Edina. The lake has a surface area of approximately 22 acres and a maximum depth of approximately 7 feet. At the Ordinary High Water Level (OHW) elevation of 875.8 feet, the lake volume is approximately 136 acre-feet. The lake is land-locked; there is no gravity outlet and the estimated natural overflow elevation is 882.5 M.S.L. The lake is shallow enough for aquatic plants to grow over the entire lake bed. In addition, it is also a polymictic lake (mixing many times per year). The lake is fertile and generally experiences poor water quality

In 2019, the Nine Mile Creek Watershed District monitored Arrowhead Lake for:

- Water chemistry- total phosphorus (TP), soluble reactive phosphorus (ortho phosphorus), total nitrogen, total Kjeldahl nitrogen, nitrate plus nitrite nitrogen, chlorophyll *a*, chloride, and turbidity.
- Water field measurements- dissolved oxygen, pH, temperature, specific conductance, and oxidation reduction potential (ORP)
- Phytoplankton and zooplankton (microscopic plants and animals)
- Macrophytes (aquatic plants)

Water quality monitoring results are summarized in Appendix A and macrophyte monitoring maps in Appendix B. Monitoring results are discussed in the following paragraphs.

3.1 Chlorides

Chloride concentrations in area lakes have increased since the early 1990s when many government agencies switched from sand or sand/salt mixtures to salt for winter road maintenance. When snow and ice melts, the salt goes with it, washing into lakes, streams, wetlands, and groundwater. It only takes 1 teaspoon of road salt to permanently pollute 5 gallons of water. And, once in the water, it is very difficult and expensive to remove.

Because high concentrations of chloride can harm fish and plant life, MPCA has established a chronic exposure chloride standard of 230 mg/L or less. All 2019 chloride measurements met the MPCA standard. The range and average of observed concentrations are summarized below:

- **Range of 2019 chloride concentrations observed in Arrowhead Lake:** From a high of 185 mg/L, measured in April, to a low of 120 mg/L, measured in September (Appendix A).
- **Average 2019 concentration:** 150 mg/L (Appendix A).

3.2 Total Phosphorus and Chlorophyll *a* Levels and Water Clarity (Secchi Depth)

The 2019 data indicate excess phosphorus was in the lake and water clarity was poor. The lake's 2019 average summer total phosphorus concentration of 74 µg/L and the lake's average summer Secchi disc transparency of 0.8 meters failed to meet the Minnesota State Water Quality Standards for shallow lakes in the North Central Hardwood Forest Ecoregion published in Minnesota Rules 7050 (Minn. R. Ch. 7050.0222 Subp 4). The lake's average summer chlorophyll *a* concentration of 18 µg/L met the MPCA standard. The standard specifies that if average summer total phosphorus and either average chlorophyll *a* or Secchi disc fail to meet the standard, lake water is impaired. Hence, the water quality in Arrowhead Lake was impaired in 2019.

Historical water quality data have been collected from Arrowhead Lake during 2004, 2011, and 2014. The data indicate water quality was poorer in 2014 and 2019 and the lake was impaired both years because the average summer total phosphorus and chlorophyll *a* concentrations failed to meet MPCA standards for shallow lakes (Figure 3-1). The lake was not impaired in 2004 and 2011 because impairment requires that both phosphorus and either chlorophyll *a* or Secchi disc must fail to meet the MPCA standards for shallow lakes. In 2004 total phosphorus failed to meet the MPCA shallow lake standard, but both chlorophyll *a* and Secchi disc met the standard. In 2011, chlorophyll *a* failed to meet the standard but both phosphorus and Secchi disc met the standard (Figure 3-1).

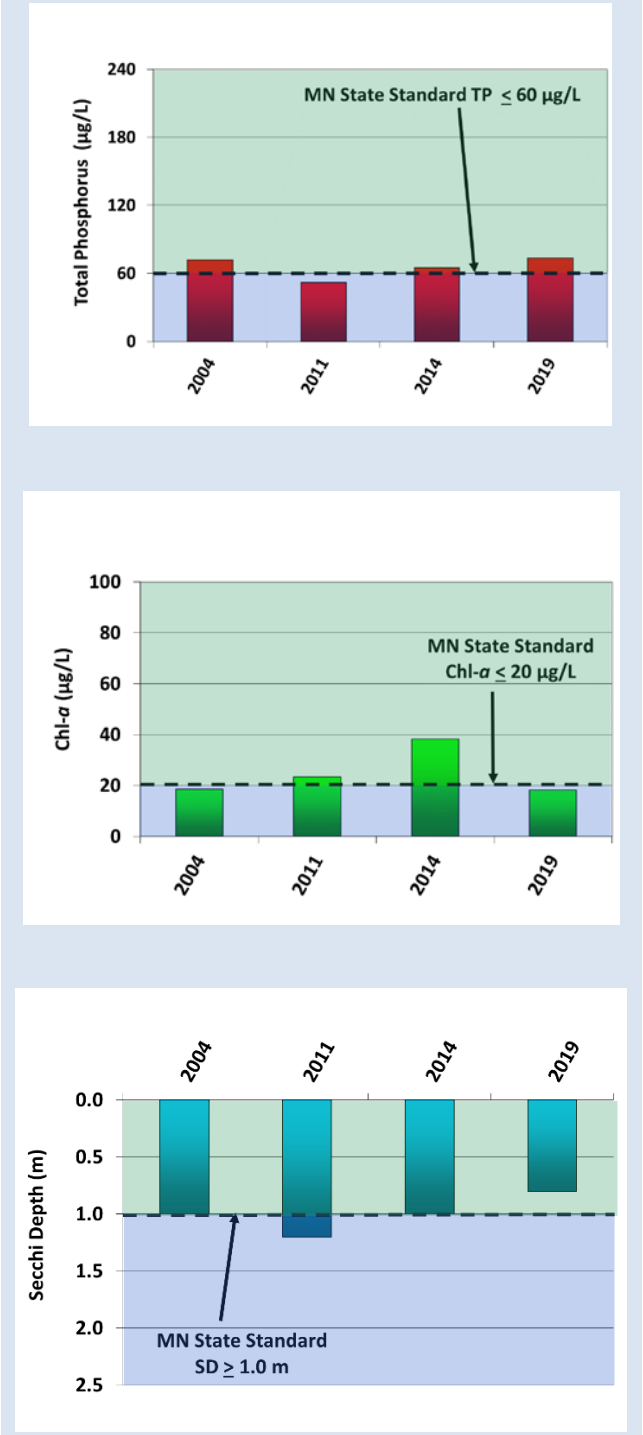


Figure 3-1 Arrowhead Lake 2004 , 2011, 2014, and 2019 summer average values
total phosphorus (top), chlorophyll *a* (middle), and Secchi disc (bottom)

The Arrowhead Lake UAA completed by the District in 2006 concluded that wet weather conditions produce the greatest strain upon water quality in Arrowhead Lake. This is the result of a higher total load of phosphorus to the lake during wet weather. Although wetter weather results in larger volumes of relatively less concentrated water reaching the lake, Arrowhead is a land-locked basin with no surface outlet. For that reason, no flushing occurs and total phosphorus accumulates in the lake, especially during periods of high watershed loading. According to the Minnesota Department of Natural Resources, 2019 was the wettest year on record for the weather station located at the Minneapolis St. Paul International Airport. In 2019, a total of 43.17 inches of precipitation was documented by the weather station, which has measured precipitation for more than 50 years[1]. The wet weather during 2019 likely caused higher phosphorus concentrations and lower water clarity in Arrowhead Lake. High lake levels in 2019 may likely have resulted in increased shoreline erosion and decay of inundated plant material along the shoreline, further increasing phosphorus loading to the lake.

The District's Water Management Plan (2017) identifies updating the Arrowhead Lake UAA as an implementation item for 2021. As part of that UAA update, it is recommended that the District identify management measures to reduce watershed phosphorus loading to the lake.

3.3 Phytoplankton and Zooplankton

Phytoplankton, also called algae, are small aquatic plants naturally present in lakes, including Arrowhead 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.

Samples of phytoplankton, microscopic aquatic plants, were collected from Arrowhead Lake (Figure 3-2) to evaluate water quality and the quality of food available to zooplankton (microscopic animals).

Phytoplankton numbers and blue-green algae numbers followed the same pattern as chlorophyll *a* increased during 2004 through 2014 and declined in 2019 (Figure 3-1 and Figure 3-3). Blue-green algae are a poor quality food because they may be toxic and may not be assimilated if ingested. Green algae are a better quality food source than blue-green algae and contribute towards a healthier zooplankton community. Numbers of green algae have increased since 2004 and have remained relatively consistent since 2011 indicating the lake has had an ample supply of good quality food for the zooplankton community (Figure 3-3).

All three groups of zooplankton (rotifers, copepods, and cladocerans) were represented in 2019; higher numbers were observed in 2019 than previous years (Figure 3-4). The data indicate the zooplankton community provided an abundant supply of food for planktivorous fish in the lake.

[1] Minnesota Department of Natural Resources. 2019. Another Very Wet Year in Minnesota. https://www.dnr.state.mn.us/climate/journal/another-very-wet-year-minnesota.html. Retrieved on March 20, 2020.

Figure 3-2 Arrowhead Lake
The phytoplankton data from Arrowhead Lake, pictured above, indicate the lake had an ample supply of good quality food for the lake's zooplankton community in 2019.

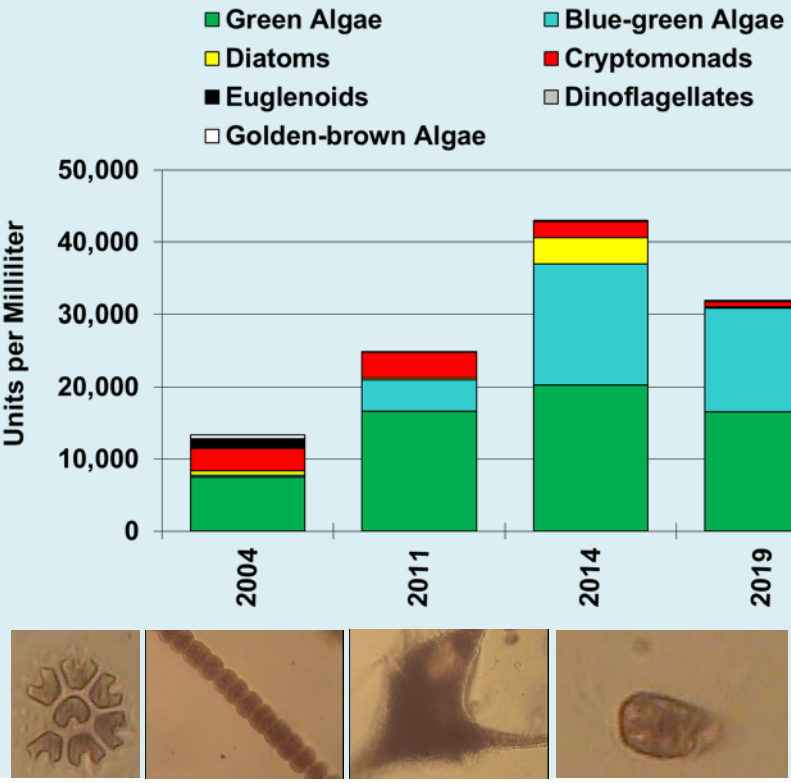


Figure 3-3 Arrowhead Lake 2004, 2011, 2014, and 2019 phytoplankton
Top, Summer average numbers and bottom, microscopic pictures of phytoplankton species found in the lake , from left to right, Pediastrum boryanum (green algae) Dolichospermum affine (blue-green algae), Ceratium hirundinella (dinoflagellate), and *Cryptomonas erosa* (cryptomonad).

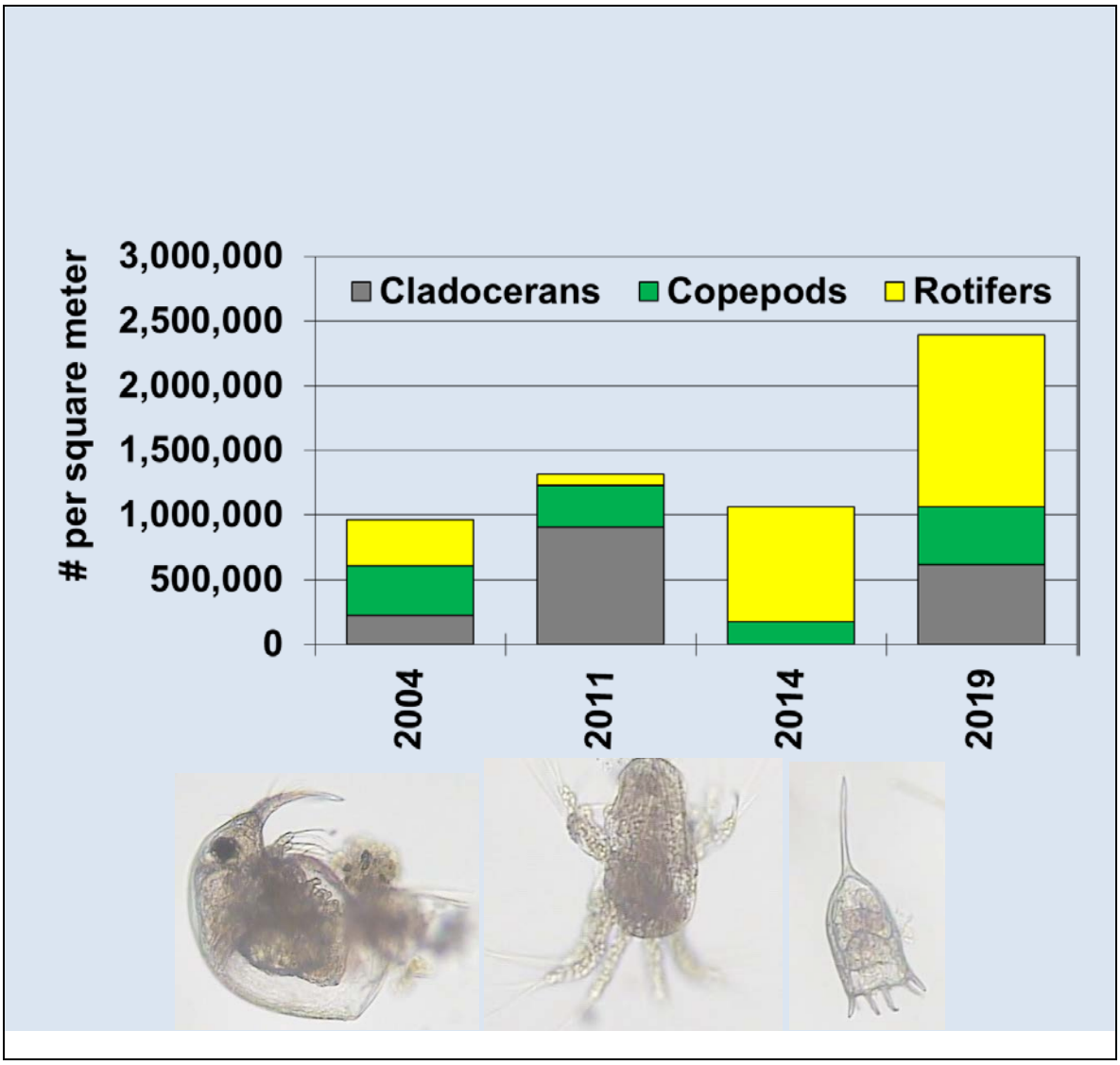


Figure 3-4 2004, 2011, 2014, and 2019 Arrowhead Lake zooplankton summer average

Top Summer average numbers and bottom, microscopic pictures of zooplankton species found in the lake, from left to right, Bosmina longirostris (cladoceran), nauplii (baby copepod), and *Keratella cochlearis* (rotifer).

3.4 Aquatic Plants

The MDNR has developed metrics to determine the overall health of a lake's aquatic plant community. The Lake Plant Eutrophication Index of Biological Integrity (IBI) is expected to eventually be used by the MPCA to determine whether a lake is meeting the federal Clean Water Act standards intended to protect aquatic life. The plant IBI includes two metrics: (1) the number of species in a lake; and (2) the "quality" of the species, as measured by the floristic quality index (FQI).

The District conducted qualitative aquatic plant surveys of Arrowhead Lake in June and August of 2019. Maps showing survey results are included in Appendix B. Plant survey data from 2004 through 2019 were assessed to determine plant IBI trends. Figure 3-5 shows the Arrowhead Lake number of species and FQI scores for that period compared to the proposed MDNR plant IBI impairment threshold.

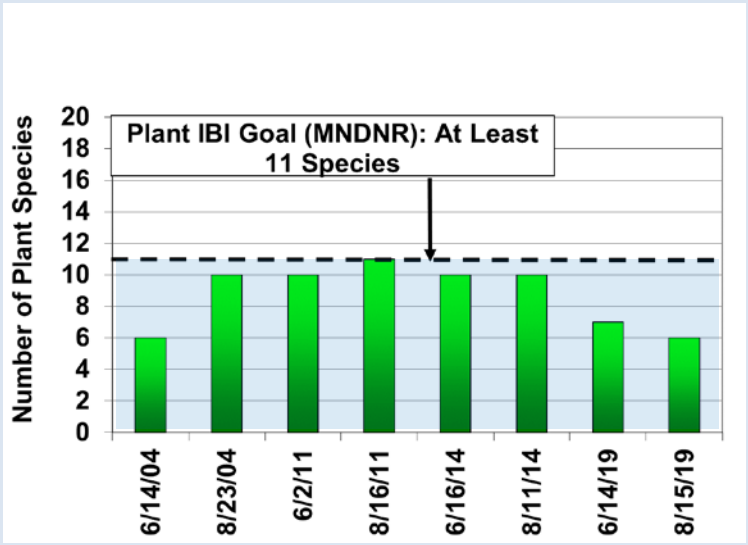


Figure 3-5.A

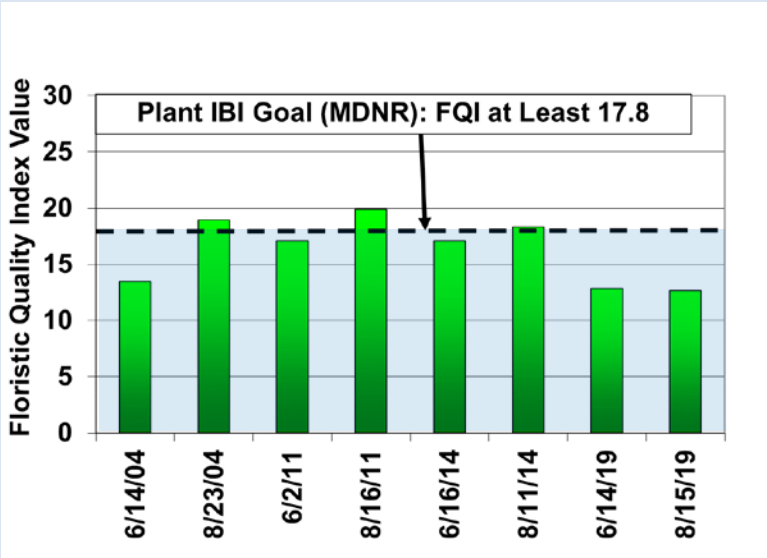


Figure 3-5.B

Figure 3-5 2004, 2011, 2014, and 2019 Arrowhead Lake Plant Index of Biotic Integrity (IBI) Values compared with Plant IBI Thresholds
Number of Plant Species (top) and Floristic Quality Index (FQI) Values (bottom).

- **Number of species:** A shallow lake (maximum depth less than 15 feet) is considered impaired when it has fewer than 11 species. During the period examined, the number of species in Arrowhead Lake ranged from 6 to 11, meeting the impairment threshold only during August 2011 (Figure 3-5.A).

- **FQI values (quality of species):** The impairment threshold for shallow lakes, as measured by FQI, is a minimum value of 17.8. During the period examined, FQI values in Arrowhead Lake ranged from 12.7 to 19.9, bettering the threshold during August 2004, August 2011, and August 2014 (Figure 3-5.B).

- **2019 results:** Both the number of species in the lake and FQI values were lower than the minimum IBI thresholds that define impairment. As such, the waters would be considered impaired for aquatic plants. In 2019, the Arrowhead Lake plant community had lower FQI scores than were observed in previous years and the number of species in August 2019 was tied with June 2004 for the lowest number of species in the lake.

  Three aquatic invasive species were found in Arrowhead Lake in 2019:

  Curly-leaf pondweed (*Potamogeton crispus*) – This species was observed at one location in the eastern portion of the lake in June. Due to its annual die-off in late June, it was not observed in August (Appendix B).

  Eurasian watermilfoil (*Myriophyllum spicatum*) – This species was observed in light density in the northern portion of the lake in June and light to moderate density in the eastern portion of the lake during both June and August (Appendix B).

  Purple loosestrife (Lythrum salicaria) – This emergent species was observed at three locations along the eastern and western shorelines in June and August (Appendix B).

3.5 Conclusions and Recommendations

Monitoring results indicate Arrowhead Lake met the MPCA chloride standard, but failed to meet MPCA water quality standards in 2019 due to excess phosphorus in the lake and poor water clarity. Aquatic plant data indicated the plant community had few species, was of poor quality, and failed to meet the MDNR proposed plant IBI impairment thresholds. The Arrowhead UAA completed in 2006 identified phosphorus loading from the lake's watershed as the largest source of phosphorus to the lake and wet weather conditions as placing the greatest strain upon the lake's water quality. The National Weather Service documented that 2019 was the wettest water year on record for the Twin Cities Metro Area.

The District's Water Management Plan (2017) identifies updating the Arrowhead Lake UAA as an implementation item for 2021. As part of that UAA update, it is recommended that the District identify management measures to reduce watershed phosphorus loading to the lake. Continuation of water quality and biological monitoring is recommended to periodically assess the condition of the lake's water quality and biological community and identify trends.

4 Indianhead Lake

Indianhead Lake is a small lake located in Edina. The lake has a surface area of approximately 14 acres and a maximum depth of approximately 6.5 feet. At the Ordinary High Water Level (OHW) elevation of 863.7 feet, the lake volume is approximately 69 acre-feet. The lake is land-locked; there is no gravity outlet and the estimated natural overflow elevation is 882.5 M.S.L. The lake is shallow enough for aquatic plants to grow over the entire lake bed. The lake is a polymictic lake (mixing many times per year). The lake is fertile and generally experiences poor water quality.

