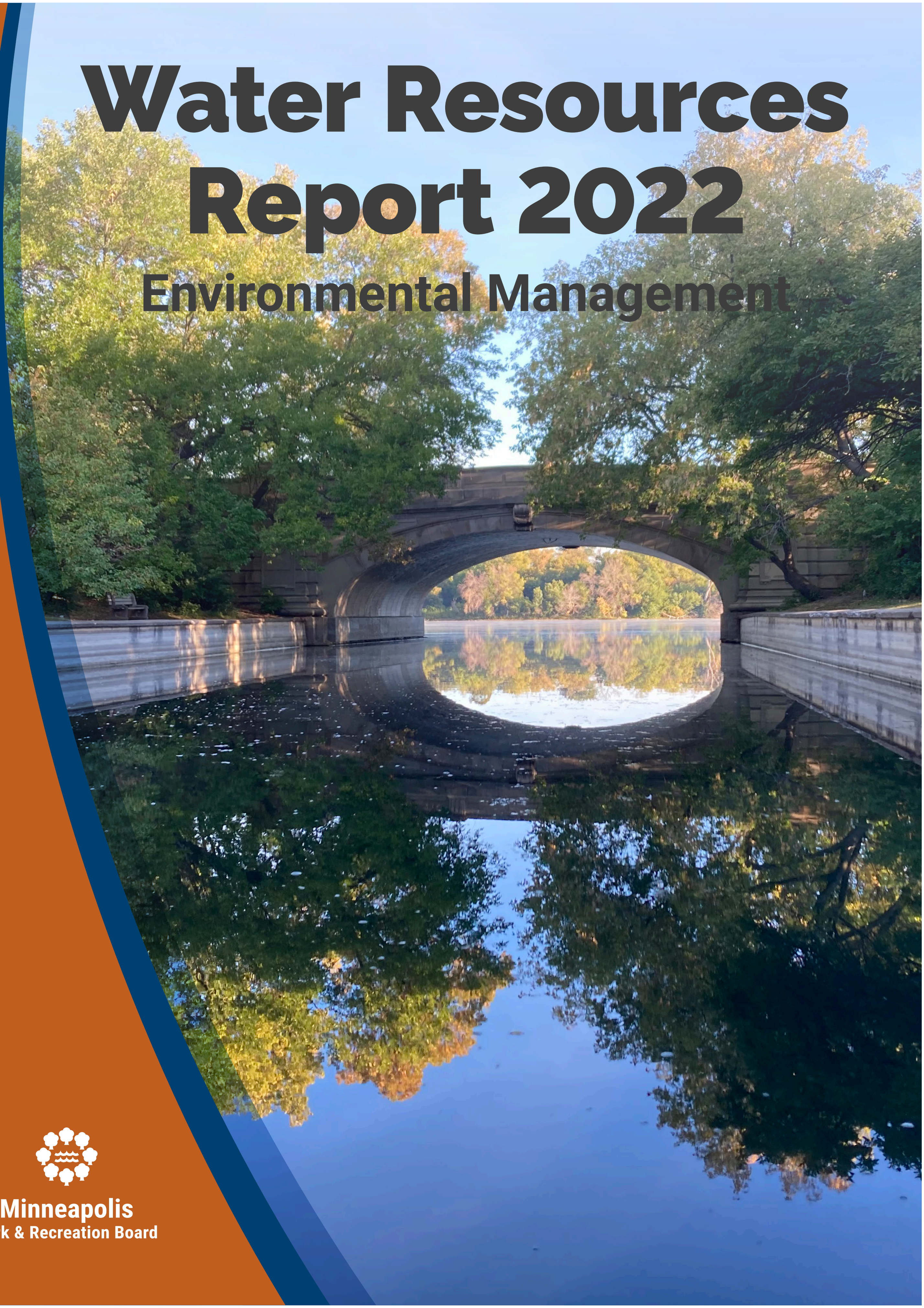
Water Resources Report 2022

Environmental Management



Minneapolis
Park & Recreation Board

2022 WATER RESOURCES REPORT

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List of Abbreviations

µg	Microgram
µm	Micrometer
µS	Microsiemens
ACSP	Audubon Cooperative Sanctuary Program
AIS	Aquatic Invasive Species
Al	Aluminum
Alk	Alkalinity
alum	Aluminum sulfate
APM	Aquatic Plant Management
AV	Area Velocity
BMP	Best Management Practices
Bray P	Bioavailable Phosphorus in soil, estimated by the Bray method
C	Celsius
CAMP	Citizen Assisted Monitoring Program
CCME	Canadian Council of Ministries of the Environment
CDS	Continuous Deflective Separation
cf	Cubic foot
cfs	Cubic feet per second
cfu	Colony forming unit
chl-*a*	Chlorophyll-*a*
cm	Centimeter
COD	Chemical Oxygen Demand
CV	Coefficient of Variance
CWP	Clean Water Partnership
DI	De-ionized
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
D-shaft	Distribution shaft
E. coli	*Escherichia coli*
eDNA	Environmental DNA
EPA	United States Environmental Protection Agency
EPA STV	EPA Statistical Threshold Values
ERA	Environmental Resource Associates
ETSD	Ephemeroptera, Trichoptera, dragonfly, and Sphaeriidae
F	Fahrenheit
FiN	Fishing in the Neighborhood Program
FLL	Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau e.V.: Landscaping and Landscape Development Research Society
FOG	Fat, Oil, and Grease
ft	Foot
g	gram
gal	gallon
geomean	Geometric mean

GIS	Geographical Information System
GPS	Global Positioning System
GSI	Green Stormwater Infrastructure
Hard	Hardness, Total as CaCO3
HAB	Harmful Algal Bloom
IAPM	Invasive Aquatic Plant Management
IBI	Index of Biological Integrity
ID	Identification
in	inch
ind	individual
IRI	Instrumental Research, Inc.
kg	Kilogram
L	Liter
LAURI	Lake Aesthetic and User Recreation Index
lb	Pound
LCC	Lake Champlain Committee
LOD	Limit of Detection
LOI OM	Loss On Ignition Organic Matter %
LSP	Lake Service Provider
m	Meter
MAISRC	Minnesota Aquatic Invasive Species Research Institute
MAX	Maximum
MCTC	Minneapolis Community and Technical College
MCWD	Minnehaha Creek Watershed District
MDH	Minnesota Department of Health
MDL	Minimum Detection Limit
mg	Milligram
MIN	Minimum
mL	Milliliter
mm	Millimeter
MN	Minnesota
MNDNR	Minnesota Department of Natural Resources
MPCA	Minnesota Pollution Control Agency
Mpls	Minneapolis
MPN	Most probable number
MPRB	Minneapolis Park and Recreation Board
MPW	Minneapolis Public Works
msl	Mean sea level
MSP	Minneapolis–St. Paul International Airport
mV	Millivolts
MWMO	Mississippi Watershed Management Organization
n	Number of samples
NA	Information Not Available
NCHF	North Central Hardwood Forests
ND	Not Detected

ng	Nanogram
NH3	Ammonia, un-ionized as N
NLA	National Lakes Assessment
NOAA	National Oceanic and Atmospheric Administration
NOx	Nitrate/Nitrite, total as N
NPDES	National Pollutant Discharge Elimination Systems
NPS	Nonpoint Source
NS	No Sample Collected
NSP	Natural Swimming Pool
NTU	Nephelometric Turbidity Unit
NWS	National Weather Service
OHWL	Ordinary High Water Level
ORP	Oxidation Reduction Potential
p	Probability value (*p*-value)
PCBs	Polychlorinated biphenyls
PE % Rec	Performance evaluation percent recovery
PFAS	Per- and Polyfluoroalkyl Substance
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctane Sulfonate
pH	Acidity
Pheo-a	Pheophytin-a
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
R^2	Coefficient of determination (R-squared)
RFU	Relative Fluorescence Units
RL	Reporting Limit
RPD	Relative Percent Difference
s	Second
SAFL	Saint Anthony Falls Laboratory
Si	Reactive Silica
SO_4	Sulfate
Sol	Soluble/dissolved
Sp. Cond.	Specific Conductivity
SRP	Soluble Reactive Phosphorus
STDEV	Standard Deviation
STEC	Shiga toxin-producing strain of E. coli
TDP	Total Dissolved Phosphorus
TDS	Total Dissolved Solids
Temp	Temperature
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
Tot	Total
TP	Total Phosphorus

TRPD	Three Rivers Park District
TSI	Trophic State Index
TSS	Total Suspended Solids
USDA APHIS WS	United States Department of Agriculture Animal and Plant Health Inspection Service Wildlife Services
USGS	United States Geological Survey
UV	Ultraviolet
VMI	Visual Monitoring Index
VSS	Volatile Suspended Solids
WHEP	Wetland Health Evaluation Program
WHO	World Health Organization
WPA	Works Progress Administration
ww	Wet weight

Executive Summary

As part of its stewardship of the lakes and other water bodies within the City of Minneapolis, the Minneapolis Park and Recreation Board (MPRB) monitors lakes, streams, and stormwater flows for excess nutrients and other water quality indicators. This report presents the results for the 2022 monitoring season. The report is based on data collected by the MPRB Environmental Management Section.

In 2022, MPRB water resources scientists monitored 12 of the city's most heavily used lakes: Bde Maka Ska, Brownie, Cedar, Diamond, Grass, Harriet, Hiawatha, Isles, Loring, Nokomis, Powderhorn, and Wirth Lakes. Historical data from 1991-2022 are used to calculate trophic state index (TSI) trends and estimate the trophic status for each lake. Diamond and Grass Lakes were not included in this analysis since TSI scores are only appropriate for deeper lake systems. Based on the trophic state report for 2022 the following observations were made:

Lakes with Improving Water Quality Indicators: 1991-2022	Bde Maka Ska Wirth Lake
Lakes with Stable: Trends 1991-2022	Brownie Lake Cedar Lake Lake Harriet Lake Hiawatha Lake of the Isles Loring Pond Lake Nokomis Powderhorn Lake Spring Lake
Lakes with Declining Water Quality Indicators: 1991-2022	No lakes with declining trend

The State of Minnesota evaluates lakes by their performance over the most recent decade. When trends are assessed over just the past decade, the lake rankings are different.

Lakes with Improving Water Quality Indicators: 2013-2022	No lakes with improving trend
Lakes with Stable Trends: 2013-2022	Bde Maka Ska Brownie Lake Cedar Lake Lake Harriet Lake of the Isles Loring Pond Powderhorn Lake Spring Lake Wirth Lake
Lakes with Declining Water Quality Indicators: 2013-2022	Lake Hiawatha Lake Nokomis

Several lakes have seen poor water quality and higher TSI scores between 2017 and 2021. Extraordinarily high rainfall amounts received in our region in recent years is a likely contributor to the change in trend from improvement towards stability in most lakes. Data from these years are the reason for the trend changes that have been detected; however, with 2022 being a dry year, better water quality and lower TSI scores were observed in Bde Maka Ska, Cedar, and Wirth Lake. Lake Hiawatha and Lake Nokomis are trending towards poorer water quality because the TSI scores have been increasing since 2014.

Despite the trend change, Bde Maka Ska and Lake Harriet frequently meet the goals set for these lakes by the Clean Water Partnership (CWP) nearly 30 years ago. In fact, Bde Maka Ska has met its goals every year since the goal was created in 1993.

Notable Events

The water quality in Bde Maka Ska and Wirth Lake remain outstanding for lakes in urban settings. Indicators show better water quality in 2022 than the early 1990s when restoration efforts began. Both lakes currently have better water quality than Minnesota Pollution Control Agency (MPCA) guidelines for water clarity, chlorophyll-*a*, and total phosphorus. Continued monitoring will assist in developing the next generation plans for Bde Maka Ska and Wirth Lake.

The TSI value for Cedar Lake showed improvement following restoration efforts through the late-1990s and remained stable until 2016. Higher levels of algae and lower water clarity from 2017-2021 led to poorer TSI scores at this lake likely due to high rainfall events; however, water clarity was significantly deeper in 2022 and phosphorus levels met the MPCA standard. Cedar Lake's TSI score met its goal in 2022.

In 2021, Kenilworth Channel, connecting Cedar Lake and Lake of the Isles, was dewatered for a naturalization and shoreline stabilization project by MPRB. While the channel was dry, a section of a sanitary sewer line parallel to the channel was replaced by the City of Minneapolis in 2021. Turbidity measurements remained low in both lakes during these projects indicating that erosion control efforts were successful. Channel work by the Met Council Southwest light rail project began in the fall of 2022, and construction will take place over winter with the channel reopening in 2023. Excess turbidity was not observed upstream or downstream of this project in 2022.

In 2022, the MPRB began developing specific cyanobacteria mitigation strategies for Cedar Lake and Lake Nokomis to address ongoing concerns about toxic cyanobacteria blooms in these lakes. This work is being undertaken because of significant blooms of cyanobacteria that have occurred at Cedar Lake and the presence of cyanotoxins that can exceed the MPCA's swimming advisory levels at Lake Nokomis. The objectives of the project are to identify the specific stressors causing beach-season and off-season cyanobacteria blooms in the lakes and identify and evaluate structural and nonstructural mitigation strategies to address the stressors in each lake.

Although Lake Harriet met MPCA eutrophication standards for water clarity, chlorophyll-*a*, and total phosphorus in 2022, the TSI score increased, nearing the early 1990s scores, indicating poorer water quality. The TSI score increased due to higher chlorophyll-*a* and total phosphorus concentrations compared to previous years. Lake Harriet also experienced an unusual short-lived cyanobacteria bloom in early June on the north side of the lake, and a blue-green algae advisory was issued at Harriet Main Beach for five days. With 2022 being a dry year Lake Harriet was isolated for much of the year, with no water entering the lake from Bde Maka Ska or exiting the lake through the open water channel, which likely negatively impacted the water quality and TSI score.

For the second year in a row, in 2022, the MPRB worked with Minneapolis Community and Technical College (MCTC) to learn more about the phosphorus content of duckweed in Loring Pond and the potential for safe duckweed reuse in horticulture or community gardens. A viable methodology was determined for use in 2022. Student involvement increased and sampling was done to observe variations in uptake of nutrients and heavy metals throughout the growing season. Future work will compare data collected at Loring Pond with literature values for health effects and suitability for use of duckweed in community garden composting.

Powderhorn Lake received a high surface area iron-ceramic treatment in 2022 to attempt to reduce the impacts of cyanobacteria. Iron has been used for decades to reduce lake phosphate in the water column in lake restoration projects, and studies show that reducing phosphorus could be effective in controlling the growth of cyanobacteria. In 2022, Powderhorn Lake was impacted by blue-green algae and did not meet shallow lake standards for water clarity, chlorophyll-*a*, and total phosphorus. Low precipitation likely impacted the success of the iron-ceramic application because there was minimal water movement across the mesh bags, limiting the amount of phosphorus from binding with the iron. Fish survey results also showed a large increase in the bullhead population in Powderhorn Lake, which is also likely contributing to cyanobacteria growth due to fish foraging in sediment.

In 2022, Lake Hiawatha did not meet the site-specific standards set by the MPCA for water clarity, chlorophyll-*a*, or total phosphorus. Water quality in Lake Hiawatha is controlled by the inflow from Minnehaha Creek and trends show that low water years correlate to poor water quality. The TSI value for Lake Hiawatha showed the worst water quality in 2022 compared to all years that the lake was monitored since 1992. Since this lake is positively influenced by Minnehaha Creek flow, low water levels and less inflow from Minnehaha Creek in 2022 likely contributed to poorer water quality conditions allowing cyanobacteria to flourish.

The MPRB monitored twelve public beaches for *Escherichia coli* (*E. coli*) in 2022. These bacteria are used as indicators of pathogens in water. Rainfall events washing bacteria off hard surfaces and through the stormwater systems as well as large numbers of waterfowl near the beaches are likely the most influential causes of higher *E. coli* levels. Beaches at Bde Maka Ska, Cedar Lake, and Lake Hiawatha were closed for parts of the swimming season due to *E. coli* levels. The online GIS-based Lake Water Quality Map (bit.ly/mplsbeaches) was updated with the most current data to better inform lake users of closures and issues that could impact human health.

Due to an increase in frequency and intensity of cyanobacteria blooms in Minneapolis lakes, the MPRB developed a cyanobacteria monitoring program for public health in 2020. MPRB staff collect information on observations using a defined Visual Monitoring Index (VMI), and sample water weekly at all 12 MPRB beaches for the most common cyanotoxins. Advisories are posted at beaches and on the MPRB Lake Water Quality Map if toxin levels exceed MPCA guidelines. In 2022, advisories were issued at beaches on Harriet, Hiawatha, Nokomis, and on Powderhorn Lake due to cyanobacteria and increased risk of a harmful algae blooms (HABs).

The natural swimming pool (NSP) at Webber Park, the first of its kind in North America, was open for the sixth full year of operation in 2022. Since the water quality in the pool depends on the ecological conditions in the system, MPRB Environmental Management and Maintenance staff monitors the physical, chemical, and biological parameters. European standards suggest that 95% of samples should meet standards, and Webber NSP has made significant progress towards this goal. In 2022, 94% of *E. coli* samples, 69% of Enterococci samples, and 97% of *Pseudomonas* samples met standards. Low bacteria levels are likely attributed to numerous bird deterrents and a secondary disinfection with UV light.

Several early detection tools, such as settling plates, shoreline surveys, and boat launch inspections, were used to search for zebra mussels in Minneapolis lakes in 2022. Zebra mussels were not found in any Minneapolis lakes where they were not expected.

Aquatic plant harvesting was carried out on Bde Maka Ska, Cedar, Harriet, Nokomis, Lake of the Isles, and Wirth Lakes in 2022 to allow for improved recreational access. MPRB staff removed 265 flatbed truck loads of plants in 2022 which is equivalent to 1,456 cubic yards of aquatic plant material. SCUBA divers were contracted to hand-harvest aquatic plants in the beach areas of Lake Nokomis and Wirth Lake. The divers removed 100 lb of aquatic plants from Lake Nokomis and 3,080 lb from Wirth Lake.

The average monthly temperatures in 2022 were above normal from May-November, and below normal from January-April and in December. The 2022 annual mean temperature was 46° F, which was 0.1° F below normal. The warmest month of the year was July, and the coolest month was January. Of the warmer than normal months, June was the most significantly elevated, at 4.2° above normal. Of the colder than normal months, February was 6.3° below normal and April was 6.5° below normal.

2022 was a dry year. The recorded precipitation total for 2022 was 22.97 inches, which was 8.65 inches below the 29-year normal. Eight months had precipitation levels below the 29-year normal and four months had precipitation levels above the 29-year normal. The wettest month of the year was August, and the driest months were September and October. The months of July and September had monthly precipitation deficits of more than 2-inches below the 29-year normal.

The MPRB monitors stormwater within Minneapolis to comply with the federal National Pollutant Discharge Elimination System (NPDES) permit. The purpose of this monitoring is to gain knowledge that can be used to improve the effectiveness of treatment best management practices (BMPs). BMPs include procedures and structures designed to help reduce and capture pollutants in stormwater runoff. In 2022, stormwater from four subwatersheds draining to Powderhorn Lake were monitored to gather information that will be used in a diagnostic study for the lake. Monitoring occurred downstream of continuous deflection separation (CDS) units. Three inlets to Camden Pond as well as the outlet were monitored to examine internal phosphorus release and the effectiveness of stormwater ponds initially built for flood control. Quarterly grab samples, including snowmelt and rainfall, were collected at seven stormwater sites. Two green stormwater infrastructure (GSI) sites, Hoyer and Windom, were monitored for plant health, soil chemistry, and pretreatment basin functionality.

Monitoring partners for 2022 included: The Friends of Lake Nokomis, Hennepin County, Minneapolis Community and Technical College (MCTC), Minneapolis Public Works, the Minnehaha Creek Watershed District, Minnesota Pollution Control Agency, the Minnesota Department of Natural Resources, the University of Minnesota St. Anthony Falls Laboratory, and the Mississippi Watershed Management Organization.

1. Monitoring Program Overview: 1991-2022

Lake Monitoring

Background

The Environmental Management Department of the Minneapolis Park and Recreation Board (MPRB) implemented a lake water quality monitoring program in 1991 as part of a diagnostic study for the Chain of Lakes Clean Water Partnership. The Chain of Lakes includes Brownie, Cedar, Isles, Bde Maka Ska, and Harriet. The monitoring program was expanded in 1992 to include Hiawatha, Nokomis, Diamond, Powderhorn, Loring, and Wirth Lakes. Monitoring at Spring Lake was added on a limited basis in 1993 and Grass Lake was added in 2002. Currently, only ice conditions are monitored at Birch and Ryan Lakes. Ryan Lake is monitored by the Met Council's Citizen-Assisted Monitoring Program (CAMP) program every two to three years and is occasionally monitored more extensively by the Shingle Creek Commission. **Figure 1-1** shows the location of waterbodies in Minneapolis. For purposes of this overview, these 15 lakes will be collectively referred to as the Minneapolis lakes.

The objectives of the MPRB lake monitoring program are to:

1. Protect public health.
2. Establish a database for tracking water quality trends.
3. Quantify and interpret both immediate and long-term changes in water quality.
4. Provide water quality information to develop responsible water quality goals.
5. Provide a basis for water quality improvement projects.
6. Evaluate the effectiveness of implemented best management practices such as ponds and grit chambers.

The intent of this overview is to provide a description of the MPRB lakes monitoring program schedule and methods.

The watersheds of the 15 Minneapolis lakes span the cities of Minneapolis, St. Louis Park, Richfield, Golden Valley, Robbinsdale, Brooklyn Center, and Edina. Residential housing is the predominant land use within all the watersheds although industrial and commercial land uses are significant in several areas. The Loring Pond watershed is predominantly parkland. All the Minneapolis lakes' watersheds are considered fully developed and little change in land use is projected although redevelopment is occurring in some areas.

The geology of the lakes and watersheds consist of Paleozoic bedrock that has been altered by fluvial processes and covered with glacial till. Area bedrock is generally concealed under 200–400 feet of unconsolidated deposits. The bedrock surface is composed of plateaus of limestone and dolomite penetrated by a system of dendritic preglacial river valleys. These river valleys were filled by a combination of fluvial sediment and late Wisconsin glacial drift. Each subsequent glacial advance stripped the landscape of overburden and filled the preglacial and interglacial valleys with drift. The last glacial episode resulted in the formation of most of the lakes in Minneapolis.

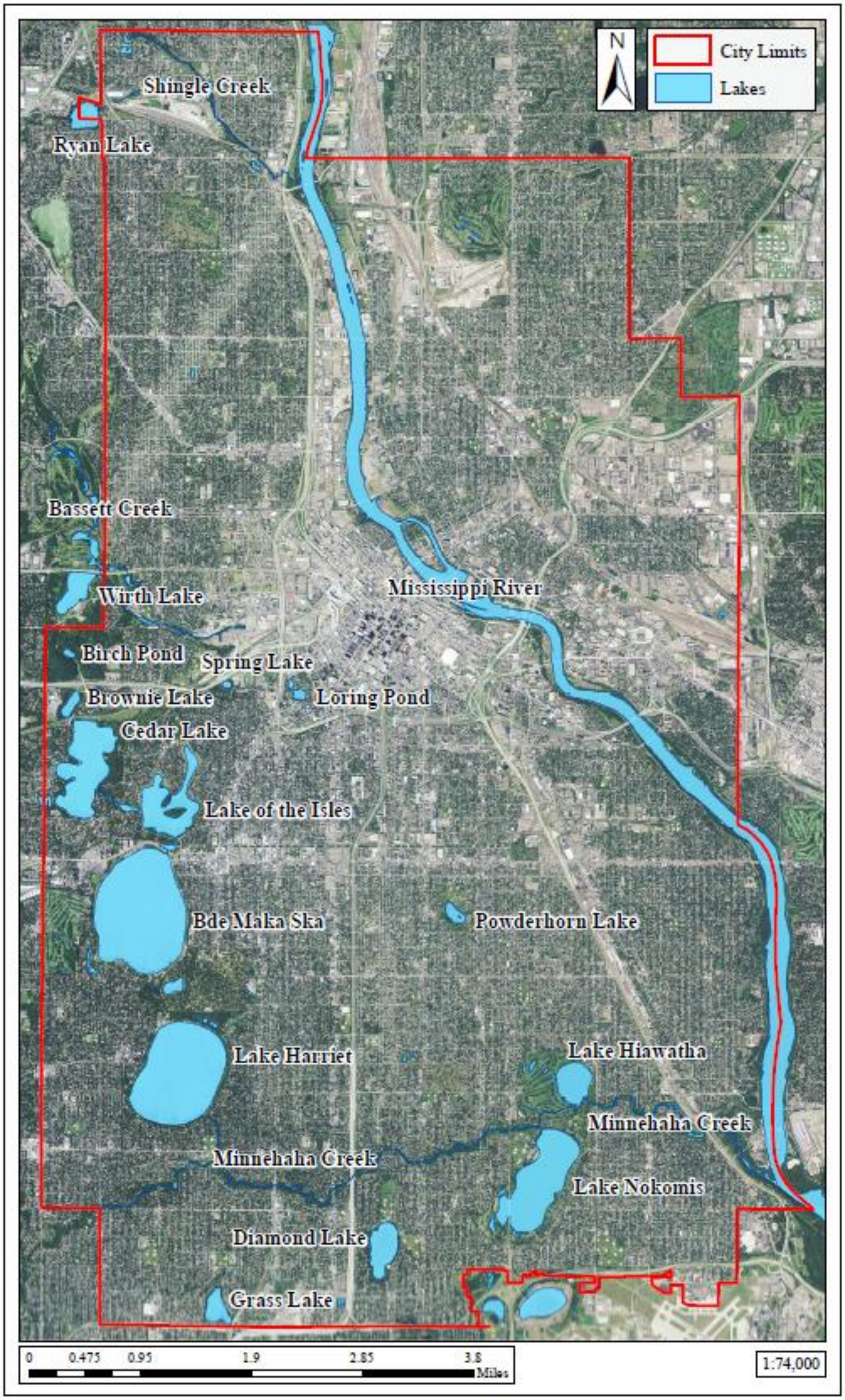


Figure 1-1. Location of waterbodies in Minneapolis.

The glacial ice sheet deposited large ice blocks at its margin as it retreated. Ice blocks that were deposited in a north-south tending pre-glacial (or interglacial) valley led to the formation of the Chain of Lakes. Lake Nokomis, Lake Hiawatha, and Powderhorn Lake formed as a result of a similar series of events in another preglacial valley (Zumberge, 1952; Balaban, 1989).

Nearly all the Minneapolis lakes were physically altered by dredging in the early 1900s (Pulscher, 1997). The Minneapolis lakes currently represent a wide range of morphometric characteristics including deep dimictic lakes (Bde Maka Ska, Cedar, Harriet, and Wirth), polymictic lakes (Hiawatha and Nokomis), protected meromictic lakes (Brownie and Spring), shallow lakes (Isles, Loring, and Powderhorn), and shallow wetland systems (Diamond and Grass), see **Table 1-1**.

Table 1-1. Minneapolis lakes physical characteristics and morphometric data.

Lake	Surface Area (acres)	Mean Depth (ft)	Max Depth (ft)	% Littoral*	Volume (ft^3)	Watershed Area (acres)	Watershed: Lake Area (ratio)	Residence Time (years)
Bde Maka Ska	419	30.0	82.0	29%	6.36×10^8	2,992	7.1	4.2
Brownie	10	22.3	47.0	76%	1.76×10^7	369	20.5	2.0
Cedar	164	20.0	51.0	38%	1.50×10^8	1,956	11.5	2.7
Diamond	52	3.2	5.8	100%	2.52×10^6	669	16.3	NA
Grass	27	2.0	4.9	NA	NA	386	14.3	NA
Harriet	341	29.0	87.0	25%	4.41×10^8	1,139	3.2	3.4
Hiawatha	53	13.4	33.0	47%	3.16×10^7	115,840	2,145	0.01
Isles	112	8.9	31.0	80%	3.92×10^7	735	7.1	0.6
Loring	7	4.9	16.0	89%	1.72×10^6	24	3.0	NA
Nokomis	201	14.1	33.0	50%	1.25×10^8	869	4.3	4.0
Powderhorn	11	3.9	24.0	83%	3.19×10^6	286	26.0	0.2
Ryan	19	NA	36.0	51%	NA	5,510	306	NA
Spring	3	9.8	27.9	NA	1.29×10^6	45	15.0	NA
Wirth	40	14.1	25.0	58%	2.37×10^7	348	9.4	NA

*Littoral area defined as less than 15 feet deep
NA= Information not available.

Methods

The 2022 lake monitoring sampling schedule of physical and chemical parameters is shown in **Table 1-2**. Most lakes followed this schedule and were sampled once in winter, March-April, and October-November, and twice per month during the period of May through September. Exceptions to the schedule were Brownie Lake and Grass Lake, which were sampled once per month.

Table 1-2. Schedule of sampled parameters for most lakes in 2022.

Parameters	Sampling frequency
Chloride, Chlorophyll-*a*, Conductivity, Dissolved oxygen, pH, Phytoplankton, Secchi Transparency, Temperature, Total Phosphorus, Soluble Reactive Phosphorus, Total Nitrogen, Phycocyanin	Once Winter Once March – April Twice per month May – September Once October – November
Silica	Once Winter Once March – April Once per month May – September Once October – November
Zooplankton	Once March – April Once per month May – September Once October – November
Alkalinity, Ammonia, Hardness, Sulfate, Total Kjeldahl Nitrogen, Nitrate/Nitrite	Once Winter Once March – April Twice between May – September Once October – November
Escherichia coli	Once May – September

All physical measurements and water samples for chemical analyses were obtained from a point directly over the deepest location in each lake at the mid-lake sampling site. The sampling stations were determined from bathymetric maps and located using handheld GPS and an electronic depth finder.

A Hydrolab Minisonde 5 Multiprobe or YSI EXO1 Multiparameter Sonde were used to record temperature, pH, specific conductivity, dissolved oxygen, phycocyanin and chlorophyll-*a* profiles. These parameters were measured at 1-meter intervals from one meter above lake bottom, as to not disturb sediments, to the surface. The multiprobes were calibrated according to the manufacturer's guidelines prior to each sampling trip. Water clarity was determined using a black and white 20-cm diameter Secchi disk on the shady side of the boat.

Two composite surface water samples were collected using a stoppered 2-meter long, 2-inch diameter white PVC tube and combined in a white plastic bucket. Water from this mixed sample was decanted into appropriate bottles for analysis. Subsurface samples were collected with a 2-liter Wildco™ Kemmerer water sampler. Chlorophyll-*a* and phytoplankton samples were stored in opaque bottles for analysis. All other samples were collected in new clear plastic bottles. Each lake sample collection regime was determined based upon maximum depth, stratification characteristics, and the results of previous studies, see **Table 1-3**.

Table 1-3. Sampling depth profiles for the 2022 MPRB lakes monitoring program.

Lake	Sample Depth (m)
Bde Maka Ska	0-2 composite, 6, 12, 18, 22
Brownie Lake	0-2 composite, 6, 12
Cedar Lake	0-2 composite, 5, 10, 14
Diamond Lake	Grab (surface)
Grass Lake	Grab (surface)
Lake Harriet	0-2 composite, 6, 12, 15, 20
Lake Hiawatha	0-2 composite, 4
Lake of the Isles	0-2 composite, 5, 8
Loring Pond	0-2 composite, 4
Lake Nokomis	0-2 composite, 4, 7
Powderhorn Lake	0-2 composite, 4, 6
Wirth Lake	0-2 composite, 4, 7

Phytoplankton samples were collected during each sampling trip in winter, spring, May through September, and fall, see **Table 1-2**. Phytoplankton were collected from the 0-2 m surface composite sample and stored in an opaque plastic container with a 25% glutaraldehyde preservative solution. Vertical zooplankton tow samples were taken at the mid-lake sampling location for each lake once per month during the growing season, May-September, and once in fall, except at Brownie, Diamond, and Grass Lake. Zooplankton were collected using an 80 µm mesh Wisconsin vertical tow net with an 11.7 cm diameter opening retrieved at a rate of 1 m/s from approximately 1 m off the bottom through the full water column to the surface. The 80 µm mesh Wisconsin bucket was rinsed with ethanol from the outside. The sample was preserved in 70% denatured histological ethanol to a mix of approximately 70% ethanol and 30% sample.

Immediately following collection all samples were placed on ice in a cooler and stored at approximately 4°C. Samples were transported to the contract laboratory for analysis within 8 hours of collection. Sampling procedures, sample preservation and holding times followed procedures described in Standard Methods (2005) or US Environmental Protection Agency (US EPA, 1979 (revised 1983)). The 2022 contract laboratory for chemical analyses was Instrumental Research, Inc. (IRI). Pace Analytical laboratory analyzed metal samples. PhycoTech, Inc. analyzed all phytoplankton and zooplankton samples. The methods and reporting limits for parameters are listed in **Table 1-4**.

More information and results for the physical and chemical parameters can be found in individual lake chapters and **Appendix B**.

Table 1-4. Methods and reporting limits used for parameter analysis in the 2022 Minneapolis lakes monitoring program.

Parameter	Method	Reporting Limit
Alkalinity	Standard Methods 2320 B	2.00 mg/L
Aluminum, Total and Soluble	EPA 200.8	30 µg/L
Ammonia	USGS I-3520-85	0.250 mg/L
Anatoxin-*a*	Enzyme Linked Immunosorbent Assay (ELISA)	0.15 ug/L
Chloride	Standard Methods 4500-Cl^- B	2.00 mg/L
Chlorophyll-*a*	Acetone extraction/spectrophotometric determination (pheophytin corrected) SM 10200 H & YSI EXO1 (field)	0.500 µg/L
Conductivity	Hydrolab Minisonde 5a Multiprobe & YSI EXO1 (field)	0.1 µS/cm
Cylindrospermopsin	Enzyme Linked Immunosorbent Assay (ELISA)	0.05ug/L
Dissolved oxygen	Hydrolab Minisonde 5a Multiprobe & YSI EXO1 (field)	0.01 mg/L
Escherichia coli	Colilert Quanti-Tray, IRI	1 MPN/100 mL
Hardness	Standard Methods 2350 C	5.00 mg/L
Iron, Total and Soluble	EPA 200.7	50 µg/L
Microcystin	Enzyme Linked Immunosorbent Assay (ELISA)	0.15 ug/L
Nitrate/Nitrate Nitrogen	Standard Methods 4500-NO_3 E	0.030 mg/L
Silica	Standard Methods 4500-SiO_2 C	0.500 mg/L
Soluble Reactive Phosphorus	Standard Methods 4500-P E	0.003 mg/L
Sulfate	ASTM D516-90	5 mg/L
Temperature	Hydrolab Minisonde 5a Multiprobe & YSI EXO1 (field)	0.01 °C
Total Kjeldahl Nitrogen	ASTM D3590 A-02	0.500 mg/L
Total Nitrogen	Standard Methods 4500 N C Alkaline persulfate oxidation/automated cadmium reduction method.	0.500 mg/L
Total Phosphorus	Standard Methods 4500-P E	0.010 mg/L
Phycocyanin	YSI EXO1 (field)	0.01 RFU
Water Clarity	Secchi disk	0.01 m

LAKE LEVELS

Background

Lake levels have been recorded by MPRB staff, since the 1970s. Lake level readings are compared to their respective Ordinary High Water Level (OHWL). The OHWL is defined by the Minnesota Department of Natural Resources (MNDNR) as the elevation to which the highest water level has been maintained for a sufficient period of time. The OHWL is determined by evidence on the landscape where the natural vegetation changes from predominantly aquatic to predominantly terrestrial (MNDNR, 1993). OHWL is not a measure of average lake level.

Methods

Lake levels are recorded weekly during open water season, from ice-out to ice-on. Recordings are based off fixed lake gages located at Bde Maka Ska, Diamond, Harriet, Hiawatha, Nokomis, Loring, Powderhorn, and Wirth, see **Figure 1-2**. The lake level reading for the interconnected Upper Chain of Lakes, which includes Brownie, Cedar, Isles, and Bde Maka Ska, is measured at the lake gage located at Bde Maka Ska.

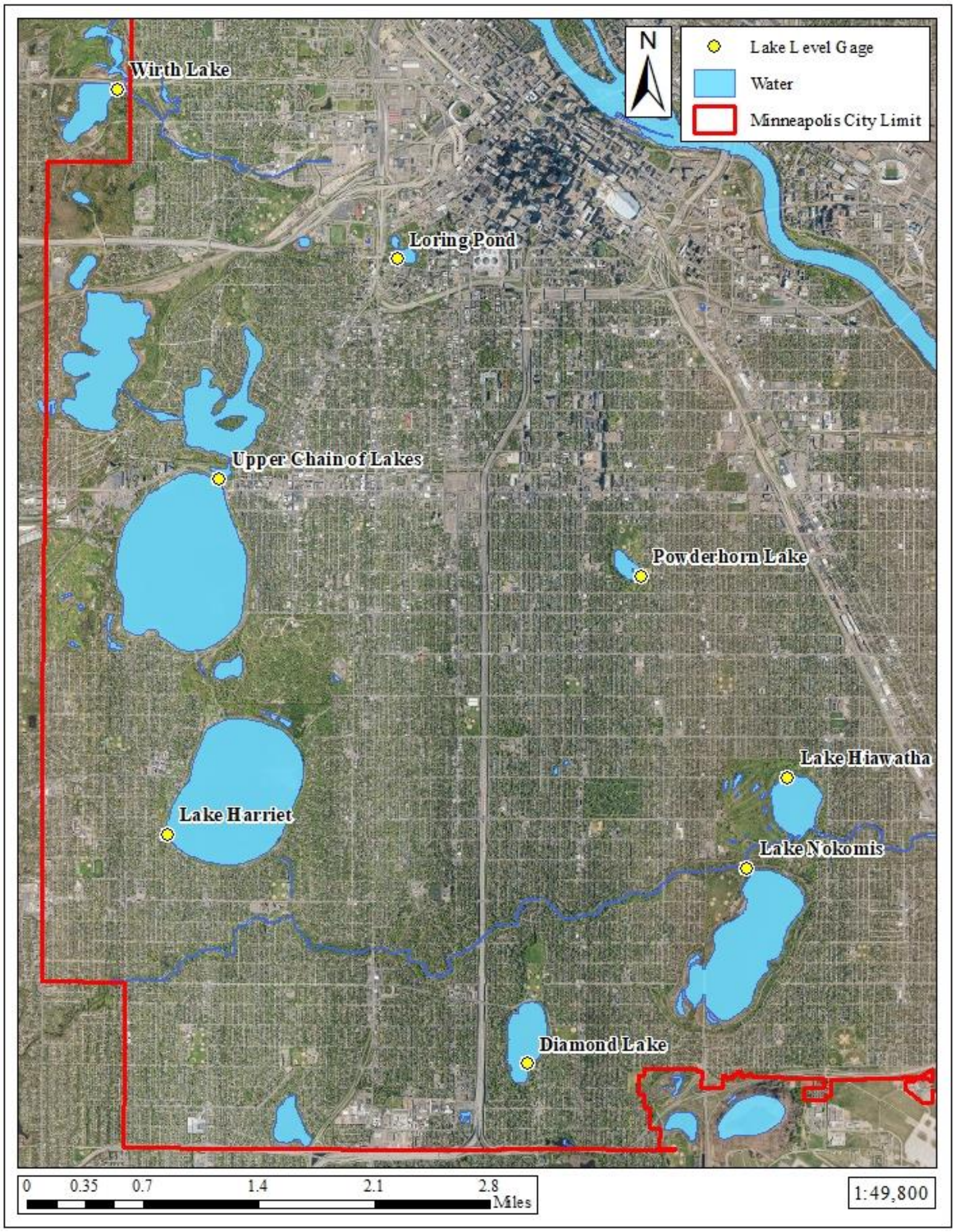


Figure 1-2. Minneapolis lake level monitoring locations. The Upper Chain of Lakes gage is representative of Bde Maka Ska, Lake of the Isles, Cedar Lake, and Brownie Lake as these waterbodies are interconnected.

Results & Discussion

Lake level data is converted to elevation in feet above mean sea level (msl), archived in a Microsoft Excel spreadsheet and reported monthly to MNDNR. Data for individual lakes can be found in their corresponding chapters. See **Chapter 17** for average annual lake levels, selected statistics for each lake with a lake gage, and water levels for Minneapolis lakes. For more information on Minnesota lake levels see https://www.dnr.state.mn.us/climate/waterlevels/lakes/index.html.

Wells

Background

Groundwater is monitored by Minneapolis Park and Recreation Board (MPRB) staff at 7 piezometric wells, all MPRB golf course irrigation wells, and 2 lake level augmentation wells. Piezometric wells are drilled to specific depths in order to monitor hydraulic head, the groundwater pressure above a known datum. Some of the piezometric wells are nested as 2 to 3 wells together and drilled to different depths. There are 4 additional piezometric wells located at Columbia Golf Course that are in place for a short-term monitoring project. Irrigation wells use groundwater for golf course turf and greens area maintenance. The irrigation well at Theodore Wirth Golf Course is used to make snow during the winter for skiing. Augmentation wells, located at Powderhorn Lake and Loring Pond, are used to maintain water levels. **Figure 1-3** is a map of the piezometric, irrigation, and augmentation well locations in Minneapolis. The Minnesota Department of Natural Resources (MDNR) issues the permits and determines pumping limits for irrigation and augmentation wells.

Methods

Piezometric well readings are taken with a Herron Instrument Water Level Meter. This water level meter is read at the top of the well casing to ± 0.01 feet and its accuracy complies with US GGG-T-106E EEC Class III protocols. Piezometric wells A, B, and C are monitored once a month January, February, March, and December and twice a month April through November. Wells D, E, F, and G are monitored quarterly. The piezometric wells at Columbia Golf Course are auto-monitored with Solinst dataloggers left in the wells. Data are downloaded every two weeks along with a water tape reading taken at that time.

Irrigation usage is recorded monthly by golf operations staff during the pump operation season of April 15th through October 15th. Winter pump usage at Wirth is recorded from November 1st through March 31st. MPRB staff determine when lake augmentation pumps need to be turned on and off and maintain records for groundwater usage monthly during the pump operation season. All monthly pumping data are reported to the MDNR and fees are paid annually in the MDNR Permitting and Reporting System (MPARS).

Results & Discussion

The piezometric well readings are taken throughout the year and data is archived in a Microsoft Excel spreadsheet.

Results from the 2022 lake augmentation well readings and annual usage can be found in the Powderhorn Lake and Loring Pond chapters. All the irrigation and augmentation wells used were below their MNDNR allotted groundwater pumping volumes.

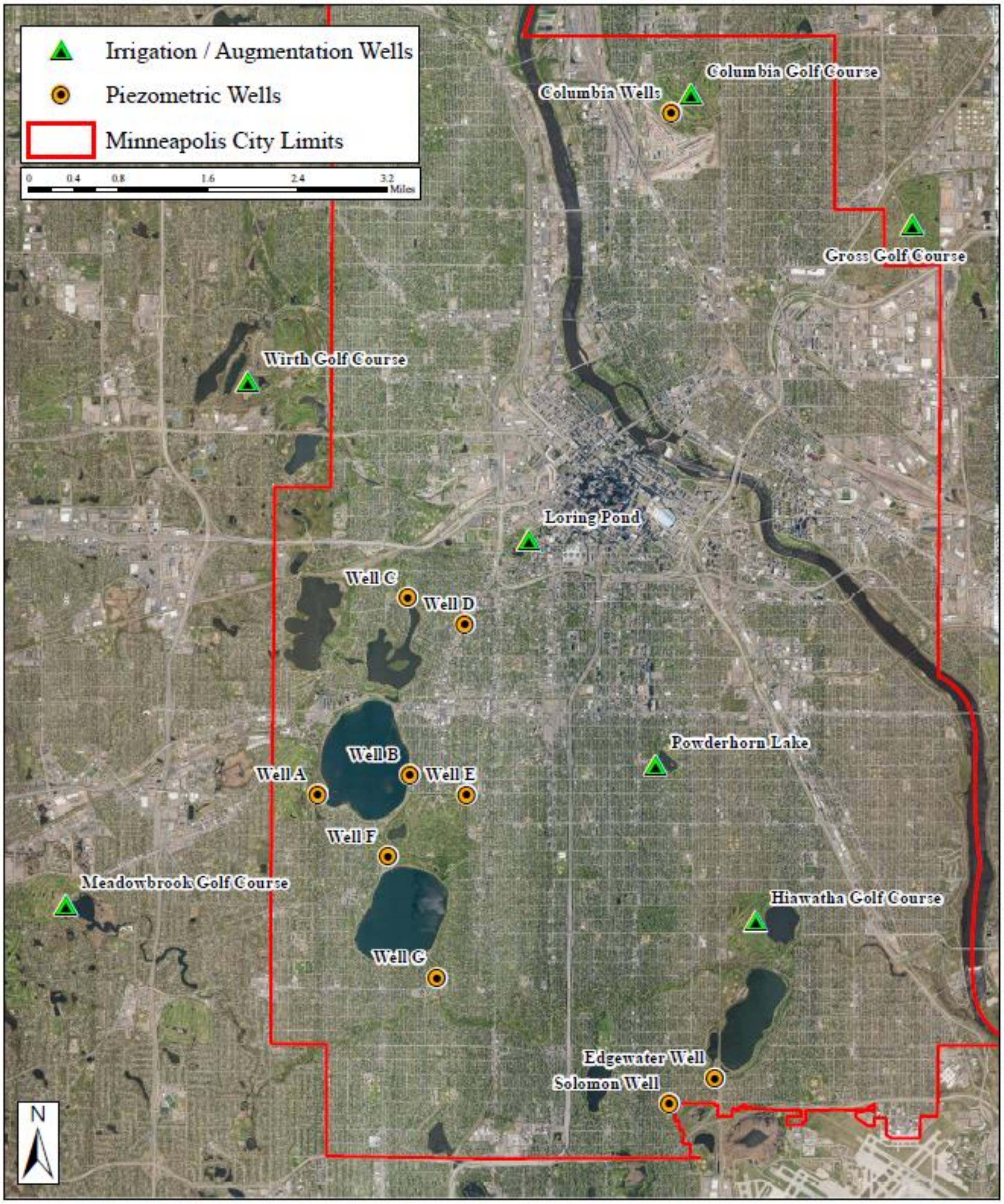


Figure 1-3. Map of piezometric and irrigation/augmentation well locations monitored by MPRB Environmental Management.

WATER QUALITY TRENDS (TSI)

Scientists analyzed water quality parameters in Minneapolis lakes sporadically since 1927 and have consistently monitored lakes bi-weekly since 1991. In 2022, the MPRB monitored 12 city lakes according to the current schedule and protocols, see **Table 1-2**. The data collected was used to determine nutrient-related water quality, trophic status, and general usability.

Trophic status is used to estimate water quality and is based on Carlson's Trophic State Index (TSI; Carlson, 1977). Trophic state is calculated using three nutrient related water quality parameters collected from surface water: water clarity (Secchi depth), chlorophyll-*a* (chl-*a*), and total phosphorus (TP).

> **Water clarity** is measured using a 20-cm black and white Secchi disk. The Secchi disk is lowered into the water until it cannot be seen. Then it is lowered a short distance further and raised until it is seen again. The average of these two numbers represents the Secchi depth. The Secchi depth is dependent on algal biomass or other factors that may limit light penetration (e.g. suspended solids, dissolved organic material).
>
> **Chlorophyll-*a*** is a pigment that algae uses to capture sunlight and is a measure of how much algal biomass is in the lake.
>
> **Total Phosphorus** is often the limiting nutrient in most freshwater lakes and therefore controls the growth of algae. By measuring TP in lake water, it is possible to estimate algal growth and the potential for high algal growth conditions, known as algal blooms.

Individual Secchi, chl-*a*, and TP TSI scores are calculated for the growing season (May-September) for each lake. The annual lake TSI score is the average of the individual Secchi, chl-*a,* and TP TSI scores. It should be noted that some annual lake TSI scores are an average of only two parameters (chl-*a* TSI and TP TSI) if a Secchi is not or cannot be taken on a particular lake. The individual TSI formulas are below.

$$Secchi\ TSI = (60 - 14.41) \times \ln(Average\ growing\ season\ Secchi\ in\ meters)$$

$$TP\ TSI\ = 14.42 \times \ln\left(Average\ growning\ season\ TP\ in\ {}^{mg}/_{L} \times 1000\right) + 4.15$$

$$Chlorophyll\text{-}a\ TSI = 9.81\ \times\ \ln(Average\ growing\ season\ chlorophyll\text{-}a\ in\ {}^{\mu g}/_{L})$$

$$Annual\ TSI = \frac{(Secchi\ TSI + Chlorophyll\text{-}a\ TSI + TP\ TSI)}{3}$$

TSI scoring is based on a 0-100 scale, although theoretically the scale has no upper or lower bounds, with higher numbers relating to higher trophic status and lower water quality. Three TSI scores are possible using the parameters described above and can be reported separately or as an average. The TSI score based on chl-*a* is thought to be the best measure of trophic state because it is the most accurate at predicting algal biomass (Carlson, 1977). TSI scores reported by the MPRB are an average of the three parameters.

It is important to consider ecoregion and land use in the surrounding watershed when using the TSI to determine lake water quality. The State of Minnesota has seven ecoregions determined by land use, soil type, and natural vegetation. Minneapolis lies within the North Central Hardwood Forests (NCHF) ecoregion, an area with fertile soils and agriculture as a dominant land use in rural areas. Lakes in this ecoregion generally have higher concentrations of nutrients and 90% of the TSI scores are between 42 and 68. In the Twin Cities metro area it is recommended that a TSI score of 59 or lower be maintained in lakes used for swimming. This recommendation is based upon the aesthetic appeal of the water body.

The Clean Water Partnership (CWP) Minneapolis Chain of Lakes Project developed long-term TSI goals for Bde Maka Ska, Brownie, Cedar, Isles and Harriet in 2001. These goals were intended to be met within five to ten years of water quality project completion. See each of these individual lake chapters for more information on the CWP TSI goals.

One of the methods used to classify lakes involves using categories based on the TSI score. Lakes generally fall into one of four categories based on trophic status that include (https://www.nalms.org/secchidipin/monitoring-methods/trophic-state-equations/):

> **Oligotrophic** (30 > TSI < 40) lakes are characterized by clear water and oxygen throughout the year in the hypolimnion. Hypolimnia of shallower lakes may become anoxic.
>
> **Mesotrophic** (40 > TSI < 50) lakes generally are moderately clear and have an increased probability of experiencing hypolimnetic anoxia during the summer months.
>
> **Eutrophic** (50 > TSI < 70) lakes are characterized by an anoxic hypolimnia, phytoplankton communities may be dominated by blue-green algae, and possible macrophyte problems.
>
> **Hypereutrophic** (TSI > 70) lakes are characterized by dense algae and macrophyte problems.

Most lakes in the NCHF ecoregion fall into the eutrophic category and the lowest trophic status lakes typically fall into the mesotrophic category. Most lakes sampled in Minneapolis are either eutrophic or mesotrophic. Detailed information on TSI scores and nutrient related water quality parameters can be found in the individual lake chapters and **Appendix A**.

Changes in lake water quality can be tracked by analyzing long-term trends in TSI scores. The MPRB uses TSI scores to assess changes in water quality and evaluate the effectiveness of restoration and management activities on the trophic state of the lakes. Linear regression analysis is a common method used for determining trends in average TSI over time. A graph was made of average annual TSI scores for each lake, which can be found in each individual lake's chapter. A trend line was fit through the data points. The linear regression line is defined as $y = mX + b$, where m is the slope of the line, which indicates the general trend of the data. The *p*-value indicates the probability of the observed trend even if there isn't one. The statistical significance of the trend is determined by a p-value of <0.05, meaning there is a 5% probability that the observed trend is false. The R^2 value indicates how well the trend fits the data with 1.00 being a perfect fit. Based upon these results it is possible to describe the direction of the trend, which is indicated by a negative or positive slope, and the degree of confidence one can place upon the trend. Better water quality and decreasing productivity in surface water is generally indicated by a decreasing TSI score and negative slope of the regression equation, which is shown in the TSI figures in each individual lake's chapter. Conversely, a positive slope and increasing TSI scores generally indicates increasing productivity and a decrease in water clarity.

Box and Whisker Plots

Box and whisker plots for the three trophic state parameters, water clarity, surface chlorophyll-*a* levels, and surface total phosphorus levels, were created for each lake and presented in individual lake chapters. The box and whisker plots are another way to detect trends and are valuable for assessing variability over the years. Box and whisker plots can be used to look at short-term (annual) and long-term variation at the same time.

For each plot, the box represents the middle 50 percent of the data from the 25th percentile to the 75th percentile. The whiskers, the vertical lines extending off the boxes, represent the data from the 25th to the 5th percentile and the 75th to the 95th percentiles. Any data falling above the 95th percentile or below the 5th percentile are marked as outliers and represented by an open circle. The bold horizontal line represents the median value.

The black circle represents the mean value of data collected during the growing season, May through September. Minnesota Pollution Control Agency (MPCA) develops deep lake, shallow lake, and site-specific standards for the trophic state parameters listed in **Table 1-5**, which applies to data collected between June and September, known as the summer mean. The red circle represents the summer mean, see **Figure 1-4**.

Table 1-5. MPCA deep lake, shallow lake, and site-specific standards for water clarity, chlorophyll-*a* and total phosphorus.

Standard	Water Clarity (m)	Chlorophyll-*a* (µg/L)	Total Phosphorus (µg/L)
Deep Lake	>1.4	<14	<40
Shallow Lake	>1	<20	<60
Site-Specific: Lake Hiawatha	>1.4	<14	<50
Site-Specific: Lake Nokomis	>1.4	<20	<50

Generally, more compact box plots with short whiskers and few outliers indicate low annual variability for the lakes. Long-term trends can be seen by the box plots trending in an up or down direction.

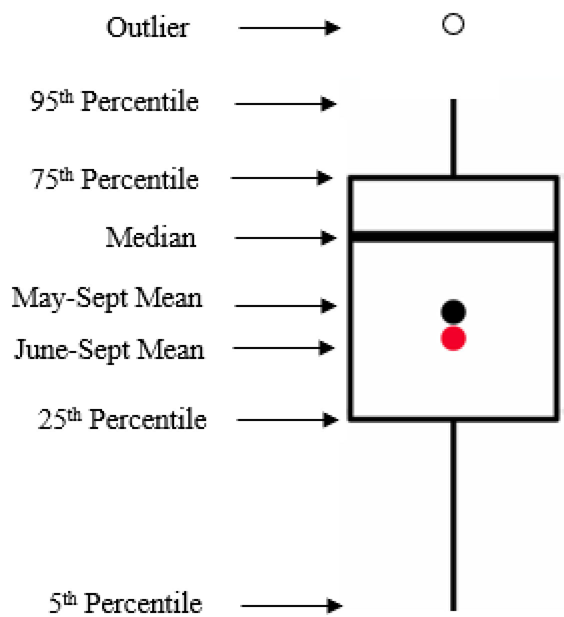


Figure 1-4. Legend for box and whisker plots.

CHLORIDE

Chloride is a naturally occurring element that is commonly found at low levels in most freshwater bodies. Chloride is a component of road salt (sodium chloride) and is found in other types of compounds that are also called salts (calcium chloride, magnesium chloride). Chloride concentrations in rivers, groundwater, and lakes have been increasing across the United States over the past few decades (Corsi, Cicco, Lutz, & Hirsch., 2015). Unnaturally high concentrations of chloride can negatively impact surface waters. High levels of chloride can change the mixing pattern of a lake and lead to very low oxygen levels in deep water. It can also lead to decreasing water clarity and induce stress or cause death of aquatic species (Bathe & Coring, 2011). Chloride is extremely soluble and once it enters a solution it is not easily removed (Novotny & Stefan, 2010).

Residential, industrial, and agricultural practices are the most common sources of chloride that enter water systems. Point sources can include wastewater effluents and industrial discharges from processing metal, paper, petroleum, textiles, and dyes. Nonpoint sources include septic systems, sewage disposal systems, and fertilizers. In colder climates the primary source of chloride in surface waters is road salt. Chloride can also enter water naturally through atmospheric deposition and weathering, but natural chloride is only present in small concentrations in urban areas (Novotny, Murphy, & Stefan, 2008).

The highest chloride concentrations in Minneapolis lakes occurs in February and March because the majority of chloride from road salts over winter is flushed into lakes in the spring when temperatures are increasing. Lowest concentrations occur in October and November because the spring influx of chloride is flushed out of the lakes during turnover. Smaller lakes generally have higher flushing rates while larger lakes have lower flushing rates and will likely experience increasing chloride concentrations in the future (Novotany *et al*., 2009). Minimum chloride concentrations are located at the lake surface, and maximum chloride concentrations are located at the bottom because the water runoff containing sodium chloride is denser and sinks to the lake bottom. As chloride continues to accumulate over time, the water quality conditions will decline in surface waters in the area and aquatic life will be impacted.

Water quality standards have been implemented to protect cool and warm water sport fish. The MPCA adopted the Environmental Protection Agency's (EPA) recommended water quality criteria for chloride. The chronic standard for chloride in the Minneapolis lakes is 230 mg/L. This is the highest concentration of chloride to which an organism can be exposed to for a longer period of time without harm. Organisms can be exposed to this level of chloride for four days or more. The acute standard for chloride in Minneapolis lakes is 860 mg/L. This is the highest concentration of chloride in which an organism can be exposed to for a short period of time and have zero to limited mortality. Organisms can persist in these high levels of concentration anywhere from one hour to four days (MPCA, 2016). According to Canadian Council of Ministries of the Environment (CCME), long-term chloride concentrations of 120 mg/L can negatively impact biota (CCME, 2011).

Monitoring data indicates that 39 waterbodies in the in the Twin Cities Metro Area exceed chloride levels protective of the aquatic community. Two of these waterbodies, Shingle Creek and Nine Mile Creek, have approved Total Maximum Daily Loads (TMDLs) while others are in the process of being developed (MPCA, 2016). State and federal agencies in some regions have changed the make-up of road salt by replacing a small amount of the sodium chloride with alternatives such as magnesium chloride and calcium chloride. Other alternatives may include calcium magnesium chloride, calcium magnesium acetate, potassium acetate, and sodium acetate. In regions where alternative road salts are used sodium chloride road salts are still applied to roads that are not located near water systems, while roads located near water are treated with alternatives. According to Ramakrishna & Viraraghavan (2005), road salts are only effective when the air temperature is greater than 16 degrees Fahrenheit (F). When road salts are applied in temperatures below that, only 10% of the snow and ice melt. The MPCA provides Smart Salting Training to improve operator effectiveness and reduce chloride pollution by 30 – 70%. For more information on Smart Salting Training see https://www.pca.state.mn.us/business-with-us/smart-salting-training.

Methods

The MPRB has monitored chloride concentrations in Minneapolis lakes since 1995 by collecting surface water samples using a composite tube and collecting deep water samples using a Kemmerer sampler. Chloride samples are collected once in winter, spring, and fall, and bimonthly between May and September. Epilimnion samples represent the top two meters of the lake and hypolimnion samples were collected approximately one meter from the bottom of the lake. Detailed information on surface and bottom chloride concentrations can be found in the individual lake chapters.

Lake Aesthetic and User Recreation Index (LAURI)

Many lake monitoring programs use Carlson's TSI to track the environmental health of a lake. The TSI index is not intuitive or readily understandable to the general public. Additionally, TSI does not measure recreational access issues.

In 2004, the MPRB worked with Barr Engineering Company with funding from Minneapolis Public Works to develop the Lake Aesthetic and User Recreation Index (LAURI). The intent of the new index was to give recreational users an easily understandable and graphical source of information about conditions affecting their use of city lakes. The two major constraints in developing the indices were that they were to be collected by existing water quality staff and within the existing budget.

In 2009, the LAURI was further refined to give a more accurate, and more science-based indicator for the public. The scoring for the aesthetic consideration portion of the LAURI was further refined in 2017 to better reflect the experience at a lake when trash is present. The revised LAURI has five indices:

1. Aesthetic Considerations (color of the water, odor of the water, and garbage/debris)
2. Water Clarity (Secchi depth)
3. Public Health (*E. coli* measured at public swimming beaches)
4. Habitat Quality (aquatic plant and fish diversity)
5. Recreational Access (availability and ease of public access)

Data for the LAURI analysis is collected during regular lake monitoring activities and once a month during beach monitoring trips during the growing season from May to September. For each of the five indices, the LAURI calculates a value that is then categorized as poor (≤3), good (3<x<7), or excellent (≥7).

The LAURI has proven to be useful to users of the Minneapolis park system. Someone interested in walking or biking around a lake may use only the aesthetic score. A swimmer may compare lakes based on the public health, aesthetic, and water quality scores. A sailor or kayak user may be primarily concerned with the recreational access score.

Aesthetic Considerations Index

The lakes are scored for water color, odor, and debris based on an assessment done from shore, dock, or boat, see **Table 1-6**. Lower numbers indicate worse aesthetics. Originally, individual color, odor, and debris scores were averaged over the season. The final aesthetic score was an average of the three individual scores. Aesthetics can be difficult to evaluate as they are strongly qualitative and dependent on individual experience. The scoring for the aesthetic index was refined in 2017 to use the lowest of the three scores, rather than an average of the three. This change was made based on feedback from lake users to better represent the impact of trash on lake aesthetics.

Table 1-6. Scoring for the aesthetic portion of LAURI.

Color	Score
Clear	10
Light brown or green	8
Bright green	5
Milky white	4
Brown, reddish, or purple	2
Gray or black	0

Odor	Score
None/Natural	10
Musty – faint	8
Musty – faint	6
Sewage, fishy, or garbage – faint	5
Sewage, fishy, or garbage – strong	2
Anaerobic or septic	0

Debris	Score
None	10
Natural	9
Foam	8
Piles of milfoil (>3)	7
Fixed trash (>3)	4
Floating trash (>3)	3
Dead fish (>5)	2
Green scum	2
Oil film	1
Sewage solids	0

Water Clarity Index

Water clarity is easy to measure and to understand. This simple measure is a good integrator of various factors affecting the eutrophication status of a lake. The lakes are separated into deep lakes and shallow lakes using criteria developed by the MPCA. A shallow lake is defined as 80% littoral (< 15 feet deep). Bde Maka Ska, Cedar, Harriet, and Wirth are considered deep lakes. Loring, Isles, Hiawatha, Nokomis, and Powderhorn are considered shallow lakes. Higher scores indicate clearer water. LAURI scoring uses the average Secchi transparency reading from all the data collected during the growing season (May-September; **Table 1-7**).

Table 1-7. Scoring for the water quality portion of LAURI.

Secchi Depth (m)	Deep Lake Score	Shallow Lake Score
0 – 0.5	1	2
0.6 – 1	2	4
1.1 – 1.5	3	6
1.6 – 2.0	4	8
2.1 – 2.5	5	10
2.6 – 3	6	10
3.1 – 3.5	7	10
3.6 – 4.0	8	10
4.1 – 4.5	9	10
>4.6	10	10

Public Health Index

To determine whether a lake meets guidelines for full-body recreational contact for people the existing beach monitoring program data were used. *E. coli*, the indicator recommended by the Environmental Protection Agency (EPA), was measured at every public beach in the park system. Beaches are located on Bde Maka Ska, Cedar, Harriet, Hiawatha, Nokomis, and Wirth Lakes. The scoring used the season long geometric mean from the beach monitoring program for each lake, see **Table 1-8**. At lakes with more than one beach, beaches were averaged together. This metric was chosen because EPA and Minnesota guidelines state that beaches should not exceed a geometric mean of 126 organisms per 100 mL during a 30-day time period. Lower numbers of organisms indicate less risk of illnesses for lake users. The scoring for the public health index was refined in 2019 to address the possibility of an *E. coli* outbreak that may not show up in the regular monitoring data.

Table 1-8. Scoring for the public health portion of LAURI. The geometric mean of *E. coli* concentrations for the year is used to determine the score. If more than one beach is present at a lake, the average of the geometric means is used.

E. coli **bacteria (MPN/100 mL)**	**Score**
<2 (Not Detected)	10
2 – 10	9
11 – 20	8
21 – 35	7
36 – 50	6
51 – 65	5
66 – 80	4
81 – 100	3
101 – 125	2
>126	1

Habitat Quality Index

LAURI assessments of habitat quality are determined by the most recent survey information. Macrophyte surveys were conducted by MPRB staff and scoring is based on presence of aquatic plants (macrophytes), density of plants, and amount of coverage, see **Table 1-9**. The more aquatic plants are observed, the higher the habitat quality index was scored. Fish surveys were conducted by MNDNR and points are awarded for diverse fish populations. The score from the aquatic plant and fish surveys are averaged for the LAURI.

Table 1-9. Scoring for the habitat portion of LAURI.

Macrophyte Species	**Score**	**Density**	**Score**	**Coverage > 15 ft**	**Score**	**# Fish species**	**Score**
0	0	Low	0	0 – 25%	2	≤6	2
1 – 2	3	Low-Medium	3	25 – 50%	4	7 – 8	4
2 – 4	6	Medium	6	50 – 75%	7	9 – 11	6
5 – 6	8	Medium-High	8	75 – 100%	10	12 – 14	8
>6	10	High	10			≥15	10

Recreational Access Index

The lakes are also scored for the quantity of recreational access points to the water. The recreational score considers the number of fishing docks or stones, beaches, boat launches, intra-lake connections, canoe racks, boat rentals, picnic areas, boardwalks, and concessions at a lake, see **Table 1-10**. While aquatic plants are a necessary part of a healthy lake ecosystem, they can also interfere with recreational uses of the lake; therefore, lakes also receive points for aquatic plant management.

Table 1-10. Scoring for the recreational access portion of LAURI. The number of fishing docks or stones, beaches, boat launches, intra lake connections, canoe racks, boat rentals, picnic areas, boardwalks, and concessions at a lake are added up. An additional four points are added to the score if the lake has an aquatic plant management program.

Total number of recreational opportunities + aquatic plant management	Score
0	1
1	2
2	3
3	4
4	5
5	6
6	7
7 – 8	8
9 – 10	9
>10	10

Winter Ice Cover

An important climatological statistic to track over time is the date that a lake freezes in the fall and the date it thaws in the spring. Ice phenology affects regional scale ecology like the migration and breeding patterns of birds, as well as in-lake ecology. Length of ice cover in our region is affected by local weather patterns as well as changes in regional and global cycles. Ice cover on Minnesota lakes has declined an average of 10-14 days over the past 50 years. Shorter seasons of ice cover negatively impact water quality by providing a longer growing season for algal blooms, potential for increased densities of aquatic invasive plants, altered lake evaporation rates that impact lake levels, increased fish kills, disruption to lake turnover and stratification, and higher phosphorus concentrations (MPCA, 2021). Ice-off and ice-on dates are given in the individual lake chapters and a comparison among lakes can be found in **Chapter 17**. Ice-off and ice-on dates are reported to the MPCA and MNDNR to include in their statewide long-term ice record.

Some caution must be used when interpreting the historical data. Over the years many different people have been responsible for writing down the dates and ice dates can be somewhat subjective with people using different observation techniques. Since 2000, the MPRB has been using the definition of ice-on as occurring when the lake is 100% covered with ice, preferably monitoring in the afternoon when ice may break up on a sunny day. Ice-off occurs when the lake is essentially ice free, when the lake is less than 10% covered with ice.

Aquatic Plants

Aquatic plants, or macrophytes, form the foundation of a healthy lake ecosystem. They provide important habitat for insect larvae, snails, and other invertebrates which are food sources for fish, frogs, turtles, and birds. Aquatic plants also provide shelter for fish and food for waterfowl. Therefore, the health of a lake depends upon having a healthy plant community. MPRB assesses macrophyte communities in the Minneapolis lakes on a rotating basis. Bde Maka Ska, Cedar, Harriet, Isles, Nokomis, and Wirth Lakes were visually assessed with a meander survey in September of 2021.

Lakes with macrophytes are usually clearer than lakes without macrophytes. Plant roots stabilize sediments and shorelines and prevent the suspension of sediments, from wind or fish, that would otherwise result in turbid or murky waters. Aquatic plant growth produces oxygen and uses nutrients from the water column and from the sediments which would otherwise be used by algae. Macrophytes add an enormous amount of habitat surface area to lakes providing habitat for microscopic plants and animals to grow and utilize nutrients otherwise available to planktonic algae. Large zooplankton use aquatic plants as a refuge against fish. Lakes with a vegetation-dominated clear state typically have more diverse fish communities and larger numbers and diversity of waterfowl.

Aquatic Plant Management Program

Overgrowth of Eurasian watermilfoil (*Myriophyllum spicatum*) is a recreational access problem in several Minneapolis lakes. From a recreational perspective, milfoil is problematic in that it forms dense floating mats that interfere with boating and swimming. From an ecological standpoint, milfoil can provide vertical structure and habitat for fish; however, it can also be too dense to provide good fish habitat. Eurasian watermilfoil also out-competes native species and may reduce the available habitat for other species.

Currently, no method has been proven to rid lakes of milfoil without non-target effects, but several management methods exist to treat the symptoms of infestation. The MPRB primarily uses mechanical harvesting to control the growth of milfoil in city lakes. Harvesting milfoil is analogous to mowing a lawn. Only the top two meters of the milfoil plants are removed but this temporarily allows for problem-free boating and swimming. Harvesting was completed on Bde Maka Ska, Cedar, Harriet, and Lake of the Isles. SCUBA divers hand pulled aquatic plants, excluding lilies, out of heavily used recreational areas in Lake Nokomis and Wirth Lake. MPRB Staff removed 265 flatbed truck loads of plants in 2022 which is equivalent to 1456 cubic yards of aquatic plant material. See **Chapter 21** and **Chapter 22** for more information on aquatic plant harvesting and aquatic invasive species.

Phytoplankton and Zooplankton Monitoring

Background

Biological parameters are routinely measured as part of a lake's assessment. Phytoplankton (algae) and zooplankton are two of the common biological parameters collected because they are essential to the aquatic food web and influence other aspects of the lake including color and clarity of the water and fish production.

Phytoplankton are microscopic plants that are an integral part of the lake community. Phytoplankton use nutrients in the water and sunlight to grow and are the base of the aquatic food web. Chlorophyll-*a* is the primary photosynthetic pigment contained in algae. Chlorophyll-*a* concentration can be easily measured in a water sample and is a common way to estimate the phytoplankton biomass in the water (Paerl, 1998).

Zooplankton are tiny animals that feed on phytoplankton and other zooplankton. They are vital to the lake community and form the second level in the food web. Rotifers and arthropods are the two most commonly found zooplankton in Minneapolis lakes. Rotifers are smaller in size but are of great importance in the aquatic food web because of their abundance, distribution, and wide range of feeding habits. Copepods and cladocerans are larger arthropods and members of the class Crustacea.

Copepods are the most diverse group of crustaceans. A cladoceran genus, *Daphnia*, is known as the common water flea and is a very well-known zooplankton.

Methods

Phytoplankton

Phytoplankton samples were collected twice a month from most of the monitored lakes (Bde Maka Ska, Cedar, Diamond, Harriet, Hiawatha, Isles, Loring, Nokomis, Powderhorn, and Wirth) except for February, April, and October which were sampled once per month. Samples were collected once a month at Brownie Lake and Grass Lake. Surface water composite samples were collected for phytoplankton using a 2-m long, stoppered 2-inch diameter PVC tube. Two such samples were mixed in a clean white plastic bucket. Water from this mixed sample was decanted into dark plastic 250mL bottles, preserved with 25% glutaraldehyde preservative, and stored at room temperature until shipped to PhycoTech Incorporated laboratory for analysis. Analysis was completed using a modified version of the phytoplankton rapid assessment count developed by Edward Swain and Carolyn Dindorf of the MPCA. This method involves a sub-sample being placed in a counting chamber and analyzed using an inverted microscope. The algal division, taxa, genus, and species are identified and the percent abundance by volume is estimated. The results are presented by division (phylum) in the individual lake chapters. Common phytoplankton divisions and a common description are given in **Table 1-11**. Chlorophyll-*a* concentrations were used to estimate phytoplankton biomass in the lakes. Each lake chapter shows chlorophyll-*a* concentrations and the distribution of phytoplankton divisions throughout the sampling season.

Table 1-11. Phytoplankton divisions and brief descriptions.

Division	Description
Bacillariophyta	Diatoms: a single-celled organism with a silica cell wall that use photosynthesis.
Chlorophyta	Green algae: photosynthetic algae which contain chlorophyll and store starch in discrete chloroplasts.
Chrysophyta	Golden-brown algae: contain chlorophyll and carotenoids and some species have cell walls composed of cellulose with large amounts of silica, while others have no cell walls.
Cryptophyta	Cryptomonads: unicellular algae, no cell wall, most species are photosynthetic while others are heterotrophic.
Cyanophyta	Cyanobacteria or Blue-green algae: photosynthetic bacteria, carry out oxygenic photosynthesis (water-oxidizing, oxygen-evolving, plank-like photosynthesis), some species carry out nitrogen fixation, often blue-green in color, have the ability to produce toxins. See **Chapter 19** for more information.
Euglenophyta	Euglenoids: unicellular flagellates, photosynthetic or heterotrophic, have distinctive cell walls composed of spiral strips called "pellicles" giving them a flexible body.
Haptophyta	Haptophytes: planktonic mixotrophs, have a unique organelle called a haptonema that assists with food gathering.
Pyrrophyta	Dinoflagellates: motile unicellular algae characterized by a pair of flagella, species contain chlorophyll, carotenoid, or are bioluminescent, commonly known for causing "red tides" in oceans.
Xanthophyta	Yellow-green algae: photosynthetic, generally not abundant, contain chlorophyll-*c* giving them the yellow-green color.

Zooplankton

Zooplankton samples were collected monthly from most Minneapolis lakes, see **Table 1-1.** Diamond and Grass Lakes were not sampled because of shallow depth and Brownie Lake was not sampled due to lower zooplankton densities compared to other Minneapolis lakes in previous years. Samples were collected using an 80-µm plankton net with an 11.7 cm diameter opening and a Wisconsin-type bucket. The net was raised from approximately one meter above the bottom to the surface at a rate of one meter per second. The captured zooplankton were rinsed into a bottle using a 70% denatured histological ethanol to a mix of approximately 70% ethanol and 30% sample. The distance the net was pulled through the water column (tow depth) was recorded on field sheets and on the bottle label. Zooplankton were identified at PhycoTech Inc. as completely as possible by class, subclass, order, suborder, family, genus, species, and subspecies. The zooplankton results were divided into groups for presentation as shown in **Table 1-12**. Results are presented in the individual lake chapters.

Table 1-12. Major zooplankton groups and brief descriptions.

Major Groups	Description
Calanoid	Phylum Arthropoda. Type of copepod. Generally herbivorous.
Cladoceran	Phylum Arthropoda. Eats algae. Commonly called the water flea.
Cyclopoid	Phylum Arthropoda. Type of copepod. Many are carnivorous.
Macroinvertebrate	Phylum Mollusca. Organisms that lack a spine and large enough to see without the aid of a microscope.
Protozoan	Single celled organisms. Many are shelled amoeba.
Rotifer	Known as the wheel animals. Eat particles up to 10 µm.

FISH STOCKING

Many of the lakes in Minneapolis are stocked with fish by the MNDNR. This information is on the MNDNR LakeFinder website (http://www.dnr.state.mn.us/lakefind/index.html).

Stocking Fish Sizes:

- Fry - Newly hatched fish. Walleye fry are 1/3 of an inch or around 8 mm.
- Fingerling - Fingerlings are one to six months old and range in size from one to twelve inches.
- Yearling - Yearling fish are at least one year old and can range from three to twenty inches.
- Adult - Adult fish that have reached maturity age.

FISH KILLS

Many of the summer fish kills in Minneapolis lakes are attributed to *columnaris* disease. The naturally occurring *Flexibacter columnaris* bacteria cause the disease. This disease is usually associated with a stress condition such as high water temperature, low dissolved oxygen concentration, crowding, or handling. Symptoms in fish include: grayish-white lesions on parts of the head, fins, gills, or body usually surrounded by an area with a reddish tinge. On crappies, the lesions are generally confined to the fins and gills and rarely extend to the body.

Columnaris is known to only infect fish species and is not a health risk to humans. The bacteria are most prevalent in lakes when water temperatures approach 65-70 degrees F from late May to late June. *Columnaris* levels can increase after a major rainfall and runoff which supply additional nutrients to area lakes. Bluegill, crappie, yellow perch, and bullhead fish species are most affected by the disease. The *columnaris* disease causes erosion of the fishes' skin leading to leakage of the bodily fluids and an influx of lake water into the fishes' body. There is little that the MNDNR or the public can do to prevent this naturally occurring phenomenon.

Fish kills in Minneapolis lakes can occasionally be attributed to carp edema virus (CEV), often known as koi sleepy disease (KSD). CEV is a double-stranded DNA virus thought to belong to the poxvirus family (*Poxviridae*) and is likely spread by diseased fish shedding the virus from gill and skin lesions. The virus was first detected in the United States in 2017 at Cottonwood Lake in Minnesota and has since been emerging as a common cause of carp die offs.

CEV typically occurs in the spring during the rainy season, when water temperatures are between 43-50 degrees F, and are associated with stress of capture. The virus only infects common carp and ornamental koi (*Cyprinus carpio*) and is not harmful to humans. Symptoms in fish include unresponsive and lethargic, motionless on side or belly, sunken eyes, pale swollen gills, and skin lesions with swelling of the underlying tissue. The severity of the virus is greatest in juveniles, while adult fish may lie motionless on the bottom. There is little that the MNDNR or the public can do to prevent this naturally occurring phenomenon.

Winter fish kills on lakes are often due to thick ice and snow cover leading to low dissolved oxygen conditions in the water below. Usually, small lakes and ponds are most affected by winter fish kills. The MPRB reports all fish kills to the MDNR via the State Duty Officer reporting system.

Emerging Contaminants

"Emerging Contaminants", or "Contaminants of Emerging Concern", is a broad term for contaminants whose effect on the environment and human health are not yet fully understood, and official regulations have not been set (MPCA, "Understanding Emerging Contaminants") Emerging contaminants can include chemicals such as those found in pharmaceuticals, personal care products, household products, agriculture, and industry, which are released into the environment and often accumulate in lakes and streams. These pollutants can reach waterbodies via direct contamination from a source, or by the accumulation of contaminants from multiple minor sources over time.

Per- and polyfluoroalkyl substances (PFAS) are a class of over 5,000 chemicals that have been produced for many commercial and industrial uses since the 1940s (MPCA, "PFAS"). PFAS are known as "forever chemicals" due to their extreme resistance to breakdown by chemical or biological processes. PFAS are known to bioaccumulate and are present in the blood serum of nearly every American. People can be exposed to PFAS from a variety of sources, including food, household products, and drinking water. Long-term PFAS exposure has been associated with adverse human health effects, including immune suppression, liver function changes, low birth weight, and some cancers. Recreation such as swimming is not considered high risk for PFAS exposure (MPCA, 2020). The Minnesota Department of Health (MDH) webpage on PFAS and Health has more information on PFAS health hazards and exposure mitigation, see https://www.health.state.mn.us/communities/environment/hazardous/topics/pfashealth.html. For comparison of PFAS in MPRB lakes, see **Chapter 17**.

The 3M and DuPont corporations started producing PFAS in Minnesota in the 1950s. 3M stopped production in 2000, and DuPont ceased production in 2015. Improper disposal of PFAS-containing waste led to significant environmental pollution and contamination of drinking water in the Eastern Twin Cities metro. The state of Minnesota sued 3M in 2010 for damage to drinking water and natural resources in the southeast Twin Cities metro and reached a settlement in 2018, wherein 3M agreed to pay $850 million to offset the costs of environmental cleanup and drinking water restoration. The Minnesota PFAS Blueprint develops short- and long-term goals, as well as legislative actions, to manage PFAS in the environment, see https://www.pca.state.mn.us/air-water-land-climate/minnesotas-pfas-blueprint.

Perfluorooctane sulfonate (PFOS) is a type of PFAS that is of highest concern related to lake health and fish consumption. PFOS bioaccumulates and is toxic to aquatic organisms. PFOS concentrations in fish tissue have been measured up to 7,000 times the PFOS concentrations of the source water. In 2004, PFOS was first detected in Bde Maka Ska, and later traced to contamination via stormwater from a chrome plating facility in St. Louis Park. Bde Maka Ska, Lake Harriet, and Lake of the Isles are on the MPCA's list of impaired waters (303(d) list) for high concentrations of PFOS in fish tissue. The current threshold for listing is a PFOS in fish tissue concentration of 50 ng/g (MPCA, 2022-b). Site-specific criteria have been set for Bde Maka Ska, which take the place of this threshold, see **Chapter 2**.

MDH posts guidelines on statewide fish consumption, as well as Waterbody Specific Safe-Eating Guidelines, see https://www.health.state.mn.us/communities/environment/fish/index.html. Cedar Lake and Lake Hiawatha are not listed as impaired for PFOS but do have Waterbody Specific Safe-Eating Guidelines. For more information on PFAS in Minneapolis lakes see individual lake chapters: **Chapter 2** for Bde Maka Ska, **Chapter 5** for Cedar Lake, **Chapter 8** for Lake Harriet, **Chapter 9** for Lake Hiawatha, and **Chapter 10** for Lake of the Isles.

Perfluorooctanoic acid (PFOA) is another type of PFAS in the environment that is connected to potential human health effects, including kidney cancer. Production of PFOA has been phased out in the United States, and human blood PFOA concentrations in the United States seem to be declining (MDH, 2022). PFOA is detectable in MPRB lakes, but concentrations are much lower than levels of concern for exposure during recreation.

Polychlorinated biphenyls (PCBs) are a class of 209 types of chemicals that were produced in the United States from 1929 until 1979, when they were banned by the Toxic Substances Control Act (US EPA, 2023). PCBs are resistant to degradation, easily move through the environment, and bioaccumulate in plants, fish, and other organisms. PCBs are widely studied and are associated with a variety of adverse human health effects, including cancers and effects to the immune, neurological, reproductive, and endocrine systems. Lake Nokomis is on the MPCA's list of impaired waters (303(d) list) for concentrations of PCBs in fish tissue, see **Chapter 12** for more information.

QUALITY ASSURANCE/QUALITY CONTROL

The contract laboratory Instrumental Research Inc. analyzed blanks and appropriate standards with each set of field samples. Both stormwater and lake equipment blanks were analyzed to detect any equipment contamination. In addition, field duplicate samples were analyzed each lake sampling trip (weekly) and blind laboratory performance standards were analyzed every month sampling occurred. Field blanks were done every sampling trip. Ideally, lake laboratory split samples are analyzed twice a year between a minimum of three labs, which was done in 2022.

Calibration blanks, reagent blanks, quality control samples, laboratory duplicate samples, and matrix spike/duplicate samples were analyzed at a 10% frequency by the contract laboratory. The quality control samples analyzed by the laboratory consisted of two sets:

- Samples of known concentration (control standards) that served as an independent verification of the calibration standards and as a quality control check for the analytical run and

- Blind monthly samples (of unknown concentration) provided by the MPRB Environmental Operations staff.

For more details and QA/QC results for 2022, see the Quality Assurance Assessment Report in **Chapter 31**.

2. Bde Maka Ska

History

Bde Maka Ska and the adjacent property were acquired by Minneapolis Park and Recreation Board (MPRB) between 1883 and 1907, **Figure 2-1**. Bde Maka Ska is part of the Chain of Lakes, which also includes Brownie, Cedar, Isles, and Harriet. The lake formerly known as Mde Medoza (Lake of the Loons) and Bde Maka Ska (White Earth Lake) was renamed after John Caldwell Calhoun after he established a military post at Fort Snelling while Secretary of War under President Monroe. In 2015, the Dakota name for the lake, Bde Maka Ska, was added to signs around the lake to honor the Dakota people and educate the public about the lake's Dakota name. In 2018 the name of the lake was officially changed back to Bde Maka Ska. Similar to the other lakes in the Minneapolis Chain of Lakes, Bde Maka Ska was dredged, and 35 acres of surrounding wetland areas were filled in the early part of the 20th century. Nearly 1.5 million cubic yards of soil were placed on the shoreline between 1911 and 1924. A water connection between Lake of the Isles and Bde Maka Ska was created in 1911 after the MRPB received numerous requests and petitions to join the lakes. A connection between Bde Maka Ska and Lake Harriet was pondered but was never implemented due to a seven-foot elevation difference between the lakes (Smith, 2008).

Figure 2-1. View of Bde Maka Ska in July 2022.

The Minneapolis Chain of Lakes Regional Park is the most visited park in the State of Minnesota with over 7.5 million user visits in 2022 (Met Council, 2023). Bde Maka Ska is the largest lake in the Minneapolis Chain of Lakes, and is a deep, dimictic, glacial kettle lake that typically remains stratified until late October. **Table 2-1** contains the physical characteristics and morphometric data for Bde Maka Ska and **Figure 2-2** shows the bathymetric map of the lake. Bde Maka Ska is part of Minnehaha Creek Watershed. The primary land-use is residential and mixed-use with Lyndale and Hennepin Avenue nearby. Runoff from the Minikahda Golf Course also drains into the lake. The construction and connection of stormsewers to Bde Maka Ska between 1910 and 1940 is thought to have had negative impact on water quality. There are a total of 28 stormwater outfalls in Bde Maka Ska, see **Appendix C**.

Bde Maka Ska receives water from Lake of the Isles through an open channel and discharges water by gravity flow through a weir, open channel, and pipe to Lake Harriet. In the 1950s, low water levels at 2.5 feet below average led to additional dredging in the channel between Bde Maka Ska and Lake of the Isles. A pumping station and pipeline were installed at Bassett Creek in 1957 to pump water into Brownie Lake to increase the lake level in the Chain of Lakes, but water levels remained low. Another pumping station and pipeline were installed in 1960 to pump water from the Mississippi River to Basset Creek and from there to Brownie Lake, which continued intermittently until the 1990s. In 1967, a pipeline and pumping station were constructed between Bde Maka Ska and Lake Harriet to help regulate water elevations in the Chain of Lakes. Between 1999 and 2001, the outlet was partially daylighted and converted to a gravity-flow connection.

Several studies performed in the 20th century found that water quality in Bde Maka Ska had degraded with human activity. A study by Klak (1933) showed that cyanobacteria were dominant by the early 1930s in Bde Maka Ska, indicating possible nutrient enrichment. Works Progress Administration built shoreline protection walls along the east shoreline in 1940 to prevent erosion. Research by Shapiro and Pfannkuch (1973) found that phosphorus levels in the sediment were about 80% higher than they had been in the prior 80 – 90 years. Total phosphorus (TP) in the water column had also increased to 50 – 60 µg/L by the 1970s from pre-industrial levels of between 16 – 19 µg/L (Brugam and Speziale, 1983). The increases in sediment and water column phosphorus appear to be due to European settlement and land clearing for agriculture in the watershed. The water pumped into the Chain of Lakes from the Mississippi River also contained high levels of phosphates.

Water quality restoration projects throughout the 1990s and early 2000s have improved water quality in Bde Maka Ska. A detailed Clean Water Partnership (CWP) diagnostic study conducted in 1991 determined that phosphorus input to the Chain of Lakes should be reduced to improve water quality. Best management practices (BMPs) were then implemented for Bde Maka Ska and included: public education, increased street sweeping, improved stormwater treatment including constructed wetlands (1999), grit chambers (1995, 1998, 1999), and an aluminum sulfate (alum) treatment to limit internal loading of phosphorus (2001). Current data analysis confirms that the BMPs are having a positive effect and that water quality in Bde Maka Ska is at, or even slightly better than historic conditions. For example, Bde Maka Ska's observed TP is similar to the TP level from 1750 and 1800 based on diatom reconstruction from sediment cores (Heiskary et al., 2004); however, diatom reconstruction data may not be accurate because there could be several non-planktonic diatoms in the sediment that are more sensitive to changes in habitat availability than to phosphorus (Sayer, 2001). **Appendix A** shows total phosphorus concentrations since 1991. Total phosphorus concentrations are shown to decrease and become less variable potentially due to the alum treatment performed on the lake in 2001.

In September 2018, two zebra mussels were found on a sailboat exiting Bde Maka Ska by a MPRB Watercraft Inspector. The Minnesota Department of Natural Resources (MNDNR) confirmed the find and added Bde Maka Ska to the Infested Waters List for zebra mussels. No additional zebra mussels have been discovered in the lake since 2018, see **Chapter 22** for additional details.

Water quality on Bde Maka Ska has been monitored by MPRB annually since 1991.

Table 2-1. Bde Maka Ska physical characteristics and morphometric data.

Surface Area (acres)	Mean Depth (ft)	Max Depth (ft)	Littoral Area*	Volume (ft^3)	Watershed Area (acres)	Watershed: Lake Area (ratio)	Residence Time (years)
419	30.0	82.0	29%	$6.36x10^8$	2,992	7.1	4.2

* Littoral area was defined as less than 15 feet deep.

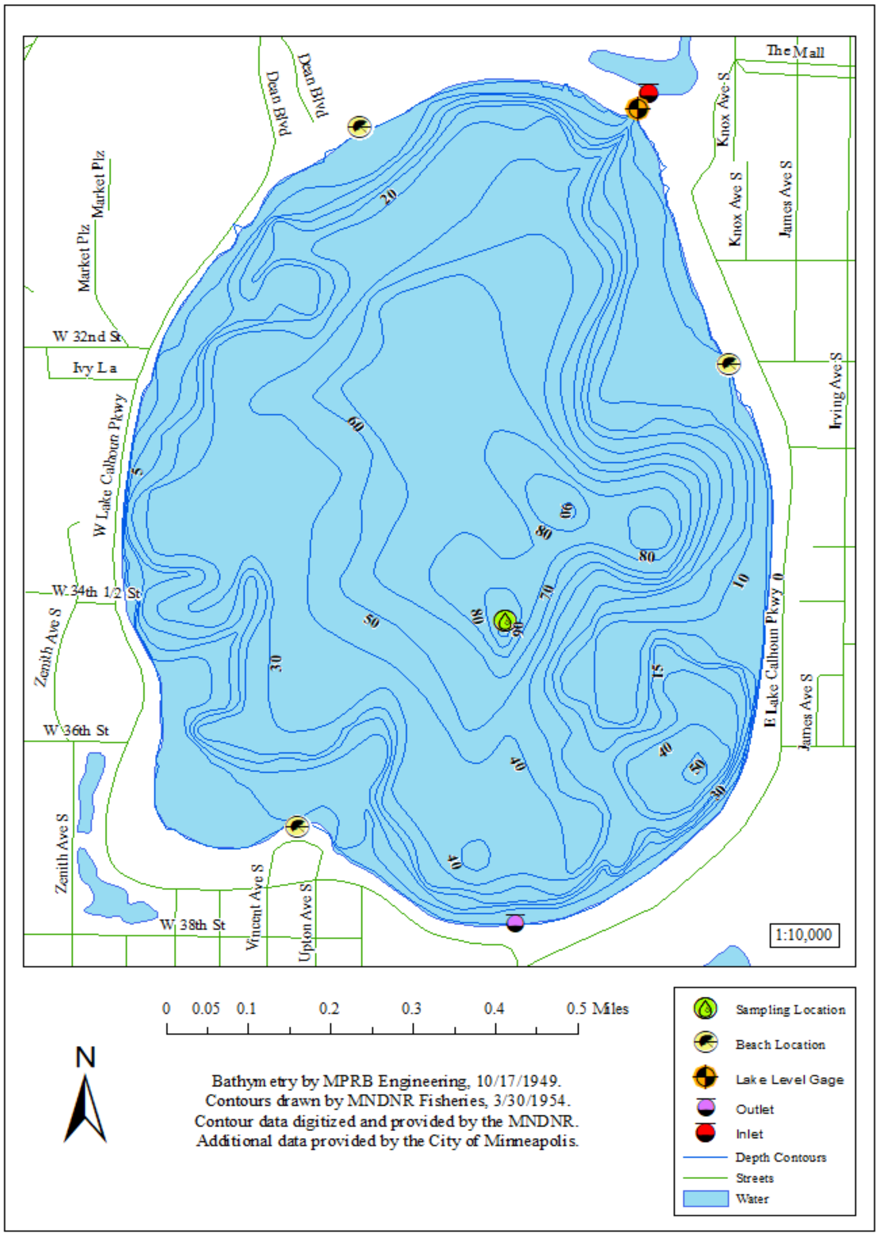


Figure 2-2. Bathymetric map with mid-lake sampling site, beach, lake level gage, outlet, and inlet locations at Bde Maka Ska.

Lake Level

The Upper Chain of Lakes are made up of four lakes, Brownie, Cedar, Lake of the Isles, and Bde Maka Ska, all connected by channels. Lake levels for each of the four lakes are measured at a lake gage in the channel between Bde Maka Ska and Lake of the Isles. The designated Ordinary High Water Level (OHWL), determined by the Minnesota Department of Natural Resources (MNDNR), for Bde Maka Ska is 853 feet above mean sea level (msl). The outlet elevation for Bde Maka Ska is 851.85 ft. msl. Lake levels for the Upper Chain of Lakes are shown in **Figure 2-3**. Lake levels in the Upper Chain of Lakes remained below the OHWL for the entire year in 2022. Lake levels were highest in May after snowmelt, then declined throughout the summer and were lowest in early August. Levels rose slightly throughout August, then declined again in September until snowfall began to raise the level in November, freezing at 1.05 ft. msl below the OHWL in December. See **Chapter 1** for details on lake level monitoring and **Chapter 17** for a comparison with other lakes.

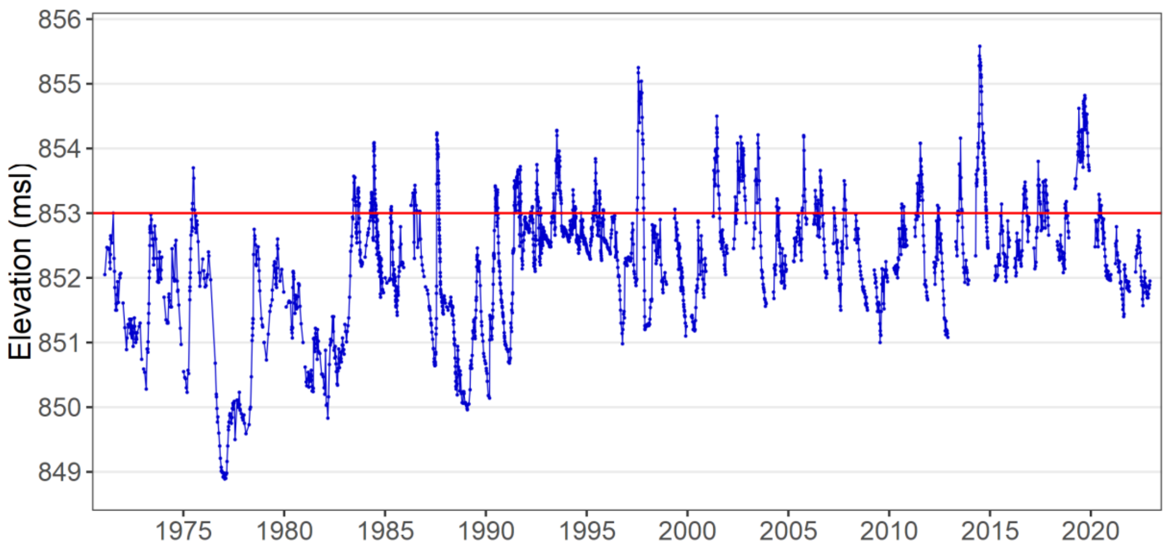


Figure 2-3. Lake levels for the Minneapolis Upper Chain of Lakes (Brownie, Cedar, Isles and Bde Maka Ska) from 1971 to 2022. Horizontal line represents the Ordinary High Water Level (853 ft msl) for Bde Maka Ska.

Water Quality Trends – Trophic State Index (TSI)

Figure 2-4 shows historical Bde Maka Ska TSI scores and trend line. There has been a significant decrease in TSI since 1991 ($p < 0.05$). This decrease has followed multiple rehabilitation efforts since 1995. The TSI score for Bde Maka Ska in 2022 was 45. The lake is now mesotrophic having moderately clear water and increasing probability of hypolimnetic anoxia during summer.

The TSI score is lower (better) than the early 1990s, before the lake and watershed improvement projects from the CWP; however, TSI scores have been slowly increasing since 2005. The CWP Minneapolis Chain of

Lakes Project developed a long-term TSI goal for Bde Maka Ska of below 51 that was intended to be met within five to ten years of water quality project completion. The TSI score has met the CWP goal every year since the goal was established in 1993.

Secchi and chlorophyll-*a* TSI scores for Bde Maka Ska are within the expected TSI range for lakes in the same ecoregion, see **Table 2-2**. The total phosphorus TSI score is below the TSI range for the ecoregion, meaning the phosphorus levels in Bde Maka Ska are lower than in comparable lakes. See Minnesota Pollution Control Agency (MPCA) Surface Water Data (https://webapp.pca.state.mn.us/wqd/surface-water/waterunit-details?wid=27-0031-00) for more information. A detailed explanation of TSI can be found in **Chapter 1**.

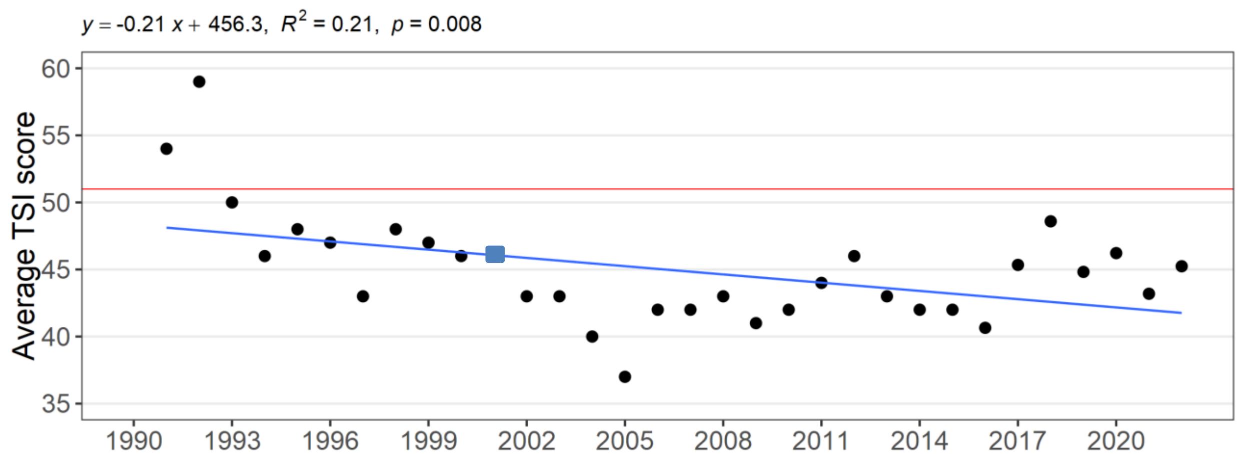


Figure 2-4. Bde Maka Ska TSI scores and linear regression from 1991-2022. The red line represents the CWP long-term TSI goal of below 51. The blue square highlights the 2001 alum treatment.

Table 2-2. Bde Maka Ska Secchi, chlorophyll-*a*, and total phosphorus TSI based on data collected between June and September of 2022 and compared to lakes in the North Central Hardwood Forest ecoregion.

	TSI	Expected TSI Range of Lakes in the Same Ecoregion	Within the Expected TSI Range of Lakes in the Same Ecoregion
Secchi	44	43-54	Within range
Chlorophyll-*a*	48	46-61	Within range
Total Phosphorus	47	49-61	Not within range, better than expected

BOX AND WHISKER PLOTS

The box and whisker plots in **Figure 2-5** show the data distribution for water clarity, chlorophyll-*a*, and total phosphorus for the past 10 years, based on data from the entire sampling season. Red horizontal lines on the graphs indicate the MPCA eutrophication standards for deep lakes, which applies to data collected between June and September. A detailed explanation of box and whisker plots can be found in **Chapter 1**. Box and whisker plots from the entire period of record, 1991-2022, can be found in **Appendix A**.

Water clarity in 2022 was comparable to previous years with an average Secchi depth of 3.7 meters, see **Figure 2-5a**. Chlorophyll-*a* and total phosphorus levels are slightly higher and more variable between 2017 and 2022 compared to previous years. The average chlorophyll-*a* concentration was 5.3 µg/L in 2022, see **Figure 2-5b**. The average total phosphorus concentration was 19 µg/L, see **Figure 2-5c**. The lake met MPCA eutrophication standards in water clarity, chlorophyll-*a*, and total phosphorus in 2022. When comparing the boxplots in **Figure 2-5** to those in **Appendix A**, it appears that the 2001 alum treatment and BMPs in the watershed have had an impact on parameters measured in Bde Maka Ska, indicating an overall water quality improvement.

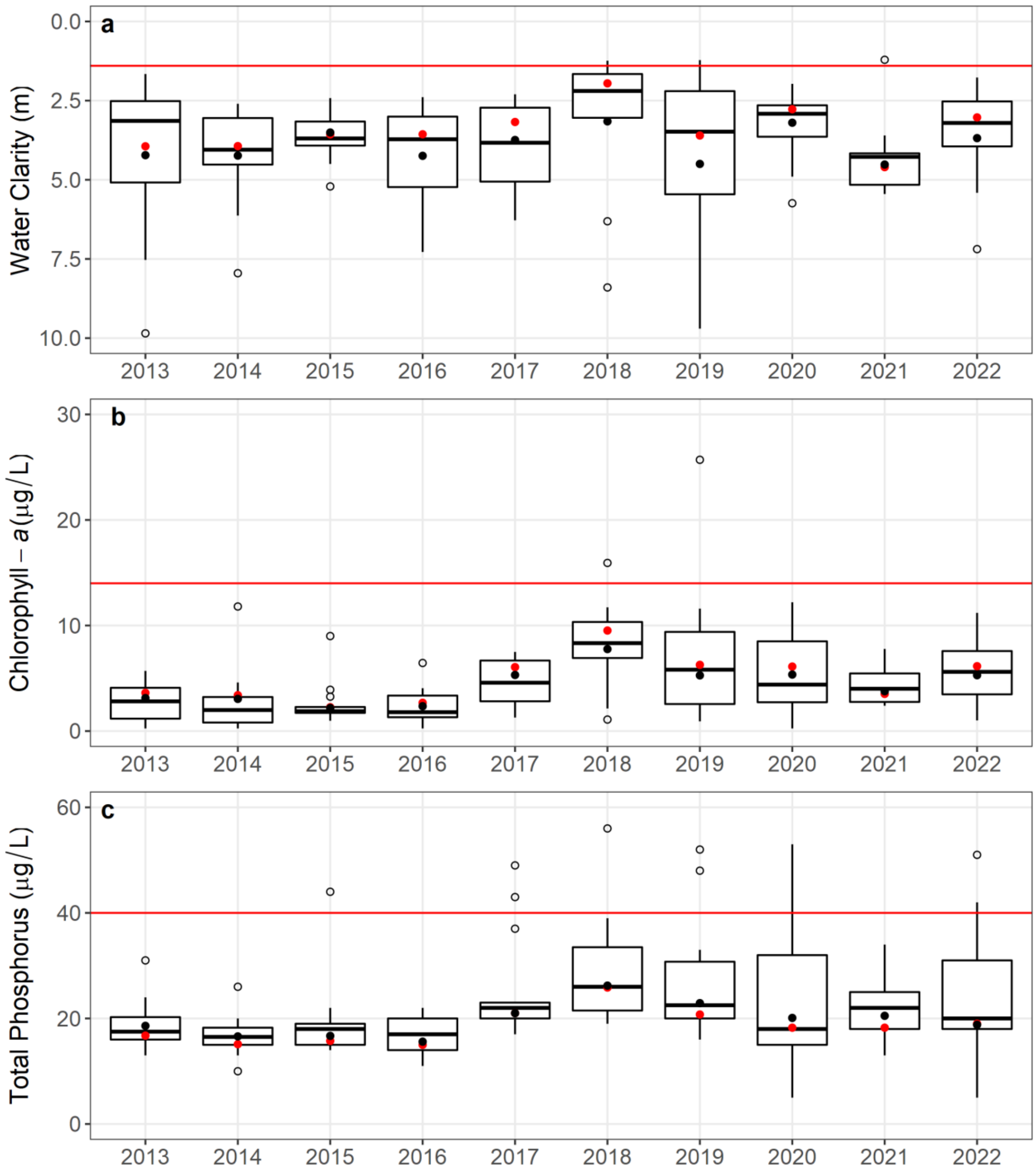


Figure 2-5. Bde Maka Ska box and whisker plots of water clarity (a), chlorophyll-*a* (b), and total phosphorus (c) from 2013-2022. Horizontal lines represent MPCA eutrophication standards for deep lakes, which applies to data collected between June and September. The red circles represent the mean value of data collected between June and September. The black circles represent the mean value of data collected during the growing season, May through September. Data from 1991-2022 can be found in Appendix A.

CHLORIDE

Chloride is a naturally occurring element that is commonly found at low levels in most freshwater bodies. Chloride is a component of road salt (sodium chloride) and is found in other types of compounds that are also called salts (calcium chloride, magnesium chloride). Unnaturally high concentrations of chloride can negatively impact surface waters. High levels of chloride can change the mixing pattern of a lake and lead to very low oxygen levels in deep water. It can also lead to decreasing water clarity, and induce stress or cause death of aquatic species (Bathe & Coring, 2011). Sources of chloride include industrial discharge, septic systems, sewage disposal systems, fertilizers, and road salt (Novotny, Murphy, & Stefan, 2008). The MPCA adopted the Environmental Protection Agency's (EPA) recommended water quality criteria for chloride which is a chronic standard of 230 mg/L and an acute standard of 860 mg/L (MPCA, 2016). The MPRB has monitored chloride concentrations in Bde Maka Ska since 1995 by collecting surface water samples using a composite tube and collecting deep water samples using a Kemmerer sampler. See **Chapter 1** for more information on chloride.

Figure 2-6 shows epilimnetic and hypolimnetic chloride concentrations in Bde Maka Ska between 1995-2022, with hypolimnion samples only collected regularly after 2010. Epilimnion samples represent the top two meters of the lake and hypolimnion samples were collected approximately one meter from the bottom of the lake. Red horizontal lines on the graph indicate the MPCA acute and chronic chloride standards. Also included on the graph, is a dotted line that represents an estimate of a concentration above which potential ecological impact could occur, at 120 mg/L. This level of potential ecological impact was developed by Canadian Council of Ministries of the Environment (CCME) and is not a Minnesota state standard but a long-term chloride concentration that could negatively impact life within the lake (CCME, 2011). Between 2010-2019 chloride concentrations in the hypolimnion were slightly higher than epilimnetic concentrations likely because runoff containing sodium chloride is denser and sinks to the lake bottom; however, between 2020-2022 chloride concentrations in the epilimnion and hypolimnion were roughly comparable. Chloride concentrations have been slowly increasing since 2006; prior to 2006 epilimnetic chloride concentrations measured below the level of ecological impact and after 2010 most samples were above this threshold. According to the Minnesota Statewide Chloride Management Plan, Bde Maka Ska is at high risk for chloride impairment (MPCA, 2018).

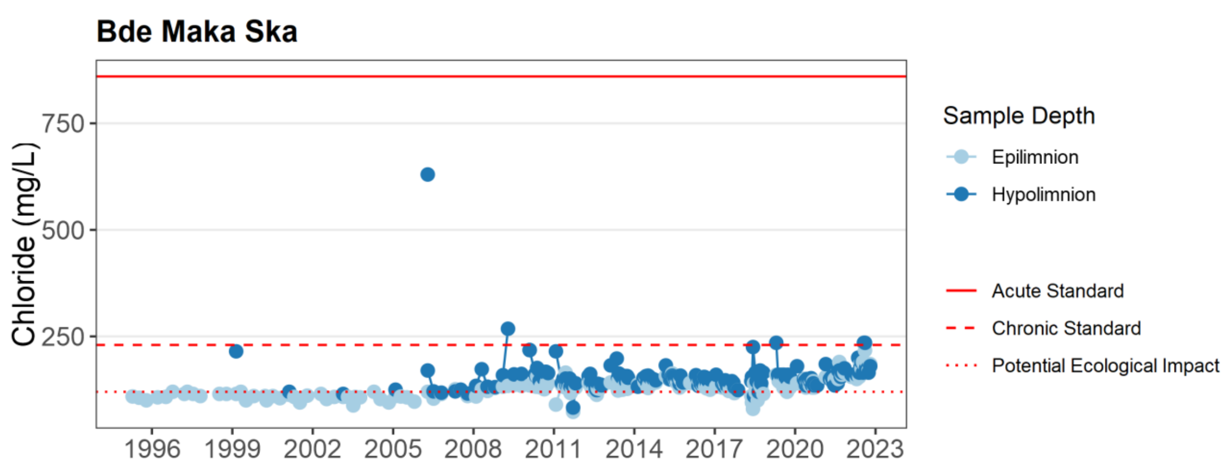


Figure 2-6. Bde Maka Ska scatterplot of epilimnetic and hypolimnetic chloride concentrations between 1995-2022. Horizonal lines represent the MPCA's acute and chronic standard and the potential ecological impact level (CCME, 2011).

BEACH MONITORING

In 2022, bacteria levels were monitored at Bde Maka Ska at three locations: 32nd Street Beach on the east side, Main Beach on the north side, and Thomas Beach on the south side of the lake. As shown in **Table 2-3** and **Figure 2-7**, *Escherichia coli* (*E. coli*) levels remained relatively low at Main Beach while 32nd Street Beach and Thomas Beach had higher *E. coli* concentrations. Both 32nd Street and Thomas Beaches experienced closures during the 2022 sampling season. Stormwater runoff, aquatic vegetation, and waterfowl waste may have contributed to high bacteria levels at these two beaches.

Bde Maka Ska 32nd Street Beach closed July 19th due to an exceedance of the single sample *E. coli* standard of 1,260 MPN/100 mL. The beach was re-sampled on July 20th and re-opened on July 21st after results had shown that *E. coli* concentrations dropped below the single-sample threshold. Bde Maka Ska 32nd Street Beach closed again on August 2nd due to an exceedance of the 30-day geometric mean standard of 126 MPN/100 mL. The beach remained closed until August 16th, when the 30-day geometric mean dropped below the threshold. Bde Maka Ska 32nd Street Beach closed again on August 23rd due to an exceedance of the single sample *E. coli* standard. The beach was re-sampled on August 24th and concentrations dropped below the single-sample threshold; however, the beach remained closed due to high chances of the concentration exceeding the 30-day geometric mean standard the following sampling session. The beach remained closed due to an exceedance of the 30-day geometric mean standard on August 29th and remained closed for the rest of the beach season. High *E. coli* concentrations may have been attributed to aquatic vegetation and waterfowl waste.

Thomas Beach at Bde Maka Ska closed on August 9th due to an exceedance of the 30-day geometric mean standard of 126 MPN/100 mL. High concentrations of bacteria that led to this closure were attributed to excessive goose activity. The beach remained closed until August 16th, when the 30-day geometric mean dropped below the threshold. Bde Maka Ska Thomas Beach closed again on August 30th due to an exceedance of the 30-day geometric mean standard. The beach remained closed for the rest of the beach season. See **Chapter 18** for more information on beaches.

Table 2-3. Summary of *E. coli* (MPN per 100 mL) data for Bde Maka Ska beaches in 2022.

Statistical Calculations	Bde Maka Ska 32nd Beach	Bde Maka Ska Main Beach	Bde Maka Ska Thomas Beach
Number of Samples	15	15	15
Minimum	2	1	1
Maximum	1454	1171	1063
Median	88	25	53
Mean	368	112	214
Geometric Mean	80	26	47
Max 30-Day Geo Mean	317	96	152
Standard Deviation	514	296	349

Figure 2-7 illustrates the trend for *E. coli* levels for the sampling season of 2022. The graphs demonstrate how much of the season was above standard levels. The running 30-day geometric mean directly correlates to single-sample exceedances.

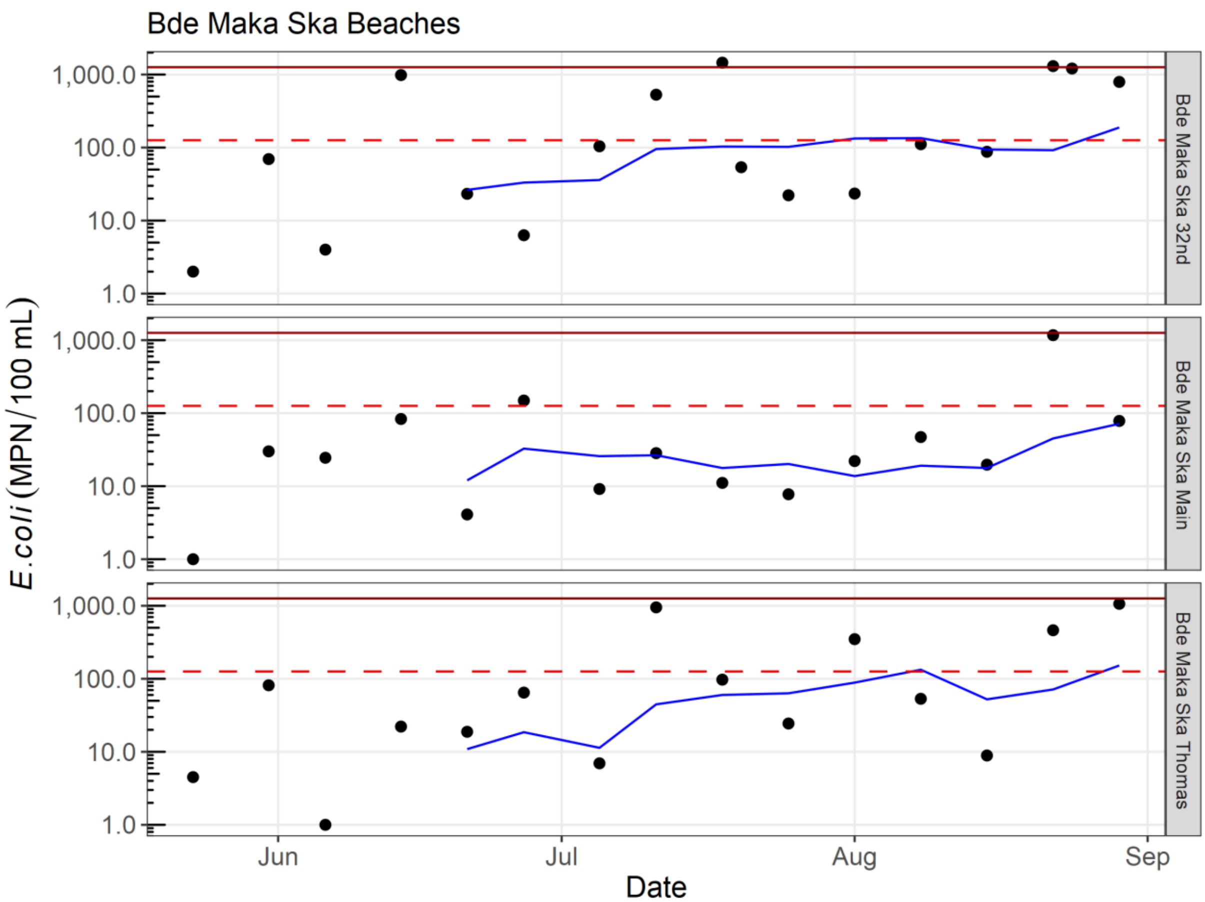


Figure 2-7. 2022 *E. coli* concentrations at Bde Maka Ska beaches. The blue line is the running 30-day geometric mean. The dashed horizontal line represents the *E. coli* standard for the 30-day geometric mean (126 MPN/100mL) and the solid horizontal line represents the single-sample maximum standard (1,260 MPN/100mL). Note the log scale on the Y-axis.

Figure 2-8 shows *E. coli* monitoring data for Bde Maka Ska beaches from 2013 to 2022 which is graphed by using box and whisker plots. The box and whisker plots show the variability in the dataset over the past 10 years with no increasing or decreasing trend in *E. coli* concentrations at all three beaches.

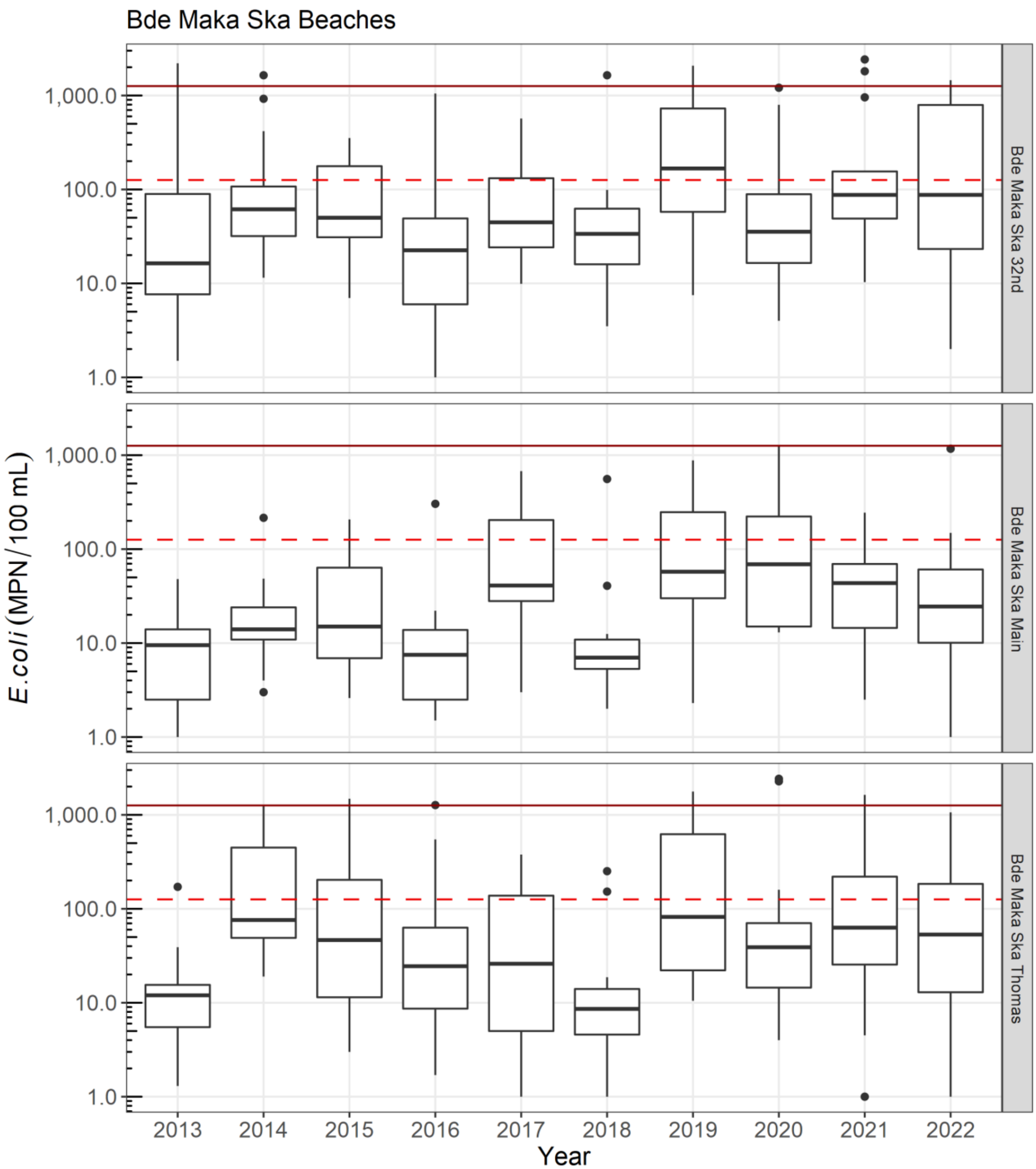


Figure 2-8. Box and whisker plots of *E. coli* concentrations (MPN per 100 mL) for Bde Maka Ska beaches from 2013-2022. The dashed horizontal line represents the *E. coli* standard for the 30-day geometric mean (126 MPN/100mL) and the solid horizontal line represents the single-sample maximum standard (1,260 MPN/100mL). Note the log scale on the Y-axis.

Figure 2-9 shows the total number of days Bde Maka beaches were closed each year due to *E. coli* exceedances for the past 10 years. Thomas Beach closed more often than other beaches between 2014-2016, but 32nd Street Beach had more closures in recent years compared to other beaches. Both of these beaches often experience high waterfowl activity, which can contribute to high *E. coli* levels due to waste. 2019 had the most beach closures at Bde Maka Ska, which may be attributed to increased stormwater runoff and erosion of sand due to the record-high rainfall that year. Bde Maka Ska beaches have closed more often over the past 4 years compared to previous years.

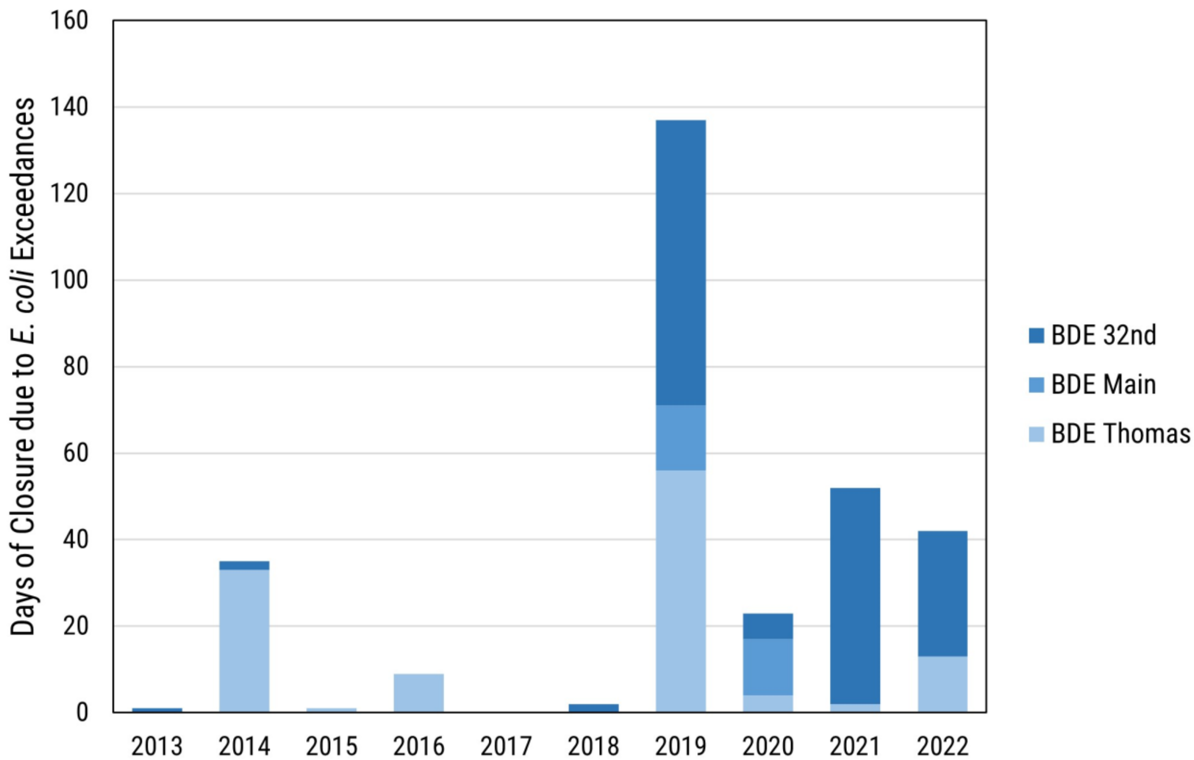


Figure 2-9. Bar graph of total number of days Bde Maka Ska beaches were closed each year due to *E. coli* exceedances from 2013-2022.

Blue-green Algae/Cyanotoxin Monitoring

Blue-green algae are not algae at all, but a type of bacteria called cyanobacteria. These photosynthetic microorganisms occur naturally in lakes, streams, and other waterbodies worldwide. When conditions are right, cyanobacteria can grow quickly to form dense accumulations called blooms. Certain varieties of cyanobacteria can produce toxins, referred to as cyanotoxins, that can cause illness in humans and animals (US EPA, 2017). Due to an increase in frequency and intensity of cyanobacteria blooms in Minneapolis lakes, the MPRB developed a cyanobacteria monitoring program for public health in 2020. MPRB staff collect information on observations using a defined Visual Monitoring Index (VMI), and sample water weekly at beaches for the most common cyanotoxins. Advisories are posted at beaches and on the MPRB Lake Water Quality Map (bit.ly/mplsbeaches) if toxin levels exceed MPCA guidelines. See **Chapter 19** for more information on blue-green algae and cyanotoxin monitoring.

In 2022, VMI observations were made during weekly beach sampling and bimonthly lake sampling on Bde Maka Ska. Cyanotoxin samples were also collected at 32nd Street Beach, Main Beach, and Thomas Beach weekly. VMI observations indicated low levels of cyanobacteria for most of the season, with minor short-lived scums observed at 32nd Street Beach and Main Beach during late June. Cyanotoxin levels were consistently low at all Bde Maka Ska beaches. Concentrations were highest in late May at 32nd Street Beach when the microcystin concentration was 2.33 µg/L, which was well within safe swimming guidelines of 6 µg/L. Although cyanobacteria were present in Bde Maka Ska in 2022, no significant cyanobacterial scums were observed, and all water samples collected were within the state guidelines for swimming.

Lake Aesthetic and User Recreation Index (LAURI)

Figure 2-10 shows the 2022 LAURI for Bde Maka Ska. Bde Maka Ska was rated good in public health, and rated excellent in aesthetics, water clarity, habitat quality and recreational access. The public health score, which is based on beach *E. coli* concentrations, was likely negatively affected by persistent late-summer goose activity at Bde Maka Ska 32nd and Thomas Beaches. Details on LAURI can be found in **Chapter 1** and comparisons with other lakes can be found in **Chapter 17**.

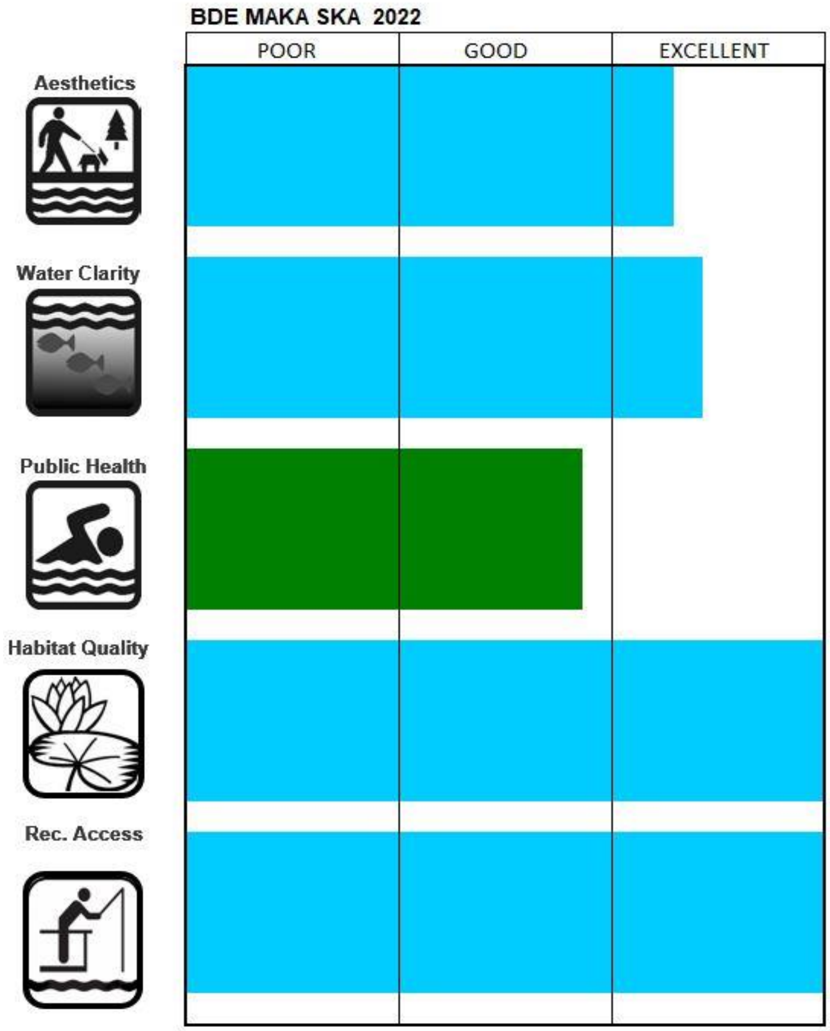


Figure 2-10. The 2022 LAURI for Bde Maka Ska.

Winter Ice Cover

Ice came off Bde Maka Ska on April 13, 2022, four days later than the average ice-off date of April 8th. Lake ice fully covered the lake on December 8, 2022, five days earlier than the average ice-on date, see **Figures 2-11 and 2-12** below. A linear regression demonstrates a slight decreasing trend in ice-off events, signifying a trend towards earlier open water; however, the data is not statistically fit (R^2 <0.95; **Figure 2-11**). The running average ice-off date has shifted to earlier dates, averaging around April 13th in the 1970's to April 4th for the past 10 years. Majority of ice-off dates have been occurring in early to mid-April over the past 70 years, with a few years with early ice-off dates in March.

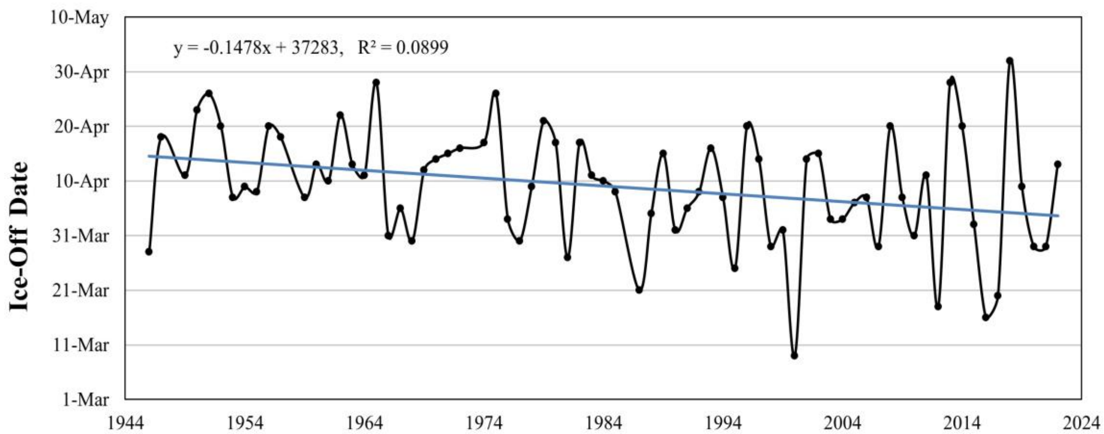


Figure 2-11. Bde Maka Ska ice-off dates for all the years of record. 73 recorded ice-off dates exist since 1946.

Fewer observations for ice-on dates exist for Bde Maka Ska. A linear regression demonstrates a slight increasing trend in ice-on events, signifying a trend towards later open water; however, the data is not statistically fit ($R^2 < 0.95$). The five latest ice-on dates have occurred since 2001, see **Figure 2-12**. Over the past 57 years Bde Maka Ska is typically frozen in early to mid-December with a few ice-on dates in January. See **Chapter 1** for details on winter ice cover records and **Chapter 17** for a comparison with other lakes.

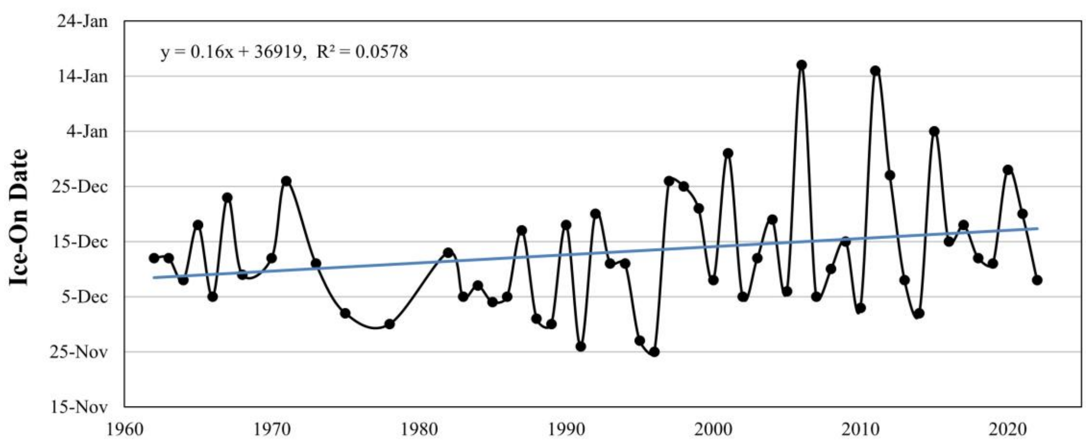


Figure 2-12. Bde Maka Ska ice-on dates for all the years of record. 53 recorded ice-on dates exist since 1962.

AQUATIC PLANT MANAGEMENT

The Minnesota Department of Natural Resources (MNDNR) requires a permit to remove or control aquatic plants. These permits limit the area from which aquatic plants can be harvested to protect fish habitat. The permits issued to the MPRB allow for harvesting primarily in swimming areas, boat launches, and in areas where public recreational access is needed. In 2022, the permitted area on Bde Maka Ska was 55 acres, which is about 48% of the littoral zone, an area 15 feet or shallower. For more information on aquatic plants see **Chapter 1** and **Chapter 21**.

PHYTOPLANKTON AND ZOOPLANKTON

Phytoplankton are microscopic plants that are an integral part of the lake community because they form the base of the aquatic food web. **Figure 2-13** shows the water clarity, chlorophyll-*a* concentrations, and relative abundance of phytoplankton divisions during 2022. Comparing these three parameters together can show how changes in the types of algae present in a lake effect water clarity and color, see the phytoplankton and zooplankton monitoring section in **Chapter 1** for additional details.

Water clarity was deepest in late May at 7.2 meters; slowly declined throughout the year and was shallowest in late August at 1.8 meters, see **Figure 2-13a**. When chlorophyll-*a* concentrations were low, the lake water was more transparent, see **Figure 2-13b**. Chlorophyll-*a* concentrations were lowest in the winter at 1.0 µg/L. Concentrations of chlorophyll-*a* were highest in fall at 11.2 µg/L when the phytoplankton community primarily consisted of cryptomonads (Cryptophyta) and blue-green algae (Cyanophyta).

The phytoplankton community primarily consisted of Cyanophyta throughout most of 2022, dominating the phytoplankton community from late May through September, see **Figure 2-13c**. Cryptophyta were present throughout the year and dominated the phytoplankton community in winter, early May, and fall. Diatoms (Bacillariphyta) dominated the phytoplankton community in spring and remained at low levels or were not present the remainder of the year. Green algae (Chlorophyta) were present throughout the year and were most abundant in early May. Golden-brown algae (Chrysophyta), euglenoids (Euglenophyta), haptophytes (Haptophyta), and dinoflagellates (Pyrrophyta) were present in low levels for the entire 2022 season.

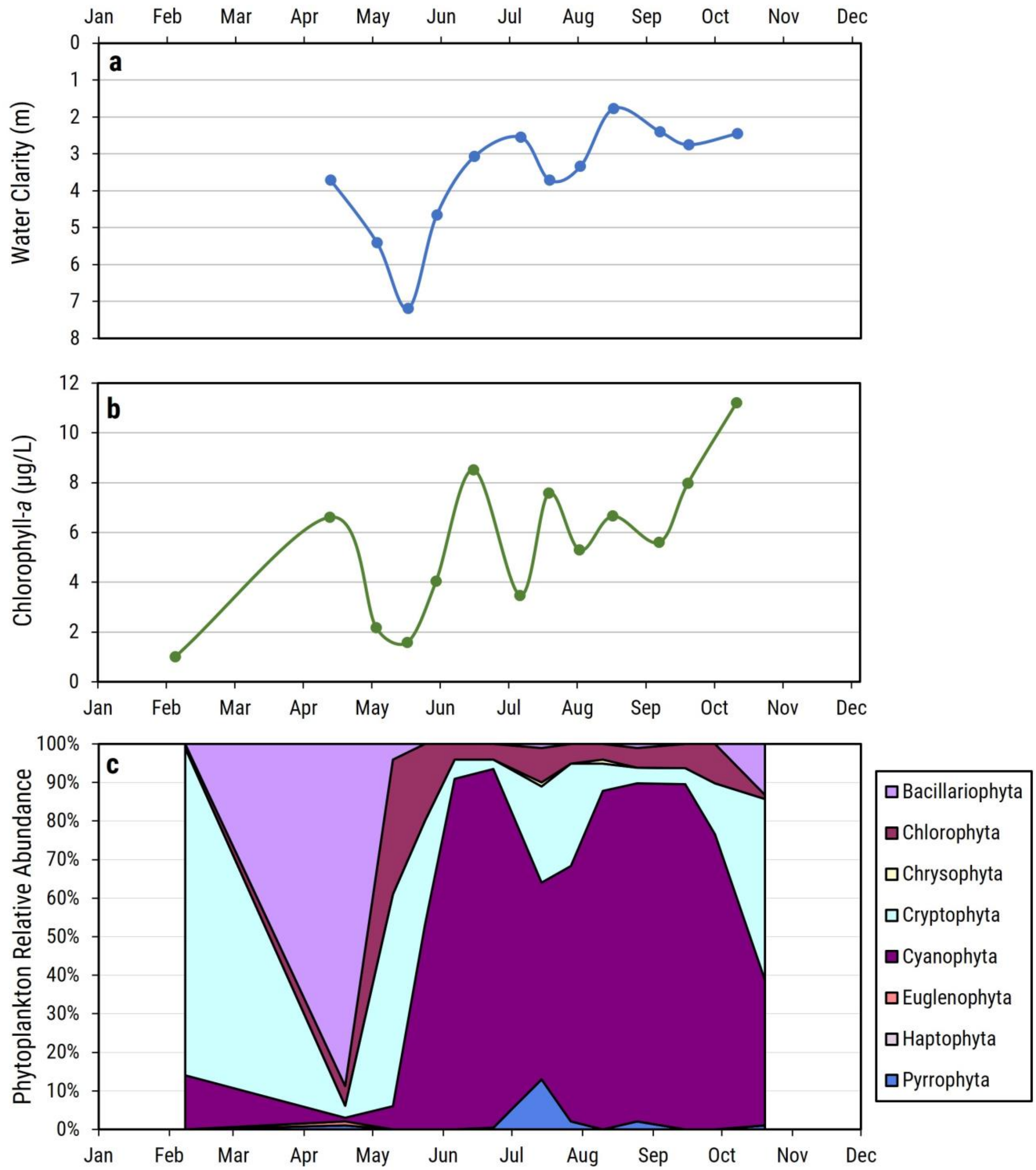


Figure 2-13. Water clarity (a), chlorophyll-a concentration (b), and relative abundance of phytoplankton (c) in Bde Maka Ska during 2022. Note that the water clarity axis is reversed.

Zooplankton are tiny animals that feed on phytoplankton and are also vital for the lake community because they form the second level of the food web along with larval fish. **Figure 2-14** shows the zooplankton abundance in Bde Maka Ska sampled throughout 2022. Nauplii and juvenile copepods were present throughout the year and were most abundant in May and April. Cladocerans were most abundant in June and May and present in lower levels the remainder of the year. Rotifers were present throughout the year and most abundant in May. Calanoids, cyclopoids, and protozoa were also present in low levels in 2022.

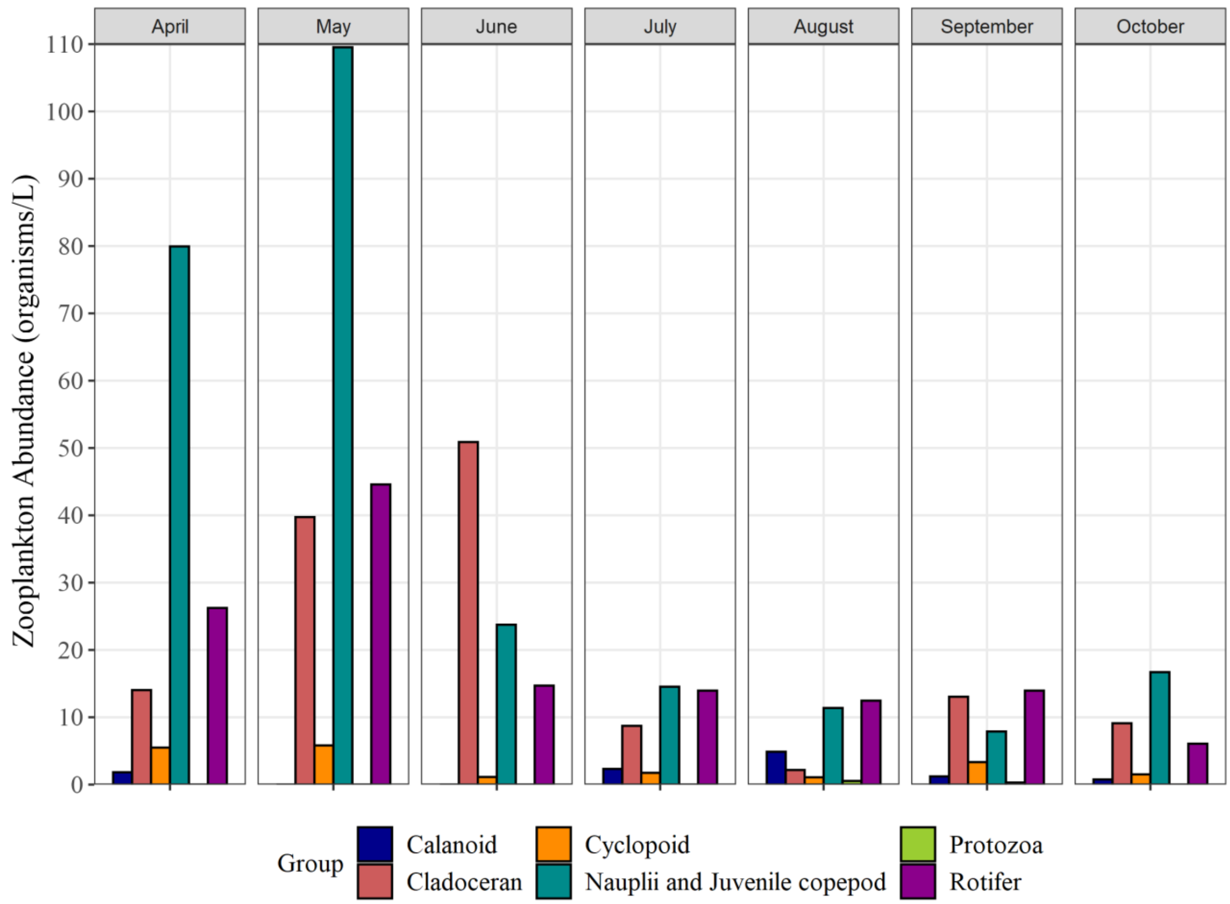


Figure 2-14. Zooplankton abundance in Bde Maka Ska during 2022.

Events Report

Loose Styrofoam

In 2022, there were several reports throughout the year that the Styrofoam floats under the floating fishing docks were degrading and Styrofoam pieces were released into the lake regularly, see **Figure 2-15.** Citizens reported finding pieces of Styrofoam along Bde Maka Ska's shoreline in early April, early and late August, early September, and mid-October. In the spring, Styrofoam was found on the southwest shoreline of Bde Maka Ska, while Styrofoam reported later in the year was either found along the north shoreline between the fishing dock and Main Beach or near the fishing dock located at 36th Street. The reason for the loose Styrofoam may be because muskrats were burrowing into the floating docks.

Multiple incident report forms were completed by MPRB staff and maintenance staff was informed to do additional clean-up. Some docks in Minneapolis lakes are part of a cooperative program run by the MNDNR, so they provided technical advice on how to repair docks and are able to provide replacement parts; however, not all docks with issues are part of the MNDNR program. In order to replace the floats, the fishing docks need to be taken apart and brought to shore. Repairs were not done in 2022 due to limited access to Bde Maka Ska with the boat launch being closed for most of the year. MPRB staff and MNDNR will continue to work together in 2023 to replace the Styrofoam floats on the fishing docks. Also, galvanized welded wire may be added to the floats in the future to protect them from muskrats.

Figure 2-15. Photo of Styrofoam scattered along the north shoreline of Bde Maka Ska in August 2022.

Spill

On May 2, 2022, MPRB maintenance staff reported water flowing down the bank on the west side of Bde Maka Ska Parkway from Minikahda Golf Course. Water was running down the bank for at least 15 minutes before the water was turned off. The source of water was likely from the irrigation system at Minikahda Club. A gully was formed on the bank and sediment that eroded from the bank washed onto the Parkway. Sediment then washed into the stormsewer causing the water to appear brown in Bde Maka Ska at the stormsewer outlet located near Ivy Lane, see **Figure 2-16a and b**. An incident report form was completed and MPRB staff reported the spill to 311 to clean up the erosion that remained on the Parkway.

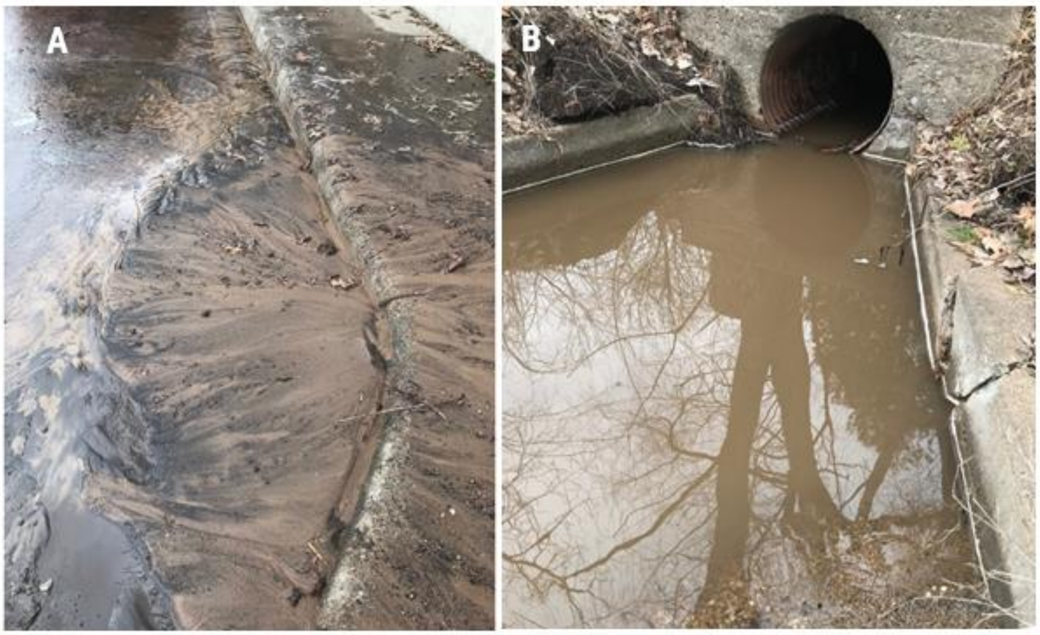


Figure 2-16. Photo of sediment washed onto Bde Maka Parkway (A) and brown water in Bde Maka Ska at the stormsewer outlet located near Ivy Lane (B).

FISH STOCKING

Muskellunge and Walleye fingerlings were stocked in Bde Maka Ska in 2022, see **Table 2-4**. Least Darters were introduced to Bde Maka Ska in 2019 to determine the feasibility of transplanting sensitive, non-game fish successfully. The Least Darters were transplanted from Cedar Lake where they naturally occur. Bde Maka Ska was selected because it was once degraded enough to extirpate the species, but now has exceptional water quality and clarity. Future monitoring will continue to determine the establishment of the Least Darter population in Bde Maka Ska (Konrad, 2019). Additional information and a definition of fry, fingerling, yearling and adult fish can be found in **Chapter 1**.

Table 2-4. Fish stocked into Bde Maka Ska over the past 10 years. Data are from the Minnesota Department of Natural Resources.

Year	Species	Number and Size	Amount
2022	Muskellunge	123 fingerlings	17.6 pounds
2022	Walleye	2,091 fingerlings	123.0 pounds
2019	Least Darter	85 adults	0.04 pounds
2019	Muskellunge	123 fingerlings	41.0 pounds
2019	Walleye	2,754 fingerlings	152.4 pounds
2018	Muskellunge	123 fingerlings	14.3 pounds
2017	Least Darter	86 adults	0.0 pounds
2017	Walleye	98 yearlings	55.0 pounds
2017	Walleye	20 adults	32.0 pounds
2017	Walleye	26 fingerlings	5.2 pounds
2016	Muskellunge	123 fingerlings	21.4 pounds
2015	Walleye	40 fingerlings	2.0 pounds
2015	Walleye	1,613 yearlings	721.4 pounds

EMERGING CONTAMINANTS

Per- and polyfluoroalkyl substances (PFAS), a class of chemicals with a range of commercial and industrial uses, have been recently identified as a concern due to their impact on environmental and human health (MPCA, "PFAS"). Perfluorooctane sulfonate (PFOS) is a type of PFAS that is of highest concern related to lake health and fish consumption. See **Chapter 1** for more information on emerging contaminants and **Chapter 17** for comparison of PFAS in MPRB lakes.

PFOS was first detected in Bde Maka Ska in 2004. In 2008, the MPCA found that the source of the PFOS contamination was a chrome plating facility in St. Louis Park (MPCA, 2023). PFOS from the facility had been transported to Bde Maka Ska via the stormsewer system. In 2010, through the MPCA's guidance, the facility eliminated its use of PFOS and began implementing projects to ensure that PFOS did not leave the site. In 2016, the facility agreed to a schedule of compliance to implement further environmental protective measures. PFOS levels in the Chain of Lakes have significantly dropped in both surface water and in fish tissue since these actions have been taken, see **Figure 2-17**. As of 2013, PFOS concentrations in Bde Maka Ska fish tissue were decreasing, and as of 2021, concentrations of PFOS in largemouth bass were about 90% lower than they had been in 2008 (MPCA, 2023). MPCA data on the concentration of PFOS in fish tissue are shown in **Table 2-5**.

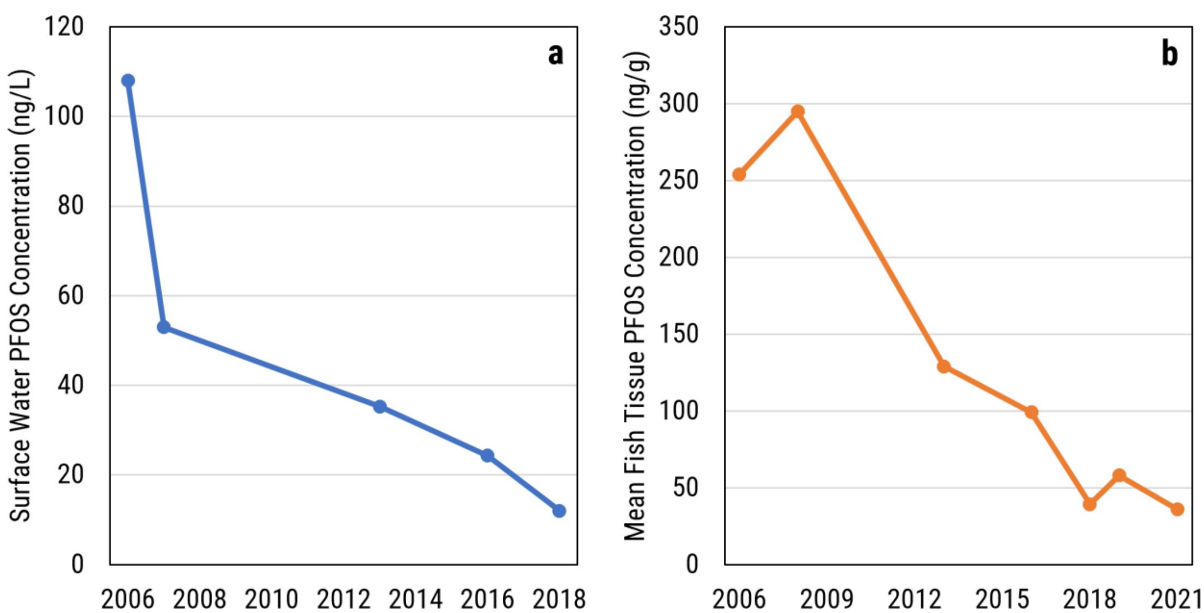


Figure 2-17. Concentration of Perfluorooctane sulfonate (PFOS) in surface water (a) and mean concentration of PFOS in fish tissue (b) in Bde Maka Ska over time. Data from MPCA (2018), MPCA (2020), and values calculated from data received via 2023 communication with MPCA staff.

Bde Maka Ska was added to the MPCA's list of impaired waters (303(d) list) in 2008 due to high concentrations of PFOS in fish tissue. Waterbody Specific Safe-Eating Guidelines for Bde Maka Ska fish consumption were set by the Minnesota Department of Health (MDH) in 2007 to minimize PFOS exposure, see https://www.dnr.state.mn.us/lakefind/fca/report.html?downum=27003100.

Table 2-5. Mean concentrations of PFOS in tissue of different species of fish in Bde Maka Ska. Data is given as the mean PFOS concentration in nanograms of contaminant per wet weight gram of fish tissue, and the number in parentheses indicates the number of individual fish sampled. NA means no fish of this species were sampled. All species mean is calculated from the given means and numbers of fish. Data received via communication with MPCA staff in 2023.

Bde Maka Ska	**2018**	**2019**	**2021**
Species	*Mean PFOS (n) ng/g ww*		
Largemouth bass	NA	66 (2)	43 (4)
Yellow perch	37 (6)	NA	NA
Northern pike	49 (5)	NA	22 (2)
Walleye	91 (2)	49 (2)	NA
All species mean	50	58	36

The MPCA developed site-specific criteria for PFOS in Bde Maka Ska due to the direct contamination of the waterbody. (MPCA, 2020). There is currently no federal or state numeric standard for PFAS in the environment, but the Clean Water Act gives the MPCA the authority to set criteria when a toxic pollutant has contaminated a specific site. Site-specific criteria are developed for targeted use in a contaminated body of water and are not intended for statewide use. These criteria are applied as indicators of a polluted state in the lake and are derived from the most stringent concentration of PFOS that could mitigate harm to humans (MPCA, 2017). Site-specific criteria are intended as regulatory goals to preserve the health of the waterbody; people looking to evaluate the risk of recreating in Bde Maka Ska should consult the Waterbody Specific Safe-Eating Guidelines set by MDH or the Swimming Guidance as seen in **Table 2-6**. Two criteria were set for Bde Maka Ska, based on designated uses of the waterbody. One criterion is set for concentrations of PFOS in surface water, which is based on the potential risk related to designated uses involving fish and recreational exposure. The second criterion is set for concentrations of PFOS in fish tissue, based on the potential risk related to designated uses involving fish consumption. This criterion of 0.37 ng/g is applied such that no more than 10% of fish from the waterbody exceed the standard to account for the variance in rate of bioaccumulation between fish species, see https://www.pca.state.mn.us/business-with-us/site-specific-water-quality-criteria for more.

Perfluorooctanoic acid (PFOA) is another type of PFAS in the environment that is connected to potential negative human health effects. Production of PFOA has been phased out in the United States, and human blood PFOA concentrations in the United States seem to be declining (MDH, 2022).

Recreation such as swimming is not considered high risk for PFAS exposure, and the concentrations of both PFOS and PFOA in Bde Maka Ska are well below the swimming guidance recommended by the MPCA.

Table 2-6. Surface water concentrations of PFOS and PFOA in Bde Maka Ska, compared to the PFOS and PFOA swimming guidance and site-specific criterion. Data is given as the mean concentration in nanograms of contaminant per liter of lake water. NA indicates no available data. Data from MPCA (2018), MPCA (2020), and from 2023 communication with MPCA staff. Swimming guidance received via communication with MPCA staff in 2023.

Bde Maka Ska	PFOS (ng/L)	PFOA (ng/L)
2006	108	19.77
2007	53	18.60
2013	35.3	NA
2016	24.3	NA
2018	12.0	9.99
Swimming Guidance	330	1,900
Site-specific criterion	0.05	

3. Birch Pond

History

Birch Pond, located on the east side of Theodore Wirth Parkway in Theodore Wirth Regional Park near the Eloise Butler Wildflower Garden and Bird Sanctuary, was acquired in 1889. The pond lies within the original Glenwood Park parcel. In 1910, the pond was named for the white birch trees which grew along its shores and hillsides. Birch Pond was used as a fish hatchery between 1893 and 1918 by the State Fish Commission and was known for good bass and perch fishing. Unlike most other Minneapolis lakes, no dredging or redesign was done to Birch Pond (Smith, 2008). Birch Pond is within the Bassett Creek Watershed.

Birch Pond is a 2.6-acre water body protected from winds by large hills and mature trees that surround it, **Figure 3-1**. **Figure 3-2** shows a map of Birch Pond. The pond's direct watershed is mainly parkland but one outfall on the west side of the pond carries stormwater to the pond from Wirth Parkway. An inlet on the east side of the lake previously carried water pumped from the Mississippi River, see **Appendix C** for stormwater outfalls. Birch Pond is a closed basin, so there is no outlet.

Figure 3-1. Birch Pond in October of 2021.

The Minneapolis Park & Recreation Board (MPRB) currently does not include Birch Pond in its regular lake sampling program and only monitors ice-off and ice-on dates.

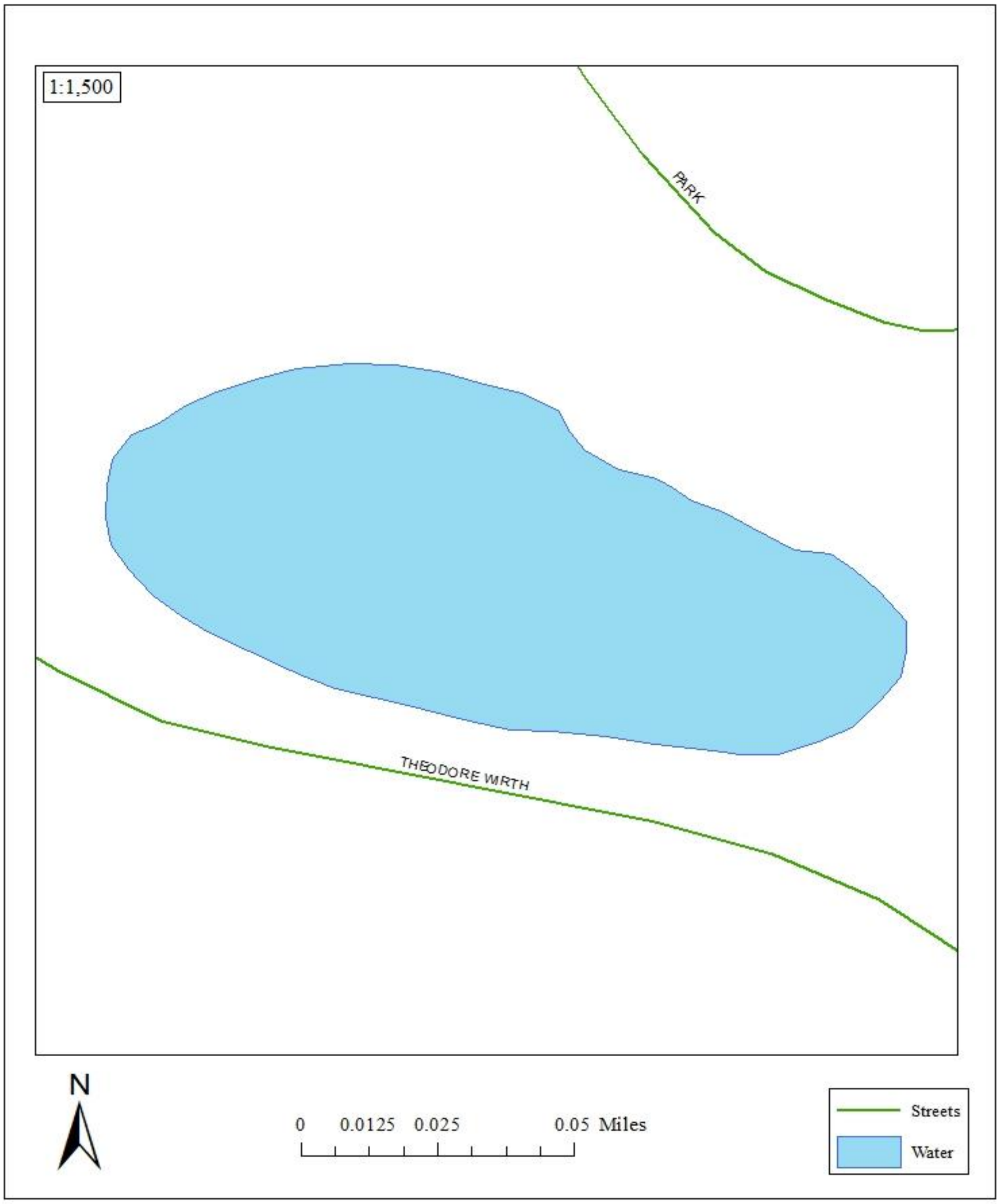


Figure 3-2. Map of Birch Pond.

Lake Level

Lake level records for Birch Pond were measured by the City of Minneapolis and the MPRB from 1928-1970. More recently, the Minnesota Department of Natural Resources (MNDNR) created an accurate benchmark and has determined an Ordinary High Water Level (OHWL) of 846.3 feet above mean sea level (msl) for Birch Pond. Lake levels in Birch Pond varied over time due to changes in climate and rainfall patterns as well as periodic augmentation through pumping. Birch Pond was once part of a water conveyance system which carried water from the Mississippi River to the Chain of Lakes. A remnant of the old conveyance system remains on the east side of the pond. There is currently not a surveyed lake level gage on Birch Pond.

Winter Ice Cover

Ice came off Birch Pond on April 11, 2022, seven days later than the average ice-off. Ice came back to the pond November 21, 2022, four days earlier than the average date for ice-on. See **Chapter 1** for details on winter ice cover records and **Chapter 17** for a comparison with other MPRB lakes.

4. Brownie Lake

History

Brownie Lake was acquired by the Minneapolis Park and Recreation Board (MPRB) in 1908. Brownie Lake is part of the Chain of Lakes, which also includes Cedar, Isles, Bde Maka Ska, and Harriet. The name of the lake predates the MPRB which was established in 1883. The lake was formerly known as Hillside Harbor. An undated handwritten note documented with the MPRB suggests that William McNair, who owned majority of the lake's surrounding land, named the lake after his daughter named "Brownie". Human activities drastically changed the shape and size of Brownie Lake over the past 150 years. Construction of the railroad tracks in 1867 caused a decrease in lake surface area of 34%. In 1917, the connection between Cedar and Brownie Lakes was completed further decreasing the surface area of the lake by dropping the water level ten feet and creating the lake that we see today (Smith, 2008). **Figure 4-1** shows a picture of Brownie Lake.

Figure 4-1. View from the south shore of Brownie Lake in July 2022.

Brownie Lake is permanently stratified due to a strong density difference that exists between water near the surface and a deeper layer of water containing high levels of dissolved minerals. Lakes that are stratified because of differences in density due to water chemistry are called meromictic lakes. The sharp density difference between the surface waters and deeper water in meromictic lakes is called a chemocline. Meromictic lakes do not mix due to the stability of the chemocline, and this quality makes them difficult to compare with dimictic or polymictic lakes. **Table 4-1** shows the physical and morphometric data of Brownie Lake and **Figure 4-2** shows the bathymetric map. Brownie Lake is part of the Minnehaha Creek Watershed and receives runoff from both Minneapolis and St. Louis Park. There are a total of four stormwater outfalls surrounding the lake, see **Appendix C**.

Water levels in Brownie Lake have been manipulated at various times in its history. In the late 1930s MPRB used city water to maintain the lake level of the Chain of Lakes, but this was not cost effective. In 1958, a pumping station was installed at Bassett Creek to pump water from the creek through a pipeline to Brownie Lake. Initially, the pumping station raised the lake levels in the Chain of Lakes but then water levels remained low. A pumping station was then constructed at the Mississippi River in 1966 to pump water from the river to Bassett Creek and into Brownie Lake. Water quality became an issue citywide in the 1970s and studies showed that there were high levels of phosphates in the river. Pumping from Mississippi River continued until the 1990s.

The MPRB and other surrounding landowners have completed several projects improving the Brownie Lake basin. In 2007, the Target Corporation rehabilitated a stormwater pipe and restored disturbed hillside vegetation on the west side of the lake. City of Minneapolis Public Works and the MPRB worked together to solve an erosion problem on the east side of Brownie Lake in 2008. The two organizations restored an eroded area and replaced an exposed and eroding stormwater outlet with a buried drop-structure and pipe.

Since 2015, Minnesota State Mankato, University of Iowa, Iowa State, and the University of Minnesota Duluth have done research on Brownie Lake because it is both iron-rich and meromictic and use the data to create modern analogs to study aspects of Precambrian oceans (Lambrecht et al., 2018).

Brownie Lake has been consistently sampled very other year since 2002 and was sampled in 2022.

Table 4-1. Brownie Lake physical characteristics and morphometric data.

Surface Area (acres)	Mean Depth (ft)	Max Depth (ft)	Littoral Area*	Volume (ft^3)	Watershed Area (acres)	Watershed: Lake Area (ratio)	Residence Time (years)
10	22.3	47.0	76%	$1.76x10^7$	369	20.5	2.0

* Littoral area defined as less than 15 feet deep.

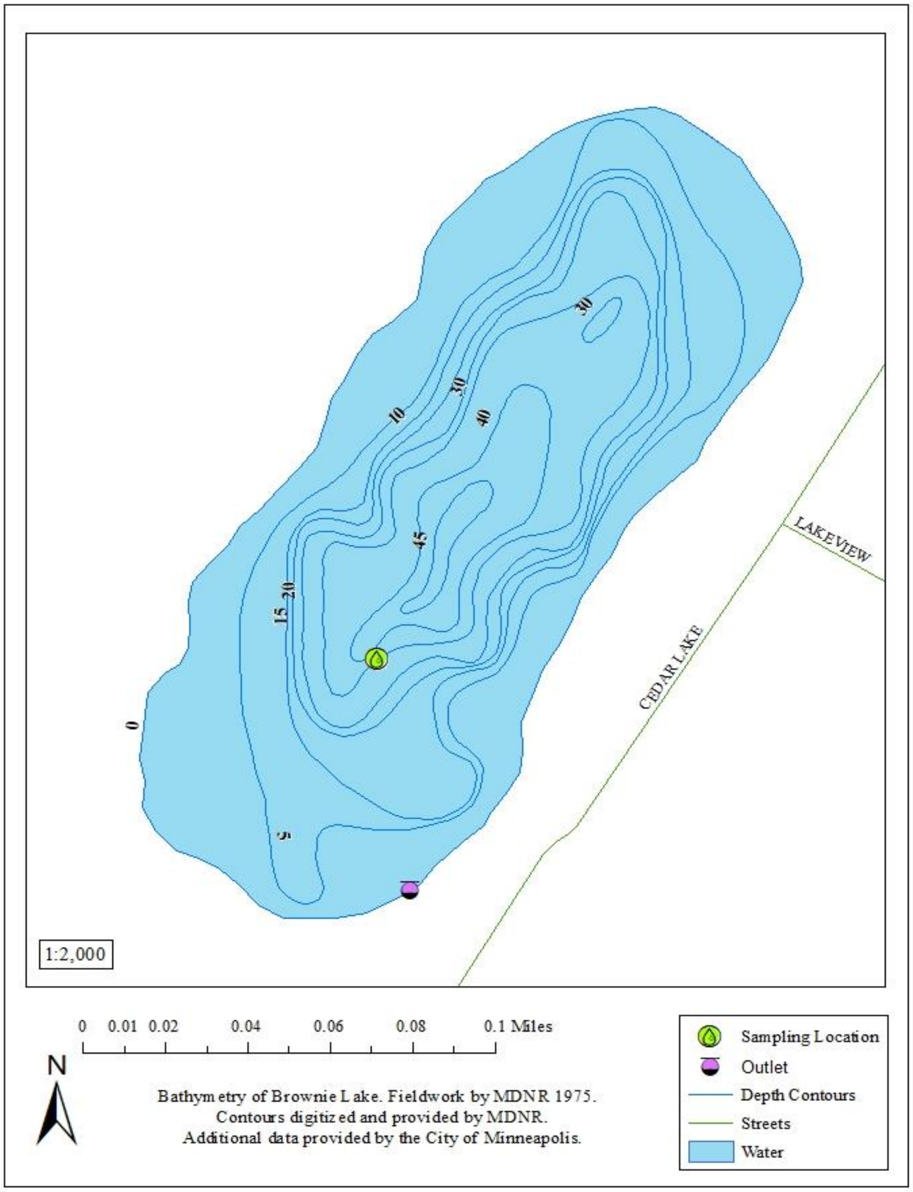


Figure 4-2. Bathymetric map with mid-lake sampling site and outlet location at Brownie Lake.

Lake Level

The Ordinary High Water Level (OHWL) for Brownie Lake, as determined by the Minnesota Department of Natural Resources (MNDNR), is 853 feet above mean sea level (msl). Lake Levels for Brownie Lake and the Upper Chain of Lakes are recorded at Bde Maka Ska. See **Chapter 2** for more information on the historic lake levels for the Upper Chain of Lakes. For details on lake level monitoring see **Chapter 1**. **Chapter 17** has a comparison of lake levels with other MPRB lakes.

Water Quality Trends – Trophic State Index (TSI)

Figure 4-3 shows historical Brownie Lake TSI scores and trend line. There has been a slight increase in TSI scores, but there has not been a significant trend in TSI from 1993-2022 ($p > 0.05$). The TSI score for Brownie Lake in 2022 was 57. According to Carlson's Trophic State Index, the lake is classified as eutrophic, which is a lake defined as having an anoxic hypolimnion and possible macrophyte problems. Brownie Lake is only sampled every other year, which likely impacts the significance of the TSI score; sampling in the 1990s was also limited to a few samples per year.

The Clean Water Partnership (CWP) Minneapolis Chain of Lakes Project developed a long-term TSI goal in 1993 to be below 55 that was intended to be met within five to ten years of water quality project completion. TSI scores in Brownie Lake have not met the CWP goal in most years, except for meeting the goal in 2014.

Secchi, chlorophyll-*a* and total phosphorus TSI scores for Brownie Lake are within the expected TSI range for lakes in the same ecoregion, see **Table 4-2**. See Minnesota Pollution Control Agency (MPCA) Surface Water Data (https://webapp.pca.state.mn.us/wqd/surface-water/waterunit-details?wid=27-0038-00) for more information. A detailed explanation of TSI can be found in **Chapter 1**.

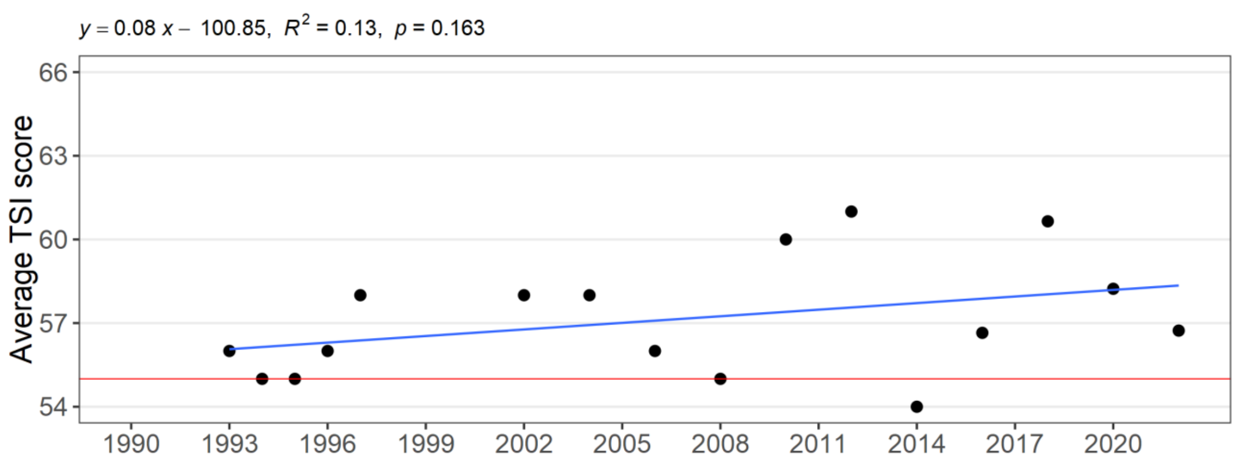


Figure 4-3. Brownie Lake TSI scores and linear regression from 1993-2022. The red line represents the CWP long-term TSI goal of below 55.

Table 4-2. Brownie Lake Secchi, chlorophyll-*a*, and total phosphorus TSI based on data collected between June and September of 2022 and compared to lakes in the North Central Hardwood Forest ecoregion.

	TSI	Expected TSI Range of Lakes in the Same Ecoregion	Within the Expected TSI Range of Lakes in the Same Ecoregion
Secchi	52	43-54	Within range
Chlorophyll-*a*	58	46-61	Within range
Total Phosphorus	57	49-61	Within range

Box and Whisker Plots

The box and whisker plots in **Figure 4-4** show the data distribution for water clarity, chlorophyll-*a*, and total phosphorus for the past 10 years, based on data from the entire sampling season. Red horizontal lines on the graphs indicate the MPCA eutrophication standards for deep lakes, which applies to data collected between June and September. A detailed explanation of box and whisker plots can be found in **Chapter 1**. Box and whisker plots from the entire period of record, 1993-2022, can be found in **Appendix A**.

Water clarity in Brownie Lake in 2022 was similar to previous years with an average Secchi depth of 1.5 meters, see **Figure 4-4a**. Algal biomass, as measured by chlorophyll-*a* concentration, was higher and more variable in 2016 and 2018. Chlorophyll-*a* concentrations have been near the MPCA eutrophication standard most years, with an average of 17 µg/L in 2022, see **Figure 4-4b**. Total phosphorus levels were similar to previous years with an average concentration of 41 µg/L, see **Figure 4-4c**. Brownie Lake met the MPCA eutrophication standards for water clarity and total phosphorus and did not meet the standard for chlorophyll-*a* in 2022. Due to Brownie Lake's permanent stratification, it may not be reasonable to compare Brownie Lake to the deep lake standard since that standard better applies to dimictic lakes. A better measure of the health of Brownie Lake may be to look at long-term trends, which show no significant change over the past 20 years ($p > 0.05$).

It is difficult to compare Brownie Lake to other Minneapolis lakes since it is meromictic and is only sampled once per month rather than twice per month that is usual with most of the other lakes. The only other meromictic lake in Minneapolis is Spring Lake.

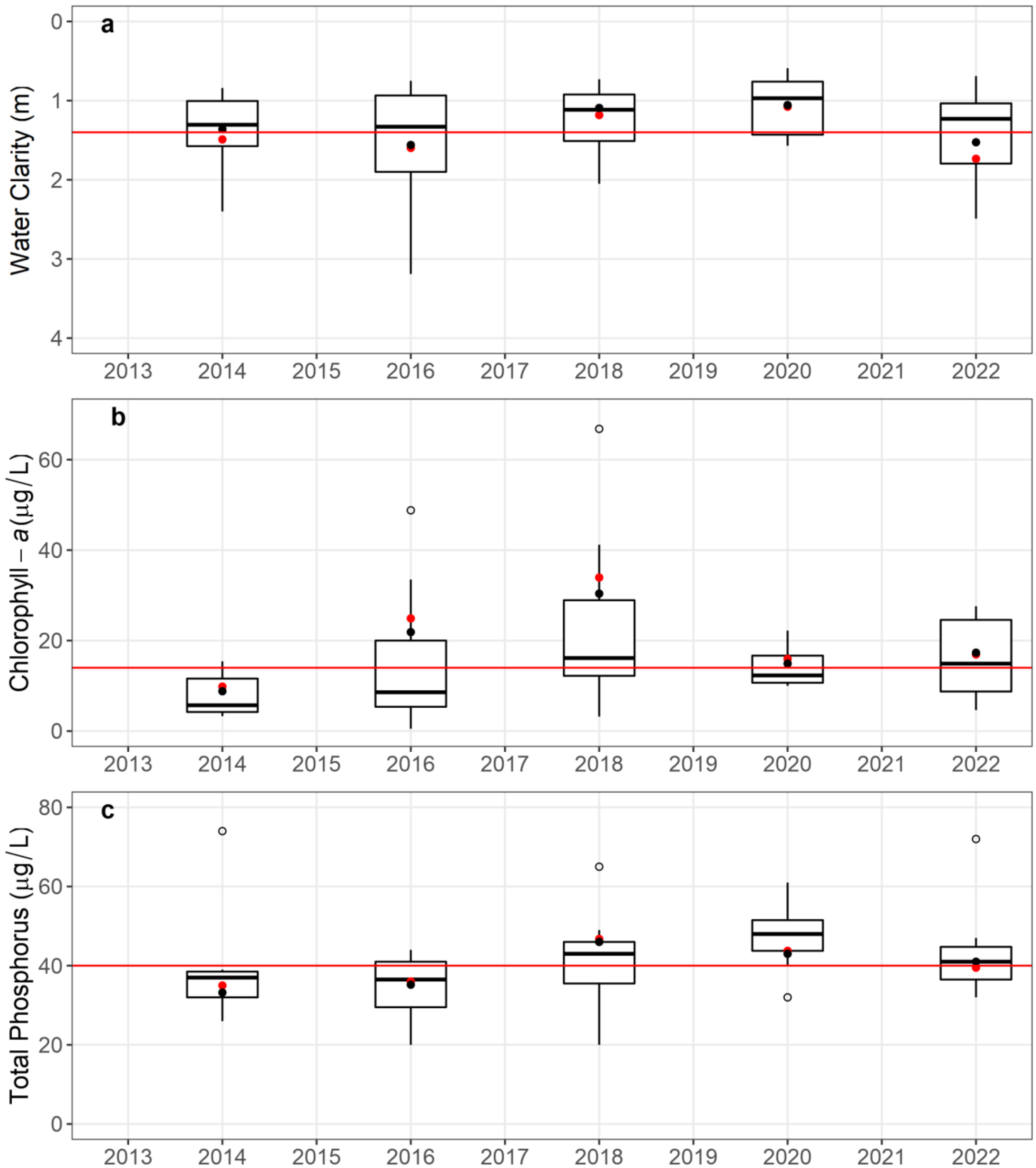


Figure 4-4. Brownie Lake box and whisker plots of water clarity (a), chlorophyll-*a* (b), and total phosphorus(c) from 2013-2022. Horizontal lines represent MPCA eutrophication standards for deep lakes, which applies to data collected between June and September. The red circles represent the mean value of data collected between June and September. The black circles represent the mean value of data collected during the growing season, May through September. Data from 1993-2022 can be found in Appendix A.