In 2019, the Nine Mile Creek Watershed District monitored Indianhead Lake for:

- Water chemistry- total phosphorus (TP), soluble reactive phosphorus (ortho phosphorus), total nitrogen, total Kjeldahl nitrogen, nitrate plus nitrite nitrogen, chlorophyll *a*, chloride, and turbidity.
- Water field measurements- dissolved oxygen, pH, temperature, specific conductance, and oxidation reduction potential (ORP)
- Phytoplankton and zooplankton (microscopic plants and animals)
- Macrophytes (aquatic plants)

Water quality monitoring results are summarized in Appendix A and macrophyte monitoring maps in Appendix B. Monitoring results are discussed in the following paragraphs.

4.1 Chlorides

Chloride concentrations in area lakes have increased since the early 1990s when many government agencies switched from sand or sand/salt mixtures to salt for winter road maintenance. When snow and ice melts, the salt goes with it, washing into lakes, streams, wetlands, and groundwater. It only takes 1 teaspoon of road salt to permanently pollute 5 gallons of water. And, once in the water, it is very difficult and expensive to remove.

Because high concentrations of chloride can harm fish and plant life, MPCA has established a chronic exposure chloride standard of 230 mg/L or less. All 2019 measurements met the MPCA standard. The range and average of observed concentrations are summarized below:

- **Range of 2019 chloride concentrations in Indianhead Lake:** From a high of 66 mg/L, measured in April, to a low of 46 mg/L, measured in September (Appendix B).
- **Average 2019 concentration:** 57 mg/L (Appendix B).

4.2 Total Phosphorus and Chlorophyll *a* Levels and Water Clarity (Secchi Depth)

The 2019 data indicate excess phosphorus was in the lake and water clarity was poor. The lake's 2019 average summer total phosphorus concentration of 146 µg/L and the lake's average summer Secchi disc transparency of 0.6 meters failed to meet the Minnesota State Water Quality Standards for shallow lakes in the North Central Hardwood Forest Ecoregion published in Minnesota Rules 7050 (Minn. R. Ch. 7050.0222 Subp 4) (Figure 4-1). The lake's average summer chlorophyll *a* concentration of 19 µg/L met the MPCA standard (Figure 4-1). The standard specifies that if average summer total phosphorus and either average chlorophyll *a* or Secchi disc fail to meet the standard, lake water is impaired. Hence, water quality in Indianhead Lake was impaired in 2019.

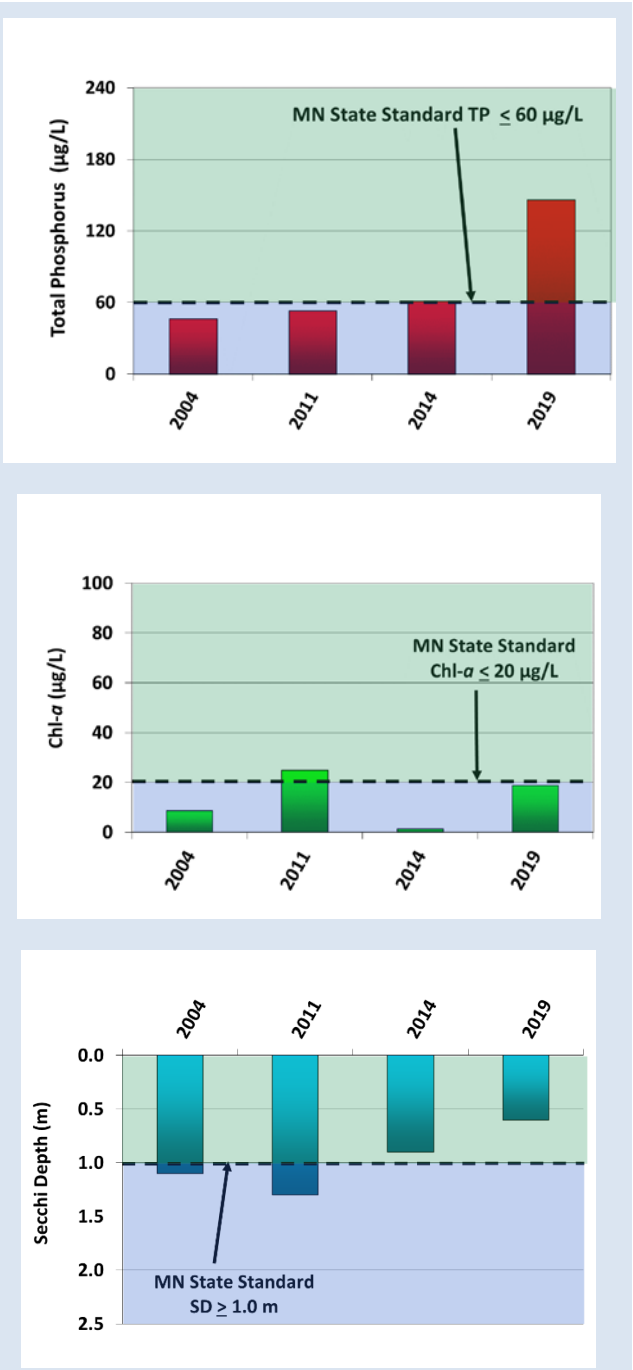


Figure 4-1 Indianhead Lake 2004, 2011, 2014, and 2019 summer average values

total phosphorus (top), chlorophyll a (middle), and Secchi disc (bottom) values during 2004, 2011, 2014, and 2019.

Historical water quality data have been collected from Indianhead Lake during 2004, 2011, and 2014. The data indicate water quality was poorer in 2019 than previous years. In 2019, summer average total phosphorus concentration was higher than previous years and summer average Secchi disc was lower than previous years. 2019 was the only year the lake failed to meet the MPCA water quality standard for shallow lakes (Figure 4-1). The standard specifies that if average summer total phosphorus and either average chlorophyll *a* or Secchi disc fail to meet the standard, lake water is impaired. Average summer chlorophyll *a* concentration failed to meet the standard during 2011 and Secchi disc failed to meet the standard in 2014. Because, the other parameters met the standard during 2011 and 2014 and all parameters met the standard in 2004, the lake was not impaired in 2004, 2011, and 2014.

The Indianhead Lake UAA completed in 2006 concluded that wet weather conditions produce the greatest strain upon water quality in Indianhead Lake. This is the result of a higher total load of phosphorus to the lake during wet weather. Although wetter weather results in larger volumes of relatively less concentrated water reaching the lake, Indianhead is a land-locked basin with no surface outlet. For that reason, no flushing occurs and total phosphorus accumulates in the lake, especially during periods of high watershed loading. According to the Minnesota Department of Natural Resources, 2019 was the wettest year on record for the weather station located at the Minneapolis St. Paul International Airport. In 2019, a total of 43.17 inches of precipitation was documented by the weather station, which has measured precipitation for more than 50 years.[2] The wet weather during 2019 caused higher phosphorus concentrations and lower water clarity in Indianhead Lake. High lake levels in 2019 may likely have resulted in increased shoreline erosion and decay of inundated plant material along the shoreline, further increasing phosphorus loading to the lake.

4.3 Phytoplankton and Zooplankton

Phytoplankton, also called algae, are small aquatic plants naturally present in lakes, including Indianhead 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.

Samples of phytoplankton, microscopic aquatic plants, were collected from Indianhead Lake (Figure 4-2) to evaluate water quality and the quality of food available to zooplankton (microscopic animals).

[2] Minnesota Department of Natural Resources. 2019. Another Very Wet Year in Minnesota. https://www.dnr.state.mn.us/climate/journal/another-very-wet-year-minnesota.html. Retrieved March 20, 2020

Figure 4-2 Indianhead Lake
2019 phytoplankton data collected from Indianhead Lake, pictured above, indicated the lake had an ample supply of good quality food for the lake's zooplankton community.

During the period of record, the phytoplankton community in Indianhead Lake has consistently been altered using algaecides (chemicals which kill algae) and dyes (chemicals that inhibit algal growth by shading). Indianhead Lake treatment with the algaecide copper sulfate has been documented for 2004, 2011, and 2014. Addition of the dye, Aquashade, to the lake has been documented for 2004, 2011, 2014, and 2019. Because the phytoplankton community has been consistently altered, phytoplankton numbers documented by monitoring do not represent natural conditions. Nonetheless, the average number of phytoplankton documented in 2019 was higher than previous years, but very close to the average number of phytoplankton documented for 2014.

The phytoplankton community in Indianhead Lake has consistently been dominated by green algae since monitoring began in 2004. Green algae are a good quality food source and contribute towards a healthy zooplankton community. Blue-green algae have consistently been present in low numbers throughout the period of record. The low numbers of blue-green algae are favorable for the lake because blue-green algae are a poor quality food for zooplankton. Blue-green algae may be toxic to zooplankton and may not be assimilated if ingested. The 2019 phytoplankton community indicates the lake has had an ample supply of good quality food for the zooplankton community (Figure 4-3).

In 2019, the zooplankton community in Indianhead Lake was healthy and balanced between the three groups of zooplankton, cladocerans, copepods, and rotifers. Numbers of cladocerans and copepods were, on average, higher in 2019 resulting in a more even distribution between the 3 groups of zooplankton.

However, the total number of zooplankton in 2019 was, on average, lower than numbers observed in 2011 and 2014. The changes in numbers probably reflect the impacts of fish predation. Decreased extent and density of aquatic plants within the lake in 2019 may have reduced hiding places for zooplankton to avoid predation from fish and resulted in lower numbers than observed in 2011 and 2014 (Figure 4-4). Nonetheless, the 2019 data indicate the zooplankton community provided an abundant supply of food for planktivorous fish in the lake.

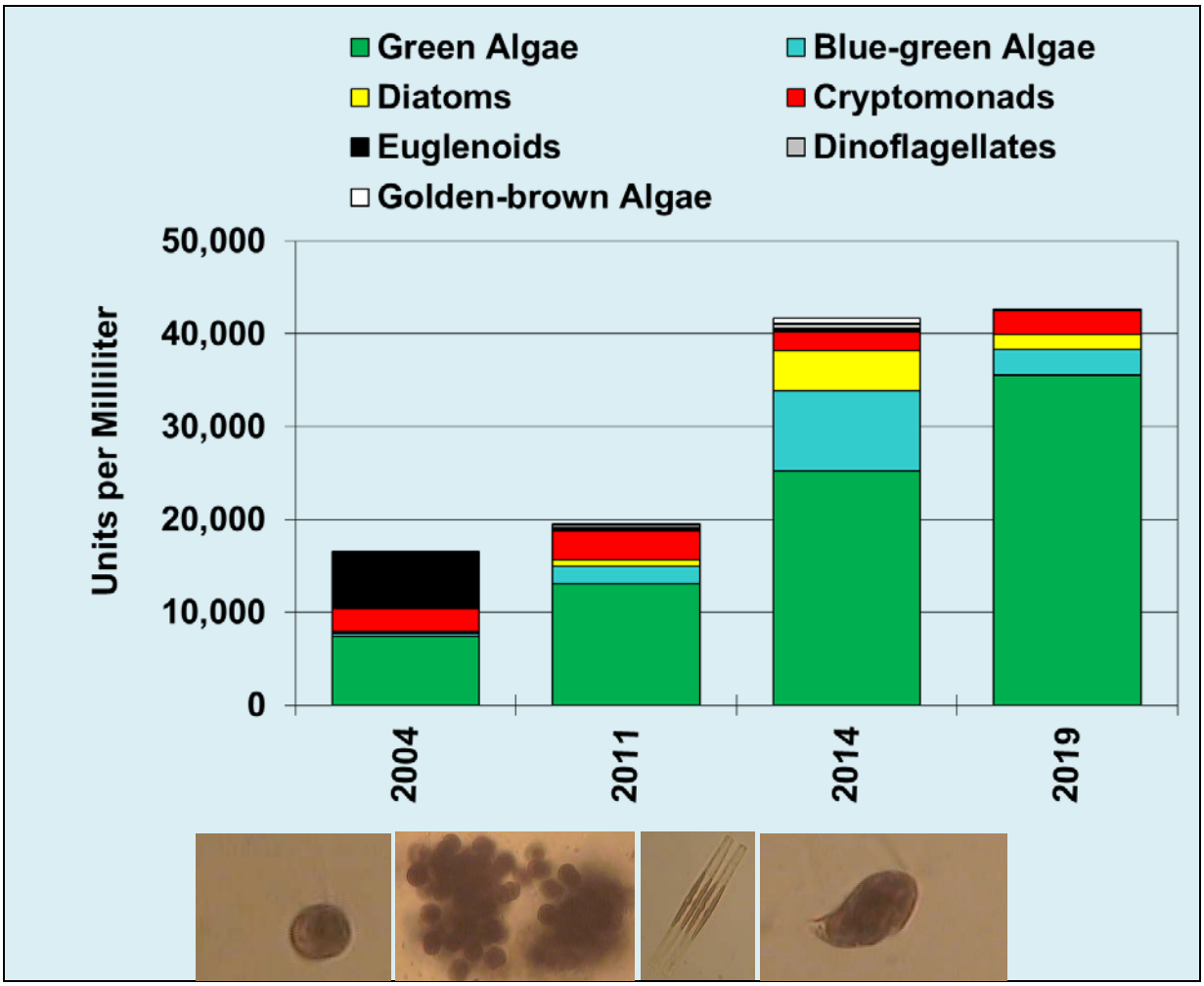
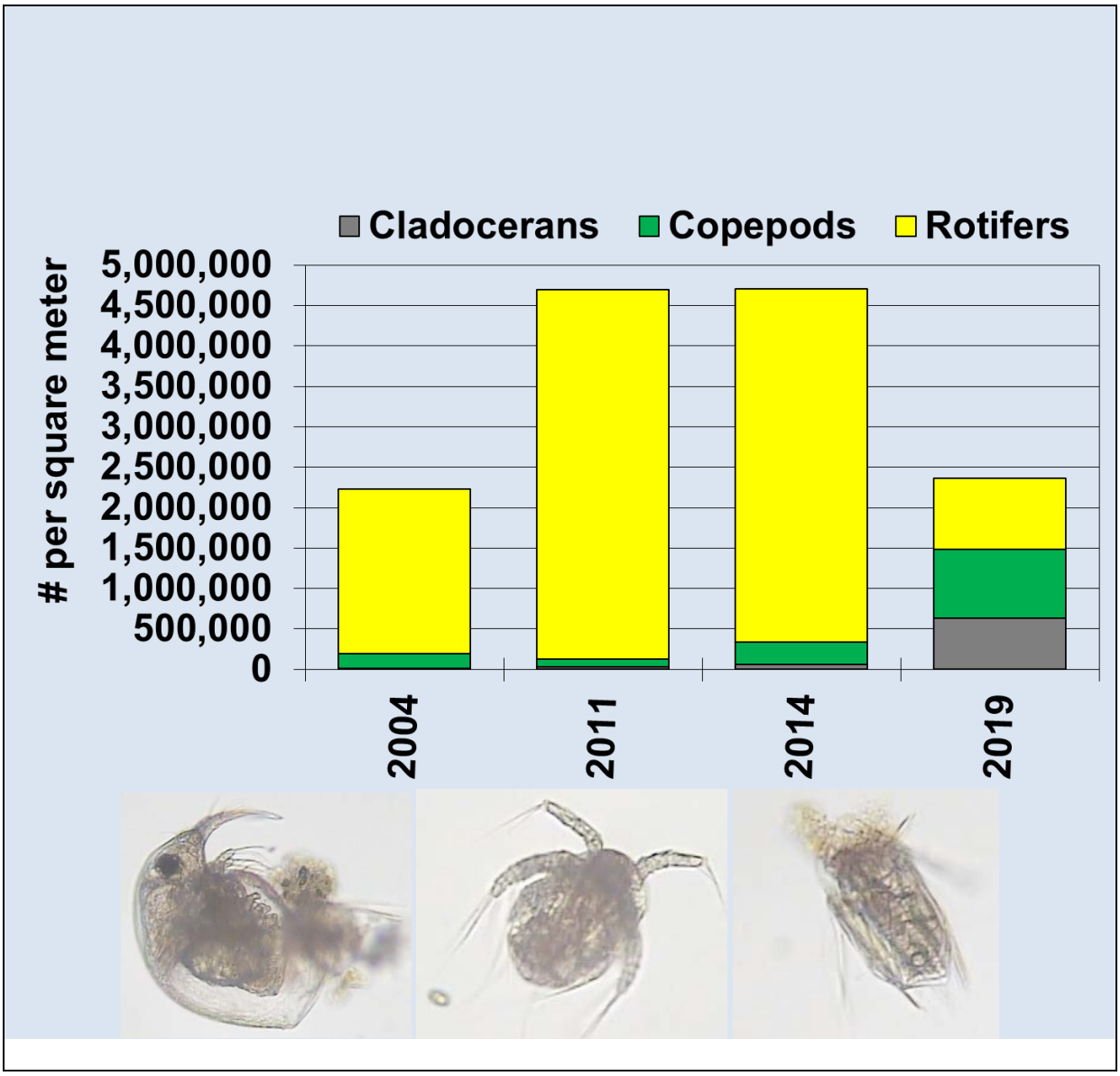


Figure 4-3 Indianhead Lake 2004, 2011, 2014, and 2019 summer average phytoplankton

Top, Indianhead Lake 2004, 2011, 2014, and 2019 summer average phytoplankton numbers and bottom, microscopic pictures of phytoplankton species found in the lake, from left to right, *Chlamydomonas globosa* (green algae) *Microcystis aeruginosa* (blue-green algae), *Fragilaria*



Top, 2004, 2011, 2014, and 2019 Indianhead Lake zooplankton numbers and bottom, microscopic pictures of zooplankton

Figure 4-4 2004, 2011, 2014, and 2019 Indianhead Lake zooplankton

species from the lake, from left to right, *Bosmina longirostris* (cladoceran), nauplii (baby copepod), and *Polyarthra vulgaris* (rotifer).

4.4 Aquatic Plants

The MDNR has developed metrics to determine the overall health of a lake's aquatic plant community. The Lake Plant Eutrophication Index of Biological Integrity (IBI) is expected to eventually be used by the MPCA to determine whether a lake is meeting the federal Clean Water Act standards intended to protect aquatic life. The plant IBI includes two metrics: (1) the number of species in a lake; and (2) the "quality" of the species, as measured by the floristic quality index (FQI).

The District conducted qualitative aquatic plant surveys of Indianhead Lake in June and August of 2019. Maps showing survey results are included in Appendix B. Plant survey data from 2004 through 2019 were assessed to determine plant IBI trends. Figure 4-5 shows the Indianhead Lake number of species and FQI scores for that period compared to the proposed MDNR plant IBI impairment threshold.

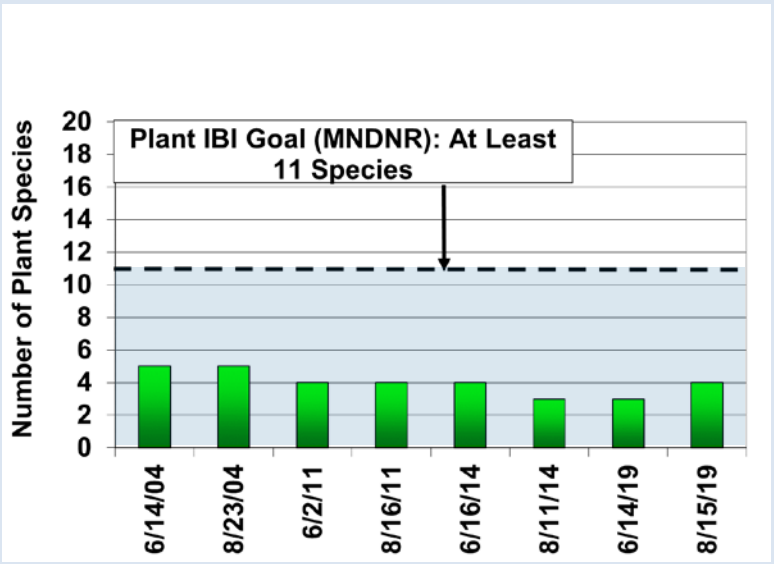


Figure 4-5.A

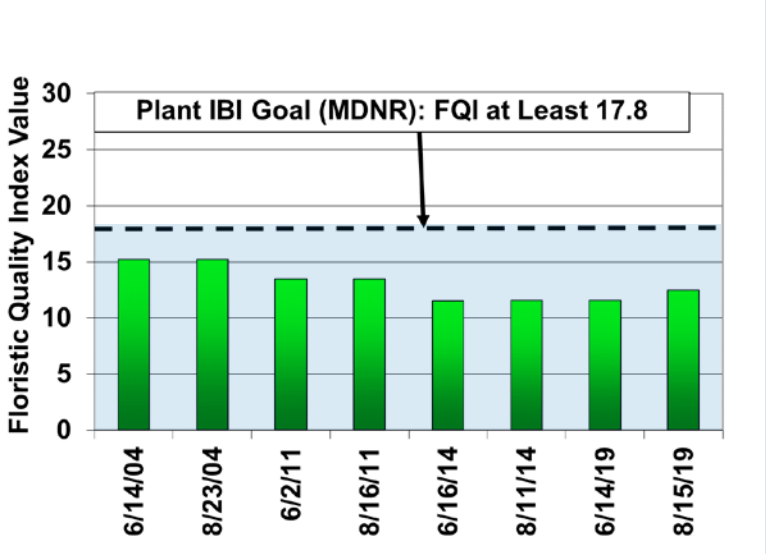


Figure 4-5.B

Figure 4-5 2004, 2011, 2014, and 2019 Indianhead Lake Plant Index of Biotic Integrity (IBI) Values compared with Plant IBI Thresholds: Number of Plant Species (top) and Floristic Quality Index (FQI) Values (bottom).

- **Number of species:** A shallow lake (maximum depth less than 15 feet) is considered impaired when it has fewer than 11 species. During the period examined, the number of species in Indianhead Lake ranged from 3 to 5 and has been less (poorer) than the minimum impairment threshold during the entire period of record (Figure 4-5.A).

- **FQI values (quality of species):** The impairment threshold for shallow lakes, as measured by FQI, is a minimum value of 17.8. During the period examined, FQI values ranged from 11.5 to 15.2 and has been less (poorer) than the minimum impairment threshold during the entire period of record (Figure 4-5.B).

- **2019 results:** Both the number of species in the lake and FQI values were poorer than the minimum IBI thresholds that define impairment. As such, the waters would be considered impaired for aquatic plants (Figure 4-5).

Two aquatic invasive species were found in Arrowhead Lake in 2019:

- **Purple loosestrife (Lythrum salicaria)** – This emergent species was first observed in 2019 at multiple locations along the eastern and western shorelines in June and August (Appendix B).
- **Yellow iris (Iris pseudacorus)**– was common and occasionally abundant along the southern shoreline in 2019. Yellow iris has consistently been prevalent along the lake's shoreline since plant surveys began in 2004 (Appendix B).

Although curly-leaf pondweed plants were not observed in Indianhead Lake in 2019, curly-leaf pondweed turions, which are reproductive winter buds that act like seeds, were observed floating in the water (Appendix B). This aquatic invasive species was previously observed in Indianhead Lake during June 2014.

4.5 Conclusions and Recommendations

Monitoring results indicate Indianhead Lake met the MPCA chloride standard, but failed to meet MPCA water quality standards in 2019 due to excess phosphorus in the lake and poor water clarity. Aquatic plant data indicated the plant community had few species, was of poor quality, and failed to meet the MDNR proposed plant IBI impairment thresholds. The Indianhead UAA completed in 2006 identified phosphorus loading from the lake's watershed as the largest source of phosphorus to the lake and wet weather conditions as placing the greatest strain upon the lake's water quality. The National Weather Service documented that 2019 was the wettest water year on record for the Twin Cities Metro Area.

The District's Water Management Plan (2017) identifies updating the Indianhead Lake UAA as an implementation item for 2021. As part of that UAA update, it is recommended that the District identify management measures to reduce watershed phosphorus loading to the lake. Continuation of water quality and biological monitoring is recommended to periodically assess the condition of the lake's water quality and biological community and identify trends.

5 Mirror Lake

Mirror Lake is located in the northwestern portion of Edina. The lake is divided into three basins; the main lake and two smaller basins to the northwest, separated from the main lake by Blake Road. The entire lake has a water surface of approximately 27 acres, with the main lake spanning just over 23 acres. The main lake has a maximum depth of approximately 25 feet and a mean depth of 12.5 feet at a water surface elevation of 904 feet MSL. At this elevation the lake volume is approximately 274 acre-feet.

The water level in the lake is controlled mainly by weather conditions (snowmelt, rainfall, and evaporation), seepage and a pumped outlet on the southwest side of the lake. Historically, Mirror Lake was considered to be landlocked. A pumped outlet from Mirror Lake was installed after 1995 to alleviate record high lake levels.

In 2019, the Nine Mile Creek Watershed District monitored Mirror Lake for:

- Water chemistry- total phosphorus (TP), soluble reactive phosphorus (ortho phosphorus), total nitrogen, total Kjeldahl nitrogen, nitrate plus nitrite nitrogen, chlorophyll *a*, chloride, and turbidity.
- Water field measurements- dissolved oxygen, pH, temperature, specific conductance, and oxidation reduction potential (ORP)
- Phytoplankton and zooplankton (microscopic plants and animals)
- Macrophytes (aquatic plants)

Water quality monitoring results are summarized in Appendix A, macrophyte monitoring maps in Appendix B, and phytoplankton data are summarized in Appendix C. Monitoring results are discussed in the following paragraphs.

5.1 Chlorides

Chloride concentrations in area lakes have increased since the early 1990s when many government agencies switched from sand or sand/salt mixtures to salt for winter road maintenance. When snow and ice melts, the salt goes with it, washing into lakes, streams, wetlands, and groundwater. It only takes 1 teaspoon of road salt to permanently pollute 5 gallons of water. And, once in the water, it is very difficult and expensive to remove.

Because high concentrations of chloride can harm fish and plant life, MPCA has established a chronic exposure chloride standard of 230 mg/L or less. All 2019 measurements met the MPCA standard. The range and average of observed concentrations are summarized below:

- **Range of 2019 chloride concentrations in Mirror Lake:** From a high of 72 mg/L, measured in April, to a low of 61 mg/L, measured in September (Appendix A).
- **Average 2019 concentration:** 66 mg/L (Appendix A).

5.2 Total Phosphorus and Chlorophyll *a* Levels and Water Clarity (Secchi Depth)

The 2019 data indicate excess phosphorus and algae were in the lake and the water clarity was poor. The lake's 2019 average summer total phosphorus and chlorophyll *a* concentrations of 89 µg/L and 30 µg/L, respectively, and the lake's average summer Secchi disc transparency of 0.6 meters failed to meet the Minnesota State Water Quality Standards for shallow lakes in the North Central Hardwood Forest Ecoregion published in Minnesota Rules 7050 (Minn. R. Ch. 7050.0222 Subp 4) (Figure 5-1).

Historical water quality data have been collected from Mirror Lake during 1990, 2001, 2004, and 2012. The data indicate 2019 water quality was within the range of historical data. During the past 30 years, excess phosphorus and algae in the lake and poor water clarity have caused all average summer total phosphorus and chlorophyll *a* concentrations and Secchi disc measurements to fail to meet the MPCA standards (Figure 5-1).

A Use Attainability Analysis (UAA) of Mirror Lake completed by the District in 2004 found the lake's poor water quality results from excess phosphorus added to the lake from both external and internal sources. The UAA concluded that 46 percent of the lake's annual phosphorus load is from watershed loading and 49 percent of the lake's annual phosphorus load is from internal sources—from mid-season die-back of curly-leaf pondweed and from lake sediments via chemical and mixing processes. The UAA modeling analysis documented the lake's very poor water quality under all climatic conditions.

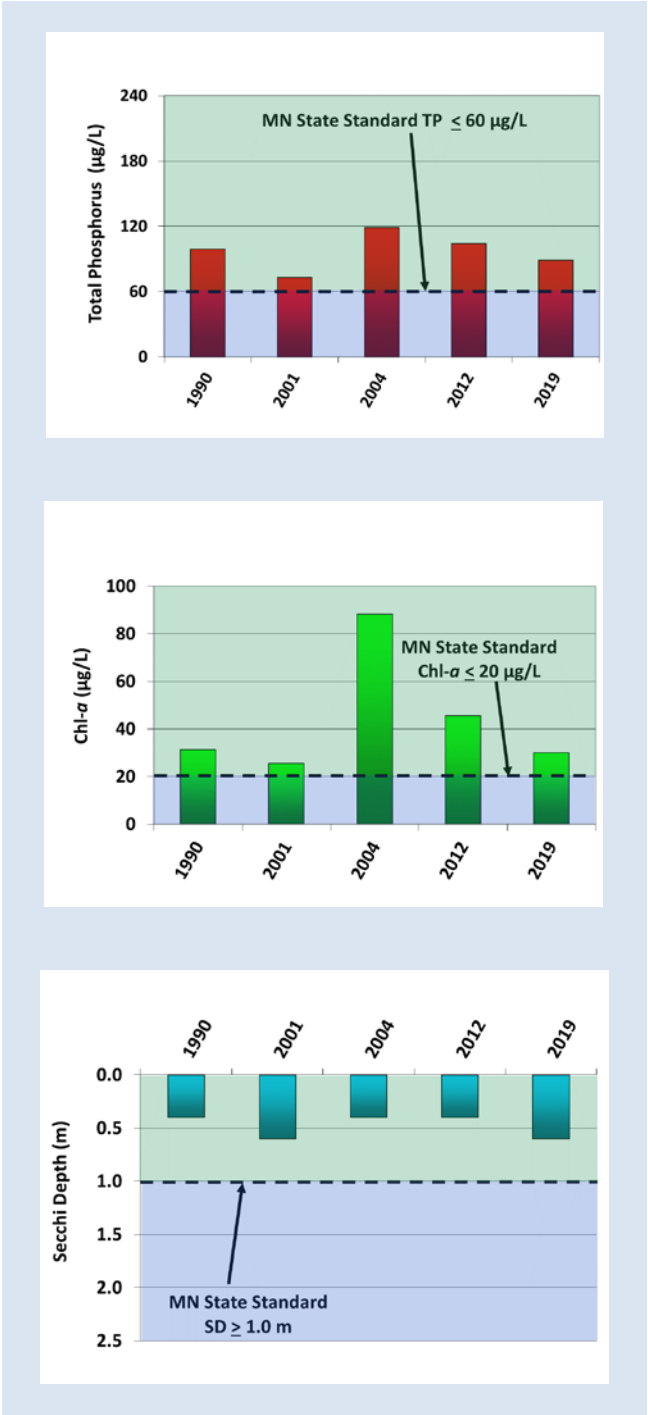


Figure 5-1 Mirror Lake summer average total phosphorus (top), chlorophyll *a* (middle), and Secchi disc (bottom) values during 1990-2019.

5.3 Phytoplankton and Zooplankton

Phytoplankton, also called algae, are small aquatic plants naturally present in lakes, including Mirror 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.

Samples of phytoplankton, microscopic aquatic plants, were collected from Mirror Lake to evaluate water quality, evaluate the quality of food available to zooplankton (microscopic animals), and estimate the public health risk posed by blue-green algae, which can produce toxins. In high concentrations, these toxins can be harmful to pet and human health. The World Health Organization (WHO) has established the following guidelines for assessing the risk posed to lake users by exposure to blue-green algae.

- Lakes with blue-green algae densities less than 20,000 cells per milliliter pose no risk to the health of humans or pets.
- Exposure to lakes with blue-green algae density levels between 20,000 and 100,000 cells per milliliter poses a low risk of adverse health impacts (i.e., skin irritation or allergenic effects such as watery eyes).
- Exposure to lakes with blue-green algae densities greater than 100,000 cells per milliliter poses a moderate health risk (i.e., long-term illness from algal toxins is possible).

Blue-green algae have dominated the Mirror Lake phytoplankton community since monitoring began in 1990 (Figure 5-2). Blue-green algae densities during 1990 and 2001 either posed no risk or a low risk of adverse health effects for lake users. (Figure 5-3). Blue-green densities and risk of adverse health effects for lake users increased between 2001 and 2004. More than 80 percent of 2004 samples had densities greater than 100,000 per milliliter, indicating exposure posed a moderate risk of adverse health impacts to lake users during much of the period examined. In 2012 and 2019, 40 percent of samples had densities greater than 100,000 per milliliter indicating exposure posed a moderate risk of adverse health impacts during nearly half of the period examined. WHO guidelines recommend that if there are 100,000 or more blue-green algae cells per milliliter of water, lab testing for algal toxins should be done to assess toxin levels and, if present, potential adverse health effects.

Blue-green algae can produce several types of toxins. The type of toxin produced depends on the type of blue-green algae in the lake. Some types of algae produce only one type of toxin while others produce several types of toxins. The types of toxins produced by blue-green algae include liver toxins, kidney toxins, nerve toxins, and skin toxins. All algal toxins contain a potential skin irritant.

The blue-green algae community within Mirror Lake has consistently been comprised of multiple species which collectively have the potential of producing multiple types of toxins. In 2019, nine toxin producing blue-green species were documented. Collectively, these species had the potential of producing

microcystin (a liver toxin), anatoxin-a (a nerve toxin), cylindrospermopsin (kidney and liver toxin), and saxitoxin (a nerve toxin). Phytoplankton data collected in 2019 are found in Appendix B

High phosphorus concentrations in lakes result in blue-green algae blooms such as were observed in Mirror Lake. Blue-green algae use whatever dissolved phosphorus is available in the water column to grow and reproduce. Their community size is a direct result of the amount of phosphorus available for growth. Because the number of blue-green algae in a lake is a direct result of the quantity of phosphorus in the lake, blue-green algae can be controlled by controlling phosphorus loading to the lake.

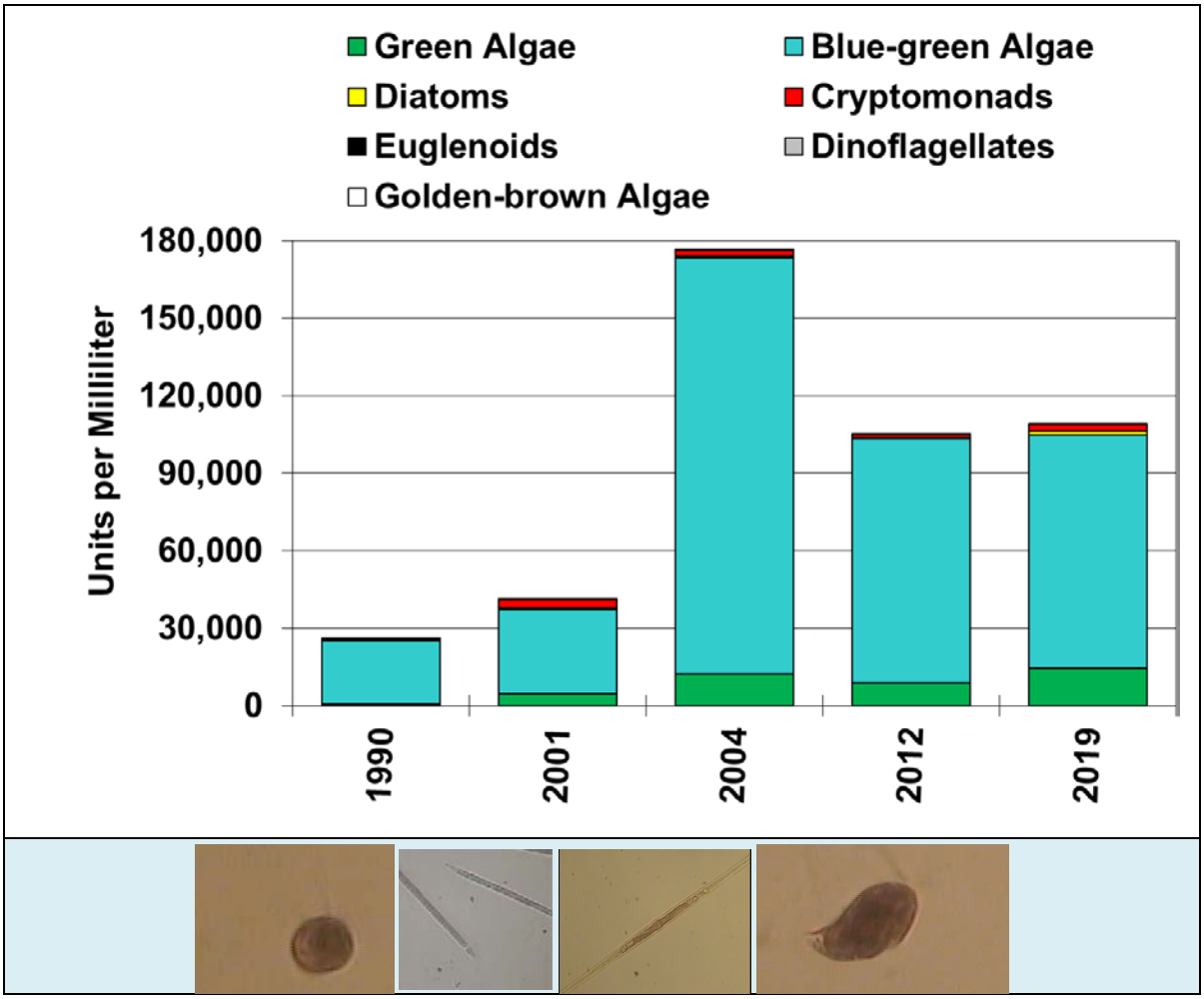


Figure 5-2 Mirror Lake 1990-2019 summer average phytoplankton

Top, phytoplankton numbers and bottom, microscopic pictures of blue-green algae species found in the lake , from left to right, *Chlamydomonas globosa* (green algae) *Cylindrospermopsis raciborskii (*blue-green algae)*, Synedra ulna (*diatom), and *Cryptomonas erosa* (cryptomonad).

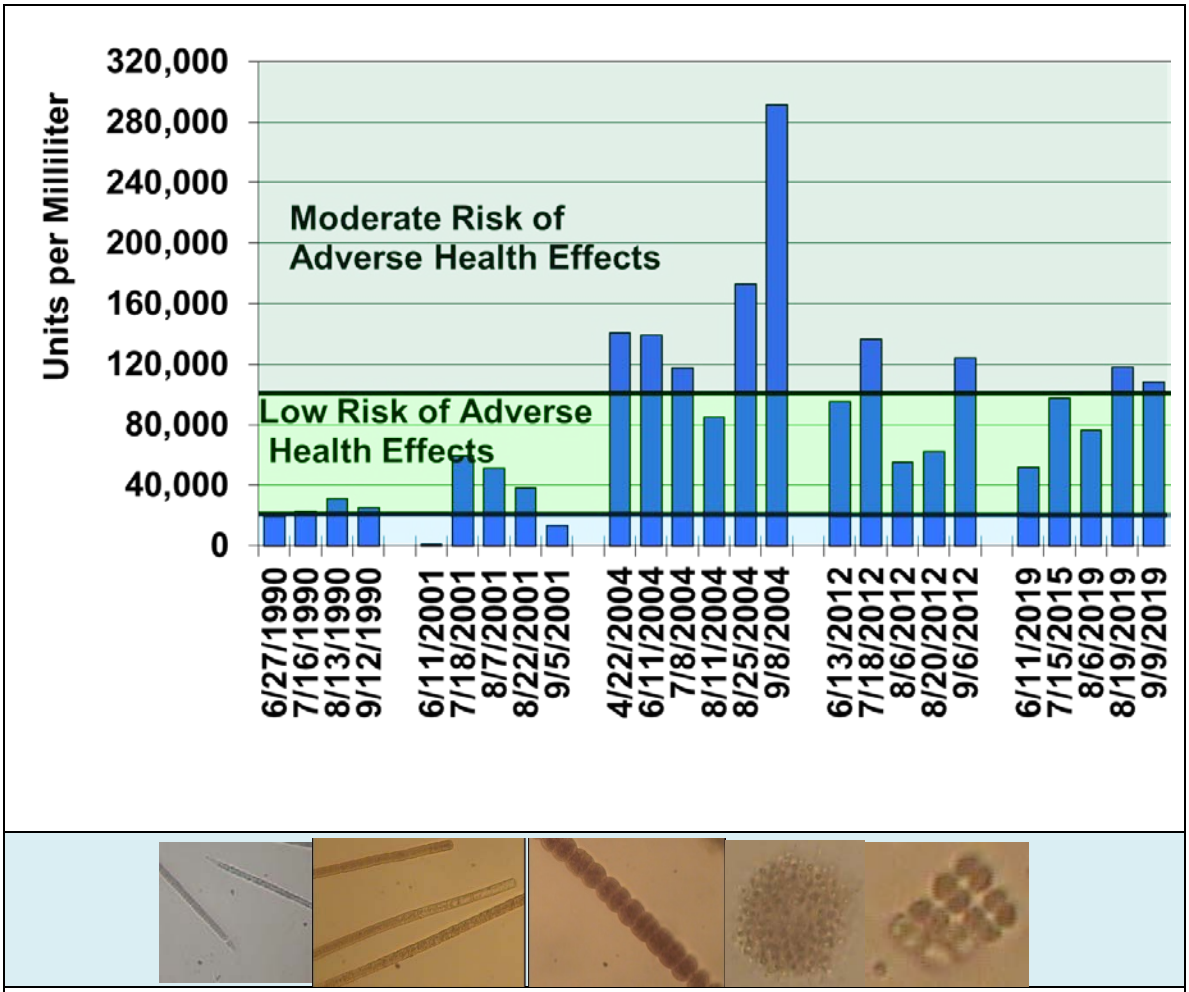


Figure 5-3 Mirror Lake 2019 blue-green algae numbers compared with World Health Organization thresholds for health impacts

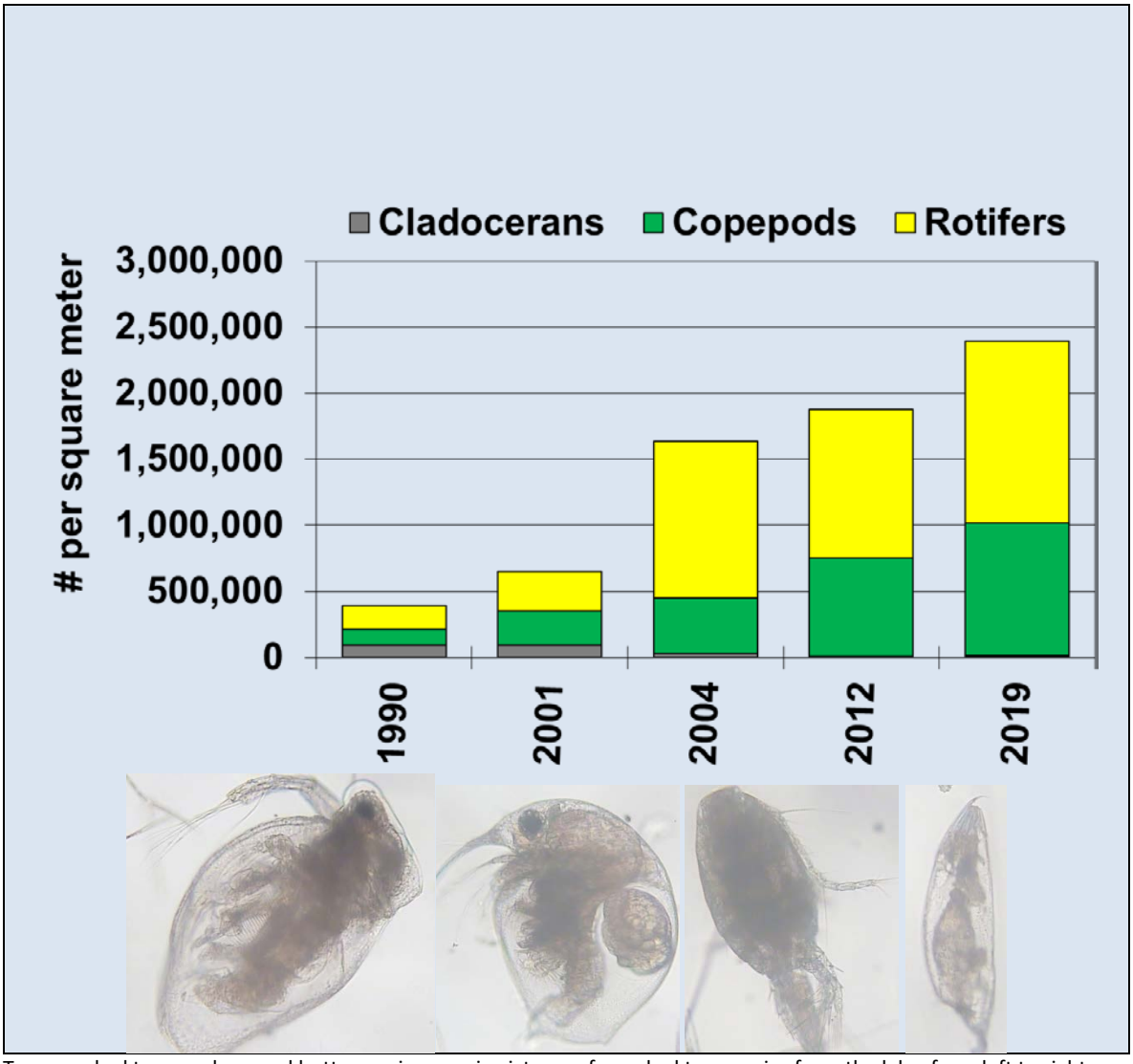
Top, Mirror Lake 2019 blue-green algae numbers compared with World Health Organization thresholds for health impacts and bottom, microscopic pictures of blue-green algae species found in the lake , from left to right, *Cylindrospermopsis raciborskii, Aphanizomenon flos-aquae*, *Dolichospermum affine*, *Microcystis incerta*, and *Merismopedia tenuissima*.