CHLORIDE

Chloride is a naturally occurring element that is commonly found at low levels in most freshwater bodies. Chloride is a component of road salt (sodium chloride) and is found in other types of compounds that are also called salts (calcium chloride, magnesium chloride). Unnaturally high concentrations of chloride can negatively impact surface waters. High levels of chloride can change the mixing pattern of a lake and lead to very low oxygen levels in deep water. It can also lead to decreasing water clarity and induce stress or cause death of aquatic species (Bathe & Coring, 2011). Sources of chloride include industrial discharge, septic systems, sewage disposal systems, fertilizers, and road salt (Novotny, Murphy, & Stefan, 2008). The MPCA adopted the Environmental Protection Agency's (EPA) recommended water quality criteria for chloride which is a chronic standard of 230 mg/L and an acute standard of 860 mg/L (MPCA, 2016). The MPRB has monitored chloride concentrations in Brownie Lake since 1995 by collecting surface water samples using a composite tube and deep water samples using a Kemmerer sampler. See **Chapter 1** for more information on chloride.

Figure 4-5 shows epilimnetic and hypolimnetic chloride concentrations in Brownie Lake between 1995-2022, with hypolimnion samples only collected regularly after 2008. Epilimnion samples represent the top two meters of the lake and hypolimnion samples were collected approximately one meter from the bottom of the lake. Red horizontal lines on the graph indicate the MPCA acute and chronic chloride standards. Also included on the graph, is a dotted line that represents an estimate of a concentration above which potential ecological impact could occur, at 120 mg/L. This level of potential ecological impact was developed by Canadian Council of Ministries of the Environment (CCME) and is not a Minnesota state standard but a long-term chloride concentration that could negatively impact life within the lake (CCME, 2011). Epilimnetic chloride concentrations have been slowly increasing since 2012; prior to 2012 epilimnetic concentrations measured between the ecological impact and the chronic standard and after 2016 most samples were above the chronic standard. Hypolimnetic chloride levels are much higher than epilimnetic levels because Brownie Lake is meromictic and water containing sodium chloride is denser and sinks to the lake bottom. Hypolimnetic concentrations have been increasing since chloride was first monitored in 2006; prior to 2020 hypolimnetic chloride concentrations measured around the acute standard and in 2020 and 2022 all samples were above this threshold. Brownie Lake was added to the MPCA's list of impaired waters (303(d) list) in 2014 due to high chloride concentrations.

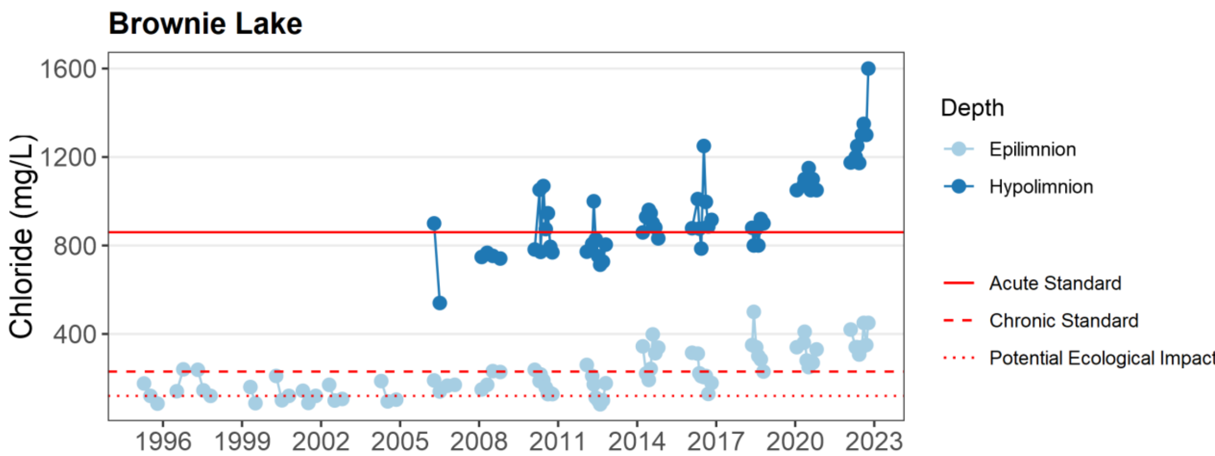


Figure 4-5. Brownie Lake scatterplot of epilimnetic and hypolimnetic chloride concentrations between 1995-2022. Horizonal lines represent the MPCA's acute and chronic standard and the potential ecological impact level (CCME, 2011).

Blue-green Algae Monitoring

Blue-green algae are not algae at all, but a type of bacteria called cyanobacteria. These photosynthetic microorganisms occur naturally in lakes, streams, and other waterbodies worldwide. When conditions are right, cyanobacteria can grow quickly to form dense accumulations called blooms. Certain varieties of cyanobacteria can produce toxins, referred to as cyanotoxins, that can cause illness in humans and animals (US EPA, 2017). Due to an increase in frequency and intensity of cyanobacteria blooms in Minneapolis lakes, the MPRB developed a cyanobacteria monitoring program for public health in 2020. MPRB staff collect information on observations using a defined Visual Monitoring Index (VMI), and sample water weekly at beaches for the most common cyanotoxins. Advisories are posted at beaches and on the MPRB Lake Water Quality Map (bit.ly/mplsbeaches) if toxin levels exceed MPCA guidelines. See **Chapter 19** for more information on blue-green algae and cyanotoxin monitoring.

In 2022, VMI observations were made during monthly lake sampling sessions on Brownie Lake. VMI observations indicated that cyanobacteria were not present most of the sampling season; however, a low density of small floating balls of cyanobacteria were observed in mid-September. Although cyanobacteria were present in Brownie Lake in 2022, no significant scums were observed, and recreation was not inhibited by cyanobacteria.

LAKE AESTHETIC AND USER RECREATION INDEX (LAURI)

Figure 4-6 shows the 2022 LAURI for Brownie Lake. Brownie Lake was rated excellent in aesthetics and good in water clarity, habitat quality, and recreational access. A lower macrophyte density and number of fish species led to a good rating for habitat quality. Since Brownie Lake does not have a swimming beach, a score was not calculated for public health. Details on LAURI can be found in **Chapter 1** and comparisons with other lakes can be found in **Chapter 17**.

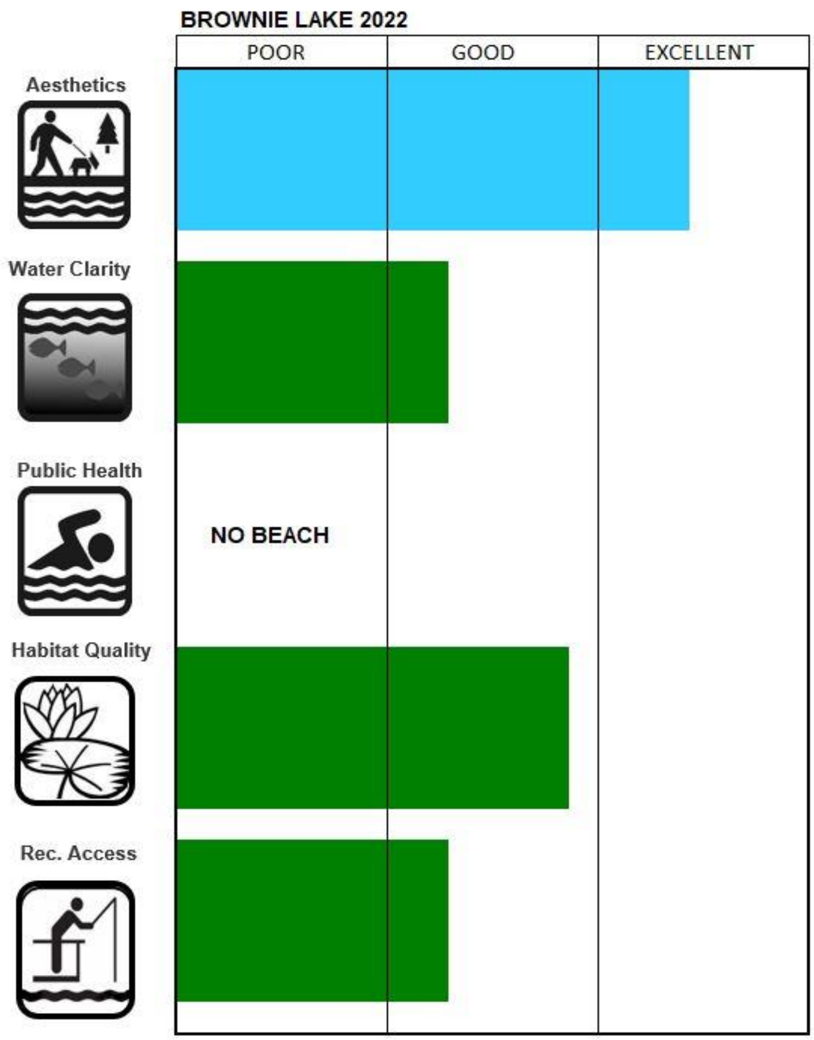


Figure 4-6. The 2022 LAURI for Brownie Lake.

Winter Ice Cover

Ice came off Brownie Lake on April 11, 2022, seven days later than the average ice-off. Ice came on the lake November 21, 2022, eight days earlier than average. See **Chapter 1** for details on winter ice cover records and **Chapter 17** for a comparison with other MPRB lakes.

Phytoplankton

Phytoplankton are microscopic plants that are an integral part of the lake community because they form the base of the aquatic food web. **Figure 4-7** shows the water clarity, chlorophyll-*a* concentrations, and relative abundance of phytoplankton divisions during 2022. Comparing these three parameters together can show how changes in the types of algae present in a lake effect water clarity and color, see the phytoplankton and zooplankton monitoring section in **Chapter 1** for additional details. No zooplankton samples were collected from Brownie Lake in 2022 due to low zooplankton densities. In 2008, zooplankton tows yielded low concentrations compared to other Minneapolis lakes.

Water clarity was shallowest in early May at 0.7 meters and deepest in September at 2.5 meters, see **Figure 4-7**. Chlorophyll-*a* concentrations were lowest in winter at 4.6 µg/L when haptophytes (Haptophyta) and euglenoids (Euglenophyta) dominated the phytoplankton population. Concentrations of chlorophyll-*a* were highest in spring at 27.6 µg/L when cryptomonads (Cryptophyta) dominated the phytoplankton community, see **Figure 4-7b, c**.

The phytoplankton community varied significantly throughout 2022 in Brownie Lake. The phytoplankton population consisted of a mix of diatoms (Bacillariophyta), green algae (Chlorophyta), Cryptophyta, blue-green algae (Cyanophyta), Euglenophyta, and Haptophyta. Golden-brown algae (Chrysophyta) and dinoflagellates (Pyrrophyta) were also present in low levels in 2022, see **Figure 4-7c**.

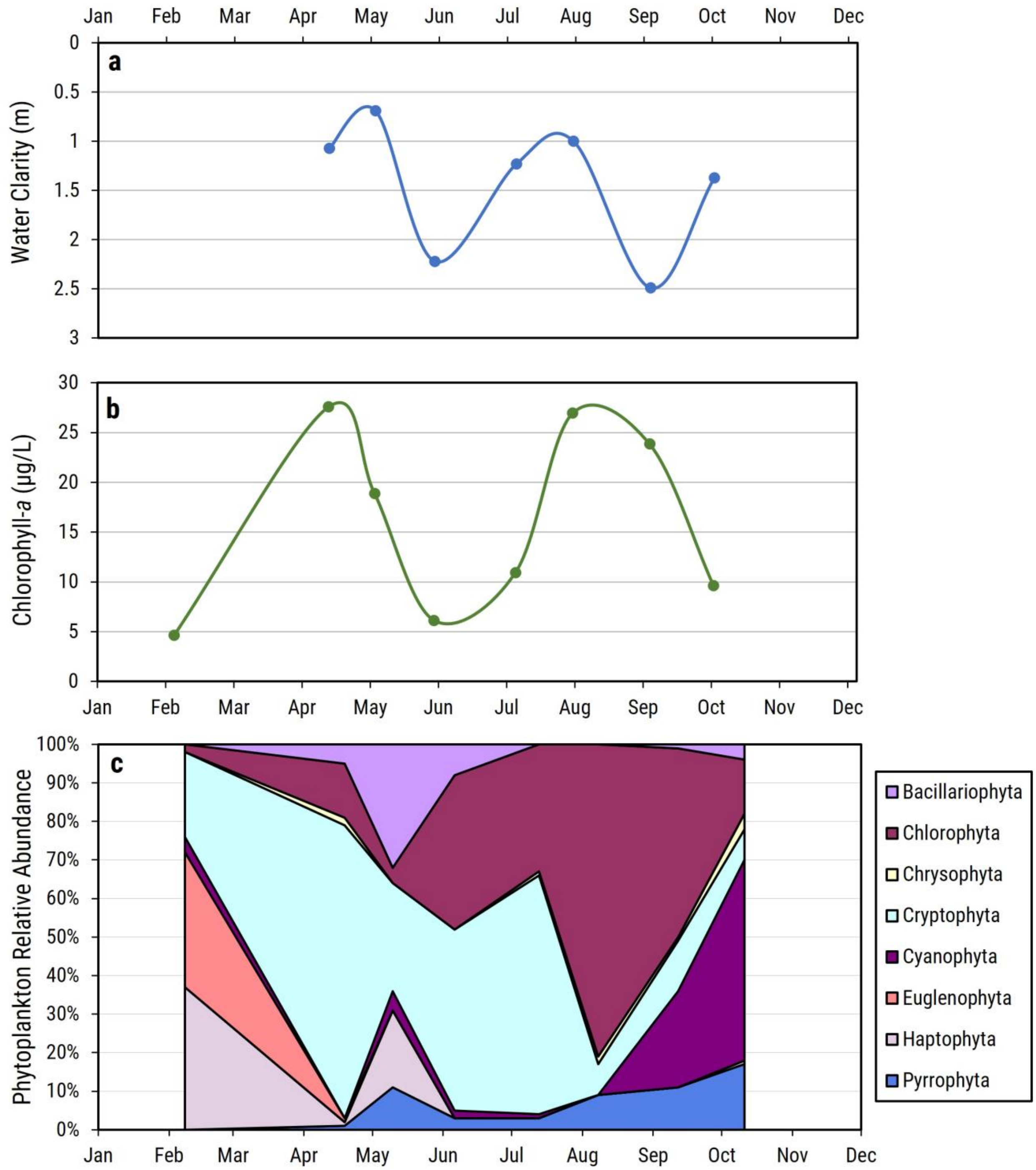


Figure 4-7. Water clarity (a), chlorophyll-*a* concentration (b), and relative abundance of phytoplankton (c) in Brownie Lake during 2022. Note that the water clarity axis is reversed.

5. Cedar Lake

History

Minneapolis Park and Recreation Board (MPRB) acquired the first section of shoreline on Cedar Lake in 1905. The lake itself was obtained completely in 1955 but the last section of shoreline was not acquired by MPRB until 1959. Cedar Lake is part of the Chain of Lakes, which also includes Brownie, Isles, Bde Maka Ska, and Harriet. Cedar Lake was named for the red cedar trees that once grew along the shores. Like the other lakes in the Chain of Lakes, Cedar Lake was altered from its natural state when it was dredged between 1913 and 1916. Channels connecting Cedar Lake to Lake of the Isles and to Brownie Lake were created in 1913 and 1917, which changed the lake level and also the shoreline (Smith, 2008). **Figure 5-1** shows a view of Cedar Lake.

Figure 5-1. View of Cedar Lake in July of 2022.

Cedar Lake is a kettle lake and is typically dimictic; however, there is evidence that in some years the lake may mix during the late summer and then re-stratify (Lee and Jontz, 1997). **Table 5-1** shows the physical characteristics and morphometric data of Cedar Lake and **Figure 5-2** shows a bathymetric map of the lake. Cedar Lake is part of the Minnehaha Creek Watershed and the land-use surrounding the lake is primarily residential and mixed-use. There are 10 stormwater outfalls surrounding the lake, see **Appendix C**. Stormwater entering the lake from outside of Minneapolis travels from Twin Lake in St. Louis Park, down west 24th Street, to the west side of Cedar Lake. When water flow from the west is low, stormwater goes to the Cedar Meadows constructed wetland through a diversion weir, and when stormwater flow is high a portion of this water flows directly into Cedar Lake.

Cedar Lake receives water from Brownie Lake and discharges water through Kenilworth Channel, an open channel, to Lake of the Isles. When the channel to Lake of the Isles was dredged in 1913, the water level in Cedar Lake dropped five feet. The new water elevation changed the shape of the lake most noticeably turning Louis Island on the west side of the lake into a peninsula.

A detailed Clean Water Partnership (CWP) diagnostic study conducted in 1991 determined that phosphorus input to the Chain of Lakes should be reduced to improve water quality. Best management practices (BMPs) were then implemented for Cedar Lake and included the construction of Cedar Meadows wetland in 1995 and an aluminum sulfate (alum) treatment in 1996. The alum treatment improved phosphorus levels at the surface and the hypolimnion and was predicted to have a treatment life span of at least seven years (Huser, 2005). Waterbody Specific Safe-Eating Guidelines for Cedar Lake fish consumption were set by the Minnesota Department of Health (MDH) in 2007 to minimize PFOS exposure, see **Chapter 1** for more information on emerging contaminants, https://www.dnr.state.mn.us/lakefind/fca/report.html?downum=27003900.

Water quality on Cedar Lake has been monitored annually since 1991.

Table 5-1. Cedar Lake physical characteristics and morphometric data.

Surface Area (acres)	Mean Depth (ft)	Max Depth (ft)	Littoral Area*	Volume (ft^3)	Watershed Area (acres)	Watershed: Lake Area (ratio)	Residence Time (years)
164	20.0	51.0	38%	1.50×10^8	1,956	11.5	2.7

* Littoral area was defined as less than 15 feet deep.

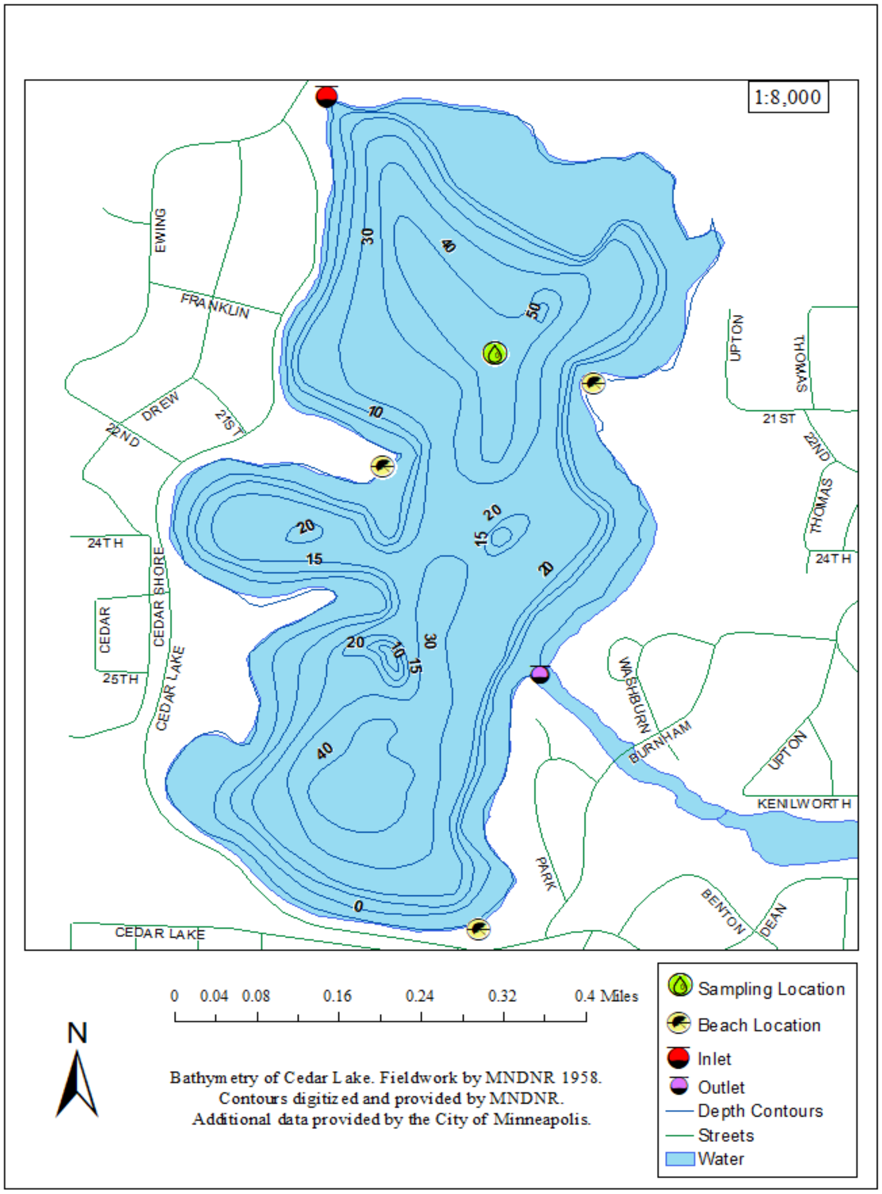


Figure 5-2. Bathymetric map with mid-lake sampling site, beach, inlet, and outlet locations at Cedar Lake.

Lake Level

The designated Ordinary High Water Level (OHWL), determined by the Minnesota Department of Natural Resources (MNDNR), for Cedar Lake is 853 feet above mean sea level (msl). The Upper Chain of Lakes are made up of four lakes including Brownie, Cedar, Lake of the Isles, and Bde Maka Ska. The water bodies are connected via channels and the lake level for the entire Upper Chain is measured at Bde Maka Ska. For more information on historic Upper Chain of Lakes water level refer to **Chapter 2**. See **Chapter 1** for details on lake level monitoring and **Chapter 17** for a comparison with other MPRB lakes.

Water Quality Trends – Trophic State Index (TSI)

Figure 5-3 shows historical Cedar Lake TSI scores and trend line. Restoration efforts that began in 1994 have helped improve water quality in the lake. There was an initial decrease in TSI after the completion of the restoration projects, but there has not been a significant trend in TSI from 1991-2022 ($p > 0.05$). The TSI score for Cedar Lake in 2022 was 49. The lake is currently mesotrophic, which is defined as having moderately clear water and increasing probability of hypolimnetic anoxia during summer.

The CWP Minneapolis Chain of Lakes Project developed a long-term TSI goal in 1993 to be below 51 that was intended to be met within five to ten years of water quality project completion. The TSI score met the CWP goal most years after completion of restoration projects, except for 2006, 2013, and 2017-21. Between 2017 and 2021 the TSI scores were much higher than the previous years, indicating worsening water quality. In 2022 the TSI score was comparable to scores prior to 2017 and met the TSI goal.

Secchi, chlorophyll-*a*, and total phosphorus TSI scores for Cedar Lake are within the expected TSI range for lakes in the same ecoregion, see **Table 5-2**. See Minnesota Pollution Control Agency (MPCA) Surface Water Data (https://webapp.pca.state.mn.us/wqd/surface-water/waterunit-details?wid=27-0039-00) for more information. A detailed explanation of TSI can be found in **Chapter 1**.

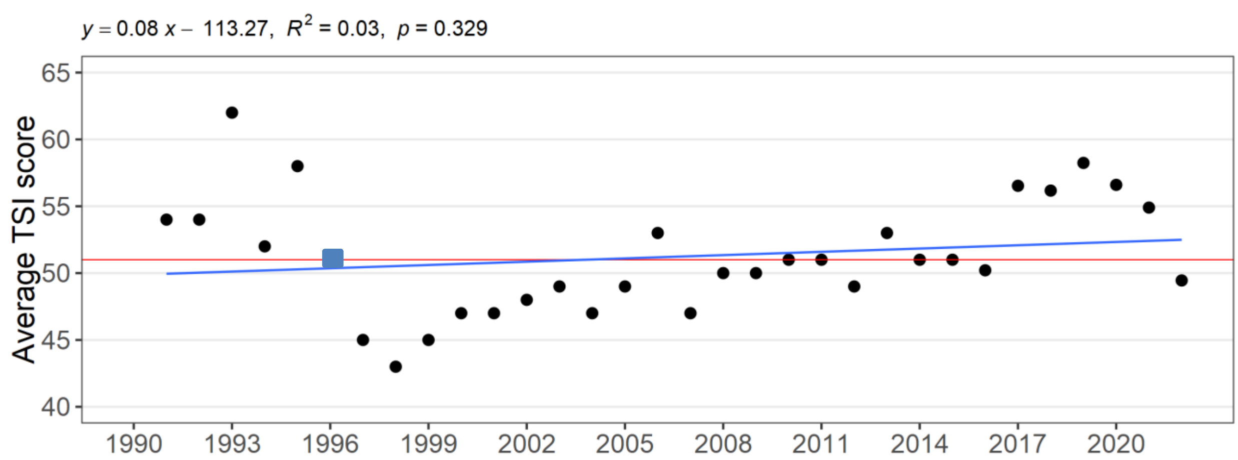


Figure 5-3. Cedar Lake TSI scores and linear regression from 1991-2022. The red line represents the CWP long-term TSI goal of below 51. The blue square highlights the 1996 alum treatment.

Table 5-2. Cedar Lake Secchi, chlorophyll-*a*, and total phosphorus TSI based on data collected between June and September of 2022 and compared to lakes in the North Central Hardwood Forest ecoregion.

	TSI	Expected TSI Range of Lakes in the Same Ecoregion	Within the Expected TSI Range of Lakes in the Same Ecoregion
Secchi	43	43-54	Within range
Chlorophyll-*a*	53	46-61	Within range
Total Phosphorus	51	49-61	Within range

Box and Whisker Plots

The box and whisker plots in **Figure 5-4** show the data distribution for water clarity, chlorophyll-*a*, and total phosphorus for the past 10 years, based on data from the entire sampling season. Red horizontal lines on the graphs indicate the MPCA eutrophication standards for deep lakes, which applies to data collected between June and September. A detailed explanation of box and whisker plots can be found in **Chapter 1**. Box and whisker plots from the entire period of record, 1991-2022, can be found in **Appendix A**.

Water clarity was much deeper and more variable in 2022 compared to previous years with an average of 3.4 meters, see **Figure 5-4a**. Chlorophyll-*a* concentrations increased between 2014 and 2019 and have been decreasing since with an average of 9 µg/L in 2022, see **Figure 5-4b**. Total phosphorus concentrations have remained relatively consistent over the past 10 years remaining near the MPCA standard, with more variability occurring in 2020. The average total phosphorus concentration was 29 µg/L in 2022, see **Figure 5-4c**. The lake met the MPCA eutrophication standards for water clarity, chlorophyll-*a*, and total phosphorus in 2022.

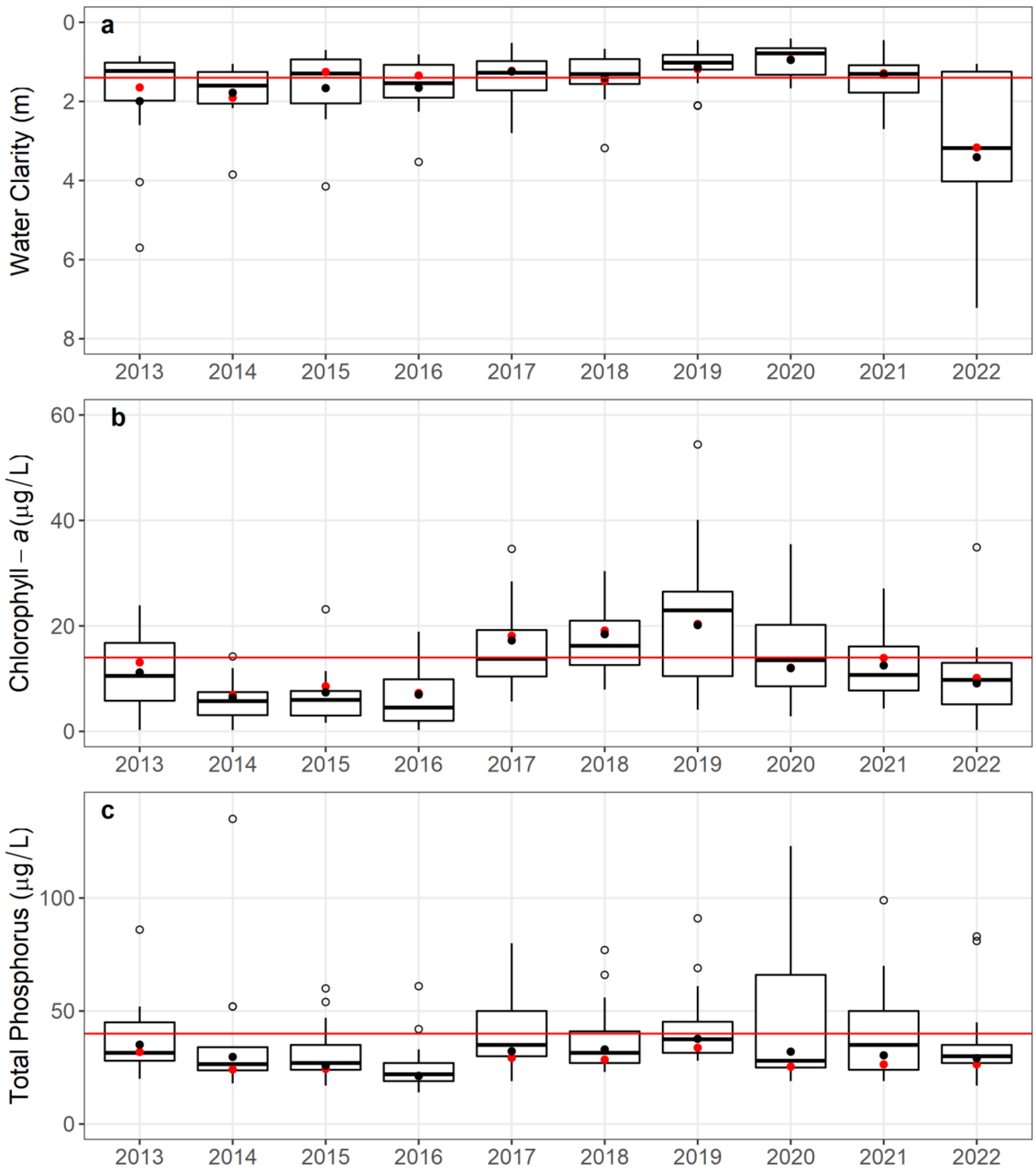


Figure 5-4. Cedar Lake box and whisker plots of water clarity (a), chlorophyll-*a* (b), and total phosphorus (c) from 2013-2022. Horizontal lines represent MPCA eutrophication standards for deep lakes, which applies to data collected between June and September. The red circles represent the mean value of data collected between June and September. The black circles represent the mean value of data collected during the growing season, May through September. Data from 1991-2022 can be found in Appendix A.

CHLORIDE

Chloride is a naturally occurring element that is commonly found at low levels in most freshwater bodies. Chloride is a component of road salt (sodium chloride) and is found in other types of compounds that are also called salts (calcium chloride, magnesium chloride). Unnaturally high concentrations of chloride can negatively impact surface waters. High levels of chloride can change the mixing pattern of a lake and lead to very low oxygen levels in deep water. It can also lead to decreasing water clarity and induce stress or cause death of aquatic species (Bathe & Coring, 2011). Sources of chloride include industrial discharge, septic systems, sewage disposal systems, fertilizers, and road salt (Novotny, Murphy, & Stefan, 2008). The MPCA adopted the Environmental Protection Agency's (EPA) recommended water quality criteria for chloride which is a chronic standard of 230 mg/L and an acute standard of 860 mg/L (MPCA, 2016). The MPRB has monitored chloride concentrations in Cedar Lake since 1995 by collecting surface water samples using a composite tube and collecting deep water samples using a Kemmerer sampler. See **Chapter 1** for more information on chloride.

Figure 5-5 shows epilimnetic and hypolimnetic chloride concentrations in Cedar Lake between 1995-2022, with hypolimnion samples collected regularly after 2006. Epilimnion samples represent the top two meters of the lake and hypolimnion samples were collected approximately one meter from the bottom of the lake. Red horizontal lines on the graph indicate the MPCA acute and chronic chloride standards. Also included on the graph, is a dotted line that represents an estimate of a concentration above which potential ecological impact could occur, at 120 mg/L. This level of potential ecological impact was developed by Canadian Council of Ministries of the Environment (CCME) and is not a Minnesota state standard but a long-term chloride concentration that could negatively impact life within the lake (CCME, 2011). Between 2010-2019 chloride concentrations in the hypolimnion were slightly higher than epilimnetic concentrations likely because runoff containing sodium chloride is denser and sinks to the lake bottom; however, between 2020-2022 chloride concentrations in the epilimnion and hypolimnion were roughly comparable. Chloride concentrations have been slowly increasing since 2008; prior to 2008 most chloride concentrations measured below the level of ecological impact and after 2018 most samples were above this threshold. Chloride concentrations in the hypolimnion exceeded the chronic standard only one time in 2019.

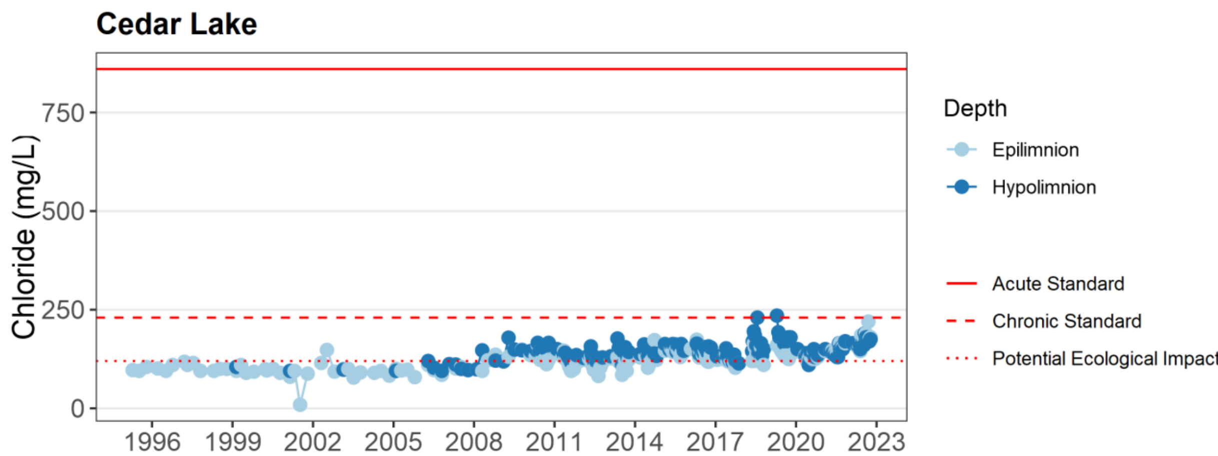


Figure 5-5. Cedar Lake scatterplot of epilimnetic and hypolimnetic chloride concentrations between 1995-2022. Horizonal lines represent the MPCA's acute and chronic standard and the potential ecological impact level (CCME, 2011).

Beach Monitoring

Escherichia coli (*E. coli*) levels were monitored at three different locations around Cedar Lake: Cedar Main Beach, Cedar Point Beach, and East Cedar Beach (Hidden) in 2022. The season-long geometric means for *E. coli* were low at all the Cedar Lake beaches, as shown in **Table 5-3** and **Figure 5-6**. East Cedar Beach was opened as a supervised public beach for the first time in 2007 and has typically had some of the lowest *E. coli* count values for all MPRB beaches. In 2022, *E. coli* levels remained relatively low at East Cedar Beach, while both Cedar Main and Cedar Point Beaches had single-sample *E. coli* exceedances leading to closures during the sampling season.

Cedar Main Beach closed July 19th due to an exceedance of the single sample *E. coli* standard of 1,260 MPN/100 mL. The beach was re-sampled on July 20th and re-opened on July 21st after results had shown that *E. coli* concentrations dropped below the single-sample threshold. Cedar Point Beach closed July 12th due to an exceedance of the single sample *E. coli* standard. The beach was re-sampled on July 13th and re-opened on July 14th after results had shown that *E. coli* concentrations dropped below the single-sample threshold. Stormwater runoff, aquatic vegetation, and waterfowl waste may have contributed to high bacteria levels at these beaches. See **Chapter 18** for more information on beach *E. coli* monitoring.

Table 5-3. Summary of *E. coli* (MPN per 100 mL) data for Cedar Lake beaches in 2022.

Statistical Calculations	East Cedar	Cedar Main	Cedar Point
Number of Samples	15	14	15
Minimum	1	1	1
Maximum	176	>2420	>2420
Median	3	14	10
Mean	24	232	195
Geometric Mean	6	18	17
Max 30-Day Geo Mean	22	35	56
Standard Deviation	47	649	617

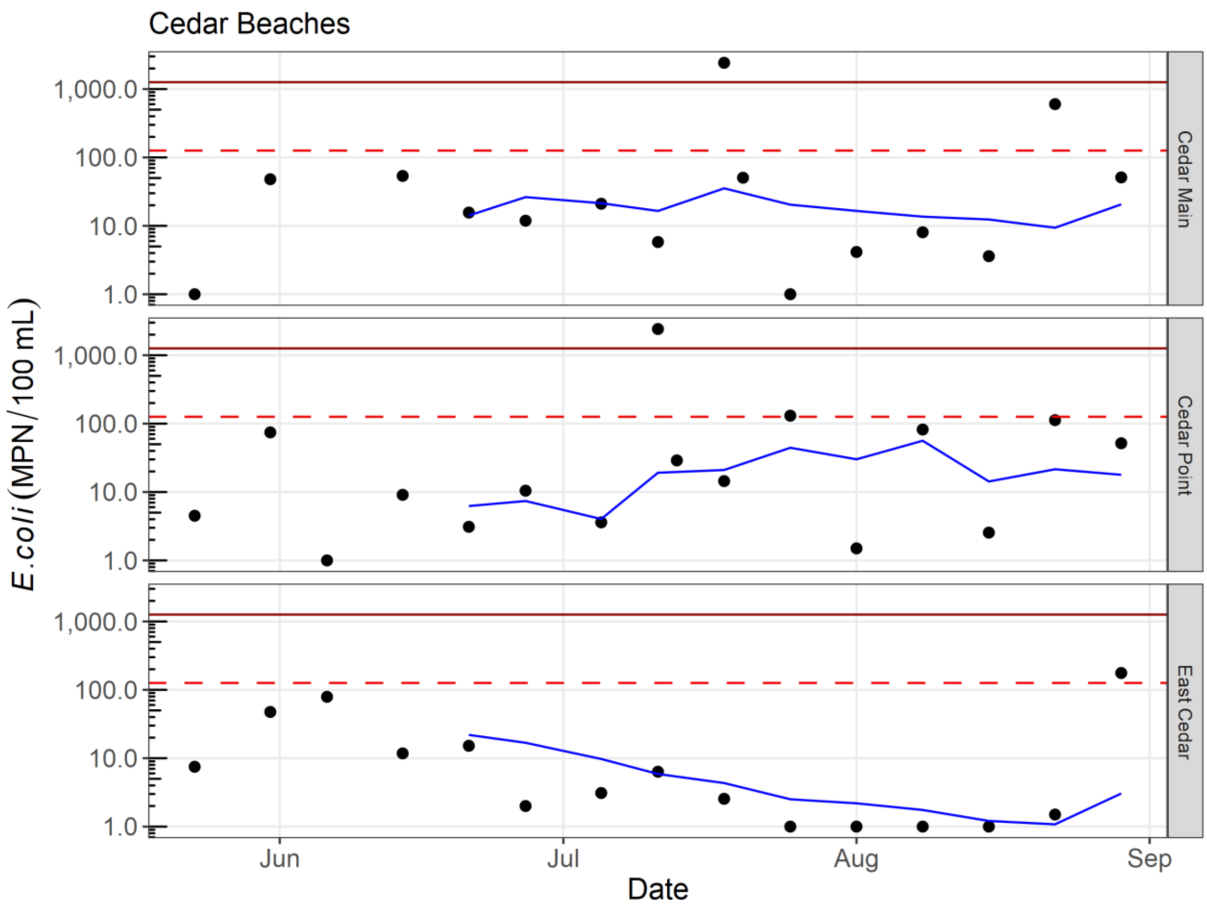


Figure 5-6. 2022 *E. coli* concentrations at the Cedar Lake beaches. Black circles are individual data points. Blue line is the running 30-day geometric mean. The dashed horizontal line represents the *E. coli* standard for the 30-day geometric mean (126 MPN/100mL) and the solid horizontal line represents the single-sample maximum standard (1,260 MPN/100mL). Note the log scale on the Y-axis.

Figure 5-7 shows *E. coli* monitoring data for Cedar Lake beaches from 2013 to 2022 which is graphed by using box and whisker plots. The box and whisker plots show the variability in bacteria levels over the past 10 years. All three Cedar Lake beaches had comparable bacteria levels to previous years in 2022.

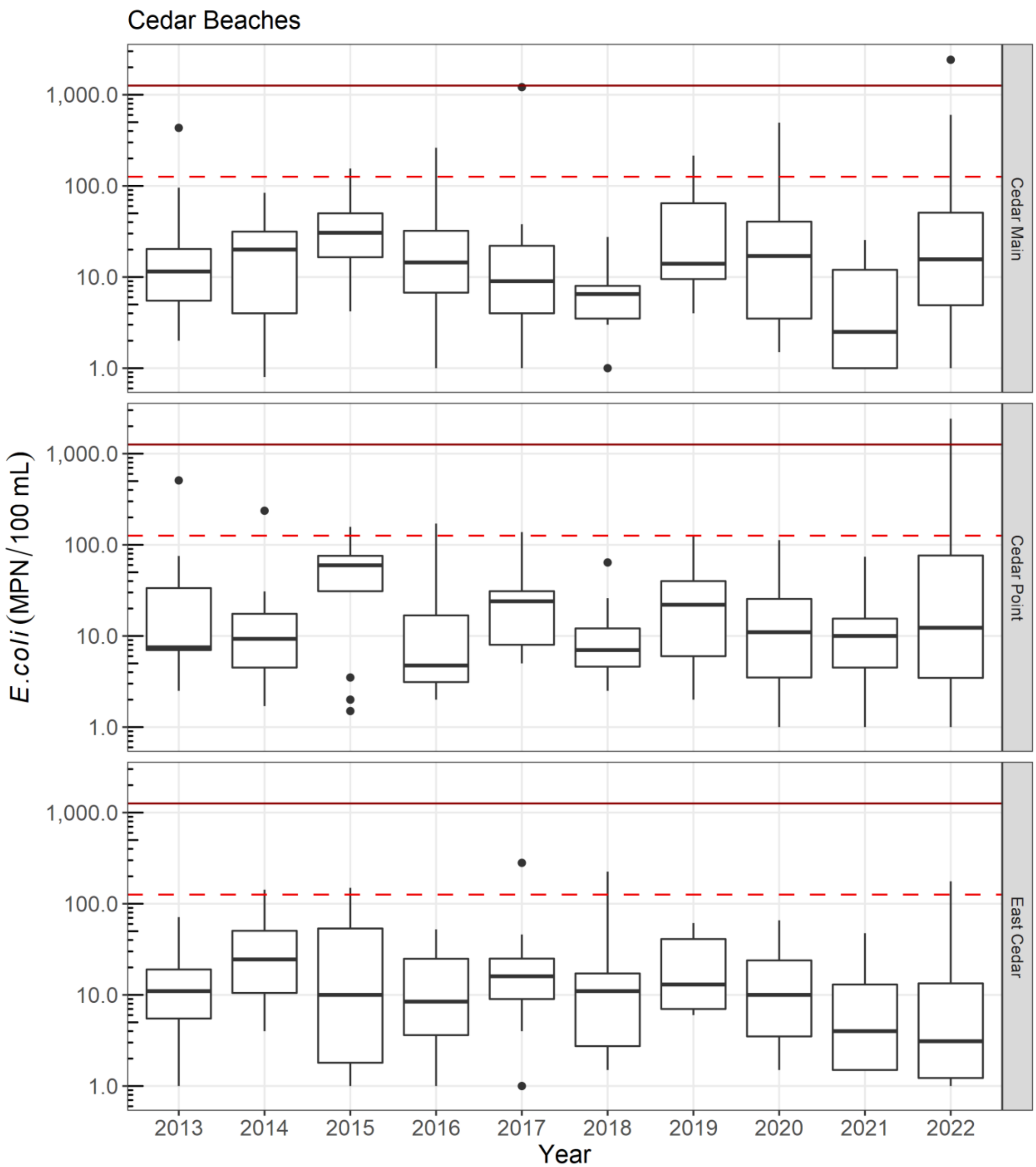


Figure 5-7. Box and whisker plots of *E. coli* concentrations (MPN/100 mL) for Cedar Lake beaches from 2013-2022. The dashed horizontal line represents the *E. coli* standard for the 30-day geometric mean (126 MPN/100mL) and the solid horizontal line represents the single-sample maximum standard (1,260 MPN/100mL). Note the log scales on each y-axis.

Figure 5-8 shows the total number of days Cedar Lake beaches were closed each year due to *E. coli* exceedances for the past 10 years. Cedar Lake beaches have generally experienced few closures. In 2021, all Cedar Lake beaches were closed for three days as a precaution due to a sewage release to a connected storm sewer line. In 2022, both Cedar Main Beach and Cedar Point Beach had single-sample exceedances, likely attributed to waterfowl waste.

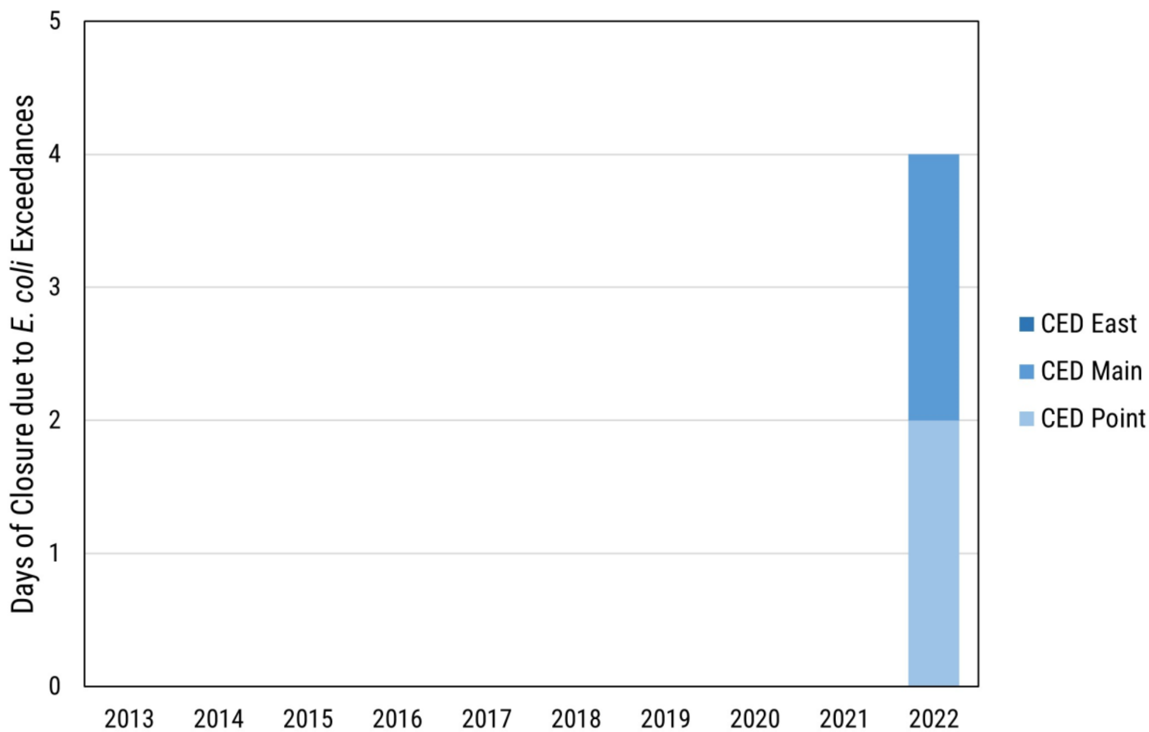


Figure 5-8. Bar graph of total number of days Cedar Lake beaches were closed each year due to *E. coli* exceedances from 2013-2022. All Cedar Lake beaches were closed for three days in 2021 due to sewage release to a connected storm sewer line; however, this is not plotted because there were no *E. coli* exceedances at this time.

Blue-green Algae/Cyanotoxin Monitoring

Blue-green algae are not algae at all, but a type of bacteria called cyanobacteria. These photosynthetic microorganisms occur naturally in lakes, streams, and other waterbodies worldwide. When conditions are right, cyanobacteria can grow quickly to form dense accumulations called blooms. Certain varieties of cyanobacteria can produce toxins, referred to as cyanotoxins, that can cause illness in humans and animals (US EPA, 2017). Due to an increase in frequency and intensity of cyanobacteria blooms in Minneapolis lakes, the MPRB developed a cyanobacteria monitoring program for public health in 2020. MPRB staff collect information on observations using a defined Visual Monitoring Index (VMI), and sample water weekly at beaches for the most common cyanotoxins. Advisories are posted at beaches and on the MPRB Lake Water Quality Map (bit.ly/mplsbeaches) if toxin levels exceed MPCA guidelines. See **Chapter 19** for more information on blue-green algae and cyanotoxin monitoring.

In 2022, VMI observations were made during weekly beach sampling and bimonthly lake sampling on Cedar Lake. Cyanotoxin samples were also collected at Main Beach, Point Beach, and East Beach weekly. VMI observations indicated low levels of cyanobacteria throughout the year. Cyanotoxin levels were consistently low at all Cedar Lake. Concentrations were highest in late August when the microcystin concentration was 0.24 µg/L at Main Beach and the anatoxin-*a* concentration was 0.28 µg/L at East Beach, which was well within safe swimming guidelines of 6 µg/L for microcystin and 7 µg/L for anatoxin-*a*. Although cyanobacteria were present in Cedar Lake in 2022, no significant scums or accumulations were observed, and all water samples collected were within the state guidelines for swimming.

Lake Aesthetic and User Recreation Index (LAURI)

The 2022 LAURI for Cedar Lake is presented in **Figure 5-9**. Cedar Lake scored excellent in aesthetics, water clarity, public health, habitat quality, and recreational access. See **Chapter 1** for details on the LAURI index.

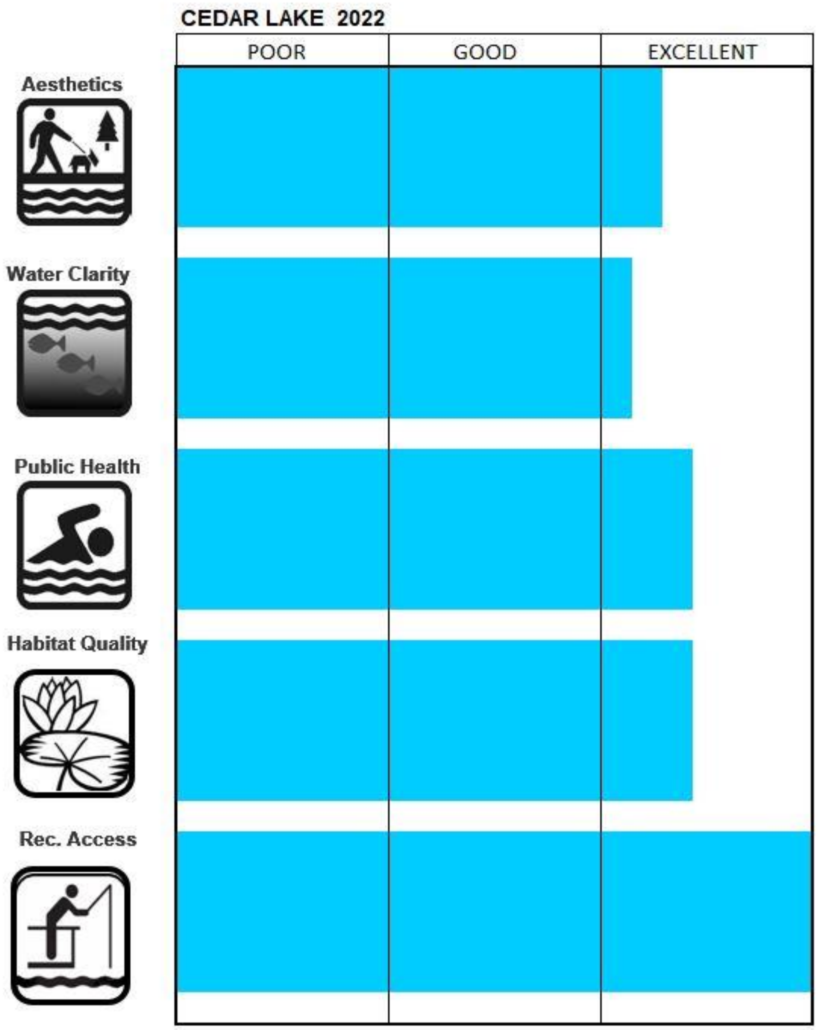


Figure 5-9. The 2022 LAURI for Cedar Lake.

Winter Ice Cover

Ice came off Cedar Lake on April 11, 2022, four days later than the average ice-off. Ice was back on the lake by December 5, 2022, one day earlier than the average ice-on date. See **Chapter 1** for details on winter ice-cover records and **Chapter 17** for a comparison with other lakes.

Aquatic Plant Management

The MNDNR requires a permit to remove or control Eurasian watermilfoil. The permit limits the area from which milfoil can be harvested to protect fish habitat. The permits issued to the MPRB allowed for harvesting primarily in swimming areas, boat launches, and shallow areas where recreational access was necessary. In 2022, the permitted area on Cedar Lake was 13 acres, which is approximately 19% of the littoral zone of the lake, the area shallower than 15 feet. See **Chapter 1** and **Chapter 21** for details on aquatic plants.

Phytoplankton and Zooplankton

Phytoplankton are microscopic plants that are an integral part of the lake community because they form the base of the aquatic food web. **Figure 5-10** shows the water clarity, chlorophyll-*a* concentrations, and relative abundance of phytoplankton divisions during 2022. Comparing these three parameters together can show how changes in the types of algae present in a lake effect water clarity and color, see the phytoplankton and zooplankton monitoring section in **Chapter 1** for additional details.

Water clarity ranged between 1.0 and 7.2 meters in 2022. The shallowest Secchi reading occurred in late June and the deepest reading occurred in late May when chlorophyll-*a* concentrations were low, see **Figure 5-10a**. Concentrations of chlorophyll-*a* were lowest in winter and late May at <0.5 µg/L when cryptomonads (Cryptophyta) dominated the phytoplankton community. Chlorophyll-*a* concentrations were highest in spring at 34.9 µg/L when the phytoplankton community primarily consisted of diatoms (Bacillariophyta), see **Figure 5-10b, c**.

The phytoplankton community primarily consisted of blue-green algae (Cyanophyta) throughout most of the 2022 sampling season, dominating the population in early June and between late July and fall, see **Figure 5-10c**. Bacillariophyta, green algae (Chlorophyta), golden-brown algae (Chrysophyta), Cryptophyta, haptophytes (Haptophyta), and dinoflagellates (Pyrrophyta) were also present at high levels. Euglenoids (Euglenophyta) and yellow-green algae (Xanthophyta) were present at low levels in 2022.

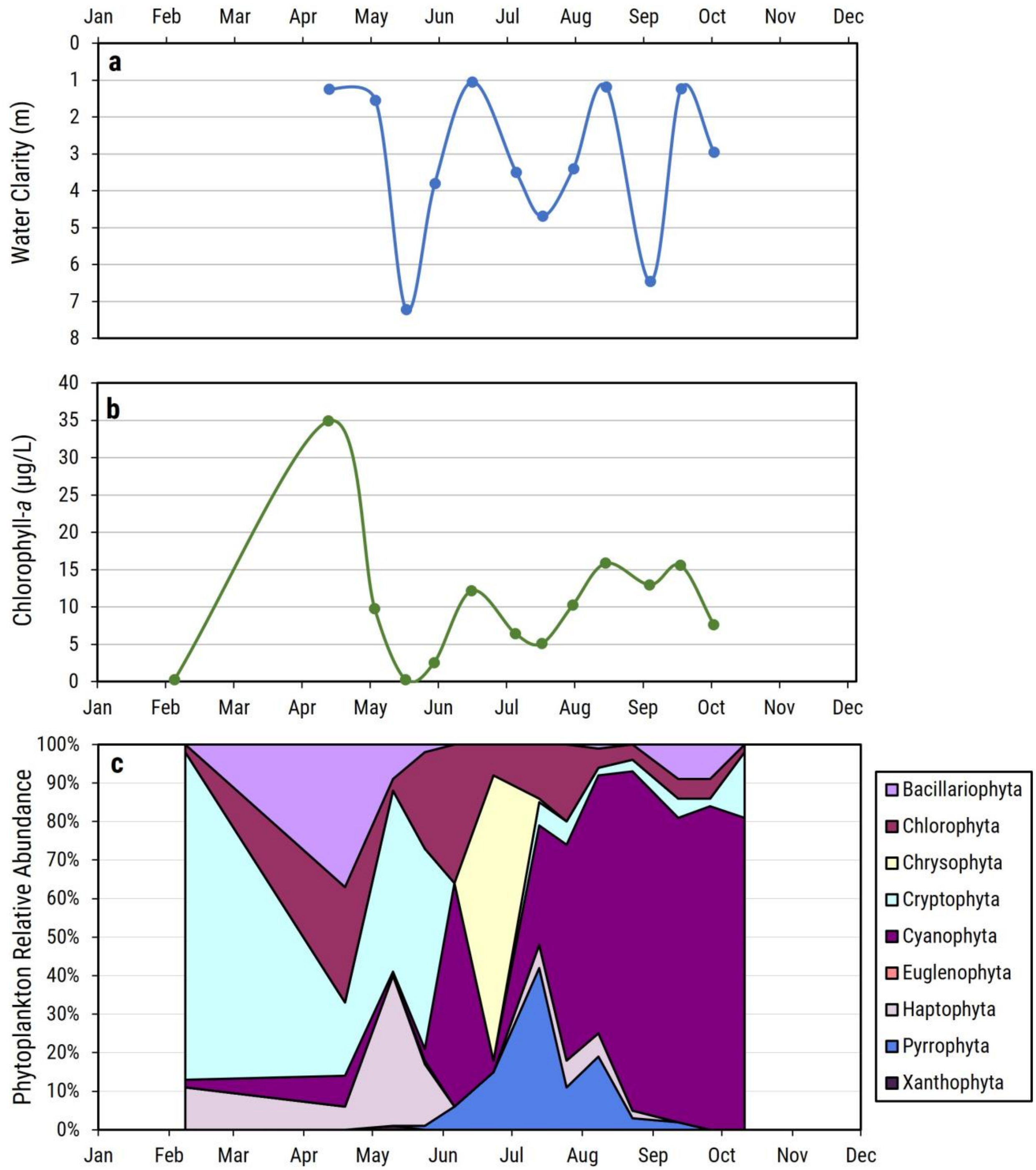


Figure 5-10. Water clarity (a), chlorophyll-*a* concentration (b), and relative abundance of phytoplankton (c) in Cedar Lake during 2022. Note that the water clarity axis is reversed.

Zooplankton are tiny animals that feed on phytoplankton and are also vital for the lake community because they form the second level of the food web along with larval fish. **Figure 5-11** shows the zooplankton abundance in Cedar Lake sampled throughout 2022. Nauplii and juvenile copepods were present throughout the year and most abundant in May. Cladocerans were present in all samples and were most abundant in October. Rotifers were also present through the year and were most abundant in May and August. Calanoids, cyclopoids, and protozoa were also present in low levels in 2022.

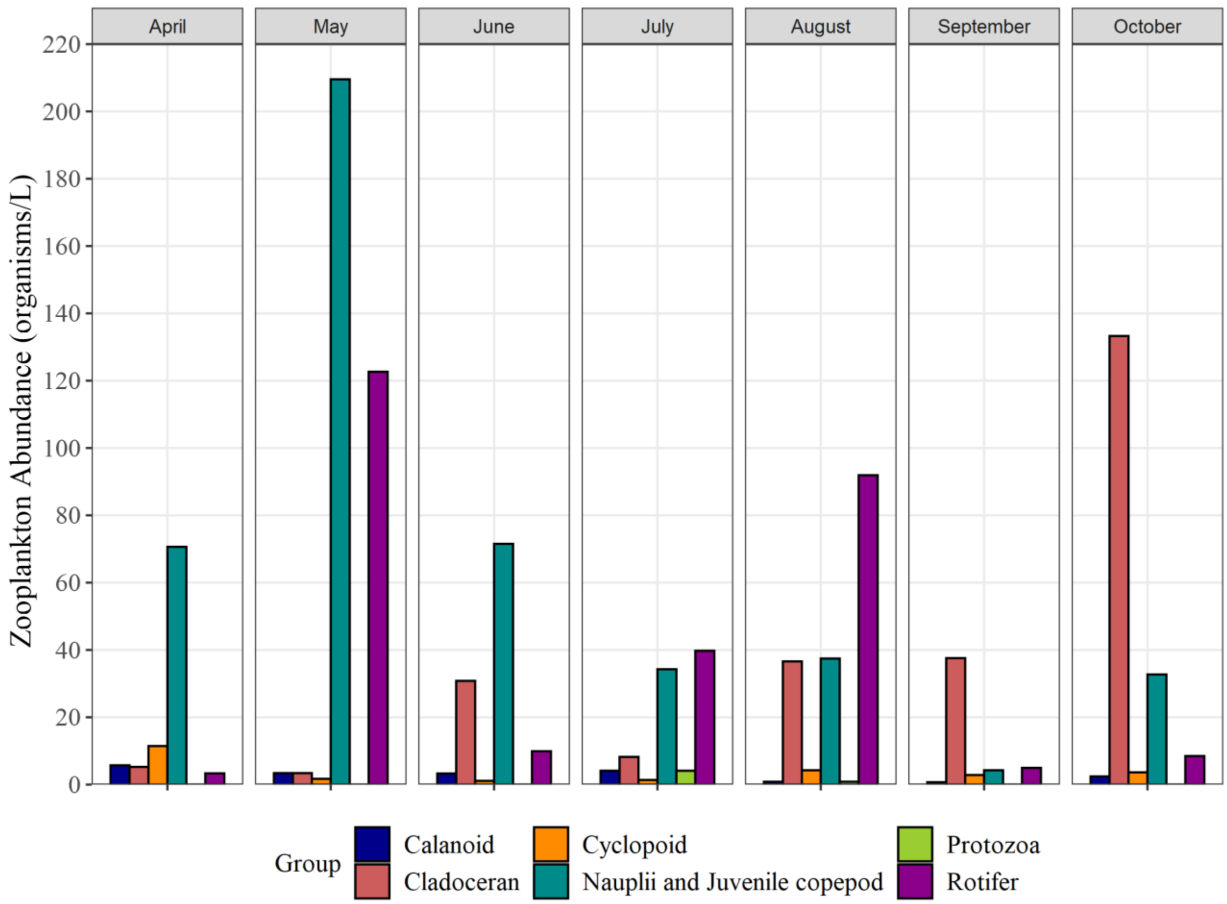


Figure 5-11. Zooplankton abundance in Cedar Lake during 2022.

Events Report

Kenilworth Channel Naturalization and Shoreline Stabilization Project

The Kenilworth Channel, which connects Cedar Lake and Lake of the Isles, closed on September 7, 2021, between the Burnham Road Bridge and Cedar Lake, to prepare for an MPRB naturalization and shoreline stabilization project. The Kenilworth Channel remained closed throughout most of 2022. Two cofferdams were installed, one at each end of the construction site, and the channel was dewatered, as shown in **Figure 5-12**. A bypass pump was installed and remained ready in the event that Cedar Lake water elevation increased; however, Cedar Lake never exceeded the water elevation standard set by the MNDNR and the bypass pump was not needed during construction. Additionally, three dewatering pumps were installed to remove excess water from the channel due to rainfall events and were run as needed to maintain conditions suitable for project work.

Turbidity curtains were installed near the cofferdams to protect the water quality of Cedar Lake and Lake of the Isles during construction. In 2021, turbidity was monitored as a proxy for sediment release at five locations throughout the construction site 2-3 times per day and reported to MPRB staff weekly, see **Figure 5-13.** Turbidity was also monitored at lake sampling sites in Cedar Lake and Lake of the Isles biweekly. In 2022, turbidity measurements were not taken within the channel construction area because the channel was not dewatered during the summer of 2022. In-lake turbidity measurements were taken in the spring and from late August to October of 2022 but were otherwise limited due to equipment malfunctions. Turbidity measurements taken during the project are shown in **Table 5-4**. Turbidity levels remained low at all sampling points except for at sampling location KC2, located within the cofferdam, indicating that sediment and nutrient release to the lake due to the project was minimized by project construction practices.

In 2021, while the channel was dry, a section of a sanitary sewer line parallel to the channel was replaced by the City of Minneapolis. During the construction of the stabilization project, the old wood walls of the channels were removed and replaced with stone, soil lifts, and plants creating a naturalized shoreline. Water was allowed to refill the channel in mid-December of 2021 (https://www.minneapolisparks.org/park_care__improvements/park_projects/current_projects/kenilworth-channel-stabilization/). Additional planting and minor areas of stabilization above the water line took place in 2022.

Channel work by the Met Council Southwest light rail project (SWLRT) project began in the fall of 2022, shown in **Figure 5-14**, and construction will take place over winter with the channel reopening in 2023 (https://content.govdelivery.com/accounts/MNORGMETC/bulletins/3414b9b).

Figure 5-12. Photo of downstream cofferdam, bypass pump (not running), and three dewatering pumps during construction of the MPRB project.

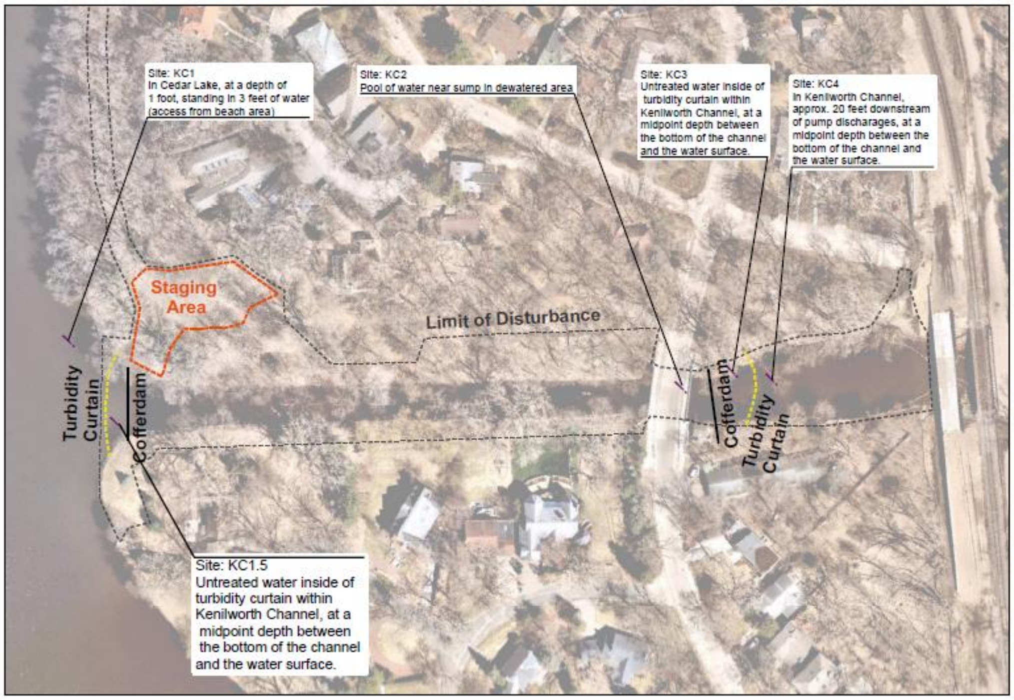


Figure 5-13. Map of turbidity measurement locations, cofferdams, and turbidity curtains in Kenilworth Channel in place for the 2021 MPRB project.

Table 5-4. Minimum, maximum, and average turbidity readings, measured in Nephelometric Turbidity Units (NTU), from Kenilworth Channel sampling locations recorded 2-3 times daily and in lake surface readings recorded biweekly between September and November of 2021. In lake surface turbidity readings recorded in spring and biweekly between late August and October of 2022. Note that most turbidity readings were similar between the lakes and within the construction site, and only sites within the cofferdam were high.

Sampling Year	Sampling Location	Minimum Turbidity (NTU)	Maximum Turbidity (NTU)	Average Turbidity (NTU)
2021	KC1	0.00	18.9	3.29
	KC1.5	0.00	12.3	2.99
	KC2	1.43	1619	164
	KC3	0.00	28.8	6.18
	KC4	0.01	10.5	2.58
	Cedar Lake	1.68	6.90	2.51
	Lake of the Isles	0.71	12.0	2.89
2022	Cedar Lake	0.00	3.40	1.90
	Lake of the Isles	0.50	4.30	2.46

Figure 5-14. Reconstruction of the historic Cedar Lake Channel Works Progress Administration (WPA) wall by the Met Council SWLRT project. (https://content.govdelivery.com/accounts/MNORGMETC/bulletins/3414b9b).

Fish Stocking

Cedar Lake is the only lake in the Minneapolis Chain of Lakes where Least Darters still naturally occur. In 2019, Least Darters were transplanted from Cedar Lake and stocked into Bde Maka Ska and Lake Harriet to determine the feasibility of transplanting sensitive, non-game fish into lakes with exceptional water quality and clarity successfully (Konrad, 2019). In 2022, Muskellunge fingerlings were stocked into Cedar Lake, see **Table 5-5**. Additional information and a definition of fry, fingerling, yearling, and adult fish sizes can be found in **Chapter 1**.

Table 5-5. Fish stocked into Cedar Lake over the past 10 years. Data are from the Minnesota Department of Natural Resources.

Year	Species	Number and Size	Amount
2022	Muskellunge	63 fingerlings	9.8 pounds
2021	Muskellunge	63 fingerlings	11.2 pounds
2018	Muskellunge	63 fingerlings	7.3 pounds
2016	Muskellunge	63 fingerlings	10.9 pounds
2015	Walleye	167 yearlings	136.1 pounds
2013	Walleye	3,640 fingerlings	146.0 pounds

Water Quality Projects

Cyanobacteria Mitigation Feasibility Study

The MPRB is developing specific cyanobacteria mitigation strategies for Cedar Lake and Lake Nokomis to address ongoing concerns about toxic cyanobacteria blooms in these lakes. This work is being undertaken because of significant blooms of cyanobacteria that have occurred at Cedar Lake and the presence of cyanotoxins that can exceed the MPCA's swimming advisory levels at Lake Nokomis. The objectives of the project are to identify the specific stressors causing beach-season and off-season cyanobacteria blooms in the lakes and identify and evaluate structural and nonstructural mitigation strategies to address the stressors each lake.

After reviewing over 20 years of water quality data it was determined that the primary drivers of cyanobacteria blooms in Cedar Lake included:

- High nutrient concentrations in the hypolimnion because of shallow anoxia and sediment phosphorus release
- Strongly stratified conditions with high nutrient concentrations at the thermocline selecting for cyanobacteria that regulate buoyancy in the summer and into the fall
- High phosphorous concentrations under winter ice as a result of high internal phosphorus loading resulting in conditions that favor cyanobacteria adapted to cold temperatures and low light conditions
- Nitrogen limitation in late summer that favors nitrogen fixing cyanobacteria

- Increased light availability during the winter if there is low snow cover or if snow is removed for recreation.

Potential mitigation strategies that could address the drivers were evaluated including:

- Targeted use of hydrogen peroxide as an algaecide
- In-lake sediment phosphorus inactivation using aluminum sulfate/sodium aluminate
- In-lake biomanipulation: carp management and aquatic plant management
- Hypolimnetic oxygenation without destratification
- Further analysis of Watershed Structural BMPs: Cedar Meadows and Brownie Lake
- Watershed source abatement: enhanced street sweeping, urban forestry, fertilizer management, pet waste management, and goose management.

In 2023 the MPRB will be working on conducting aquatic plant survey work at Cedar Lake and evaluating potential carp movement and barrier effectiveness. Cedar Meadows is a constructed wetland which is part of a stormwater treatment system completed in 1996 that diverts water from the Twin Lakes watershed to the constructed wetland before it enters Cedar Lake. Carp barriers were installed in the past but were sometimes removed due to obstruction issues and may require maintenance or replacement. Cedar Meadows wetland ponds and bypass will be evaluated for the potential of carp movement and barrier effectiveness. A high carp concentration in Cedar Lake could reduce the longevity of any future in-lake treatment and reduce the effectiveness of Cedar Meadows wetland in reducing nutrient inputs, so maintaining the effectiveness of the barriers put in place in the past protects past and future water quality investments in the lake.

Emerging Contaminants

Per- and polyfluoroalkyl substances (PFAS), a class of chemicals with a range of commercial and industrial uses, have been recently identified as a concern due to their impact on environmental and human health (MPCA, “PFAS”). Perfluorooctane sulfonate (PFOS) is a type of PFAS that is of concern related to fish consumption. Perfluorooctanoic acid (PFOA) is another type of PFAS in the environment that is connected to potential negative human health effects. See **Chapter 1** for more information on emerging contaminants and **Chapter 17** for comparison of PFAS in MPRB lakes.

Cedar Lake is not on the MPCA’s list of impaired waters (303(d) list) for high concentrations of PFOS in fish tissue. The current threshold for listing is a PFOS in fish tissue concentration of 50 ng/g (MPCA, 2022-b). Due to its connection to Bde Maka Ska, Waterbody Specific Safe-Eating Guidelines for Cedar Lake fish consumption were set by the Minnesota Department of Health (MDH) in 2007 to minimize PFOS exposure, see https://www.dnr.state.mn.us/lakefind/fca/report.html?downum=27003900. MPCA data on the concentration of PFOS in fish tissue are shown in **Table 5-6**.

Table 5-6. Concentrations of PFOS in fish tissue of different species of fish in Cedar Lake, compared to the fish tissue PFOS concentration threshold for the 303(d) impaired waters list. Data is given as the mean PFOS concentration in nanograms of contaminant per wet weight gram of fish tissue, and the number in parentheses indicates the number of individual fish sampled. NA means no fish of this species were sampled. The all-species mean is calculated from the given means and numbers of fish. Data received via communication with MPCA staff in 2023.

Cedar Lake	**2018**	**2021**
Species	*Mean PFOS (n) ng/g ww*	
Black crappie	9 (5)	11 (5)
Bluegill	17 (5)	4 (5)
Largemouth bass	16 (5)	11 (5)
Northern pike	NA	5 (2)
Walleye	23 (5)	26 (1)
White sucker	NA	1 (1)
All species mean	12	9
Fish tissue PFOS concentration threshold for 303(d) impaired waters list	50	

Recreation such as swimming is considered low risk for PFAS exposure, and the concentrations of both PFOS and PFOA in Cedar Lake are well below the swimming guidance recommended by the MPCA, see **Table 5-7**.

Table 5-7. Surface water concentrations of PFOS and PFOA in Cedar Lake, compared to the PFOS and PFOA swimming guidance. Data is given as the mean concentration in nanograms of contaminant per liter of lake water. Data retrieved from MPCA (2018). Swimming guidance received via communication with MPCA staff in 2023.

Cedar Lake	**PFOS (ng/L)**	**PFOA (ng/L)**
2007	5.75	8.19
2018	4.71	3.71
Swimming Guidance	330	1,900

6. Diamond Lake

History

Diamond Lake and surrounding park areas were donated to the Minneapolis Park and Recreation Board (MPRB) between 1926 and 1936. In 1937, a project was proposed to dredge Diamond Lake, generating fill to deposit in Pearl Lake to create Pearl Park; however, the Board voted against the dredging project and decided to use fill from airport properties instead. A drain from Pearl Park was installed to divert water to Diamond Lake and prevent flooding in the park (Smith, 2008). **Figure 6-1** shows a photo of Diamond Lake.

Figure 6-1. Diamond Lake in October of 2022.

Diamond Lake is a small, shallow water body. The National Wetlands Inventory classifies Diamond Lake as a permanently flooded lacustrine/limnetic system with an unconsolidated bed (L1UBH). The fringe of Diamond Lake is classified as palustrine semi-permanently flooded wetland with emergent vegetation (PEMF) (USFWS, 2012). **Table 6-1** shows physical characteristics and morphometric data of Diamond Lake and **Figure 6-2** shows a map of the lake. The lake is part of the Minnehaha Creek Watershed and is surrounded by residential neighborhoods and parkland, but also receives stormwater runoff from nearby highways.

Water levels in Diamond Lake have fluctuated due to land-use changes in the surrounding watershed. City of Minneapolis installed stormsewers in 1940 and Diamond Lake currently has 11 stormwater outfalls, see **Appendix C**. By 1941, 800 acres of developed land was draining into Diamond Lake causing drastic water elevation fluctuations. In 1942, the Works Progress Administration (WPA) constructed an overflow outlet to control water elevation and an outflow pipe that carried water from the northeast shore to Minnehaha Creek. Construction of Interstate 35W during the 1960s added several miles of highway runoff to Diamond Lake. In 1991, the MPRB placed a weir at the Diamond Lake outlet at 822.0 feet above mean sea level (msl) allowing for higher water than the previous outlet, which was 820.1 ft msl. The increase in water elevation was desired to encourage establishment of aquatic plants and to restore wildlife habitat in Diamond Lake. In 2007, construction began on the 35W/HWY62 improvement project that again changed the drainage areas in the Diamond Lake watershed.

In 1953, the Minnesota Department of Natural Resources (MNDNR) completed a water quality survey and determined that the lake could not be considered a fish supporting lake due to the lack of oxygen during the winter months (MNDNR, 1953). MPRB sampling has confirmed that Diamond Lake freezes to the bed during some winters.

The Diamond Lake Management Plan was developed in partnership between the Healthy Lake and River Partnership Committee, Friends of Diamond Lake, and the MPRB in 2009. The management plan was intended to create a record of historic and existing conditions and influences on the lake as well as to set goals and strategies for the preservation and protection of Diamond Lake. The 2009 management plan can be found on the MPRB web site:
https://www.minneapolisparks.org/_asset/rx1dll/diamond_lake_management_plan.pdf. To date, the management plan has been used by the Friends of Diamond Lake to obtain grant funding for stormwater management on private properties in the watershed.

Water quality on Diamond Lake has been monitored annually since 1992.

Table 6-1. Diamond Lake physical characteristics and morphometric data.

Surface Area (acres)	Mean Depth (ft)	Max Depth (ft)	Littoral Area*	Volume (ft^3)	Watershed Area (acres)	Watershed: Lake Area (ratio)
52	3.2	5.8	100%	$2.52x10^6$	669	16.3

* Littoral area was defined as less than 15 feet deep.

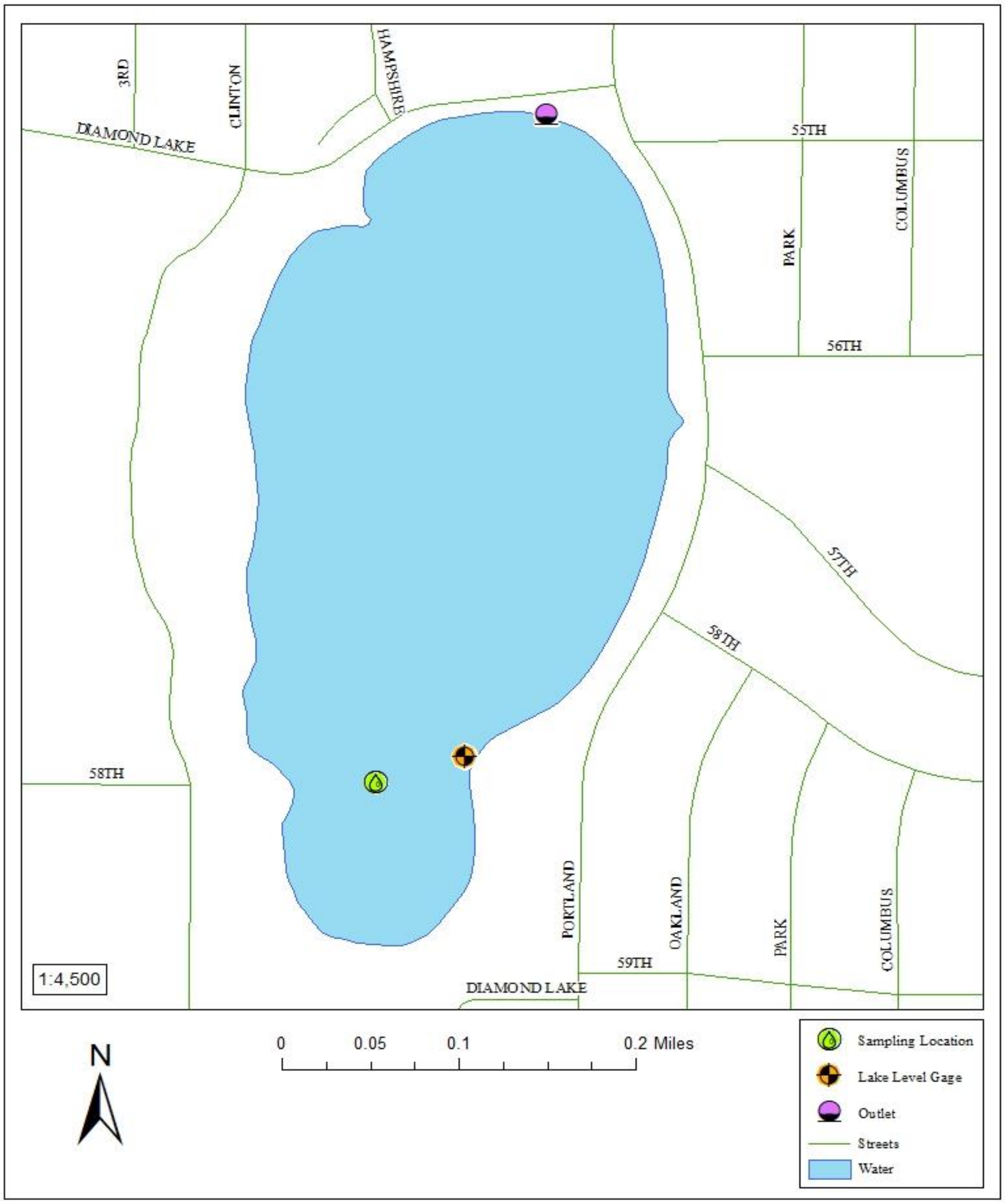


Figure 6-2. Map of Diamond Lake with mid-lake sampling site, lake level gage, and outlet location.

Lake Level

The lake level for Diamond Lake is measured at a lake gage near the Diamond Lake Lutheran Church. **Figure 6-3** shows lake level results starting in 2000. The designated Ordinary High Water Level (OHWL), determined by the Minnesota Department of Natural Resources (MNDNR), for Diamond Lake is 822.5 ft msl. The lake level for 2022 remained below OHWL for most of the year, except for two times in May following rainfall events. The lake froze 1.46 ft below the OHWL in November of 2022.

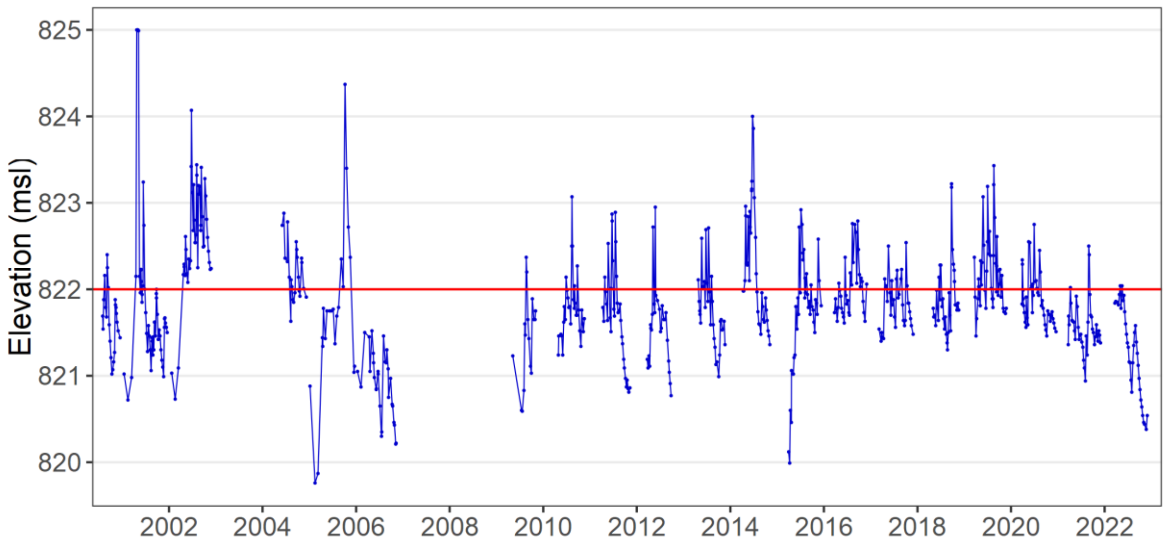


Figure 6-3. Lake levels for Diamond Lake from 2000-2022. Horizontal line represents the Ordinary High Water elevation (822 ft msl) for Diamond Lake.

Water Quality Trends – Trophic State Index (TSI)

Figure 6-4 shows the TSI scores and linear regression from 1992–2022 at Diamond Lake. There is no significant trend in the TSI since 1992 ($p > 0.05$). The 2022 TSI score for Diamond Lake, calculated using chlorophyll-*a* and total phosphorus concentrations, was 66. Water clarity was not used in TSI calculations of Diamond Lake because the lake is often either clear to the bottom or the Secchi disk is obscured by dense aquatic plant growth. Carlson's TSI Index would classify Diamond Lake as eutrophic; however, the index was developed for lakes without non-algal turbidity and with low macrophyte populations. Diamond Lake does not meet these criteria. It is a fertile, very shallow water body with high non-algal turbidity and thick aquatic plant beds. In 2004, the sampling location changed from a grab sample off a dock on the northeast side of the lake to a grab sample over the deep spot in the southern part of the lake from a canoe. A detailed explanation of TSI can be found in **Chapter 1**.

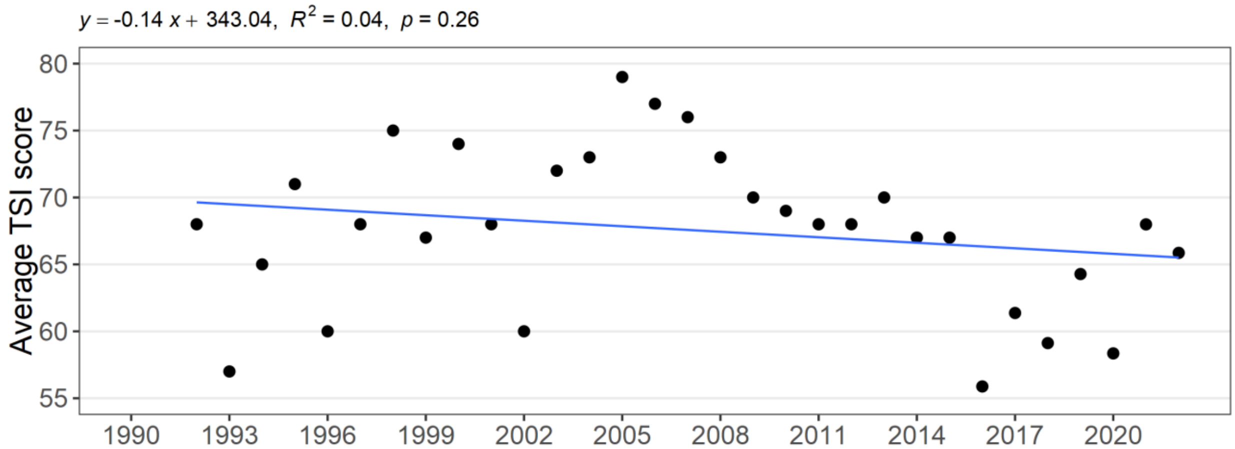


Figure 6-4. Diamond Lake TSI scores and linear regression from 1992 to 2022.

BOX AND WHISKER PLOTS

The box and whisker plots in **Figure 6-5** show the data distribution for chlorophyll-*a* and total phosphorus for the past 10 years, based on data from the entire sampling season. A detailed explanation of box and whisker plots can be found in **Chapter 1**. Box and whisker plots from the entire period of record, 1992-2022, can be found in **Appendix A**.

Diamond Lake has limited water clarity data due to its shallowness and high macrophyte density. Thick macrophyte growth, especially lily pads and filamentous algae, were noted during most of the sampling season. No Secchi disk readings were taken in 2022. Chlorophyll-*a* concentrations have been relatively consistent over the past 10 years with the exception of higher and more variable levels in 2013, 2014 and 2021. In 2022 the average chlorophyll-*a* level was 15 µg/L, see **Figure 6-5a**. Total phosphorus concentrations were similar to previous years with an average of 129 µg/L, see **Figure 6-5b**. The highest outlier for both chlorophyll-*a* and total phosphorus were from winter samples.

Generally, data from Diamond Lake is more variable than deeper lakes. Increased variability in the Diamond Lake data could be influenced by seasonal water level changes, stormwater influx, and because it is a semi-permanently flooded wetland.

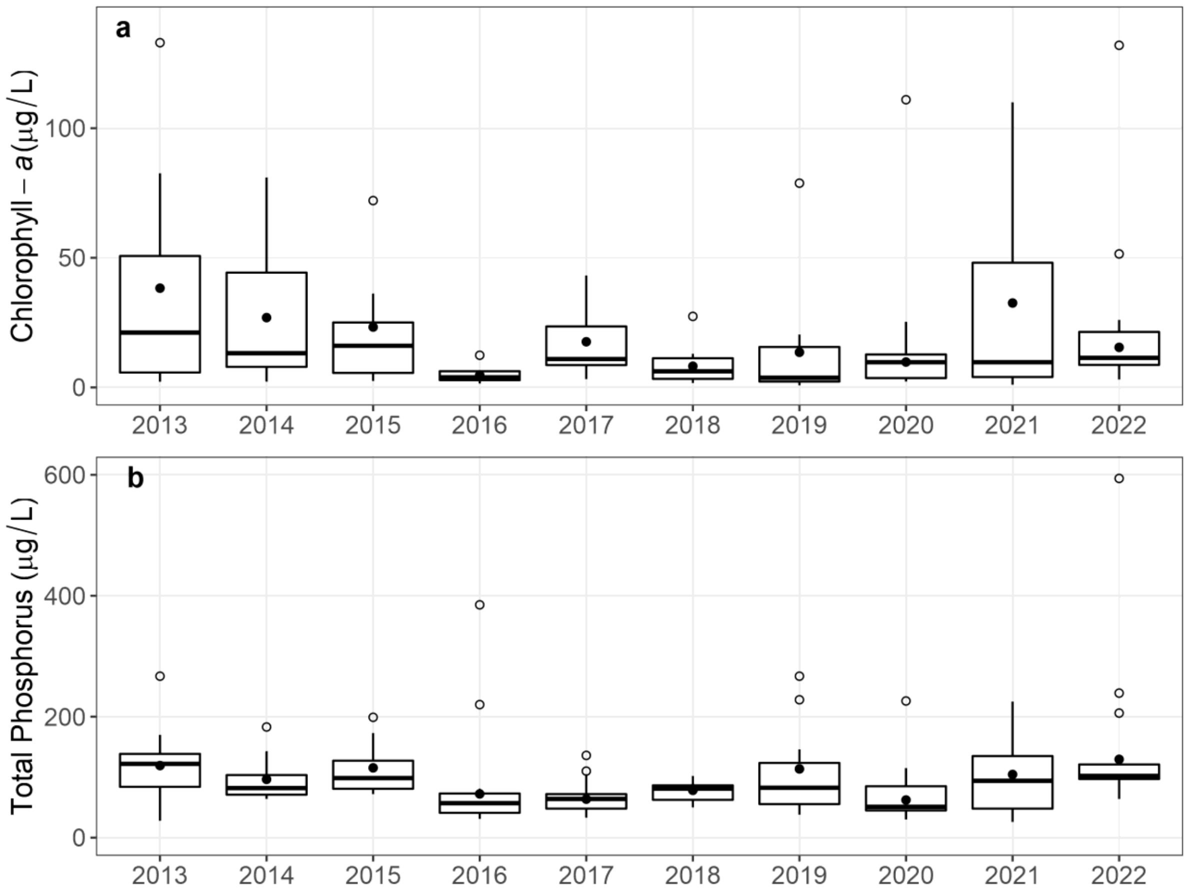


Figure 6-5. Box and whisker plots of Diamond Lake chlorophyll-*a* (a) and total phosphorus (b) from 2013-2022. The black circles represent the mean value of data collected during the growing season, May through September. Data from 1992-2022 can be found in Appendix A.

Chloride

Chloride is a naturally occurring element that is commonly found at low levels in most freshwater bodies. Chloride is a component of road salt (sodium chloride) and is found in other types of compounds that are also called salts (calcium chloride, magnesium chloride). Unnaturally high concentrations of chloride can negatively impact surface waters. High levels of chloride can change the mixing pattern of a lake and lead to very low oxygen levels in deep water. High concentrations can also decrease water clarity and induce stress or cause death of aquatic species (Bathe & Coring, 2011). Sources of chloride include industrial discharge, septic systems, sewage disposal systems, fertilizers, and road salt (Novotny, Murphy, & Stefan, 2008). The Minnesota Pollution Control Agency (MPCA) adopted the Environmental Protection Agency's (EPA) recommended water quality criteria for chloride which is a chronic standard of 230 mg/L and an acute standard of 860 mg/L (MPCA, 2016). The MPRB has monitored chloride concentrations in Diamond Lake since 1995, except between 1998-2001, by collecting surface water samples using a five-gallon bucket. See **Chapter 1** for more information on chloride.

Figure 6-6 shows surface chloride concentrations in Diamond Lake between 1995-2022. Red horizontal lines on the graph indicate the MPCA acute and chronic chloride standards. Also included on the graph is a dotted line that represents an estimate of a concentration above which potential ecological impact could occur, at 120 mg/L. This level of potential ecological impact was developed by Canadian Council of Ministries of the Environment (CCME) and is not a Minnesota state standard but a long-term chloride concentration that could negatively impact life within the lake (CCME, 2011). Chloride concentrations in Diamond Lake are highly variable ranging from below the level of ecological impact to well above the acute standard. Increased variability of chloride levels may be influenced by stormwater influx and because it is a semi-permanently flooded wetland. Diamond Lake was added to MPCA's list of impaired waters (303(d) list) in 2014 because several chloride concentrations exceeded the chronic standard.

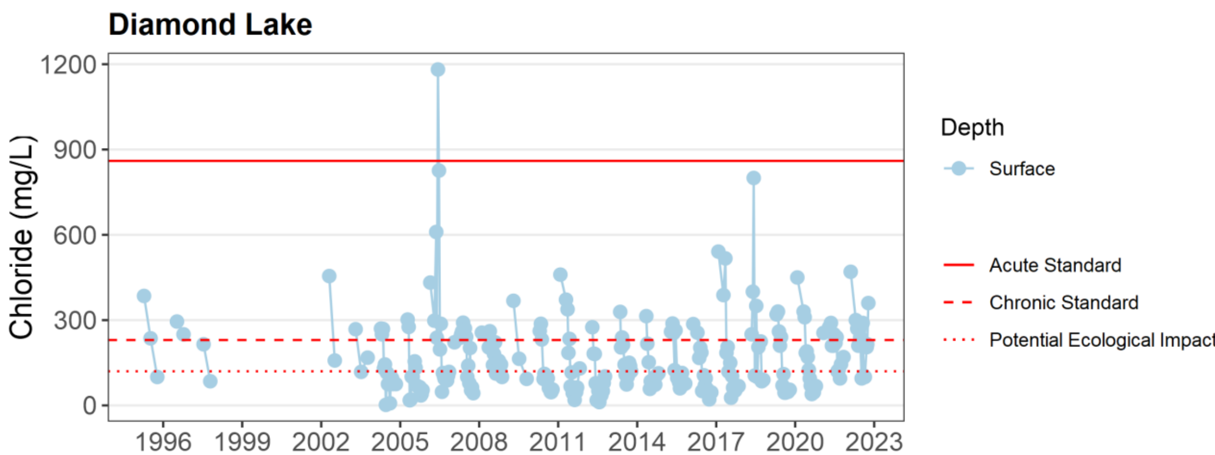


Figure 6-6. Diamond scatterplot of surface chloride concentrations between 1995-2022. Horizontal lines represent the MPCA's acute and chronic standard and the potential ecological impact level (CCME, 2011).

Blue-green Algae Monitoring

Blue-green algae are not algae at all, but a type of bacteria called cyanobacteria. These photosynthetic microorganisms occur naturally in lakes, streams, and other waterbodies worldwide. When conditions are right, cyanobacteria can grow quickly to form dense accumulations called blooms. Certain varieties of cyanobacteria can produce toxins, referred to as cyanotoxins, that can cause illness in humans and animals (US EPA, 2017). Due to an increase in frequency and intensity of cyanobacteria blooms in Minneapolis lakes, the MPRB developed a cyanobacteria monitoring program for public health in 2020. MPRB staff collect information on observations using a defined Visual Monitoring Index (VMI), and sample water weekly at beaches for the most common cyanotoxins. Advisories are posted at beaches and on the MPRB Lake Water Quality Map (bit.ly/mplsbeaches) if toxin levels exceed MPCA guidelines. See **Chapter 19** for more information on blue-green algae and cyanotoxin monitoring.

In 2022, VMI observations were made during bimonthly lake sampling sessions on Diamond Lake. VMI observations indicated that cyanobacteria were not present the entire sampling season, and that recreation was not inhibited by cyanobacteria.

Lake Aesthetic and User Recreation Index (LAURI)

Figure 6-7 shows the 2022 LAURI for Diamond Lake. Diamond Lake was rated excellent in aesthetics, good in habitat quality, and poor in recreational access. Since Diamond Lake does not have a swimming beach, a score was not calculated for public health. Details on LAURI can be found in **Chapter 1** and comparisons with other lakes can be found in **Chapter 17**.

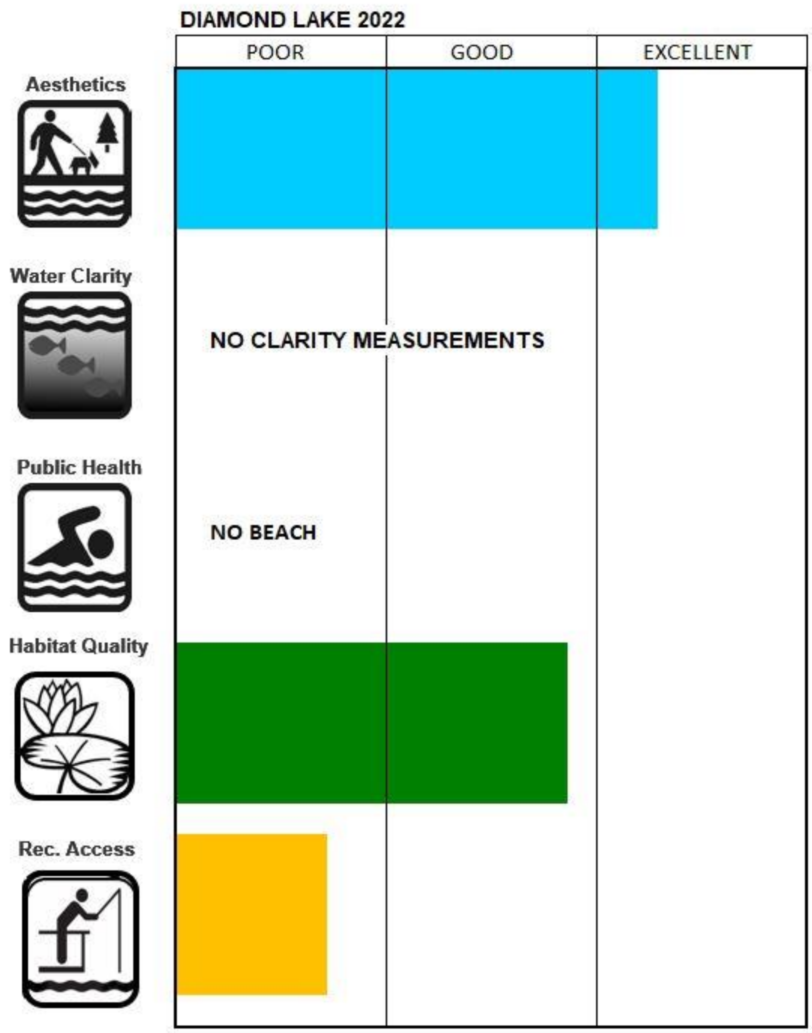


Figure 6-7. The 2022 LAURI for Diamond Lake.

Winter Ice Cover

Ice came off Diamond Lake on April 6, 2022, 5 days later than the average ice-off. Ice came back on to Diamond Lake on November 30, 2022, two days after the average ice-on date. See **Chapter 1** for details on winter ice cover records and **Chapter 17** for a comparison with other lakes.

PHYTOPLANKTON

Phytoplankton are microscopic plants that are an integral part of the lake community because they form the base of the aquatic food web. **Figure 6-8** shows the chlorophyll-*a* concentrations and relative abundance of phytoplankton divisions during 2022. Comparing these two parameters together can show how changes in the types of algae present in a lake effect water color. See the phytoplankton and zooplankton monitoring section in **Chapter 1** for additional details. Zooplankton are not sampled at Diamond Lake due to the shallow depth.

Chlorophyll-*a* concentrations were highest in winter at 131.6 µg/L when green algae (Chlorophyta) dominated the phytoplankton community. Concentrations remained below 30 µg/L for most of the season with the lowest levels in late May at 3.0 µg/L. Chlorophyll-*a* concentrations were higher in early August reaching 51.5 µg/L when the phytoplankton community primary consisted of euglenoids (Euglenophyta), see **Figure 6-8a, b**.

The phytoplankton community consisted of a mix of Chlorophyta, golden-brown algae (Chrysophyta), cryptomonads (Cryptophyta), blue-green algae (Cyanophyta), and Euglenophyta. Diatoms (Bacillariophyta), haptophytes (Haptophyta), and dinoflagellates (Pyrrophyta) were also present in low levels in 2022, see **Figure 6-8b**.

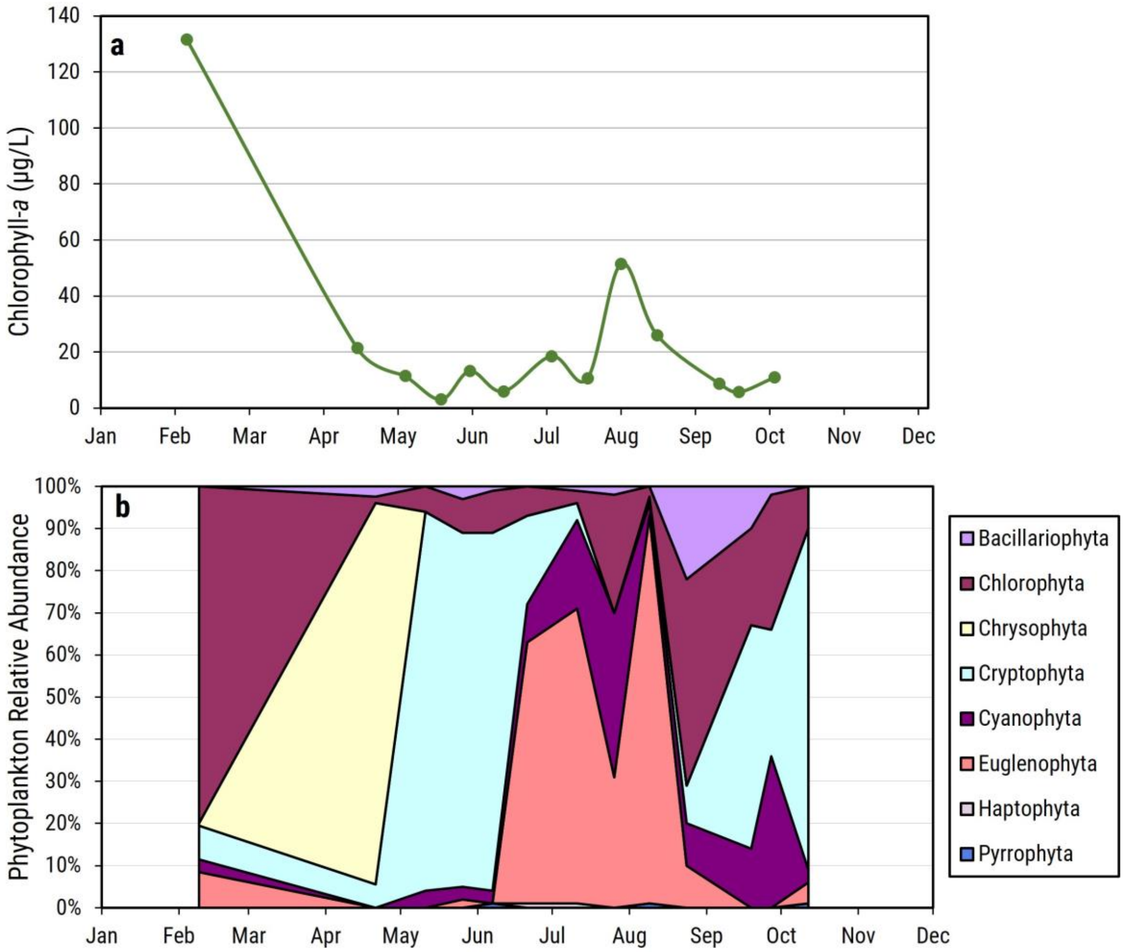


Figure 6-8. Chlorophyll-*a* concentration (a) and relative abundance of phytoplankton (b) in Diamond Lake during 2022.

Wetland Health Evaluation Project (WHEP)

The wetland fringe of Diamond Lake was evaluated by the Wetland Health Evaluation Project (WHEP) led by Hennepin County and a group of citizen volunteers. 2022 was the eighteenth year that Diamond Lake was evaluated in the WHEP program. Diamond Lake was rated excellent for invertebrate quality and moderate for vegetation quality in 2022. Results of the wetland evaluation are presented in **Chapter 23**.

Chinese Mystery Snails (*Cipangopaludina chinensis)* have been found in Diamond Lake. They were found by WHEP volunteers in 2008-2013 and 2015-2019. WHEP volunteers have noted more empty shells and younger snails in recent years, likely because muskrats took up residence sometime between 2010 and 2011, and eat snails.

7. GRASS LAKE

History

Grass Lake was created during the construction of Minnesota State Highway 62. The highway separated one waterbody into two new lakes: Grass Lake to the north and Richfield Lake to the south.

The National Wetlands Inventory classifies Grass Lake as a permanently flooded lacustrine/littoral system with an unconsolidated bed (L2UBH). **Figure 7-1** shows a picture of Grass Lake. Physical characteristics and morphometric data for Grass Lake are presented in **Table 7-1** and **Figure 7-2** shows a map of the lake. Grass Lake is in the Minnehaha Creek Watershed and is predominantly surrounded by residential neighborhoods. Grass Lake receives a considerable amount of stormwater runoff from Interstate 35W. There are 12 stormwater inlets and one outlet pipe, see **Appendix C**.

Grass Lake was added to the Minneapolis Park & Recreation Board (MPRB) lake sampling program in 2002. It is typically sampled every other year and was monitored in 2022.

Figure 7-1. Grass Lake in October 2021.

Table 7-1. Grass Lake physical characteristics and morphometric data. OHWL = Ordinary High Water Level.

Surface Area (acres)	Mean Depth (ft)	Max Depth (ft)	Watershed Area (acres)	Watershed: Lake Area (ratio)	OHWL (ft msl)
27	2.0	4.9	386	14.3	830.9

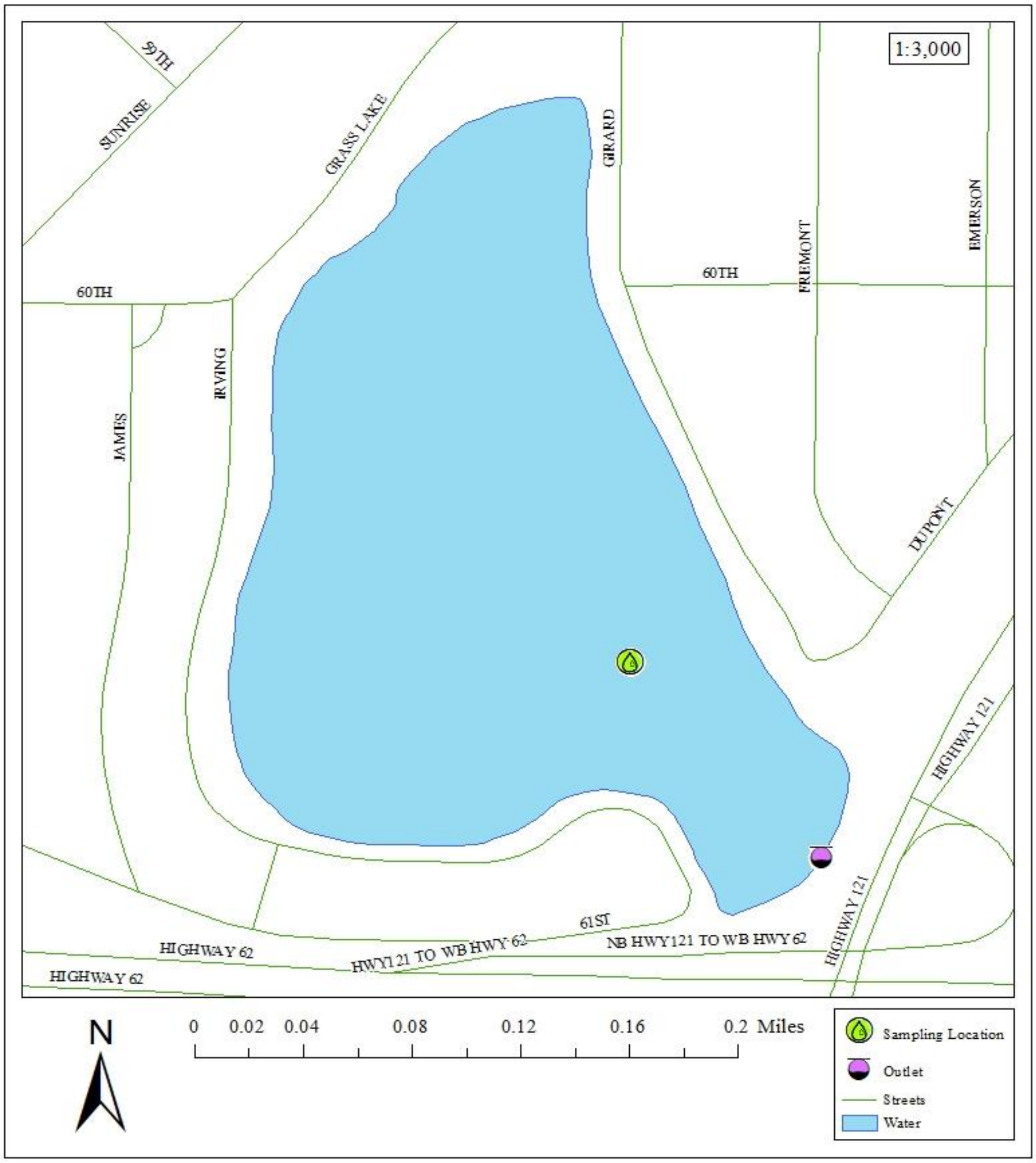


Figure 7-2. Map of Grass Lake with mid-lake sampling site and outlet location.

WATER QUALITY TRENDS – TROPHIC STATE INDEX (TSI)

Figure 7-3 shows the TSI scores and linear regression from 2002-2022 at Grass Lake. There is no significant trend in TSI scores over the last 20 years ($p > 0.05$); however, the lake is only sampled every-other year and sampling locations have changed. The 2022 TSI score, calculated using chlorophyll-*a* and total phosphorus concentrations, for Grass Lake was 71. Water clarity was not used in TSI calculations of Grass Lake because the lake is often either clear to the bottom or the Secchi disk is obscured by dense aquatic plant growth. Carlson's TSI Index would classify Grass Lake as hypereutrophic; however, the index was developed for lakes without non-algal turbidity and with low macrophyte populations. Grass Lake does not meet these criteria. It is a fertile, very shallow water body with high non-algal turbidity and thick aquatic plant beds.

This data includes samples from three different locations, potentially biasing the results. The original sample location on the southeast corner near the outlet has been inaccessible since 2008 due to a construction project. The very high TSI in 2003 could be an outlier, as the following years ranged between 55 and 65 until 2018. Subsequently, TSI scores increased again between 2018 and 2022 ranging from 71 to 74, indicating worsening water quality. Additional years of monitoring will be needed to discern a trend from the natural variation seen in Grass Lake. A detailed explanation of TSI can be found in **Chapter 1**.

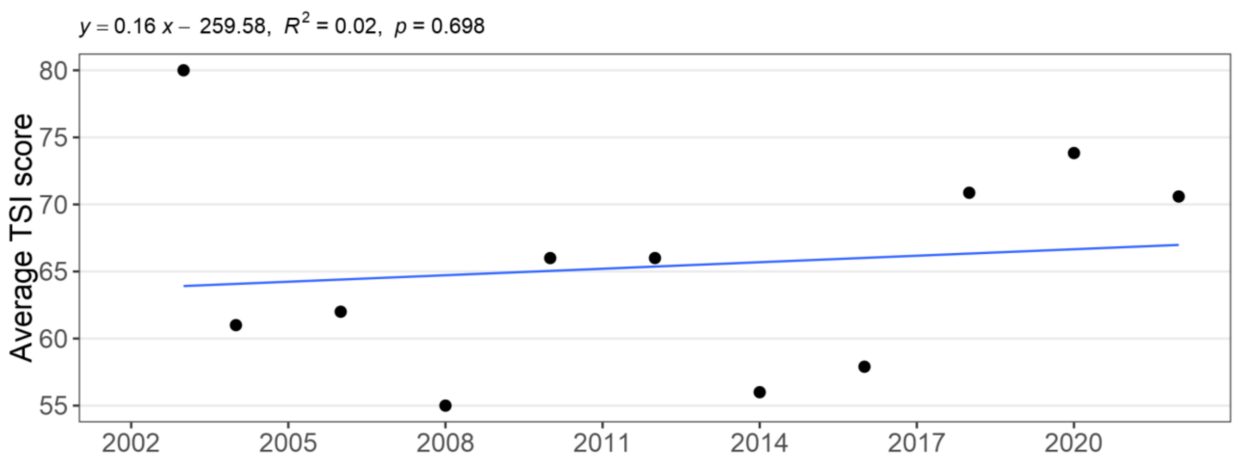


Figure 7-3. Grass Lake TSI scores and linear regression for monitored years from 2002 to 2022. Note: the sampling location changed in 2008 and again in 2016.

Box and Whisker Plots

The box and whisker plots in **Figure 7-4** show the data distribution for chlorophyll-*a,* total phosphorus, and total nitrogen for the past 10 years, based on data from the entire sampling season. A detailed explanation of box and whisker plots can be found in **Chapter 1**. Box and whisker plots from the entire period of record, 2002-2022, can be found in **Appendix A**.

Secchi readings are not taken due to the shallowness of the wetland. Grass Lake can freeze to the bed in some years, making it impossible to collect a winter sample. Variations in the Grass Lake data may be due to climatic differences, the monthly sampling regime, or the variability of the wetland. In 2022, chlorophyll-*a*, total phosphorus, and total nitrogen concentrations were similar to 2020, having higher and more variable concentrations compared to previous years. The average chlorophyll-*a* concentration was 27.4 µg/L. The average total phosphorus concentration was 169 µg/L. The average total nitrogen concentration was 1.23 mg/L.

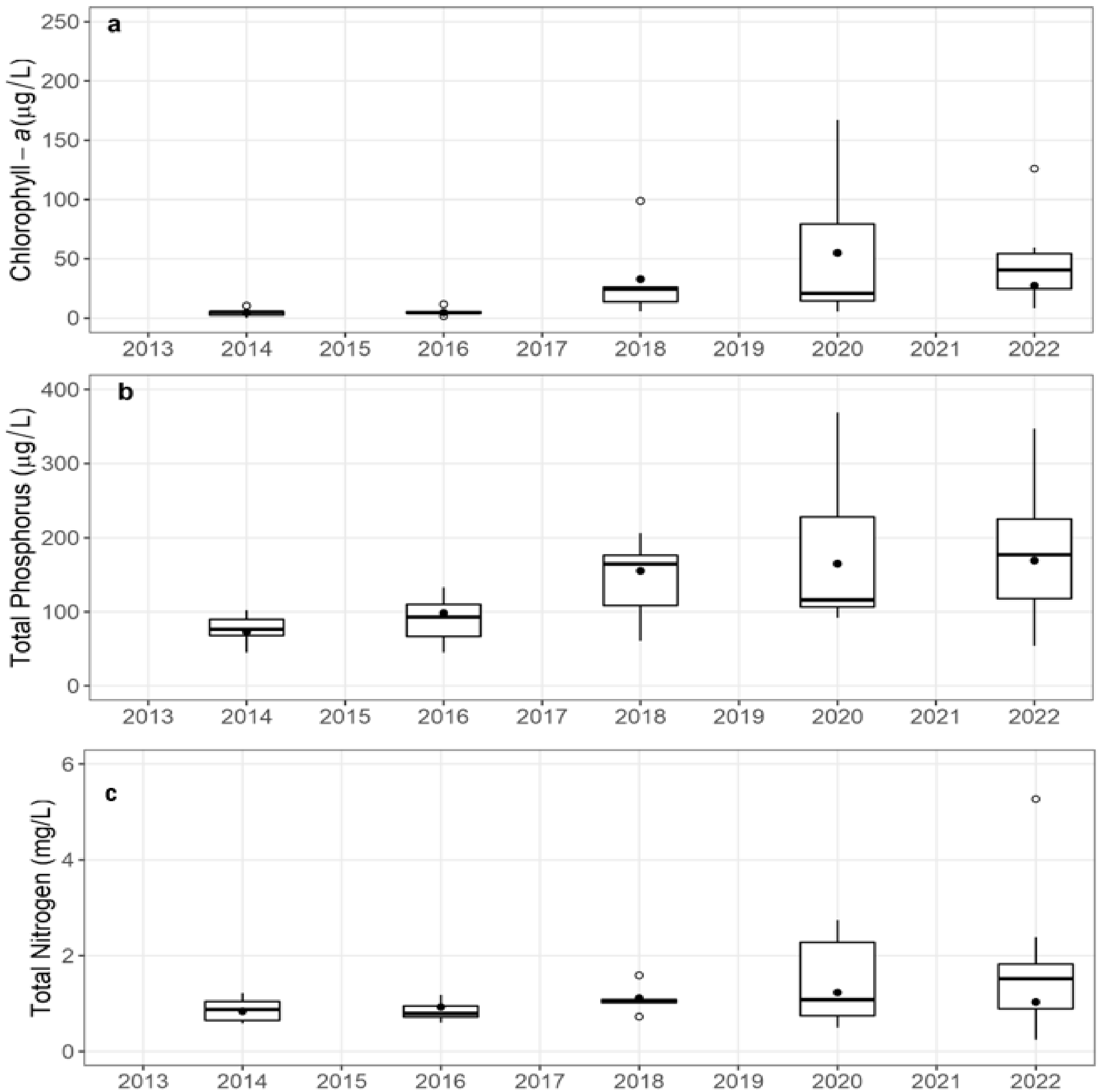


Figure 7-4. Grass Lake box and whisker plots of chlorophyll-*a* (a), total phosphorus (b), and total nitrogen (c) from 2013-2022. The black circles represent the mean value of data collected during the growing season, May through September. Data from 2002-2022 can be found in Appendix A.

Chloride

Chloride is a naturally occurring element that is commonly found at low levels in most freshwater bodies. Chloride is a component of road salt (sodium chloride) and is found in other types of compounds that are also called salts (calcium chloride, magnesium chloride). Unnaturally high concentrations of chloride can negatively impact surface waters. High levels of chloride can change the mixing pattern of a lake and lead to very low oxygen levels in deep water. It can also lead to decreasing water clarity and induce stress or cause death of aquatic species (Bathe & Coring, 2011). Sources of chloride include industrial discharge, septic systems, sewage disposal systems, fertilizers, and road salt (Novotny, Murphy, & Stefan, 2008). The Minnesota Pollution Control Agency (MPCA) adopted the Environmental Protection Agency's (EPA) recommended water quality criteria for chloride which is a chronic standard of 230 mg/L and an acute standard of 860 mg/L (MPCA, 2016). The MPRB has monitored chloride concentrations in Grass Lake since 2006 by collecting surface grab samples using a five-gallon bucket. See **Chapter 1** for more information on chloride.

Figure 7-5 shows surface chloride concentrations in Grass Lake between 2006-2022. Red horizontal lines on the graph indicate the MPCA acute and chronic chloride standards. Also included on the graph is a dotted line that represents an estimate of a concentration above which potential ecological impact could occur, at 120 mg/L. This level of potential ecological impact was developed by the Canadian Council of Ministries of the Environment (CCME) and is not a Minnesota state standard but a long-term chloride concentration that could negatively impact life within the lake (CCME, 2011). Chloride concentrations in Grass Lake have remained relatively low since 2006 with most samples below the level of ecological impact and only four samples exceeding this threshold; however, chloride concentrations continue to increase over time. Grass Lake chloride levels have never exceeded the chronic standard.

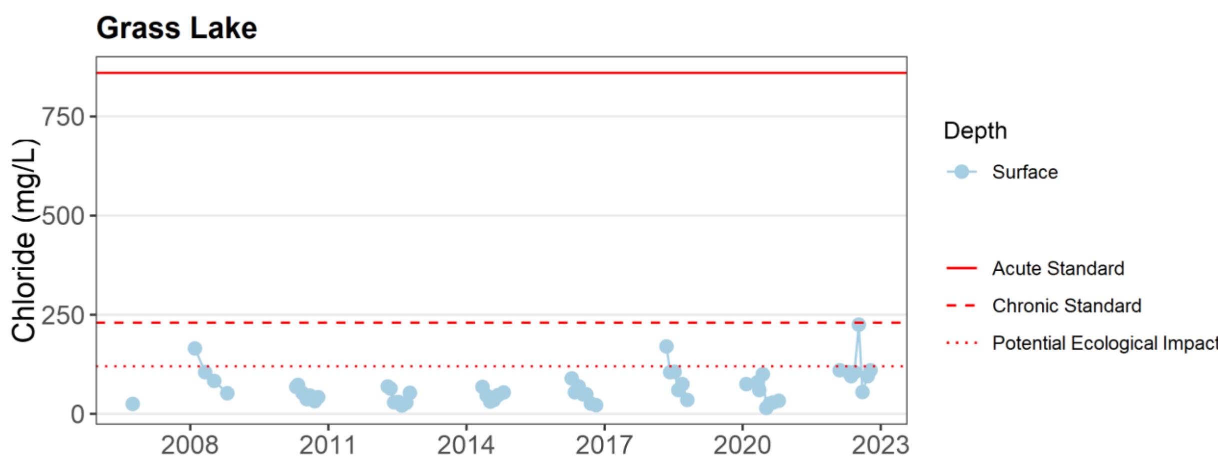


Figure 7-5. Grass Lake scatterplot of surface chloride concentrations between 2006-2022. Horizontal lines represent the MPCA's acute and chronic standard and the potential ecological impact level (CCME, 2011).

Blue-green Algae Monitoring

Blue-green algae are not algae at all, but a type of bacteria called cyanobacteria. These photosynthetic microorganisms occur naturally in lakes, streams, and other waterbodies worldwide. When conditions are right, cyanobacteria can grow quickly to form dense accumulations called blooms. Certain varieties of cyanobacteria can produce toxins, referred to as cyanotoxins, that can cause illness in humans and animals (US EPA, 2017). Due to an increase in frequency and intensity of cyanobacteria blooms in Minneapolis lakes, the MPRB developed a cyanobacteria monitoring program for public health in 2020. MPRB staff collect information on observations using a defined Visual Monitoring Index (VMI), and sample water weekly at beaches for the most common cyanotoxins. Advisories are posted at beaches and on the MPRB Lake Water Quality Map bit.ly/mplsbeaches if toxin levels exceed MPCA guidelines. See **Chapter 19** for more information on blue-green algae and cyanotoxin monitoring.

In 2022, VMI observations were made during monthly lake sampling sessions on Grass Lake. VMI observations indicated that cyanobacteria were not present most of the sampling season; however, a low density of small floating balls of cyanobacteria were observed in mid-September. Although cyanobacteria were present in Grass Lake in 2022, no significant scums were observed, and recreation was not inhibited by cyanobacteria.

Winter Ice Cover

Ice cover data for Grass Lake has fewer observations than other lakes as monitoring started in 2004. Ice came off Grass Lake on April 4, 2022, two days later than average for the lake since records began. Ice was back on Grass Lake on December 19, 2022, fourteen days later than average. See **Chapter 1** for details on winter ice cover records and **Chapter 17** for a comparison with other lakes.

Phytoplankton

Phytoplankton are microscopic plants that are an integral part of the lake community because they form the base of the aquatic food web. **Figure 7-6** shows the concentration of chlorophyll-*a* and the relative abundance of phytoplankton divisions during 2022. Comparing these two parameters together can show how changes in the types of algae present in a lake effect water color, see the phytoplankton and zooplankton monitoring section in **Chapter 1** for additional details. Zooplankton are not sampled at Grass Lake due to the shallow depth.

Chlorophyll-*a* concentrations were initially high in winter at 125.6 µg/L when the phytoplankton community primarily consisted of green algae (Chlorophyta), see **Figure 7-6a, b**. Concentrations of chlorophyll-*a* remained below 60 µg/L for the remainder of the season. The lowest chlorophyll-*a* concentration occurred in August at 8.4 µg/L. The phytoplankton community changed drastically throughout the 2022 sampling season consisting of a mix of Chlorophyta, cryptomonads (Cryptophyta), blue-green algae (Cyanophyta) and euglenoids (Euglenophyta). Diatoms (Bacillariophyta), golden-brown algae (Chrysophyta), dinoflagellates (Pyrrophyta), and yellow-green algae (Xanthophyta) were also present in low levels in 2022.

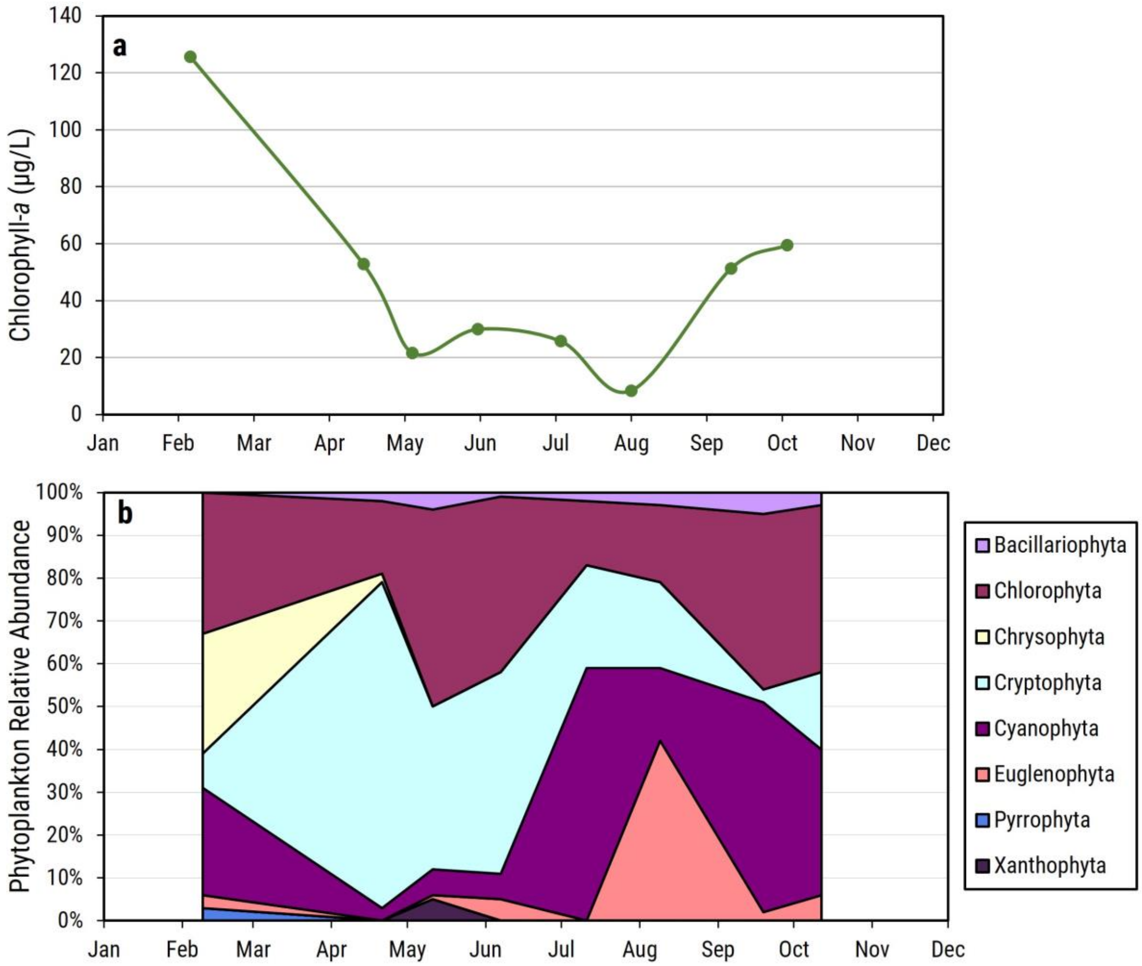


Figure 7-6. Chlorophyll-*a* concentration (a) and relative abundance of phytoplankton (b) in Grass Lake during 2022.

Wetland Health Evaluation Project (WHEP)

The wetland fringe of Grass Lake was evaluated by the Wetland Health Evaluation Project (WHEP) led by Hennepin County and a group of citizen volunteers in 2022. Results of the wetland evaluation are presented in **Chapter 23**. Grass Lake received a moderate rating for both invertebrate and vegetation quality. 2022 was the eighth year that Grass Lake was evaluated in the WHEP program.

8. Lake Harriet

History

Colonel W.S. King donated a majority of Lake Harriet and surrounding areas to the Minneapolis Park & Recreation Board (MPRB) in 1885. The MPRB acquired the remainder of the surrounding land between 1883-1898 and 1921. Lake Harriet is part of the Chain of Lakes, which also includes Brownie, Cedar, Isles, and Bde Maka Ska. One of the original Dakota names for the lake is Bde Unma. Lake Harriet was later named after Harriet Lovejoy Leavenworth, the wife of Colonel Leavenworth. There was less dredging and filling at Lake Harriet compared to the other MPRB lakes. A marshland on the northeast corner of the lake was filled to make room for the parkway. The wetland at the north end of the lake that is now Robert's Bird Sanctuary was deemed too expensive to fill. A navigable open water connection between Bde Maka Ska and Lake Harriet was pondered but was never implemented due to a seven-foot elevation difference between the lakes (Smith, 2008). Today, after several modifications to the inlet and outlet, there is, on average, a four-foot difference between the two lakes.

Lake Harriet is a deep kettle lake that generally remains strongly stratified from May through October. The lake is shown below in **Figure 8-1**. **Table 8-1** shows the physical characteristics and morphometric data of Lake Harriet and **Figure 8-2** shows a bathymetric map. Lake Harriet is part of Minnehaha Creek Watershed and is primarily surrounded by residential neighborhoods and the historic Lakewood Cemetery located on the north side of the lake. There are a total of 24 stormwater outfalls surrounding Lake Harriet, see **Appendix C**.

Figure 8-1. View of Lake Harriet from southwest shore in August of 2022.

Lake Harriet receives water from Bde Maka Ska. In 1967, a pumping station and pipeline were constructed between Lake Harriet and Bde Maka Ska to control water levels in the Upper Chain of Lakes. In 1999, it was replaced with a gravity outlet, open channel, and pipe connection. The inlet into Lake Harriet consists of a pipe under the water near the boat launch on the northwest corner of the lake. In the winter flowing water from the inlet can create a large area of thin ice or open water near the boat launch. Lake Harriet discharges to Minnehaha Creek through a submerged manifold diffuser, pipe, and open channel located at the southern edge of the lake.

An increase in stormsewer discharge since the 1920s led to increased phosphorus levels that peaked in the 1970s. Brugam and Speziale (1983) analyzed sediment cores and determined that European-American settlement in the 1850s led to increased sedimentation rate due to land clearing and agriculture. Diatom reconstruction of total phosphorus suggests that pre-European phosphorus levels were around 20 µg/L; however, diatom reconstruction data may not be accurate because there are several non-planktonic diatoms in the sediment that are more sensitive to changes in habitat availability than to phosphorus (Sayer, 2001). Recent observed data have shown a decline in phosphorus levels since the 1990s and suggest concentrations in Lake Harriet have returned to levels similar to pre-European settlement (Heiskary et al., 2004).

Restoration techniques and best management practices (BMPs) have improved water quality in Lake Harriet. A detailed Clean Water Partnership (CWP) diagnostic study conducted in 1991 determined that phosphorus input to the Chain of Lakes should be reduced to improve water quality. In 1994 the Minneapolis Chain of Lakes Clean Water Partnership was formed. BMPs implemented as a part of the Clean Water Partnership included: public education, increased street sweeping, constructed wetlands (1998), and grit chambers (1994-1996). In 2001, an aluminum sulfate (alum) treatment was also carried out on areas of the lake shallower than 25 feet in an attempt to control filamentous algae growth in the littoral zone by limiting the available phosphorus. Though not part of the project's original intention, the alum had an unexpected benefit of limiting internal phosphorus loading in the entire lake (Huser, 2005). Current trophic state index (TSI) scores confirm that the BMPs have positively affected water quality in Lake Harriet.

In 2010, the MPRB and the City of Minneapolis received a Clean Water Partnership Grant for a diagnostic study of Lake Harriet to update and intensify existing studies at the lake and provide planning toward implementing a second phase of improvements for water quality. The study was completed in 2013. Information from the study has been used to inform projects in the area, such as a flood abatement project in the Fulton Neighborhood. In September 2017, a single zebra mussel was found on a boat cover recovered from the bottom of Lake Harriet by a MPRB Water Quality Staff member. The Minnesota Department of Natural Resources (MNDNR) confirmed the find and added Lake Harriet to the Infested Water List for zebra mussels. No additional zebra mussels have been discovered during early detection methods since the occurrence, see the **Chapter 22** for additional details.

Water quality on Lake Harriet has been monitored annually by MPRB since 1991.

Table 8-1. Lake Harriet physical characteristics and morphometric data.

Surface Area (acres)	Mean Depth (ft)	Max Depth (ft)	Littoral Area*	Volume (ft^3)	Watershed Area (acres)	Watershed: Lake Area (ratio)	Residence Time (years)
341	29.0	87.0	25%	$4.41 x 10^8$	1,139	3.2	3.4

* Littoral area was defined as less than 15 feet deep.

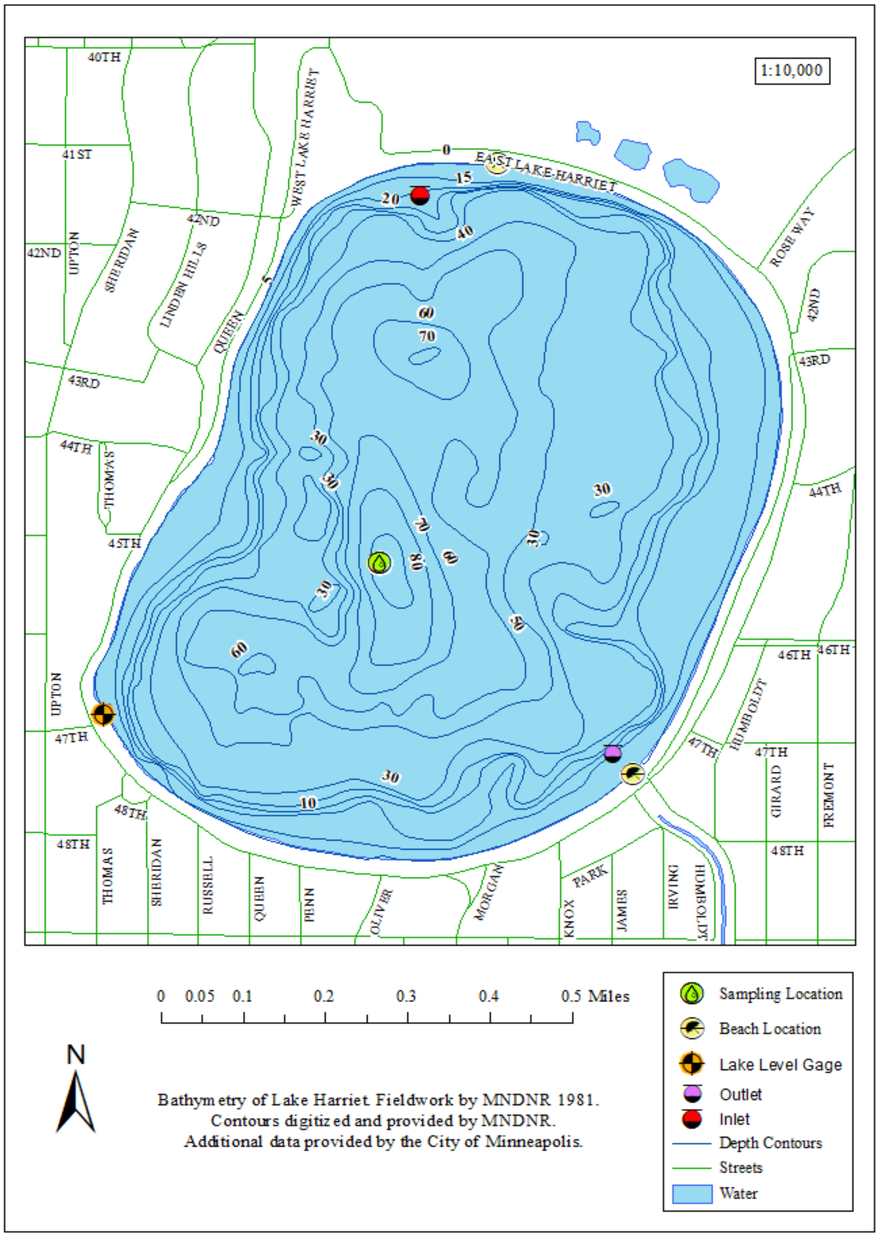


Figure 8-2. Bathymetric map with mid-lake sampling site, beach, lake level gage, outlet, and inlet locations at Lake Harriet.

Lake Level

Historic lake levels for Lake Harriet are shown in **Figure 8-3**. The Ordinary High Water Level (OHWL), determined by the MNDNR, for Lake Harriet is 848 ft msl. The lake remained below the OHWL the entire year in 2022 and froze below the OHWL in December. See **Chapter 1** for details on lake level monitoring and **Chapter 17** for a comparison between other MPRB lake levels.

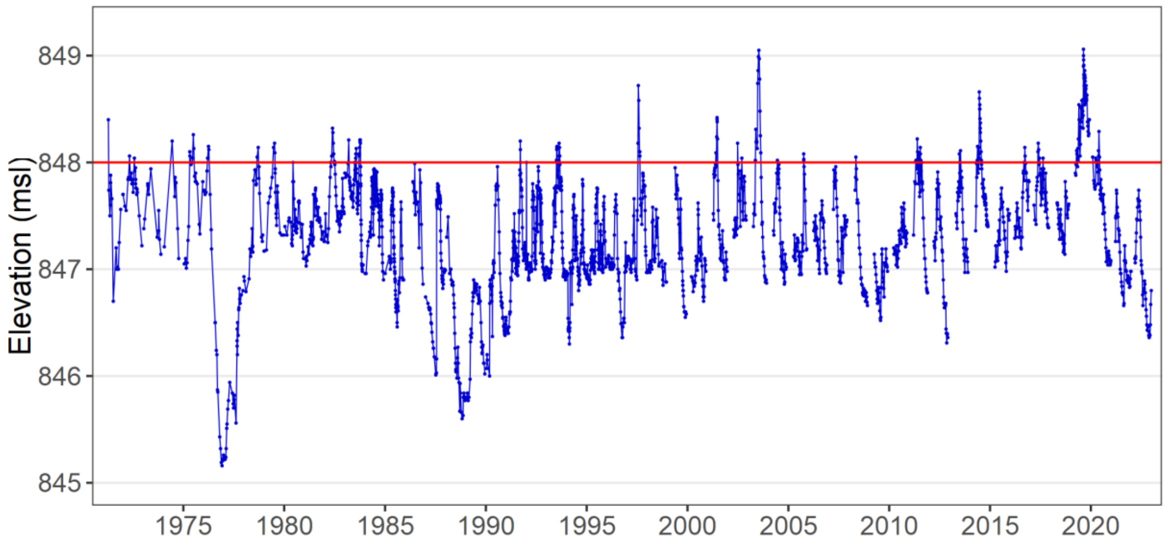


Figure 8-3. Lake levels for Lake Harriet from 1970 to 2022. Horizontal line represents the Ordinary High Water Level elevation (848 ft msl) for Lake Harriet.

Water Quality Trends – Trophic State Index (TSI)

Figure 8-4 shows historical Lake Harriet TSI scores and trend line. There has been a decrease in TSI scores from 1991-2022, but there is no significant trend ($p > 0.05$). Lake Harriet experienced a few years with lower TSI scores following a littoral alum treatment in 2001. The TSI score for Lake Harriet in 2022 was 50. The lake is currently eutrophic, which is defined as having an anoxic hypolimnion and possible macrophyte problems.

The TSI score was higher (worse) in 2022 and was comparable to scores in the early 1990s, before the lake and watershed improvement projects from the CWP. The CWP Minneapolis Chain of Lakes Project developed a long-term TSI goal to be below 47 that was intended to be met within five to ten years of water quality project completion. The Lake Harriet TSI score has met the CWP goal most years, except for 2006, 2008, 2018, 2019, and 2022.

Secchi, chlorophyll-*a*, and total phosphorus TSI scores for Lake Harriet are within the expected TSI range for lakes in the same ecoregion, see **Table 8-2**. For more information see Minnesota Pollution Control Agency (MPCA) Surface Water Data (https://webapp.pca.state.mn.us/wqd/surface-water/waterunit-details?wid=27-0016-00). A detailed explanation of TSI can be found in **Chapter 1**.

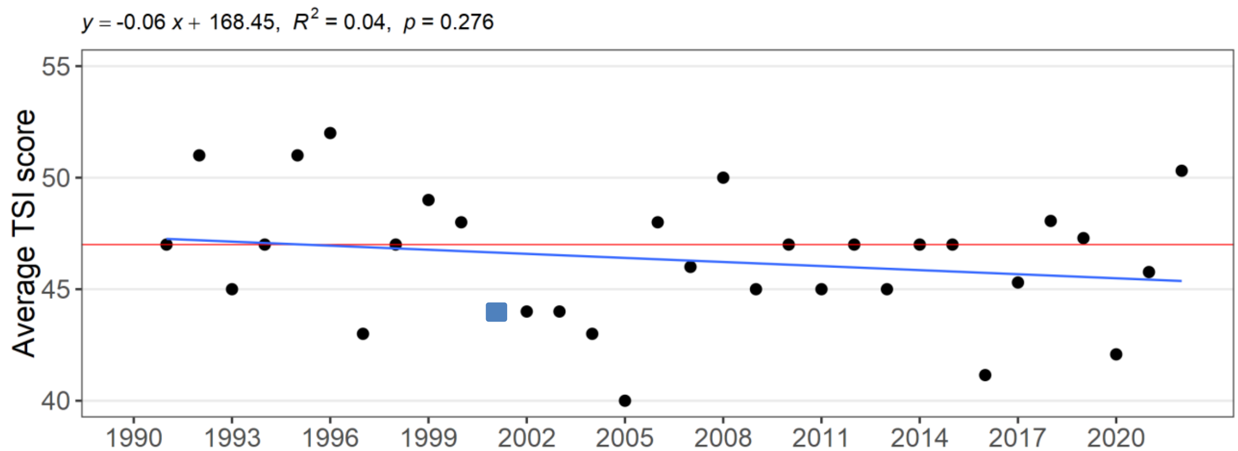


Figure 8-4. Lake Harriet TSI scores and linear regression from 1991-2022. The red line represents the CWP long-term TSI goal of below 47. The blue square highlights the 2001 alum treatment.

Table 8-2. Lake Harriet Secchi, chlorophyll-*a*, and total phosphorus TSI based on data collected between June and September of 2022 and compared to lakes in the North Central Hardwood Forest ecoregion.

	TSI	Expected TSI Range of Lakes in the Same Ecoregion	Within the Expected TSI Range of Lakes in the Same Ecoregion
Secchi	46	43-54	Within range
Chlorophyll-*a*	55	46-61	Within range
Total Phosphorus	51	49-61	Within range

Box and Whisker Plots

The box and whisker plots in **Figure 8-5** show the data distribution for water clarity, chlorophyll-*a*, and total phosphorus for the past 10 years, based on data from the entire sampling season. Red horizontal lines on the graphs indicate the MPCA eutrophication standards for deep lakes, which applies to data collected between June and September. A detailed explanation of box and whisker plots can be found in **Chapter 1**. Box and whisker plots from the entire period of record, 1991-2022, can be found in **Appendix A**.

Water clarity was comparable to previous years with an average of 3.1 meters in 2022, see **Figure 8-5a**. Chlorophyll-*a* concentrations were higher and more variable compared to previous years with an average of 11 µg/L, see **Figure 8-5b**. Chlorophyll-*a* levels were highest in winter and spring while the lake was not thermally stratified. Total phosphorus (TP) concentrations were similar to previous years with an average of 31 µg/L, see **Figure 8-5c**. Lake Harriet met MPCA eutrophication standards for water clarity, chlorophyll-*a*, and total phosphorus in 2022.

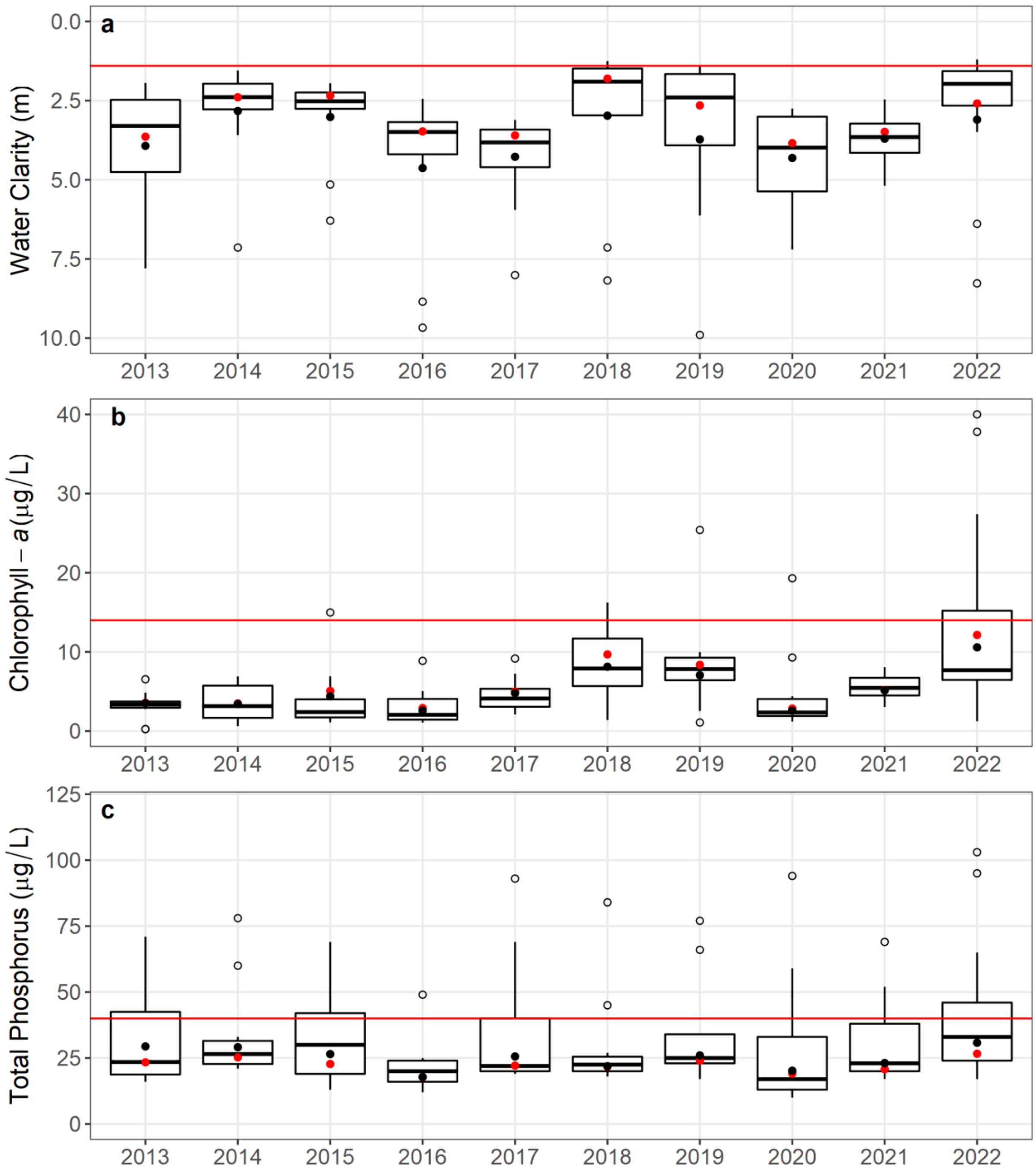


Figure 8-5. Lake Harriet box and whisker plots of water clarity (a), chlorophyll-*a* (b), and total phosphorus(c) from 2013-2022. Horizontal lines represent MPCA eutrophication standard for deep lakes, which applies to data collected between June and September. The red circles represent the mean value of data collected between June and September. The black circles represent the mean value of data collected during the growing season, May through September. Data from 1991-2022 can be found in Appendix A.

CHLORIDE

Chloride is a naturally occurring element that is commonly found at low levels in most freshwater bodies. Chloride is a component of road salt (sodium chloride) and is found in other types of compounds that are also called salts (calcium chloride, magnesium chloride). Unnaturally high concentrations of chloride can negatively impact surface waters. High levels of chloride can change the mixing pattern of a lake and lead to very low oxygen levels in deep water. It can also lead to decreasing water clarity and induce stress or cause death of aquatic species (Bathe & Coring, 2011). Sources of chloride include industrial discharge, septic systems, sewage disposal systems, fertilizers, and road salt (Novotny, Murphy, & Stefan, 2008). The MPCA adopted the Environmental Protection Agency's (EPA) recommended water quality criteria for chloride which is a chronic standard of 230 mg/L and an acute standard of 860 mg/L (MPCA, 2016). The MPRB has monitored chloride concentrations in Lake Harriet since 1995 by collecting surface water samples using a composite tube and collecting deep water samples using a Kemmerer sampler. See **Chapter 1** for more information on chloride.

Figure 8-6 shows epilimnetic and hypolimnetic chloride concentrations in Lake Harriet between 1995-2022, with hypolimnion samples only collected regularly after 2006. Epilimnion samples represent the top two meters of the lake and hypolimnion samples were collected approximately one meter from the bottom of the lake. Red horizontal lines on the graph indicate the MPCA acute and chronic chloride standards. Also included on the graph, is a dotted line that represents an estimate of a concentration above which potential ecological impact could occur, at 120 mg/L. This level of potential ecological impact was developed by Canadian Council of Ministries of the Environment (CCME) and is not a Minnesota state standard but a long-term chloride concentration that could negatively impact life within the lake (CCME, 2011). Chloride concentrations have been slowly increasing over time; prior to 2008 most chloride concentrations measured below the level of ecological impact and in 2022 all samples were above this threshold. Also, in June of 2022 one chloride sample reached the chronic standard of 230 mg/L.

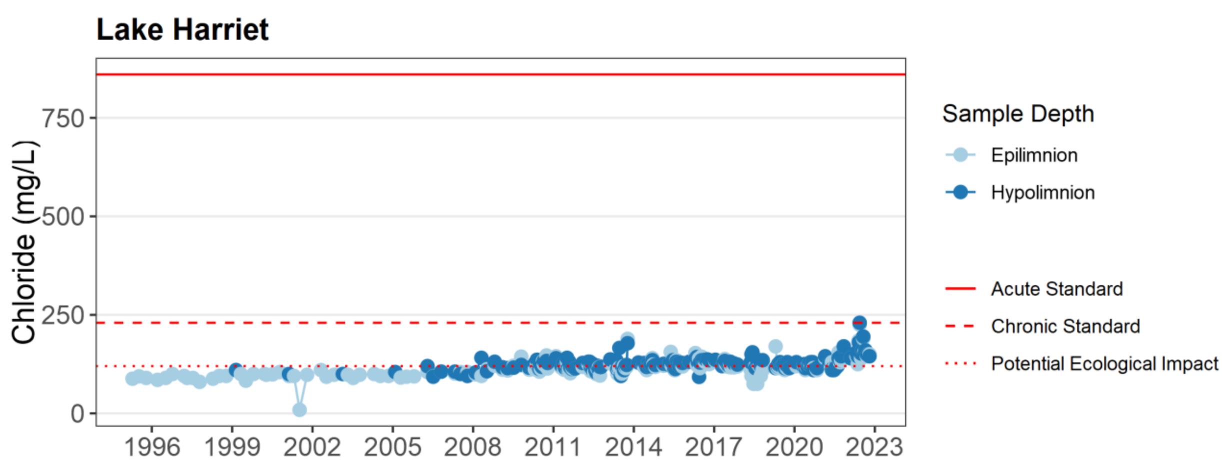


Figure 8-6. Lake Harriet scatterplot of epilimnetic and hypolimnetic chloride concentrations between 1995-2022. Horizonal lines represent the MPCA's acute and chronic standard and the potential ecological impact level (CCME, 2011).

BEACH MONITORING

Escherichia coli (*E. coli*) levels were sampled at two different locations on Lake Harriet in 2022: Harriet Main Beach and Harriet Southeast Beach. As shown in **Table 8-3** and **Figure 8-7**, *E. coli* counts were low at both beaches and they remained open for entire 2022 sampling season. See **Chapter 18** for more information on beaches.

Table 8-3. Summary of *E. coli* (MPN per 100 mL) data for Lake Harriet beaches in 2022.

Statistical Calculations	Harriet Main	Harriet SE
Number of Samples	15	15
Minimum	1	1
Maximum	246	327
Median	10	32
Mean	38	67
Geometric Mean	11	19
Max 30-Day Geo Mean	29	43
Standard Deviation	66	103

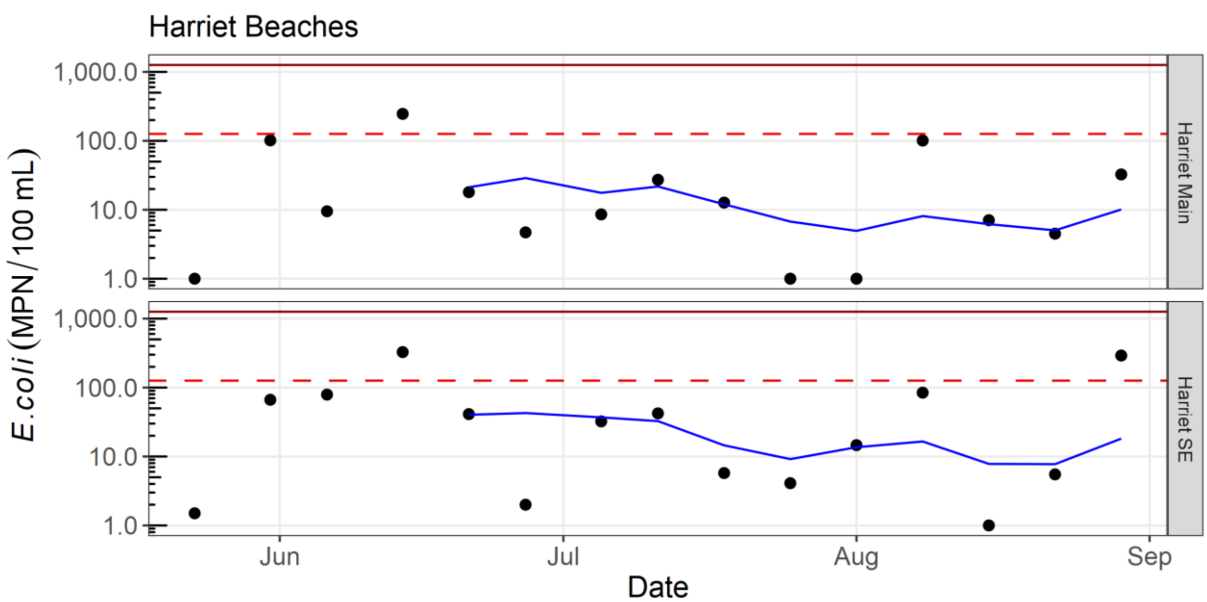


Figure 8-7. 2022 *E. coli* concentrations at the Lake Harriet beaches. Blue line is the running 30-day geometric mean. The dashed horizontal line represents the *E. coli* standard for the 30-day geometric mean (126 MPN/100mL) and the solid horizontal line represents the single-sample maximum standard (1,260 MPN/100mL). Note the log scale on the Y-axis.

Figure 8-8 shows *E. coli* monitoring data for Lake Harriet beaches from 2013 to 2022 which is graphed by using box and whisker plots. The *E. coli* results from 2022 at Harriet Main Beach were typical compared to previous years.

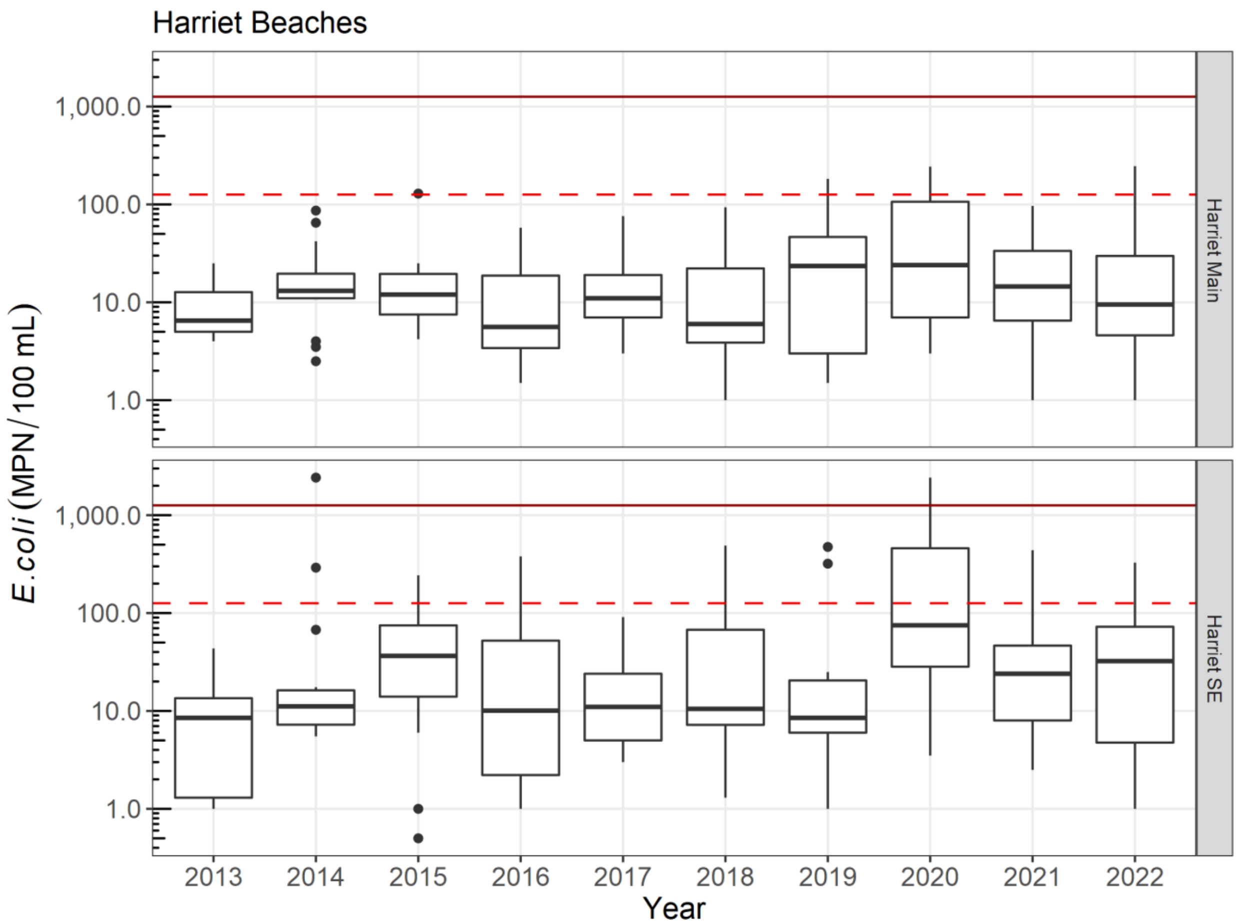


Figure 8-8. Box and whisker plots of *E. coli* concentrations (MPN/100 mL) for Lake Harriet beaches from 2013-2022. The dashed horizontal line represents the *E. coli* standard for the 30-day geometric mean (126 MPN/100mL) and the solid horizontal line represents the single-sample maximum standard (1,260 MPN/100mL). Note the log scale on the Y-axis.

Figure 8-9 shows the total number of days Lake Harriet beaches were closed each year due to *E. coli* exceedances for the past 10 years. Harriet Southeast Beach closed three times in 2020 due to high *E. Coli* levels, which were likely be attributed to waterfowl activity, waterfowl waste, and aquatic vegetation debris at the beach.

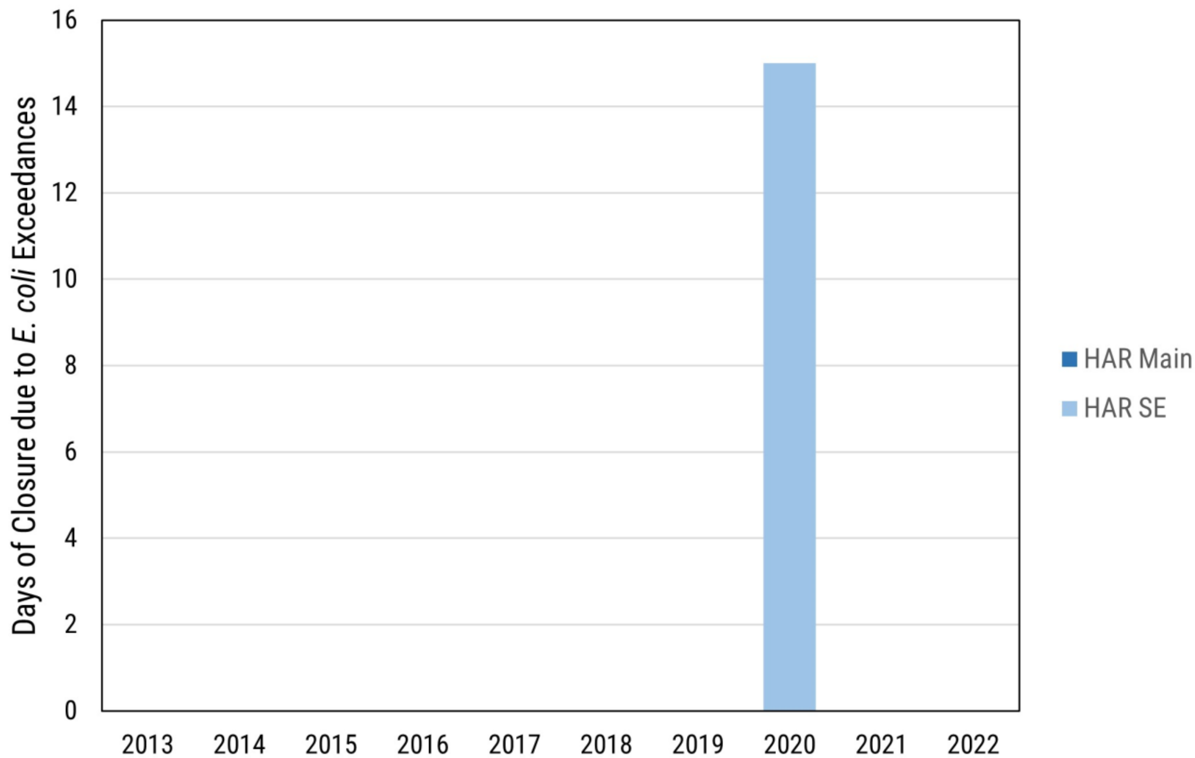


Figure 8-9. Bar graph of total number of days Lake Harriet beaches were closed each year due to *E. coli* exceedances from 2013-2022.

Blue-green Algae/Cyanotoxin Monitoring

Blue-green algae are not algae at all, but a type of bacteria called cyanobacteria. These photosynthetic microorganisms occur naturally in lakes, streams, and other waterbodies worldwide. When conditions are right, cyanobacteria can grow quickly to form dense accumulations called blooms. Certain varieties of cyanobacteria can produce toxins, referred to as cyanotoxins, that can cause illness in humans and animals (US EPA, 2017). Due to an increase in frequency and intensity of cyanobacteria blooms in Minneapolis lakes, the MPRB developed a cyanobacteria monitoring program for public health in 2020. MPRB staff collect information on observations using a defined Visual Monitoring Index (VMI), and sample water weekly at beaches for the most common cyanotoxins. Advisories are posted at beaches and on the MPRB Lake Water Quality Map (bit.ly/mplsbeaches) if toxin levels exceed MPCA guidelines. See **Chapter 19** for more information on blue-green algae and cyanotoxin monitoring.

In 2022, VMI observations were made during weekly beach sampling and bimonthly lake sampling on Lake Harriet. Cyanotoxin samples were also collected at Main Beach and Southeast Beach weekly. VMI observations indicated low levels of cyanobacteria for most of the season, with minor short-lived scums observed at Main Beach during early and late July. Cyanotoxin levels were consistently low at both Harriet beaches. Concentrations were highest in early August at Southeast Beach when the microcystin concentration was 1.18 µg/L, which was well within safe swimming guidelines of 6 µg/L.

On June 10, 2022, a citizen reported a significant amount of cyanobacteria scum at Main Beach. MPRB Water Quality staff confirmed that a cyanobacteria bloom was present using VMI observations, and an advisory was posted on the Lake Water Quality Map and informational signage was posted at the beach. The advisory was removed 6 days later when both VMI observations and cyanotoxin samples indicated a low level of cyanobacteria.

LAKE AESTHETIC AND USER RECREATION INDEX (LAURI)

Figure 8-10 shows the 2022 LAURI for Lake Harriet. Lake Harriet ranked excellent in aesthetics, water clarity, public health, habitat quality, and recreational access. Details on the LAURI can be found in **Chapter 1**.

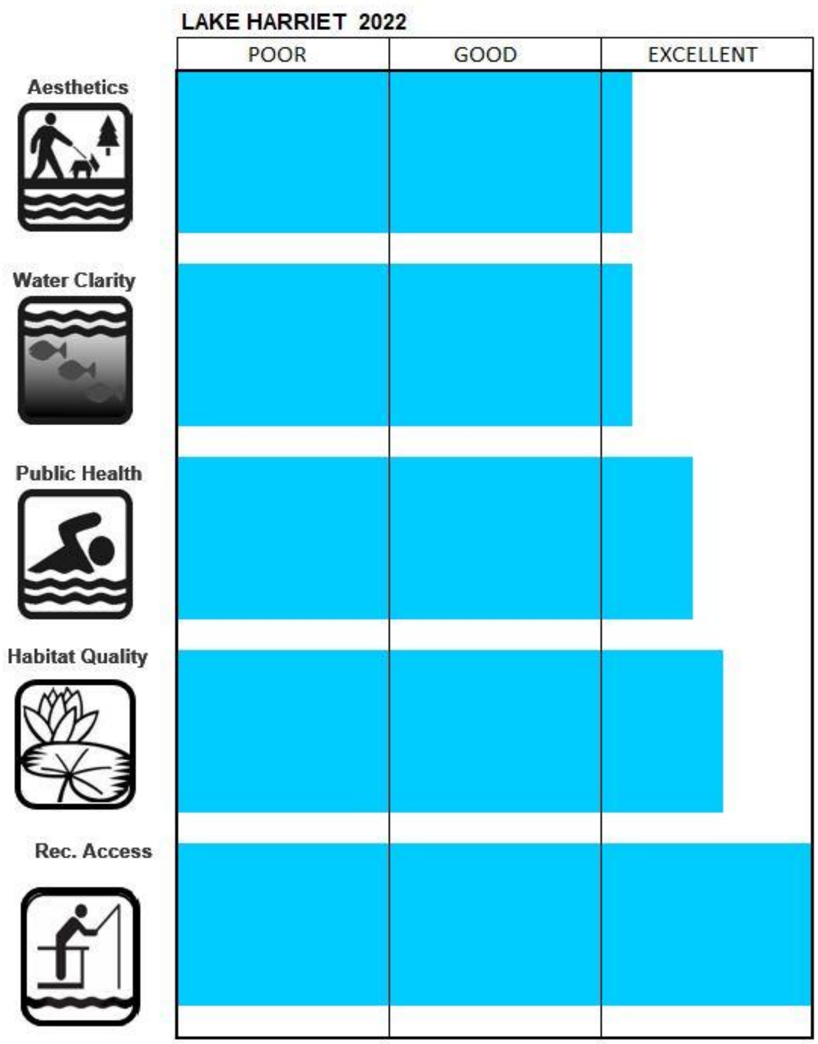


Figure 8-10. The 2022 LAURI for Lake Harriet.

WINTER ICE COVER

Ice came off on Lake Harriet April 12, 2022, seven days later than the average ice-off date. Ice completely covered Lake Harriet for the season on December 8, 2022, six days earlier than the average ice-on date. See **Chapter 1** for details on winter ice cover records and **Chapter 17** for a comparison with other lakes.

AQUATIC PLANT MANAGEMENT

The MNDNR requires a permit to remove or control aquatic plants. These permits limit the area of aquatic plants that can be harvested in order to protect fish habitat. The permits issued to the MPRB allowed for harvesting primarily in swimming areas, boat launches and in shallow areas where recreational access was necessary. The permitted area for aquatic plant harvest in 2022 on Lake Harriet was 44 acres, which is 50% of the littoral zone of the lake, the area shallower than 15 feet. More information on aquatic plants can be found in **Chapter 1** and **Chapter 21**.

PHYTOPLANKTON AND ZOOPLANKTON

Phytoplankton are microscopic plants that are an integral part of the lake community because they form the base of the aquatic food web. **Figure 8-11** shows the water clarity, chlorophyll-*a* concentrations, and relative abundance of phytoplankton divisions during 2022. Comparing these three parameters together can show how changes in the types of algae present in a lake effect water clarity and color, see the phytoplankton and zooplankton monitoring section in **Chapter 1** for additional details.

Water clarity was shallowest in the spring at 1.2 meters and deepest in late May at 8.3 meters when chlorophyll-*a* concentrations were low, see **Figure 8-11a, b**. Water clarity remained shallower than 4 meters between late June and fall. Chlorophyll-*a* concentrations were lowest in late May at 1.2 µg/L and were highest in late June at 40.0 µg/L when the phytoplankton community consisted of green algae (Chlorophyta) and blue-green algae (Cyanophyta), see **Figure 8-11b, c**.

The phytoplankton community primarily consisted of Cyanophyta throughout 2022; however, diatoms (Bacillariophyta) dominated the population in the spring and in late June the phytoplankton population also had high levels of Chlorophyta. Cryptomonads (Cryptophyta) were present throughout most of the year and were most abundant in May. Golden-brown algae (Chrysophyta), haptophytes (Haptophyta), and dinoflagellates (Pyrrophyta) were present in low levels in 2022, **Figure 8-11c**.

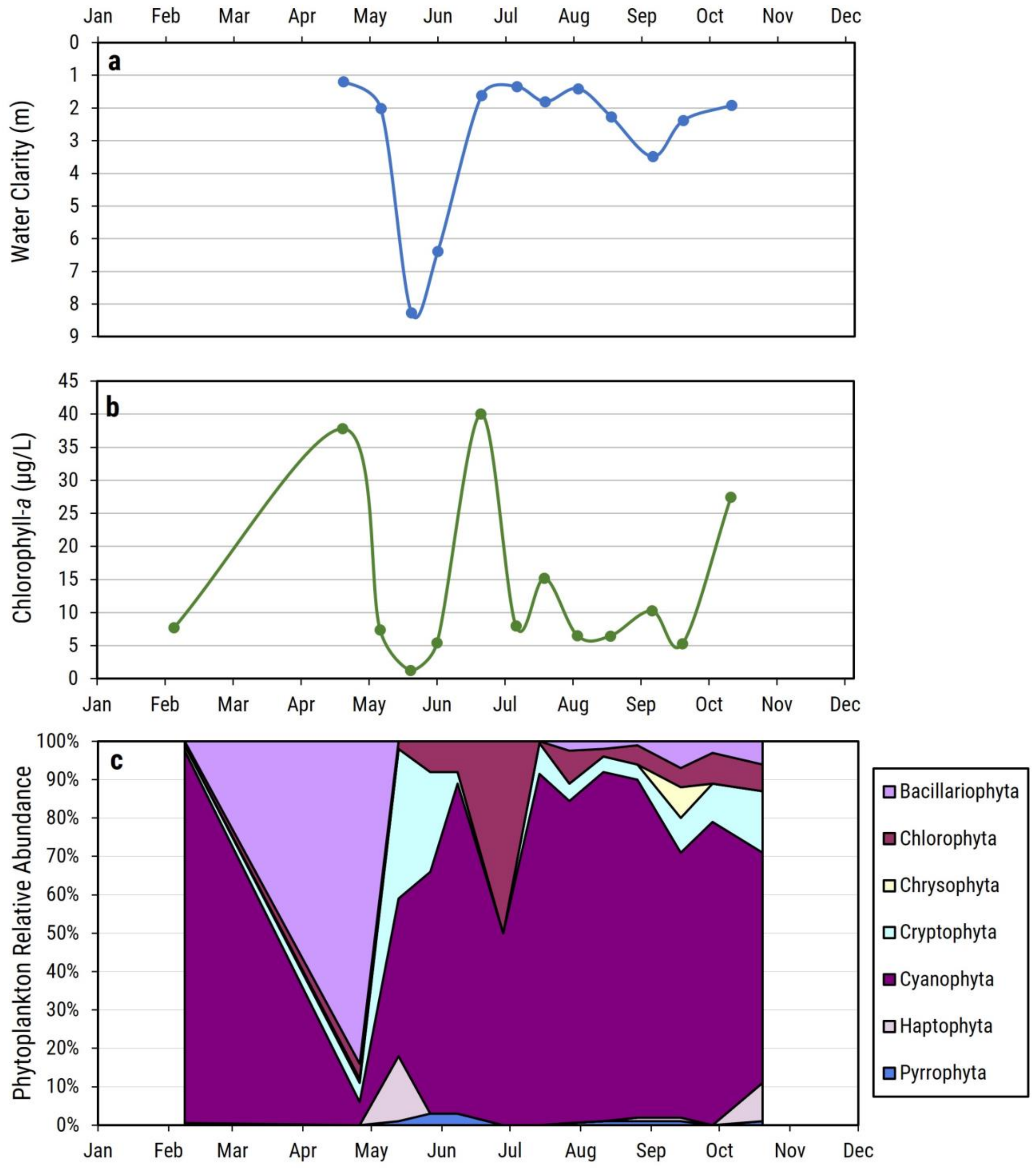


Figure 8-11. Water clarity (a), chlorophyll-*a* concentration (b), and relative abundance of phytoplankton (c) in Lake Harriet during 2022. Note that the water clarity axis is reversed.

Zooplankton are tiny animals that feed on phytoplankton and are also vital for the lake community because they form the second level of the food web along with larval fish. **Figure 8-12** shows the zooplankton abundance in Lake Harriet sampled throughout 2022. Rotifer and nauplii and juvenile copepods were present throughout the year and were most abundant in April and May. Calanoids, cladocerans, cyclopoids, and protozoa were also present in low levels in 2022.

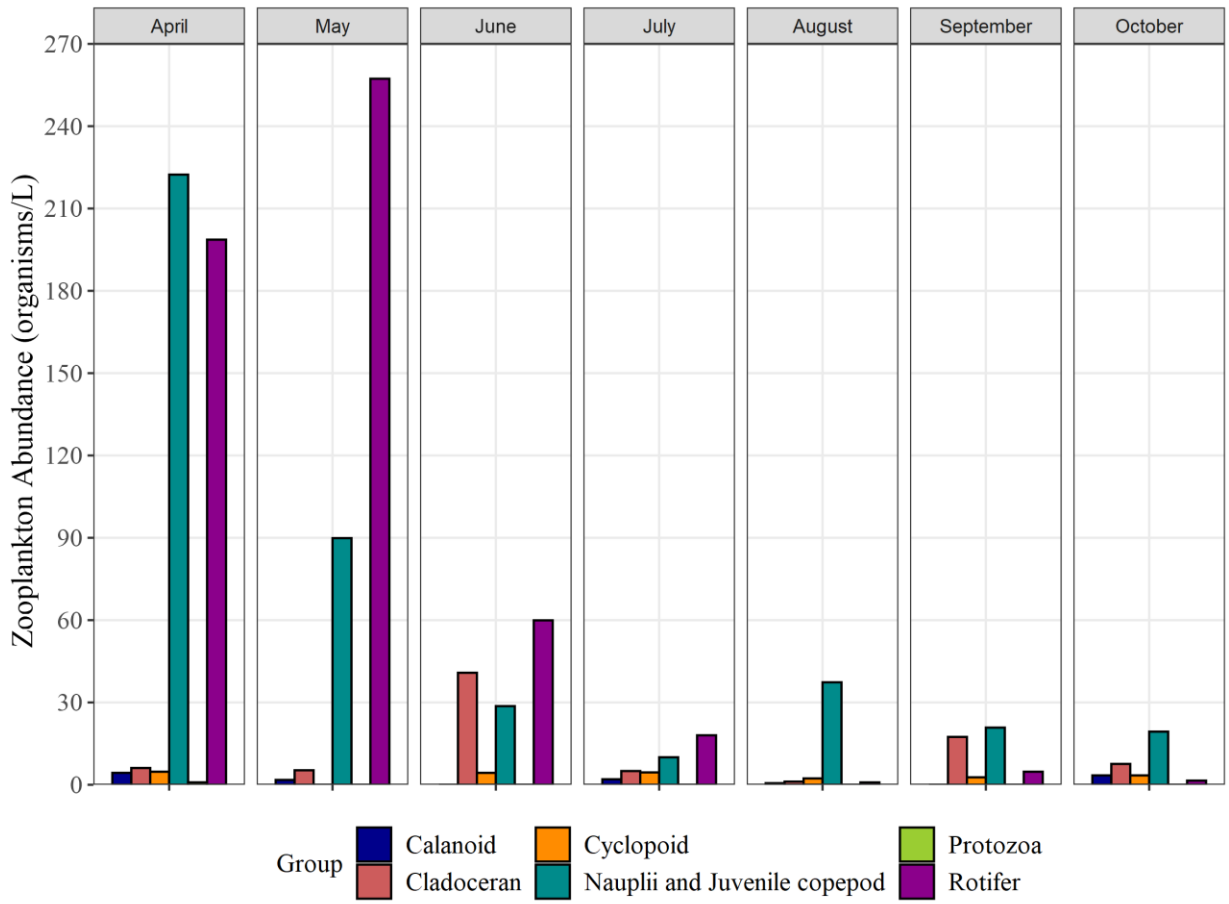


Figure 8-12. Zooplankton abundance in Lake Harriet during 2022.

Events Report

On June 13, 2022, Water Quality staff reported 30 dead sunfish on the north side of Lake Harriet between the boat launch and Main Beach. MPRB staff took photos of the fish, and an Incident Report was completed describing the fish kill event. *Columnaris* disease, caused by the naturally occurring *Flexibacter columnaris* bacteria, was the suspected cause of mortality since the fish kill only consisted of sunfish. *Columnaris* disease is usually associated with a stress condition such as high water temperatures, low dissolved oxygen concentration, crowding, or handling. Water quality data showed increasing spring water temperatures at this time with a surface temperature of 67 degrees Fahrenheit. Another minor fish kill occurred in Lake Harriet in late July. See the fish kill section in **Chapter 1** for additional details.

FISH STOCKING

In 2022, Muskellunge and Walleye fingerlings were stocked into Lake Harriet. Least Darters were transplanted from Cedar Lake and were introduced to Lake Harriet in 2019 to determine the feasibility of transplanting sensitive, non-game fish successfully. This lake was selected because it was once degraded enough to extirpate the species, but now has exceptional water quality and clarity. Future monitoring will continue to determine the establishment of the Least Darter population in Lake Harriet (Konrad, 2019). **Table 8-4** shows amount of fish stocked into the lake by species, number and size, and amount. Additional information and a definition of fry, fingerling, yearling and adult size fish can be found in **Chapter 1**.

Table 8-4. Fish stocked into Lake Harriet over the past 10 years. Data are from the Minnesota Department of Natural Resources.

Year	Species	Number and Size	Amount
2022	Muskellunge	165 fingerlings	15.4 pounds
2022	Walleye	3,600 fingerlings	249.0 pounds
2021	Muskellunge	85 fingerlings	15.2 pounds
2020	Walleye	3,772 fingerlings	106.0 pounds
2019	Least Darter	174 adults	0.1 pounds
2019	Walleye	1,865 fingerlings	105.9 pounds
2018	Muskellunge	85 fingerlings	9.9 pounds
2018	Walleye	45 fingerlings	3.0 pounds
2018	Walleye	334 yearlings	167.0 pounds
2018	Walleye	519 yearlings	79.8 pounds
2016	Muskellunge	85 fingerlings	14.8 pounds
2016	Walleye	916 fingerlings	79.0 pounds
2015	Walleye	165 yearlings	114.0 pounds
2014	Walleye	2,545 fingerlings	114.9 pounds
2013	Walleye	2,890 fingerlings	115.6 pounds

EMERGING CONTAMINANTS

Per- and polyfluoroalkyl substances (PFAS), a class of chemicals with a range of commercial and industrial uses, have been recently identified as a concern due to their impact on environmental and human health (MPCA, "PFAS"). Perfluorooctane sulfonate (PFOS) is a type of PFAS that is of highest concern related to fish consumption. Perfluorooctanoic acid (PFOA) is another type of PFAS in the environment that is connected to potential negative human health effects. See **Chapter 1** for more information on emerging contaminants and **Chapter 17** for comparison of PFAS in MPRB lakes.

PFOS contamination of Bde Maka Ska from a chrome plating facility in St. Louis Park affects Lake Harriet due to its position downstream of Bde Maka Ska, see **Chapter 2**. Lake Harriet was added to the Minnesota Pollution Control Agency's (MPCA) list of impaired waters (303(d) list) in 2008 due to high concentrations of PFOS in fish tissue. The current threshold for listing is a PFOS in fish tissue concentration of 50 ng/g (MPCA, 2022-b). Waterbody Specific Safe-Eating Guidelines for Lake Harriet fish consumption were set by the Minnesota Department of Health (MDH) in 2007 to minimize PFOS exposure. In 2020, the "do not eat" order for Lake Harriet largemouth bass was removed due to reduction in PFOS, see https://www.dnr.state.mn.us/lakefind/fca/report.html?downum=27001600. MPCA data on the concentration of PFOS in fish tissue are shown in **Table 8-5**.

Table 8-5. Concentrations of PFOS in fish tissue of different species of fish in Lake Harriet, compared to the fish tissue PFOS concentration threshold for the 303(d) impaired waters list. Data is given as the mean PFOS concentration in nanograms of contaminant per wet weight gram of fish tissue, and the number in parentheses indicates the number of individual fish sampled. NA means no fish of this species were sampled. All species mean is calculated from the given means and numbers of fish. Data received via communication with MPCA staff in 2023.

Lake Harriet	2018	2019	2021
Species	*Mean PFOS (n) ng/g ww*		
Black crappie	73 (2)	44 (5)	34 (5)
Bluegill	68 (5)	26 (5)	19 (10)
Largemouth bass	97 (5)	88 (4)	77 (5)
Yellow perch	50 (5)	NA	NA
Northern pike	NA	NA	37 (3)
Walleye	NA	80 (1)	33 (2)
All species mean	72	52	37
Fish tissue PFOS concentration threshold for 303(d) impaired waters list	50		

Recreation such as swimming is not considered high risk for PFAS exposure, and the concentrations of both PFOS and PFOA in Lake Harriet are well below the swimming guidance recommended by the MPCA, see **Table 8-6**.

Table 8-6. Surface water concentrations of PFOS and PFOA in Lake Harriet, compared to the PFOS and PFOA swimming guidance. Data is given as the mean concentration in nanograms of contaminant per liter of lake water. Data retrieved from MPCA (2018). Swimming guidance received via communication with MPCA staff in 2023.

Lake Harriet	PFOS (ng/L)	PFOA (ng/L)
2007	30.9	17.3
2018	11.57	9.55
Swimming Guidance	330	1,900

9. Lake Hiawatha

History

Lake Hiawatha was acquired by the Minneapolis Park & Recreation Board (MPRB) in 1922. At that time, the lake was a wetland named Rice Lake for the stands of wild rice that grew in its shallow waters. The lake was also referred to as Mud Lake in the past. Lake Hiawatha was renamed after Henry Wadsworth Longfellow's poem "Song of Hiawatha" in 1925 (Smith, 2008). Major changes were made to the shape and depth of Lake Hiawatha in the early part of the 20th century in an attempt to improve water quality and to make it more desirable to build and live near the lake. Beginning in 1929, over 1.25 million cubic yards of material were dredged from the lake and used to construct Hiawatha Golf Course. Today Lake Hiawatha is part of the Lake Nokomis–Lake Hiawatha Regional Park. A photo of Lake Hiawatha is shown in **Figure 9-1**.

Figure 9-1. Lake Hiawatha in August of 2022.

Table 9-1 shows the physical characteristics and morphometric data of Lake Hiawatha and **Figure 9-2** shows the bathymetric map. Lake Hiawatha has an extremely large watershed, measuring 115,840 acres, due its connection with Minnehaha Creek. In addition to water inputs from the creek, there are also seven stormwater outfalls surrounding the lake, see **Appendix C**. An immense volume of runoff from the very large watershed reduces the residence time of water in the lake. The residence time of water in Lake Hiawatha is 11 days, or less, on average, which is very short compared to most other lakes in Minneapolis that have residence times of up to four years. The short residence time affects all aspects of the lake. The most obvious effect is a generally less than expected level of algae in the water based on the amount of phosphorus present, but in years with low creek flow like 2000, 2007, 2009, 2012, 2021, and 2022 residence time increased and algae growth was high.

The volume of water flowing to Lake Hiawatha has other repercussions. The large amount of runoff from the surrounding watershed accounts for approximately 88% of the phosphorus input to the lake (EPA, MPCA and MCWD, 2013). The fluctuations in the flow from the creek also cause the water level in Lake Hiawatha to vary widely. Additionally, the creek and stormwater inflow can cause the lake to mix during the summer months. Flow contributed from Minnehaha Creek formed a sediment delta at the point where the creek meets the lake. Another delta formed due to sediment inflow from a large stormwater pipe at the north side of the lake.

In 2013, a Total Maximum Daily Load (TMDL) study was completed because Lake Hiawatha was added to the Minnesota Pollution Control Agency's (MPCA) list of impaired waters (303(d) list) in 2002 due to excess nutrients, and Lake Hiawatha and Minnehaha Creek were assigned phosphorus load reductions (EPA, MPCA and MCWD, 2013). Zebra mussels (*Dreissena polymorpha*) were discovered on a sampling plate in the lake in 2013. Zebra mussels had been expected to arrive in Lake Hiawatha within a few years after their discovery in Lake Minnetonka in 2010, due to its direct connection with Minnehaha Creek. Colonies of bryozoans, forming gelatinous balls of various sizes are commonly found in Lake Hiawatha in late summer months, see **Figure 9-3**. Waterbody Specific Safe-Eating Guidelines for Lake Hiawatha fish consumption were set by the Minnesota Department of Health (MDH) to minimize PFOS exposure, see **Chapter 1** for more information on emerging contaminants, https://www.dnr.state.mn.us/lakefind/fca/report.html?downum=27001800.

Lake Hiawatha water quality has been monitored annually by MPRB staff since 1992.

Table 9-1. Lake Hiawatha physical characteristics and morphometric.

Surface Area (acres)	Mean Depth (ft)	Max Depth (ft)	Littoral Area*	Volume (ft^3)	Watershed Area (acres)	Watershed: Lake Area (ratio)	Residence Time (years)
53	13.4	33.0	47%	$3.16x10^7$	115,840	2,145	0.01

*Littoral area defined as less than 15 feet deep.

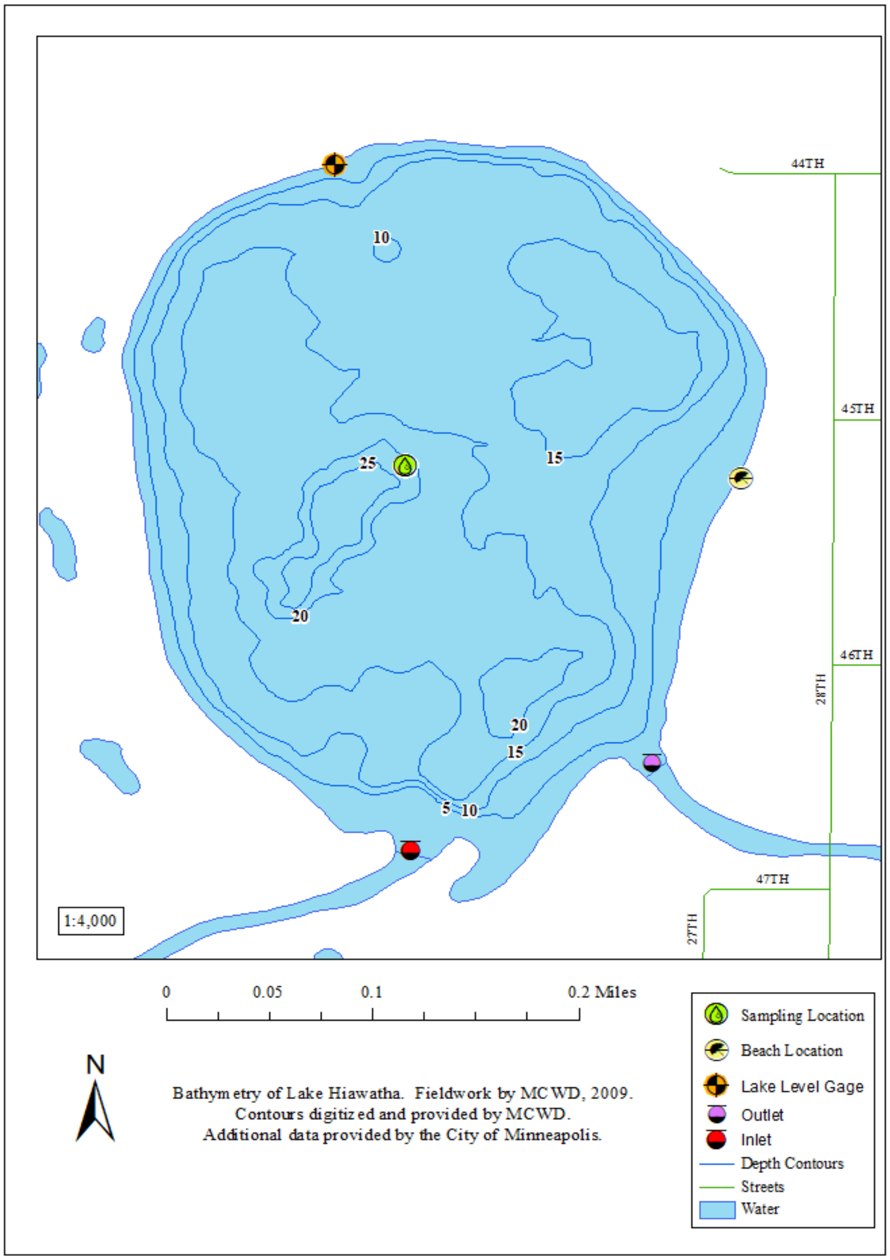


Figure 9-2. Bathymetric map with mid-lake sampling site, beach, lake level gage, outlet and inlet location at Lake Hiawatha.

Figure 9-3. Gelatinous bryozoan colony found in Lake Hiawatha in August 2020.

LAKE LEVEL

The record of lake levels for Lake Hiawatha are shown in **Figure 9-4**. Over five feet of water level variation can be seen in Lake Hiawatha due to the influence of Minnehaha Creek and discharge from the dam at Gray's Bay on Lake Minnetonka. The Ordinary High Water Level (OHWL), as determined by the Minnesota Department of Natural Resource (MNDNR), is 812.8 feet above mean sea level (msl). Lake levels remained below the OHWL throughout 2022, freezing below the OHWL in December.

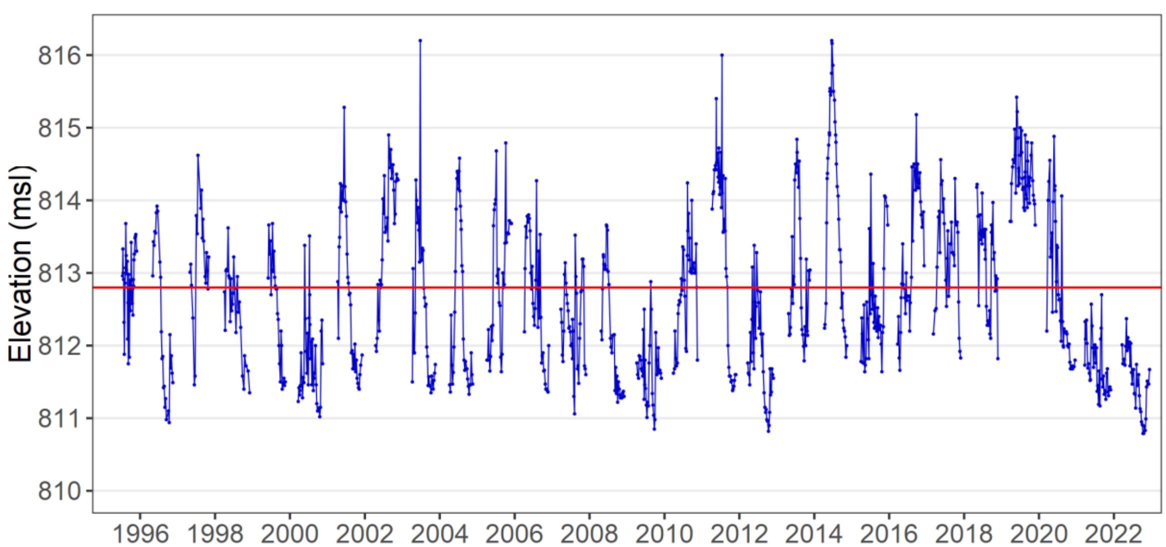


Figure 9-4. Lake levels for Lake Hiawatha from 1995-2022. Horizontal line represents the Ordinary High Water elevation (812.8 ft msl) for Lake Hiawatha.

WATER QUALITY TRENDS – TROPHIC STATE INDEX (TSI)

Figure 9-5 shows historic Lake Hiawatha TSI scores and trend line. There has been a slight increase in TSI scores from 1992-2022, but there is no significant trend ($p > 0.05$). The high p-value indicates there is weak evidence that the TSI score is increasing over time. The lack of significant trend means the lake is neither improving nor getting worse; however, it does appear that low water years correlate to poor water quality. The TSI score of Lake Hiawatha mainly reflects the water it receives from Minnehaha Creek. Abnormally high TSI scores seen in the years 2000, 2007, 2009, 2012, 2021, and 2022 coincide with drought years when Minnehaha Creek was dry for at least a portion of the summer. The high flow from Minnehaha Creek from 2013-2019 may have contributed to the lower TSI scores during that time period. The TSI score for Lake Hiawatha in 2022 was 69. The lake is currently eutrophic, having an anoxic hypolimnion, and the phytoplankton community is dominated by blue-green algae.

Secchi, chlorophyll-*a,* and total phosphorus TSI scores for Lake Hiawatha are above the TSI range for the ecoregion, meaning water clarity is shallower and chlorophyll-*a* and phosphorus levels are higher than in comparable lakes, see **Table 9-2**. See MPCA Surface Water Data (https://webapp.pca.state.mn.us/wqd/surface-water/waterunit-details?wid=27-0018-00) for more information. A detailed explanation of TSI can be found in **Chapter 1**.

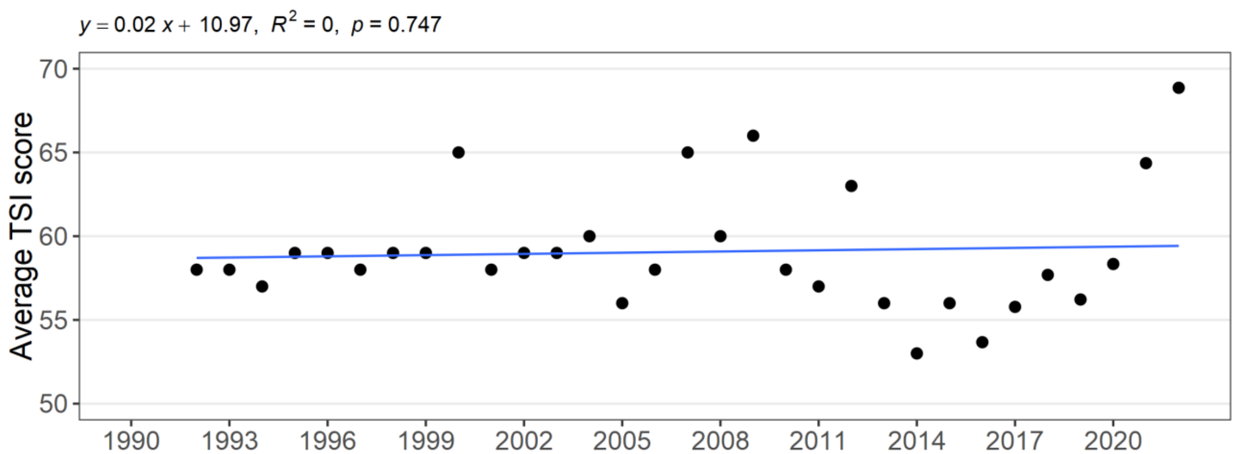


Figure 9-5. Lake Hiawatha TSI scores and liner regression from 1992-2022.

Table 9-2. Lake Hiawatha Secchi, chlorophyll-*a*, and total phosphorus TSI based on data collected between June and September of 2022 and compared to lakes in the North Central Hardwood Forest ecoregion.

	2022 TSI	Expected TSI Range of Lakes in the Same Ecoregion	Within the Expected TSI Range of Lakes in the Same Ecoregion
Secchi	64	43-54	Not within range, worse than expected
Chlorophyll-*a*	72	46-61	Not within range, worse than expected
Total Phosphorus	74	49-61	Not within range, worse than expected

Box and Whisker Plots

The box and whisker plots in **Figure 9-6** show the data distribution for water clarity, chlorophyll-*a*, and total phosphorus for the past 10 years, based on data from the entire sampling season. Red horizontal lines on the graphs indicate the site-specific standards, which applies to data collected between June and September. The Environmental Protection Agency (EPA) approved a 50 µg/L total phosphorus standard for Lake Hiawatha in 2013 (US EPA, 2013). A detailed explanation of box and whisker plots can be found in **Chapter 1**. Box and whisker plots from the entire period of record, 1992-2022, can be found in **Appendix A**.

Water clarity has become increasingly shallower and chlorophyll-*a* and total phosphorus concentrations have become increasingly higher over the past three years. The average Secchi depth in 2022 was 0.84 meters, see **Figure 9-6a**. Chlorophyll-*a* concentrations were higher and more variable with an average of 60 µg/L, see **Figure 9-6b**. Total phosphorus levels were also higher and more variable in 2022 with an average concentration of 121 µg/L, see **Figure 9-6c**. Hiawatha did not meet the site-specific standards for water clarity, chlorophyll-*a*, or total phosphorus in 2022.

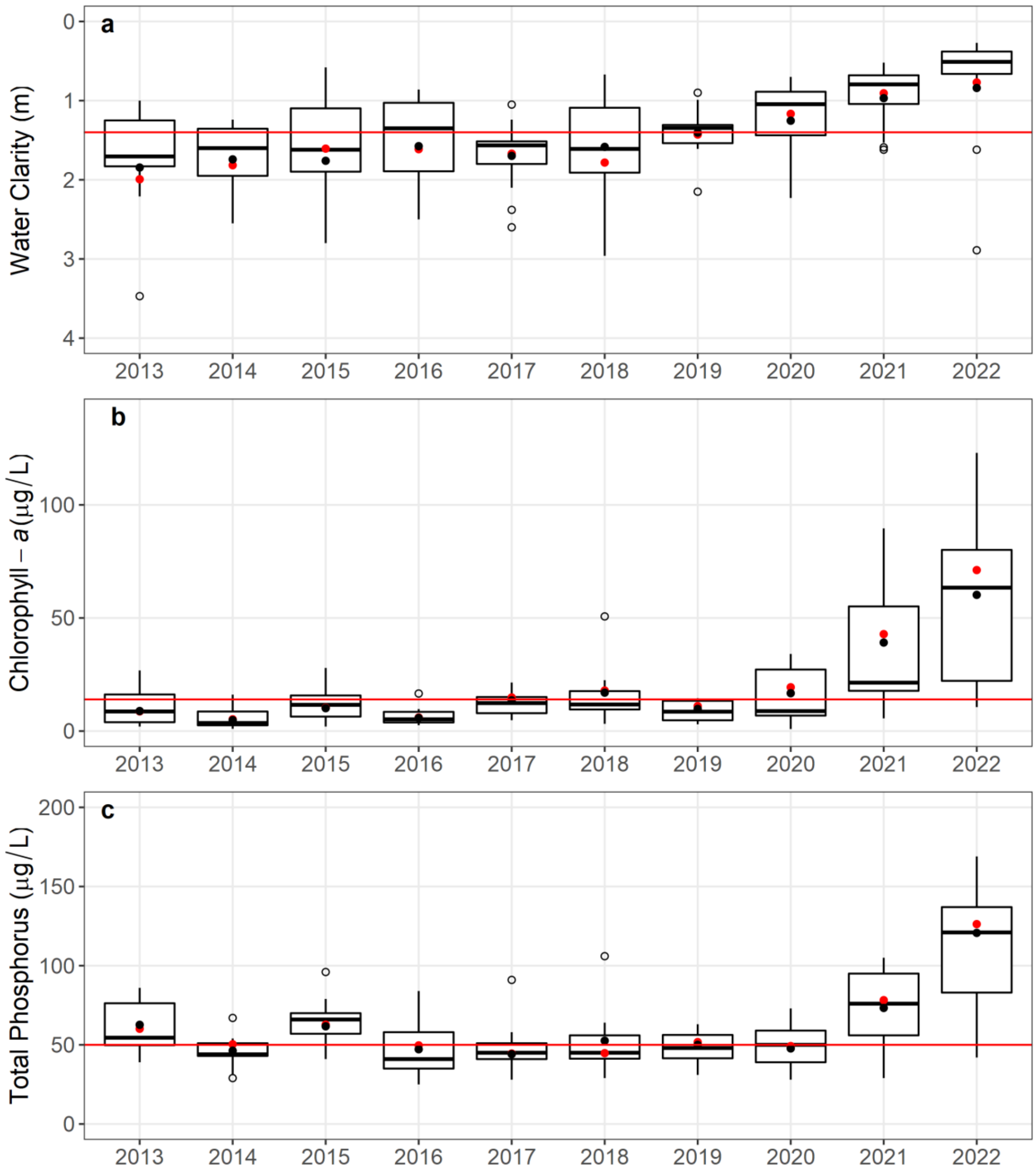


Figure 9-6. Lake Hiawatha box and whisker plots of water clarity (a), chlorophyll-*a* (b), and total phosphorus (c) from 2013-2022. Horizontal lines represent Lake Hiawatha site-specific eutrophication standards, which applies to data collected between June and September. The red circles represent the mean value of data collected between June and September. The black circles represent the mean value of data collected during the growing season, May through September. Data from 1992-2022 can be found in Appendix A.

Chloride

Chloride is a naturally occurring element that is commonly found at low levels in most freshwater bodies. Chloride is a component of road salt (sodium chloride) and is found in other types of compounds that are also called salts (calcium chloride, magnesium chloride). Unnaturally high concentrations of chloride can negatively impact surface waters. High levels of chloride can change the mixing pattern of a lake and lead to very low oxygen levels in deep water. It can also lead to decreasing water clarity and induce stress or cause death of aquatic species (Bathe & Coring, 2011). Sources of chloride include industrial discharge, septic systems, sewage disposal systems, fertilizers, and road salt (Novotny, Murphy, & Stefan, 2008). The MPCA adopted the EPA's recommended water quality criteria for chloride which is a chronic standard of 230 mg/L and an acute standard of 860 mg/L (MPCA, 2016). The MPRB has monitored chloride concentrations in Lake Hiawatha since 1994 by collecting surface water samples using a composite tube and collecting deep water samples using a Kemmerer sampler. See **Chapter 1** for more information on chloride.

Figure 9-7 shows epilimnetic and hypolimnetic chloride concentrations in Lake Hiawatha between 1994-2022, with hypolimnion samples only collected regularly after 2006. Epilimnion samples represent the top two meters of the lake and hypolimnion samples were collected approximately one meter from the bottom of the lake. Red horizontal lines on the graph indicate the MPCA acute and chronic chloride standards. Also included on the graph, is a dotted line that represents an estimate of a concentration above which potential ecological impact could occur, at 120 mg/L. This level of potential ecological impact was developed by Canadian Council of Ministries of the Environment (CCME) and is not a Minnesota state standard but a long-term chloride concentration that could negatively impact life within the lake (CCME, 2011). Chloride concentrations in Lake Hiawatha are variable due to the influence of Minnehaha Creek and the immense volume of runoff from the sizeable watershed. Concentrations have been slightly increasing since 2018; in 2018 and 2019 all epilimnetic and hypolimnetic chloride concentrations measured below the level of ecological impact and in 2022 most samples were above this threshold. According to the Minnesota Statewide Chloride Management Plan, Lake Hiawatha is at high risk for chloride impairment (MPCA, 2018).

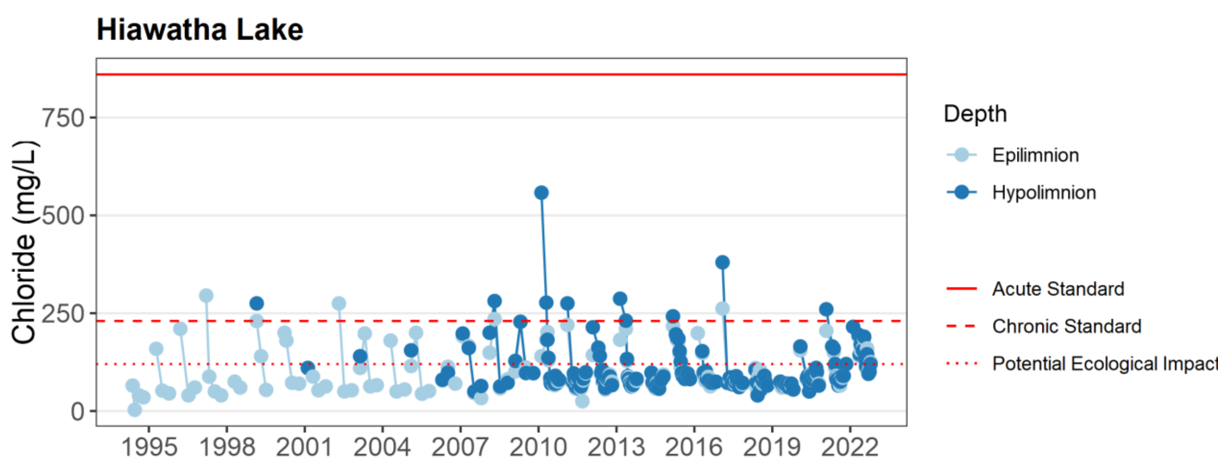


Figure 9-7. Lake Hiawatha scatterplot of epilimnetic and hypolimnetic chloride concentrations between 1994-2022. Horizonal lines represent the MPCA's acute and chronic standard and the potential ecological impact level (CCME, 2011).

Beach Monitoring

Bacteria levels, shown in **Table 9-3** and **Figure 9-8**, were monitored weekly from June through August at Hiawatha Beach in 2022. *Escherichia coli* (*E. coli*) levels at the beach remained below the single sample standard of 1,260 MPN/100 mL from early summer until August. Hiawatha Beach first closed on June 22nd due to exceedance of the 30-day geomean standard of 126 MPN/100mL. The beach remained closed until July 26th, when the 30-day geomean dropped below the threshold. Hiawatha Beach closed again on August 9th due to exceedance of the single sample exceedance. The beach was re-sampled on August 10th and re-opened on August 11th after results had shown that *E.coli* concentrations dropped below the single sample threshold. Hiawatha Beach closed again on August 30th due to exceedance of both the single sample and 30-day geomean standard and remained closed the rest of the sampling season. See **Chapter 18** for more information on beach monitoring.

Table 9-3. Summary of *E. coli* (MPN per 100 mL) data for the Lake Hiawatha Beach in 2022.

Statistical Calculations	Hiawatha
Number of Samples	15
Minimum	9
Maximum	2420
Median	112
Mean	428
Geometric Mean	146
Max 30-Day Geo Mean	429
Standard Deviation	695

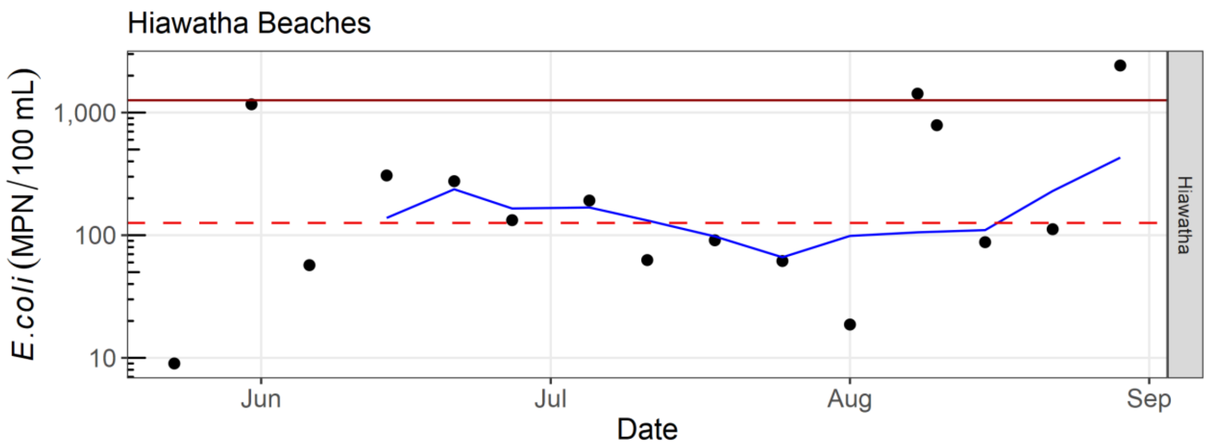


Figure 9-8. 2022 *E. coli* concentrations at Hiawatha Beach. Blue line is the running 30-day geometric mean. The dashed horizontal line represents the *E. coli* standard for the 30-day geometric mean (126 MPN/100mL) and the solid horizontal line represents the single-sample maximum standard (1,260 MPN/100mL). Note the log scale on the Y-axis.

Figure 9-9 shows *E. coli* monitoring data for Hiawatha Beach from 2013 to 2022, which is graphed by using a box and whisker plot. The range of results at Lake Hiawatha is larger than at the other lakes in Minneapolis due to the influences Minnehaha Creek and stormwater have on the lake's water quality. The large amount of water entering Lake Hiawatha from Minnehaha Creek flushes the system and could either increase or decrease bacteria concentrations depending on the water quality of the creek. Stormwater from 7 inlets around the lake likely increases bacteria concentrations in Lake Hiawatha.

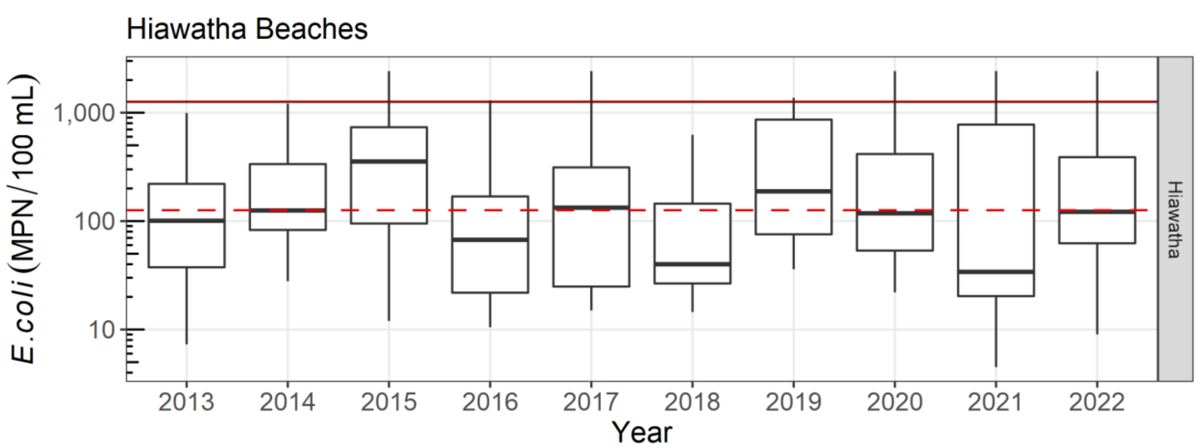


Figure 9-9. Box and whisker plots of *E. coli* concentrations (MPN/100 mL) for the Lake Hiawatha Beach from 2013 to 2022. Note the log scale on the Y-axis. The dashed horizontal line represents the *E. coli* standard for the 30-day geometric mean (126 MPN/100mL) and the solid horizontal line represents the single-sample maximum standard (1,260 MPN/100mL).

Figure 9-10 shows the total number of days Hiawatha Beach was closed each year due to *E. coli* exceedances for the past 10 years. Hiawatha Beach is frequently closed and has the highest number of closures of all MPRB beaches. Due to Lake Hiawatha's connection to Minnehaha Creek and the large surrounding watershed, a high volume of stormwater runoff passes through the lake, which can lead to high bacteria levels at the beach and more frequent beach closures.

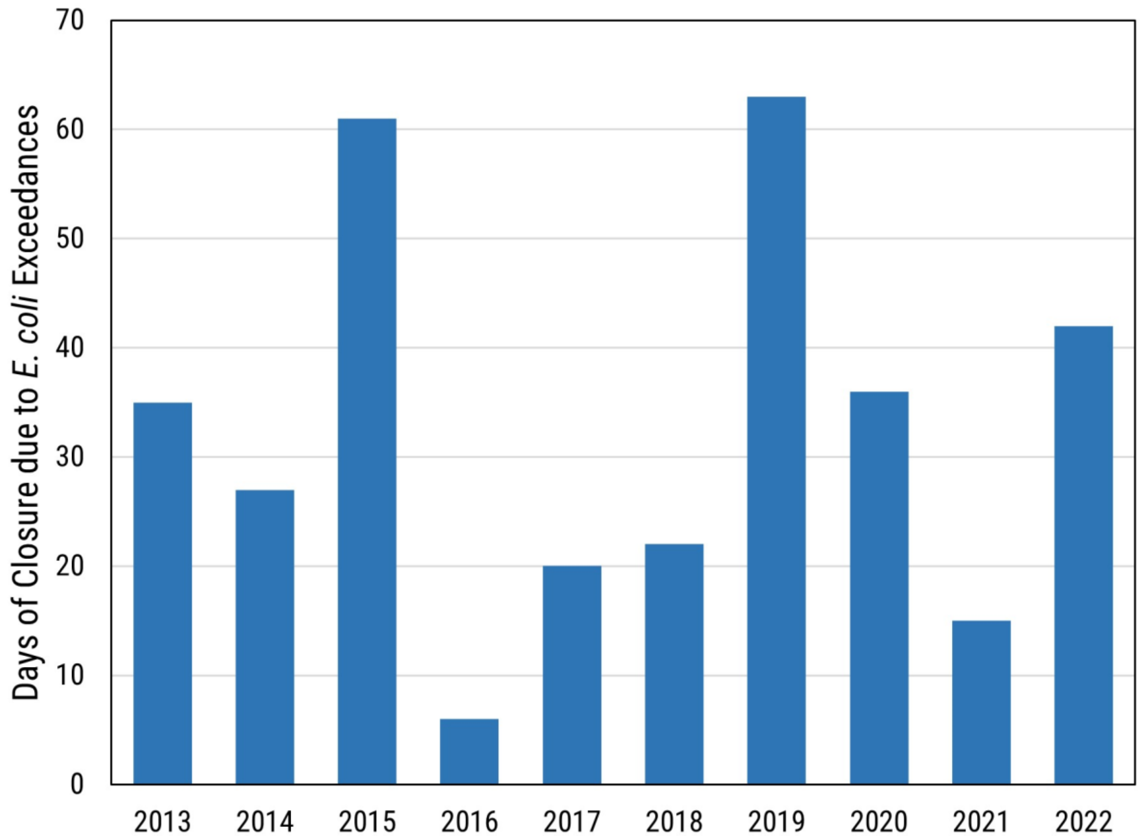


Figure 9-10. Bar graph of total number of days Hiawatha Beach was closed each year due to *E. coli* exceedances from 2013-2022.

Blue-green Algae/Cyanotoxin Monitoring

Blue-green algae are not algae at all, but a type of bacteria called cyanobacteria. These photosynthetic microorganisms occur naturally in lakes, streams, and other waterbodies worldwide. When conditions are right, cyanobacteria can grow quickly to form dense accumulations called blooms. Certain varieties of cyanobacteria can produce toxins, referred to as cyanotoxins, that can cause illness in humans and animals (US EPA, 2017). Due to an increase in frequency and intensity of cyanobacteria blooms in Minneapolis lakes, the MPRB developed a cyanobacteria monitoring program for public health in 2020. MPRB staff collect information on observations using a defined Visual Monitoring Index (VMI), and sample water weekly at beaches for the most common cyanotoxins. Advisories are posted at beaches and on the MPRB Lake Water Quality Map (bit.ly/mplsbeaches) if toxin levels exceed MPCA guidelines. See **Chapter 19** for more information on blue-green algae and cyanotoxin monitoring.

In 2022, VMI observations were made during weekly beach sampling and bimonthly lake sampling on Lake Hiawatha. Cyanotoxin samples were also collected at Hiawatha Beach weekly. VMI observations indicated higher levels of cyanobacteria in the spring and fall when surface scum was present, open water was discolored, and water clarity was poor. On June 8, 2022, an advisory was posted on the Lake Water Quality Map and informational signage was posted at the beach. The advisory was removed 8 days later when both VMI observations and cyanotoxin samples indicated a low level of cyanobacteria. Another advisory was posted on September 22nd and remained in effect until ice-on for a total of 74 days. Cyanotoxin levels were consistently low at Hiawatha Beach. Concentrations were highest in late August when the microcystin concentration was 1.73 µg/L, which was well within safe swimming guidelines of 6 µg/L.

LAKE AESTHETIC AND USER RECREATION INDEX (LAURI)

The LAURI for Lake Hiawatha is shown in **Figure 9-11**. In 2022, Lake Hiawatha scored good in aesthetics, water clarity, habitat quality, and recreational access, but poor in public health due to high bacteria levels detected at beaches during the swim season. Details on the LAURI index can be found in **Chapter 1**.

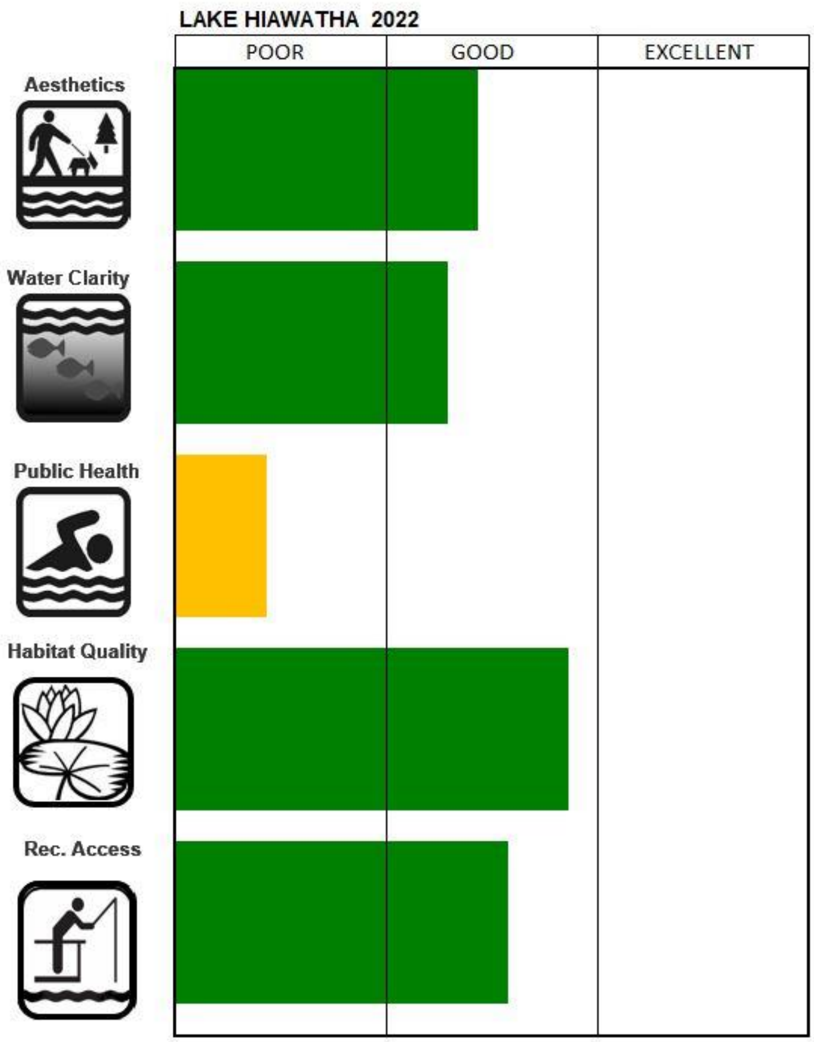


Figure 9-11. The 2022 LAURI for Lake Hiawatha.

Winter Ice Cover

Ice came off Lake Hiawatha on April 11, 2022, seven days earlier than average. Ice returned to the lake for the winter on December 19, 2022, fifteen days later than the average ice-on date. The flow from Minnehaha Creek sometimes causes open water throughout the winter on Lake Hiawatha, but the lake is considered frozen if 5% of the lake or less is open near the creek inlet. See **Chapter 1** for details on winter ice cover records and **Chapter 17** for a comparison with other lakes.

Phytoplankton and Zooplankton

Phytoplankton are microscopic plants that are an integral part of the lake community because they form the base of the aquatic food web. **Figure 9-12** shows the water clarity, chlorophyll-*a* concentrations, and relative abundance of phytoplankton divisions during 2022. Comparing these three parameters together can show how changes in the types of algae present in a lake effect water clarity and color, see the phytoplankton and zooplankton monitoring section in **Chapter 1** for additional details.

Water clarity was initially shallower in the spring and increased in early June with the deepest reading at 2.9 meters, see **Figure 9-12a**. Water clarity remained shallower than 1 meter for the rest of the sampling season reaching its shallowest reading in the fall at 0.3 meters. Chlorophyll-*a* concentrations were lowest in late May at 10.6 µg/L when the phytoplankton community primarily consisted of diatoms (Bacillariophyta) and cryptomonads (Cryptophyta). Blue-green algae (Cyanophyta) dominated the phytoplankton population when chlorophyll-*a* concentrations were highest in mid-September at 123 µg/L, see **Figure 9-12b, c**.

Cyanophyta dominated the phytoplankton community throughout most of the 2022 sampling season in Lake Hiawatha except in spring and late May when Bacillariophyta dominated the population. Cryptophyta were present throughout the year and were most abundant in winter and late May. Green algae (Chlorophyta) were also present throughout the year and were most abundant in winter and early May. Golden-brown algae (Chrysophyta), euglenoids (Euglenophyta), haptophytes (Haptophyta), and dinoflagellates (Pyrrophyta) were present in low percentages in 2022, see **Figure 9-12c**.

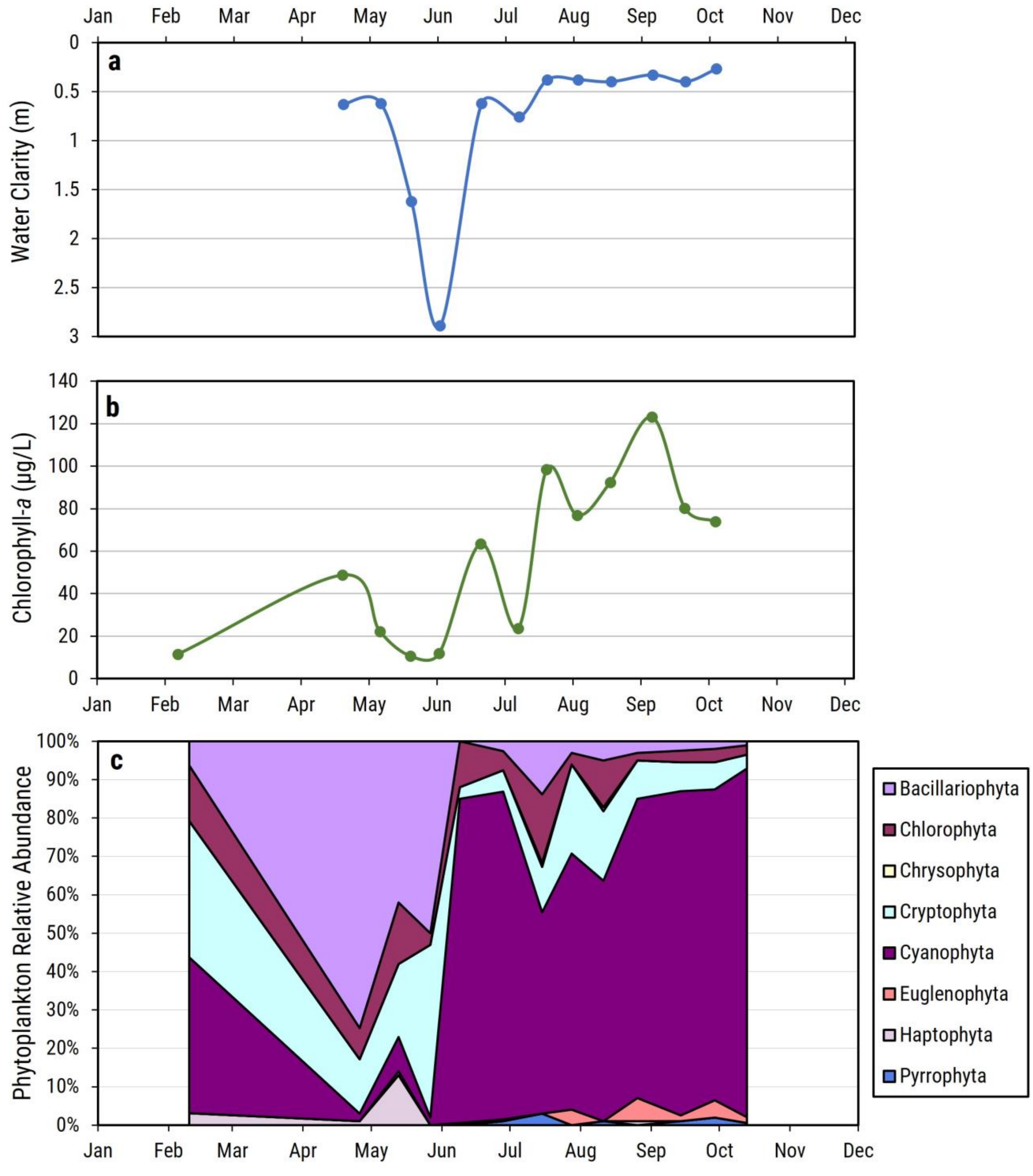


Figure 9-12. Water clarity (a), chlorophyll-*a* concentration (b), and relative abundance of phytoplankton (c) in Lake Hiawatha during 2022. Note that the water clarity axis is reversed.

Zooplankton are tiny animals that feed on phytoplankton and are also vital for the lake community because they form the second level of the food web along with larval fish. **Figure 9-13** shows the zooplankton abundance in Lake Hiawatha sampled throughout 2022. Rotifers and nauplii and juvenile copepods were abundant in May and October. Cladocerans were present throughout the year and were most abundant in June. Calanoids and cyclopoids were present in low levels in 2022.

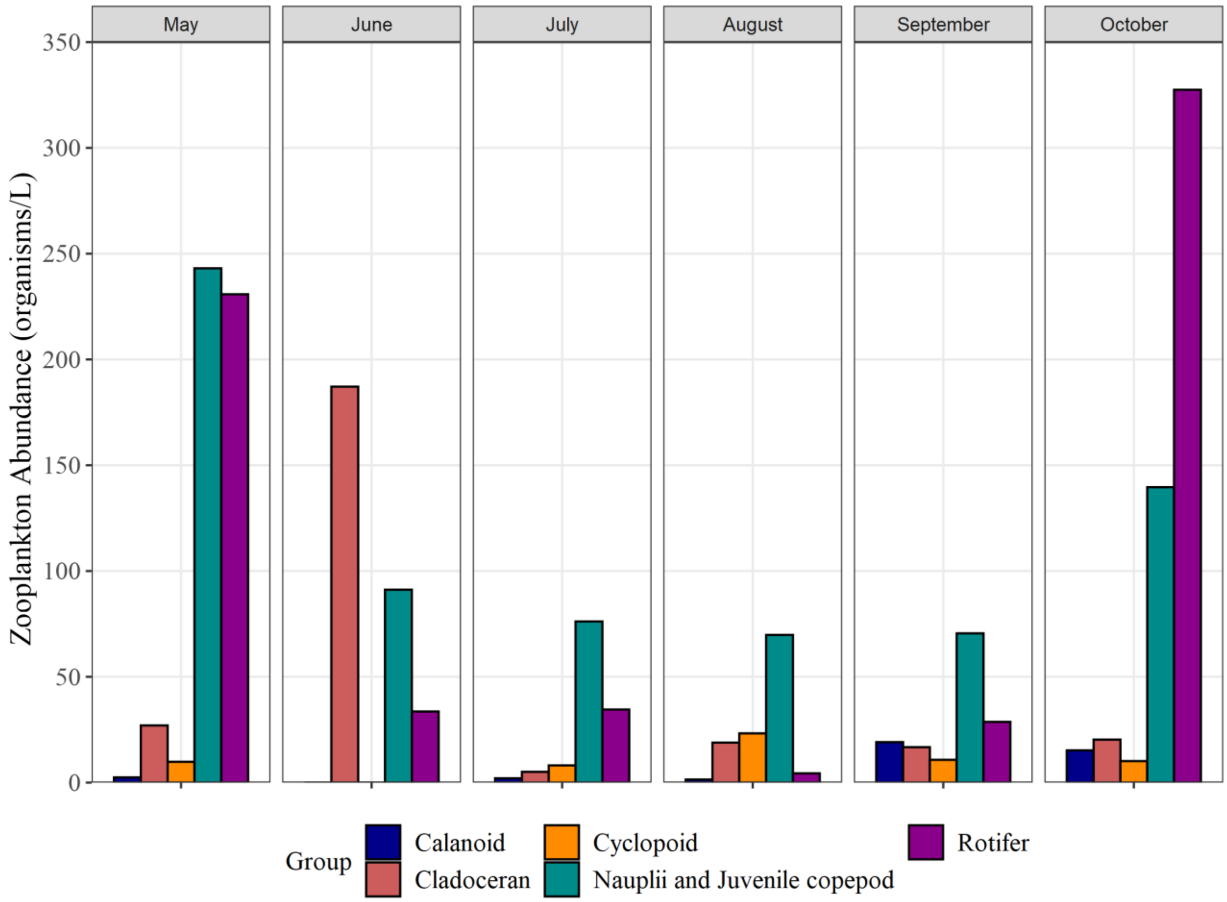


Figure 9-13. Zooplankton abundance in Lake Hiawatha during 2022.

Events Report

Lake Hiawatha collects trash flowing down Minnehaha Creek and from stormsewers, especially after large rainstorms. Several efforts have begun in recent years to remove trash from Lake Hiawatha. Friends of Lake Hiawatha perform annual lake clean-ups and completed trash surveys in 2015 and 2018. During the surveys the amount of trash removed from the park was not only weighed, but individual pieces of trash were also separated into categories, counted, and even sorted by brand names. Since 2008, the Earth Day Clean-up event has inspired more than 20,000 volunteers to remove more than 160,000 pounds of garbage from Minneapolis Parks, including Lake Hiawatha Park. See **Table 9-4** for MPRB-wide Earth Day Event information from the past 10 years. In 2017, the University of Minnesota completed a project in which several citizen-level best management practices (BMPs) were recommended to mitigate trash upstream of Lake Hiawatha. As part of a pilot project, in 2018, Public Works Surface Water and Sewer Division retrofitted three manholes upstream of Lake Hiawatha with trash screens designed to capture floatable trash and debris in the stormsewer before entering the lake (City of Minneapolis, 2021). In 2022, the Freshwater Society received a grant for trash mitigation and worked on developing a plan with the MPRB and City of Minneapolis on how to implement a structural trash BMP at Lake Hiawatha, which is anticipated to be installed in spring of 2023.

Table 9-4. MPRB-wide Earth Day Events over the past 10 years.

Year	Number of Sites	Number of Volunteers	Volunteer Hours	Trash (lb)	Recyclables (lb)	Metals (lb)	Total (lb)
2013*							
2014		>1,700		6,700	1,100	250	8,050
2015	38	1,850	4,625	8,480	620	1,460	10,560
2016	36	1,437	3,592.5				10,380
2017	38	1,809	4,522.5				7,700
2018	34	501	1,252.5				4,720
2019	43	1,897	4,742.5	7,760		1,200	8,960
2020*		>600	1,500				
2021*		502	1,255	2,359			
2022	31	1,112	2,795	3,640			

*Limited information: 2013 Earth Day Clean-up was cancelled due to snow. 2020 and 2021 had limited information due to a "Do-it-yourself" Clean-up to prevent the spread of COVID-19.

Emerging Contaminants

Per- and polyfluoralkyl substances (PFAS), a class of chemicals with a range of commercial and industrial uses, have been recently identified as a concern due to their impact on environmental and human health (MPCA, "PFAS"). Perfluorooctane sulfonate (PFOS) is a type of PFAS that is of highest concern related to fish consumption. Perfluorooctanoic acid (PFOA) is another type of PFAS in the environment that is connected to potential negative human health effects. See **Chapter 1** for more information on emerging contaminants and **Chapter 17** for comparison of PFAS in MPRB lakes.

Lake Hiawatha is not on the MPCA's list of impaired waters (303(d) list) for high concentrations of PFOS in fish tissue. The current threshold for listing is a PFOS in fish tissue concentration of 50 ng/g (MPCA, 2022-b). Due to its connection to Bde Maka Ska and Lake Harriet via Minnehaha Creek, Waterbody Specific Safe-Eating Guidelines for Lake Hiawatha fish consumption were set by the Minnesota Department of Health (MDH) to minimize PFOS exposure, see https://www.dnr.state.mn.us/lakefind/fca/report.html?downum=27001800. MPCA data on the concentration of PFOS in fish tissue are shown in **Table 9-5**.

Table 9-5. Concentrations of PFOS and PFOA in fish tissue Lake Hiawatha, compared to the fish tissue PFOS concentration threshold for the 303(d) impaired waters list. Data is given as the mean concentration in nanograms of contaminant per gram of fish tissue. Data retrieved from MPCA (2018). NA indicates no available data.

Lake Hiawatha	Mean PFOS (ng/g)	Mean PFOA (ng/g)
2007	30.89	2.64
2018	20.30	NA
Fish tissue PFOS concentration threshold for 303(d) impaired waters list	50	

Recreation such as swimming is not considered high risk for PFAS exposure, and the concentrations of both PFOS and PFOA in Lake Hiawatha are well below the swimming guidance recommended by the MPCA, see **Table 9-6**.

Table 9-6. Surface water concentrations of PFOS and PFOA in Lake Hiawatha, compared to the PFOA and PFOS swimming guidance. Data is given as the mean concentration in nanograms of contaminant per liter of lake water. Data retrieved from MPCA (2018). Swimming guidance received via communication with MPCA staff in 2023.

Lake Hiawatha	PFOS (ng/L)	PFOA (ng/L)
2018	4.87	3.70
Swimming Guidance	330	1,900

10. Lake of the Isles

History

The parkland around Lake of the Isles was acquired by the Minneapolis Park and Recreation Board (MPRB) in 1886 through purchase, donation, and condemnation. Lake of the Isles is part of the Chain of Lakes, which also includes Brownie, Cedar, Bde Maka Ska, and Harriet. The lake was named for the four islands that were present in the lake prior to alteration of the park. One of the islands was eliminated in 1884 by the Chicago Milwaukee and Saint Paul Railway when tracks were laid on fill between Bde Maka Ska and Lake of the Isles. Half a million cubic yards of material were dredged between 1889 and 1911 eliminating a second island and increasing the lake area to 120 acres. The lake was further modified by filling 80 acres of marsh to create parkland, deepen the North arm to a uniform depth, and replace the marshy east side of the lake with an upland shoreline. The lake was dredged to an average depth of eight feet, which significantly expanded the size of the southern island. The connection of Isles to Bde Maka Ska was completed in 1911 and was celebrated by citywide festivities. The connection between Isles and Cedar was completed in 1913 (Smith, 2008). **Figure 10-1** shows Lake of the Isles in the fall.

Figure 10-1. Lake of the Isles in October 2022.

Lake of the Isles is a shallow lake with dense stands of macrophytes. The lake becomes thermally stratified and then periodically mixes due to wind throughout the summer. **Table 10-1** shows physical characteristics and morphometric data of Lake of the Isles. **Figure 10-2** shows the Lake of the Isles bathymetry. Lake of the Isles is part of Minnehaha Creek Watershed and the primary land-use around the lake is residential and mixed-use. There are total of 22 stormwater outfalls surrounding the lake, see **Appendix C**.

Lake of the Isles receives water from Cedar Lake and discharges to Bde Maka Ska through open channels. Theodore Wirth attempted to decrease water levels in the Chain of Lakes by six inches in 1935 to reduce erosion along the shoreline at Lake of the Isles. City water was pumped into the lakes in the late 1930s to maintain water levels. The channel between Isles and Bde Maka Ska was dredged in 1950 to deepen the channel for boat transportation. During low water years there was significant aquatic plant growth throughout the lake and the channels.

By the late 1960s all the wetlands outside of parkland were fully filled in for housing development and there were no wetlands remaining to serve as natural filters for stormwater runoff entering the lake. In 1987 Eurasian milfoil was identified in the lake and was spread to the other Chain of Lakes by 1996, which led to a harvesting program under permit from the Minnesota Department of Natural Resources (MNDNR). Lake of the Isles was part of the Clean Water Partnership (CWP) project for the Chain of Lakes and was the focus of multiple restoration activities. Grit chambers and Continuous Deflective Separation (CDS) units were installed in 1994, 1997, and 1999 for stormwater sediment removal, and constructed wetland detention ponds for further treatment of incoming stormwater. Also, a whole lake alum treatment was applied to the lake in 1997 to limit the internal loading of phosphorus

Water quality on Lake of the Isles has been monitored annually since 1991.

Table 10-1. Lake of the Isles physical characteristics and morphometric data.

Surface Area (acres)	Mean Depth (ft)	Max Depth (ft)	Littoral Area*	Volume (ft^3)	Watershed Area (acres)	Watershed: Lake Area (ratio)	Residence Time (years)
112	8.9	31.0	80%	$3.92x10^7$	735	7.1	0.6

* Littoral area was defined as less than 15 feet deep.

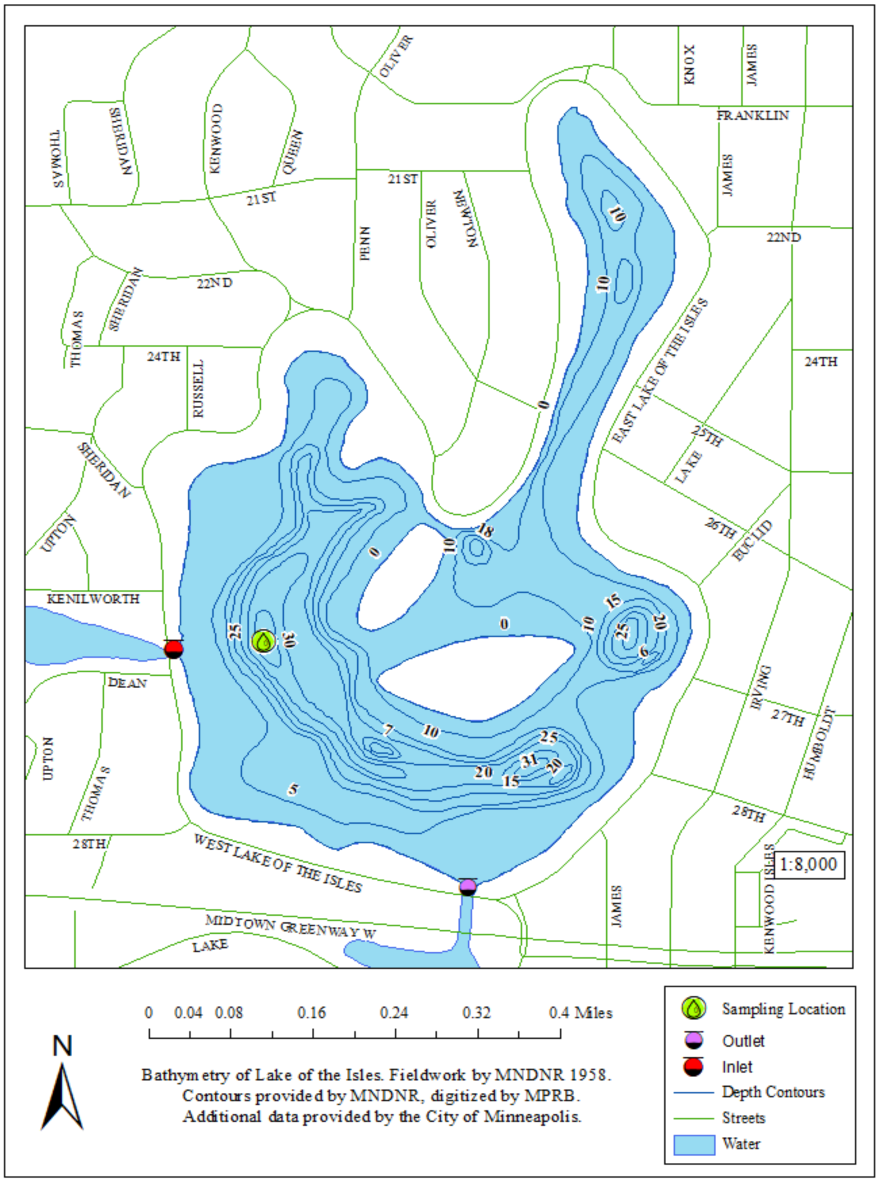


Figure 10-2. Bathymetric map with mid-lake sampling site, outlet, and inlet locations at Lake of the Isles.

Lake Level

The Ordinary High Water Level (OHWL), designated by the MNDNR, for Lake of the Isles is 853 feet above mean sea level (msl). Lake levels for Isles, and the Upper Chain of Lakes, are recorded at a lake gage located in the channel between Lake of the Isles and Bde Maka Ska. Information on historic lake levels for the Upper Chain of Lakes can be found in **Chapter 2**. See **Chapter 1** for details on lake level monitoring and **Chapter 17** for a comparison with other MPRB lakes.

Water Quality Trends – Trophic State Index (TSI)

Figure 10-3 shows historical Lake of the Isles TSI scores and trend line. There has been a slight decrease in TSI scores from 1991-2022, but there is no significant trend ($p > 0.05$). The alum treatment in 1997 coincided with the lowest TSI score for Lake of the Isles. The TSI score for Lake of the Isles in 2022 was 55. The lake is currently eutrophic with an anoxic hypolimnion and macrophyte problems, having been infested with Eurasian watermilfoil since 1995.

The CWP Minneapolis Chain of Lakes Project developed a long-term TSI goal to be below 57 that was intended to be met within five to ten years of water quality project completion. In 2022 the TSI score met the CWP goal, and the TSI scores have fluctuated between 52 and 62 since the goal was established. The CWP did not expect that Lake of the Isles would achieve the TSI goal without the implementation of aggressive and costly management practices throughout the watershed due to the large number of stormwater inlets coupled with the shallowness of the lake and macrophytes problems.

Secchi, chlorophyll-*a,* and total phosphorus TSI scores for Lake of the Isles are within the expected TSI range for lakes in the same ecoregion, see **Table 10-2**. See Minnesota Pollution Control Agency (MPCA) Surface Water Data (https://webapp.pca.state.mn.us/wqd/surface-water/waterunit-details?wid=27-0040-00) for more information. A detailed explanation of TSI can be found in **Chapter 1**.

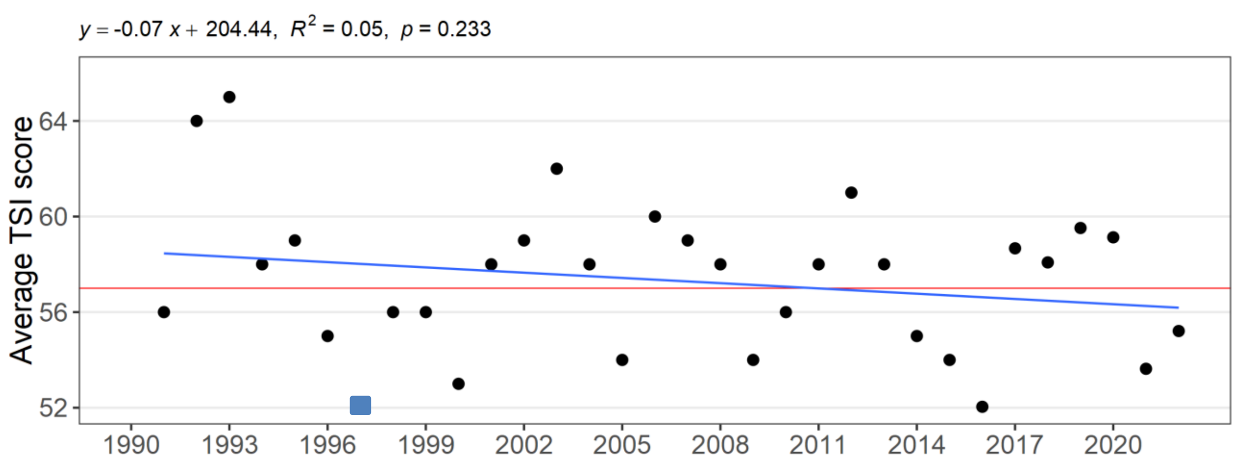


Figure 10-3. Lake of the Isles TSI scores and linear regression from 1991-2022. The red line represents the CWP long-term TSI goal of below 57. The blue square highlights the 1997 alum treatment.

Table 10-2. Lake of the Isles Secchi, chlorophyll-*a*, and total phosphorus TSI based on data collected between June and September of 2022 and compared to lakes in the North Central Hardwood Forest ecoregion.

	TSI	Expected TSI Range of Lakes in the Same Ecoregion	Within the Expected TSI Range of Lakes in the Same Ecoregion
Secchi	53	43-54	Within range
Chlorophyll-*a*	58	46-61	Within range
Total Phosphorus	57	49-61	Within range

Box and Whisker Plots

The box and whisker plots in **Figure 10-4** show the data distribution for water clarity, chlorophyll-*a*, and total phosphorus for the past 10 years, based on data from the entire sampling season. Red horizontal lines on the graphs indicate the MPCA eutrophication standards for shallow lakes, which applies to data collected between June and September. A detailed explanation of box and whisker plots can be found in **Chapter 1**. Box and whisker plots from the entire period of record, 1991-2022, can be found in **Appendix A**.

Water clarity in 2022 was comparable to previous years with an average Secchi depth of 1.8 meters, see **Figure 10-4a**. Chlorophyll-*a* was lower than the previous five years with an average concentration of 14.8 µg/L in 2022, see **Figure 10-4b**. Total phosphorus concentrations were similar to previous years with an average concentration of 40 µg/L but less variable in 2022, see **Figure 10-4c**. The lake met MPCA eutrophication standards for water clarity, chlorophyll-*a*, and total phosphorus in 2022.

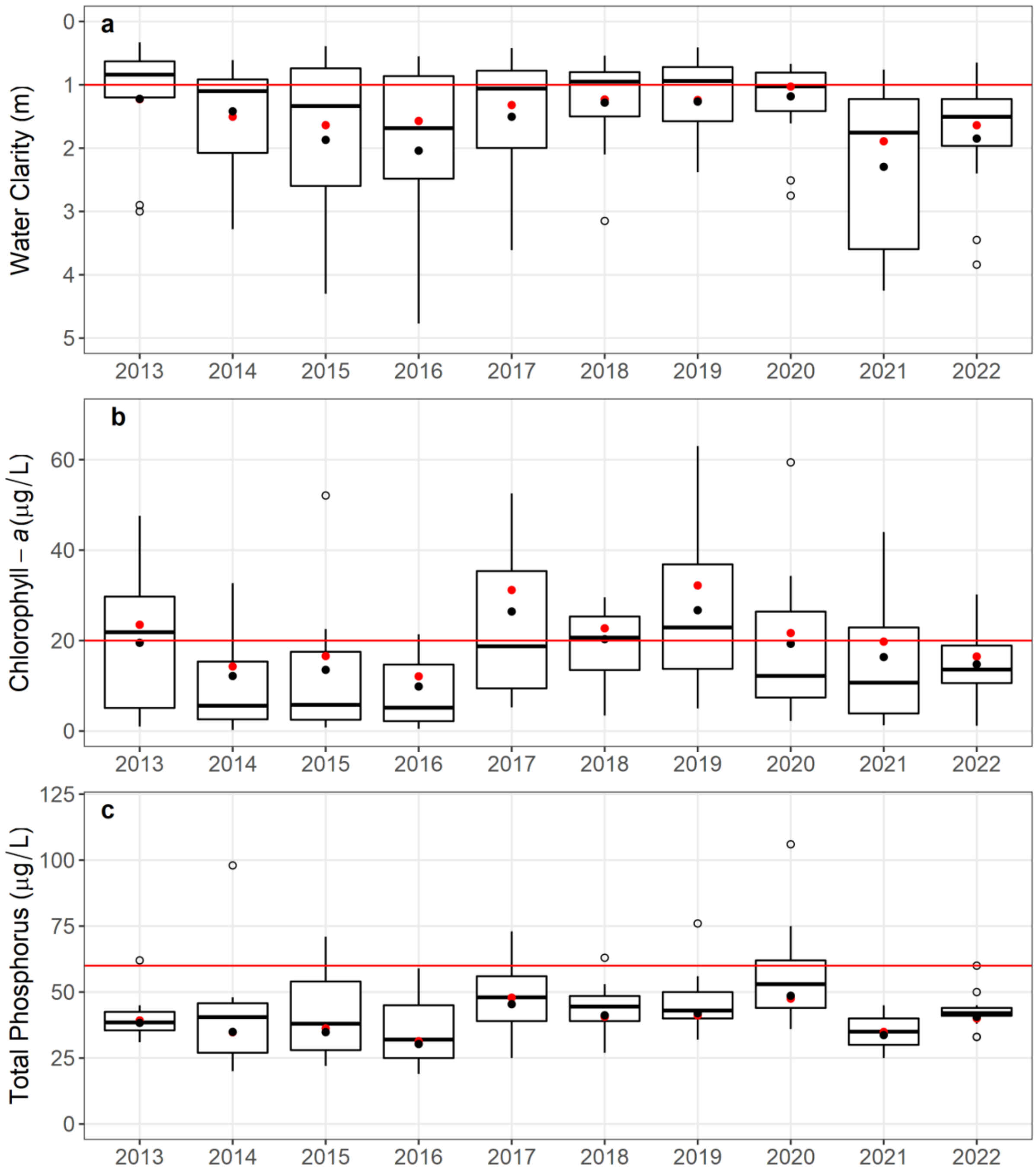


Figure 10-4. Lake of the Isles box and whisker plots of water clarity (a), chlorophyll-*a* (b), and total phosphorus (c) from 2013-2022. Horizontal lines represent MPCA eutrophication standard for shallow lakes, which applies to data collected between June and September. The red circles represent the mean value of data collected between June and September. The black circles represent the mean value of data collected during the growing season, May through September. Data from 1991-2022 can be found in Appendix A.

CHLORIDE

Chloride is a naturally occurring element that is commonly found at low levels in most freshwater bodies. Chloride is a component of road salt (sodium chloride) and is found in other types of compounds that are also called salts (calcium chloride, magnesium chloride). Unnaturally high concentrations of chloride can negatively impact surface waters. High levels of chloride can change the mixing pattern of a lake and lead to very low oxygen levels in deep water. It can also lead to decreasing water clarity and induce stress or cause death of aquatic species (Bathe & Coring, 2011). Sources of chloride include industrial discharge, septic systems, sewage disposal systems, fertilizers, and road salt (Novotny, Murphy, & Stefan, 2008). The MPCA adopted the Environmental Protection Agency's (EPA) recommended water quality criteria for chloride which is a chronic standard of 230 mg/L and an acute standard of 860 mg/L (MPCA, 2016). The MPRB has monitored chloride concentrations in Lake of the Isles since 1995 by collecting surface water samples using a composite tube and collecting deep water samples using a Kemmerer sampler. See **Chapter 1** for more information on chloride.

Figure 10-5 shows epilimnetic and hypolimnetic chloride concentrations in Lake of the Isles between 1995-2022, with hypolimnion samples only collected regularly after 2006. Epilimnion samples represent the top two meters of the lake and hypolimnion samples were collected approximately one meter from the bottom of the lake. Red horizontal lines on the graph indicate the MPCA acute and chronic chloride standards. Also included on the graph, is a dotted line that represents an estimate of a concentration above which potential ecological impact could occur, at 120 mg/L. This level of potential ecological impact was developed by Canadian Council of Ministries of the Environment (CCME) and is not a Minnesota state standard but a long-term chloride concentration that could negatively impact life within the lake (CCME, 2011). Between 2010-2013 chloride concentrations in the hypolimnion were slightly higher than epilimnetic concentrations, with the most significant difference in 2013, likely because runoff containing sodium chloride is denser and sinks to the lake bottom. Since 2013 chloride concentrations in the epilimnion and hypolimnion have been roughly comparable. Chloride concentrations have been slowly increasing since 2006; prior to 2006 most chloride concentrations measured below the level of ecological impact and after 2020 all samples were above this threshold. According to the Minnesota Statewide Chloride Management Plan, Lake of the Isles is at high risk for chloride impairment (MPCA, 2018).

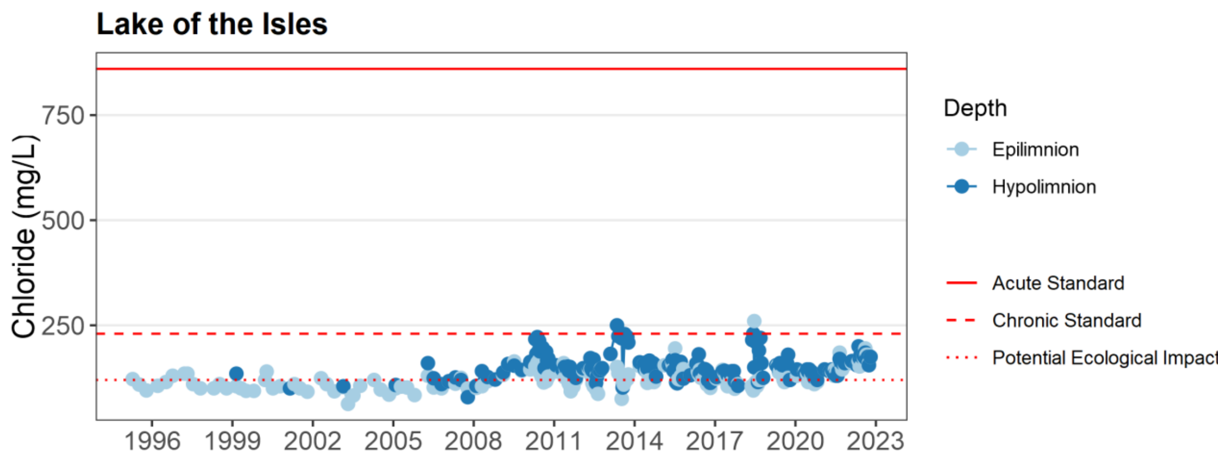


Figure 10-5. Lake of the Isles scatterplot of epilimnetic and hypolimnetic chloride concentrations between 1995-2022. Horizontal lines represent the MPCA's acute and chronic standard and the potential ecological impact level (CCME, 2011).

Blue-green Algae Monitoring

Blue-green algae are not algae at all, but a type of bacteria called cyanobacteria. These photosynthetic microorganisms occur naturally in lakes, streams, and other waterbodies worldwide. When conditions are right, cyanobacteria can grow quickly to form dense accumulations called blooms. Certain varieties of cyanobacteria can produce toxins, referred to as cyanotoxins, that can cause illness in humans and animals (US EPA, 2017). Due to an increase in frequency and intensity of cyanobacteria blooms in Minneapolis lakes, the MPRB developed a cyanobacteria monitoring program for public health in 2020. MPRB staff collect information on observations using a defined Visual Monitoring Index (VMI), and sample water weekly at beaches for the most common cyanotoxins. Advisories are posted at beaches and on the MPRB Lake Water Quality Map (bit.ly/mplsbeaches) if toxin levels exceed MPCA guidelines. See **Chapter 19** for more information on blue-green algae and cyanotoxin monitoring.

In 2022, VMI observations were made during bimonthly lake sampling sessions on Lake of the Isles. VMI observations indicated that cyanobacteria were present in low levels in late June, late September, and October when a low density of small floating balls of cyanobacteria were observed. Although cyanobacteria were present in Lake of the Isles in 2022, no significant scums were observed, and recreation was not inhibited by cyanobacteria.

LAKE AESTHETIC AND USER RECREATION INDEX (LAURI)

The LAURI for Lake of the Isles is shown in **Figure 10-6**. In 2022, Lake of the Isles scored excellent in aesthetics, water clarity, habitat quality, and recreational access. Since Lake of the Isles does not have a swimming beach, a score was not calculated for public health. For more details on LAURI see **Chapter 1**.

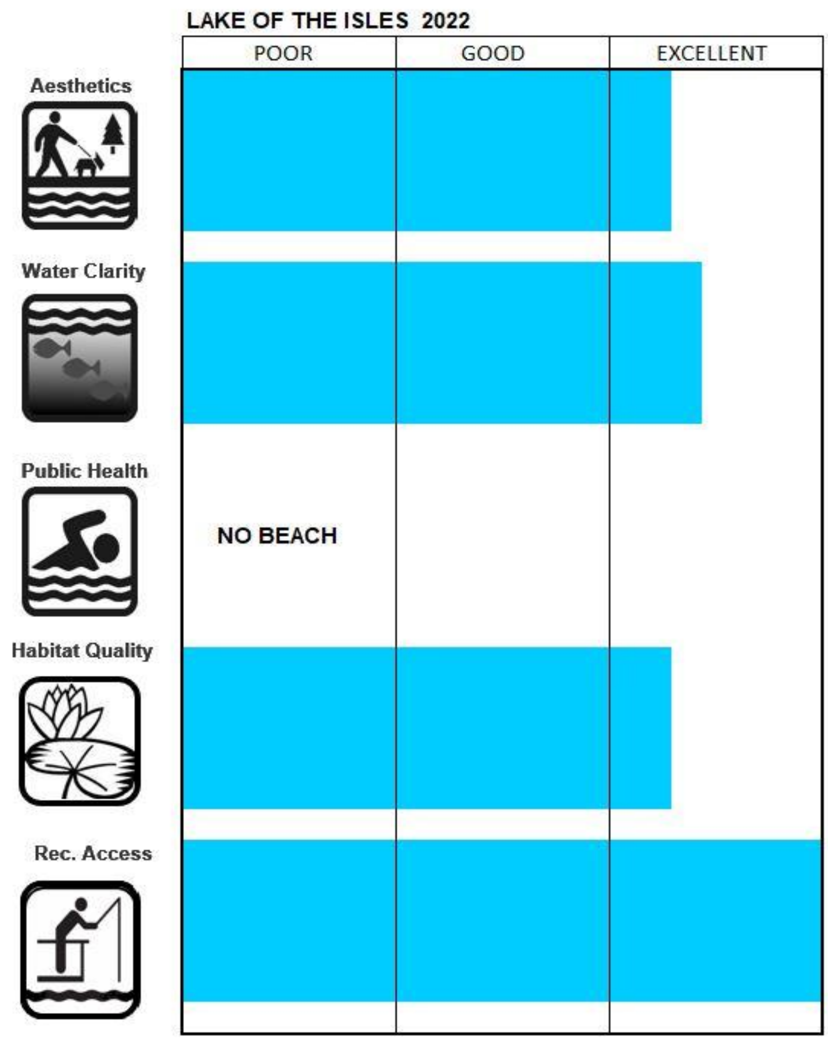


Figure 10-6. The LAURI for Lake of the Isles in 2022.

Winter Ice Cover

Ice came off Lake of the Isles on April 11, 2022, which is six days later than the average ice-off. Ice fully covered the lake on November 21, 2022, which is eleven days earlier than average for Lake of the Isles. See **Chapter 1** for details on winter ice cover records and **Chapter 17** for a comparison with other lakes.

Aquatic Plant Management

The MNDNR requires a permit to remove or control aquatic plants. In order to protect fish habitat, the MNDNR permit limits the area from which aquatic plants can be harvested. The permits issued to the MPRB allowed for harvesting primarily in swimming areas, boat launches, and in shallow areas where recreational access was necessary. The area permitted for aquatic plant harvesting in Lake of the Isles in 2022 was 38 acres which is just over 41% of the littoral zone, the area shallower than 15 feet. See **Chapter 1** and **Chapter 21** for details on aquatic plants.

Phytoplankton and Zooplankton

Phytoplankton are microscopic plants that are an integral part of the lake community because they form the base of the aquatic food web. **Figure 10-7** shows the water clarity, chlorophyll-*a* concentrations, and relative abundance of phytoplankton divisions during 2022. Comparing these three parameters together can show how changes in the types of algae present in a lake affect water clarity and color, see the phytoplankton and zooplankton monitoring section in **Chapter 1** for additional details.

Water clarity was deepest in late May at 3.8 meters and shallowest in early August at 0.65 meters, see **Figure 10-7a**. Chlorophyll-*a* concentrations were lowest in winter at 1.2 µg/L, see **Figure 10-7b**. Concentrations of chlorophyll-*a* were highest in spring at 30.2 µg/L when the phytoplankton community primarily consisted of diatoms (Bacillariophyta).

The phytoplankton community was dominated by blue-green algae (Cyanophyta) between June and September of 2022, see **Figure 10-7c**. Cryptomonads (Cryptophyta) were present throughout the year and dominated the phytoplankton community in winter. Bacillariophyta were most abundant in spring while golden-brown algae (Chrysophyta) were most abundant in May and fall. Green algae (Chlorophyta), euglenoids (Euglenophyta), haptophytes (Haptophyta), and dinoflagellates (Pyrrophyta) were also present in low percentages.

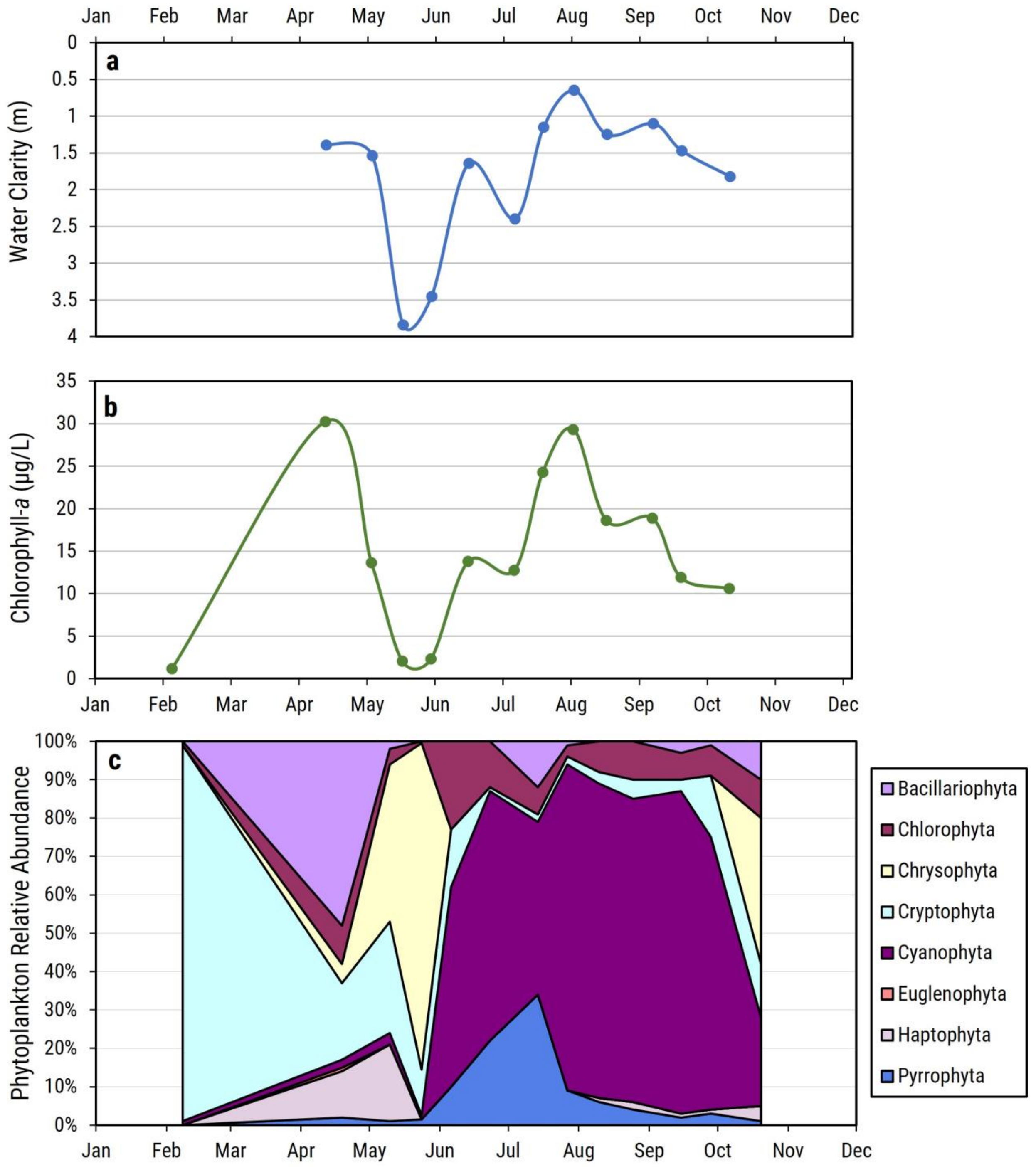


Figure 10-7. Water clarity (a), chlorophyll-*a* concentration (b), and relative abundance of phytoplankton (c) in Lake of the Isles during 2022. Note that the water clarity axis is reversed.

Zooplankton are tiny animals that feed on phytoplankton and are also vital for the lake community because they form the second level of the food web along with larval fish. **Figure 10-8** shows the zooplankton abundance in Lake of the Isles sampled throughout 2022. Nauplii and juvenile copepods were present throughout the year and were most abundant in May. Cladocerans were present in all samples and were most abundant in October. Rotifers were also present throughout 2022 and were most abundant in April and June. Calanoids and cyclopoids were also present in low levels.

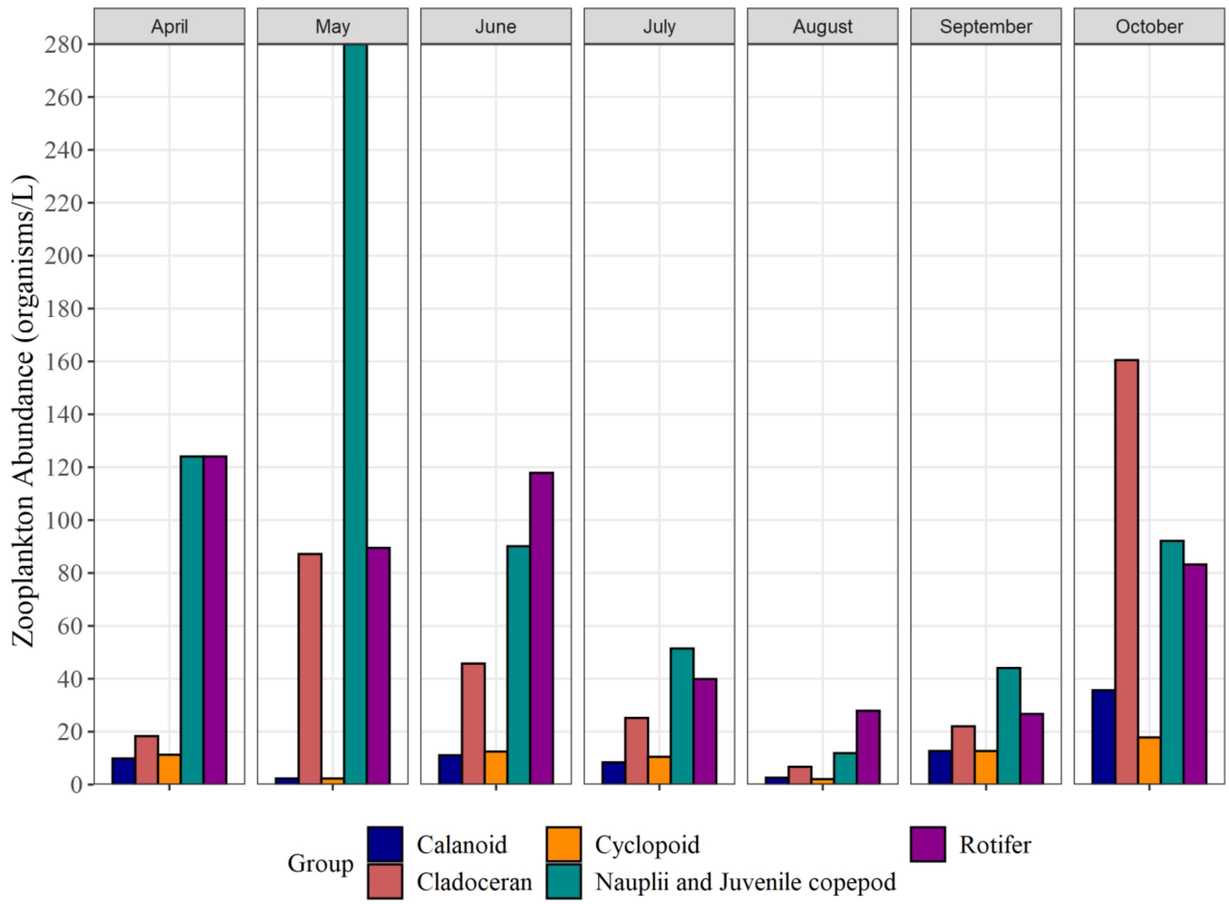


Figure 10-8. Zooplankton abundance in Lake of the Isles during 2022.

EVENTS REPORT

Kenilworth Channel Naturalization and Shoreline Stabilization Project

The Kenilworth Channel, which connects Cedar Lake and Lake of the Isles, closed on September 7, 2021, between the Burnham Road Bridge and Cedar Lake to prepare for an MPRB-led naturalization and shoreline stabilization project. The Kenilworth Channel remained closed throughout most of 2022. Two cofferdams were installed, one at each end of the construction site, and the channel was dewatered, as shown in **Figure 10-9**. A bypass pump was installed and ready in the event that Cedar Lake water elevation increased; however, Cedar Lake never exceeded the water elevation standard set by the MNDNR and the bypass pump was not used during the construction process. Additionally, three dewatering pumps were installed to remove excess water from the channel due to rainfall events and were run as needed.

Turbidity curtains were installed near the cofferdams to protect the water quality of Cedar Lake and Lake of the Isles during construction. In 2021, turbidity was monitored as a proxy for sediment release at five locations throughout the construction site 2-3 times per day and reported to MPRB staff weekly, see **Figure 10-10.** Turbidity was also monitored at lake sampling sites in Cedar Lake and Lake of the Isles biweekly. In 2022, turbidity measurements were not taken within the channel construction area because the channel was not dewatered during the summer of 2022. In-lake turbidity measurements were taken in the spring and from late August to October of 2022 but were otherwise limited due to equipment malfunctions. Turbidity measurements taken during the project are shown in **Table 10-3**. Turbidity levels remained low at all sampling points except for at sampling location KC2, located within the cofferdam, indicating that sediment and nutrient release to the lake due to the project was minimized by project construction practices.

In 2021, while the channel was dry, a section of a sanitary sewer line parallel to the channel was replaced by the City of Minneapolis. During the construction of the stabilization project, the old wood walls of the channels were removed and replaced with stone, soil lifts, and plants creating a naturalized shoreline. Water was allowed to refill the channel in mid-December of 2021 (https://www.minneapolisparks.org/park_care__improvements/park_projects/current_projects/kenilworth-channel-stabilization/). Additional planting and minor areas of stabilization above the water line took place in 2022.

Channel work by the Met Council Southwest light rail project (SWLRT) project began in the fall of 2022 and construction will take place over winter with the channel reopening in 2023 (https://content.govdelivery.com/accounts/MNORGMETC/bulletins/3414b9b).

Figure 10-9. Photo of downstream cofferdam, bypass pump (not running), and three dewatering pumps.

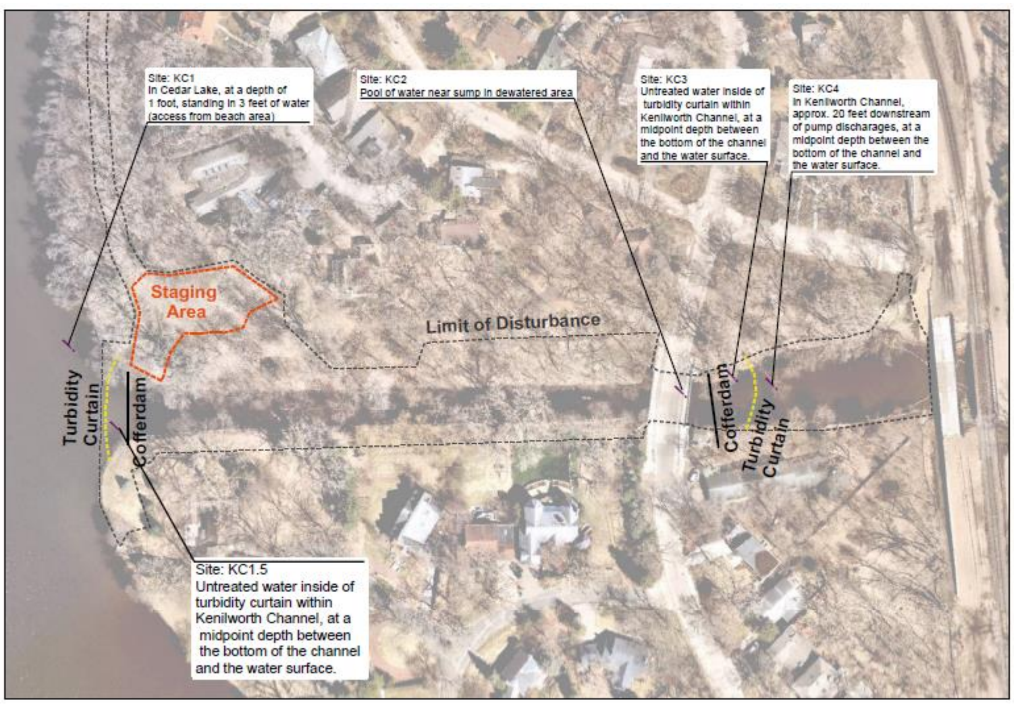


Figure 10-10. Map of turbidity measurement locations, cofferdams, and turbidity curtains in Kenilworth Channel.

Table 10-3. Minimum, maximum, and average turbidity readings, measured in Nephelometric Turbidity Units (NTU), from Kenilworth Channel sampling locations recorded 2-3 times daily and in lake surface readings recorded biweekly between September and November of 2021. In lake surface turbidity readings recorded in spring and biweekly between late August and October of 2022. Note that most turbidity readings were similar between the lakes and within the construction site, and only sites within the cofferdam were high.

Sampling Year	Sampling Location	Minimum Turbidity (NTU)	Maximum Turbidity (NTU)	Average Turbidity (NTU)
2021	**KC1**	0.00	18.9	3.29
	KC1.5	0.00	12.3	2.99
	KC2	1.43	1619	164
	KC3	0.00	28.8	6.18
	KC4	0.01	10.5	2.58
2022	**Cedar Lake**	1.68	6.90	2.51
	Lake of the Isles	0.71	12.0	2.89

Emerging Contaminants

Per- and polyfluoroalkyl substances (PFAS), a class of chemicals with a range of commercial and industrial uses, have been recently identified as a concern due to their impact on environmental and human health (MPCA, "PFAS"). Perfluorooctane sulfonate (PFOS) is a type of PFAS that is of highest concern related to fish consumption. Perfluorooctanoic acid (PFOA) is another type of PFAS in the environment that is connected to potential negative human health effects. See **Chapter 1** for more information on emerging contaminants and **Chapter 17** for comparison of PFAS in MPRB lakes.

Lake of the Isles was added to the MPCA's list of impaired waters (303(d) list) in 2008 due to high concentrations of PFOS in fish tissue. The current threshold for listing is a PFOS in fish tissue concentration of 50 ng/g (MPCA, 2022-b). Waterbody Specific Safe-Eating Guidelines for Lake of the Isles fish consumption were set by the Minnesota Department of Health (MDH) in 2007 to minimize PFOS exposure, see https://www.dnr.state.mn.us/lakefind/fca/report.html?downum=27004000. MPCA data on the concentration of PFOS in fish tissue are shown in **Table 10-4**.

Table 10-4. Concentrations of PFOS in fish tissue of different species of fish in Lake of the Isles, compared to the fish tissue PFOS concentration threshold for the 303(d) impaired waters list. Data is given as the mean PFOS concentration in nanograms of contaminant per wet weight gram of fish tissue, and the number in parentheses indicates the number of individual fish sampled. NA means no fish of this species were sampled. All species mean is calculated from the given means and numbers of fish. Data received via communication with MPCA staff in 2023.

Lake of the Isles	2018	2021
Species	*Mean PFOS (n) ng/g ww*	
Black crappie	28 (5)	23 (5)
Bluegill	21 (5)	15 (5)
Largemouth bass	23 (5)	27 (5)
Yellow perch	9 (2)	NA
Northern pike	37 (4)	NA
All species mean	25	22
Fish tissue PFOS concentration threshold for 303(d) impaired waters list	50	

Recreation such as swimming is not considered high risk for PFAS exposure, and the concentrations of both PFOS and PFOA in Lake of the Isles are well below the swimming guidance recommended by the MPCA, see **Table 10-5**.

Table 10-5. Surface water concentrations of PFOS and PFOA in Lake of the Isles, compared to the PFOS and PFOA swimming guidance. Data is given as the mean concentration in nanograms of contaminant per liter of lake water. Data retrieved from MPCA (2018). Swimming guidance received via communication with MPCA staff in 2023.

Lake of the Isles	PFOS (ng/L)	PFOA (ng/L)
2007	18.1	13.9
2018	4.7	4.86
Swimming Guidance	330	1,900

11. Loring Pond

History

Loring Park was acquired in 1883 and was initially named Central Park. In 1890 it was renamed Loring Park in honor of Charles M. Loring, the first president of the Board of Park Commissioners and known as the Father of the Minneapolis Park System. The pond's current shape was created by connecting two small bodies of water, Jewett Lake and Johnson's Pond, with an open-water channel. The smaller north bay of the pond was originally a wetland. In the winter of 1883-1884, peat was sawn out of the frozen ground to create a bay that would hold open water. **Figure 11-1** shows a photo of modern Loring Pond.

Figure 11-1. View of Loring Pond in October 2022.

Loring Pond is a shallow waterbody with an average depth of about five feet. **Table 11-1** shows the physical characteristics and morphometric data of Loring Pond. **Figure 11-2** is a map of the pond showing estimated depth. Loring Pond is within the watershed regulated by the Mississippi Watershed Management Organization (MWMO). Stormwater diversion has reduced the watershed of Loring Pond to the surrounding 24.1 acres of parkland in the 1990s. The lake has a negative water balance, meaning it loses more water than it receives, so in dry years MPRB uses groundwater augmentation well to maintain water levels. During intense rainstorms, water from the Lowry Hill tunnel backs up into Loring Pond through its outlet. There are currently no stormwater outfalls that flow to Loring Pond, see **Appendix C**.

Several attempts were made in the 1970s to improve water quality in Loring Pond. An Olszewski tube was installed in an attempt to drain high-nutrient water from beneath the hypolimnion out of the lake. The tube never functioned properly and was abandoned. The pipe was capped in 2014 to limit water loss from the pond. Dredging of the north bay from 1976 to 1977 also did not improve the water quality of the lake.

Further lake restoration and park improvement projects were initiated in 1997. The north bay was fully sealed and lined, and the south bay was partially sealed and lined. The liner beneath both bays was vented. An aerator was installed to help prevent oxygen depletion during the summer months. Multiple vegetation restoration projects were completed throughout the park. In 1999, the shoreline was planted with native vegetation in cooperation with the Minnesota Department of Natural Resources (MNDNR) and the Friends of Loring Park. The native shoreline restoration provided a buffer strip for waterfowl management, protection against shoreline erosion, pollutant filtration, and improved lake aesthetics.

In 2007, the north bay was dredged again to remove accumulated sediment and restore original depths in the channel between the two bays. To accomplish this, the northern bay was dewatered and the water level in the southern bay was lowered. The project had the unintended consequence of stimulating cattail growth that led to a multi-year cattail removal project that the Minneapolis Park and Recreation Board (MPRB) began in 2013 and is ongoing.

Water quality on Loring Pond has been monitored annually since 1992 but was not sampled in 1997.

Table 11-1. Loring Pond physical characteristics and morphometric data.

Surface Area (acres)	Mean Depth (ft)	Max Depth (ft)	Littoral Area*	Volume (ft^3)	Watershed Area (acres)	Watershed: Lake Area (ratio)
7	4.9	16.0	89%	1.72×10^6	24	3.0

* Littoral area was defined as less than 15 feet deep.

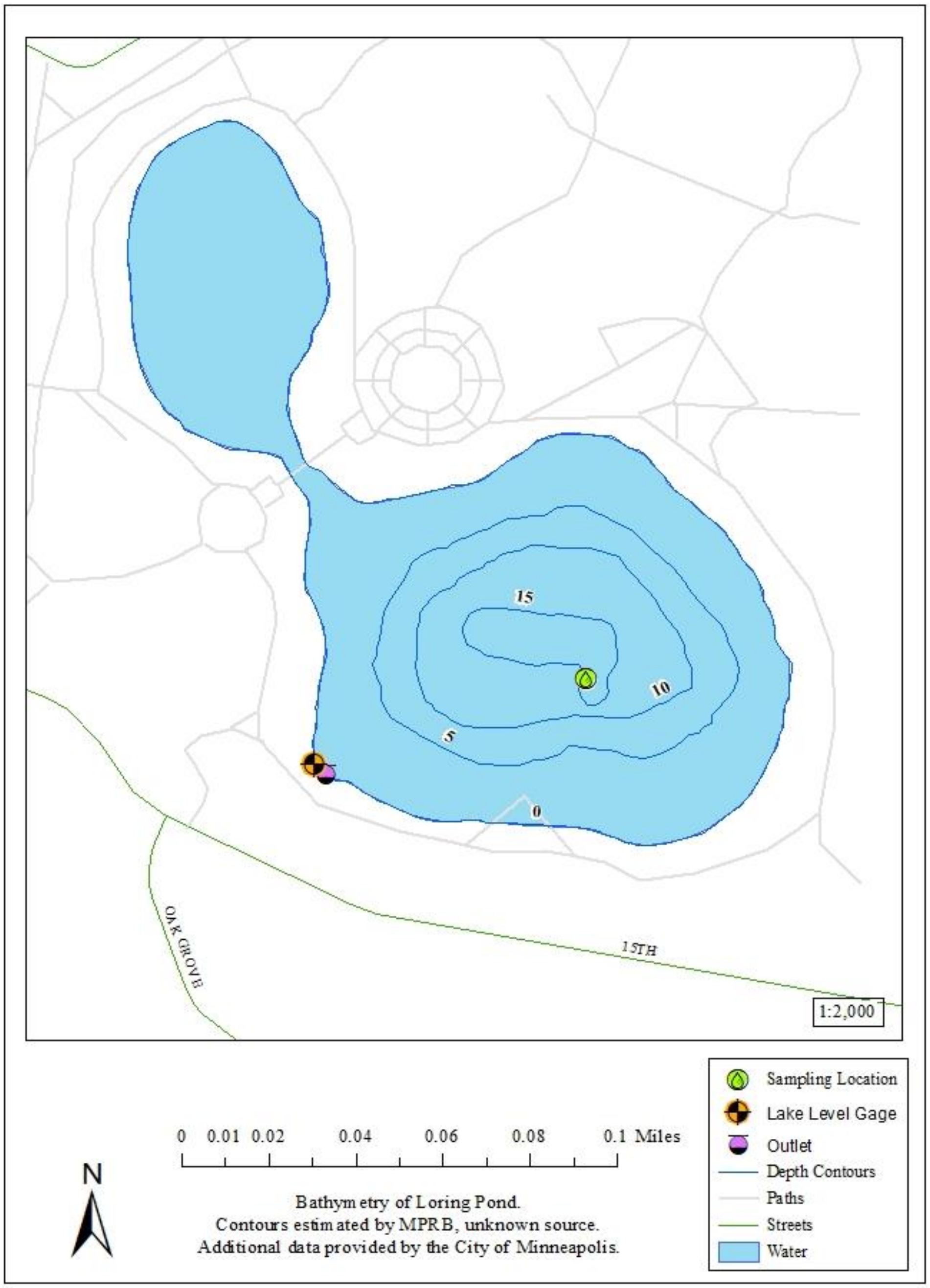


Figure 11-2. Bathymetric map with mid-lake sampling site, lake level gage, and outlet location at Loring Pond.

Lake Level

Lake levels for Loring Pond are shown in **Figure 11-3**. The water level in Loring Pond is influenced by an augmentation well that is used to pump groundwater into the lake periodically throughout the year. The elevation of the lake outlet is 813.3 feet above mean sea level (msl) while the bottom elevation at the deepest point is 801 feet above msl. The deepest point of the lake is 10 feet above the water table at 791 feet above the msl, meaning the lake is perched, causing the lake to lose water quickly in years with normal precipitation (Barr Engineering Company, 1997).

Dewatering for the north bay dredging project lowered water levels in Loring significantly in 2007. Peaks in **Figure 11-3** are likely due to high-intensity rain events in which stormsewer backflow enters Loring Pond through the outlet raising pond water significantly. Water pressure from stormsewer backflow caused the Loring Pond outlet to deteriorate. In 2011, MPRB staff repaired the cement at the base of the outlet and re-installed the outlet board. Water levels were manipulated throughout 2014, with water being allowed to drain down throughout the summer and then raised to the top of the outlet wall as part of a cattail removal project. Water levels were then kept near the top of the outlet from 2015 to 2016 by using the augmentation well in order to prevent cattail regrowth. MPRB has been trying to keep the lake level as high as possible to prevent cattails from sprouting while remaining within the pumping limits issued by the MNDNR.

The Ordinary High Water Level (OHWL), designated by the MNDNR, for Loring Pond is 818.0 feet above msl. Levels in Loring Pond were low during 2022, dropping below OHWL in early June, all of July, and most of September. Loring Pond froze below the OHWL in December. See **Chapter 1** for details on lake level monitoring and **Chapter 17** for a comparison between other MPRB lake levels.

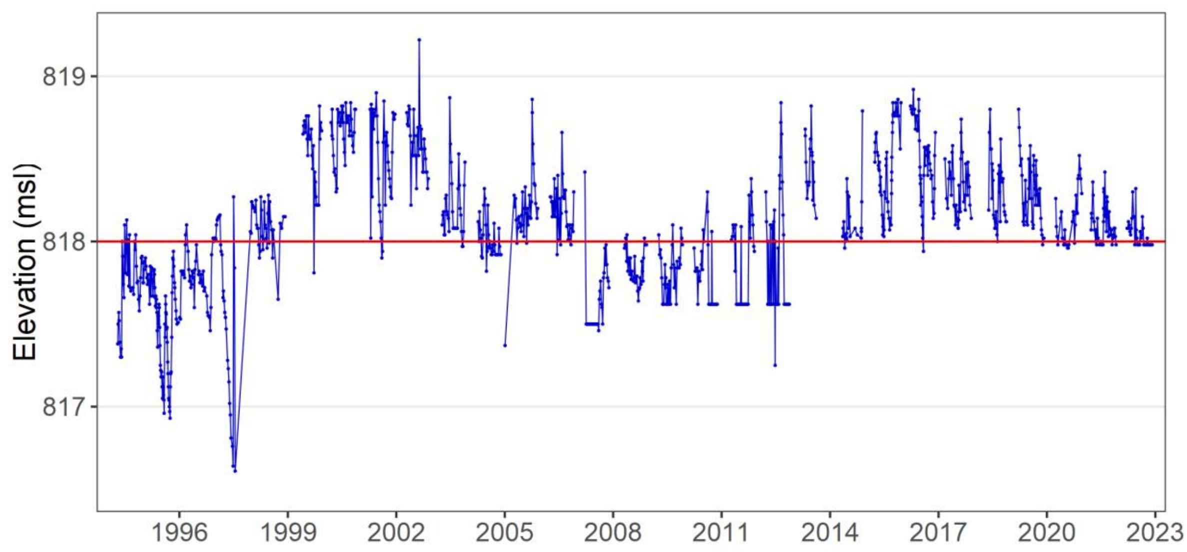


Figure 11-3. Lake levels for Loring Pond from 1994-2022. Water levels frequently dropped below the gage in the 2000s and level readings couldn't be accurately measured during that time. In 2022, when the lake level dropped below the gage the value was recorded as <7.16, which is the lowest reading available on the lake gage. Horizontal line represents the Ordinary High Water Level elevation (818.0 ft. msl) for Loring Pond.

Augmentation Wells

An augmentation well is used to maintain the water levels at Loring Pond. The MNDNR issued permit #1993-6190 and determined the current augmentation wells pumping limit of 12 million gallons. The MPRB records groundwater usage monthly. **Table 11-2** shows annual usage for the past five years. In 2015, a long-term permit was granted to augment 12 million gallons annually to maintain the lake level. In 2015 and 2016, a temporary permit was granted to augment 12 million gallons in addition to the annual 12 million gallon allocation to aid in removing cattails. Groundwater continued to be pumped into Loring Pond throughout 2022 to keep water levels higher for cattail mitigation and waterfowl health.

Table 11-2. Loring Pond annual pumping volume in gallons.

2017 Total	2018 Total	2019 Total	2020 Total	2021 Total	2022 Total
5,310,240 gal	10,267,200 gal	1,959,600 gal	10,670,160 gal	12,044,640 gal	10,599,780 gal

Water Quality Trends – Trophic State Index (TSI)

Figure 11-4 shows historical Loring Pond TSI scores and trend line. There is no significant trend in TSI from 1992-2022 ($p > 0.05$). Multiple disturbances have occurred at Loring Pond that had large influences on the water quality. Dredging projects that disturbed all or a large portion of the lake occurred in 1997-1998 and during the summer of 2007. In 2016, a large amount of groundwater was pumped into the lake, possibly causing cleaner groundwater to displace the more nutrient rich lake water, which could have resulted in a better TSI score that year. The TSI score for Loring Pond in 2022 was 67, classifying the pond as eutrophic.

The 303(d) assessment for eutrophication factors is limited to lakes of ten acres or greater (MPCA, 2014); therefore, at seven acres in size, Loring Pond is too small to be assessed, but it is still useful to compare Loring's data to the shallow lake standards to assess lake water quality. Secchi, chlorophyll-*a*, and total phosphorus TSI scores for Loring Pond are above the TSI range for the ecoregion, meaning water clarity is shallower and chlorophyll-*a* and total phosphorus levels in Loring Pond are higher than in comparable lakes. For more information see Minnesota Pollution Control Agency (MPCA) Surface Water Data (https://webapp.pca.state.mn.us/wqd/surface-water/waterunit-details?wid=27-0655-02). A detailed explanation of TSI can be found in **Chapter 1**.

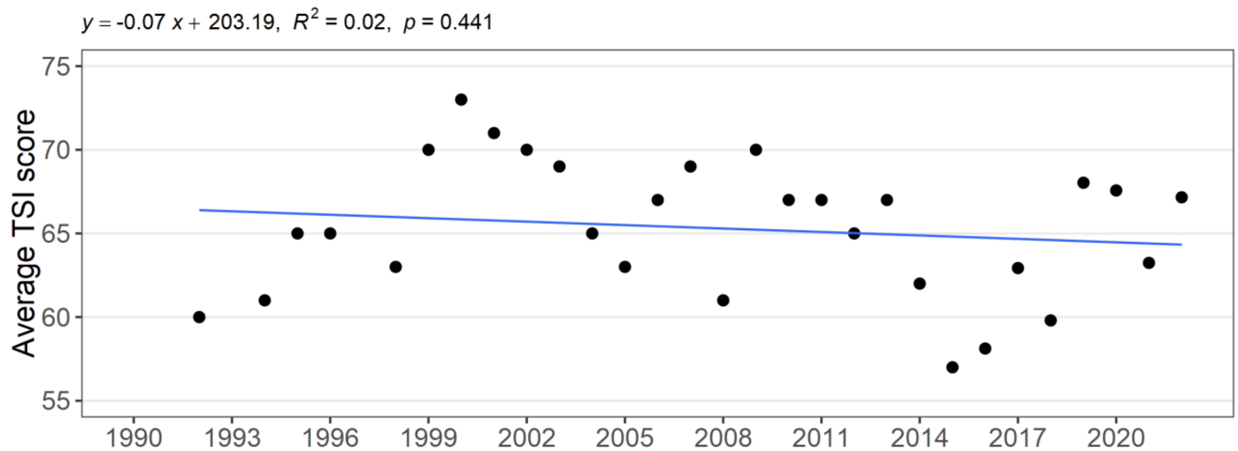


Figure 11-4. Loring Pond TSI data and linear regression from 1992 to 2022.

Box and Whisker Plots

The box and whisker plots in **Figure 11-5** show the data distribution for water clarity, chlorophyll-*a*, and total phosphorus for the past 10 years, based on data from the entire sampling season. Red horizontal lines on the graphs indicate the MPCA eutrophication standards for shallow lakes, which applies to data collected between June and September. A detailed explanation of box and whisker plots can be found in **Chapter 1**. Box and whisker plots from the entire period of record, 1992-2022, can be found in **Appendix A**.

The lake does not meet MPCA's size criteria for assessing eutrophication factors; however, it is still useful to compare Loring's data to the shallow lake standards to assess lake water quality. In 2022 the water clarity was comparable to the past three years but shallower than previous years with an average of 0.79 meters, see **Figure 11-5a**. Chlorophyll-*a* was comparable to the past three years but higher than previous years with an average concentration of 40 µg/L, see **Figure 11-5b**. Total phosphorus concentrations were similar to last year but lower than previous years with an average of 105 µg/L, see **Figure 11-5c**. Loring Pond is a small eutrophic lake and high productivity of plants and algae can be expected.

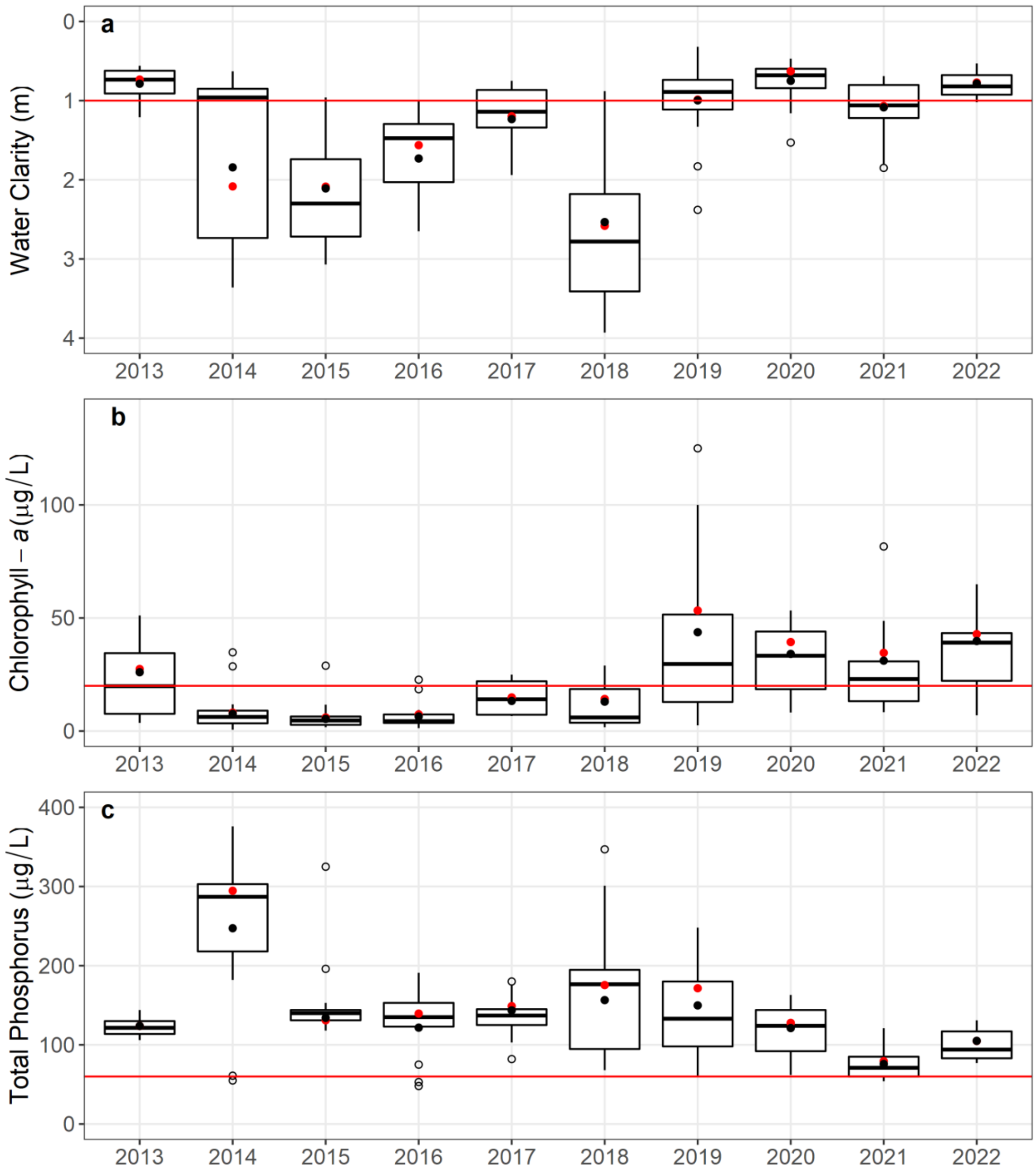


Figure 11-5. Loring Pond box and whisker plots of water clarity (a), chlorophyll-*a* (b), and total phosphorus (c) data from 2013-2022. Horizontal lines represent MPCA eutrophication standards for shallow lakes, which applies to data collected between June and September. The red circles represent the mean value of data collected between June and September. The black circles represent the mean value of data collected during the growing season, May through September. Data from 1992-2022 can be found in Appendix A.

CHLORIDE

Chloride is a naturally occurring element that is commonly found at low levels in most freshwater bodies. Chloride is a component of road salt (sodium chloride) and is found in other types of compounds that are also called salts (calcium chloride, magnesium chloride). Unnaturally high concentrations of chloride can negatively impact surface waters. High levels of chloride can change the mixing pattern of a lake and lead to very low oxygen levels in deep water. It can also lead to decreasing water clarity and induce stress or cause death of aquatic species (Bathe & Coring, 2011). Sources of chloride include industrial discharge, septic systems, sewage disposal systems, fertilizers, and road salt (Novotny, Murphy, & Stefan, 2008). The MPCA adopted the Environmental Protection Agency's (EPA) recommended water quality criteria for chloride which is a chronic standard of 230 mg/L and an acute standard of 860 mg/L (MPCA, 2016). The MPRB has monitored chloride concentrations in Loring Pond since 1995 by collecting surface water samples using a composite tube and collecting deep water samples using a Kemmerer sampler. See **Chapter 1** for more information on chloride.

Figure 11-6 shows epilimnetic and hypolimnetic chloride concentrations in Loring Pond between 1995-2022, with hypolimnion samples only collected regularly after 2007. Epilimnion samples represent the top two meters of the lake and hypolimnion samples were collected approximately one meter from the bottom of the lake. Red horizontal lines on the graph indicate the MPCA acute and chronic chloride standards. Also included on the graph, is a dotted line that represents an estimate of a concentration above which potential ecological impact could occur, at 120 mg/L. This level of potential ecological impact was developed by Canadian Council of Ministries of the Environment (CCME) and is not a Minnesota state standard but a long-term chloride concentration that could negatively impact life within the lake (CCME, 2011). Most hypolimnetic samples were roughly comparable to epilimnetic samples; however, there were a few hypolimnetic samples that were significantly higher and exceeded the acute standard. Chloride concentrations in Loring Pond are highly variable with concentrations ranging from 16 mg/L to 1,273 mg/L. Loring Pond chloride concentrations roughly compare to precipitation patterns, particularly between 2012 and 2013, when there was a significant increase in both chloride and precipitation. Although there are no stormwater outfalls entering Loring Pond, during intense rainstorms, water from the Lowry Hill tunnel can back up into Loring Pond through its outlet, which may be introducing road salts into the pond. Loring Pond was added to the MPCA's list of impaired waters (303(d) list) in 2014 due to high chloride concentrations.

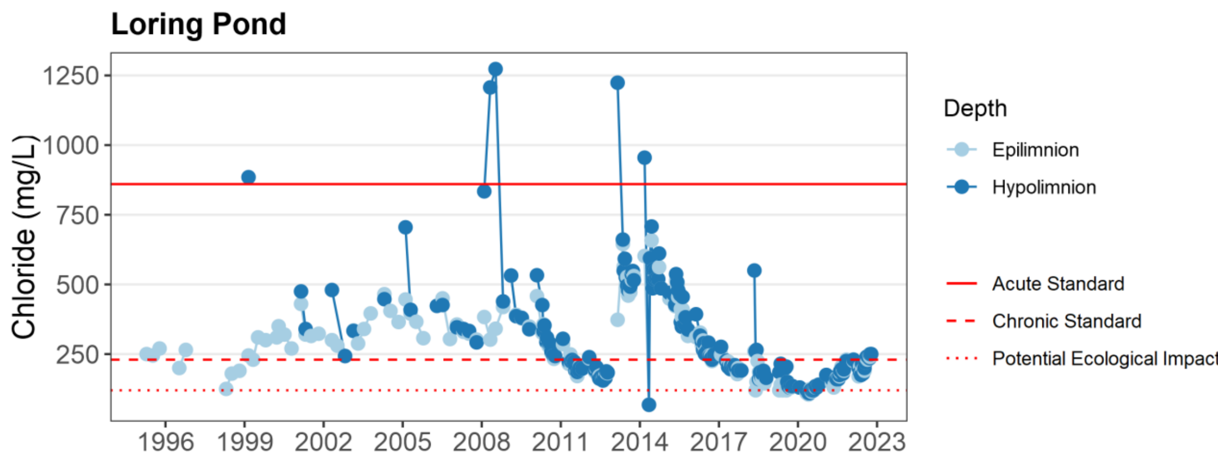


Figure 11-6. Loring Pond scatterplot of epilimnetic and hypolimnetic chloride concentrations between 1995-2022. Horizonal lines represent the MPCA's acute and chronic standard and the potential ecological impact level (CCME, 2011).

Blue-green Algae Monitoring

Blue-green algae are not algae at all, but a type of bacteria called cyanobacteria. These photosynthetic microorganisms occur naturally in lakes, streams, and other waterbodies worldwide. When conditions are right, cyanobacteria can grow quickly to form dense accumulations called blooms. Certain varieties of cyanobacteria can produce toxins, referred to as cyanotoxins, that can cause illness in humans and animals (US EPA, 2017). Due to an increase in frequency and intensity of cyanobacteria blooms in Minneapolis lakes, the MPRB developed a cyanobacteria monitoring program for public health in 2020. MPRB staff collect information on observations using a defined Visual Monitoring Index (VMI), and sample water weekly at beaches for the most common cyanotoxins. Advisories are posted at beaches and on the MPRB Lake Water Quality Map (bit.ly/mplsbeaches) if toxin levels exceed MPCA guidelines. See **Chapter 19** for more information on blue-green algae and cyanotoxin monitoring.

In 2022, VMI observations were made during bimonthly lake sampling sessions on Loring Pond. VMI observations indicated that cyanobacteria were not present the entire sampling season, and recreation was not inhibited by cyanobacteria.

Lake Aesthetic and User Recreation Index (LAURI)

The LAURI for Loring Pond is shown in **Figure 11-7**. In 2022, Loring Pond scored excellent in aesthetics and good in water clarity. The lake scored poor in habitat quality due to the low number of macrophyte and fish species. The macrophyte data is over ten years old and more aquatic plants have been observed in Loring Pond in recent years, so the habitat quality score may improve when a new survey is completed. Loring Pond also scored poor in recreational access. Loring Pond does not have a swimming beach and was therefore not scored for public health. Details on the LAURI can be found in **Chapter 1**.

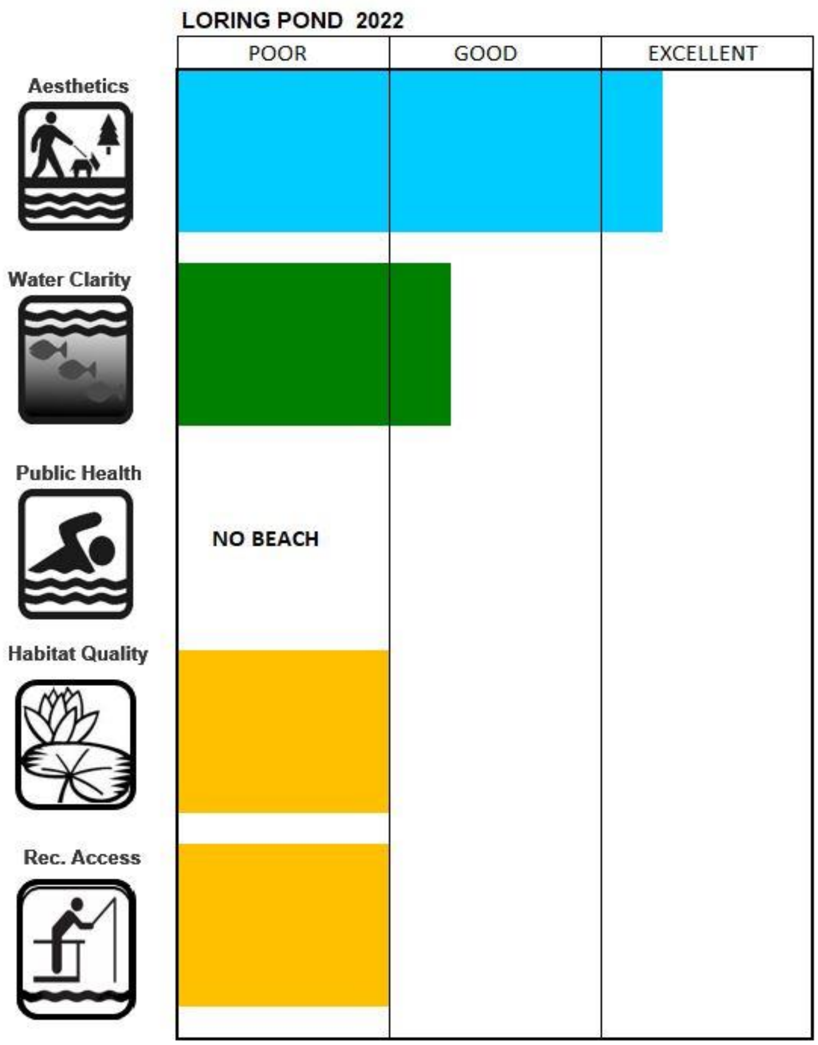


Figure 11-7. The 2022 LAURI for Loring Pond.

Winter Ice Cover

Ice came off Loring Pond on April 5, 2022, three days later than the average ice-off. Ice came onto the pond on November 21, 2022, ten days earlier than the average ice-on date for Loring Pond. See **Chapter 1** for details on winter ice cover records and **Chapter 17** for a comparison with other lakes.

Phytoplankton and Zooplankton

Phytoplankton are microscopic plants that are an integral part of the lake community because they form the base of the aquatic food web. **Figure 11-8** shows the water clarity, chlorophyll-*a* concentrations, and relative abundance of phytoplankton divisions during 2022. Comparing these three parameters together can show how changes in the types of algae present in a lake effect water clarity and color, see the phytoplankton and zooplankton monitoring section in **Chapter 1** for additional details.

Water clarity was initially deeper earlier in the sampling season and became shallower throughout the sampling season with the shallowest reading in late August at 0.5 meters. Water clarity was deeper again later in the sampling season with the deepest clarity in late September at 1 meter, see **Figure 11-8a**. Chlorophyll-*a* concentrations were lowest in winter at 7 µg/L. Concentrations of chlorophyll-a were highest in early August at 64.9 µg/L when the phytoplankton community was dominated by green algae (Chlorophyta) **Figure 11-8b**.

The phytoplankton community in Loring Pond consisted of a mix of diatoms (Bacillariophyta), Chlorophyta, cryptomonads (Cryptophyta), euglenoids (Euglenophyta), and dinoflagellates (Pyrrophyta). Golden-brown algae (Chrysophyta), blue-green algae (Cyanophyta), haptophytes (Haptophyta) and yellow-green algae (Xanthophyta) were also present in low percentages in 2022, see **Figure 11-8c**.

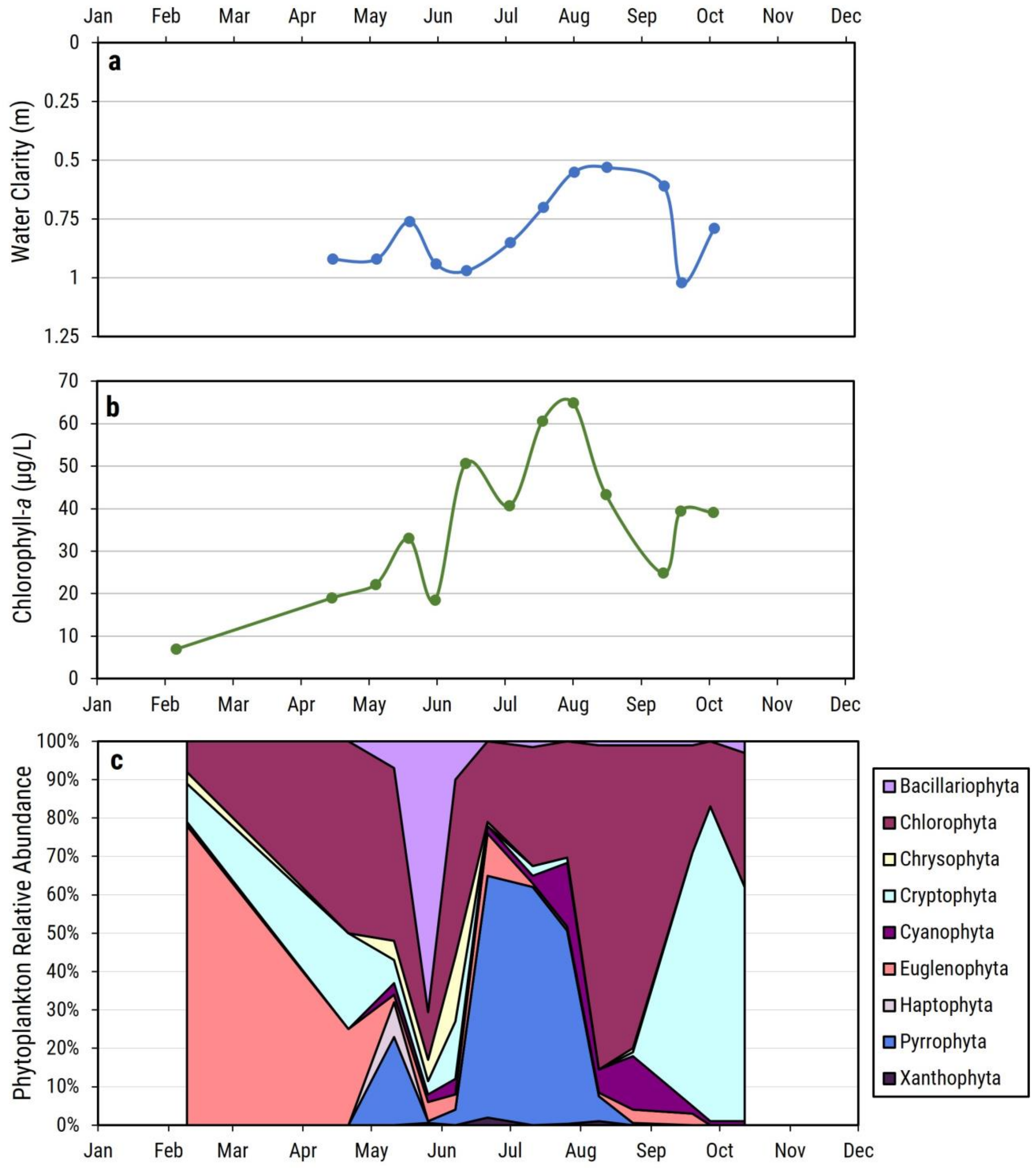


Figure 11-8. Water clarity (a), chlorophyll-*a* concentration (b), and relative abundance of phytoplankton (c) in Loring Pond during 2022. Note that the water clarity axis is reversed.

Zooplankton are tiny animals that feed on phytoplankton and are also vital for the lake community because they form the second level of the food web along with larval fish. **Figure 11-9** shows the zooplankton abundance in Loring Pond sampled throughout 2022. Cladocerans were present between June and September and were extremely abundant in September. Rotifers were also present in most samples and were most abundant in May. Nauplii and juvenile copepods, calanoids, and cyclopoids were present in low levels in 2022.

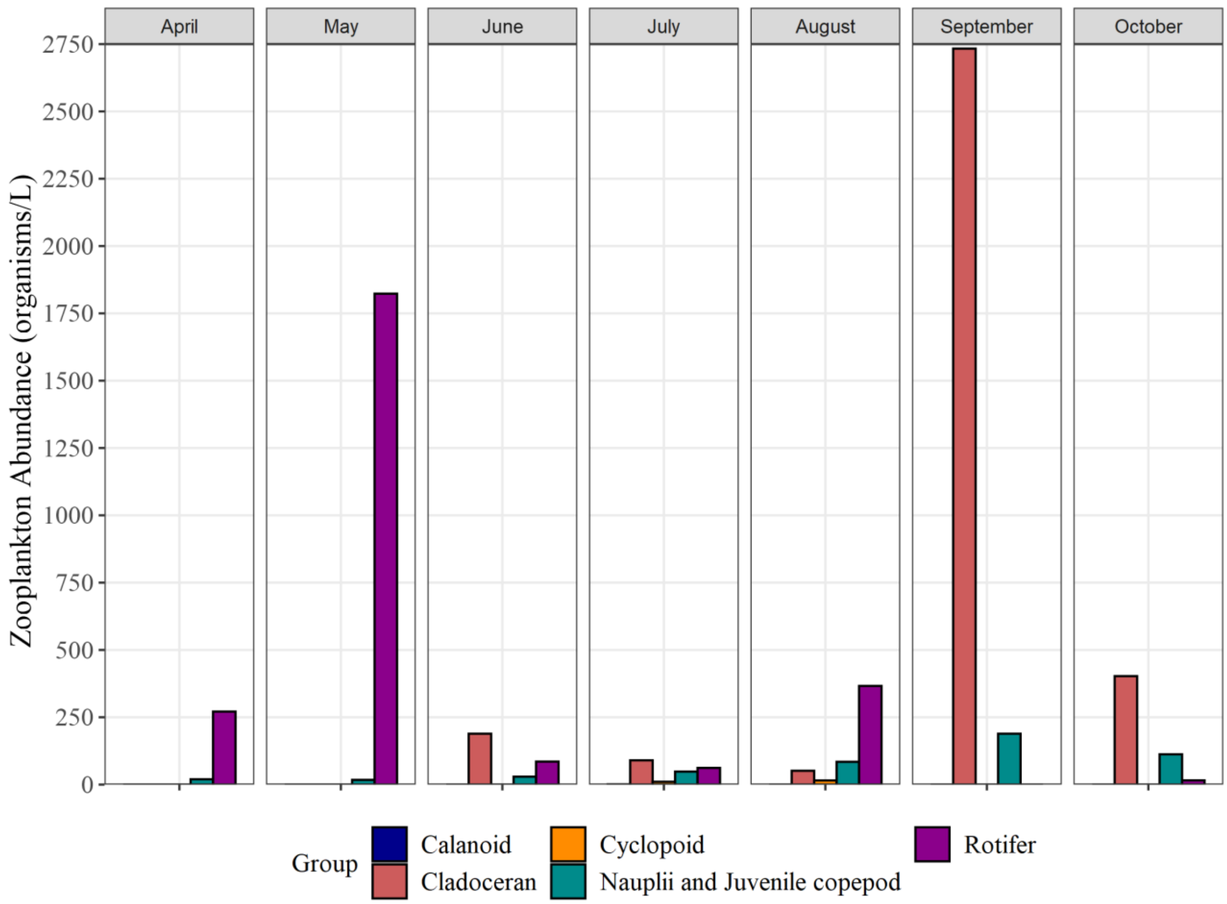


Figure 11-9. Zooplankton abundance in Loring Pond during 2022.

FISH STOCKING

Loring Pond is stocked with fish by the MNDNR as part of the Fishing in the Neighborhood (FiN) program. Black crappie and bluegill sunfish were stocked in Loring Pond in 2022, see **Table 11-3**. Additional information and a definition of fry, fingerling, yearling, and adult fish sizes can be found in **Chapter 1**.

Table 11-3. Fish stocked into Loring Pond over the past 10 years. Data are from the Minnesota Department of Natural Resources.

Year	Species	Number and Size	Amount
2022	Bluegill	120 adults	12.0 pounds
2022	Black Crappie	180 adults	18.0 pounds
2021	Black Crappie	100 adults	16.0 pounds
2021	Bluegill Sunfish	200 adults	16.0 pounds
2021	Channel Catfish	1,190 fingerlings	15.9 pounds
2021	Northern Pike	2 adults	18.0 pounds
2019	Bluegill	300 adults	50.0 pounds
2018	Channel Catfish	400 fingerlings	10.7 pounds
2017	Channel Catfish	100 adults	200.0 pounds
2016	Channel Catfish	108 adults	194.6 pounds
2014	Black Crappie	92 adults	51.1 pounds
2014	Bluegill	35 adults	10.3 pounds
2014	Channel Catfish	70 adults	107.7 pounds

WATER QUALITY PROJECTS

For the second year in a row, in 2022, the MPRB worked with Minneapolis Community and Technical College (MCTC) to learn more about the phosphorus content of duckweed in Loring Pond and the potential for safe duckweed reuse in horticulture or community gardens. MCTC students observed duckweed cover, collected duckweed, and processed it for analysis at an external lab. In 2022, a viable methodology was determined. Student involvement and sampling was increased in 2022 to observe duckweed densities and any variation in the uptake of nutrients and heavy metals throughout the growing season. Future work will compare data collected at Loring Pond with literature values for health effects and suitability for use of duckweed in community garden composting.

12. Lake Nokomis

History

In 1907, the Minneapolis Park and Recreation Board (MRPB) purchased an area of open water, wetland and a peat bog known as Lake Amelia, later renamed Lake Nokomis. At that time, wetlands were viewed as unsanitary, so Theodore Wirth developed a plan to make the area more desirable for development and to protect public health. The lake was dredged between 1914 and 1917, moving nearly 2.5 million cubic yards of material to increase the park by 100 acres, and create beaches, solid shoreline, and parkways around the lake. The final average depth of the lake was deeper than originally designed because sand was found on the bottom of the lake and was used for Main Beach. The newly created parkland settled, as Wirth predicted, and was corrected by a 1934 Works Progress Administration project (Smith, 2008). A photograph of Lake Nokomis is presented below in **Figure 12-1.**

Figure 12-1. View of Lake Nokomis in June of 2022.

Lake Nokomis is a shallow polymictic lake, which mixes many times during the growing season. Mixing potential is increased when higher than normal wind speeds occur along the north-south fetch of the lake. Strong winds blowing along the long axis of the lake have the effect of destabilizing the water column and mixing hypolimnetic phosphorus into the surface water where it can be utilized by algae near the surface. **Table 12-1** contains physical characteristics and morphometric data on Lake Nokomis and **Figure 12-2** is a bathymetric map of the lake. Lake Nokomis is part of the Minnehaha Creek Watershed and the primary land-uses around the lake are residential and parkland. There are a total of 16 stormwater outfalls surrounding Lake Nokomis, see **Appendix C**.

Table 12-1. Nokomis Lake physical characteristics and morphometric data.

Surface Area (acres)	Mean Depth (ft)	Max Depth (ft)	Littoral Area*	Volume (ft^3)	Watershed Area (acres)	Watershed: Lake Area (ratio)	Residence Time (years)
201	14.1	33.0	50%	$1.25x10^8$	869	4.3	4.0

* Littoral area was defined as less than 15 feet deep.

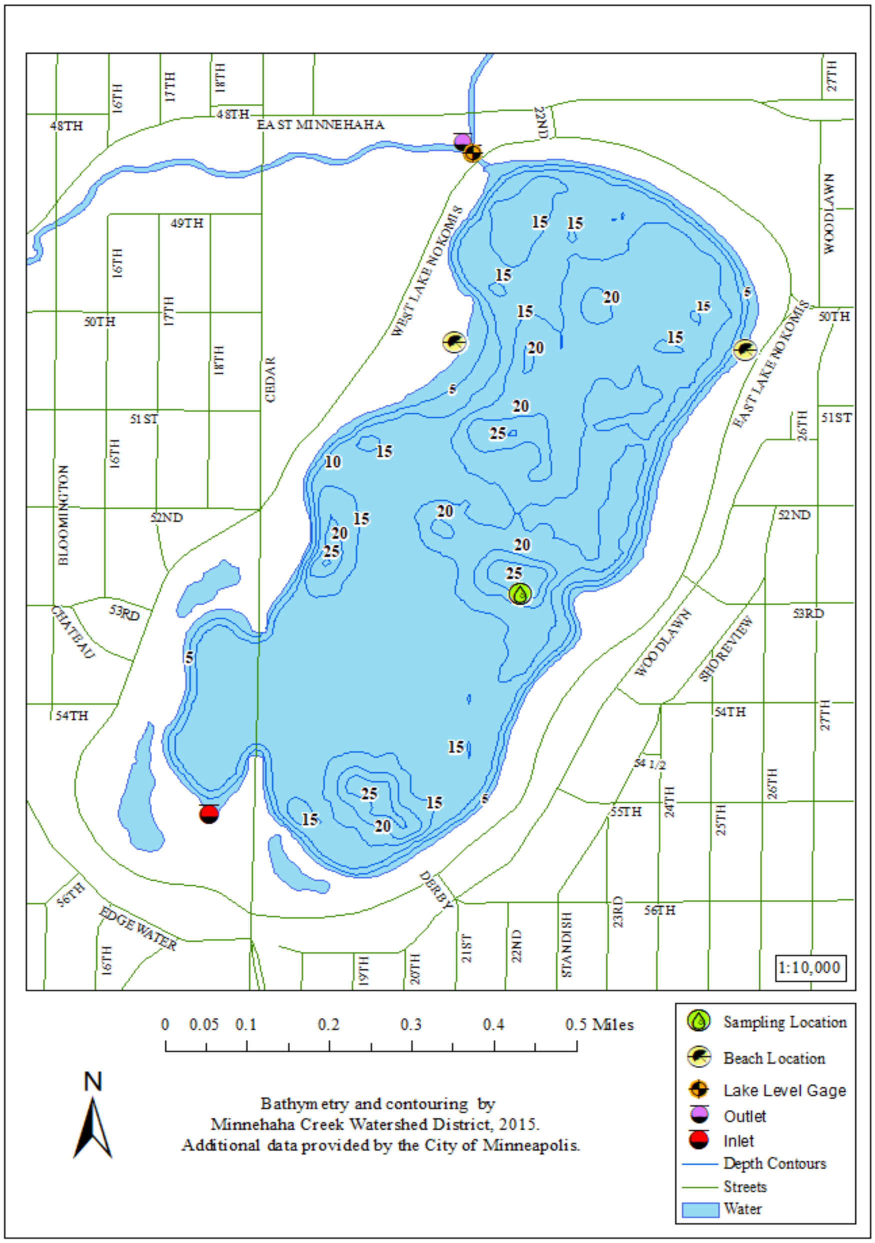


Figure 12-2. Bathymetric map of Lake Nokomis with mid-lake sampling site, beach, lake level gage, outlet, and inlet locations. Based on data collected by the Minnehaha Creek Watershed District.

Lake Nokomis receives water from Legion and Solomon Lakes at the southwest end of the lake and discharges to Minnehaha Creek through a weir on the northwest corner of the lake. The current stoplog weir structure at the outlet to Nokomis was installed in 2012 by Minnehaha Creek Watershed District (MCWD). The structure shown in **Figure 12-3c** has a fixed weir deck beneath removeable stop logs. This structure allows the lake to flow out during periods of high water yet prevents the creek from flowing into the lake when the structure is closed. The weir runout on the stone weir deck is at an elevation of 815.1 feet above mean sea level (msl) and the top of the weir is at 818 ft msl.

The original structure at the Lake Nokomis outlet was installed by MPRB in 1931; the weir deck can be seen in **Figure 12-3 a-1.** A wooden weir was also constructed in 1937 in the bed of Minnehaha Creek downstream of the Nokomis outlet weir deck, see Figure **12-3 a-2**. The purpose of the downstream weir was to give the MPRB the ability to divert creek flow into Lake Nokomis. It is thought that in the past, water was diverted to Lake Nokomis from the creek for the following reasons: to fill the lake after dredging, to maintain water levels during drought conditions, and to save excess water in the lake that could be released back to the creek to create flow over the falls if the creek went dry. Remnants of the old downstream weir, that is no longer in use, are still visible today in the bed of Minnehaha Creek.

Later, in 2002, an inflatable weir was installed on top of the old stone weir deck. The inflatable weir was operated to block high flows from Minnehaha Creek from entering the lake in order to reduce nutrient inputs to Lake Nokomis. The inflatable structure had been recommended by the Blue Water Partnership and was made operational in 2003, see **Figure 12-3 b-2**. **Figure 12-3 b-1** shows the original weir deck. The old weir deck is also present in the photo of the current stop log weir, **Figure 12-3c**, but is not visible because the weir is closed and the creek is high. The 1931 stone weir deck remains the control structure for the lake, and its elevation has remained the same since 1931 throughout all the projects.

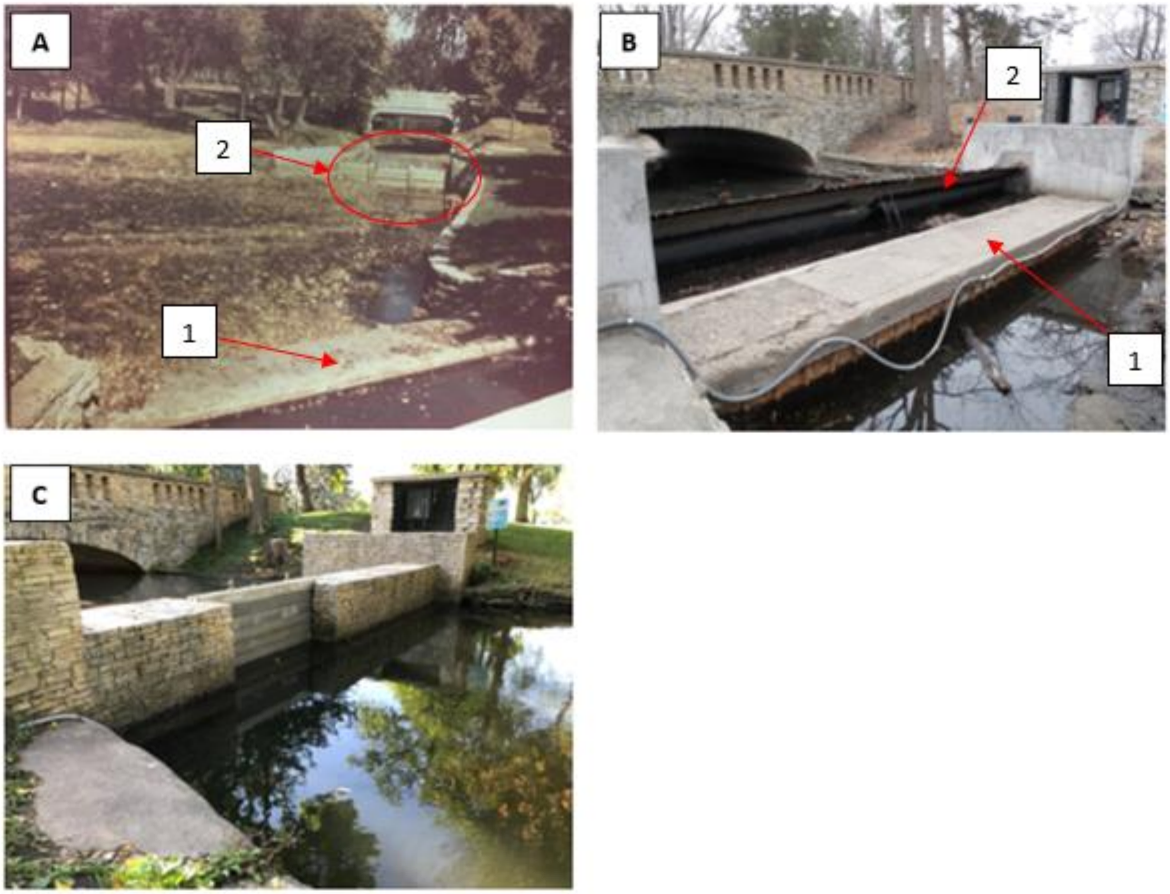


Figure 12-3. Historic weir structures at Lake Nokomis outlet including the original weir deck outlet structure (a-1), a wooden weir in Minnehaha Creek (a-2), original weir deck (b-1), inflatable weir (b-2) and stop log weir (c) that currently controls the outlet to the lake. Photo B was taken in 2012 and Photo C was taken in 2018. It is unknown when Photo A was taken.

Lake Nokomis has been impacted over the years from changes to the landscape and watershed surrounding the lake. In 1945, the Minneapolis Health Department closed the Mother Lake inlet due to pollutants from an upstream garbage dump polluting Lake Nokomis. Closing the inlet caused the water level to drop a foot. The inlet was reopened about one year later after the dump was shut down. Low water levels in the 1950s increased plant growth significantly and Lake Nokomis was treated with sodium arsenite. In the 1960s low areas surrounding the lake were refilled, Nokomis Main Beach was rebuilt with more sand, and much of the shoreline wall that had been constructed in the 1930s was removed. A water quality study in 1973 concluded that the elimination of wetlands and marshes had a negative impact on water quality because there was no system to filter stormwater runoff (Smith, 2008).

Numerous restoration projects have been implemented to improve water quality in Lake Nokomis. With increased development around the lake over the years, the impact of stormwater on water quality became a greater concern. The Blue Water Commission, a citizen advisory committee consisting of representatives from three Nokomis and Hiawatha neighborhood associations, was established in 1997 to examine water quality issues. As a part of this effort, the Lakes Nokomis and Hiawatha Diagnostic-Feasibility Study was completed in 1998 by the Minnehaha Creek Watershed District (MCWD). The 1998 Blue Water Commission: Report and Recommendations for the Management of Lake Nokomis and Hiawatha (BWC, 1998) included the committees recommended actions based on the study and prioritized citizen identified issues. Increased street sweeping, grit chambers, and stormwater wetlands were implemented in 2001. The 2001 conversion of eight acres of a low lying cattail marsh (previously known as the Nokomis Southwest Lagoon) on the southwest corner of the lake into the Gateway, Amelia, and Knoll stormwater wetland ponds we see today are a result of the collaborative work of the Blue Water Commission, MCWD, and the MPRB.

In 2002, an inflatable weir was installed on top of the old stone weir deck to block high flows from Minnehaha Creek from entering the lake in order to reduce nutrient inputs to Lake Nokomis. In 2011, a Total Maximum Daily Load (TMDL) study was done because Lake Nokomis was added to the Minnesota Pollution Control Agency's (MPCA) list of impaired waters (303(d) list) in 2002 due to excess nutrients, and Minneapolis and Richfield were assigned phosphorus load reductions (MPCA and MCWD, 2011). The current stoplog weir structure at the outlet to Nokomis was installed in 2012 allowing the lake to flow out during periods of high water and preventing the creek from flowing into the lake when the structure is closed. In 2013, a flocculation treatment system was installed on the north side of Taft Lake to eliminate excess phosphorus from Richfield drainage and remove dissolved pollutant loads from stormsewer runoff before discharging downstream to Lake Nokomis (https://www.minnehahacreek.org/project/taft-legion-volume-and-load-reduction-project).

The fish community in Lake Nokomis may be negatively impacting water quality in the lake by disturbing sediment which releases nutrients to the water causing low water clarity and increased algae blooms., and several studies and projects over the years have been attempted to understand and reduce negative effects this issue. Initially, an attempt was made to seine and remove carp from the lake during the winter of 2001-02 to limit internal phosphorus loading caused by the fish foraging in the sediment. A MCWD-led biomanipulation project later aimed to reduce sediment disturbance by burrowing fish in Lake Nokomis and was completed in 2013. Based on follow-up fish surveys, it was concluded that there was a reduction in burrowing species within the fish community achieved from the project. Although the project achieved its goal, there was less of an effect on phosphorus concentrations in the lake than was predicted. Lack of clear success in the biomanipulation project led to the idea that that the carp population should be re-evaluated, which led to the 2016-2019 Carp Integrated Pest Management (IPM) Project. There were three key findings from this newest project: Lake Nokomis supports elevated carp biomass which leads to internal phosphorus loading, carp movement was documented between Taft Lake, Solomon Wetland, and Lake Nokomis, and that high water, debris, and the morphology of Lake Nokomis make standard carp removal methods a challenge. Management practices suggested as a result of the study include: installation of carp barriers to prevent carp movement, removal of adult carp biomass within Lake Nokomis to be below the 100 kg/ha ecological tipping point, and potential future studies to determine role of the Nokomis outlet weir with regard to carp movement (Havranek, Newman, & Wein, 2019). Carp management remains an ongoing project at Lake Nokomis and will be a long term endeavor.

Lake Nokomis was added to the MPCA's list of impaired waters (303(d) list) in 1998 due to high concentrations of polychlorinated biphenyls (PCBs) in fish tissue, see **Chapter 1** for more information on emerging contaminants.

Water quality on Lake Nokomis has been monitored annually since 1992.

LAKE LEVEL

Weekly lake level measurements recorded at Lake Nokomis from 1999 through 2022 are shown in **Figure 12-4**. The Ordinary High Water Level (OHWL), designated by the Minnesota Department of Natural Resources (MNDNR), for Lake Nokomis is 815.4 feet above mean sea level (msl). Nokomis lake levels were very low between 2003 to 2011 due to a combination of factors including: several consecutive drought years, less discharge from the Mother Lake watershed, and the separation of Lake Nokomis from Minnehaha Creek. High precipitation in 2014 resulted in flooding, and Lake Nokomis reached the highest water levels ever recorded in June of that year at 818.03 ft msl. Between 2014 and 2020 water levels in Lake Nokomis were high but started declining again in 2021 along with a decrease in annual precipitation. Lake levels in 2022 were above the OHWL during most of May, then dropped below the OHWL and continued to decline the rest of the season. The lake froze 1.98 ft msl below the OHWL in November of 2022.

In 2021, MCWD installed a real-time gage near the outlet of Lake Nokomis that measures the lake level every five minutes.

Persistent high groundwater levels in the Lake Nokomis area after the 2014 flood led to the formation of a multiagency technical team that attempted to understand:

- Are surface and groundwater levels near Lake Nokomis increasing?
- To what extend do groundwater levels interact with surface water levels in this area?
- What are the potential impacts to public and private infrastructure?
- If groundwater and/or surface water levels are rising, why and what can be done?

Members of the technical team include: The MPRB, MNDNR, MCWD, City of Minneapolis, and the Metropolitan Council Environmental Services (MCES). See **Water Quality Projects** section for more information on Lake Nokomis groundwater and surface water evaluation.

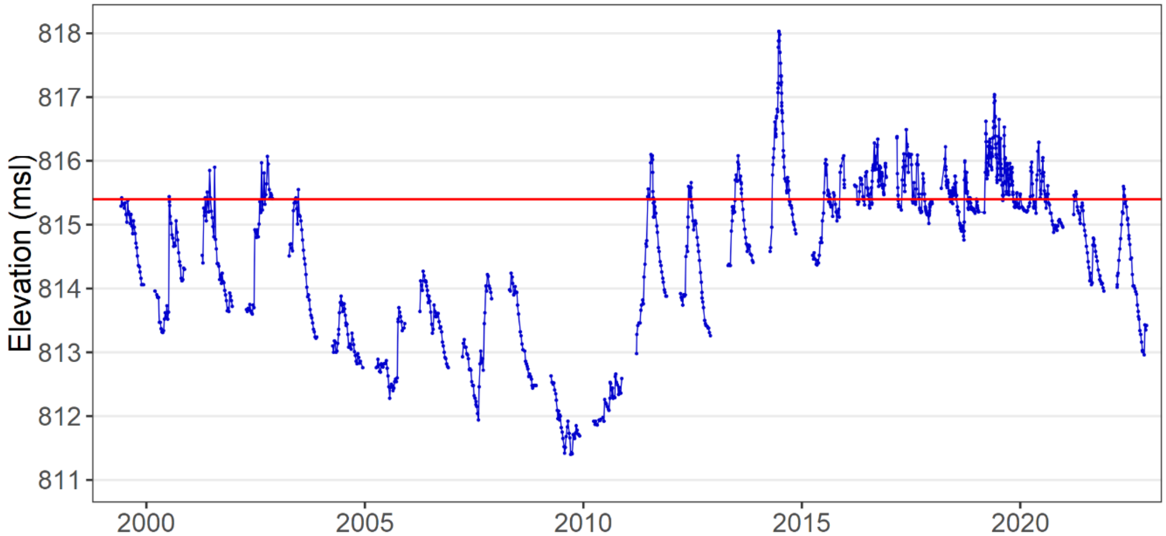


Figure 12-4. Lake levels for Lake Nokomis from 1999-2022. Horizontal line represents the Ordinary High Water elevation (815.4 ft msl) for Lake Nokomis.

Water Quality Trends – Trophic State Index (TSI)

Figure 12-5 shows historical Lake Nokomis TSI scores and trend line. There is no significant trend in TSI scores from 1992 to 2022 ($p > 0.05$); however, there has been an increasing trend since 2014 indicating worsening water quality. The TSI score for Lake Nokomis in 2022 was 64, classifying the lake as eutrophic. Blue-green algae often dominate the phytoplankton community in eutrophic lakes, and algal scums can occur.

Secchi, chlorophyll-*a,* and total phosphorus TSI scores for Lake Nokomis are above the TSI range for the ecoregion, meaning the water clarity is shallower and chlorophyll-*a* and total phosphorus levels in Lake Nokomis are higher than in comparable lakes, see **Table 12-2**. See MPCA Surface Water Data (https://webapp.pca.state.mn.us/wqd/surface-water/waterunit-details?wid=27-0019-00) for more information. A detailed explanation of TSI can be found in **Chapter 1**.

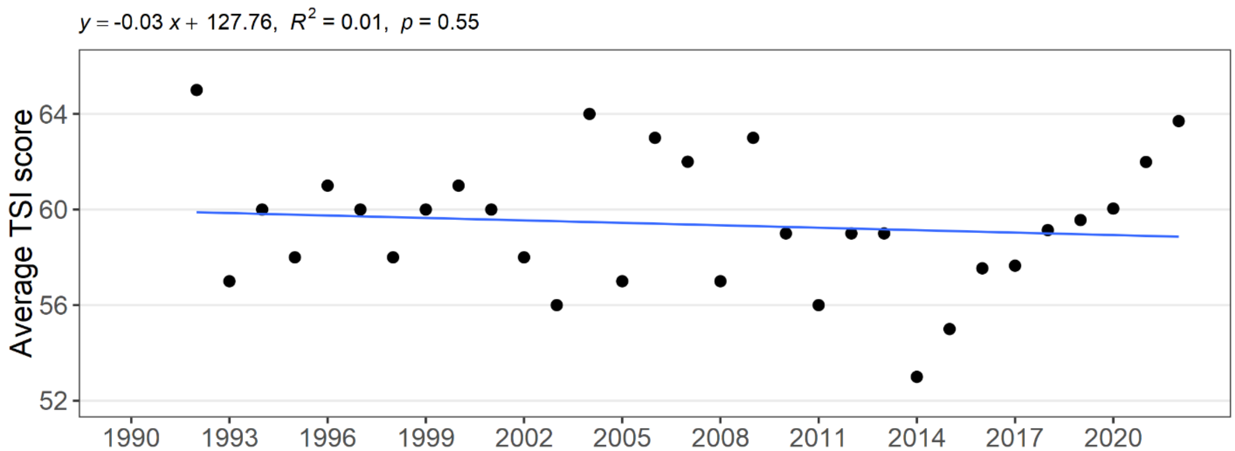


Figure 12-5. Lake Nokomis TSI scores and linear regression from 1992-2022.

Table 12-2. Lake Nokomis Secchi, chlorophyll-*a*, and total phosphorus TSI based on data collected between June and September of 2022 and compared to lakes in the North Central Hardwood Forest ecoregion.

	TSI	Expected TSI Range of Lakes in the Same Ecoregion	Within the Expected TSI Range of Lakes in the Same Ecoregion
Secchi	63	43-54	Not within range, worse than expected
Chlorophyll-*a*	70	46-61	Not within range, worse than expected
Total Phosphorus	67	49-61	Not within range, worse than expected

Box and Whisker Plots

The box and whisker plots in **Figure 12-6** show the data distribution for water clarity, chlorophyll-*a*, and total phosphorus for the past 10 years, based on data from the entire sampling season. Red horizontal lines on the graphs indicate the site-specific standards, which applies to data collected between June and September. The MPCA site specific eutrophication standard for water clarity is greater than 1.4 meters and less than 20 µg/L for chlorophyll-*a*. The US EPA approved a site-specific 50 µg/L total phosphorus standard for Lake Nokomis in 2013 (US EPA, 2013) because data showed that goals should be met at this phosphorus level. A detailed explanation of box and whisker plots can be found in **Chapter 1**. Box and whisker plots from the entire period of record, 1992-2022, can be found in **Appendix A**.

Water clarity ranged from 0.3 to 4.4 meters in 2022 with average of 1.2 meters, see **Figure 12-6a**. Chlorophyll-*a* levels were higher and more variable between 2018 and 2022 compared to previous years. Over the past 10 years, the highest chlorophyll-*a* concentrations were observed in 2022 with an average of 45.5 µg/L, see **Figure 12-6b**. Total phosphorus concentrations have become more variable in the past seven years. The highest and most variable total phosphorus levels were observed in 2022 with an average of 73 µg/L, see **Figure 12-6c**. Lake Nokomis did not meet the site-specific standards for water clarity, chlorophyll-*a*, or total phosphorus in 2022.

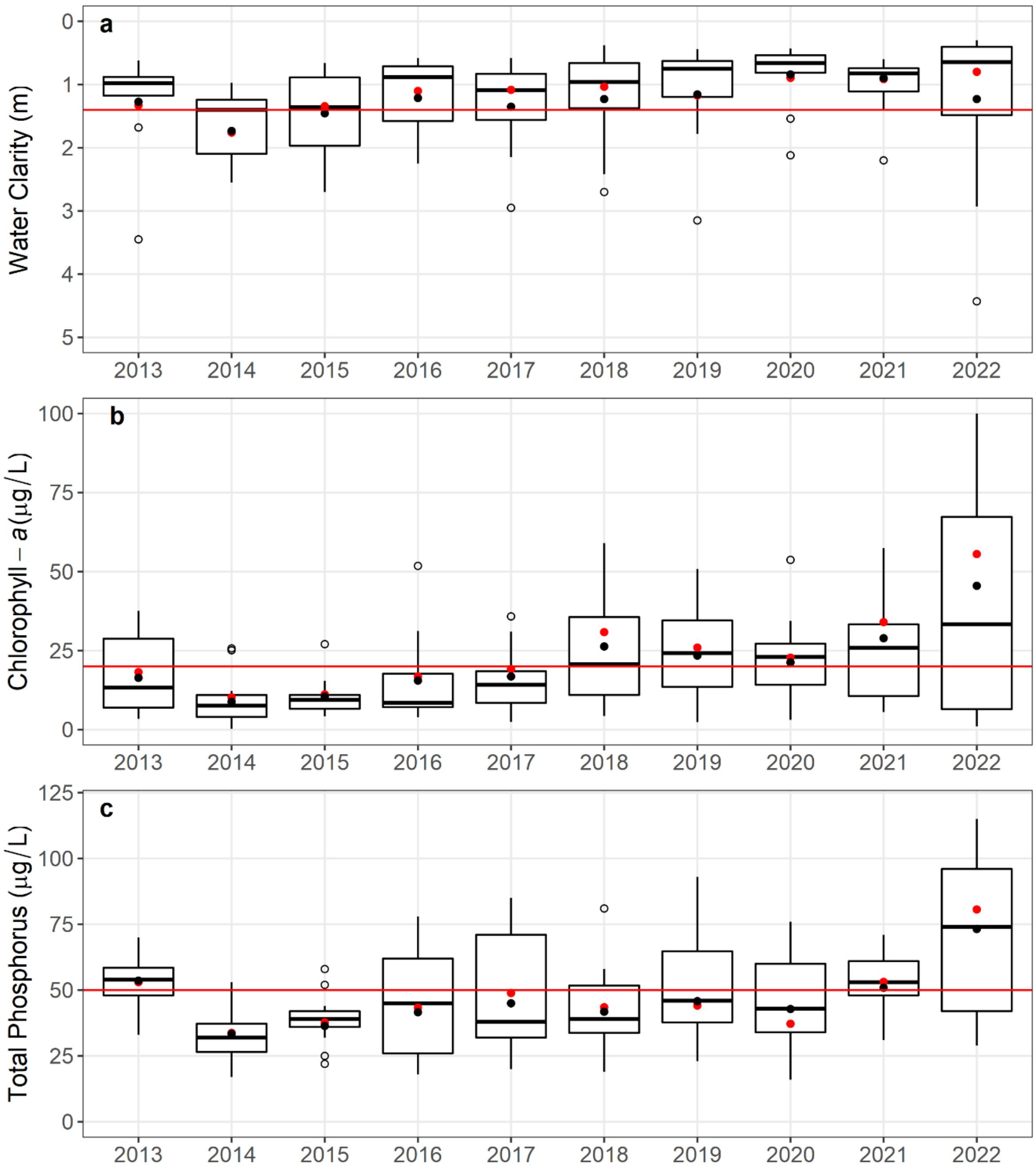


Figure 12-6. Lake Nokomis box and whisker plots of water clarity (a), chlorophyll-*a* (b), and total phosphorus (c) data from 2013-2022. Horizontal lines represent Lake Nokomis site-specific eutrophication standards, which applies to data collected between June and September. The red circles represent the mean value of data collected between June and September. The black circles represent the mean value of data collected during the growing season, May through September. Data from 1992-2022 can be found in Appendix A.

CHLORIDE

Chloride is a naturally occurring element that is commonly found at low levels in most freshwater bodies. Chloride is a component of road salt (sodium chloride) and is found in other types of compounds that are also called salts (calcium chloride, magnesium chloride). Unnaturally high concentrations of chloride can negatively impact surface waters. High levels of chloride can change the mixing pattern of a lake and lead to very low oxygen levels in deep water. It can also lead to decreasing water clarity and induce stress or cause death of aquatic species (Bathe & Coring, 2011). Sources of chloride include industrial discharge, septic systems, sewage disposal systems, fertilizers, and road salt (Novotny, Murphy, & Stefan, 2008). The MPCA adopted the Environmental Protection Agency's (EPA) recommended water quality criteria for chloride which is a chronic standard of 230 mg/L and an acute standard of 860 mg/L (MPCA, 2016). The MPRB has monitored chloride concentrations in Lake Nokomis since 1994 by collecting surface water samples using a composite tube and collecting deep water samples using a Kemmerer sampler. See **Chapter 1** for more information on chloride.

Figure 12-7 shows epilimnetic and hypolimnetic chloride concentrations in Lake Nokomis between 1994-2022, with hypolimnion samples only collected regularly after 2006. Epilimnion samples represent water in the top two meters of the lake and hypolimnion samples were collected approximately one meter from the bottom of the lake. Red horizontal lines on the graph indicate the MPCA acute and chronic chloride standards. Also included on the graph, is a dotted line that represents an estimate of a concentration above which potential ecological impact could occur, at 120 mg/L. This level of potential ecological impact was developed by Canadian Council of Ministries of the Environment (CCME) and is not a Minnesota state standard but a long-term chloride concentration that could negatively impact life within the lake (CCME, 2011). Most chloride concentrations in the epilimnion and hypolimnion are roughly comparable because Lake Nokomis is a shallow polymictic lake, which mixes many times during the growing season. Chloride concentrations in Lake Nokomis are relatively low with most concentrations below the level of ecological impact; however, concentrations have slowly increased over time and in 2022 most samples were above this threshold.

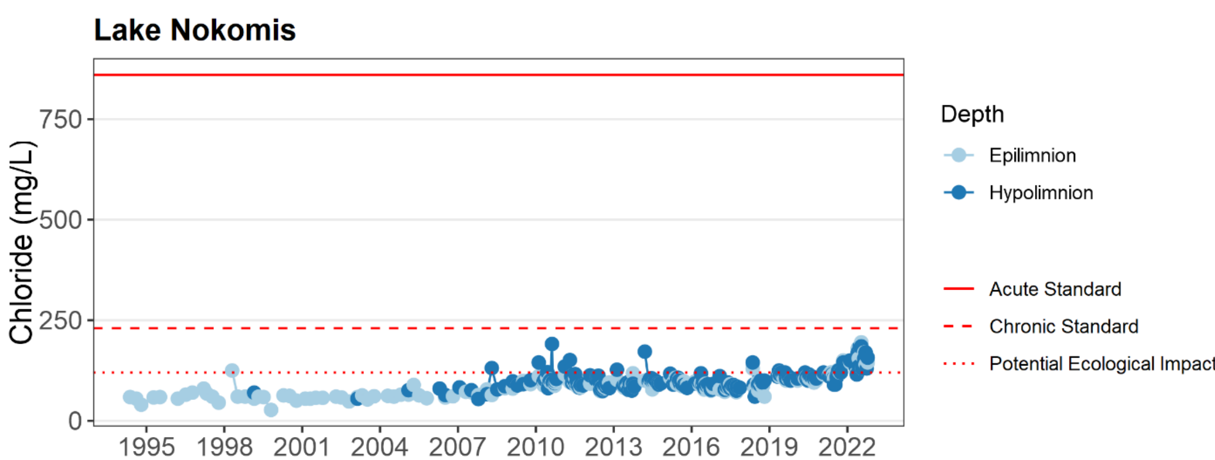


Figure 12-7. Lake Nokomis scatterplot of epilimnetic and hypolimnetic chloride concentrations between 1994-2022. Horizonal lines represent the MPCA's acute and chronic standard and the potential ecological impact level (CCME, 2011).

Beach Monitoring

Bacteria levels were monitored at Nokomis Main Beach and Nokomis 50th Street Beach between late May and August of 2022. As shown in **Table 12-3** and **Figure 12-8**, *Escherichia coli* (*E. coli*) levels were low for both beaches in 2022. There were no closures at either beach on Lake Nokomis during the 2022 beach season due to the exceedance of *E. coli* standards. See **Chapter 18** for more information on beach monitoring.

Table 12-3. Summary of *E. coli* (MPN per 100 mL) data for Lake Nokomis beaches in 2022.