Unlike phytoplankton, zooplankton do not produce their own food. As "filter feeders," they eat millions of small algae; given the right quantities and species, they can filter the volume of an entire lake in a matter of days. They are also a valuable food source for planktivorous fish and other organisms. Fish generally select the largest zooplankters they see and prefer cladocerans to copepods because cladocerans swim slowly and lack the copepods' ability to escape predation by jerking or jumping out of the way.

Zooplankton numbers have consistently increased during the period of record and 2019 observed the highest average number of zooplankton to date. The increase is a favorable change for the lake. However, the reason for the increase is not obvious (Figure 5-4).

The community composition throughout the period of record reflects the impact of fish predation. Cladocerans are most vulnerable to fish predation and their numbers have consistently been very low in

the lake. Because of their small size, rotifers are the least preferred by fish and, hence, are least vulnerable to fish predation. Rotifer numbers were consistently higher than cladoceran and copepod numbers throughout the period of record (Figure 5-4). Copepods' ability to escape predation enabled them to be prevalent in the lake throughout the period of record (Figure 5-4).



Top, zooplankton numbers and bottom, microscopic pictures of zooplankton species from the lake, from left to right,

Figure 5-4 1990-2019 Mirror Lake zooplankton
Ceriodaphnia sp. (cladoceran), *Bosmina longirostris* (cladoceran), *Cyclops sp*. (copepod), and *Trichocerca cylindrica* (rotifer).

5.4 Aquatic Plants

The MDNR has developed metrics to determine the overall health of a lake's aquatic plant community. The Lake Plant Eutrophication Index of Biological Integrity (IBI) is expected to eventually be used by the MPCA to determine whether a lake is meeting the federal Clean Water Act standards intended to protect aquatic life. The plant IBI includes two metrics: (1) the number of species in a lake; and (2) the "quality" of the species, as measured by the floristic quality index (FQI).

The District conducted qualitative aquatic plant surveys of Mirror Lake in June and August of 2019. Maps showing survey results are included in Appendix B. Plant survey data from 2001 through 2019 were assessed to determine plant IBI trends. Figure 5-5 shows the Mirror Lake number of species and FQI scores for that period compared to the proposed MDNR plant IBI impairment threshold.

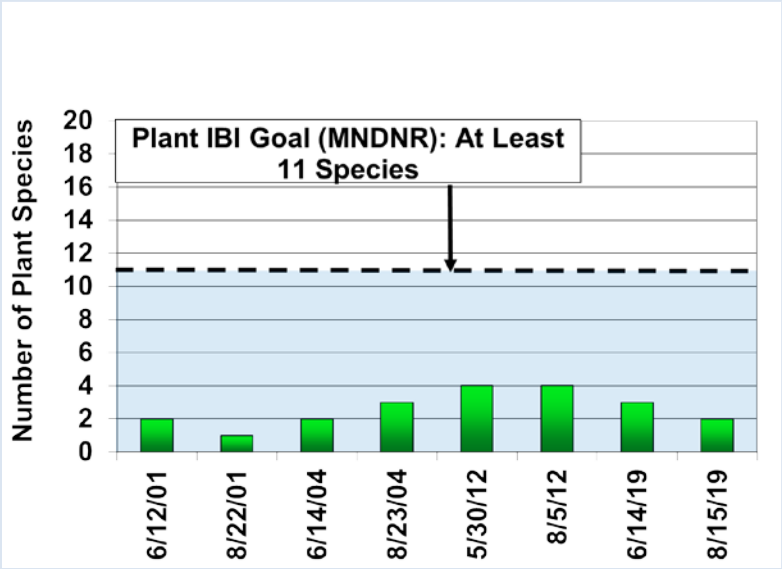


Figure 5-5.A

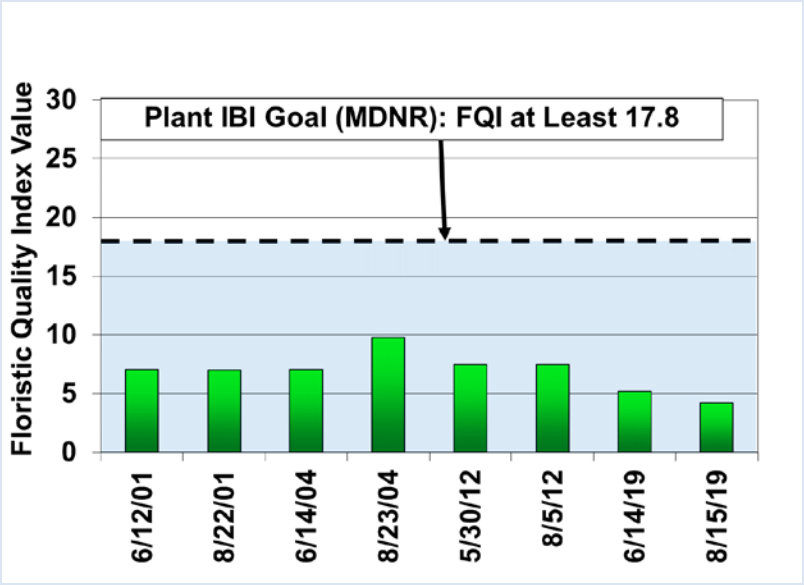


Figure 5-5.B

Figure 5-5 2001, 2004, 2012, and 2019 Mirror Lake Plant Index of Biotic Integrity (IBI) Values compared with Plant IBI Thresholds: Number of Plant Species (top) and Floristic Quality Index (FQI) Values (bottom).

Number of species: A shallow lake (maximum depth less than 15 feet) is considered impaired when it has fewer than 11 species. During the period examined, the number of species in Mirror Lake ranged from 1 to 4 and has been less (poorer) than the minimum impairment threshold during the entire period of record (Figure 5-5.A).

FQI values (quality of species): The impairment threshold for shallow lakes, as measured by FQI, is a minimum value of 17.8. During the period examined, FQI values in Mirror Lake ranged from 4.2 to 9.8, less (poorer) than the minimum impairment threshold during the entire period of record (Figure 5-5.B).

- **2019 results:** Both the number of species in the lake and FQI values were less (poorer) than the minimum IBI thresholds that define impairment. As such, the waters would be considered impaired for aquatic plants (Figure 5-5).

Two aquatic invasive species were found in Mirror Lake in 2019:

- **Curly-leaf pondweed (*Potamogeton crispus*)** – In June, this species was observed at a light density in the northeastern area of the lake. Due to its annual die-off in late June, it was not observed in August (Appendix B).
- **Purple loosestrife (Lythrum salicaria)** – This emergent species was observed along the northern and eastern shorelines in June and August (Appendix B).

Curly-leaf pondweed and purple loosestrife have been observed in Mirror Lake during the entire period examined.

5.5 Conclusions and Recommendations

2019 results indicate that Mirror Lake met MPCA water quality standard for chlorides. The MPCA standards for Secchi disc (measure of clarity), total phosphorus, and chlorophyll *a* were not met during the entire period of record. Since 2004, blue-green algae numbers have been within the moderate risk of adverse health impacts for lake users due to the potential for algal toxins in the water—more than 80 percent of samples in 2004 and 40 percent of samples in 2012 and 2019. The number of plant species found in the lake and the quality of the plant community measured by FQI were poorer than the proposed minimum IBI thresholds that define impairment during the entire period examined. As such the waters would be considered impaired for aquatic plants.

The *Mirror Lake Use Attainability Analysis* completed by the District in 2004 concluded the cause of the lake's water quality problem is excess phosphorus loading from the lake's watershed (46 percent of annual load) and from internal sources (49 percent of the annual load). Internal sources include mid-season die-back of curly-leaf pondweed and lake sediments via release of phosphorus from lake bottom sediments. The Mirror Lake UAA recommended an alum treatment to reduce phosphorus loading from sediment. An alum treatment for Mirror Lake would improve water quality and reduce numbers of blue-green algae in the lake. Modeling completed for the UAA predicted the alum treatment alone would not improve the water quality enough to meet State water quality standards. However, reducing the numbers of blue-green algae in the lake would reduce risk of adverse health impacts for lake users. The UAA also recommended several potential best management practices (BMPs) to reduce the external watershed load to Mirror Lake. Modeling completed for the UAA predicted that watershed measures would not significantly improve lake water quality, but predicted that the reduction in watershed phosphorus loading would increase the longevity of in-lake management measures such as an alum treatment. The UAA also recommended herbicide treatment of curly-leaf pondweed if it began to dominate the

submerged plant community and recommended management of purple loosestrife by either chemical treatment or biological means if it began to dominate the emergent plant community.

The District's Water Management Plan (2017) identifies updating the Mirror Lake UAA as an implementation item for 2022. As part of that UAA update, it is recommended that the District confirm the recommendation to conduct an alum treatment, and identify additional management measures to reduce watershed phosphorus loading to the lake. Continuation of water quality and biological monitoring is recommended to periodically assess the condition of the lake's water quality and biological community and identify trends.

6 Normandale Lake

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 late-1970s. The lake has a water surface area of approximately 116 acres, maximum depth of approximately 9 feet, and a mean depth of 3.0 feet at the normal water surface elevation of approximately 808 feet. At this elevation, the lake volume is approximately 290 acre-feet.

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

In 2019, the District began implementation of a water quality improvement project for Normandale Lake. A drawdown of the lake was completed in fall of 2018 to expose the lake bed to a winter freeze and freeze out curly-leaf pondweed (CLP), an invasive plant species, which dies off in late-June, senesces, and adds phosphorus to the lake. This summer addition of phosphorus fuels algal growth and degrades lake water quality. The lake was treated with alum in spring of 2019 to reduce the release of phosphorus from lake bottom sediments into the water column.

In 2019, the Nine Mile Creek Watershed District monitored Normandale Lake for:

- Water chemistry- total phosphorus (TP), soluble reactive phosphorus (ortho phosphorus), total nitrogen, total Kjeldahl nitrogen, nitrate plus nitrite nitrogen, chlorophyll *a*, chloride, and turbidity.
- Water field measurements- dissolved oxygen, pH, temperature, specific conductance, and oxidation reduction potential (ORP)
- Macrophytes (aquatic plants)

Water quality monitoring results are summarized in Appendix A and macrophyte monitoring maps in Appendix D. Monitoring results are discussed in the following paragraphs.

6.1 Chlorides

Chloride concentrations in area lakes have increased since the early 1990s when many government agencies switched from sand or sand/salt mixtures to salt for winter road maintenance. When snow and ice melts, the salt goes with it, washing into lakes, streams, wetlands, and groundwater. It only takes 1 teaspoon of road salt to permanently pollute 5 gallons of water. And, once in the water, it is very difficult and expensive to remove chloride.

Because high concentrations of chloride can harm fish and plant life, MPCA has established a chronic exposure chloride standard of 230 mg/L or less. All 2019 measurements met the MPCA standard. The range and average of observed concentrations are summarized below:

- **Range of 2019 chloride concentrations in Normandale Lake:** From a high of 208 mg/L, measured in April, to a low of 40 mg/L, measured in late August (Appendix A).
- **Average 2019 concentration:** 194 mg/L (Appendix A).

6.2 Total Phosphorus and Chlorophyll *a* Levels and Water Clarity (Secchi Depth)

The 2019 data indicate excess phosphorus was in the lake, but algal levels and water clarity were good. The lake's summer average total phosphorus and chlorophyll *a* concentrations were 63 µg/L and 11.2 µg/L respectively. The lake's summer average Secchi depth (water clarity) was 1.2 meters. Total phosphorus failed to meet the Minnesota State Water Quality Standard for shallow lakes in the North Central Hardwood Forest Ecoregion published in Minnesota Rules 7050 (Minn. R. Ch. 7050.0222 Subp 4), but both chlorophyll *a* and Secchi depth met the State standard (Figure 6-1). Because both chlorophyll *a* met the standard, the lake was not impaired in 2019. The standard specifies that the lake is impaired when total phosphorus and either chlorophyll *a* or Secchi disc fail to meet the State standard.

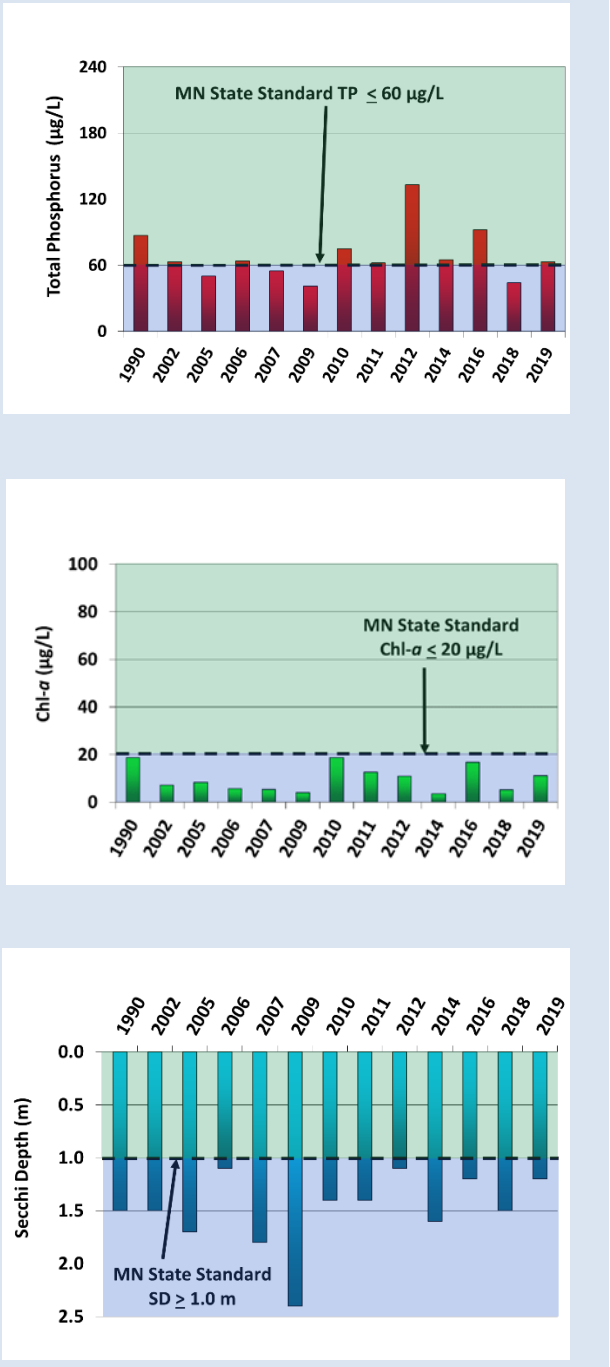


Figure 6-1 **Normandale Lake summer average total phosphorus (top), chlorophyll *a* (middle), and Secchi disc (bottom) values during 1990-2019.**

Historical water quality data have been periodically collected from Normandale Lake during 1990 through 2019. The 2019 data indicate water quality was within the range of historical data (Figure 6-1). Normandale Lake has historically met the State 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 ranged from 1.1 to 2.4 meters. Summer average total phosphorus has ranged from 41 to 133 µg/L, with several years, including 2019, exceeding the State maximum impairment threshold (Figure 6-1).

The 2018 Engineer's Report for the Normandale Lake water quality improvement project concluded that 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. According to the MDNR, 2019 was the wettest year on record for the weather station located at the Minneapolis St. Paul International Airport. In 2019, a total of 43.17 inches of precipitation was documented by the weather station, which has measured precipitation for more than 50 years.[3] Wet weather during 2019 resulted in higher phosphorus loads to Normandale Lake (Figure 6-2) which likely resulted in a summer average total phosphorus concentration that exceeded the State criteria. The 2019 average summer total phosphorus concentration of 63 µg/L was very close to meeting the State criteria for shallow lakes of 60 µg/L despite the higher phosphorus loading to the lake caused by the wet weather.

Figure 6-2 Normandale Lake
In 2019, the wet weather added higher phosphorus loads to Normandale Lake, pictured above, likely resulting in a summer average total phosphorus concentration that didn't meet shallow lakes phosphorus criteria.

[3] Minnesota Department of Natural Resources. 2019. Another Very Wet Year in Minnesota. https://www.dnr.state.mn.us/climate/journal/another-very-wet-year-minnesota.html. Retrieved March 20, 2020

6.3 Aquatic Plants

The MDNR has developed metrics to determine the overall health of a lake's aquatic plant community. The Lake Plant Eutrophication Index of Biological Integrity (IBI) is expected to eventually be used by the MPCA to determine whether a lake is meeting the federal Clean Water Act standards intended to protect aquatic life. The plant IBI includes two metrics: (1) the number of species in a lake; and (2) the "quality" of the species, as measured by the floristic quality index (FQI).

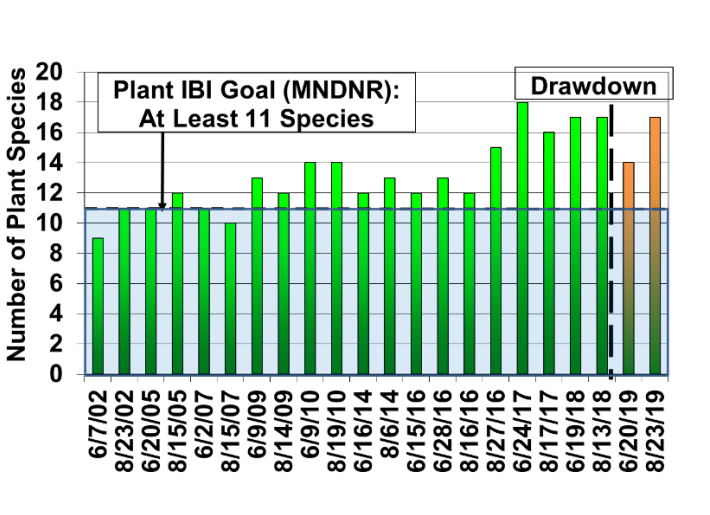


Figure 6-3.A

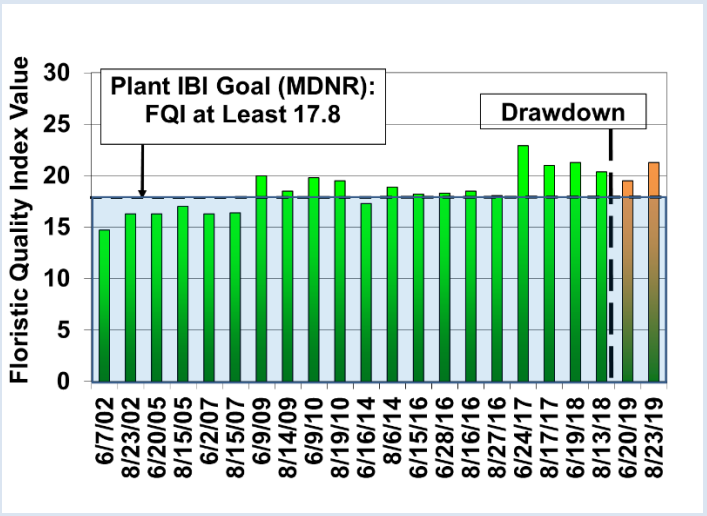


Figure 6-3.B

Figure 6-3 **2002-2019 Normandale Lake Plant Index of Biotic Integrity (IBI) Threshold Values compared with Plant IBI Thresholds: Number of Plant Species (top) and Floristic Quality Index (FQI) Values (bottom).**

The District conducted point-intercept and biomass aquatic plant surveys of Normandale Lake in June and August of 2019. Results are included in Appendix D. Plant survey data from 2002 through 2019 were assessed to determine plant IBI trends. Figure 6-3 shows the Normandale Lake number of species and FQI scores for that period compared to the proposed MDNR plant IBI impairment threshold. The green bars depict data collected before completion of the water quality improvement project (drawdown and alum treatment) while the orange bars depict data collected in 2019 after the completion of the project.

- **Number of species:** A shallow lake (maximum depth less than 15 feet) is considered impaired when it has fewer than 11 species. During the period examined, the number of species in Normandale Lake ranged from 9 to 18. The number of species in the lake has been better than the impairment threshold since 2009. Higher numbers of plant species have been observed since August of 2016 than in previous years (Figure 6-3.A).