Statistical Calculations	Nokomis 50th	Nokomis Main
Number of Samples	15	15
Minimum	3	1
Maximum	52	83
Median	7	9
Mean	15	15
Geometric Mean	10	8
Max 30-Day Geo Mean	19	15
Standard Deviation	14	20

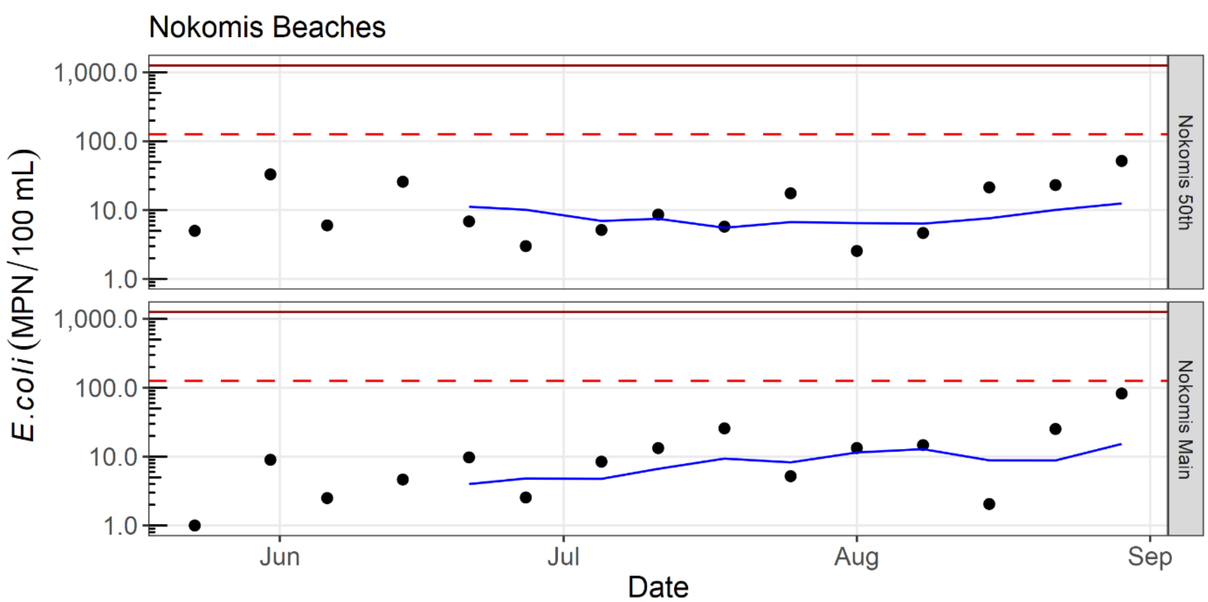


Figure 12-8. 2022 *E. coli* concentrations at the Lake Nokomis beaches. Blue line is the running 30-day geometric mean. The dashed horizontal line represents the *E. coli* standard for the 30-day geometric mean (126 MPN/100mL) and the solid horizontal line represents the single-sample maximum standard (1,260 MPN/100mL). Note the log scale on the Y-axis.

Figure 12-9 shows *E. coli* monitoring data for Lake Nokomis beaches from 2013 to 2022 which is graphed by using box and whisker plots. The box and whisker plots show the variability in the dataset over the past 10 years.

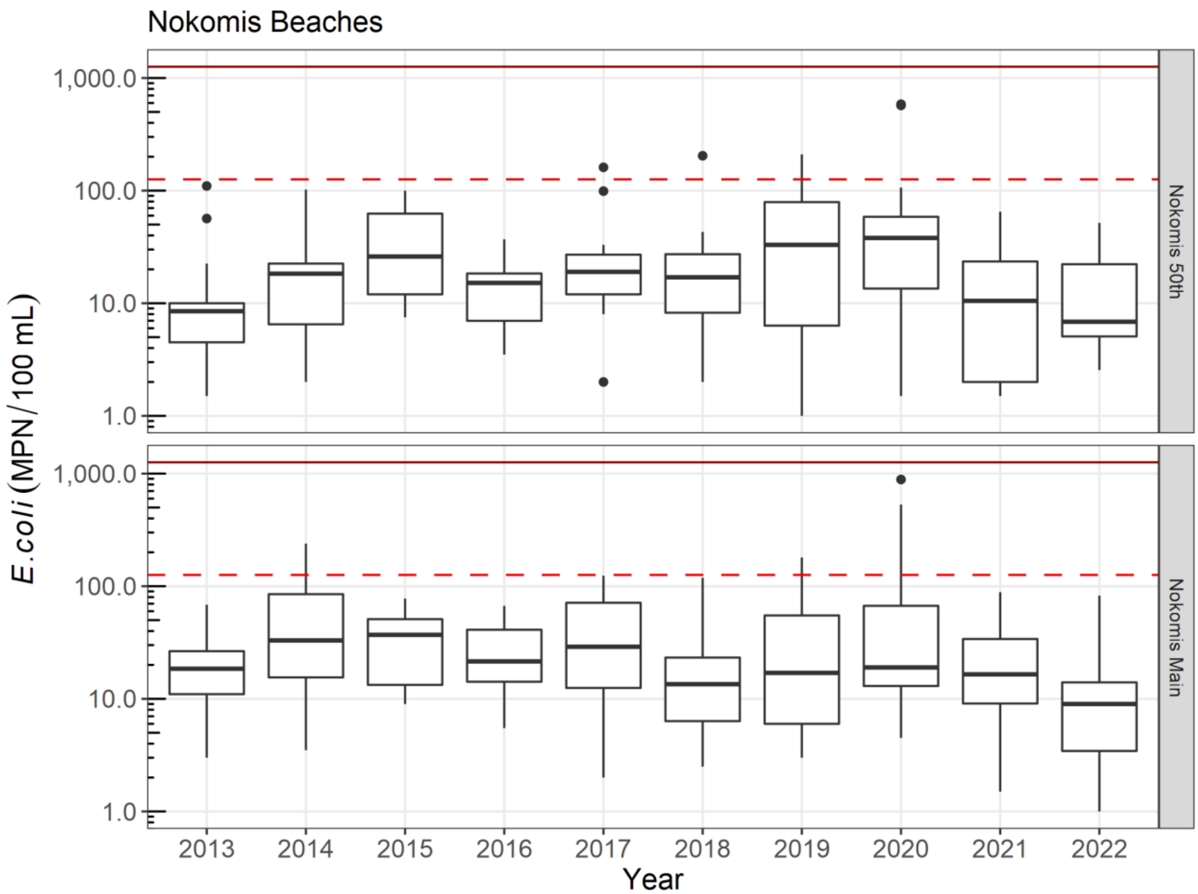


Figure 12-9. Box and whisker plots of *E. coli* concentrations (MPN/100 mL) for Lake Nokomis beaches from 2013-2022. The dashed horizontal line represents the *E. coli* standard for the 30-day geometric mean (126 MPN/100mL) and the solid horizontal line represents the single-sample maximum standard (1,260 MPN/100mL). Note the log scale on the Y-axis.

Nokomis beaches have not had any closures due to an exceedence of *E. coli* standards from the weekly beach monitoring program during the past 10 years. In 2019, both beaches were closed for 20 days due to an outbreak of Shiga-toxin producing strain of *E. coli* reported by the Minnesota Department of Health (MDH).

Blue-green Algae/Cyanotoxin Monitoring

Blue-green algae are not algae at all, but a type of bacteria called cyanobacteria. These photosynthetic microorganisms occur naturally in lakes, streams, and other waterbodies worldwide. When conditions are right, cyanobacteria can grow quickly to form dense accumulations called blooms. Certain varieties of cyanobacteria can produce toxins, referred to as cyanotoxins, that can cause illness in humans and animals (US EPA, 2017). Due to an increase in frequency and intensity of cyanobacteria blooms in Minneapolis lakes, the MPRB developed a cyanobacteria monitoring program for public health in 2020. MPRB staff collect information on observations using a defined Visual Monitoring Index (VMI), and sample water weekly at beaches for the most common cyanotoxins. Advisories are posted at beaches and on the MPRB Lake Water Quality Map (bit.ly/mplsbeaches) if toxin levels exceed MPCA guidelines. See **Chapter 19** for more information on blue-green algae and cyanotoxin monitoring.

In 2022, VMI observations were made during weekly beach sampling and bimonthly lake sampling on Lake Nokomis. Cyanotoxin samples were also collected at Main Beach and 50th Street Beach each week. VMI observations indicated low levels of cyanobacteria between May and mid-July, with minor short-lived algae scums observed at Main Beach in late June and early July. On July 26, 2022, an advisory was issued due to a whole-lake cyanobacteria bloom that caused discoloration of the open water and shallow water clarity. The advisory was posted on the Lake Water Quality Map and informational signage was posted at both Nokomis beaches. Cyanotoxin results indicated that cyanobacteria were present in early July when microcystin was detected at low levels. Microcystin concentrations continued to increase throughout the summer and exceeded the MPCA guidelines of 6 μg/L in late August. The advisory remained on the Lake Water Quality Map and yellow advisory signage was posted at both Nokomis beaches. Microcystin concentrations remained above the MCPA guidelines until late September, reaching the highest concentration of 22.8 μg/L in mid-September. Microcystin concentrations were similar between Nokomis Main Beach and 50th Street Beach. Microcystin levels at Main Beach in 2022 are shown in **Figure 12-10**. The whole-lake blue-green algae advisory was posted between late July and mid-November for a total of 118 days.

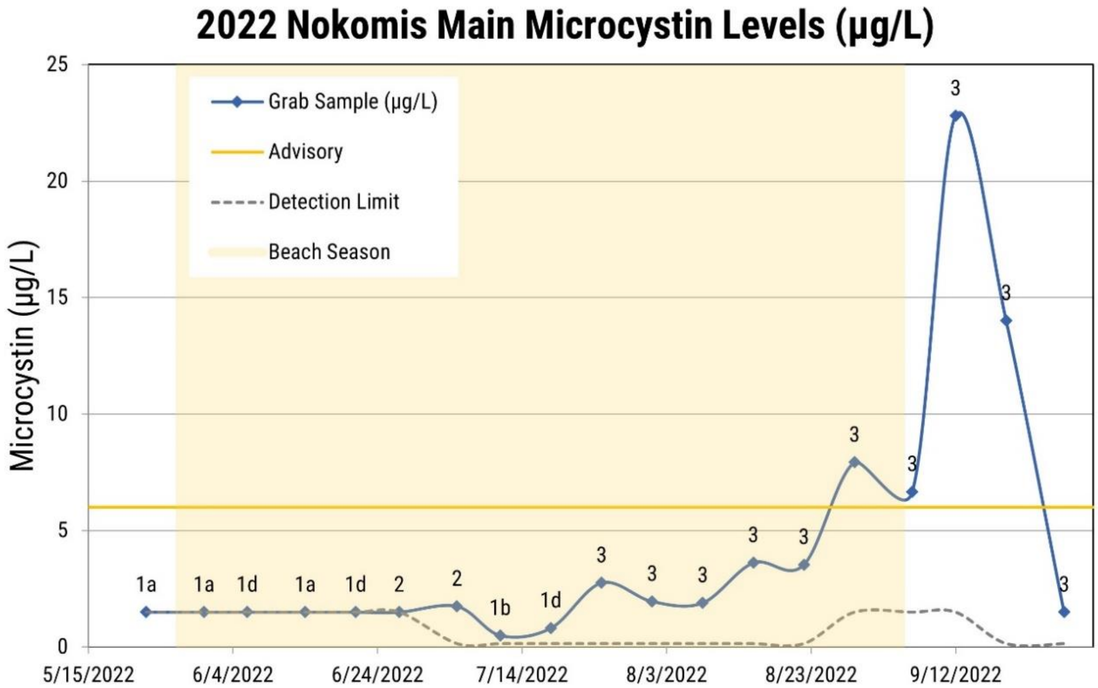


Figure 12-10. Scatterplot of microcystin concentrations on Nokomis Main Beach in 2022. The blue diamonds represent the microcystin concentrations of the grab samples. Numerical values indicate the VMI level. A horizontal yellow line represents the advisory standard (6 µg/L), and a dotted grey line indicates the detection limit. Note that different dilutions have different detection limits.

LAKE AESTHETIC AND USER RECREATION INDEX (LAURI)

Figure 12-11 shows the LAURI ratings for Lake Nokomis. In 2022, the lake scored excellent in public health, and recreational access, and good in aesthetics, water clarity and habitat quality. Late-season cyanobacteria blooms lead to scums, discoloration, and poor clarity, which lower the water clarity and aesthetics scores. Low water clarity prevents light from penetrating into the water column and limits the amount of plant growth in the lake. See **Chapter 1** for details on the LAURI index.

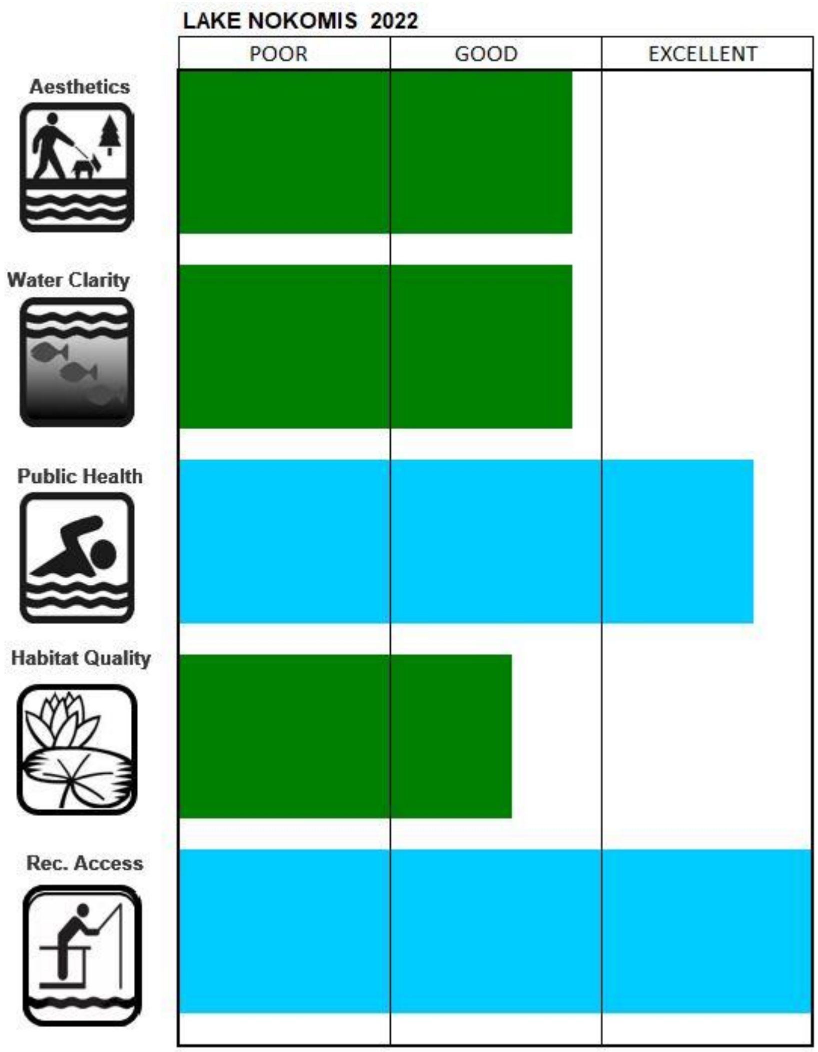


Figure 12-11. The 2022 LAURI Index scores for Lake Nokomis.

Winter Ice Cover

Ice came off Lake Nokomis on April 11, 2022, six days later than the average ice-off. Ice came back onto the lake for the winter on November 30, 2022, two days earlier than the average ice-on date for Lake Nokomis. See **Chapter 1** for detailed winter ice records and **Chapter 17** for comparison with other lakes.

Aquatic Plant Management

The MNDNR requires a permit to remove or control aquatic plants. Permits limit the area from which aquatic plants can be harvested in order to protect fish habitat. The permits issued to the MPRB allow for harvesting primarily in swimming areas, boat launches and in shallow areas where recreational access is necessary. The permitted area on Lake Nokomis in 2022 was 22 acres, which is 22% of the littoral zone, the area shallower than 15 feet. Approximately 100 pounds of aquatic plants were removed from the beach areas at Lake Nokomis using contracted SCUBA divers. See **Chapter 1** and **Chapter 21** for details on aquatic plants.

Phytoplankton and Zooplankton

Phytoplankton are microscopic plants that are an integral part of the lake community because they form the base of the aquatic food web. **Figure 12-12** shows the water clarity, chlorophyll-*a* concentrations, and relative abundance of phytoplankton divisions during 2022. Comparing these three parameters together can show how changes in the types of algae present in a lake effect water clarity and color, see the phytoplankton and zooplankton monitoring section in **Chapter 1** for additional details.

Water clarity was deeper earlier in the sampling season reaching the deepest clarity in late May at 4.4 meters when chlorophyll-*a* concentrations were low. Water clarity remained shallower than 1 meter between late June and fall reaching the shallowest clarity in early August at 0.3 meters, see **Figure 12-12a**. Chlorophyll-*a* concentrations were lowest in late May at 1 µg/L when cryptomonads (Cryptophyta) dominated the phytoplankton community. Chlorophyll-*a* levels increased throughout the summer and were highest in early September at 100 µg/L when blue-green algae (Cyanophyta) dominated the phytoplankton community, see **Figure 12-12b, c**.

The phytoplankton community in Lake Nokomis predominately consisted of Cyanophyta. Diatoms (Bacillariophyta), green algae (Chlorophyta), and Cryptophyta were also present throughout the year and were most abundant in the spring. Golden-brown algae (Chrysophyta), euglenoids (Euglenophyta), and dinoflagellates (Pyrrophyta) were present in low percentages in 2022, see **Figure 12-12c**.

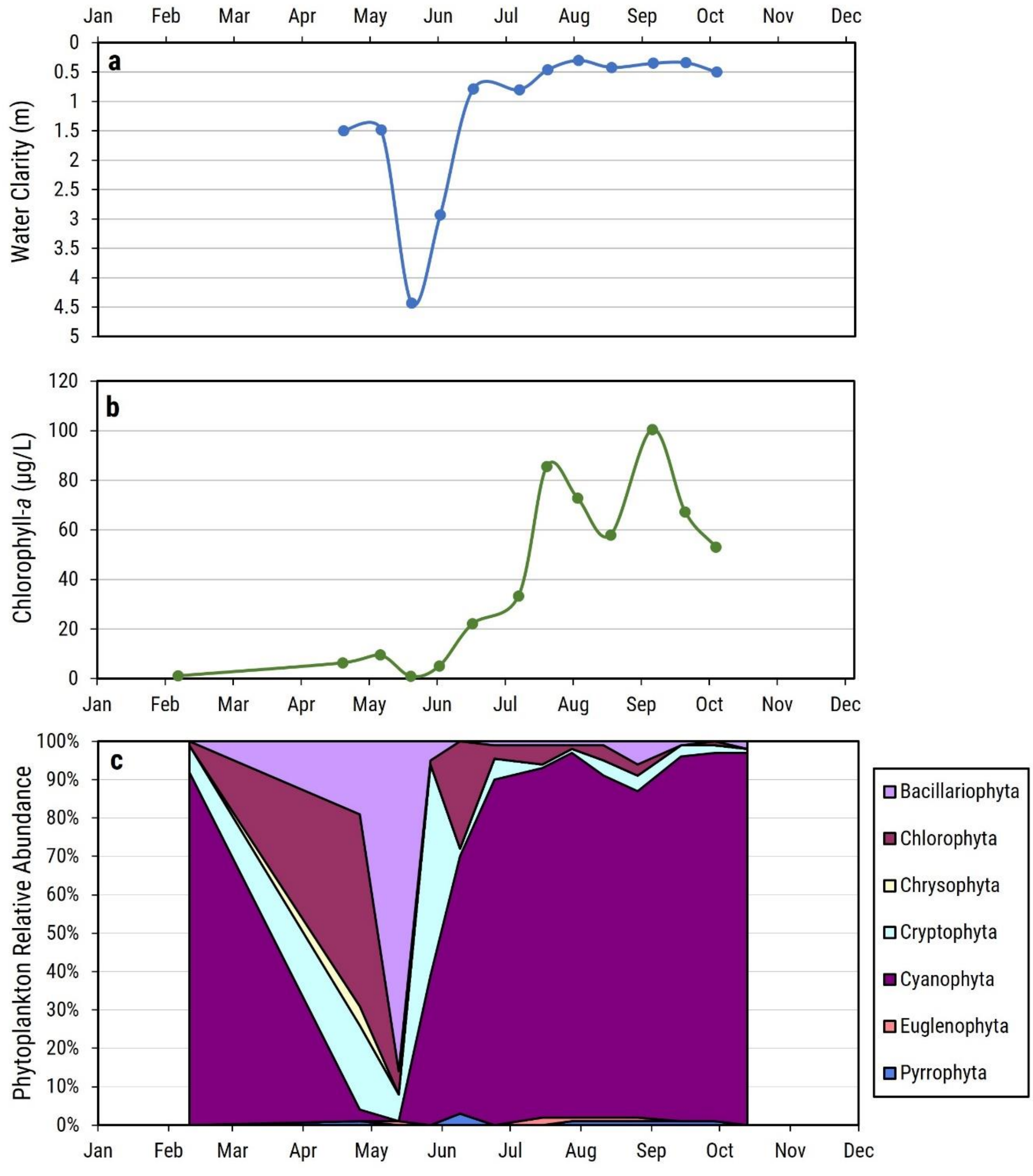


Figure 12-12. Water clarity (a), chlorophyll-*a* concentration (b), and relative abundance of phytoplankton (c) in Lake Nokomis during 2022. Note that the water clarity axis is reversed.

Zooplankton are tiny animals that feed on phytoplankton and are also vital for the lake community because they form the second level of the food web along with larval fish. **Figure 12-13** shows the zooplankton distribution in Lake Nokomis sampled throughout 2022. Nauplii and juvenile copepods dominated the zooplankton population most of the year and were most abundant in October. Rotifers were present in all samples and were most abundant in May. Cladocerans were also present throughout 2022 and were most abundant in October. Calanoids, cyclopoids, and protozoa were present in low levels.

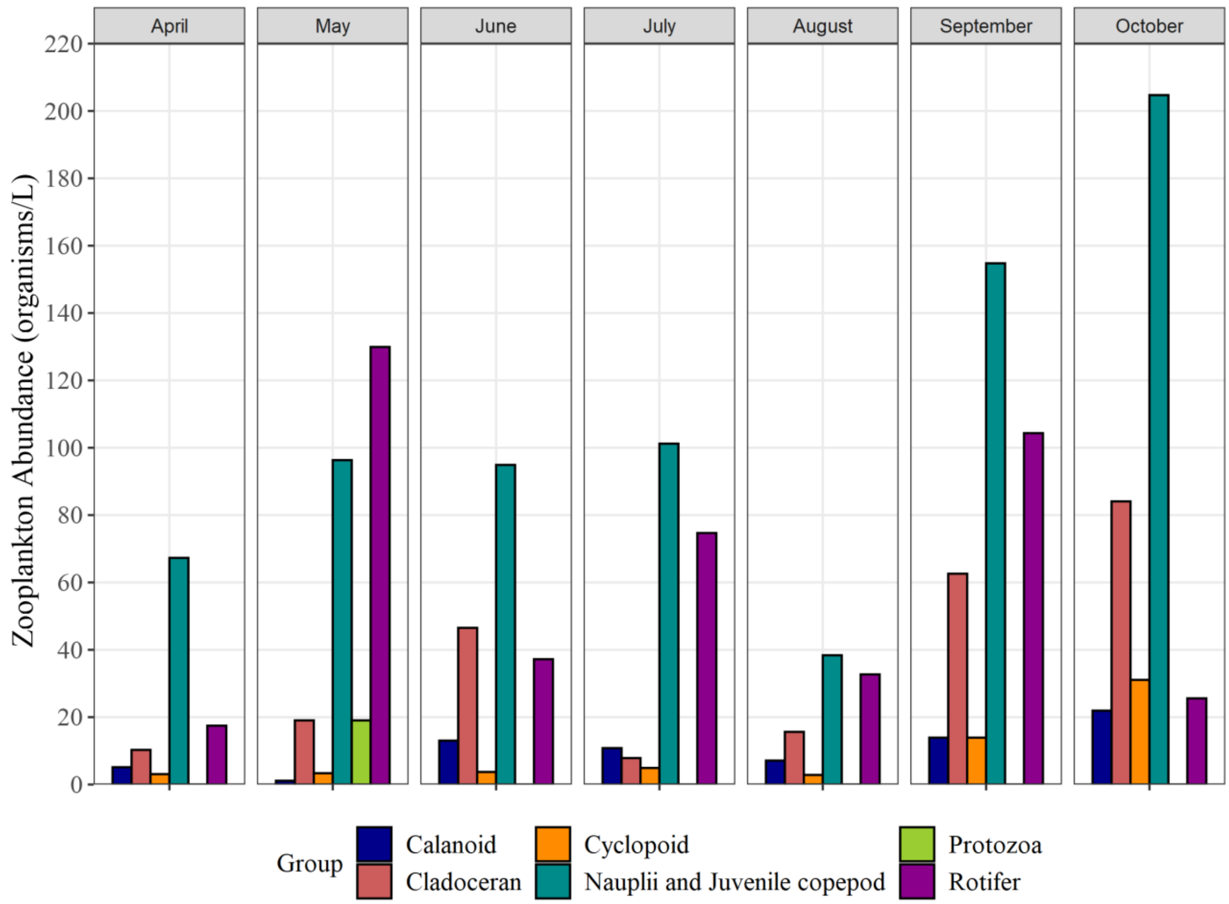


Figure 12-13. Zooplankton density in Lake Nokomis during 2022.

Fish Stocking

Table 12-4 shows the fish stocked into Lake Nokomis over the past decade. Tiger muskellunge yearlings and walleye fingerlings were stocked in Lake Nokomis in 2022. Additional information and a definition of fry, fingerling, yearling and adult fish can be found in **Chapter 1**.

Table 12-4. Fish stocked into Lake Nokomis over the past 10 years. Data are from the Minnesota Department of Natural Resources.

Year	Species	Number and Size	Amount
2022	Tiger Muskellunge	260 yearlings	86.6 pounds
2022	Walleye	3,400 fingerlings	200.0 pounds
2020	Tiger Muskellunge	140 fingerlings	35.0 pounds
2019	Walleye	2,054 fingerlings	116.7 pounds
2019	Walleye	509 yearlings	134.0 pounds
2018	Tiger Muskellunge	200 fingerlings	66.7 pounds
2017	Walleye	123 fingerlings	152.5 pounds
2016	Tiger Muskellunge	250 fingerlings	89.3 pounds
2015	Walleye	495 yearlings	390.0 pounds
2014	Tiger Muskellunge	200 fingerlings	41.2 pounds
2013	Walleye	8,476 fingerlings	321.1 pounds

Water Quality Projects

Lake Nokomis Groundwater and Surface Water Evaluation

The City of Minneapolis has received comments and complaints over deteriorating private sewer laterals and groundwater impacting basements and foundations from 21 property owners located in three different areas between 2013 and 2019. Solomon Park and Lake Nokomis Park also experienced extensively flooded areas during this time period, which coincided with the seven wettest years on record for our area. During this period, our region accumulated a surplus of precipitation equal to an entire extra years' worth of precipitation (32 inches of excess precipitation).

To better understand the area's groundwater system and its connections to Lake Nokomis, Minnehaha Creek, and resident water issues, six groundwater observation wells have been installed. Two shallow water table wells, one in Solomon Park and one in Nokomis Park, a deeper water table well at Nokomis Park, and a buried artesian well (a deeper well separated and below the water table aquifer) at Solomon Park. Additionally, the Minnesota Department of Natural Resources (MNDNR) installed two deep bedrock wells in Solomon Park to provide ongoing information on groundwater levels and movement in the area (https://www.dnr.state.mn.us/waters/cgm/index.html).

Additionally, a multi-agency team gathered information on precipitation, geology, hydrology, lake water levels, creek water levels, and reviewed historic records including newspaper and MPRB annual reports. The team also actively engaged the community and affected residents through participation in five public meetings with residents and policy makers, holding an open house, responding to emails, and creating a City of Minneapolis email list and webpage.

Outcomes from the multi-agency effort included:

- A report titled "Lake Nokomis Groundwater and Surface Water Evaluation."
- A third-party technical review of the above report, which was performed by groundwater experts from the University of Minnesota.
- An at-a-glance overview of the effort intended for a non-technical audience.
- Assembly of resources for homeowners who have experienced high water levels.

These reports and detailed information are currently hosted on the City of Minneapolis project page: https://www2.minneapolismn.gov/government/departments/public-works/surface-water-sewers/programs-policy/lake-nokomis/.

After extensive analysis it was found that property owners in the areas of concern experienced water issues for slightly different reasons due to the different characteristics at each location and how that unique group of characteristics responded to record-breaking precipitation based on: the geologic history of the area, presence of peat soils, residential development, and the respective elevations of each area. Below, water concerns from each area and their reported causes are briefly summarized based on the 2022 technical report findings.

In the Solomon Park area, 5 residents reported wet backyards. In this area, some homes were built on or adjacent to former mapped wetlands with peat soils. Peat soils prevented record-breaking precipitation from soaking into the ground and resulted in standing water.

West Nokomis area residents reported wet basements in just over a dozen homes. In this area, some homes were built adjacent to historically filled wetlands, in areas where peat was deposited, in areas of naturally occurring peat soils, and in some cases directly over the former stream channel between Mother Lake and Lake Nokomis. Affected basements in this area are 5-feet to 19-feet above the levels of Lake Nokomis, Minnehaha Creek, and the regional shallow groundwater table, indicating that these features are not contributing to the water issues at the home sites. This information indicates that water issues at home sites likely resulted from localized perched groundwater systems that were caused by record breaking precipitation being trapped by peat soils.

Wet basements were also reported by 3 residents along Lake Nokomis Parkway. In this area, some homes were built over former wetlands, within the formerly larger Lake Nokomis basin, and below the current normal water level of Lake Nokomis. Record-breaking precipitation and groundwater recharge likely exacerbated existing water issues in this area due to the area's specific geologic history.

Cyanobacteria Mitigation Feasibility Study

MPRB is developing specific cyanobacteria mitigation strategies for Cedar Lake and Lake Nokomis to address ongoing concerns about toxic cyanobacteria blooms in these lakes. This work is being undertaken because the presence of cyanotoxins have been detected at levels that can exceed the MPCA's swimming advisory levels at Lake Nokomis, and significant blooms of cyanobacteria have occurred at Cedar Lake. The objectives of the project are to identify the specific stressors causing beach-season and off-season cyanobacteria blooms in the lakes and identify and evaluate structural and nonstructural mitigation strategies to address the stressors at the individual lakes.

After reviewing over 20 years of water quality data it was determined that the primary drivers of cyanobacteria blooms in Lake Nokomis included:

- Weakly stratified conditions with high nutrient concentrations near the lake bottom selecting for cyanobacteria that regulate buoyancy in the summer and into fall
- High nutrient concentrations occur in the hypolimnion because of large areas of anoxia and sediment phosphorus release
- A large carp population that may be exacerbating internal phosphorus loading in the lake
- While phosphorus concentrations under winter ice as a result of internal phosphorus loading is moderate, conditions favor cyanobacteria adapted to cold temperatures and low light conditions
- Nitrogen limitation in late summer that favors nitrogen fixing cyanobacteria
- Increased light availability during the winter because of snow plowing and removal to support local pond hockey activities.

Potential mitigation strategies that could address the drivers were evaluated including:

- Targeted use of hydrogen peroxide algaecide
- In-lake sediment phosphorus inactivation using aluminum sulfate/sodium aluminate
- In-lake biomanipulation: carp management and aquatic plant management
- Aeration and artificial circulation
- Further analysis of Watershed Structural BMPs: Nokomis Wetlands and Solomon Wetland
- Watershed source abatement: enhanced street sweeping, urban forestry, fertilizer management, pet waste management, and goose management.

Mitigation strategies could potentially improve water clarity in the lake when implemented. One anticipated consequence of clear water is that aquatic plant populations may increase to nuisance levels at Lake Nokomis when the algae population is reduced. Understanding the current aquatic plant population will assist in creating future aquatic plant management plans for the lake that will preserve recreation and encourage native plant growth. Additionally, as identified in the Carp IPM Project (Havranek et al., 2019) carp populations in Lake Nokomis are high enough that water quality is impacted by their natural behavior. Reduction in the carp population will also preserve the lifespan of future water quality improvement projects, protecting the investment in water quality at this site.

In 2023 the MPRB will conduct aquatic plant survey work and continue to determine how to best address the high carp population at Lake Nokomis.

13. Powderhorn Lake

History

Powderhorn Lake was acquired by the Minneapolis Park and Recreation Board (MPRB) in 1890 and was named because its original shape resembled a bag for gunpowder. Dipper dredge operations were conducted shortly thereafter from 1894 to 1904, reducing the size of the lake by eight acres and creating an island. Between 1924 and 1925 the south end of the lake was deepened by hydraulic dredging with nearly 150,000 cubic yards of spoils used to fill the north half to create parkland (Smith, 2008). A photograph of Powderhorn Lake is presented below in **Figure 13-1.**

Figure 13-1. Powderhorn Lake in August 2022.

Powderhorn is a shallow lake with an island and one deeper hole at its southeastern end. **Table 13-1** contains physical characteristics and morphometric data, and **Figure 13-2** is a bathymetric map of Powderhorn Lake. Powderhorn Lake is part of the Minnehaha Creek Watershed, and the primary land-use is residential and mixed-use.

Powderhorn Lake receives large amounts of stormwater runoff and water from the lake discharges using a pump through the stormwater system to the Mississippi River. Stormwater impacts water quality in Powderhorn Lake due to nutrient input. There are six stormwater outfalls surrounding the lake with most of the watershed drained through the west side of the lake, see **Appendix C**.

Restoration activities at Powderhorn Lake began to be implemented in 1975 when a temporary summer aerator was installed to increase oxygen content in deeper water and to prevent fish kills. The MPRB received permit approval from the MNDNR to install an augmentation well in 1979 to manage lake levels and improve water quality. In 1995, a permanent winter aeration system was installed with the Minnesota Department of Natural Resources (MNDNR) to provide a refuge for fish and prevent winter fish kills. An outlet pump system was constructed in 1996-1997 to maintain the water level of the lake. The MPRB and Minneapolis Public Works developed a major restoration plan for Powderhorn Lake in 1999. In 2001, five continuous deflective separation (CDS) grit chambers were installed to remove solids from stormwater inflow. In 2002, native shoreline plants were installed to improve aesthetics and habitat, and to filter overland flow from the park. Restoration also included repairing the historic Works Progress Administration (WPA) stone wall, removing concrete sluiceways that previously carried street runoff directly to the lake, and installing a permanent summer aerator. An aluminum sulfate (alum) treatment was conducted in May 2003 to attempt to limit phosphorus availability. The winter aeration structure failed in winter of 2022, so fish kills are expected in Powderhorn Lake until the structure is fixed.

Historically, Powderhorn Lake had less than one foot of water clarity due to cyanobacteria blooms. MPRB started treating the lake with barley straw in 2004 in an attempt to control cyanobacteria growth. Between 2005 and 2013 fewer cyanobacteria blooms occurred, water clarity improved and aquatic plants were abundant, but other types of nuisance conditions occurred as filamentous algae and duckweed grew heavily at different times. Significant cyanobacteria blooms began again in 2015 and there have been few aquatic plants present in recent years. It is suspected that the summer and winter aeration systems may play a role in increasing nutrient cycling, and MPRB is investigating and testing various options.

In 2007 the invasive species *Egeria densa* (Brazilian waterweed) was discovered growing in several small stands in the lake. During the fall of 2007, the MNDNR treated the invasive plant with the herbicide Diquat to target and eradicate the unwanted species. A total of 1.4 acres of the lake were treated across two treatment areas. One area had 28 ounces of Diquat applied and the other area had 2.54 gallons applied. At the request of the MNDNR, the MPRB did not use the Powderhorn Lake winter aeration system during the winter of 2007. MPRB also intentionally did not run the inflow or outflow pump during the growing season between 2007 and 2014 to prevent good growing conditions and spreading of the invasive species. The invasive plant has not been identified in the lake since the herbicide treatment and Powderhorn Lake was removed from the infested waters list for this species in 2014. The MNDNR based the decision to remove the lake from the infested waters list on 5 years of observations and plant surveys indicating no presence of *Egeria densa*. Because this invasive plant was eradicated, MPRB was able to use the outflow pump again to maintain lake levels.

Minnesota Pollution Control Agency (MPCA) removed Powderhorn Lake from the MPCA's list of impaired waters (303(d) list) in 2012 due to a strong trend towards improved water quality. Subsequently, the lake did not meet standards for clarity or chlorophyll-*a* for seven years and was put back on the list of impaired waters in 2018. City of Minneapolis and MPRB will continue to evaluate the lake for potential improvement options. Improving oxygen levels, along with reducing trash accumulation, phosphorus, and algae growth are all areas where improvements could continue at the lake.

Water quality on Powderhorn Lake has been monitored annually since 1992.

Table 13-1. Powderhorn Lake physical characteristics and morphometric data.

Surface Area (acres)	Mean Depth (ft)	Max Depth (ft)	Littoral Area*	Volume (ft^3)	Watershed Area (acres)	Watershed: Lake Area (ratio)	Residence Time (years)
11	3.9	24.0	83%	3.19×10^6	286	26.0	0.2

* Littoral area was defined as less than 15 feet deep.

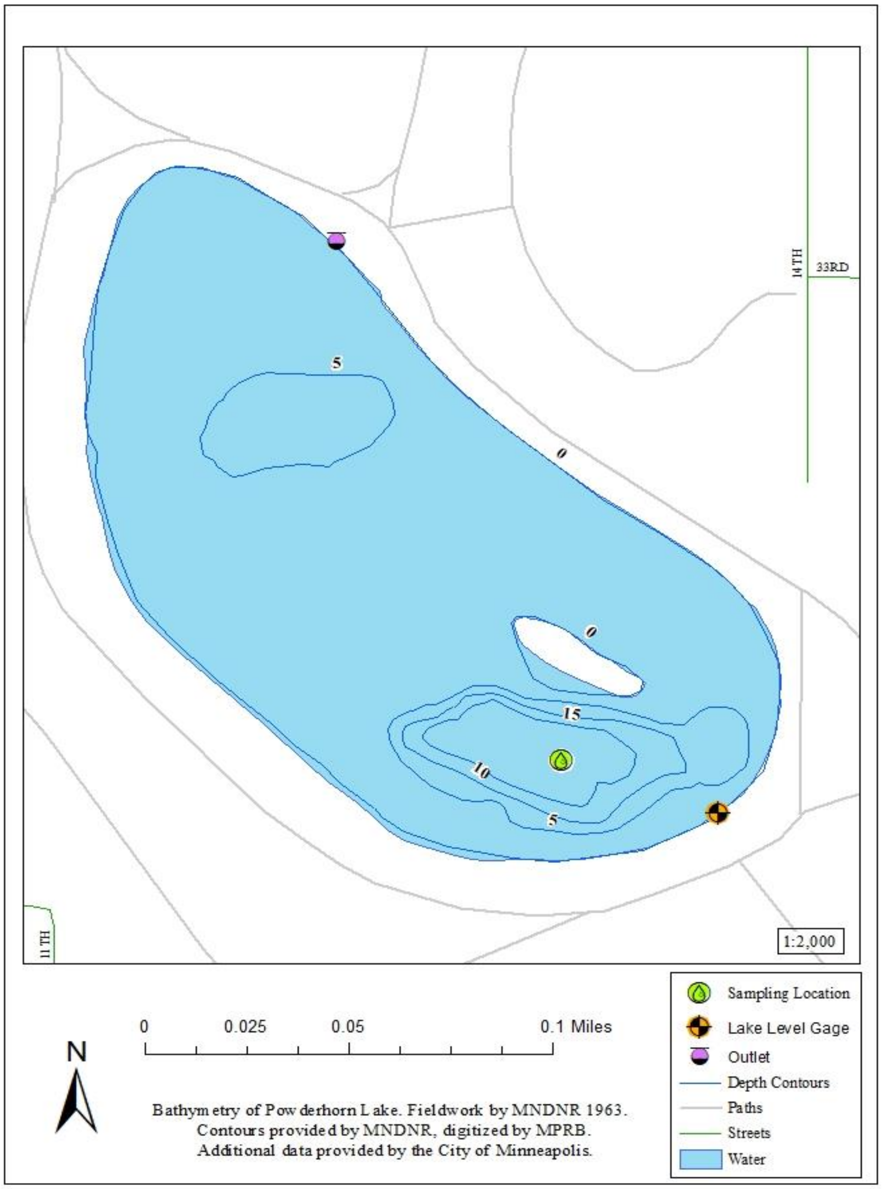


Figure 13-2. Bathymetric map with mid-lake sampling site, lake level gage, and outlet location at Powderhorn Lake.

LAKE LEVEL

Powderhorn Lake levels from 1999-2022 are shown in **Figure 13-3**. Historically, Powderhorn Lake often had low water levels that impacted the aesthetics of the park. Powderhorn does not have a designated Ordinary High Water Level (OHWL), determined by the Minnesota Department of Natural Resources (MNDNR) due to the widely fluctuating stormwater impact on the lake levels. The lake receives input from stormwater and has no natural outlet, so lake levels have often been managed through groundwater augmentation and an outlet pump; however, neither system was used in 2022. Lake levels in Powderhorn Lake remained low throughout 2022. See **Chapter 1** for details on lake level monitoring and **Chapter 17** for a comparison between other MPRB lake levels.

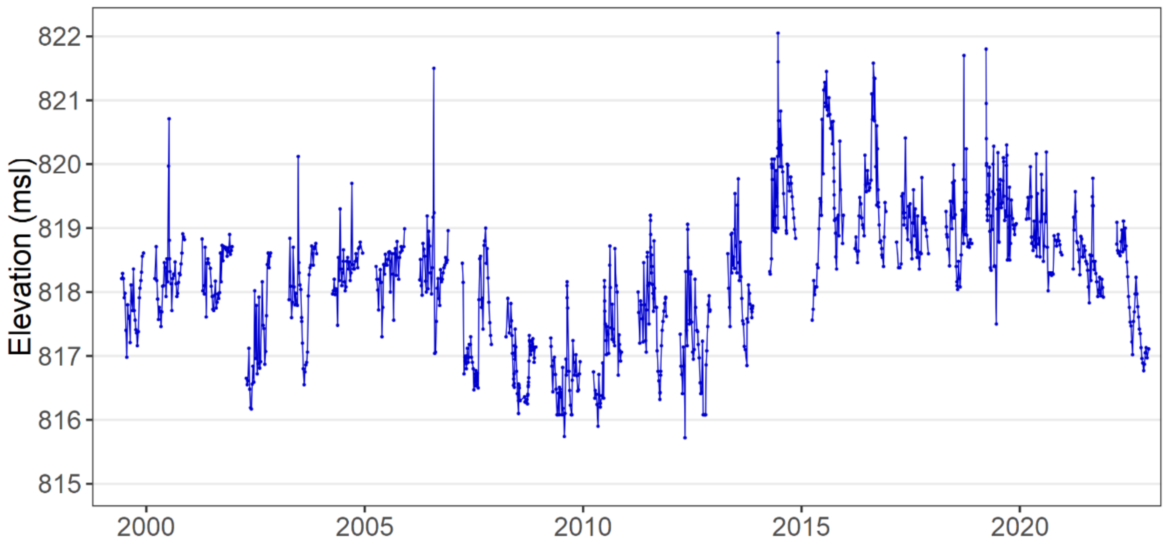


Figure 13-3. Powderhorn Lake levels from 1999-2022.

Augmentation Well

The MPRB maintains a water appropriation permit, MNDNR permit #1979-6007, to pump groundwater from a well into Powderhorn Lake to increase the level of the lake. The MNDNR issues the permit to appropriate groundwater and determines annual pumping volume limits for appropriate groundwater resource use. In the past, up to 26 million gallons per year was permitted to be pumped into Powderhorn Lake. Through the years the permitted amount has changed due to changes in state law to the current allotment of 10 million gallons per year. The MPRB staff determine when the pump needs to be turned on and off and maintain records for groundwater usage monthly when the groundwater pump is operational. All monthly pumping data are reported to the MNDNR annually in the MNDNR Permitting and Reporting System. The augmentation well was previously used for aesthetic purposes and to facilitate ice rink maintenance. Augmentation pumping was not done in 2022 and has not been utilized since 2015 due to recent years of high levels of precipitation maintaining higher lake levels. See **Chapter 1** for detailed information on MPRB augmentation wells.

Outlet Pumping

Powderhorn Lake has no natural outlet. When high water in the lake impacts the park, water must be pumped out of the lake and into a stormsewer pipe leading to the Mississippi River. The MPRB currently maintains a water appropriation permit, MNDNR permit #2015-2234, to pump a maximum of 49 million gallons from Powderhorn Lake if necessary to maintain fishing dock access, prevent parkland flooding, and prevent excessive shoreline damage. The pump is operated by Minneapolis Public Works, but MPRB staff determine when the pump needs to be turned on and off and maintain the records for permitting. Pump data is recorded monthly and reported annually to the MNDNR.

In the past, the MNDNR permit allowed only 3.5 million gallons to be pumped. After the invasive species *Egeria densa was* discovered in 2007, the MPRB intentionally did not run the outflow pump between 2007 and 2014 to prevent the species from escaping the lake and consequently invading another waterbodies. In 2015 a temporary permit was issued to lower the level of the lake to allow for repair of the teahouse sculpture. In 2016, the long-term permit was amended to allow 19 million gallons to be pumped due to sustained high water conditions that were damaging the shoreline and making the dock inaccessible. The permit was amended again in 2019 increasing the number of gallons to be pumped to 49 million, after it was determined that 19 million gallons of pumping was not enough to keep the dock accessible after record-breaking precipitation.

The outlet pump was not used in 2022 for the first year since 2015. **Table 13-2** shows the amount of water that was pumped out from Powderhorn in the last five years. 2019 was the wettest year on record and had the highest amount of water, 38.2 million gallons, pumped from the outlet.

Table 13-2. Powderhorn Lake yearly outlet pumping volume in gallons.

2018	2019	2020	2021	2022
14,163,600 gal	38,194,200 gal	17,430,600 gal	3,597,000 gal	0 gal

WATER QUALITY TRENDS – TROPHIC STATE INDEX (TSI)

Figure 13-4 shows the historical Powderhorn Lake TSI scores and a trend line. There is no significant trend in TSI scores between 1992 to 2022 ($p > 0.05$). The restoration efforts appeared to improve TSI scores from 2001-2009. CDS units decreased sediment inputs, annual barley straw treatments increased water clarity, and an alum treatment briefly decreased phosphorus and increased water clarity. Since 2009, TSI scores have an increasing trend indicating worse water quality; however, TSI scores were lower in 2018, 2019, and 2021. The TSI score for Powderhorn Lake in 2022 was 74, classifying the lake as hypereutrophic, which is characterized by dense algae growth.

Secchi, chlorophyll-*a*, and total phosphorus TSI scores for Powderhorn Lake are above the TSI range for the ecoregion, meaning water clarity is shallower and chlorophyll-*a* and total phosphorus levels in Powderhorn Lake are higher than in comparable lakes, see **Table 13-3**. For more information see MPCA Surface Water Data (https://webapp.pca.state.mn.us/wqd/surface-water/waterunit-details?wid=27-0014-00). A detailed explanation of TSI can be found in **Chapter 1**.

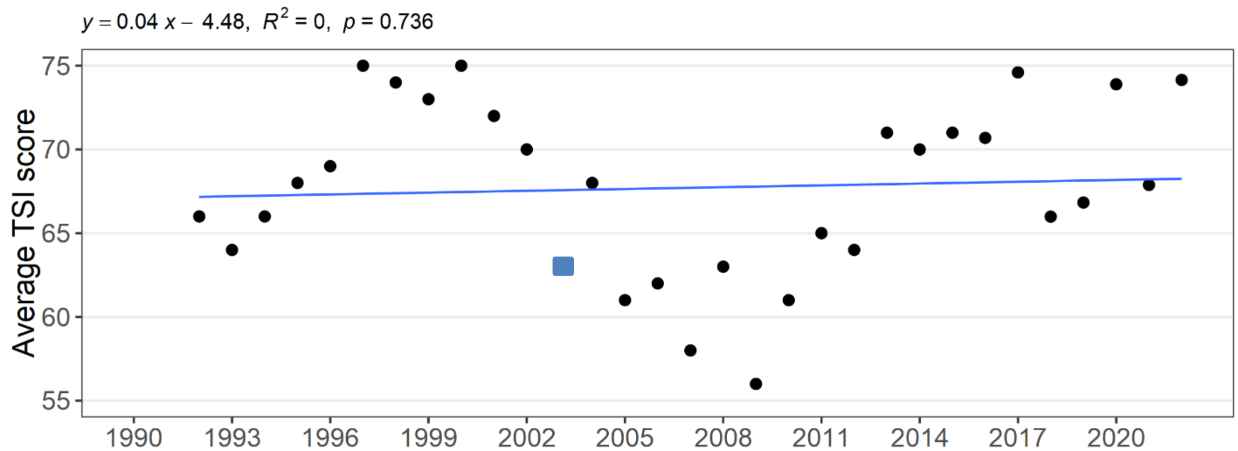


Figure 13-4. Powderhorn Lake TSI scores and linear regression from 1992-2022. The blue square highlights the 2003 alum treatment.

Table 13-3. Powderhorn Lake Secchi, chlorophyll-*a*, and total phosphorus TSI based on data collected between June and September of 2022 and compared to lakes in the North Central Hardwood Forest ecoregion.

	TSI	Expected TSI Range of Lakes in the Same Ecoregion	Within the Expected TSI Range of Lakes in the Same Ecoregion
Secchi	75	43-54	Not within range, worse than expected
Chlorophyll-*a*	72	46-61	Not within range, worse than expected
Total Phosphorus	81	49-61	Not within range, worse than expected

Box and Whisker Plots

The box and whisker plots in **Figure 13-5** show the data distribution for water clarity, chlorophyll-*a*, and total phosphorus for the past 10 years, based on data from the entire sampling season. Red horizontal lines on the graphs indicate the MPCA eutrophication standards for shallow lakes, which applies to data collected between June and September. A detailed explanation of box and whisker plots can be found in **Chapter 1**. Box and whisker plots from the entire period of record, 1992-2022, can be found in **Appendix A**.

Water clarity in 2022 was comparable to previous years with an average of 0.44 meters, see **Figure 13-5a**. Chlorophyll-*a* concentrations have been relatively consistent over the past 10 years except for in 2017, 2020, and 2022 when concentrations were even higher and more variable. The average chlorophyll-*a* concentration in 2022 was 60.6 µg/L, see **Figure 13-5b**. Total phosphorus has varied over the past 10 years with higher concentrations in 2017, 2020, and 2022. In 2022, the average total phosphorus level was 188 µg/L, see **Figure 13-5c**. The lake exceeded MPCA eutrophication standards for water clarity, chlorophyll-*a*, and total phosphorus in 2022. Since 2009 all three parameters worsened with no perceived explanation.

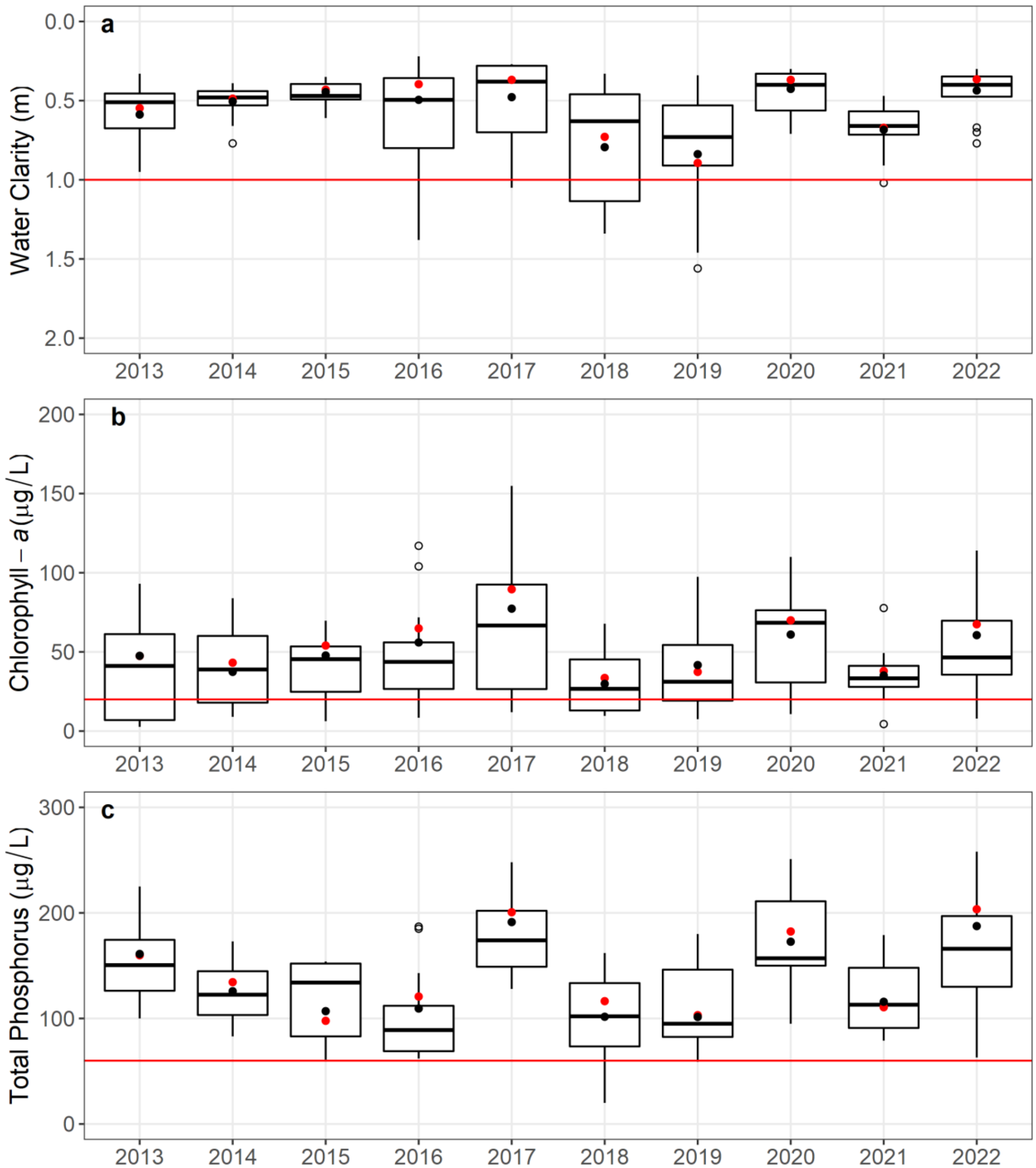


Figure 13-5. Powderhorn Lake box and whisker plots of water clarity (a), chlorophyll-*a* (b), and total phosphorus (c) from 2013-2022. Horizontal lines represent MPCA eutrophication standard for shallow lakes, which applies to data collected between June and September. The red circles represent the mean value of data collected between June and September. The black circles represent the mean value of data collected during the growing season, May through September. Data from 1992-2022 can be found in Appendix A.

Nitrogen levels varied greatly between 1995 and 2001 ranging from 0.84 to 4.62 mg/L, and decreased between 2002 and 2012 ranging from 0.12 to 2.57 mg/L. Between 2012 and 2017 the average total nitrogen levels slowly increased, but since 2017 total nitrogen levels have been slightly lower, see **Figure 13-6**. The reason for decreasing and increasing nitrogen levels is unknown. CDS units and grit chambers were installed in the watershed in 2001, but the mechanism by which these BMPs would influence nitrogen is not known.

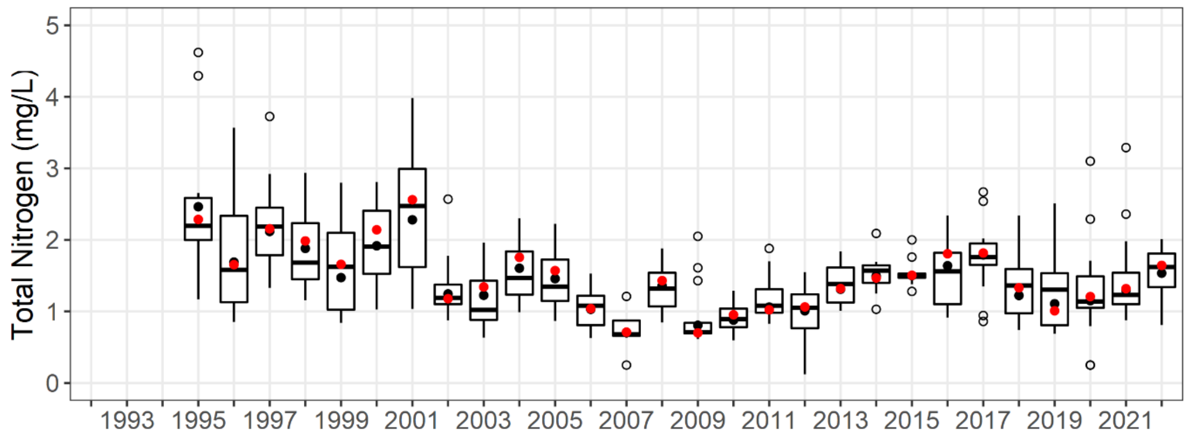


Figure 13-6. Powderhorn Lake box and whisker plot of total nitrogen from 1994-2022. The black circles represent the mean value of data collected during the growing season, May through September. The red circles represent the mean value of data collected between June and September.

CHLORIDE

Chloride is a naturally occurring element that is commonly found at low levels in most freshwater bodies. Chloride is a component of road salt (sodium chloride) and is found in other types of compounds that are also called salts (calcium chloride, magnesium chloride). Unnaturally high concentrations of chloride can negatively impact surface waters. High levels of chloride can change the mixing pattern of a lake and lead to very low oxygen levels in deep water. It can also lead to decreasing water clarity and induce stress or cause death of aquatic species (Bathe & Coring, 2011). Sources of chloride include industrial discharge, septic systems, sewage disposal systems, fertilizers, and road salt (Novotny, Murphy, & Stefan, 2008). The MPCA adopted the Environmental Protection Agency's (EPA) recommended water quality criteria for chloride which is a chronic standard of 230 mg/L and an acute standard of 860 mg/L (MPCA, 2016). The MPRB has monitored chloride concentrations in Powderhorn Lake since 1995 by collecting surface water samples using a composite tube and collecting deep water samples using a Kemmerer sampler. See **Chapter 1** for more information on chloride.

Figure 13-7 shows epilimnetic and hypolimnetic chloride concentrations in Powderhorn Lake between 1995-2022, with hypolimnion samples only collected regularly after 2006. Epilimnion samples represent the top two meters of the lake and hypolimnion samples were collected approximately one meter from the bottom of the lake. Red horizontal lines on the graph indicate the MPCA acute and chronic chloride standards. Also included on the graph, is a dotted line that represents an estimate of a concentration above which potential ecological impact could occur, at 120 mg/L. This level of potential ecological impact was developed by Canadian Council of Ministries of the Environment (CCME) and is not a Minnesota state standard but a long-term chloride concentration that could negatively impact life within the lake (CCME, 2011). Chloride concentrations in the hypolimnion are significantly higher than epilimnetic concentrations likely because runoff containing sodium chloride is denser and sinks to the lake bottom. Chloride concentrations in Powderhorn Lake are highly variable, ranging from 17 mg/L to 660 mg/L, because the lake receives large amounts of stormwater runoff. Powderhorn Lake was added to the MPCA's list of impaired waters (303(d) list) in 2014 due to high chloride concentrations.

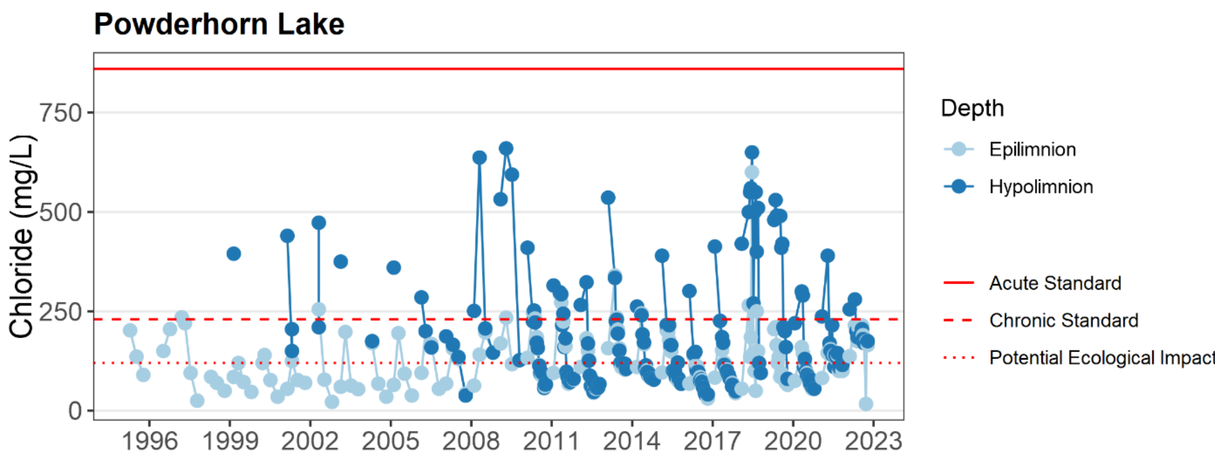


Figure 13-7. Powderhorn Lake scatterplot of epilimnetic and hypolimnetic chloride concentrations between 1995-2022. Horizonal lines represent the MPCA's acute and chronic standard and the potential ecological impact level (CCME, 2011).

Blue-green Algae/Cyanotoxin Monitoring

Blue-green algae are not algae at all, but a type of bacteria called cyanobacteria. These photosynthetic microorganisms occur naturally in lakes, streams, and other waterbodies worldwide. When conditions are right, cyanobacteria can grow quickly to form dense accumulations called blooms. Certain varieties of cyanobacteria can produce toxins, referred to as cyanotoxins, that can cause illness in humans and animals (US EPA, 2017). Due to an increase in frequency and intensity of cyanobacteria blooms in Minneapolis lakes, the MPRB developed a cyanobacteria monitoring program for public health in 2020. MPRB staff collect information on observations using a defined Visual Monitoring Index (VMI), and sample water weekly at beaches for the most common cyanotoxins. Advisories are posted at beaches and on the MPRB Lake Water Quality Map (bit.ly/mplsbeaches) if toxin levels exceed MPCA guidelines. See **Chapter 19** for more information on blue-green algae and cyanotoxin monitoring.

In 2022, VMI observations and cyanotoxin samples were collected during biweekly lake sampling sessions on Powderhorn Lake. VMI observations indicated that cyanobacteria were not visible in the winter and between April and June. Low levels of cyanobacteria were observed throughout July and early August, with minor streaks of blue-green algae on the surface. The VMI indicated a full lake cyanobacteria bloom with surface scum present between late August through October. Cyanotoxin results indicated that cyanobacteria were present in late July when microcystin concentrations exceeded the MPCA guidelines at 6.02 µg/L, see **Figure 13-8**. A blue-green algae advisory was issued in early August and MPCA informational signage was posted on the shoreline and on the Lake Water Quality Map. Water Quality staff also distributed multilanguage educational materials in the recreation center and worked with the Environmental Education Department on relocating canoe programs to other lakes. Cyanotoxin results remained below the MPCA guidelines the rest of the sampling season; however, the advisory remained posted until late October due to high visual presence. The blue-green algae advisory was posted for a total of 82 days.

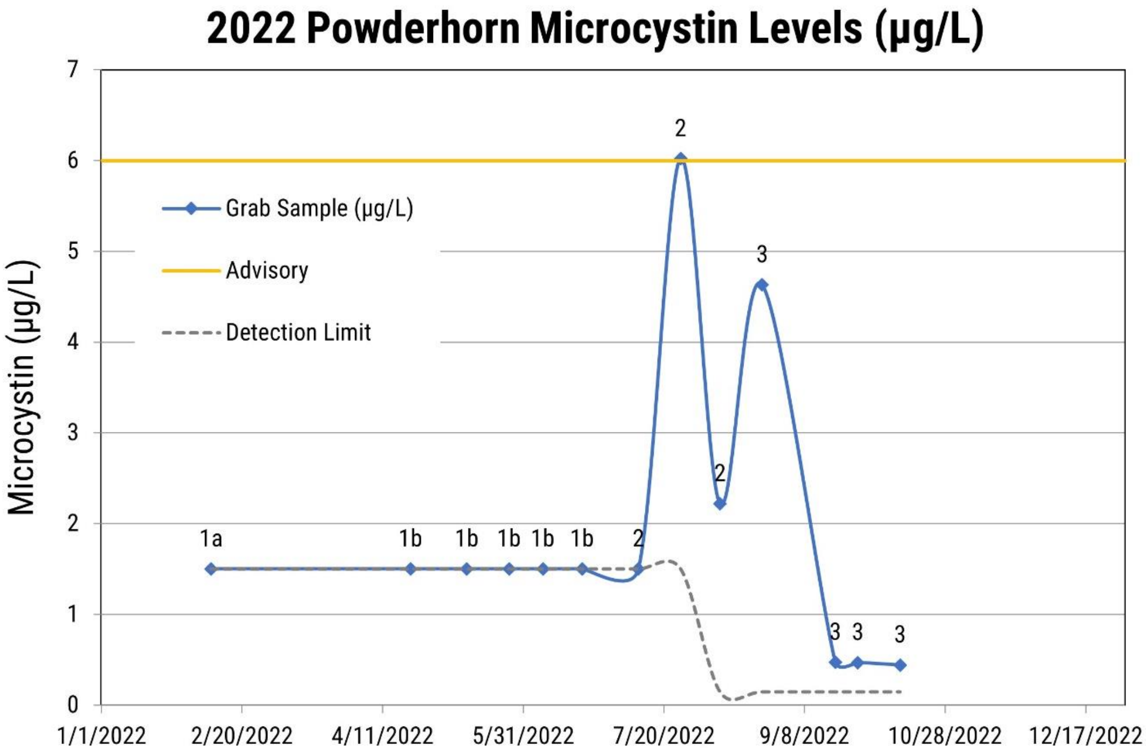


Figure 13-8. Scatterplot of microcystin concentrations on Powderhorn Lake in 2022. Blue diamonds represent the microcystin concentrations of the grab samples. Numerical values indicate the VMI level. A horizontal yellow line represents the advisory standard (6 µg/L), and a dotted grey line indicates the detection limit. Note that different dilutions have different detection limits.

Lake Aesthetic and User Recreation Index (LAURI)

The LAURI for Powderhorn Lake is shown in **Figure 13-9**. In 2022, Powderhorn Lake scored good in aesthetics and poor in water clarity, habitat quality, and recreational access opportunities. Fewer fish species were observed in the fish survey completed in 2022 than in surveys from previous years. According to previous plant surveys the lake contains four aquatic plant species, but there is typically low density and coverage. More aquatic plant growth was observed in 2022; however, this did not affect the habitat quality score because an aquatic plant survey was not conducted this year. Powderhorn Lake does not have a swimming beach and therefore was not scored for public health. See **Chapter 1** for details on the LAURI.

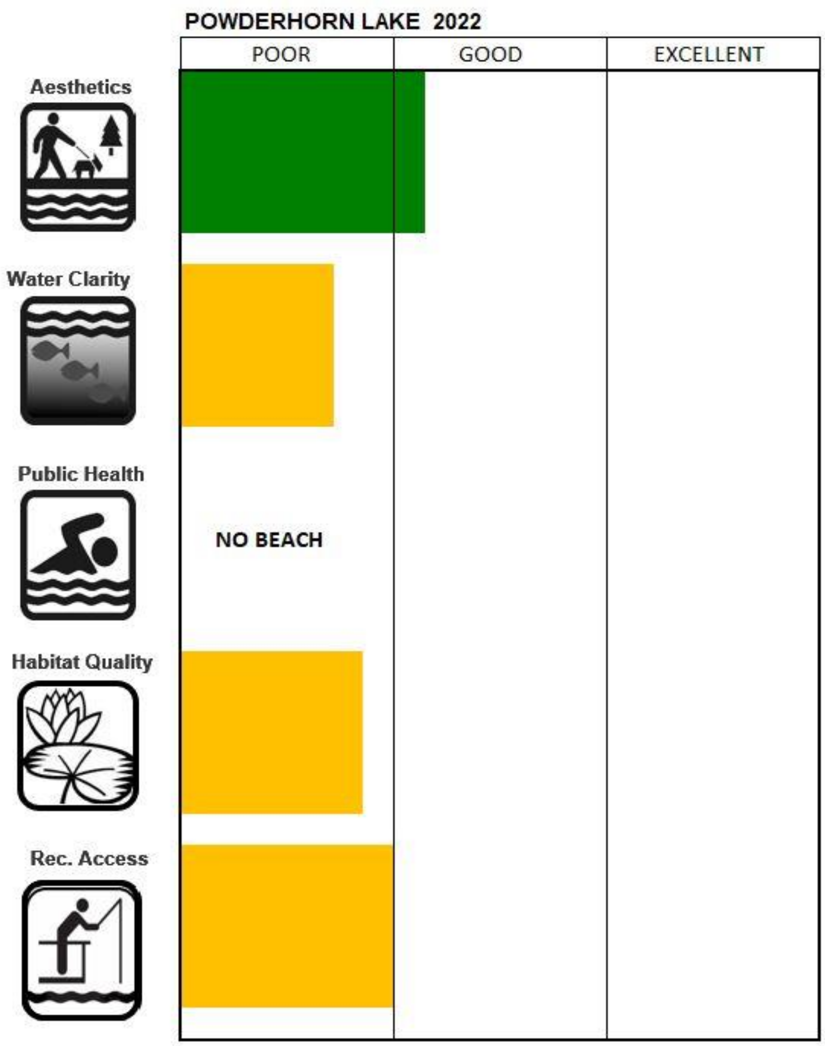


Figure 13-9. The 2022 LAURI for Powderhorn Lake.

Winter Ice Cover

Ice came off Powderhorn Lake on April 8, 2022, five days later than the average ice-off date. Ice came back onto the lake on December 19, 2022, nineteen days later than the average ice-on date. Waterfowl have been known to keep portions of the lake ice free for longer on Powderhorn Lake in some years. See **Chapter 1** for details on winter ice cover records and **Chapter 17** for a comparison with other lakes.

Phytoplankton and Zooplankton

Phytoplankton are microscopic plants that are an integral part of the lake community because they form the base of the aquatic food web. **Figure 13-10** shows the water clarity, chlorophyll-*a* concentrations, and relative abundance of phytoplankton divisions during 2022. Comparing these three parameters together can show how changes in the types of algae present in a lake effect water clarity and color, see the phytoplankton and zooplankton monitoring section in **Chapter 1** for additional details.

Water clarity was shallow in 2022 remaining below 1 meter for the entire sampling season. Water clarity was deepest in early May at 0.8 meters and shallowest in late July at 0.3 meters, see **Figure 13-10a**. Chlorophyll-*a* concentrations were lowest in the winter at 7.9 µg/L and increased throughout the year reaching the highest concentration in late September at 114 µg/L when the phytoplankton community primarily consisted of blue-green algae (Cyanophyta), see **Figure 13-10b, c**.

Cyanophyta dominated the phytoplankton community in Powderhorn Lake in the winter and between late July and fall. Cryptomonads (Cryptophyta) were present for most of the year and dominated the population in spring. Green algae (Chlorophyta) were present throughout the year and dominated the phytoplankton community between May and early July. Diatoms (Baciliariophyta) were abundant in early May and present in low levels the remainder of the year. Golden-brown algae (Chrysophyta), euglenoids (Euglenophyta), and haptophytes (Haptophyta) were present in low levels in 2022, see **Figure 13-10c**.

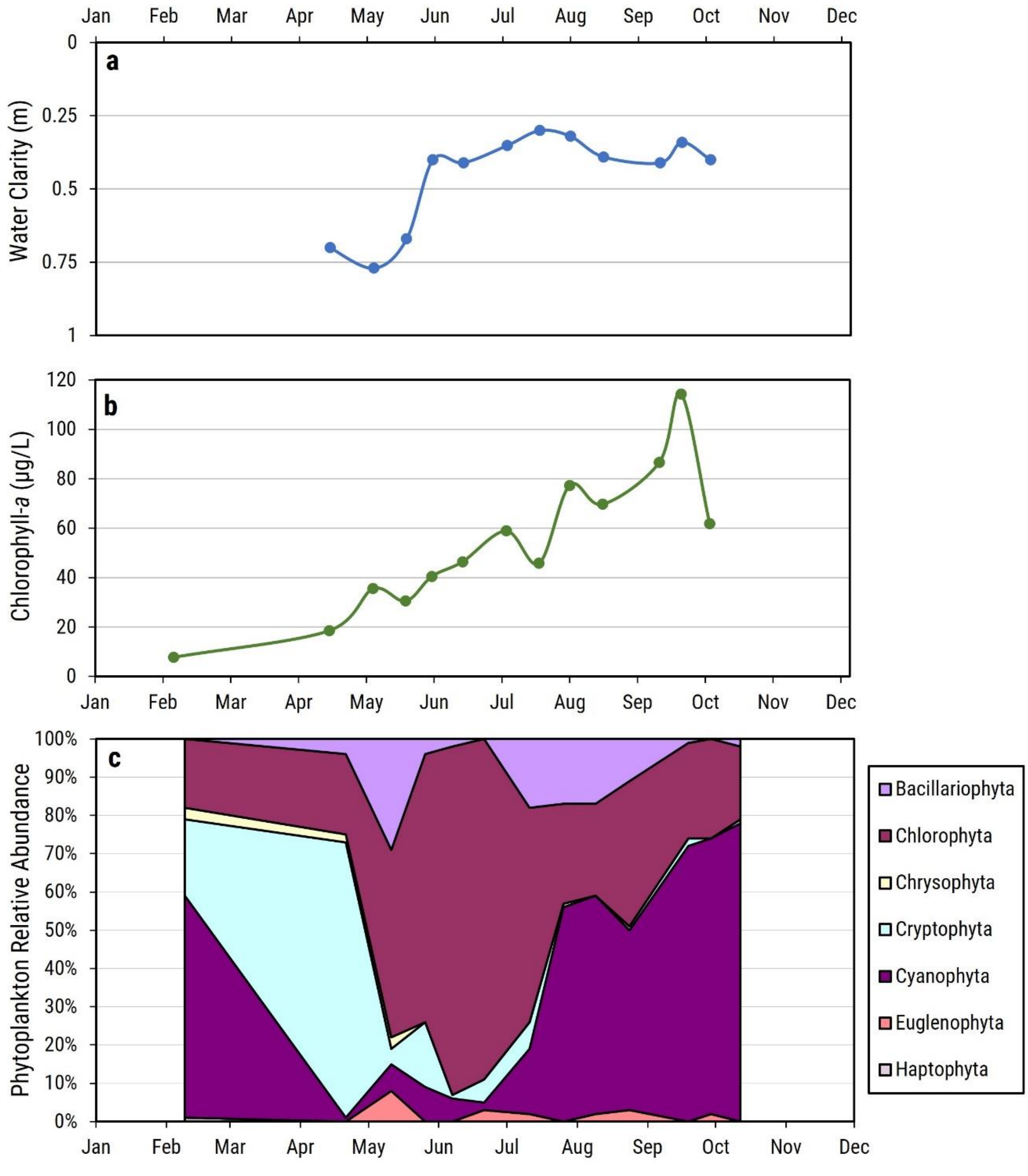


Figure 13-10. Water clarity (a), chlorophyll-*a* concentration (b), and relative abundance of phytoplankton (c) in Powderhorn Lake during 2022. Note that the water clarity axis is reversed.

Zooplankton are tiny animals that feed on phytoplankton and are also vital for the lake community because they form the second level of the food web along with larval fish. **Figure 13-11** shows the zooplankton distribution in Powderhorn Lake sampled throughout 2022. Cladocerans were present throughout most of the sampling season and were most abundant in June. Rotifers were most abundant in April and were present in lower levels throughout the year. Nauplii and juvenile copepods were present in all samples and were most abundant in May. Cyclopoids and protozoa were present in low levels in 2022. Note there was no August sample because the sample bottle was destroyed during transportation.

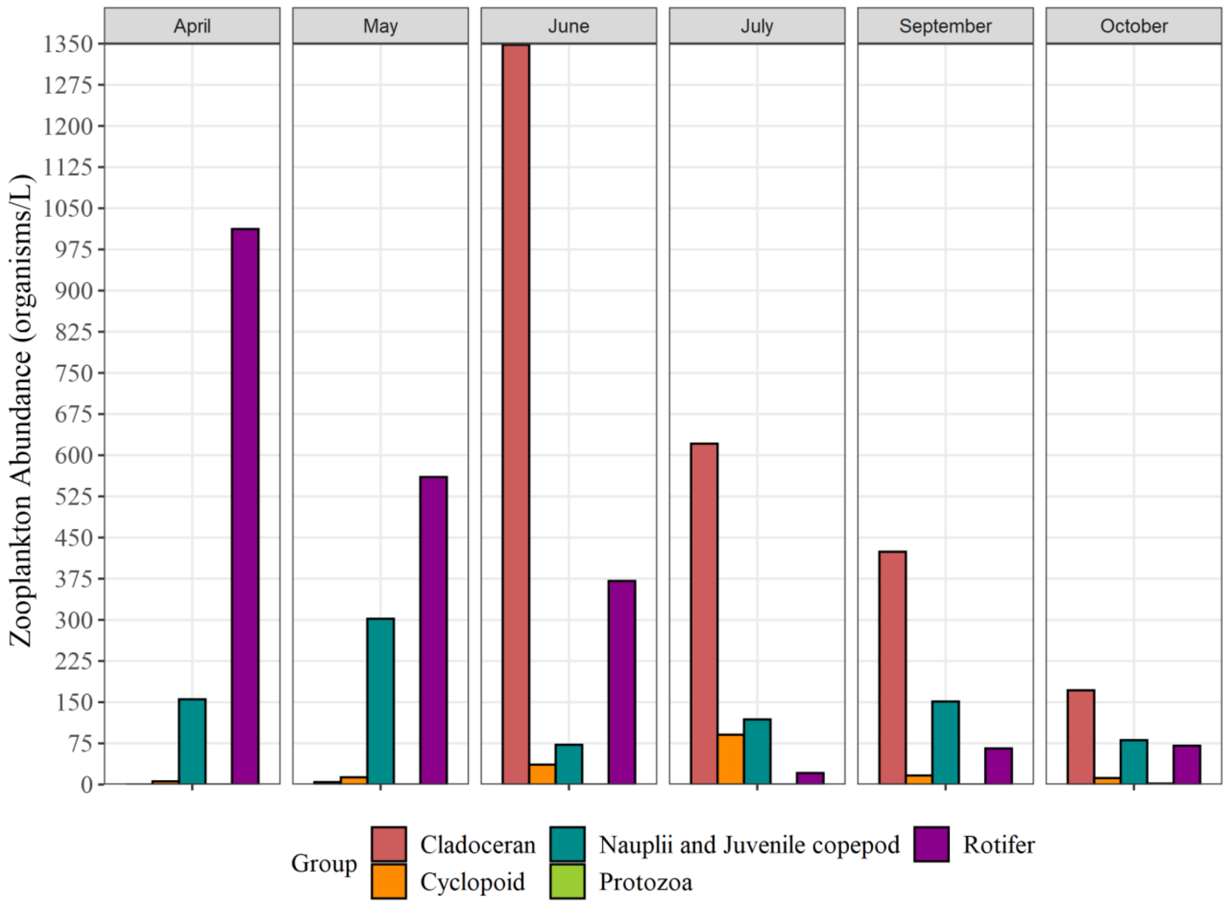


Figure 13-11. Zooplankton density in Powderhorn Lake during 2022.

FISH STOCKING

Powderhorn Lake has been stocked by the MNDNR as a Fishing in the Neighborhood (FiN) lake since 1980. **Table 13-4** shows fish stocked into Powderhorn Lake over the past decade. Black crappie, bluegill sunfish, largemouth bass, and northern pike were stocked into Powderhorn Lake in 2022. Additional fish stocking information can be found in **Chapter 1**.

Table 13-4. Fish stocked into Powderhorn Lake over the past 10 years. Data are from the Minnesota Department of Natural Resources.

Year	Species	Number and Size	Amount
2022	Bluegill	673 adults	58.8 pounds
2022	Black Crappie	576 adults	61.7 pounds
2022	Largemouth Bass	3 adults	2.0 pounds
2022	Northern Pike	20 adults	30.8 pounds
2021	Black Crappie	109 adults	17.4 pounds
2021	Bluegill Sunfish	550 adults	44.0 pounds
2021	Channel Catfish	1,190 fingerlings	15.9 pounds
2021	Northern Pike	28 adults	87.3 pounds
2021	Yellow Perch	135 adults	9.0 pounds
2019	Black Crappie	39 adults	11.8 pounds
2019	Bluegill	982 adults	170.7 pounds
2018	Channel Catfish	800 fingerlings	21.4 pounds
2017	Bluegill	200 adults	62.5 pounds
2016	Bluegill	353 adults	90.5 pounds
2016	Channel Catfish	206 adults	371.2 pounds
2016	Pumpkinseed Sunfish	40 adults	11.8 pounds
2015	Bluegill	300 adults	66.7 pounds
2015	Channel Catfish	251 adults	402.6 pounds
2014	Black Crappie	3 adults	1.0 pounds
2014	Bluegill	346 adults	97.5 pounds
2014	Channel Catfish	173 adults	240.0 pounds
2014	Hybrid Sunfish	4 adults	1.0 pounds
2014	Pumpkinseed Sunfish	4 adults	1.0 pounds

WATER QUALITY PROJECTS

The water quality in Powderhorn Lake appeared to be declining since 2009. There were several theories as to why the water quality declined including the potential unintended impacts of barley straw, the aeration system, and high water level of the lake. To determine if these theories held true, sampling data was analyzed and compared between when these potential factors were and were not present. MPRB tested some of these theories to determine if changes in lake management could have a positive effect on the water quality. See the 2021 Water Resources Report for more information: https://www.minneapolisparks.org/wp-content/uploads/2023/01/2021-Water-Resources-Report-.pdf.

Iron-ceramic Application

Iron has been used for decades to reduce lake phosphate in the water column in lake restoration projects and stormwater treatment. Studies also show that reducing phosphorus could be effective in controlling the growth of cyanobacteria. One potential way to remove phosphorus from Powderhorn could be to use a proprietary iron-ceramic material to bring phosphorus in the water column into contact with iron. In the presence of oxygen, phosphorus attaches, or binds, to the iron-enriched material and is removed from the water column so it can't be released into the water and used as food for cyanobacteria (Funes et al., 2017).

On May 4, 2022, a proprietary iron-ceramic was applied to Powderhorn Lake to attempt to reduce cyanobacteria growth by removing phosphorus from the water column, see **Figure 13-12**. A total of 200 pounds of iron-ceramic material was separated into nine nylon mesh bags. The bags were staked along the shoreline of the lake, with several bags placed near the stormwater outfalls to bind total phosphorus entering the lake from stormwater runoff, see **Figure 13-13**. The iron-ceramic was removed from the lake on October 3, 2022. The material was stored for the winter and can be reused in the future. MPRB monitored total and dissolved iron prior to, during, and after the study period in addition to the regular sampling program to determine if any influence on the lake could be detected, see **Figure 13-14**. There was no significant trend in total or dissolved iron concentrations over the 2022 sampling season in Powderhorn Lake, based on MPRB water quality test results. Also, there was no difference in iron concentrations when the media was in the lake compared to when it was not in the lake.

Cyanobacteria blooms continued to be an issue in Powderhorn Lake between late July and October in 2022. Low precipitation likely impacted the success of the iron-ceramic application because there was minimal water movement across the mesh bags, limiting the amount of phosphorus from binding with the iron. In 2023, MPRB plans to continue using the iron-ceramic in Powderhorn Lake, but the mesh bags will be placed near the summer aeration system to increase water movement across the iron media.

In addition to the iron-ceramic treatment, a fish survey was also conducted on October 4, 2022, to continue monitoring the impacts of fish on the internal loading of nutrients in the lake. Six trapnets were placed throughout Powderhorn Lake for one night. Five fish species were found during the survey, see **Table 13-5**. Results showed a large increase in the bullhead population between 2021 and 2022. The high density of bullheads is likely contributing to excessive cyanobacteria growth in the lake. Bullheads negatively impact water quality by stirring up the bottom sediment which can increase internal phosphorus loading and turbidity in the lake and decrease macrophyte production.

Figure 13-12. Iron-ceramic media in a mesh bag (a) and photo of mesh bags being staked along the shoreline at Powderhorn Lake (b).

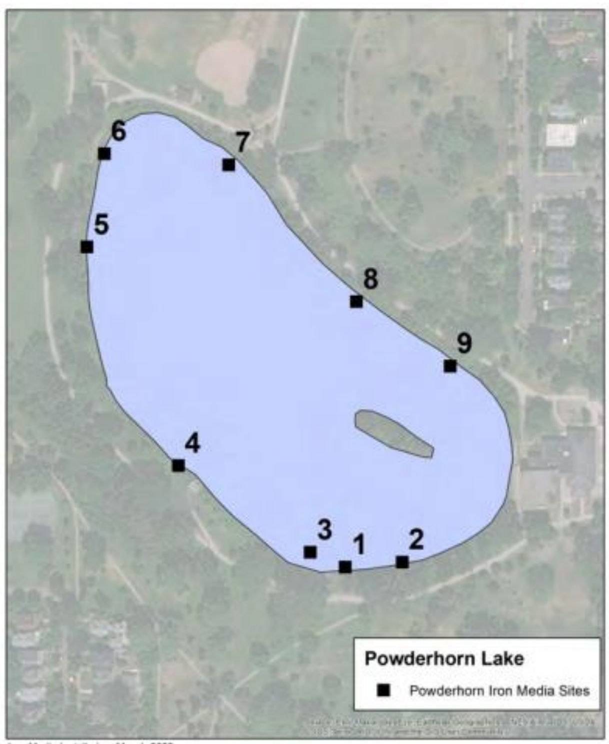
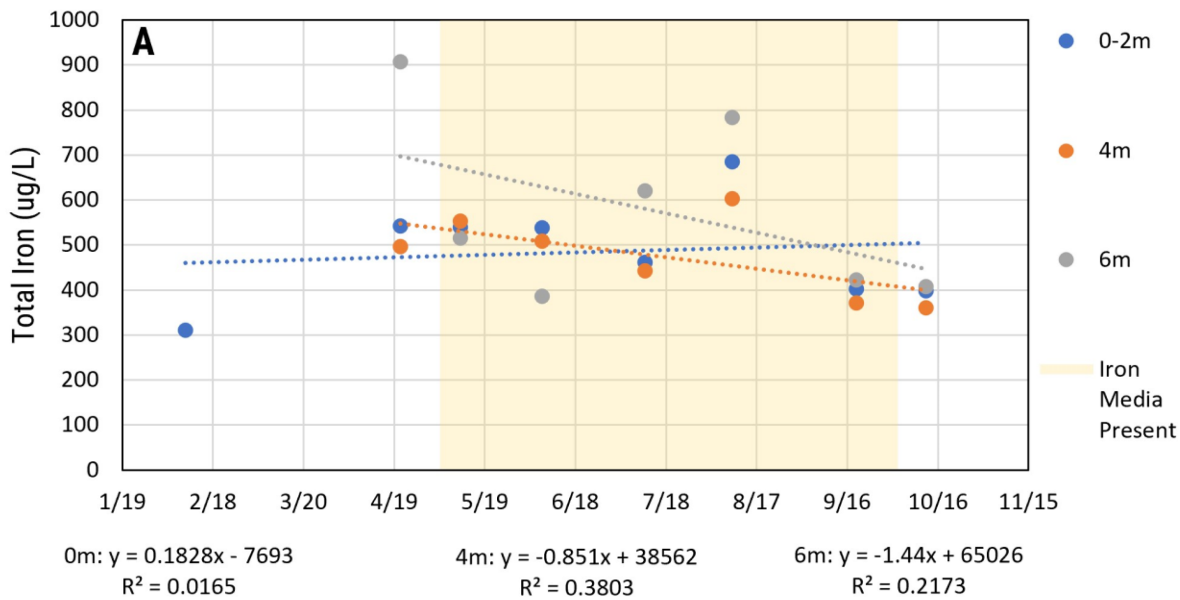


Figure 13-13. Locations where iron-ceramic was staked in Powderhorn Lake in 2022.



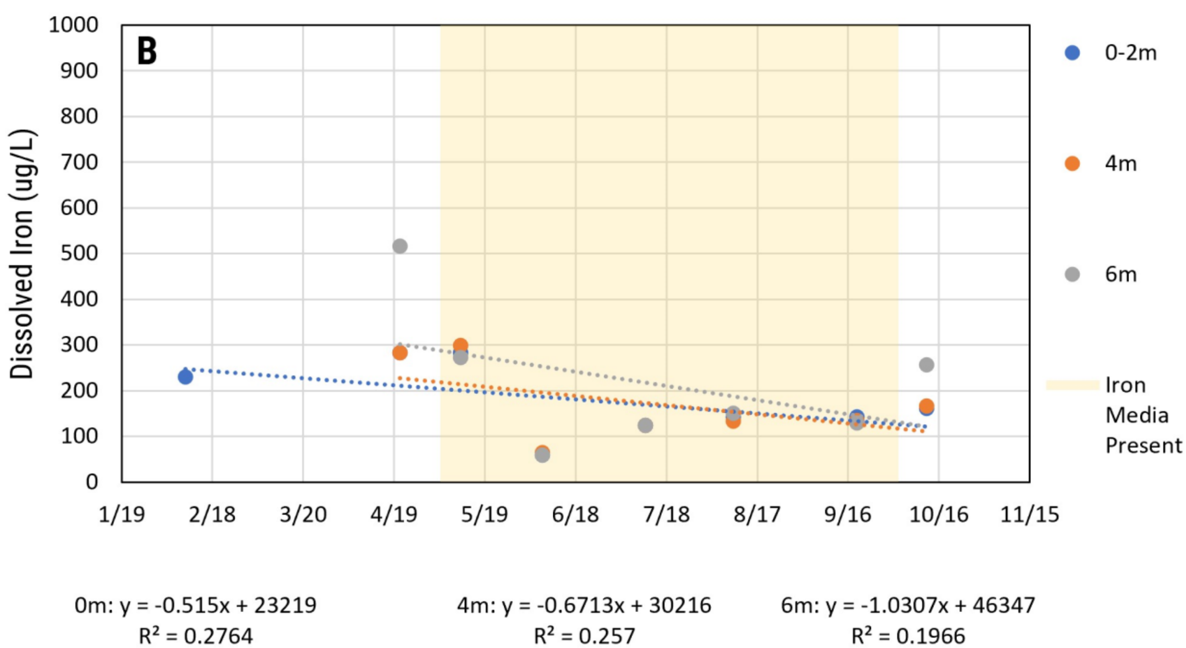


Figure 13-14. Total iron (a) and dissolved iron (b) concentrations in Powderhorn Lake in 2022. Blue circles represent concentrations at 0-2 meters, orange circles represent concentrations at 4 meters, and grey circles represent concentrations at 6 meters. The shaded area represents when the iron media was in the lake.

Table 13-5. Powderhorn Lake trapnet results for fish surveys between 1980 and 2022. Surveys conducted between 1980 and 2016 were conducted by MNDNR and 2021 and 2022 surveys were conducted by Blue Water Science. N = number of trapnets used.

	1980 N=4	1985 N=4	1990 N=4	1995 N=6	2003 N=9	2007 N=9	2016 N=8	2021 N=6	2022 N=6
Black bullhead	1.8	11	0.8	96	28	33	45	449	615
Black crappie	2.3	4.5	1.0	31	25	1.6		16	27
Bluegill	1.0	1.3	0.5	4.0	26	11	21	0.8	1.5
Bowfin					0.1				
Channel catfish							0.4		
Goldfish	0.3	11	1.8	0.8			1.4		
Green sunfish				4.3					
Hybrid sunfish		0.5		2.7	0.1	0.2	0.9	0.7	
Northern pike								0.2	
Pumpkinseed				10	0.6	7.0	0.6	2.8	6.7
White crappie	1.0	2.3	0.3						
Yellow perch								0.7	12

14. Ryan Lake

History

Ryan Lake is a small body of water that borders the cities of Robbinsdale, Brooklyn Center, and Minneapolis. The Canadian Pacific Railway owns a rail line corridor in the Humboldt Industrial Park that runs along the northern shore of the lake. Minneapolis Park and Recreation Board (MPRB) maintains land on the east side of the lake. MPRB installed a new dock on the east side for use by the public in 2006. A small rain garden was constructed in the spring of 2006 and canoe racks were installed in 2018. Private residents own the west and the south shores of Ryan Lake. A photograph of Ryan Lake is presented below in **Figure 14-1**.

Figure 14-1. View of Ryan Lake in November 2022.

Ryan Lake is a deep, mesotrophic lake that has relatively good water quality. **Table 14-1** shows the physical characteristics and morphometric data of Ryan Lake and **Figure 14-2** shows a bathymetric map of the lake. Ryan Lake is part of the Shingle Creek Watershed and the primary land-use surrounding the lake is residential and mixed-use.

Ryan Lake receives water from Lower Twin Lake and discharges into Shingle Creek. Ryan Lake has been monitored periodically through the Metropolitan Council's Citizen Assisted Monitoring Program (CAMP) since 1994 and was last monitored in 2020. Over the years, the Ryan Lake CAMP score has fluctuated between a "B" and "D", with a most recent score of a "B" in 2020. Additional information on the CAMP monitoring at Ryan Lake can be found through the Metropolitan Council webpage https://metrocouncil.org/Wastewater-Water/Services/Water-Quality-Management/Lake-Monitoring-Analysis/Citizen-Assisted-Monitoring-Program.aspx or the Shingle Creek Watershed Management Commission webpages http://www.shinglecreek.org/commissions.html.

Ryan Lake was previously listed on the Minnesota Pollution Control Agency (MPCA) list of impaired waters (303(d) list) for excess nutrients. A total maximum daily load (TMDL) and an implementation plan were approved in 2007 along with the Twin Lake chain of lakes in St. Louis Park. In the five years following, multiple projects focused on reducing phosphorus loading from the watershed http://www.shinglecreek.org/tmdls.html. Ryan Lake was delisted in 2014 because the nutrient load from the watershed was greatly reduced due to restoration efforts and applicable water quality standards were attained. According to the Minnesota Statewide Chloride Management Plan, Ryan Lake is also at high risk for chloride impairment (MPCA, 2018). Ryan Lake receives extra nutrients from stormwater and from internal loading from sediment, aquatic vegetation, and rough fish. The focus over the next few years will be on controlling rough fish and invasive aquatic vegetation. More information can be found on the MPCA webpage under the Twin and Ryan Lakes - Excess Nutrients TMDL Project https://www.pca.state.mn.us/sites/default/files/wq-iw8-05e.pdf. Ryan Lake has experienced several winter fish kills due to low dissolved oxygen levels.

The Twin Lake chain includes four lakes: Upper, Middle, and Lower Twin Lakes and Ryan Lake. Upper Twin Lake contributes substantial load to downstream lakes including Ryan Lake, thus improvements in the upper chain should result in improvements in the lower chain. Between 2015 and 2019 a carp management project was done on Twin Lake to reduce the carp population in order to reduce phosphorus loading and improve water quality in the chain. The project was successful in removing nearly half the estimated biomass of common carp in the Twin Lake chain. A fish barrier was installed on the weir of Ryan Creek to prevent carp from recolonizing and spawning in Ryan Lake and Shingle Creek (Wenck, 2019).

Table 14-1. Ryan Lake physical characteristics and morphometric data. (msl = mean sea level)

Surface Area (acres)	Max Depth (ft)	Littoral Area*	Watershed Area (acres)	Watershed: Lake Area (ratio)	OHWL (ft msl)
19	36.0	51%	5,510	306	849.6

* Littoral area was defined as less than 15 feet deep.

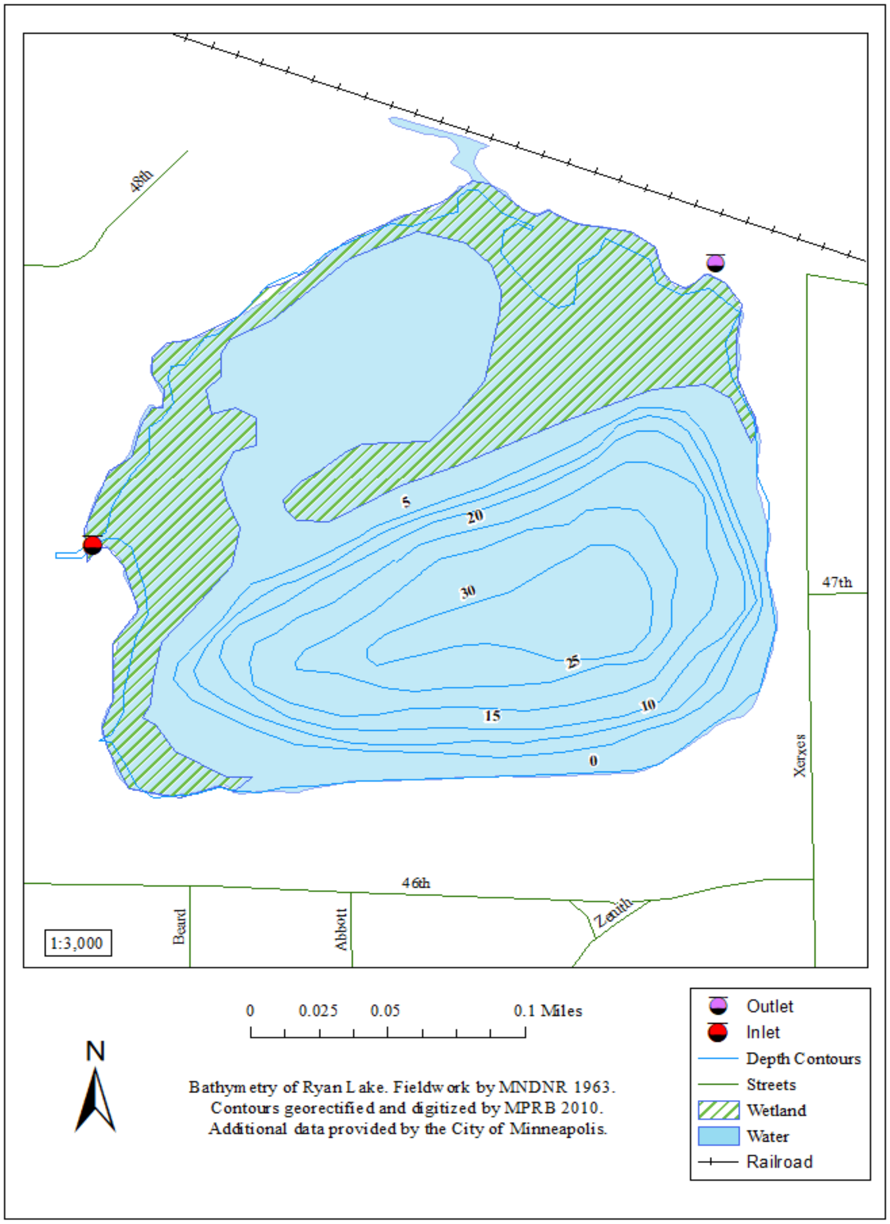


Figure 14-2. Bathymetric map of Ryan Lake.

Winter Ice Cover

Ice came off of Ryan Lake on April 8, 2022, four days later than the average. Ice came back on Ryan Lake on November 30, 2022, seven days earlier than the average ice-on date. See **Chapter 1** for details on winter ice cover records and **Chapter 17** for a comparison with other lakes.

Events Report

On April 24, 2022, MPRB Maintenance staff reported several dozens of dead carp on Ryan Lake. Maintenance staff sent photos of the dead fish to Water Quality staff who also identified the fish as carp. Maintenance staff removed the dead fish and Water Quality staff completed an Incident Report describing the fish kill event. Low dissolved oxygen concentrations during the winter were likely the cause of the fish kill event because ice-off had recently occurred and it appeared that the fish had been dead for some time when they were discovered. See the fish kill section in **Chapter 1** for additional details.

Fish Stocking

Ryan Lake is stocked with fish by the Minnesota Department of Natural Resources (MNDNR) as part of the Fishing in the Neighborhood (FiN) program. **Table 14-2** shows fish stocked into Ryan Lake over the past decade. Bluegill sunfish were stocked in Ryan Lake in 2022. Additional information on fish stocking can be found in **Chapter 1**.

Table 14-2. Fish stocked into Ryan Lake over the past 10 years. Data are from the Minnesota Department of Natural Resources.

Year	Species	Number and Size	Amount
2022	Bluegill	450 adults	39.0 pounds
2021	Bluegill	209 adults	40.0 pounds
2019	Bluegill	308 adults	49.9 pounds
2018	Walleye	50,000 fry	0.6 pounds
2017	Northern Pike	16 adults	24.6 pounds
2014	Black Crappie	9 adults	4.0 pounds
2014	Bluegill	14 adults	1.8 pounds
2014	Largemouth Bass	3 adults	5.0 pounds
2014	Northern Pike	9 adults	3.0 pounds
2014	Pumpkinseed Sunfish	15 adults	2.7 pounds
2014	White Crappie	5 adults	4.0 pounds
2013	Yellow Perch	130 yearlings	5.0 pounds

15. Spring Lake

History

Spring Lake was acquired by the Minneapolis Park and Recreation Board (MPRB) in 1893 through a special assessment requested by citizens. Spring Lake Park is located to the west of Loring Pond adjacent to Kenwood Parkway and the Parade Stadium grounds in central Minneapolis. Today the lake appears secluded, but at the time of purchase, Spring Lake was the park's focal point. In an unusual move for the time, the area including the lake and surrounding land was designated as a bird sanctuary and kept undeveloped. Historic photos and documents show that the north side of the lake was once a railroad yard. A photograph of Spring Lake is presented below in **Figure 15-1**.

Figure 15-1. View of Spring Lake in October 2021.

Spring Lake is small, protected meromictic lake. Meromictic lakes do not mix completely so that the deeper layers of the lake remain continually stratified. It is difficult to compare meromictic lakes with dimictic or polymictic lakes, since their chemical, physical, and trophic structures are much different. Spring Lake is very sheltered from the wind and is deep for its size. These two factors also contribute to the unusual chemical structure of the lake. **Table 15-1** shows the physical characteristics and morphometric data of the lake and **Figure 15-2** shows a map of Spring Lake. Despite being surrounded by parkland on three sides, Spring Lake receives runoff from the urbanized area around it. Highway 394 borders the northwest portion of the riparian zone and contributes stormwater runoff to the lake. Spring

Lake also receives water from a 195-acre subwatershed of the Bassett Creek watershed. There are three stormwater outfalls surrounding Spring Lake, see **Appendix C**.

Spring Lake was added to the MPRB lake sampling program in 1995. It is typically sampled every other year and was not monitored in 2022. The lake was sampled each year from 2011-2015 to attempt to assess potential water quality effects of several artificial islands that were installed.

Table 15-1. Spring Lake physical characteristics and morphometric data. (msl = mean sea level)

Surface Area (acres)	Mean Depth (ft)	Max Depth (ft)	Volume (ft^3)	Watershed Area (acres)	Watershed: Lake Area (ratio)	OHWL (ft msl)
3	9.8	27.9	$1.29x10^6$	45	15.0	820.46

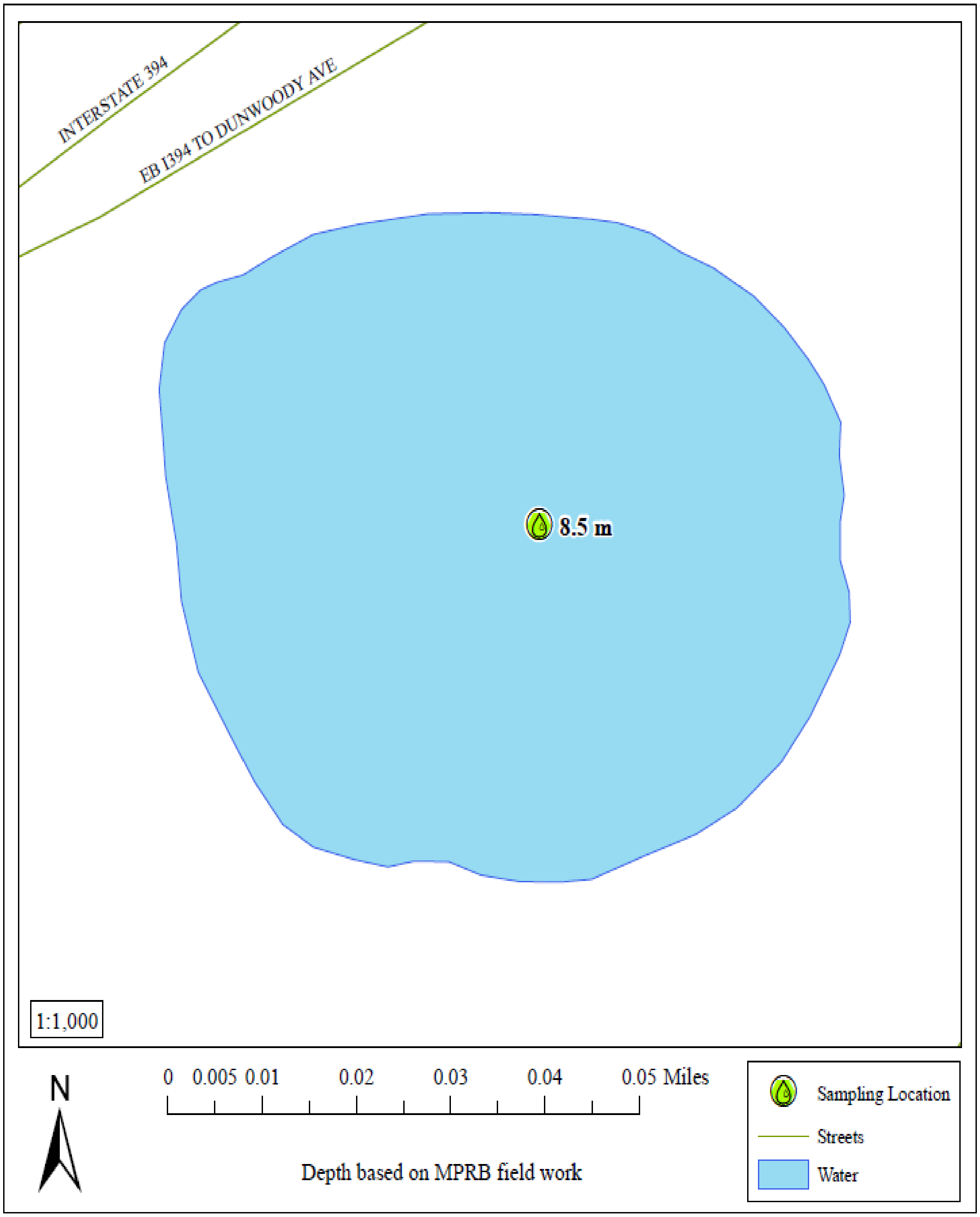


Figure 15-2. Map with mid-lake sampling site at Spring Lake.

Water Quality Trends – Trophic State Index (TSI)

Figure 15-3 shows historical Spring Lake TSI scores and trend. There is no significant trend in TSI from 1995-2021 ($p > 0.05$). Spring Lake is sampled less frequently than other MPRB lakes, and its sampling schedule has changed several times. From 1999–2001, samples were collected quarterly and only one sample per year was collected during the growing season; therefore, a TSI score could not be calculated. From 2002-2010, samples were collected monthly every other year. From 2011-2015, samples were collected monthly every year. Since 2016, samples have been collected monthly every other year. The TSI score for Spring Lake in 2021 was 78, classifying the lake as hypereutrophic.

Secchi, chlorophyll-*a*, and total phosphorus TSI scores for Spring Lake are above the TSI range for the ecoregion. This means water clarity is shallower and chlorophyll-*a* and total phosphorus levels in Spring Lake are higher than in comparable lakes in the ecoregion; however, it may be more reasonable to compare Spring Lake with other meromictic lakes, see **Table 15-2**. For more information see Minnesota Pollution Control Agency (MPCA) Surface Water Data (https://webapp.pca.state.mn.us/wqd/surface-water/waterunit-details?wid=27-0654-00). A detailed explanation of TSI can be found in **Chapter 1**.

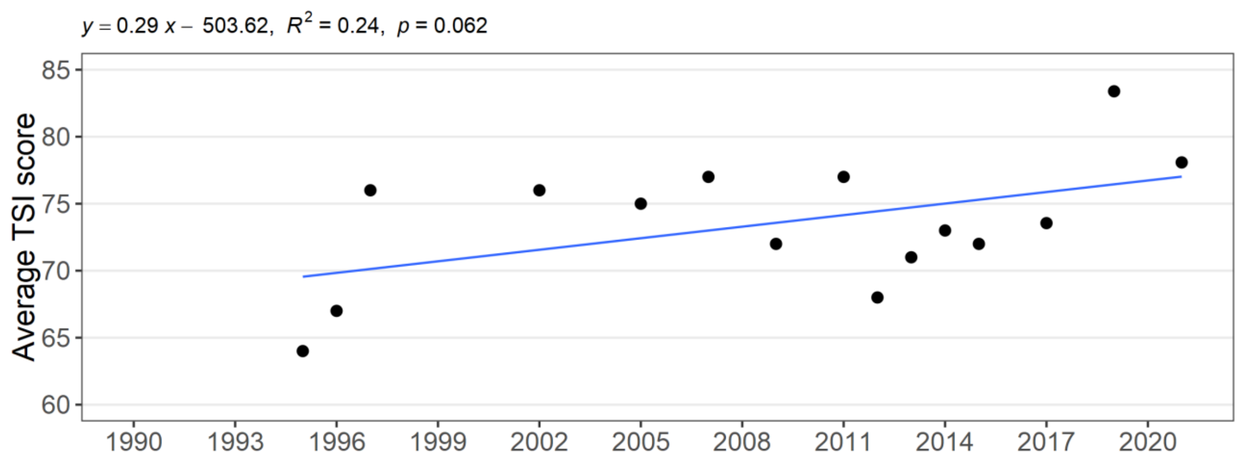


Figure 15-3. Spring Lake TSI scores and linear regression from 1995-2021.

Table 15-2. Spring Lake Secchi, chlorophyll-*a*, and total phosphorus TSI based on data collected between June and September of 2021 and comparison to lakes in the same ecoregion.

	TSI	Expected TSI Range of Lakes in the Same Ecoregion	Within the Expected TSI Range of Lakes in the Same Ecoregion
Secchi	62	43-54	Not within range, worse than expected
Chlorophyll-*a*	82	46-61	Not within range, worse than expected
Total Phosphorus	94	49-61	Not within range, worse than expected

Box and Whisker Plots

The box and whisker plots in **Figure 15-4** show the data distribution for water clarity, chlorophyll-*a*, and total phosphorus between 2012 to 2021, based on data from the entire sampling season. Red horizontal lines on the graphs indicate the MPCA eutrophication standards for shallow lakes, which applies to data collected between June and September. The 303(d) assessment for eutrophication factors is limited to lakes of ten acres or greater (MPCA, 2014); therefore, at three acres in size, Spring Lake is too small to be assessed, but it is still useful to compare Spring's data to the shallow lake standards to assess lake water quality. A detailed explanation of box and whisker plots can be found in **Chapter 1**. Box and whisker plots from the entire period of record, 1994-2021, can be found in **Appendix A**.

Water clarity in 2021 was similar to previous years with an average Secchi depth of 1.07 meters. Chlorophyll-*a* concentrations ranged between 1.47 and 298 µg/L with higher concentrations in spring, August, and September. Historically, total phosphorus concentrations have been high in Spring Lake. In 2021 phosphorus levels had an average of 569 µg/L, which far exceeds the MPCA standard. Since 2011, duckweed (*Lemna spp.*) has covered the lake for much of the summer. The thick layer of duckweed can shade photosynthetic algae and create low dissolved oxygen levels as algae decomposes. The fresh oxygenated layer that typically forms on the surface of Spring Lake was very thin to non-existent in 2021 due to excessive algae growth caused by high concentrations of phosphorus. As the algae die and decompose, the process consumes dissolved oxygen.

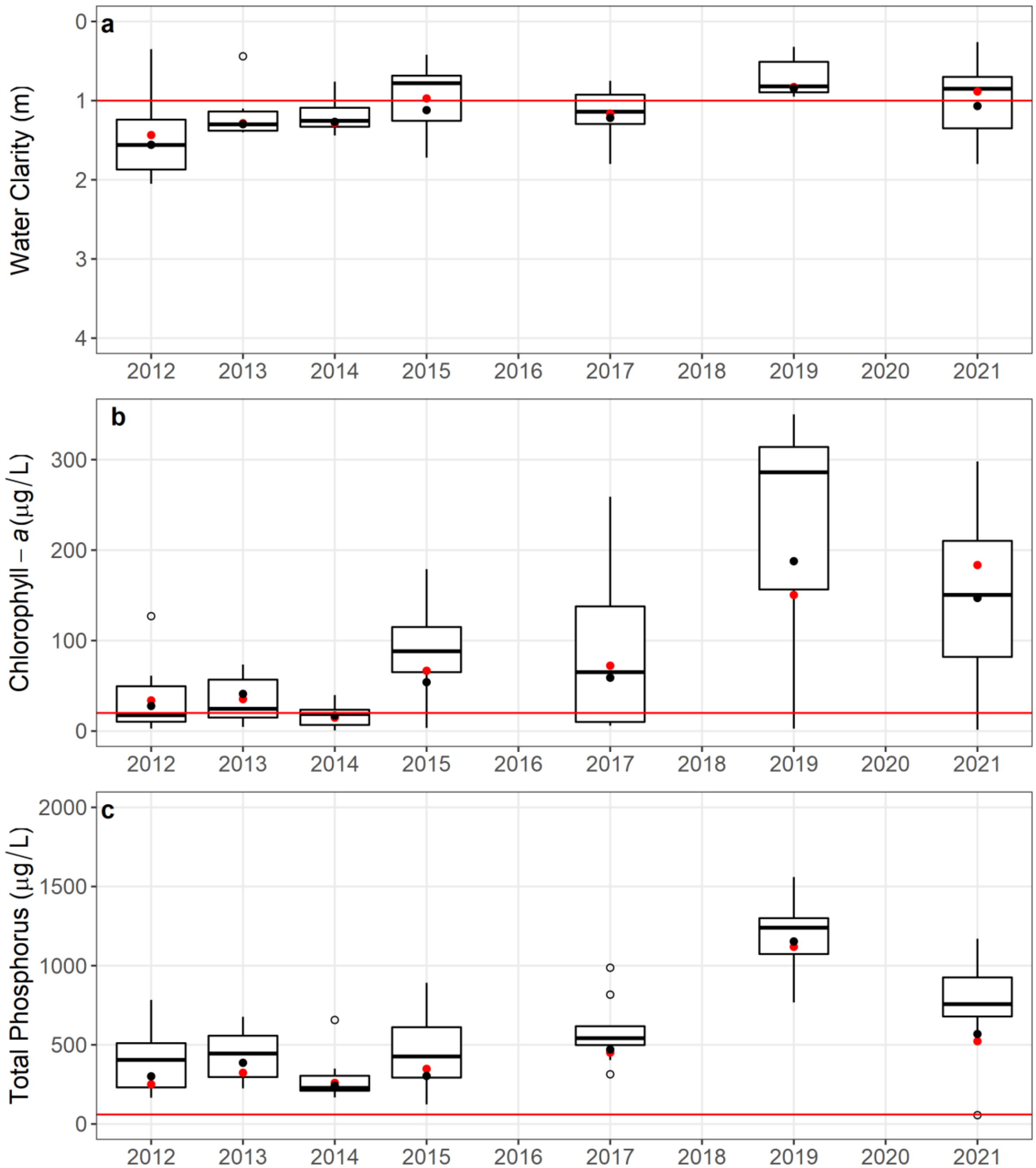


Figure 15-4. Spring Lake box and whisker plots of water clarity (a), chlorophyll-*a* (b), and total phosphorus (c), from 2012-2021. Horizontal lines represent MPCA eutrophication standard for shallow lakes, which applies to data collected between June and September. The red circles represent the mean value of data collected between June and September. The black circles represent the mean value of data collected during the growing season, May through September. Data from 1994-2021 can be found in Appendix A.

CHLORIDE

Chloride is a naturally occurring element that is commonly found at low levels in most freshwater bodies. Chloride is a component of road salt (sodium chloride) and is found in other types of compounds that are also called salts (calcium chloride, magnesium chloride). Unnaturally high concentrations of chloride can negatively impact surface waters. High levels of chloride can change the mixing pattern of a lake and lead to very low oxygen levels in deep water. It can also lead to decreasing water clarity and induce stress or cause death of aquatic species (Bathe & Coring, 2011). Sources of chloride include industrial discharge, septic systems, sewage disposal systems, fertilizers, and road salt (Novotny, Murphy, & Stefan, 2008). The MPCA adopted the Environmental Protection Agency's (EPA) recommended water quality criteria for chloride which is a chronic standard of 230 mg/L and an acute standard of 860 mg/L (MPCA, 2016). The MPRB has monitored chloride concentrations in Spring Lake since 1995 by collecting surface water samples using a composite tube and collecting deep water samples using a Kemmerer sampler. See **Chapter 1** for more information on chloride.

Figure 15-5 shows epilimnetic and hypolimnetic chloride concentrations in Spring Lake between 1995-2021, with hypolimnion samples only collected regularly after 2002. Epilimnion samples represent the top two meters of the lake and hypolimnion samples were collected approximately one meter from the bottom of the lake. Red horizontal lines on the graph indicate the MPCA acute and chronic chloride standards. Also included on the graph is a dotted line that represents an estimate of a concentration above which potential ecological impact could occur, at 120 mg/L. This level of potential ecological impact was developed by the Canadian Council of Ministries of the Environment (CCME) and is not a Minnesota state standard but a long-term chloride concentration that could negatively impact life within the lake (CCME, 2011). Epilimnetic chloride concentrations slowly increased from 1995, when concentrations slightly exceeded the chronic standard, to 2011, when concentrations well exceeded the acute standard. Epilimnetic concentrations decreased between 2011-2017 and have been increasing since then with chloride concentrations below or around the acute standard in 2021. Hypolimnetic chloride levels are much higher than epilimnetic levels because Spring Lake is meromictic and water containing sodium chloride is dense and sinks to the lake bottom. Hypolimnetic concentrations have been increasing since 2002, except for 2017 and 2019 when concentrations slightly decreased. Almost all chloride measurements in Spring Lake deep water samples exceed the acute standard and almost all surface water samples exceed the chronic standard. Spring Lake was added to the MPCA's list of impaired waters (303(d) list) in 2014 due to high chloride concentrations.

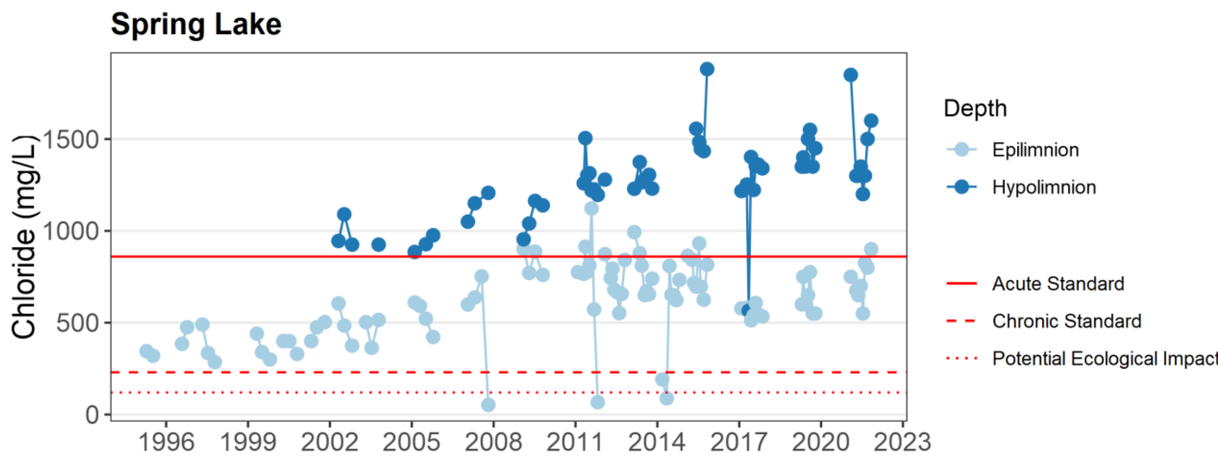


Figure 15-5. Spring Lake scatterplot of epilimnetic and hypolimnetic chloride concentrations between 1995-2021. Horizonal lines represent the MPCA's acute and chronic standard and the potential ecological impact level (CCME, 2011).

Winter Ice Cover

The ice came off Spring Lake on April 4, 2022, 3 days later than the average ice-off. Ice covered Spring Lake on November 30, 2022, one day later than the average ice-on date for the lake. See **Chapter 1** for details on winter ice cover records and **Chapter 17** for a comparison with other lakes.

Phytoplankton and Zooplankton

Phytoplankton are microscopic plant life that form the foundation of the food web in lakes. Chlorophyll-*a* is the main pigment used by phytoplankton for photosynthesis and can be used as a proxy for the density of phytoplankton growth. **Figure 15-6** shows the water clarity, chlorophyll-*a* concentrations, and relative abundance of phytoplankton divisions for Spring Lake in 2021. Although zooplankton weren't sampled, observations of surface water noted bright red zooplankton on several occasions. Certain zooplankton can produce a red substance similar to hemoglobin that is used to store oxygen when zooplankton live in low-oxygen environments.

Water clarity and chlorophyll-*a* concentrations in Spring Lake are related. In May when water clarity was deepest at 1.8 meters, chlorophyll-*a* levels were lowest at 1.47 µg/L. Water clarity continued to get shallower throughout the year with the shallowest reading in the fall at 0.26 meters. Chlorophyll-*a* concentrations continued to increase throughout the year, peaking in September at 298 µg/L, and decreased again in the fall, see **Figure 15-6a, b**.

The phytoplankton community in Spring Lake primarily consisted of cryptomonads (Cryptophyta) in 2021. Green algae (Chlorophyta) were abundant in May. Diatoms (Bacillariophyta), golden-brown algae (Chrysophyta), blue-green algae (Cyanophyta), and dinoflagellates (Pyrrophyta) were also present in small numbers, see **Figure 15-6c**. In past sampled years, Spring Lake has had a diverse phytoplankton community; however, the community has consisted of mostly *C. erosa*, a species of Cryptophyta, since 2011. Duckweed (*Lemna)* cover in recent years may be affecting the phytoplankton community composition, since *C. erosa* can survive in low light conditions.

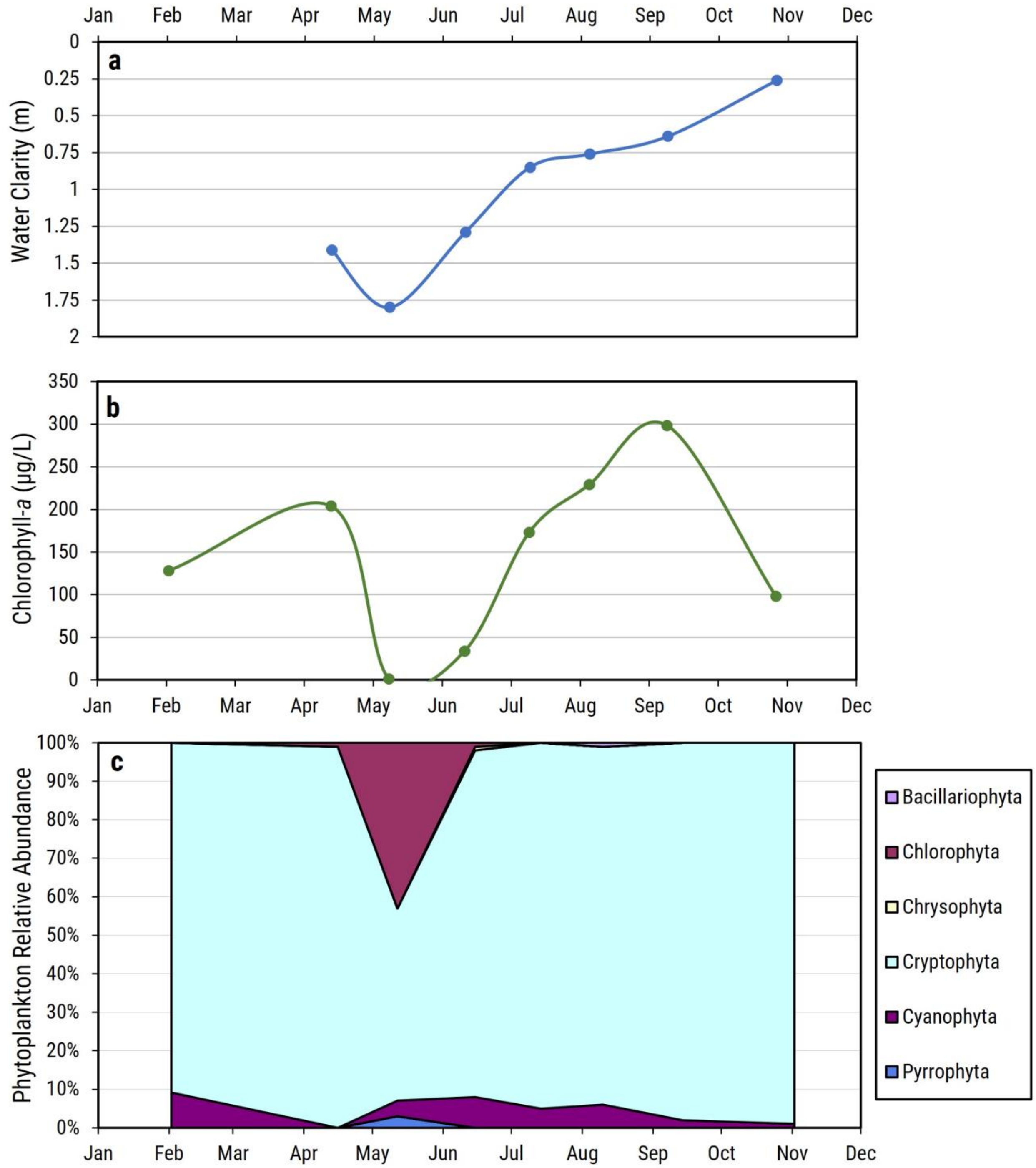


Figure 15-6. Water clarity (a), chlorophyll-*a* concentration (b), and relative abundance of phytoplankton (c) in Spring Lake during 2021. Note that the water clarity axis is reversed.

16. Wirth Lake

History

Wirth Lake was acquired by the Minneapolis Park and Recreation Board (MPRB) in 1909. It was originally known as Keegan's Lake and renamed to Glenwood Lake in 1890. The lake was renamed yet again in 1938 after Theodore Wirth at the end of his tenure as Park Superintendent. As with most other MPRB lakes, thousands of cubic yards of sediment from Wirth were dredged. The spoils were used to raise the parkland near Glenwood Avenue. Wirth Lake Beach was constructed with sand purchased from sources outside of the MPRB. The lake is shown below in **Figure 16-1**.

Figure 16-1. Wirth Lake in October 2022.

Wirth Lake is generally dimictic but can mix during extreme circumstances in the summer such as strong winds, excessive stormwater inflow, and Bassett Creek backflowing to the lake (Barr, 2010). **Table 16-1** shows the physical characteristics and morphometric data of Wirth Lake and **Figure 16-2** shows a bathymetric map. Wirth Lake is part of Bassett Creek Watershed, and the primary land-use of the surrounding area is residential and parkland. There are five stormwater outfalls on Wirth Lake, see **Appendix C**.

Wirth Lake receives water from a pond system to the west and wetland system on the southeast side of the lake, and discharges water to Bassett Creek. Attempts in restoring Wirth Lake began in 1977 when a chemical called rotenone was used to remove rough fish from the lake. Subsequently the lake was stocked with channel catfish, largemouth bass, walleye, and bluegills. A new outlet was installed in

1978. A summer aerator was installed and operated from the early 1980s until 1991 when it was deemed unnecessary and was abandoned. In 1996, a weir was installed at the outlet. A portable winter aerator was used for a few years before a permanent aeration system was installed on the northwest corner of Wirth Lake in 2002. In 2010, a Total Maximum Daily Load (TMDL) study began after Wirth Lake was added to the Minnesota Pollution Control Agency's (MPCA) list of impaired waters (303(d) list) in 2002 due to excess nutrients. The wasteload allocation represented a 45% reduction in phosphorus load to Wirth Lake, which was to be achieved by reducing backflow from Bassett Creek at the outlet during high creek flow events. In 2013, the outlet structure was renovated to reduce backflow events by installing two collapsible check valves and a trash rack; a new lake gage was also installed. Wirth lake was removed from the impaired waters list in 2014 due to restoration activities.

Water quality on Wirth Lake has been monitored annually since 1992.

Table 16-1. Wirth Lake physical characteristics and morphometric data.

Surface Area (acres)	Mean Depth (ft)	Max Depth (ft)	Littoral Area*	Volume (ft^3)	Watershed Area (acres)	Watershed: Lake Area (ratio)
40	14.1	25.0	58%	2.37×10^7	348	9.4

* Littoral area was defined as less than 15 feet deep.

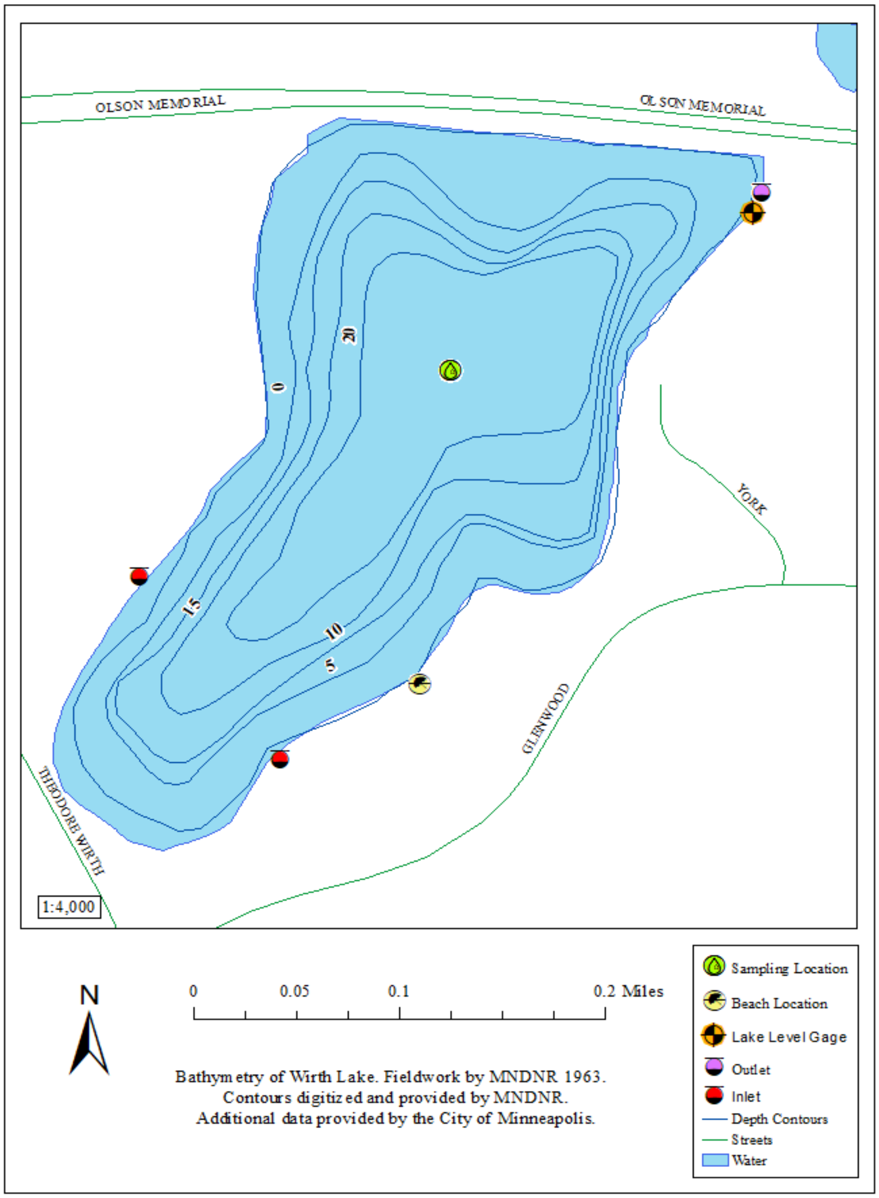


Figure 16-2. Bathymetric map with mid-lake sampling site, beach, lake level gage, outlet, and inlet locations at Wirth Lake.

Lake Level

The lake levels for Wirth Lake from 1971 to 2022 are shown in **Figure 16-3**. The Ordinary High Water Level (OHWL), designated by the Minnesota Department of Natural Resources (MNDNR), for Wirth Lake is 818.9 feet above mean sea level (msl). The effects of the outlets installed in 1978 and in 1996 on water level fluctuations can be seen in the graph below. The installation of the 1996 outlet led to fewer events backing up water from Bassett Creek into the lake. In response to the TMDL study, two check valves and a trash rack were installed at the outlet in 2013 to reduce backflow from Bassett Creek and decrease the external phosphorus load. Lake levels remained below the OHWL for all of 2022 and froze below the OHWL in November. See **Chapter 1** for details on lake level monitoring and **Chapter 17** for a comparison between other MPRB lake levels.

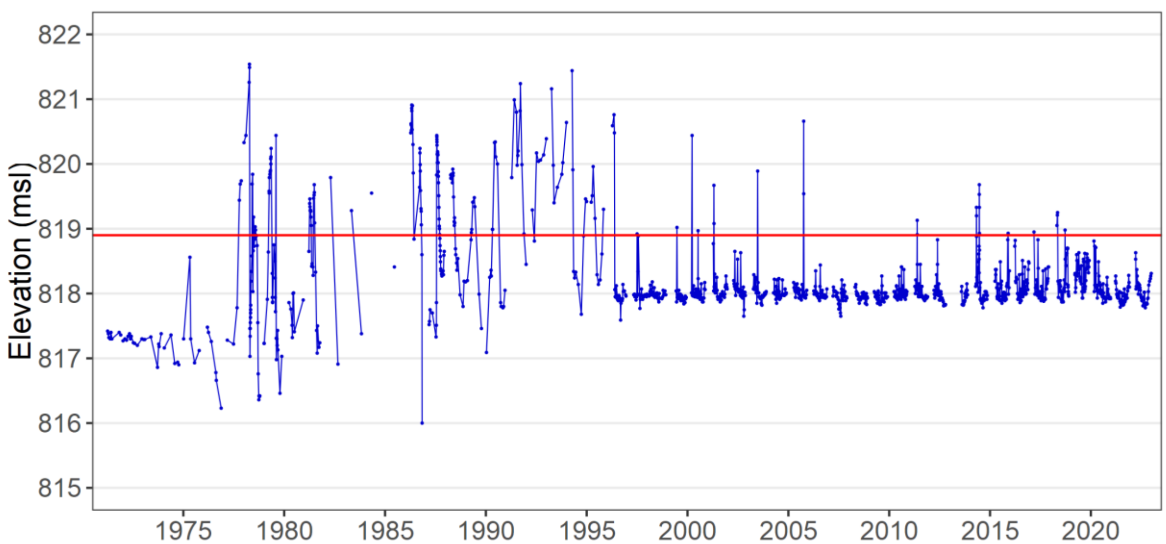


Figure 16-3. Lake levels for Wirth Lake from 1970–2022. Horizontal line represents the Ordinary High Water elevation (818.9 ft msl) for Wirth Lake.

Water Quality Trends – Trophic State Index (TSI)

Figure 16-4 shows historical Wirth Lake TSI scores and trend line. There has been a significant decrease in TSI score from 1992-2022 (p < 0.05), indicating improving water quality. The TSI score for Wirth Lake in 2022 was 48, classifying the lake as mesotrophic, which is defined has having moderately clear water and increasing probability of hypolimnetic anoxia during summer.

Secchi and chlorophyll-*a* TSI scores for Wirth Lake are within the expected TSI range for lakes in the same ecoregion, see **Table 16-2**. The total phosphorus TSI score was below the TSI range for the ecoregion, meaning total phosphorus levels in Wirth Lake are lower than in comparable lakes. See MPCA Surface Water Data (https://webapp.pca.state.mn.us/wqd/surface-water/waterunit-details?wid=27-0037-00) for more information. A detailed explanation of TSI can be found in **Chapter 1**.

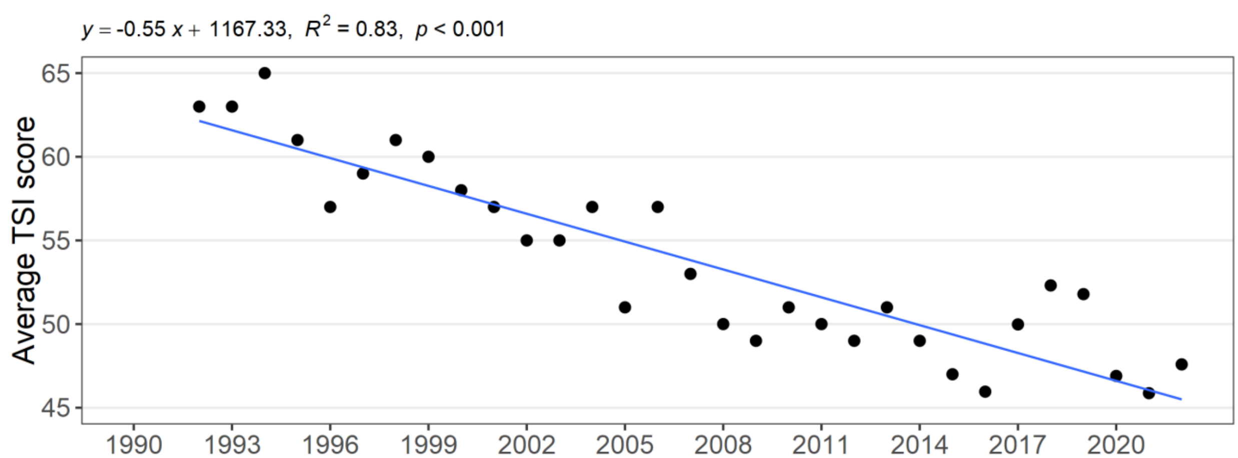


Figure 16-4. Wirth Lake TSI scores and linear regression from 1992-2022.

Table 16-2. Wirth Lake Secchi, chlorophyll-*a*, and total phosphorus TSI based on data collected between June and September of 2022 and compared to lakes in the North Central Hardwood Forest ecoregion.

	TSI	Expected TSI Range of Lakes in the Same Ecoregion	Within the Expected TSI Range of Lakes in the Same Ecoregion
Secchi	43	43-54	Within range
Chlorophyll-*a*	50	46-61	Within range
Total Phosphorus	48	49-61	Not within range, better than expected

Box and Whisker Plots

The box and whisker plots in **Figure 16-5** show the data distribution for water clarity, chlorophyll-*a*, and total phosphorus for the past 10 years, based on data from the entire sampling season. Red horizontal lines on the graphs indicate the MPCA eutrophication standards for deep lakes, which applies to data collected between June and September. A detailed explanation of box and whisker plots can be found in **Chapter 1**. Box and whisker plots from the entire period of record, 1992-2022, can be found in **Appendix A**.

Water clarity has been relatively consistent over the past 10 years with an average Secchi depth of 3.1 meters in 2022, see **Figure 16-5a**. Chlorophyll-*a* concentrations were lower than 2017-2019 levels and comparable to other years with an average concentration of 6.4 µg/L, see **Figure 16-5b**. Total phosphorus concentrations have been relatively consistent since 2020 and slightly lower than previous years with an average of 25 µg/L in 2022. Higher concentrations of total phosphorus occurred in spring and late May, see **Figure 16-5c**. The lake met MPCA eutrophication standards for water clarity, chlorophyll-*a*, and total phosphorus in 2022. When comparing data from the last 10 years, seen in **Figure 16-5**, to older data found in **Appendix A**, it appears the separation of Bassett Creek from Wirth Lake in 1996 and upstream water quality improvements in the lake's watershed may be responsible for continued improvement in Wirth Lake. The 2013 outlet renovations were intended to reduce backflow events from Bassett Creek and reduce external phosphorus loading; however, water quality improvements are likely not seen over the past ten years due to high precipitation events since 2014.

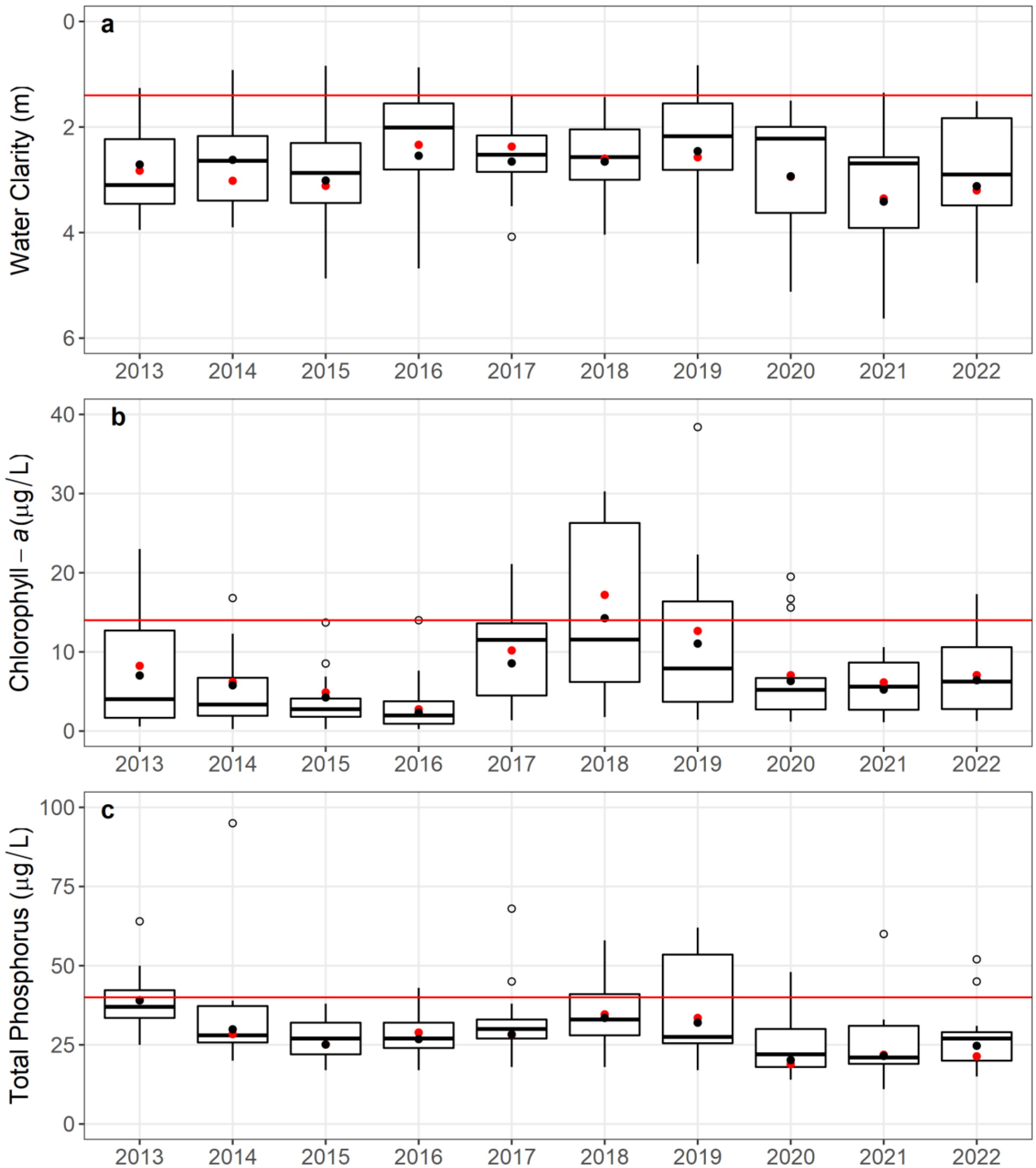


Figure 16-5. Wirth Lake box and whisker plots of water clarity (a), chlorophyll-*a* (b), and total phosphorus (c) data from 2013-2022. Horizontal lines represent MPCA eutrophication standard for deep lakes, which applies to data collected between June and September. The red circles represent the mean value of data collected between June and September. The black circles represent the mean value of data collected during the growing season, May through September. Data from 1992-2022 can be found in Appendix A.

CHLORIDE

Chloride is a naturally occurring element that is commonly found at low levels in most freshwater bodies. Chloride is a component of road salt (sodium chloride) and is found in other types of compounds that are also called salts (calcium chloride, magnesium chloride). Unnaturally high concentrations of chloride can negatively impact surface waters. High levels of chloride can change the mixing pattern of a lake and lead to very low oxygen levels in deep water. It can also lead to decreasing water clarity and induce stress or cause death of aquatic species (Bathe & Coring, 2011). Sources of chloride include industrial discharge, septic systems, sewage disposal systems, fertilizers, and road salt (Novotny, Murphy, & Stefan, 2008). The MPCA adopted the Environmental Protection Agency's (EPA) recommended water quality criteria for chloride which is a chronic standard of 230 mg/L and an acute standard of 860 mg/L (MPCA, 2016). The MPRB has monitored chloride concentrations Wirth Lake since 1994 by collecting surface water samples using a composite tube and collecting deep water samples using a Kemmerer sampler. See **Chapter 1** for more information on chloride.

Figure 16-6 shows epilimnetic and hypolimnetic chloride concentrations in Wirth Lake between 1994-2022, with hypolimnion samples only collected regularly after 2006. Epilimnion samples represent the top two meters of the lake and hypolimnion samples were collected approximately one meter from the bottom of the lake. Red horizontal lines on the graph indicate the MPCA acute and chronic chloride standards. Also included on the graph, is a dotted line that represents an estimate of a concentration above which potential ecological impact could occur, at 120 mg/L. This level of potential ecological impact was developed by Canadian Council of Ministries of the Environment (CCME) and is not a Minnesota state standard but a long-term chloride concentration that could negatively impact life within the lake (CCME, 2011). Between 2010-2020 chloride concentrations in the hypolimnion were significantly higher than epilimnetic concentrations likely because runoff containing sodium chloride is denser and sinks to the lake bottom. Other factors that may have impacted water quality include disturbances in the watershed or backflow from Bassett Creek. In 2021 and 2022 chloride concentrations in the epilimnion and hypolimnion were roughly comparable and remained below the chronic standard. Epilimnetic chloride concentrations have been slowly increasing since 2006; prior to 2006 most concentrations measured below the level of ecological impact and after 2010 most samples were above this threshold. Wirth Lake was added to the MPCA's list of impaired waters (303(d) list) in 2016 due to high chloride concentrations.

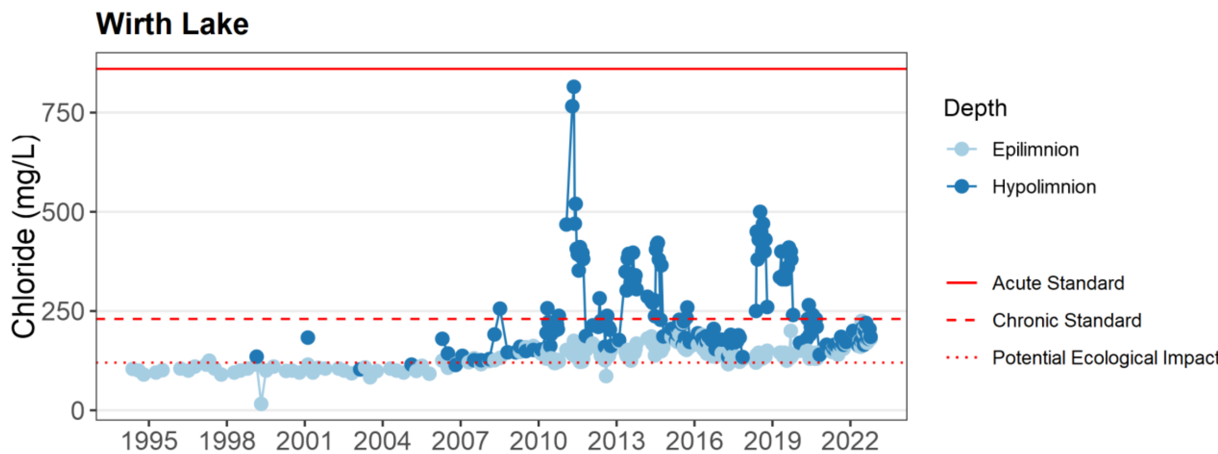


Figure 16-6. Wirth Lake scatterplot of epilimnetic and hypolimnetic chloride concentrations between 1994-2022. Horizonal lines represent the MPCA's acute and chronic standard and the potential ecological impact level (CCME, 2011).

Beach Monitoring

Table 16-3 and **Figure 16-7** show *Escherichia coli* (*E. coli*) levels that were monitored weekly from late May through August at Wirth Beach in 2022. *E. coli* concentrations stayed relatively low throughout the summer in 2022 and there were no closures due to exceedance of *E. Coli* standards. See **Chapter 18** for more information on beaches.

Table 16-3. Summary of *E. coli* (MPN per 100 mL) data for Wirth Beach in 2022.

Statistical Calculations	Wirth
Number of Samples	15
Minimum	1
Maximum	617
Median	3
Mean	66
Geometric Mean	8
Max 30-Day Geo Mean	24
Standard Deviation	161

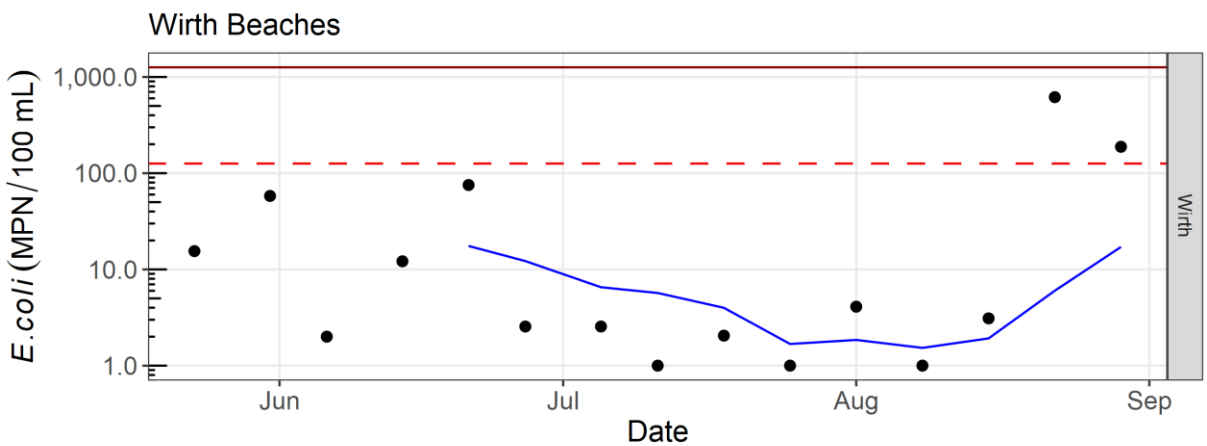


Figure 16-7. 2022 *E. coli* concentrations at Wirth Beach. Blue line is the running 30-day geometric mean. The dashed horizontal line represents the *E. coli* standard for the 30-day geometric mean (126 MPN/100mL) and the solid horizontal line represents the single-sample maximum standard (1,260 MPN/100mL). Note the log scale on the Y-axis.

Figure 16-8 shows *E. coli* monitoring data for Wirth Beach from 2013 to 2022 which is graphed by using a box and whisker plot. The box and whisker plots show the high variability in *E. coli* concentrations over the years. The highest *E. coli* concentrations in the last 10 years had occurred in 2021.

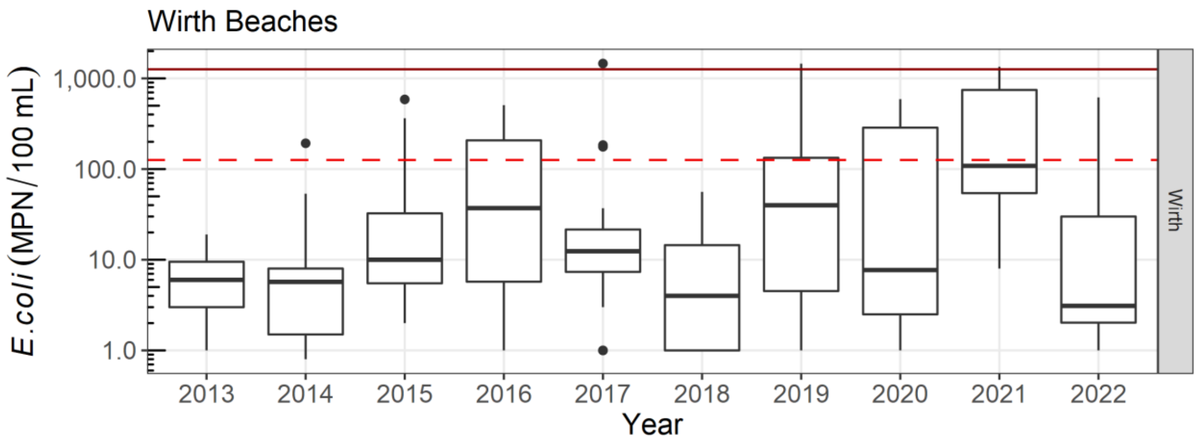


Figure 16-8. Box and whisker plot of E. coli concentrations (MPN/100 mL) for Wirth Beach from 2013–2022. The dashed horizontal line represents the E. coli standard for the 30-day geometric mean (126 MPN/100mL) and the solid horizontal line represents the single-sample maximum standard (1,260 MPN/100mL). Note the log scale on the Y-axis.

Figure 16-9 shows the total number of days Wirth Beach was closed each year due to *E. coli* exceedances for the past 10 years. Wirth Beach has historically been closed late in the season due to waterfowl activity related to migration.

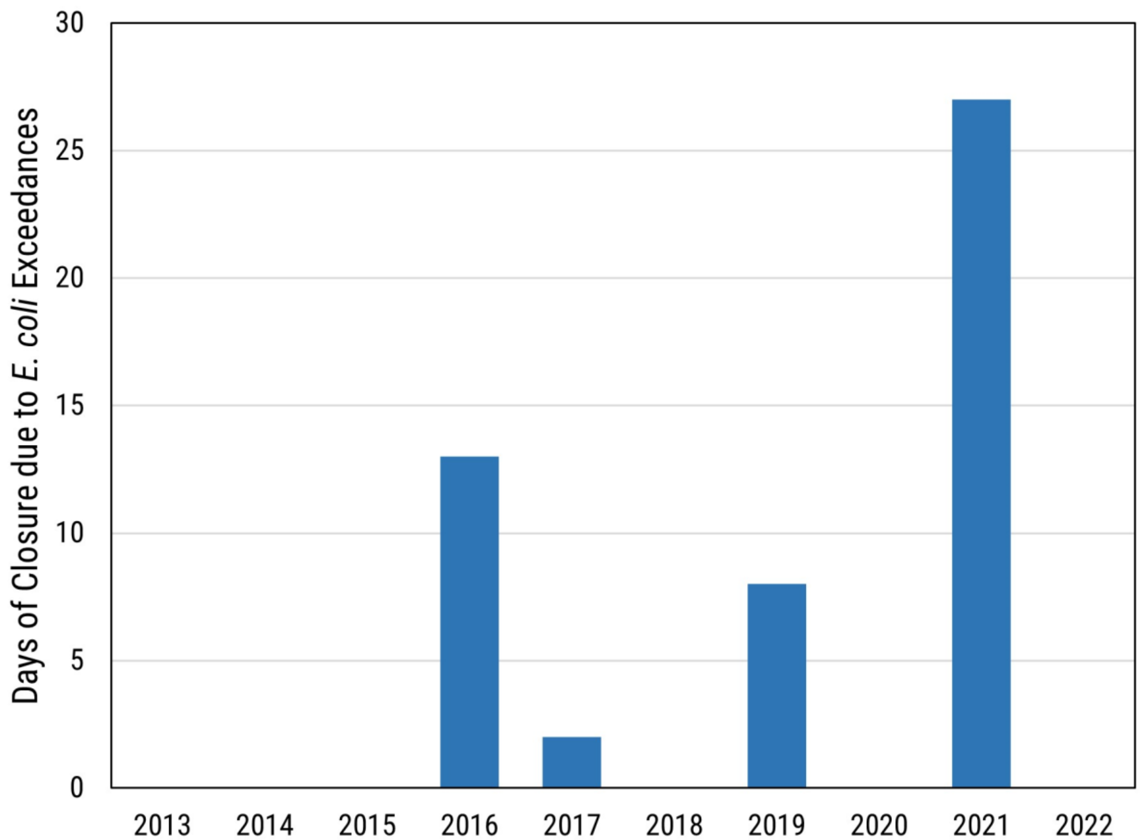


Figure 16-9. Bar graph of total number of days Wirth Beach was closed each year due to *E. coli* exceedances from 2013-2022. Years where no bar is present had no beach closures.

Blue-green Algae/Cyanotoxin Monitoring

Blue-green algae are not algae at all, but a type of bacteria called cyanobacteria. These photosynthetic microorganisms occur naturally in lakes, streams, and other waterbodies worldwide. When conditions are right, cyanobacteria can grow quickly to form dense accumulations called blooms. Certain varieties of cyanobacteria can produce toxins, referred to as cyanotoxins, that can cause illness in humans and animals (US EPA, 2017). Due to an increase in frequency and intensity of cyanobacteria blooms in Minneapolis lakes, the MPRB developed a cyanobacteria monitoring program for public health in 2020. MPRB staff collect information on observations using a defined Visual Monitoring Index (VMI), and sample water weekly at beaches for the most common cyanotoxins. Advisories are posted at beaches and on the MPRB Lake Water Quality Map (bit.ly/mplsbeaches) if toxin levels exceed MPCA guidelines. See **Chapter 19** for more information on blue-green algae and cyanotoxin monitoring.

In 2022, VMI observations were made during weekly beach sampling and bimonthly lake sampling on Wirth Lake. Cyanotoxin samples were also collected at Wirth Beach weekly. Both VMI observations and cyanotoxin levels indicated low levels of cyanobacteria throughout the year. Cyanotoxin concentrations were highest in late August when the microcystin concentration was 0.32 µg/L, which was well within safe swimming guidelines. Although cyanobacteria were present in Wirth Lake in 2022, no significant blue green algae accumulations or scums were observed, and all water samples tested were within the state guidelines for swimming.

Lake Aesthetic and User Recreation Index (LAURI)

The 2022 LAURI for Wirth Lake is shown in **Figure 16-10**. Wirth Lake scored excellent for aesthetics, water clarity, public health, habitat quality and recreational access opportunities. Details on the updated LAURI can be found in **Chapter 1**.

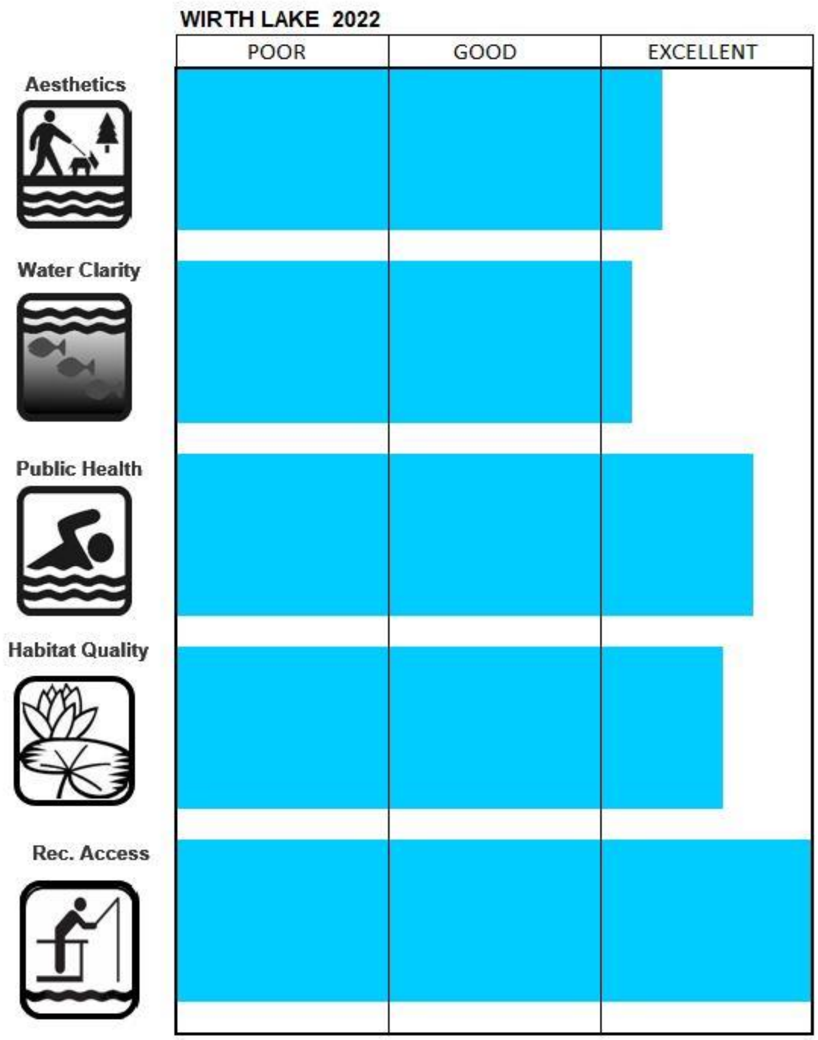


Figure 16-10. Wirth Lake LAURI for 2022.

Winter Ice Cover

Ice came off Wirth Lake on April 11, 2022, nine days later than average ice-off. Ice came onto the lake for the winter on November 22, 2022, eight days earlier than the average ice-on date. Details on winter ice cover records can be found in **Chapter 1** and a comparison with other lakes can be found in **Chapter 17**.

Aquatic Plant Management

The MNDNR requires a permit to remove or control aquatic plants. Aquatic plant control permits limit the area from which plants can be harvested to protect fish habitat. The permits issued to the MPRB allow for harvesting at the beach and the boat launch to improve recreational access. The permitted area on Wirth Lake in 2022 was 2 acres which is 8% of the littoral zone of the lake, or the area shallower than 15 feet. The MPRB contracts with SCUBA divers to remove vegetation from areas around the swimming beach, boardwalk, and boat launch. Approximately 3,080 pounds of aquatic plants were removed from Wirth Lake in 2022. See **Chapter 1** and **Chapter 21** for details on aquatic plants.

Phytoplankton and Zooplankton

Phytoplankton are microscopic plants that are an integral part of the lake community because they form the base of the aquatic food web. **Figure 16-11** shows the water clarity, chlorophyll-*a* concentrations, and relative abundance of phytoplankton divisions during 2022. Comparing these three parameters together can show how changes in the types of algae present in a lake effect water clarity and color, see the phytoplankton and zooplankton monitoring section in **Chapter 1** for additional details.

Water clarity closely followed chlorophyll-*a* concentrations throughout 2022, see **Figure 16-11a, b**. Water clarity was shallowest in the spring at 1.5 meters when chlorophyll-*a* concentrations were highest at 17.3 µg/L. Cryptomonads (Cryptophyta) dominated the phytoplankton community at this time. Water clarity was deepest in late June at 5 meters when chlorophyll-*a* concentrations were lowest at 1.3 µg/L. The phytoplankton community primarily consisted of dinoflagellates (Pyrrophyta) at this time, see **Figure 16-11b, c**.

Cryptophyta were present throughout the year and dominated the phytoplankton community between winter and May. Pyrrophyta dominated the population in June and blue-green algae (Cyanophyta) dominated the population between July and fall. Diatoms (Bacillariophyta), green algae (Chlorophyta), golden-brown algae (Chrysophyta), and haptophytes (Haptophyta) were present in low levels in 2022, see **Figure 16-11c**.

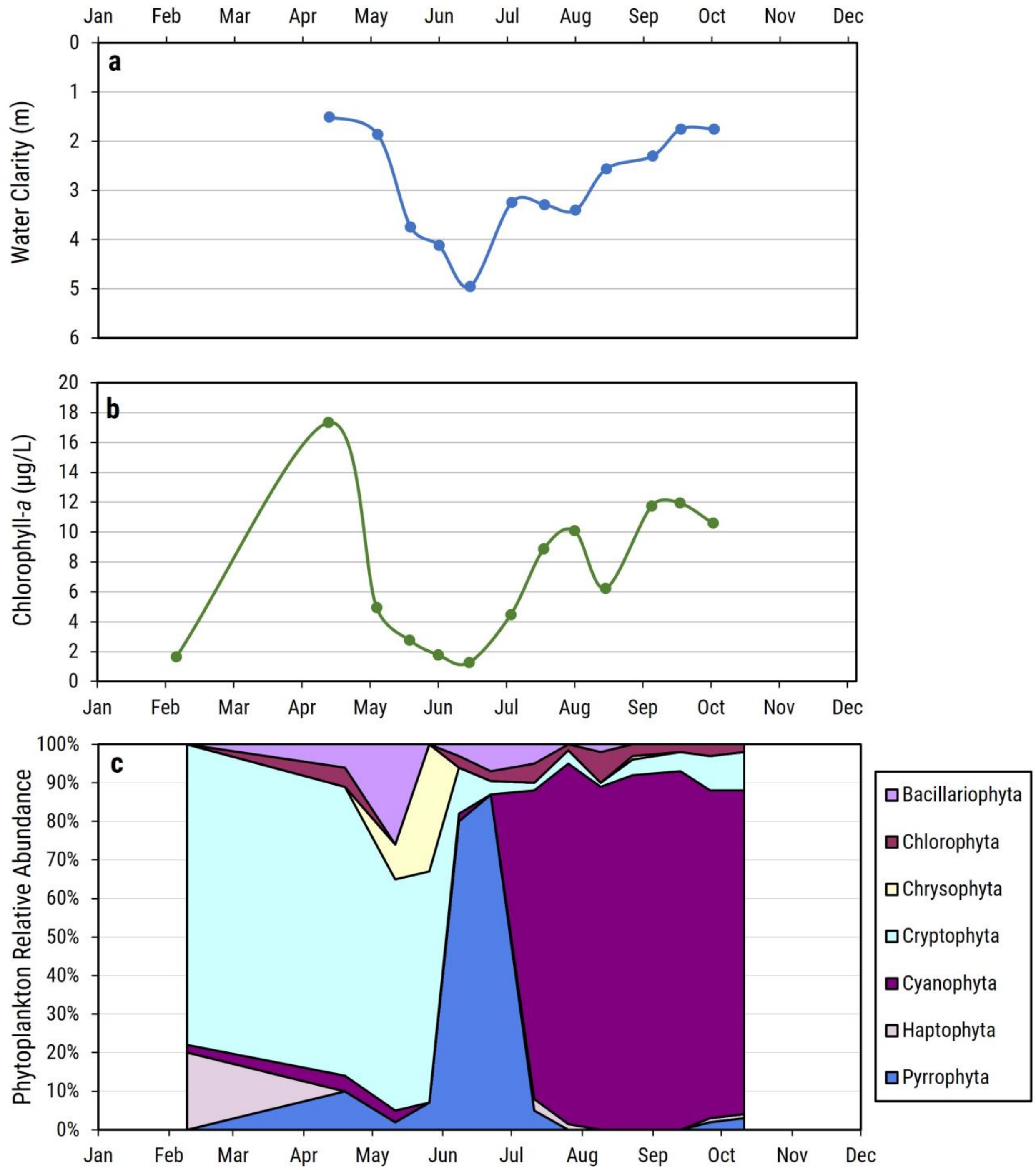


Figure 16-11. Water clarity (a), chlorophyll-*a* concentration (b), and relative abundance of phytoplankton (c) in Wirth Lake during 2022. Note that the water clarity axis is reversed.

Zooplankton are tiny animals that feed on phytoplankton and are also vital for the lake community because they form the second level of the food web along with larval fish. **Figure 16-12** shows the zooplankton distribution in Wirth Lake sampled throughout 2022. Nauplii and juvenile copepods dominated the zooplankton population throughout the year and were most abundant in May. Cladocerans were present throughout the year and were most abundant in October. Calanoid, cyclopoid, protozoa, and rotifers were present in low levels in 2022.

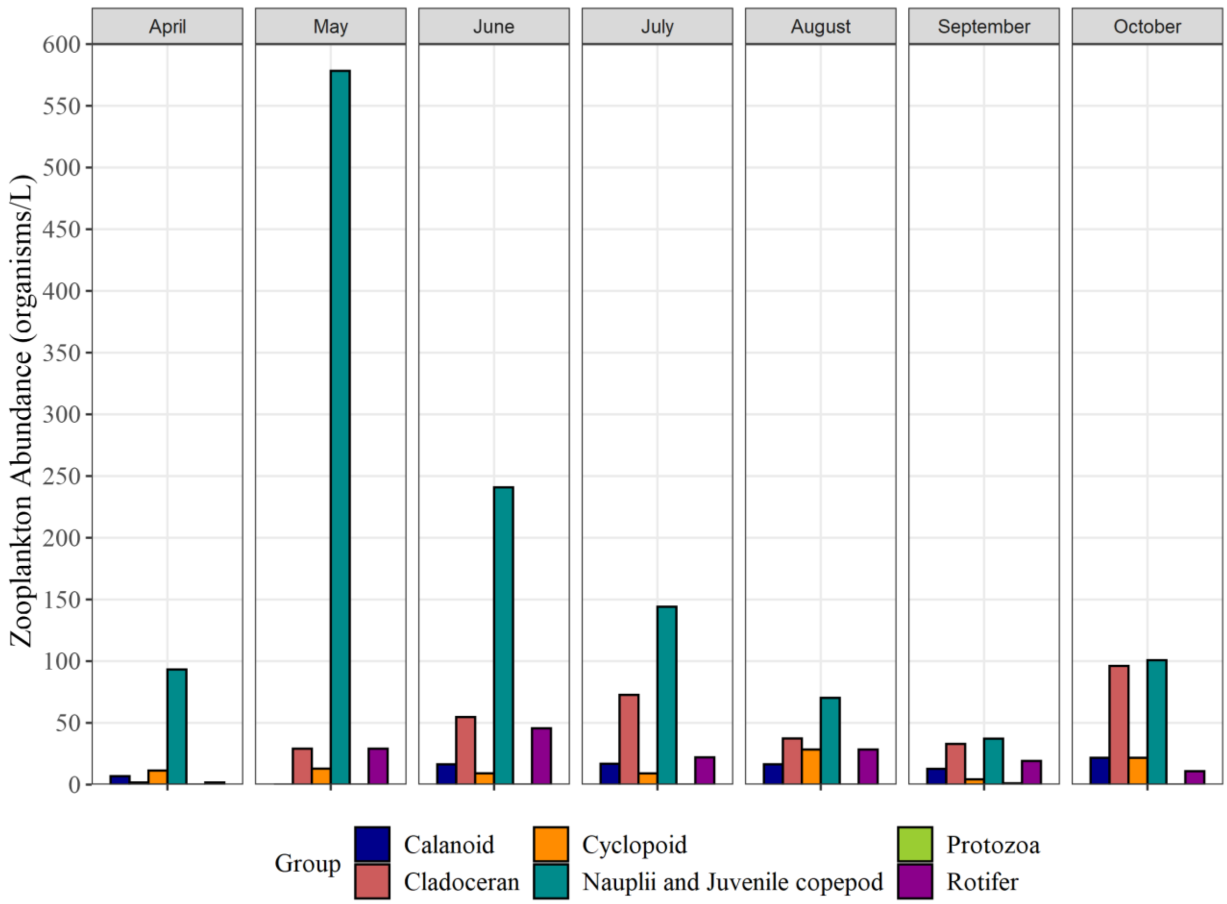


Figure 16-12. Zooplankton density in Wirth Lake during 2022.

Fish Stocking

Wirth Lake is stocked with fish by the MNDNR as part of the Fishing in the Neighborhood (FiN) program. **Table 16-4** shows fish stocked into Wirth Lake over the past decade. Bluegill sunfish, black crappie, and northern pike were stocked in Wirth Lake in 2022. Additional fish stocking information can be found in **Chapter 1**.

Table 16-4. Fish stocked into Wirth Lake over the past 10 years. Data are from the Minnesota Department of Natural Resources.

Year	Species	Number and Size	Amount
2022	Bluegill	264 adults	26.4 pounds
2022	Black Crappie	100 adults	10.0 pounds
2022	Northern Pike	24 adults	55.8 pounds
2021	Black Crappie	50 adults	16.7 pounds
2021	Bluegill Sunfish	100 adults	28.6 pounds
2021	Northern Pike	7 adults	60.0 pounds
2020	Bluegill	30 adults	7.4 pounds
2019	Bluegill	308 adults	49.9 pounds
2018	Walleye	11,500 fry	0.1 pounds
2017	Walleye	10,000 fry	0.1 pounds
2012	Walleye	23,000 fry	0.2 pounds

Wetland Health Evaluation Project (WHEP)

The Wirth Beach wetland was evaluated by the Wetland Health Evaluation Project (WHEP) led by Hennepin County and a group of citizen volunteers. This site was selected by MPRB staff to monitor how invertebrate populations re-established after restoration efforts that occurred in 2012. Wirth Beach Wetland received a moderate rating for invertebrate quality and an excellent rating for vegetation quality. 2022 was the ninth year that the Wirth Beach wetland was evaluated in the WHEP program. Results of the wetland evaluation are presented in **Chapter 23**.

17. Comparison Among Lakes

Physical Characteristics

Understanding the physical characteristics of a lake is important when interpreting data from an individual lake and when comparing groups of lakes. Shallow and deep lakes respond in distinct ways to environmental and watershed changes and may require entirely different approaches for rehabilitation. Lakes with large watershed to lake area ratios are typically more eutrophic and may be more complicated to manage if their watersheds cross political boundaries. A lake's residence time can also influence its overall physical condition, with long residence times causing delayed effect of rehabilitation efforts. **Table 17-1** presents the physical characteristics and morphometric data of the Minneapolis lakes.

Table 17-1. Minneapolis lakes physical characteristics and morphometric data.

Lake	Surface Area (acres)	Mean Depth (ft)	Max Depth (ft)	% Littoral*	Volume (ft^3)	Watershed Area (acres)	Watershed: Lake Area (ratio)	Residence Time (years)
Bde Maka Ska	419	30.0	82.0	29%	$6.36x10^8$	2,992	7.1	4.2
Brownie	10	22.3	47.0	76%	$1.76x10^7$	369	20.5	2.0
Cedar	164	20.0	51.0	38%	$1.50x10^8$	1,956	11.5	2.7
Diamond	52	3.2	5.8	100%	$2.52x10^6$	669	16.3	NA
Grass	27	2.0	4.9	NA	NA	386	14.3	NA
Harriet	341	29.0	87.0	25%	$4.41x10^8$	1,139	3.2	3.4
Hiawatha	53	13.4	33.0	47%	$3.16x10^7$	115,840	2,145	0.01
Isles	112	8.9	31.0	80%	$3.92x10^7$	735	7.1	0.6
Loring	7	4.9	16.0	89%	$1.72x10^6$	24	3.0	NA
Nokomis	201	14.1	33.0	50%	$1.25x10^8$	869	4.3	4.0
Powderhorn	11	3.9	24.0	83%	$3.19x10^6$	286	26.0	0.2
Ryan	19	NA	36.0	51%	NA	5,510	306	NA
Spring	3	9.8	27.9	NA	$1.29x10^6$	45	15.0	NA
Wirth	40	14.1	25.0	58%	$2.37x10^7$	348	9.4	NA

* Littoral area defined as less than 15 feet deep. NA= Information not available.

Summary statistics of interest include:

- Largest Lake: Bde Maka Ska at 419 acres.
- Smallest Lake: Spring Lake at 3 acres.
- Deepest Lake: Lake Harriet at 87 feet.
- Largest Watershed: Lake Hiawatha at 115,840 acres.
- Smallest Watershed: Loring Pond at 24 acres.
- Longest Residence Time: Bde Maka Ska at 4.2 years.
- Shortest Residence Time: Lake Hiawatha at 11 days.

Water Quality Trends – Trophic state index (TSI)

The Minneapolis Park and Recreation Board (MPRB) calculates a trophic state index score (TSI) for each lake using chlorophyll-*a*, water clarity, and total phosphorus measurements. TSI scores can be used to evaluate changes in an individual lake or to compare lakes to each other. Detailed information on TSI scores can be found in **Chapter 1**.

In 2022, MPRB scientists monitored 12 of the city's most frequently used lakes. The data collected were used to calculate a TSI score for each of the lakes. Lower TSI scores indicate deep water clarity, lower levels of algae in the water column, and/or lower phosphorus concentrations. Minneapolis lies within the North Central Hardwood Forests (NCHF) ecoregion, an area with fertile soils and agriculture as a dominant land use in rural areas. Most lakes sampled in Minneapolis are either eutrophic or mesotrophic. Bde Maka Ska, Cedar, and Wirth are mesotrophic having moderately clear water and potential for hypolimnetic anoxia frequently during the summer. Brownie, Lake of the Isles, Harriet, and Hiawatha are eutrophic having an anoxic hypolimnion and potential for nuisance growth of aquatic plants. Nokomis and Loring are also eutrophic with high algal productivity. Powderhorn is hypereutrophic having dense algae. Blue-green algae dominates the phytoplankton community on both Lake Nokomis and Powderhorn Lake, resulting in periodic appearance of algal scum on these lakes. Spring Lake was also classified as hypereutrophic with very high nutrient concentrations, but was not sampled in 2022. Scores for Diamond and Grass Lake are not included since these lakes are too shallow to calculate the Secchi portion of the TSI index, see **Figure 17-1**.

Changes in lake water quality can be tracked by looking for trends in TSI scores over time. Trends were identified by using a linear regression of the TSI scores through time. **Table 17-2** shows the trends in TSI scores since 1991, the year sampling began for most lakes. Since the record for some lakes is so long, and because many large water quality improvement projects took place in the late 1990s and early 2000s, the long-term water quality trend and 10-year trends for the Minneapolis lakes can be different. **Table 17-3** shows the TSI trends since 2013. For more detailed information on a particular lake's trend in TSI scores and related water quality parameters, see the individual lake sections. Details on TSI scores and linear regression analyses can be found in **Chapter 1**.

TSI scores and linear regressions for all the Minneapolis lakes since 1991 are shown in **Figure 17-2** (https://www.nalms.org/secchidipin/monitoring-methods/trophic-state-equations/)**.** A negative slope in the linear regression indicates improving water quality, while a positive slope indicates declining water quality. These values are especially important for monitoring long-term trends including data from 10 plus years. Historical trends in TSI scores are used by lake managers to assess improvement or degradation of water quality.

Water Quality Trophic State Index

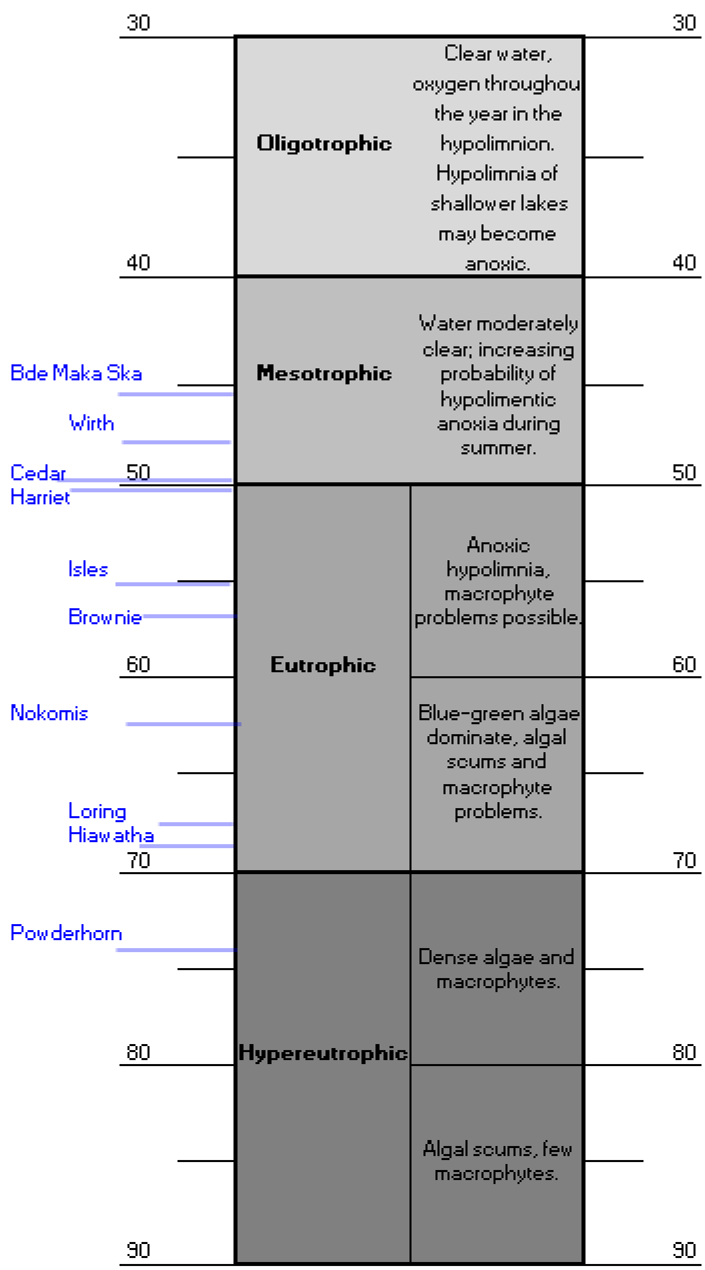


Figure 17-1. 2022 lake trophic state comparison. The hypolimnion is the deeper layer of water in a stratified lake, typically cooler than the epilimnion. In general, the deeper lakes have lower TSI scores and are higher up on this graphic.

Table 17-2. Water quality trends in Minneapolis lakes from 1991-2022.

Lakes with Improving Water Quality Indicators	Bde Maka Ska Wirth Lake
Lakes with Stable Trends	Brownie Lake Cedar Lake Lake Harriet Lake Hiawatha Lake of the Isles Loring Pond Lake Nokomis Powderhorn Lake Spring Lake
Lakes with Declining Water Quality Indicators	No lakes with declining trend

Table 17-3. Water quality trends in Minneapolis lakes from 2013-2022.

Lakes with Improving Water Quality Indicators	No lakes with improving trend
Lakes with Stable Trends	Bde Maka Ska Brownie Lake Cedar Lake Lake Harriet Lake of the Isles Loring Pond Powderhorn Lake Spring Lake Wirth Lake
Lakes with Declining Water Quality Indicators	Lake Hiawatha Lake Nokomis

There has been a significant improvement in water quality indicators in Bde Maka Ska since the early 1990s (linear regression, $p < 0.05$). Although water quality in Bde Maka Ska has improved over time, TSI scores have slowly been increasing since 2005. The TSI score between 2017 and 2022 was higher than the previous few years due to higher chlorophyll-*a* and total phosphorus concentrations but were still below the early 1990s scores. In 2022, the TSI score slightly increased due to shallower water clarity and higher chlorophyll-*a* concentrations.

Water quality improvement at Wirth Lake has been occurring since 1992, going from a eutrophic system dominated by algal growth to a moderately clear mesotrophic system (linear regression, $p < 0.05$). The TSI score at Wirth Lake slightly increased in 2022 due to shallower water clarity and higher chlorophyll-*a* concentrations.

Most of the Minneapolis lakes have no directional trend in water quality indicators since the early 1990s, which is expected. Decreasing trends in TSI scores, showing improving water quality, occurred when water quality management projects were in place. The water quality in Brownie Lake has been relatively stable, with no significant trend since 1993. Brownie Lake was monitored in 2022 and is monitored every other year. The water quality in Cedar Lake showed improvement following restoration efforts through the late

1990s, but TSI scores have gradually been increasing since that time. The Cedar Lake TSI scores between 2017 and 2021 were the highest they have been since the early 1990s due to shallower water clarity and higher chlorophyll-*a* concentrations. In 2022, the Cedar TSI score decreased due to much deeper water clarity and lower chlorophyll-*a* concentrations. Lake Harriet experienced a few years with lower, relatively stable TSI scores following a littoral alum treatment in the mid-2000s, as well as lower TSI scores in 2016 and 2020. The TSI score in Lake Harriet was higher in 2022 compared to previous years due to shallower water clarity and higher chlorophyll-*a* and total phosphorus concentrations but the trend was not significant (linear regression, $p > 0.05$). Previously, water quality in Lake Nokomis improved following a biomanipulation project that was completed in 2013. In recent years Lake Nokomis has had higher algal concentrations and increasing TSI scores indicating worsening water quality over the past 10 years (linear regression, $p < 0.05$); however, there is no significant trend since 1992. Lake Hiawatha is heavily influenced by inflow from Minnehaha Creek and the lake has poorer water quality during drought years when residence time increases. In 2021 and 2022 there was less precipitation compared to previous years and TSI scores have been increasing indicating worsening water quality over the past 10 years (linear regression, $p < 0.05$); however, there is no significant trend since 1992. The water quality in Lake of the Isles varies from year to year with lower TSI scores in recent years compared to the early 1990s but there is no significant trend (linear regression, $p > 0.05$). Loring Pond had worsening water quality immediately following a dredging project in 1997; however, between 2000 and 2015 TSI scores decreased indicating improving water quality. Since 2015, the TSI scores in Loring Pond have been slowly increasing due to shallower water clarity and higher chlorophyll-*a* concentrations, particularly in 2019, 2020 and 2022. Powderhorn Lake has experienced a wide variation in water quality, with the worst TSI scores in the late 1990s and the best scores in the late 2000s. Powderhorn has had poor water quality most years since 2013 with blue-green algae blooms leading to shallow water clarity. The TSI scores were higher in 2017, 2020 and 2022 due to shallower water clarity and higher chlorophyll-*a* and total phosphorus concentrations. Water quality in Spring Lake is variable and there has been no significant trend in any direction since 1994. Spring Lake is monitored every other year and was not monitored in 2022. The TSI score was higher in 2019 and 2021 than previous years due to higher total phosphorus concentrations.

Diamond Lake and Grass Lake are not included in this analysis, since TSI scores are only appropriate for deeper lake systems and there are no water clarity measurements available for these shallow lakes. There are no lakes in Minneapolis with significant declines in water quality indicators since the early 1990s; however, water quality trends over the past 10 years indicate that Lake Hiawatha and Lake Nokomis water quality is declining as seen in increasing TSI scores in recent years. In 2021, the water quality trends on Cedar Lake over the past 10 years indicated that the water quality was declining, but in 2022 the lake was listed as having a stable trend since the water clarity was significantly deeper and chlorophyll-*a* concentrations were lower in 2022.

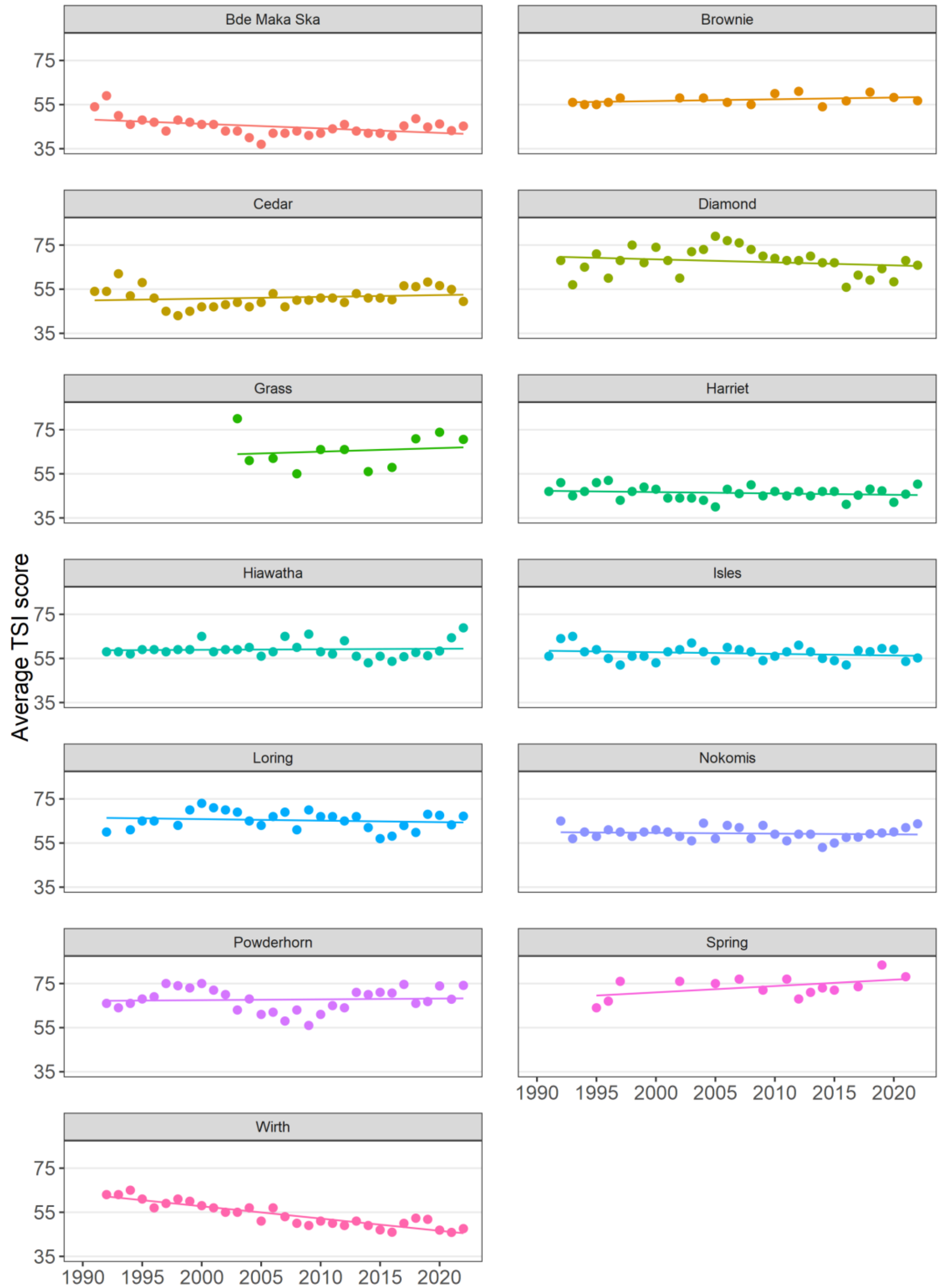


Figure 17-2. TSI scores and regression analysis for selected Minneapolis lakes 1991–2022. Lower TSI scores indicate high water clarity, low levels of algae in the water column, and/or low phosphorus concentrations. A negative slope indicates improving water quality, while a positive slope indicates declining water quality. Only Bde Maka Ska and Wirth have statistically significant trends ($p < 0.05$).

CHLORIDE

Chloride is a naturally occurring element that is commonly found at low levels in most freshwater bodies. Chloride is a component of road salt (sodium chloride) and is found in other types of compounds that are also called salts (calcium chloride, magnesium chloride). Unnaturally high concentrations of chloride can negatively impact surface waters. High levels of chloride can change the mixing pattern of a lake and lead to very low oxygen levels in deep water. It can also lead to decreasing water clarity and induce stress or cause death of aquatic species (Bathe & Coring, 2011). Sources of chloride include industrial discharge, septic systems, sewage disposal systems, fertilizers, and road salt (Novotny, Murphy, & Stefan, 2008). The Minnesota Pollution Control Agency (MPCA) adopted the Environmental Protection Agency's (EPA) recommended water quality criteria for chloride which is a chronic standard of 230 mg/L and an acute standard of 860 mg/L (MPCA, 2016). The MPRB has monitored chloride concentrations in MPRB Lakes since 1994 by collecting surface water samples using a composite tube and collecting deep water samples using a Kemmerer sampler. See **Chapter 1** for more information on chloride.

Figure 17-3 shows epilimnetic and hypolimnetic chloride concentrations in MPRB Lakes between 1994-2022. Epilimnion samples represent the top two meters of the lake and hypolimnion samples were collected approximately one meter from the bottom of the lake. Hypolimnetic chloride samples were not regularly sampled until between 2006-2010. Red horizontal lines on the graph indicate the MPCA acute and chronic chloride standards. Also included on the graph, is a dotted line that represents an estimate of a concentration above which potential ecological impact could occur, at 120 mg/L. This level of potential ecological impact was developed by Canadian Council of Ministries of the Environment (CCME) and is not a Minnesota state standard but a long-term chloride concentration that could negatively impact life within the lake (CCME, 2011).

Chloride concentrations in MPRB lakes have increased over time. Bde Maka Ska, Cedar, Grass, Harriet, Isles, and Lake Nokomis chloride concentrations were below the level of ecological impact in the late 1990s to early 2000s; however, concentrations have increased over time and in recent years most samples have exceeded this threshold. Chloride concentrations in Diamond, Hiawatha, and Powderhorn Lake are highly variable likely due to the large amount of stormwater entering these lakes. Hypolimnetic chloride concentrations in Brownie and Spring Lake are significantly higher than epilimnetic concentrations because these lakes are meromictic, meaning these lakes do not mix, and water containing chloride is denser and sinks to the lake bottom. Chloride concentrations in Loring Pond are highly variable with concentrations ranging from 16 mg/L to 1,273 mg/L. Loring Pond chloride concentrations roughly compare to precipitation patterns, particularly between 2012 and 2013, with higher chloride concentrations correlating to years with more precipitation due to increased stormwater runoff. In Wirth Lake, hyplolimnetic concentrations well exceeded the chronic standard and were significantly higher than epilimnetic concentrations between 2010-2020; however, in 2021 and 2022 chloride concentrations in the epilimnion and hypolimnion were roughly comparable and remained below the chronic standard. Lakes that are at high risk for chloride impairment according to the Minnesota Statewide Chloride Management Plan and lakes that are listed on the MPCA's list of impaired waters (303(d) list) due to high chloride concentrations are shown in **Table 17-4** (MPCA, 2018).

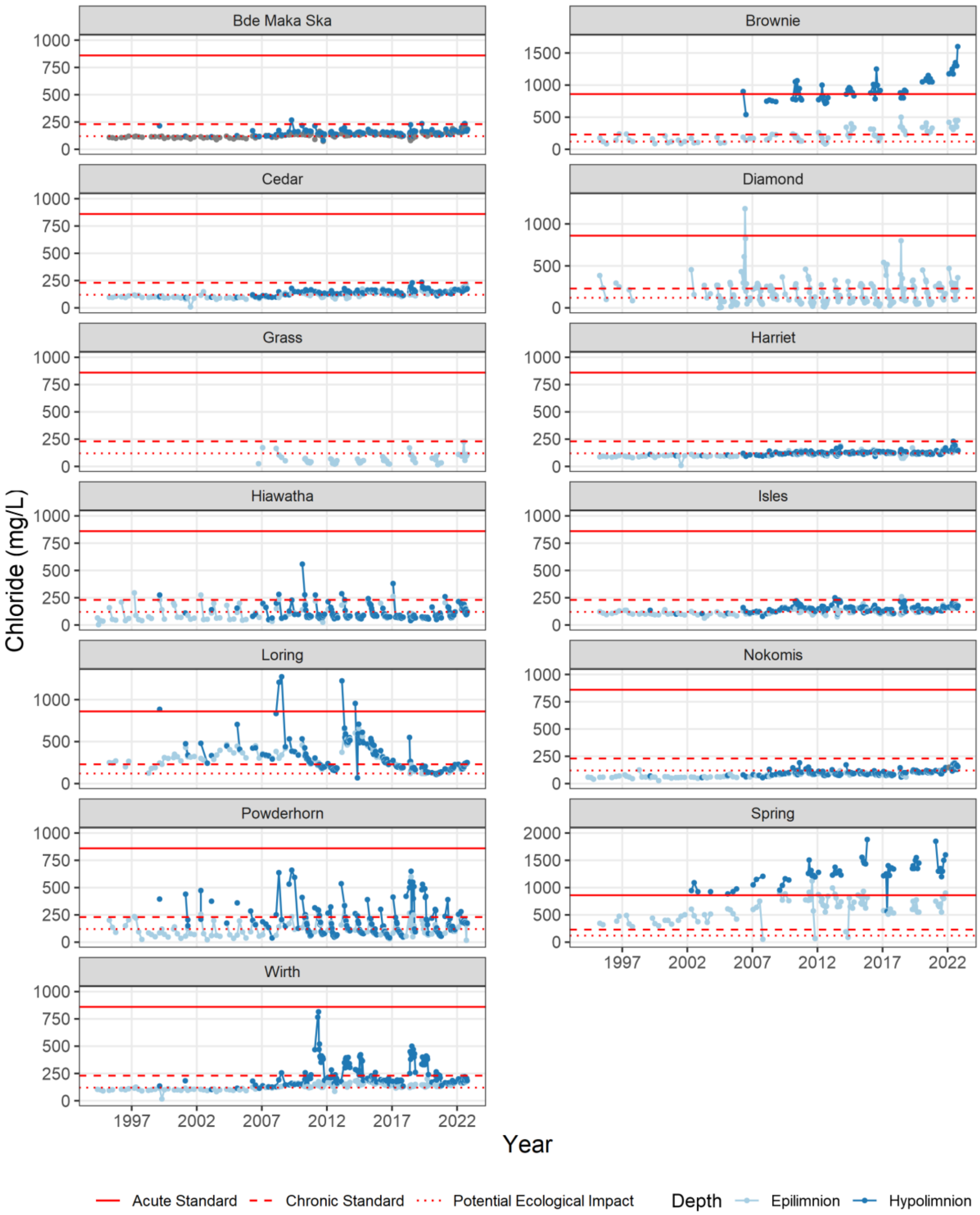


Figure 17-3. Scatterplot of epilimnetic and hypolimnetic chloride concentrations in Minneapolis Lakes between 1994-2022. Horizontal lines represent the MPCA's acute and chronic standard and the potential level that could impact biota (CCME, 2011).

Table 17-4. Minneapolis lakes that are at high risk of chloride impairment according to the Minnesota Statewide Chloride Management Plan (2018), and lakes that are listed on the MPCA's list of impaired waters (303(d) list) due to high chloride concentrations.

Lakes at high risk of chloride impairment	Bde Maka Ska Lake Hiawatha Lake of the Isles Ryan Lake
Lakes on MPCA's list of impaired waters	Brownie Lake Diamond Lake Loring Pond Powderhorn Lake Spring Lake Wirth Lake

Lake Levels

Lake levels vary annually based on precipitation, stream flow, and stormwater inflow. According to the National Weather Service, 2019 was reported as the wettest year on record, with 43.19 inches total annual precipitation in Minneapolis. In 2022, total annual precipitation was 22.97 inches. Based on data from the U.S. Drought Monitor, Hennepin County experienced drought conditions all of 2022, except a ten-week period during the spring (https://droughtmonitor.unl.edu/DmData/DataTables.aspx?state,mn). See **Chapter 29** for more information on annual precipitation. In 2022, all lake level averages were below their corresponding 10-year averages, shown in **Tables 17-5** and **17-6**. Historical lake levels can be found in the individual lake chapters.

Table 17-5. Average annual lake levels in feet above msl for 2013-2022. Loring Pond Levels cannot be reliably read during low water conditions, biasing the level readings.

Lake	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Chain§	852.7	853.8	852.4	852.7	853.0	852.6	854.2	852.6	852.0	852.1
Diamond	821.7	822.2	822.4	822.9	821.8	821.9	822.2	821.9	821.6	821.3
Harriet	847.5	847.8	847.4	847.6	847.7	847.5	848.5	847.6	847.1	847.0
Hiawatha	813.1	814.1	812.5	813.3	813.3	813.2	814.4	812.7	811.7	811.5
Loring*	817.9	814.9	818.5	818.5	818.3	818.3	818.3	818.2	818.1	818.0
Nokomis	815.1	816.4	815.2	815.7	815.5	815.4	815.9	815.4	814.7	814.3
Powderhorn*	818.2	819.7	819.6	819.6	819.0	819.0	819.4	818.9	818.6	818.0
Wirth	818.1	818.5	818.3	818.3	818.1	818.3	818.3	818.1	818.0	818.0

§ The Chain of Lakes includes: Bde Maka Ska, Cedar, Isles, & Brownie.
* In dry years the level can be below recordable stage and levels can be augmented with groundwater.

Table 17-6. Selected statistics for lakes with level data based on data from 2013-2022. MSL = mean sea level. Loring Pond Levels cannot be reliably read during low water conditions, biasing the level readings.

Lake	10-year average (ft msl)	2022 average (ft msl)	2022 comparison to 10-year average (ft)	Standard deviation around 10-year average (ft)
Chain	853.0	852.1	-0.9	0.9
Diamond	821.9	821.3	-0.6	0.5
Harriet	847.6	847.0	-0.6	0.5
Hiawatha	813.0	811.5	-1.5	1.2
Loring	818.3	818.0	-0.3	0.2
Nokomis	815.5	814.3	-1.2	0.7
Powderhorn	819.1	818.0	-1.1	0.9
Wirth	818.2	818.0	-0.2	0.3

Groundwater was pumped into Loring Pond throughout 2022 to maintain higher water levels for cattail mitigation and waterfowl health. The lake gage at Loring Pond is only occasionally functional in very low water conditions because the area is being filled in by cattails and sediment. In 2022, when the lake level dropped below the gage the value was recorded as <7.16, which is the lowest reading available on the lake gage. Large storms have caused stormwater to periodically backflow into the pond through outlet over the past 10 years and can be seen in the lake level graph in Loring's individual lake chapter, **Chapter 11**.

Powderhorn Lake can be augmented by a groundwater well during dry periods, and an outlet pump can be used to prevent flooding after a storm event; however, neither system was used in 2022. The lake was 1.1 feet below its 10-year average in 2022, see **Table 17-6**. Powderhorn Lake is strongly influenced by stormwater in most years. Large storms and high groundwater can influence lake levels and form peaks in the data. See **Figure 17-4** for Minneapolis lake levels for 2022.

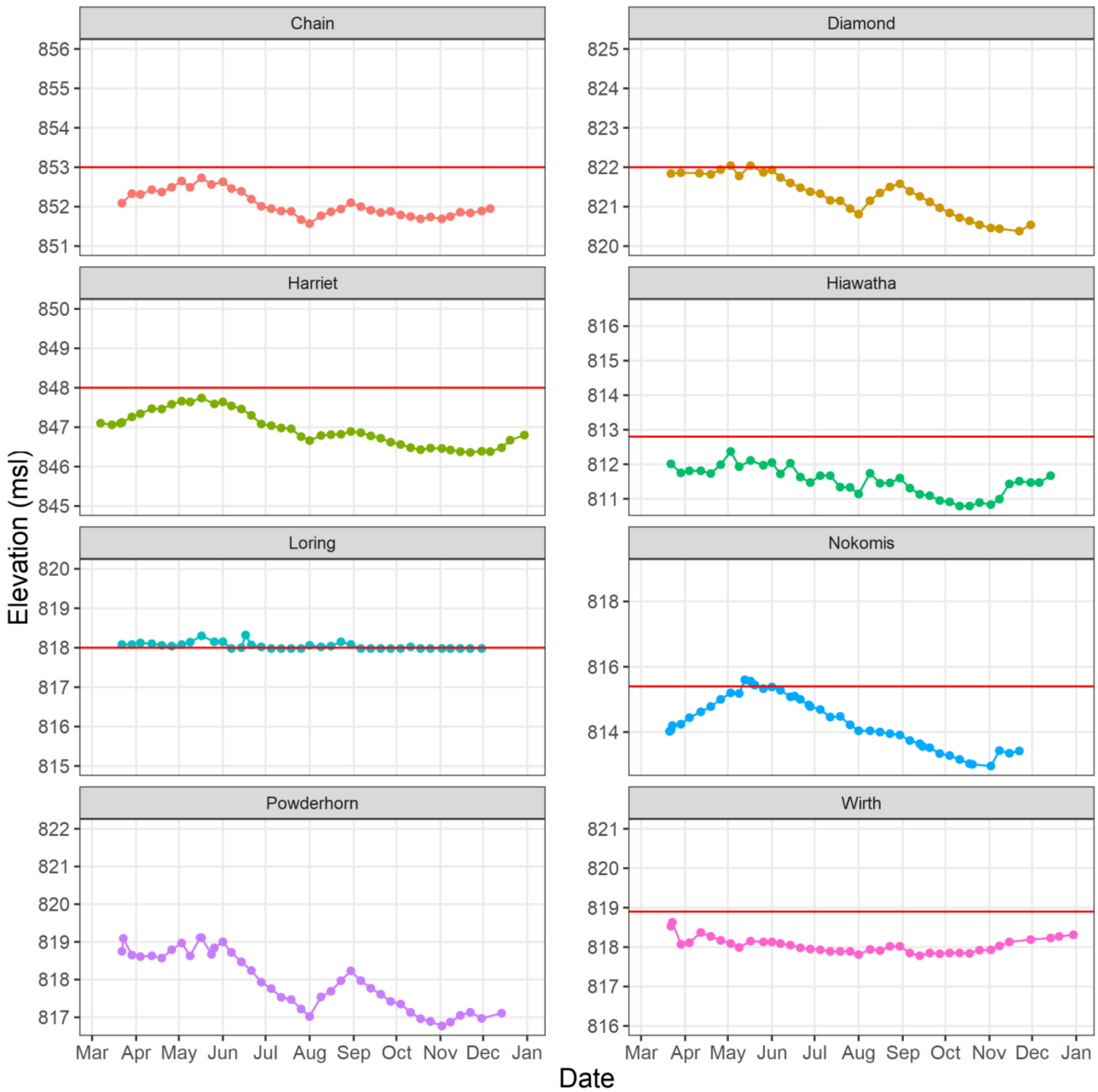


Figure 17-4. Lake levels for the Minneapolis Lakes in 2022. Horizontal lines represent ordinary high water level (OHWL). Note the MNDNR has not designated an OHWL for Powderhorn Lake.

Lake Hiawatha levels are influenced by the inflow of Minnehaha Creek which changes depending on the operation of the Lake Minnetonka outlet dam and rainfall conditions. The dam at Gray's Bay, operated by Minnehaha Creek Watershed District (MCWD), opened June 1, 2022, with 12 cubic feet per second (cfs) of discharge. Flow to the creek from the dam remained at 12 cfs until July. The dam closed on July 21, 2022 when Lake Minnetonka reached the drawdown level of 928.6 ft, and was not reopened for the rest of the year. The creek bed was dry throughout late summer and fall of 2022. The 2022 average Hiawatha lake level was 1.5 feet below the 10-year average for the lake.

Lake Nokomis had a six-year streak of high water between 2014 and 2019; however, lake levels have declined in recent years and remained below the OHWL elevation for most of 2022. Higher lake levels occurred in May of 2022 after snowmelt, just above the OHWL, and declined significantly throughout the rest of the year falling well below the OHWL. The MPRB operates a stop log weir at the outlet of Lake Nokomis to Minnehaha Creek which allows the lake to overflow during periods of high water, yet prevents the creek from flowing into the lake to reduce nutrient inputs and prevent zebra mussel introduction into Lake Nokomis. Water levels in the Lake Nokomis outlet were below the weir sill elevation for 358 days of 2022. Lake Nokomis levels and weir operations allowed for only 15 days of lake outflow in 2022. Weir operations are based on a DNR-approved operation plan and done in consultation with MCWD.

Lake Aesthetic and User Recreation Index (LAURI)

The LAURI was developed by MPRB and Barr Engineering Company to provide recreational users with an additional source of information about the health of MPRB lakes. The LAURI provides lake users with an easily understandable recreational suitability indicator for the MPRB lakes. Background information on the LAURI can be found in **Chapter 1**. The scores have been used by the City of Minneapolis, the Minneapolis Greenprint, and Results Minneapolis as a Citywide Metric.

All scores in the LAURI are between 1 and 10 with 10 as the best possible score. **Table 17-7** shows the LAURI scores of each lake for 2022. The LAURI parameters for all the lakes together are presented in **Figure 17-5.** The Citywide LAURI scored excellent for recreational access, and good for aesthetics, water clarity, public health, and habitat quality. Cyanobacteria blooms occurred on several MPRB lakes between 2020 and 2022 and likely contributed to lowering the aesthetics score from excellent to good.

Table 17-7. 2022 sub-scores and classifications for each LAURI category.

Lake	Aesthetics	Water Clarity	Public Health Index	Habitat Quality	Recreation Access
Bde Maka Ska	7.7	8.0	6.0	10.0	10.0
Cedar	7.5	7.0	8.0	8.3	10.0
Harriet	7.4	7.0	8.0	8.5	10.0
Hiawatha*	4.7	4.0	1.0	6.3	5.0
Isles*	7.9	8.0	NA	7.5	10.0
Loring*	7.7	4.0	NA	3.0	3.0
Nokomis*	6.1	6.0	9.0	5.3	10.0
Powderhorn*	3.9	2.0	NA	3.0	3.0
Wirth	7.9	7.0	9.0	8.5	10.0

LEGEND

Excellent	**Good**	**Poor**

* Denotes shallow lake.
NA = no swimming beach.

In general, lakes with the best habitat quality also had the best clarity and aesthetics. Lakes with poor clarity, odor, or trash problems scored lower in aesthetics. Lower public health scores for Lake Hiawatha due to high *E. coli* may have been caused by waterfowl waste. Larger lakes had better recreational access scores due to more opportunities to access the water through boating.

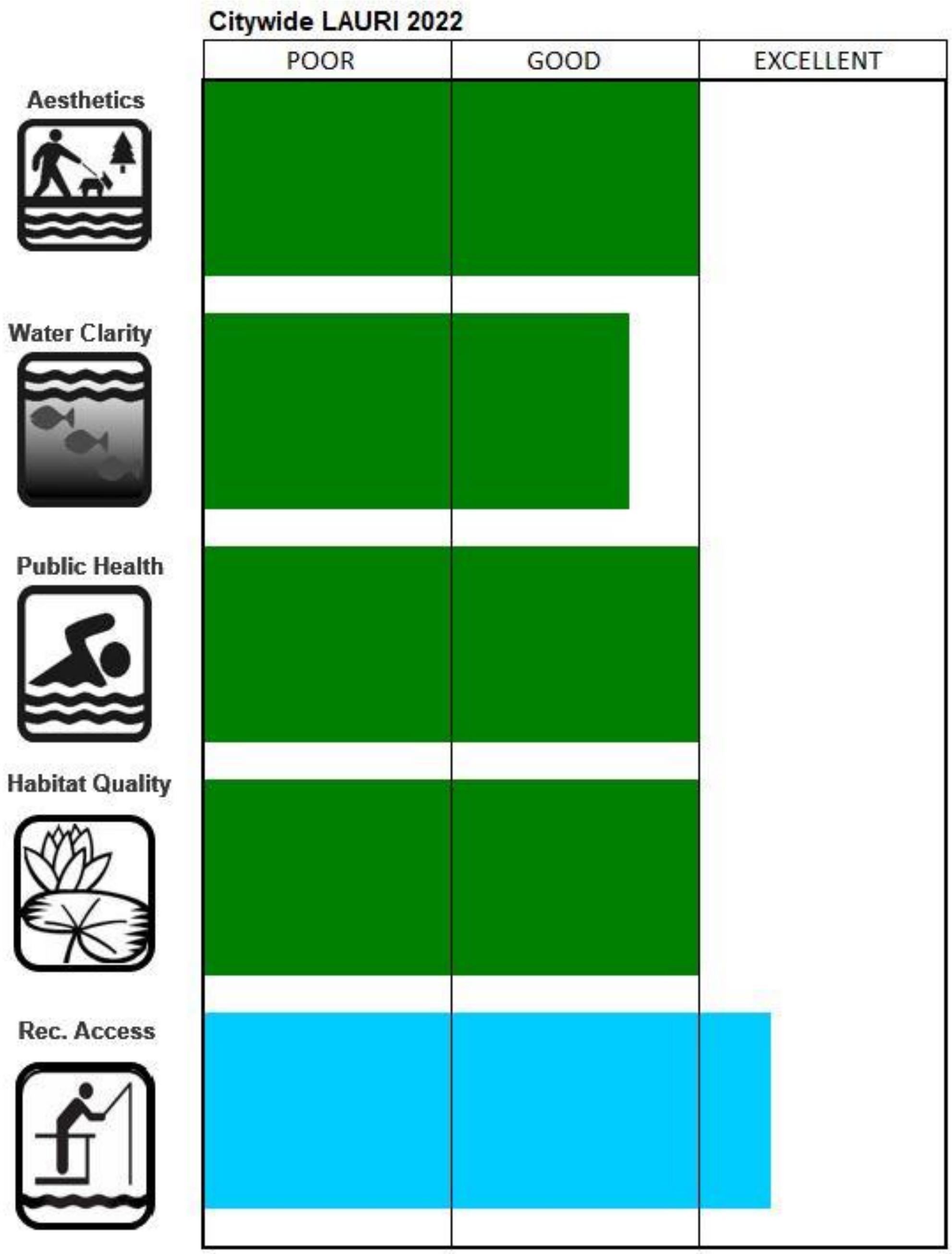


Figure 17-5. 2022 average LAURI for Minneapolis. Includes: Bde Maka Ska, Cedar, Harriet, Hiawatha, Isles, Loring, Nokomis, Powderhorn, and Wirth Lake.

WINTER ICE COVER

Lake size typically influences the date ice forms on the lakes, with the larger lakes freezing later than some of the smaller lakes in Minneapolis. Ice came off the lakes starting April 4th, with the last lake opening on April 13th, as shown in **Table 17-8.** The date that ice completely covered the lake, shown in **Table 17-9**, ranges from November 21st to December 19th, with an average ice-on date of December 2nd. **Table 17-10** shows the average length of ice cover in days for each decade between 1962 and 2022. **Figure 17-6** demonstrates ice-free periods for all the lakes since 1962. Not every lake has data for each year; however, some trends have been shown over time. For larger lakes, Bde Maka Ska, Lake Harriet, Lake Nokomis, and Lake Hiawatha, ice-free periods have increased slightly over time. Some lakes, like Brownie and Loring, have remained relatively stable in ice-free periods. While other lakes, like Birch Pond, are experiencing a longer period of ice cover. Fluctuation in ice-free period over time can serve as an indicator of climate change. As temperatures begin to get warmer and seasonality shifts, we see a shift in ice-free and ice-covered periods. For further information on winter ice cover records see **Chapter 1** and individual lake chapters.

Table 17-8. Statistics related to ice-off dates.

Lake	2022 Ice-Off	Earliest Ice-Off	Year Occurred	Latest Ice-Off	Year Occurred	Mean	Median	Years of Data
Bde Maka Ska	4/13	3/9	2000	5/2	2018	4/8	4/9	73
Birch	4/11	3/8	2000	4/30	2018	4/4	4/4	37
Brownie	4/11	3/9	2000	4/30	2018	4/3	4/3	41
Cedar	4/11	3/9	2000	5/1	2018	4/6	4/6	49
Diamond	4/6	3/6	2000	4/27	2018	4/1	4/2	30
Grass	4/4	3/14	2016	4/27	2018	4/1	4/1	17
Harriet	4/12	3/9	2000	5/2	2018	4/6	4/7	55
Hiawatha	4/11	3/8	2000	4/26	2013, 2018	4/3	4/3	48
Isles	4/11	3/8	2000	5/1	2018	4/5	4/5	53
Loring	4/5	3/6	2000	4/26	2018	4/1	4/3	42
Nokomis	4/11	3/8	2000	5/1	2018	4/4	4/4	51
Powderhorn	4/8	3/8	2000	4/29	2018	4/3	4/3	43
Ryan	4/8	3/15	2016	4/30	2018	4/4	4/3	19
Spring	4/8	3/6	2000	4/26	2018	3/31	4/1	32
Wirth	4/11	3/7	2000	4/30	2018	4/2	4/3	46

Table 17-9. Statistics related to ice-on dates.

Lake	First ice-on date 2022	Final ice-on date 2022	Earliest Ice-On	Year Occurred	Latest Ice-On	Year Occurred	Mean	Median	Years of Data
Bde Maka Ska	12/8	12/8	11/25	1996	1/16	2006-07	12/13	12/11	53
Birch	11/21	11/21	11/1	1991	12/16	1998	11/25	11/26	37
Brownie	11/21	11/21	11/5	1991	12/21	2015	11/29	11/30	41
Cedar	12/5	12/5	11/18	1989	12/21	1998, 1999, 2001, 2015	12/4	12/4	41
Diamond	11/21	11/30	11/13	2014	12/20	2001	12/2	12/3	28
Grass	11/21	12/19	11/13	2014	12/17	2021	12/4	12/6	17
Harriet	12/5	12/8	11/25	1996	1/16	2006-07	12/13	12/11	50
Hiawatha	12/5	12/19	11/1	1991	1/31	2006-07	12/4	12/3	42
Isles	11/21	11/21	11/5	1991	1/2	2006-07	12/1	12/2	48
Loring	11/21	11/21	11/1	1991	12/21	1999, 2001, 2015	12/1	12/2	38
Nokomis	11/30	11/30	11/1	1991	1/17	2011-12	12/2	12/2	43
Powderhorn	11/21	12/19	11/1	1991	12/21	2015	11/30	12/1	38
Ryan	11/22	11/30	11/17	2014	1/16	2006-07	12/7	12/2	16
Spring	11/21	11/30	11/10	1995	12/20	2001	11/29	11/30	32
Wirth	11/22	11/22	11/5	1991	12/21	2001, 2015	11/30	12/2	42

Table 17-10. Average length in days of ice cover for each decade between 1962 and 2022.

Lake	1962-1969	1970-1979	1980-1989	1990-1999	2000-2009	2010-2019	2020-2022
Bde Maka Ska	118.6	125.6	119.7	117.7	110.0	109.4	104.7
Birch	118.5	NA	NA	134.9	129.4	130.0	135.0
Brownie	118.5	NA	146.0	132.5	122.8	124.1	120.7
Cedar	124.0	130.0	142.0	125.3	117.1	121.7	119.7
Diamond	118.5	NA	NA	NA	122.1	121.7	110.0
Harriet	117.6	121.3	120.0	117.6	109.6	109.2	103.7
Hiawatha	130.0	NA	125.5	131.4	111.6	116.4	114.7
Isles	126.0	129.5	131.8	134.8	117.2	120.5	112.0
Loring	124.0	NA	131.0	132.1	115.0	121.7	113.7
Nokomis	132.3	NA	132.7	131.9	119.7	115.9	118.3
Powderhorn	136.3	NA	133.0	132.4	121.1	123.4	117.0
Spring	118.5	NA	NA	127.7	119.7	124.4	113.0
Wirth	118.5	NA	131.5	131.7	119.9	119.6	118.0

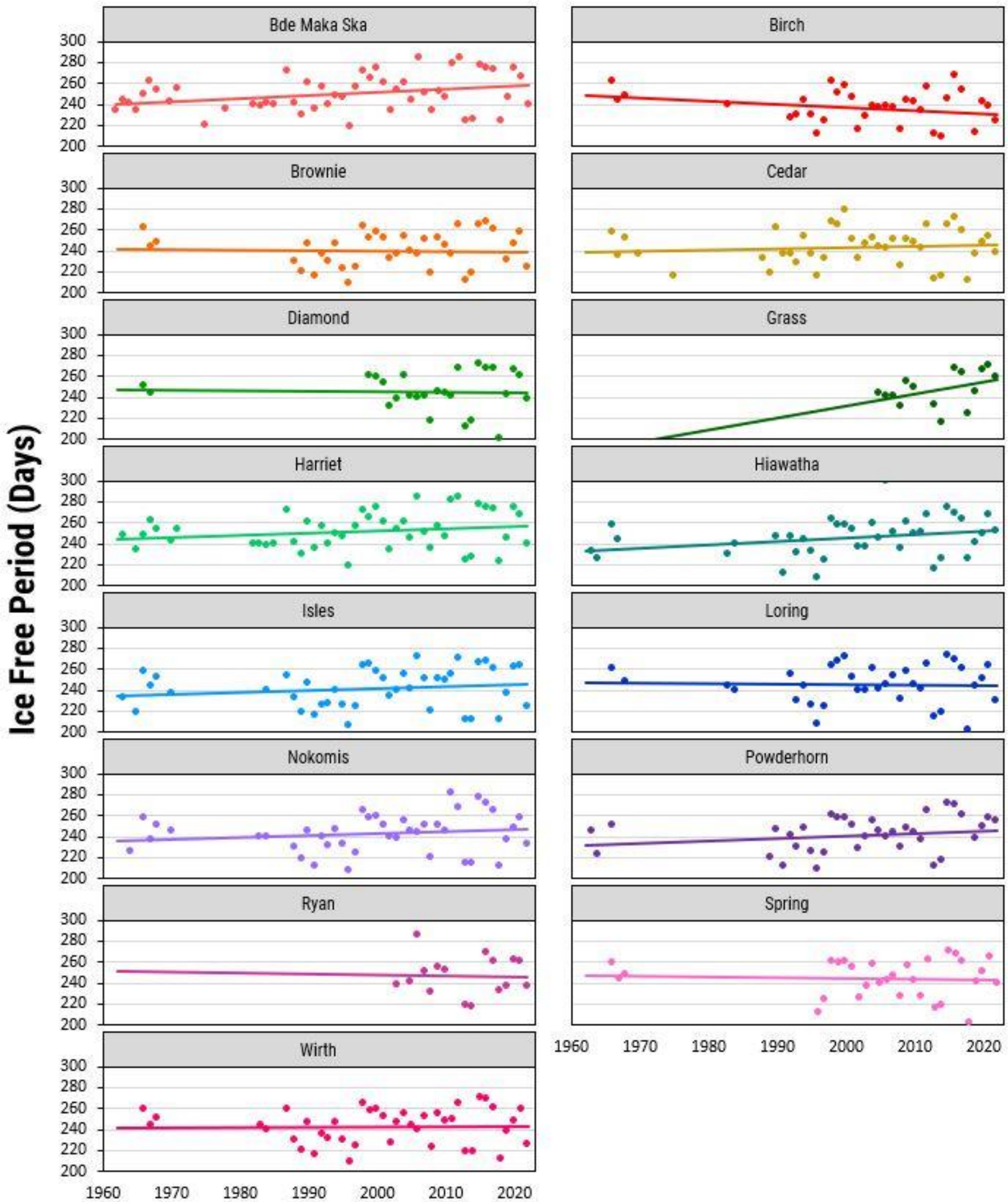


Figure 17-6. Ice free period (days) on Minneapolis lakes between 1962 and 2022.

EMERGING CONTAMINANTS

Per- and polyfluoroalkyl substances (PFAS) are a class of over 5,000 chemicals produced for many commercial and industrial uses since the 1940s (MPCA, "PFAS"). PFAS are known as "forever chemicals" due to their extreme resistance to breakdown by chemical or biological processes. They are known to bioaccumulate and have been recently identified as a concern due to their impact on environmental and human health. The Minnesota Department of Health (MDH) page on PFAS and Health has more information on PFAS health hazards and exposure mitigation, see https://www.health.state.mn.us/communities/environment/hazardous/topics/pfashealth.html. The Minnesota PFAS Blueprint develops short- and long-term goals, as well as legislative actions, to manage PFAS in the environment, see https://www.pca.state.mn.us/air-water-land-climate/minnesotas-pfas-blueprint. See **Chapter 1** for overview of emerging contaminants.

Perfluorooctane sulfonate (PFOS) is a type of PFAS that is of highest concern related to fish consumption. PFOS bioaccumulate in fish tissue, and PFOS concentrations in fish tissue have been measured up to 7,000 times the PFOS concentrations of the source water. MDH posts guidelines on statewide fish consumption, as well as Waterbody Specific Safe-Eating Guidelines, see https://www.health.state.mn.us/communities/environment/fish/index.html. For more information on PFAS in MPRB lakes, including impaired water listings and Waterbody Specific Safe-Eating Guidelines, see individual lake chapters: **Chapter 2** for Bde Maka Ska, **Chapter 5** for Cedar Lake, **Chapter 8** for Lake Harriet, **Chapter 9** for Lake Hiawatha, and **Chapter 10** for Lake of the Isles.

The mean concentrations of PFOS in fish tissue over time in these five lakes is charted in **Figure 17-7**. Concentrations have been declining since the contamination source to Bde Maka Ska was discovered in 2008 and PFOS mitigation projects began.

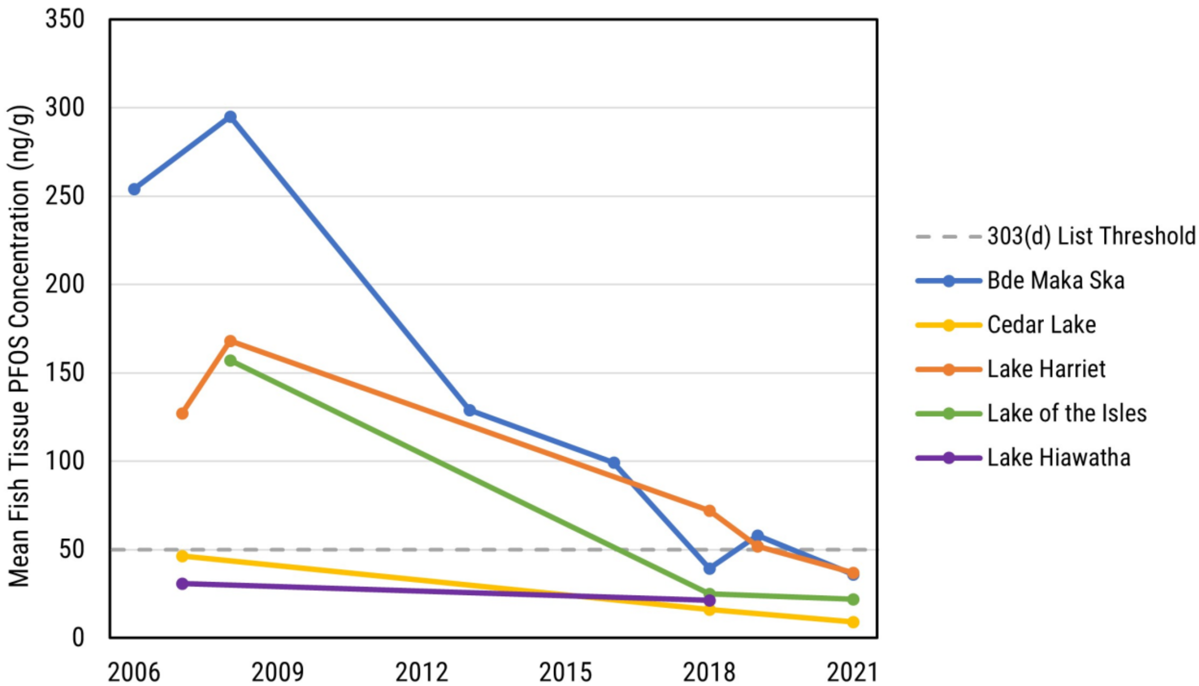


Figure 17-7. Mean fish tissue concentrations of PFOS by lake compared to the current fish tissue PFOS threshold for the 303(d) list, at 50 ng/g. The threshold does not apply to Bde Maka Ska, which has site-specific criteria. Data from MPCA (2018), MPCA (2020), and values calculated from data received via 2023 communication with MPCA staff.

Perfluorooctanoic acid (PFOA) is another type of PFAS in the environment that is connected to potential negative human health effects. Production of PFOA has been phased out in the United States, and human blood PFOA concentrations in the United States seem to be declining (MDH, 2022).

Surface water concentrations of PFOS and PFOA in Cedar Lake, Lake of the Isles, Bde Maka Ska, Lake Harriet, and Lake Hiawatha are all well below the MPCA's swimming guidance. Additionally, every lake with multiple years of surface water data shows a decline in the surface water concentrations of PFOS and PFOA, see **Table 17-11.**

Table 17-11. 2007 and 2018 surface water concentrations of PFOS and PFOA by lake, compared to the PFOS and PFOA swimming guidance. Data is given as the mean concentration in nanograms of contaminant per liter of lake water. Data retrieved from MPCA (2018). Swimming guidance received via communication with MPCA staff in 2023. Note that more PFOS data is available for Bde Maka Ska, see Chapter 2.

Water body	PFOS (ng/L)		PFOA (ng/L)	
	2007	2018	2007	2018
Cedar Lake	5.75	4.71	8.19	3.71
Lake of the Isles	18.1	4.7	13.9	4.86
Bde Maka Ska	53	11.93	18.60	9.99
Lake Harriet	30.9	11.57	17.3	9.55
Lake Hiawatha	NA	4.87	NA	3.70
Swimming Guidance	330		1,900	

Bde Maka Ska had been contaminated with PFOS that had traveled from a chrome plating facility in St. Louis Park via stormwater. Water flows through the Chain of Lakes from north to south, so the lowest PFOS concentrations are found in Cedar Lake and Lake of the Isles, which are both upstream of Bde Maka Ska. The highest PFOS concentrations are found in Bde Maka Ska, which was the original recipient of the PFOS contamination, and in Lake Harriet, which is downstream of Bde Maka Ska. Lake Hiawatha is located further downstream and has low concentrations as well, possibly due to the amount of water that flows in from other sources via Minnehaha Creek, diluting the water that comes from Lake Harriet. Continuous efforts to keep PFAS from entering MPRB lakes is necessary to continue to protect the health of the lakes, the people that use them, and the surrounding ecosystem.

18. Public Beach *E. Coli* Bacteria Monitoring

Background

The Minneapolis Park and Recreation Board (MPRB) has twelve official beaches located on six lakes, as shown in **Figure 18-1**. Prior to 2003 the City of Minneapolis Environmental Health Department monitored the beaches for fecal coliform bacteria. MPRB began beach monitoring in 2003 and tested the beaches for *Escherichia coli* (*E. coli*) as well as fecal coliform bacteria. In 2004, MPRB began following the United States Environmental Protection Agency (EPA) recommendation to monitor the beaches for *E. coli* alone. EPA guidelines for *E. coli* require that a single sample should not exceed 235 organisms per 100 mL of water and that the geometric mean of not less than five samples equally spaced over a 30-day period should not exceed 126 organisms per 100 mL of water (US EPA, 1986). MPRB began following these standards in 2004. Epidemiological testing allowed the Minnesota Pollution Control Agency (MPCA) to develop an inland lake standard of 1,260 organisms per 100 mL, which the MPRB has followed as the single-sample standard since 2006.

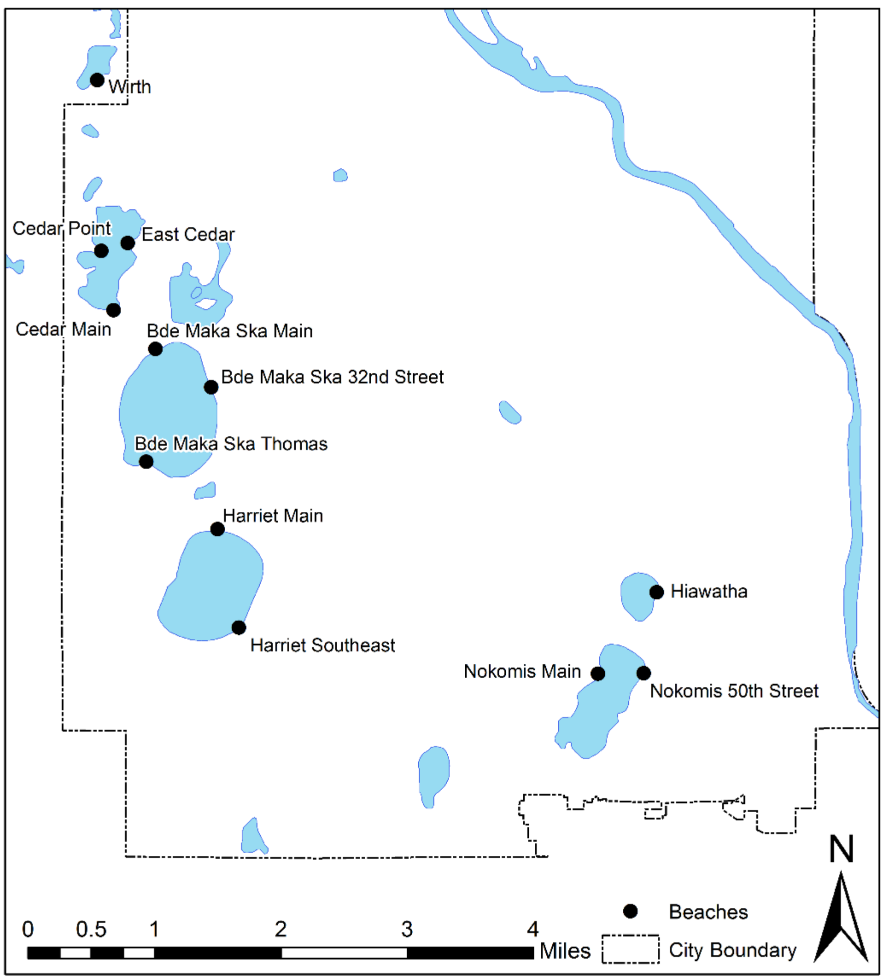


Figure 18-1. Map of the MPRB public beaches monitored in 2022.

A great diversity of pathogenic microorganisms exists and testing for a large array of microbes would be time consuming and expensive. Due to this difficulty, *E. coli* is used as an indicator organism for monitoring and regulation. *E. coli* is a proxy for the measure of fecal contamination in recreational waters (US EPA, 2005). Indicator organisms do not cause illness under normal conditions which makes them useful when determining if a potential health risk is present in the lake water. Bacteria can enter the aquatic environment from agricultural and stormwater runoff, direct discharge of waste from mammals and birds, and from untreated human sewage. Elevated bacteria levels generally occur in aquatic environments after rain events when bacteria from various sources are washed into the lakes. Elevated bacteria levels in the MPRB lakes usually return to normal levels within 24 to 48 hours of a rain event.

Potential sources of *E. coli* in lake water include:

- Foreshore beach sand and shoreline bank erosion
- Organic debris (wood, algae mats, aquatic plants, etc.)
- Leaking diapers and defecation of beach users
- Stormwater runoff and stream inflows
- Sewage spills near the beach or sewer line break discharges in the watershed
- Wild and domestic animal waste (such as geese, gulls, raccoons, dogs, etc.)

Initial research used to develop *E. coli* as an indicator organism held that it did not survive well outside of the digestive systems of warm-blooded animals. Half-lives of approximately one day in water, one and a half days in sediment, and three days in soil were once thought to be typical survival rates of *E. coli* outside of its host environment (Winfield and Groisman, 2003).

E. coli has now been found to survive and grow outside of its host environment. Research shows that algae can be a potential source of *E. coli*. Whitman et al. (2003) found that *Cladophora* (green algae) mats in Lake Michigan could supporting *E. coli* in significant numbers. Bacteria from the dried mats grew upon re-hydration even after 6 months. A common filamentous algae species, *Cladophora*, has been found to be an environmental reservoir for *Salmonella*, and potentially other pathogens, including *Campylobacter* and a Shiga toxin-producing strain of *E. coli* (STEC), *Shigella* (Byappanahalli et al, 2009).

Minneapolis Public Works, in collaboration with Burns & McDonnell, the University of Minnesota, and the Minnehaha Creek Watershed District, completed a Minnehaha Creek Bacterial Source Identification Study (2019) on the sources, pathways, and potential impacts of *E. coli* detected in Minnehaha Creek. *E. coli* in the study area originated primarily from natural sources such as birds, and regrowth in the environment, while dog and human waste sources were minimal. Several reservoirs of *E. coli* were identified in the study area including grassy areas, in-stream sediment, soil in streambanks and riparian areas, soil from road construction, organic debris in street gutters, and improperly managed temporary toilets. Over-irrigation of lawns was also found to transport *E. coli* from the watershed to the creek. Some stormwater management practices may also contribute to elevated *E. coli* levels, including discharge from grit chamber maintenance directly to the creek, improperly managed road construction activities, and lack of street sweeping leading to organic matter accumulating in gutters.

Beach sand has also been identified as another potential growth medium for *E. coli.* A study by Whitman and Nevers (2003) showed that *E. coli* can sustain itself in wet beach sand that can then serve as a non-point source of bacterial contamination. Another study by Byappanahalli et al. (2003) found *E. coli* to be ubiquitous and persistent in a Midwestern Lake Michigan coastal stream. *E. coli* was common in stream banks, and wetted sediments acted as a source of contamination to the stream. Genthner et al. (2005) found that after tidal events, the swash zone, the area of beach where waves continuously wash up on the sand, harbored higher densities of microorganisms and indicator bacteria, which is partially attributable to entrapment. It has been shown that bacteria survival and growth is enhanced by biological factors, such as nutrients and protection from predation, and by physical factors, such as particulate matter, periodic wetting and drying, and protection from solar irradiation. In studies in the Upper Midwest, Ishii et al. (2005) found significant populations of viable, naturalized *E. coli* in northern temperate soils in three Lake Superior watersheds. Ishii et al. (2007) found that the distribution of human and naturalized sources of *E. coli* at beaches can change over the course of a summer. These findings make the interpretation of *E. coli* levels at beaches a complicated endeavor, as multiple sources may cause elevated bacteria levels, and it is not well understood how many pathogens also become naturalized.

In the EPA Environmental Health Perspective (2005), the number of illnesses attributable to recreational water exposures was reported to be increasing. In Minnesota, there were 56 reported recreational water illness outbreaks from 2009-2018. The outbreaks were associated with 6 different pathogens, and 9 of the 56 outbreaks occurred in lakes and rivers (Minnesota Department of Health, 2018).

Water Quality Web Map

In 2020, the MPRB developed an online GIS-based Lake Water Quality Map, shown in **Figure 18-2,** to better communicate beach advisories, closures, and notifications to lake and beach users. This map has continued to be a vital communication tool to convey information to the public visually and in real-time. Water quality status, sampling date, water temperature, water clarity, microcystin data, and *E. coli* data were updated weekly with graphics indicating if beaches were open or closed based on *E. coli* monitoring results. In 2022, locations marked in yellow indicated an “advisory” for the presence of cyanobacteria based on the visual observation of a bloom or elevated cyanotoxin levels. See **Chapter 19** for more information on cyanobacteria and cyanotoxin monitoring. The map includes water quality information for all Minneapolis lakes and can be found on the MPRB website bit.ly/mplsbeaches.

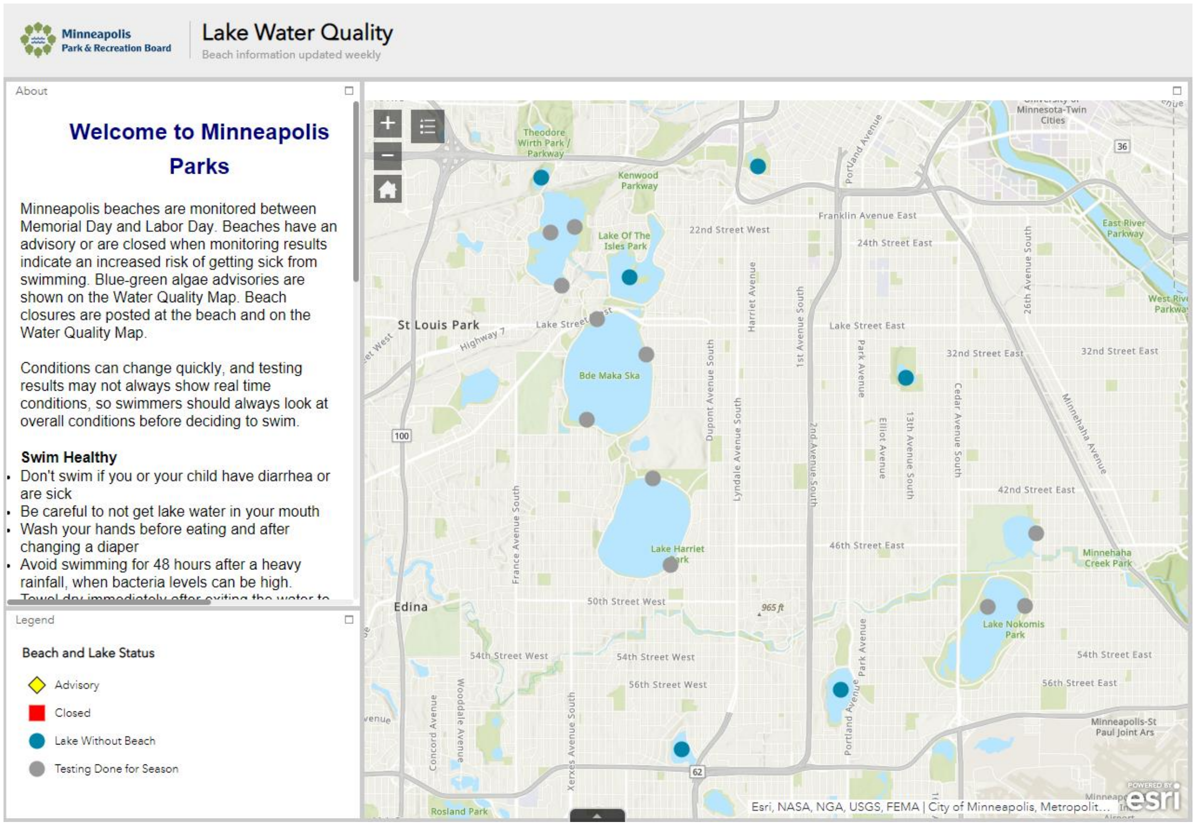


Figure 18-2. Example of the MPRB Lake Water Quality Map showing the water quality status of the beaches and lakes monitored by MPRB Water Resources staff in 2022.

Methods

Samples were collected at all Minneapolis beaches the first day of every week during the 2022 beach season, from May 23rd through September 5th. *E. coli* field duplicates were also collected every sampling day on a rotating weekly schedule. Beaches monitored in the 2022 MPRB program were:

- Bde Maka Ska 32nd Street
- Bde Maka Ska Main (North)
- Bde Maka Ska Thomas (South)
- Cedar Main (South)
- Cedar Point
- East Cedar (Hidden)
- Harriet Main
- Harriet Southeast
- Hiawatha
- Nokomis 50th Street (East)
- Nokomis Main
- Wirth Main

Two *E. coli* samples were taken from each beach in knee deep water (1.8 feet) roughly six to twelve inches below the surface on the left and right sides of the beach. *E. coli* is not often found to be uniform across the beach area and the sample values are averaged to give a more comprehensive picture of the bacteria levels found at the beach.

Samples for the 2022 cyanotoxin sampling program were also collected during the weekly beach monitoring program, refer to **Chapter 19** for more details.

Separate coolers were used to transport *E. coli* samples in an ice bath and cyanotoxin samples on ice to the MPRB contract laboratory, Instrumental Research Incorporated (IRI). IRI used a Colilert Quanti-Tray to determine the most probable number (MPN) of *E. coli* colonies in the samples. One MPN is equal to 1 colony formed unit (CFU). CFU is calculated from the bacterial and fungal colonies growing on a solid agar plate while MPN is calculated from viable bacteria growing in a liquid medium. Water temperatures were measured in the field using a digital thermometer, and air temperature was recorded from the Apple Weather app. Precipitation data was sourced from the National Oceanic and Atmospheric Administration (NOAA).

Parameters recorded at the beach during sampling included:

- Current weather, including air temperature, wind speed and direction, and cloud cover
- Water conditions, including water temperature and presence of foam
- Number of swimmers in the water, broken down by adults, children, and children in diapers
- Number of beachgoers not in the water, broken down by adults, children, and children in diapers
- Number of geese, ducks, and gulls on the beach
- Cyanobacteria Visual Monitoring Index (VMI) rating (See **Chapter 19**)
- Additional comments on notable beach conditions, such as debris, evidence of waterfowl activity, and turtle sightings
- Data for the Lake Aesthetic and User Recreation Index (LAURI) (See **Chapter 1**)

Additional data compiled in relation to beach monitoring were:

- Quantity of rainfall in the 48 hours prior to beach sampling
- Hours since last rain event ended
- Intensity of last rain event

RESULTS & DISCUSSION

Specific lake and beach results are discussed in each of the lake chapters. Refer to **Chapter 19** for cyanobacteria monitoring results. **Table 18-1** shows the basic descriptive statistics of *E. coli*, MPN organisms per 100 mL of water, in the beach water sampled during the 2022 beach monitoring season starting May 23rd, 2022 and ending September 5th, 2022. Most beaches had low season-long geometric means, but there were several beach closures during 2022.

Table 18-1. Minimum, maximum, median, mean, geometric mean (entire season), and maximum 30-day geometric mean for *E. coli* values (MPN/100 mL) from the twelve beaches monitored by the MPRB in 2022.

Statistical Calculations	Bde Maka Ska			Cedar			Harriet		Hiawatha	Nokomis		Wirth
	32nd	Main	Thomas	East	Main	Point	Main	SE	Beach	50th	Main	Beach
Number of Samples	15	15	15	15	14	15	15	15	15	15	15	15
Minimum	2	1	1	1	1	1	1	1	9	3	1	1
Maximum	1454	1171	1063	176	2420	2420	246	327	2420	52	83	617
Median	88	25	53	3	14	10	10	32	112	7	9	3
Mean	368	112	214	24	232	195	38	67	428	15	15	66
Geometric Mean	80	26	47	6	18	17	11	19	146	10	8	8
Max 30-Day Geo Mean	317	96	152	22	35	56	29	43	429	19	15	24
Standard Deviation	514	296	349	47	649	617	66	103	695	14	20	161

Beach Closures

Bde Maka Ska Main Beach remained open for the entire 2022 sampling season. Bde Maka Ska 32nd Street Beach closed July 19th due to an exceedance of the single sample *E. coli* standard of 1,260 MPN/100 mL. The beach was re-sampled on July 20th and re-opened on July 21st after results had shown that *E. coli* concentrations dropped below the single-sample threshold. Bde Maka Ska 32nd Street Beach closed again on August 2nd due to an exceedance of the 30-day geometric mean standard of 126 MPN/100 mL. The beach remained closed until August 16th, when the 30-day geometric mean dropped below the threshold. Bde Maka Ska 32nd Street Beach closed again on August 23rd due to an exceedance of the single sample *E. coli* standard. The beach was re-sampled on August 24th, but the decision was made to keep the beach closed despite *E. coli* concentrations dropping below the single-sample threshold due to high chances of 30-day geometric mean exceedance after the next sampling. The beach remained closed due to an exceedance of the 30-day geometric mean standard on August 29th and remained closed for the rest of the beach season. High *E. coli* concentrations may have been attributed to piles of decomposing aquatic vegetation and waterfowl waste in the beach area.

Thomas Beach at Bde Maka Ska closed on August 9th due to an exceedance of the 30-day geometric mean standard. High concentrations of bacteria that led to this closure were attributed to excessive goose activity in the weeks preceding. The beach remained closed until August 16th, when the 30-day geometric mean dropped below the threshold. Bde Maka Ska Thomas Beach closed again on August 30th due to an exceedance of the 30-day geometric mean standard. The beach remained closed for the rest of the beach season.

East Cedar Beach remained open for the entire 2022 sampling season. Cedar Main Beach closed on July 19th due to an exceedance of the single sample *E. coli* standard. The beach was re-sampled on July 20th and re-opened on July 21st after results had shown that *E. coli* concentrations dropped below the single-sample threshold. Cedar Point Beach closed July 12th due to an exceedance of the single sample *E. coli* standard. The beach was re-sampled on July 13th and re-opened on July 14th after results had shown that *E. coli* concentrations dropped below the single-sample threshold.

There were no closures at either Harriet Main or Harriet Southeast Beaches during the 2022 beach season due to the exceedance of *E. coli* standards.

Hiawatha Beach first closed on June 22nd due to exceedance of the 30-day geomean standard. The beach remained closed until July 26th, when the 30-day geometric mean dropped below the threshold. Hiawatha Beach closed again on August 9th due to exceedance of the single sample *E. coli* standard. The beach was re-sampled on August 10th and re-opened on August 11th after results had shown that *E. coli* concentrations dropped below the single-sample threshold. Hiawatha Beach closed again on August 30th due to exceedance of both the single sample *E. coli* standard and exceedance of the 30-day geomean standard and remained closed the rest of the sampling season.

There were no closures at either Nokomis 50th Street or Nokomis Main Beaches during the 2022 beach season due to the exceedance of *E. coli* standards. There were no closures at Wirth Beach due to exceedance of *E. coli* standards in 2022. **Figure 18-3** shows the cumulative days of closure due to *E. coli* exceedances at all Minneapolis Beaches by year for the last ten years.

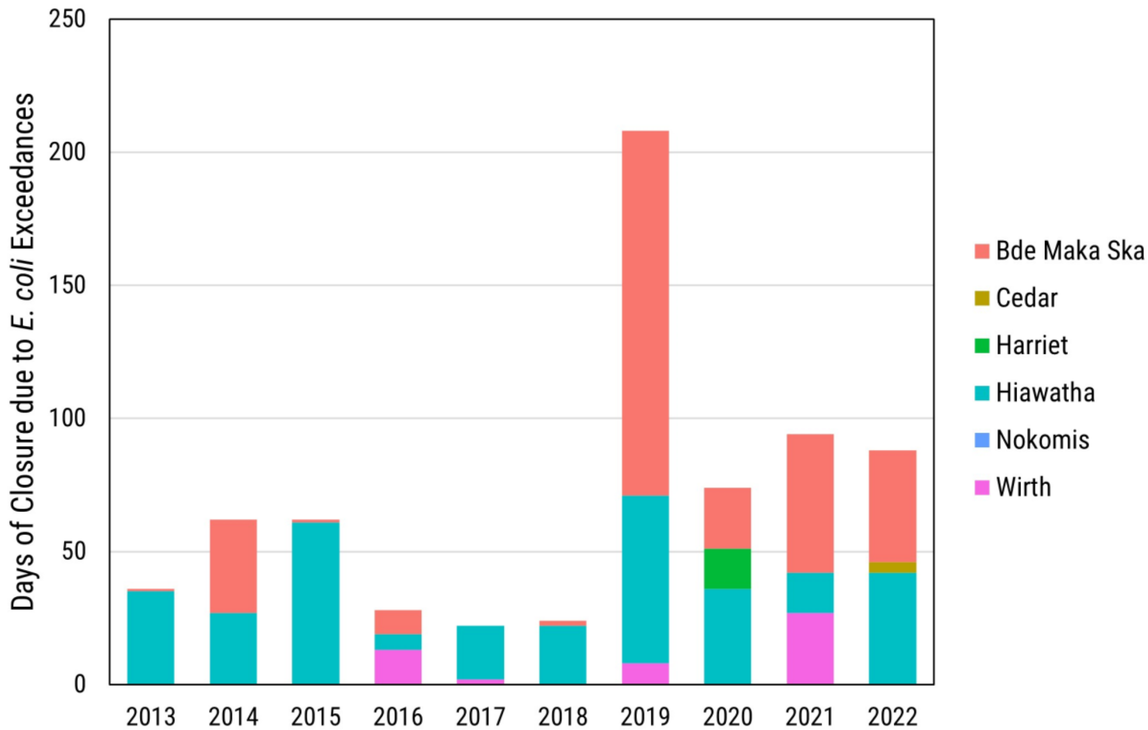


Figure 18-3. Bar graph of total number of days Minneapolis beaches were closed each year due to E. coli exceedances from 2013-2022.

Precipitation and waterfowl activity are generally the most influential causes of elevated *E. coli* levels in Minneapolis lakes. 2019 had the highest precipitation on record and more than twice as many days of beach closure than any of the other of the last ten years, see **Chapter 29** for more on climate. Flocks of waterfowl are often observed on and near many of the beaches that have consistently experienced closures including Hiawatha Beach, Bde Maka Ska 32nd Street Beach, and Bde Maka Ska Thomas Beach. The MPRB employs a variety of strategies for Canada Goose management. In recent years, the focus has shifted from comprehensive goose mitigation throughout the MPRB system toward more targeted management of geese for the protection of human health and reduction of damage to park property. Beginning in 2021, the MPRB has had Cooperative Service Agreement with the United States Department of Agriculture Animal and Plant Health Inspection Service Wildlife Services (USDA APHIS WS) for Canada Goose management and removal. Environmental education efforts have been made to educate the public not to feed wildlife such as ducks and geese, to reduce habituation, see **Chapter 30** for more on Water Quality Education. Canada Goose numbers often significantly increase at beaches during the late summer and fall due to their migration habits, which leads to more frequent closures towards the end of beach season.

Rain washes bacteria from surfaces, such as roads, parking lots, roofs, and sidewalks, which is then transported to the lakes via the stormsewer system. Surface runoff from larger precipitation events can also erode beach sand and shoreline soils, washing naturalized bacteria into the lake. High rainfall events that precede sampling often correspond with elevated *E. coli* concentrations, and subsequent beach closures. **Table 18-2** shows the number of storms during the past five beach seasons, the amount of rain received in the largest single rain event, the average amount of precipitation per rain event, and the total amount of rain received during the beach seasons. Rain data was collected at the MPRB Southside Service Center rain gage.

The relationship between rain and *E. coli* at the beaches is complex. Differences in the timing and pattern of rainfall may be more influential on *E. coli* levels than rainfall amounts. The combination of rain intensity and duration may also influence bacteria at some of the beaches.

Table 18-2. Number of storms, largest storm (inches), average storm (inches), and total rain (inches) for the 2018–2022 beach seasons (entire months of June, July, and August). A storm is defined as having more than 0.10 inches of precipitation and separated from other rainfall events by at least eight hours.

Year	2018	2019	2020	2021	2022
Number of storms	18	26	20	9	14
Maximum rain single event (in)	1.27	2.58	2.18	1.48	0.84
Average rain per event (in)	0.56	0.64	0.57	0.68	0.36
Total rain (in)	10.16	17.20	11.11	9.81	5.72

Discussion

It is difficult to assess the quality of water the same day of sample collection since laboratory testing for *E. coli* requires 24 hours to complete. This lag time between sample collection and receipt of test results can sometimes result in the posting of a beach closure after the conditions that instigated the closure have passed. A study by Ha Kim and Grant (2004) found that the public is incorrectly notified about current water quality status and beaches are incorrectly posted up to 40% of the time. Closures due to single-sample exceedances of the MPCA inland lake standard of 1,260 organisms per 100 mL of water, which represents *E. coli* levels at a single point in time, may be prone to posting errors related to this lag time issue. The MPCA single-sample standard represents very high level of *E. coli*, which is not typically sustained over long periods. The US EPA geometric mean standard used by MPRB is that the 30-day geometric mean is not to exceed 126 organisms per 100 mL. Closures based on this standard are not affected by the lag time issue, as this measurement illustrates the ongoing trend in *E. coli* levels, rather than a snapshot of a single event. Therefore, closures based on this standard can more reliably reflect contamination concerns.

MPRB Environmental Water Resources staff stays up-to-to-date on current *E. coli* and beach pathogen research and testing methodology, to inform beach management decisions using the best available methods and data.

19. Blue-Green Algae/Cyanotoxin Monitoring

Background

Introduction

Blue-green algae are not algae at all, but types of bacteria called cyanobacteria. They are photosynthetic microorganisms that occur naturally in lakes, streams, and other waterbodies. When conditions are right, cyanobacteria grow quickly to form blooms. Blooms are often described as looking like pea soup or spilled paint and can be any color, not always green, see **Figure 19-1**. Blooms aren't always large and dense and can sometimes cover small portions of the lake with little visible algae present. They can also release a swampy odor when the cells break down. The conditions for cyanobacteria to reproduce rapidly and produce blooms depend on several factors; some of these include: the cyanobacteria genera present, nutrient loading and availability, light availability, water temperature, pH changes, turbulence, and alteration of water flow (Paerl & Otten, 2013). Blooms are typically the most severe in July and August when water temperatures are warmest, greater than or equal to 68 degrees Fahrenheit, and water is nutrient-rich. Anthropogenic factors such as urban, industrial, and agricultural activities have increased nutrient over-enrichment or eutrophication of waterbodies, allowing cyanobacteria to thrive. While the process of nutrient loading promotes cyanobacteria growth, warmer temperatures, more intense precipitation events, and longer stratification periods due to climate change also could stimulate more intense and frequent cyanobacteria blooms. Minneapolis Park and Recreation Board (MPRB) staff have noted an increase in frequency and severity of cyanobacteria blooms in Minneapolis lakes in recent years.

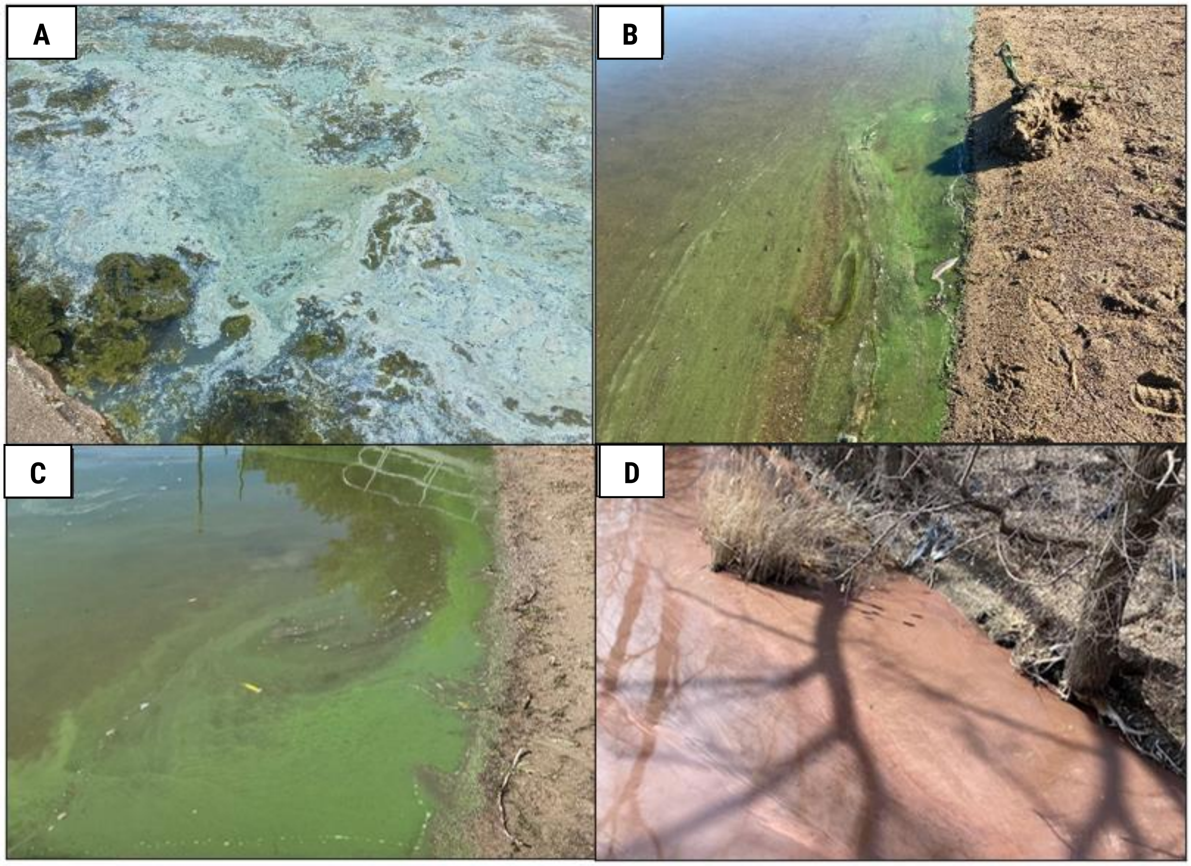


Figure 19-1. Photos of cyanobacteria blooms in MPRB Lakes. Harriet boat launch June 2022 (A), Lake Hiawatha Beach June 2022 (B), Lake Nokomis boat launch August 2022 (C), and North shore of Cedar Lake April 2020 (D).

Cyanotoxins

Certain varieties of cyanobacteria can produce toxins, referred to as cyanotoxins, that can cause illness in humans and animals (US EPA, 2017). Different types of cyanotoxins that are often monitored include microcystin, anatoxin, and cylindrospermopsin. A single cyanobacteria taxon can produce multiple types of cyanotoxins and each cyanobacterium can produce toxins of varying toxicity (Buratti et al., 2017). Cyanobacteria make lots of different compounds, some of which are irritating but not toxic, and only a few of these unusual compounds have been studied. Blooms are harmful when they produce toxins that can make humans and animals sick, these are referred to as harmful algal blooms (HABs). It is impossible to tell by looking at a bloom if it is harmful or not. For more information on cyanotoxins and corresponding health effects visit: https://www.epa.gov/cyanohabs/learn-about-cyanobacteria-and-cyanotoxins.

An increase in frequency and intensity of cyanobacteria blooms has raised awareness for public concern due to the potential for blooms to produce cyanotoxins. If humans, pets, or wildlife ingest cyanotoxin-producing cyanobacteria, they can become minorly or fatally sick depending on the level of toxicity and amount ingested. See **Table 19-1** for the possible level of exposure to cyanotoxins in relation to recreational water activities. There have been several reports of eye, ear, sinus, and flu-like complaints particularly from open water swimmers that may be consistent with exposure to cyanobacteria according to the Minnesota Department of Health. Phytoplankton communities have been monitored on MPRB lakes since 2001, and data has shown that cyanobacteria species that have toxin-producing potential are present. For these reasons, the MPRB staff began monitoring cyanobacteria blooms in 2020.

Table 19-1. Possible level of exposure to algae toxins in relation to recreational water activities (MPCA, 2022-a). The amount of time spent doing activities will also affect level of exposure to algae toxins. *Note MPRB lakes are not drinking water sources.

Activities	Level of exposure to algae toxins
Drinking (incidental or intentional)*	Highest
Swimming, diving, water skiing, windsurfing, tubing, paddle boarding	High
Canoeing, kayaking, sailing, personal watercraft	Moderate
Fishing, boating, fish consumption	Low

In 2022, cyanobacteria was monitored by collecting water samples and analyzing them for concentrations of three cyanotoxins: microcystin, cylindrospermopsin, and anatoxin-*a*. A Visual Monitoring Index (VMI) and total algae probe were also used. The MPRB collects information on cyanobacteria during the summer beach season, year-round lake monitoring, and when responding to reports from citizens.

Minnesota Department of Health (MDH) recommends response monitoring in the form of identifying blooms, notifying the public, and testing for cyanotoxins if a severe bloom is occurring. In 2022, current standards recommended by Minnesota Pollution Control Agency (MPCA) were used for blue-green algae advisories, see **Table 19-2**. More information on HAB water recreation advisories can be found here: https://www.pca.state.mn.us/water/harmful-algae-blooms-water-recreation-advisories.

Table 19-2. 2022 MPRB cyanotoxin and VMI standards.

Toxin	Advisory
Microcystin	≥ 6 µg/L
Cylindrospermopsin	≥ 15 µg/L
Anatoxin-*a*	≥ 7 µg/L
VMI	3

METHODS

In 2022, the MPRB monitored for cyanobacteria during open-water beach monitoring and year-round lake sampling. Water samples were collected and sent a contracted lab for cyanotoxin analysis of microcystin, cylindrospermopsin, and anatoxin-*a* levels. Pigments produced by cyanobacteria were measured at the mid-lake sampling location using a total algae probe. Visual indicators of cyanobacteria growth were assessed in lakes and at beaches using a Visual Monitoring Index (VMI). Lastly, parameters related to microcystin risk, including chlorophyll-*a*, Secchi depth, and pH, were collected at the mid-lake sampling location.

Cyanotoxin Sampling

Cyanotoxin samples were collected during beach monitoring and lake sampling. All cyanotoxin samples were analyzed for microcystin. Cylindrospermopsin and anatoxin-*a* were analyzed between July and August at all MPRB beaches. Anatoxin-*a* was analyzed in late May and June at Lake Nokomis beaches. Cylindrospermopsin and anatoxin-*a* were analyzed between July and September at Powderhorn Lake. Sampling periods were chosen because previously collected phytoplankton data showed that is when toxin-producing species were present in MPRB lakes.

During beach monitoring, cyanotoxins were measured in grab samples that were collected weekly at the center of the beach at all 12 MPRB beaches, see **Table 19-3**. At Powderhorn Lake, cyanotoxins were analyzed from composite or grab samples that were collected in winter, spring, bimonthly between May and September, and in the fall. At Bde Maka Ska, Cedar, Harriet, and Lake Nokomis cyanotoxins were analyzed from composite samples collected in winter and spring. See **Table 19-4** for the description of each sample type.

Table 19-3. Beach monitoring locations in 2022.

2022 Beach Monitoring Locations			
Bde Maka Ska 32nd Street	Cedar Main	Harriet Main	Nokomis 50th Street
Bde Maka Ska Main	Cedar Point	Harriet Southeast	Nokomis Main
Bde Maka Ska Thomas	East Cedar	Hiawatha	Wirth

Table 19-4. Cyanobacteria monitoring sample types and descriptions.

Sample Type	Description
Grab	6” – 12” below the surface, mid forearm or elbow depth
Composite	0-2m sample taken with the 2m long stoppered 2” diameter PVC tube

All cyanotoxin samples were collected in an unrinsed 250 mL bottle wrapped in aluminum foil. Immediately following collection, samples were placed on ice in a cooler and stored at approximately 4°C. Samples were transported to MPRB’s contract laboratory and analyzed via the enzyme linked immunosorbent assay (ELISA) method. All samples were lysed three times. Lysing is the breaking down of the membrane of a cell and is done by freezing and thawing samples. This method most accurately determines the amount of toxin ingested if lake water is swallowed. Samples were either run at a 1:1 dilution, or a 10:1 dilution to obtain results that showed whether or not the advisory threshold was exceeded.

Total Algae Probe

Phycocyanin and chlorophyll-*a* concentrations were measured on all MPRB lakes sampled in 2022. A YSI EXO1 total algae probe was used to measure these concentrations in relative fluorescence units (RFU). Phycocyanin is a green pigment found in cyanobacteria and can be used as a proxy indicator for blue-green algae blooms. Although there is no standard for phycocyanin concentrations, studies show that phycocyanin and chlorophyll-*a* concentrations strongly correlate to microcystin levels, and these parameters can be used to predict when cyanobacteria blooms occur (Mchau, Makule, Machunda et al., 2019).

While lake monitoring, phycocyanin and chlorophyll-*a* concentrations were measured at 1-meter intervals from one meter above lake bottom, as to not disturb sediments, to the surface on most lakes. Only surface readings were collected on Diamond and Grass Lake due to the shallowness of these waterbodies. The total algae probe was calibrated according to the manufacturer's guidelines, using rhodamine dye, prior to each sampling trip.

Cyanobacteria Visual Monitoring Index (VMI)

MPRB used a Visual Monitoring Index (VMI) to assess the amount of cyanobacteria present in a consistent and reproduceable manner during all beach sampling sessions and when monitoring lakes. The method MPRB used was based on criteria developed by the Vermont Department of Environmental Conservation and the Lake Champlain Committee, see https://www.lakechamplaincommittee.org/lcc-at-work/cyanobacteria-in-lake. The VMI category was noted by a trained observer based on the visual lake conditions using the definitions provided by the VMI, shown in **Table 19-5**. Photos of blooms were also taken by MPRB staff when the VMI category was a 2 or a 3 to document bloom conditions.

Table 19-5. Visual Monitoring Index categories with short descriptions.

VMI Category	Description
1a	Clear visibility, no cyanobacteria
1b	Brown/turbid, less visibility, no cyanobacteria
1c	No cyanobacteria however, other phenomenon such as pollen, duckweed, and filamentous algae are present
1d	Tiny amounts of cyanobacteria, low density green floating balls may be present, no clumps, no surface or shore accumulations, water appears clear but can see some cyanobacteria
2	No observed bloom, numerous balls of cyanobacteria in the water column, not accumulating at surface but may have narrowband on shore, open water not discolored
3	Full-lake bloom visible, extensive scum on the surface, open water discolored

Visual Monitoring Index (VMI) Category Descriptions

VMI categories are determined based on specific observations. The following section includes detailed descriptions of each category including images that clearly demonstrate specific characteristics. Images were taken by the Lake Champlain Committee (LCC) and MPRB staff.

Category 1a: No cyanobacteria observed and clear water. Any organisms floating in the water column are clear rather than green. Leafy or grass-like plants, including duckweed, may be present. Foam may also be present. Objects sitting lower in the water column are clearly visible. Overall appearance of water is clear as seen in **Figure 19-2**.

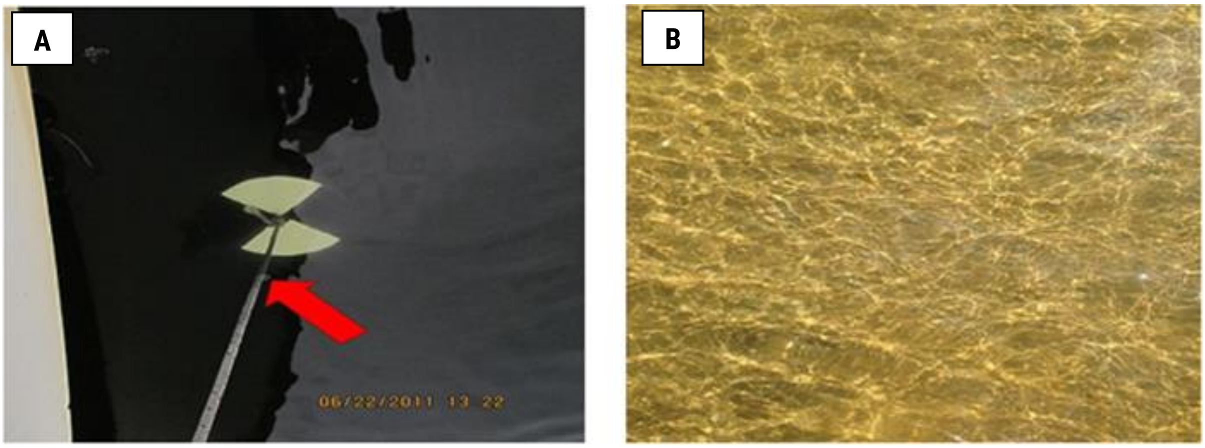


Figure 19-2. Images from the LCC of Category 1a: no cyanobacteria observed. Images A and B show clear water by the visible Secchi disc and lake bottom.

Category 1b: No cyanobacteria observed but conditions are brown and turbid. **Figure 19-3** shows brown water that is turbid with low visibility through the water column but does not indicate a presence of cyanobacteria.

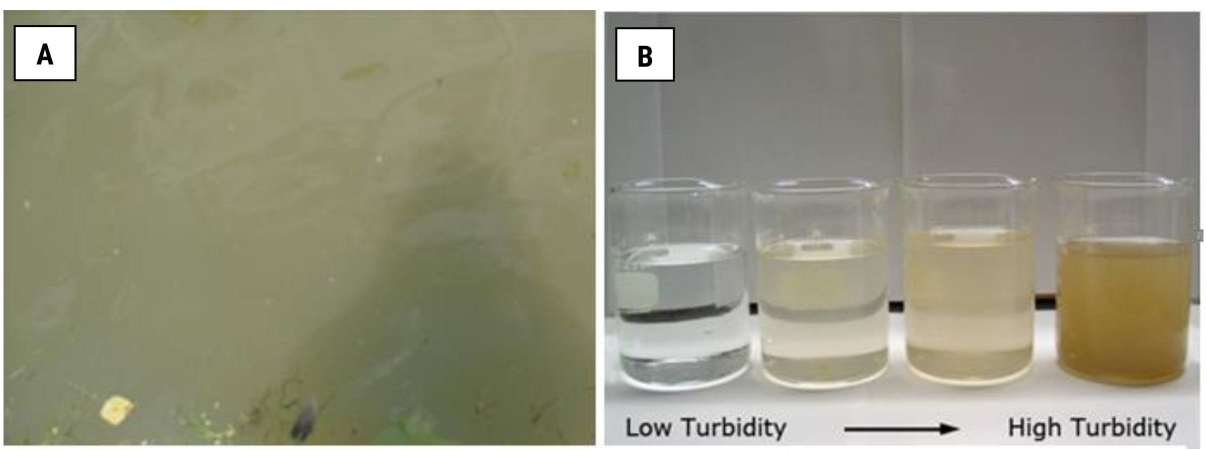


Figure 19-3. Images taken by LCC of Category 1b: no cyanobacteria observed but the conditions are brown and turbid. Image A shows brown/turbid conditions in the field while B is a comparison of low to high turbidity in the lab.

Category 1c: No cyanobacteria observed but other phenomena present. Other material, as shown in **Figure 19-4**, may include:

- Filamentous green algae that appear stringy, with long strands or attached to the bottom of the lake
- Pollen
- Iron oxidizing bacteria
- Duckweed

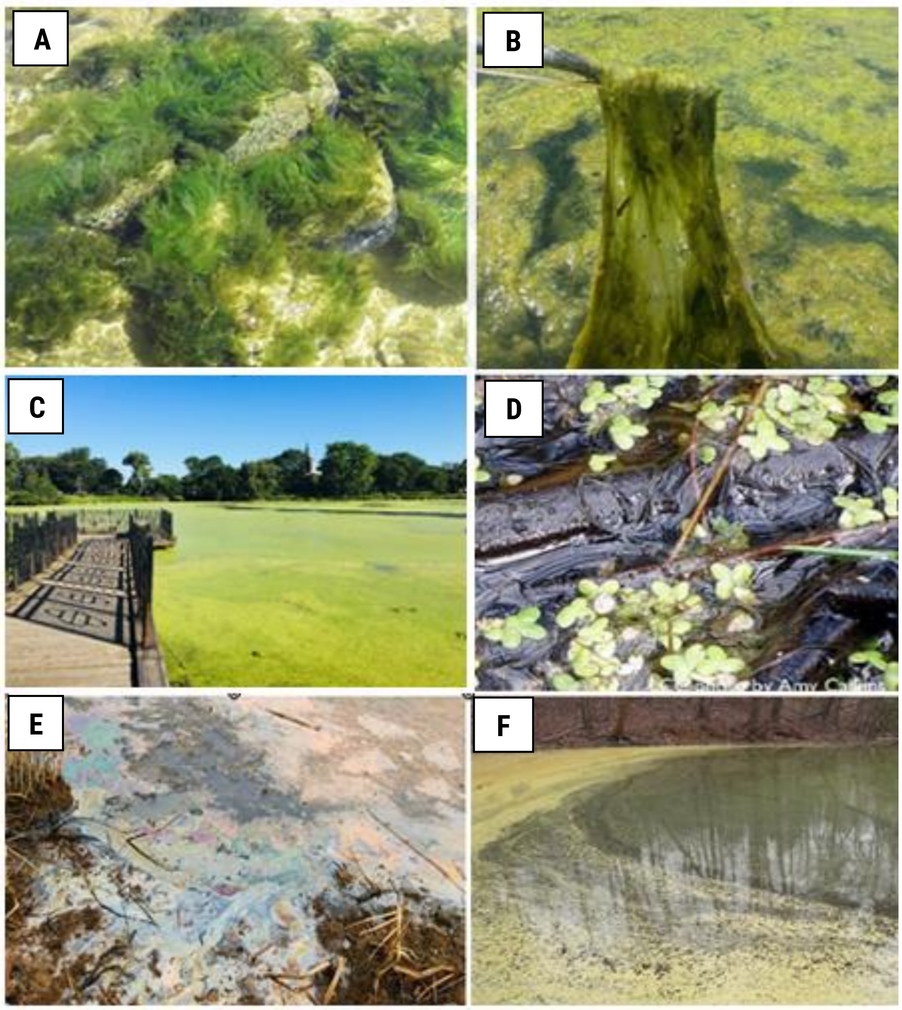


Figure 19-4. Images from the LCC of Category 1c: no cyanobacteria observed but other phenomena present such as filamentous algae (A and B), duckweed (C and D), iron oxidizing bacteria (E), and pollen (F).

Category 1d: Very little cyanobacteria observed. Tiny specks of algae are present, but no striations or clumps. Green floating balls may be visible, as shown in **Figure 19-5**, but only on close inspection and in densities so low that they do not impair recreational enjoyment of the water. There are no surface or near shore accumulations of cyanobacteria. Water appears perfectly clear but close inspection shows some cyanobacteria present.

Figure 19-5. Image from LCC of Category 1d jar test: little cyanobacteria observed. Tiny specks present, but no striations or clumps.

Category 2: Low alert with cyanobacteria observed but at less than “bloom” levels. Numerous green balls that are pinhead size or larger can be seen floating in water column but not accumulated at the water surface. Possible smaller than softball sized patches of cyanobacteria accumulation may be seen in the water column. Open-water color is not green and a possible narrow band of cyanobacteria may have accumulated at the shoreline, as seen in **Figure 19-6**. Some cyanobacteria are observed in the water but not a uniform layer.

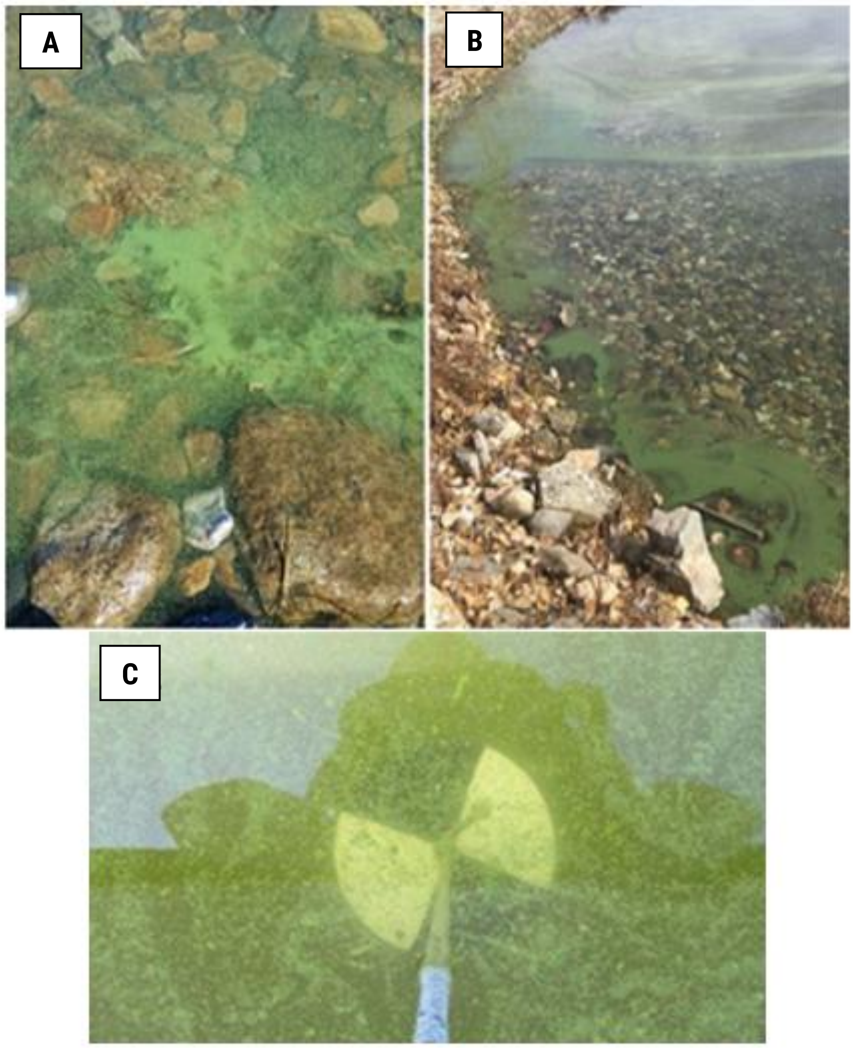


Figure 19-6. Images from LCC of Category 2: Low alert, cyanobacteria observed but at less than “bloom” levels as seen by the bands of cyanobacteria present at the shoreline in image A and B. Image C shows reduced clarity but not green structure covering the Secchi disc in open water.

Category 3: High alert, cyanobacteria bloom observed in progress. Extensive surface scum on the water and color may range from green, electric blue, to brownish red. Usually, the scum on the water is accompanied by a thick accumulation at shoreline. Open water also appears to be discolored as shown in **Figure 19-7**.

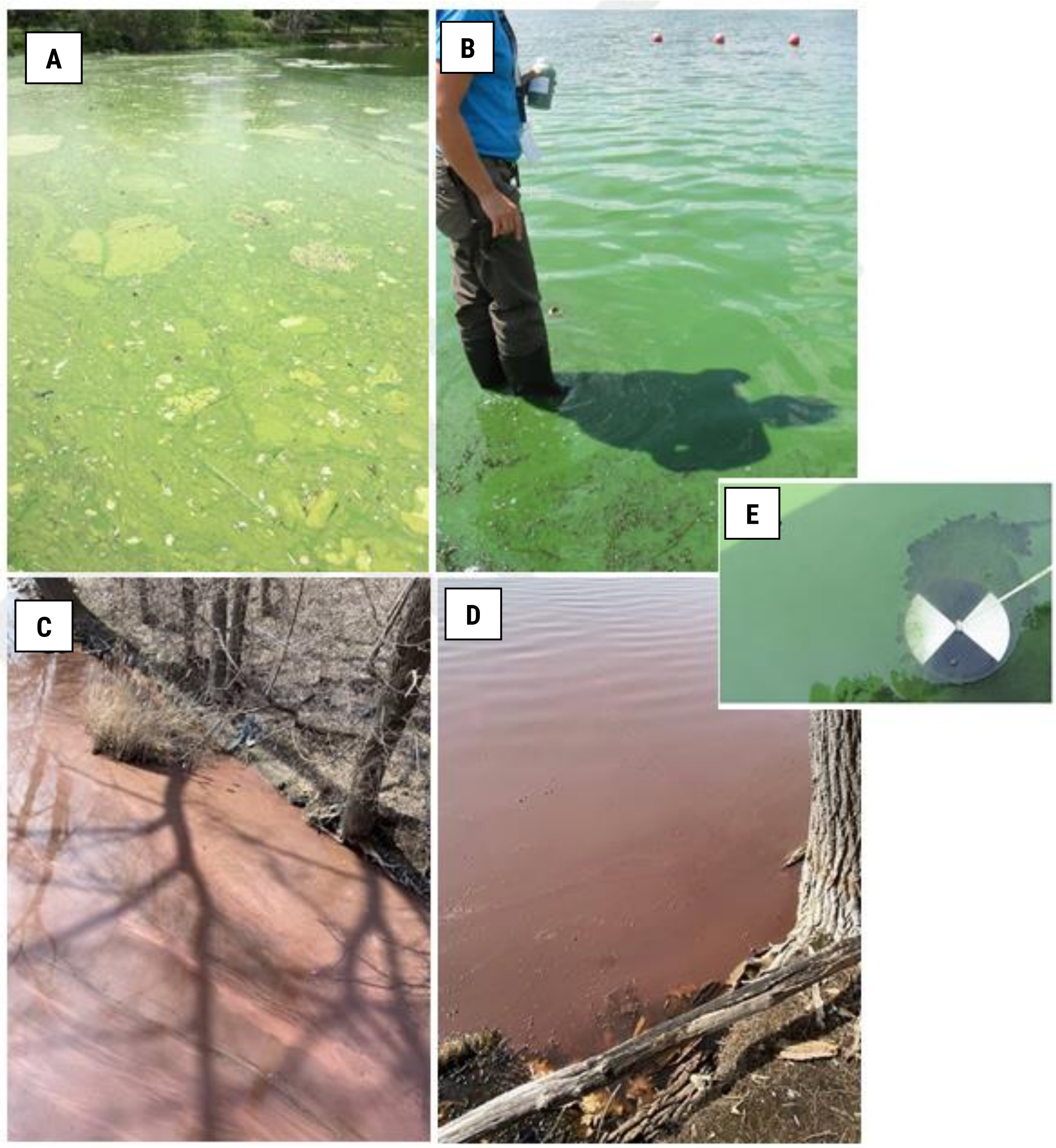


Figure 19-7. Images from MPRB of Category 3: Cyanobacteria bloom observed in progress. A continuous layer of cyanobacteria observed at the surface and not stringy as seen in images A, B, C and D. Thick surface scum present as seen covering the Secchi disc in image E.

Parameters Related to Microcystin Risk

Matt Lindon and Steve Heiskary's 2009 study, based on data collected in the National Lakes Assessment, found that microcystin levels that were designated as being "moderate to high risk" correlated with thresholds of three parameters: chlorophyll-*a* greater than 30 µg/L, Secchi depth less than 0.5 meters, and pH greater than or equal to 9.0 (Lindon & Heiskary, 2009), see **Table 19-6**. Lindon and Heiskary designated risk categories, with "moderate risk" being a microcystin level of 10-20 µg/L, which is greater than the MPRB advisory level for microcystin at 6 µg/L. The three parameters are common in lake monitoring programs and, along with visual assessment, could help in determining potential for moderate to high risk microcystin concentrations in a lake when more robust cyanobacteria and cyanotoxin monitoring is not available. In 2021, MPRB used these measurements to supplement visual monitoring of blooms in helping to determine if conditions warranted the posting of an advisory, prior to the use of a total algae probe and the cyanotoxin monitoring program. At MPRB mid-lake sampling locations, conditions similar to those in the study with a moderate microcystin risk were found in late summer and fall in Lake Hiawatha, Lake Nokomis, and Powderhorn Lake.

Table 19-6. Parameter thresholds that correlate to moderate to high microcystin risk.

Parameter	Threshold correlated to moderate to high microcystin risk
Secchi Depth (m)	<0.5
pH (units)	≥9.0
Chlorophyll-*a* (µg/L)	>30

RESULTS

Cyanotoxin Results

Beach Monitoring

The 2022 microcystin results at all 12 MPRB beaches are shown in **Figure 19-8**. Samples were either run at a 1:1 or 10:1 dilution, so the detection limits were not consistent throughout the monitoring season. Most samples are below the MPCA advisory level, with only 4% of samples exceeding the standard. There was not much spatial differentiation in microcystin concentrations within lakes as levels were similar between beaches located on the same lake. Microcystin concentrations were higher later in the season, starting to increase in late July and are highest in September. All microcystin concentrations that exceeded the advisory standard were taken at Lake Nokomis late in the season. Microcystin concentrations were high in Lake Nokomis when the phytoplankton community primarily consisted of *Raphidiopsis raciborskii* and *Planktothrix agardhii*. All cylindrospermopsin and anatoxin-*a* concentrations throughout the sampling season were either low or non-detect at all beaches.

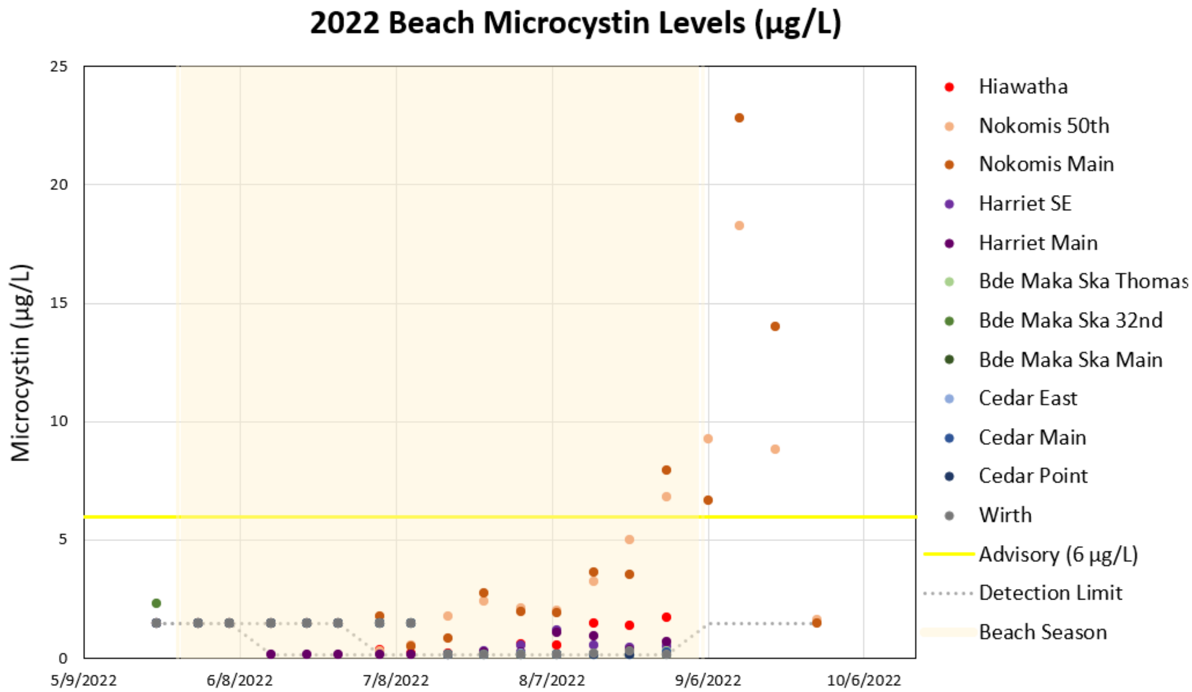


Figure 19-8. Scatterplot of microcystin concentrations at all 12 MPRB beaches in 2022. Circles represent the microcystin concentrations of grab samples. The shaded area shows the beach season, a horizontal yellow line represents the advisory standard (6 µg/L), and a dotted grey line indicates the detection limit. Note that different dilutions have different detection limits, and several grab samples are overlapping as there are a total of 187 samples.

Lake Sampling

Figure 19-9 shows all microcystin results on Powderhorn Lake in 2022. Cyanotoxin results indicated that cyanobacteria were present in late July when microcystin concentrations exceeded the MPCA guidelines at 6.02 µg/L. Microcystin concentrations remained below the MPCA guidelines the rest of the sampling season but were relatively high throughout August. Microcystin concentrations were high when the phytoplankton community primarily consisted of *Microcystis aeruginosa*. All microcystin samples collected while lake sampling at Bde Maka Ska, Cedar, Harriet, and Nokomis were below the detection limit. All cylindrospermopsin and anatoxin-*a* levels on Powderhorn Lake were low or below the method detection limit.

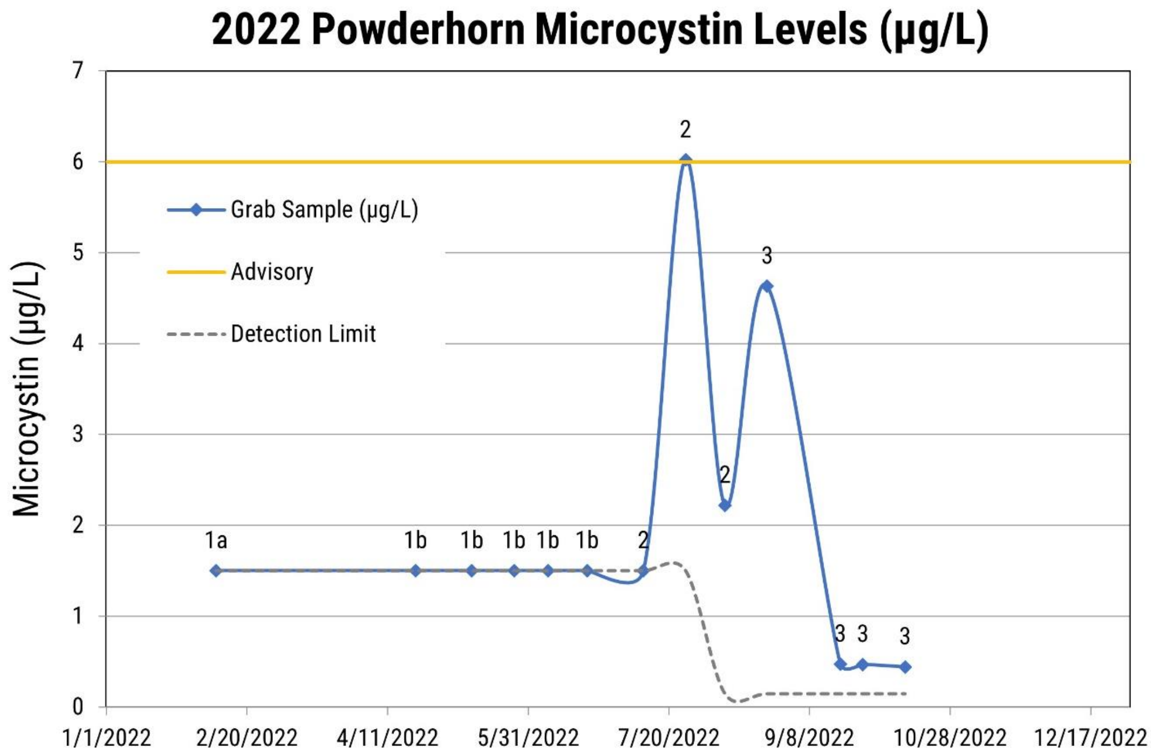


Figure 19-9. Scatterplot of microcystin concentrations on Powderhorn Lake in 2022. Blue diamonds represent the microcystin concentrations of the grab samples. Numerical data labels indicate the VMI category. A horizontal yellow line represents the advisory standard (6 µg/L), and a dotted grey line indicates the detection limit. Note detection limits changed based on the sample dilution.

Total Algae Probe

The relationship between several water quality parameters listed below and phycocyanin concentrations were assessed as a proxy indicator for HABs.

- Microcystin (µg/L)
- Chlorophyll-*a* (RFU)
- pH (units)
- Total Nitrogen (mg/L)
- Secchi (m)
- Total Phosphorus (mg/L)
- Chlorophyll-*a* (µg/L)

Phycocyanin concentrations were measured on all lakes. Data from Hiawatha, Nokomis, and Powderhorn Lakes were plotted since these lakes had the highest phycocyanin readings, ranging from 0.01 to 14.7 RFU. Each lake parameter was plotted against the phycocyanin reading at 1 meter using Microsoft Excel and a linear trendline was graphed. The parameters are listed in increasing order of correlation, with microcystin having the lowest R squared (R^2) value and chlorophyll-*a* (µg/L) having the highest R^2 value. There may not have been a strong correlation between microcystin and phycocyanin because microcystin was collected at the beach while phycocyanin was monitored at the mid-lake sampling location, and each parameter was collected on different days most of the time. There may have been a weak correlation between several parameters because there were not a significant number of toxin forming blooms in 2022 with only 4% of the samples exceeding the advisory level. Total phosphorus (mg/L) and chlorophyll-*a* (µg/L) had the strongest correlation with phycocyanin, see **Figure 19-10** and **Figure 19-11**.

Figure 19-10 shows the relationship between phycocyanin and total phosphorus on Hiawatha, Nokomis, and Powderhorn. Each lake shows a positive correlation; however, there is no significant trend ($R^2 < 0.95$). **Figure 19-11** shows the relationship between phycocyanin and chlorophyll-*a* (µg/L) on Hiawatha, Nokomis, and Powderhorn. Each lake shows a positive correlation and there is a stronger correlation between phycocyanin and chlorophyll-*a* than total phosphorus; however, there is still no significant trend ($R^2 < 0.95$). Powderhorn Lake is different than Nokomis and Hiawatha because it contains a summer aeration system, which may have affected the results because of constant mixing.

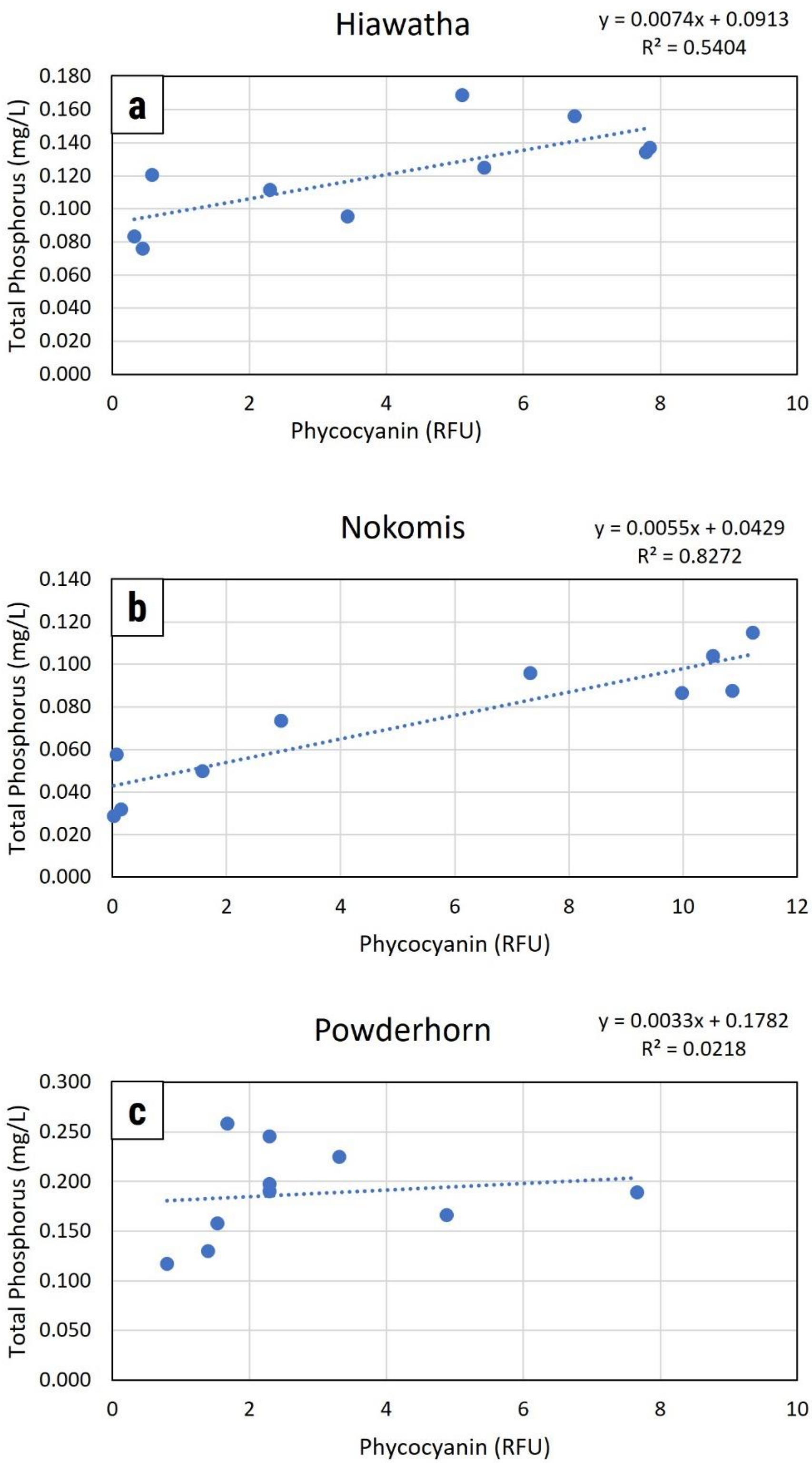


Figure 19-10. Scatterplot of the relationship between phycocyanin and total phosphorus on Hiawatha, Nokomis, and Powderhorn Lakes in 2022.

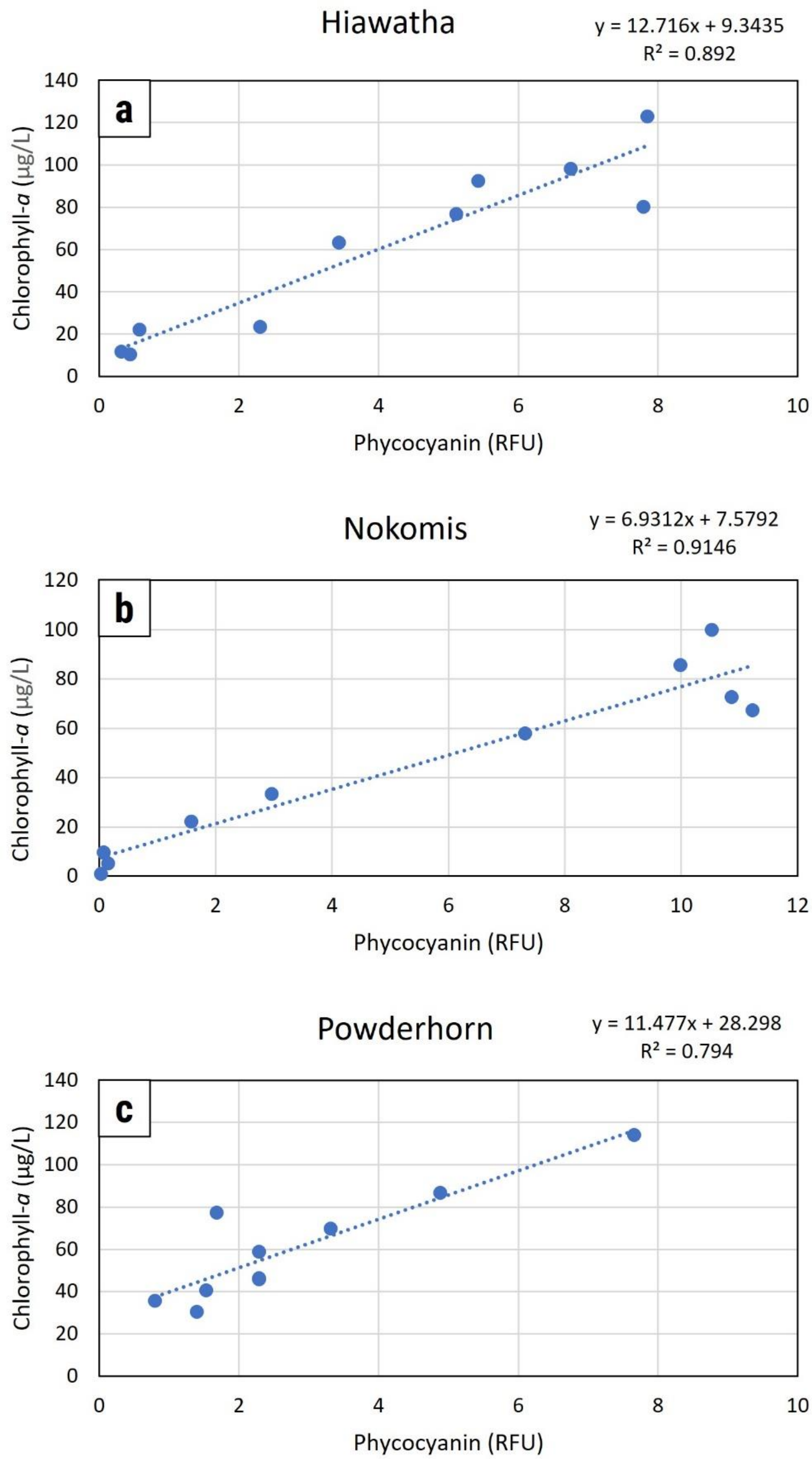


Figure 19-11. Scatterplot of the relationship between phycocyanin and chlorophyll-*a* on Hiawatha, Nokomis, and Powderhorn Lakes in 2022.

Cyanobacteria Visual Monitoring Index

Results from the cyanobacteria VMI observed weekly during beach monitoring can be seen in **Table 19-7**. Beaches that were categorized as a VMI of 3 were marked in the MPRB Lake Water Quality Map (bit.ly/mplsbeaches) with a yellow diamond indicating an advisory for the presence of cyanobacteria. A VMI of 3, or advisory level conditions of an ongoing bloom, occurred on Lake Nokomis between late July and late September in 2022.

Visual indications of cyanobacteria were observed at Hiawatha, Nokomis Main, Harriet Main, Bde Maka Ska 32nd, and Bde Maka Ska Main Beach in late June or early July. Minor short-lived scums, a VMI of 2, were present at these beaches but did not warrant an advisory. An advisory was issued for Lake Nokomis in late July when both 50th Street Beach and Main Beach had a VMI of 3, or full-lake bloom, present. The advisory was issued for 118 days and was removed in late November when the VMI decreased to 1a.

Table 19-7. Results of the VMI taken weekly during beach monitoring from May 23rd to September 27th, 2022. The shaded cells show when a VMI Category 3 was recorded at MPRB beaches. NA = No VMI recorded.

Beach Location	5/23	5/31	6/6	6/14	6/21	6/27	7/5	7/11	7/18	7/25	8/1	8/8	8/15	8/22	8/29	9/6	9/12	9/19	9/27
Hiawatha	1a	1b	1d	1d	2	1d	1b	1b	1b	1b	1b	1b	1b	1b	1b	NA	NA	NA	NA
Nokomis 50th	1a	1a	1a	1a	1d	1d	1d	1d	1b	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Nokomis Main	1a	1a	1d	1a	1d	2	2	1b	1d	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Harriet SE	1a	1a	1a	1d	1d	1d	1d	1d	1a	1d	1a	1a	1a	1a	1a	NA	NA	NA	NA
Harriet Main	1a	1a	1d	1a	1d	1d	2	1d	1a	2	1a	1a	1a	1a	1a	NA	NA	NA	NA
Bde Maka Ska Thomas	1c	1a	1a	1a	1d	1a	1a	1a	1a	1a	1a	1a	1a	1a	1a	NA	NA	NA	NA
Bde Maka Ska 32nd	1a	1a	1a	1a	1a	2	1a	1a	1a	1a	1a	1a	1a	1a	1a	NA	NA	NA	NA
Bde Maka Ska Main	1a	1a	1a	1a	1a	2	1a	1a	1a	1a	1a	1a	1a	1a	1a	NA	NA	NA	NA
Cedar East	1a	1b	1b	1a	1a	1a	1a	1a	1a	1a	1a	1a	1a	1a	1b	NA	NA	NA	NA
Cedar Main	1a	1c	NA	1d	1d	1a	1a	1a	1a	1a	1a	1a	1a	1a	1b	NA	NA	NA	NA
Cedar Point	1a	1a	1d	1a	1d	1a	1a	1a	1a	1a	1a	1a	1a	1a	1b	NA	NA	NA	NA
Wirth	1a	1b	1a	1a	1a	1a	1a	1a	1a	1a	1a	1a	1a	1a	1b	NA	NA	NA	NA

1a: clear visibility, no blue-green algae
1b: brown/turbid, less visibility, no blue-green algae
1c: no blue-green algae, other phenomenon present (pollen, duckweed, filamentous algae)
1d: tiny amounts of blue-green algae, low density green floating balls may be present, no clumps, no surface or shore accumulations, water appears clear but can see some blue-green algae.
2: no observed bloom, numerous balls of blue-green algae in the water column, not accumulating at the surface but may have narrow band on shore, open water not discolored.
3: severe bloom visible, open water fully discolored, looks like spilled paint, no clarity

Water Quality Parameters Related to Microcystin Risk

Lindon and Heiskary (2009) identified thresholds for three common lake monitoring parameters that correlated to a greater chance of moderate to high risk of microcystin: high pH, high chlorophyll-*a*, and low Secchi depth. Nine out of the twelve lakes monitored by MPRB in 2022 had values that exceeded these thresholds, indicating higher likelihood for moderate to high microcystin risk. Data for these three parameters and VMI observances are shown in **Table 19-8** for the monitoring sessions when one or more parameter exceeded the thresholds. Values of pH, chlorophyll-*a*, and Secchi depth that exceeded the thresholds and VMI category 3 are highlighted in yellow. Chlorophyll-*a* exceeded the threshold more than any other parameter. More than one parameter exceeded the thresholds 47% of the time that a threshold exceedance occurred. See **Appendix D** for all cyanobacteria and cyanotoxin results from 2022.

Table 19-8. 2022 water quality data related to microcystin risk that exceeded the threshold for moderate to high microcystin risk. The values that exceeded these thresholds (pH ≥ 9, chlorophyll-*a* > 30 ug/L, and Secchi depth < 0.5 m) are highlighted in yellow. VMIs of 3 are also highlighted in yellow.

Lake Name	Date	pH units	Chl-a µg/L	Secchi meters	VMI
Cedar	4/19/2022	8.17	34.9	1.25	1a
Diamond	2/9/2022	NA	132	NA	1a
Diamond	8/9/2022	7.03	51.5	NA	1c
Grass	2/9/2022	NA	126	NA	1a
Grass	4/21/2022	8.36	52.8	NA	1a
Grass	9/19/2022	7.36	51.3	NA	1d
Grass	10/12/2022	7.07	59.4	NA	1a
Harriet	4/26/2022	8.42	37.8	1.20	1b
Harriet	6/28/2022	8.85	40.0	1.62	1d
Hiawatha	4/26/2022	8.39	48.7	0.63	1b
Hiawatha	6/28/2022	8.56	63.4	0.62	1d
Hiawatha	7/28/2022	8.06	98.2	0.38	1b
Hiawatha	8/11/2022	8.85	76.8	0.38	1b
Hiawatha	8/26/2022	8.85	92.4	0.40	1b
Hiawatha	9/14/2022	8.23	123	0.33	1d
Hiawatha	9/29/2022	7.69	80.1	0.40	3
Hiawatha	10/13/2022	7.66	73.9	0.27	3
Isles	4/19/2022	8.50	30.2	1.39	1b
Loring	5/26/2022	7.80	33.0	0.76	1b
Loring	6/21/2022	8.28	50.7	0.97	1a
Loring	7/11/2022	7.57	40.7	0.85	1a
Loring	7/26/2022	7.69	60.6	0.70	1c
Loring	8/9/2022	7.91	64.9	0.55	1a
Loring	8/24/2022	8.06	43.3	0.53	1c

Table 19-8. Continued. 2022 water quality data related to microcystin risk that exceeded the threshold for moderate to high microcystin risk. The values that exceeded these thresholds (pH ≥ 9, chlorophyll-*a* > 30 ug/L, and Secchi depth < 0.5 m) are highlighted in yellow. VMIs of 3 are also highlighted in yellow.

Lake Name	Date	pH units	Chl-a µg/L	Secchi meters	VMI
Loring	9/27/2022	7.89	39.4	1.02	1b
Loring	10/12/2022	8.27	39.1	0.79	1b
Nokomis	7/15/2022	8.65	33.3	0.80	1a
Nokomis	7/28/2022	8.54	85.6	0.46	1a
Nokomis	8/11/2022	9.11	72.8	0.30	3
Nokomis	8/26/2022	8.89	58.0	0.42	3
Nokomis	9/14/2022	8.92	100	0.35	3
Nokomis	9/29/2022	8.06	67.3	0.34	3
Powderhorn	5/11/2022	7.80	35.6	0.77	1b
Powderhorn	5/26/2022	7.06	30.6	0.67	1b
Powderhorn	6/7/2022	7.07	40.5	0.40	1b
Powderhorn	6/21/2022	7.63	46.5	0.41	1b
Powderhorn	7/11/2022	7.63	58.9	0.35	2
Powderhorn	7/26/2022	7.06	45.8	0.30	2
Powderhorn	8/9/2022	7.25	77.4	0.32	2
Powderhorn	8/24/2022	7.22	69.7	0.39	3
Powderhorn	9/19/2022	8.35	86.7	0.41	3
Powderhorn	9/27/2022	8.72	114	0.34	3
Powderhorn	10/12/2022	8.72	61.8	0.40	3

Lake monitoring data for pH, chlorophyll-*a*, and Secchi depth was compared to the cyanotoxin data from samples collected during beach monitoring at Bde Maka Ska, Cedar Lake, Lake Harriet, Lake Hiawatha, Lake Nokomis, and Wirth Lake, and mid-lake samples taken during lake monitoring on Powderhorn Lake. Cyanotoxin concentrations were either low or not detected throughout most of the sampling season. In Powderhorn Lake, one or more of the parameters exceeded a threshold correlated to moderate to high microcystin risk 85% of the times that the lake was monitored, but only 8% of cyanotoxin samples exceeded the MPRB advisory level for microcystin concentrations. This lake contains a summer aeration system, which may have affected the results because of constant water mixing.

Table 19-9 compares pH, chlorophyll-*a*, and Secchi depth data collected bimonthly at the mid-lake sampling location on Lake Nokomis to cyanotoxin samples collected at Nokomis Main Beach. During seven lake monitoring days, between mid-July and October, one or more of the parameters exceeded the threshold correlated to moderate to high microcystin risk, shown in yellow. Secchi depth and chlorophyll-*a* concentration most often exceeded the thresholds. Microcystin concentrations started increasing in mid-July at the same time as the threshold exceedances began to occur. Two cyanotoxin samples that exceeded the advisory standard for microcystin concentration, shown in orange on the table, occurred while one or more of the parameters exceeded its threshold. All of the cyanotoxin samples that exceeded the microcystin advisory standard occurred during times when one or more of the parameters exceeded the threshold correlated to moderate to high microcystin risk. A possible discrepancy may exist between cyanotoxin data collected at the beach and lake monitoring data collected at the mid-lake sampling site, due to the location of sampling and the samples being taken on different days.

Table 19-9. Lake Nokomis lake monitoring data for parameters related to microcystin risk compared to Nokomis Main Beach microcystin data. The values that exceeded these thresholds (pH ≥ 9, chlorophyll-a > 30 ug/L, and Secchi depth < 0.5 m) are highlighted in yellow. Values that exceed the MPRB microcystin advisory standard are highlighted in orange.

Date	Secchi m	pH units	Chl-*a* µg/L	Date	Microcystin µg/L
2/10/2022	NA	NA	1.20		
4/26/2022	1.50	8.36	6.45		
5/13/2022	1.48	8.48	9.61		
5/27/2022	4.43	8.22	1.03	5/23/2022	<1.5
6/9/2022	2.93	8.33	5.19	6/6/2022	<1.5
6/24/2022	0.79	8.33	22.1	6/27/2022	<1.5
7/15/2022	0.80	8.65	33.3	7/18/2022	0.817
7/28/2022	0.46	8.54	85.6	7/25/2022	2.759
8/11/2022	0.30	9.11	72.8	8/8/2022	1.900
8/26/2022	0.42	8.89	58.0	8/29/2022	7.930
9/14/2022	0.35	8.92	100	9/12/2022	22.80
9/29/2022	0.34	8.06	67.3	9/27/2022	<1.5
10/13/2022	0.50	7.89	53.1		

Communication

The MPRB Lake Water Quality Map (bit.ly/mplsbeaches) was used to communicate the potential for health risk due to cyanobacteria in 2022. During the 2022, a yellow diamond on the map was used to indicate an advisory when there was a VMI of 3, or when microcystin, cylindrospermopsin, or anatoxin-*a* concentrations exceeded the MPCA swimming standards. During an advisory the map indicated that “Blue-green algae may be present” and a link to the MPCA blue-green algae website (https://www.pca.state.mn.us/air-water-land-climate/blue-green-algae-and-harmful-algal-blooms) was provided for beach goers who desired additional information on cyanobacteria. The advisory designation was used when conditions did not warrant beach closure conditions but indicated the need for increased awareness. It is important to note that cyanobacteria conditions can change quickly and move throughout the lake due to weather and wind, so it is important to always look at the water conditions before entering the water. Lake users are encouraged during advisory conditions to stay out of the water if a bloom is observed.

In 2022, signage was also posted at MPRB beaches during an advisory. When an advisory was issued due to a VMI of 3 MPCA informational signage was posted, and when an advisory was issued due to cyanotoxin levels yellow advisory signage was posted at the beach.

The MPRB website includes a cyanobacteria information page that describes what blooms look like, why they are harmful, tips for dog owners, and how to prevent HABs related illnesses (https://www.minneapolisparks.org/park-care-improvements/water_resources/lake_water_resources/blue-green-algae/). The MPRB also provides updates when cyanobacteria blooms are present in Minneapolis lakes on Facebook and Twitter. Water Quality staff worked with the Environmental Education Department on when to alter canoe program locations on lakes where HABs were present in 2022. Water quality staff have also had discussions with the Aquatics Department and are using this data to determine the best locations to have swim lessons in the future.

DISCUSSION

During the 2022 beach monitoring season, most microcystin samples were below the MPCA advisory level. Microcystin concentrations were low or not detected throughout the entire sampling season on 5 of the 6 lakes with beaches. There was little spatial differentiation in microcystin concentrations within lakes as levels were similar between beaches located on the same lake. Microcystin concentrations were higher later in the season, starting to increase in late July and were highest in September. All microcystin concentrations that exceeded the advisory standard were taken at Lake Nokomis during and after the beach season between late August and throughout September. Powderhorn Lake microcystin concentrations exceeded the MPCA guidelines one time in late July. Although microcystin concentrations remained relatively high throughout August, all detections were below the MPCA guidelines. All cylindrospermopsin and anatoxin-*a* concentrations throughout 2022 were low or non-detect in all beach and lake monitoring samples.

High VMI did not always indicate high cyanotoxin levels, however, in 2022, when high cyanotoxin levels did occur, cyanobacteria were visually detectable. According to the Lake Champlain Committee, VMI observations should ideally be made between 10am and 3pm due to cyanobacteria buoyancy. During the beach season, many VMI observations were made before 10am because bacteria samples taken during beach monitoring had to be collected in a timely manner in order to get results back early enough to close beaches if necessary. The reason higher VMIs were not consistent with higher cyanotoxin levels may be because MPRB staff were making observations before 10am. After the beach season, when cyanotoxin samples and VMIs were collected on Lake Nokomis during the recommended time between 10am and 3pm, there was a higher correlation with 75% of the samples with a VMI of 3 having microcystin concentrations that exceeded the advisory standard.

When comparing the relationship between phycocyanin concentrations with other water quality parameters collected during lake monitoring, phycocyanin had the strongest correlation with total phosphorus (mg/L) and chlorophyll-*a* (µg/L). Phycocyanin had the weakest correlation with microcystin concentrations. There may not have been a strong correlation between microcystin and phycocyanin because microcystin was collected at the beach while phycocyanin was monitored at the mid-lake sampling location, each parameter was collected on different days most of the time, and microcystin concentrations were low or non-detect throughout most of the sampling season.

Lindon and Heiskary (2009) found that a greater likelihood of moderate to high microcystin risk correlated to values beyond thresholds for three parameters: low Secchi depth, high pH, and high chlorophyll-*a*. In 2022, only one surface pH measurement exceeded the threshold, but did not correlate to high microcystin. Low Secchi depth and high chlorophyll-*a* concentrations were more frequently observed during the 2022 lake sampling season. All of the 2022 MPRB cyanotoxin samples that exceeded the microcystin advisory standard occurred during times when both Secchi depth and chlorophyll-*a* exceeded the threshold correlated to moderate to high microcystin risk. These thresholds can be helpful in estimating the likelihood of microcystin levels reaching levels of concern, but there is not a direct enough correlation for practical use as a predictive tool. In 2022, most exceedances of the thresholds were not connected to high microcystin concentrations. Additionally, MPRB staff do not receive chlorophyll-*a* results until approximately one month after samples are collected, so this data arrives too late to be actionable.

In 2023, microcystin, cylindrospermopsin, and anatoxin-*a* will be sampled at all 12 MPRB beaches weekly during the swim season and at Powderhorn Lake bimonthly. All samples will be run at the 10:1 dilution so higher toxin concentrations are detected quicker rather than re-running samples. The total algae probe will continue to be used while lake monitoring to collect chlorophyll-*a* and phycocyanin data throughout the water column on all MPRB lakes; this data will then be compared to other water quality parameters to build correlations that help predict when cyanobacteria blooms occur. Also, the VMI category descriptions will be updated to better represent blooms observed on Minneapolis lakes using data collected since 2020. MPRB staff plan to continue recording the VMI while beach and lake monitoring and will additionally monitor the VMI at ponds while stormwater sampling. Lastly, during lake monitoring, parameters that are related to microcystin risk will continue to be monitored and compared to cyanotoxin levels.

EVENTS REPORTS

Lake Hiawatha

On June 8, 2022, a spring bloom of blue-green algae was reported by a citizen at Hiawatha Beach. MPRB Water Quality staff confirmed the bloom, and it was rated with a VMI Category 3. An advisory was posted on the Lake Water Quality Map and informational signage was posted at the beach. The advisory was removed 8 days later when both VMI observations and cyanotoxin samples indicated a low level of cyanobacteria. Another advisory was posted on September 22nd due to a VMI Category 3 and remained in effect until ice-on for a total of 74 days.

Lake Harriet

On June 10, 2022, a citizen reported a significant amount of cyanobacteria scum at Lake Harriet Main Beach. MPRB Water Quality staff confirmed the bloom, and it was rated with a VMI Category 3. An advisory was posted on the Lake Water Quality Map and informational signage was posted at the beach. The advisory was removed 6 days later when both VMI observations and cyanotoxin samples indicated a low level of cyanobacteria.

Lake Nokomis

On July 26, 2022, an advisory was issued for both Nokomis Main Beach and 50th Street Beach due to a whole-lake cyanobacteria bloom that caused discoloration of the open water and shallow water clarity. The advisory was posted on the Lake Water Quality Map and informational signage was posted at both Nokomis beaches. Microcystin concentrations exceeded the MPCA guidelines in late August at both Nokomis beaches at 6.8 and 7.9 µg/L. The advisory continued to remain on the Lake Water Quality Map and yellow advisory signage was posted at both Nokomis beaches. Microcystin concentrations remained above the MCPA guidelines until late September, reaching the highest concentration of 22.8

µg/L in mid-September. The blue-green algae advisory was posted between late July and mid-November for a total of 118 days.

Powderhorn Lake

Cyanotoxin samples collected while lake monitoring indicated that cyanobacteria were present on Powderhorn Lake in late July when microcystin concentrations exceeded the MPCA guidelines at 6.02 µg/L. A blue-green algae advisory was issued in early August and MPCA informational signage was posted on the shoreline and on the Lake Water Quality Map. Water Quality staff also distributed multilanguage educational materials in the recreation center and worked with the Environmental Education Department on relocating canoe programs to other lakes. Cyanotoxin concentrations remained below the MPCA guidelines the rest of the sampling season; however, the advisory remained posted until late October due to high VMI levels. A full lake cyanobacteria bloom with surface scum was present between late August through October. The blue-green algae advisory was posted for a total of 82 days.

WATER QUALITY PROJECTS

Iron-ceramic Application on Powderhorn Lake

Iron has been used for decades to reduce lake phosphate in the water column in lake restoration projects and stormwater treatment. Studies show that reducing phosphorus could be effective in controlling the growth of cyanobacteria. Water movement across iron-ceramic material brings phosphorus in the water column in contact with iron. Phosphorus attaches, or binds, to the iron-enriched material and is removed from the water column so it can't be released into the water and used as food for cyanobacteria. On May 4, 2022, iron-ceramic was applied to Powderhorn Lake to attempt reduce the impacts of cyanobacteria. See **Chapter 13** for more information on the iron-ceramic application on Powderhorn Lake.

Cyanobacteria Mitigation Feasibility Study on Cedar Lake and Lake Nokomis

The MPRB is developing specific cyanobacteria mitigation strategies for Cedar Lake and Lake Nokomis to address ongoing concerns about toxic cyanobacteria blooms in these lakes. This work is being undertaken because of significant blooms of cyanobacteria that have occurred at Cedar Lake and the presence of cyanotoxins that can exceed the MPCA's swimming advisory levels at Lake Nokomis. The objectives of the project are to identify the specific stressors causing beach-season and off-season cyanobacteria blooms in the lakes and identify and evaluate structural and nonstructural mitigation strategies to address the stressors each lake. See **Chapter 5** and **Chapter 12** for more information on the cyanobacteria mitigation feasibility study.

20. Webber Natural Swimming Pool

History

Webber Park was named in 1939 for Charles C. Webber, who donated the land in memory of his late son. Originally, a dam across Shingle Creek created a 2-acre pool known as Camden Pond. Overflow water was used to fill this swimming pool in summer and the pond was used for ice skating in winter. In the 1950s, a flood prevention project rerouted Shingle Creek to the north to increase the drop in the creek from 1.5 to 5 feet. The project removed the dam that impounded Webber Lagoon and created a new configuration of Webber Pond that existed until 2013. **Figure 20-1** shows a photo of the lower pool at Webber Natural Swimming Pool.

Figure 20-1. Lower pool at Webber Natural Swimming Pool in June 2022.

On August 14, 2013, Webber Park was redeveloped to make way for the Webber Natural Swimming Pool (NSP). Minneapolis Park and Recreation Board (MPRB) contracted BioNova Natural Pool and Landform companies to create the first public natural filtration swimming pool in the United States. The pool consists of two swimming basins, called the upper and lower pools, and a regeneration basin. Additionally, a stormwater pond was designed to treat runoff from the area surrounding the pool. The pool's total swimming area covers more than 21,000 square feet and contains approximately 500,000 gallons of water. The upper pool is smaller and shallower with a depth of 3'7". The lower pool features an open swimming area with a depth of 6'4", jumping platform area with a depth of 11'7", and lap swimming area with a depth of 6'0". The Webber NSP relies on a biological filtration system rather than chlorine disinfection to maintain water quality. Water flows from the swimming area through fine filters that remove particulate matter and then through a 16,500-square foot regeneration pond to remove nutrients before returning to the swimming area. The regeneration basin contains plants, gravel, and other aggregates, but does not contain any soil. The plant and microbial communities must rely on the nutrients in the water to grow, making nutrients unavailable to nuisance algae and shift the microbial community to nonpathogenic organisms. An ultraviolet (UV) disinfection system was added in 2019, prior to the swim season, as part of the sanitation process of the pool. This system uses UV radiation to inactivate various microbial communities such as bacteria, fungi, and viruses.

The order of water flow and filtration for Webber NSP is as follows: all of the pool water circulates through the regeneration basin, is pumped through the UV disinfection system, and is pumped back into the pool every 12 hours. The pool first opened to the public in July of 2015 and was open weekly from Tuesday to Sunday between Memorial Day and Labor Day in 2022.

Background

Fecal contamination of water is a potential health risk to the users of recreational waters. *Escherichia coli* (*E. coli*) is an indicator for fecal contamination in recreational waters. While indicator organisms themselves do not cause illness under normal conditions, they may indicate the presence of other disease-causing pathogens. According to Bionova Inc, the presence of elevated Enterococci indicates the presence of birds in the regeneration area, and elevated *Pseudomonas aeruginosa* suggests the presence of excess sediment in the pool system, indicating that maintenance must be increased. Potential sources of bacteria to the pool include wild and domestic animal waste, leaking diapers, bather defecation, organic debris, swimmers' bodies, and naturalized growth on the NSP surfaces.

From 2004 to the present, MPRB Environmental Management staff have monitored the Minneapolis beaches for *E. coli* as an indicator of the presence of harmful bacteria as recommended by the United States Environmental Protection Agency (US EPA). Knowledge gained from the *E. coli* beach monitoring program, along with EPA, World Health Organization (WHO), and FLL (Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau e.V.: Landscaping and Landscape Development Research Society) guidance has been used to create the Webber NSP standards and protocols.

The NSP at Webber Park is held to a combination of current standards recommended by the German FLL, EPA Beach Act Statistical Threshold Values (EPA STV) (US EPA, 2012), and WHO standards until the EPA or State of Minnesota-approved standards are available for natural swimming pools, see **Table 20-1**. The FLL standards Scope of Validity (FLL, 2011) applies to "operation inspection, servicing, upkeep, and repair of outdoor pools with biological water purification used publicly, commercially, and not solely for private purposes."

The FLL (2011) standards document notes that 95% of samples should meet the guidelines during 1 year of operation in order for sampling to be reduced to twice per week. MPRB has interpreted this statement to mean that it is expected, in a well-run NSP, that up to 5% of the samples in a year may exceed standards. As a certain number of periodic exceedances are likely, it is necessary to plan for pool management during times when FLL standards are not met. After consideration of several sets of standards, and consultation with Bionova engineers on European protocols, it was decided by MPRB that the EPA STV would be used as a "not to exceed standard" for the Webber NSP.

The EPA Beach Act Standards were not created for use in NSPs but are at similar, slightly more restrictive levels than the European Union Freshwater Standards (EU, 2006) that are used to regulate certain types of NSPs in Europe. EPA STV values are lower than current State of Minnesota standards for *E. coli* at beaches, and by using this more restrictive standard for the NSP, it is expected that public health will be preserved. The FLL standards for *E. coli*, Enterococci, and *Pseudomonas aeruginosa* are used as the primary standards for public health protection in the pool, due to the type of NSP built at Webber Park. The EPA STV level for *E. coli* and Enterococci are used as a "not to exceed" standard. Since there is no EPA standard set for *Pseudomonas aeruginosa*, a WHO guideline from 2000 (WHO, 2000) is used as the "not to exceed" standard for this organism.

Table 20-1. MPRB bacteria standards for Webber NSP.

Indicator Organism	FLL (CFU/100 mL)	Not to exceed EPA STV (MPN/100 mL)
Escherichia coli	≤100	≤410
Enterococci	≤50	≤130
Pseudomonas aeruginosa	≤10	≤100 (WHO)

Testing available to MPRB produces results in units termed MPN or most probable number rather than CFU or colony forming units. It is MPRB's intention to use State of Minnesota, EPA methods, and/or FLL equivalent tests, and receiving data in the MPN format meets these criteria.

When bacteria levels are at or below FLL standards, the pool remains open and regular maintenance continues. If bacteria levels exceed the FLL standards once, the pool is resampled after appropriate additional maintenance is performed. If bacteria levels continue to exceed the FLL standard, the pool is closed until the standard is met again. If bacteria levels exceed the "not to exceed" value, in line with the EPA STV or WHO standard, the pool is closed. After appropriate maintenance, the pool is then retested and reopened when bacteria levels fall at or below FLL standards.

FLL (2011) standards note that Legionella bacteria testing is required in regular sampling if pool water is technologically heated. Webber NSP is not technologically heated, instead relying on the sun for heat, so these bacteria are not part of the regular sampling program.

Excess algal growth can not only be a nuisance to swimmers, but also a safety concern if the blooms limit visibility to the bottom of the pool. Algal biomass is restricted by removing nutrients, most notably phosphorus, from the water and sequestering them in the plants and biofilms within the regeneration basin. Municipal water is pumped into the regeneration basin to maintain pool levels and must be first run through a phosphate filter to limit the phosphorus concentration in the pool water and limit algae growth. Maintenance staff keep daily records of quantities of water added to the regeneration basin.

Secondary disinfection with ultraviolet light was installed to ensure that bacteria standards are not exceeded, and pool operations are not disrupted. The UV disinfection system relies on ultraviolet rays to neutralize harmful microorganisms by targeting their genetic core. In May of 2019, two separate UV systems were installed on the pipelines that carry water to the upper and lower pools. This system is beneficial to Webber NSP on account of its ability to eliminate harmful microorganisms without the use of chemicals.

Since 2019, the MPRB has held a Cooperative Service Agreement with the United States Department of Agriculture Animal and Plant Health Inspection Service Wildlife Services (USDA APHIS WS) for waterfowl management services at Webber NSP. USDA APHIS WS develops strategies to deter ducks from the area, with the goal of keeping concentrations of Enterococci, which is generally associated with waterfowl waste, from reaching levels that could result in pool closures.

Groundwater Pumping

When the pool is emptied in the spring and fall, water from the deep diving well must be pumped out of the pool and into the nearby stormwater pond. The MPRB currently maintains a water appropriation permit, Minnesota Department of Natural Resources (MNDNR) permit #2017-0030 to pump a maximum of one million gallons for this use. The pump is operated by MPRB maintenance staff, who report pumping rates and times to MPRB Water Quality staff, who maintain the records for permitting. Water Quality staff report the calculated volume of groundwater pumped to the MNDNR annually.

METHODS

Water Quality staff monitored water in the upper pool, lower pool, and regeneration basin for *E. coli*, Enterococci, and *Pseudomonas aeruginosa* bacteria throughout the season. The bacteria samples for the regeneration basin were taken from the pumps pumping water from the regeneration basin to the pool. Bacteria samples were collected every Monday from early May to the end of August. Additional sampling was performed on Wednesday and Thursday if the Monday results exceeded the FLL standard.

MPRB maintenance staff observe water clarity three times per day. This was previously done by lowering a black and white 20-cm diameter Secchi disk into the deep diving well of the pool, but the Secchi disk is no longer used for this purpose, since the pool is clear to the bottom. Probes installed in the pumphouse monitor water temperature, pH, oxidative reduction potential (ORP), and specific conductivity and were replaced in 2020. Measurements of pH, temperature, and specific conductivity were taken monthly using a YSI EXO1 and compared to probe data to assure accuracy.

Grab samples were taken from the upper pool, lower pool, and regeneration basin for total phosphorus, soluble reactive phosphorus, total nitrogen, nitrate/nitrite, ammonia, alkalinity, hardness, chlorophyll-*a*, and phytoplankton enumeration. Both chlorophyll-*a* and phytoplankton samples were stored in opaque bottles for analysis, and the phytoplankton samples were preserved with 2.5 milliliters of 25% glutaraldehyde solution. Horizontal zooplankton tow samples were taken in each basin using an 80-µm mesh tow net retrieved at a rate of 1 meters per second. The 80-µm mesh was rinsed with ethanol from the outside of the net. The samples were preserved with 70% denatured histological ethanol to a mix of approximately 30% sample 70% ethanol.

Due to bacteria exceedances in the 2022 season, the regeneration basin's ability to filter was tested by collecting grab samples for bacteria testing in the return side and suction side distributions shafts (D-shafts). The D-shafts surround the entire regeneration basin. The return side D-shafts are located on the west half where water gets pumped into the regeneration basin after flowing through the fine filter tank, and the suction side D-shafts are on the east side where water gets pumped out of the regeneration basin into the pump house. The return side and suction side are interspersed with 16 D-shafts each.

Immediately following collection, all samples were placed on ice in a cooler and stored at approximately 4°C. Bacteria and chemistry samples were transported to the contract laboratory for analysis within 8 hours of collection. Sampling procedures, sample preservation, and holding times followed procedures described in Standard Methods (2005) or US Environmental Protection Agency (US EPA, 1979/1983) and can be found in **Table 20-2**. The contract laboratory for bacteria and chemical analyses was Instrumental Research, Inc. (IRI). PhycoTech, Inc. analyzed all phytoplankton and zooplankton samples.

Table 20-2. List of physical, chemical, and biological parameters along with the method used in 2022.

Parameter	Sampling location	MPRB method
Escherichia coli	Upper pool, Lower pool, & Pumps	SM 9223 Colilert
Enterococcus	Upper pool, Lower pool, & Pumps	Enterolert
Pseudomonas aeruginosa	Upper pool, Lower pool, & Pumps	Pseudolert
Water temperature	Fine filter tank & Regeneration basin	YSI EXO 1
pH value	Fine filter tank & Regeneration basin	YSI EXO 1
Specific Conductivity	Fine filter tank & Regeneration basin	YSI EXO 1
Alkalinity	Upper pool, Lower pool, & Regeneration basin	SM 2320 B.
Total phosphorus	Upper pool, Lower pool, & Regeneration basin	SM 4500 P.E.
Soluble reactive phosphorus	Upper pool, Lower pool, & Regeneration basin	SM 4500 P.E.
Total nitrogen	Upper pool, Lower pool, & Regeneration basin	SM 4500 N.C.
Nitrate/nitrite	Upper pool, Lower pool, & Regeneration basin	USGS I-3520-85
Ammonia	Upper pool, Lower pool, & Regeneration basin	SM 4500 NO3 E.
Hardness	Upper pool, Lower pool, & Regeneration basin	SM 2350 C.
Chlorophyll-*a*	Upper pool, Lower pool, & Regeneration basin	SM 10200 H
Phytoplankton	Upper pool, Lower pool, & Regeneration basin	Rapid assessment and biomass estimate
Zooplankton	Upper pool, Lower pool, & Regeneration basin	Horizontal tow 80 µm

Results & Discussion

Bacteria

E. coli concentrations in the NSP were low for most of 2022. Levels exceeded the FLL standard of 100 MPN per 100 mL four times, but stayed below EPA STV threshold of 410 MPN per 100 mL, see **Figure 20-2a**. In 2022, 92% of samples stayed below the FLL standard for *E. coli*. Although *E. coli* is present in the environment, it is most commonly found in the lower intestines of warm-blooded organisms, and the presence of *E. coli* in the pool is likely indicative of fecal pollution. High concentrations of *E. coli* are likely due to waterfowl activity.

Enterococci concentrations in the NSP were variable during 2022. Levels exceeded the FLL standard of 50 MPN per 100 mL fifteen times, and exceeded the EPA STV threshold of 130 MPN per 100 mL eight times. A total of 65% of the samples met the FLL standard in 2022, see **Figure 20-2b**. The upper pool was closed due to Enterococci levels in the pool exceeding the EPA STV standard on July 6th, 2022. The upper pool remained closed and lower pool was closed on July 7th due to levels exceeding the FLL standard in both pools. Both pools reopened on July 8th, when Enterococci levels dropped below the FLL standard. Enterococci is generally associated with waterfowl waste, so many strategies are used, in partnership with the USDA APHIS WS, to mitigate waterfowl activity in the pool and regeneration basin. Webber Park is located within the Mississippi River Flyway, which makes it more difficult to consistently deter all waterfowl throughout the season, especially at night.

Pseudomonas aeruginosa concentrations exceeded the FLL standard of 10 MPN per 100 mL once the lower pool in June, see **Figure 20-2C**. A total of 98% of the Pseudomonas aeruginosa samples met the FLL standard. No samples exceeded the WHO standard of 100 MPN per 100 mL. *Pseudomonas* is a common bacterium in soils and excess sediment in the pool is typically thought to be the cause of elevated concentrations.

Bacteria samples were collected in the distributions shafts (D-shafts) once in 2022, in early August, when bacteria levels had been elevated in the pools. The D-shafts surround the entire regeneration basin, with 16 return side D-shafts located on the west half where water gets pumped from the output of the fine filter tank to the regeneration basin and 16 suction side D-shafts located on the east side where water gets pumped from the regeneration basin to the pump house. All 32 D-shafts were sampled for *E. coli* and Enterococci. The results showed the highest concentrations of Enterococci on the suction side, with Enterococci levels in six of the D-shafts exceeding the EPA STV standard. Additionally, the *E. coli* level in one suction-side D-shaft exceeded the FLL standard. On the return side, Enterococci levels exceeded the FLL standard in two of the D-shafts and exceeded the EPA STV standard in three of the D-shafts. One return-side D-shaft also exceeded the EPA STV standard for *E. coli*. This trend was somewhat surprising, as generally the return side is expected to exhibit higher bacteria concentrations due to the flow pattern of the system; the reason for high concentrations of bacteria in the D-shafts is unknown.

Water Chemistry

Temperature, pH, specific conductivity, and Oxidation Reduction Potential (ORP) were measured at two locations: water from the fine filter tank (System 1) and water leaving the regeneration basin (System 2). Water temperature was above the FLL recommendation of less than 25 degrees Celsius (77 degrees Fahrenheit) from mid-June through late August in System 1 and between late June and early August, except for two days, in System 2. The FLL states that if water temperatures in System 2 remain above

28 degrees Celsius (82.4 degrees Fahrenheit) for five consecutive days, additional bacteria testing must be done. This did not occur in the 2022 season, and no additional sampling occurred, see **Figure 20-3a**. The FLL recommends the pH of the pool to be between 6 and 8.5 since people with sensitive skin may experience some skin irritation with pH values greater than 9. The pH remained within the FLL recommendations the entire 2022 sampling season, see **Figure 20-3b**. Specific conductivity remained within the FLL recommended range of 200-1000 μS/cm during the entire 2022 sampling season, see **Figure 20-3c**. There is no FLL recommended value for ORP, but Bionova Engineers recommend values greater than 150 mV. ORP values remained above 150 mV for most of the 2022 season, but System 1 registered values below the recommended value three times, see **Figure 20-3d**.

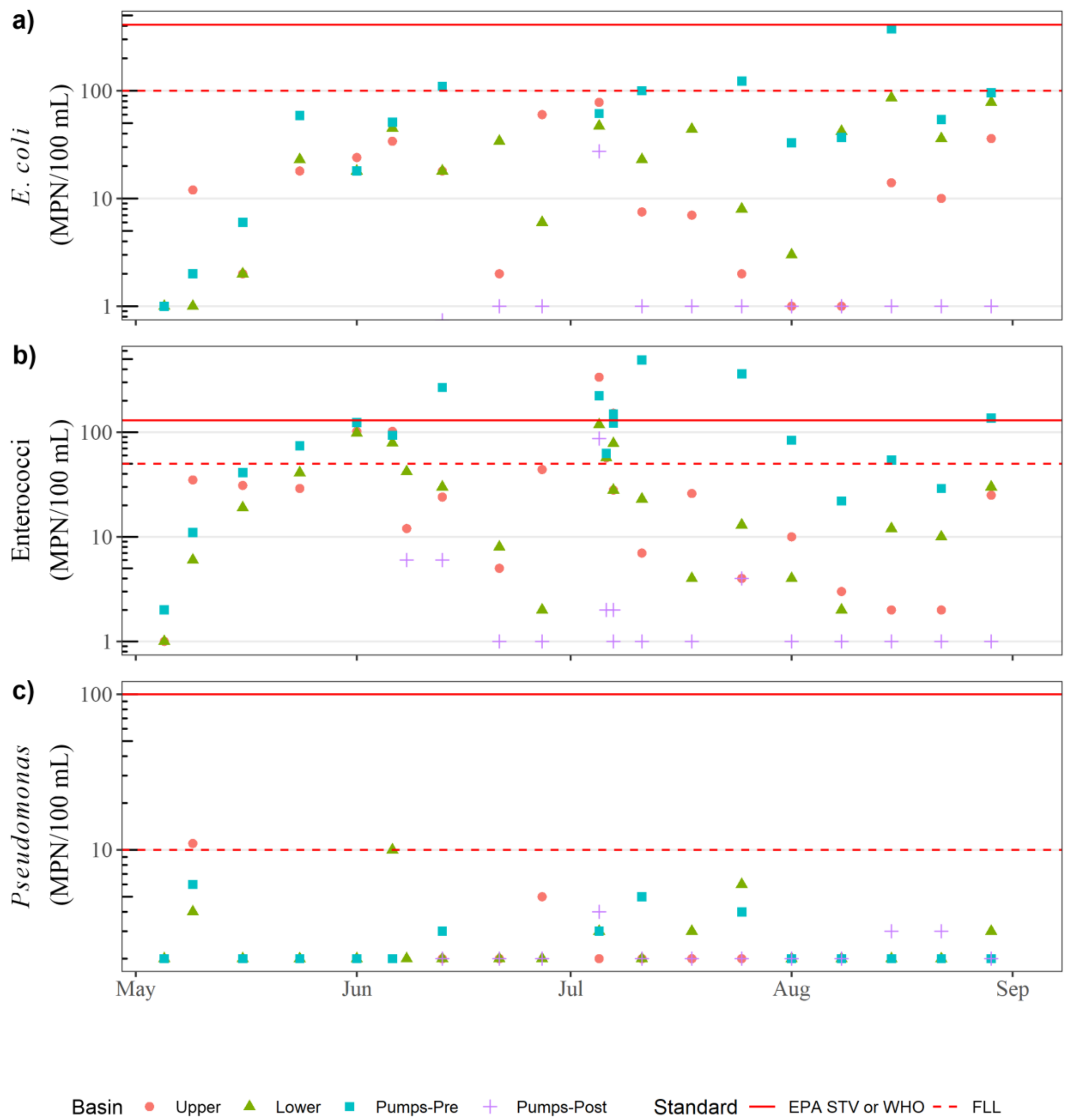


Figure 20-2. Webber Pool *E. coli* (a), Enterococci (b) and *Pseudomonas aeruginosa* (c) concentrations in 2022. The dashed horizontal lines represent the FLL standard and solid horizontal lines represent either the EPA STV threshold for *E. coli* and Enterococci or the WHO guideline for *Pseudomonas*. Note the log scales on each y-axis. Icons below the dashed line meet the FLL standard.

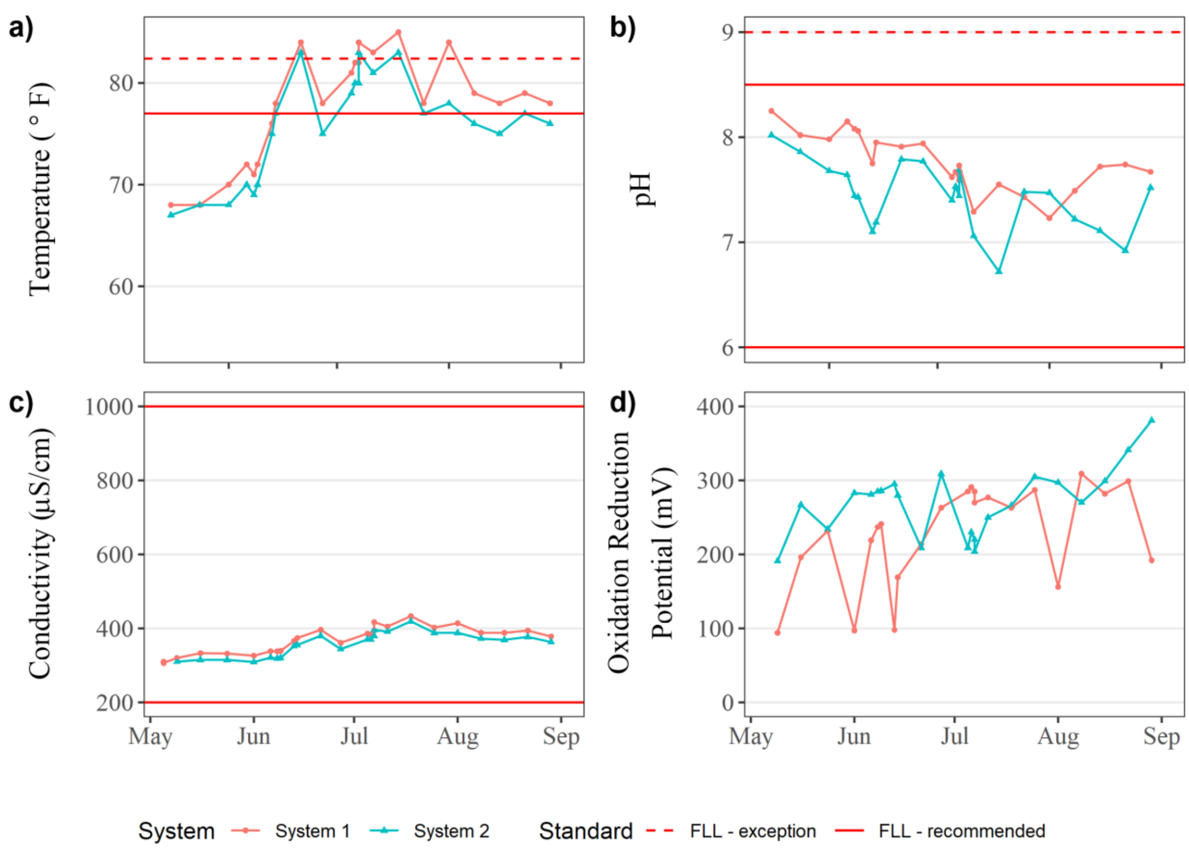


Figure 20-3. Webber Pool temperature (a), pH (b), specific conductivity (c), and oxidation reduction potential (d) in 2022. The horizontal lines represent the FLL recommended values and the dashed horizontal lines represent acceptable levels as an exception according to the FLL. There is no FLL recommended value for ORP.

Chlorophyll-*a* values were within the range of previous years' observations, though they peaked later in the season than typical. The highest levels of chlorophyll-*a* were observed in the upper pool in August, see **Figure 20-4a**. The upper pool was noted to be very green at this time, and higher concentrations may be a result of pool cleaning prior to testing. During the cleaning process algae may have been scraped off the pool walls, increasing chlorophyll-*a* levels. Chlorophyll-*a* concentrations can be affected by the UV disinfection system because UV radiation destroys pigments in the photosynthetic apparatus and decreases plant growth. Total phosphorus levels remained below the FLL recommended value of 0.010 mg/L during the entire sampling season in 2022, see **Figure 20-4b**. Nitrate/nitrite concentrations were low throughout the entire season remaining less than 1 mg/L in 2022, well within the FLL recommendation of less than 30 mg/L, see **Figure 20-4c**. Alkalinity was also well below the FLL recommended value of 200 mg/L throughout 2022, ranging between 74 and 85 mg/L in all three basins, see **Figure 20-4d**. Hardness was initially above the FLL recommended value of 100 mg/L in all three basins, indicating that the water was high in mineral content. Hardness levels decreased significantly throughout the summer but exceeded the FLL recommendation once more in the upper pool in July, see **Figure 20-4e**.

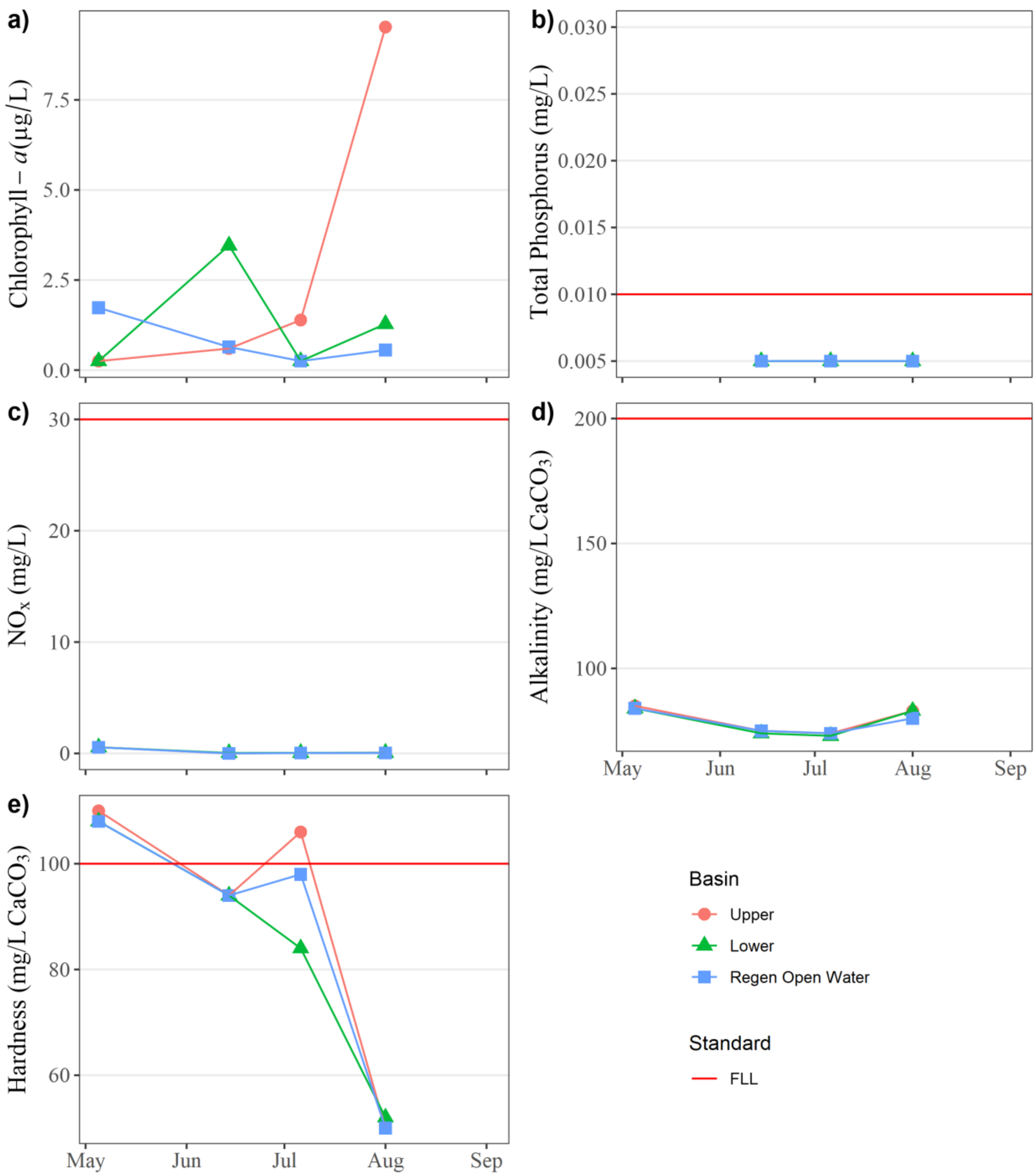


Figure 20-4. Webber Pool chlorophyll-*a* (a), total phosphorus (b), nitrate/nitrite (c), alkalinity (d) and hardness (e) in 2022. The horizontal lines represent the FLL recommended values.

Phytoplankton

Phytoplankton are microscopic plants that are an integral part of natural swimming pools because they form the base of the aquatic food web. Phytoplankton consume phosphorus and convert it into plant biomass, which can be filtered out of the water. They produce oxygen, which supports the pool's zooplankton community that further contributes to NSP health. An excess of phytoplankton can outcompete the plants in the regeneration basin, interfere with pumping and filtration systems, or inhibit pool safety by limiting visibility to the bottom of the pool (Littlewood, 2014). Phytoplankton biovolume by division for 2022 is displayed in **Figure 20-5**. Algal biomass was low the entire sampling season in the upper and lower pools and was largely comprised of a mix of diatoms (Bacillariophyta), green algae (Chlorophyta), golden-brown algae (Chrysophyta), and blue-green algae (Cyanophyta). Algal biomass was below the FLL recommended value of 1 mm^3/L in the upper and lower pools but exceeded the FLL recommendation in the regeneration basin in July of 2022. The phytoplankton community in the regeneration basin was predominantly green algae at that time. This exceedance can be attributed to high concentrations of filamentous algae that were observed during sampling.

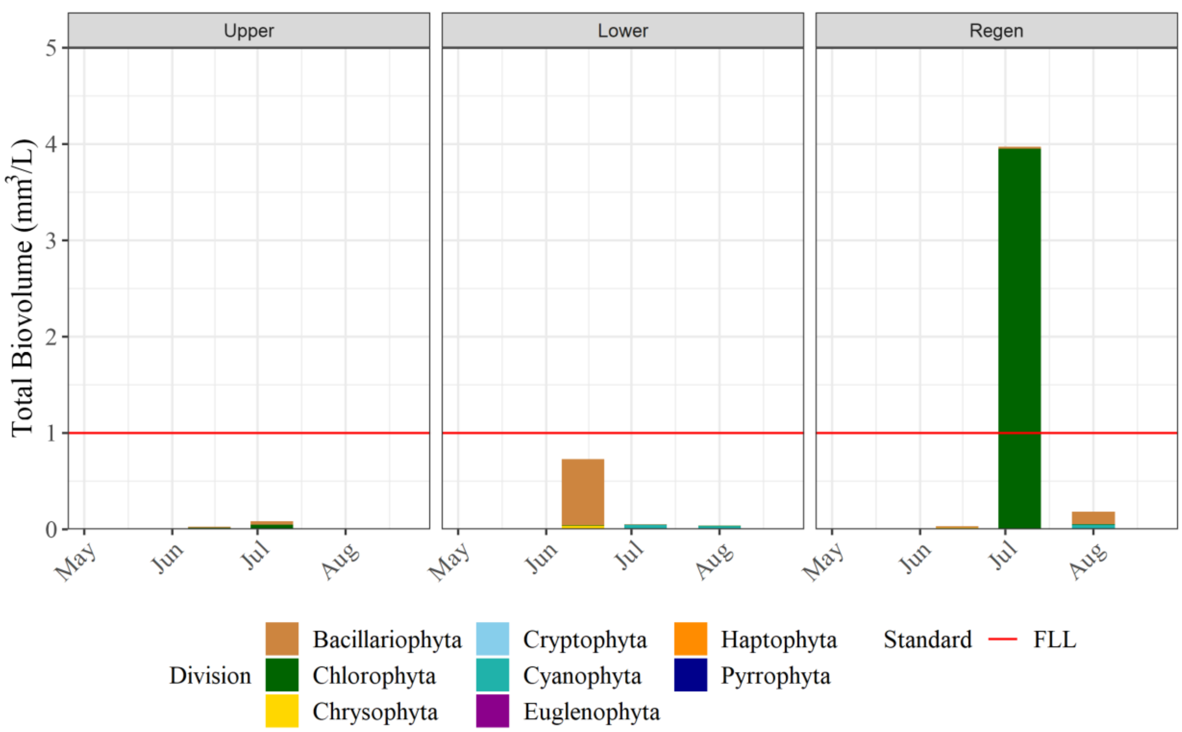


Figure 20-5. Webber Pool phytoplankton biomass in 2022. The horizontal line represents the FLL recommended maximum value.

Zooplankton

Zooplankton are tiny animals that feed on phytoplankton and are vital for natural swimming pools because they act as a live filtering system within the pool. There is no FLL recommendation for zooplankton abundance in natural swimming pools. Zooplankton concentrations in the two pools and the regeneration basin are within a comparable range to previous years' data. These concentrations are low in comparison to concentrations generally found in lakes. The highest abundance of zooplankton measured in 2022 occurred in the regeneration basin in July, see **Figure 20-6**. This abundance corresponded to the high concentration of phytoplankton in the basin at the time. The zooplankton community is beneficial in filtering bacteria in the pool water. Copepods have been found to have the greatest filtration capacity, with a single individual filtering an average of 64.8 milliliters of water per day (mL/ind/day), followed by cladocerans, which filter an average of 33.3 mL/ind/day, and rotifers, which filter an average of 8.5 mL/ind/day (Eydeler et al. 2010). The majority of the zooplankton in all three basins were nauplii and juvenile copepods, rotifers, and cladocerans, with lower levels of calanoids, cyclopoids, macroinvertebrates, and protozoa.