- **FQI values (quality of species):** The impairment threshold for shallow lakes, as measured by FQI, is a value of 17.8. During the period examined, FQI values ranged from 14.7 to 22.9. FQI scores have been consistently better than the impairment threshold since August 2014 (Figure 6-3.B).

- **2019 results:** Both the number of species in the lake and FQI values were better than the minimum IBI thresholds that define impairment. As such, the Normandale Lake would not be considered impaired for aquatic plants (Figure 6-3).

Comparison of Pre- and Post-Project Data to Assess Changes After Completion of Water Quality Improvement Project: The water quality improvement projects implemented in 2018 and 2019 have resulted in an overall improvement to the plant community. The drawdown reduced the frequency of the targeted aquatic invasive species curly-leaf pondweed (CLP) (*Potamogeton crispus*) – from a range of 47 to 85 percent of sampling locations in June during 2016 through 2018 to 22 percent of sampling locations in June 2019 (Figure 6-4)—and reduced biomass of curly-leaf pondweed, measured as wet weight—from a range of 25 to 230 grams per sample location, on average, in June during 2017 through 2018 to an average of 6 grams per sample location in June 2019 (Figure 6-5).

Native plant species responded to the reduction of CLP by increased frequency of three native species – small pondweed (*Potamogeton pusillus*), sago pondweed (*Stuckenia pectinata*), and horned pondweed (*Zanichellia palustris*) (Appendix D). The number of species in the lake remained the same after the project—17 during both August 2018 and August 2019, but the quality of the plant community measured by FQI improved after the project—from 20.3 in August of 2018 to 21.3 in August 2019 (Figure 6-3).

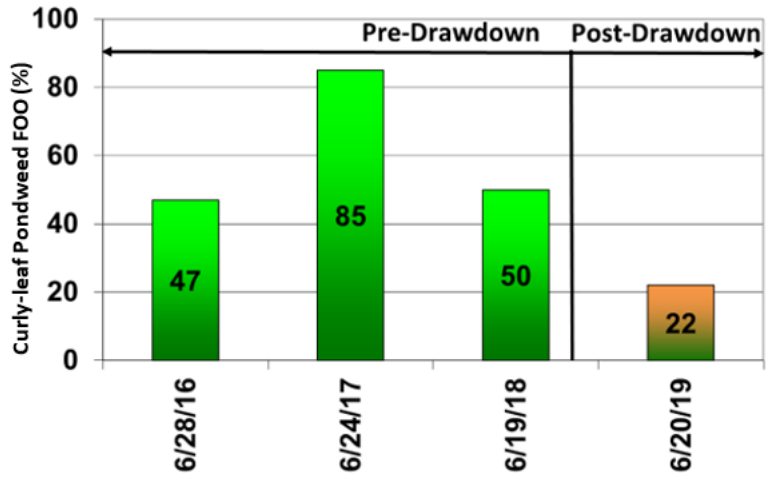


Figure 6-4 2016-2019 Curly-leaf Pondweed Frequency of Occurrence (FOO)

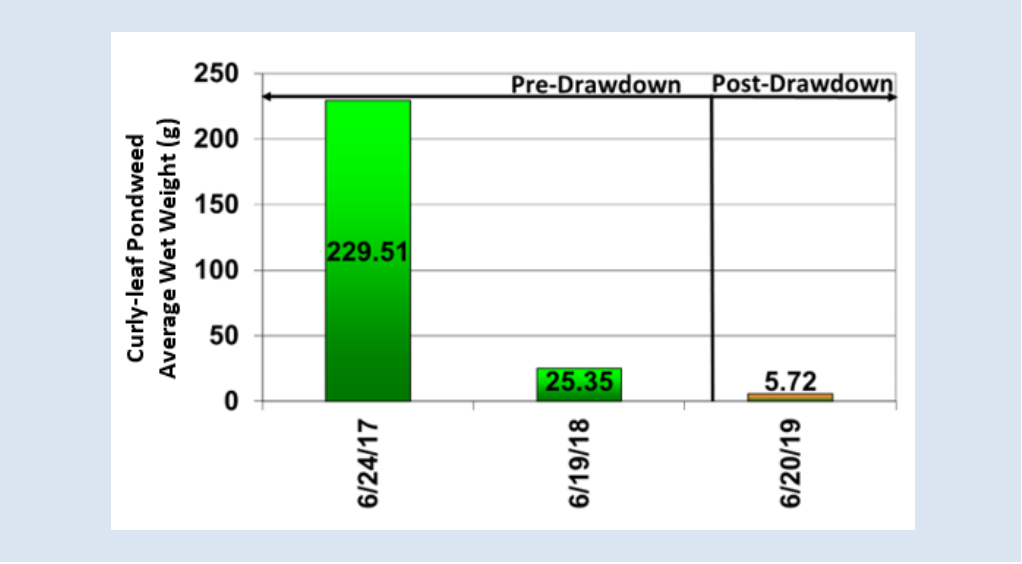


Figure 6-5 2017-2019 Curly-leaf Pondweed Biomass (Average Wet Weight Per Sample Location)

In 2019, four aquatic invasive species were known to be present in Normandale Lake: CLP, Eurasian watermilfoil (EWM), reed canary grass, and hybrid cattail.

- **Curly-leaf pondweed (*Potamogeton crispus*) CLP):** CLP has been documented in the lake during the entire period of record, 2002 through 2019. A drawdown in fall of 2018 reduced CLP frequency and biomass in Normandale Lake (Figure 6-4 and Figure 6-5). In 2020, the District intends to treat the remaining CLP with herbicide.

- **EWM (*Myriophyllum spicatum*):** Eurasian watermilfoil was first observed in Normandale Lake in June 2017 when it was collected on the rake at three locations and visually observed at two additional locations. It was not observed in the lake in August 2017. In June 2018, Eurasian watermilfoil (EWM) was not collected on the rake, but was visually observed at two locations. In August 2018, EWM was collected on the rake at one location and visually observed along the north shoreline, where it was beginning to form EWM beds. A EWM "bed" is an area where EWM makes up more than half of the area's plants and is generally continuous with clearly defined borders. In 2019, EWM was not observed in the lake during June or August, but a small cluster of EWM occurred just upstream of the lake in August.

- **Reed canary grass:** Reed canary grass extent has not changed since first observed in the lake in 2016—reed canary grass was common along the shoreline.

- **Hybrid cattail –** The extent of this emergent species has not changed since first observed in the lake in 2016—was observed at one location (Appendix D).

6.4 Conclusions and Recommendations

2019 results indicate that Normandale Lake met MPCA water quality standards for chlorides. Secchi disc (measure of clarity), and chlorophyll *a* concentrations met the state eutrophication criteria for shallow lakes. The average summer phosphorus concentration did not meet the shallow lakes phosphorus criterion of 60 µg/L, , but the summer average value of 63 µg/L was close. According to the MDNR plant IBI, the lake's plant community is not impaired.

In 2018, the District began implementation of a water quality improvement project for Normandale Lake. A drawdown of the lake was completed in fall of 2018 to expose the lake bed to a winter freeze and freeze out CLP. A comparison of pre- and post-project aquatic plant data to assess changes after completion of a drawdown and alum treatment documented an overall improvement in the plant community in 2019. CLP frequency and biomass declined in 2019, frequency of three native species increased, and quality of the plant community, measured by FQI, improved. An alum treatment was completed in spring of 2019. Herbicide treatment of the remaining CLP will occur in 2020 with additional herbicide treatments completed in subsequent years as needed to reduce CLP.

In 2019, four aquatic invasive species, CLP, EWM, reed canary grass, and hybrid cattail were present in the lake. As noted in the previous paragraph, the District's water quality improvement project reduced CLP frequency and biomass. EWM was not observed in the lake during 2019, but a small cluster occurred just upstream of the lake in August. Reed canary grass and hybrid cattail extent have not changed since first observed in the lake in 2016—reed canary grass was common along the shoreline and hybrid cattail was observed at one location.

Continuation of water quality and biological monitoring is recommended in upcoming years to assess the impacts of the improvement project(s) on the condition of the lake's water quality and biological community.

7 Lake Edina

Lake Edina is a small shallow lake located in Edina with a surface area of 24 acres and a maximum depth of 1.2 meters (approximately 4 feet). The lake is shallow enough for aquatic plants to grow over the entire lake bed. In addition, it is also a polymictic lake (mixing many times per year).

In 2019, the Nine Mile Creek Watershed District monitored Lake Edina for macrophytes (aquatic plants) to further assess the extent of curly-leaf pondweed (CLP) and Eurasian watermilfoil (EWM), two aquatic invasive species observed in previous plant surveys and considered for potential herbicide treatment. Monitoring results are discussed in the following paragraphs.

7.1 Aquatic Plants

The District conducted point intercept plant surveys of Lake Edina in June and August of 2019. A grid of 100 sample points were monitored during each survey. Maps showing survey results are included in Appendix E.

Four aquatic invasive species were observed during 2019.

Eurasian watermilfoil (*Myriophyllum spicatum*) – In June, Eurasian watermilfoil (EWM) was found throughout the lake, collected on the rake at 25 locations, and visually observed at an additional 35 locations (Appendix E). In August, EWM was primarily found in the northern half of the lake, collected on the rake at 16 locations, and visually observed at 10 locations (Appendix E). Eurasian watermilfoil was first observed in Lake Edina during 2017 when it was documented in the northern and western areas of the lake.

Figure 7-1 Lake Edina
A severe algal bloom during August in Lake Edina, pictured above, reduced water clarity to just a couple of inches. Many plant species seen in June were not present or were in the process of dying back in August, apparently due to the poor water clarity. Photo Credit: Endangered Resource Services, LLC.

Yellow iris (*Iris pseudacorus*) – Yellow iris was common and occasionally abundant along the southern shoreline in 2019. Yellow iris has consistently been prevalent along the lake's shoreline since plant surveys began in 2008.

Purple loosestrife (*Lythrum salicaria*) – Purple loosestrife was observed at one location along the southern shoreline in 2019 (Appendix E). Purple loosestrife has been documented along the lake's shoreline since plant surveys began in 2008.

Narrow-leaved cattail (*Typha angustfolia*) – Narrow-leaved cattail was observed at 3 locations in June and 4 locations in August 2019 (Appendix E).

Curly-leaf pondweed (CLP), an aquatic invasive species, was not observed in Lake Edina during 2019 but had been consistently observed in the lake in one or two locations during the period of record (2008, 2012, 2015, and 2017). The MDNR has developed metrics to determine the overall health of a lake's aquatic plant community. The Lake Plant Eutrophication Index of Biological Integrity (IBI) is expected to eventually be used by the MPCA to determine whether a lake is meeting the federal Clean Water Act standards intended to protect aquatic life. The plant IBI includes two metrics: (1) the number of species in a lake; and (2) the "quality" of the species, as measured by the floristic quality index (FQI).

Plant survey data from 2008 through 2019 were assessed to determine plant trends. Figure 7-2 shows the Lake Edina number of species and FQI scores for that period compared to the proposed MDNR Plant IBI impairment threshold.

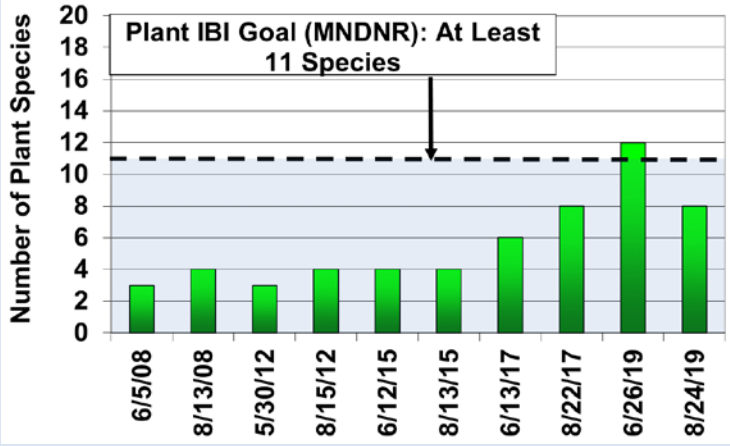


Figure 7-2.A

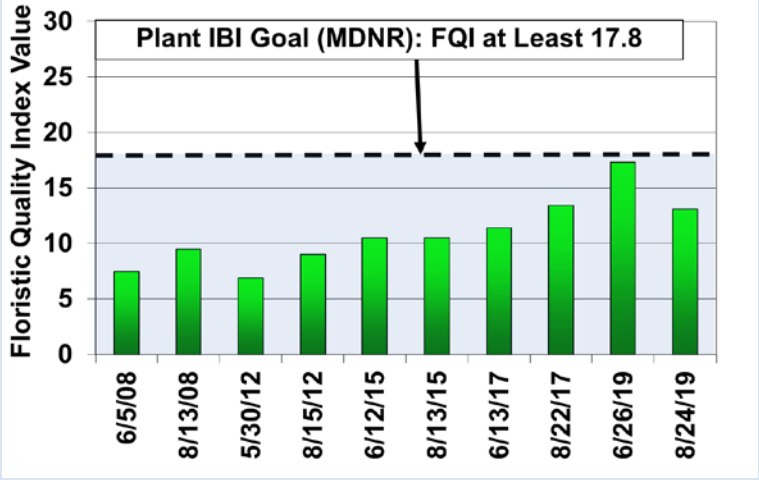


Figure 7-2.B

- **Number of species:** A shallow lake is considered impaired when it has fewer than 11 species. During the period

Figure 7-2 **2008-2019 Lake Edina Plant Index of Biotic Integrity (IBI) Values compared with Plant IBI Thresholds: Number of Plant Species (top) and Floristic Quality Index (FQI) Values (bottom).**

examined, the number of species in Lake Edina ranged from 3 to 12. The June 2019 value of 12 was better than the impairment threshold, but all other values during the period of record were below the minimum IBI threshold that defines impairment (Figure 7-2.A).

- **FQI values (quality of species):** The impairment threshold for shallow lakes, as measured by FQI, is a minimum value of 17.8. During the period examined, FQI values ranged from 6.9 to 17.3. Although all values were below the minimum IBI threshold that defines impairment, the June 2019 value of 17.3 was close (Figure 7-2.B).

- **2019 results:** Although the number of species in the lake in June was better than the minimum IBI threshold that defines impairment, the number of species in the lake in August and the FQI values during June and August were below the minimum IBI thresholds that define impairment. As such, the waters would be considered impaired for aquatic plants (Figure 7-2). Reductions in the number of species in the lake and FQI during August appears to be due to severe algal blooms that reduced water transparency in the lake (Figure 7-1).

7.2 Conclusions and Recommendations

Aquatic plant data indicated the plant community had few species, was of poor quality, and failed to meet the MDNR proposed plant IBI impairment thresholds. Poor water quality is the cause of the lake's poor plant community. In 2019, severe algal blooms in August limited water clarity to just a couple of inches. Many plant species seen in June were not present or were in the process of dying back in August due to the poor water clarity.

The District completed a Use Attainability Analysis of Lake Cornelia and Lake Edina in July of 2019 to identify water quality improvement measures for both lakes. The UAA concluded that the poor water quality in Lake Edina is primarily due to excess phosphorus in the lake, which fuels algal production and decreases water clarity. Phosphorus in Lake Edina comes from runoff from the watershed (external sources) and flows from upstream Lake Cornelia. Modeling indicates that during 2017, flows from upstream Lake Cornelia comprised nearly two thirds of the annual phosphorus load to Lake Edina. Because the water quality of Lake Edina is highly influenced by the water quality of Lake Cornelia, the recommended management strategy to improve water quality in Lake Edina is to implement the recommendations for upstream Lake Cornelia. Opportunities to reduce phosphors from the direct watershed to Lake Edina will also be considered.

Eurasian watermilfoil spread rapidly since first observed in the lake in 2017 and was found throughout Lake Edina during June 2019. Consideration of treatment of invasive Eurasian watermilfoil in Lake Edina is recommended to prevent it from further threatening the lake's aquatic plant community and to minimize the plant fragments conveyed to Nine Mile Creek and downstream Normandale Lake.

Continuation of water quality and biological monitoring is recommended to periodically assess the condition of the lake's water quality and biological community and identify trends.

8 Lake Smetana

Lake Smetana is a shallow, 56-acre lake within the "Golden Triangle" area of Eden Prairie, an industrial park surrounded by Interstate 494 and U.S. Highways 212 and 169. The lake is situated along the South Branch of Nine Mile Creek, approximately 1.3 stream miles downstream of Bryant Lake within the Nine Mile Creek watershed. With an average depth of 3 feet and maximum depth of 10 feet, the lake is shallow enough for plants to grow over the entire lake. It is a polymictic lake, mixing many times per year.

Water quality in Lake Smetana has improved in the past decade and the lake currently meets water quality. The water quality improvements are in large part due to the water quality projects implemented in upstream Bryant Lake, most markedly the 2008 alum treatment to reduce the release of phosphorus from the lake bottom sediments.

In 2019, the Nine Mile Creek Watershed District monitored Lake Smetana (Pictured in Figure 8-1) for macrophytes (aquatic plants) to assess plant species present and their biomass, and further assess the extent of curly-leaf pondweed in the lake, in support of the Lake Smetana Use Attainability Analysis (UAA) update underway in 2019-2020. Maps summarizing the results of the macrophyte surveys are included in Appendix F. Monitoring results are discussed in the following paragraphs.

Figure 8-1 Lake Smetana
In 2019, a dense plant growth was observed throughout Lake Smetana, pictured above. Coontail (Ceratophyllum demersum) and white water crowfoot (Ranunculus aquatilis) dominated the plant community. (Photo Credit: Endangered Resource Services, LLC.)

8.1 Aquatic Plants

The District conducted point intercept aquatic plant surveys of Lake Smetana in June and August of 2019. Biomass samples were collected to determine wet and dry weights of individual species. of Maps showing survey results are included in Appendix F.

The MDNR has developed metrics to determine the overall health of a lake's aquatic plant community. The Lake Plant Eutrophication Index of Biological Integrity (IBI) is expected to eventually be used by the MPCA to determine whether a lake is meeting the federal Clean Water Act standards intended to protect aquatic life. The plant IBI includes two metrics: (1) the number of species in a lake; and (2) the "quality" of the species, as measured by the floristic quality index (FQI).

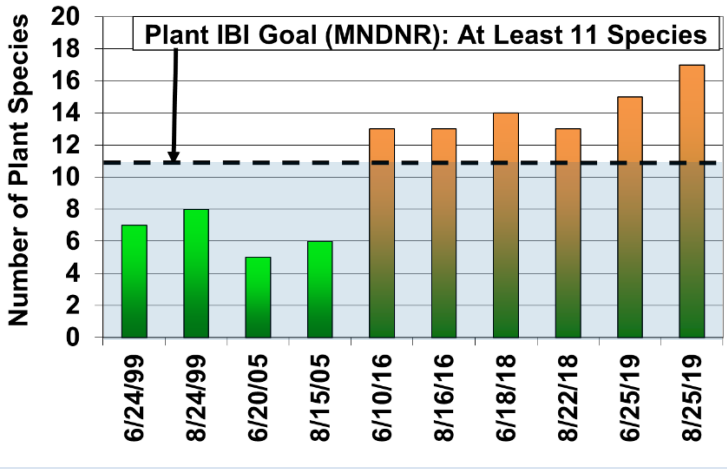


Figure 8-2.A

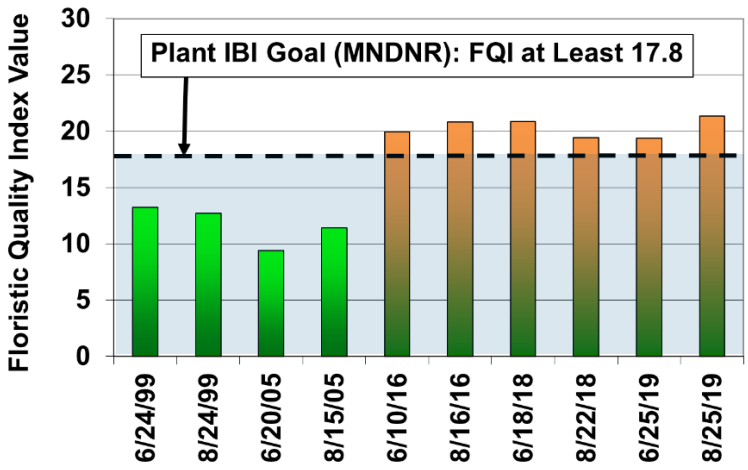


Figure 8-2.B

Figure 8-2 1999-2019 Lake Smetana Plant Index of Biotic Integrity (IBI) Values compared with Plant IBI Thresholds: Number of Plant Species (top) and Floristic Quality Index (FQI) Values (bottom).

Plant survey data from 1999 through 2019 were assessed to determine plant IBI trends. Figure 8-2 shows the Lake Smetana number of species and FQI scores for that period compared to the proposed MDNR plant IBI impairment threshold. The green bars depict data collected before completion of the Bryant Lake water quality improvement project while the orange bars depict data collected after completion of the water quality improvement project.

- **Number of species:** A shallow lake is considered impaired when it has fewer than 11 species. During the period examined, the number of species in Lake Smetana ranged from 7 to 17 and has been better than the impairment threshold since completion of the Bryant Lake water quality improvement

project (Figure 8-2.A). The increase in species numbers is a positive result of the water quality improvement project.

- **FQI values (quality of species):** The impairment threshold for shallow lakes, as measured by FQI, is a minimum value of 17.8. During the period examined, FQI values ranged from 9.4 to 21.3, better than the threshold since completion of the Bryant Lake water quality improvement project (Figure 8-2.B). The increase in FQI is a positive result of the water quality improvement project.
- **2019 results:** Both the number of species in the lake and FQI values were higher in 2019 than previous years – 15 to 17 species in 2019 compared with 7 to 14 in previous years; FQI values of 19.4 to 21.3 in 2019 compared with 9.4 to 20.9 in previous years. Both the number of species and FQI values were better than the minimum IBI thresholds that define impairment. As such, Lake Smetana would not be considered impaired for aquatic plants (Figure 8-2).

In 2019, bearded stonewort (*Lychnothamnus barbatus*) was first observed in Lake Smetana. Bearded stonewort is in the family Characeae, an algae that resembles rooted aquatic plants and obtains all of its nutrients from the water. This nutrient absorber can reduce phosphorus concentrations and improve water quality.