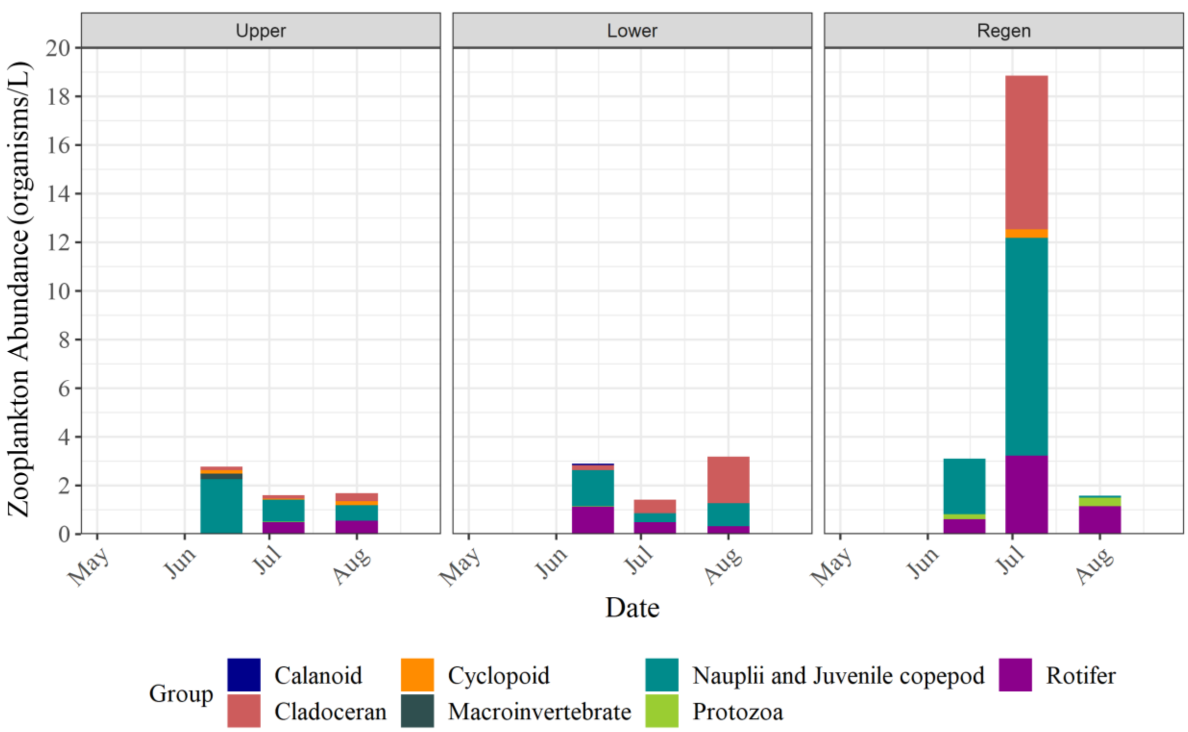


Figure 20-6. Webber Pool zooplankton abundance in 2022.

21. Aquatic Plant Harvesting Program

Background

Aquatic plants are an essential component of healthy lake ecosystems, as they provide food and shelter to wildlife, improve water clarity and quality, and stabilize lake shorelines and bottoms. See Minnesota Department of Natural Resources (MNDNR) value of aquatic plants web page (https://www.dnr.state.mn.us/shorelandmgmt/apg/value.html) for more information. However, aquatic plants can grow to nuisance densities that interfere with human activities such as swimming and boating. Minneapolis Park and Recreation Board (MPRB) utilizes mechanical plant harvesting to maintain recreational access to high-traffic areas within the city lakes. Lower-traffic areas of the lakes are not harvested so that the lakes' ecological integrity can be maintained.

The MNDNR manages two permitting programs that dictate where harvesting can and cannot occur in lakes across the state. The MNDNR's Invasive Aquatic Plant Management (IAPM) permit manages invasive species such as Eurasian watermilfoil and curly-leaf pondweed. The MNDNR's Aquatic Plant Management (APM) program manages all plants in a targeted area, regardless of whether they are native or invasive. To assist with the expense of management of aquatic invasive species (AIS), the MNDNR has grant funds available for organizations like MPRB that receive IAPM permits.

Before MPRB applies for annual harvesting permits, the plant community in each of the lakes must be mapped in a delineation survey. The mapping process involves travelling the areas of the lake less than 15-feet deep and sampling the aquatic plant community at 10-40 sites, depending on the size of the lake. Species present in a sample location are noted and their relative abundance on a scale of one to three is recorded along with the GPS coordinates at each site. Special attention is given to sampling the plant community near high-traffic areas of the lakes such as boat launches, inlets, outlets, fishing piers, beaches, and sailboat buoy fields. The distribution and abundance of AIS around each lake determine whether an IAPM or APM permit will be appropriate for each lake during the particular year. Delineation surveys for the 2022 aquatic plant harvesting program occurred in September of 2021. Since Eurasian watermilfoil, the primary target of MPRB's harvesting efforts, is a perennial plant, its distribution within a lake in a given summer is similar to its distribution within the same lake during September of the year prior. Conducting delineation surveys in September of the previous year allows staff to apply for the permits and any associated grant funding during the winter months and be prepared to start harvesting in May of the following year.

Harvesting using MPRB-owned mechanical harvesters like the one depicted in **Figure 21-1** was completed on Bde Maka Ska, Cedar, Harriet, and Isles via an IAPM permit in 2022. Harvesters remove the top two meters of the aquatic plants, temporarily allowing for problem-free boating and swimming. The results of 2022's harvesting activities are listed in **Table 21-1**. MPRB staff removed 265 flatbed truck loads of plants in 2022 which is equivalent to 1456 cubic yards of aquatic plant material. The harvesting program resulted in 179 truckloads of plant material removed in 2020 and 271 truckloads of plant material removed in 2021. A cold spring in 2022 meant that aquatic plant growth got off to a slow start while the hot summer and low water levels sped up plant growth later in the season. High density growth was observed in invasive species such as Eurasian watermilfoil and native species like coontail.

In addition to operating the harvesters, MPRB utilized a specialized lake service company to remove nuisance aquatic plants at Wirth and Nokomis beaches by hand via SCUBA. **Figure 21-2** depicts hand removal of aquatic plants. Harvesting was conducted via an IAPM permit at Wirth Lake in 2022 and an

APM permit at Lake Nokomis in 2022. The APM permit at Lake Nokomis was due to AIS being detected at very low densities during the Lake Nokomis September 2020 delineation.

MPRB harvests plants in zebra mussel-infested lakes after uninfested lakes to reduce the risk of unintentionally moving invasive species to new waterbodies. MPRB currently owns two harvesting machines and arranges for one to stay on Lake Harriet all summer while the second rotates among the Upper Chain lakes, which include Bde Maka Ska, Lake of the Isles, and Cedar Lake. The Upper Chain machine always moves from Cedar to Isles to Bde Maka Ska and not vice-versa, since Bde Maka Ska is designated as infested with zebra mussels and the other two lakes are not.

Figure 21-1. Aquatic plant harvesting machine in operation at Lake Harriet.

Table 21-1. 2022 harvesting data.

	Bde Maka Ska	Cedar	Isles	Harriet	Nokomis	Wirth
Acres of permitted harvesting	55	13	38	44	22	2
Percent of littoral zone* permitted to harvest	48%	19%	41%	50%	22%	8%
Amount of aquatic plants harvested (lb)	213,564	32,856	209,457	657,120	100	3,080

*Littoral area was defined as less than 15 feet deep.

Figure 21-2. Hand removal of aquatic plants at Wirth Lake via SCUBA diving.

Eurasian Watermilfoil (*Myriophyllum spicatum*)

Macrophyte surveys by Shapiro (1975) documented aquatic plants growing along the shoreline to about 15 feet of water in Bde Maka Ska and Lake Harriet at that time. Lake of the Isles and Lake Nokomis only had plants growing out to about 5 to 6 feet of water depth. Wirth Lake only had a shallow ring of aquatic plants growing out to 3 feet of water depth. Intact and robust native plant communities are better able to withstand pressure from invasive species infestation. Therefore, the lack of plant growth throughout the Minneapolis lakes may have left them vulnerable to invasion by Eurasian watermilfoil (*Myriophyllum spicatum*) two decades later.

Eurasian watermilfoil, hereafter referred to as milfoil, has been an ongoing concern in several Minneapolis lakes since its initial discovery in Lake of the Isles in 1988. From an ecological standpoint, it out-competes native species and changes the habitat for fish and other organisms. Recreation can be impeded as well, as milfoil often forms dense floating mats that interfere with boating and swimming.

In the early 2000s, the MPRB and the University of Minnesota released aquatic weevils that eat milfoil into small test plots at Cedar Lake, Lake of the Isles, Lake Harriet, and Lake Hiawatha. The weevils were not successful at controlling milfoil. The most likely explanation is that the high density of sunfish in the lakes fed on the weevils and limited their population. In 2017, researchers at the University of Minnesota studied the use of underwater cameras to measure macrophyte density in Cedar Lake to further understanding about plant growth and density. Milfoil continues to grow at high densities throughout the Chain of Lakes and Wirth Lake annually. Milfoil growth in Lake Nokomis is variable from one year to the next and is likely influenced by fluctuations in water clarity.

Curly-leaf pondweed (*Potamogeton crispus*)

In 1910, curly-leaf pondweed (*Potamogeton crispus*) was the first documented invasive aquatic plant species in the state of Minnesota. Curly-leaf pondweed has an unusual life cycle in that it is an annual that begins growing under the ice during winter months and dies back in June. After mild winters, curly-leaf pondweed often produces thick mats of vegetation in the spring that are a nuisance for boating;

however, this plant can be held to a low density by harsh Minnesota winters. The macrophyte surveys conducted by Shapiro in 1974 documented curly-leaf pondweed in Bde Maka Ska, Lake Harriet, Lake of the Isles, and Lake Nokomis. These surveys were carried out in late-July which was likely too late in the season to capture the full extent of curly-leaf pondweed in the Minneapolis lakes.

Curly-leaf pondweed continues to achieve nuisance densities in the Minneapolis lakes, especially in Lake of the Isles and nearby Kenilworth Channel. Throughout the summer, curly-leaf pondweed dies back and is gradually replaced by Eurasian watermilfoil, coontail, or other native species. Thus, the aquatic plant delineations performed by staff each September underestimate the amount of curly-leaf pondweed that would have been present in the lakes earlier in the summer. MPRB's aquatic plant harvesting staff report removing large amounts of curly-leaf pondweed from the lakes in May and June each year.

COONTAIL (*CERATOPHYLLUM DEMERSUM*)

Coontail (*Ceratophyllum demersum*) is a native plant species that is found throughout all the harvested lakes in Minneapolis and can sometimes grow to a density that is a nuisance for recreation like milfoil or curly-leaf pondweed. MPRB's aquatic plant harvesting activities focus on removing primarily invasive species from the lakes, but when coontail grows interspersed with milfoil or curly-leaf pondweed, the harvesting equipment will indiscriminately remove the coontail as well. Coontail is a valuable member of the plant community, providing food and shelter to a variety of fish and waterfowl species, so it is left undisturbed in non-harvested portions of the lakes.

22. Aquatic Invasive Species Program

Background

Many invasive species of plants, animals, and pathogens have established themselves in Minnesota throughout the last 150 years. There are significant concerns about the potential negative financial impacts of aquatic invasive species (AIS) to Minneapolis waterbodies from recreational, tourism, and management perspectives. AIS also threaten the ecological integrity of Minneapolis waterbodies. Havel et al. (2015) described a wide variety of ecological impacts that AIS can have on waterbodies, including shifting the way that energy and nutrients flow through food webs, outcompeting native organisms for limited resources, and changing the species diversity and richness of local native communities.

The Minneapolis Park and Recreation Board (MPRB) has been actively monitoring AIS since the late-1980s when Eurasian watermilfoil (*Myriophyllum spicatum*) was first discovered in the Chain of Lakes, which includes Brownie Lake, Cedar Lake, Lake of the Isles, and Bde Maka Ska. Over time, MPRB has developed a comprehensive AIS program that encompasses a variety of prevention, early detection, response, and management activities. This chapter is a summary of MPRB's 2022 AIS activities.

Infestation Status

As of December 2022, Minneapolis lakes are home to seven different aquatic invasive species: zebra mussels (*Dreissena polymorpha*), European carp (*Cyprinus carpio*), goldfish (*Carassius auratus*), Chinese mystery snails (*Cipangopaludina chinensis*), banded mystery snails (*Vivaparus georgianus*), Eurasian watermilfoil (*Myriophyllum spicatum*), and curly-leaf pondweed (*Potamogeton crispus*), as shown in **Figure 22-1**. The MNDNR and other local agencies have created many online resources that summarize the origin, distribution, and ecology of these and other AIS.

One species of contemporary concern in Minneapolis is the zebra mussel (*Dreissena polymorpha*). Zebra mussels have been found in Bde Maka Ska, Lake Harriet, and Lake Hiawatha. Lake Hiawatha was designated infested with zebra mussels in 2010 due to its connection with Minnehaha Creek and Lake Minnetonka. In August 2013, zebra mussels were confirmed as present in Lake Hiawatha and have been found around the entire lake in subsequent surveys. Similarly, Lake Nokomis has been declared infested with zebra mussels due to its connection with Minnehaha Creek; however, zebra mussels have never been detected in Lake Nokomis. A single adult zebra mussel was discovered in Lake Harriet in 2017. No additional mussels were found after 67 hours of shoreline, snorkel, and SCUBA surveys around the lake, and none were detected by other early detection techniques to date. Two live juvenile zebra mussels were found on the bottom of a previously moored sailboat exiting Bde Maka Ska on September 30, 2018. No additional zebra mussels were found after over 30 hours of searching using wading, snorkeling, and SCUBA diving, and none were detected using early detection methods to date. A variety of early detection tools continue to be used yearly to search for zebra mussels in Wirth Lake, the Chain of Lakes, Lake Nokomis, and Lake Hiawatha.

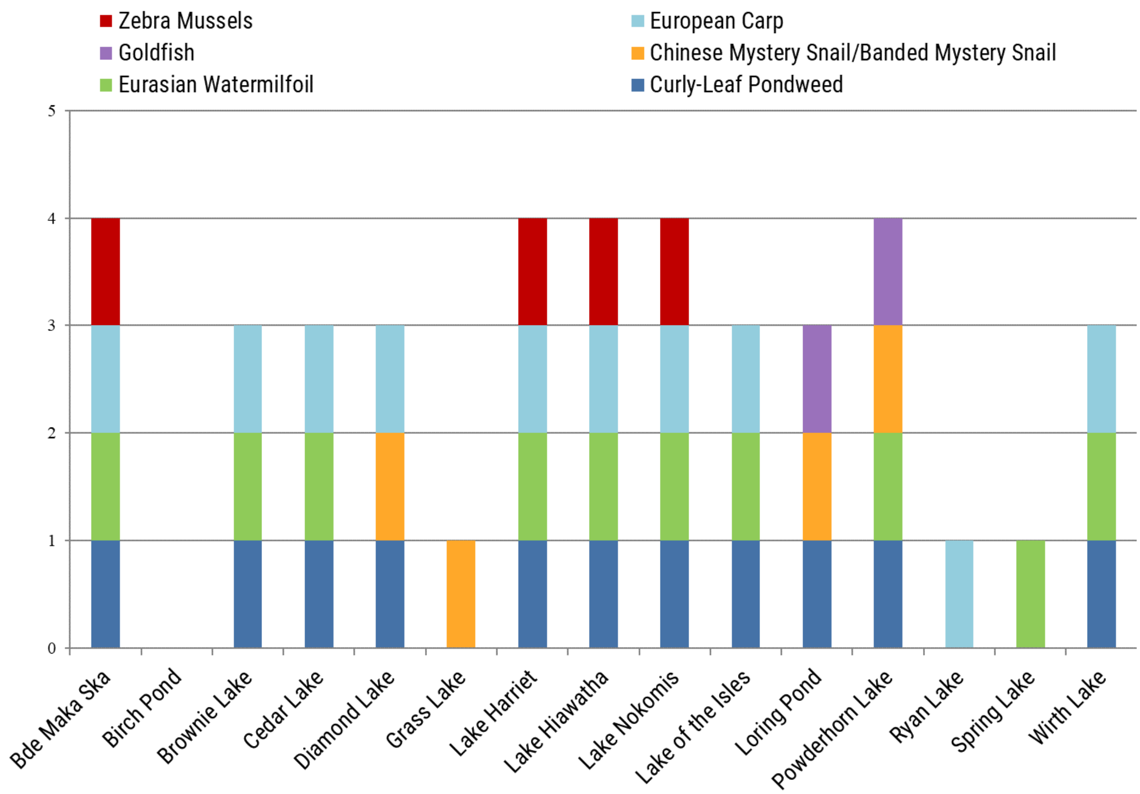


Figure 22-1. Aquatic invasive species found in MPRB lakes according to data collected by MNDNR, WHEP, and MPRB. Birch Pond, Ryan Lake, and Grass Lake have not been surveyed thoroughly for invasive species. Zebra mussels have not been confirmed present in Lake Nokomis, though the lake is designated as infested due to its connection with Minnehaha Creek.

PREVENTION

Watercraft Education and Inspection Program

The MPRB Watercraft Inspection and Education program completed its tenth year in 2022. MPRB watercraft inspectors conducted 5,582 inspections and assisted 9,188 non-boater patrons in 2022. This was a significant decrease in activity compared to the past two years. A record high number of boaters used the Minneapolis boat launches in 2020 and 2021. At that time, it seemed as though high numbers of people turned to boating as a safe, socially distanced activity during the pandemic. In 2022, boating activity seemed to be returning to pre-pandemic levels. Further decreasing the numbers, the launch at Bde Maka Ska was closed for a significant portion of the boating season. Detailed reports related to the 2022 Watercraft Inspection and Education program have been prepared and are available upon request.

Violations

According to Minnesota state law, owners of watercraft and water-related equipment are prohibited from transporting aquatic plants, prohibited species of aquatic animals, and lake water, as well as being prohibited to travel with their drain plugs in place. Inspectors require removal of these items before allowing a boat to launch or travel. In total, plants, animals, mud, or water were found on 75 entering watercraft and 479 exiting watercraft in 2022. The number of instances that these items were found on exiting watercraft is likely higher than the number of times they were found on entering watercraft because inspectors may have started their inspection of exiting boats before the owner had time to completely clean off their boat. It is common for boats and trailers to pick up Eurasian watermilfoil and other plants when leaving the lake. The inspectors ensure that all the plants are removed from the boat and trailer before it drives away from the lake.

Of the 75 entering watercraft that were in violation of AIS laws in 2022, 77 different violating items were found. In other words, in some instances, a single watercraft could be transporting both plants and water or other combinations of violating items. Aquatic plants accounted for 66% of incoming AIS violations. Water accounted for 14% of incoming AIS violations and mud accounted for 15.5%. These discoveries highlight the continued value of the program, as plants, animals, mud, and water are all capable of contributing to new AIS infestations in the Minneapolis lakes.

MPRB watercraft inspectors logged a total of two zebra mussel violations in 2022. This means that on two separate occasions boaters arrived at the Minneapolis lakes with zebra mussels present on their boat or trailer. One violation occurred on a fishing boat at Lake Harriet, and one occurred on a sailboat at Lake Nokomis. The number of zebra mussel violations in previous years has ranged from zero in 2020 to 18 in 2014. Zebra mussel violations have occurred 83 times in the history of the program. Of those 83 violations, 37 were at Lake Harriet, 26 were at Lake Nokomis, and 20 were at Bde Maka Ska.

Last Waterbody Visited and Threat of New AIS

Each time an inspection is conducted, the inspector asks the boater which waterbody they visited previously. The answers that boaters provide give insight into how AIS move around Minnesota. According to the 2022 data, 1,424 boaters, who together account for 26% of the total inspections, reported that they had previously been at a Minneapolis lake. While some boaters may not have been entirely truthful and provided this answer to avoid scrutiny, there are likely many others who stay in the Minneapolis area throughout the entire season. Beyond Minneapolis lakes, some of the most frequent previous waterbodies include:

- Lake Minnetonka (87 boaters)
- Mississippi River (53 boaters)
- St. Croix River (26 boaters)
- Bryant Lake (30 boaters)
- Bush Lake (20 boaters)
- Lake Waconia (18 boaters)
- White Bear Lake (15 boaters)

Boaters came in lesser quantities from lakes all over the state, as well as from Iowa and Wisconsin. The last waterbody data can also be used to assess the risk of new AIS being introduced to MPRB waterbodies. Two AIS that threaten Minneapolis lakes are starry stonewort (*Nitellopsis obtusa*) and the spiny water flea (*Bythotrephes longimanus*). In 2022, MPRB staff performed inspections on 75 watercraft that had previously been in starry stonewort-infested waterbodies and 32 watercraft that has previously been in spiny water flea-infested waterbodies.

SCUBA Permit

A group of MPRB staff met throughout summer 2018 to establish a permitting program for SCUBA divers that visit Minneapolis water bodies. MPRB ordinance PB3-4 allowed for the creation of a SCUBA permit, but no permitting program had existed in recent years. Starting in 2019, anyone who SCUBA dived in any Minneapolis water body was asked to obtain a free permit from the MPRB ActiveNet website. Divers only needed to obtain the permit once during the year, regardless of how many Minneapolis water bodies they had planned to visit. In all, 7 SCUBA permits were issued in 2022. MPRB's Aquatic Invasive Species Program Administrator contacted each permittee via email to provide information about best practices for SCUBA diving.

Lake Service Provider Training for MPRB Staff and Outside Organizations

The MNDNR operates a Lake Service Provider (LSP) Permit and Certification program that provides AIS education to individuals and entities that rent, install or move water-related equipment in public water bodies. The definition of an LSP applies to the MPRB itself, as well as several outside organizations that operate at Minneapolis water bodies. As such, the MPRB maintains an active LSP certification and requires that any organizations who hold a permit with the MPRB, that fall under the LSP category, have a current LSP permit and certification. MPRB's LSP certification was renewed in 2020 and will expire at the end of 2022.

AIS Prevention Plans for Sailing Organizations

Since 2015, MPRB staff have maintained and annually updated an AIS Prevention Plan for Minneapolis sailing schools and yacht clubs. The plan lists sailing activities that have a high potential for spreading AIS and provides best practices for preventing the spread.

Changes to MPRB Staff Workflow

As mentioned above, Lake Harriet was designated as infested with zebra mussels by the MNDNR in 2017, and Bde Maka Ska in 2018. In response, MPRB staff adjusted internal workflow procedures to minimize the potential for new introductions. The biggest threat seen at the time was potentially introducing Bde Maka Ska's zebra mussel population into the rest of the Chain of Lakes. To prevent this, MPRB Water Quality staff and aquatic plant harvesting staff followed protocols in 2019-2022 that allowed them to exclusively visit uninfested lakes before infested lakes.

Early Detection

Zebra Mussel Settling Plate Program

Zebra mussel settling plates, like the one shown in **Figure 22-2**, are a commonly utilized tool for detecting zebra mussels in newly infested water bodies. The plates are made of PVC and are hung from a dock or other fixed object so that they are suspended approximately one foot from the lake bottom. The plates are checked for zebra mussel growth by boat inspectors and are placed back into the water without being cleaned.

Figure 22-2. Clean zebra mussel sampling plate.

MPRB staff and volunteers from the Friends of Lake Nokomis monitored zebra mussel settling plates at the following lakes in 2022: Wirth, Cedar, Lake of the Isles, Bde Maka Ska, Harriet, Nokomis, and Hiawatha. Lake Hiawatha was the only lake where zebra mussels were detected in 2021, and none were found in 2022. In 2020, inspectors found several thousand zebra mussels on the Hiawatha plate, as shown in **Figure 22-3**. Lake Hiawatha has been infested with zebra mussels for several years, due to its connectivity with Minnehaha Creek. Two main factors might have caused the decreased abundance of zebra mussels on the Lake Hiawatha plate in 2022. First, a large gelatinous bryozoan colony grew on the Lake Hiawatha plate for much of the open-water season and may have out-competed zebra mussels for space. Second, due to decreased flow in Minnehaha Creek in 2022 from drought conditions, Lake Hiawatha may have received fewer zebra mussel propagules from Lake Minnetonka.

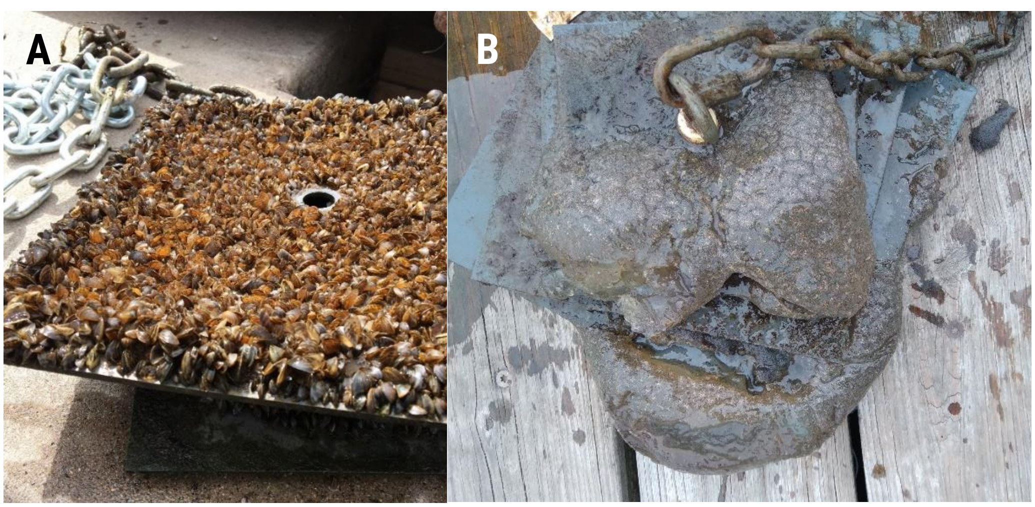


Figure 22-3. (A) Lake Hiawatha zebra mussel sampling plate covered with several thousand zebra mussels in September 2020. (B) Gelatinous bryozoan colony growing on the Lake Hiawatha plate in 2022.

Zebra Mussel Veliger Sampling Program

Zebra mussel veligers are a microscopic larval life stage that can be collected from the water column via a zooplankton net tow. Veliger sampling can be highly sensitive and is a valuable early detection tool. Due to low staffing level, the MPRB was not able to conduct veliger sampling in 2022.

Buoy Inspections

Similar to zebra mussel settling plates, beach and sailboat buoys serve as suitable zebra mussel substrate. MPRB watercraft inspectors inspected most of the beach buoys from Bde Maka Ska, Lake Harriet, and Lake Nokomis after they were removed from the lakes in the fall. Zebra mussels were not found on any of the beach buoys. Beach buoys from Cedar Lake and Lake Hiawatha were not inspected by AIS staff. As shown in **Figure 22-4**, zebra mussels have been found on the Lake Hiawatha beach buoys in previous years.

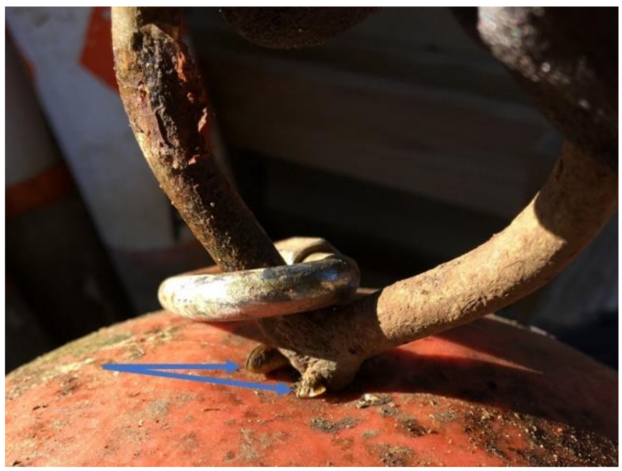


Figure 22-4. Close-up view of Lake Hiawatha beach buoy during an inspection in September 2020. The blue arrows indicate the location of two zebra mussels attached to the buoy.

MPRB watercraft inspectors were able to inspect most of the sailboat buoys at Bde Maka Ska, Lake Harriet, and Lake Nokomis as they were removed in the fall. No evidence of zebra mussels or any other unexpected AIS was observed in 2022.

Weekly Boat Launch Surveys

Once per week from June to September specially trained watercraft inspectors came early to their shift or stayed late at their shift to conduct early detection surveys of the boat launches at Bde Maka Ska, Lake Harriet, and Lake Nokomis. The surveys, as depicted in **Figure 22-5**, involved entering the water while wearing waders and a life jacket and inspecting the dock, the boat ramp, plants, rocks, sticks, and other debris for approximately a half hour. The inspectors were trained to identify native and invasive plants and animals, so they used the surveys to look for a variety of plant and animal AIS. No unexpected AIS were observed during the surveys in 2022.

Figure 22-5. MPRB watercraft inspector performing a boat launch AIS survey at Lake Harriet in June 2020.

Lake Nokomis Weir Operation

The outlet from Lake Nokomis to Minnehaha Creek is a short channel with a concrete fixed weir that can be adjusted with removable metal stop logs to control the release of water from Lake Nokomis or prevent water from the creek from backflowing into the lake. The goals of the structure include increasing the protection of Lake Nokomis from polluted stormsewer discharges and from the movement of zebra mussels from Minnehaha Creek to the lake. The MPRB and Minnehaha Creek Watershed District manage the weir using an established Operating Plan based on lake and creek levels, precipitation, and amount of water released from Grays Bay Dam.

Environmental DNA Monitoring

Environmental DNA (eDNA) is organismal DNA that originates from cellular material shed by organisms (via skin, excrement, etc.) into aquatic or terrestrial environments. eDNA can be measured using a variety of molecular laboratory techniques and is important for the early detection of invasive species. Due to low staff level, eDNA monitoring was not conducted in 2022.

Cedar Lake Zebra Mussel Survey

Staff from MPRB and Blue Water Science conducted surveys for zebra mussels at Cedar Lake on October 19th. Blue Water Science snorkeled during the survey while MPRB staff checked rocks and other substrate along the shoreline using waders. In total, 8.83 hours of searching were conducted in 2022, and no zebra mussels were found.

Response

Bde Maka Ska Zebra Mussel Infestation Status

As a follow-up to 2018's zebra mussel discovery in Bde Maka Ska, a variety of early detection tools including eDNA monitoring and surveys were used to search for zebra mussels in Bde Maka Ska between 2019 and 2022. No evidence of additional zebra mussels was observed in any of these years. There does not appear to be a well-established population of zebra mussels in Bde Maka Ska at this time.

Lake Harriet Zebra Mussel Infestation Status

As a follow-up to 2017's zebra mussel discovery in Lake Harriet, a variety of early detection tools including eDNA monitoring and surveys were used to search for zebra mussels in Lake Harriet between 2018 and 2022. No evidence of additional zebra mussels was observed in any of these years. There does not appear to be a well-established population of zebra mussels in Lake Harriet at this time.

Management

In addition to managing submerged aquatic vegetation in Wirth Lake, Cedar Lake, Lake of the Isles, Bde Maka Ska, Lake Harriet, and Lake Nokomis via harvesting, staff monitor the status of other AIS populations in and around MPRB water bodies and consider appropriate management strategies. For example, Brazilian waterweed (*Egeria densa*) was detected in Powderhorn Lake and successfully eradicated using the herbicide Diquat in 2007. The lake was subsequently removed from the MNDNR's Infested Waters List.

Staff performed a survey of the emergent plant flowering rush (*Butomus umbellatus*) in Minnehaha Creek in 2018 and determined that management was not needed at that time. The flowering rush that was observed occurred at low-densities and did not appear to be out-competing native species.

Invasive *Phragmites*

In fall 2021, MPRB began managing *Phragmites australis* spp. *australis*, an invasive species of wetland grass found around the Chain of Lakes. Invasive *Phragmites* can overtake shoreline areas and create unsuitable habitat for desirable plant and animal species. Also, since mature *Phragmites* plants can grow to a height of 15 feet tall or more, they can serve as a significant aesthetic nuisance along lake shorelines. Invasive *Phragmites* can reproduce and spread both sexually by seed and asexually by rhizome, stolon, and stem fragments. This makes it a very difficult plant to contain in a small area.

Invasive *Phragmites* was elevated from the "restricted" category to the "control" category of the Minnesota Department of Agriculture's Noxious Weed List in 2021, meaning that MPRB was legally obligated to manage it for the first time in 2021. According to Minnesota Aquatic Invasive Species Research Center (MAISRC), the most effective management strategy for invasive *Phragmites* involves:

Summer mow (optional) -> Fall herbicide -> Winter mow -> Evaluate -> Follow-up treatment

This management cycle is generally used for three consecutive years. See MAISRC Invasive Phragmites management recommendations (https://maisrc.umn.edu/phragmites-management) for more information.

To manage the existing populations of invasive *Phragmites*, MPRB followed MAISRC's recommended approach. The following four sites of invasive *Phragmites* were surveyed by MPRB staff, confirmed by experts at MAISRC, and treated in 2022:

- A portion of the shoreline on the south side of Lake of the Isles near the MPRB dog park
- A portion of the shoreline west of Thomas Beach on the south side of Bde Maka Ska
- A stretch along the channel connecting Bde Maka Ska to Lake Harriet near William Berry Parkway
- A section near the sand volleyball courts located by Wirth Beach

During 2022, a new, small population of invasive *Phragmites* was discovered at the Lyndale Sculpture Gardens by an MPRB horticulture supervisor. The site will continue to be monitored in 2023 and staff will decide what treatment plan is appropriate.

The herbicide that was used for the invasive *Phragmites* treatments was Habitat, which contains the active ingredient imazapyr. Habitat is specifically formulated to affect plants and poses a minimal health risk to humans, pets, or other animals. As depicted in **Figure 22-6**, the herbicide was accurately administered by a licensed applicator via backpack sprayer to limit wind drift and limit damage to non-target plants.

Figure 22-6. Invasive *Phragmites* herbicide treatment occurring at Lake of the Isles.

Follow-up mowing and herbicide treatments occurred in 2022 and will occur again in 2023. The sites will be surveyed each year and will be revegetated with native species in 2024. The revegetation species will be chosen to complement the existing plant community at each of the sites. The populations at Thomas Beach and William Berry Parkway already showed great improvements after treatments in 2022.

The MPRBs goal is to control the species, thereby preventing it from maturing, dispersing, and causing damage to infrastructure, and protecting sensitive natural resource areas. If new *Phragmites* sites are discovered on MPRB property in the future, MPRB will make management determinations on a site-by-site basis. MAISRC's recommended management techniques may change in the future as additional research on *Phragmites* management is conducted. MPRB plans to stay up to date with MAISRC's recommendations to ensure that the most effective and environmentally friendly management techniques are being utilized.

Java Waterdropwort

Java waterdropwort, (*Oenanthe javanica*) is a perennial herb native to East Asia and Australia. It was first introduced to North America by the horticultural industry and marketed as an ornamental wetland plant and a medicinal herb. It has since escaped from cultivation into natural areas where it has become invasive. In October of 2022, the MPRB received notice from the MNDNR about a sighting of Java waterdropwort near Wirth Lake, **Figure 22-7**. The report was submitted on iNaturalist, a social networking app that allows citizens and scientists alike to map and share observations of biodiversity. MPRB staff responded to search the area until finding the patch of plants. Vegetative samples were collected and brought to the MNDNR for confirmation. There have been no other sightings of Java waterdropwort in MPRB parks as of January 2023. In 2023, the MPRB will continue to monitor the site at Wirth Lake and develop an appropriate treatment plan.

Figure 22-7. Invasive Java waterdropwort on the eastern shore of Wirth Lake.

23. Wetland Health Evaluation Project (WHEP)

Figure 23-1. MuckStars team working hard at Robert's Bird Sanctuary. Photo taken by Ann Journey.

Background

The Wetland Health Evaluation Project (WHEP) began in 1997 in Dakota County with Environmental Protection Agency (US EPA) funding. In 2001, Hennepin County began its own WHEP program as a pilot project. The pilot program was successful at both the county and local levels and has continued as a partnership between the two counties, cities, and other water management organizations. WHEP utilizes teams of trained volunteers, as seen in **Figure 23-1**, to collect and analyze wetland vegetation and invertebrate data to characterize wetland health. Hennepin County Environmental Services staff then cross-check, synthesize, and report the collected data back to partner organizations and to the public.

The Minneapolis Park and Recreation Board (MPRB) has sponsored citizen volunteer teams who have monitored wetlands within the park system each year since 2002. Every summer wetlands are selected to be monitored within Minneapolis depending on the needs of the MPRB. The wetlands monitored during 2022 were: a portion of the wetland edge of Diamond Lake, Grass Lake, Wirth Beach Restored Wetland, Webber Regeneration Pond, and Webber Stormwater Pond. The Roberts Bird Sanctuary wetland is also monitored annually as a reference wetland site for the City of Minneapolis.

For more information see the Minnesota WHEP website at http://www.mnwhep.org.

METHODS

Volunteers for the project are trained in three sessions by Minnesota Pollution Control Agency (MPCA) staff. Training sessions cover monitoring methods, macroinvertebrate identification, and vegetation identification. Spot checks and quality control checks are conducted by other citizen teams and by a technical expert for quality assurance purposes.

Sampling from the wetlands includes both vegetation and invertebrate data. All wetland evaluation and sampling protocols followed the *Vegetation Method for Wetland Evaluation* (Gernes, 2002). A vegetation survey was performed in a 100-square meter plot considered representative of the entire wetland for each site. Additionally, an invertebrate survey was completed with three full dipnet samples within the emergent vegetation zone and near the shoreline.

The information from the WHEP survey is used to evaluate the wetland's biological health based on metrics developed by the MPCA. An index of biotic integrity (IBI) has been developed by the MPCA to include both vegetation and invertebrate metrics. The IBI metrics are listed below.

<u>Vegetation IBI Metrics (identification to genus level)</u>

- Total number of forbs, woody species, and grass-like plants
- Total number of mosses, lichens, liverworts, and macro-algae (*Chara* and *Nitella*)
- Cover of sedge (*Carex*)
- Presence of Bladderwort (*Ultricularia*)
- Total number of "Aquatic Guild" plants
- Cover of plants with persistent standing litter

<u>Invertebrate IBI Metrics (identification to family level)</u>

- Leech: Number and type of leeches in net and bottle trap samples
- Corixid: Proportion of Water Boatmen (*Corixidae*) in a bottle trap in relation to the total number of aquatic beetles and all bugs in the sample. This metric was dropped from the invertebrate IBM Metrics in 2016.
- Odonate: Number of different types of dragonflies and damselfly nymphs in dip-net samples
- ETSD: Total number of mayflies, plus the number and type of caddis flies, plus presence of fingernail clams and dragonflies
- Snail: Number of different types of snails
- Total Taxa: Number of taxa above, plus the number of crustaceans, plus the presence of *Chaoborus*

The ratings used for the invertebrate and vegetation IBI at the Minneapolis wetlands from 2002 to 2015, shown in **Table 23-1**, included all the above listed Invertebrate metrics. Re-analysis of invertebrate results in 2015 showed that bottle trap data were not essential to the condition assessment. In 2016, Hennepin County WHEP stopped using bottle traps, which were previously utilized in addition to two dipnet samples for invertebrate surveys, to align with MPCA protocols. The 2016 adjusted invertebrate assessment was based on a maximum 25-point IBI score which included five points each for the Leech, Snail, Odonate, ETSD and Total Taxa metrics. The Corixid Proportion, which was counted in the earlier metric, was dropped.

Ratings developed for the invertebrate and vegetation IBI from 2016 to present are shown below in **Table 23-2**. The IBI assessment is useful to give a wetland a qualitative description that makes it easier to communicate results. Wetlands with poor ratings would have minimal species richness and diversity indicating disturbance and poor wetland health. A wetland with a rating of excellent would have high diversity and species richness indicating a healthy wetland and relatively minimal ecological disturbance.

Table 23-1. Ratings for the invertebrate and vegetation IBIs from 2002 to 2015. The greyed sections indicate the Invertebrate Scores and Quality Ratings before 2016 when the Corixid Proportion was dropped from the IBI Assessment to better align with MPCA protocols.

Invertebrate Index of Biotic Integrity		Vegetation Index of Biotic Integrity	
Sum of Invertebrate Metric Scores	**Invertebrate Quality Rating**	**Sum of Vegetation Metric Scores**	**Vegetation Quality Rating**
6-14	Poor	7-15	Poor
15-22	Moderate	16-25	Moderate
23-30	Excellent	26-35	Excellent

Table 23-2. Ratings for the invertebrate and vegetation IBIs from 2016 to present.

Invertebrate Index of Biotic Integrity		Vegetation Index of Biotic Integrity	
Sum of Invertebrate Metric Scores	**Invertebrate Quality Rating**	**Sum of Vegetation Metric Scores**	**Vegetation Quality Rating**
5-11	Poor	7-15	Poor
12-18	Moderate	16-25	Moderate
19-25	Excellent	26-35	Excellent

RESULTS AND DISCUSSION

During the summer of 2022, WHEP-trained volunteers, as seen in **Figure 23-2**, monitored six wetlands within the MPRB system. Roberts Bird Sanctuary was monitored for the 20th year serving as a reference wetland for the Minneapolis WHEP program. IBI scores for other monitored wetlands can be compared to the reference wetland scores to determine the effects of inter-annual variation or regional changes (drought, wet periods, plant diseases, etc.) on wetland health.

Figure 23-2. WHEP volunteers at Grass Lake (A) and Webber Regeneration Basin (B). Photos taken by Ann Journey.

Roberts Bird Sanctuary (Reference Site)

The Roberts Bird Sanctuary is located north of Lake Harriet. The Sanctuary is a natural area that has been preserved, and thus has been used as a reference wetland for the Minneapolis WHEP program. The wetland within the Sanctuary is estimated to be 10 acres in size. The WHEP team accesses the monitoring location near a tamarack stand from the boardwalk. The team moved the sampling location to the north side of the pond in 2021 but returned to their usual location in 2022. **Table 23-3** shows the results for all 20 years of monitoring at the Roberts Bird Sanctuary. In 2022, the wetland received a moderate rating for both invertebrate and vegetation quality.

WHEP volunteers were once again able to conduct eight dip net efforts in 2022 after downsizing their operations during the COVID-19 pandemic. Despite drier conditions, submergent and floating leaved forbs thrived, as did grass-like vegetation. This, along with the decrease of large trees in sampling areas, indicates changing conditions in the wetland. What once was a wooded and clear-watered bog is transforming into something warmer and grassier, which may negatively affect diversity in key groups in the future. Notable vertebrate notes from the team included wood ducks, white-tailed deer, and tree frogs.

Table 23-3. WHEP scores at the Roberts Bird Sanctuary Site. The greyed sections of the Invertebrate Score and Quality Rating indicate years when the IBI was based on the inclusion of the Corixid Proportion as seen in Table 23-1. The Corixid Proportion was dropped beginning in 2016.

Year	Invertebrate Score	Invertebrate Quality Rating	Vegetation Score	Vegetation Quality Rating
2003	20	Moderate	17	Moderate
2004	20	Moderate	17	Moderate
2005	22	Moderate	15	Poor
2006	22	Moderate	17	Moderate
2007	28	Excellent	13	Poor
2008	20/22	Moderate/Moderate	21/17	Moderate/Moderate
2009	26	Excellent	19	Moderate
2010	20/22	Moderate/Moderate	21/19	Moderate/Moderate
2011	22/23	Moderate/Moderate	21/23	Moderate/Moderate
2012	26	Excellent	11	Poor
2013	24	Excellent	15	Poor
2014	26	Excellent	15	Poor
2015	22	Moderate	21	Moderate
2016	17	Moderate	21	Moderate
2017	27	Excellent	21	Moderate
2018	13	Moderate	25	Moderate
2019	17	Moderate	21	Moderate
2020	11	Poor	19	Moderate
2021	13	Moderate	19	Moderate
2022	17	Moderate	21	Moderate

Diamond Lake Wetland Fringe

Diamond Lake is a small shallow water body. The National Wetlands Inventory classifies Diamond Lake as a permanently flooded lacustrine/limnetic system with an unconsolidated bed (L1UBH). The fringe of Diamond Lake is classified as palustrine semi permanently flooded wetland with emergent vegetation (PEMF) (USFWS, 2012). The lake has been monitored annually since 1992 as part of MPRB's lake sampling water quality program. See **Chapter 6** for more information on Diamond Lake. Diamond Lake has been monitored 18 times in the WHEP Program. This site is in an urban setting with a large fully built-out watershed and provides valuable bird habitat.

The wetland fringe at Diamond Lake had historically received poor ratings, but over time has moved to more moderate and excellent ratings in both vegetation and invertebrates as seen in **Table 23-4**. MPRB Field staff believe that muskrats eating away some of the cattails may be making openings for native species to thrive. In 2022, the Diamond Lake Wetland Fringe rated excellent for invertebrate quality and remained moderate for vegetation quality. Wood ducks, cormorants, mallards, chipmunks, and muskrats were noted by the sampling team. Leeches, caddisflies, and mayflies were in abundance along with several varieties of snails. Banded and/or Chinese mystery snails (*Vivaparus georgianus* and/or *Cipangopaludina chinensis*) have historically been found in Diamond Lake, though no snails were seen in 2021 or 2022.

Table 23-4. WHEP scores at Diamond Lake. The greyed sections of the Invertebrate Score and Quality Rating indicate years when the IBI was based on the inclusion of the Corixid Proportion as seen in Table 23-1. The Corixid Proportion was dropped beginning in 2016.

Year	Invertebrate Score	Invertebrate Quality Rating	Vegetation Score	Vegetation Quality Rating
2002	8	Poor	13	Poor
2005	14	Poor	7	Poor
2006	16	Moderate	13	Poor
2008	10	Poor	15	Poor
2009	18	Moderate	11	Poor
2010	24	Excellent	20	Moderate
2011	8	Poor	11	Poor
2012	24	Excellent	15	Poor
2013	26	Excellent	15	Poor
2014	19	Moderate	12	Poor
2015	18/16	Moderate/Moderate	19/15	Moderate/Poor
2016	17	Moderate	17	Moderate
2017	21	Excellent	19	Moderate
2018	19	Moderate	19	Moderate
2019	17	Moderate	27	Excellent
2020	17	Moderate	21	Moderate
2021	25	Excellent	21	Moderate
2022	21	Excellent	23	Moderate

Grass Lake Wetland

Grass Lake was created during the construction of State Highway 62. The highway separated one waterbody into two new lakes: Grass Lake to the north and Richfield Lake to the south. The area is known for birdwatching. The lake has typically been monitored every other year since 2002 as part of MPRB's lake sampling water quality program. See **Chapter 7** for more information on Grass Lake. Grass Lake has been evaluated for eight years as part of the WHEP program, as presented below in **Table 23-5**. In 2022, Grass Lake received a moderate rating for both invertebrate quality and vegetation quality.

Drought impacted the MuckStar's access to Grass Lake in 2022. Dip netting was restricted to the southeast corner by a stormwater culvert where, due to low water levels, much of the emergent vegetation such as cattails were found out of the water. Aquatic plants were limited with only a few species found in the channel while grasses and forbs filled in the areas that were dryer due to low water levels. A few new species of snails and leeches were noted by the team.

Table 23-5. WHEP scores at Grass Lake Wetland. The greyed sections of the Invertebrate Score and Quality Rating indicate years when the IBI was based on the inclusion of the Corixid Proportion as seen in Table 23-1. The Corixid Proportion was dropped beginning in 2016.

Year	Invertebrate Score	Invertebrate Quality Rating	Vegetation Score	Vegetation Quality Rating
2003	18	Moderate	19	Moderate
2004	16	Moderate	19	Moderate
2017	15	Moderate	15	Poor
2018	13	Moderate	21	Moderate
2019	15	Moderate	23	Moderate
2020	17	Moderate	21	Moderate
2021	9	Poor	19	Moderate
2022	17	Moderate	19	Moderate

Figure 23-3. WHEP volunteers conducting a vegetation survey at Grass Lake. Photo taken by Ann Journey.

Wirth Beach Restored Wetland

Wirth Beach Restored Wetland is located near the southern tip of Wirth Lake just southwest of the swimming beach. The site has inlets from the Wirth wetland areas south of Glenwood Ave, parkland to the south and west, and from the basins adjacent to the parking lot to the east of the wetland. The Wirth Beach Restored Wetland flows into Wirth Lake. Additionally, there are multiple springs at the north end of the wetland. The original wetland had been filled with debris from the old Wirth Beach House and was a mix of cattail and purple loosestrife. Debris was removed and the wetland was replanted in 2011.

The scores and ratings from all nine years that the Wirth Beach Restored Wetland has been included in the WHEP monitoring program are shown in **Table 23-6**. Wirth Beach Restored Wetland received a moderate rating for invertebrate quality and an excellent rating for vegetation quality in 2022. During the plant survey conducted in July of 2019 the WHEP team discovered bladderwort (*Utricularia sp*.) for the first time. This discovery is notable because bladderwort is considered an indicator of good water quality. However, 2022 yielded a lower amount of bladderwort plants than expected, accompanied by a decrease in grass-like vegetation, forbs, and woody plants. Leeches continued to be low in abundance and diversity while five varieties of snails were present in large densities.

Table 23-6. WHEP scores at Wirth Beach Restored Wetland. The greyed sections of the Invertebrate Score and Quality Rating indicate years when the IBI was based on the inclusion of the Corixid Proportion as seen in Table 23-1. The Corixid Proportion was dropped beginning in 2016.

Year	Invertebrate Score	Invertebrate Quality Rating	Vegetation Score	Vegetation Quality Rating
2014	18	Moderate	25	Moderate
2015	20	Moderate	27	Excellent
2016	15	Moderate	25	Moderate
2017	17	Moderate	27	Excellent
2018	13	Moderate	27	Excellent
2019	15	Moderate	21	Moderate
2020	23	Excellent	29	Excellent
2021	23	Excellent	29	Excellent
2022	17	Moderate	31	Excellent

Figure 23-4. Dragonfly found at Wirth Beach Restored Wetland. Photo taken by Ann Journey.

Webber Regeneration Basin

The Webber Regeneration Basin is located in Webber Park and is part of the Webber Natural Swimming Pool. The 0.4-acre constructed wetland receives no runoff from the surrounding land. The entire 500,000 gallons of water from the pool circulates continuously through the basin, through the UV disinfection system, and back into the pool every 12 hours. The regeneration basin consists of plants, gravel, and other aggregates. This basin does not contain natural soil; therefore, the plants need to acquire all their nutrients from the water itself. The pool is filled with city water in the spring and any additional city water added later in the season is run through a phosphate filter to limit phosphorus addition to the system. Environmental Management staff monitor water in the Webber upper pool, lower pool, and regeneration basin throughout the swim season for bacteria, water chemistry, and phytoplankton and zooplankton species. See **Chapter 20** for more information on Webber Natural Swimming Pool.

Table 23-7 shows the scores and ratings from all seven years that the Webber Regeneration Basin has been included in the WHEP monitoring program. The Regeneration Basin received a moderate rating for both invertebrate and vegetation quality in 2022. The WHEP team noted a more stream-like invertebrate community developing. Notable species this year included dragonflies, painted turtles, and toads. They also observed an abundance of water lilies and filamentous algae.

Table 23-7. WHEP scores at Webber Regeneration Basin.

Year	Invertebrate Score	Invertebrate Quality Rating	Vegetation Score	Vegetation Quality Rating
2016	9	Poor	21	Moderate
2017	19	Excellent	27	Excellent
2018	15	Moderate	23	Moderate
2019	15	Moderate	21	Moderate
2020	19	Excellent	25	Moderate
2021	19	Excellent	27	Excellent
2022	15	Moderate	25	Moderate

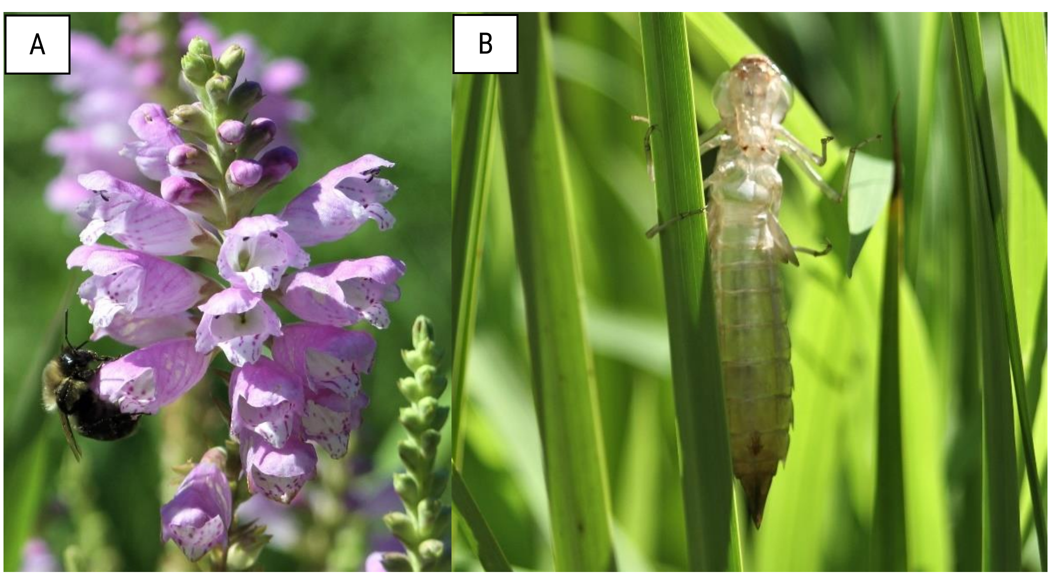


Figure 23-5. Bumblebee (A) and dragonfly nymph exoskeleton (B) in the regeneration basin. Photo taken by Ann Journey.

Webber Stormwater Pond

The Webber Stormwater Pond is located adjacent to the Webber Natural Swimming Pool in Webber Park. The 0.25-acre pond was created to treat runoff from the surrounding three acres before it enters Shingle Creek. The scores and ratings from all seven years that the Webber Stormwater Pond has been included in the WHEP monitoring program are shown in **Table 23-8**. Webber Stormwater Pond received an excellent rating for invertebrate quality and a moderate rating for vegetation quality in 2022. Construction along Webber Parkway decreased traffic in the park, leading to less trash in the pond and possibly more diversity in invertebrate species. The team noted redwing blackbirds, cowbirds, mallards, bullfrogs, and fathead minnows. Invasive rusty crayfish have been seen at this site in the past but are not established and haven't been observed since 2020.

Table 23-8. WHEP scores at Webber Stormwater Pond.

Year	Invertebrate Score	Invertebrate Quality Rating	Vegetation Score	Vegetation Quality Rating
2016	11	Poor	21	Moderate
2017	21	Excellent	29	Excellent
2018	19	Excellent	19	Moderate
2019	19	Excellent	27	Excellent
2020	21	Excellent	19	Moderate
2021	15	Moderate	19	Moderate
2022	21	Excellent	21	Moderate

Figure 23-6. WHEP team searching for invertebrates at Webber Stormwater Pond. Photo taken by Ann Journey.

24. Stormwater Quarterly Grab Monitoring

Background

As part of the federal Clean Water Act, the Minneapolis Park and Recreation Board (MPRB) and the City of Minneapolis are co-signatories on the Environmental Protection Agency (EPA) issued National Pollutant Discharge Elimination System (NPDES) Municipal Separate Stormsewer System (MS4) Permit.

The purpose of monitoring via grab samples is to characterize the seasonality of runoff for parameters that cannot be collected with flow-weighted composite auto-monitoring, such as pH, *Escherichia coli* (*E. coli*), and Fat Oil & Grease (FOG). Criteria for snowmelt sample collection was a winter snowpack melt event. Criteria for spring, summer, and fall grab sample collection was precipitation event greater than 0.10 inches separated by at least 8 hours from other rain events.

Grab samples can be challenging to obtain, as specific timing of rain events in relation to MPRB and lab working hours are required for samples to be collected and analyzed. Ideally, annual quarterly grab monitoring includes: two snowmelt grab samples, and one grab sample each in spring, summer, and fall, but the NPDES permit allows for some flexibility. Quarterly grab monitoring includes pH measurement, and samples analyzed for *E. coli*, NPDES water chemistry, and Fat Oil and Grease (FOG). The latest NPDES permit prescribed that if a FOG sample was measured greater than 15 mg/L at a site, then that site would continue to be monitored throughout the permit cycle. Chemistry parameters that are analyzed from grab samples, as required by the NPDES permit, are outlined in **Table 24-1**.

Grab sampling characterizes a point in time of a snowmelt or rain event. The first snowmelt event in a year usually has higher pollutant concentration than subsequent snowmelt events. The chemical concentrations can change over time throughout a storm event. The beginning of a storm mobilizes fine particles and FOG material previously deposited on hard surfaces. Chemical concentrations can have significant variance between storm events depending on the amount of time since the last precipitation event, since pollutants accumulate on surfaces over time and then wash off into the stormwater in a melt or rain event.

In 2018 quarterly grabs were collected at sites representing different land use types. Following snowmelt, grab samples could not be collected from the Pershing Park land use site since auto-monitoring equipment was housed in an equipment box on top of the manhole. The 61st & Lyndale site had extensive road construction and stormwater pipe replacement beginning mid-summer 2018 that restricted access.

In 2019, the grab sites were changed to the Powderhorn Lake Inlets: SE, S, and W and the 24th Ave. SE & Elm St. SE infiltration basin Inlets: N and S. The intention was to continue sampling at the 61st & Lyndale site, but the site was again inaccessible due to the stormwater pipe replacement and road reconstruction.

In 2020, the quarterly grab sites were, 24th Ave. SE & Elm St. SE Inlets: N and S and Powderhorn Inlets: SE, S, and W, and 61st & Lyndale. In 2020, after several unsuccessful attempts were made, the Powderhorn Inlet N site was deemed physically inaccessible to collect grab samples and dropped from grab sampling. 2020 was also a difficult year for field work with the COVID-19 pandemic restrictions.

In 2021, grab sampling was completed at six sites: Powderhorn Lake Inlets SE, S, and W, 24th Ave SE & Elm St. SE infiltration basin N and S Inlets, and 61st & Lyndale were all successfully monitored.

In 2022, grab sampling included seven sites: three Powderhorn Lake inlets (W, SE, S), three Camden Pond inlets (NNW, SNW, SW), and the 61st & Lyndale site. Due to a lack of significant storm events in the summer and fall, a grab sample in the fall quarter was unable to be collected in 2022.

METHODS

Grab Sampling

Grab samples are either taken directly from the stormsewer using a modified pool skimmer pole, or from an aliquot taken in a clean white 5-gallon bucket on a rope. If adequate flow was not available to use the pool skimmer, a bucket was lowered into the stormsewer and rinsed once before the aliquot was collected to be sub-sampled. Per sampling protocol, water chemistry sample bottles were rinsed once before sample collection, whereas E. coli and FOG sample bottles were not rinsed. FOG samples were collected in amber glass bottles. All samples were stored and transported on ice to the laboratory, along with a field blank. **Table 24-1** shows the NPDES chemistry parameters analyzed in each sample collected. **Table 24-2** shows approved methods, reporting limits, and holding times for each parameter as reported by the contract laboratory Instrumental Research, Inc. (IRI).

The pH measurement was analyzed in the field by a hand-held Oakton pH meter. The pH meter was calibrated prior to sampling using a two-point calibration. The pH probe was rinsed with the grab sample water and the pH measurement was taken directly from the aliquot.

Samples could only be collected when enough flow was present to collect a sample. Snowmelt and precipitation needed to produce at least 1 inch of stage in the pipe to be sampled. Precipitation events needed to be greater than 0.10 inches to produce enough runoff.

Staff attempted to collect quarterly rainfall grab samples on 4/5/22, 5/25/22, 6/13/22, and 8/12/22, shown in **Table 24-5**. Not every site was able to be sampled with each precipitation event due to limited flow, but samples were collected wherever possible. Additionally, parameters with short holding times such as *E. coli* could not be analyzed if collected on Friday due to lab hours.

All FOG, NPDES water chemistry, and *E. coli* samples were analyzed at Instrumental Research Incorporated (IRI) Laboratory in Fridley, Minnesota. Metals (copper, zinc, lead) and DOC samples were analyzed by Pace Laboratory in Minneapolis, MN.

Table 24-1. Chemistry parameters monitored as required by the NPDES permit.

Parameter	Abbreviation	Units
Chemical Oxygen Demand	COD	mg/L
Dissolved Organic Carbon	DOC	mg/L
Chloride, Total	Cl	mg/L
***E. coli* (*Escherichia Coli*)**	*E. coli*	MPN/100mL
Hardness	Hard	mg/L
Copper, Total	Cu	µg/L
Lead, Total	Pb	µg/L
Zinc, Total	Zn	µg/L
Nitrite/Nitrate, Total as N	NOx	mg/L
Total Nitrogen	TN	mg/L
pH	pH	standard unit
Fat, Oil, and Grease (FOG)	FOG	mg/L
Phosphorus, Total Dissolved	TDP	mg/L
Phosphorus, Total	TP	mg/L
Solids, Total Dissolved	TDS	mg/L
Solids, Total Suspended	TSS	mg/L
Solids, Volatile Suspended	VSS	mg/L

Table 24-2. Analysis method, reporting limit, and holding times for parameters used by Instrumental Research, Inc. and Pace Laboratories.

Parameter	Method	Reporting Limit	Holding Times
COD	SM 5220-D	20 mg/L	28 days
DOC	SM 5310-C-00	1.5 mg/L	28 days
Chloride, Total	SM 4500-Cl^- B	2.0 mg/L	28 days
***E. coli* (*Escherichia Coli*)**	SM 9223 B	1 MPN per 100mL	< 24hrs
Hardness	SM 2350 C	5.0 mg/L	6 months
Copper, Total	EPA 200.8	1 µg/L	6 months
Lead, Total	EPA 200.8	0.10 µg/L	6 months
Zinc, Total	EPA 200.7	20 µg/L	6 months
Nitrite/Nitrate, Total as N	SM 4500-NO_3 E	0.030 mg/L	28 days
Total Nitrogen	Alk Persulfate Oxidation method	0.500 mg/L	28 days
pH	SM 4500 H^+ B	0.01 units	15 minutes
Fat, Oil, and Grease (FOG)	EPA 1664A	5.0 mg/L	28 days
Phosphorus, Total Dissolved	SM 4500-PE	0.010 mg/L	48 hours
Phosphorus, Total	SM 4500-PE	0.010 mg/L	48 hours
Solids, Total Dissolved	SM 2540 C	5.0 mg/L	7 days
Solids, Total Suspended	SM 2540 D	1.0 mg/L	7 days
Solids, Volatile Suspended	EPA 160.4	2.0 mg/L	7 days

The 2022 grab sampling sites are shown below. **Figure 24-1** shows the location of the 61st & Lyndale site. **Figure 24-2** shows the location of the Camden Pond inlets NNW, SNW, and SW. **Figure 24-3** shows the location of the Powderhorn Lake inlets SE, S, and W. **Table 24-3** shows the land use and drainage area for the sample sites at the Powderhorn inlets and 61st & Lyndale. **Table 24-4** shows land use and drainage area for the sample sites at the Camden inlets.

Figure 24-1. Aerial photo of the 61st & Lyndale stormwater quarterly grab monitoring site.

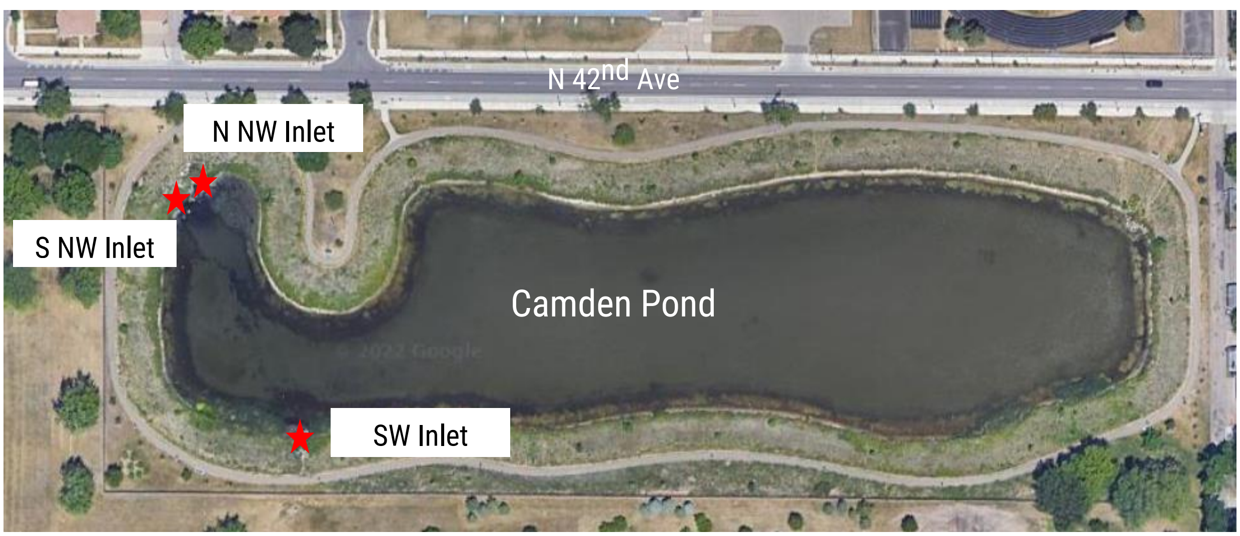


Figure 24-2. Aerial photo of Camden Pond quarterly grab monitoring sites.

Figure 24-3. Aerial photo of the Powderhorn quarterly grab monitoring sites.

Table 24-3. The Powderhorn Inlets SE, S, and W and 61st & Lyndale sites monitored quarterly for NPDES chemistry, *E. coli*, pH, and FOG, and their location, main land uses, drainage area, and percent impervious surfaces.

Site ID	Powderhorn Inlet SE	Powderhorn Inlet S	Powderhorn Inlet W	61st & Lyndale
Location	3421 15th Ave S.	13th Ave S. and E. 35th St.	3318 19th Ave S.	335 ft. east of 61st St and Harriet Ave S.
Land Use	Single family, right of way, park	Single family, right of way	Single family, right of way	Commercial/Industrial
Drainage Area	70.0 acres	81.2 acres	99.4 acres	34.9 acres
Imperviousness	43.9%	49.6%	51.5%	

Table 24-4. The Camden Central Pond sites monitored for NPDES chemistry, *E. coli*, pH, and FOG.

Site ID	Camden Inlet N NW	Camden Inlet S NW	Camden Inlet SW
Location	4200 Newton Ave N	4200 Newton Ave N	4200 Newton Ave N
Land Use	Single family, right of way	Single family, right of way	Institutional (cemetery)
Drainage Area	10.5	127.8	84.2
Imperviousness	48.0%	44.9%	9.9%

Quality Assurance Practices

A variety of quality assurance quality control (QAQC) measures were taken to ensure defensible data. Ten percent of the samples were laboratory quality assurance samples e.g., duplicates, spikes. A field blank was also generated for each sampling trip and was analyzed for all NPDES chemical parameters. Field blanks consisted of deionized water which accompanied samples from the field sites to the analytical laboratory. All field blank parameters were below the reporting limits in 2022. As part of the overall QAQC program, blind monthly performance samples of known concentration were made for all monitored parameters and delivered to IRI. If any parameter failed, all the data for that parameter were flagged for the entire month. COD was flagged during the month of February in 2022. This was the only flag of the year.

Field measurements were recorded on a Field Measurement Form in the 2022 Field Logbook. Electronic data from the laboratory were forwarded to the MPRB in preformatted Excel spreadsheets via email. Electronic data from the laboratory were checked and passed laboratory quality assurance procedures. Protocols for data validity followed those defined in the Stormwater Monitoring Program Manual (MPRB, 2001). For statistical calculations data reported below the reporting limit, the reporting limit value was divided in half.

Manual transcription of data was minimized to reduce error introduction. A minimum of 10% of the final data were checked by hand against the raw data sent by the laboratory to ensure there were no errors entering, manipulating, or transferring the data. See **Chapter 31** for more information on quality assurance protocol.

A Chain of Custody form accompanied each set of sample bottles delivered to the lab. Each sample container was labeled indicating the date and time of collection, the site location, and the field personnel initials. Samples were transported to the laboratory on ice in a cooler. The time that each grab sample was collected was recorded onto field sheets. A complete description of methods can be found in the Stormwater Monitoring Program Manual (MPRB, 2001). Common statistics were calculated using Microsoft Excel.

Results and Discussion

The 2022 quarterly snowmelt grab sampling schedule is shown in **Table 24-5**. The 2022 quarterly precipitation grab sampling schedule and associated precipitation event data are shown in **Table 24-6**.

The 2022 quarterly grab chemistry results are shown in **Table 24-7**. The snowmelt samples show higher concentrations of pollutants as compared to summer samples, but lower *E. coli* levels. This is expected, as snowmelt is the release of 4-5 months of deposition and debris from the watershed. *E. coli* bacteria do not survive well in colder conditions, and thus tend to have low concentrations in snowmelt samples. The pH ranged from 5.5 to 9.0 across all quarterly grab monitoring sites, with most sites generally measuring a higher pH in the colder months.

The 2022 grab sampling statistics of geometric mean, arithmetic mean, maximum value (MAX), minimum value (MIN), standard deviation (STDEV), number of samples collected, and the coefficient of variation (COV) are shown in **Table 24-8**. The geometric mean is a valuable statistic as it accurately controls for data with a wide range and outliers.

Table 24-5. Snowmelt grab samples collected in 2022. ⊗ = Grab sample collected. NS = No sample collected.

Date	Powderhorn In S	Powderhorn In SE	Powderhorn In W	Camden In N NW	Camden In S NW	Camden In SW	61st & Lyndale
2/28/22	⊗	⊗	⊗	NS	⊗	⊗	⊗
3/8/22	⊗	⊗	⊗	NS	NS	NS	⊗
3/15/22	NS	NS	NS	⊗	⊗	⊗	NS
4/5/22	⊗	⊗	⊗	NS	⊗	NS	⊗

Table 24-6. Stormwater precipitation grab samples collected with event precipitation data in 2022. Pow = Powderhorn. ⊗ = Grab sample collected. NS = No sample collected.

Start Date	Start Time	End Date	End Time	Rain (inches)	Duration (hours)	Intensity (in/hour)	Hours since last rain	Pow In S	Pow In SE	Pow In W	Camden In N NW	Camden In S NW	Camden In SW	61st & Lyndale
4/5/2022	10:15	04/06/22	5:45	0.5	19.5	0.026	34.75	⊗	⊗	⊗	NS	⊗	NS	⊗
5/25/2022	0:30	05/25/22	12:45	0.58	12.25	0.047	113.25	⊗	⊗	⊗	⊗	⊗	⊗	NS
6/13/2022	6:00	06/13/22	8:00	0.10	2.00	0.045	47.75	NS	NS	NS	NS	NS	NS	⊗
8/12/2022	4:00	08/12/22	7:45	0.84	3.75	0.224	101	⊗	⊗	⊗	⊗	⊗	⊗	⊗

Table 24-7. The 2022 quarterly NPDES chemistry grab sample results. COD data in red were flagged as a result of the blind monthly performance checks with the contracting laboratory. FOG data in red are greater than 15 mg/L.

Date	Time	Site Location	TP mg/L	TDP mg/L	SRP mg/L	TN mg/L	NO_3/NO_2 mg/L	Cl mg/L	Hardness mg/L	TSS mg/L	VSS mg/L	TDS mg/L	COD mg/L	FOG mg/L	*E. coli* MPN	pH Unit	Cu µg/L	Pb µg/L	Zn µg/L	DOC mg/L
2/28	**12:25**	**61st & Lyndale**	1.50	0.26	0.23	13.0	6.75	7398	410	760	98	11854	521.0	24.7	10	9.90	68.1	17.9	356	31.3
2/28	**14:00**	**Camden In S NW**	0.75	0.12	0.08	4.33	0.38	3799	120	182.5	67	6190	333.3	26.1	323	7.90	43.8	18.4	262	18.0
2/28	**14:15**	**Camden In SW**	0.16	0.10	0.08	2.18	0.93	38.0	252	18.8	6.6	363	<20.0	<5.0	73	8.30	8.40	0.81	<20.0	9.0
2/28	**13:30**	**Pow In S**	1.02	0.20	0.12	6.42	0.49	3599	110	254	106	5653	448.5	35.5	583	7.90	48.7	37.3	320	26.3
2/28	**12:50**	**Pow In SE**	1.05	0.15	0.08	7.09	0.39	5098	160	258	106	8132	454.6	33.7	97	8.20	46.0	37.5	322	32.1
2/28	**13:15**	**Pow In W**	1.17	0.09	0.07	5.23	0.14	3699	160	472	250	5875	520.6	43.5	97	8.10	65.5	65.6	460	26.2
3/8	**12:05**	**61st & Lyndale**	0.68	0.15	0.04	2.76	0.88	1949	164	303	40	3144	198.5	9.9	24	9.80	28.4	6.7	155	12.6
3/8	**12:40**	**Pow In S**	0.64	0.19	<0.003	6.38	0.45	1450	76	116	48	2443	236.1	14.3	190	8.10	31.0	17.3	133	19.4
3/8	**12:30**	**Pow In SE**	0.58	0.17	0.05	5.74	0.36	2199	120	78	33	3813	236.1	15.8	137	8.30	25.0	11	112	22.0
3/8	**12:55**	**Pow In W**	0.55	0.21	0.18	4.42	0.51	1300	84	67	29	2043	170.8	7.6	83.9	8.00	20.9	10.3	116	15.9
3/15	**12:50**	**Camden NW N**	0.57	0.41	<0.003	4.07	0.41	410.0	48	15.2	10	742	48.30	<5.0	313	6.40	12.8	1.9	48.4	14.2
3/15	**12:38**	**Camden NW S**	0.44	0.25	0.07	3.33	0.53	610.0	132	22.3	12.3	1188	61.90	<5.0	1986	6.40	12.0	2.4	42	16.9
3/15	**13:05**	**Camden SW**	0.73	0.35	0.09	3.33	0.41	44.0	56	94.7	44.7	188	163.2	6.53	>2420	5.50	43.6	3.7	43.6	27.3
4/5	**12:50**	**61st & Lyndale**	0.67	0.12	0.11	3.30	0.69	120.0	68	318	70.0	300	152.0	<5.0	816	8.60	34.9	62	267	11.2
4/5	**14:00**	**Camden In SW**	0.05	0.05	0.04	1.62	1.15	11.0	292	2.2	<2.0	373	7.45	<5.0	20	7.60	3.90	<0.1	<20.0	4.0
4/5	**13:15**	**Pow In S**	0.28	0.06	0.06	2.13	0.54	60.0	26.0	46.7	19.3	173	75.60	<5.0	1439	7.30	22.2	13.8	72.7	15.1
4/5	**13:10**	**Pow In SE**	0.25	0.07	0.06	2.43	0.46	20.0	21.0	38.7	16.7	105	43.60	<5.0	703	7.50	15.3	10.0	58.8	13.8
4/5	**13:25**	**Pow In W**	0.33	0.06	0.04	2.34	0.41	80.0	32.0	79.3	28.7	180	103.0	<5.0	776	7.01	27.8	23.6	94.8	12.9

Table 24-7. (continued) The 2022 quarterly NPDES chemistry grab sample results. NS = no sample.

Date	Time	Site	TP mg/L	TDP mg/L	SRP mg/L	TN mg/L	NO3NO2 mg/L	Cl mg/L	Hardness mg/L	TSS mg/L	VSS mg/L	TDS mg/L	COD mg/L	FOG mg/L	*E. coli* MPN	pH Unit	Cu µg/L	Pb µg/L	Zn µg/L	DOC mg/L
5/25	**9:30**	**Cam In S NW**	0.39	0.17	0.12	1.38	0.31	10.0	38.0	30.7	16.7	92.5	53.9	<5.0	3448	7.00	16.9	4.1	54.9	9.7
5/25	**9:45**	**Cam In SW**	0.18	0.10	0.07	1.25	0.72	4.0	140.0	12.0	6.7	222.5	20.7	<5.0	1354	7.30	7.0	0.9	<20	5.9
5/25	**8:50**	**Pow In S**	0.43	0.16	0.11	1.66	0.17	8.0	28.0	38.7	26.0	62.5	75.2	<5.0	2987	7.30	17.0	8.8	66.3	13.8
5/25	**8:40**	**Pow In SE**	0.37	0.18	0.14	1.53	0.28	6.0	30.0	20.7	14.7	77.5	58.8	<5.0	4106	7.50	24.8	4.4	45.0	15.1
5/25	**9:00**	**Pow In W**	0.42	0.19	0.13	1.54	0.24	10.0	26.0	48.0	36.0	67.5	58.3	<5.0	1935	7.10	19.8	21.4	103.0	13.4
6/13	**8:30**	**61st & Lyndale**	1.30	1.05	0.20	4.01	0.24	45.0	66.0	112.0	50.0	217.5	263.4	<5.0	NS	7.60	39.0	5.2	165.0	52.7
8/12	**8:15**	**61st & Lyndale**	0.33	0.13	NS	0.87	0.25	4.5	26.0	79.2	10.0	57.5	55.7	<5.0	NS	9.00	15.0	6.8	68.7	4.2
8/12	**9:20**	**Cam In N NW**	0.13	0.07	NS	0.78	0.18	<2.0	8.0	8.4	2.6	35.0	10.0	<5.0	NS	6.90	11.2	2.4	25.0	2.2
8/12	**9:15**	**Cam In S NW**	0.21	0.14	NS	1.35	0.75	3.0	28.0	13.2	5.2	60.0	25.8	<5.0	NS	7.30	7.9	1.6	26.7	4.0
8/12	**9:30**	**Cam In SW**	0.06	0.05	NS	0.98	0.34	<2.0	24.0	4.8	<2.0	32.5	29.0	<5.0	NS	6.60	4.3	<0.6	<20	4.0
8/12	**8:40**	**Pow In S**	0.18	0.11	0.09	0.83	0.26	<2.0	14.0	18.0	8.0	40.0	48.6	<5.0	NS	7.10	7.7	4.3	39.0	4.9
8/12	**8:35**	**Pow In SE**	0.19	0.11	0.09	0.96	0.22	<2.0	16.0	14.4	5.6	40.0	32.8	<5.0	NS	7.50	7.4	3.3	32.9	4.7
8/12	**8:50**	**Pow In W**	0.17	0.11	0.09	0.98	0.21	2.5	12.0	14.2	7.6	25.0	25.7	<5.0	NS	7.10	8.1	4.1	33.5	4.3

Table 24-8. The 2022 quarterly stormwater grab sampling statistics.

	TP mg/L	TDP mg/L	SRP mg/L	TN mg/L	NO3NO2 mg/L	Cl mg/L	Hardness mg/L	TSS mg/L	VSS mg/L	TDS mg/L	COD mg/L	FOG mg/L	*E. coli* MPN	pH Std Unit	Cu µg/L	Pb µg/L	Zn µg/L	DOC mg/L
MEAN (geometric)	0.379	0.142	0.075	2.39	0.409	58.3	54.5	46.7	18.5	331	82.2	4.87	444	7.54	18.2	5.58	71.0	11.4
MEAN (arithmetic)	0.504	0.180	0.093	3.13	0.631	1000	87.8	111	37.1	1683	147	8.81	2005	7.59	23.7	12.8	116	14.8
MAX	1.50	1.05	0.229	13.0	6.75	7398	410.0	760.0	250.0	11854	521	43.5	24200	9.90	68.1	65.6	460	52.7
MIN	0.055	0.045	0.002	0.783	0.136	1.00	8.00	2.20	1.00	25.0	7.45	2.15	10.0	5.50	3.90	0.050	10.0	2.20
MEDIAN	0.403	0.142	0.085	2.26	0.402	41.0	52.0	42.7	18.0	203	61.9	2.50	643	7.50	18.4	5.95	66.3	13.6
STDEV	0.370	0.179	0.051	2.57	1.14	1821	92.0	164	49.2	2884	157	11.5	4875	0.923	17.2	16.6	118	10.9
NUMBER	32	32	27	32	32	32	32	32	32	32	31	31	24	32	32	32	31	32
COV	0.734	0.991	0.545	0.820	1.81	1.82	1.05	1.47	1.32	1.71	1.07	1.31	2.43	0.121	0.727	1.29	1.02	0.734

FOG (Fat, Oil, and Grease) Pilot Study

The FOG study was initially a 2-year study to gather FOG data over the course of the NPDES permit. If no FOG values were found to be greater than 15 mg/L, then the study would end. If a FOG value exceeded 15 mg/L that site would continue FOG monitoring, so monitoring has continued. All sites except Camden Inlets NNW and SW registered FOG values greater than 15 mg/L in 2022.

Each year of FOG sampling data is shown below. **Table 24-9** contains FOG data from 2022. **Table 24-10** contains FOG data from the entirety of the study from 2018 to 2022.

In 2018, none of the FOG data were above 15 mg/L. In 2019, the only FOG data above 15 mg/L were 2 samples from 61st & Lyndale snowmelt. In 2020, the data reported above 15 mg/L were from snowmelt samples collected at Powderhorn Inlets S and W. In 2021, the samples above 15 mg/L were from 24th & Elm Inlet S, 61st & Lyndale, and the Powderhorn Inlets S, SE, and W snowmelt samples. In 2022, samples above 15 mg/L were collected from 61st & Lyndale, Powderhorn Inlets S, SE, and W, and Camden Inlet SNW. Camden Inlet NNW was not sampled for snowmelt and Camden Inlet SW showed low levels of FOG throughout the year.

Table 24-9. FOG results in mg/L from grab samples collected in 2022. Samples over 15 mg/L are in red.

2022	2/28	3/8	3/15	4/5	5/25	6/13	8/12
61st & Lyndale	24.7	9.9		<5.00		<5.00	<5.00
CAM IN NNW			<5.00		<5.00		<5.00
CAM IN SNW	26.1		<5.00		<5.00		<5.00
CAM IN SW	<5.00		6.53	<5.00	<5.00		<5.00
POW IN S	35.5	14.3		<5.00	<5.00		<5.00
POW IN SE	33.7	15.8		<5.00	<5.00		<5.00
POW IN W	43.5	7.6		<5.00	<5.00		<5.00

Table 24-10. FOG event dates and grab samples collected from 2018-2022. Data greater than 15 mg/L is in red.

2018 Sites	10-Jan	19-Jan	26-Jan	19-Mar	26-Mar	12-Jul	13-Jul	1-Oct
14th & Park	<5.00	6				<5.00		<5.00
22nd & Aldrich	8	8		6			<5.00	<5.00
61st & Lyndale		<5.00	9					
Pershing				<5.00	<5.00			
2019 Sites	**12-Mar**	**13-Mar**	**19-Mar**	**20-Mar**	**8-May**	**27-Jun**	**26-Aug**	**12-Sep**
14th & Park	9	10						
22nd & Aldrich		7						
24th & Elm In N					<5.00	<5.00	<5.00	<5.00
24th & Elm In S					<5.00	<5.00	<5.00	<5.00
61st & Lyndale	21	19						
Pershing			<5.00	<5.00				
Winter Basin In S					<5.00	<5.00	6	6
Winter Basin In W					5	5	5	<5.00
2020 Sites	**24-Feb**	**3-Mar**	**4-Mar**	**7-Jul**	**14-Jul**	**21-Jul**		
24th & Elm In N		<5.00	<5.00		<5.00	<5.00		
24th & Elm In S		<5.00	<5.00		<5.00	<5.00		
24th & Elm N Out					7			
61st & Lyndale				6		<5.00		
POW IN S	31	14		3		<5.00		
POW IN SE		6	6	5		<5.00		
POW IN W	109	13		4		<5.00		
2021 Sites	**22-Feb**	**23-Feb**	**24-Feb**	**25-Feb**	**8-Apr**	**27-May**	**14-Jul**	**24-Aug**
24th & Elm N	11	<5.00			<5.00	<5.00	<5.00	<5.00
24th & Elm S	14	31			<5.00	<5.00	NS	<5.00
61st & Lyndale	16	14.8			6	<5.00	<5.00	<5.00
POW IN S			23	18	5	<5.00	14.7	<5.00
POW IN SE			14	17	5	11	<5.00	<5.00
POW IN W	63	85			<5.00	<5.00	9	<5.00
2022 Sites	**28-Feb**	**8-Mar**	**15-Mar**	**5-Apr**	**25-May**	**13-Jun**	**12-Aug**	
61st & Lyndale	24.7	9.9		<5.00		<5.00	<5.00	
CAM IN NNW			<5.00		<5.00		<5.00	
CAM IN SNW	26.1		<5.00		<5.00		<5.00	
CAM IN SW	<5.00		6.53	<5.00	<5.00		<5.00	
POW IN S	35.5	14.3		<5.00	<5.00		<5.00	
POW IN SE	33.7	15.8		<5.00	<5.00		<5.00	
POW IN W	43.5	7.6		<5.00	<5.00		<5.00	

CONCLUSIONS

Grab samples of stormwater represent event chemistry at a point in time. Following sample handling protocol, some parameters can only be characterized by a grab sample, e.g., pH, *E. coli*, and FOG. Timing of a runoff event is critical for grab sample collection. Flow must occur when staff are available, travel between sites during a storm is possible, and the laboratory is available to receive samples with short holding times like *E. coli*.

In 2022, seven sites were successfully monitored quarterly for NPDES water chemistry, *E. coli*, pH, and FOG. The sites included:

- Camden Pond Inlets N NW, S NW, and SW
- 61st & Lyndale
- Powderhorn Inlets SE, S, and W

The 2022 quarterly grab sampling data show that snowmelt generally had high values for all chemical parameters when compared to runoff at other times of the year. Phosphorus, solids, metals, and FOG data were much higher during snowmelt. The *E. coli* levels were low for snowmelt and higher in the warmer months. This was expected since *E. coli* are temperature-dependent organisms. All chloride concentrations were high during snowmelt and were lower the rest of the year. The chloride source is likely road salt application over the winter months.

The 2022 pH values ranged between 5.5 and 9.0. The pH values were consistently high at 61st & Lyndale compared to the other sites. High pH values at 61st & Lyndale were likely due to the cement plant located across the street from the sampling location, which produces alkaline runoff.

FOG data have been collected from 2018 - 2022. The only FOG samples that were greater than 15 mg/L were seen during the 2019 - 2022 snowmelt events. The only non-snowmelt FOG sample that approached the 15 mg/L threshold was on 7/14/21 where the Powderhorn Inlet S sample was 14.7 mg/L. It appears that FOG values greater than 15 mg/L generally do not occur outside of snowmelt. Snowmelt is a unique event that contributes pollution from 4-5 months over a few low-flow events. Snowmelt samples are polluted from material deposited in the watershed over the winter, and it is common to see an oily sheen on a snowmelt grab sample. Powderhorn Inlet W registers the highest levels of FOG compared to the other sites. It is unknown why this is occurring, as the land use type for this site is comparable to the other Powderhorn Inlets, but similar levels of FOG are not seen there.

25. Camden Pond Monitoring

Background

Camden Pond was constructed by the City of Minneapolis in 2007 for flood control. Later, the space around the pond was redesigned as a scenic location by adding plants, benches, and a walking path. Camden Pond is 4.09 acres with a maximum depth of 6.4 ft and accumulates sediment at a rate of around 0.44% of its volume per year (Stantec Consulting Services, 2021). As of 2020, only 6.2% of the pond volume had filled with sediment, so the pond has never needed to be dredged. The pond is classified as polymictic. The drainage area of Camden Pond is 235 acres of mainly park and residential land uses, with 75 of those acres being impervious surfaces.

Camden Pond, shown in **Figure 25-1**, was part of the 2020-2021 Minneapolis Park and Recreation Board (MPRB) pond monitoring study and was selected for further monitoring in 2022 based on the study results. Camden Pond was one of the older ponds in the study and showed the highest potential internal phosphorus loading out of all ponds in the study. A study of Camden Pond's inlets and outlet was started in 2022 with the goal of determining more definitive mass balance, removal efficiency, and nutrient loads. This study aims to provide insight into whether a pond originally intended for flood control purposes could have or be modified to have positive water quality impacts. Monitoring sites are pictured in **Figure 25-2**.

Figure 25-1. Camden Outlet stormwater monitoring site located northeast of Camden Pond.

The purpose of monitoring the stormwater inlets and outlet of Camden Pond was to:

1. Measure the pollutant loads of the tributary pipes entering Camden Pond and compare with pollutant loads at the pond outlet.
2. Assess how a pond originally intended for flood control is affecting stormwater quality.
3. Measure the true storage capacity of the pond and compare to its designed capacity.
4. Comply with the National Pollutant Discharge Elimination System (NPDES) Permit provision to monitor stormwater BMPs for the purpose of adaptive management.

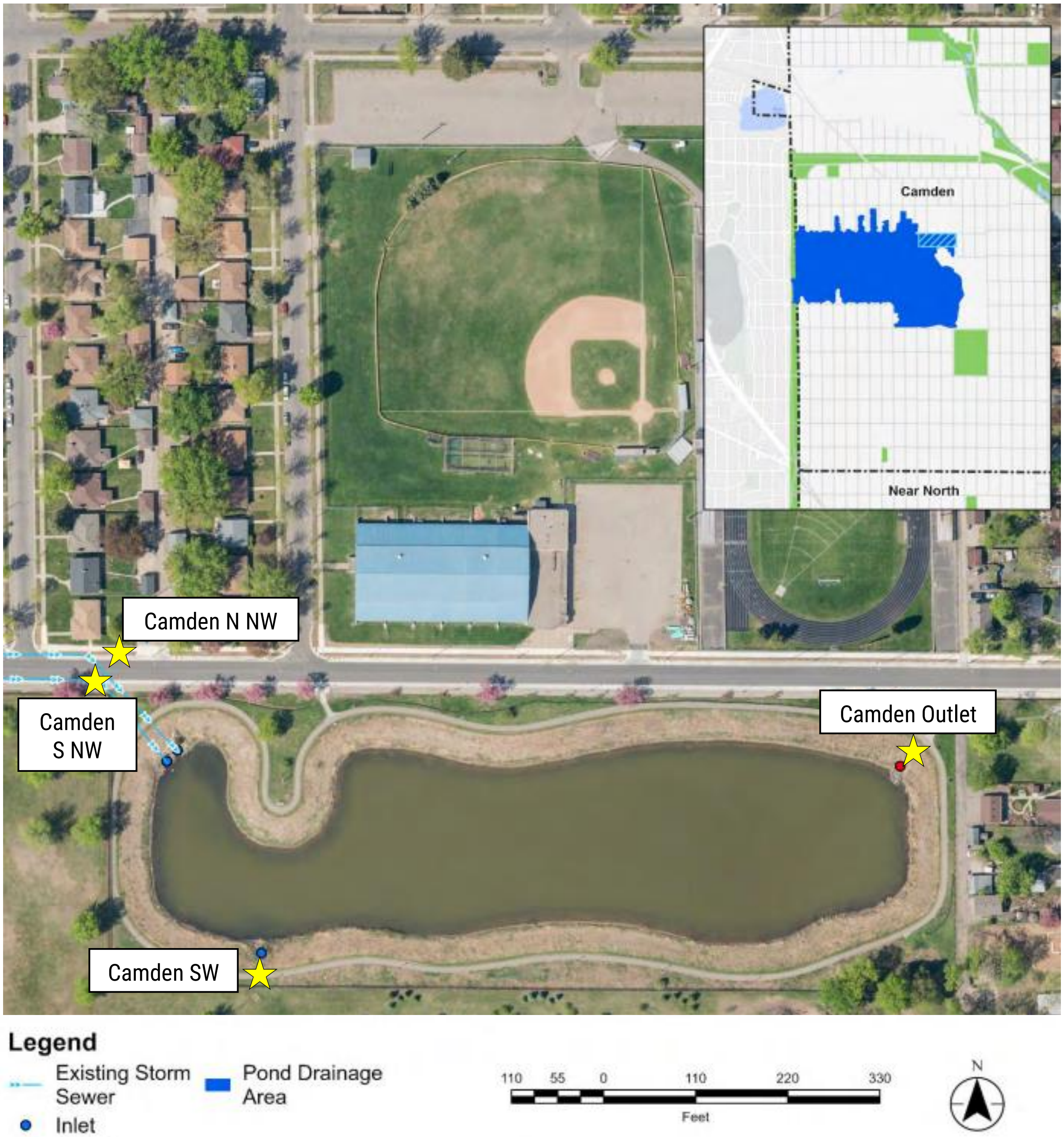


Figure 25-2. Aerial view of Camden Pond with the four inlet and outlet locations (Stantec Consulting Services, 2021). MPRB monitoring sites are marked with yellow stars.

METHODS

Site Installation

Monitoring equipment at each of the sites included: ISCO 2150 datalogger, 2105ci LTE combined interface module/modem, low-profile area velocity (AV) probe, and a 3700 ISCO sampler complete with tubing and intake strainer. Cables and tubing were anchored with zip-ties to the sidewall eyebolts. AV probes and intake strainers were pointed upstream and fastened to the pipe. For sites with potential for standing water, Camden Inlet N NW and S NW, the strainer and probe were attached to the pipe using a steel spring ring, **Figure 25-3**. The equipment at these sites were hung from eyebolts below grade in the manhole with an above grade antenna. The other two sites, Camden Inlet SW and Camden Outlet, had above grade monitoring boxes with access holes for tubing and cables. Monitoring boxes were rectangular 4 ft x 3 ft x 3 ft locking wooden boxes which safely protected and housed both the sampler and datalogger equipment. Camden Outlet had an additional 2150 datalogger and AV probe that measured the water level of the pond. The probe was aligned at the same elevation as the invert (bottom) of the outlet pipe. Images of each site can be found in **Figure 25-4**.

The dataloggers used cell phone modems to remotely upload data to the MPRB ISCO database server from Monday through Friday. An antenna was installed at each site to allow for remote communication with the datalogger. The datalogger could also be remotely programmed to turn the samplers on/off, adjust the level, pacing, or triggers, or to download data.

Camden site installs were delayed in 2022 because of supply chain issues and scheduling difficulties with the MPRB Cement Shop. The amount of standing water that would be present in the pipes was not known prior to installs, so spring rings were later deemed necessary and did not arrive until May 25, 2022. Additionally, due to the busy nature of the spring/summer season, finding time for the Cement Shop to install anchor points and antennas delayed installs further. Equipment was installed in late June and began sampling during a storm event on July 12, 2022.

Figure 25-3. Photo of the AV probe and intake strainer on a spring ring at Camden Inlet N NW in November. The blue arrow points in the direction of water flow.

Sample Collection

The samplers were equipped with 24 one-liter bottles, 3/8-inch inner-diameter vinyl tubing, and an intake strainer that filtered out large particulates. Samplers were multiplexed and collected four flow-weighted samples per 1-L bottle, allowing a maximum of 96 samples to be collected over a storm event. A storm event is defined as a storm with greater than 0.10 inches of precipitation separated by eight or more hours from other storms. Some sites were programmed to pulse the samplers at a level trigger threshold after a set volume or pacing had passed. Other sites required a more complex program using hysteresis and flow rate as the trigger. More information about sampler programming can be found in the discussion section of this chapter.

Figure 25-4. The four Camden Pond monitoring sites: Camden Inlet N NW (A), Camden Inlet S NW (B), Camden Inlet SW (C), and Camden Outlet (D).

Monitoring Parameters and Methods

A list of the chemical parameters required by the NPDES permit for analysis of auto-monitored composite stormwater samples is shown in **Table 25-1**. NPDES permit-required chemistry methods, reporting limits and holding times for auto-monitored composite samples used in this project are also shown in this table. For more information on grab sampling parameters see **Chapter 24**.

Table 25-1. The list of required NPDES permit parameters to be monitored. This table shows analysis method, reporting limit, and holding times for parameters analyzed by Instrumental Research Inc. and Pace Laboratories.

Parameter	Abbreviation	Units	Method	Reporting Limit	Holding Time
Chemical Oxygen Demand	COD	mg/L	SM 5220-D	20 mg/L	28 days
Dissolved Organic Carbon	DOC	mg/L	SM 5310-C-00	1.5 mg/L	28 days
Chloride, Total	Cl	mg/L	SM 4500-Cl^- B	2.0 mg/L	28 days
Hardness	Hard	mg/L	SM 2350 C	5.0 mg/L	6 months
Copper, Total	Cu	µg/L	EPA 200.8	1 µg/L	6 months
Lead, Total	Pb	µg/L	EPA 200.8	0.10 µg/L	6 months
Zinc, Total	Zn	µg/L	EPA 200.7	20 µg/L	6 months
Nitrate/Nitrite, Total as N	NOx	mg/L	SM 4500-NO_3 E	0.030 mg/L	28 days
Total Nitrogen	TN	mg/L	Alkaline Persulfate Oxidation	0.500 mg/L	28 days
Phosphorus, Total Dissolved	TDP	mg/L	SM 4500-PE	0.010 mg/L	48 hours
Phosphorus, Total	TP	mg/L	SM 4500-PE	0.010 mg/L	48 hours
Solids, Total Dissolved	TDS	mg/L	SM 2540 C	5.0 mg/L	7 days
Solids, Total Suspended	TSS	mg/L	SM 2540 D	1.0 mg/L	7 days
Solids, Volatile Suspended	VSS	mg/L	EPA 160.4	2.0 mg/L	7 days

RESULTS

Sample Collection

In 2022, rainfall grab and flow-weighted composite samples were collected from storm events ranging from 0.25 to 0.84 inches of precipitation. The MPRB defines a storm event as having greater than 0.10 inches of precipitation and separated by eight hours or more from other storm events. Due to the drought this year, samples from storms having less than 0.10 inches of precipitation were included in the data analysis. Snowmelt grab samples were collected from four snowmelt events at the pond inlets. **Table 25-2** shows the snowmelt grab samples collected. **Table 25-3** shows the rainfall grab samples collected, along with precipitation data. Precipitation was measured by a rain gauge at MPRB's Southside Operations Center. The Camden Outlet site was not a grab sample site. See **Chapter 24** for more information on grab sampling.

The 2022 NPDES chemical concentrations and statistics for flow-weighted composite samples the Camden Inlets N NW, S NW, SW, and the Outlet site can be seen in **Table 25-4** through **Table 25-7**. If less than values were present, half the value was used for statistical calculations. The statistics calculated for each site were the geometric mean (GEOMEAN), arithmetic mean, maximum (MAX), minimum (MIN), median, standard deviation (STDEV), number of samples, and coefficient of variation (COV). The geometric means from **Tables 25-4** through **Table 25-7** were calculated using only composite data and used in nutrient load calculations, shown in **Table 25-8**.

Table 25-2. The 2022 snowmelt events sampled or attempted to sample at the three Camden Inlets via grabs. ⊗ = grab sample. NS = No Sample.

Date	Camden Inlet N NW	Camden Inlet S NW	Camden Inlet SW
2/28/22	⊗	⊗	⊗
3/8/22	NS	NS	NS
3/15/22	⊗	⊗	⊗

Table 25-3. The 2022 precipitation events sampled or attempted to be sampled at the three Camden Inlets via grabs. ⊗ = quarterly grab sample, ⊗/C = Quarterly grab samples with a flow-paced composite. NS = No Sample. Precipitation data was measured by the MPRB weather station located at SSOC.

Start Date	Start Time	End Date	End Time	Rain (inches)	Duration (hours)	Intensity (in/hour)	Hours since last rain	Camden In N NW	Camden In S NW	Camden In SW
4/5/2022	10:15	04/06/22	5:45	0.50	19.5	0.026	34.8	NS	⊗	NS
5/25/2022	0:30	05/25/22	12:45	0.58	12.3	0.047	113	⊗	⊗	⊗
6/13/2022	6:00	06/13/22	8:00	0.09	2.00	0.045	47.8	NS	NS	NS
8/12/2022	4:00	08/12/22	7:45	0.84	3.75	0.224	101	⊗/C	⊗/C	⊗/C

Stormwater Chemistry

Table 25-4. Camden Inlet N NW 2022 chemistry and statistics. Grab samples are denoted with a * by Date Sampled. NS = no sample, TP = Total Phosphorus, TDP = Total Dissolved Phosphorus, SRP = Soluble Reactive Phosphorus, TN = Total Nitrogen, NOx = Nitrate/Nitrite, Cl = Chloride, TSS = Total Suspended Solids, VSS = Volatile Suspended Solids, TDS = Total Dissolved Solids, COD = Chemical Oxygen Demand, FOG = Fat Oil and Grease, Cu = Copper, Pb = Lead, Zn = Zinc, DOC = Dissolved Organic Carbon.

Date Sampled	TP mg/L	TDP mg/L	SRP mg/L	TN mg/L	NOx mg/L	Cl mg/L	Hardness mg/L	TSS mg/L	VSS mg/L	TDS mg/L	COD mg/L	FOG mg/L	E. Coli MPN	Cu µg/L	Pb µg/L	Zn µg/L	DOC mg/L
3/15/2022*	0.570	0.413	<0.003	4.07	0.409	410	48	15	10	742	48	2.15	313	13	2	48	14
5/25/2022*	0.358	0.169	0.063	1.88	0.137	13	24	23	12	70	27	<5.0	>24200	13	2	39	7
7/12/2022	0.507	0.217	0.114	3.24	0.249	30	44	8	4	NS	42	NS	NS	NS	NS	NS	NS
8/12/2022	0.210	0.077	0.061	1.70	0.343	3	14	40	17	25	29	NS	NS	12	6	43	4
8/12/2022*	0.134	0.071	NS	0.783	0.180	<2.0	8	8	3	35	<20	<5.0	NS	11	2	25	2
8/18/2022	0.225	0.064	NS	1.55	0.933	5	14	58	20	47	41	NS	NS	9	9	71	4
GEOMEAN (composite only)	0.288	0.102	0.083	2.04	0.430	8.32	20.5	26.5	11.3	34.5	36.5	-	-	10.2	6.96	55.5	3.90
ARITHMETIC MEAN (all samples)	0.334	0.168	0.060	2.20	0.375	77	25	25	11	184	33	2.4	12257	12	4	45	6
MAX	0.570	0.413	0.114	4.07	0.933	410	48	58	20	742	48	2.5	>24200	13	9	71	14
MIN	0.134	0.064	0.002	0.783	0.137	1	8	8	3	25	10	2.2	313	9	2	25	2
MEDIAN	0.292	0.123	0.062	1.79	0.296	9	19	19	11	47	35	2.5	12257	12	2	43	4
STDEV	0.175	0.135	0.046	1.21	0.291	163	17	20	7	313	14	0.2	16891	2	3	17	5
NUMBER	6	6	4	6	6	6	6	6	6	5	6	3.0	2	5	5	5	5
COV	0.525	0.800	0.769	0.551	0.776	2.11	0.666	0.785	0.619	1.70	0.421	0.085	1.38	0.145	0.700	0.372	0.762

Table 25-5. Camden Inlet S NW 2022 chemistry and statistics. Grab samples are denoted with a * by Date Sampled. Values in red were flagged during monthly blind performance checks with the contracting laboratory. NS = no sample, TP = Total Phosphorus, TDP = Total Dissolved Phosphorus, SRP = Soluble Reactive Phosphorus, TN = Total Nitrogen, NOx = Nitrate/Nitrite, Cl = Chloride, TSS = Total Suspended Solids, VSS = Volatile Suspended Solids, TDS = Total Dissolved Solids, COD = Chemical Oxygen Demand, FOG = Fat Oil and Grease, Cu = Copper, Pb = Lead, Zn = Zinc, DOC = Dissolved Organic Carbon.

Date Sampled	TP mg/L	TDP mg/L	SRP mg/L	TN mg/L	NOx mg/L	Cl mg/L	Hardness mg/L	TSS mg/L	VSS mg/L	TDS mg/L	COD mg/L	FOG mg/L	E. Coli MPN	Cu µg/L	Pb µg/L	Zn µg/L	DOC mg/L
2/28/2022*	0.752	0.115	0.085	4.33	0.381	3799	120	183	67	6190	333	26	323	44	18	262	18
3/15/2022*	0.440	0.254	0.070	3.33	0.533	610	136	22	12	1188	62	4.7	1986	12	2	42	17
5/25/2022*	0.387	0.173	0.124	1.38	0.311	10	38	31	17	92	54	<5.0	3448	17	4	55	10
7/13/2022	0.604	0.335	0.225	NS	NS	35	NS	52	34	NS	NS	NS	NS	NS	NS	NS	NS
8/12/2022	0.267	0.158	0.150	1.74	1.064	10	42	24	10	95	29	NS	NS	9	3	33	6
8/12/2022*	0.206	0.137	NS	1.35	0.750	3	28	13	5	60	26	<5.0	NS	8	2	27	4
GEOMEAN (composite only)	0.403	0.182	0.120	2.16	0.550	54	59	36	17	329	61	-	-	14	4	56	9
ARITHMETIC MEAN (all samples)	0.443	0.195	0.131	2.43	0.608	744	73	54	24	1525	101	9	1919	18	6	84	11
MAX	0.75	0.335	0.225	4.332	1.064	3799	136	182.5	67	6190	333	26	3448	44	18	262	18
MIN	0.206	0.115	0.070	1.352	0.311	3.0	28	13.2	5	60	26	3	323	8	2	27	4
MEDIAN	0.414	0.166	0.124	1.74	0.533	22.5	42	27	15	95	54	4	1986	12	3	42	10
STDEV	0.206	0.083	0.061	1.34	0.306	1515	51	64	23	2651	131	11	1564	15	7	100	6
NUMBER	6	6	5	5	5	6	5	6	6	5	5	4	3	5	5	5	5
COV	0.464	0.427	0.470	0.551	0.503	2.04	0.700	1.19	0.958	1.74	1.30	1.28	0.815	0.834	1.22	1.20	0.578

Table 25-6. Camden Inlet SW 2022 stormwater chemistry and statistics. Grab samples are denoted with a * by Date Sampled. Values in red were flagged during monthly blind performance checks with the contracting laboratory. NS = no sample, TP = Total Phosphorus, TDP = Total Dissolved Phosphorus, SRP = Soluble Reactive Phosphorus, TN = Total Nitrogen, NOx = Nitrate/Nitrite, Cl = Chloride, TSS = Total Suspended Solids, VSS = Volatile Suspended Solids, TDS = Total Dissolved Solids, COD = Chemical Oxygen Demand, FOG = Fat Oil and Grease, Cu = Copper, Pb = Lead, Zn = Zinc, DOC = Dissolved Organic Carbon.

Date Sampled	TP mg/L	TDP mg/L	SRP mg/L	TN mg/L	NOx mg/L	Cl mg/L	Hardness mg/L	TSS mg/L	VSS mg/L	TDS mg/L	COD mg/L	FOG mg/L	E. Coli MPN	Cu µg/L	Pb µg/L	Zn µg/L	DOC mg/L
2/28/2022*	0.16	0.10	0.082	2.2	0.93	38	252	19	7	362	<20	<5.0	73	8.0	1	<20	9
3/15/2022*	0.72	0.35	0.089	3.3	0.41	44	56	95	45	188	163	6.5	>2420	43.6	3.7	43.6	27
4/5/2022*	0.05	0.05	0.042	1.6	1.15	11	292	2	<2	373	7	<5.0	20	4.0	<0.1	<20	4
5/25/2022*	0.18	0.10	0.071	1.2	0.72	4	140	12	7	223	21	<5.0	1354	7.0	1	<20	6
7/13/2022	0.46	0.17	0.117	1.5	0.64	5	80	213	70	135	60	NS	NS	16	4	20	10
7/23/2022	0.57	0.37	NS	2.3	1.30	80	68	59	22	137	72	NS	NS	30	4	25	14
8/3/2022	1.21	0.27	0.175	3.4	1.03	40	45	297	77	99	267	NS	NS	32	20	74	17
8/6/2022	0.28	0.13	0.089	1.1	0.67	50	34	60	22	75	59	NS	NS	NS	NS	NS	NS
8/7/2022	0.24	0.08	0.047	0.8	0.33	<2	28	52	19	63	56	NS	NS	16	5	38	6
8/12/2022*	0.06	0.05	NS	1.0	0.34	<2	24	5	<2	33	29	<5.0	NS	4.0	<0.5	<20	4
8/12/2022	0.26	0.06	NS	1.8	0.69	2	24	65	19	38	39	NS	NS	15	4	30	5
8/18/2022	0.14	0.06	NS	1.8	1.41	3	24	38	15	55	39	NS	NS	18	3	30	5
8/19/2022	0.14	0.06	NS	1.0	0.57	3	38	39	16	58	40	NS	NS	19	2	<20	5
8/27/2022	0.29	0.13	NS	1.9	1.01	<2	24	73	26	47	62	NS	NS	10	4	32	9
8/29/2022	0.16	0.06	NS	2.7	0.83	<2	26	50	15	50	33	NS	NS	7.8	2.9	24.4	3
GEOMEAN (composite only)	0.296	0.114	0.0869	1.66	0.783	5.40	35.5	72.3	24.7	68.9	58.5	-	-	16.7	4.16	27.7	7.45
ARITHMETIC MEAN (all samples)	0.33	0.14	0.09	1.84	0.80	19	77	72	24	129	64	3	967	17	4	26	9
MAX	1.21	0.37	0.17	3.40	1.41	80	292	297	77	373	267	7	2420	44	20	74	27
MIN	0.05	0.05	0.04	0.83	0.33	1	24	2	1	33	7	3	20	4	0	10	3
MEDIAN	0.24	0.10	0.08	1.76	0.72	4	38	52	19	75	40	3	714	16	3	25	6
STDEV	0.31	0.11	0.04	0.82	0.33	25	85	80	23	112	67	2	1148	12	5	18	7
NUMBER	15	15	9	15	15	15	15	15	15	15	15	5	4	14	14	14	14
COV	0.93	0.79	0.48	0.45	0.42	1.3	1.2	1.1	0.95	0.87	1.1	0.55	1.2	0.70	1.3	0.68	0.73

Table 25-7. Camden Outlet 2022 stormwater chemistry and statistics. NS = no sample, TP = Total Phosphorus, TDP = Total Dissolved Phosphorus, SRP = Soluble Reactive Phosphorus, TN = Total Nitrogen, NOx = Nitrate/Nitrite, Cl = Chloride, TSS = Total Suspended Solids, VSS = Volatile Suspended Solids, TDS = Total Dissolved Solids, COD = Chemical Oxygen Demand, Cu = Copper, Pb = Lead, Zn = Zinc, DOC = Dissolved Organic Carbon.

Date Sampled	TP mg/L	TDP mg/L	SRP mg/L	TN mg/L	NOx mg/L	Cl mg/L	Hardness mg/L	TSS mg/L	VSS mg/L	TDS mg/L	COD mg/L	Cu µg/L	Pb µg/L	Zn µg/L	DOC mg/L
8/19/2022	0.30	0.056	0.004	3.51	0.497	80	62	36	31	172	100	13	1	<20	9
8/20/2022	0.238	0.102	0.005	3.17	1.724	65	58	35	28	185	52	12	1	23	9
8/29/2022	0.231	0.048	NS	3.374	0.228	65	62	29	29	163	64	10	<0.5	24	9
GEOMEAN	0.26	0.07	0.00	3.35	0.58	70	61	33	29	173	69	12	1	18	9
ARITHMETIC MEAN	0.26	0.07	0.00	3.35	0.82	70	61	33	29	173	72	12	1	19	9
MAX	0.30	0.10	0.00	3.51	1.72	80	62	36	31	185	100	13	1	24	9
MIN	0.23	0.05	0.00	3.17	0.23	65	58	29	28	163	52	10	0	10	9
MEDIAN	0.24	0.06	0.00	3.37	0.50	65	62	35	29	172	64	12	1	23	9
STDEV	0.04	0.03	0.00	0.17	0.80	9	2	4	2	11	25	2	0	8	0
NUMBER	3	3	2	3	3	3	3	3	3	3	3	3	3	3	3
COV	0.157	0.421	0.160	0.050	0.98	0.12	0.04	0.11	0.06	0.07	0.35	0.132	0.48	0.41	0.05

Stormwater Hydrographs

The hydrographs for level and flow measured from June through October 27 at the Camden Inlets N NW, S NW, SW, and Camden Outlet are presented in **Figures 25-5** through **Figures 25-8**.

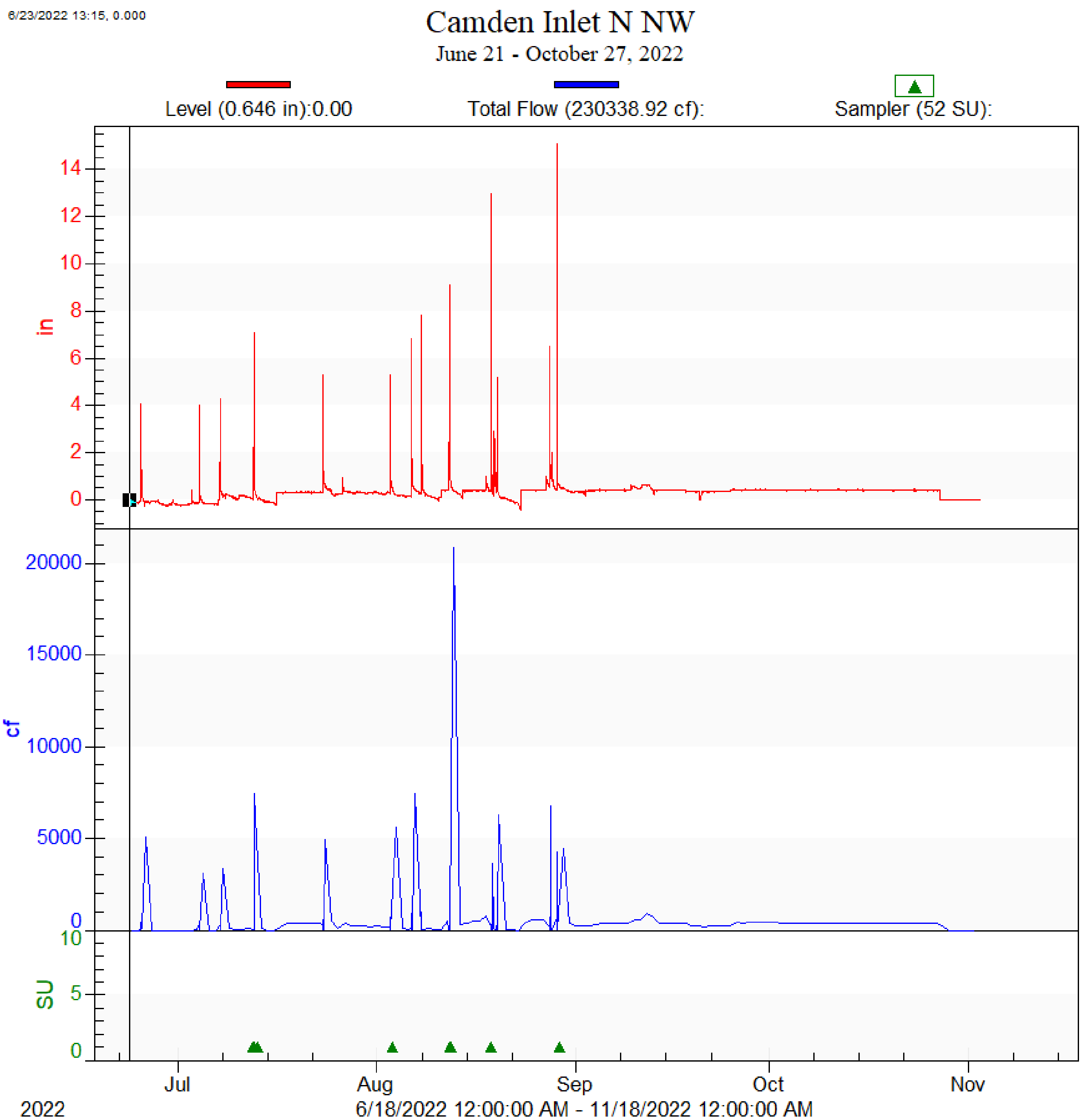


Figure 25-5. Camden Inlet N NW hydrograph of level and flow. Green triangles represent when the auto-sampler attempted to take a sample. Flow monitoring began on June 21 and ended on October 27, 2022.

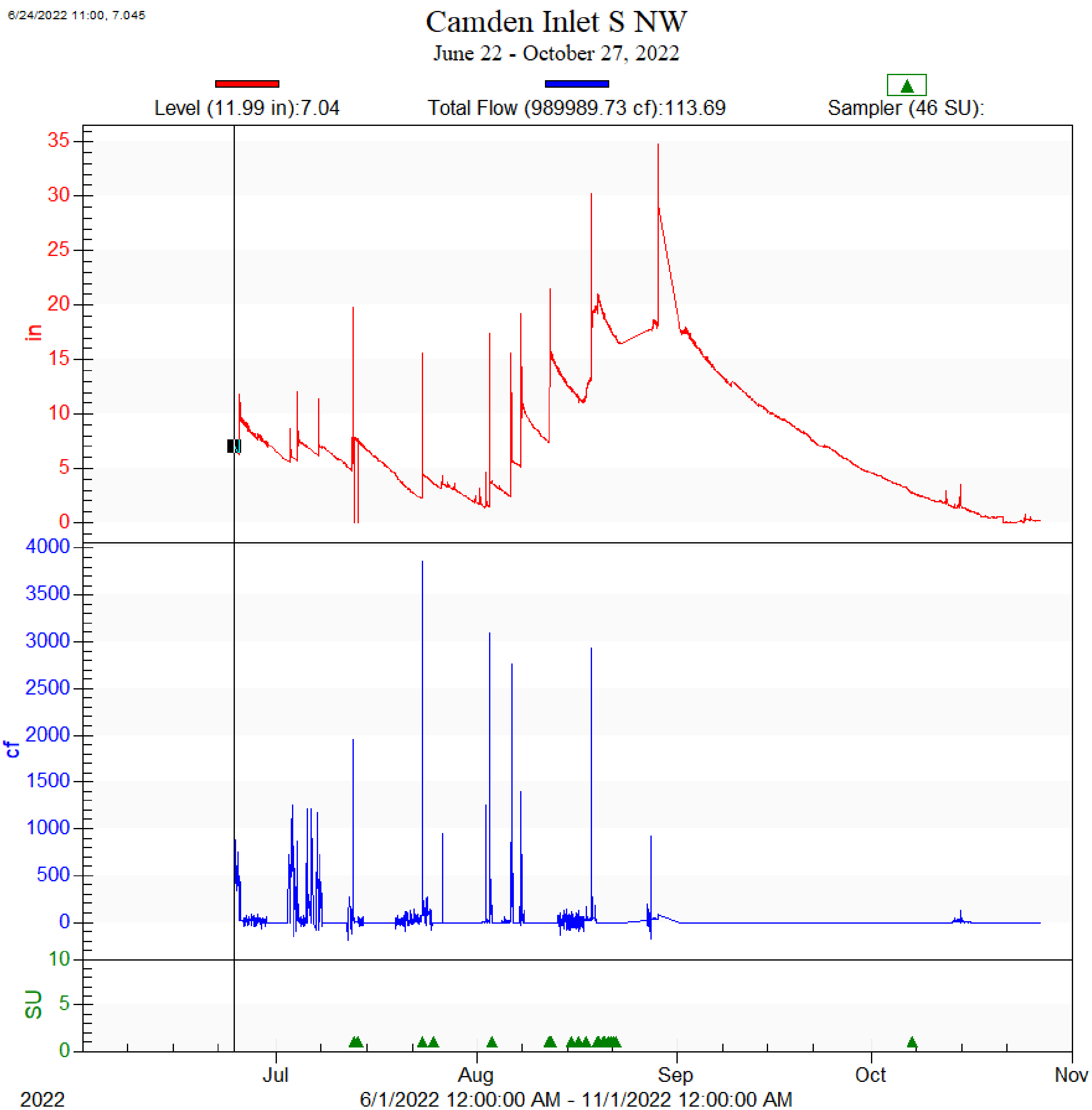


Figure 25-6. Camden Inlet S NW hydrograph of level and flow. Green triangles represent when the auto-sampler attempted to take a sample. The level and total flow series were edited to mitigate the influence of backflow on the data. Note that Camden S NW has around 7 inches of standing water. Flow monitoring began on June 22 and ended on October 27, 2022.

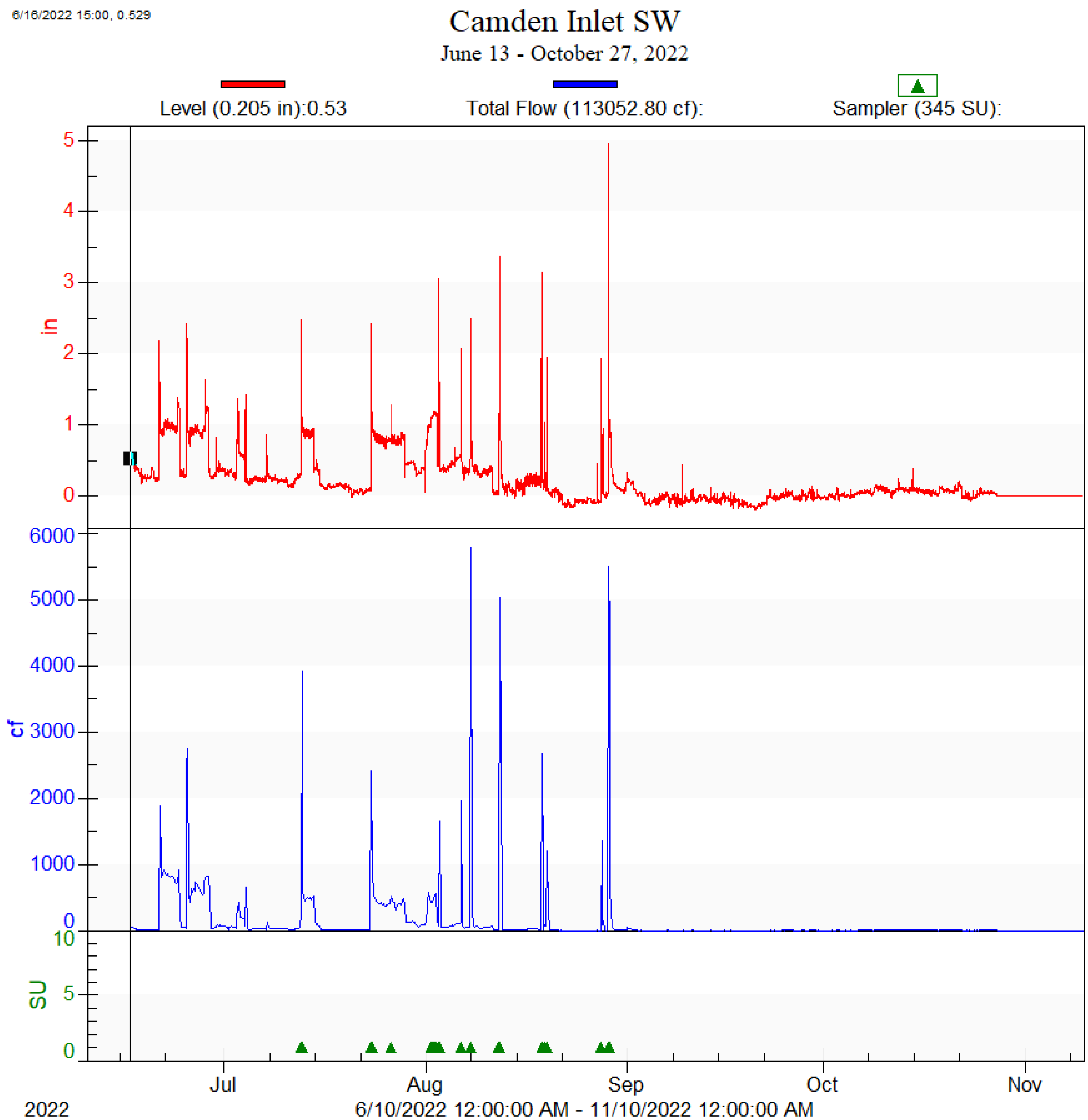


Figure 25-7. Camden Inlet SW hydrograph of level and flow. Green triangles represent when the auto-sampler attempted to take a sample. Flow monitoring began on June 13 and ended on October 27, 2022.

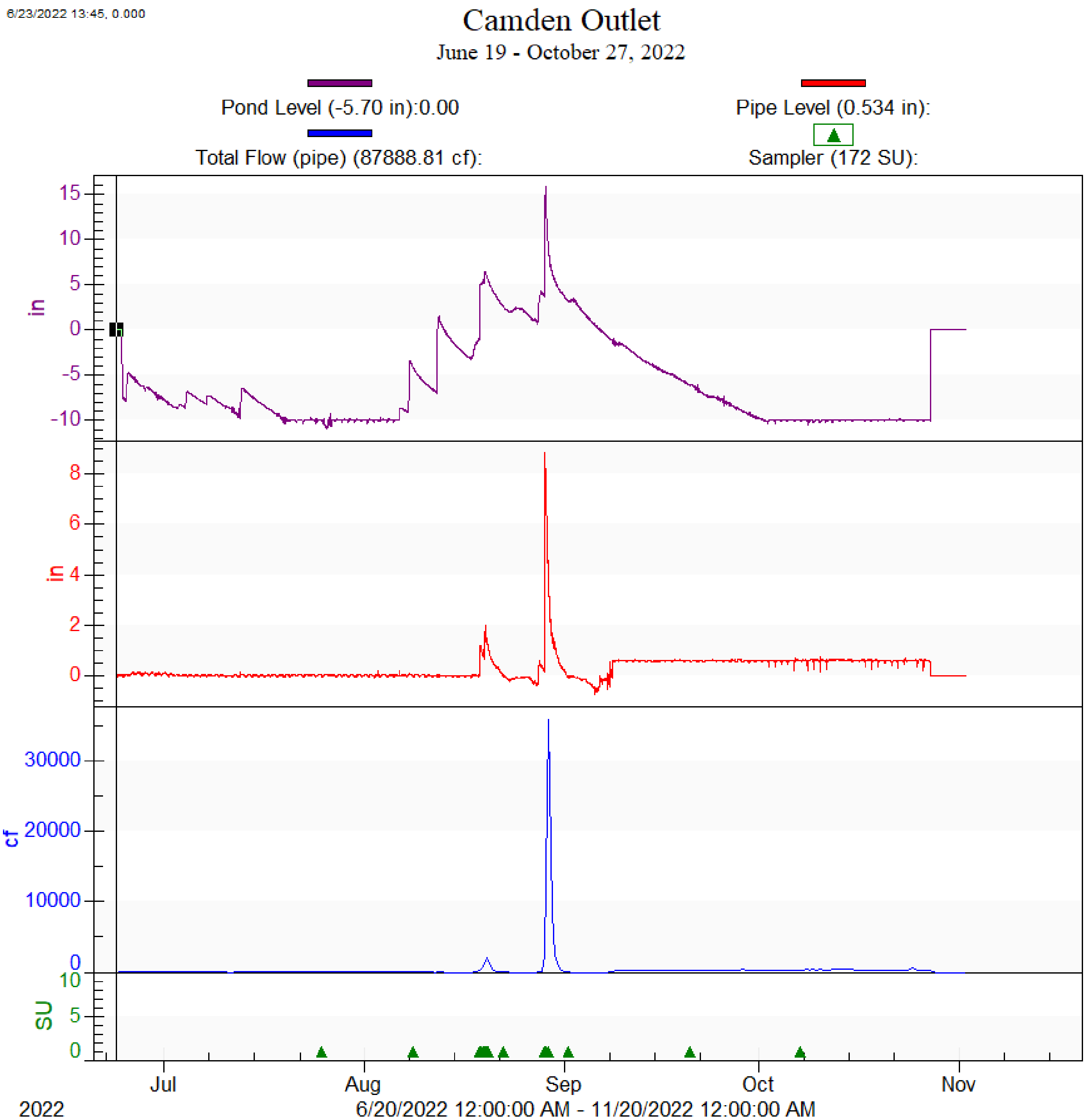
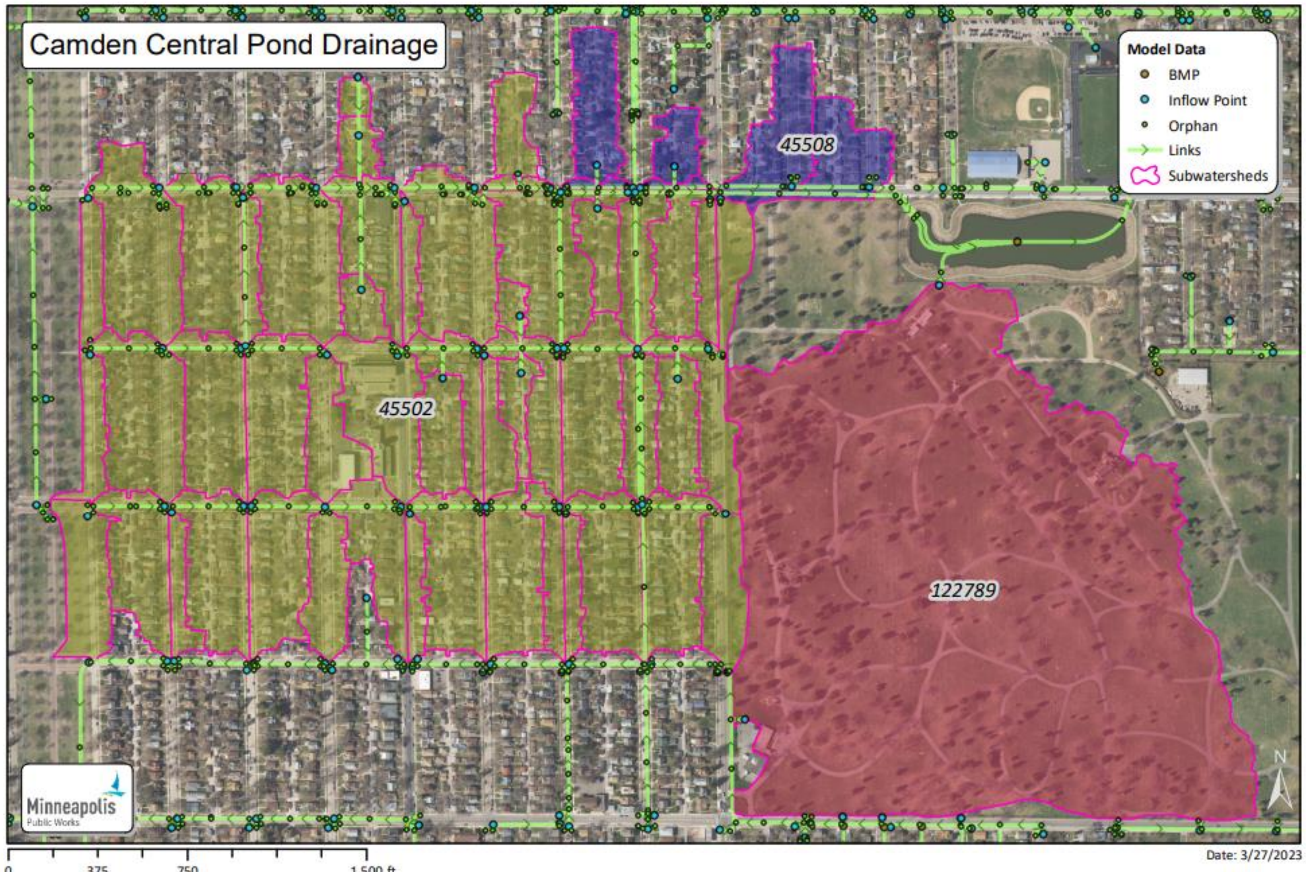


Figure 25-8. Camden Outlet hydrograph of pond level, pipe level, and pipe flow. Green triangles represent when the auto-sampler attempted to take a sample from flow in the pipe. Flow monitoring began on June 19 and ended on October 27, 2022. Flow registered on the pipe probe once the pond level reached ~5 inches. The pond probe was positioned higher than the actual water level of the pond for the majority of the monitoring season, as evident by flat level readings in August and October when the pond level reduced to -10 inches or lower.

Table 25-8. Composite sampling storm events and corresponding flow data from each monitoring site. NS = no sample. Precipitation data was measured at the Crystal Airport in Brooklyn Center, MN. Flow data was estimated using the hydrographs generated by the auto-samplers, see Figures 25-5 to 25-8. Note that some samples taken at the Outlet did not correspond with a precipitation event and were thus excluded from this table.

Rain Event Date	Duration (hours)	Precip. (inches)	Cam In N NW (cf)	Cam In S NW (cf)	Cam in SW (cf)	Cam Outlet (cf)
7/12/2022	2	0.25	14769	49083	5757	NS
7/23/2022	4	0.37	NS	NS	4842	NS
8/3/2022	1	0.03	NS	NS	1783	NS
8/6/2022	6	0.29	NS	NS	2138	NS
8/7/2022	3	0.95	NS	NS	6272	NS
8/12/2022	4	1.26	41245	149351	7633	NS
8/18/2022	4	0.38	8680	NS	3507	NS
8/19/2022	9	0.76	NS	NS	1564	1156
8/27/2022	5	0.71	NS	NS	1572	NS



ID	Area (acres)	Impervious	Institutional	Multi-Family	Office	Park, Recreational, or Preserve	Retail and Other Commercial	Right of Way	Single Family Attached	Single Family Detached	Undeveloped
45508	10.5	48.0%	5.5%	0.0%	0.0%	0.0%	0.0%	23.4%	0.0%	71.1%	0.0%
45502	127.8	44.9%	5.4%	0.6%	0.1%	2.0%	0.5%	28.1%	1.0%	61.9%	0.2%
122789	84.2	9.9%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Figure 25-9. Aerial map of Camden Pond showing watershed sizes and land use breakdowns. Map provided by the City of Minneapolis Public Works.

Chemical load calculations using the geometric mean of each chemical parameter for composite samples are shown in **Table 25-9** The largest calculated load in pounds for each parameter are highlighted in orange. **Table 25-10** shows relative percentages for each site for the total flow, total drainage area, and total loads for each parameter, calculated using information from **Figure 25-9**. While the load inputs are calculated from measured data, the flow-weighted samples were only collected between July through October, so the data does not provide a comprehensive view of the entire year. The monitoring period had only 5.93 inches of precipitation, while the yearly total was 22.97 inches. See **Chapter 29** for more information on climate.

Chemical Load Tables

Table 25-9. The 2022 flow totals, calculated pollutant loads, and removal efficiency for Camden Inlets N NW, S NW, SW, and Camden Outlet. The Total Loading column is summed using data from the three inlets. Removal Efficiency was calculated using Total Loading and Camden Outlet data. Flow was measured from July to October. Orange highlights indicate the largest calculated load for a parameter.

Site Name	Cam Inlet N NW	Cam Inlet S NW	Cam Inlet SW	Total Loading	Cam Outlet	Removal Efficiency
Total Flow (L)	**6,522,472**	**28,033,367**	**3,201,304**	**37,757,143**	**24,887,365**	**-**
TP (lb)	4.15	24.8	2.09	31.0	1.40	95%
TDP (lb)	1.47	14.2	0.803	16.5	0.358	98%
SRP (lb)	1.20	11.4	0.614	13.2	0.0238	100%
TN (lb)	29.4	108	11.7	149	18.4	88%
NOx (lb)	6.19	65.8	5.53	77.5	3.18	96%
Cl (lb)	120	1156	38.1	1,314	382	71%
Hardness (lb)	295	2596	251	3,141	333	89%
TSS (lb)	381	2183	510	3,075	181	94%
VSS (lb)	163	1140	174	1,477	160	89%
TDS (lb)	496	5871	487	6,853	948	86%
COD (lb)	525	1782	413	2,719	380	86%
Cu (lb)	147	544	118	809	0.06417	100%
Pb (lb)	100	161	29.3	290	0.00275	100%
Zn (lb)	799	2052	196	3,046	0.0963	100%
DOC (lb)	56.1	371	52.6	479	49.9	90%

Table 25-10. The 2022 relative percentages for each site for the total flow, total drainage area, and total loads for each parameter.

Site Name	Cam Inlet N NW	Cam Inlet S NW	Cam Inlet SW
% Of total flow	17.3	74.2	8.48
% Of total drainage area	4.72	57.4	37.8
% Of total TP load	13.4	79.9	6.73
% Of total TDP load	8.89	86.2	4.86
% Of total SRP load	9.10	86.2	4.66
% Of total TN load	19.7	72.4	7.88
% Of total NOx load	7.98	84.9	7.13
% Of total Cl load	9.11	88.0	2.90
% Of total Hardness load	9.39	82.6	7.98
% Of total TSS load	12.4	71.0	16.6
% Of total VSS load	11.0	77.2	11.8
% Of total TDS load	7.23	85.7	7.10
% Of total COD load	19.3	65.5	15.2
% Of total Cu load			
% Of total Pb load	18.1	67.2	14.6
% Of total Zn load	34.5	55.4	10.1
% Of total DOC load	26.2	67.4	6.42

DISCUSSION

Chemical Load Calculations

Camden Inlet S NW produced the largest loads across all measured parameters, as seen in **Table 25-9**. This makes sense, as its drainage area is 74% of the total drainage area for the pond, as shown in **Table 25-10**. While Camden Inlet SW does have a large drainage area, it is mainly comprised of pervious surfaces and has little to no vehicle traffic, so it did not contribute significant pollutant loads. Camden Inlet N NW, despite having a much smaller drainage area than the SW site, registered higher loads for all parameters except SRP, NOx, and Hardness when compared to the SW site.

Camden Outlet recorded significantly lower loads of all parameters as compared to the three inlets; however, this can be partially attributed to the lack of significant precipitation due to a regional drought during most of the monitoring season. Because of this, the pond only outflowed three times, so the true efficiency of the pond cannot accurately be determined using this year’s data. When comparing the total loads flowing into the pond with the loads from the Outlet, it appears as though the pond is performing well at removing pollutants. Removal efficiencies ranged from 71% for Cl to 100% for SRP, Cu, Pb, and Zn. All parameters registered lower levels at the Outlet than at the inlets.

Sampler Programming

2022 was the first year that the MPRB studied Camden Pond using auto-samplers, which presented many challenges in setting up monitoring sites and troubleshooting problems. The groundwork done this season will allow for more effective monitoring at Camden Pond in future years. Determining the appropriate programming for each site proved to be especially difficult. Standard sampler setup for the MPRB is to trigger the sampler when water level in the pipe reaches 1-inch and then take samples at regular intervals measured in cubic feet (cf). The sample pacing depends on the size of the pipe and the size of the watershed. Programming for each monitoring site was adjusted based on observations of hydrographs produced during storms, **Figure 25-10**.

Figure 25-10. MPRB staff reprogramming the sampler at Camden S NW.

Camden Outlet, N NW Inlet, and SW Inlet were all initially programmed to trigger off a 1-inch level and take samples every several hundred cubic feet. After viewing data from several storms, it was determined that the samples were being collected too close together and did not accurately capture the entire storm event. To mitigate this, the volumetric pacing between samples was increased, sometimes multiple times, until samples were captured across the whole storm event.

Camden Inlet S NW was a more difficult case, as the pipe regularly has around 7 inches of standing water, shown in **Figure 25-11**. This introduces the issue of backflow, where water flows from the pond into the pipe rather than the other way around. This back and forth “sloshing” effect can distort the hydrograph, as shown in **Figure 25-12**, and make it difficult to capture representative samples.

Figure 25-11. Image of Camden S NW pipe with some standing water. This image was taken at the end of the monitoring season, several months into a severe drought. Note the water line markings on the side of the pipe (blue dashed lines), showing the usual level of standing water.

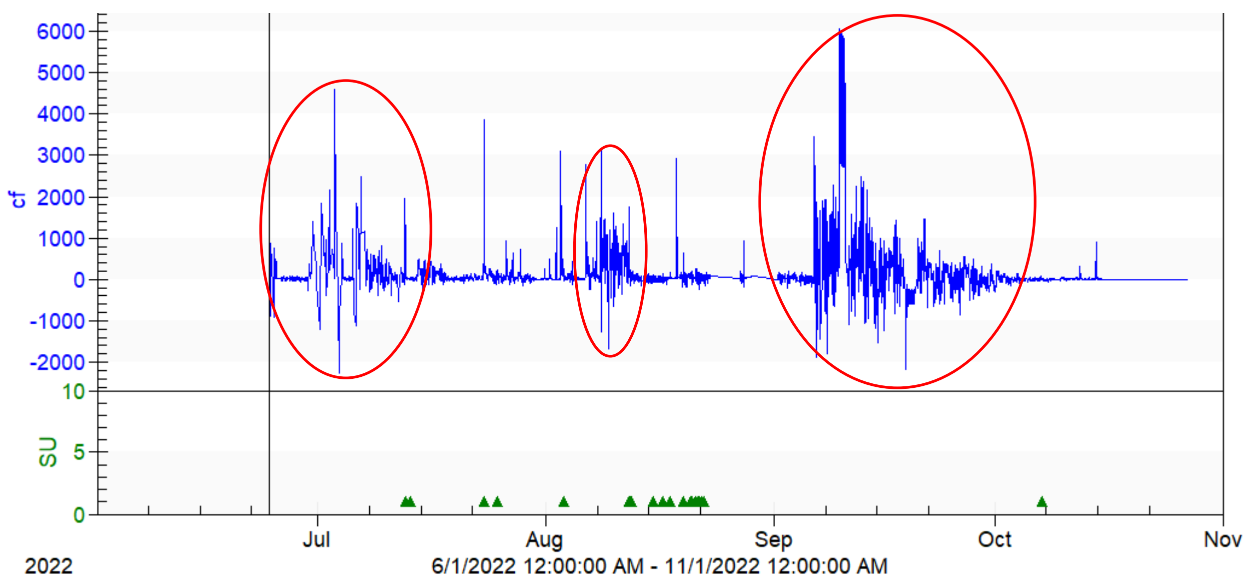


Figure 25-12. A graph of the original total flow data from Camden Inlet S NW. Areas showing evidence of backflow, represented by rapid, dramatic oscillations between positive and negative flow, are circled in red.

Initially, the Camden S NW sampler was programmed to trigger off a 7.5-inch level and a pacing of 200 cf. The pacing was increased several times but still was not effective in capturing samples from the entire hydrograph. Eventually, staff elected to alter the programming to use the concept of hysteresis for the trigger along with a set pacing. For the first attempt the trigger was set at greater than 2 cubic feet per second (cfs) for 3 minutes with 500 cf pacing. This means that the sampler triggered once the rate of flow in the pipe remained at or above 2 cfs for at least 3 minutes, and then took samples every 500 cf that flowed by. Since this formula does not rely on water level as the trigger, some impact from backflow can be avoided. The trigger was increased to greater than 2.5 cfs for 3 minutes, and then again to greater than 5 cfs for 2 minutes, with some improvement in sampling success. A lack of precipitation towards the end of the monitoring season ended the window of experimentation earlier than expected, so it is likely that further fine-tuning will be necessary in subsequent years of the study.

One potential solution for the S NW site could be to move the monitoring site farther upstream. By relocating the sampling site one to two blocks away from the pond, standing water and backflow could likely be avoided; however, any stormwater inputs between the monitoring site and the pond inlet would not be accounted for. Another option would be to trigger the S NW sampler off the level measured by the N NW sampler, as the pipes run parallel to one another. When comparing hydrographs from both sites, peak flow and level are roughly comparable. The N NW site does not have standing water or backflow and was more successful in capturing samples during the 2022 season. The consequence of this setup would be if the N NW site malfunctions, the S NW site will not be able to collect samples.

Study Design

The primary intention of this study was to measure the efficiency of Camden Pond at removing nutrients from stormwater and preventing them from flowing downstream. This was done by measuring stormwater inputs (Camden Inlets N NW, S NW, and SW) and comparing results with measurements from the pond outlet (Camden Outlet). The City of Minneapolis has particular interest in this as the pond was not originally intended for nutrient removal and was built for flood control purposes. A secondary goal was to assess how much storage capacity the pond truly contained, as compared to what was originally calculated by the designers/engineers.

In 2022, the scope of the study was severely limited by the lack of significant precipitation events, especially later in the monitoring season. The pond only outflowed three times during the monitoring season, so few comparisons could be made between the quality of inflowing verses outflowing water. Additionally, the actual pond level was often below the pond level probe, making an assessment of the pond storage capacity difficult to accurately measure. Several more years of data during years with higher precipitation will be necessary to draw meaningful conclusions. In the future, the MPRB is interested in making more observations on blue-green algae levels in Camden Pond using a visual monitoring index (VMI) during future monitoring. The connection between algae blooms and nutrient loading is well known, and this relationship is of interest to the MPRB as algae blooms can be harmful to public health (Paerl & Otten, 2013).

Conclusions

Load calculations were completed for each inflowing Camden Pond watershed monitored and removal efficiencies were calculated for the pond outlet.

- The lack of significant precipitation in 2022 made it difficult to accurately assess the pond's performance. More years of data collection will be necessary to make confident assertions and accurately assess load and pond performance.
- The ability to accurately calculated removal efficiency was very limited since only a small number of samples could be collected in 2022 due to the regional drought.
- Removal efficiencies for all parameters were over 70% indicating the pond was effective at treating stormwater inputs.

The true storage capacity of Camden Pond could not accurately be assessed in 2022.

- The pond level probe was often above the actual water level of the pond, making for inaccurate measurements.
- Calculations of storage capacity were not performed due to the lack of quality data.

Sampler programming and site set-up provided many monitoring challenges in 2022.

- This was the first year the MPRB monitored Camden Pond using auto-samplers.
- Much of the monitoring season was spent troubleshooting equipment and experimenting with sampler programming. This prevented the full provisions of the NPDES permit from being met.
- The N NW monitoring site proved especially difficult to monitor due to issues with backflow. The MPRB has developed strategies to potentially mitigate this in the future.

NPDES Permit provisions for stormwater monitoring were met or were attempted in 2022.

- All monitoring for the NPDES permit as it applied to this project was attempted to be completed, see **Table 25-11**. This included continuous flow monitoring starting between June 13 and June 24 and ending on October 27, 2022. Site installs were delayed due to late receipt of equipment and issues coordinating with the MPRB cement shop for hardware installations.
- At least ten flow-weighted composite samples that were collected and analyzed for NPDES chemistry at the SW site. Due to technical issues with equipment and sampler programming, fewer than ten composite samples were collected at the N NW and S NW sites. Only three samples were collected at the Outlet due to the regional drought causing low water levels in the pond.
- Quarterly grab samples were taken or attempted to be taken and analyzed for NPDES chemistry, FOG, and *E.coli* at the three inlets.

Table 25-11. Summary of stormwater sampling at Camden Pond in 2022. Camden Outlet was not attempted for grab sampling.

Site Name	Camden Inlet N NW	Camden Inlet S NW	Camden Inlet SW	Camden Outlet
# Of grab samples	2	3	4	-
# Of composite samples	4	3	11	3

The MPRB will continue to update the study design and site setup in future years of monitoring.

- Sampling during a year with normal levels of precipitation will allow more study goals to be met.
- The pond level probe will be placed at a lower elevation to account for the low water level of the pond.
- Site sampler pacing will continue to be updated to best fit the generated hydrographs.
- The MPRB will assess algae blooms via a visual monitoring index at Camden Pond to monitor the presence of blue-green algae blooms during the monitoring season.

26. Powderhorn Lake Inlet Monitoring

Background

The City of Minneapolis Public Works (MPW) and the Minneapolis Park and Recreation Board (MPRB) developed a major restoration plan for Powderhorn Lake in 1999. In 2001, five continuous deflective separation (CDS) grit chambers were installed to remove solids from stormwater inflow see **Figure 26-4**. A drawing of a CDS unit is shown in **Figure 26-2**. The Powderhorn Lake watersheds are shown in **Figure 26-3**.

Despite this and other restoration work, the lake was listed as impaired and placed on the Environmental Protection Agency (EPA) 303(d) list based on eutrophication and biological indicators in 2001. Powderhorn Lake later trended towards better water quality and met state standards for several years and was subsequently removed from the 303(d) list in 2012. After relapsing to poor water quality, Powderhorn was relisted on the EPA 303(d) list as impaired for nutrients in 2018.

The purpose of monitoring the stormwater inlets into Powderhorn Lake was to:

1. Measure the pollutant load of the main tributaries to Powderhorn Lake. This information can be used to assist in any future external load reduction plans.
2. Trouble shoot the CDS unit functionality, since work done in 2020 discovered that the CDS units were not functioning as designed.
3. Comply with the National Pollutant Discharge Elimination System (NPDES) Permit provision to monitor stormwater BMPs for the purpose of adaptive management.

In 2022, four of the largest Powderhorn Lake watershed inlets were auto-monitored downstream of their CDS units. Current watershed monitoring work at Powderhorn began in 2019. Refer to the Water Resources Report from 2019, 2020, and 2021, found at https://www.minneapolisparks.org/park-care-improvements/water_resources/, for more information on Powderhorn Lake inlet monitoring. The MPRB also studied CDS and sump units at Powderhorn Lake from 2002-2004 and neighborhood rain garden effectiveness in 2009.

Figure 26-1. Images of the four Powderhorn Lake stormwater monitoring sites.

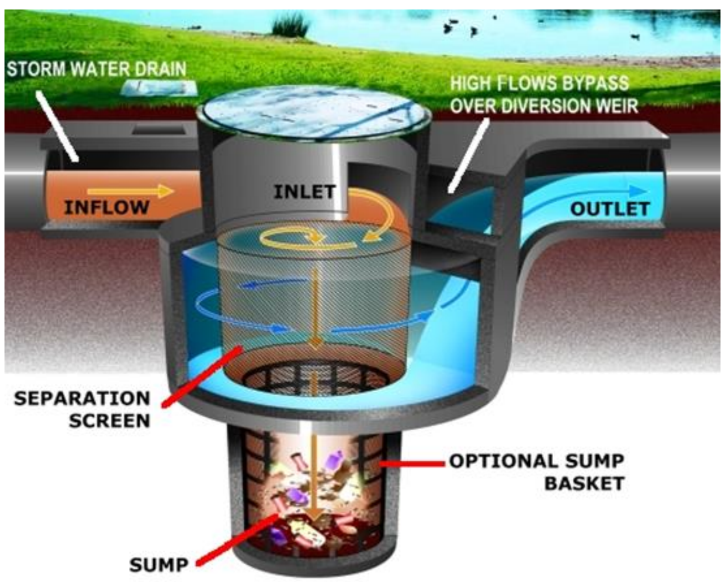


Figure 26-2. Cross section showing components of a CDS grit chamber unit. Image source: https://prismatech.com.my/products-ecoclean-cds.php archives.

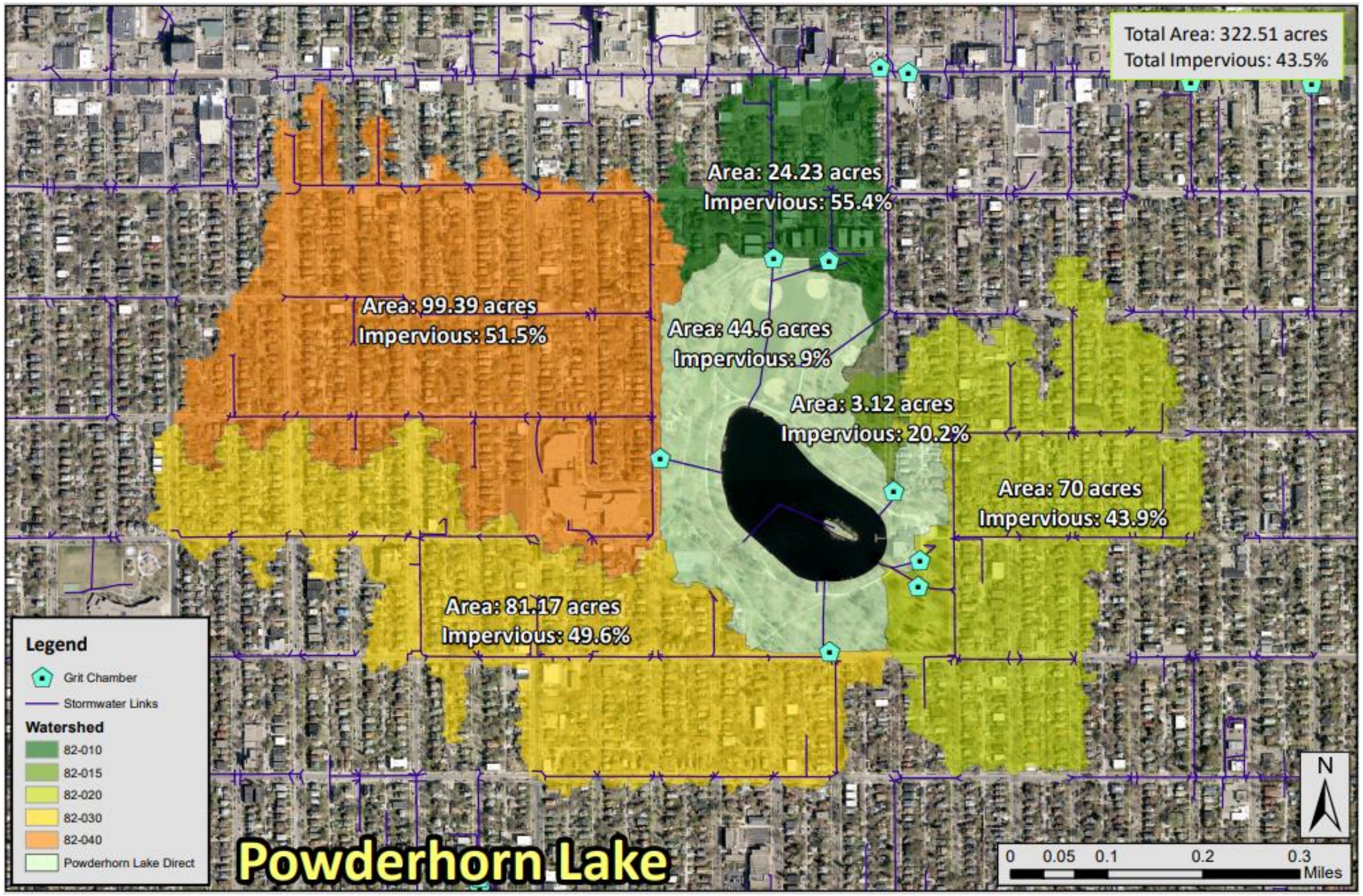


Figure 26-3. Powderhorn Lake watershed drainage areas shown with subwatershed sizes. All inlets have CDS units except the 3.12-acre area which has a sump catch basin. The dark green area in the north contains two CDS units – the MPRB monitors only the eastern one, which receives runoff from 12.87 acres. Map provided by Minneapolis Public Work

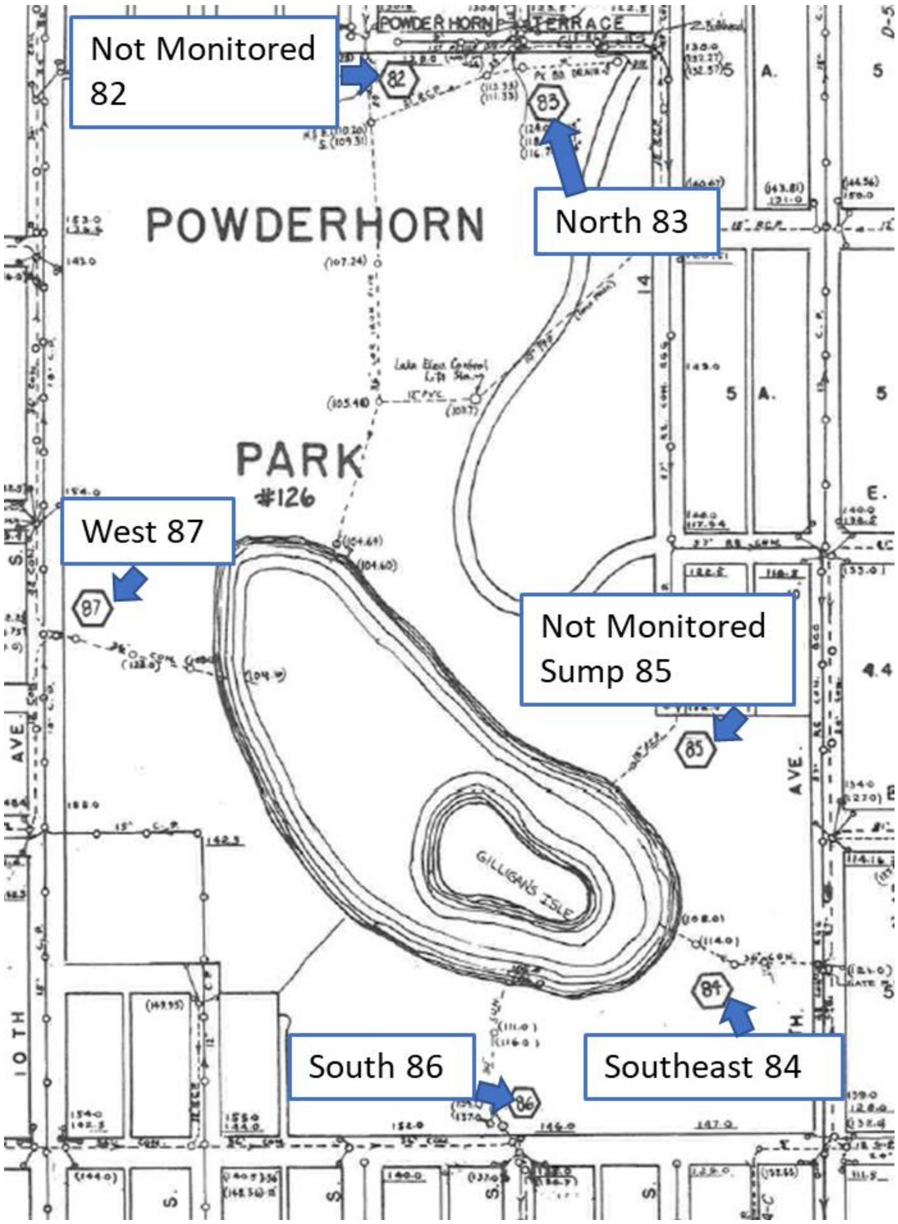


Figure 26-4. Map of CDS surrounding Powderhorn Park with Minneapolis Public Works ID numbers.

There are five CDS grit chambers and one sump structure installed in-line with stormwater pipes leading to Powderhorn Lake. A sump is a pit, typically in a catch basin, that traps solids. **Table 26-1** shows the Powderhorn CDS grit chambers with Minneapolis Public Works ID numbers, location, and drainage areas for each unit. CDS unit 82 was not monitored since it is adjacent to and has an almost identically sized watershed to CDS unit 83. Sump 85 was not monitored because it makes up only about 1% of the entire

Powderhorn watershed, at 3.12 acres and 20.2% impervious surfaces, and likely does not contribute a significant nutrient loading to the lake.

Table 26-1. A list of the Best Management Practices (BMP's) surrounding Powderhorn Lake, their MPRB name, Minneapolis ID number, BMP type, drainage area, location, and pipe size.

MPRB Site Name	Minneapolis Grit ID #	BMP Type	Drainage Area (Acres)	Location	Outlet Pipe Size (Inches)
	82	CDS Hydrodynamic Separator	11.4	12th Ave S and Powderhorn Terrace	24
Powderhorn Inlet North	83	CDS Hydrodynamic Separator	12.9	13th Ave S and Powderhorn Terrace	21
Powderhorn Inlet Southeast	84	CDS Hydrodynamic Separator	68.8	3421 15th Ave S	36
	85	Sump Manhole	3.1	3329 14th Ave S	15
Powderhorn Inlet South	86	CDS Hydrodynamic Separator	81.2	13th Ave S and East 35th Street	30
Powderhorn Inlet West	87	CDS Hydrodynamic Separator	99.4	3318 10th Ave S opposite of house #3318	36

METHODS

Site Installation

Monitoring equipment at each of the sites included: ISCO 2150 datalogger, 2105ci LTE combined interface module/modem, low-profile AV probe, and a 3700 ISCO sampler complete with tubing and intake strainer. Area velocity (AV) probes and intake strainers were oriented to point upstream, **Figure 26-5**. The equipment at the North Inlet was hung from eyebolts below grade in the manhole, while all the other sites had above-grade monitoring boxes with access holes for tubing and cables drilled through the manhole collars. Cables and tubing were anchored with zip-ties to the sidewall eyebolts or side-iron manhole ladders. Monitoring boxes were rectangular 4 ft x 3 ft x 3 ft locking wooden boxes which protected and housed both the sampler and datalogger equipment. The boxes were not able to keep out rodents, which occasionally chewed on cables and made nests under the equipment. Future above-ground installations will have all holes plugged with steel wool to deter rodent activity.

The dataloggers used cell phone modems to remotely upload data to the MPRB ISCO database server from Monday through Friday. A cell phone antenna was installed at each site to allow communication with the datalogger. The datalogger could also be remotely accessed to turn the samplers on/off, adjust the level, pacing, and triggers, or download data.

Sites were installed in late April/early May and began taking samples during a storm event on May 12, 2022. Sites were uninstalled in late October.

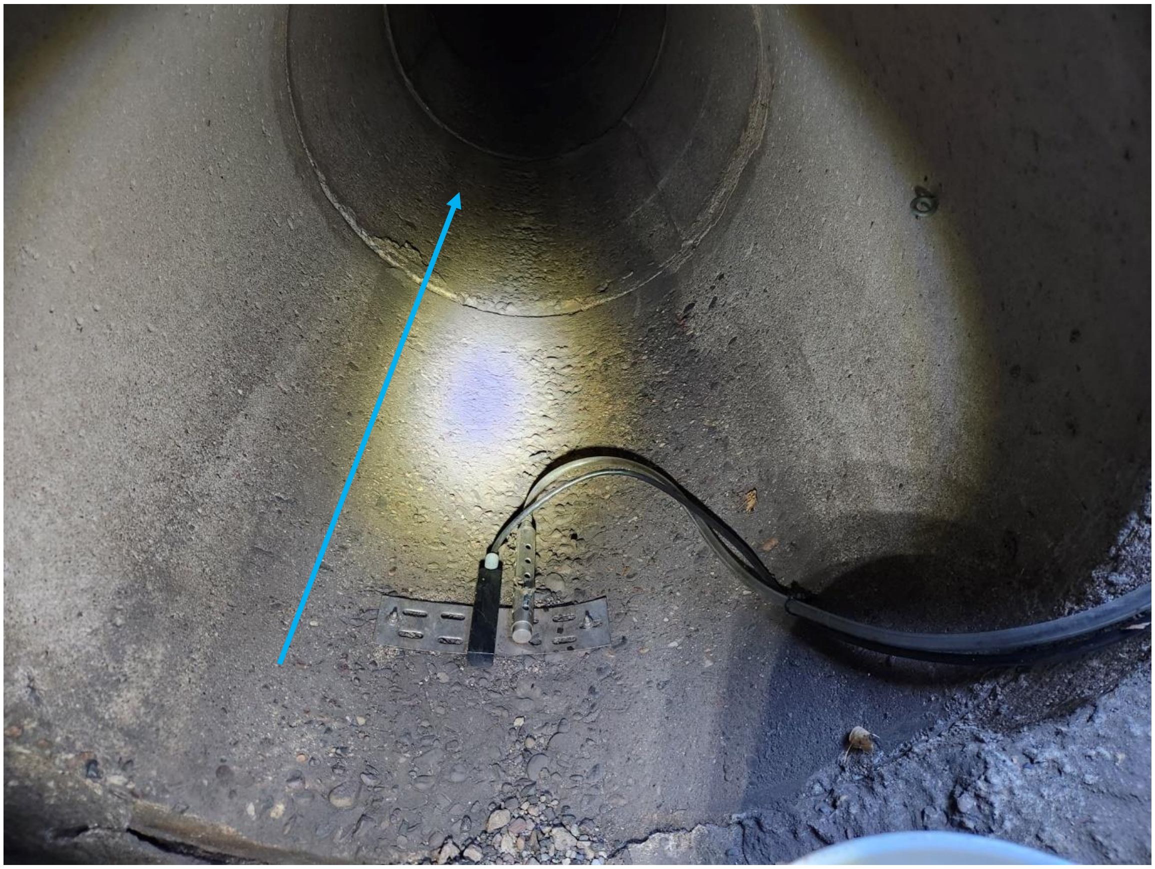


Figure 26-5. Photo of the AV probe and intake strainer at Powderhorn Inlet SE in October. The equipment is attached to a stainless-steel plate that is bolted into the pipe. The blue arrow indicates direction of water flow.

Sample Collection

All samplers were multiplexed, flow-paced, equipped with 24 one-liter bottles, 3/8 inch inner-diameter vinyl tubing, and an intake strainer. They collected four samples per 1-L bottle, and each sampler contained 24 1-L bottles. This allowed a maximum of 96 samples to be collected over a storm event and create a flow-weighted composite. The dataloggers were programmed to pulse the samplers after a 1 inch trigger and after a set volume or pacing had passed. The pacing depended on the size of the pipe at the site.

In 2022, all Powderhorn monitoring was done downstream of the CDS units to enable sampling of nutrient inputs to the lake. The samplers collected material less than 3/8 inches in size that bypassed over the internal weir or passed through the CDS chamber screen in addition to flow through the CDS unit. Solid material greater than 3/8 inches were not sampled, such as leaf litter, cigarette butts, plastic bags, or various other debris.

In previous years, the South, West, and Southeast Inlets had significant by-pass flows at the internal CDS overflow weirs. It is believed that this situation was caused by the CDS screens becoming plugged. When routine bypass occurs, water backs up the upstream pipes, past the CDS unit, and sand and solids settle in the upstream pipe. Bypass and in-pipe solids settling were not concerns in 2022 mainly due to the lack of significant storm events.

Monitoring Parameters and Methods

A list of the chemical parameters required by the NPDES permit for analysis of auto-monitored composite stormwater samples is shown in **Table 26-2**. NPDES permit-required chemistry methods, reporting limits and holding times for auto-monitored composite samples used in this project are also shown in this table.

Table 26-2. Chemistry parameters required for auto-monitored stormwater samples by the NPDES permit. Analysis method, reporting limit, and holding times for parameters analyzed by Instrumental Research, Inc. and Pace Laboratories.

Parameter	Abbreviation	Units	Method	Reporting Limit	Holding Time
Chemical Oxygen Demand	COD	mg/L	SM 5220-D	20 mg/L	28 days
Dissolved Organic Carbon	DOC	mg/L	SM 5310-C-00	1.5 mg/L	28 days
Chloride, Total	Cl	mg/L	SM 4500-Cl^- B	2.0 mg/L	28 days
Hardness	Hard	mg/L	SM 2350 C	5.0 mg/L	6 months
Copper, Total	Cu	µg/L	EPA 200.8	1 µg/L	6 months
Lead, Total	Pb	µg/L	EPA 200.8	0.10 µg/L	6 months
Zinc, Total	Zn	µg/L	EPA 200.7	20 µg/L	6 months
Nitrate/Nitrite, Total as N	NOx	mg/L	SM 4500-NO_3 E	0.030 mg/L	28 days
Total Nitrogen	TN	mg/L	Alkaline Persulfate Oxidation	0.500 mg/L	28 days
Phosphorus, Total Dissolved	TDP	mg/L	SM 4500-PE	0.010 mg/L	48 hours
Phosphorus, Total	TP	mg/L	SM 4500-PE	0.010 mg/L	48 hours
Solids, Total Dissolved	TDS	mg/L	SM 2540 C	5.0 mg/L	7 days
Solids, Total Suspended	TSS	mg/L	SM 2540 D	1.0 mg/L	7 days
Solids, Volatile Suspended	VSS	mg/L	EPA 160.4	2.0 mg/L	7 days

Results

Sample Collection

In 2022, rainfall grab and composite samples were collected during storms ranging from 0.10 to 1.23 inches of precipitation. Due to the regional drought, samples from storms with less than 0.10 inches of precipitation were sometimes included in the data. Snowmelt grab samples were collected from three snowmelt events at the Powderhorn Inlets S, SE, and W sites. Powderhorn Inlet N was inaccessible for grab sampling. **Table 26-3** shows the snowmelt grab samples collected. See **Chapter 24** for more information on grab sampling. **Table 26-4** shows the precipitation and flow-weighted composite storm samples collected. **Figure 26-6** shows what composite samples look like in the field. Precipitation was measured by a rain gauge at MPRB's southside service center located at 3800 Bryant Ave. S. in Minneapolis, MN. A precipitation event was defined as a storm greater than 0.10 inches and separated by eight hours or more from other precipitation.

The 2022 NPDES chemical concentrations and statistics for the composite samples collected at Powderhorn Inlets S, SE, W, and N can be seen in **Table 26-5** through **Table 26-8**. If less than values were present, half the value was used for statistical calculations. The statistics calculated for each site were the geometric mean (GEOMEAN), arithmetic mean, maximum (MAX), minimum (MIN), standard deviation (STDEV), number of samples, and coefficient of variance (CV). Note that the geometric means were calculated using only data from composite samples. Arithmetic means were calculated using data from composite and grab samples. If a sample was not analyzed and no data are presented it is marked NS for no sample, usually due to low volume. Storm event data and congruent flow data are found in **Table 26-**9. The geometric means in **Tables 26-5** through **Table 26-8** were used for load calculations, which are found in **Table 26-10** and **Table 26-11**.

Figure 26-6. Photo of ISCO 3700 autosampler with flow-weighted composite samples inside.

Table 26-3. The 2022 snowmelt grab events staff sampled or attempted to sample at the Powderhorn Inlets. ⊗ = quarterly grab sample. NS = No Sample.

Date	Powderhorn In S	Powderhorn In SE	Powderhorn In W
2/28/22	⊗	⊗	⊗
3/8/22	⊗	⊗	⊗
3/15/22	NS	NS	NS

Table 26-4. The 2022 rainfall grab events sampled or attempted to be sampled at the three Powderhorn Inlets. ⊗ = quarterly grab samples, ⊗/C = Quarterly grab samples with a flow-paced composite. NS = No Sample.

Start Date	Start Time	End Date	End Time	Rain (inches)	Duration (hours)	Intensity (in/hour)	Hours since last rain	Powderhorn In S	Powderhorn In SE	Powderhorn In W
4/5/2022	10:15	04/06/22	5:45	0.5	19.5	0.026	34.75	⊗	⊗	⊗
5/25/2022	0:30	05/25/22	12:45	0.58	12.25	0.047	113.25	⊗/C	⊗/C	⊗/C
6/13/2022	6:00	06/13/22	8:00	0.09	2.00	0.045	47.75	NS	NS	NS
8/12/2022	4:00	08/12/22	7:45	0.84	3.75	0.224	101	⊗/C	⊗/C	⊗/C

Stormwater Chemistry

Table 26-5. Powderhorn Inlet N 2022 composite sample chemistry and statistics. NS = No sample. TP = Total Phosphorus, TDP = Total Dissolved Phosphorus, SRP = Soluble Reactive Phosphorus, TN = Total Nitrogen, NOx = Nitrate/Nitrite, Cl = Chloride, TSS = Total Suspended Solids, VSS = Volatile Suspended Solids, TDS = Total Dissolved Solids, COD = Chemical Oxygen Demand, FOG = Fat Oil and Grease, Cu = Copper, Pb = Lead, Zn = Zinc, DOC = Dissolved Organic Carbon.

Date Sampled	TP mg/L	TDP mg/L	SRP mg/L	TN mg/L	NOx mg/L	Cl mg/L	Hardness mg/L	TSS mg/L	VSS mg/L	TDS mg/L	COD mg/L	Cu µg/L	Pb µg/L	Zn µg/L	DOC mg/L
5/11/2022	1.725	0.476	0.213	8.01	0.044	13.5	48	468	161	90.0	524	55.9	88.8	252	17.9
6/30/2022	1.299	0.704	0.610	NS	NS	NS	NS	5	140	68.0	NS	NS	NS	NS	NS
7/10/2022	1.278	0.379	0.277	7.281	NS	NS	NS	42	34	NS	NS	NS	NS	NS	NS
7/12/2022	1.182	0.257	0.139	2.13	0.354	7.0	36.0	231	89.0	82.5	165	43.0	52.4	182	15.1
7/26/2022	1.274	0.659	0.366	6.42	0.177	45.0	60.0	94.0	46.0	188	200	39.0	17.5	137	46.6
8/3/2022	1.346	0.535	0.088	6.70	<0.03	45.0	60.0	118	61.5	195	270	NS	NS	NS	NS
8/6/2022	0.596	0.302	0.182	2.04	0.332	4.5	30.0	54.5	29.0	85.0	77.3	26.6	7.6	120	15.3
8/8/2022	0.371	0.220	0.148	1.702	0.469	4.0	24.0	31.0	14.3	55.0	55.5	19.4	6.2	53.2	9.0
8/12/2022	0.531	0.196	0.126	NS	NS	7.3	28.0	63.3	29.3	NS	NS	NS	NS	NS	NS
8/17/2022	0.648	0.356	0.101	3.39	2.17	7.5	42.0	61.0	28.0	113	135	27.9	8.5	121	29.2
8/18/2022	0.393	0.150	0.088	1.56	1.50	3.0	22.0	117	39.8	37.5	99.1	25.4	20.8	96.8	5.1
8/19/2022	0.339	0.106	NS	2.20	0.94	3.5	20.0	141	49.0	37.5	113	30.6	25.2	107	4.7
8/28/2022	0.342	0.198	0.124	2.35	1.23	5.5	18.0	64.0	27.2	52.5	91.8	16.5	15.3	79.2	7.2
8/29/2022	NS	NS	0.102	NS	NS	8.0	30.0	28.8	17.2	<5.0	71.6	NS	NS	NS	NS
MEAN (geometric)	0.740	0.301	0.16	3.30	0.35	8.16	32.9	68.1	42.4	59.0	131	29.6	18.6	117	12.7
MEAN (arithmetic)	0.87	0.35	0.20	3.98	0.72	12.8	35.4	108	54.7	83.8	164	31.6	26.9	128	16.7
MAX	1.72	0.70	0.61	8.01	2.17	44.9	60.0	468.	161	195	524	55.9	88.8	252	46.6
MIN	0.34	0.11	0.09	1.56	0.02	3.00	18.0	4.6	14.3	2.5	55.5	16.5	6.20	53.2	4.70
MEDIAN	0.65	0.30	0.14	2.35	0.41	7.16	30.0	63.7	36.9	75.2	113	27.9	17.5	120.0	15.1
STDEV	0.49	0.19	0.15	2.55	0.72	15.3	14.2	118	45.0	58.0	135	12.4	27.1	59.0	13.6
NUMBER	13	13	13	11	10	12	13	14	14	12	11	9	9	9	9
CV	0.559	0.552	0.753	0.640	0.989	1.19	0.401	1.093	0.824	0.692	0.826	0.393	1.007	0.463	0.82

Table 26-6. Powderhorn Inlet S 2022 chemistry data. Grab samples are denoted with a * by Date Sampled. Values in red were flagged during monthly blind QAQC performance checks with the contracting laboratory. NS = No sample. TP = Total Phosphorus, TDP = Total Dissolved Phosphorus, SRP = Soluble Reactive Phosphorus, TN = Total Nitrogen, NOx = Nitrate/Nitrite, Cl = Chloride, TSS = Total Suspended Solids, VSS = Volatile Suspended Solids, TDS = Total Dissolved Solids, COD = Chemical Oxygen Demand, FOG = Fat Oil and Grease, Cu = Copper, Pb = Lead, Zn = Zinc, DOC = Dissolved Organic Carbon.

Date Sampled	TP mg/L	TDP mg/L	SRP mg/L	TN mg/L	NOx mg/L	Cl mg/L	Hardness mg/L	TSS mg/L	VSS mg/L	TDS mg/L	COD mg/L	FOG mg/L	E. Coli MPN	Cu µg/L	Pb µg/L	Zn µg/L	DOC mg/L
2/28/2022*	1.02	0.201	0.120	6.42	0.490	3599	110	254	106	5653	449	35.5	583	48	37	320	26
3/8/2022*	0.635	0.191	<0.003	6.38	0.450	1450	76	116	48	2443	236	14.3	190	31	17.3	133	19
4/5/2022*	0.277	0.064	0.060	2.13	0.545	60	26	47	19	172	76	<5.0	1439	22	14	73	15
5/11/2022	0.746	0.224	0.050	4.03	0.119	5	30	217	84	65	202	NS	NS	31	58	98	9
5/25/2022*	0.428	0.164	0.114	1.66	0.172	8	28	39	26	63	75	<5.0	2987	17	9	66	14
5/25/2022	0.580	0.361	0.072	1.94	0.030	9	36	38	30	90	92	NS	NS	27	8	60	18
5/30/2022	0.839	0.197	0.091	3.40	0.550	9	38	228	80	93	211	NS	NS	39	80	167	13
6/30/2022	1.25	0.430	0.400	NS	NS	NS	NS	3	158	74	NS	NS	NS	NS	NS	NS	NS
7/5/2022	0.990	0.310	0.130	2.98	0.070	25	52	84	30	143	96	NS	NS	26	15	84	30
7/7/2022	2.27	0.175	0.088	2.97	NS	NS	NS	100	45	NS	NS	NS	NS	NS	NS	NS	NS
7/10/2022	1.92	0.472	0.344	6.04	NS	NS	NS	109	62	NS	NS	NS	NS	NS	NS	NS	NS
7/12/2022	1.44	0.324	0.151	1.78	0.066	25	92	292	108	120	180	NS	NS	43	63	172	21
7/26/2022	1.31	0.618	0.239	4.50	0.623	35	88	63	41	265	199	NS	NS	NS	NS	NS	NS
8/3/2022	2.49	1.21	0.470	7.61	NS	45	120	61	33	308	320	NS	NS	NS	NS	NS	NS
8/6/2022	0.816	0.294	0.188	2.73	0.311	7	38	115	54	105	199	NS	NS	38	24	126	21
8/8/2022	0.431	0.119	0.068	1.43	0.219	4	20	89	43	55	109	NS	NS	24	17	73	8
8/12/2022*	0.178	0.107	0.092	0.83	0.262	1	14	18	8	40	49	<5.0	NS	8	4	39	5
8/12/2022	0.350	0.117	0.095	1.98	0.523	3	20	58	29	55	58	NS	NS	22	14	79	8
8/18/2022	0.772	0.229	0.050	2.23	2.19	9	48	96	54	134	172	NS	NS	28	23	129	32
8/18/2022	0.439	0.117	0.051	1.07	1.06	5	28	141	58	55	183	NS	NS	31	49	133	7
8/19/2022	0.438	0.098	NS	2.68	0.748	4	26	211	87	53	152	NS	NS	39	74	149	5
8/28/2022	0.424	0.175	0.097	2.71	1.19	7	26	130	59	65	97	NS	NS	22	39	92	8

Table 26-6 (Continued). Powderhorn Inlet S 2022 statistics.

	TP mg/L	TDP mg/L	SRP mg/L	TN mg/L	NOx mg/L	Cl mg/L	Hardness mg/L	TSS mg/L	VSS mg/L	TDS mg/L	COD mg/L	FOG mg/L	E. Coli MPN	Cu µg/L	Pb µg/L	Zn µg/L	DOC mg/L
GEOMEAN (composite only)	0.892	0.267	0.130	2.95	0.292	10.3	41.3	85.3	55.1	98.5	146	-	-	29.9	28.9	106	13.4
ARITHMETIC MEAN (all samples)	0.911	0.282	0.148	3.21	0.534	280	48.2	114	57.4	502	166	11.5	1300	29.2	32.0	117	15.3
MAX	2.49	1.21	0.470	7.61	2.19	3599	120	292	158	5652	449	35.5	2987	48.7	80.0	320	32.0
MIN	0.178	0.064	0.050	0.828	0.030	1.00	14.0	2.58	8.00	40.0	48.6	2.50	190	7.70	4.30	39.0	4.90
MEDIAN	0.759	0.199	0.096	2.71	0.467	9.00	36.0	98.0	51.0	91.3	172	2.50	1011	27.9	22.8	98.0	13.8
STDEV	0.640	0.249	0.121	1.93	0.528	868	32.5	79.8	35.0	1321	98.6	14.4	1240	10.2	24.4	65.1	8.64
NUMBER	22	22	20	21	18	19	19	22	22	20	19	5	4	17	17	17	17
COV	0.702	0.883	0.821	0.599	0.988	3.11	0.674	0.700	0.610	2.63	0.594	1.26	0.954	0.349	0.763	0.555	0.566

Table 26-7. Powderhorn Inlet SE 2022 stormwater chemistry and statistics. Grab samples are denoted with a * by Date Sampled. Values in red were flagged during monthly blind QAQC performance checks with the contracting laboratory. NS = No sample. TP = Total Phosphorus, TDP = Total Dissolved Phosphorus, SRP = Soluble Reactive Phosphorus, TN = Total Nitrogen, NOx = Nitrate/Nitrite, Cl = Chloride, TSS = Total Suspended Solids, VSS = Volatile Suspended Solids, TDS = Total Dissolved Solids, COD = Chemical Oxygen Demand, FOG = Fat Oil and Grease, Cu = Copper, Pb = Lead, Zn = Zinc, DOC = Dissolved Organic Carbon.

Date Sampled	TP mg/L	TDP mg/L	SRP mg/L	TN mg/L	NOx mg/L	Cl mg/L	Hardness mg/L	TSS mg/L	VSS mg/L	TDS mg/L	COD mg/L	FOG mg/L	E. Coli MPN	Cu µg/L	Pb µg/L	Zn µg/L	DOC mg/L
2/28/2022*	1.05	0.15	0.08	7.09	0.39	5098	160	258	106	8132	455	33.7	97	46	38	322	32
3/8/2022*	0.58	0.17	0.05	5.74	0.36	2199	120	78	33	3813	236	15.8	137	25	11	112	22
4/5/2022*	0.25	0.07	0.06	2.43	0.46	20	21	39	17	105	44	<5.0	NS	15	10	59	14
5/11/2022	0.59	0.14	0.07	2.93	0.32	3	16	249	104	45	155	NS	NS	29	36	71	6
5/25/2022*	0.37	0.18	0.14	1.53	0.28	6	30	21	15	78	59	<5.0	4106	25	4	45	15
5/25/2022	0.54	0.38	0.09	2.24	<0.04	9	38	35	26	100	97	NS	NS	26	8	70	16
5/30/2022	0.89	0.23	0.13	3.75	0.26	8	28	324	121	65	228	NS	NS	37	89	209	10
6/30/2022	1.33	0.27	0.16	NS	NS	NS	NS	3	260	127	NS	NS	NS	NS	NS	NS	NS
7/5/2022	0.88	0.36	0.13	3.60	<0.04	17	84	63	26	134	114	NS	NS	26	10	78	31
7/12/2022	1.65	0.32	0.15	5.88	<0.04	6	80	361	147	97	333	NS	NS	41	69	196	19
8/12/2022*	0.19	0.11	0.09	0.96	0.22	<2	16	14	6	40	33	<5.0	NS	7	3	33	5
8/12/2022	0.40	0.11	0.11	1.89	0.39	<2	20	85	38	42	85	NS	NS	23	15	67	7
8/17/2022	0.78	0.32	0.03	3.21	2.65	7	40	110	51	117	174	NS	NS	33	24	144	30
GEOMEAN (composite only)	0.802	0.245	0.0987	3.16	0.117	5.51	36.8	81.2	70.9	83.6	152	-	-	30.0	25.0	106	14.1
ARITHMETIC MEAN (all samples)	0.730	0.216	0.100	3.44	0.448	615	54	126	73	992	168	11	1447	28	26	117	17
MAX	1.65	0.376	0.164	7.091	2.652	5098	160	361	260	8132	455	34	4106	46	89	322	32
MIN	0.190	0.075	0.033	0.963	0.015	1	16	3	6	40	33	3	97	7	3	33	5
MEDIAN	0.590	0.184	0.092	3.07	0.301	7	34	78	38	100	134	3	137	26	13	75	16
STDEV	0.427	0.102	0.041	1.90	0.711	1546	47	126	73	2380	127	14	2303	11	27	86	10
NUMBER	13	13	13	12	12	12	12	13	13	13	12	5	3	12	12	12	12
COV	0.585	0.473	0.41	0.553	1.588	2.52	0.858	1.00	0.997	2.40	0.760	1.205	1.59	0.381	1.038	0.734	0.57

Table 26-8. Powderhorn Inlet W 2022 stormwater chemistry. Grab samples are denoted with a * by Date Sampled. Values in red were flagged during monthly blind QAQC performance checks with the contracting laboratory. NS = No sample. TP = Total Phosphorus, TDP = Total Dissolved Phosphorus, SRP = Soluble Reactive Phosphorus, TN = Total Nitrogen, NOx = Nitrate/Nitrite, Cl = Chloride, TSS = Total Suspended Solids, VSS = Volatile Suspended Solids, TDS = Total Dissolved Solids, COD = Chemical Oxygen Demand, FOG = Fat Oil and Grease, Cu = Copper, Pb = Lead, Zn = Zinc, DOC = Dissolved Organic Carbon.

Date Sampled	TP mg/L	TDP mg/L	SRP mg/L	TN mg/L	NOx mg/L	Cl mg/L	Hardness mg/L	TSS mg/L	VSS mg/L	TDS mg/L	COD mg/L	FOG mg/L	E. Coli MPN	Cu µg/L	Pb µg/L	Zn µg/L	DOC mg/L
2/28/2022*	1.17	0.09	0.07	5.23	0.14	3699	160	472	250	5875	521	44	97	66	66	460	26
3/8/2022*	0.55	0.21	0.18	4.42	0.51	1300	84	67	29	2043	171	8	84	21	10	116	16
4/5/2022*	0.33	0.06	0.04	2.34	0.41	80	32	79	29	180	103	<5.0	NS	28	24	95	13
5/11/2022	0.70	0.18	0.07	3.61	0.28	6	25	211	79	47	123	NS	NS	35	64	105	7
5/25/2022*	0.42	0.19	0.13	1.54	0.24	10	26	48	36	67	58	<5.0	1935	20	21	103	13
5/25/2022	0.54	0.38	0.10	2.19	0.08	9	30	28	20	85	77	NS	NS	22	7	51	14
6/30/2022	1.21	0.49	0.48	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
7/5/2022	1.41	0.27	0.13	6.17	0.07	25	80	155	74	195	184	NS	NS	NS	NS	NS	NS
7/13/2022	0.78	0.17	0.06	1.36	0.21	7	96	314	116	70	104	NS	NS	36	43	106	14
7/27/2022	1.05	0.41	0.17	4.01	0.54	40	80	73	38	225	184	NS	NS	41	17	85	52
8/3/2022	1.50	0.64	0.07	7.37	0.09	40	108	131	68	273	338	NS	NS	NS	NS	NS	NS
8/6/2022	0.83	0.22	0.13	3.27	0.54	7	40	135	49	110	221	NS	NS	40	41	155	23
8/7/2022	0.34	0.10	0.05	1.07	0.22	3	16	37	17	52	94	NS	NS	20	12	55	6
8/12/2022*	0.17	0.11	0.09	0.98	0.21	2	12	14	8	25	26	<5.0	NS	8	4	34	4
8/12/2022	0.35	0.11	0.09	1.44	0.57	2	18	76	36	45	52	NS	NS	23	19	64	5
8/18/2022	0.69	0.37	0.08	5.57	2.96	9	60	35	21	137	136	NS	NS	17	12	74	34
8/18/2022	0.36	0.11	0.04	1.01	0.98	4	22	94	40	45	94	NS	NS	31	35	98	6
8/19/2022	0.52	0.09	NS	2.41	0.72	5	27	247	86	47	131	NS	NS	36	89	163	4
8/28/2022	0.41	0.19	0.13	2.00	1.10	5	24	115	55.5	52.5	86	NS	NS	18	35	81	8

Table 26-8 (Continued). Powderhorn Inlet W 2022 stormwater statistics. TP = Total Phosphorus, TDP = Total Dissolved Phosphorus, SRP = Soluble Reactive Phosphorus, TN = Total Nitrogen, NOx = Nitrate/Nitrite, Cl = Chloride, TSS = Total Suspended Solids, VSS = Volatile Suspended Solids, TDS = Total Dissolved Solids, COD = Chemical Oxygen Demand, FOG = Fat Oil and Grease, Cu = Copper, Pb = Lead, Zn = Zinc, DOC = Dissolved Organic Carbon.

	TP mg/L	TDP mg/L	SRP mg/L	TN mg/L	NOx mg/L	Cl mg/L	Hardness mg/L	TSS mg/L	VSS mg/L	TDS mg/L	COD mg/L	FOG mg/L	E. Coli MPN	Cu µg/L	Pb µg/L	Zn µg/L	DOC mg/L
GEOMEAN (composite only)	0.677	0.221	0.0992	2.62	0.370	8.33	39.0	99.8	46.1	85.7	125	-	-	27.5	26.1	88.1	11.2
ARITHMETIC MEAN (all samples)	0.702	0.231	0.118	3.11	0.548	292	52	130	58	532	150	12	705.3	29	31	115	15
MAX	1.50	0.638	0.481	7.372	2.961	3699	160	472	250	5875	521	44	1935	66	89	460	52
MIN	0.170	0.057	0.042	0.978	0.069	2	12	14	8	25	26	3	83.9	8	4	34	4
MEDIAN	0.550	0.192	0.092	2.375	0.345	8	31	86	39	77	113	3	97	25	23	97	13
STDEV	0.394	0.157	0.100	1.96	0.673	903	41	117	55	1411	118	18	1065	14	24	98	13
NUMBER	19	19	18	18	18	18	18	18	18	18	18	5	3	16	16	16	16
COV	0.561	0.680	0.847	0.631	1.23	3.09	0.78	0.91	0.95	2.65	0.78	1.53	1.51	0.471	0.78	0.85	0.85

Stormwater Hydrographs

The hydrographs for level and flow measured from May through November at the Powderhorn Inlets N, SE, S, and W are presented in **Figures 26-7** through **Figures 26-10**.

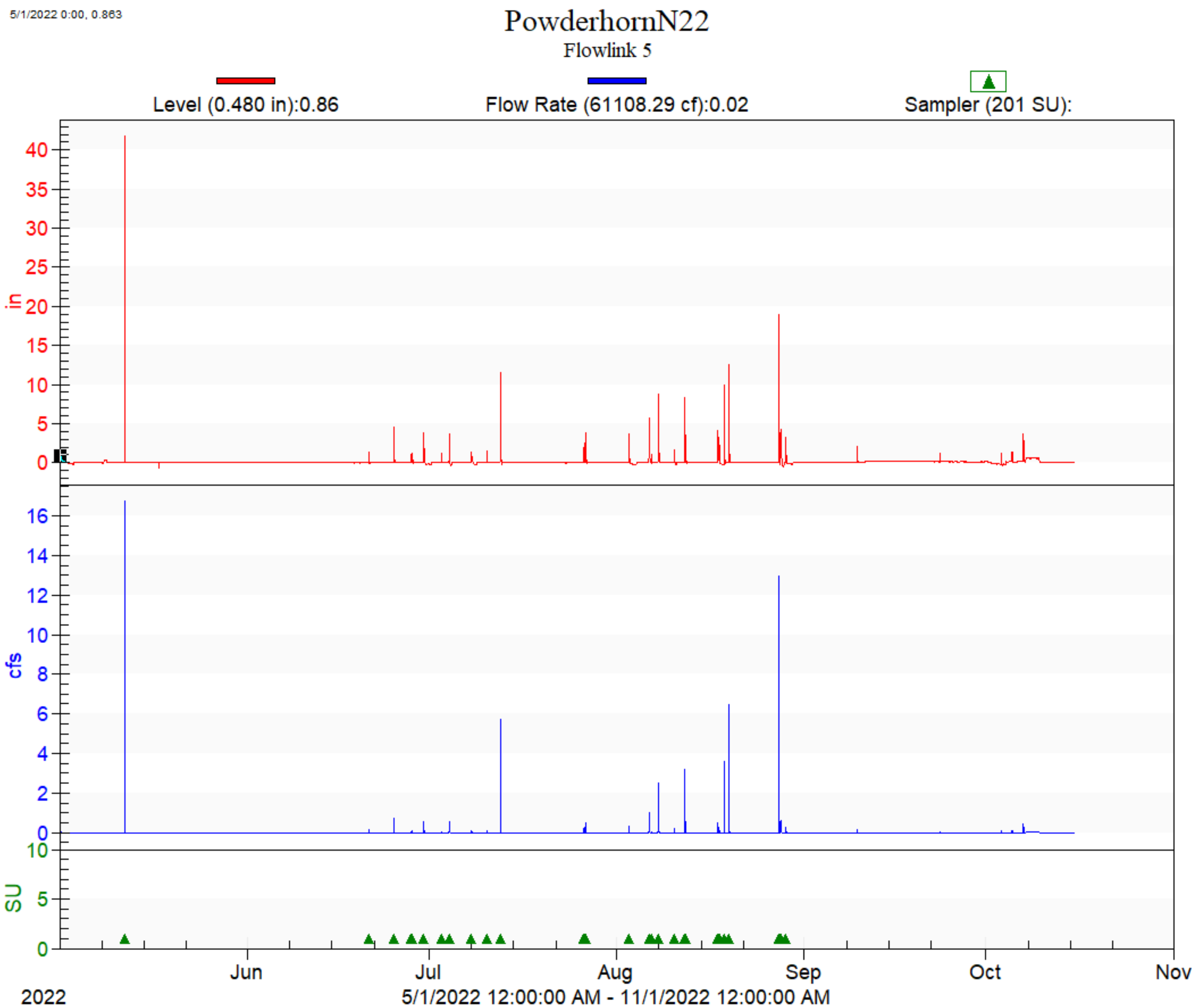


Figure 26-7. Powderhorn Inlet N hydrograph of level and flow from April 29 to October 27, 2022. Green triangles represent when the auto-sampler attempted to take a sample.

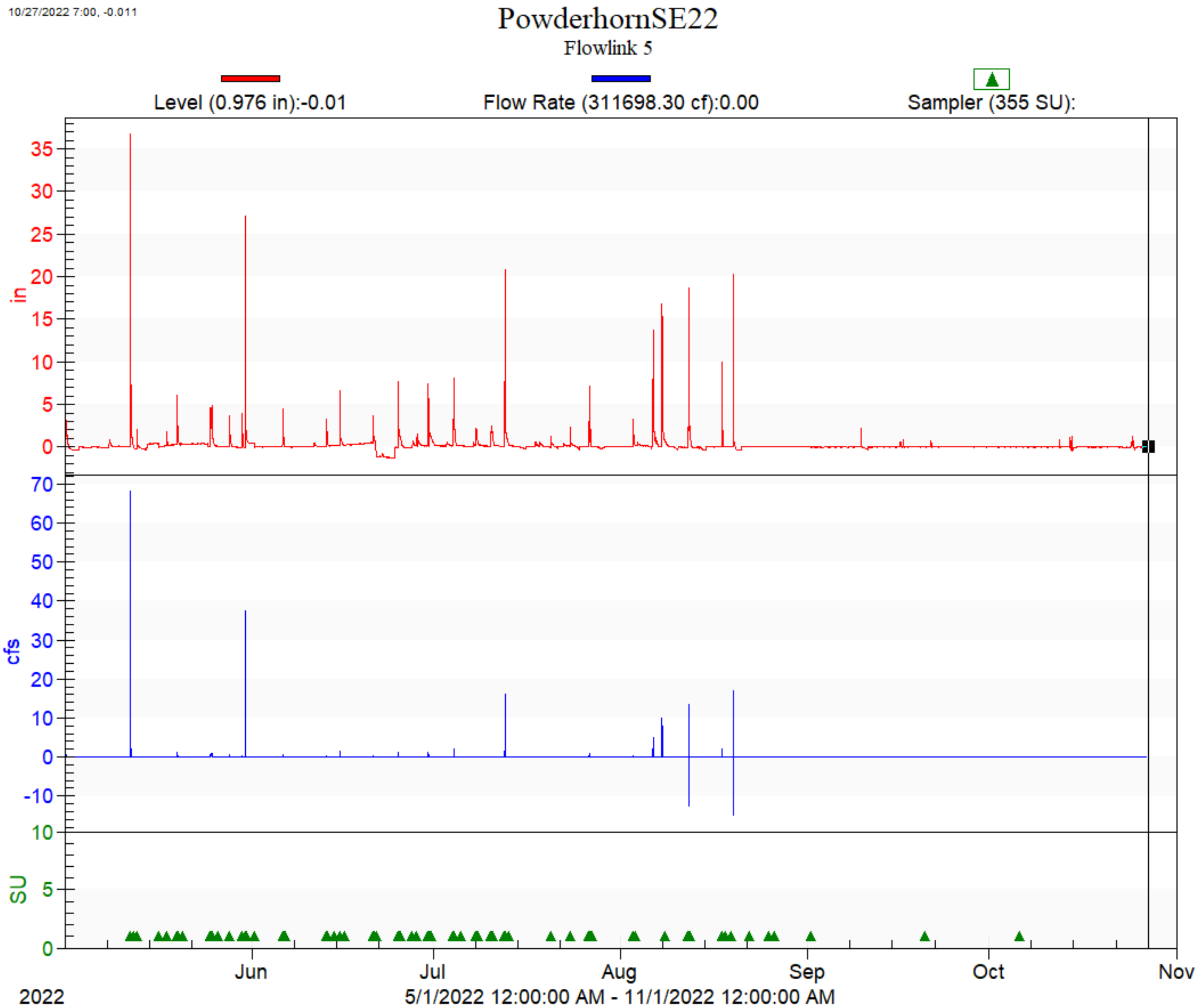


Figure 26-8. Powderhorn Inlet SE hydrograph of level and flow from April 27 to October 27, 2022. Green triangles represent when the auto-sampler attempted to take a sample.

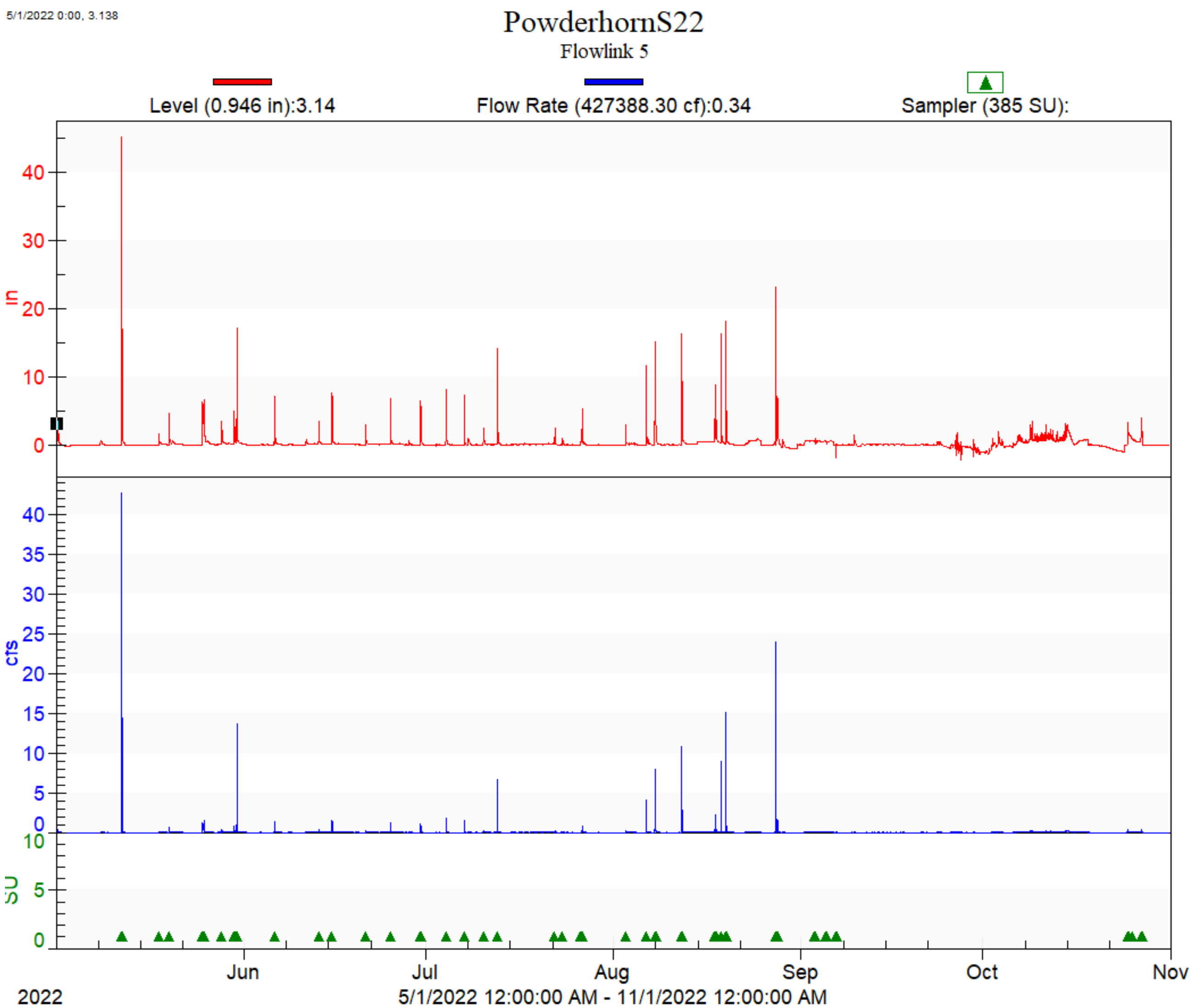


Figure 26-9. Powderhorn Inlet S hydrograph of level and flow from April 29 to October 27, 2022. Green triangles represent when the auto-sampler attempted to take a sample.

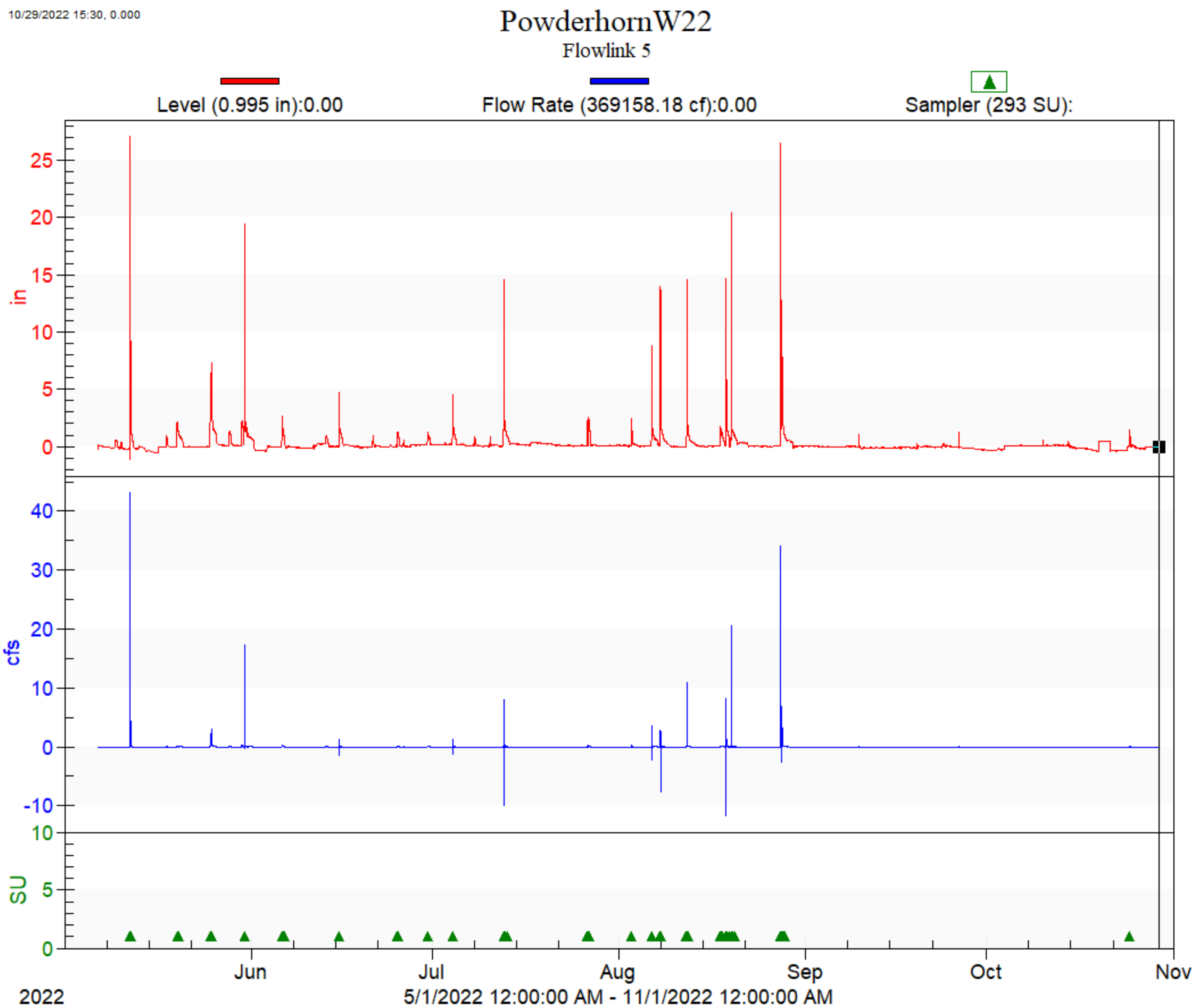


Figure 26-10. Powderhorn Inlet W hydrograph of level and flow from May 6 to October 27, 2022. Green triangles represent when the auto-sampler attempted to take a sample.

Table 26-9. Composite sampling storm events and corresponding flow data from each monitoring site. NS = no sample. Precipitation data was measured at the Minneapolis-St. Paul International Airport (MSP). Flow data was estimated using the hydrographs generated by the auto-samplers, see Figures 26-7 to 26-10.

Rain Event Date	Duration (hours)	Precip. (inches)	Pow In N (cf)	Pow In SE (cf)	Pow In S (cf)	Pow In W (cf)
5/11/2022	2.75	1.23	4150	100968	90305	99987
5/25/2022	13.8	0.6	NS	14662	28726	44043
5/30/2022	2.75	0.62	NS	35476	29647	NS
6/30/2022	3.50	0.07	714	2968	2665	1479
7/5/2022	4.25	0.24	NS	9171	6090	1578
7/7/2022	7.75	0.09	NS	NS	1020	NS
7/10/2022	4.00	0.11	522	NS	931	NS
7/12/2022	9.25	0.38	7406	18210	12828	14729
7/26/2022	6.25	0.16	2637	NS	3009	5129
8/3/2022	1.50	0.02	1277	NS	908	1979
8/6/2022	12.0	0.58	6136	NS	16451	1339
8/7/2022	3.50	0.78	8558	NS	36469	3559
8/12/2022	3.75	0.84	13333	30261	34725	37935
8/17/2022	7.50	0.14	4376	5192	NS	NS
8/18/2022	2.00	0.25	NS	NS	11976	10781
8/19/2022	6.75	0.34	8697	NS	15143	25637
8/28/2022	0.250	0.02	5404	NS	10770	17298
8/29/2022	1.00	0.01	955	NS	NS	NS

Load calculations using the geometric mean for each chemical parameter at each site are shown in **Table 26-10** and **Table 26-11**. Loads were calculated in pounds for each site by multiplying the geometric mean for each parameter by the liters of flow and a conversion factor.

It should be noted that while these load inputs are measured data, the flow-weighted samples were only collected from May through October, and the snowmelt samples were grab samples. The flow-weighted sample measurement period had approximately 10.39 inches of precipitation, while the yearly total was 22.97 inches. In 2022, Minneapolis received significantly less precipitation than the 29-year annual average precipitation of 31.62 inches (NWS/NOAA). See **Chapter 29** for more information on climate.

Table 26-10. The 2022 flow totals and load calculations for Powderhorn Inlets N, S, SE, and W. Orange highlights indicate the largest load for a parameter.

Site Name	Pow Inlet N	Pow Inlet S	Pow Inlet SE	Pow Inlet W
Total Flow (L)	3,343,213	13,185,230	11,936,967	10,450,247
TP (lb)	5.46	25.9	21.1	15.6
TDP (lb)	2.22	7.77	6.46	5.10
SRP (lb)	1.21	3.77	2.60	2.28
TN (lb)	24.3	85.6	83.2	60.3
NOx (lb)	2.55	8.49	3.07	8.52
Cl (lb)	60.1	299	145	192
Hardness (lb)	237	1201	969	900
TSS (lb)	502	2478	2137	2299
VSS (lb)	312	1602	1865	1063
TDS (lb)	435	2863	2201	1976
COD (lb)	967	4243	4013	2874
Cu (lb)	0.218	0.869	0.790	0.633
Pb (lb)	0.137	0.841	0.658	0.602
Zn (lb)	0.859	3.07	2.80	2.03
DOC (lb)	93.8	389	372	257

Table 26-11. The 2022 load per area calculations for Powderhorn Inlets N, S, SE, and W. Green highlights indicate the largest load/acre for a parameter.

Site	Pow Inlet N	Pow Inlet S	Pow Inlet SE	Pow Inlet W
Acreage	12.91	81.17	70.0	99.39
TP (lb/acre)	0.423	0.319	0.301	0.157
TDP (lb/acre)	0.172	0.096	0.092	0.051
SRP (lb/acre)	0.093	0.046	0.037	0.023
TN (lb/acre)	1.88	1.05	1.19	0.606
NOx (lb/acre)	0.197	0.105	0.044	0.086
Cl (lb/acre)	4.66	3.69	2.07	1.93
Hardness (lb/acre)	18.4	14.8	13.8	9.05
TSS (lb/acre)	38.9	30.5	30.5	23.1
VSS (lb/acre)	24.2	19.7	26.6	10.7
TDS (lb/acre)	33.7	35.3	31.4	19.9
COD (lb/acre)	74.9	52.3	57.3	28.9
Cu (lb/acre)	0.0169	0.0107	0.0113	0.0064
Pb (lb/acre)	0.0106	0.0104	0.00940	0.00606
Zn (lb/acre)	0.0666	0.0378	0.0400	0.0204
DOC (lb/acre)	7.26	4.79	5.32	2.59

DISCUSSION

Pollutant Load Calculations

The largest overall external load to Powderhorn Lake appears to be coming from Powderhorn Inlet S, which drains an area of 81.17 acres. This watershed produced the largest overall load for the following chemical parameters:

- TP
- TDP
- SRP
- TN
- Cl
- Hardness
- TSS
- TDS
- COD
- Cu
- Pb
- Zn
- DOC

When breaking down the load calculations into load per acre, the Powderhorn Inlet N site (12.91 acres) had the highest load per acre for all chemical parameters except VSS and TDS. This may be in part due to equipment issues that prevented flow from being recorded at the end of the monitoring season, which inflated these numbers. The largest watershed is Powderhorn Inlet W (99.4 acres), which registered some of the lowest numbers out of all sites for both loads and load/acre in most parameters. Powderhorn Inlet W did record the highest load for NOx, but when taking its size into account this was not notable. Powderhorn Inlet SE (68.75 acres) had similar loads as Powderhorn Inlet S, though slightly lower, and had the highest load and load/acre for VSS.

Powderhorn Inlets S and SE should be a high priority in reducing external loading to Powderhorn Lake. It is unclear why these mostly residential watersheds would be producing such a large external load, but the effects of this nutrient loading on Powderhorn Lake are apparent. The lake was frequently covered by HABs during 2022 to the point of disrupting recreation activities due to high levels of cyanotoxins in the water, **Figure 26-11**. See **Chapter 13** for more information on Powderhorn Lake and **Chapter 19** for more information on harmful algae blooms.

Figure 26-11. A blue green algae bloom at Powderhorn Lake during the summer of 2022. The inlet pictured on the left connects directly to the SE Inlet stormwater monitoring site.

Monitoring Challenges

The 2022 stormwater monitoring season posed several challenges. Primarily, the lack of significant precipitation events prevented staff from collecting as many storm samples as intended. Minneapolis received 8.65 fewer inches of precipitation this year compared to the 29-year normal, according to NOAA, and 3 inches fewer than in 2021. Much of the rainfall during the monitoring season came in the form of small, short-lived spurts of precipitation, and did not amount to enough flow to trigger the auto samplers. This was especially true during the final months of the monitoring season when, according to the United States Drought Monitor (USDM), the Twin Cities area was in a severe drought. The timing of the storms also posed some difficulties, as many significant precipitation events occurred outside of the workday or over the weekend, hindering staff's ability to collect samples in a timely manner. Several important chemical parameters have limited holding times and were not able to be analyzed after more than 48 hours had passed.

In addition to climatological challenges, equipment failures and environmental factors also affected the stormwater monitoring practices. Two of the Powderhorn sites needed an area velocity probe replaced, twice at Powderhorn N and three times at Powderhorn SE, due to damage done by storms or animals. The N and SE Inlets had problems with animals chewing on cables and knocking over antennas. The N and W Inlets had equipment washed away during large early-season storm events. In the future, more steps will be taken to protect equipment from these influences, such as plugging holes in sampling boxes with steel wool to deter rodents.

CDS Unit Functionality

The CDS units around Powderhorn Lake have been malfunctioning due to significant clogging and sediment deposition in the upstream pipes and within the units themselves. When the units clog, they become anoxic and solids break down into smaller-sized or dissolved material which then exits through the CDS screens during the next storm event. A clogged CDS unit provides minimal treatment since water will bypass the unit entirely when it cannot exit through the screen. The City of Minneapolis has observed that the external side of the CDS screens can become clogged, but there are no access ports to easily clean them. City of Minneapolis staff are exploring options that will allow for access and cleaning of the external screens to ensure CDS functionality.

In 2022, individual CDS unit inlet/outlet efficacy was not evaluated. In the short-term, to reduce the external load to Powderhorn Lake, the CDS units should be retrofit to allow for thorough cleaning and more frequent maintenance. Future monitoring of individual CDS unit inlet/outlet and any bypass may be needed to determine if the units are working effectively and to determine an appropriate maintenance schedule. Due to higher amounts of overall loading coming from the S and SE drainage areas, these could be designated priority watersheds for enhanced street sweeping and public educational activities or other best management practice installations.

CONCLUSIONS

Pollutant loads to Powderhorn Lake were calculated using data collected during the monitoring season.

- Load calculations were completed for each Powderhorn Lake watershed monitored and key contributors were identified as the S and SE watersheds. This information can be used to assist in any future external load reduction plans.
- Powderhorn Inlets S and SE were the watershed that had the highest loading per acre and the highest loading based on total flow. Both watersheds registered higher levels of TP compared to the others.

CDS unit functionality was assessed and findings were consistent with previous years of the study.

- CDS units at Powderhorn Lake are often clogged with debris and unable to function as designed.
- Units are effective at filtering stormwater until their external screens clog, allowing stormwater to bypass the units and proceed downstream with minimal treatment.
- Units should be retrofitted to have maintenance access ports for cleaning of the external screens or replaced with a different design that does not have issues with clogging.
- CDS units 84 and 86 should be the priority to decrease loading to Powderhorn Lake.

Monitoring challenges mainly included equipment failures from natural causes and a limiting amount of precipitation.

- The Twin Cities area was in a drought for most of the monitoring season, limiting the number of stormwater samples collected.

- Multiple sites had equipment failures and needed replacement during the monitoring season. The damage to the sites was mainly from rodents chewing cables and large storms ripping equipment off of their anchors.

Most NPDES Permit provisions for stormwater monitoring were met in 2022.

- All monitoring for the NPDES permit as it applied to this project was attempted to be completed, see **Table 26-12**. Flow monitoring was completed starting between April 27 and May 6 and ending on October 27.
- At least ten flow-weighted composite storms were collected and analyzed for NPDES chemistry for Inlets N, S, and W. Only eight samples were collected at Inlet SE due to multiple equipment failures throughout the monitoring season.
- Quarterly grab samples were taken and analyzed for NPDES chemistry, FOG, and *E. coli* at all sites except Powderhorn Inlet N, which was deemed inaccessible for grab sampling in 2021.

Table 26-12. Summary of stormwater sampling at Powderhorn Lake in 2022.

Site Name	Powderhorn Inlet N	Powderhorn Inlet S	Powderhorn Inlet SE	Powderhorn Inlet W
# Of grab samples	-	5	5	5
# Of composite samples	14	17	8	14

27. Hoyer and Windom Green Stormwater Infrastructure (GSI) Monitoring

Background

The purpose of the Hoyer and Windom Green Stormwater Infrastructure (GSI) monitoring is to better understand how effective these structures are at flood control and reducing the impacts of stormwater runoff. A secondary goal is to assess the performance of different GSI site designs in natural conditions and use that information to enhance future designs. Due to an ordinance change, the City of Minneapolis is building numerous small-footprint infiltration/filtration basins throughout the city. Many of these GSI Best Management Practices (BMPs) treat less than 1 acre of impervious surface. The City of Minneapolis chose two GSI sites to be monitored 2022, Hoyer and Windom. This was the second year this project was conducted.

This project is a partnership between the City of Minneapolis, Saint Anthony Falls Hydrology Laboratory (SAFL) at the University of Minnesota, the Mississippi Watershed Management Organization (MWMO), and the Minneapolis Park and Recreation Board (MPRB). The funding, survey, and GIS data used in the project were supplied by the City of Minneapolis. Monitoring of rainfall, flow, infiltration tests, and flood functionality tests were the responsibility of both the City and SAFL. Public outreach and education were the responsibility of MWMO. Confined space entry, soil sampling/testing, and monthly observational field inspection data were the responsibility of the MPRB.

The Hoyer GSI site is in Northeast Minneapolis and includes three different basins located in the same neighborhood, shown in **Figure 27-1**. They drain approximately 0.072 acres of a residential watershed, of which 0.0407 acres are impervious, and were designed primarily for flood control. Hoyer A is at the southeast corner of 36 ½ Avenue NE and Fillmore Street NE and has been monitored since 2021. Two additional sites were added to the project in 2022: Hoyer B at the northwest corner of that same intersection, and Hoyer C on the southeast corner of 36 ½ Avenue NE and Buchanan Street SE. All sites had underdrain caps and boots installed on July 19th, 2022. Each site has a brick-filtered splash pad pretreatment basin and an overflow inlet.

Figure 27-1. The Hoyer A (1), B (2), and C (3) GSI basins in the summer of 2022 , and site locations shown in map view (4).

The Windom GSI site, shown in **Figure 27-2,** is in Southwest Minneapolis on the block of West 62nd Street and Dupont Avenue South. It drains approximately 3.67 acres of a residential watershed, of which 0.506 acres are impervious. The Windom site has a capped underdrain and was designed for stormwater infiltration. The site includes five Rain Guardian Bunker pretreatment basins along a main bioretention channel.

Figure 27-2. The Windom GSI basin in fall of 2022 in southwest Minneapolis. A Rain Guardian Bunker pretreatment basin filled with leaves can be seen in the lower left corner.

METHODS

Equipment Setup

Nova Lynx tipping bucket rain gauges were installed at Hoyer A and Windom with HOBO Pendant dataloggers, shown in **Figure 27-3**. HOBO MX2001-01-SS water level loggers were installed at the surface grade of both sites to determine ponding drawdown time as seen in **Figure 27-4**. One HOBO MX2001-04-SS water level logger was installed in the underdrain behind a spring ring V-notch weir at Hoyer A, shown in **Figure 27-5**. A HOBO water level logger was not installed in the Windom underdrain in 2022, but it may be installed in 2023. Hoyer and Windom each had HOBO surface level and rain gauge equipment installed on September 30th, 2021.

Figure 27-3. A rain gauge being installed at the Hoyer GSI site.

Figure 27-4. A surface HOBO water level logger being installed at the Windom GSI site.

Infiltration Testing

The sites were flooded using a truck full of non-potable water to discharge a known volume into the GSI curb-cut inlet. The purpose of the infiltration test was to flood the GSI basin and measure: 1) the time it took for saturation and ponding to occur, and 2) the time it took for any ponding to draw down to the surface. The intention was to first simulate a 1-inch design storm and see if there was ponding or infiltration in the GSI. Then, additional water was added to test the limits of the BMP by inundating it beyond its design capacity and observe the effects. A flood/hydrant test was conducted at Hoyer A and C on October 4th, 2022, shown in **Figure 27-5**.

Figure 27-5. A flood test on 10/4/2022 at Hoyer A. Sandbags were used to direct flow into the grate.

During the Hoyer flood test, it was noticed that the underdrain discharge water was brown and darker compared to the clear inlet water. It was assumed the coloration was due to the compost added to the Hoyer GSI. During flood testing in 2021, similar results were observed. Because of this observation, grab samples were collected from both the inlet and the underdrain outlet, shown in **Figure 27-6.** National Pollutant Discharge Elimination System (NPDES) water chemistry parameters were analyzed for both the inlet and outlet samples to determine how the GSI was contributing nutrients/pollutants to runoff.

Figure 27-6. Samples of the clear inlet water, right, and colored underdrain outlet water, left, during the Hoyer GSI flood/hydrant test on October 4th, 2022.

Soil Sampling

Soil samples were collected on July 12th, 2022, at both Hoyer and Windom. The soil samples were collected from three predetermined sub-sample locations at the bottom of each basin and composited, shown in **Figure 27-7**. The sampling protocol was: 1) surface debris was cleared, 2) a 4-inch diameter hole was dug 6 inches of depth, and 3) soil samples were collected with a trowel. Three sub-samples were combined into one Ziplock bag constituting one composite sample. The Ziplock bags were labeled with the site name and the date collected. Soil samples were analyzed by the University of Minnesota Soil Lab.

The GSI soil chemistry tests performed at the University of Minnesota Soils Laboratory were:

- Phosphorus (Bray P)
- Loss on ignition – organic matter % (LOI OM)
- Total nitrogen %
- Chloride
- Total solids moisture %
- Total solids %
- Elemental metals, shown in **Table 27-4**

Figure 27-7. A soil sub-sample being collected by MPRB staff at the Hoyer A GSI site.

Field Observations

Monthly field observations and measurements were taken at each GSI site as shown in **Table 27-1**. Photos of each pretreatment basin and infiltration basin were also taken monthly.

Table 27-1. Field observational data collected monthly at each GSI site.

Parameter	Metric				
Weather Conditions	Wind Direction	Wind Speed	Air Temperature	% Cloud Cover	
Plant Health	% Alive	% Stressed	% Dead		
Inlet Conditions	Photograph	% Pretreatment Basin Filled	Sediment Material Inches	Sediment Material Makeup	Evidence of Erosion After Pretreatment
General GSI Conditions	Signs of Inlet Bypass	Signs of Ponding	Soil Sample Collected		

RESULTS

Pretreatment Basin Design

MPRB collected observations and photographs monthly, as detailed in **Table 27-1**. This data allowed the functionality of the pretreatment basins to be determined. The purpose of a pretreatment basin is to filter out particulates and lower the energy level of incoming stormwater before it enters the infiltration basin. Windom and Hoyer GSI each employed a different pretreatment basin design, shown in **Figure 27-8**.

Figure 27-8. (1) A pretreatment basin at Windom GSI. (2) A pretreatment basin at Hoyer GSI.

Windom employs a Rain Guardian Bunker style of pretreatment basin. There is a top grate intended to filter large detritus before stormwater enters the lower chamber. There, smaller particulates are meant to settle out of suspension before passing through another grate and exiting the pretreatment system onto a concrete splash pad. The top grate can be removed for cleaning the interior. These systems worked fairly well in 2022, though after instances of heavy rainfall the top grate became clogged with leafy debris and sediment, as shown in **Figure 27-9**. This suggests that more frequent cleaning may be necessary to ensure the functionality of this type of pretreatment basin. The basins are not adjacent to private property so this task would be the responsibility of the City of Minneapolis.

Figure 27-9. (1) A Windom pretreatment basin clogged with leaves in October 2022. (2) A Windom pretreatment basin clogged with sediment, soil, and leaves in June 2022.

Hoyer employs a type of pretreatment basin design that utilizes two rows of bricks with small gaps between them to filter out debris/sediment and decrease water energy, see **Figure 27-10**. The bricks are organized in arcs and attached to a concrete splash pad, which empties into an infiltration basin lined with plants and trees. This design proved to be moderately effective at filtering out sediment and debris but struggled more with erosion than the Windom design. The sites were not built exactly to specifications due to communication errors between the contractors and engineers, so spacing between bricks was variable. This resulted in either sediment clogging the gaps and allowing water to bypass the pretreatment basin or water flowing around the inlet and not being filtered at all, depending on if the gaps were too small or too large.

Hoyer B had a large gap between both rows of bricks on the left side of the pretreatment basin. This allowed water to slip straight through without dropping much of its sediment load or losing energy, resulting in a deep channel eroding into the infiltration basin. Hoyer C had the opposite problem. There, the bricks have little to no space between them, causing sediment to build up to the point of water flowing over the bricks. This caused significant erosion in the area immediately beyond the pretreatment basin, including erosion underneath the splash pad itself. If this level of erosion continues, structural issues may result. One positive note about these designs is the ease of cleaning. There is no grate to remove, and debris can be vacuumed or swept away easily without specialized equipment. These basins are located adjacent to private property and will primarily be maintained by homeowners, which likely influenced the selection of this design.

Figure 27-10. (1) The pretreatment basin at Hoyer B showing how large gaps allowed water to travel straight into the infiltration basin. (2) The pretreatment basin at Hoyer C showing how sediment build up allowed water to bypass filtration. Blue arrows show the path of water flow, which was determined by the distribution of sediment and erosion in the basins.

Hoyer Water Chemistry

The water chemistry results from the 2022 Hoyer flood test are shown in **Table 27-2a** and **27-2b**. The inlet samples were taken directly from the discharge end of the water truck that contained non-potable water. The outlet samples were taken from a boot in the stormsewer where the capped underdrain outlets to the stormsewer. Outlet sample concentrations were higher than inlet sample concentrations for all parameters except ammonia. *Escherichia coli* (*E. coli*) levels increased significantly at Hoyer A but did not change at Hoyer C. Concentrations of critical nutrients like nitrogen and phosphorus increased after passing through the GSI filters, indicating that material from the overlaying media may be leaching into the stormsewer. GSI sites are no longer constructed with this kind of bioretention media due to this issue.

Table 27-2a. Water chemistry data from the Hoyer A flood/hydrant test on 10/4/22.

Parameter	Units	Hoyer A In	Hoyer A Out	Percent Increase/Decrease
Chemical Oxygen Demand	mg/L	<15	127	1593%
E. Coli	MPN/100mL	<1	387	77300%
Hardness	mg/L CaCO3	83	129	55%
Ammonia	mg/L	0.48	<0.06	-94%
Nitrate/Nitrite	mg/L	0.70	3.15	350%
Total Kjeldahl Nitrogen	mg/L	0.60	3.60	500%
Total Phosphorus	mg/L	0.25	1.66	564%
Soluble Reactive Phosphorus	mg/L	0.16	1.27	689%
Sulfate	mg/L	23.4	31.7	35%
Total Dissolved Solids	mg/L	156	388	149%
Total Suspended Solids	mg/L	<3	172	11367%
Volatile Suspended Solids	mg/L	<3	22	1367%

Table 27-2b. Water chemistry data from the Hoyer C flood/hydrant test on 10/4/22.

Parameter	Units	Hoyer C In	Hoyer C Out	Percent Increase/Decrease
Chemical Oxygen Demand	mg/L	<15	120	1500%
E. Coli	MPN/100mL	<1	<1	0%
Hardness	mg/L CaCO3	92	167	82%
Ammonia	mg/L	0.51	0.16	-69%
Nitrate/Nitrite	mg/L	0.75	4.18	457%
Total Kjeldahl Nitrogen	mg/L	0.66	1.80	173%
Total Phosphorus	mg/L	0.24	1.31	455%
Soluble Reactive Phosphorus	mg/L	0.15	0.78	404%
Sulfate	mg/L	23.4	27.3	17%
Total Dissolved Solids	mg/L	159	284	79%
Total Suspended Solids	mg/L	<3	429	28500%
Volatile Suspended Solids	mg/L	<3	23	1433%

GSI Soil Sample Chemistry

Soil elemental chemistry data were collected monthly in 2021 to create a baseline dataset for each site and have been averaged in the following data tables. In 2022 soil samples were collected only once at each site on 7/12/2022. As more stormwater infiltrates, it would be expected that soil chemistry may change. **Table 27-3** shows the GSI baseline soil sample results for phosphorus, nitrogen, chloride, percent solids, and organic matter compared with data from 2022. **Table 27-4** shows a list of the elemental chemistry components analyzed at the University of Minnesota Soils lab. **Table 27-5a and b** shows the elemental chemistry of the GSI soil samples.

The baseline soil tests in 2021 showed the Hoyer A and Windom site's soils were similar, but had differences in nitrogen, organic matter, total solids moisture, total solids moisture %, and total solids content. In 2022, Hoyer A decreased in moisture percent, but increased in Bray P, LOI OM, chloride, total nitrogen, and percent solids. Windom decreased in Bray P, chloride, and percent solids, but increased in LOI OM, total nitrogen, and percent moisture. Hoyer B and C were not part of the study in 2021 so there is no data to compare them to. This year, Hoyer sites had higher Bray P, LOI OM, chloride, and soil moisture than Windom, which had higher total nitrogen and percent solids.

Elemental chemistry results for Windom show increasing concentrations in all elements except Ca, Cr, Mg, Mn, and P, while all concentrations increased for Hoyer A, compared to 2021. Windom had higher Al, As, Co, Pb, and V than the Hoyer sites in 2022. Hoyer sites had higher B, Ba, Ca, Cd, Cu, K, Li, Mg, Mn, Mo, Na, P, S, Si, Sr, and Zn than Windom. Both sites had similar levels of Be, Cr, Fe, Ni, Rb, and Ti.

Table 27-3. The soil test data from each of the GSI sites in 2021 and 2022. LOI OM = Loss on ignition - organic matter. Data from 2021 are averages from data collected over 3 months.

		Bray P	LOI OM	Chloride	Total Nitrogen	Total Solids	
		(mg/kg soil)	(%)	(mg/kg soil)	(% N)	Moisture (%)	Solids (%)
2021	**Hoyer A**	49.0	2.05	11.6	0.118	16.95	85.1
	Windom	48.3	1.40	9.80	0.087	6.800	93.2
2022	**Hoyer A**	71.4	4.48	14.2	0.154	10.75	89.1
	Hoyer B	60.6	3.24	13.4	0.122	12.22	87.8
	Hoyer C	65.4	3.62	12.9	0.194	11.38	88.6
	Windom	36.8	2.44	7.27	0.646	7.927	92.1

Table 27-4. List of the GSI soil chemistry element symbols and element names analyzed at the University of Minnesota Soils Laboratory.

SYMBOL	ELEMENT
Al	Aluminum
As	Arsenic
B	Boron
Ba	Barium
Be	Beryllium
Ca	Calcium
Cd	Cadmium
Co	Cobalt
Cr	Chromium
Cu	Copper
Fe	Iron
K	Potassium
Li	Lithium
Mg	Magnesium
Mn	Manganese
Mo	Molybdenum
Na	Sodium
Ni	Nickel
P	Phosphorus
Pb	Lead
Rb	Rubidium
S	Sulfur
Si	Silicon
Sr	Strontium
Ti	Titanium
V	Vanadium
Zn	Zinc

Table 27-5a. GSI soil elemental chemistry data from 2021 and 2022. MDL = minimum detection limit. The Limit of Detection (LOD), a batchwise instrument detection limit, is expressed in units of mg/L solution independent of dilution factors used to calculate sample concentrations.

Date	Site	Al mg/kg	As mg/kg	B mg/kg	Ba mg/kg	Be mg/kg	Ca mg/kg	Cd mg/kg	Co mg/kg	Cr mg/kg	Cu mg/kg	Fe mg/kg	K mg/kg	Li mg/kg
MDL		0.061	0.011	0.033	0.001	0.000	0.226	0.001	0.001	0.001	0.005	0.032	0.353	0.001
LOD		0.007	0.005	0.002	0.001	0.001	0.156	0.001	0.001	0.001	0.008	0.006	0.021	0.001
2021	Windom	2484	<0.013	<0.001	25.6	<0.001	10075	<0.001	3.50	7.98	7.92	7945	352.3	3.62
	Hoyer A	2024	<0.013	<0.001	22.7	<0.001	29022	<0.001	2.35	5.85	5.53	6823	344.5	3.06
2022	Windom	2839	3.95	4.37	36.6	0.130	7979	0.095	3.60	7.46	8.04	8372	379.6	3.69
	Hoyer A	2393	1.74	7.84	36.2	0.140	30309	0.110	2.95	8.03	9.03	8101	565.7	4.04
	Hoyer B	2269	1.93	5.96	30.9	0.100	31573	0.078	2.86	6.83	11.7	7511	462.9	4.00
	Hoyer C	2619	3.30	6.15	40.5	0.120	28141	0.140	3.22	7.54	9.04	9705	499.0	4.06

Table 27-5b. GSI soil elemental chemistry data from 2021 and 2022. MDL = minimum detection limit. The Limit of Detection (LOD), a batchwise instrument detection limit, is expressed in units of mg/L solution independent of dilution factors used to calculate sample concentrations.

Date	Site	Mg mg/kg	Mn mg/kg	Mo mg/kg	Na mg/kg	Ni mg/kg	P mg/kg	Pb mg/kg	Rb mg/kg	S mg/kg	Si mg/kg	Sr mg/kg	Ti mg/kg	V mg/kg	Zn mg/kg
MDL		0.068	0.009	0.001	0.054	0.008	0.023	0.009	0.073	0.020	0.137	0.001	0.005	0.011	0.028
LOD		0.004	0.016	0.001	0.008	0.006	0.018	0.005	0.062	0.012	0.024	0.001	0.004	0.021	0.004
2021	Windom	4018	252.3	<0.001	61.7	8.46	338.3	5.27	1.39	277.0	585.7	9.21	128.3	11.5	15.6
	Hoyer	8069	198.5	<0.001	82.9	5.35	397.0	3.98	1.18	600.0	742.5	18.8	104.5	9.28	13.5
2022	Windom	2858	242.3	0.160	66.4	8.75	326.5	10.2	15.6	301.6	877.2	9.59	129.2	13.9	24.4
	Hoyer A	9299	254.0	0.210	154.1	8.42	435.6	4.95	3.75	684.6	1336	22.1	141.4	9.75	35.1
	Hoyer B	10202	250.7	0.330	78.8	6.98	439.8	5.18	13.2	651.6	1240	18.9	134.2	9.60	25.4
	Hoyer C	8567	321.0	0.170	69.3	8.27	442.7	9.46	15.7	673.0	1313	18.9	128.2	11.8	29.1

Maintenance Activity

Site maintenance, including basin watering and grate cleaning, was performed by a contractor at each GSI site in 2022. **Figure 27-11** shows a water truck at Hoyer A watering the infiltration basin. These activities were done only a few times in 2022 to help ensure vegetation health and keep the site aesthetically pleasing. This level of maintenance mostly preserved natural conditions, whereas in 2021 sites were maintained much more frequently. Starting in the fall of 2022, these sites were no longer under the warranty of the contractors and upkeep is now the responsibility of homeowners with adjacent property. MWMO will help conduct education and outreach to help residents learn how to monitor and care for the basins. The City of Minneapolis will continue to inspect the basins once or twice per year and perform cleaning and repairs as needed.

Figure 27-11. The Hoyer A GSI site being watered by a subcontractor during the summer of 2021.

CONCLUSION

In 2022, the MPRB monitored pretreatment basin functionality, analyzed infiltration testing data, performed soil sampling, and assessed future maintenance needs. Information was gathered regarding the efficacy of two types of pretreatment basins and how they may need improvements in design or maintenance. These design practices have already been implemented with newly constructed GSI. Further monitoring at the GSI will be important to better determine the effects of GSI sites on stormwater quality over time.

The Hoyer GSI sites were built for flood control and originally had open underdrains connecting them to the stormsewer. Results from grab sampling during the flood test show that the basins were exporting nutrients rather than retaining them. The underdrains were capped in 2022 which allowed water to infiltrate into the native soil below the bioretention media rather than entering the stormsewer and carry nutrients downstream. Data from this study helped determine that low-nutrient materials should be used in the infiltration basin to reduce water quality impacts downstream, when dealing with uncapped underdrains.

Baseline soils data was collected in 2021 and comparisons were made with data from 2022. This data is important to assess how the sites are infiltrating stormwater, identify which contaminants are washing in from the street, and determine if pollutants are accumulating in the infiltration media. Contaminants/nutrients like chloride, phosphorus, nitrogen, and lead are of particular interest due to their association with negative environmental and human impacts. Additional years of data will provide more information about nutrient transference and if there are pollutants building up at the soil surface.

The functionality of the inlets and vegetation could be better ascertained due to the preservation of more natural conditions in 2022. In 2021, the sites were frequently watered and cleaned, so natural conditions were not preserved. Notably, the late summer and fall of 2022 had few significant precipitation events, which hindered this study. More information about the site's functionality will be determined during average and high precipitation years and when maintenance practices are more normal. In the case of Hoyer, the MPRB recommends the development of a survey that homeowners can fill out to report their maintenance activities. This information will be important to keep track of to determine the true conditions of the study. Homeowners could report on aspects such as frequency of watering and sweeping/vacuuming, take photos of the inlets, and include any other observations they deem important. This would also be a great way to get the public engaged and curious about green stormwater infrastructure.

Detailed analysis of flood test data, infiltration tests, and monitoring data will be provided by SAFL in a future report.

28. Golf Course Wetland Monitoring

Background

The Audubon Cooperative Sanctuary Program (ACSP) for Golf is an education and certification program that contains tools that can help golf courses protect the environment and preserve natural areas: https://auduboninternational.org/acsp/. The program can guide golf courses in their desire to enhance natural areas that provide wildlife habitat. Audubon International provides both a Site Assessment and Environmental Planning Form as guidance for certification. The areas used for the certification process are:

- Environmental Planning
- Wildlife and Habitat Management
- Chemical Use Reduction and Safety
- Water Conservation
- Water Quality Management
- Outreach and Education

To fulfil the Water Quality Management portion of the ACSP for Golf certification, Environmental Management assists the Minneapolis Park and Recreation Board (MPRB) golf courses in collecting water and vegetation data. Theodore Wirth and Meadowbrook Golf Courses have requested annual monitoring since 2001. Columbia, Hiawatha, and Gross Golf Courses have included environmental monitoring in their programs since 2009. The data and reports derived from this monitoring is shared with each golf course annually to integrate into their final certification application. Additionally, the data is shared with the goal of implementing improvements to plant diversity and water quality, which leads to improved land/water stewardship.

Golf course foremen assisted Water Resources staff in choosing representative water bodies on each MPRB course. A visual survey of terrestrial, wetland, and aquatic vegetation was conducted at each sample site. The ACSP for Golf suggests the monitoring of basic physical water quality parameters, including temperature (Temp °C), conductivity (Sp. Cond.), pH, and dissolved oxygen (DO). These parameters were measured with a Hydrolab Minisonde 5 Multiprobe. The ACSP for Golf also suggests the monitoring of chemical parameters via sample analysis, including total phosphorus (TP), nitrate/nitrite (NOx), and ammonia (NH_3). Water samples were analyzed at Instrumental Research, Inc. in Fridley, MN. Standard MPRB sampling and QA/QC procedures were followed. This report details the last two years of data. Older data can be found in previous Annual Water Resources reports at https://www.minneapolisparks.org/park_care__improvements/water_resources/ located under the "Data Collection and Reporting" tab.

COLUMBIA GOLF COURSE

Three ponds on the Columbia Golf Course were chosen for monitoring and are pictured in **Figure 28-1** and shown in map view in **Figure 28-2**. The Hole 4 Pond receives water from a groundwater well used to irrigate the golf course. The Driving Range Pond receives surface drainage from the driving range and drains to an unsampled pond downstream of Hole 4 Pond. The Outlet Pond is the last pond in the series and outlets to a storm sewer that drains to the Mississippi River. Columbia Golf Course has been monitored for Audubon since 2008. On July 21st, 2022, aquatic, terrestrial, and wetland plants in the ponds and surrounding buffer zones were surveyed. Multiprobe water data and water chemistry sampling were also conducted for all ponds.

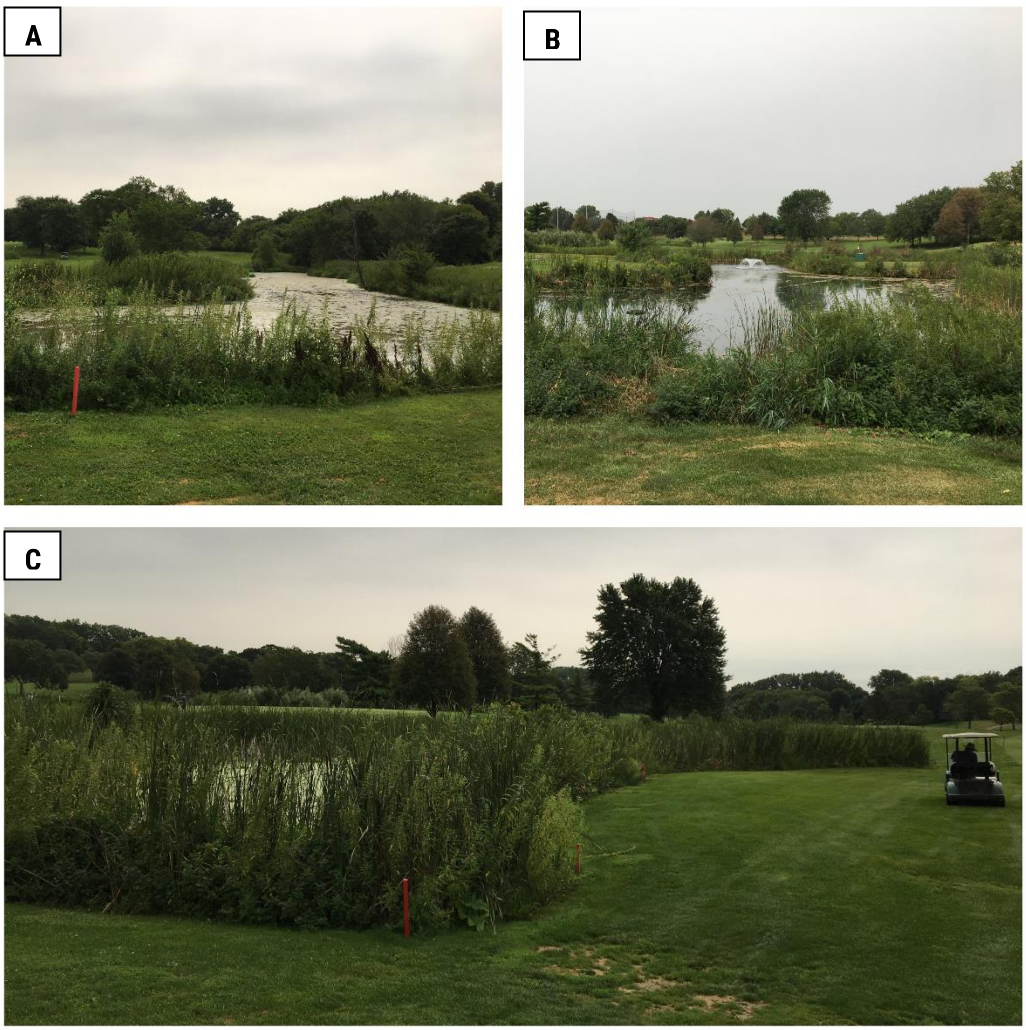


Figure 28-1. Photographs of Columbia Golf Course Ponds: Hole 4 Pond (A), Outlet Pond (B), and Driving Range Pond (C).

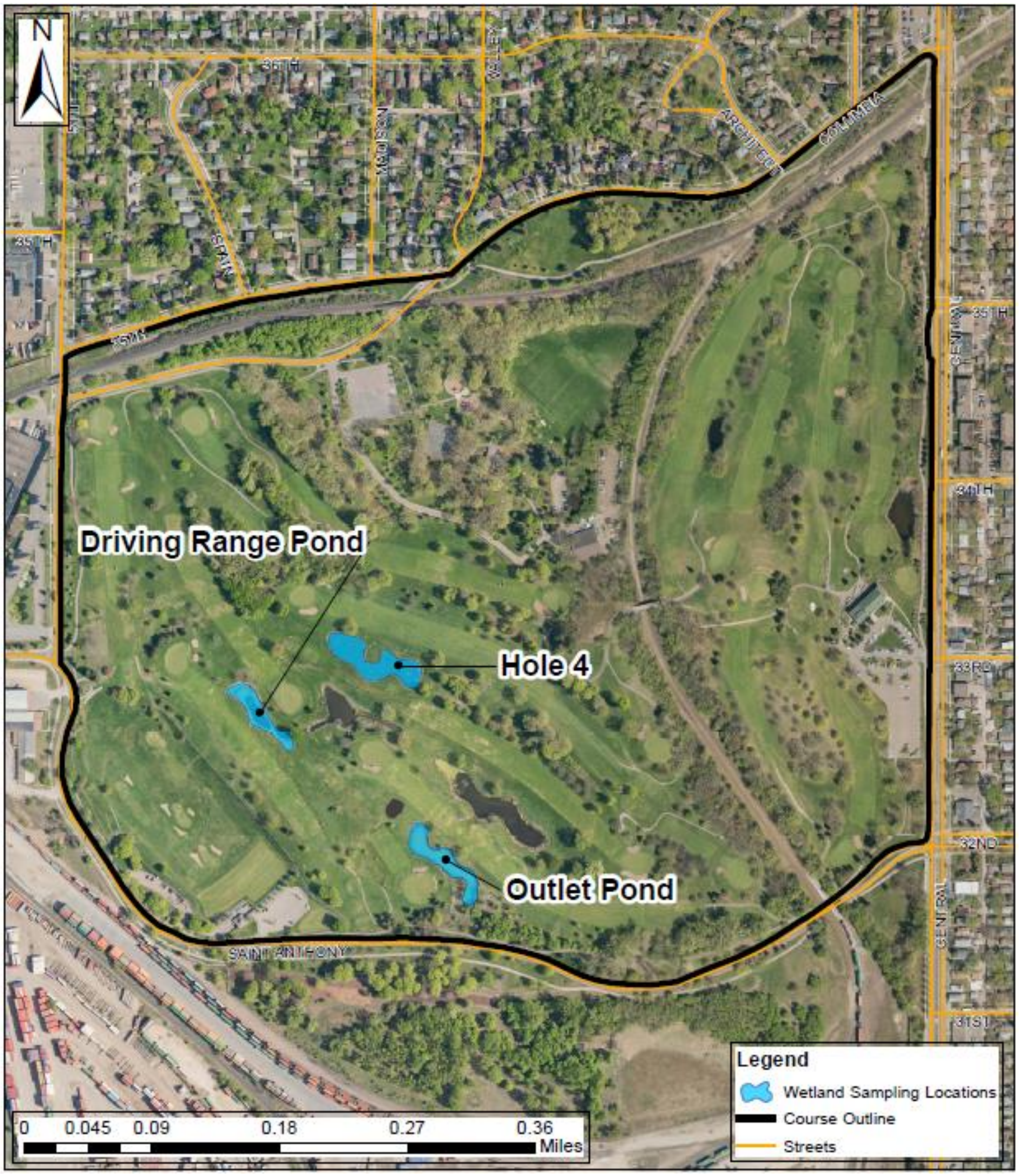


Figure 28-2. Aerial photograph of Columbia Golf Course and the sampling locations.

All plant species identified from Columbia Golf Course are presented in **Table 28-1**. The most prevalent species in the last two years include: thistle, Kentucky bluegrass, smartweed, cattail, stinging nettle, blue vervain, and curled dock.

Table 28-1. Dominant plants surrounding the Columbia Golf Course Ponds.

Columbia Golf Course		Hole 4 Pond		Driving Range Pond		Outlet Pond	
Wetland and Upland Plants							
Scientific Name	**Common Name**	2021	2022	2021	2022	2021	2022
Ambrosia artemisiifolia	Common Ragweed	X					
Arctium minus	Burdock	X					
Asclepias incarnata	Marsh Milkweed		X				
Asclepias syriaca	Common Milkweed				X		
Aster spp	Aster 1		X				X
Cerastium vulgatum	Mouse-eared Chickweed		X				
Cirsium spp	Thistle	X	X	X	X		
Fraxinus Pennsylvanica	Green Ash			X	X		
Poa pratensis	Kentucky Bluegrass	X	X		X	X	X
Polygonum pensylvanicum	Smartweed	X		X		X	
Rumex crispus	Curled Dock		X		X	X	X
Salix spp	Sandbar Willow					X	
Schoenoplectus acutus	Hardstem Bulrush					X	
Scirpus fluviatilis	River Bulrush					X	
Sinapis spp	Mustard	X	X			X	X
Solanum dulcamara	Bittersweet Nightshade	X	X	X			
Solidago spp	Goldenrod					X	
Sonchus arvensis	Sow Thistle		X	X	X		
Typha spp	Cattail	X	X	X	X	X	X
Ulmaceaespp	Elm	X				X	
Urtica dioica	Stinging Nettle	X	X	X	X	X	X
Verbena hastata	Blue Vervain	X	X	X		X	X
Vitus riparia	Riverbank Grape	X	X				
Aquatic Plants							
Scientific Name	**Common Name**	2021	2022	2021	2022	2021	2022
Filamentous algae	Filamentous algae	X	X	X		X	X
Chara spp	Muskgrass	X					
Lemna minor	Lesser Duckweed	X	X	X	X	X	X
Potamogeton spp	Narrow Leaf Pondweed	X					
Potamogeton pectinatus	Sago Pondweed	X	X				

The 2021 and 2022 water quality monitoring results from the Hydrolab and water chemistry, at Columbia Golf Course are shown in **Table 28-2**. Hole 4 Pond receives water from a groundwater well with an aeration fountain, so higher dissolved oxygen concentrations are expected at this location. Contrary to expectations, the dissolved oxygen content across all ponds was much lower in 2022 than in 2021, possibly due to higher levels of algae from increased levels of TP. Data from Hole 4 Pond and Driving Range Pond showed a significant increase in TP, while Outlet Pond experienced a decrease in TP. Hole 4 Pond experienced an increase in NH_3, and all ponds showed a decrease in NOx. It is unknown why this occurred. Definitive conclusions cannot be drawn from a single sample taken once a year but may provide a general overview.

Table 28-2. Water quality monitoring results for Columbia Golf Course 2021 and 2022.

Columbia	Date	Time	Temp °C	DO% Sat	DO mg/L	pH Units	Sp.Cond. µS/cm	TP mg/L	NH3 mg/L	NOx mg/L
Hole 4 Pond	8/4/2021	14:17	18.2	158	14.89	8.0	1344	0.018	<0.250	0.077
Hole 4 Pond	7/21/2022	9:38	18.04	37.3	3.49	7.76	1425	0.030	0.744	<0.030
Driving Range Pond	8/4/2021	14:26	28.4	151	11.77	8.2	1700	0.934	2.854	0.063
Driving Range Pond	7/21/2022	9:49	25.21	9.6	0.78	7.8	1624	1.800	2.854	<0.030
Outlet Pond	8/4/2021	14:39	25.3	129	10.60	7.7	2075	0.468	5.184	0.614
Outlet Pond	7/21/2022	10:03	19.89	68.7	6.19	7.55	2094	0.104	2.599	0.203

Gross National Golf Course

Three ponds and a low area site were chosen on Gross National Golf Course. Photographs are presented in **Figure 28-3** of the ponds, and a map in **Figure 28-4**. Pond 7 is one of the oldest water bodies on the golf course and may be a remnant of a natural wetland. It is hydrologically isolated, with no drain tile outlets and no connection to the golf course irrigation system. Ponds 12 and 14 were constructed in the mid-1990s to help improve drainage on the golf course. Drain tile from the surrounding fairways leads to each of these ponds. Groundwater for irrigation is pumped to Pond 14, which then drains to Pond 12. The low area was originally chosen as an additional vegetation survey site since it contained different vegetation than most of the golf course, but it has been dry the last few years. Gross Golf Course has been monitored for Audubon since 2008. On July 20th, 2022, aquatic, terrestrial, and wetland plants in the ponds and surrounding buffer zones were surveyed. Hydrolab multiprobe water data and water chemistry were also conducted for all ponds.

Figure 28-3. Photographs of Gross National Golf Course Ponds: Pond 7 (A), Pond 12 (B), Pond 14 (C), and the low area (D).

Figure 28-4. Aerial photograph of Gross Golf Course and the sampled locations.

All species identified from Gross Golf Course are presented in **Table 28-3**. Kentucky bluegrass and daisy fleabane were the most prevalent species surveyed in the past two years. Smartweed and flat sedge were not observed in 2022. Lesser duckweed was also present in Ponds 7 and 12 for both years. In 2017, much of the vegetation surrounding the water bodies was cut down and continues to be mowed to the water's edge, causing a reduction of species diversity. Additionally, all ponds had aeration fountains and were dyed blue in 2022. The low area exhibited the most terrestrial species diversity but lacked aquatic species since the location is a wetland rather than a pond.

Table 28-3. Dominant plants at the Gross National Golf Course sample sites.

Gross Golf Course		Pond 7		Pond 12		Pond 14		Low Area	
Wetland and Upland Plants									
Scientific Name	**Common Name**	2021	2022	2021	2022	2021	2022	2021	2022
Arctium ssp	Burdock							X	X
Cirsium spp	Thistle						X		
Cirsium avense	Canadian Thistle		X					X	X
Cyperus odoratus	Flat sedge	X		X					
Erigeron annuus	Daisy fleabane		X				X	X	X
Eupatorium perfoliatum	Boneset		X				X		
Glechoma hederacea	Ground Ivy (Creeping Charlie)		X						
Hackelia virginiana	Virginia Stickseed							X	
Juglans	Walnut Tree							X	
Parthenocissus quinquefolia	Virginia Creeper							X	
Persicaria spp.	Smartweed/Lady's Thumb						X		
Phalaris arundinacea	Reed Canary Grass	X	X						X
Plantago major	Common Plantain								
Poa pratensis	Kentucky Bluegrass	X	X	X	X	X		X	X
Polygonum pensylvanicum	Smartweed	X		X		X			
Rhus spp	Sumac							X	
Rudbeckia hirta	Black eyed susan						X		
Scirpus fluviatilis	River Bulrush			X	X				
Scirpus validus	Soft stem Bulrush			X		X	X		
Sonchus ssp	Sow Thistle						X	X	X
Solidago canadensis	Canada goldenrod							X	
Thalictrum dasycarpum	Purple Meadow Rue							X	
Urtica dioica	Stinging Nettle							X	
Vitus riparia	Riverbank Grape							X	
Aquatic Plants									
Scientific Name	**Common Name**	2021	2022	2021	2022	2021	2022	2021	2022
Filamentous algae	Filamentous algae			X	X	X			
Lemna minor	Lesser Duckweed	X	X	X	X				

Water quality monitoring results for Gross Golf Course are shown in **Table 28-4**. In 2022, dissolved oxygen levels decreased in all ponds with the most significant decrease in Pond 12, likely due to higher water temperatures in 2022. Phosphorus levels increased in Ponds 7 and 12 and decreased slightly in Pond 14. Ammonia and nitrates/nitrites remained relatively low for both Ponds 12 and 14 but increased in Pond 12 compared to 2021. Definitive conclusions cannot be drawn from a single sample once a year but can provide general information.

Table 28-4. Water quality monitoring results for Gross National Golf Course for 2021 and 2022.

Gross	Date	Time	Temp °C	DO% Sat	DO mg/L	pH Units	Sp.Cond. µS/cm	TP mg/L	NH3 mg/L	NOx mg/L
Pond 7	8/4/2021	10:52	22.5	80	6.94	8.2	620	0.904	1.198	1.149
Pond 7	7/20/2022	11:10	24.05	77.4	6.42	7.94	589.9	1.040	0.584	0.050
Pond 12	8/4/2021	11:12	22.7	103	8.95	8.5	494	0.080	<0.250	<0.030
Pond 12	7/20/2022	11:16	25.01	41.4	3.38	7.86	526.3	0.119	0.573	0.055
Pond 14	8/4/2021	11:07	23.9	107	9.10	8.4	539	0.196	<0.250	<0.030
Pond 14	7/20/2022	11:23	24.6	83.3	6.84	8.13	452.9	0.186	0.595	<0.030

Hiawatha Golf Course

Water quality staff, in consultation with the golf course foreman, chose four representative sample sites at the Hiawatha Golf Course. Ponds 1, 2 and 3 are part of an interconnected chain of ponds pumped to Lake Hiawatha, see **Figure 28-5** and **Figure 28-6.** During storm events, stormwater from neighborhood streets and the golf course parking lot drain to Pond 1. The ponds drain in sequence from Pond 1 to Pond 2, and then to Pond 3. Stormwater and groundwater carried by piped connections between Ponds 1-3 are the two sources of water. Pond 4 is on the west side of Lake Hiawatha and is filled by surface runoff and groundwater. It drains to a smaller pond to the north that is pumped into Lake Hiawatha. Hiawatha Golf Course has been monitored for Audubon since 2008. On July 20th, 2022, aquatic, terrestrial, and wetland plants in the ponds and surrounding buffer zones were surveyed. Hydrolab multiprobe water data and water chemistry were also conducted for all ponds.

Figure 28-5. Photographs of Hiawatha Golf Course Ponds 1 (A), 2 (B), 3 (C), and 4 (D).

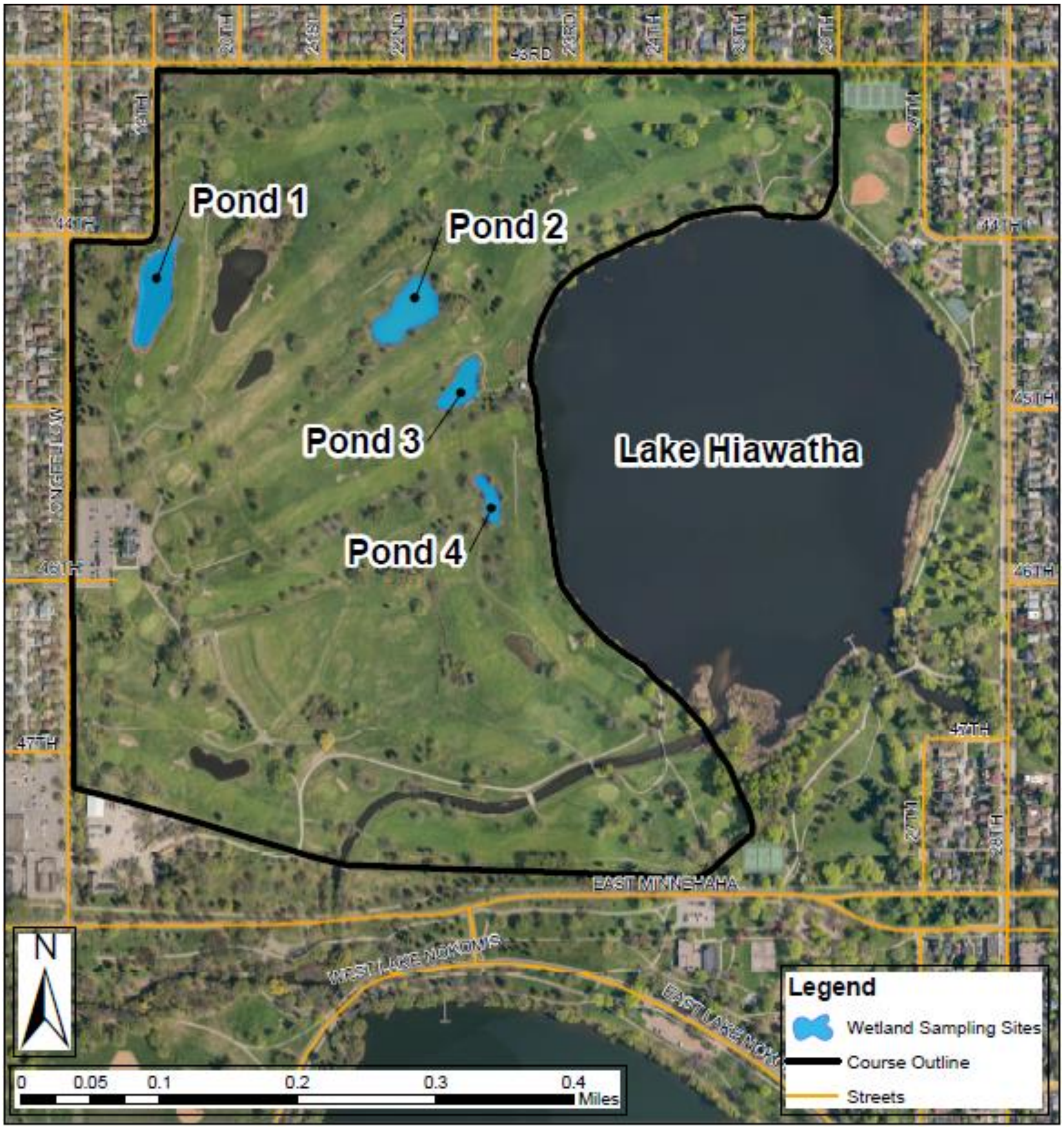


Figure 28-6. Aerial photograph of Hiawatha Golf Course and the sampling locations.

All species identified from Hiawatha Golf Course are presented in **Table 28-5.** Giant ragweed, thistle, Kentucky bluegrass, reed canary grass, and common sow thistle were the most prevalent species surveyed in the past two years. New aquatic plants were observed at Ponds 3 and 4 that were not found there in previous years.

Table 28-5. Dominant plants at the Hiawatha Golf Course sample sites.

Hiawatha Golf Course		**Pond 1**		**Pond 2**		**Pond 3**		**Pond 4**	
Wetland and Upland Plants									
Scientific Name	**Common Name**	2021	2022	2021	2022	2021	2022	2021	2022
Acer spp	Maple (saplings)	X	X					X	
Ambrosia artemisiifolia	Common Ragweed	X		X		X		X	
Ambrosia trifida	Giant Ragweed		X	X		X	X	X	X
Arctium minus	Burdock								X
Asclepias spp	Milkweed							X	
Aster spp	Aster		X		X		X		
Carex spp	Sedge	X	X						
Chenopodium	Goosefoot	X							
Cirsium arvense	Canada Thistle					X		X	
Cirsium spp	Thistle	X	X	X	X	X	X	X	X
Echinocystis lobata	Wild Cucumber							X	
Impatiens capensis	Spotted Touch-Me-Not (Jewelweed)	X						X	
Eupatorium perfoliatum	Common Boneset	X							
Fraxinus pennsylvanica	Green Ash							X	
Gleditsia triacanthos	Honey Locust			X	X				
Larix laricina	Tamarack					X			
Phalaris arundinacea	Reed Canary Grass		X	X	X	X	X	X	X
Phleum pratense	Timothy Hay (Meadow Cat's-Tail)							X	
Poa pratensis	Kentucky Bluegrass	X	X	X	X	X	X	X	X
Polygonum hydropier	Smartweed	X	X						
Populus deltoides	Cottonwood			X	X				
Rhus	Sumac							X	
Rumex crispus	Curled Dock				X	X	X	X	
Salix spp	Sandbar Willow	X	X		X			X	X
Solanum dulcamara	Bittersweet Nightshade	X							
Scirpoides holoschoenus	Bulrush	X							
Sonchus oleraceous	Common Sow Thistle	X	X	X	X	X	X	X	
Typha spp	Cattail	X	X						
Unknown	Annual Weeds					X	X	X	X
Urtica diotica	Stinging Nettle	X	X			X	X		X
Verbena hastata	Blue Vervain	X	X			X	X		
Aquatic Plants									
Scientific Name	**Common Name**	2021	2022	2021	2022	2021	2022	2021	2022
Ceratophyllum demersum	Coontail						X		
Filamentous Algae	Filamentous Algae								X
Lemna minor	Lesser Duckweed						X	X	X
Potamogeton pectinatus	Sago Pondweed						X		

Water quality monitoring results for Hiawatha Golf Course are shown in **Table 28-6**. In 2022, Ponds 1, 3, and 4 decreased in dissolved oxygen, with the most dramatic drop being in Ponds 3 and 4. Ponds 2 and 4 experienced increases in total phosphorus, while Pond 1 decreased, and Pond 3 didn't change. Nitrates/nitrites decreased across all ponds except Pond 1, while ammonia levels increased significantly across all ponds. Definitive conclusions cannot be drawn from a single sample once a year but can provide general information.

Table 28-6. Water quality monitoring results for Hiawatha Golf Course for 2021 and 2022.

Hiawatha	Date	Time	Temp °C	DO% Sat	DO mg/L	pH Units	Sp.Cond. µS/cm	TP mg/L	NH3 mg/L	NOx mg/L
Pond 1	8/5/2021	9:26	23.1	79	6.78	7.9	1004	0.139	0.492	<0.030
Pond 1	7/20/2022	9:44	24.56	52.3	4.29	7.73	874.4	0.109	0.648	<0.030
Pond 2	8/5/2021	9:44	18.7	71	6.63	7.8	999	0.050	0.492	1.637
Pond 2	7/20/2022	9:53	18.93	84.3	7.72	7.7	963.3	0.107	0.776	0.437
Pond 3	8/5/2021	9:49	21.6	107	9.39	7.9	963	0.179	<0.250	0.814
Pond 3	7/20/2022	10:06	22.96	66.8	5.65	7.82	935.9	0.176	1.085	0.145
Pond 4	8/5/2021	10:03	21.5	88	7.78	7.9	899	0.191	1.485	1.284
Pond 4	7/20/2022	10:15	22.79	34.3	2.91	7.51	951.1	0.327	2.215	<0.030

Meadowbrook Golf Course

Four water bodies have been historically monitored at Meadowbrook Golf Course: Meadowbrook Lake, Wetland C, Wetland L, and Wetland N. Photographs are shown in **Figure 28-7** and a map in **Figure 28-8**. Each of the sampled water bodies on the Meadowbrook Golf Course have unique hydrologic characteristics. Wetland C is the furthest upstream and only receives runoff from the surrounding course. Wetland N is near the course edge and receives stormwater from the adjacent neighborhood. Wetland L is an isolated pond, and Minnehaha Creek flows through Meadowbrook Lake. Meadowbrook Golf Course has been monitored for Audubon since 2000. On July 18th, 2022, Hydrolab multiprobe measurements and water chemistry samples were taken. Aquatic, terrestrial, and wetland plants in the ponds and surrounding buffer zones were also surveyed.

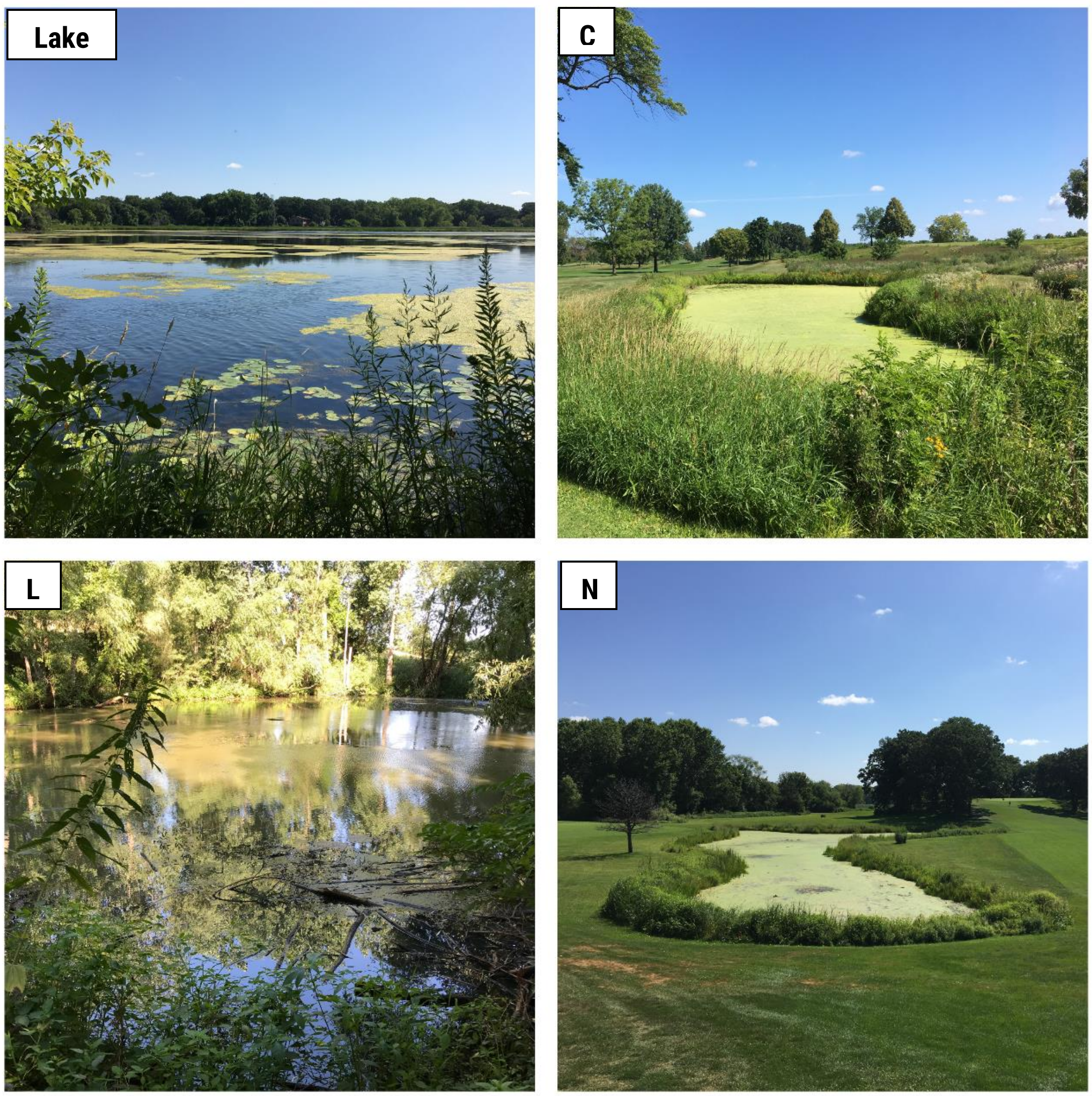


Figure 28-7. Photographs of Meadowbrook Golf Course Meadowbrook Lake, Wetland C, Wetland L, and Wetland N.

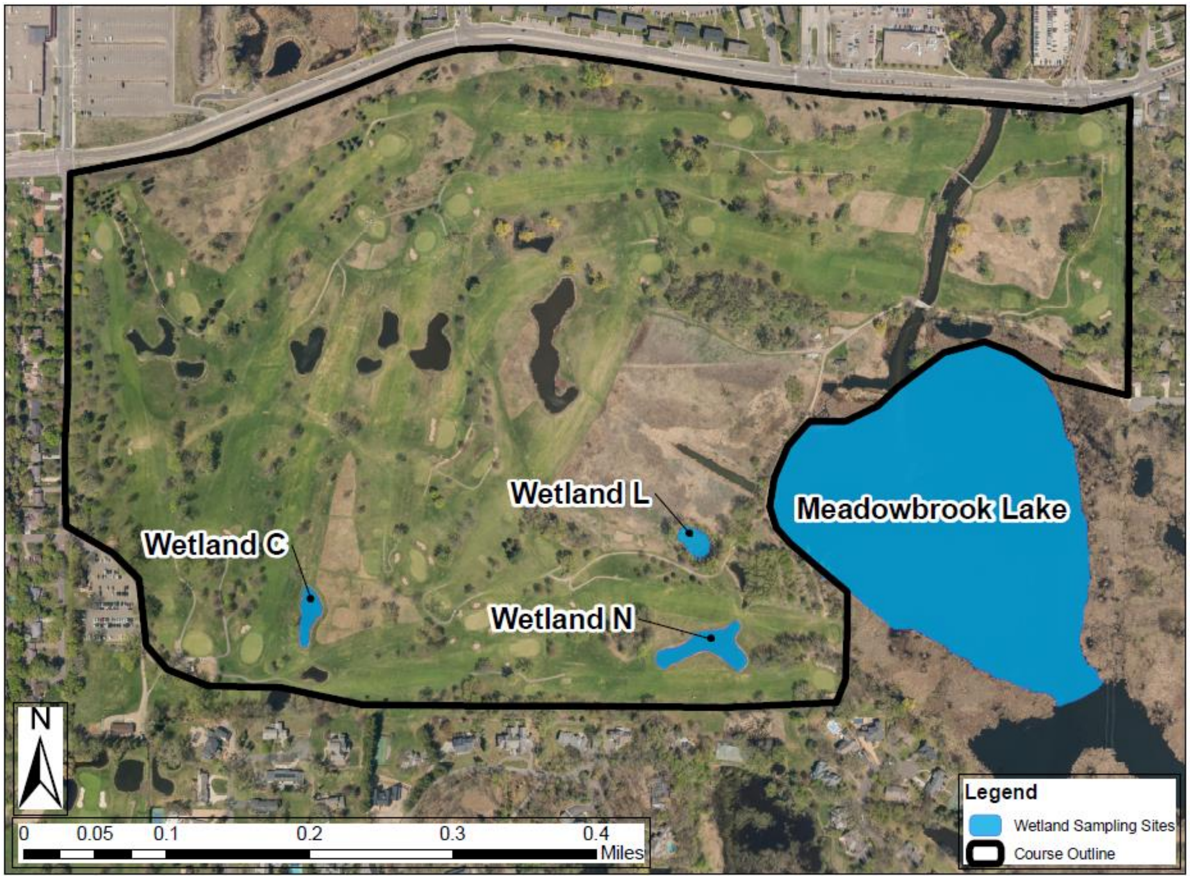


Figure 28-8. Aerial photograph of Meadowbrook Golf Course and the sampling locations.

All species identified from Meadowbrook Golf Course are presented in **Table 28-7.** Reed canary grass, blue vervain, Kentucky bluegrass, giant ragweed, and stinging nettle were the most prevalent buffer zone species surveyed in the past two years. Lesser duckweed and watermeal were the most common aquatic species observed.

Note that Wetland L was not accessed between 2015-2020 due to flooding and overgrowth at the usual sampling location. MPRB staff were able to start sampling the site again in 2021 using a new location on the south side.

Table 28-7. Dominant buffer zone plants surrounding the Meadowbrook Golf Course sample site.

Meadowbrook Golf Course		**Wetland C**		**Wetland N**		**Wetland L**		**Lake**	
Wetland and Upland Plants									
Scientific Name	**Common Name**	2021	2022	2021	2022	2021	2022	2021	2022
Ambrosia trifida	Giant Ragweed		X	X	X	X	X		
Arctium minus	Burdock	X	X	X	X				
Asclepias incarnata	Marsh Milkweed		X	X	X				
Asclepias syriaca	Common Milkweed	X	X						
Asclepias sonchus	Sow Thistle	X							
Carex spp	Sedge spp			X	X				
Cirsium avense	Canadian Thistle	X	X	X	X				
Erigeron annuus	Daisy fleabane		X						X
Eupatorium perfoliatum	Boneset						X		
Fraxinus pennsylvanica	Green Ash		X			X			
Harkelia virginiana	Virginia Stick-Seed (Beggars Lice)		X						
Impatiens capensis	Spotted Touch-Me-Not (Jewelweed)	X				X			
Phalaris arundinacea	Reed Canary Grass	X	X	X	X	X	X	X	X
Poa pratensis	Kentucky Bluegrass	X	X	X	X	X	X		
Polygonum hydropier	Common Smartweed	X					X		
Populus deltoides	Eastern Cottonwood							X	X
Potentilla norvegica	Rough Cinquefoil								X
Rhamnus cathartica	Buckthorn							X	X
Rubus idaeus	Wild Red Raspberry					X			
Rudbeckia hirta	Black eyed susan	X	X						
Salix exigua	Sandbar Willow	X	X			X			
Sambucus	Elderberry			X					
Sedge spp.	Sedge spp		X						
Solanum dulcamara	Bittersweet Nightshade						X		X
Solidago canadensis	Canada Goldenrod				X				
Sonchus oleraceus	Common Sow-thistle		X	X	X				
Sparganium eurycarpum	Giant Bur-Reed		X	X	X				
Typha latifolia	Broad-Leaved Cattail	X	X	X	X				
Typha X glauca	Hybrid Cattail	X	X	X	X				
Ulmus pumilla	Siberian Elm	X						X	X
Urtica dioica	Stinging Nettle		X	X	X	X	X	X	X
Verbena hastata	Blue Vervain	X	X	X	X			X	X
Vicia cracca	Cow Vetch	X	X						
Vitus riparia	Riverbank Grape							X	

Table 28-7 (continued). Dominant aquatic plants within the Meadowbrook Golf Course sample site.

Meadowbrook Golf Course (Continued)		**Wetland C**		**Wetland N**		**Wetland L**		**Lake**	
Floating Aquatic Plants									
Scientific Name	**Common Name**	2021	2022	2021	2022	2021	2022	2021	2022
Lemna gibba	Fat Duckweed	**X**							
Lemna minor	Lesser Duckweed	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Nymphaea odorata	White Water Lily							**X**	**X**
Spirodela polyrhiza	Big Duckweed						**X**	**X**	**X**
Wolffia columbiana	Watermeal	**X**	**X**	**X**	**X**			**X**	**X**
Submerged Aquatic Plants									
Scientific Name	**Common Name**	2021	2022	2021	2022	2021	2022	2021	2022
Ceratophyllum demersum	Coontail								**X**
Elodea canadensis	Canadian Waterweed								**X**
Filamentous algae	Filamentous Algae					**X**			**X**
Myriophyllum spicatum	Eurasian Watermilfoil							**X**	**X**
Potamogeton berchtoldii	Narrow leaved pondweed							**X**	
Utricularia vulgaris	Common Bladderwort								**X**

Water quality monitoring results for Meadowbrook Golf Course are shown in **Table 28-8**. Meadowbrook Lake experienced increases in total phosphorus and ammonia content, but no significant change in nitrate/nitrites. Wetland C and Wetland N, historically, have had low levels of dissolved oxygen due to the abundance of organic decomposition that is typical of wetland ecosystems. Contrary to expectations, in 2022 these wetlands showed a significant increase in dissolved oxygen saturation. Wetlands C and L show a significant decrease in ammonia levels, while Wetland N increased slightly. Definitive conclusions cannot be drawn from a single sample once a year but may help provide a general overview.

Table 28-8. Water quality monitoring results for Meadowbrook Golf Course for 2021 and 2022.

Meadowbrook	**Date**	**Time**	**Temp °C**	**DO% Sat**	**DO mg/L**	**pH Units**	**Sp.Cond. µS/cm**	**TP mg/L**	**NH3 mg/L**	**NOx mg/L**
Meadowbrook Lake	8/3/2021	8:53	22.6	80	6.93	7.9	603	0.025	0.348	<0.030
Meadowbrook Lake	7/18/2022	10:37	29.34	75.2	5.74	8.6	507.6	0.504	0.435	<0.030
Wetland C	8/3/2021	8:27	19.9	8	0.70	8.0	340	2.678	1.739	<0.030
Wetland C	7/18/2022	9:58	28.58	72.2	5.58	8.06	343.6	0.410	0.776	<0.030
Wetland L	8/3/2021	9:01	13.7	99	8.39	7.5	802	0.382	3.826	0.081
Wetland L	7/18/2022	10:51	20.96	23.9	2.12	7.6	1007	0.351	1.234	0.032
Wetland N	8/3/2021	8:37	19.2	6	0.51	7.5	498	0.969	0.900	<0.030
Wetland N	7/18/2022	10:22	29.39	114.1	8.7	7.97	237	0.825	1.160	<0.030

Theodore Wirth Golf Course

In consultation with the golf course foreman, three sample sites were chosen at Theodore Wirth Golf Course. The Inlet and Outlet of Bassett Creek are monitored to assess how the golf course may be affecting stream water quality. The Par 3 Wetland is unconnected to Bassett Creek and located adjacent to a developed housing complex and receives stormwater runoff from this region. **Figure 28-9** and **Figure 28-10** show photographs and the map location of the monitoring sites on the golf course. Theodore Wirth Golf Course has been monitored since 2000. On July 18th, 2022, Hydrolab multiprobe measurements, water chemistry, aquatic, terrestrial, and wetland plants in the ponds and surrounding buffer zones were surveyed.

Figure 28-9. Photographs of Wirth Golf Course Bassett Creek Outlet (A), Bassett Creek Inlet (B), and Par 3 Wetland (C).

Figure 28-10. Aerial photograph of Theodore Wirth golf course and the sampled locations.

All species identified from Theodore Wirth Golf Course are presented in **Table 28-9.** The most prevalent species at this location in the last two years included: Canadian thistle, reed canary grass, and sow thistle.

Table 28-9. Wetland and upland vegetation monitoring results for the Theodore Wirth Golf Course.

Theodore Wirth Golf Course		Bassett Inlet		Bassett Outlet		Par 3 Wetland	
Wetland and Upland Plants							
Scientific Name	Common Name	2021	2022	2021	2022	2021	2022
Ambrosia artemisiifolia	Common Ragweed	X					
Asclepias syriaca L.	Common Milkweed	X					
Aster lanceolatus	Panicled Aster			X			
Aster	Aster			X			
Bromus spp	Smooth Brome			X			
Carex	Sedge	X					
Cirsium avense	Canadian Thistle	X	X			X	X
Eupatorium perfoliatum	Common Boneset	X	X				
Euphorbia esuela	Leafy Spurge				X		
Impatiens pallida	Pale Jewelweed						X
Iris versicolor L.	Blue Flag Iris				X		
Lepidium densiflorum	Green-flowered Peppergrass				X		
Lotus corniculatus	Birdsfoot Trefoil	X	X				
Lythrum salicaria	Purple Loosestrife		X				
Melilotus officinalis	Sweet Clover			X			
Monarda fistulosa	Wild Bergamot				X		
Phalaris arundinacea	Reed Canary Grass	X		X		X	X
Poa pratensis	Kentucky Bluegrass	X				X	X
Polygonum amphibium	Water Smartweed			X		X	X
Rhamnus cathartica	Buckthorn			X			
Rudbeckia hirta	Black Eyed Susan	X					
Rumex crispus	Curled Dock	X	X				
Salix exigua	Sandbar Willow	X	X			X	
Scirpus cespitosus	Green Bullrush		X				
Solanum dulcamara	Bittersweet Nightshade				X	X	
Solidago spp.	Goldenrod		X				
Sonchus arvensis	Sow Thistle	X	X		X	X	
Typha angustifolia	Narrow Leaved Cattail					X	
Typha latifolia	Broad Leaved Cattail					X	
Typha X glauca	Hybrid Cattail					X	
Verbena hastata	Blue Vervain			X	X		
Vitus riparia	Riverbank Grape	X					

Table 28-9 (continued). Aquatic vegetation monitoring results for the Wirth Golf Course.

Theodore Wirth Golf Course (Continued)		Bassett Inlet		Bassett Outlet		Par 3 Wetland	
Floating Aquatic Plants							
Scientific Name	**Common Name**	2021	2022	2021	2022	2021	2022
Lemna minor	Lesser Duckweed	**X**		**X**	**X**	**X**	**X**
Lemna trisulca	Star Duckweed					**X**	
Potamogeton natans	Floating Pondweed			**X**	**X**		
Spirodela polyrhiza	Big Duckweed				**X**	**X**	**X**
Typha	Cattail	**X**					
Wolffia columbiana	Watermeal			**X**		**X**	**X**
Submerged Aquatic Plants							
Scientific Name	**Common Name**	2021	2022	2021	2022	2021	2022
Ceratophyllum demersum	Coontail					**X**	
Potamogeton berchtoldii	Narrow-Leaf Pondweed			**X**			
Potamogeton nodusus	Long-Leaf Pondweed				**X**		
Potamogeton pectinatus	Sago Pondweed					**X**	

Monitoring results for Wirth Golf Course are shown in **Table 28-10.** The Bassett Creek Inlet showed consistently high concentrations of oxygen as it entered Wirth Golf Course, while the Outlet showed a major decrease in oxygen concentration. Both the Inlet and the Outlet showed increases in organic nutrient concentrations. The Par 3 Wetland historically contained low amounts of dissolved oxygen, which is typical of a wetland with an abundance of organic decomposition, but DO levels have remained high from 2021-22. The Par 3 Wetland also saw a decrease in both TP and NH_3, with no change in NOx. Definitive conclusions cannot be drawn from a single sample once a year but may help provide a general overview.

Table 28-10. Water quality monitoring results for Wirth Golf Course for 2021 and 2022.

Theodore Wirth	Date	Time	Temp °C	DO% Sat	DO mg/L	pH Units	Sp.Cond. µS/cm	TP mg/L	NH3 mg/L	NOx mg/L
Bassett Inlet	8/3/2021	11:08	19.3	86	7.91	8.0	1267	0.095	<0.250	<0.030
Bassett Inlet	7/18/2022	12:04	24.62	85.3	7.07	7.72	1234	0.263	0.488	0.286
Bassett Outlet	8/3/2021	11:30	23.1	98	8.38	8.0	1225	0.152	0.271	<0.030
Bassett Outlet	7/18/2022	12:30	27.76	30.9	2.42	7.62	1206	0.392	0.541	<0.030
Par 3 Wetland	8/3/2021	10:49	23.4	99	8.39	8.3	495	0.560	1.872	<0.030
Par 3 Wetland	7/18/2022	11:44	30.38	105.8	7.92	8.22	496.6	0.166	1.064	<0.030

Chemistry Summary

Table 28-11. Arrows denote the directionality of change across parameters of interest from 2021-2022. Blue arrows indicate a decrease, red arrows indicate an increase, and ≈ denotes no significant change.

		Temp	DO%	pH	TP	NH3	NOx
COLUMBIA	Hole 4	↓	↓	↓	↑	↑	↓
	Driving Range	↓	↓	↓	↑	≈	↓
	Outlet	↓	↓	↓	↓	↓	↓
GROSS	Pond 7	↑	↓	↓	↑	↓	↓
	Pond 12	↑	↓	↓	↑	↑	↑
	Pond 14	↑	↓	↓	≈	↑	≈
HIAWATHA	Pond 1	↑	↓	↓	≈	↑	≈
	Pond 2	↑	↑	↓	↑	↑	↓
	Pond 3	↑	↓	↓	≈	↑	↓
	Pond 4	↑	↓	↓	↑	↑	↓
MEADOWBROOK	Lake	↑	↓	↑	↑	↑	≈
	Wetland C	↑	↑	≈	↓	↓	≈
	Wetland L	↑	↓	↑	≈	↓	↓
	Wetland N	↑	↑	↑	↓	↑	≈
WIRTH	Inlet	↑	↓	↓	↑	↑	↑
	Outlet	↑	↓	↓	↑	↑	≈
	Par 3	↑	↑	↓	↓	↓	≈

Two-year results for all golf courses are shown in **Table 28-11.** All courses except Columbia experienced an increase in surface water temperatures. In the case of Columbia, monitoring was performed much later in the day in 2021 than in 2022 which explains why the increasing trend is not exhibited. Dissolved oxygen content decreased at most ponds, likely due to higher water temperatures. All courses except Meadowbrook experienced a drop in average pH. Total phosphorus results were mixed, with notable increases at Gross and Hiawatha Golf Course. Ammonia levels were also mixed, though Hiawatha Golf Course experienced a large increase across all ponds. Nitrate/nitrite results were overall lower than last year. Definitive conclusions cannot be drawn from a single sample once a year but may help provide a general overview.

29. Climatological Summary

National Weather Service Data

Annual climate data are tracked and reported due to its year-to-year variability and significant impact on water resources. **Table 29-1** and **Figure 29-1** show the Minneapolis National Weather Service (NWS) total monthly precipitation and monthly average temperature for 2022. **Figure 29-2** shows yearly precipitation from the last decade using NWS data. The NWS data are collected at the Minneapolis—St. Paul International Airport (MSP). These annual data are from January through December and not the water year from October through September. Normal is defined by the NWS using the MSP airport data from 1981 – 2010, where the 29-year normal annual temperature is 46.1° Fahrenheit (F), and the 29-year normal annual precipitation is 30.61 inches.

The climate of Minneapolis, Minnesota is classified as humid continental, typically with hot summers and cold winters. In 2022, average daily temperatures were below the normal for January through March, above normal from May to November, and below the normal again in December. The 2022 annual mean temperature was 46° F, which was 0.1° F below normal, **Table 29-1**. The warmest month of the year was July, and the coolest month was January. Generally, the warmer months were warmer than the 29-year normal for that month, and the colder months were colder than the normal for that month.

Overall, 2022 was a dry year, **Figure 29-2**. Based on data from the U.S. Drought Monitor, Hennepin County experienced drought conditions for all of 2022, except a ten-week period during the spring (https://droughtmonitor.unl.edu/DmData/DataTables.aspx?state,mn)**.**The 2022 annual precipitation total was 22.97 inches, which was 8.65 inches below the 29-year normal, **Table 29-1**. Eight months had below the 29-year average normal precipitation and four months had above the 29-year average normal precipitation. The wettest month of the year was August, and the driest months were September and October. The months of June, July, September, and October had monthly precipitation deficits of more than 2-inches from the 29-year normal.

Table 29-1. Minneapolis precipitation, mean temperature, and deviation from the 29-year normal as recorded by the National Weather Service/NOAA (MSP Airport) in 2022.

Month	Total Precipitation (inches)	30-Year Normal Comparison	Mean Temp. (F)	30-Year Normal Comparison
January	0.64	0.26" below normal	10.7°	4.9° below normal
February	0.78	0.01" above normal	14.5°	6.3° below normal
March	2.95	1.06" above normal	31.8°	1° below normal
April	3.99	1.33" above normal	41°	6.5° below normal
May	3.33	0.03" below normal	61°	1.9° above normal
June	1.13	3.12" below normal	73°	4.2° above normal
July	1.18	2.86" below normal	76.3°	2.5° above normal
August	4.27	0.03" below normal	72.5°	1.3° above normal
September	0.24	2.84" below normal	66°	4° above normal
October	0.24	2.19" below normal	51.8°	2.9° above normal
November	2.4	0.63" above normal	35°	1.3° above normal
December	1.82	0.66" above normal	17.9°	1.8° below normal
Annual Data	22.97	8.65" below normal	46°	0.1° below normal

All NWS data were obtained from National Oceanic and Atmospheric Administration (NOAA) monthly publications. The NWS 29-year normal (1981-2010) annual precipitation and temperature were obtained from NOAA website at https://www.ncdc.noaa.gov/cdo-web/datatools/lcd.

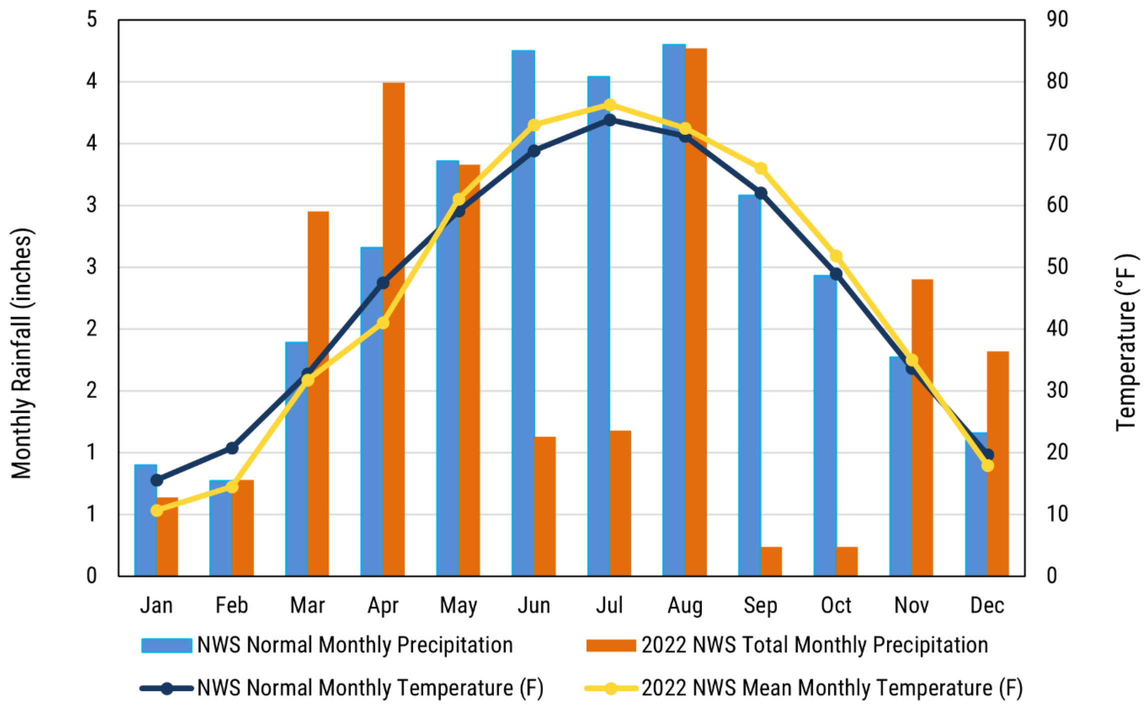


Figure 29-1. Comparison showing the NWS 29-year normal with 2022 temperature and precipitation data from the NWS.

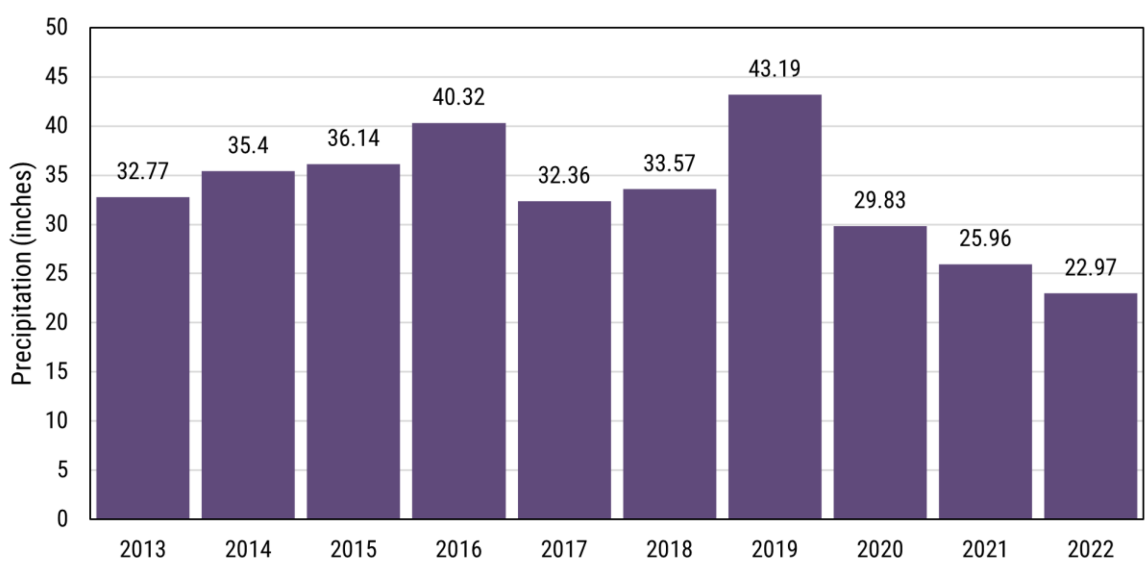


Figure 29-2. 10-year precipitation data from the NWS.

Twin Cities Rain Gauge Comparison

To better understand the local spatial pattern of precipitation, monthly NWS rainfall data were compared to the Minneapolis Park and Recreation Board (MPRB) weather station. The MPRB operates a heated tipping bucket rain gauge and a Davis Vantage Pro2 weather station in southwest Minneapolis, located on the roof of the Southside Service Center at 3800 Bryant Ave. South, Minneapolis, MN, as seen in **Figure 29-3**. The NWS heated tipping bucket rain gauge is located at the Minneapolis–St. Paul International Airport (MSP). It should be noted that heated tipping bucket rain gauges sublime a small amount of frozen precipitation before it can be measured, and it is lost.

Figure 29-3. The weather station on the roof of the MPRB Southside Service Center.

The monthly precipitation and the differences between the MPRB and NWS can be seen in **Table 29-2**. These data illustrate the spatial variability of precipitation across the landscape. **Figure 29-4** shows the locations of each weather station in map view.

Table 29-2. Monthly precipitation totals for 2022 recorded at both the NWS (MSP Airport) and MPRB (Southside Service Center) rain gauges. Months with a * represent the NWS and MPRB heated rain gauges and their water equivalent.

2022 Month	MPRB (inches)	NWS (inches)
January*	0.09	0.64
February*	0.07	0.78
March*	2.3	2.95
April	3.18	3.99
May	2.9	3.33
June	0.78	1.13
July	1.13	1.18
August	3.81	4.27
September	0.23	0.24
October	0.04	0.24
November*	1.29	2.4
December*	1.08	1.82
Annual	16.9	22.97

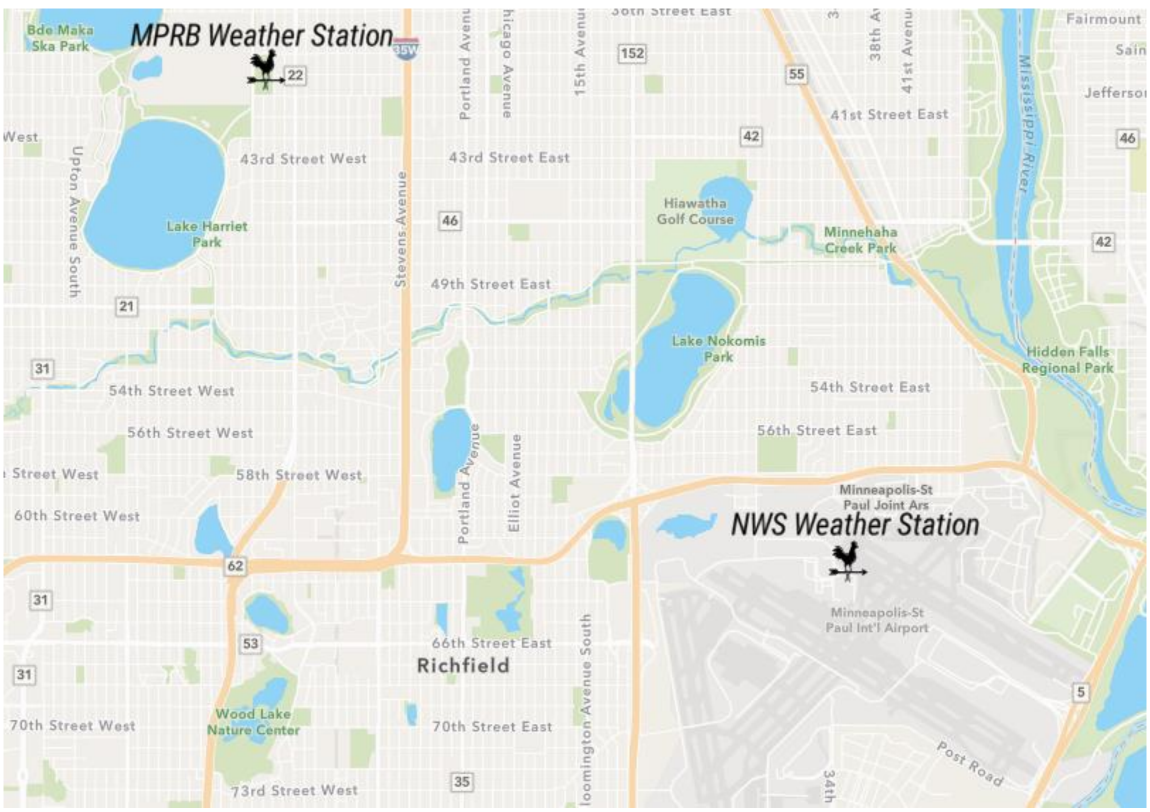


Figure 29-4. A map showing the locations of MPRB and NWS weather stations. The stations are approximately 4.5 miles apart.

30. Water Quality Education

Activities

In 2022, the Minneapolis Park & Recreation Board's (MPRB) Environmental Management Naturalist staff offered 191 program hours of in-person programming and interacted with nearly 2,500 people in neighborhood and regional parks throughout the city. **Figure 30-1** shows two participants for weekly free programing at Loring Park. Additionally, educational sign prompts, offered in both Spanish and English were placed in 7 park locations, and 8 local hardware stores were furbished with displays to educate customers about the use of salt for winter snow and ice management. All program locations are shown in **Figure 30-2**. Education staff utilized portable mini-golf, bean bag toss, an aerial photo floor graphic of the city and its watersheds, and other hands-on learning activities about stormwater and human impacts on the water quality in Minneapolis.

Figure 30-1. Two youth getting ready to canoe on Loring Pond with MPRB staff assisting.

Minnehaha Park

A moveable water quality education exhibit was deployed at Minnehaha Park near the pavilion that houses the popular restaurant, Sea Salt Eatery. Spinning cubes on the installation can be rotated to provide information about watersheds, stormwater runoff, and actions people can take to positively impact water quality. This location was chosen because of the consistent captive audience of people standing in line waiting to order food. Intermittent staff observations throughout the season confirmed that many of the people waiting in line were reading from the exhibit.

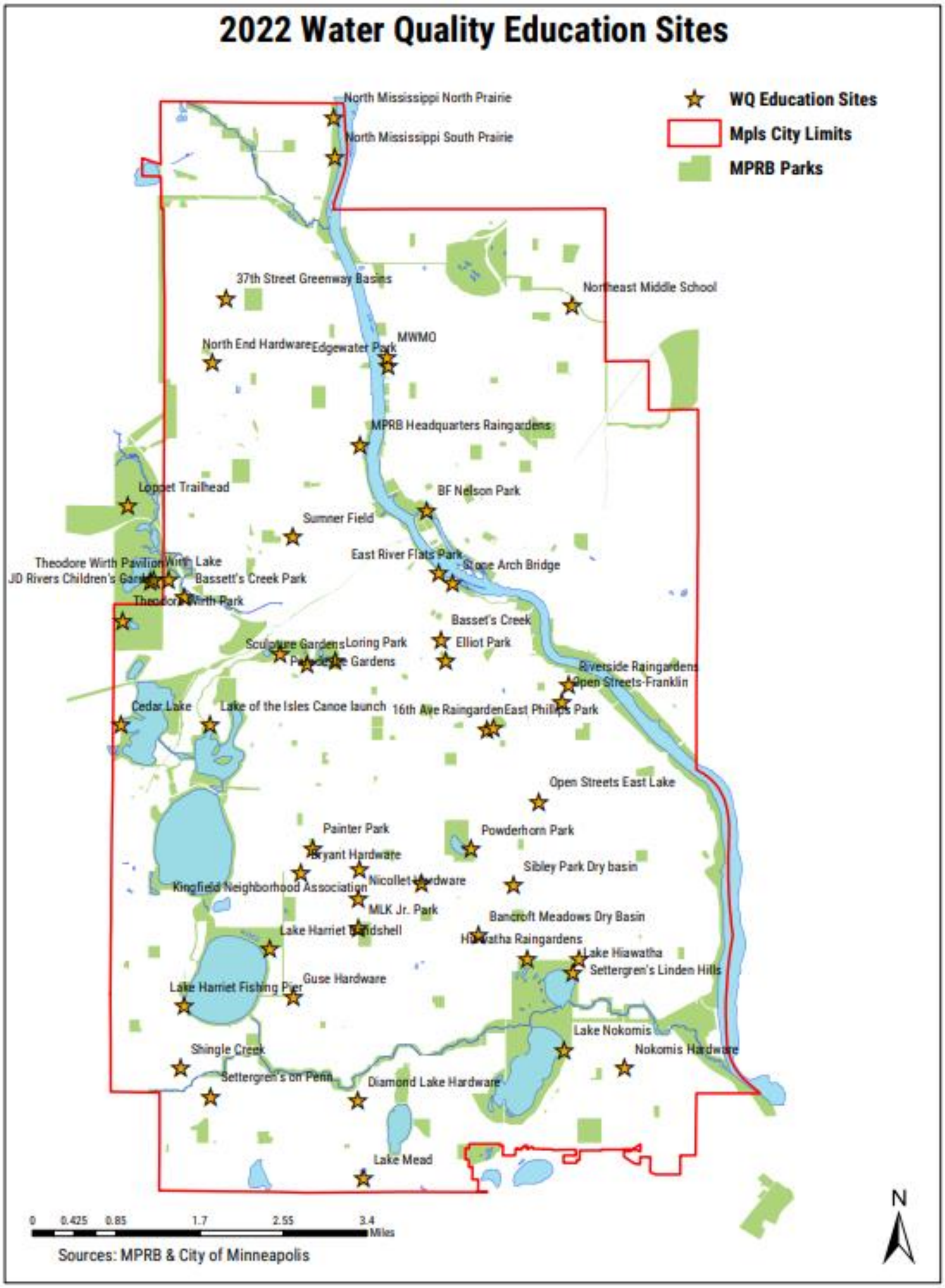


Figure 30-2. Map of water quality education sites in 2022.

Water Quality Water Trail

In June, the Water Trail, which is a series of buoys designed to follow like a trail on the water, was deployed in the lagoon west of the bridge in Lake Nokomis. A set of 10 stand up paddleboard (SUP) yoga poses were designed to float above the waterline on buoys holding water quality education messages. Shoreline signs were also posted for the summer season, letting park visitors know about the new resource, see **Figure 30-3**. **Figure 30-4** shows two adults engaging with one of the educational buoys.

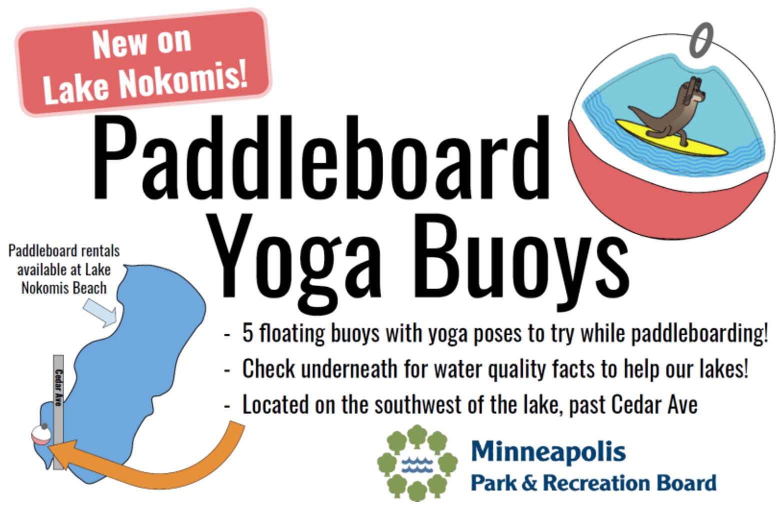


Figure 30-3. Shoreline sign posted around the Nokomis Lagoon to draw attention to this new resource.

Figure 30-4. A small group testing out a stop on The Water Trail in the Lake Nokomis Lagoon.

AQUATIC INVASIVE SPECIES EDUCATION

The MPRB continued its extensive Aquatic Invasive Species (AIS) Inspection & Education Program at the public boat launches located at Bde Maka Ska, Lake Harriet, and Lake Nokomis. The boat launches are staffed seven days a week from May 1 to December 1, and all trailered boats entering and leaving the lakes are inspected for AIS. In addition to providing watercraft inspections, staff are an information source for the park visitors. Staff directly interacted with 9,188 park visitors in 2022. Access to the Bde Maka Ska launch was impacted in the 2022 season by the construction project to rebuild the Bde Maka Ska Refectory building. The launch was only open for about 16% of the season due to the construction, which decreased the number of park visitor interactions with AIS Inspectors. Adjacent to the AIS booths are sandwich boards, see **Figure 30-5**, with action steps people can take to be a good water steward. The sandwich board messages can be changed out daily based on weather, time of year, etc. Annually, more than seven million people visit the Chain of Lakes, and more than one million visit Lake Nokomis.

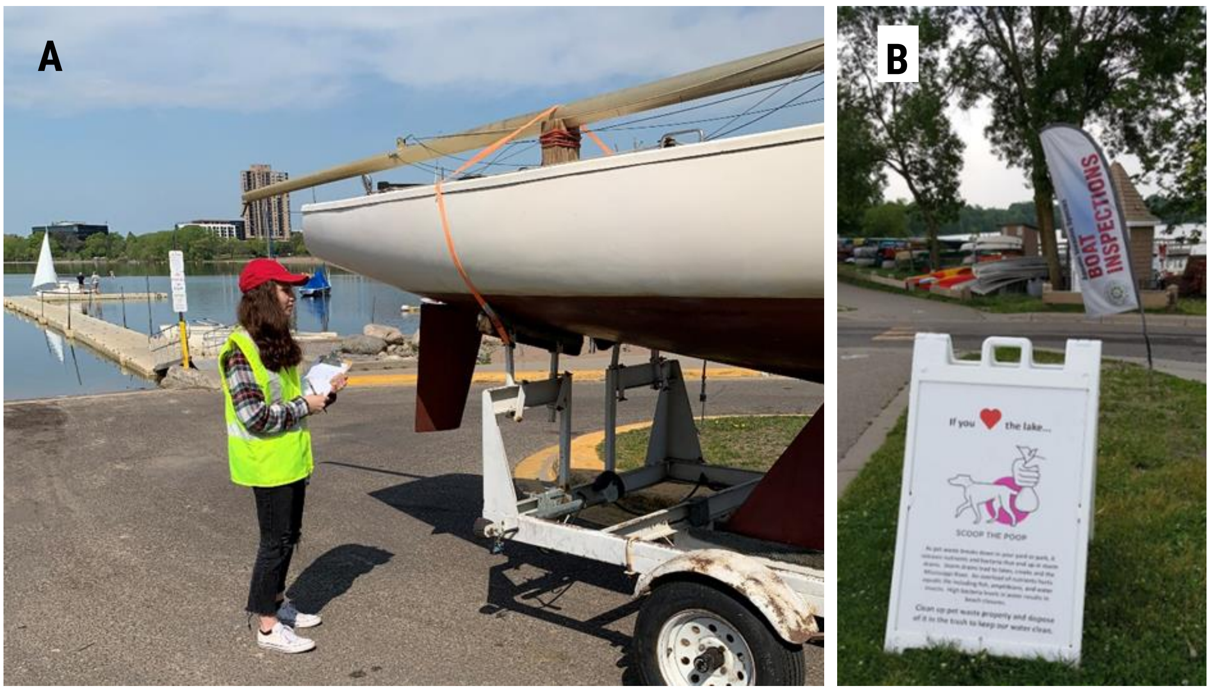


Figure 30-5. Aquatic Invasive Species boat inspection (a) and water quality education at boat launches (b).

Canines for Clean Water Campaign

According to US Census data, there were 188,017 households in Minneapolis in 2020. Using American Veterinary Medical Association ownership rates, an estimated 115,500 dogs live within Minneapolis city limits. The US Environmental Protection Agency has calculated the average dog produces 0.75 pounds of waste each day. That means Minneapolis dogs are generating an estimated 87,000 pounds of solid waste each day. Initiated in 2009, Canines for Clean Water is a water quality education program targeting dog owners to build awareness of the impacts of this waste when it is not properly disposed of and empowering people to take action and make a difference.

In 2022, MPRB's seven dog parks were sites that received a series of six educational sign prompts about the importance of picking up dog droppings to protect Minneapolis water quality. **Figure 30-6** shows an example of one of these signs, all of which were offered in both Spanish and English.

Figure 30-6. An example of the signs posted in Minneapolis Dog Parks.

The Canines for Clean Water movie series returned for summer of 2022. Dogs and their humans were invited to enjoy a night out at the movies at a different park each Thursday evening in August. The movies shown were dog-themed, and some parks hosted fun pre-movie activities like neighborhood dog shows, as well as being joined by Water Quality Educators to learn about the importance of picking up their dog's poop. **Figure 30-7** shows staff setting up for the movie event at North Mississippi Regional Park.

Figure 30-7. MPRB staff and partner organizations setting up education tables before the Canines for Clean Water movie series.

Both canines and humans were invited to sign the Canines for Clean Water Pledge. Dogs signed with a paw dipped in mud. Most humans preferred to sign their name with a pen, though the fingerprint-in-mud option was available for them as well. Dogs who took the pledge were rewarded with swag! We distributed attractive bandanas with the Canines for Clean Water logo on them, so that dogs could show their pride in making the commitment to having their owners clean up after them. **Figure 30-8** features one of the canine supporters ready to go with their brand-new bandana.

Figure 30-8. Dog who visited the educational table to sign the Canines for Clean Water pledge, wearing one of the free bandanas distributed at the event.

Don't Feed the Ducks Campaign

Based on a successful pilot program in 2016 that focused on persuading park patrons to not feed the ducks, the MPRB moved forward with fabrication of permanent education pieces in 2017. In 2022, our largest yellow duck ambassador continued the mission along the Lake Harriet shoreline, adjacent to the seasonal restaurant Bread & Pickle. See **Figure 30-9** for the scale of our giant buoy rubber duck ambassador.

Figure 30-9. Photo of the Lake Harriet rubber duck buoy of the Don't Feed the Ducks Campaign.

The recently redesigned sandwich board signs asking park visitors to not feed the wildlife were also deployed at more locations, including Bde Maka Ska, Lake Harriet, Lake Nokomis, Loring Pond, and Powderhorn Lake. These signs encourage visitors to "photo don't feed" as an alternative way to connect with ducks and geese living around our lakes. See **Figure 30-10** for examples of these newly designed signs.

Figure 30-10. Example of goose sign posted at Bde Maka Ska, and duck sign at Lake Harriet encouraging people to take pictures rather than offer food to the wildlife with the hashtag #PhotoDontFeed.

Earth Day Watershed Clean-up

Going back more than 25 years, the MPRB Earth Day Watershed Clean-up event has inspired more than 27,000 residents to remove an estimated 190,000 pounds of garbage from Minneapolis parks. Trash bags, gloves, and instructions were made available for pick up at participating park sites. **Figure 30-11** pictures volunteers removing garbage from East River Flats Park**.**

Figure 30-11. Photos from the 2022 Earth Day Watershed Clean-up.

In 2022, this single-day event engaged 1,112 volunteers at 31 sites throughout the City of Minneapolis to remove trash that might otherwise have ended up in our water ways. See the complete list in **Table 30-1**.

Table 30-1. Locations of the 2022 Earth Day Watershed Clean-up.

Earth Day Clean-up Location	ZIP CODE	Earth Day Clean-up Location	ZIP CODE
Armitage Park	55410	Lake Nokomis	55417
Bassett's Creek	55404	Longfellow Park	55406
Bde Maka Ska East	55417	Loring Park	55403
Beltrami Park	55413	Lynnhurst Park	55419
Boom Island	55413	Mueller Park	55405
Bryant Square Park	55408	Pearl Park	55419
Cedar Lake	55416	Powderhorn Park	55407
Creekview Park	55430	Sibley Park	55407
E River Flats Park	55455	Sumner Field	55411
Elliot Park	55404	Theodore Wirth Park	55411
Father Henn Bluff Park	55414	Triangle Park	55417
Folwell Park	55412	W River Pkwy & 36th	55406
James I. Rice Park	55401	W River Pkwy & 44th	55406
Kenny Park	55419	Waite Park	55418
Lake Harriet	55409	Whittier Park	55405
Lake of the Isles East	55405		

Mississippi River Green Team

The Mississippi River Green Team, as seen in **Figure 30-12,** is a conservation-based teen crew engaged in daily hands-on environmental work throughout the summer. The crew consists of up to 18 youth and two supervisors, who work mostly in the natural areas of the Minneapolis park system, and within the watershed of the Mississippi Watershed Management Organization (MWMO). Typical workdays included visiting such park sites, such as B. F. Nelson Park, East Phillips Park, Mill Ruins Park, Minneapolis Sculpture Gardens, Elliot Park, Parade Ice Garden, and North Mississippi Regional Park, to conduct invasive species removal, weed wrenching, planting, watering, and mulching.

The crew were scheduled for weekly career exposure days designed to provide them with a chance to meet professionals and have experience in a variety of green fields. They participated in activities such as stenciling storm drains and delivering literature to raise awareness of the connection between the stormwater in the street to the Mississippi River, studying macroinvertebrates and their connection to water quality, and surveying for invasive worms impacting forest ecosystems. They also completed several educational experiences including the Sustainable Land Training with MetroBlooms, the Stormwater 101 lesson with staff at the MWMO, learning about the history of the Mississippi River at several locations to explore how humans have impacted and depend on the river.

Figure 30-12. The 2022 Mississippi River Green Team standing outside of the Mississippi Watershed Management Organization building. Staff are wearing yellow shirts, and turquoise shirts are worn by Green Team members.

The Mississippi River Green Team is made possible through a partnership between the Minneapolis Park & Recreation Board and the Mississippi Watershed Management Organization.

The Green Team is also supported by City of Minneapolis Public Works through their contract with *Landbridge Ecological*, which manages vegetation at stormwater Best Management Practices (BMPs) throughout the city. Landbridge and the Green Team's work in 2022 focused on weed and invasive species management at 16th Ave Rain Garden, 37th Greenway Raingardens, Columbus Wet and Dry Basin, Bancroft Meadows Dry Basin, Heritage Park, Hiawatha Raingardens, Lake Mead, Lowell curve, Riverside Rain Garden at Svea Triangle, Sibley Park Dry Basin, Shingle Creek, and Sumner Field.

31. Quality Assurance Assessment Report

Background

Environmental monitoring and management require the collection of highly reliable and verifiable data. Data accepted for inclusion in a database must be of known quality and must meet established criteria. A Quality Assurance Program is a defined protocol for sample collection, handling, and analysis to ensure that the quality of the data collected is quantified and tracked. Quality Assurance consists of two components (Standard Methods for the Examination of Water and Wastewater, 2005):

> Quality Assessment (QA), Periodic evaluations of laboratory performance through the submission and analysis of externally provided blanks, standard solutions, duplicates, and split samples.
>
> Quality Control (QC), Documented operator competence, recovery of known additions, and analysis of internally provided reagent blanks, proper equipment calibration, and maintenance of control charts.

Description

This Quality Assurance Project Plan (QAPP) describes the procedures and quality control measures used for water quality monitoring and laboratory analyses completed in 2022 for the MPRB Lake Monitoring Program, the National Pollutant Discharge Elimination Systems (NPDES) stormwater monitoring, and other studies. The project activities for lake sampling are detailed in the Lake Monitoring Program Overview, **Chapter 1**. Stormwater monitoring procedures are explained in the Stormwater Monitoring Program Manual (Minneapolis Park & Recreation Board, 2001).

QA/QC definitions, as presented by T.A. Dillaha, et al. (1988) and Standard Methods (2005), are used in the presentation of the information in this document.

> Precision is a measure of the degree of agreement between independent measurements of some property. Precision is concerned with the closeness of the results and is usually expressed in terms of the standard deviation of the data for duplicate or replicate analyses. Precision is a measure of how close the results are together with respect to each other not how close they are to a true value.
>
> Accuracy is a measure of the degree of agreement of a measured value with an accepted reference or true value. It is usually expressed in terms of percent recovery of the expected value of a standard solution and is an expression of the amount of bias in the data. Accuracy is a measure of how close the results are to a known true value.
>
> Representativeness is a measure of the degree to which data accurately and precisely represent the characteristics of the population which is being monitored.
>
> Completeness is a measure of the amount of valid data obtained from a measurement system compared to the amount expected to be obtained under correct normal conditions. For example, a data set for a lake will not be complete if the laboratory did not analyze all expected parameters. Completeness is usually expressed as a percent of the true value.

Comparability expresses the confidence with which one data set, measuring system, or piece of equipment can be compared with another. Data can be considered comparable if they are similar to those reported by others in the literature, data from previous years, and if the analysis procedures produce results similar to those reported by other laboratories for split samples.

The frequencies of quality assessment and quality control activities are set forth to ensure the validity of the database is listed in **Table 31-1**. The QA/QC plan follows the recommendations of Standard Methods for the Examination of Water and Wastewater (2005).

Table 31-1. Summary and frequency of QA/QC activities.

Sample Type	Description	Function	Frequency
Equipment Blank	Reagent-grade de-ionized water subject to sample collection, processing, and analysis	Estimating background values due to sample collection, processing, and analysis	End of sampling season
Bottle Blank/Field Blank	Reagent-grade de-ionized water subject to sample processing and analysis	Estimating background values due to sample processing and analysis; carried in the field	One/sampling trip
Field Duplicate	Duplicate of lake and beach sampling procedures	Estimating lab batch and sampling procedure precision	One/sampling trip
Blind QA/QC Audit Standard	Synthetic sample with chemical concentrations similar to a natural sample	Estimating overall batch precision and lab bias	One/Month
Laboratory Calibration Standard	Standard solution from a source other than the control standard	Calibrate the instrument before samples are analyzed	One/lab batch (10% of samples)
Laboratory Calibration Blank	Reagent-grade de-ionized water analyzed along sample batch	Identifying signal drift and contamination of samples	One/lab batch (10% of samples)
Laboratory Reagent Blank	Reagent-grade de-ionized water plus reagents included with each sample batch	Identifying contamination of reagents	One/lab batch (10% of samples)
Laboratory Control Standard	Standard solution from a source other than calibration standard	Determining accuracy and consistency of instrument calibration	One/lab batch (10% of samples)
Split Samples	Split of lake sample sent to at least three different laboratories for analysis	Determining comparability	Two/ sampling season
Laboratory Duplicate	Split of sample aliquot	Determining analytical precision within batches	10% of samples (at least one per batch)
Laboratory Matrix Spike/Matrix Spike Duplicate	Known spike of a sample and recovery of known additions	Determining percent recovery of parameter analyzed	10% of samples (at least one per batch)

OBJECTIVES

The primary objective of this QAPP is to ensure and identify the completeness, representativeness, precision, accuracy, and comparability of the data collected. The following pages summarize these data characteristics for results from both field measurements and parameters as analyzed by Instrumental

Research Inc. (IRI) located in Fridley, MN.

This program was designed to clearly establish which data were fully useable, of questionably usability, or unusable. Quantitative data quality descriptions have been included to provide data users with background on why certain data were deemed to be questionable or unusable. This enables the data user to apply stringent acceptance limits on defining usability to meet the objectives of their own analyses. Quantitative data quality indicators were calculated for each analysis method individually. To estimate quantitative data quality indicators on a method-by-method basis, all samples analyzed using a given method were treated as belonging to the same population (Fairless and Bates, 1989).

The QAPP set target frequencies for all QA/QC activities:

A. For every sampling batch analyzed, the laboratory included blanks, standards, and duplicates for each set of samples analyzed.
B. Ten percent of all laboratory samples were run in duplicate.
C. At the end of the season, equipment blanks were run on lake and stormwater sampling equipment.
D. A bottle field blank was associated with every sampling trip.
E. One laboratory reagent blank was analyzed for every ten samples run.
F. Filter blanks were analyzed where appropriate.
G. A matrix spike was analyzed in the laboratory with every ten samples.

Blind performance evaluation samples of known concentration were submitted monthly to the laboratory by the MPRB for analysis. The performance evaluation samples served as a quality assessment of monthly analytical runs. IRI used the following procedures during each analytical run:

A. Blanks for water and reagents (one for each) were analyzed for every 10 samples run.
B. A standard of known concentration was analyzed for each analytical run.
C. One spike (recovery of known additions) was analyzed for every 10 samples run.
D. One duplicate sample was analyzed for every 10 samples run, which included duplicate spikes.

Additional quality control measures used in the contract laboratory were as follows:

A. Control charts were maintained for all routinely measured parameters and analyses were not performed unless control (reference) samples fell within the specified acceptance limits see **Table 31-2**.
B. Experienced individuals trained technicians before they could conduct analyses by themselves, and their supervisors routinely reviewed their performance.
C. Laboratory blanks, standards, and QC samples were run with each set of cyanotoxin samples (microcystin, anatoxin-a).

Table 31-2. IRI analytical laboratory and Pace laboratory methods, reporting limits (RL), the performance evaluation percent recovery (PE % Rec) acceptance limits, and relative percent difference (RPD) allowed with duplicates. MPN = most probable number.

Parameter	Abbreviation	Method	IRI RL	Pace RL	PE % Rec Limits	Duplicate RPD Limits
Alkalinity, Total	Alk	Standard Methods 2320 B	2.0 mg/L	-	80-120	±10%
Aluminum, Total*	Tot-Al	EPA 200.8	30 µg/L	-	80-120	±10%
Aluminum, Soluble*	Sol-Al	EPA 200.8	30 µg/L	-	80-120	±10%
Ammonia, Un-ionized as N	NH_3	USGS I-3520-85	0.250 mg/L	-	80-120	±10%
Chemical Oxygen Demand	COD	Standard Methods 5220D	20.0 mg/L	-	80-120	±10%
Chloride, Total	Cl	Standard Methods 4500-Cl^- B	2.0 mg/L	-	80-120	±10%
Chlorophyll-*a*	Chl-*a*	Acetone extraction/spectrophotometric determination (pheophytin corrected) SM 10200 H	0.5 µg/L	-	-	±10%
Copper, Total	Cu	EPA 200.8	-	1 µg/L	80-120	±10%
Dissolved Organic Carbon	DOC	Standard Methods 5310C	-	1.5 mg/L	80-120	±10%
Escherichia coli	*E. coli*	Colilert Quanti-Tray, IRI	1 MPN per 100ml	-	-	-
Fat, Oil, and Grease	FOG	EPA 1664A(HEM)	5.0 mg/L	-	80-120	±10%
Hardness, Total as $CaCO_3$	Hard	Standard Methods 2350 C	5.0 mg/L	-	80-120	±10%
Iron, Total	Tot-Fe	EPA 200.7	50 µg/L	-	80-120	±10%
Iron, Soluble	Sol-Fe	EPA 200.7	50 µg/L	-	80-120	±10%
Kjeldahl Nitrogen, Total	TKN	ASTM D3590 A-02	0.500 mg/L	-	80-120	±10%
Lead, Total	Pb	Standard Methods 3500-Pb B	-	0.1 µg/L	80-120	±10%
Nitrite+Nitrate	NOx or NO_2NO_3	Standard Methods 4500-NO_3 E	0.030 mg/L	-	80-120	±10%
Nitrogen, Total (persulfate)	TN	Standard Methods 4500 N C Alkaline persulfate oxidation/automated cadmium reduction method.	0.500 mg/L	-	80-120	±10%
Phosphorus, Dissolved	TDP	Standard Methods 4500-P A, B, G	0.010 mg/L	-	80-120	±10%
Phosphorus, Total	TP	Standard Methods 4500-P E	0.010 mg/L	-	80-120	±10%
Silica, Reactive	Si	Standard Methods 4500-SiO_2 C	0.500 mg/L	-	-	±10%
Solids, Total Dissolved	TDS	Standard Methods 2540 C	5.0 mg/L	-	80-120	±10%
Solids, Total Suspended	TSS	Standard Methods 2540 D	1.0 mg/L	-	80-120	±10%

* Aluminum was initially analyzed using EPA 200.7 but changed later in the season to EPA 200.8.

Table 31-2 (Continued). IRI analytical laboratory and Pace laboratory methods, reporting limits (RL), the performance evaluation percent recovery (PE % Rec) acceptance limits, and relative percent difference (RPD) allowed with duplicates.

Parameter	Abbreviation	Method	IRI RL	Pace RL	PE % Rec Limits	Duplicate RPD Limits
Solids, Volatile Suspended	VSS	Standard Methods 2540 E	2.0 mg/L	-	80-120	±10%
Soluble Reactive Phosphorus	SRP	Standard Methods 4500-P E	0.003 mg/L	-	80-120	±10%
Sulfate	SO_4	ASTM D516-90	5.0 mg/L	-	80-120	±10%
Zinc, Total	Zn	Standard Methods 3500-Zn B	-	20 µg/L	80-120	±10%

METHODS

Laboratory results and field data were entered into a spreadsheet. Data were evaluated to determine usability according to the methods, **Table 31-2**. Data were categorized into one of three levels of usability: fully usable, questionable usability, or unusable. To be fully usable the data had to meet all the data quality criteria: completeness, representativeness, comparability, precision, and accuracy. Data rated as questionable usability met all but one of the quality criteria. Unusable data were those that were known to contain significant errors or data that met fewer than four of the data quality criteria.

Completeness

Data sets were deemed to be complete if fewer than 5% of the data were missing or not analyzed appropriately.

Representativeness

Data sets were deemed to be representative if samples were collected according to the sampling schedule and standard collection and handling methods were followed. Monitoring locations, frequencies, and methods followed suggested protocol to ensure representativeness (Wedepohl et al., 1990).

Comparability

Data for a given parameter were deemed to be highly comparable if the laboratory split results from all three labs for that parameter had a coefficient of variation (CV) of less than 20% and if reported values were consistent with past results. If the CV between labs for a given parameter was more than 20%, but most data reported were within 20%, the data set for that parameter was deemed to be moderately comparable.

Coefficient of Variation = standard deviation/mean.

Precision

Data sets were deemed precise if two criteria were met (Standard Methods, 2005):

The relative percent difference of results for each pair of duplicate analyses was within acceptance limits for each given parameter.

Relative Percent Difference (RPD) $= \frac{|x_1 - x_2|}{(x_1 + x_2) \div 2} \times 100\%$

The percent recovery of known standard additions met the established acceptance limits for each parameter.

Percent Recovery (% Rec) $= \frac{observed\ value}{expected\ value} \times 100\%$

Precision was further quantified by calculating the average range and standard deviation of results for duplicates.

Average Range (R) = $\frac{\sum|x_1 - x_2|}{n}$

Standard Deviation (estimated) $stdev = \sqrt{\frac{\Sigma(x - x\ sample\ mean)^2}{n-1}}$

Accuracy

Data sets were deemed accurate if the percent recovery reported for performance evaluation standards fell within the established acceptance limits for each given parameter and had been deemed precise. **Table 31-2** shows the percent recovery estimates bias in the data set. Together, bias and precision reflect overall data set accuracy (Standard Methods, 2005). Low bias and high precision translate to high accuracy.

The standard solutions used for performance evaluation samples were manufactured by Environmental Resource Associates (ERA) located in Golden, Colorado, and diluted by MPRB staff to achieve the desired concentrations. ERA provided performance acceptance limits on the Certificate of Analysis for the recovery of each analyte. These performance limits defined acceptable analytical results given the limitations of the United States Environmental Protection Agency (US EPA) approved and Standard Methods methodologies (US EPA Reports, 1979, 1980, 1985, 1986). The acceptance limits were based on data generated by laboratories in ERA's InterLab program and data from the US EPA and closely approximated the 95% confidence interval. If a laboratory failed a blind monthly performance standard all the monthly data for that parameter were flagged as questionable. Laboratories were allowed ± 20% recovery for all parameters except soluble reactive phosphorus and total dissolved phosphorus data which were allowed ± 30% recovery due to the low phosphorus concentrations.

The contract laboratories provided minimum detection limits (MDL) and reporting limits (RL). The IRI laboratory calculated the MDL based upon documented performance studies and the RL are two to five times the MDL. **Table 31-2** lists the reporting limits for analyses as provided by IRI.

Results and Discussion

If the blind monthly performance standard failed to achieve the required percent recovery (±20%), the entire month's data were flagged by underlining the data and marking it in red. There was one parameter flagged in 2022: February COD. While April COD did not technically meet our standards, this was due to proximity of the true value to the minimum detection limit, so data was not flagged. Additionally, July TN and TKN were initially flagged due to a dilution error while preparing the standards on part of the MPRB. Upon realizing this, the flag was removed.

Completeness

The data collected in 2022 was deemed to be complete. Missing data and improper analyses accounted for less than 1% of the samples collected. A minimum of 10% of the final data were checked by hand against the raw data sent by the laboratories to ensure there were no errors entering or transferring the data.

Representativeness

The 2022 lakes data were deemed to be representative of actual in-lake conditions. Samples were collected over the deepest point of each lake to create a profile at appropriate depths. The duration of monitoring, sampling frequency, site location, and depth intervals sampled met or exceeded the recommendations to collect representative data and to account for seasonal changes and natural variability (Wedepohl et al., 1990). Sample collection and handling followed established protocol for monitoring water quality as detailed in Standard Methods for the Examination of Water and Wastewater (2005). NPDES stormwater samples were collected in accordance with the Stormwater Monitoring Program Manual (MPRB, 2001).

Stormwater samples were collected using both best available technology and appropriate sampling protocols. *E. coli*, pH, and FOG samples were all collected as grab samples. Stormwater NPDES hydrograph composite chemistry samples were collected by multiplexed flow-weighted auto-samplers, with the intake strainers pointed upstream to collect the most accurate solids sample profile (EPA ASCE stormwater monitoring manual, 2002).

Grab samples were collected at both Webber Natural Swimming Pool and beaches for bacteria, as well as cyanotoxins at beaches, using appropriate sampling protocols.

Comparability

Between Years

The 2022 lakes data were deemed to be comparable to previous years' data. In reviewing box and whisker plots of water clarity, chlorophyll-*a* and total phosphorus data, reported values appeared to be consistent with previous years for most lakes; however, Cedar, Harriet, Hiawatha and Lake Nokomis did vary compared to previous years. Water clarity was deeper in Cedar Lake in 2022 compared to previous years. Lake Harriet had higher chlorophyll-*a* concentrations compared to previous years. In 2022, Lake Hiawatha had shallower water clarity and higher chlorophyll-*a* and total phosphorus concentrations. Lastly, Lake Nokomis had higher chlorophyll-*a* and total phosphorus concentrations.

Between Laboratories

To determine data comparability between laboratories lake samples were split in the field and shared with MPRB, Minnehaha Creek Watershed District (MCWD), and Three Rivers Park District (TRPD). The MPRB used IRI Laboratory in Fridley, MN. MCWD used RMB Laboratory in Bloomington, MN, and TRPD uses their own in-house laboratory. Data for a given parameter were deemed to be highly comparable if the laboratory split results for that parameter from all the laboratories had a coefficient of variation (CV) less than 20% and if reported values were consistent with past results. Generally, if the CV between laboratories for a given parameter was more than 20% then the data set for that parameter was deemed to be moderately comparable. If most of the parameters tested for the data set had a laboratory outlier the comparability was deemed low.

Care must be taken when interpreting these data at very low levels or near reporting limits. For example, the CV between 1 and 2 µg/L is 47%, but the CV between 10 and 11 µg/L is 7%. Both have a difference of 1 µg/L. The rule of sensibility was used to evaluate low level data and whether to flag it or not. The rule of sensibility is applying common sense to data interpretation. Low level samples less than 5 times the reporting limit, ± the reporting limit is used as an acceptable range. Samples greater than 5 times the reporting limit ± 20% of the CV is used as an acceptable range.

The MPRB shared round-robin format split samples with the participating laboratories from the sampling events on June 22nd and September 13th, 2022. The results from all participating agencies split samples are summarized in **Table 31-3** through **Table-31-7** and in **Figures 31-1** through **31-5**. The 2022 lake split data set were deemed to be overall highly comparable to data analyzed by TRPD and MCWD. **Table 31-3** through **Table 31-7** show the coefficient of variation was greater than 20% for two chlorophyll-*a* (Chl-*a*), four total phosphorus (TP), eight soluble reactive phosphorus (SRP) samples, and five chloride (Cl) samples, all highlighted in red. Note: since the TRPD is an in-house laboratory the reporting limit for SRP is 6 µg/L, but they sometimes do provide lower values. This could impact the averages since some labs can report lower values than other labs. Split data can only be compared when there are three samples analyzed by three different laboratories, only then can an outlier be seen.

The split samples for chlorophyll-*a* were highly comparable as seen in **Figure 31-1**. All laboratories used a spectrophotometer. There were two outliers, samples 1 and 5, analyzed by MCWD and TRPD, respectively. Chlorophyll-*a* concentrations can be extremely variable due to inherent sampling limitations and plankton patchiness as well as the difficulty in laboratory grinding and analysis. The average CV for chlorophyll-*a* was 19%.

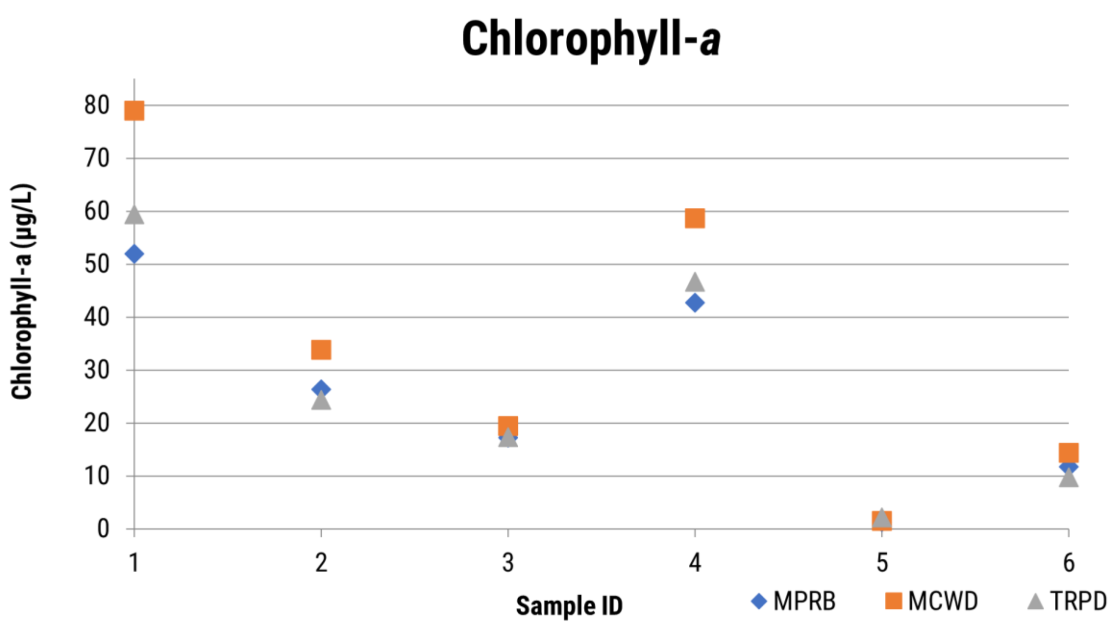


Figure 31-1. Plot of chlorophyll-*a* split sample results reported for 2022.

Table 31-3. Summary of Chl-*a* split sample results reported by IRI/MRPB, MCWD, and TRPD in 2022. CV = Coefficient of Variation. Split failures are highlighted in red.

ID	Parameter	Units	Depth	Lake	MPRB	MCWD	TRPD	CV
1	**Chl-a**	mg/M^3	0	Sar	52.0	79.00	59.40	22%
2	**Chl-a**	mg/M^3	0-2	Long Lake	26.32	33.80	24.40	18%
3	**Chl-a**	mg/M^3	0	WTS	17.22	19.4	17.3	7%
4	**Chl-a**	mg/M^3	0-2	Parley	42.74	58.70	46.70	17%
5	**Chl-a**	mg/M^3	0-2	WIR	1.28	1.48	2.20	29%
6	**Chl-a**	mg/M^3	0-2	WIR	11.75	14.42	9.80	19%

TP splits had moderate comparability as seen in **Figure 31-2**. There were 4 outliers: samples 8, 16, and 17, analyzed by MCWD, and sample 11, analyzed by TRPD. Phosphorus is an important and limiting aquatic nutrient and accuracy for this element is critical. The average CV for TP was 20%. Many of the phosphorus samples have low-level concentrations.

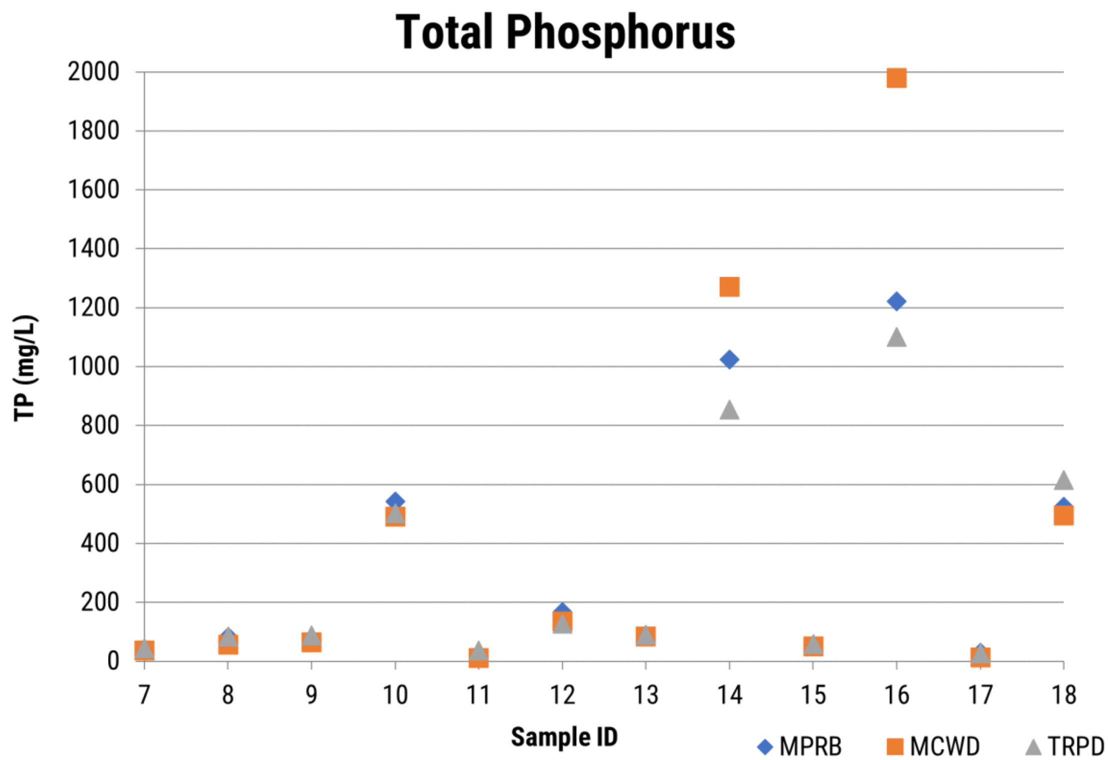


Figure 31-2. Scatter plot of Total Phosphorus split sample results reported for 2022.

Table 31-4. Summary of TP split sample results reported by IRI/MRPB, MCWD, and TRPD in 2022. CV = Coefficient of Variation. Split failures are highlighted in red.

ID	Parameter	Units	Depth	Lake	MPRB	MCWD	TRPD	CV
7	TP	mg/l	0	WTS	40.0	36.0	44.0	10%
8	TP	mg/l	14	WTS	82.0	56.0	84.1	21%
9	TP	mg/l	0-2	Parley	66.0	65.0	88.5	18%
10	TP	mg/l	5	Parley	542.0	491.0	502.0	5%
11	TP	mg/l	0-2	WIR	15.0	12.0	36.7	63%
12	TP	mg/l	7	WIR	168.0	136.0	128.0	15%
13	TP	mg/l	0	Sar	88.0	85.0	89.4	3%
14	TP	mg/l	17	Sar	1024.0	1270.0	853.8	20%
15	TP	mg/l	0-2	Long Lake	52.0	51.0	58.9	8%
16	TP	mg/l	8.5	Long Lake	1222.0	1980.0	1100.3	33%
17	TP	mg/l	0-2	WIR	28.0	13.0	27.8	38%
18	TP	mg/l	7	WIR	525.0	494.0	614.7	12%

SRP split samples are shown in **Figure 31-3**. IRI and RMB had a reporting limit of 0.003 mg/L, while TRPD has a reporting limit of 0.006 mg/L but since it is an in-house laboratory, they sometimes provide results below the Reporting Limit (RL). The low-level split SRP data must be deemed of questionable comparability especially at concentrations below 0.006 mg/L. Users of these data must decide if this loss of resolution at low concentrations is of significant concern for any given data application. There were 8 outliers, samples 19 and 30, analyzed by TRPD, samples 21 and 25, analyzed by MPRB, and samples 23, 26, 27, and 29, analyzed by MCWD. All of the outliers were at low concentrations. The average CV for SRP was 32%.

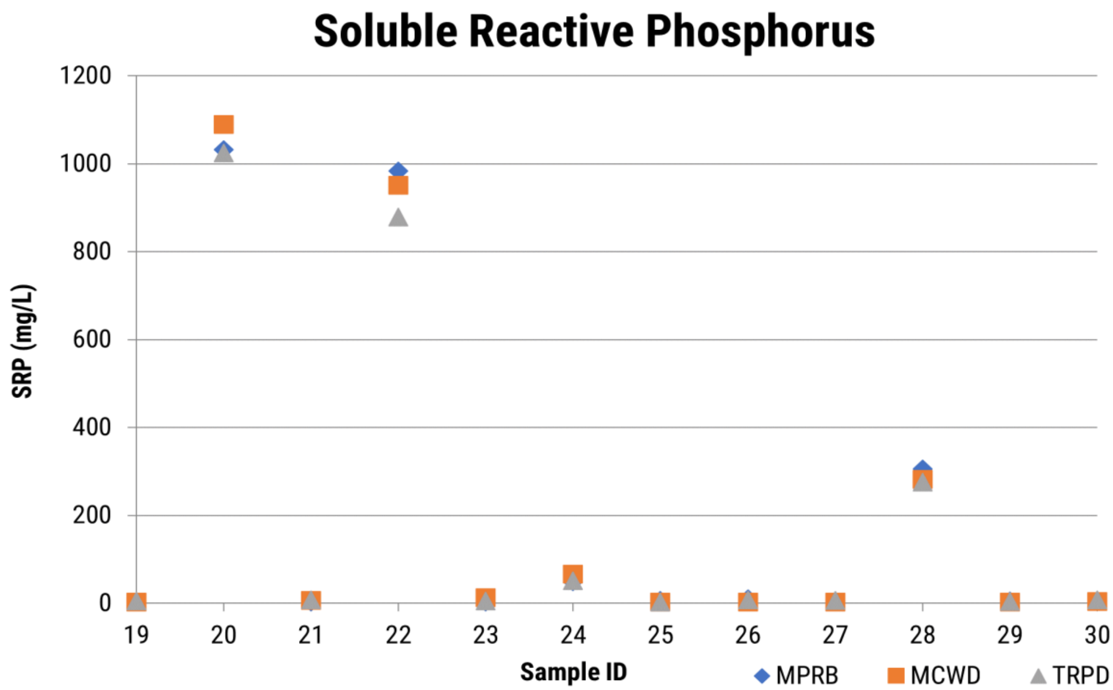


Figure 31-3. Scatter plot of Soluble Reactive Phosphorus split sample results reported for 2022.

Table 31-5. Summary of SRP split sample results reported by IRI/MRPB, MCWD, and TRPD in 2022. CV = Coefficient of Variation. Split failures are highlighted in red. Underlined values are below the detection limit.

ID	Parameter	Units	Depth	Lake	MPRB	MCWD	TRPD	CV
19	**SRP**	mg/L	0-2	Long	4.0	3.0	5.9	34%
20	**SRP**	mg/L	8.5	Long	1032	1090	1024	3%
21	**SRP**	mg/L	0	Sar	3.0	6.0	7.7	43%
22	**SRP**	mg/L	17	Sar	983.0	951.0	879.3	6%
23	**SRP**	mg/L	0-2	WIR	3.0	13.0	4.9	76%
24	**SRP**	mg/L	7	WIR	49.0	67.0	51.7	17%
25	**SRP**	mg/L	0	WTS	6.0	3.0	2.6	48%
26	**SRP**	mg/L	14	WTS	10.0	3.0	7.5	52%
27	**SRP**	mg/L	0-2	Parley	5.0	3.0	6.9	39%
28	**SRP**	mg/L	5	Parley	306.0	282.0	275.2	6%
29	**SRP**	mg/L	0-2	WIR	5.0	3.0	4.1	25%
30	**SRP**	mg/L	7	WIR	5.0	4.0	7.5	33%

TN splits were completed by IRI, TRPD, and MCWD as seen in **Figure 31-4**. TRPD and MPRB (IRI) perform a persulfate digestion and MCWD (RMB) performs a sum of the nitrogen species TKN and NO_3NO_2. There were no outliers detected and the average CV was 12%.

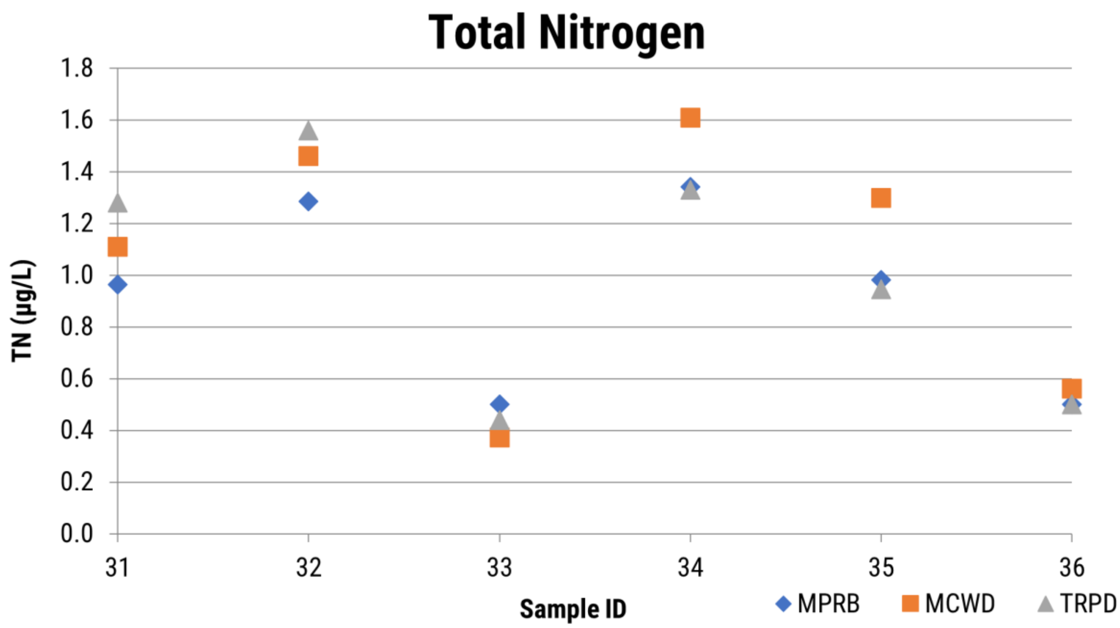


Figure 31-4. Scatter plot of Total Nitrogen split sample results reported for 2022.

Table 31-6. Summary of TN split sample results reported by IRI/MRPB, MCWD, and TRPD in 2022. CV = Coefficient of Variation. Split failures are highlighted in red. Underlined values are below the detection limit.

ID	Parameter	Units	Depth	Lake	MPRB	MCWD	TRPD	CV
31	**TN**	mg/l	0	WTS	0.96	1.11	1.28	14%
32	**TN**	mg/l	0-2	Parley	1.29	1.46	1.56	10%
33	**TN**	mg/l	0-2	WIR	<u>0.500</u>	0.37	0.44	15%
34	**TN**	mg/l	0	Sar 0M	1.34	1.61	1.33	11%
35	**TN**	mg/l	0-2	Long Lake	0.98	1.30	0.95	18%
36	**TN**	mg/l	0-2	WIR	<u>0.500</u>	0.561	<u>0.500</u>	7%

Chloride splits were completed by IRI, TRPD, and MCWD as seen in **Figure 31-5**. There were 5 outliers in 2022, though all had CVs very close to 20%. The outliers included samples 37, 38, and 40, analyzed by MCWD, and Samples 44 and 46, analyzed by MPRB. The average CV for chloride was 16%.

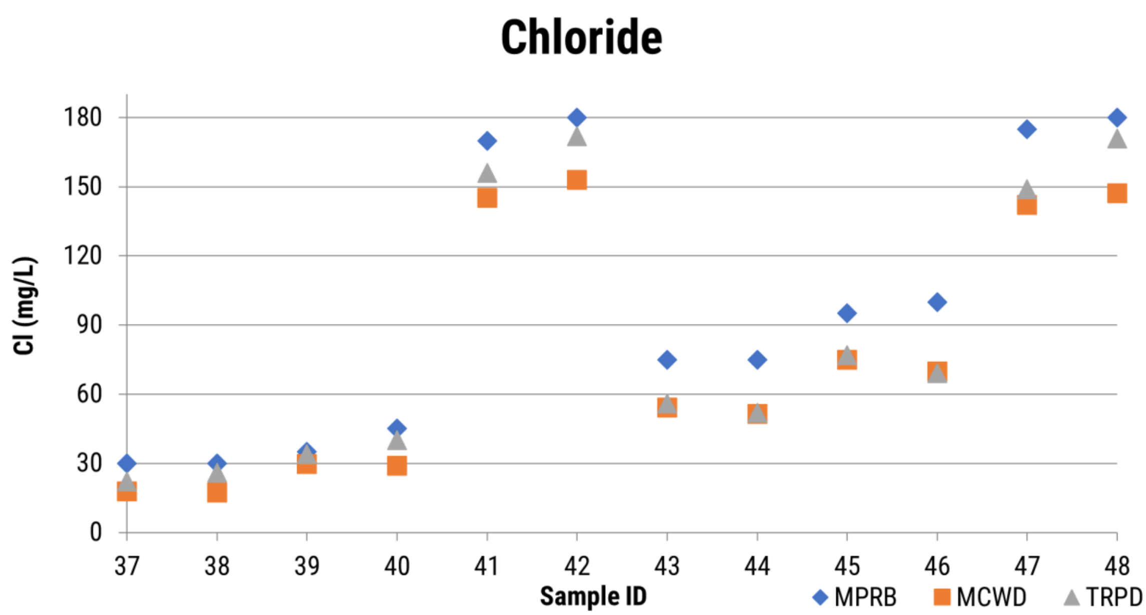


Figure 31-5. Scatter plot of Chloride split sample results reported for 2022.

Table 31-7. Summary of Cl split sample results reported by IRI/MRPB, MCWD, and TRPD in 2022. CV = Coefficient of Variation. Split failures are highlighted in red.

ID	Parameter	Units	Depth	Lake	MPRB	MCWD	TRPD	CV
37	**Cl**	mg/l	0	WTS	30.0	17.8	22.0	27%
38	**Cl**	mg/l	14	WTS	30.0	17.4	26.0	26%
39	**Cl**	mg/l	0-2	Parley	35.0	29.7	34.0	9%
40	**Cl**	mg/l	5	Parley	45.0	29.0	40.0	22%
41	**Cl**	mg/l	0-2	WIR	169.9	145.0	156.0	8%
42	**Cl**	mg/l	7	WIR	179.9	153.0	171.9	8%
43	**Cl**	mg/l	0	Sar	75.0	54.2	56.0	19%
44	**Cl**	mg/l	17	Sar	75.0	51.4	52.0	23%
45	**Cl**	mg/l	0-2	Long Lake	95.0	75.0	77.0	13%
46	**Cl**	mg/l	8.5	Long Lake	100.0	69.9	69.0	22%
47	**Cl**	mg/l	0-2	WIR	174.9	142.0	149.0	11%
48	**Cl**	mg/l	7	WIR	179.9	147.0	170.9	10%

The comparability of the inter-laboratory split sample within each of the parameters differed slightly. **Table 31-8** details the variability within parameters and lists the determined level of comparability for each. The comparability between years was determined by comparing 2022 values to previous year's data. 2022 had similar or worse comparability between labs than 2021. TP and SRP appeared to have more outliers than in previous years. The final CV calculated for SRP should not be used if many are below or near detection limit values.

Table 31-8. 2022 comparability of parameters analyzed as a part of the inter-laboratory split sample program and compared to previous year's data. Values listed are the range and mean for the coefficient of variation between labs.