Bearded stonewort was observed at three locations in June (2 percent of sample locations) and had an average rake density of 1.7 (moderate density) (Appendix F). Bearded stonewort expanded to four locations by August and increased its density to an average rake density of 3.0, which is the maximum density measured by the rake (Appendix F).

In 2019, four aquatic invasive species were found in Lake Smetana.

Curly-leaf pondweed (*Potamogeton crispus*): Curly-leaf pondweed (CLP) was present at 38 percent of sample locations in June. On average, CLP density was moderate with an average rake density of 1.6 on a scale of 1 to 3 with increasing numbers indicating increasing density. CLP annually dies off at the end of June and begins its new growing season in late summer or fall. Consequently, it was found at less than 2 percent of sample locations in August and average density was 1.0 (light density) (Appendix F). In 2019, CLP co-existed with native plants in Lake Smetana at low to moderate densities and did not appear to have a negative effect on the lake's plant community or water quality.

Eurasian watermilfoil (*Myriophyllum spicatum*): The first observation of Eurasian watermilfoil (EWM) in Lake Smetana occurred in June 2019. Although present, EWM was comparatively rare during both June and August. In June, EWM was only seen at 1 sample location plus a couple of plants at the boat landing, a frequency of less than 1 percent and a rake density of 1.0 (light). In August, it was not collected on the rake, but was visually observed at one sample location (Appendix F).

Purple loosestrife (*Lythrum salicaria*): This emergent species was observed along the shoreline at two sample points in June and three sample points in August. The plants showed some beetle damage indicating some biological management by beetles (Appendix F).

Narrow-leaved cattail (Typha angustifolia): Dense growths of narrow-leaved cattail were observed at 7 locations in June and 9 locations in August (Appendix F).

8.2 Conclusions and Recommendations

Aquatic plant data indicated the plant community met the Minnesota Department of Natural Resources (MDNR) proposed plant Index of Biological Integrity (IBI) impairment thresholds (i.e., the lake's plant community is not impaired). Although CLP has expanded its extent in the lake since 2016 and EWM first appeared in the lake during 2019, neither species is currently causing problems in the lake. The *Lake Smetana Water Quality Study, Use Attainability Analysis* (draft, February 2020) concluded that CLP is not having a significant negative effect on the total phosphorus concentrations of Lake Smetana. However, the growth of CLP and EWM and the effects of CLP on lake water quality should continue to be tracked with periodic monitoring and aquatic plant surveys. Introduction of additional purple loosestrife eating beetles could be considered to increase biological control of purple loosestrife along the shoreline of the lake.

9 Southeast Anderson Lake

Southeast Anderson Lake is located in Bloomington. The lake is quite shallow, especially in comparison with its large surface area of approximately 81 acres. It has a maximum depth of approximately 9 feet and a mean depth of approximately 5 feet. The lake is shallow enough for plants to grow over the entire lake. It is a polymictic lake, mixing many times per year.

Southeast Anderson Lake was annually treated with herbicide during 2009 through 2014 to control curly-leaf pondweed (CLP) and reduce internal phosphorus loading. Curly-leaf pondweed (CLP), an aquatic invasive species, dies off in late June, senesces, and adds phosphorus to the lake which fuels algal growth and reduces lake water quality. At the conclusion of the project, CLP was not observed in the lake. The density of CLP turions, which act like seeds, was reduced by the project, but turions were still present when the project concluded.

Figure 9-1 A healthy plant community was found in Southeast Anderson Lake, pictured above in 2019, but several aquatic invasive species were also present in the lake. (Photo Credit: Endangered Resource Services, LLC.)

The *Nine Mile Creek Watershed District Water Management Plan* (2017, amended 2018) identified implementation of improvement recommendations in Southeast Anderson Lake in 2020, including alum treatment of phosphorus-rich lake sediments and additional curly-leaf pondweed management as needed, based on recommendations from the *Southeast, Southwest, and Northwest Anderson Lakes Use Attainability Analyses* (2005). In 2019, the Nine Mile Creek Watershed District conducted aquatic plant surveys on Southeast Anderson Lake, pictured in Figure 9-1, to further assess the extent of curly-leaf pondweed and Eurasian watermilfoil in the lake and provide information required for permitting if the District decided to pursue curly-leaf pondweed treatment in 2020 or subsequent years. Maps

summarizing monitoring results are included in Appendix G. Monitoring results are discussed in the following paragraphs.

9.1 Aquatic Plants

The District conducted point intercept aquatic plant surveys of Southeast Anderson Lake in June and August of 2019. Maps showing survey results are included in Appendix G.

The MDNR has developed metrics to determine the overall health of a lake's aquatic plant community. The Lake Plant Eutrophication Index of Biological Integrity (IBI) is expected to eventually be used by the MPCA to determine whether a lake is meeting the federal Clean Water Act standards intended to protect aquatic life. The plant IBI includes two metrics: (1) the number of species in a lake; and (2) the "quality" of the species, as measured by the floristic quality index (FQI).

Plant survey data from 1991 through 2019 were assessed to determine plant IBI trends. Figure 9-2 shows the Southeast Anderson Lake number of species and FQI scores for that period compared to the proposed MDNR plant IBI impairment threshold. The green bars depict data collected before completion of the water quality improvement project while the orange bars depict data collected during and after completion of the water quality improvement project.

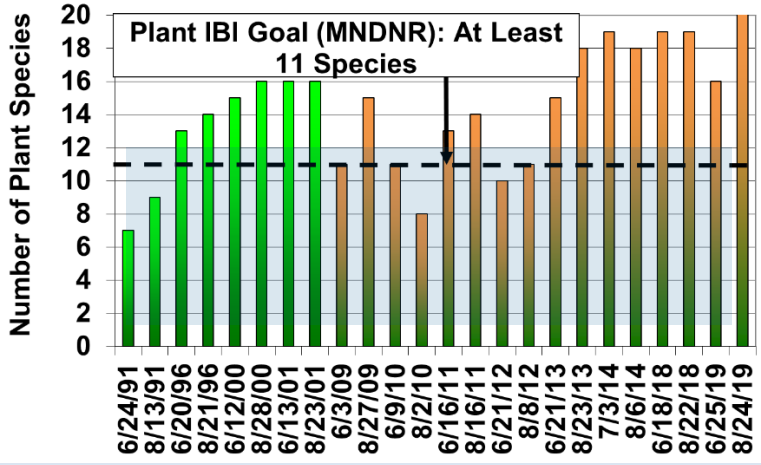


Figure 9-2.A

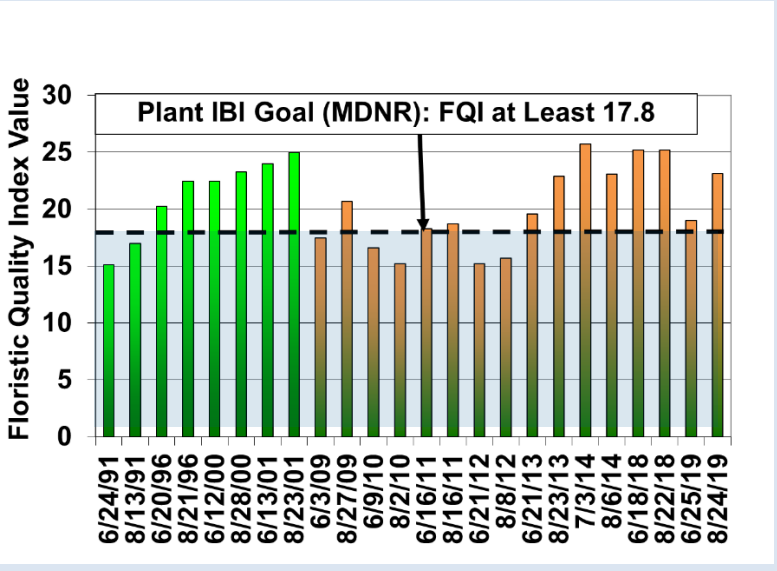


Figure 9-2.B

Figure 9-2 1991-2019 Southeast Anderson Lake Plant Index of Biotic Integrity (IBI) Values compared with Plant IBI Thresholds: Number of Plant Species (top) and Floristic Quality Index (FQI) Values (bottom).

- **Number of species:** A shallow lake (maximum depth less than 15 feet) is considered impaired when it has fewer than 11 species. During the period examined, the number of species in Southeast Anderson Lake ranged from 7 to 21 and has been better than the impairment threshold since August 2012. Higher numbers of species were observed from August 2013 through 2019 than in previous years (Figure 9-2.A). The increase in species numbers is a positive result of the lake's water quality improvement project.

- **FQI values (quality of species):** The impairment threshold for shallow lakes, as measured by FQI, is a minimum value of 17.8. During the period examined, FQI values in Southeast Anderson Lake ranged from 15.1 to 25.7, better than the threshold since 2013 (Figure 9-2.B).

- **2019 results:** Both the number of species in the lake (16 in June and 21 in August) and FQI values (19.0 in June and 23.1 in August) exceeded the minimum IBI thresholds that define impairment. As such, the waters would not be considered impaired for aquatic plants (Figure 9-2). The number of species observed in August was the highest number of species observed during the period of record.

While the lake's current plant community is healthy and meets proposed plant IBI impairment standards, six invasive species pose a threat to the health of the plant community. The two most prolific species, curly-leaf pondweed (*Potamogeton crispus*) and Eurasian watermilfoil (*Myriophyllum spicatum*) pose the greatest threat.

Annual herbicide treatments in Southeast Anderson Lake during 2009 through 2014 successfully reduced curly-leaf pondweed (CLP) and improved lake water quality. At the conclusion of the project, CLP was not observed in the lake. The density of CLP turions, which act like seeds, was reduced by the project, but turions were still present when the project concluded. Since 2014, these turions have replenished the CLP in the lake. In June 2019, CLP was documented at 70 percent of sample points and the average rake density was 1.8 on a scale of 1 to 3; increasing numbers indicate increasing density. CLP annually dies off at the end of June and begins its new growing season in late summer or fall. Consequently, it was found at less than 1 percent of sample locations in August (Appendix G). Phosphorus loading from the CLP die-off can adversely impact lake water quality.

In 2017, Eurasian watermilfoil (*Myriophyllum spicatum*) (EWM) was first observed in the lake near the boat launch on the southeast side of the lake. In 2018, EWM was observed throughout the lake with densities ranging from light to heavy. In 2019, EWM was found at 31 percent of sample locations in June and at 36 percent of sample locations in August. Average rake density was 1.8 during both June and August (Appendix G). EWM has rapidly spread throughout the lake and is currently, on average, at a medium density. Continued increases in extent and density could diminish the health of the plant community by displacing native species.

Four additional aquatic invasive species were documented in Southeast Anderson Lake in 2019 (Appendix G):

- **Purple loosestrife (*Lythrum salicaria*):** This emergent species was observed along the shoreline at three locations in June and two locations in August (Appendix G).
- **Yellow iris (*Iris pseudacorus*)**: The first observation of yellow iris occurred in August 2019 at one location (Appendix G). The appearance of yellow iris is concerning because it spreads rapidly and competes with native shoreland vegetation. Its root system forms a dense mat which compacts the soil and inhibits seed germination of other plants. Because it is only present at one location, it would be relatively easy to remove it either by manual removal or by treating with a herbicide.
- **Narrow-leaved cattail (*Typha angustifolia*)**: This emergent species was present at 5 percent of sample locations in both June and August. The average rake density rating was 2.7 in June and 2.4 in August, indicating very dense growth (Appendix G).
- **Reed canary grass (*Phalaris arundinacea*)**: Reed canary grass was present at 3 percent of sample locations in June and at less than 1 percent of sample locations in August. Average rake density was 1.3 in June and 2.0 in August indicating a range from light to moderate density (Appendix G).

9.2 Conclusions and Recommendations

Aquatic plant data indicated the plant community met the Minnesota Department of Natural Resources (MDNR) proposed plant Index of Biological Integrity (IBI) impairment thresholds (i.e., the lake's plant community is not impaired). However, the appearance and expansion of CLP in the lake during the past five years and appearance and expansion of EWM during the past 2 years is unfavorable for the Southeast Anderson Lake native plant community. The addition of phosphorus from decaying CLP after its annual die-off in late June is unfavorable for the lake's water quality. Consideration of management of CLP and EWM to protect, and if possible improve, the health of the native plant community and the lake's water quality is recommended.

In the summer of 2019, Barr and District staff reviewed the 2018 and historical water quality monitoring data from Southeast Anderson Lake in detail to evaluate pursuit of an alum treatment and/or additional CLP management in 2020, as identified in the *Nine Mile Creek Watershed District Water Management Plan* (2017, amended 2018). The 2018 summer average phosphorus concentration in Southeast Anderson Lake was one of the best years on record. Because of the good water quality exhibited in 2018, and associated uncertainty regarding necessity of conducting an alum treatment or additional herbicide treatment, District staff decided to delay implementation of additional improvement measures until additional data is collected.

Continuation of water quality and biological monitoring is recommended to periodically assess the condition of the lake's water quality and biological community and identify trends.

10 Nine Mile Creek Stream Monitoring

Because the primary use of Nine Mile Creek is ecological—a place for fish and aquatic life to live—the focus of the Nine Mile Creek monitoring program is evaluation of the stream's fish and aquatic life community as well as the ecosystem components essential for the survival of fish and aquatic life (Figure 10-1). The 2019 Nine Mile Creek monitoring program included:

- March through October monthly measurements of specific conductance, dissolved oxygen, pH, temperature, turbidity, and flow.
- Annual habitat monitoring during summer (i.e., stream substrate type, depth of fine sediment, percent embeddedness, and length of eroded streambank).
- Annual monitoring of the fish community during summer.
- Annual monitoring of the macroinvertebrate community during October.

Ten locations were monitored in 2019. Four locations were monitored on the North Fork, three locations on the South Fork, and three locations on the Main Stem. Monitoring locations are shown on Figure 1-2.

Figure 10-1 Downstream Main Stem Location ECU-7C (Shorthead Redhorse Fish)

The primary use of Nine Mile Creek is a place for fish and aquatic life to live, such as the shorthead redhorse fish swimming in downstream Main Stem Location ECU-7C, pictured above.

Data collected during 2019 were evaluated to determine whether:

- Specific conductance, dissolved oxygen, pH, and temperature, levels met Minnesota Pollution Control Agency (MPCA) standards for Class 2B waters published in Minnesota Rules 7050.
- Flow and water quality data were consistent with historical values.
- 2019 fish and aquatic life communities were consistent with the stream's ecological use determined from assessments completed in 1997 and 2003.
- The 2019 fish and invertebrate communities were consistent with historical data.

10.1 Nine Mile Creek Water Quality

The 2019 water quality of Nine Mile Creek was better than 2018 despite higher flows and increased runoff due to wet weather. The levels of specific conductance, dissolved oxygen, pH, temperature, and turbidity generally met MPCA standards for Minnesota Class 2B waters (MPCA Standard). Overall, the 2019 values were within MPCA standards 90 percent of the time. The Main Stem and South Fork met MPCA standards most frequently (94 percent and 93 percent, respectively) followed by the North Fork (86 percent of the time).

Consistent with previous years, the specific conductance criterion was met less frequently in 2019 than other MPCA standards. All Nine Mile Creek temperature and pH measurements, 88 percent of the dissolved oxygen measurements, and 74 percent of the specific conductance measurements met MPCA standards. Specific conductance is a measure of the conductive ions in water from dissolved and inorganic materials such as alkalis, chlorides, sulfides, and carbonate compounds. High specific conductance measurements in Nine Mile Creek that fail to meet MPCA standards result from the discharge of excess chlorides from deicing chemicals (salt) to the creek. The MPCA has listed Nine Mile Creek as impaired for chlorides since 2004.

Figure 10-2 Downstream North Fork Location ECU-2A
In 2019, the North Fork average annual specific conductance was lower than annual averages during 2008 through 2018. Pictured above is downstream North Fork location ECU-2A on June 3, 2019.

Specific conductance measurements from Nine Mile Creek met the MPCA standard more frequently in 2019 than 2018—74 percent met the MPCA standard in 2019 compared with 45 percent in 2018. As in previous years, the North Fork locations met the MPCA standard for specific conductance less frequently than other sampling locations—44 percent of the North Fork measurements met the MPCA specific conductance standard in 2019 compared with 88 percent of Main Stem and 100 percent of South Fork measurements.

Figure 10-3 Downstream South Fork Location ECU-5A
In 2019, the South Fork met the MPCA dissolved oxygen standard less frequently than the Main Stem and North Fork. Pictured above, the downstream South Fork location ECU-5A on June 3, 2019.

In 2019, Nine Mile Creek specific conductance measurements were lower than measurements made in recent years. For the North Fork (Figure 10-2), the 2019 average annual specific conductance measurement of 995 µmhos per centimeter (cm) at 25°C was lower than annual averages from 2010 through 2018 — ranged from 1,069 to 1,281 µmhos per cm at 25 °C. For the Main Stem (Figure 10-4), the 2019 average annual specific conductance measurement of 740 µmhos per cm at 25°C was lower than annual averages from 2008 through 2018 — ranged from 750 to 1,099 µmhos per cm at 25°C. For the South Fork (Figure 10-3), the 2019 average annual specific conductance measurement of 728 µmhos per cm at 25°C was lower than annual averages measured during 2008 through 2016 (776 to 955 µmhos per cm at 25°C) and 2018 (867 µmhos per cm at 25°C).

Consistent with previous years, the South Fork of Nine Mile Creek (Figure 10-3) met the MPCA dissolved oxygen standard less frequently than the North Fork and Main Stem in 2019—71 percent of South Fork dissolved oxygen measurements met the standard compared with 100 percent of North Fork and 92 percent of Main Stem measurements.

In 2019, wet weather and higher watershed runoff increased flow at all monitoring locations. The 2019 annual average discharge (flow) for the Main Stem (67 cubic feet per second), (Figure 10-4. Figure 10-5, and Figure 10-8) (and South Fork (17 cubic feet per second) (Figure 10-3) were the highest measured to date. The 2019 North Fork annual average discharge (9 cubic feet per second) was higher than all annual average values during the period examined, except for 2001 (15 cubic feet per second) and 1998 (13 cubic feet per second). According to the MDNR,

2019 was the wettest year on record for the Minneapolis St. Paul International Airport (MSP) weather station, with a total of 43.17 inches of precipitation.

Figure 10-4 Downstream Main Stem Location ECU-7C
In 2019, the average annual discharge at the Main Stem was higher than all annual average values during the period examined. Pictured above, the downstream Main Stem location ECU 7C on July 3, 2019.

10.2 Ecological Use

Ecological use is a term used to describe the fish assemblage/aquatic life use that the stream has the capacity to support per the stream's flow, water quality, and habitat characteristics. The ecological uses are broken into the following categories:

- Coldwater Fish (Class A)
- Warmwater Sport Fish (Class B)
- Intolerant Forage Fish (Class C)
- Tolerant Forage Fish (Class D
- Tolerant Macroinvertebrates (Class E)

The District completed a habitat assessment of Nine Mile Creek and evaluated historical flow, water quality, and fish data in 1997 to identify the stream's attainable ecological uses. During 1998 through 2001, flow, water quality, and fish data collected from the stream were annually assessed to determine whether the stream was consistently supporting its designated attainable ecological uses. In 2003 the District again completed a habitat assessment and evaluated historical flow, water quality, and fish data to identify any needed changes to the stream's designated attainable ecological uses. Since 2003, flow, water quality, and fish data have been annually evaluated to determine whether the stream has consistently supported its designated ecological uses.

In 2019, the eight ecological use monitoring stations (Figure 1-2) were monitored for fish during June through early July. The 2019 fish communities in the North Fork, upstream South Fork (ECU-3A), and middle (ECU-7B) (Figure 10-8) and downstream (ECU-7C), (Figure 10-5) Main Stem locations were consistent with their attainable ecological uses, verifying that the stream was supporting the fish communities that it had the capacity to support.

Figure 10-5 Upstream Main Stem Location ECU-7A
In 2018, a tolerant forage fish assemblage, an indicator of average to poor water quality, was observed at the most upstream Main Stem location, ECU-7A, pictured above.

The 2019 fish community found in the upstream Main Stem location (ECU-7A) (Figure 10-5) was poorer than its designated attainable ecological use. The fish community met the criteria for a tolerant forage fish community, an indicator of average to poor water quality and habitat, compared with its designated attainable ecological use of intolerant forage fish, an indicator of better water quality and habitat. However, the 2019 ecological use value at this location was very near the boundary for an intolerant fish community indicating the fish community was very close to its designated ecological use (Figure 10-6). Over time, frequent fluctuations in the fish community have been observed at this location varying between warmwater sportfish, intolerant forage fish, and tolerant forage fish (Figure 10-6). A comparison of 2018 and 2019 values indicates the fish community in 2019 was slightly better than the fish community in 2018, although both were within the tolerant forage fish category. Changes in the fish community over time have been attributed to varying oxygen conditions due to impacts from upstream Marsh Lake. Water exiting the marsh may have either lower or higher oxygen levels than downstream locations, depending upon biological processes occurring within the marsh.

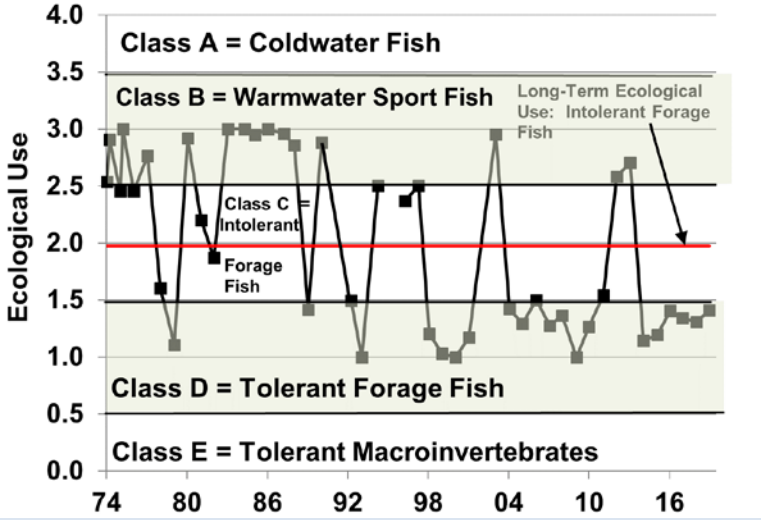


Figure 10-6 1974-2019 Main Stem ECU 7A Ecological Use (Type of Fish Community)

The 2019 fish community found in the downstream South Fork location (ECU-5A) (Figure 10-7) was better than its designated attainable ecological use. The fish community met the criteria for an intolerant forage fish community, an indicator of better water quality and habitat, compared with its designated attainable ecological use of tolerant forage fish, an indicator of average to poor water quality and habitat. The 2019 fish community was of higher quality than fish communities observed at this location in recent years (Figure 10-7).

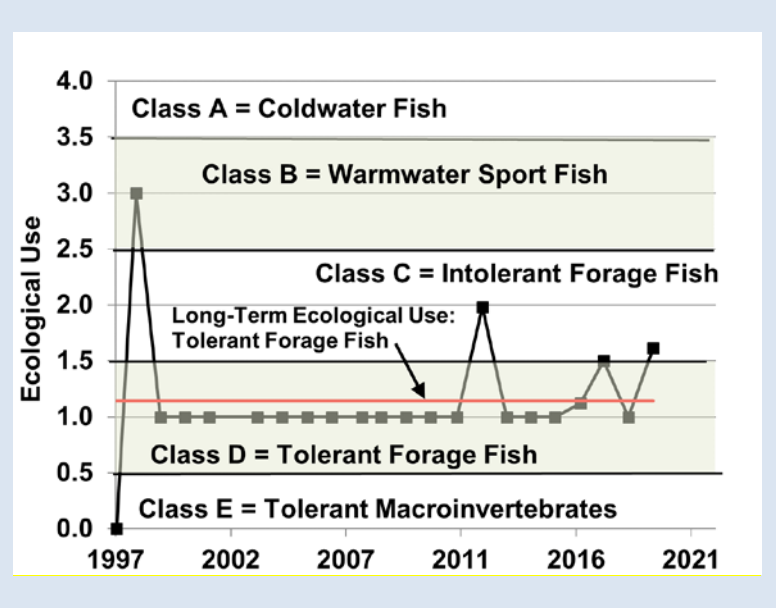


Figure 10-7 1997-2019 South Fork ECU 5A Ecological Use (Type of Fish Community)

10.3 Fish IBI

Fish collected from the eight ecological use monitoring stations (Figure 1-2) in Nine Mile Creek in 2019 were assessed to determine the Fish Index of Biotic Integrity (IBI) value for 2019 and whether this value was consistent with historical data.

The Fish IBI used to assess Nine Mile Creek was developed during the Minnesota River Assessment Project (MRAP) during the mid-1990's. The MRAP Fish IBI was used by the MPCA to determine fish impairment in streams tributary to the Minnesota River, including Nine Mile Creek, from the mid-1990s through 2018. During this period, the MRAP Fish IBI defined impairment as failing to meet a threshold score of 30 or greater out of a possible score of 60. Only streams with a watershed area of at least 5 square miles were obligated to comply with the MRAP Fish IBI impairment threshold.

Minnesota has adopted changes to its water quality standards that establish biological water quality standards for all Minnesota streams and rivers, including Nine Mile Creek. The changes were approved by the United States Environmental Protection Agency on June 26, 2018.

Although the MPCA has assessed streams for biological impairment in the past, previous MPCA water quality standards (Minn. Rule Chapters 7050 and 7052) did not contain biological standards. Previous standards focused on water quality rather than the quality of the aquatic life communities. Adding biological criteria to the water quality standards improved the protection of fish and macroinvertebrates living in Minnesota streams.

The MPCA developed fish and macroinvertebrate Index of Biotic Integrity (IBI) tools and selected scores for the standards that are comparable with streams that have healthy fish and macroinvertebrate communities. The Fish IBI and Macroinvertebrate IBI standards distinguish between healthy fish and

macroinvertebrate communities to be protected and unhealthy fish and macroinvertebrate communities in need of improvement.

The Fish IBI added to the water quality standards is different from the MRAP Fish IBI previously used to assess Nine Mile Creek and other streams within the Minnesota River watershed. In addition, the MPCA has added a macroinvertebrate IBI to the water quality standards to assess the health of macroinvertebrate communities in Minnesota streams.

The 2019 fish data were assessed with the MRAP Fish IBI to evaluate consistency with historical data. In the future, the District could consider using the MPCA-recommended IBIs to assess the fish and macroinvertebrate communities of Nine Mile Creek to determine whether or not the stream is biologically impaired for fish and/or macroinvertebrates.

All 2019 values were within the range of MRAP Fish IBI values observed during 2003 through 2018. A comparison of 2019 values with 2018 values indicates 2019 MRAP Fish IBI values were:

- the same as 2018 values at North Fork location ECU-2 (Figure 10-17), South Fork location ECU-5A (Figure 10-3), and Main Stem location ECU-7B (Figure 10-8).
- higher (better) than the 2018 value at Main Stem location ECU-7A (Figure 10-5).
- lower (poorer) than 2018 values at North Fork location ECU-2A (Figure 10-2) and Main Stem location ECU-7C (Figure 10-4).

Figure 10-8 Middle Main Stem Location ECU-7B
The 2019 MRAP Fish IBI value at the middle Main Stem Location ECU-7B, pictured above, was the same as 2018, indicating the fish community at this location was stable in 2019.

The 2019 MRAP Fish IBI values were assessed to determine whether the values met the impairment threshold minimum of 30. In 2019, two of the six Nine Mile Creek monitoring locations with a watershed area greater than 5 square miles had values higher (better) than the impairment threshold minimum – the most upstream (ECU-7A) (Figure 10-5) and downstream (ECU-7C) (Figure 10-4) Main Stem locations (Figure 10-9). MRAP Fish IBI values from the most downstream location of Nine Mile Creek, ECU-7C, were consistently higher than the impairment threshold minimum during the entire period of record (i.e., 2003 through 2019). Values from all other locations have fluctuated and have sometimes been higher and sometimes lower than the impairment threshold minimum. In 2006 and 2012, MRAP Fish IBI values from all Nine Mile Creek locations were higher than the impairment threshold minimum (Figure 10-9)

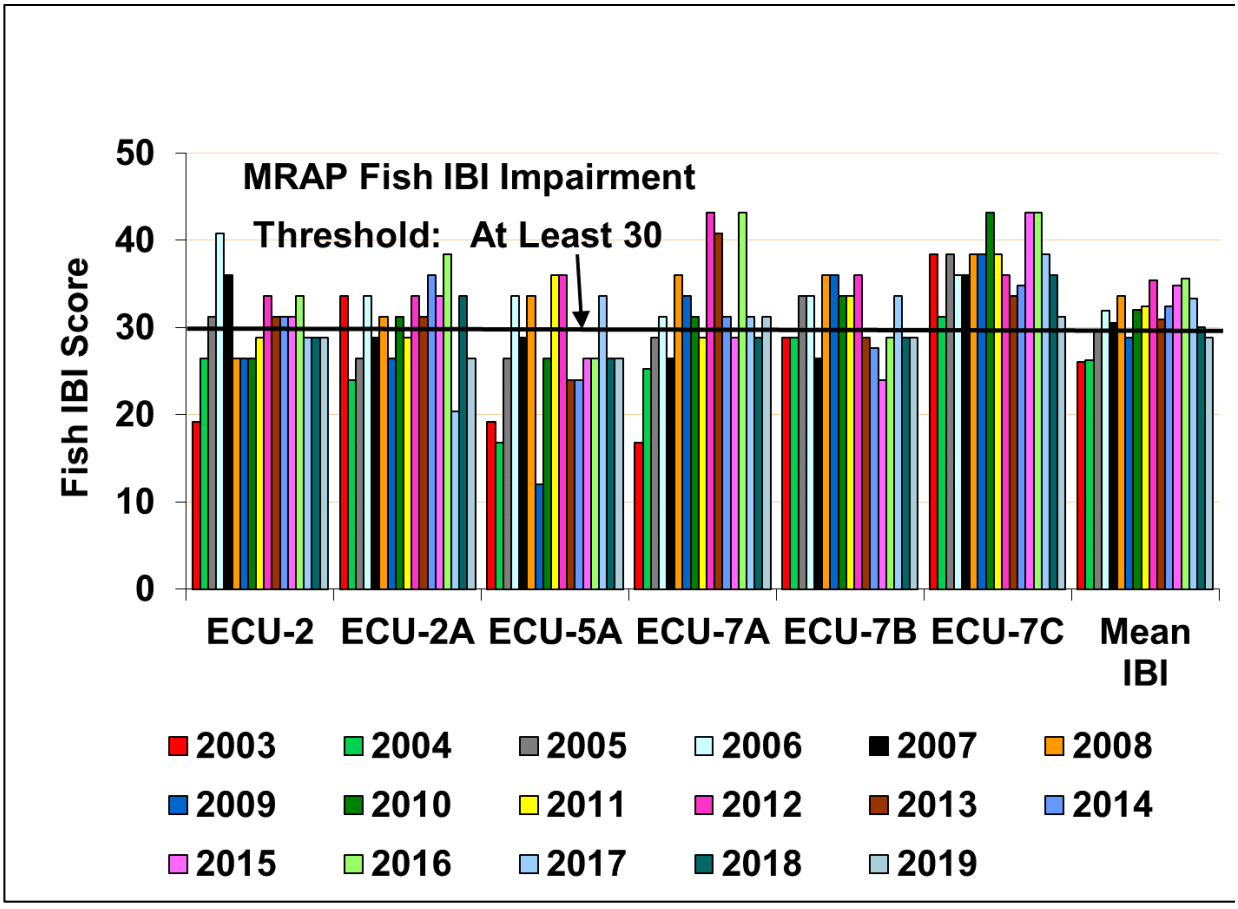


Figure 10-9 2003-2019 Nine Mile Creek MRAP Fish IBI Scores

10.4 Macroinvertebrates

Nine Mile Creek macroinvertebrates (bugs that can be seen with the naked eye) were monitored at the eight ecological use monitoring stations (Figure 1-2) during October. The data were assessed using two biotic indices to evaluate the water quality of Nine Mile Creek. The Hilsenhoff Biotic Index (HBI) was used to assess the long-term oxygen content of the stream. HBI assesses stream oxygen by determining the average tolerance of the macroinvertebrate community to low oxygen conditions. A second index, the Invertebrate Community Index (ICI), provides a broader view of the stream's water quality than the HBI, determining the average tolerance of the macroinvertebrate community to a wide range of pollutants.

In 2019, HBI scores from most locations were consistent with past scores. However, significant improvements in HBI scores were documented in 2019 for the middle North Fork location (ECU-2 (Figure 10-17), the downstream South Fork location (ECU-5A) (Figure 10-3), and the upstream Main Stem location (ECU-7A) (Figure 10-5).

The 2019 HBI score of 5.28 at North Fork location ECU-2 was significantly lower (better) than the 2018 score and was lower (better) than scores observed at this location during 1994 through 2018 (Figure 10-10).

The ICI score also improved in 2019 (Figure 10-11). The 2019 improvements in HBI and ICI scores are likely a result of the Edina stream stabilization project completed by the District during 2017 through 2018. The improved scores at ECU-2 indicate stabilization of the stream has improved water quality, despite the increased flows resulting from the unusually wet weather during 2019. According to the MDNR, 2019 was the wettest year on record for the Minneapolis St. Paul International Airport (MSP) weather station.

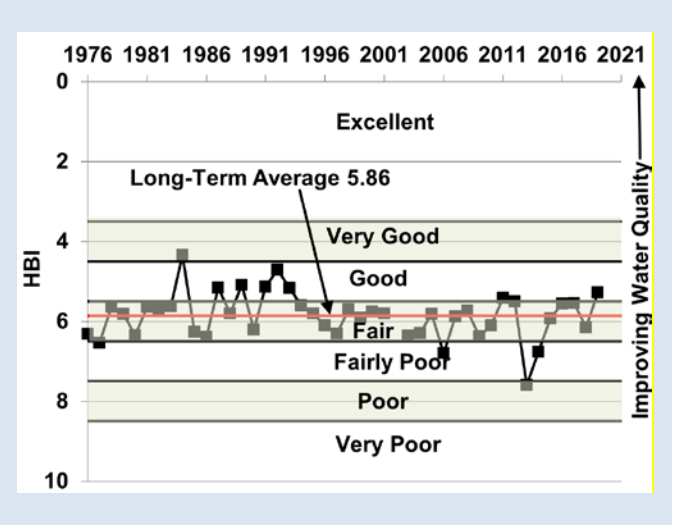


Figure 10-10 **1976 2019 Nine Mile Creek HBI: Middle North Fork Location, ECU 2**

Increased numbers of caddisflies in the stream at middle North Fork location ECU-2 (Figure 10-12) in 2019 indicate that the stream stabilization project has reduced sediment in the stream. Excess sediment is particularly detrimental to caddisflies because they gather food by filtering the water through capture nets. The stress of excess suspended solids in the stream can reduce the relative abundance of caddisflies due to reduced feeding efficiency. Historically, caddisfly numbers at the middle North Fork location ECU-2 have fluctuated, indicating variability of sediment in the stream. Caddisfly numbers at this location increased in 2019 despite the wet weather and increased flows in the stream (Figure 10-12). The increase indicates sediment concentrations in the stream were lower in 2019.

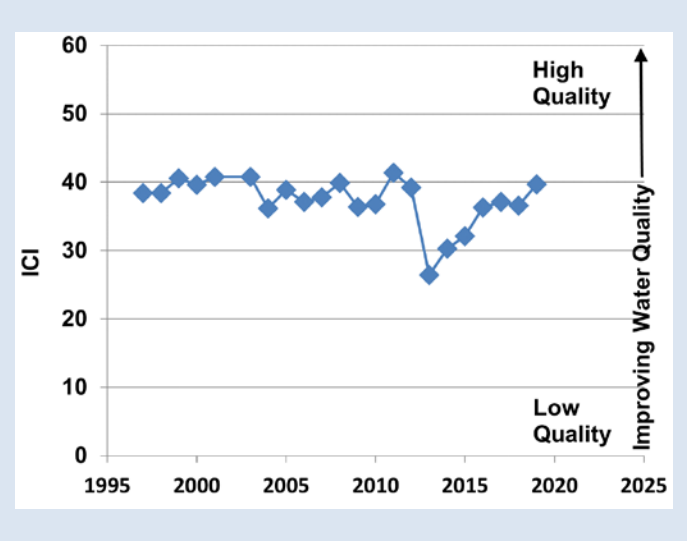


Figure 10-11 **2019 Nine Mile Creek ICI: Middle North Fork Location, ECU 2**

The 2019 HBI score of 6.68 at the downstream South Fork location ECU-5A (Figure 10-3) was significantly lower (better) than the 2018 score and was the lowest (best) HBI score observed during the period of record (1997 through 2019) (Figure 10-13). The improved 2019 HBI score at this location indicates oxygen levels were better in 2019 than in previous years of monitoring. The long-term average HBI for this location, 7.81 (Figure 10-13) indicates oxygen levels are typically poor. The HBI score in 2019 indicates oxygen levels improved from poor in 2018 to fairly poor in 2019 and were very close to being fair. The improved oxygen conditions in 2019 were likely a result of flow increases from the wet weather. As noted previously, 2019 was the wettest year on record for the Minneapolis St. Paul International Airport (MSP) weather station.

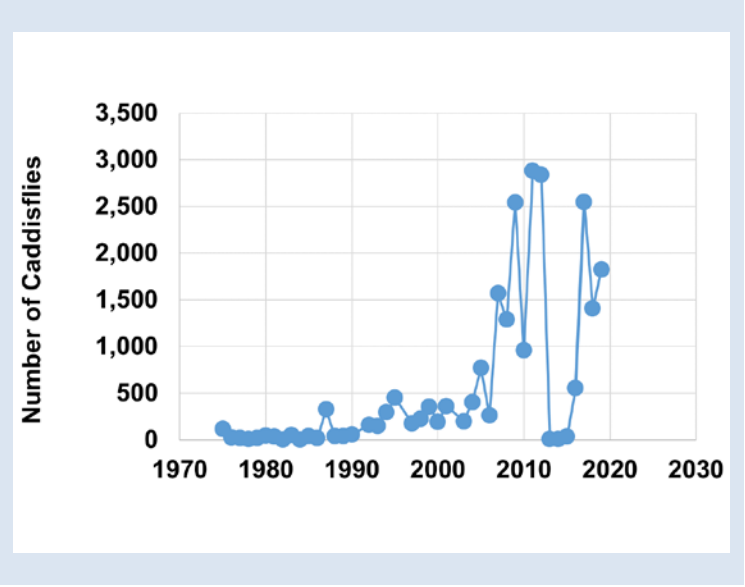


Figure 10-12 **1975 2019 Nine Mile Creek Caddisfly Numbers: Middle North Fork Location, ECU 2**

The 2019 ICI score at this location (32.8) was higher than the 2018 score (26.5) and was the second highest (best) score observed during the period of record (1997 through 2019) (Figure 10-14). The higher score indicates the overall water quality of the downstream South Fork location ECU-5A was better in 2019 than all previous years monitored except 2004 when a score of 33.4 was observed (Figure 10-14). ICI scores range from 0 to 60 with increasing scores indicating improving water quality. The midpoint of this range, 30, indicates average water quality conditions. The 1997 through 2019 average ICI score for the downstream

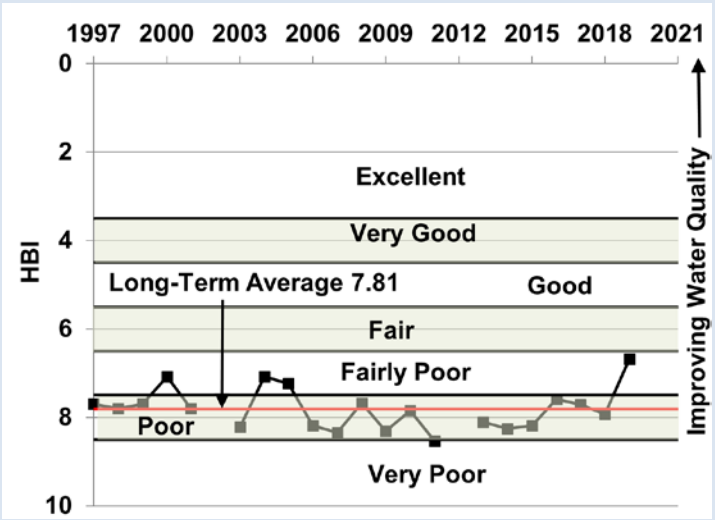


Figure 10-13 **1997 - 2019 Nine Mile Creek HBI: Downstream South Fork Location, ECU 5A**

South Fork location ECU-5A is 28.3 indicating this location has generally observed water quality that is slightly below average. The 2019 score of 32.8 indicates the water quality at this location improved to slightly above average.

The higher HBI and ICI scores in 2019 under record high rainfall conditions indicate the watershed is well managed such that increased runoff to the stream did not result in increased pollutant loading and resultant increased stress on the macroinvertebrate community in 2019. Instead, increased runoff and higher flows in 2019 improved the macroinvertebrate community at this location.

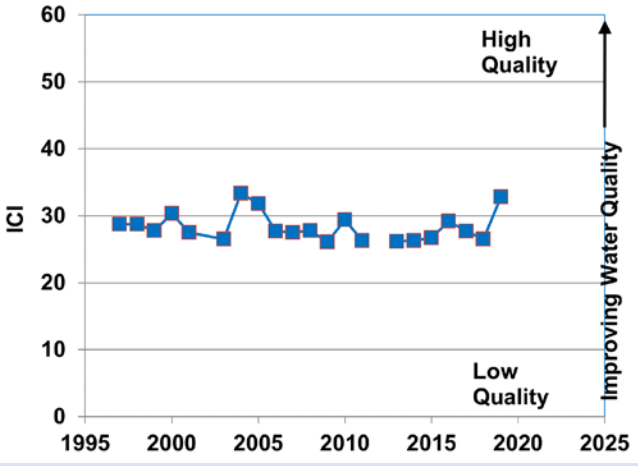


Figure 10-14 **1997 - 2019 Nine Mile Creek ICI: Downstream South Fork Location, ECU 5A**

The HBI and ICI values from the most upstream location on the Main Stem of Nine Mile Creek (ECU-7A) indicated water quality improvement occurred in 2019. The change in HBI score was statistically significant. The 2019 improvement in water quality was preceded by a decline in water quality in 2018. Frequent fluctuations in both HBI and ICI values have occurred at this location during the period of record (Figure 10-15 and Figure 10-16). These fluctuations are primarily due to the influence of Marsh Lake on the oxygen concentrations of downstream waters. Oxygen levels within Marsh Lake fluctuate due to biological activity within the marsh. Plant photosynthesis during the day raises oxygen levels and at night plant respiration lowers oxygen levels. Water exiting the marsh may have either lower or higher oxygen levels than downstream locations, depending upon biological processes occurring within the marsh. The resultant fluctuations in stream oxygen levels downstream of Marsh Lake cause changes in the macroinvertebrate assemblage, reflected by fluctuating HBI and ICI values. As noted previously, the fluctuating oxygen levels at this location also cause fluctuations in the fish community. In 2019, both the fish community and the macroinvertebrate community improved at this location, indicating improved oxygen conditions.

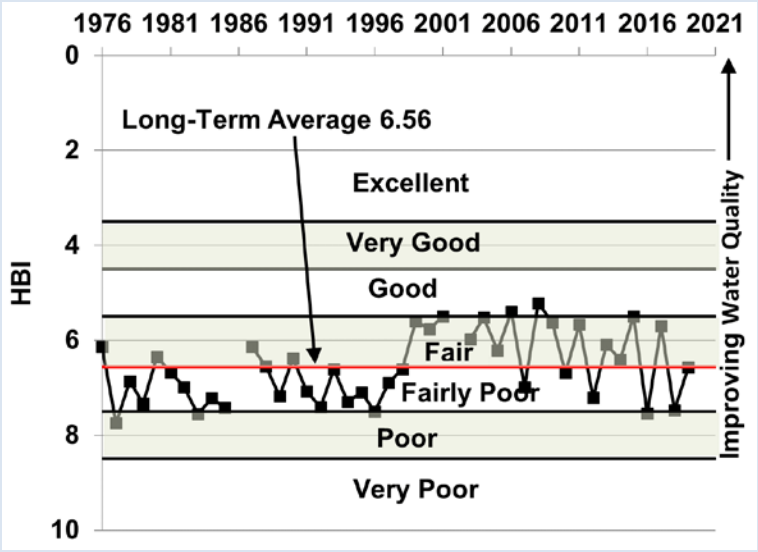


Figure 10-15 **1976 - 2019 Nine Mile Creek HBI: Upstream Main Stem Location, ECU-7A**

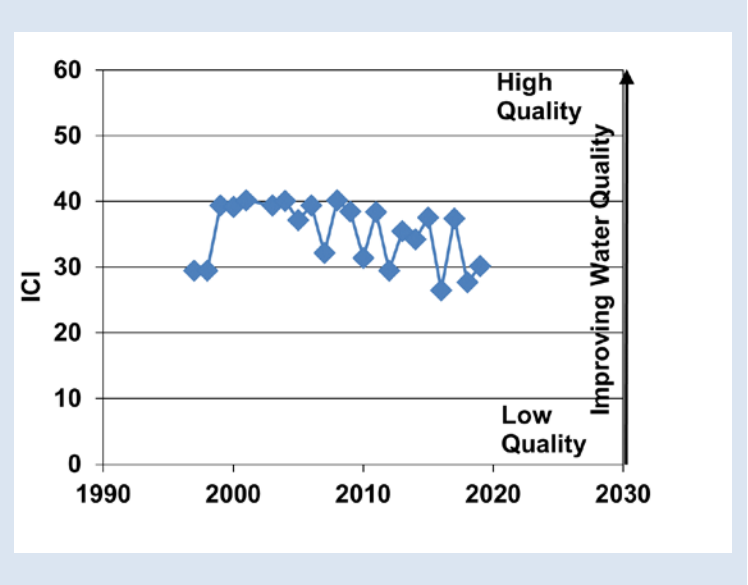


Figure 10-16 **1997 2019 Nine Mile Creek ICI: Upstream Main Stem Location, ECU-7A**

10.5 Stream Monitoring Conclusions and Recommendations

2019 Nine Mile Creek water quality and biological data are summarized in Table 10-1.

The 2019 water quality of Nine Mile Creek was better than 2018 despite higher flows and increased runoff due to wet weather. Overall, the 2019 water quality values were within MPCA standards 90 percent of the time. Individual sample locations met the MPCA standard from 81 to 97 percent of the time.

2019 specific conductance measurements indicate Nine Mile Creek chloride levels were lower in 2019 than recent years. Nine Mile Creek has been listed on the Minnesota Pollution Control Agency's (MPCA) 303(d) list since 2004 for impairment due to chloride levels in excess of the state water quality chronic standard of 230 milligrams per liter. Specific conductance is a measurement of the conductive ions in water from dissolved and inorganic materials, including chlorides, and as such provides an indication of changing chloride levels. Lower average annual specific conductance values were observed in Nine Mile Creek in 2019 than during the past 9 years on the North Fork and the past 11 years on the Main Stem. For the South Fork, average annual specific conductance values in 2019 were lower than values observed during 2008 through 2016 and 2018. Because specific conductance levels were lower in 2019 than 2018, Nine Mile Creek met the MPCA specific conductance standard more frequently in 2019 - 74 percent of the time compared with 45 percent in 2018.

Nine Mile Creek macroinvertebrate data were assessed using Hilsenhoff's Biotic Index (HBI) and the Invertebrate Community Index (ICI). HBI evaluates long-term oxygen content of the stream and the ICI provides a broader assessment of the stream's water quality. In 2019, most Nine Mile Creek HBI and ICI scores were consistent with past scores indicating the stream's water quality was stable. However, significant improvements in HBI scores were documented in 2019 for the middle North Fork location (ECU-2) (Figure 10-10 and Figure 10-17), the downstream South Fork location (ECU-5A) (Figure 10-3 and Figure 10-13), and the upstream Main Stem location (ECU-7A) (Figure 10-5 and Figure 10-15). Improved

ICI scores were also found at each of these locations indicating a broader water quality improvement that extended beyond improved oxygen. The improved water quality at the middle North Fork location (ECU-2) is likely a result of the Edina stream stabilization project completed by the District during 2017 through 2018. An increase in numbers of caddisflies at this location in 2019 indicates the stream stabilization project has reduced sediment in the stream (Figure 10-12). The improved HBI and ICI scores at the downstream South Fork location ECU-5A in 2019 under record high rainfall conditions indicate the watershed is well managed such that increased runoff to the stream did not result in increased pollutant loading and resultant increased stress on the macroinvertebrate community in 2019. Instead, increased runoff and higher flows in 2019 improved the macroinvertebrate community at this location.

Frequent fluctuations in both HBI and ICI values have occurred at upstream Main Stem location ECU-7A during the period of record. (Figure 10-5. Figure 10-15, and Figure 10-16). These fluctuations are primarily due to the influence of Marsh Lake on the oxygen concentrations of downstream waters. Oxygen levels within Marsh Lake fluctuate due to biological activity within the marsh. Plant photosynthesis during the day raises oxygen levels and at night plant respiration lowers oxygen levels. Water exiting the marsh may have either lower or higher oxygen levels than downstream locations, depending upon biological processes occurring within the marsh. The resultant fluctuations in stream oxygen levels downstream of Marsh Lake cause changes in the macroinvertebrate assemblage, reflected by fluctuating HBI and ICI values. The District could consider evaluating the feasibility of increasing oxygen levels in the water leaving Marsh Lake to help improve habitat for fish and macroinvertebrates.

Figure 10-17 Middle North Fork Location ECU-2
In 2019, significant improvement in HBI score and improvement in ICI score were documented for the middle North Fork location (ECU-2) pictured above.

The term attainable ecological use describes the fish community that can be supported by a stream's habitat flow, and water quality. The District assessed Nine Mile Creek in 1997 and 2003 to determine the stream's attainable ecological uses. The District annually assesses the Nine Mile Creek fish community to determine whether the stream is supporting a fish community that is consistent with its attainable

ecological use. In 2019, the fish communities in Nine Mile Creek were consistent with or better than the stream's attainable ecological use. The 2019 fish communities of the North Fork, the upstream South Fork (ECU-3A) (Figure 10-18), and the middle (ECU-7B) (Figure 10-8), and downstream (ECU-7C) (Figure 10-4) Main Stem locations were consistent with their attainable ecological uses. The fish community in the upstream Main Stem location (ECU-7A) (Figure 10-5 and Figure 10-6) was poorer than its attainable ecological use, but was very close to attainment. The fish community at the downstream South Fork location (ECU-5A) (Figure 10-3 and Figure 10-7) was better than its attainable ecological use and was of higher quality than fish communities observed at this location in recent years.

Figure 10-18 Upstream South Fork Location ECU-3A
The 2019 fish community in the upstream South Fork location (ECU-3A), pictured above, was consistent with its designated ecological use.

A Fish IBI was used to assess the fish communities of Nine Mile Creek to determine whether the 2019 fish communities were consistent with previous years. The Fish IBI used for this assessment was the Minnesota River Assessment Project (MRAP) Fish IBI that had been used by the MPCA to assess streams within the Minnesota River Watershed to determine biological impairment for fish from the mid-1990s through 2018. The assessment indicated the 2019 Nine Mile Creek Fish IBI values were consistent with historical values. A comparison of 2018 and 2019 Fish IBI values indicates 2019 Fish IBI values were:

- the same as 2018 values at North Fork location ECU-2 (Figure 10-17), South Fork location ECU-5A (Figure 10-3), and Main Stem location ECU-7B (Figure 10-8).
- higher (better) than the 2018 value at Main Stem location ECU-7A (Figure 10-5).
- lower (poorer) than 2018 values at North Fork location ECU-2A (Figure 10-2) and Main Stem location ECU-7C (Figure 10-4).

Minnesota has adopted changes to its water quality standards that establish biological water quality standards for all Minnesota streams and rivers, including Nine Mile Creek. The changes were approved by the United States Environmental Protection Agency on June 26, 2018.

Although the MPCA has assessed streams for biological impairment in the past, previous MPCA water quality standards (Minn. Rule Chapters 7050 and 7052) did not contain biological standards. Previous standards focused on water quality rather than the quality of the aquatic life communities. Adding biological criteria to the water quality standards improved the protection of fish and macroinvertebrates living in Minnesota streams.

The MPCA developed fish and macroinvertebrate Index of Biotic Integrity (IBI) tools and selected scores for the standards that are comparable with streams that have healthy fish and macroinvertebrate communities. The Fish IBI and Macroinvertebrate IBI standards distinguish between healthy fish and macroinvertebrate communities to be protected and unhealthy fish and macroinvertebrate communities in need of improvement.

The Fish IBI recently added to the water quality standards is different from the MRAP Fish IBI previously used to assess Nine Mile Creek and other streams within the Minnesota River watershed. In addition, the MPCA has added a macroinvertebrate IBI to the water quality standards to assess the health of macroinvertebrate communities in Minnesota streams. The Fish IBI and Macroinvertebrate IBI are used by the MPCA to determine whether or not Minnesota streams are biologically impaired.

In the future, the District could consider using the MPCA-recommended IBIs to assess the fish and macroinvertebrate communities of Nine Mile Creek to determine whether or not the stream is biologically impaired for fish and/or macroinvertebrates. If the stream is identified as biologically impaired using these methods, the District could consider applying the fish IBI and macroinvertebrate IBI to past fish and macroinvertebrate data from Nine Mile Creek to compare historic results using the two methods. The comparison would indicate when the stream became impaired, whether the impairment has been continuous or intermittent, and, if intermittent, under what climatic conditions the impairment has generally occurred. The data would help the District identify management measures to improve the biological community toward attainment of the Fish IBI and macroinvertebrate IBI standards.

Continued monitoring at the annual stream monitoring stations is recommended to maintain this long-term record of water quality and biota in Nine Mile Creek and to assess the biological community to determine changes in stream habitat or water quality that warrant further investigation or management measures.

Table 10-1 Nine Mile Creek 2019 Water Quality and Biological Data Summary

Station	% of Values Within MPCA Criteria (2019)	# of Values Outside of Historical Range (2019)	Potential Ecological Use Classification[1]	Actual Ecological Use: From Fish Data 2019	Historical Ecological Use (From Long-Term Fish Data)[1]	Attainable Ecological Use[1]	HBI Water Quality Classification from Invert. Data (2019)
ECU-1A	81	2	E	D (1.02)	D (1.21)	D	7.29 (Fairly Poor)
ECU-2	88	0	D	D (1.12)	D (1.26)	D	5.28 (Good)
ECU-2A	88	0	D	C (2.01)	C (1.54)	C	5.92 (Fair)
N3	88	1	--	--	--	--	--
ECU-3A	94	0	E	D (1.29)	D (1.03)	D	7.43 (Fairly Poor)
N2	88	5	--	--	--	--	--
ECU-5A	97	1	D	C (1.62)	D (1.15)	D	6.68 (Fairly Poor)
ECU-7A/N1	91	1	D	D (1.41)	C (1.97)	C	6.57 (Fairly Poor)
ECU-7B	94	1	D	D (1.00)	D (1.38)	D	5.21 (Good)
ECU-7C	97	2	D	C (1.88)	C (1.88)	C	4.42 (Very Good)
Average	90	--	D	D (1.42)	D (1.43)	D	6.10 (Fair)

[1] Ecological Use classification from *Nine Mile Creek Water Management Plan* (2004), from 2003 monitoring data, from 2003 fish data, and from 1974-2003 fish data:

A = cold water sport fish,

B = warm water sport fish,

C = intolerant forage fish, intolerant macroinvertebrates, or a valuable population of tolerant forage fish;

D = tolerant or very tolerant forage fish or rough fish or tolerant macroinvertebrates, and

E = very tolerant macroinvertebrates or no aquatic life

11 Lake Level Monitoring

11.1 Lake Level Observations

The lake level recording program initiated by the Nine Mile Creek Watershed District in 1960 was comprised of the three Anderson Lakes and Bush Lake. The program was enlarged in 1963 to include Hawkes Lake, Mirror Lake, and Shady Oak Lake. The following year the program was again expanded to monitor a total of 26 lakes in the watershed. Measurements of Mud Lake (Bredesen Park) and of Girard Pond were discontinued in 1964 because extensive weed growth in the summer made periodic readings impractical. In 1973, Lakes Minnetoga and Smetana were added to the program. Since then, the number of lakes being monitored has fluctuated over time in response to specific data needs.

In 2019, the Nine Mile Creek Watershed District recorded monthly lake levels at 29 lakes and public waters throughout the Nine Mile Creek watershed. The locations of the lake gages are shown in Figure 1-1. Lake level readings are taken monthly, usually at the same time the groundwater levels are measured. The levels of the lakes are generally measured using an engineering level from permanent structures along the shore. Lake levels in Normandale Lake are measured using a continuous gage installed within the bypass manhole near the lake outlet.

Lake levels are influenced by groundwater conditions, local precipitation, size of the drainage area, land surface area, outlet elevation and configuration, local land use, and a variety of other factors. The effects of these influences on the lakes differ. As a consequence, there is no general uniformity in the fluctuation of the lakes in the watershed. Table 11-1 summarizes the lake level observations at the beginning of 2019 (12/28/2018) and end of 2019 (1/3/2020). Graphs showing measured lake levels from January 2000 through January 2020 are included in Appendix H.

2019 was the wettest year on record for the Twin Cities metropolitan area, with a total of 43.17 inches of precipitation measured at the Minneapolis St. Paul International Airport weather station. Not only has 2019 been a wet year, but the Twin Cities metro area has been in a wet cycle over the past decade, experiencing the wettest five years (2015 - 2019), wettest six years (2014 – 2019) and wettest seven years on record (2013 - 2019). The 2010s were the wettest decade on record in Minnesota (DNR, 2020) (DNR, 2020). This wet period has resulted in high water levels in several land-locked lakes throughout the Nine Mile Creek watershed. Several lakes were pumped during portions of 2019, including Arrowhead Lake, Bush Lake, Hawkes Lake, Indianhead Lake, Mirror Lake, and Shady Oak Lake. Hawkes Lake, Mirror Lake, and Bush Lake have permanent lift stations. Temporary pumping occurred in the following lakes within the District in 2019 due to high water levels: Arrowhead Lake (21 million gallons), Indianhead Lake (18 million gallons), and Shady Oak Lake (124 million gallons).

Table 11-1 summarizes the net change in lake levels between the beginning of 2019 (12/28/2018) and end of 2019 (1/3/2020). During 2019, the net change in lake levels from the beginning to the end of 2019 varied considerably, ranging from a drop of 1.2 feet at Oxboro Lake to an increase of 8 feet at Birch Island

Lake. Table 11-1[4] also lists the maximum fluctuation of each lake level during 2019. The maximum fluctuation of 9.0 feet was observed at Birch Island Lake in Eden Prairie.

Table 11-1 also summarizes historic high and low water elevations for each lake. Historic high water levels were reached in 2019 in Shady Oak Lake and Lone Lake in Minnetonka and Indianhead Lake in Edina.

[4] *Hydroclimatic conditions and changes in the Twin Cities*. Kenny Blumenfeld, Minnesota DNR. 2020.

Table 11-1. Summary of 2019 Monthly Observed Lake Levels

Lake	Measured Lake Level- December 2018 (12/28/2018)	Measured Lake Level- January 2020 (1/3/2020)	Net Change in Measured Lake Levels- (12/28/2018 - 1/3/2020)	Maximum 2019 Fluctuation	Historical High Water Elevation		Historical Low Water Elevation	
	[feet MSL]	[feet MSL]	[feet]	[feet]	[feet MSL]	Date	[feet MSL]	Date
NW Anderson	839.8	839.4	-0.3	1.4	841.8	7/24/1987	833	1/5/2009
SE Anderson	838.0	839.9	1.9	2.9	841.8	7/24/1987	833.1	2/28/2013
SW Anderson	839.8	839.6	-0.3	1.2	841.8	7/24/1987	835.1	12/8/1964
Arrowhead[1]	875.1	875.8	0.7	3.1	878.6	7/24/1987	871.4	2/18/1981
Birch Island[3]	879.7	887.7	8.0	9.2	891.2	3/24/1969	875.1	2/28/2013
Bryant	851.0	851.3	0.3	1.1	854.8	7/24/1987	849.3	1/14/1977
Bush[2]	833.2	833.8	0.6	1.5	836.9*	6/11/1999*	826	8/8/1964
N Cornelia	859.8	859.7	-0.1	2.5	864.1	7/24/1987	858.1	12/8/1967
S Cornelia	859.2	859.2	0.0	0.2	864.1	7/24/1987	858.1	12/8/1967
Edina	821.4	822.3	0.9	1.1	825.4	7/24/1987	817.8	2/9/1982
N Garrison	862.7	863.2	0.4	0.5	864.8	4/10/1965	860.7	2/28/2012
S Garrison	861.8	861.8	0.0	0.4	863.3	4/10/1965	860.7	12/30/2011
Glen[3]	902.4	904.7	2.3	2.9	905	8/6/1965	898.2	7/30/2010
Hawkes[2]	885.6	886.7	1.1	1.6	892.2	7/24/1987	881.6	1/14/1977
Indianhead[1]	863.2	863.8	0.6	2.2	865.2	5/31/2019	861.0	2/28/2013
Lone[1]	899.0	901.6	2.6	2.7	901.6 ~~901.1~~	10/25/2019 ~~4/4/1966~~	895.4	2/6/1990
Minnetoga	896.5	896.5	0.0	0.5	899.1	7/24/1987	894.1	2/6/1990
Mirror[2]	907.9	908.3	0.5	1.0	912.1	7/24/1987	901.8	1/14/1977
Normandale	802.1[4]	808.8[5]	6.7	8.8	815.8	7/24/1987	-	-
Oxboro	805.1	804.0	-1.2	1.8	813.3	7/24/1987	797.9	1/15/1991
Pauly's Pond	816.1	817.4	1.3	1.6	821.2	7/24/1987	811.8	7/29/1988
Penn (Lower)	806.2	808.0	1.8	2.3	816.6	7/24/1987	802.3	2/28/2013
Rose	924.3	925.3	1.0	1.8	928.4	4/4/1966	919.6	1/8/1990
Shady Oak[1]	903.4	903.7	0.3	2.3	905.6 ~~904.4~~	5/31/2019 ~~4/4/1966~~	897.8	1/29/1990
Skriebakken	805.5	804.9	-0.5	1.4	811.3	7/24/1987	801.2	1/22/1977
Smetana	835.0	835.2	0.2	1.2	840.6	7/24/1987	830.2	11/8/1976
Wing	939.8	939.9	0.1	1.6	941.5	7/24/1987	933.5	1/31/1989
Valley View	862.4	863.0	0.6	0.9	865.4	7/24/1987	860.1	2/28/2012
Wanda Miller	820.2	821.9	1.7	1.7	826.7	7/24/1987	814.8	2/28/2013

[1] Land-locked lakes

[2] Pumped outlet

[3] High surface outlets that can likely handle bounce (haven't discharged since 1987)

[4] Lake surface elevation observed on 1/3/2019.

[5] Lake surface elevation observed on 12/31/2019

12 Groundwater Well Monitoring

12.1 Groundwater Well Observations

The Nine Mile Creek Watershed District's groundwater monitoring program began in 1962 when 18 groundwater observation wells were installed at various locations throughout the watershed. The following year, the program was augmented by the installation of 20 additional wells. Since inception of the program, the number of groundwater wells being monitored has fluctuated over time, with wells being added in response to specific information needs and other monitoring wells being lost as land development occurred. In 1989, sixteen groundwater monitoring wells were in operation. In 1999, 12 wells were active. In 2019, only six of the groundwater observation wells remain active.

Table 12-1 summarizes the groundwater level observations from 2019. The table includes measured groundwater observations from the beginning of 2019 (12/28/2018) and end of 2019 (1/3/2020), as well as the corresponding net change in groundwater levels during that time period. During 2019, groundwater elevations increased in all six of the District's observation wells. The net change in groundwater elevation ranged from 0.7 feet in Well 35 to 4.1 feet in Well 41, with an average change of +1.9 feet. Table 12-1 also lists the maximum fluctuation of each well during 2019. The maximum fluctuation ranged from approximately 0.7 feet at Well 26 to 4.1 feet at Well 7, with an average maximum fluctuation of 2.8 feet.

Table 12-1 summarizes the highest and lowest readings of the water table at each well and the date of occurrence. A record high water level was recorded in Well 41 in 2019 (8/26/2019).

Graphs of the observed groundwater levels for each active monitoring site from January 2000 through January 2020 are included in Appendix I.

Table 12-1. Summary of 2019 Monthly Observed Groundwater Levels.

Well ID	Measured Groundwater Level- December 2018 (12/26/2018) [feet MSL]	Measured Groundwater Level- January 2020 (1/2/2020) [feet MSL]	Net Change (12/26/2018 - 1/2/2020) [feet]	Maximum 2019 Fluctuation [feet]	Historical High Water Elevation		Historical Low Water Elevation	
					[feet MSL]	Date	[feet MSL]	Date
7	875.32	879.42	4.10	4.10	894.88	3/25/2004	857.20	10/17/1989
22	797.82	800.00	2.18	2.48	802.30	5/3/1966	791.00	5/31/1990
26	820.11	820.82	0.71	0.72	827.93	4/29/2003	813.40	12/1/1964
35	843.32	843.99	0.67	3.27	848.65	3/15/2005	834.10	1/1/1964
41	882.13	884.86	2.73	3.91	885.8 ~~881.2~~	8/26/2019 ~~8/12/1987~~	871.00	8/10/1977
52	852.45	853.39	0.94	2.07	854.96	3/17/2003	849.10	9/15/1994

Appendices

Available as Separate PDFs