Parameter	2022 CV Range	2022 CV Mean %	Comparability Between labs
Chlorophyll-*a*	7-29%	19%	High
Total Phosphorus	3-63%	20%	High
Soluble Reactive Phosphorus	3-76%	32%	Moderate
Total Nitrogen	7-18%	12%	High
Chloride	8-27%	16%	High

Precision

The first criterion used for assessing data precision was the relative percent difference (RPD) between duplicates. For reporting and calculation purposes, the average of duplicate samples was used.

Field Duplicates

Field duplicates test the reproducibility of field methods and lake uniformity. **Table 31-9** summarizes the results from field duplicate samples in 2022. All duplicates were acceptable in 2022. Significant differences between duplicates were defined as having a RPD greater than 20%. The goal is to have the average RPD for parameters to be 10% or less, but when using descriptive statistics and values are near the reporting limit, the RPD calculations are skewed by the small values. Sometimes, these data are still considered acceptable. For example, low values of 0.003 mg/L and 0.004 mg/L have an RPD of 29%, which should not be considered a true duplicate failure but rather a statistical anomaly because the values are so small. The difference in some samples may also be the result of lake or pond sediment being disturbed by a boat anchor, malfunction of a water sampling device such as the Kemmerer sampler, or a high level of particles in the epilimnion. A thorough investigation should consider any potential cause of a duplicate failure.

Table 31-9. 2022 summary of field duplicate sample results and acceptability for IRI Laboratory.

Parameter	Average Relative % Difference	Average Range	Standard Deviation	Acceptable
Chlorophyll-*a*	9.03	1.75	6.7	Yes
Pheophytin-a	7.83	0.19	5.2	Yes
Silica	4.60	0.06	3.5	Yes
Total Phosphorus	4.64	1.03	3.7	Yes
Soluble Reactive Phosphorus	7.33	4.34	8.5	Yes
Total Kjeldahl Nitrogen	2.44	0.014	1.8	Yes
Total Nitrogen	5.26	0.185	3.2	Yes
NOx	1.86	0.001	2.0	Yes
Alkalinity	0.30	0.200	0.4	Yes
Hardness	2.89	1.60	3.8	Yes
Chloride	3.13	3.15	3.4	Yes
Sulfate	3.23	0.171	3.0	Yes
DOC	1.18	0.050	1.7	Yes
Total Aluminum	0.00	0.00	0.0	Yes
Soluble Aluminum	0.00	0.00	0.0	Yes
Total Iron	3.15	30.3	1.4	Yes
Soluble Iron	8.01	27.2	3.5	Yes

Lab Duplicates

IRI reported all internal QA/QC results to the MPRB. The reported RPD values for duplicate analyses were within acceptance limits. All duplicate analyses were deemed acceptable.

Performance Evaluation Samples

The second criterion for assessing data precision was percent recovery of blind monthly performance evaluation samples. Performance evaluation standards were purchased from ERA in Golden, CO. MPRB water resources staff used prepared standards mixed to concentrations similar to those being measured in the field for submission to the contract laboratory. **Table 31-10** and **Figures 31-6** through **Figure 31-9** summarize the performance evaluation sample results for each parameter. Chemical oxygen demand in February was flagged due to the percent recovery being outside the target range. The same parameter was initially flagged in April but was cleared due to the ERA value being below the reporting limit of 20. In July, Total Nitrogen and Total Kjeldahl Nitrogen were initially flagged due to a dilution error on the MPRBs part but were later cleared since IRI was not at fault. Dilution errors do not reflect inaccuracy in laboratory analysis, but rather inaccuracy in standard preparation.

Table 31-10. Performance evaluation samples analyzed by IRI in 2022. Flagged parameters are indicated in red. Recovery values denoted with asterisks were initially flagged but later cleared.

Sample ID	Date	Parameter	ERA value	IRI Value	% Recovery
1	2/8/2022	Alkalinity	171	179	105%
2	4/18/2022	Alkalinity	271	271	100%
3	5/27/2022	Alkalinity	68.2	64	94%
4	6/8/2022	Alkalinity	68.2	64	94%
5	7/14/2022	Alkalinity	50.9	50	98%
6	8/9/2022	Alkalinity	68.2	64	94%
7	9/8/2022	Alkalinity	68.4	60	88%
8	2/8/2022	Chloride	44	48	109%
9	4/18/2022	Chloride	50.1	56	112%
10	5/27/2022	Chloride	50.1	50	100%
11	6/8/2022	Chloride	50.1	56	112%
12	7/14/2022	Chloride	53.3	54	101%
13	8/9/2022	Chloride	50.1	54	108%
14	9/8/2022	Chloride	58.5	66	113%
15	2/8/2022	Chemical Oxygen Demand	27.52	20.8	76%
16	4/18/2022	Chemical Oxygen Demand	<20	14.1	*91%
17	5/27/2022	Chemical Oxygen Demand	22	22.6	103%
18	6/8/2022	Chemical Oxygen Demand	22	20	91%
19	7/14/2022	Chemical Oxygen Demand	22	22.6	103%
20	8/9/2022	Chemical Oxygen Demand	44	42.1	96%
21	9/8/2022	Chemical Oxygen Demand	56	48.9	87%
22	2/8/2022	Copper	788	811	103%
23	4/18/2022	Copper	764	825	108%
24	5/27/2022	Copper	764	812	106%
25	6/8/2022	Copper	764	830	109%
26	7/14/2022	Copper	764	864	113%
27	8/9/2022	Copper	764	748	98%
28	9/8/2022	Copper	148.4	155	104%
29	2/8/2022	Dissolved Organic Carbon	8	7.7	96%
30	4/18/2022	Dissolved Organic Carbon	8	8	100%
31	5/27/2022	Dissolved Organic Carbon	8	8.6	108%
32	6/8/2022	Dissolved Organic Carbon	8	8	100%
33	7/14/2022	Dissolved Organic Carbon	8	8.6	108%
34	8/9/2022	Dissolved Organic Carbon	8	8	100%
35	9/8/2022	Dissolved Organic Carbon	8	7.5	94%

Table 31-10 (continued). Performance evaluation samples analyzed by IRI in 2022. Flagged parameters are indicated in red. Values denoted with asterisks were initially flagged but later cleared.

Sample ID	Date	Parameter	ERA value	IRI Value	% Recovery
36	2/8/2022	E. Coli A	526 (125-1090)	461	100%
37	5/27/2022	E. Coli A	333(145-566)	228	100%
38	7/14/2022	E. Coli A	1320 (620-2220)	687	100%
39	9/8/2022	E. Coli A	459	326	71%
40	2/8/2022	E. Coli B	<1	<1	100%
41	5/27/2022	E. Coli B	<1	<1	100%
42	7/14/2022	E. Coli B	<1	<1	100%
43	9/8/2022	E. Coli B	<1	<1	100%
44	6/8/2022	Iron	124.4	126	101%
45	7/14/2022	Iron	124.4	116	93%
46	8/9/2022	Iron	124.4	128	103%
47	9/8/2022	Iron	664	606	91%
48	2/8/2022	Fat, Oil, and Grease	132	132	100%
49	4/18/2022	Fat, Oil, and Grease	125	121.9	98%
50	5/27/2022	Fat, Oil, and Grease	125	122	98%
51	2/8/2022	Ammonia	3.12	3.05	98%
52	4/18/2022	Ammonia	1.368	1.35	99%
53	5/27/2022	Ammonia	1.368	1.34	98%
54	6/8/2022	Ammonia	1.368	1.29	94%
55	7/14/2022	Ammonia	1.368	1.37	100%
56	8/9/2022	Ammonia	1.386	1.2	87%
57	9/8/2022	Ammonia	1.668	1.62	97%
58	2/8/2022	Nitrate/Nitrite	0.834	0.781	94%
59	4/18/2022	Nitrate/Nitrite	3.56	3.49	98%
60	5/27/2022	Nitrate/Nitrite	3.56	3.726	105%
61	6/8/2022	Nitrate/Nitrite	3.56	3.64	102%
62	7/14/2022	Nitrate/Nitrite	3.56	3.98	112%
63	8/9/2022	Nitrate/Nitrite	3.56	3.87	109%
64	9/8/2022	Nitrate/Nitrite	3.3	3.39	103%
65	2/8/2022	Lead	7.76	7.8	101%
66	4/18/2022	Lead	23.16	24.3	105%
67	5/27/2022	Lead	23.16	23.7	102%
68	6/8/2022	Lead	23.16	25.1	108%
69	7/14/2022	Lead	23.16	26.5	114%
70	8/9/2022	Lead	23.16	22.3	96%
71	9/8/2022	Lead	38.68	43.6	113%

Table 31-10 (continued). Performance evaluation samples analyzed by IRI in 2022. Flagged parameters are indicated in red. Values denoted with asterisks were initially flagged but later cleared.

Sample ID	Date	Parameter	ERA value	IRI Value	% Recovery
72	2/8/2022	Sulfate	13.5	12.9	96%
73	4/18/2022	Sulfate	19.7	17.3	88%
74	5/27/2022	Sulfate	19.7	17.2	87%
75	6/8/2022	Sulfate	19.7	16.3	83%
76	7/14/2022	Sulfate	28.9	27.1	94%
77	8/9/2022	Sulfate	19.7	17.4	88%
78	9/8/2022	Sulfate	40.5	40.3	100%
79	2/8/2022	Soluble Reactive Phosphorus	0.0488	0.039	80%
80	4/18/2022	Soluble Reactive Phosphorus	0.053	0.053	100%
81	5/27/2022	Soluble Reactive Phosphorus	0.053	0.051	96%
82	6/8/2022	Soluble Reactive Phosphorus	0.053	0.052	98%
83	7/14/2022	Soluble Reactive Phosphorus	0.053	0.053	100%
84	8/9/2022	Soluble Reactive Phosphorus	0.053	0.05	94%
85	9/8/2022	Soluble Reactive Phosphorus	0.0357	0.034	95%
86	2/8/2022	Total Dissolved Phosphorus	0.0488	0.041	84%
87	4/18/2022	Total Dissolved Phosphorus	0.053	0.054	102%
88	5/27/2022	Total Dissolved Phosphorus	0.053	0.058	109%
89	6/8/2022	Total Dissolved Phosphorus	0.053	0.058	109%
90	7/14/2022	Total Dissolved Phosphorus	0.053	0.059	111%
91	8/9/2022	Total Dissolved Phosphorus	0.053	0.06	113%
92	9/8/2022	Total Dissolved Phosphorus	0.0357	0.035	98%
93	2/8/2022	Total Dissolved Solids	34	33.8	99%
94	4/18/2022	Total Dissolved Solids	68.2	66	97%
95	5/27/2022	Total Dissolved Solids	271	27.1	10%
96	6/8/2022	Total Dissolved Solids	271	267	99%
97	7/14/2022	Total Dissolved Solids	258	253	98%
98	8/9/2022	Total Dissolved Solids	271	276	102%
99	9/8/2022	Total Dissolved Solids	317	304	96%
100	2/8/2022	Total Kjeldahl Nitrogen	2.02	2.16	107%
101	4/18/2022	Total Kjeldahl Nitrogen	5.46	5.27	97%
102	5/27/2022	Total Kjeldahl Nitrogen	5.46	5.14	94%
103	6/8/2022	Total Kjeldahl Nitrogen	5.46	5.41	99%
104	7/14/2022	Total Kjeldahl Nitrogen	5.46	<.5	*8%
105	8/9/2022	Total Kjeldahl Nitrogen	5.46	5.21	95%
106	9/8/2022	Total Kjeldahl Nitrogen	6.94	6.74	97%

Table 31-10 (continued). Performance evaluation samples analyzed by IRI in 2022. Flagged parameters are indicated in red. Values denoted with asterisks were initially flagged but later cleared.

Sample ID	Date	Parameter	ERA value	IRI Value	% Recovery
107	2/8/2022	Total Nitrogen	2.02	1.93	96%
108	4/18/2022	Total Nitrogen	5.46	5.24	96%
109	5/27/2022	Total Nitrogen	5.46	5.33	98%
110	6/8/2022	Total Nitrogen	5.46	5.2	95%
111	7/14/2022	Total Nitrogen	5.46	<.5	*9%
112	8/9/2022	Total Nitrogen	5.46	5.06	93%
113	9/8/2022	Total Nitrogen	6.94	6.32	91%
114	2/8/2022	Total Hardness	176	184	105%
115	4/18/2022	Total Hardness	170	164	96%
116	5/27/2022	Total Hardness	170	166	98%
117	6/8/2022	Total Hardness	183	190	104%
118	7/14/2022	Total Hardness	170	160	94%
119	8/9/2022	Total Hardness	170	160	94%
120	9/8/2022	Total Hardness	206	196	95%
121	2/8/2022	Total Phosphorus 01	0.0283	0.026	92%
122	4/18/2022	Total Phosphorus 01	0.0855	0.083	97%
123	5/27/2022	Total Phosphorus 01	0.0855	0.088	103%
124	6/8/2022	Total Phosphorus 01	0.0855	0.089	104%
125	7/14/2022	Total Phosphorus 01	0.085	0.09	106%
126	8/9/2022	Total Phosphorus 01	0.0855	0.092	108%
127	9/8/2022	Total Phosphorus 01	0.0835	0.078	93%
128	2/8/2022	Total Phosphorus 02	0.566	0.56679	100%
129	4/18/2022	Total Phosphorus 02	1.71	1.7	99%
130	5/27/2022	Total Phosphorus 02	1.71	1.785	104%
131	6/8/2022	Total Phosphorus 02	1.71	1.85	108%
132	7/14/2022	Total Phosphorus 02	1.71	1.89	111%
133	8/9/2022	Total Phosphorus 02	1.71	1.94	113%
134	9/8/2022	Total Phosphorus 02	1.67	1.65	99%
135	2/8/2022	Total Suspended Solids	63	64	102%
136	4/18/2022	Total Suspended Solids	92.5	91	98%
137	5/27/2022	Total Suspended Solids	92.5	84	91%
138	6/8/2022	Total Suspended Solids	53.7	51	95%
139	7/14/2022	Total Suspended Solids	92.5	91	98%
140	8/9/2022	Total Suspended Solids	92.5	88	95%
141	9/8/2022	Total Suspended Solids	84	82	98%

Table 31-10 (continued). Performance evaluation samples analyzed by IRI in 2022. Flagged parameters are indicated in red. Values denoted with asterisks were initially flagged but later cleared.

Sample ID	Date	Parameter	ERA value	IRI Value	% Recovery
142	2/8/2022	Zinc	424	450	106%
143	4/18/2022	Zinc	297.6	300	101%
144	5/27/2022	Zinc	297.6	285	96%
145	6/8/2022	Zinc	297.6	299	100%
146	7/14/2022	Zinc	297.6	277	93%
147	8/9/2022	Zinc	297.6	300	101%
148	9/8/2022	Zinc	528	495	94%

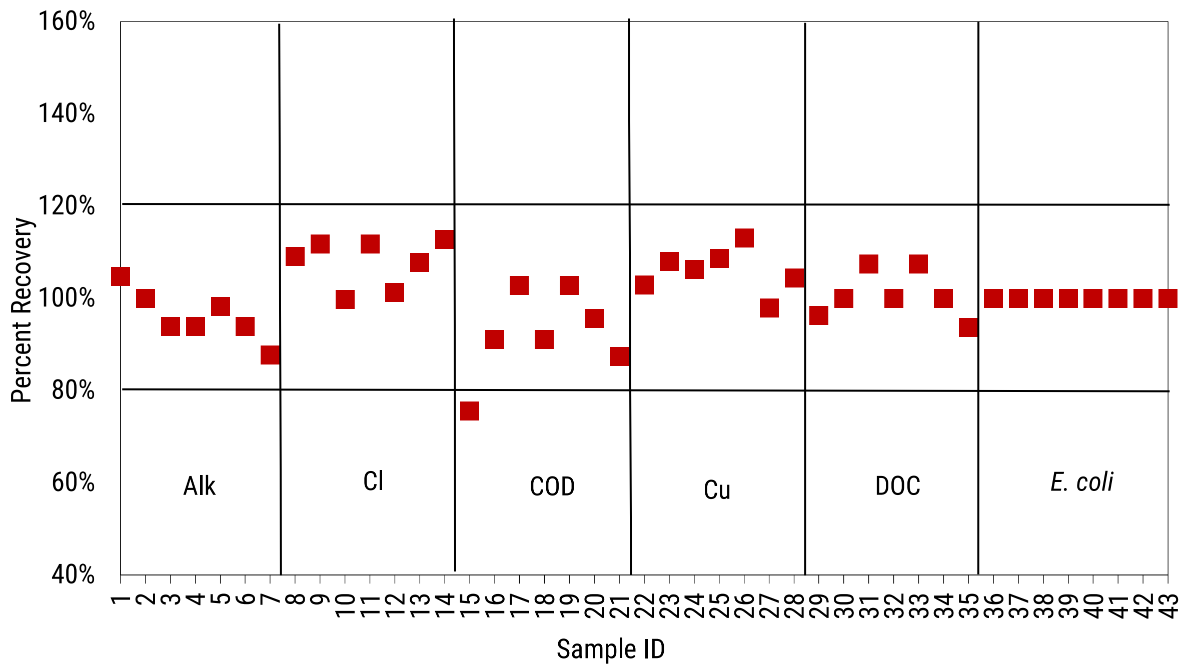


Figure 31-6. Scatter plot of reported percent recoveries for performance evaluation samples in 2022. See Table 31-10 to reference ID numbers with descriptions and results.

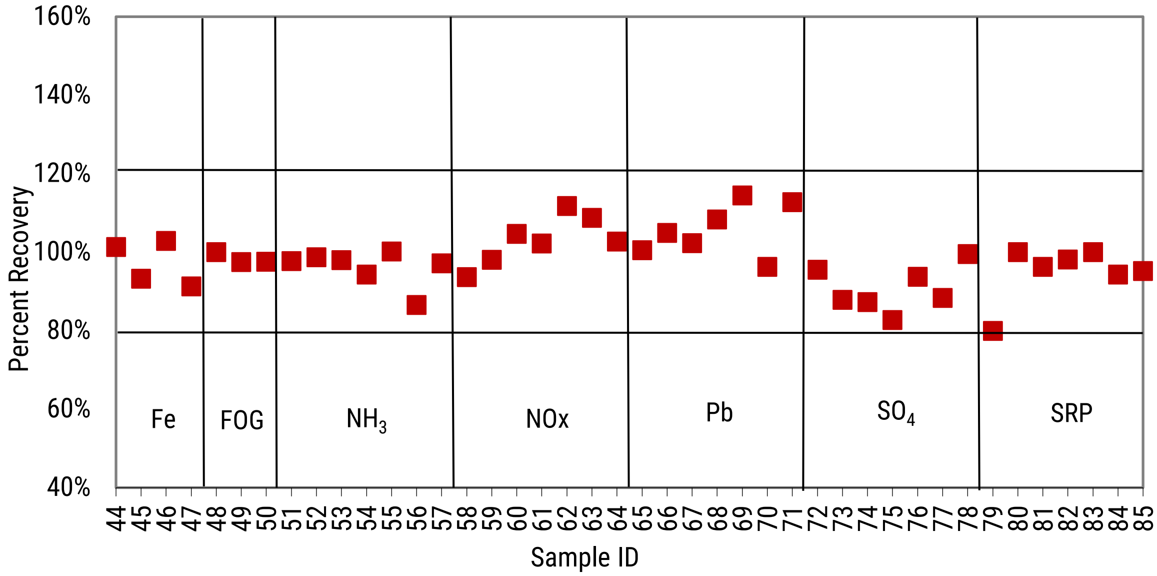


Figure 31-7. Scatter plot of reported percent recoveries for performance evaluation samples in 2022. See Table 31-10 to reference ID numbers with descriptions and results.

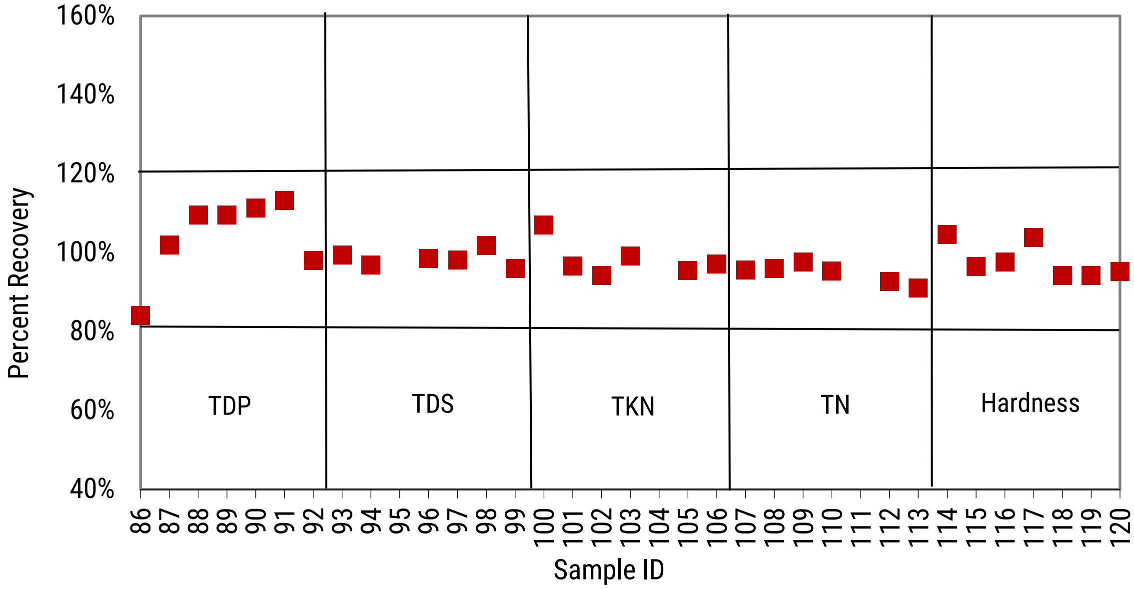


Figure 31-8. Scatter plot of reported percent recoveries for performance evaluation samples in 2022. See Table 31-10 to reference ID numbers with descriptions and results. Samples 95 and 104 are excluded to due dilution error.

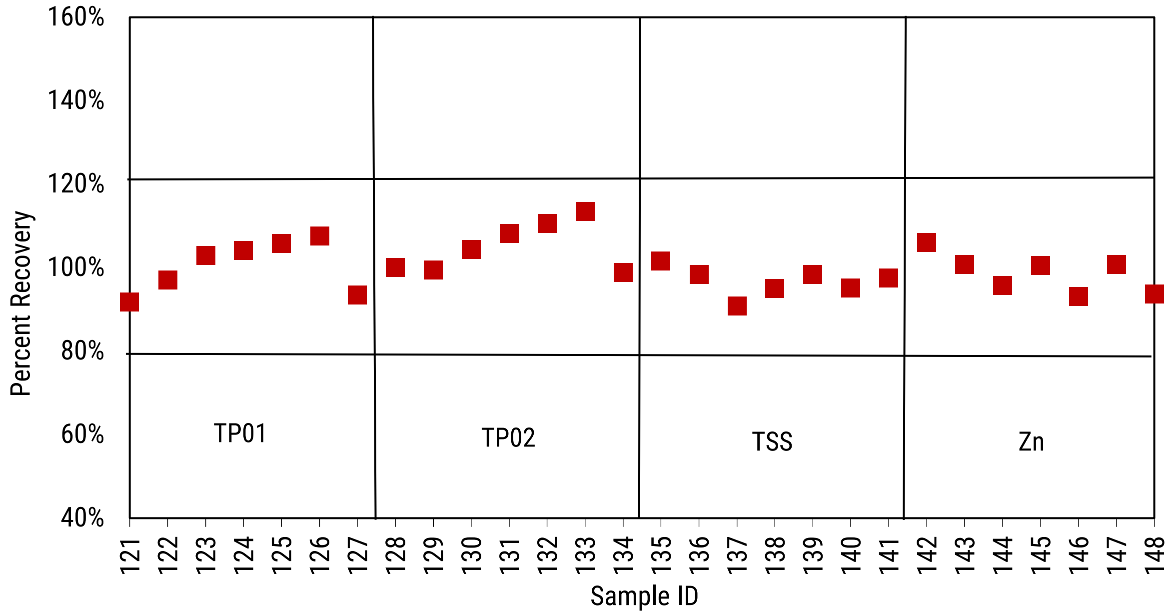


Figure 31-9. Scatter plot of reported percent recoveries for performance evaluation samples in 2022. See Table 31-10 to reference ID numbers with descriptions and results.

All performance evaluation standards were acceptable for all months, except for COD in February. Alkalinity, chloride, hardness, TDS, FOG, and TSS are pre-made and are the only standards that do not require dilution. The remaining standards were diluted before they were submitted to the lab.

All *E. coli* standards were acceptable. The performance acceptance limits for *E. coli* supplied by ERA are much wider than for the other parameters, (± 50%). The coliform standards are shipped directly to the MPRB laboratory IRI from ERA.

SRP and TDP performance evaluation samples were mixed to low concentrations approximately 10-20 times the reporting limit. Standard Methods (2005) recommends that performance evaluation samples be mixed to a minimum concentration of 5 times the reporting limit. Because of the low concentrations the acceptance limit for SRP and TDP were historically widened from the recommended 80-120% range to 70-130% recovery.

Analysis of Equipment Blanks and Field Blanks

Equipment blanks were run for lake and stormwater sampling equipment. Lake equipment was scrubbed and rinsed before running de-ionized (DI) water through each piece of equipment (composite tube, bucket, and Kemmerer). The stormwater equipment blank used the equipment removed from one site for the year and consisted of the intake strainer, tubing, and 3700 ISCO sampler. One rinse cycle of DI water was done and then DI water was pumped into a clean container for final collection and analysis. Final 2022 results from lake equipment blanks yielded non-detects for all parameters and equipment. Stormwater equipment blanks yielded hits for TP, TDP, SRP, NO_x, TSS, and VSS. The intake tubing was visibly dirty upon removal from the field which likely caused the contamination, rather than the tubing itself. Due to short staffing, tubing could not be replaced during the season.

The 2022 results from the bottle/field blanks which were carried in the field unopened yielded non-detects for all parameters. Reagent blanks run by IRI laboratories during batch analyses resulted in no detectable levels for all parameters analyzed.

Recovery of Known Additions and Internally Supplied Standard Solutions

All recovery values for spike samples/known additions reported by IRI were within acceptance limits. All reported recoveries for internally supplied standards of known concentration were within acceptance limits.

Final Assessment of Data Usability

Table 31-7 lists the overall completeness, representativeness, comparability, and precision determined for the 2022 data by parameter. Completeness refers to having less than 5% of data missing. Representativeness refers to how the samples represent natural conditions. Comparability refers to the parameter's performance in splits. Precision refers to the parameter's performance with lab duplicates, field blanks, and monthly performance evaluations. All additional parameters not analyzed by IRI and collected in the field: dissolved oxygen, temperature, conductivity, pH, turbidity, and water clarity were deemed to be fully usable. These measurements followed standard methods and protocols for collection and daily equipment calibration.

The 2022 data designated as questionable may still meet the data quality needs of some analyses. Users of these data should assess if the data quality indicators discussed in this document meet their needs. Much of the data designated as questionably usable are categorized as such because of a missed performance evaluation standard or split samples with low comparability.

The chemical parameters designated as questionably usable on **Table 31-11** are for months that either failed a blind monthly performance standard parameter or the comparability of a split sample parameter was of concern. When reviewing the monthly performance and split samples, the rule of sensibility must be applied, and the percent recovery must be viewed in relation to the recovery values (low or high), stability of the test, and the multiple of the detection limit to create the reporting limit used for the data.

Table 31-11. Summary of 2022 data usability by parameter. √ = acceptance criteria were met, ¤ = some data was of questionable usability.

Parameter	Completeness	Representativeness	Comparability	Precision
Alkalinity	√	√	√	√
Aluminum, Total	√	√	√	√
Aluminum, Soluble	√	√	√	√
Ammonia	√	√	√	√
Chemical Oxygen Demand	√	√	√	¤
Conductivity	√	√	√	√
Chloride	√	√	√	√
Chlorophyll-*a*	√	√	√	√
Copper	√	√	√	√
Dissolved Organic Carbon	√	√	√	√
E. coli	√	√	√	√
Hardness	√	√	√	√
Iron, Total	√	√	√	√
Iron, Soluble	√	√	√	√
Lead	√	√	√	√
Nitrate/Nitrite	√	√	√	√
Pheophytin-a	√	√	√	√
pH	√	√	√	√
Silica	√	√	√	√
Soluble Reactive Phosphorus	√	√	¤	√
Sulfate	√	√	√	√
Total Dissolved Phosphorus	√	√	√	√
Total Dissolved Solids	√	√	√	√
Total Kjeldahl Nitrogen	√	√	√	√
Total Nitrogen	√	√	√	√
Total Phosphorus	√	√	√	√
Total Suspended Solids	√	√	√	√
Volatile Suspended Solids	√	√	√	√
Zinc	√	√	√	√

32. Additional Sources of Water Quality Information

Minneapolis Park and Recreation Board

Water Quality Homepage
https://www.minneapolisparks.org/park_care__improvements/water_resources

Blue-Green Algae Information Page
https://www.minneapolisparks.org/park-care-improvements/water_resources/lake_water_resources/blue-green-algae/

Lake Water Quality Map
bit.ly/mplsbeaches
https://minneapolisparks.maps.arcgis.com/apps/webappviewer/index.html?id=88319f73c7904adcbabccacdff38bbf1

City of Minneapolis

Storm and Surface Water Management Website
http://www.ci.minneapolis.mn.us/stormwater/

City of Minneapolis Project Page
https://www2.minneapolismn.gov/government/departments/public-works/surface-water-sewers/programs-policy/

Watershed Management Organizations

Bassett Creek Watershed Management Commission
http://www.bassettcreekwmo.org/

Minnehaha Creek Watershed District
http://www.minnehahacreek.org/

Mississippi Watershed Management Organization
http://www.mwmo.org/

Shingle Creek Watershed Management Commission
http://www.shinglecreek.org/

Hennepin County or Metro Resources

Hennepin County Environmental Services
https://mrbdc.mnsu.edu/contacts/hennepin-county-environmental-services

Hennepin County Wetland Health Evaluation Project (WHEP)
https://www.hennepin.us/your-government/get-involved/wetland-health-evaluation-program

Hennepin County Public Beaches
https://www.hennepin.us/residents/health-medical/public-swim-beaches

Metropolitan Council – Environmental Services
https://metrocouncil.org/About-Us/What-We-Do/Departments/Environmental-Services.aspx

State of Minnesota Resources

Minnesota Department of Natural Resources
Information on lake surveys, maps, fish stocking, fish advisories and more.
http://www.dnr.state.mn.us/lakefind/

Aquatic Invasive Species
http://www.dnr.state.mn.us/invasives/index_aquatic.html

Groundwater Monitoring
https://www.dnr.state.mn.us/waters/cgm/index.html.

Minnesota Pollution Control Agency
Information on environmental monitoring, clean-up, and more.
https://www.pca.state.mn.us/

Minnesota Pollution Control Agency Blue-Green Algae
https://www.pca.state.mn.us/water/blue-green-algae-and-harmful-algal-blooms

Minnesota Pollution Control Agency Blue-Green Algae Advisories
https://www.pca.state.mn.us/water/harmful-algae-blooms-water-recreation-advisories

Minnesota Pollution Control Agency PFAS Blueprint
https://www.pca.state.mn.us/sites/default/files/p-gen1-22.pdf

Minnesota Department of Health
http://www.health.state.mn.us/

Minnesota Lake Superior Beach Monitoring Program
http://www.mnbeaches.org

Minnesota Department of Agriculture – Water
https://www.mda.state.mn.us/protecting/waterprotection

Minnesota Sea Grant
http://www.seagrant.umn.edu

University of Minnesota Extension Service
http://www.extension.umn.edu/water

US Federal Government

US Army Corps of Engineers St. Paul District
https://www.mvp.usace.army.mil/

US Geological Survey – Minnesota (Stream data and links to the national website)
https://www.usgs.gov/centers/umid-water/data-tools

US Geological Survey – Nonindigenous Aquatic Species (Information and maps of invasive aquatic plants and animals) http://nas.er.usgs.gov/default.aspx

Environmental Protection Agency
https://www.epa.gov/environmental-topics/water-topics

Environmental Protection Agency Healthy Beaches
https://www.epa.gov/beaches/learn-human-health-beach

Environmental Protection Agency Cyanobacteria and Cyanotoxins
https://www.epa.gov/cyanohabs/learn-about-cyanobacteria-and-cyanotoxins

National Oceanic and Atmospheric Administration (NOAA)
https://www.noaa.gov/
https://www.ncdc.noaa.gov/IPS/lcd/lcd.html?_page=1&state=MN&stationID=14922&_target2=Next+%253E

Other Resources

Minnesota Climatology Working Group
https://climateapps.dnr.state.mn.us/index.htm

Ice On/Out Information (From Environment Canada)
https://www.naturewatch.ca/icewatch/

Midwest Invasive Plant Network
http://www.mipn.org

Minnesota Invasive Species Advisory Council
http://www.mda.state.mn.us/misac/

Minnesota Aquatic Invasive Species Research Center (MAISRC)
https://www.maisrc.umn.edu/

Nokomis Groundwater Website
https://www2.minneapolismn.gov/government/departments/public-works/surface-water-sewers/programs-policy/lake-nokomis/

Grays Bay Twitter Site
https://twitter.com/graysbaydam

Minnehaha Creek USGS Station
https://waterdata.usgs.gov/mn/nwis/uv/?site_no=05289800&PARAmeter_cd=00065,00060

Shingle Creek USGS Station
https://waterdata.usgs.gov/mn/nwis/uv/?site_no=05288705&PARAmeter_cd=00065,00060

Lake Champlain Committee
https://www.lakechamplaincommittee.org/get-involved/volunteers/cyanobacteriamonitors/categorization-of-water-conditions

California Guidance for Cyanobacteria
https://mywaterquality.ca.gov/habs/resources/habs_response.html

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APPENDIX A

This section contains box-and-whisker plots and a table of outliers that were removed for each of the regularly monitored Minneapolis lakes for the entire period of record. A detailed explanation of box-and-whisker plots can be found in **Chapter 1**. See **Figure A-1** for the legend describing the box and whisker plots.

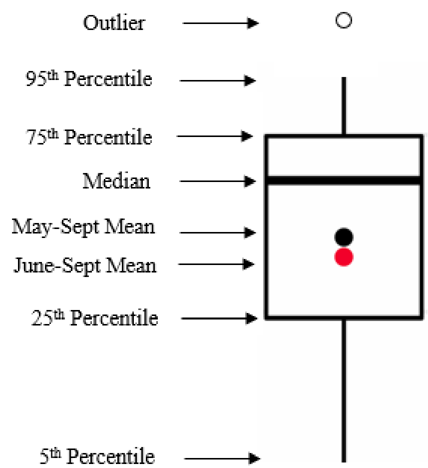
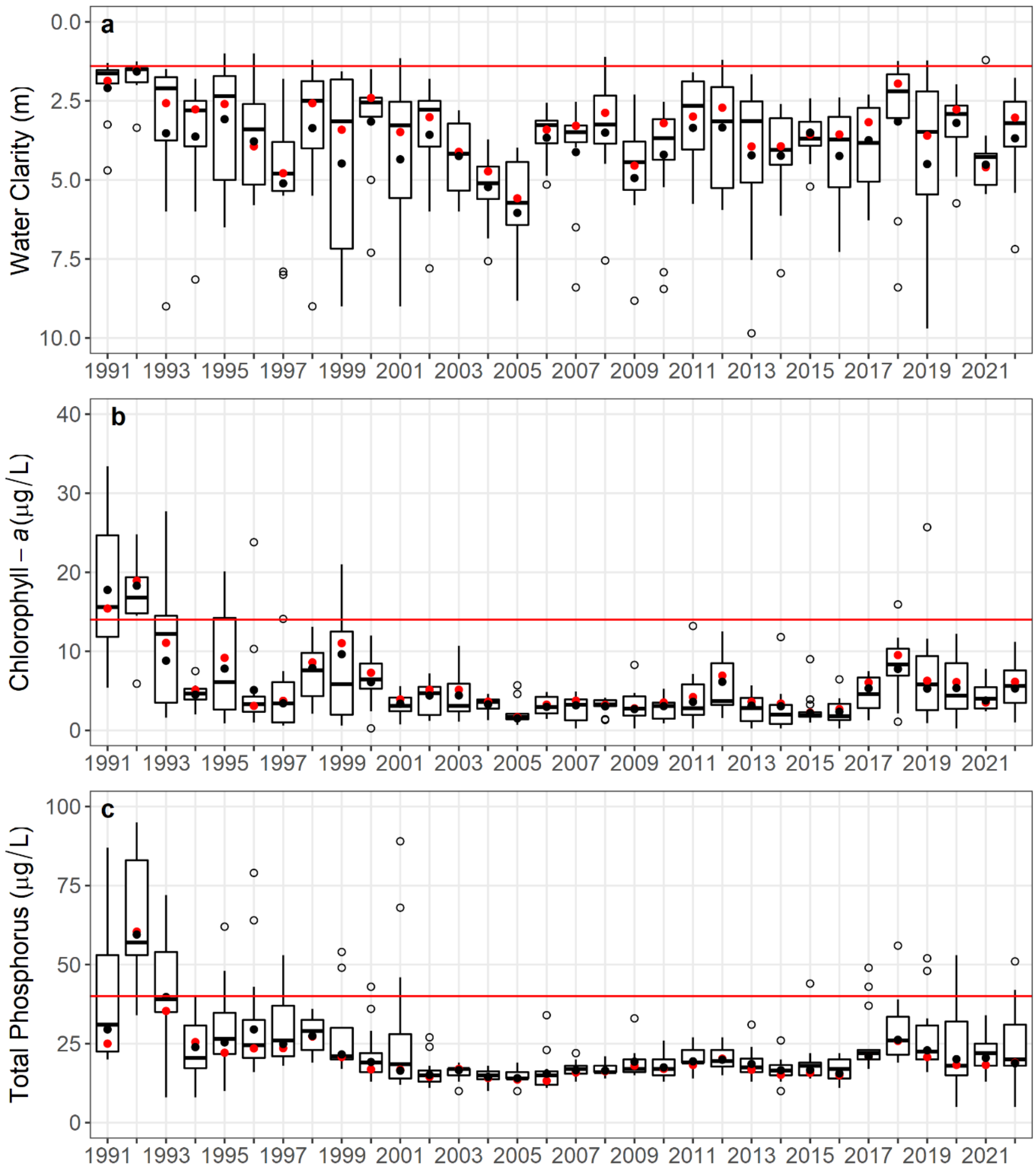
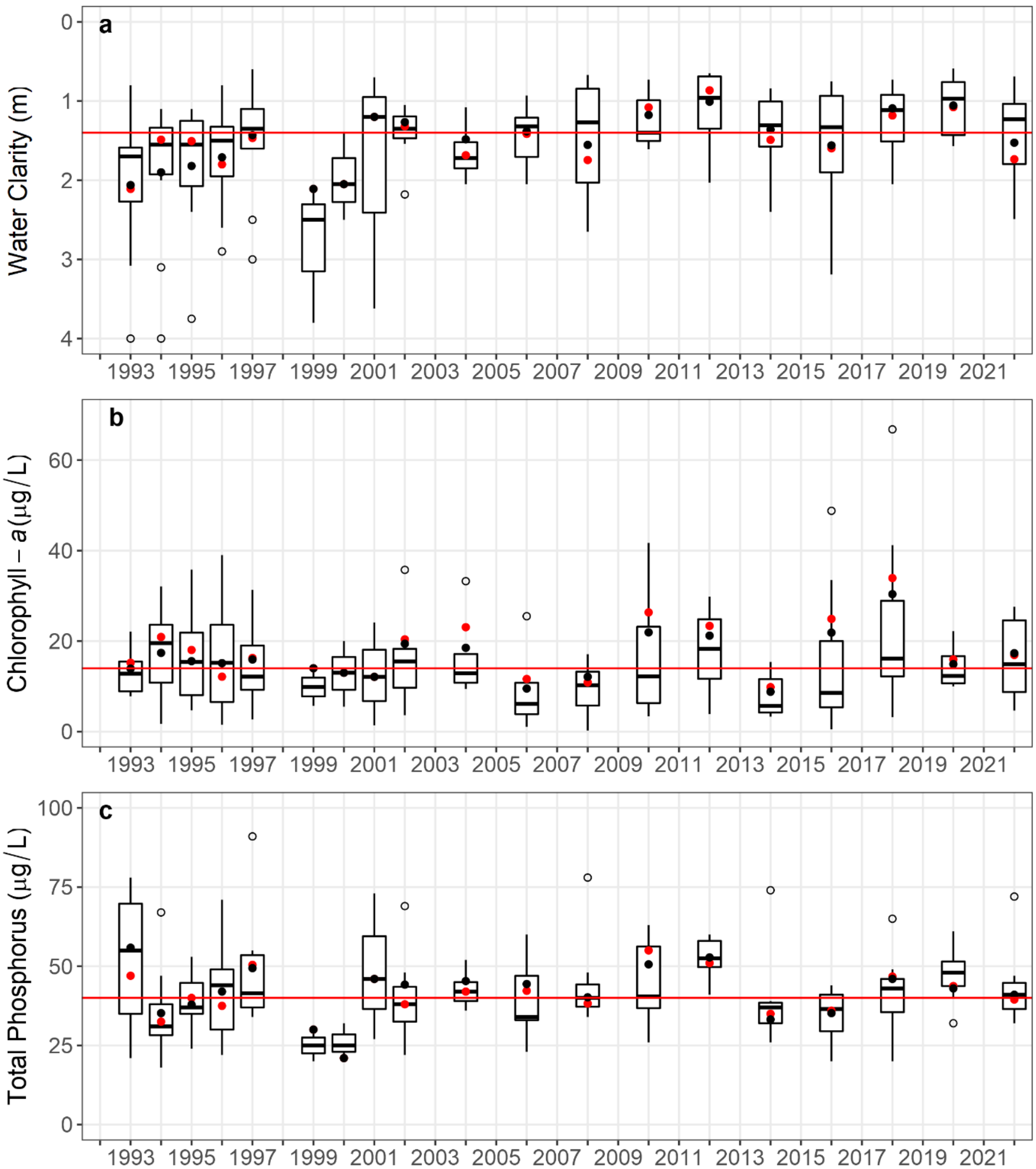


Figure A-1. Legend for box and whisker plots.

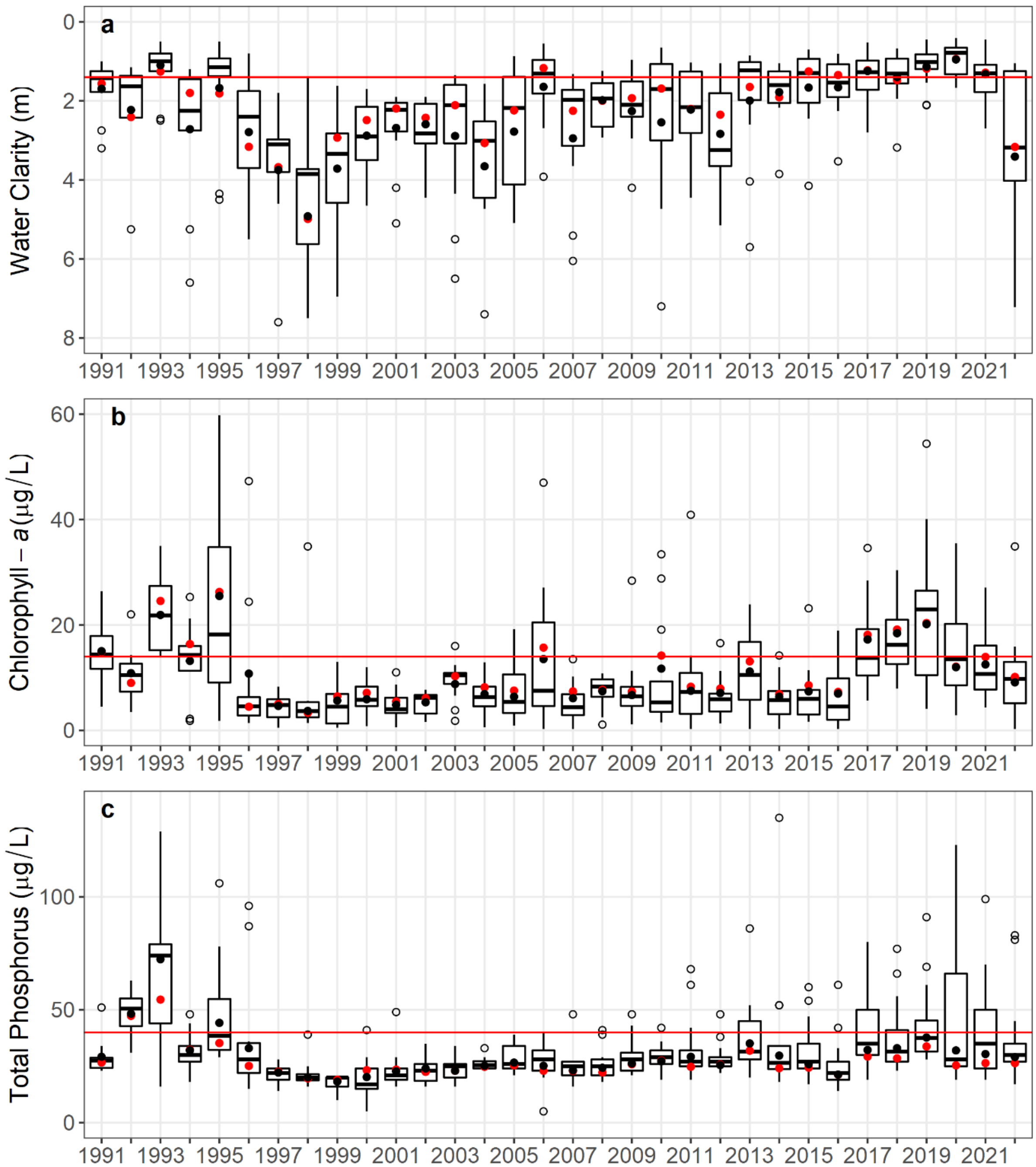
Bde Maka Ska 1991-2022



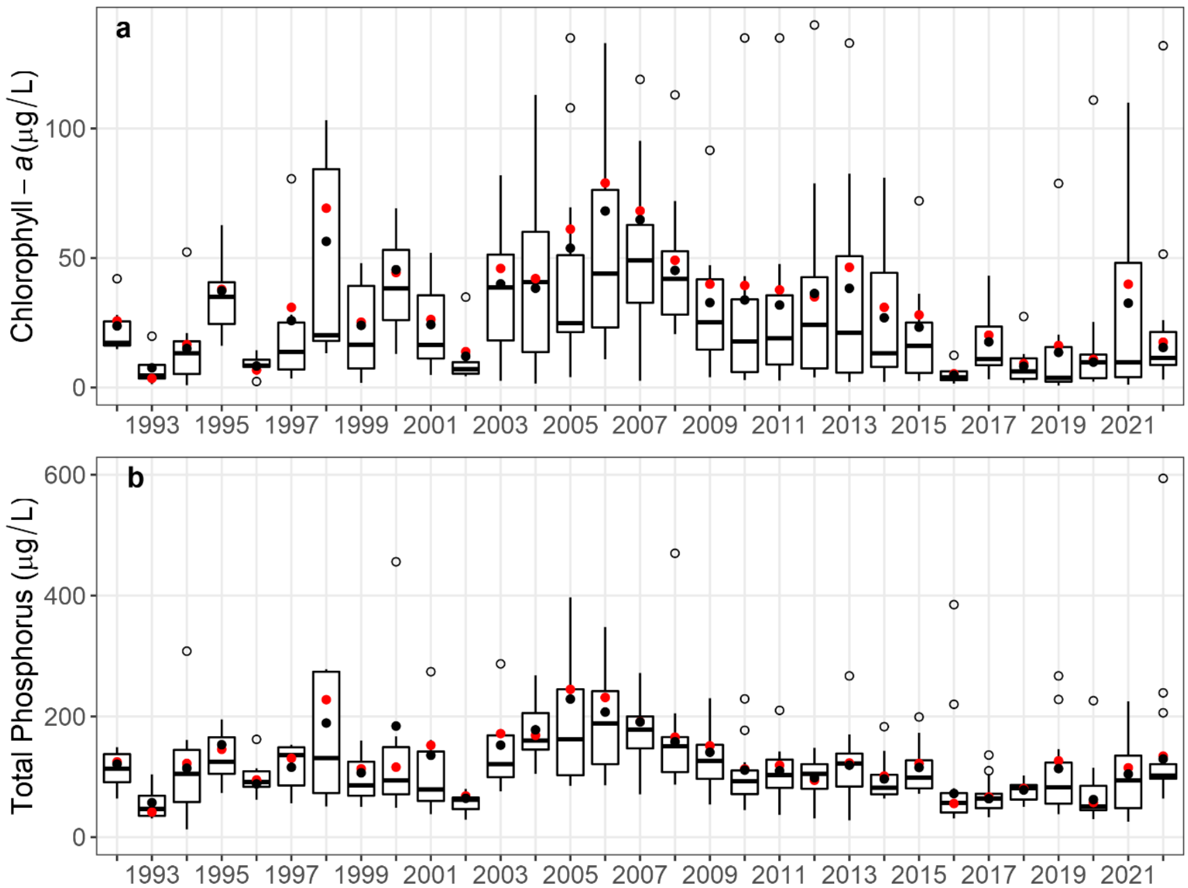
Brownie Lake 1993-2022



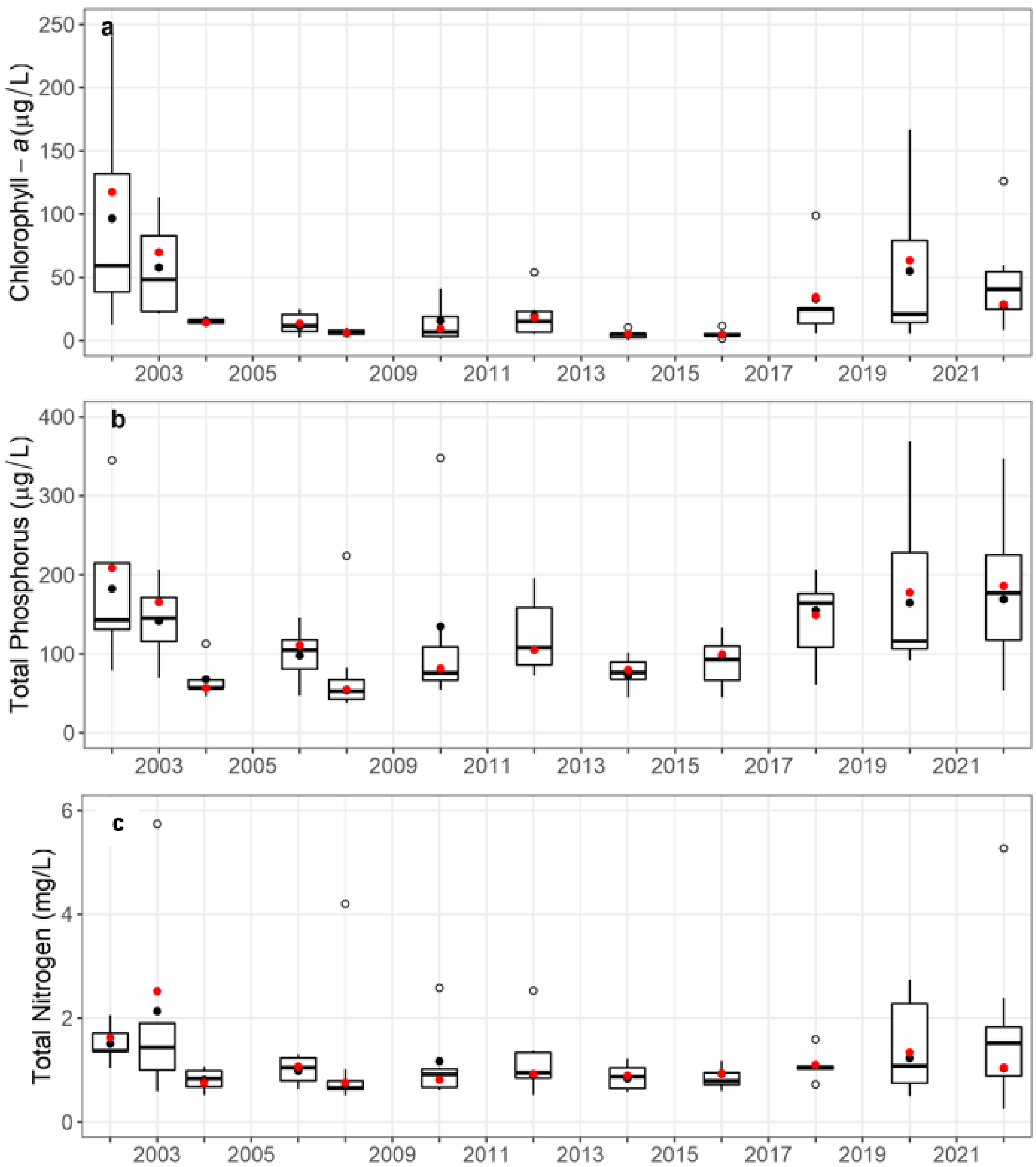
Cedar Lake 1991-2022



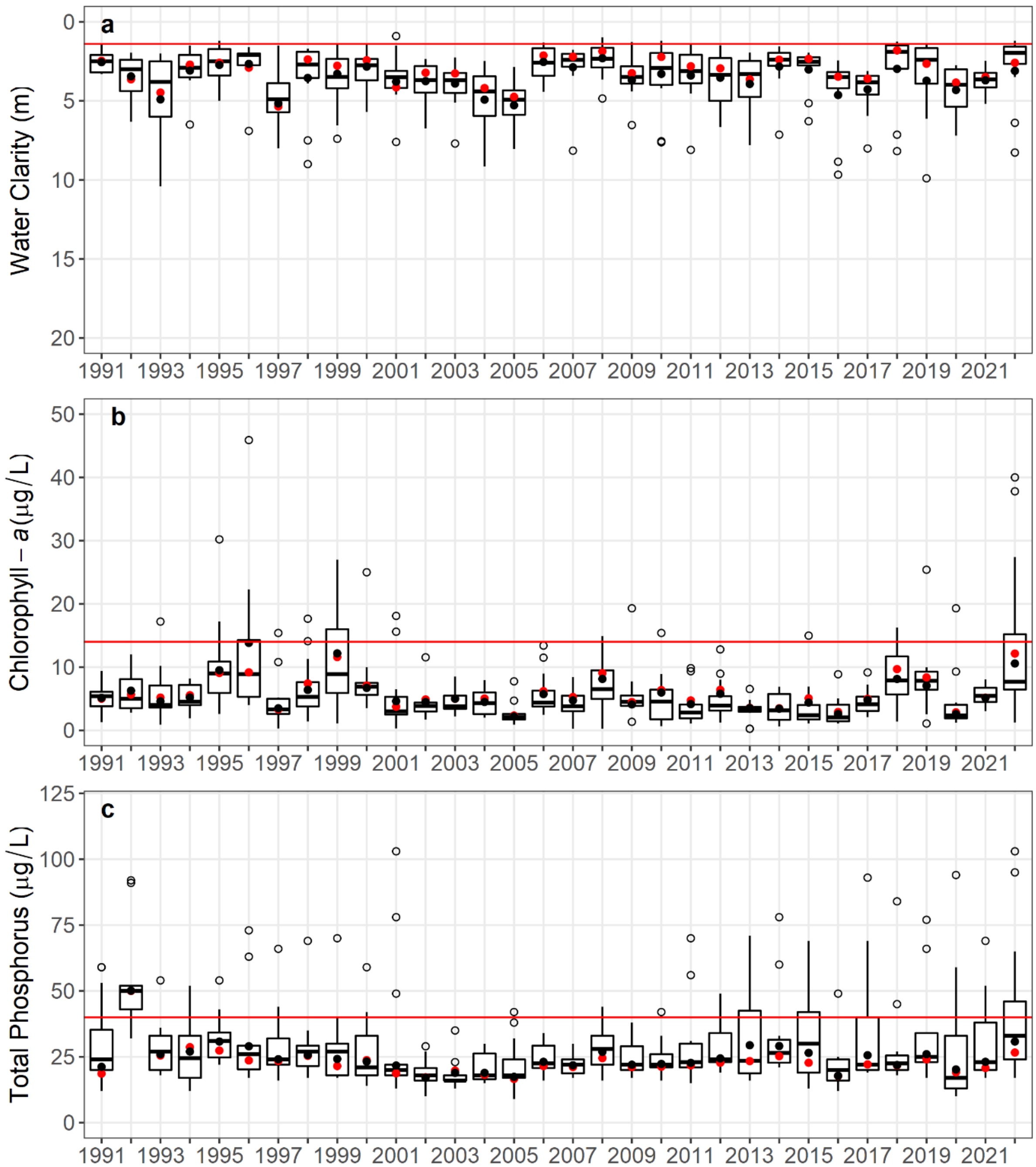
Diamond Lake 1992-2022



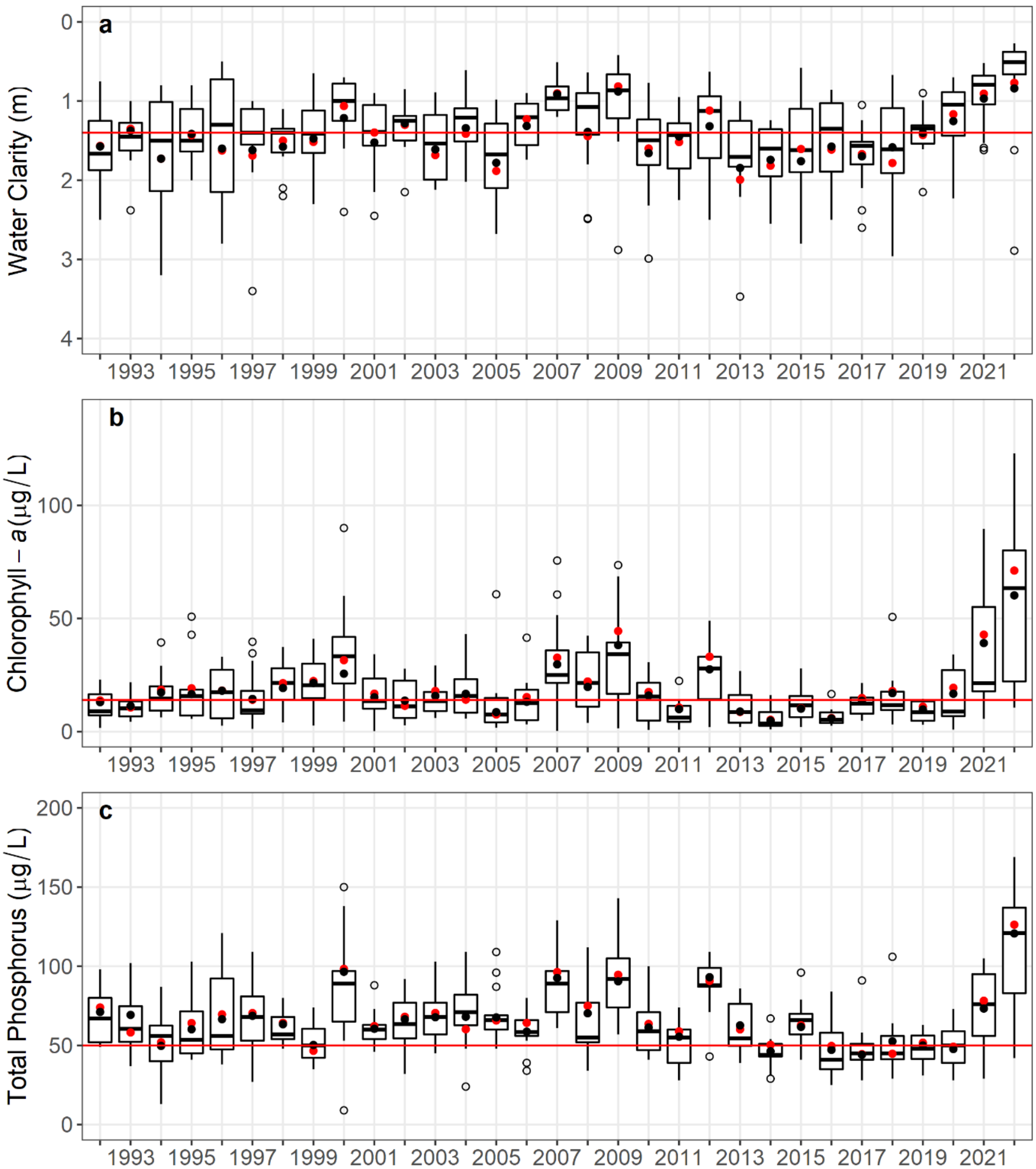
Grass Lake 2002-2022



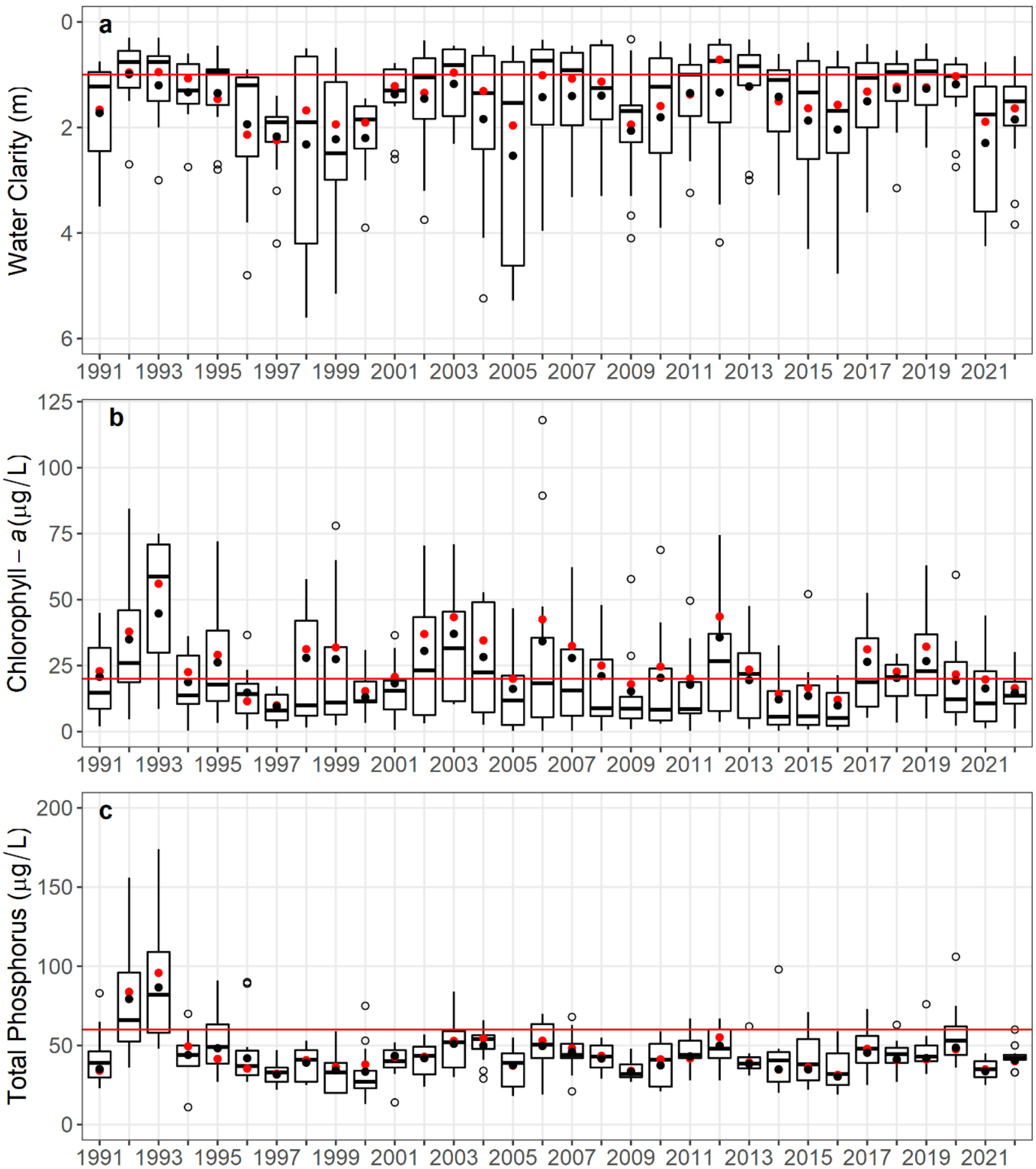
Lake Harriet 1991-2022



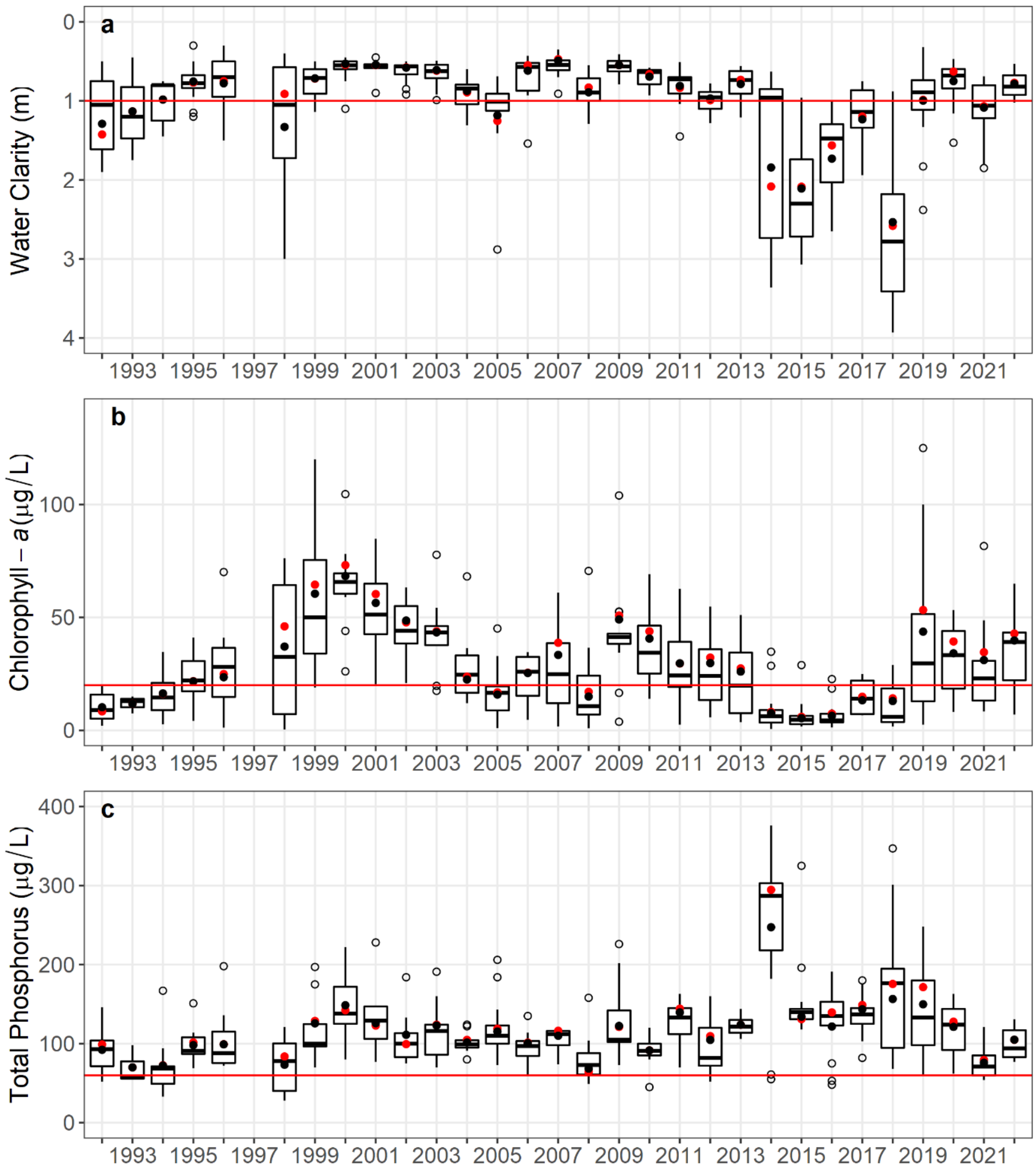
Lake Hiawatha 1992-2022



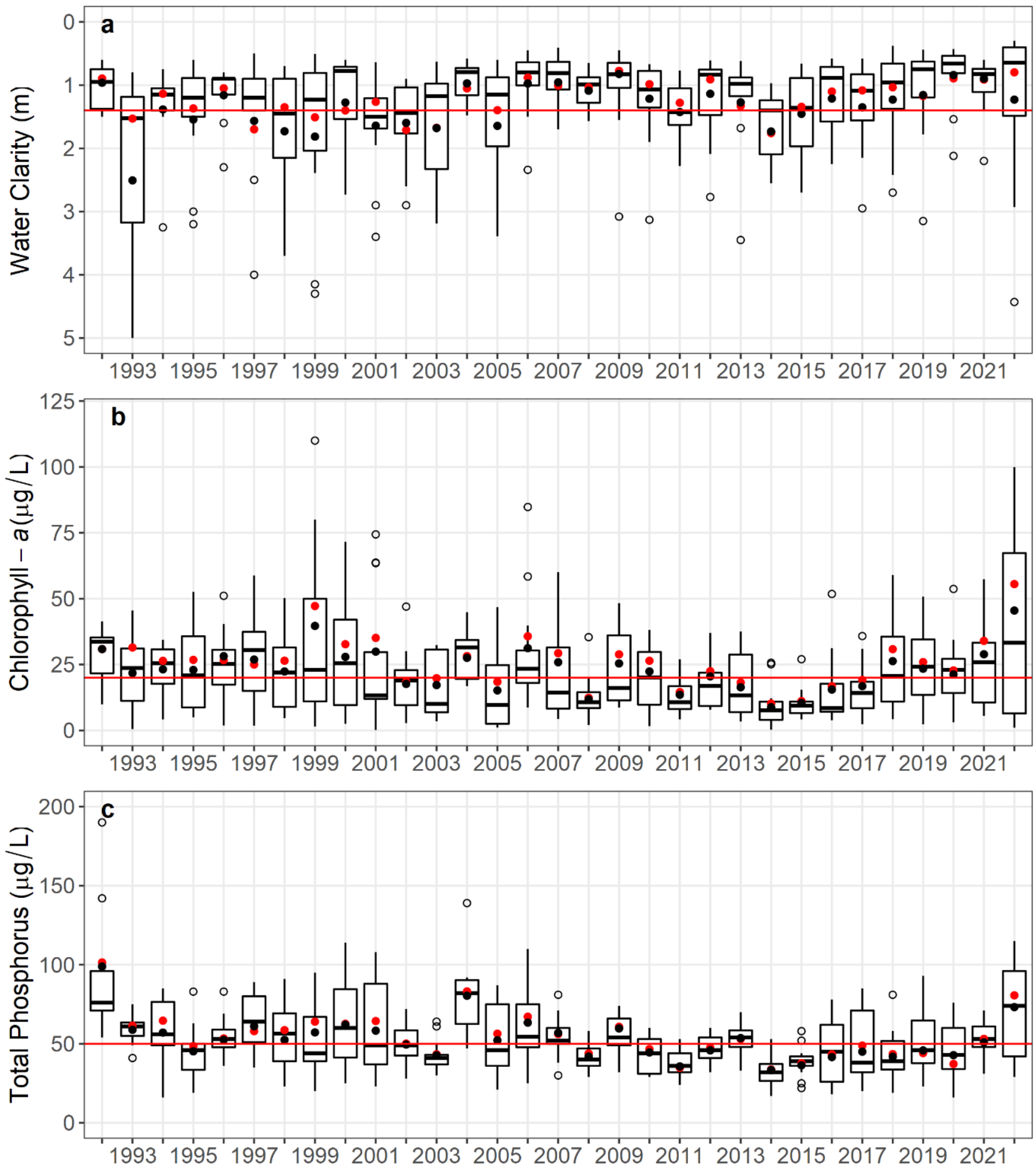
Lake of the Isles 1991-2022



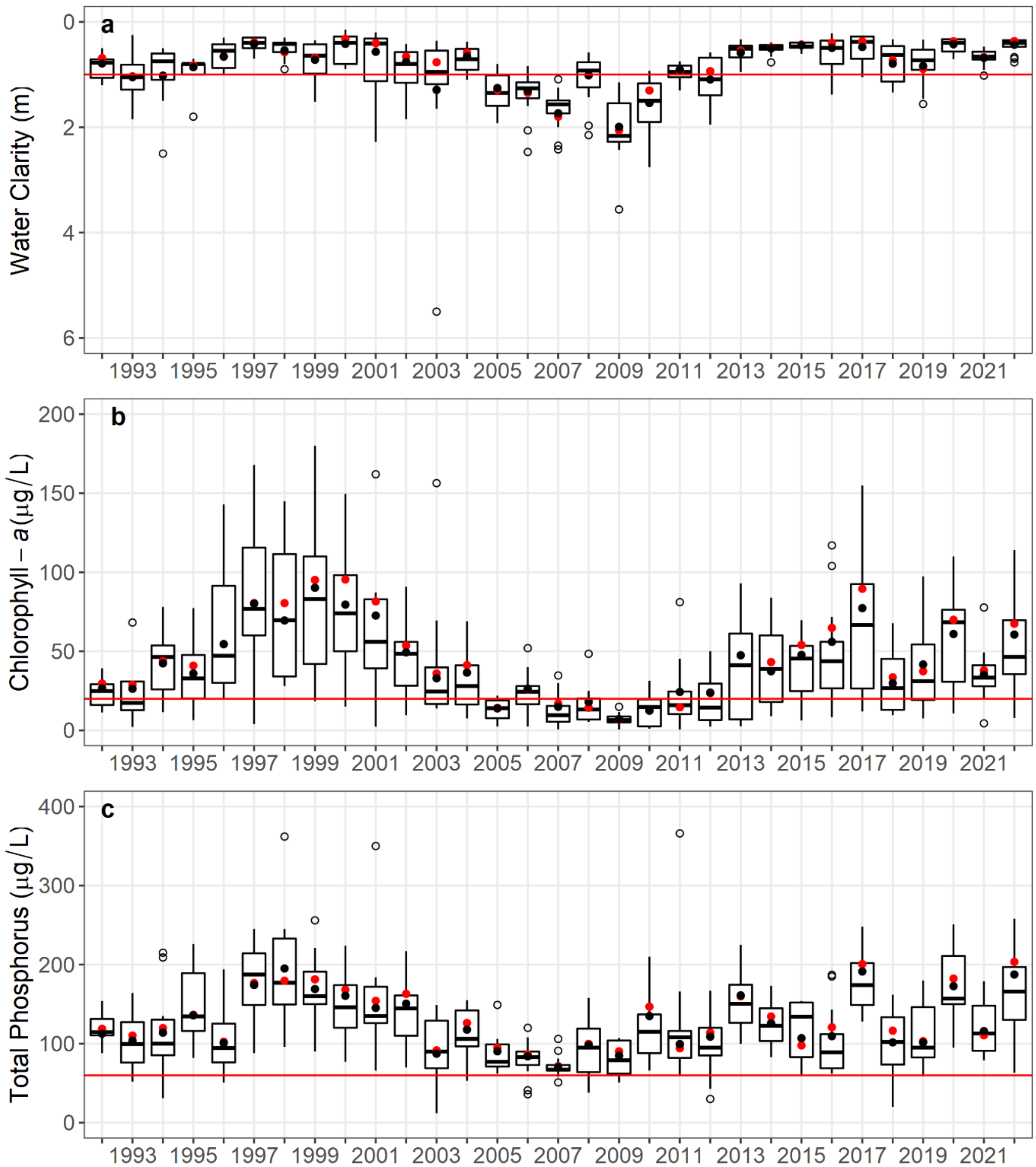
Loring Pond 1992-2022. Note: Loring was not sampled in 1997.



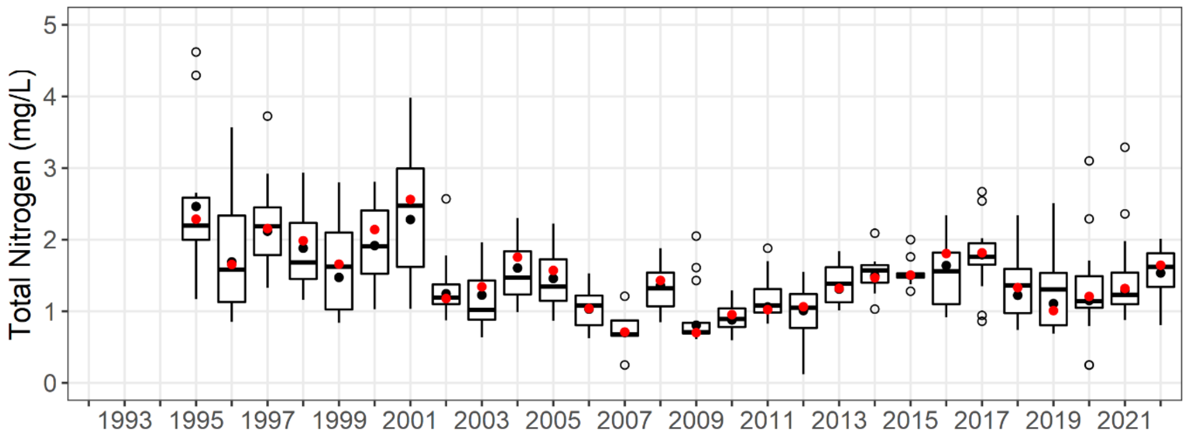
Lake Nokomis 1992-2022



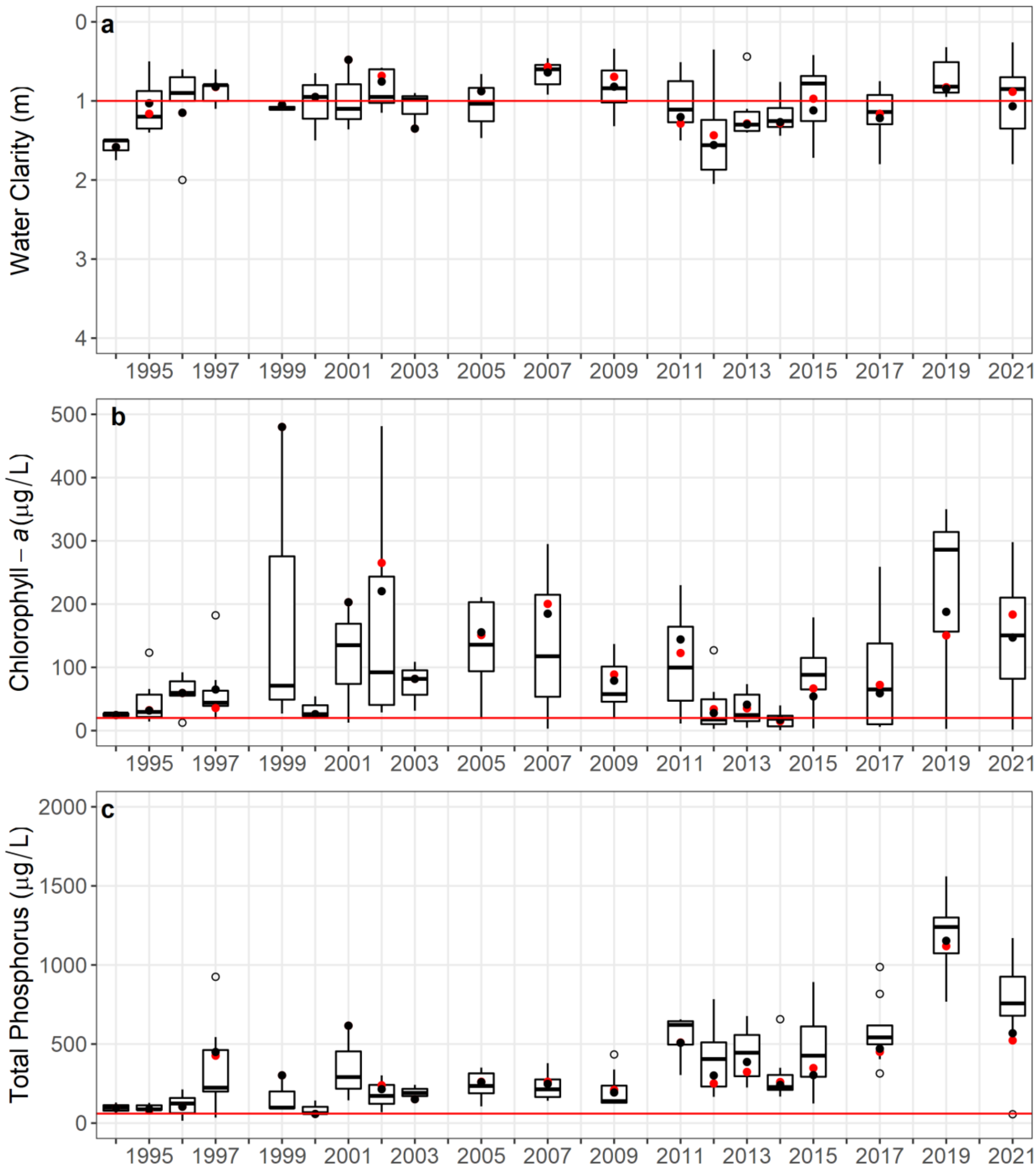
Powderhorn Lake 1992-2022



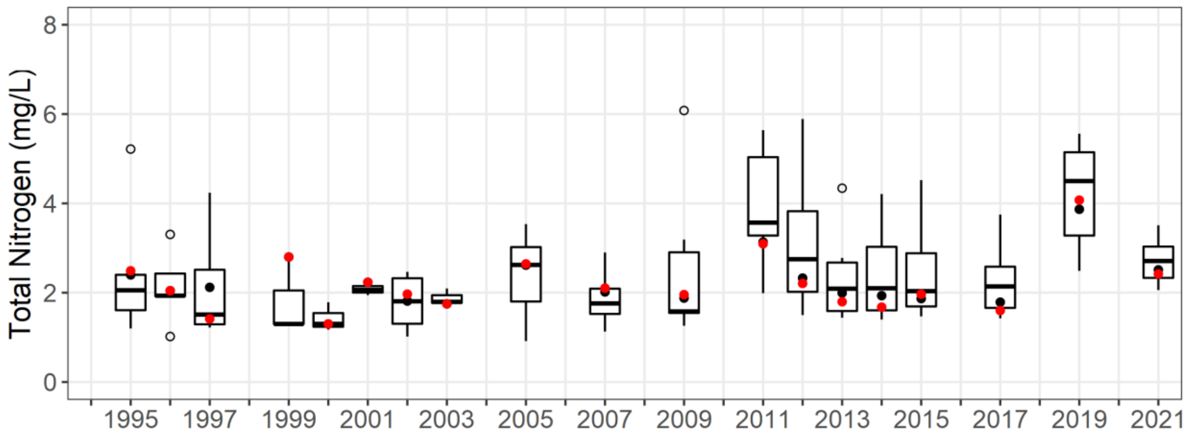
Powderhorn Lake Total Nitrogen 1995-2022



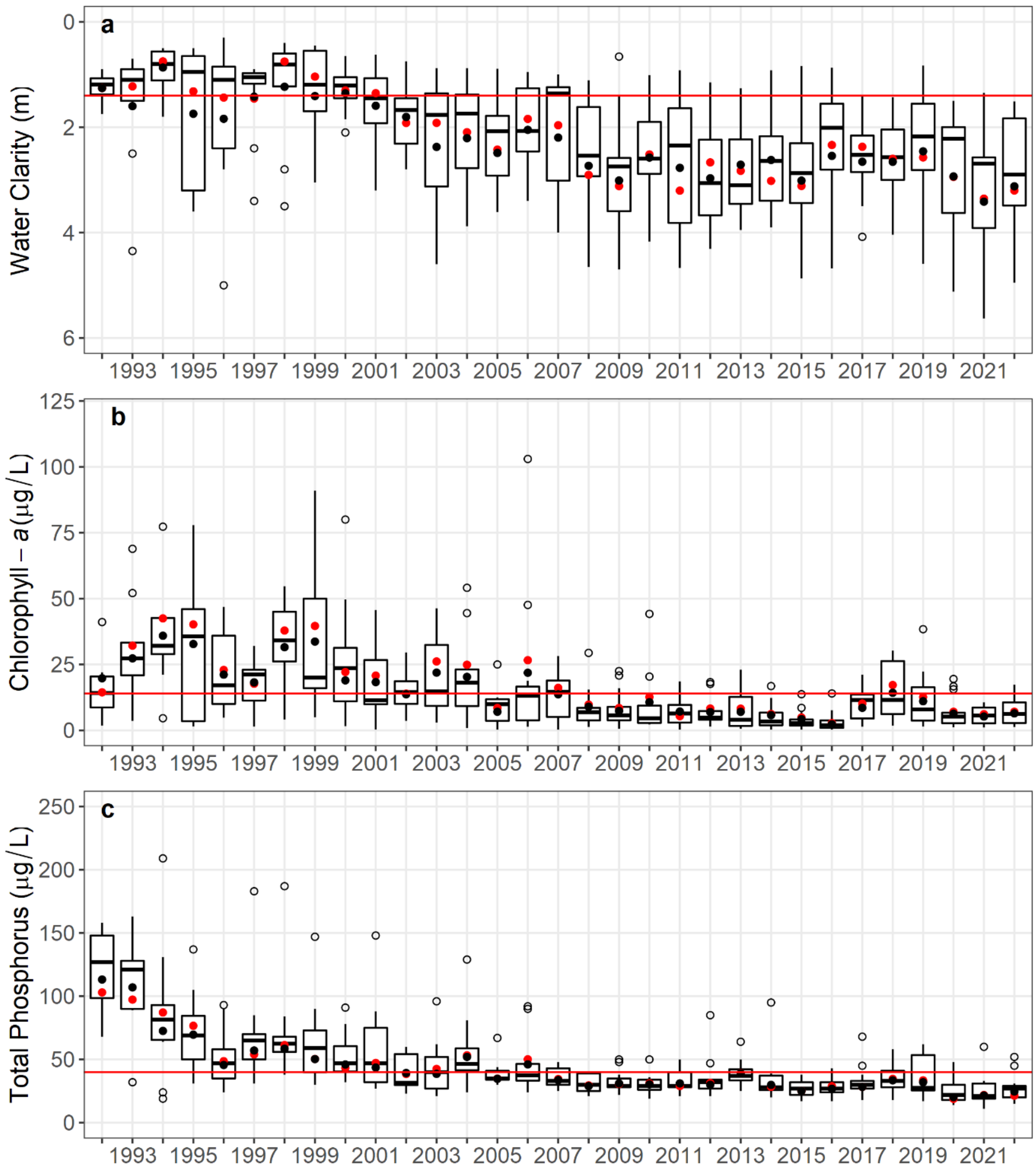
Spring Lake 1994-2021



Spring Lake 1995- 2021 Total Nitrogen



Wirth Lake 1992-2022



Wirth Lake 1994-2022 Total Nitrogen

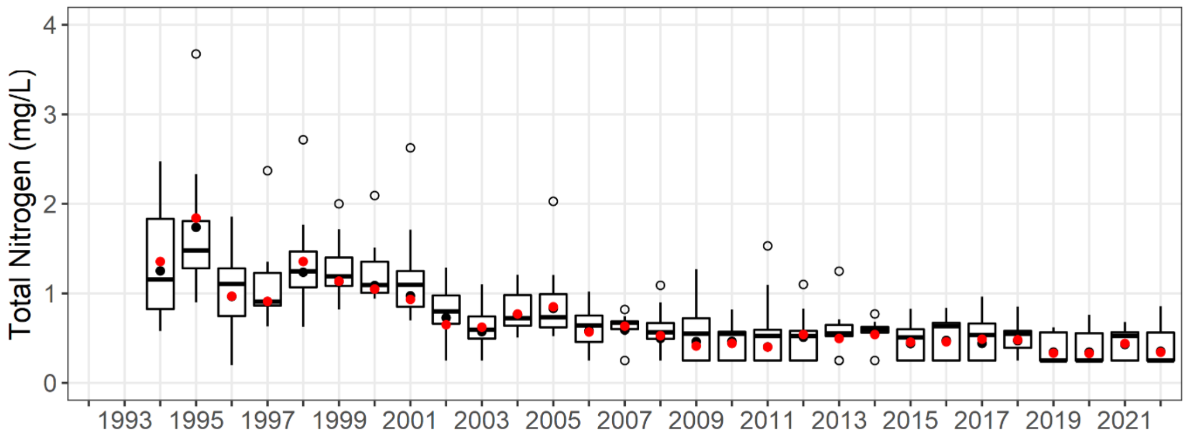


Table A-1. Box and whisker plot outliers removed

Lake	Date	Parameter	Units	Outlier Value
Bde Maka Ska	10/20/1999	Chl-*a*	µg/L	41.0
Bde Maka Ska	3/21/2000	Chl-*a*	µg/L	82.0
Bde Maka Ska	4/24/2001	Chl-*a*	µg/L	45.9
Bde Maka Ska	5/15/2015	TP	µg/L	0.245
Bde Maka Ska	6/26/1996	TN	mg/L	6.00
Bde Maka Ska	5/25/1999	TN	mg/L	4.20
Bde Maka Ska	9/27/1999	TN	mg/L	2.30
Brownie	8/27/1996	TN	mg/L	3.50
Cedar	7/25/1995	TN	mg/L	2.92
Cedar	9/27/1999	TN	mg/L	2.80
Diamond	2/17/2016	Chl-*a*	µg/L	614
Diamond	7/21/2005	TP	µg/L	0.740
Diamond	7/21/2005	Chl-*a*	µg/L	227
Diamond	1/31/2011	TP	µg/L	0.521
Diamond	5/18/2015	TN	mg/L	9.80
Grass	9/10/2003	Chl-*a*	µg/L	418
Grass	2/7/2008	Chl-*a*	µg/L	314
Grass	9/10/2003	TP	µg/L	0.511
Grass	1/31/2020	TP	µg/L	0.761
Harriet	4/19/2011	Chl-*a*	µg/L	39.0
Harriet	5/11/1995	TN	mg/L	3.14
Hiawatha	7/19/2000	Chl-*a*	µg/L	150
Hiawatha	3/18/1996	TP	µg/L	0.228
Loring	8/19/1999	Chl-*a*	µg/L	200
Loring	3/22/2000	Chl-*a*	µg/L	200
Loring	7/19/2000	Chl-*a*	µg/L	270
Loring	2/22/2001	Chl-*a*	µg/L	275
Loring	7/10/1995	TN	mg/L	8.88
Powderhorn	2/22/2001	Chl-*a*	µg/L	315
Powderhorn	4/30/1997	TP	µg/L	0.708
Spring	9/12/2014	Chl-*a*	µg/L	629

Appendix B

This section contains lake monitoring data for 2022.

Lake ID	Lake Name	Date MM/DD/YYYY	Time HH:MM	Secchi meters	Depth meters	Temp °C	%DO	DO mg/L	pH units	SpCond µS/cm	Phycocyanin RFU	Chlorophyll-a RFU	TurbSC NTU	Chl-a mg/M3	Pheo-a mg/M3	Silica mg/L	TP mg/L	SRP mg/L	TKN mg/L	TN mg/L	NO3NO2 mg/L	NH3 mg/L	Alk mg/L	Hard mg/L	Cl mg/L	SO4 mg/L	E. Coli mpn/100 mL	DOC mg/L	Fe µg/L	DFe µg/L	Al µg/L	DAl µg/L	Microcystin µg/L	Cylindro. µg/L	Anatoxin-a µg/L
27-0031	Bde Maka Ska	2/8/2022	10:30		0									1.01	0.250	0.250	0.042	0.027	0.605	0.780	0.082	0.612	131	156	155	9.70							<1.5		
27-0031	Bde Maka Ska	2/8/2022	10:30		6												0.038	0.029																	
27-0031	Bde Maka Ska	2/8/2022	10:30		12												0.054	0.042																	
27-0031	Bde Maka Ska	2/8/2022	10:30		18												0.122	0.097																	
27-0031	Bde Maka Ska	2/8/2022	10:30		22												0.182	0.144							160	10.3									
27-0031	Bde Maka Ska	4/19/2022	12:10	3.71	0	4.9	84.7	10.93	8.1	765			1.1	6.62	1.65	0.970	0.051	0.026	0.569	0.724	0.177	0.376	130	156	150	9.12									
27-0031	Bde Maka Ska	4/19/2022	12:09		1	4.6	84.2	10.97	8.1	766			1.1																						
27-0031	Bde Maka Ska	4/19/2022	12:08		2	4.2	83.8	11.04	8.1	763			1.1																						
27-0031	Bde Maka Ska	4/19/2022	12:07		3	4.0	83.6	11.04	8.1	764			1.1																						
27-0031	Bde Maka Ska	4/19/2022	12:05		4	4.0	83.3	11.01	8.1	764			1.1																						
27-0031	Bde Maka Ska	4/19/2022	12:03		5	4.0	82.9	10.96	8.1	764			1.1																						
27-0031	Bde Maka Ska	4/19/2022	12:02		6	4.0	82.7	10.94	8.1	765			1.1				0.058	0.028																	
27-0031	Bde Maka Ska	4/19/2022	12:00		7	3.9	82.4	10.92	8.1	766			1.1																						
27-0031	Bde Maka Ska	4/19/2022	11:59		8	4.0	81.9	10.85	8.1	764			1.1																						
27-0031	Bde Maka Ska	4/19/2022	11:58		9	4.0	81.6	10.81	8.1	764			1.1																						
27-0031	Bde Maka Ska	4/19/2022	11:57		10	3.9	81.9	10.85	8.1	764			1.2																						
27-0031	Bde Maka Ska	4/19/2022	11:55		11	3.9	81.6	10.81	8.1	764			1.2																						
27-0031	Bde Maka Ska	4/19/2022	11:54		12	3.9	81.5	10.80	8.1	764			1.2				0.056	0.028																	
27-0031	Bde Maka Ska	4/19/2022	11:53		13	3.9	81.9	10.85	8.1	764			1.2																						
27-0031	Bde Maka Ska	4/19/2022	11:52		14	3.9	81.3	10.78	8.1	764			1.2																						
27-0031	Bde Maka Ska	4/19/2022	11:51		15	3.9	81.3	10.77	8.1	764			1.2																						
27-0031	Bde Maka Ska	4/19/2022	11:49		16	3.9	81.7	10.83	8.1	765			1.2																						
27-0031	Bde Maka Ska	4/19/2022	11:47		17	3.9	81.3	10.77	8.1	765			1.2																						
27-0031	Bde Maka Ska	4/19/2022	11:45		18	3.9	81.4	10.78	8.1	764			1.2				0.051	0.029																	
27-0031	Bde Maka Ska	4/19/2022	11:44		19	3.9	81.5	10.80	8.1	764			1.2																						
27-0031	Bde Maka Ska	4/19/2022	11:43		20	4.0	81.6	10.81	8.0	764			1.1																						
27-0031	Bde Maka Ska	4/19/2022	11:41		21	4.0	81.3	10.77	8.0	764			1.1																						
27-0031	Bde Maka Ska	4/19/2022	11:40		22	4.0	81.3	10.77	8.0	764			1.1				0.054	0.029							160	8.92									
27-0031	Bde Maka Ska	4/19/2022	11:38		23	4.0	81.5	10.80	8.0	764			1.0																						
27-0031	Bde Maka Ska	4/19/2022	11:37		24	4.0	81.1	10.74	8.0	764			1.1																						
27-0031	Bde Maka Ska	4/19/2022	11:35		25	3.9	73.9	9.79	7.8	764																									
27-0031	Bde Maka Ska	5/10/2022	11:01	5.41	0	11.3	106.5	11.63	8.1	766	0.00	0.22		2.17	0.542	0.250	0.031	0.018	0.658	0.889	0.166	0.125	124	156	200	8.34									
27-0031	Bde Maka Ska	5/10/2022	11:00		1	11.3	106.4	11.63	8.1	766	0.00	0.31																							
27-0031	Bde Maka Ska	5/10/2022	11:00		2	11.2	106.7	11.68	8.1	766	0.03	0.39																							
27-0031	Bde Maka Ska	5/10/2022	11:00		3	11.0	106.6	11.73	8.1	766	0.00	0.45																							
27-0031	Bde Maka Ska	5/10/2022	10:59		4	10.6	106.6	11.83	8.1	766	0.02	0.49																							
27-0031	Bde Maka Ska	5/10/2022	10:59		5	10.3	106.5	11.91	8.1	765	0.00	0.49																							
27-0031	Bde Maka Ska	5/10/2022	10:58		6	9.9	105.5	11.91	8.1	766	0.00	0.50					0.048	0.018																	
27-0031	Bde Maka Ska	5/10/2022	10:58		7	9.1	105.0	12.07	8.1	766	0.00	0.45																							
27-0031	Bde Maka Ska	5/10/2022	10:58		8	8.6	103.7	12.08	8.0	767	0.00	0.40																							
27-0031	Bde Maka Ska	5/10/2022	10:57		9	8.3	103.5	12.15	8.0	768	0.00	0.38																							
27-0031	Bde Maka Ska	5/10/2022	10:57		10	7.9	102.7	12.15	8.0	768	0.00	0.33																							
27-0031	Bde Maka Ska	5/10/2022	10:57		11	7.8	102.3	12.13	8.0	768	0.00	0.31																							
27-0031	Bde Maka Ska	5/10/2022	10:57		12	7.6	100.9	12.05	8.0	769	0.00	0.32					0.034	0.020																	
27-0031	Bde Maka Ska	5/10/2022	10:56		13	7.3	99.8	12.01	8.0	770	0.00	0.31																							
27-0031	Bde Maka Ska	5/10/2022	10:56		14	7.0	99.0	11.99	8.0	771	0.00	0.26																							
27-0031	Bde Maka Ska	5/10/2022	10:56		15	7.0	98.9	11.98	8.0	771	0.00	0.26																							
27-0031	Bde Maka Ska	5/10/2022	10:55		16	7.0	98.8	11.97	8.0	771	0.00	0.29																							
27-0031	Bde Maka Ska	5/10/2022	10:55		17	7.0	98.6	11.95	8.0	771	0.03	0.31																							
27-0031	Bde Maka Ska	5/10/2022	10:54		18	6.9	98.3	11.93	8.0	771	0.00	0.29					0.034	0.022																	
27-0031	Bde Maka Ska	5/10/2022	10:54		19	6.9	98.2	11.92	8.0	771	0.00	0.29																							
27-0031	Bde Maka Ska	5/10/2022	10:54		20	6.9	98.0	11.89	8.0	771	0.00	0.26																							
27-0031	Bde Maka Ska	5/10/2022	10:53		21	6.9	97.5	11.85	8.0	771	0.02	0.92																							
27-0031	Bde Maka Ska	5/10/2022	10:52		22	6.9	97.2	11.81	8.0	771	0.00	0.33					0.039	0.023							200	8.41									
27-0031	Bde Maka Ska	5/10/2022	10:52		23	6.9	96.9	11.77	8.0	771	0.00	0.29																							
27-0031	Bde Maka Ska	5/10/2022	10:51		23.4	6.8	96.6	11.75	7.9	772	0.01	0.40																							
27-0031	Bde Maka Ska	5/24/2022	11:35	7.19	0	16.1	120.3	11.83	8.3	751	0.00	0.26		1.59	0.937		0.005	0.004		0.654					155										
27-0031	Bde Maka Ska	5/24/2022	11:34		1	16.1	120.1	11.82	8.3	751	0.00	0.26																							
27-0031	Bde Maka Ska	5/24/2022	11:34		2	16.0	119.5	11.77	8.3	751	0.00	0.33																							
27-0031	Bde Maka Ska	5/24/2022	11:33		3	15.9	119.0	11.74	8.3	751	0.00	0.41																							
27-0031	Bde Maka Ska	5/24/2022	11:32		4	15.8	118.6	11.73	8.3	751	0.00	0.46																							
27-0031	Bde Maka Ska	5/24/2022	11:32		5	14.7	110.7	11.21	8.0	755	0.00	0.61																							
27-0031	Bde Maka Ska	5/24/2022	11:31		6	11.3	104.4	11.41	7.9	760	0.00	0.88					0.027	0.005																	
27-0031	Bde Maka Ska	5/24/2022	11:30		7	9.9	99.7	11.26	7.9	763	0.00	1.13																							
27-0031	Bde Maka Ska	5/24/2022	11:29		8	9.4	94.5	10.79	7.8	765	0.00	1.05																							
27-0031	Bde Maka Ska	5/24/2022	11:29		9	9.1	93.7	10.79	7.8	766	0.00	0.57																							
27-0031	Bde Maka Ska	5/24/2022	11:27		10	8.6	84.6	9.85	7.6	767	0.00	0.39																							
27-0031	Bde Maka Ska	5/24/2022	11:26		11	8.3	86.6	10.15	7.7	767	0.00	0.29																							
27-0031	Bde Maka Ska	5/24/2022	11:26		12	8.0	89.0	10.51	7.7	767	0.00	0.24					0.046	0.032																	
27-0031	Bde Maka Ska	5/24/2022	11:23		13	7.8	86.5	10.27	7.7	767	0.00	0.17																							
27-0031	Bde Maka Ska	5/24/2022	11:22		14	7.6	84.0	10.02	7.6	768	0.00	0.17																							
27-0031	Bde Maka Ska	5/24/2022	11:20		15	7.5	79.2	9.48	7.6	769	0.00	0.12																							
27-0031	Bde Maka Ska	5/24/2022	11:19		16	7.4	75.4	9.04	7.5	769	0.00	0.14																							
27-0031	Bde Maka Ska	5/24/2022	11:19		17	7.4	71.9	8.62	7.5	770	0.00	0.16																							
27-0031	Bde Maka Ska	5/24/2022	11:18		18	7.4	70.0	8.40	7.5	770	0.00	0.11					0.072	0.052																	
27-0031	Bde Maka Ska	5/24/2022	11:17		19	7.3	68.0	8.17	7.4	771	0.00	0.14																							
27-0031	Bde Maka Ska	5/24/2022	11:15		20	7.3	63.8	7.66	7.4	771	0.00	0.14																							
27-0031	Bde Maka Ska	5/24/2022	11:15		21	7.3	62.2	7.47	7.4	772	0.00	0.14																							
27-0031	Bde Maka Ska	5/24/2022	11:13		22	7.3	58.4	7.02	7.4	772	0.00	0.17					0.112	0.079							165										
27-0031	Bde Maka Ska	5/24/2022	11:12		23	7.3	53.0	6.37	7.4	773	0.00	0.19																							
27-0031	Bde Maka Ska	5/24/2022	11:11		24	7.3	42.6	5.13	7.3	776	0.00	0.70																							
27-0031	Bde Maka Ska	5/24/2022	11:10		24.4	7.4	5.7	0.69	6.6	793	0.00	0.00																							
27-0031	Bde Maka Ska	6/6/2022	12:00	4.65	0	19.5	117.5	10.76	8.5	755	0.08	0.32		4.04	0.673	0.250	0.019	0.004		0.559					185										
27-0031	Bde Maka Ska	6/6/2022	11:59		1	18.9	115.2	10.67	8.5	754	0.11	0.37																							
27-0031	Bde Maka Ska	6/6/2022	11:59		2	18.8	114.7	10.66	8.5	755	0.13	0.40																							
27-0031	Bde Maka Ska	6/6/2022	11:58		3	18.7	114.4	10.65	8.5	755	0.11	0.41																							
27-0031	Bde Maka Ska	6/6/2022	11:57		4	18.5	112.3	10.50	8.5	754	0.15	0.43																							
27-0031	Bde Maka Ska	6/6/2022	11:56		5	18.3	110.4	10.37	8.4	755	0.19	0.41																							
27-0031	Bde Maka Ska	6/6/2022	11:55		6	15.5	94.0	9.36	8.0	764	0.00	0.39					0.027	0.004																	
27-0031	Bde Maka Ska	6/6/2022	11:54		7	12.1	89.8	9.63	7.9	774	0.03	0.72																							
27-0031	Bde Maka Ska	6/6/2022	11:53		8	9.4	78.0	8.91	7.8	775	0.01	0.57																							
27-0031	Bde Maka Ska	6/6/2022	11:53		9	9.1	71.0	8.18	7.7	777	0.01	0.47																							
27-0031	Bde Maka Ska	6/6/2022	11:52		10	8.8	69.8	8.10	7.6	777	0.00	0.38																							
27-0031	Bde Maka Ska	6/6/2022	11:51		11	8.4	68.3	7.98	7.6	777	0.00	0.20																							
27-0031	Bde Maka Ska	6/6/2022	11:51		12	8.0	69.3	8.18	7.6	778	0.00	0.22					0.065	0.048																	
27-0031	Bde Maka Ska	6/6/2022	11:49		13	7.9	64.6	7.66	7.6	778	0.00	0.25																							
27-0031	Bde Maka Ska	6/6/2022	11:48		14	7.6	60.6	7.22	7.5	779	0.00	0.19																							
27-0031	Bde Maka Ska	6/6/2022	11:48		15	7.6	58.6	6.99	7.5	779	0.00	0.21																							

Lake ID	Lake Name	Date MM/DD/YYYY	Time HH:MM	Secchi meters	Depth meters	Temp °C	%DO	DO mg/L	pH units	SpCond µS/cm	Phycocyanin RFU	Chlorophyll-a RFU	TurbSC NTU	Chl-a mg/M3	Pheo-a mg/M3	Silica mg/L	TP mg/L	SRP mg/L	TKN mg/L	TN mg/L	NO3NO2 mg/L	NH3 mg/L	Alk mg/L	Hard mg/L	Cl mg/L	SO4 mg/L	E. Coli mpn/100 mL	DOC mg/L	Fe µg/L	DFe µg/L	Al µg/L	DAl µg/L	Microcystin µg/L	Cylindro. µg/L	Anatoxin-a µg/L
27-0031	Bde Maka Ska	6/6/2022	11:46		16	7.5	56.2	6.71	7.5	780	0.00	0.15																							
27-0031	Bde Maka Ska	6/6/2022	11:45		17	7.5	52.2	6.24	7.5	780	0.00	0.17																							
27-0031	Bde Maka Ska	6/6/2022	11:44		18	7.5	49.9	5.97	7.5	781	0.00	0.16					0.121	0.090																	
27-0031	Bde Maka Ska	6/6/2022	11:43		19	7.5	48.4	5.79	7.5	781	0.00	0.16																							
27-0031	Bde Maka Ska	6/6/2022	11:43		20	7.4	47.0	5.63	7.4	781	0.00	0.17																							
27-0031	Bde Maka Ska	6/6/2022	11:42		21	7.4	45.3	5.42	7.4	782	0.00	0.19																							
27-0031	Bde Maka Ska	6/6/2022	11:41		22	7.4	44.8	5.37	7.4	782	0.00	0.18					0.159	0.118							175										
27-0031	Bde Maka Ska	6/6/2022	11:40		23	7.4	42.5	5.09	7.4	784	0.00	0.19																							
27-0031	Bde Maka Ska	6/6/2022	11:39		24	7.5	39.3	4.70	7.4	784	0.00	0.18																							
27-0031	Bde Maka Ska	6/6/2022	11:38		25	7.5	40.9	4.90	7.2	792	2.26	12.40																							
27-0031	Bde Maka Ska	6/23/2022	10:38	3.07	0	25.2	115.6	9.50	8.6	764	0.15	0.53		8.52	0.792		0.018	0.004		0.517					175										
27-0031	Bde Maka Ska	6/23/2022	10:38		1	25.2	115.4	9.48	8.6	764	0.18	0.63																							
27-0031	Bde Maka Ska	6/23/2022	10:37		2	25.1	114.7	9.43	8.6	764	0.20	0.67																							
27-0031	Bde Maka Ska	6/23/2022	10:36		3	24.9	111.6	9.21	8.6	764	0.29	0.69																							
27-0031	Bde Maka Ska	6/23/2022	10:35		4	23.5	105.1	8.91	8.5	764	0.76	0.69																							
27-0031	Bde Maka Ska	6/23/2022	10:35		5	20.7	103.4	9.25	8.4	764	1.48	0.88																							
27-0031	Bde Maka Ska	6/23/2022	10:33		6	15.7	69.3	6.86	7.8	769	0.16	0.39					0.039	0.005																	
27-0031	Bde Maka Ska	6/23/2022	10:32		7	12.8	66.4	7.02	7.6	775	0.00	0.25																							
27-0031	Bde Maka Ska	6/23/2022	10:32		8	10.3	60.9	6.81	7.6	782	0.00	0.19																							
27-0031	Bde Maka Ska	6/23/2022	10:31		9	9.5	57.5	6.54	7.5	782	0.00	0.20																							
27-0031	Bde Maka Ska	6/23/2022	10:29		10	9.0	45.7	5.26	7.5	784	0.00	0.15																							
27-0031	Bde Maka Ska	6/23/2022	10:28		11	8.7	41.3	4.80	7.4	785	0.00	0.17																							
27-0031	Bde Maka Ska	6/23/2022	10:26		12	8.2	56.1	6.59	7.5	783	0.00	0.15					0.096	0.073																	
27-0031	Bde Maka Ska	6/23/2022	10:25		13	7.9	49.5	5.86	7.5	783	0.00	0.09																							
27-0031	Bde Maka Ska	6/23/2022	10:23		14	7.7	43.6	5.19	7.4	784	0.00	0.11																							
27-0031	Bde Maka Ska	6/23/2022	10:22		15	7.6	34.2	4.08	7.4	786	0.00	0.13																							
27-0031	Bde Maka Ska	6/23/2022	10:21		16	7.6	30.7	3.67	7.4	786	0.00	0.10																							
27-0031	Bde Maka Ska	6/23/2022	10:20		17	7.5	28.4	3.40	7.4	787	0.00	0.13																							
27-0031	Bde Maka Ska	6/23/2022	10:19		18	7.5	26.9	3.21	7.3	787	0.00	0.12					0.186	0.144																	
27-0031	Bde Maka Ska	6/23/2022	10:18		19	7.5	24.1	2.89	7.3	788	0.00	0.12																							
27-0031	Bde Maka Ska	6/23/2022	10:17		20	7.5	20.5	2.45	7.3	788	0.00	0.14																							
27-0031	Bde Maka Ska	6/23/2022	10:16		21	7.5	18.0	2.16	7.3	789	0.00	0.14																							
27-0031	Bde Maka Ska	6/23/2022	10:15		22	7.4	15.5	1.86	7.3	790	0.00	0.19					0.222	0.181							190										
27-0031	Bde Maka Ska	6/23/2022	10:14		23	7.4	14.0	1.68	7.3	796	0.00	0.27																							
27-0031	Bde Maka Ska	6/23/2022	10:13		24	8.2	13.0	1.53	7.2	788	0.17	2.56																							
27-0031	Bde Maka Ska	7/14/2022	9:19	2.55	0	25.4	108.5	8.88	8.5	757	0.08	0.79		3.48	0.579	1.65	0.017	0.002	0.782	0.844	0.015	0.125	108	134	190	8.41									
27-0031	Bde Maka Ska	7/14/2022	9:18		1	25.4	108.2	8.86	8.5	757	0.07	1.03																							
27-0031	Bde Maka Ska	7/14/2022	9:17		2	25.3	107.1	8.78	8.5	757	0.08	1.08																							
27-0031	Bde Maka Ska	7/14/2022	9:17		3	25.2	105.3	8.66	8.5	757	0.10	0.94																							
27-0031	Bde Maka Ska	7/14/2022	9:16		4	25.1	103.1	8.49	8.5	757	0.12	1.03																							
27-0031	Bde Maka Ska	7/14/2022	9:14		5	22.6	39.2	3.38	7.7	767	0.27	0.54																							
27-0031	Bde Maka Ska	7/14/2022	9:12		6	18.3	8.8	0.83	7.5	773	0.05	0.38					0.019	0.002																	
27-0031	Bde Maka Ska	7/14/2022	9:10		7	13.3	32.1	3.35	7.6	778	0.00	0.30																							
27-0031	Bde Maka Ska	7/14/2022	9:09		8	10.6	28.4	3.16	7.5	782	0.00	0.23																							
27-0031	Bde Maka Ska	7/14/2022	9:08		9	9.7	21.5	2.44	7.5	783	0.00	0.17																							
27-0031	Bde Maka Ska	7/14/2022	9:07		10	9.0	18.5	2.13	7.5	785	0.00	0.14																							
27-0031	Bde Maka Ska	7/14/2022	9:06		11	8.7	26.1	3.02	7.5	783	0.00	0.14																							
27-0031	Bde Maka Ska	7/14/2022	9:05		12	8.4	26.6	3.11	7.5	782	0.00	0.12					0.114	0.076																	
27-0031	Bde Maka Ska	7/14/2022	9:04		13	7.9	22.5	2.67	7.5	783	0.00	0.11																							
27-0031	Bde Maka Ska	7/14/2022	9:03		14	7.7	11.3	1.34	7.4	785	0.00	0.11																							
27-0031	Bde Maka Ska	7/14/2022	9:02		15	7.6	1.9	0.23	7.4	788	0.00	0.13																							
27-0031	Bde Maka Ska	7/14/2022	9:01		16	7.6	1.0	0.12	7.4	788	0.00	0.17																							
27-0031	Bde Maka Ska	7/14/2022	8:59		17	7.5	1.1	0.14	7.4	788	0.00	0.13																							
27-0031	Bde Maka Ska	7/14/2022	8:58		18	7.5	1.3	0.15	7.4	789	0.00	0.16					0.257	0.208																	
27-0031	Bde Maka Ska	7/14/2022	8:57		19	7.5	1.5	0.18	7.4	790	0.00	0.18																							
27-0031	Bde Maka Ska	7/14/2022	8:56		20	7.5	1.8	0.22	7.4	791	0.00	0.19																							
27-0031	Bde Maka Ska	7/14/2022	8:55		21	7.5	2.3	0.27	7.4	791	0.00	0.16																							
27-0031	Bde Maka Ska	7/14/2022	8:55		22	7.5	3.2	0.38	7.4	793	0.00	0.16					0.276	0.242							165	7.09									
27-0031	Bde Maka Ska	7/27/2022	9:07	3.71	0	24.3	95.9	8.01	8.3	765	0.06	0.48		7.58	1.55		0.017	0.004		0.250					185										
27-0031	Bde Maka Ska	7/27/2022	9:06		1	24.3	95.5	7.97	8.3	765	0.10	0.61																							
27-0031	Bde Maka Ska	7/27/2022	9:05		2	24.3	95.1	7.94	8.3	765	0.10	0.62																							
27-0031	Bde Maka Ska	7/27/2022	9:04		3	24.3	94.5	7.89	8.3	765	0.06	0.60																							
27-0031	Bde Maka Ska	7/27/2022	9:04		4	24.3	93.6	7.82	8.3	765	0.12	0.58																							
27-0031	Bde Maka Ska	7/27/2022	9:03		5	24.1	90.3	7.57	8.3	765	0.07	0.57																							
27-0031	Bde Maka Ska	7/27/2022	9:01		6	21.0	6.5	0.58	7.4	776	0.00	0.34					0.023	0.004																	
27-0031	Bde Maka Ska	7/27/2022	9:00		7	13.3	17.2	1.79	7.4	785	0.00	0.35																							
27-0031	Bde Maka Ska	7/27/2022	8:59		8	11.2	10.0	1.09	7.4	787	0.00	0.34																							
27-0031	Bde Maka Ska	7/27/2022	8:58		9	10.0	6.2	0.69	7.3	786	0.00	0.34																							
27-0031	Bde Maka Ska	7/27/2022	8:57		10	9.3	7.8	0.89	7.3	787	0.00	0.19																							
27-0031	Bde Maka Ska	7/27/2022	8:56		11	8.9	12.4	1.43	7.3	786	0.00	0.11																							
27-0031	Bde Maka Ska	7/27/2022	8:54		12	8.4	13.4	1.56	7.3	784	0.00	0.13					0.123	0.098																	
27-0031	Bde Maka Ska	7/27/2022	8:53		13	8.1	13.4	1.59	7.3	785	0.00	0.08																							
27-0031	Bde Maka Ska	7/27/2022	8:52		14	7.8	4.6	0.55	7.3	788	0.00	0.11																							
27-0031	Bde Maka Ska	7/27/2022	8:50		15	7.7	0.8	0.10	7.3	788	0.00	0.08																							
27-0031	Bde Maka Ska	7/27/2022	8:49		16	7.7	0.9	0.11	7.3	790	0.00	0.11																							
27-0031	Bde Maka Ska	7/27/2022	8:48		17	7.6	1.1	0.13	7.3	791	0.00	0.12																							
27-0031	Bde Maka Ska	7/27/2022	8:47		18	7.6	1.1	0.14	7.3	792	0.00	0.15					0.274	0.224																	
27-0031	Bde Maka Ska	7/27/2022	8:46		19	7.5	1.2	0.15	7.3	794	0.00	0.16																							
27-0031	Bde Maka Ska	7/27/2022	8:45		20	7.5	1.3	0.16	7.3	795	0.00	0.15																							
27-0031	Bde Maka Ska	7/27/2022	8:44		21	7.5	1.6	0.19	7.3	796	0.00	0.16																							
27-0031	Bde Maka Ska	7/27/2022	8:43		22	7.5	1.9	0.23	7.3	796	0.00	0.16					0.361	0.282							235										
27-0031	Bde Maka Ska	7/27/2022	8:42		23	7.5	2.5	0.29	7.3	796	0.00	0.19																							
27-0031	Bde Maka Ska	7/27/2022	8:41		24	7.5	3.2	0.38	7.2	802	0.00	0.39																							
27-0031	Bde Maka Ska	7/27/2022	8:40		25	7.6	4.7	0.57	6.9	799	0.00	0.17																							
27-0031	Bde Maka Ska	8/10/2022	9:31	3.34	0	24.8	108.9	9.01	8.4	768	0.01	0.36		5.29	0.522	1.65	0.018	0.005		0.250					217		3								
27-0031	Bde Maka Ska	8/10/2022	9:30		1	24.7	108.5	9.00	8.4	767	0.03	0.76																							
27-0031	Bde Maka Ska	8/10/2022	9:29		2	24.6	108.0	8.97	8.4	767	0.09	0.87																							
27-0031	Bde Maka Ska	8/10/2022	9:28		3	24.4	108.0	9.00	8.4	766	0.10	1.08																							
27-0031	Bde Maka Ska	8/10/2022	9:27		4	24.1	100.6	8.43	8.3	766	0.12	1.22																							
27-0031	Bde Maka Ska	8/10/2022	9:24		5	24.0	93.2	7.84	8.3	766	0.14	1.38																							
27-0031	Bde Maka Ska	8/10/2022	9:22		6	22.5	51.4	4.44	7.7	772	0.08	0.46					0.019	0.004																	
27-0031	Bde Maka Ska	8/10/2022	9:18		7	18.0	2.8	0.27	7.3	782	0.03	0.84																							
27-0031	Bde Maka Ska	8/10/2022	9:17		8	11.8	1.2	0.12	7.3	784	0.06	1.08																							
27-0031	Bde Maka Ska	8/10/2022	9:16		9	10.1	0.9	0.10	7.2	789	0.00	0.36																							
27-0031	Bde Maka Ska	8/10/2022	9:15		10	9.3	0.9	0.10	7.2	789	0.00	0.21																							
27-0031	Bde Maka Ska	8/10/2022	9:14		11	8.7	1.2	0.13	7.2	787	0.00	0.11																							
27-0031	Bde Maka Ska	8/10/2022	9:13		12	8.3	0.9	0.11	7.2	787	0.00	0.16					0.150	0.117																	

Lake ID	Lake Name	Date MM/DD/YYYY	Time HH:MM	Secchi meters	Depth meters	Temp °C	%DO	DO mg/L	pH units	SpCond µS/cm	Phycocyanin RFU	Chlorophyll-a RFU	TurbSC NTU	Chl-a mg/M3	Pheo-a mg/M3	Silica mg/L	TP mg/L	SRP mg/L	TKN mg/L	TN mg/L	NO3NO2 mg/L	NH3 mg/L	Alk mg/L	Hard mg/L	Cl mg/L	SO4 mg/L	E. Coli mpn/100 mL	DOC mg/L	Fe µg/L	DFe µg/L	Al µg/L	DAl µg/L	Microcystin µg/L	Cylindro. µg/L	Anatoxin-a µg/L
27-0031	Bde Maka Ska	8/10/2022	9:12		13	8.1	1.1	0.13	7.2	789	0.00	0.13																							
27-0031	Bde Maka Ska	8/10/2022	9:11		14	7.9	1.3	0.15	7.2	791	0.00	0.13																							
27-0031	Bde Maka Ska	8/10/2022	9:10		15	7.7	1.4	0.16	7.3	793	0.00	0.17																							
27-0031	Bde Maka Ska	8/10/2022			16																														
27-0031	Bde Maka Ska	8/10/2022			17																														
27-0031	Bde Maka Ska	8/10/2022			18												0.324	0.273																	
27-0031	Bde Maka Ska	8/10/2022			19																														
27-0031	Bde Maka Ska	8/10/2022			20																														
27-0031	Bde Maka Ska	8/10/2022			21																														
27-0031	Bde Maka Ska	8/10/2022			22												0.371	0.314							235										
27-0031	Bde Maka Ska	8/10/2022			23																														
27-0031	Bde Maka Ska	8/10/2022			24																														
27-0031	Bde Maka Ska	8/10/2022			25																														
27-0031	Bde Maka Ska	8/10/2022			26																														
27-0031	Bde Maka Ska	8/25/2022	9:30	1.77	0	24.1	115.5	9.70	8.5	760	0.09	0.90		6.66	1.04		0.020	0.004		0.250					180										
27-0031	Bde Maka Ska	8/25/2022	9:29		1	24.1	115.1	9.66	8.6	759	0.09	0.96																							
27-0031	Bde Maka Ska	8/25/2022	9:29		2	24.0	114.7	9.63	8.6	760	0.09	0.98																							
27-0031	Bde Maka Ska	8/25/2022	9:28		3	24.0	114.2	9.59	8.6	760	0.08	0.98																							
27-0031	Bde Maka Ska	8/25/2022	9:28		4	24.0	113.4	9.53	8.6	759	0.11	1.01																							
27-0031	Bde Maka Ska	8/25/2022	9:27		5	23.3	100.8	8.58	8.4	762	0.18	1.22																							
27-0031	Bde Maka Ska	8/25/2022	9:25		6	22.3	57.6	5.00	7.8	774	0.18	1.27					0.022	0.004																	
27-0031	Bde Maka Ska	8/25/2022	9:24		7	20.0	1.5	0.13	7.4	782	0.15	0.80																							
27-0031	Bde Maka Ska	8/25/2022	9:23		8	12.8	0.6	0.06	7.3	790	0.01	0.47																							
27-0031	Bde Maka Ska	8/25/2022	9:22		9	11.3	0.6	0.06	7.3	790	0.01	0.48																							
27-0031	Bde Maka Ska	8/25/2022	9:20		10	9.9	0.5	0.06	7.3	792	0.00	0.30																							
27-0031	Bde Maka Ska	8/25/2022	9:19		11	9.1	0.6	0.06	7.3	790	0.00	0.25																							
27-0031	Bde Maka Ska	8/25/2022	9:18		12	8.5	0.5	0.06	7.3	789	0.00	0.14					0.141	0.081																	
27-0031	Bde Maka Ska	8/25/2022	9:18		13	8.4	0.6	0.07	7.3	790	0.00	0.12																							
27-0031	Bde Maka Ska	8/25/2022	9:17		14	8.1	0.6	0.07	7.3	791	0.00	0.12																							
27-0031	Bde Maka Ska	8/25/2022	9:17		15	7.9	0.7	0.08	7.3	794	0.00	0.18																							
27-0031	Bde Maka Ska	8/25/2022	9:15		16	7.7	0.8	0.10	7.2	797	0.00	0.13																							
27-0031	Bde Maka Ska	8/25/2022	9:14		17	7.6	0.9	0.11	7.2	798	0.00	0.12																							
27-0031	Bde Maka Ska	8/25/2022	9:13		18	7.6	1.1	0.13	7.2	799	0.00	0.13					0.365	0.320																	
27-0031	Bde Maka Ska	8/25/2022	9:12		19	7.5	1.2	0.15	7.2	799	0.00	0.15																							
27-0031	Bde Maka Ska	8/25/2022	9:12		20	7.5	1.3	0.16	7.2	801	0.00	0.18																							
27-0031	Bde Maka Ska	8/25/2022	9:11		21	7.5	1.5	0.18	7.2	801	0.00	0.11																							
27-0031	Bde Maka Ska	8/25/2022	9:10		22	7.5	1.7	0.20	7.2	801	0.00	0.15					0.427	0.366							175										
27-0031	Bde Maka Ska	8/25/2022	9:10		23	7.5	1.9	0.23	7.2	801	0.00	0.15																							
27-0031	Bde Maka Ska	8/25/2022	9:09		24	7.5	2.2	0.26	7.2	806	0.00	0.44																							
27-0031	Bde Maka Ska	8/25/2022	9:09		25	7.4	2.5	0.30	6.7	842	0.00	0.00																							
27-0031	Bde Maka Ska	9/15/2022	9:23	2.40	0	21.8	102.5	8.98	8.4	768	0.06	0.40		5.61	0.561	2.26	0.021	0.003		0.694					185										
27-0031	Bde Maka Ska	9/15/2022	9:21		1	21.8	102.2	8.96	8.4	768	0.07	0.51																							
27-0031	Bde Maka Ska	9/15/2022	9:20		2	21.8	101.9	8.92	8.4	768	0.07	0.50																							
27-0031	Bde Maka Ska	9/15/2022	9:19		3	21.8	101.5	8.89	8.4	768	0.08	0.49																							
27-0031	Bde Maka Ska	9/15/2022	9:18		4	21.8	100.1	8.77	8.4	769	0.09	0.60																							
27-0031	Bde Maka Ska	9/15/2022	9:17		5	21.6	97.5	8.57	8.4	769	0.08	0.66																							
27-0031	Bde Maka Ska	9/15/2022	9:14		6	21.5	81.5	7.19	8.2	774	0.09	0.81					0.019	0.004																	
27-0031	Bde Maka Ska	9/15/2022	9:13		7	20.0	11.8	1.07	7.5	798	0.06	1.07																							
27-0031	Bde Maka Ska	9/15/2022	9:12		8	15.0	0.6	0.06	7.3	791	0.05	0.39																							
27-0031	Bde Maka Ska	9/15/2022	9:11		9	11.4	0.5	0.05	7.3	794	0.00	0.36																							
27-0031	Bde Maka Ska	9/15/2022	9:10		10	10.2	0.4	0.05	7.3	793	0.13	1.33																							
27-0031	Bde Maka Ska	9/15/2022	9:09		11	9.5	0.4	0.04	7.2	794	0.00	0.28																							
27-0031	Bde Maka Ska	9/15/2022	9:08		12	8.7	0.4	0.05	7.3	789	0.00	0.08					0.140	0.101																	
27-0031	Bde Maka Ska	9/15/2022	9:06		13	8.2	0.4	0.05	7.3	791	0.00	0.16																							
27-0031	Bde Maka Ska	9/15/2022	9:05		14	8.0	0.5	0.06	7.2	793	0.00	0.17																							
27-0031	Bde Maka Ska	9/15/2022	9:03		15	7.9	0.6	0.07	7.2	794	0.00	0.15																							
27-0031	Bde Maka Ska	9/15/2022	9:02		16	7.7	0.7	0.08	7.2	797	0.00	0.12																							
27-0031	Bde Maka Ska	9/15/2022	8:59		17	7.7	0.8	0.10	7.2	798	0.00	0.13																							
27-0031	Bde Maka Ska	9/15/2022	8:58		18	7.6	0.9	0.11	7.2	799	0.00	0.13					0.313	0.293																	
27-0031	Bde Maka Ska	9/15/2022	8:57		19	7.6	1.0	0.12	7.2	799	0.00	0.16																							
27-0031	Bde Maka Ska	9/15/2022	8:57		20	7.6	1.1	0.13	7.2	800	0.00	0.11																							
27-0031	Bde Maka Ska	9/15/2022	8:56		21	7.6	1.2	0.15	7.2	800	0.00	0.10																							
27-0031	Bde Maka Ska	9/15/2022	8:54		22	7.5	1.5	0.18	7.2	801	0.00	0.12					0.366	0.339							175										
27-0031	Bde Maka Ska	9/15/2022	8:53		23	7.5	1.8	0.21	7.2	802	0.00	0.11																							
27-0031	Bde Maka Ska	9/15/2022	8:50		24	7.5	7.5	0.89	6.9	815	0.36	0.40																							
27-0031	Bde Maka Ska	9/28/2022	9:24	2.75	0	17.6	91.6	8.73	8.3	780	0.13	0.91		7.98	1.01		0.022	0.003		0.250					170										
27-0031	Bde Maka Ska	9/28/2022	9:24		1	17.6	91.1	8.68	8.3	780	0.17	0.99																							
27-0031	Bde Maka Ska	9/28/2022	9:24		2	17.6	90.6	8.64	8.3	780	0.13	0.94																							
27-0031	Bde Maka Ska	9/28/2022	9:23		3	17.6	90.4	8.61	8.3	780	0.16	0.91																							
27-0031	Bde Maka Ska	9/28/2022	9:23		4	17.6	90.1	8.59	8.2	780	0.09	0.91																							
27-0031	Bde Maka Ska	9/28/2022	9:22		5	17.6	89.5	8.53	8.3	780	0.15	0.97																							
27-0031	Bde Maka Ska	9/28/2022	9:21		6	17.6	89.3	8.51	8.3	780	0.13	1.13					0.022	0.003																	
27-0031	Bde Maka Ska	9/28/2022	9:21		7	17.5	88.5	8.44	8.3	780	0.13	0.99																							
27-0031	Bde Maka Ska	9/28/2022	9:19		8	16.8	75.7	7.32	8.0	804	0.06	0.67																							
27-0031	Bde Maka Ska	9/28/2022	9:17		9	12.4	0.8	0.09	7.3	785	0.24	0.67																							
27-0031	Bde Maka Ska	9/28/2022	9:17		10	10.0	0.7	0.08	7.3	793	0.04	0.54																							
27-0031	Bde Maka Ska	9/28/2022	9:16		11	9.4	0.6	0.07	7.3	794	0.00	0.33																							
27-0031	Bde Maka Ska	9/28/2022	9:16		12	8.7	0.6	0.07	7.3	793	0.00	0.19					0.137	0.093																	
27-0031	Bde Maka Ska	9/28/2022	9:15		13	8.2	0.7	0.08	7.2	792	0.00	0.18																							
27-0031	Bde Maka Ska	9/28/2022	9:14		14	8.0	0.7	0.09	7.2	795	0.00	0.20																							
27-0031	Bde Maka Ska	9/28/2022	9:14		15	7.9	0.8	0.09	7.2	796	0.00	0.22																							
27-0031	Bde Maka Ska	9/28/2022	9:13		16	7.8	0.8	0.10	7.2	798	0.00	0.19																							
27-0031	Bde Maka Ska	9/28/2022	9:12		17	7.7	0.9	0.11	7.2	800	0.00	0.25																							
27-0031	Bde Maka Ska	9/28/2022	9:12		18	7.7	1.0	0.12	7.2	800	0.00	0.19					0.347	0.313																	
27-0031	Bde Maka Ska	9/28/2022	9:11		19	7.6	1.1	0.13	7.2	801	0.00	0.19																							
27-0031	Bde Maka Ska	9/28/2022	9:10		20	7.6	1.2	0.14	7.2	802	0.00	0.18																							
27-0031	Bde Maka Ska	9/28/2022	9:10		21	7.6	1.3	0.16	7.1	802	0.00	0.22																							
27-0031	Bde Maka Ska	9/28/2022	9:09		22	7.6	1.5	0.18	7.1	802	0.00	0.22					0.390	0.355							165										
27-0031	Bde Maka Ska	9/28/2022	9:08		23	7.6	1.8	0.22	7.1	802	0.00	0.23																							
27-0031	Bde Maka Ska	9/28/2022	9:07		24	7.5	2.4	0.28	7.1	804	0.00	0.35																							
27-0031	Bde Maka Ska	9/28/2022	9:06		25	7.6	3.8	0.45	7.0	815	0.96	3.16																							
27-0031	Bde Maka Ska	10/20/2022	9:57	2.45	0	10.7	79.2	8.78	8.0	789	0.10	1.38		11.2	1.68	2.79	0.040	0.008	0.542	0.643	0.098	0.317	140	156	185	9.51									
27-0031	Bde Maka Ska	10/20/2022	9:57		1	10.7	79.0	8.75	8.0	789	0.20	1.82																							
27-0031	Bde Maka Ska	10/20/2022	9:56		2	10.7	78.7	8.72	8.0	789	0.21	1.61																							
27-0031	Bde Maka Ska	10/20/2022	9:56		3	10.7	78.5	8.70	8.0	789	0.18	1.89																							
27-0031	Bde Maka Ska	10/20/2022	9:55		4	10.7	78.2	8.66	8.0	789	0.18	1.49																							
27-0031	Bde Maka Ska	10/20/2022	9:54		5	10.7	78.0	8.64	8.0	789	0.18	2.10																							
27-0031	Bde Maka Ska	10/20/2022	9:54		6	10.7	78.1	8.65	8.0	789	0.18	1.63					0.039	0.007																	

Lake ID	Lake Name	Date MM/DD/YYYY	Time HH:MM	Secchi meters	Depth meters	Temp °C	%DO	DO mg/L	pH units	SpCond µS/cm	Phycocyanin RFU	Chlorophyll-a RFU	TurbSC NTU	Chl-a mg/M3	Pheo-a mg/M3	Silica mg/L	TP mg/L	SRP mg/L	TKN mg/L	TN mg/L	NO3NO2 mg/L	NH3 mg/L	Alk mg/L	Hard mg/L	Cl mg/L	SO4 mg/L	E. Coli mpn/100 mL	DOC mg/L	Fe µg/L	DFe µg/L	Al µg/L	DAl µg/L	Microcystin µg/L	Cylindro. µg/L	Anatoxin-a µg/L
27-0031	Bde Maka Ska	10/20/2022	9:53		7	10.7	77.6	8.60	8.0	790	0.24	1.96																							
27-0031	Bde Maka Ska	10/20/2022	9:53		8	10.7	77.4	8.58	8.0	789	0.17	1.41																							
27-0031	Bde Maka Ska	10/20/2022	9:51		9	10.7	75.8	8.40	7.9	790	0.18	1.90																							
27-0031	Bde Maka Ska	10/20/2022	9:51		10	10.7	74.1	8.21	7.9	790	0.16	1.67																							
27-0031	Bde Maka Ska	10/20/2022	9:50		11	10.6	68.5	7.60	7.9	790	0.00	1.20																							
27-0031	Bde Maka Ska	10/20/2022	9:49		12	10.4	60.2	6.71	7.8	794	0.00	0.55					0.039	0.014																	
27-0031	Bde Maka Ska	10/20/2022	9:48		13	10.1	44.4	4.99	7.6	793	0.00	0.33																							
27-0031	Bde Maka Ska	10/20/2022	9:47		14	9.6	10.2	1.16	7.3	792	0.00	0.18																							
27-0031	Bde Maka Ska	10/20/2022	9:47		15	7.8	1.0	0.12	7.2	797	0.00	0.19																							
27-0031	Bde Maka Ska	10/20/2022	9:46		16	7.7	1.1	0.13	7.2	799	0.00	0.18																							
27-0031	Bde Maka Ska	10/20/2022	9:45		17	7.7	1.2	0.14	7.2	799	0.00	0.19																							
27-0031	Bde Maka Ska	10/20/2022	9:45		18	7.6	1.3	0.15	7.1	800	0.00	0.24					0.385	0.383																	
27-0031	Bde Maka Ska	10/20/2022	9:44		19	7.6	1.3	0.16	7.1	800	0.00	0.20																							
27-0031	Bde Maka Ska	10/20/2022	9:43		20	7.6	1.5	0.17	7.1	800	0.00	0.22																							
27-0031	Bde Maka Ska	10/20/2022	9:42		21	7.6	1.6	0.19	7.1	801	0.00	0.22																							
27-0031	Bde Maka Ska	10/20/2022	9:42		22	7.6	1.8	0.21	7.1	801	0.00	0.38					0.412	0.406							180	7.05									
27-0031	Bde Maka Ska	10/20/2022	9:41		23	7.6	2.0	0.24	7.1	801	0.00	0.24																							
27-0031	Bde Maka Ska	10/20/2022	9:40		24	7.6	2.3	0.27	7.1	802	0.00	0.31																							
27-0031	Bde Maka Ska	10/20/2022	9:40		25	7.6	2.7	0.32	6.6	809	0.00	0.00																							
27-0038	Brownie	2/8/2022	13:15		0									4.64	2.09	5.45	0.038	0.011	1.53	1.72	0.316	1.16	173	240	420	16.5									
27-0038	Brownie	2/8/2022	13:15		6												1.12	0.101																	
27-0038	Brownie	2/8/2022	13:15		12												3.97	0.301							1175	9.10									
27-0038	Brownie	4/19/2022	9:48	1.07	0	5.4	110.4	14.04	8.2	1283			5.6	27.6	6.04	4.18	0.072	0.005	0.702	0.803	0.072	0.125	107	144	340	11.3									
27-0038	Brownie	4/19/2022	9:47		1	5.4	110.0	14.03	8.1	1285			5.5																						
27-0038	Brownie	4/19/2022	9:46		2	6.1	56.3	7.04	7.5	1667			5.3																						
27-0038	Brownie	4/19/2022	9:44		3	4.7	0.0	0.00	7.2	2572			5.8																						
27-0038	Brownie	4/19/2022	9:42		4	5.0	4.6	0.59	7.1	3076			4.6																						
27-0038	Brownie	4/19/2022	9:41		5	5.7	0.3	0.03	6.9	3621			4.8																						
27-0038	Brownie	4/19/2022	9:38		6	6.2	1.4	0.17	6.8	3789			4.4				2.56	0.021																	
27-0038	Brownie	4/19/2022	9:37		7	6.5	1.8	0.22	6.8	3890			4.4																						
27-0038	Brownie	4/19/2022	9:36		8	6.6	1.2	0.14	6.8	3987			4.6																						
27-0038	Brownie	4/19/2022	9:34		9	6.7	2.2	0.27	6.8	4027			4.9																						
27-0038	Brownie	4/19/2022	9:33		10	6.6	1.4	0.17	6.7	4058			5.3																						
27-0038	Brownie	4/19/2022	9:32		11	6.7	1.5	0.18	6.6	4095			5.4																						
27-0038	Brownie	4/19/2022	9:31		12	6.6	0.8	0.10	6.5	4134			5.6				3.81	0.409							1200	2.50									
27-0038	Brownie	5/10/2022	9:19	0.69	0	16.3	130.2	12.73	9.0	1070	0.65	16.29		18.9	3.00	1.59	0.047	0.007	0.695	0.778	0.015	0.125	91	128	340	12.2									
27-0038	Brownie	5/10/2022	9:19		1	15.9	125.9	12.42	8.9	1062	0.82	21.62																							
27-0038	Brownie	5/10/2022	9:18		2	9.5	118.3	13.45	8.2	1414	2.36	26.00																							
27-0038	Brownie	5/10/2022	9:15		3	6.0	2.1	0.26	6.9	2720	1.54	5.11																							
27-0038	Brownie	5/10/2022	9:15		4	5.7	2.2	0.27	6.7	3197	0.08	0.98																							
27-0038	Brownie	5/10/2022	9:15		5	6.3	2.4	0.29	6.4	3790	0.03	0.96																							
27-0038	Brownie	5/10/2022	9:14		6	6.6	2.7	0.32	6.4	3888	0.00	0.89					2.04	0.008																	
27-0038	Brownie	5/10/2022	9:14		7	6.7	2.9	0.35	6.4	3937	0.03	0.92																							
27-0038	Brownie	5/10/2022	9:13		8	6.8	3.3	0.39	6.4	3996	0.01	0.92																							
27-0038	Brownie	5/10/2022	9:13		9	6.9	3.6	0.43	6.4	4023	0.01	0.87																							
27-0038	Brownie	5/10/2022	9:13		10	6.9	4.3	0.51	6.4	4070	0.08	1.34																							
27-0038	Brownie	5/10/2022	9:12		11	6.9	4.8	0.57	6.4	4111	0.02	1.10																							
27-0038	Brownie	5/10/2022	9:12		12	6.9	6.2	0.75	6.3	4128	0.27	0.08					4.30	0.048							1250	2.50									
27-0038	Brownie	6/6/2022	9:20	2.22	0	20.5	113.5	10.18	8.2	1182	0.07	1.42		6.14	1.23	2.54	0.041	0.004		0.813					307										
27-0038	Brownie	6/6/2022	9:20		1	20.4	105.5	9.49	8.1	1169	0.11	2.28																							
27-0038	Brownie	6/6/2022	9:19		2	16.8	36.9	3.57	7.2	1506	0.33	4.82																							
27-0038	Brownie	6/6/2022	9:18		3	11.4	1.4	0.15	6.8	2211	3.99	13.89																							
27-0038	Brownie	6/6/2022	9:18		4	7.1	1.0	0.12	6.6	2986	0.25	1.95																							
27-0038	Brownie	6/6/2022	9:17		5	6.3	1.0	0.12	6.4	3522	0.03	1.11																							
27-0038	Brownie	6/6/2022	9:16		6	6.4	1.2	0.14	6.4	3828	0.01	1.10					1.76	0.044																	
27-0038	Brownie	6/6/2022	9:16		7	6.7	1.3	0.16	6.3	3955	0.02	1.08																							
27-0038	Brownie	6/6/2022	9:15		8	6.8	1.4	0.17	6.3	4035	0.00	1.09																							
27-0038	Brownie	6/6/2022	9:15		9	6.9	1.6	0.19	6.3	4076	0.00	1.02																							
27-0038	Brownie	6/6/2022	9:14		10	6.9	1.8	0.21	6.2	4115	0.04	1.03																							
27-0038	Brownie	6/6/2022	9:13		11	7.0	2.0	0.25	6.2	4130	0.00	1.05																							
27-0038	Brownie	6/6/2022	9:13		12	7.0	2.7	0.32	6.2	4147	0.06	1.78					4.19	0.075							1173										
27-0038	Brownie	6/6/2022	9:12		13	7.2	3.4	0.40	6.2	4142	0.00	0.02																							
27-0038	Brownie	7/13/2022	10:02	1.23	0	24.8	110.9	9.16	8.1	1406	0.17	3.35		10.9	2.05	7.27	0.044	0.002	0.846	0.979	0.065	0.125	150	256	340	33.0									
27-0038	Brownie	7/13/2022	10:01		1	24.2	77.5	6.48	7.7	1462	0.08	2.93																							
27-0038	Brownie	7/13/2022	9:59		2	21.4	68.5	6.03	7.5	1708	0.43	9.75																							
27-0038	Brownie	7/13/2022	9:59		3	16.1	1.5	0.14	7.0	2051	3.85	43.32																							
27-0038	Brownie	7/13/2022	9:58		4	9.0	1.0	0.12	6.7	3096	0.24	4.85																							
27-0038	Brownie	7/13/2022	9:57		5	6.8	1.0	0.12	6.5	3645	0.02	2.15																							
27-0038	Brownie	7/13/2022	9:56		6	6.6	1.1	0.13	6.4	3836	0.00	1.60					1.68	0.383																	
27-0038	Brownie	7/13/2022	9:56		7	6.7	1.2	0.15	6.4	3942	0.00	1.58																							
27-0038	Brownie	7/13/2022	9:55		8	6.8	1.3	0.15	6.4	4004	0.00	1.24																							
27-0038	Brownie	7/13/2022	9:55		9	6.9	1.4	0.16	6.4	4056	0.00	1.37																							
27-0038	Brownie	7/13/2022	9:55		10	7.0	1.4	0.17	6.4	4098	0.00	1.14																							
27-0038	Brownie	7/13/2022	9:54		11	7.0	1.6	0.19	6.4	4114	0.00	1.20																							
27-0038	Brownie	7/13/2022	9:53		12	7.1	1.9	0.23	6.4	4131	0.01	1.88					4.67	0.405							1300	2.50									
27-0038	Brownie	7/13/2022	9:53		13	7.2	2.3	0.27	6.3	4132	0.00	0.02																							
27-0038	Brownie	8/8/2022	11:35	1.00	0	23.6	111.7	9.43	8.2	1500	0.37	5.75		26.9	1.67	9.83	0.041	0.002		0.556					450		272								
27-0038	Brownie	8/8/2022	11:34		1	23.1	108.6	9.26	8.2	1479	0.50	8.90																							
27-0038	Brownie	8/8/2022	11:32		2	22.2	77.9	6.76	7.8	1520	0.43	7.47																							
27-0038	Brownie	8/8/2022	11:31		3	18.7	1.1	0.10	7.4	2010	5.19	24.16																							
27-0038	Brownie	8/8/2022	11:30		4	10.5	0.5	0.05	7.0	3162	0.58	6.34																							
27-0038	Brownie	8/8/2022	11:29		5	7.7	0.3	0.04	6.8	3644	0.10	2.97																							
27-0038	Brownie	8/8/2022	11:28		6	6.9	0.3	0.03	6.8	3854	0.02	2.45					1.37	0.063																	
27-0038	Brownie	8/8/2022	11:27		7	6.7	0.3	0.03	6.7	3953	0.04	1.98																							
27-0038	Brownie	8/8/2022	11:27		8	6.8	0.3	0.04	6.7	4020	0.00	1.95																							
27-0038	Brownie	8/8/2022	11:25		9	6.9	0.5	0.06	6.7	4076	0.00	1.85																							
27-0038	Brownie	8/8/2022	11:24		10	7.0	0.5	0.06	6.7	4120	0.00	1.74																							
27-0038	Brownie	8/8/2022	11:23		11	7.0	0.7	0.08	6.7	4146	0.00	1.72																							
27-0038	Brownie	8/8/2022	11:22		12	7.1	0.7	0.09	6.6	4178	0.01	2.06					1.60	0.503							1350										
27-0038	Brownie	8/8/2022	11:21		13	7.1	1.0	0.11	6.6	4195	0.05	2.44																							
27-0038	Brownie	9/12/2022	9:33	2.49	0	16.4	99.4	9.72	7.5		0.08	0.11		23.8	3.28	7.46	0.032	0.004		0.250					350										
27-0038	Brownie	9/12/2022	9:32		1	21.6	65.5	5.75	7.8	1318	0.21	5.16																							
27-0038	Brownie	9/12/2022	9:32		2	21.5	63.6	5.60	7.8	1320	0.22	2.75																							
27-0038	Brownie	9/12/2022	9:31		3	21.3	46.7	4.12	7.6	1381	0.21	4.67																							
27-0038	Brownie	9/12/2022	9:28		4	13.2	1.7	0.17	6.8	3018	0.54	4.91																							
27-0038	Brownie	9/12/2022	9:27		5	8.9	1.3	0.15	6.6	3642	0.26	4.17																							
27-0038	Brownie	9/12/2022	9:27		6	7.3	1.4	0.17	6.6	3863	0.14	3.13					1.12	0.016																	
27-0038	Brownie	9/12/2022	9:25		7	6.9	1.5	0.19	6.5	3948	0.00	2.44																							

Lake ID	Lake Name	Date MM/DD/YYYY	Time HH:MM	Secchi meters	Depth meters	Temp °C	%DO	DO mg/L	pH units	SpCond µS/cm	Phycocyanin RFU	Chlorophyll-a RFU	TurbSC NTU	Chl-a mg/M3	Pheo-a mg/M3	Silica mg/L	TP mg/L	SRP mg/L	TKN mg/L	TN mg/L	NO3NO2 mg/L	NH3 mg/L	Alk mg/L	Hard mg/L	Cl mg/L	SO4 mg/L	E. Coli mpn/100 mL	DOC mg/L	Fe µg/L	DFe µg/L	Al µg/L	DAl µg/L	Microcystin µg/L	Cylindro. µg/L	Anatoxin-a µg/L
27-0038	Brownie	9/12/2022	9:25		8	6.9	1.8	0.21	6.5	4008	0.00	2.10																							
27-0038	Brownie	9/12/2022	9:24		9	6.9	2.2	0.26	6.4	4070	0.00	1.96																							
27-0038	Brownie	9/12/2022	9:23		10	7.0	2.6	0.31	6.4	4113	0.00	1.88																							
27-0038	Brownie	9/12/2022	9:22		11	7.1	3.5	0.41	6.3	4143	0.00	2.00																							
27-0038	Brownie	9/12/2022	9:21		12	7.3	5.0	0.59	6.4	4164	4.70	29.36					1.41	0.031							1300										
27-0038	Brownie	10/11/2022	9:52	1.37	0	14.8	56.2	5.66	7.7	1534	0.12	2.18		9.61	3.17	4.84	0.032	0.004	0.757	0.771	0.094	0.392	157	250	450	27.4									
27-0038	Brownie	10/11/2022	9:51		1	14.7	55.2	5.57	7.7	1534	0.16	3.74																							
27-0038	Brownie	10/11/2022	9:50		2	14.7	48.7	4.92	7.7	1534	0.14	3.71																							
27-0038	Brownie	10/11/2022	9:49		3	14.5	39.1	3.97	7.6	1546	0.06	1.42																							
27-0038	Brownie	10/11/2022	9:47		4	13.6	1.7	0.18	6.9	3022	2.76	10.77																							
27-0038	Brownie	10/11/2022	9:47		5	9.9	1.5	0.17	6.7	3629	0.28	4.65																							
27-0038	Brownie	10/11/2022	9:46		6	7.6	1.5	0.18	6.7	3869	0.20	3.97					2.21	0.203																	
27-0038	Brownie	10/11/2022	9:45		7	7.1	1.8	0.22	6.6	3962	0.10	3.12																							
27-0038	Brownie	10/11/2022	9:44		8	7.0	2.2	0.26	6.6	4035	0.04	2.55																							
27-0038	Brownie	10/11/2022	9:44		9	7.0	2.6	0.31	6.6	4080	0.03	2.31																							
27-0038	Brownie	10/11/2022	9:43		10	7.1	3.3	0.39	6.6	4113	0.03	2.15																							
27-0038	Brownie	10/11/2022	9:42		11	7.2	4.7	0.56	6.5	4147	0.04	2.18																							
27-0038	Brownie	10/11/2022	9:42		12	7.2	7.8	0.93	6.5	4181	0.03	2.24					4.62	1.18							1600	2.50									
27-0039	Cedar	2/8/2022	12:30		0									0.250	0.250	4.84	0.083	0.056	1.61	1.69	0.015	1.27	151	180	165	12.2							<1.5		
27-0039	Cedar	2/8/2022	12:30		5												0.085	0.061																	
27-0039	Cedar	2/8/2022	12:30		10												0.131	0.110																	
27-0039	Cedar	2/8/2022	12:30		14												0.238	0.182							165	11.1									
27-0039	Cedar	4/19/2022	10:35	1.25	0	4.7	94.7	12.31	8.2	770			3.4	34.9	11.3	4.22	0.081	0.006	1.10	1.28	0.476	0.321	137	168	155	10.8		7.10			100	100	<1.5		
27-0039	Cedar	4/19/2022	10:34		1	4.4	95.7	12.51	8.2	769			3.5																						
27-0039	Cedar	4/19/2022	10:33		2	4.4	95.0	12.45	8.2	769			2.1																						
27-0039	Cedar	4/19/2022	10:32		3	4.3	93.3	12.24	8.1	769			2.0																						
27-0039	Cedar	4/19/2022	10:30		4	4.2	92.4	12.15	8.1	769			2.0																						
27-0039	Cedar	4/19/2022	10:28		5	4.2	95.6	12.57	8.1	770			2.0				0.090	0.006													100	100			
27-0039	Cedar	4/19/2022	10:27		6	4.2	98.8	13.00	8.1	770			2.0																						
27-0039	Cedar	4/19/2022	10:25		7	4.2	95.3	12.53	8.1	769			1.9																						
27-0039	Cedar	4/19/2022	10:23		8	4.2	94.1	12.38	8.1	769			1.9																						
27-0039	Cedar	4/19/2022	10:22		9	4.2	91.4	12.01	8.1	770			1.9																						
27-0039	Cedar	4/19/2022	10:21		10	4.2	93.3	12.27	8.1	769			1.8				0.080	0.006													100	100			
27-0039	Cedar	4/19/2022	10:19		11	4.2	89.3	11.74	8.1	770			1.8																						
27-0039	Cedar	4/19/2022	10:17		12	4.2	88.9	11.71	8.1	770			1.7																						
27-0039	Cedar	4/19/2022	10:16		13	4.2	88.6	11.66	8.1	770			1.7																						
27-0039	Cedar	4/19/2022	10:14		14	4.2	88.8	11.68	8.0	769			1.6				0.088	0.006							160	10.9					100	100			
27-0039	Cedar	4/19/2022	10:12		15	4.2	88.9	11.70	8.0	770			1.5																						
27-0039	Cedar	4/19/2022	10:10		16	4.2	88.7	11.65	8.0	768			1.1																						
27-0039	Cedar	4/19/2022	10:09		16.2	4.2	89.0	11.70	7.9	769			0.8																						
27-0039	Cedar	5/10/2022	9:50	1.55	0	13.3	132.9	13.87	8.8	752	0.20	4.68		9.76	3.55	0.250	0.045	0.007	0.859	0.988	0.015	0.321	125	156	160	10.2		8.20			100	100			
27-0039	Cedar	5/10/2022	9:49		1	12.9	134.5	14.17	8.8	752	0.28	6.64																							
27-0039	Cedar	5/10/2022	9:48		2	12.3	137.1	14.65	8.8	753	0.31	7.26																							
27-0039	Cedar	5/10/2022	9:47		3	11.8	135.6	14.64	8.8	756	0.29	6.63																							
27-0039	Cedar	5/10/2022	9:46		4	10.9	130.6	14.39	8.7	756	0.28	5.89																							
27-0039	Cedar	5/10/2022	9:45		5	8.9	116.7	13.51	8.6	765	0.16	3.30					0.045	0.007													100	100			
27-0039	Cedar	5/10/2022	9:44		6	7.9	111.5	13.20	8.5	772	0.09	2.01																							
27-0039	Cedar	5/10/2022	9:43		7	7.7	108.9	12.98	8.5	773	0.10	1.69																							
27-0039	Cedar	5/10/2022	9:42		8	7.3	93.5	11.24	8.2	778	0.07	1.59																							
27-0039	Cedar	5/10/2022	9:41		9	7.1	88.5	10.69	8.2	780	0.06	1.44																							
27-0039	Cedar	5/10/2022	9:39		10	6.8	78.9	9.59	7.9	783	0.07	1.66					0.037	0.007													100	100			
27-0039	Cedar	5/10/2022	9:38		11	6.6	72.4	8.85	7.8	785	0.03	1.43																							
27-0039	Cedar	5/10/2022	9:37		12	6.6	69.8	8.54	7.8	785	0.05	1.22																							
27-0039	Cedar	5/10/2022	9:36		13	6.4	63.4	7.79	7.7	786	0.03	1.24																							
27-0039	Cedar	5/10/2022	9:35		14	6.4	60.2	7.41	7.6	787	0.04	1.22					0.044	0.008							165	10.9					100	100			
27-0039	Cedar	5/10/2022	9:34		15	6.3	55.2	6.80	7.6	789	0.01	0.82																							
27-0039	Cedar	5/24/2022	10:00	7.22	0	17.6	96.7	9.21	8.3	736	0.00	0.11		0.250	0.250		0.035	0.010		0.898					145										
27-0039	Cedar	5/24/2022	9:58		1	17.6	95.5	9.10	8.3	736	0.00	0.14																							
27-0039	Cedar	5/24/2022	9:57		2	17.1	91.2	8.78	8.3	736	0.00	0.17																							
27-0039	Cedar	5/24/2022	9:56		3	16.6	89.6	8.71	8.3	734	0.00	0.15																							
27-0039	Cedar	5/24/2022	9:55		4	13.0	86.5	9.09	8.1	759	0.00	0.19																							
27-0039	Cedar	5/24/2022	9:54		5	10.2	83.7	9.38	8.0	765	0.00	0.21					0.036	0.015																	
27-0039	Cedar	5/24/2022	9:53		6	9.1	71.0	8.17	7.8	770	0.00	0.24																							
27-0039	Cedar	5/24/2022	9:52		7	8.1	61.2	7.21	7.6	776	0.00	0.22																							
27-0039	Cedar	5/24/2022	9:50		8	7.7	50.3	5.99	7.4	778	0.00	0.22																							
27-0039	Cedar	5/24/2022	9:49		9	7.5	47.2	5.65	7.4	779	0.00	0.21																							
27-0039	Cedar	5/24/2022	9:48		10	7.2	36.2	4.36	7.3	780	0.00	0.25					0.050	0.026																	
27-0039	Cedar	5/24/2022	9:47		11	7.0	29.4	3.56	7.2	782	0.00	0.22																							
27-0039	Cedar	5/24/2022	9:46		12	7.0	21.0	2.55	7.2	783	0.00	0.25																							
27-0039	Cedar	5/24/2022	9:44		13	6.8	9.4	1.15	7.1	786	0.00	0.49																							
27-0039	Cedar	5/24/2022	9:36		14	6.8	1.2	0.15	7.2	787	0.00	0.46					0.118	0.038							150										
27-0039	Cedar	5/24/2022	9:35		15	6.8	1.1	0.14	7.2	787	0.00	0.49																							
27-0039	Cedar	5/24/2022	9:32		16	6.6	1.1	0.13	7.4	827	0.97	13.72																							
27-0039	Cedar	6/6/2022	10:09	3.80	0	20.2	120.4	10.87	8.6	736	0.00	0.53		2.54	0.703	0.580	0.027	0.006		0.690					185										
27-0039	Cedar	6/6/2022	10:08		1	20.1	118.1	10.71	8.6	737	0.00	0.61																							
27-0039	Cedar	6/6/2022	10:08		2	19.9	114.2	10.38	8.5	739	0.05	0.90																							
27-0039	Cedar	6/6/2022	10:07		3	19.0	97.7	9.04	8.4	741	0.02	0.74																							
27-0039	Cedar	6/6/2022	10:06		4	16.7	76.0	7.37	8.1	749	0.01	0.86																							
27-0039	Cedar	6/6/2022	10:05		5	11.9	56.3	6.07	7.8	772	0.00	0.69					0.034	0.019																	
27-0039	Cedar	6/6/2022	10:04		6	9.8	49.7	5.62	7.7	781	0.00	0.53																							
27-0039	Cedar	6/6/2022	10:03		7	8.8	40.4	4.68	7.6	785	0.00	0.51																							
27-0039	Cedar	6/6/2022	10:02		8	8.2	21.3	2.51	7.4	788	0.00	0.40																							
27-0039	Cedar	6/6/2022	10:01		9	7.7	1.9	0.23	7.3	791	0.00	0.40																							
27-0039	Cedar	6/6/2022	10:00		10	7.3	1.6	0.20	7.3	794	0.00	0.40					0.094	0.057																	
27-0039	Cedar	6/6/2022	9:59		11	7.2	1.9	0.22	7.3	796	0.00	0.43																							
27-0039	Cedar	6/6/2022	9:58		12	7.1	2.4	0.29	7.3	798	0.06	0.50																							
27-0039	Cedar	6/6/2022	9:57		13	7.0	2.9	0.35	7.3	801	0.08	0.53																							
27-0039	Cedar	6/6/2022	9:55		14	6.9	4.2	0.50	7.3	803	0.05	0.54					0.161	0.084							165										
27-0039	Cedar	6/6/2022	9:54		15	6.9	6.7	0.81	7.2	807	0.09	0.59																							
27-0039	Cedar	6/23/2022	9:05	1.05	0	25.9	132.2	10.72	8.7	735	0.07	1.95		12.2	1.17		0.032	0.005		0.652					170										
27-0039	Cedar	6/23/2022	9:04		1	25.9	131.5	10.67	8.7	735	0.14	1.51																							
27-0039	Cedar	6/23/2022	9:03		2	25.9	130.3	10.58	8.7	734	0.18	3.55																							
27-0039	Cedar	6/23/2022	9:02		3	24.8	114.6	9.48	8.5	736	0.17	2.52																							
27-0039	Cedar	6/23/2022	9:01		4	20.0	56.0	5.08	7.8	754	0.19	3.99																							
27-0039	Cedar	6/23/2022	9:01		5	13.1	27.3	2.86	7.5	781	0.03	1.67					0.027	0.004																	
27-0039	Cedar	6/23/2022	9:00		6	10.4	6.5	0.73	7.4	790	0.00	0.91																							
27-0039	Cedar	6/23/2022	8:59		7	9.1	6.4	0.73	7.4	792	0.00	0.51																							

Lake ID	Lake Name	Date MM/DD/YYYY	Time HH:MM	Secchi meters	Depth meters	Temp °C	%DO	DO mg/L	pH units	SpCond µS/cm	Phycocyanin RFU	Chlorophyll-a RFU	TurbSC NTU	Chl-a mg/M3	Pheo-a mg/M3	Silica mg/L	TP mg/L	SRP mg/L	TKN mg/L	TN mg/L	NO3NO2 mg/L	NH3 mg/L	Alk mg/L	Hard mg/L	Cl mg/L	SO4 mg/L	E. Coli mpn/100 mL	DOC mg/L	Fe µg/L	DFe µg/L	Al µg/L	DAl µg/L	Microcystin µg/L	Cylindro. µg/L	Anatoxin-a µg/L
27-0039	Cedar	6/23/2022	8:58		8	8.2	1.8	0.22	7.3	796	0.09	0.51																							
27-0039	Cedar	6/23/2022	8:57		9	7.7	2.0	0.24	7.3	800	0.14	0.59																							
27-0039	Cedar	6/23/2022	8:56		10	7.4	2.2	0.26	7.2	803	0.04	0.57					0.125	0.083																	
27-0039	Cedar	6/23/2022	8:55		11	7.2	2.5	0.30	7.2	803	0.00	0.50																							
27-0039	Cedar	6/23/2022	8:54		12	7.1	2.9	0.35	7.2	805	0.00	0.45																							
27-0039	Cedar	6/23/2022	8:54		13	7.0	3.4	0.41	7.2	810	0.00	0.49																							
27-0039	Cedar	6/23/2022	8:53		14	6.9	4.1	0.49	7.2	814	0.00	0.50					0.223	0.152							165										
27-0039	Cedar	6/23/2022	8:52		15	6.9	6.0	0.73	7.2	815	0.00	0.54																							
27-0039	Cedar	7/13/2022	10:49	3.50	0	25.8	110.0	8.95	8.7	743	0.00	0.56		6.41	0.250	0.955	0.027	0.002	0.974	1.06	0.015	0.253	104	136	177	9.72		8.00			15	15			
27-0039	Cedar	7/13/2022	10:47		1	25.7	109.2	8.89	8.6	742	0.00	1.05																							
27-0039	Cedar	7/13/2022	10:46		2	25.6	107.9	8.80	8.6	741	0.02	2.03																							
27-0039	Cedar	7/13/2022	10:45		3	25.5	104.7	8.57	8.6	739	0.02	2.10																							
27-0039	Cedar	7/13/2022	10:44		4	21.9	63.4	5.54	8.2	755	0.47	10.54																							
27-0039	Cedar	7/13/2022	10:42		5	16.1	7.8	0.76	7.5	777	0.40	7.82					0.052	0.002													15	15			
27-0039	Cedar	7/13/2022	10:35		6	11.2	0.9	0.09	7.4	785	2.31	2.49																							
27-0039	Cedar	7/13/2022	10:32		7	9.3	0.8	0.10	7.3	786	0.07	0.66																							
27-0039	Cedar	7/13/2022	10:30		8	8.3	0.9	0.11	7.3	794	0.00	0.66																							
27-0039	Cedar	7/13/2022	10:29		9	7.8	1.0	0.12	7.2	796	0.00	0.96																							
27-0039	Cedar	7/13/2022	10:27		10	7.5	1.1	0.14	7.2	801	0.00	0.45					0.193	0.123													15	15			
27-0039	Cedar	7/13/2022	10:27		11	7.3	1.3	0.15	7.2	804	0.00	0.42																							
27-0039	Cedar	7/13/2022	10:26		12	7.1	1.5	0.18	7.2	806	0.00	0.39																							
27-0039	Cedar	7/13/2022	10:25		13	7.0	1.8	0.22	7.1	815	0.00	0.42																							
27-0039	Cedar	7/13/2022	10:23		14	6.9	2.2	0.27	7.0	822	0.00	0.46					0.348	0.232							160	8.64					15	15			
27-0039	Cedar	7/13/2022	10:22		15	7.0	3.0	0.37	6.7	853	0.44	1.24																							
27-0039	Cedar	7/25/2022	11:19	4.69	0	25.6	98.3	8.03	8.4	765	0.10	1.06		5.13	1.04		0.017	0.002		0.548					185										
27-0039	Cedar	7/25/2022	11:18		1	25.4	97.5	7.97	8.4	764	0.10	1.30																							
27-0039	Cedar	7/25/2022	11:17		2	25.4	95.5	7.83	8.4	764	0.09	2.00																							
27-0039	Cedar	7/25/2022	11:17		3	25.3	92.8	7.61	8.3	764	0.10	2.23																							
27-0039	Cedar	7/25/2022	11:15		4	25.0	85.2	7.02	8.2	762	0.14	1.65																							
27-0039	Cedar	7/25/2022	11:13		5	17.5	31.7	3.03	7.7	778	1.15	8.00					0.029	0.002																	
27-0039	Cedar	7/25/2022	11:10		6	11.9	2.8	0.30	7.4	788	1.25	7.49																							
27-0039	Cedar	7/25/2022	11:10		7	9.7	1.1	0.12	7.3	795	4.55	3.17																							
27-0039	Cedar	7/25/2022	11:08		8	8.5	1.0	0.12	7.2	803	0.27	1.21																							
27-0039	Cedar	7/25/2022	11:08		9	7.8	1.1	0.13	7.2	807	0.10	0.80																							
27-0039	Cedar	7/25/2022	11:07		10	7.5	1.1	0.14	7.1	811	0.05	0.60					0.212	0.144																	
27-0039	Cedar	7/25/2022	11:07		11	7.3	1.2	0.14	7.1	814	0.04	0.57																							
27-0039	Cedar	7/25/2022	11:06		12	7.1	1.3	0.16	7.0	818	0.08	0.55																							
27-0039	Cedar	7/25/2022	11:05		13	7.0	1.5	0.19	7.0	827	0.05	0.56																							
27-0039	Cedar	7/25/2022	11:05		14	6.9	1.6	0.20	6.9	838	0.07	0.59					0.447	0.350							190										
27-0039	Cedar	7/25/2022	11:04		15	6.8	1.9	0.23	6.8	842	0.11	0.64																							
27-0039	Cedar	7/25/2022	11:03		16	6.8	2.9	0.35	6.7	859	0.59	1.01																							
27-0039	Cedar	8/8/2022	12:04	3.40	0	24.8	93.1	7.70	8.5	786	0.09	0.59		10.3	1.37	1.41	0.026	0.005		0.639					190		1								
27-0039	Cedar	8/8/2022	12:03		1	24.7	92.3	7.65	8.5	782	0.12	1.06																							
27-0039	Cedar	8/8/2022	12:02		2	24.5	92.9	7.73	8.6	771	0.18	2.20																							
27-0039	Cedar	8/8/2022	12:02		3	24.4	92.5	7.71	8.6	771	0.28	3.87																							
27-0039	Cedar	8/8/2022	12:01		4	24.2	83.8	7.02	8.6	770	0.18	2.94																							
27-0039	Cedar	8/8/2022	12:00		5	21.6	31.8	2.80	8.0	784	1.44	5.30					0.045	0.002																	
27-0039	Cedar	8/8/2022	11:59		6	14.3	2.8	0.28	7.7	791	4.37	8.58																							
27-0039	Cedar	8/8/2022	11:57		7	10.4	0.9	0.10	7.6	798	1.77	1.66																							
27-0039	Cedar	8/8/2022	11:56		8	8.5	0.8	0.09	7.6	806	0.29	1.18																							
27-0039	Cedar	8/8/2022	11:56		9	7.8	0.9	0.11	7.5	812	0.15	0.86																							
27-0039	Cedar	8/8/2022	11:55		10	7.5	1.0	0.11	7.4	818	0.11	0.73					0.243	0.165																	
27-0039	Cedar	8/8/2022	11:54		11	7.2	1.1	0.14	7.4	821	0.05	0.63																							
27-0039	Cedar	8/8/2022	11:53		12	7.2	1.3	0.16	7.4	824	0.07	0.64																							
27-0039	Cedar	8/8/2022	11:52		13	7.0	1.7	0.20	7.3	832	0.04	0.62																							
27-0039	Cedar	8/8/2022	11:51		14	6.9	1.9	0.23	7.2	841	0.09	0.68					0.511	0.414							180										
27-0039	Cedar	8/8/2022	11:51		15	6.9	2.3	0.28	7.2	846	0.11	0.78																							
27-0039	Cedar	8/8/2022	11:50		16	6.9	2.9	0.35	6.9	871	0.12	0.26																							
27-0039	Cedar	8/23/2022	10:21	1.19	0	22.7	100.8	8.69	7.5		0.00	0.00	0.9	15.9	1.30		0.024	0.002		0.646					180										
27-0039	Cedar	8/23/2022	10:19		1	24.4	132.3	11.04	8.8	760	0.73	2.60																							
27-0039	Cedar	8/23/2022	10:18		2	24.0	133.0	11.17	8.8	759	1.18	4.35																							
27-0039	Cedar	8/23/2022	10:16		3	23.5	94.5	8.02	8.5	763	1.81	4.41																							
27-0039	Cedar	8/23/2022	10:15		4	23.1	66.0	5.64	8.2	765	1.22	3.82																							
27-0039	Cedar	8/23/2022	10:13		5	21.9	1.3	0.12	7.5	774	0.26	1.59					0.041	0.002																	
27-0039	Cedar	8/23/2022	10:12		6	15.3	1.1	0.11	7.5	791	2.38	2.34																							
27-0039	Cedar	8/23/2022	10:11		7	10.9	1.0	0.11	7.3	791	0.19	1.09																							
27-0039	Cedar	8/23/2022	10:09		8	8.8	0.9	0.10	7.3	806	0.09	0.86																							
27-0039	Cedar	8/23/2022	10:08		9	8.0	1.0	0.12	7.2	813	0.08	0.68																							
27-0039	Cedar	8/23/2022	10:07		10	7.6	1.2	0.14	7.2	818	0.06	0.61					0.241	0.179																	
27-0039	Cedar	8/23/2022	10:06		11	7.3	1.3	0.16	7.2	818	0.00	0.54																							
27-0039	Cedar	8/23/2022	10:05		12	7.2	1.6	0.19	7.1	826	0.04	0.52																							
27-0039	Cedar	8/23/2022	10:04		13	7.0	1.9	0.23	7.0	833	0.01	0.56																							
27-0039	Cedar	8/23/2022	10:03		14	6.9	2.7	0.33	7.0	848	0.04	0.62					0.501	0.422							180										
27-0039	Cedar	8/23/2022	10:00		15	6.9	4.2	0.51	6.9	849	0.03	0.63																							
27-0039	Cedar	9/12/2022	11:12	6.46	0	22.3	83.5	7.25	8.4	762	0.61	0.88	2.3	13.0	0.593	2.04	0.030	0.004		0.686					220										
27-0039	Cedar	9/12/2022	11:12		1	22.3	81.9	7.11	8.4	762	0.71	1.04																							
27-0039	Cedar	9/12/2022	11:11		2	22.2	75.7	6.58	8.3	762	0.79	1.29																							
27-0039	Cedar	9/12/2022	11:10		3	22.1	73.6	6.41	8.3	762	0.78	1.16																							
27-0039	Cedar	9/12/2022	11:09		4	21.9	60.6	5.30	8.2	764	0.69	1.11																							
27-0039	Cedar	9/12/2022	11:08		5	21.6	45.2	3.97	8.0	763	0.40	0.88					0.027	0.002																	
27-0039	Cedar	9/12/2022	11:07		6	16.7	1.4	0.14	7.4	795	0.35	1.99																							
27-0039	Cedar	9/12/2022	11:06		7	11.9	1.0	0.11	7.3	797	0.05	1.09																							
27-0039	Cedar	9/12/2022	11:05		8	9.6	1.0	0.11	7.3	807	0.00	0.70																							
27-0039	Cedar	9/12/2022	11:03		9	8.3	1.1	0.13	7.2	819	0.00	0.58																							
27-0039	Cedar	9/12/2022	11:02		10	7.8	1.2	0.14	7.1	822	0.00	0.53					0.293	0.280																	
27-0039	Cedar	9/12/2022	11:02		11	7.5	1.4	0.16	7.1	824	0.00	0.51																							
27-0039	Cedar	9/12/2022	11:00		12	7.3	1.7	0.21	7.0	832	0.00	0.53																							
27-0039	Cedar	9/12/2022	10:59		13	7.1	2.1	0.25	7.0	841	0.00	0.56																							
27-0039	Cedar	9/12/2022	10:58		14	7.0	2.5	0.30	7.0	847	0.00	0.56					0.529	0.493							170										
27-0039	Cedar	9/12/2022	10:58		15	6.9	3.3	0.40	6.9	860	0.53	1.19																							
27-0039	Cedar	9/26/2022	11:03	1.24	0	18.5	78.7	7.36	8.2	769	0.30	0.61	2.9	15.6	1.71		0.028	0.002		0.741					175										
27-0039	Cedar	9/26/2022	11:03		1	18.5	78.4	7.34	8.2	769	0.51	0.86																							
27-0039	Cedar	9/26/2022	11:02		2	18.5	77.9	7.29	8.2	769	0.59	0.90																							
27-0039	Cedar	9/26/2022	11:01		3	18.5	76.9	7.20	8.2	769	0.58	0.99																							
27-0039	Cedar	9/26/2022	11:00		4	18.4	76.0	7.12	8.2	769	0.53	1.00																							

Lake ID	Lake Name	Date MM/DD/YYYY	Time HH:MM	Secchi meters	Depth meters	Temp °C	%DO	DO mg/L	pH units	SpCond µS/cm	Phycocyanin RFU	Chlorophyll-a RFU	TurbSC NTU	Chl-a mg/M3	Pheo-a mg/M3	Silica mg/L	TP mg/L	SRP mg/L	TKN mg/L	TN mg/L	NO3NO2 mg/L	NH3 mg/L	Alk mg/L	Hard mg/L	Cl mg/L	SO4 mg/L	E. Coli mpn/100 mL	DOC mg/L	Fe µg/L	DFe µg/L	Al µg/L	DAl µg/L	Microcystin µg/L	Cylindro. µg/L	Anatoxin-a µg/L
27-0039	Cedar	9/26/2022	10:59		5	18.4	74.9	7.02	8.2	769	0.54	0.86					0.027	0.002																	
27-0039	Cedar	9/26/2022	10:58		6	18.3	71.5	6.71	8.2	769	0.54	0.85																							
27-0039	Cedar	9/26/2022	10:56		7	12.0	1.0	0.11	7.3	807	0.05	1.03																							
27-0039	Cedar	9/26/2022	10:55		8	9.7	1.0	0.11	7.2	815	0.00	0.58																							
27-0039	Cedar	9/26/2022	10:55		9	8.5	1.0	0.12	7.2	820	0.00	0.51																							
27-0039	Cedar	9/26/2022	10:54		10	8.0	1.1	0.13	7.1	825	0.00	0.48					0.292	0.268																	
27-0039	Cedar	9/26/2022	10:53		11	7.7	1.2	0.15	7.1	828	0.00	0.46																							
27-0039	Cedar	9/26/2022	10:52		12	7.3	1.4	0.17	7.0	833	0.00	0.42																							
27-0039	Cedar	9/26/2022	10:51		13	7.1	1.8	0.22	6.9	847	0.00	0.55																							
27-0039	Cedar	9/26/2022	10:50		14	7.0	2.3	0.28	6.9	856	0.00	0.61					0.555	0.519							170										
27-0039	Cedar	9/26/2022	10:49		15	6.9	3.7	0.44	6.9	864	0.42	0.84																							
27-0039	Cedar	10/11/2022	9:27	2.96	0	15.4	73.2	7.30	8.0	778	0.12	0.92	0.0	7.65	1.01	1.68	0.035	0.010	0.778	0.985	0.228	0.328	122	154	180	10.8		8.90			15	15			
27-0039	Cedar	10/11/2022	9:27		1	15.4	73.0	7.28	8.0	778	0.25	1.37																							
27-0039	Cedar	10/11/2022	9:26		2	15.4	72.8	7.26	8.0	778	0.23	1.38																							
27-0039	Cedar	10/11/2022	9:26		3	15.4	72.5	7.23	8.0	778	0.22	1.21																							
27-0039	Cedar	10/11/2022	9:24		4	15.4	70.6	7.04	8.0	778	0.21	1.15																							
27-0039	Cedar	10/11/2022	9:23		5	15.3	64.9	6.49	8.0	778	0.18	1.13					0.031	0.005													15	15			
27-0039	Cedar	10/11/2022	9:23		6	15.1	58.4	5.86	7.9	778	0.08	0.74																							
27-0039	Cedar	10/11/2022	9:21		7	14.5	38.2	3.88	7.7	781	0.03	0.60																							
27-0039	Cedar	10/11/2022	9:20		8	9.7	1.9	0.21	7.2	815	0.07	1.25																							
27-0039	Cedar	10/11/2022	9:19		9	8.6	2.0	0.24	7.2	823	0.00	0.68																							
27-0039	Cedar	10/11/2022	9:18		10	8.0	2.2	0.26	7.1	828	0.00	0.59					0.320	0.319														15			
27-0039	Cedar	10/11/2022	9:17		11	7.6	1.1	0.13	7.0	832	0.00	0.57																							
27-0039	Cedar	10/11/2022	9:16		12	7.3	1.2	0.15	7.0	840	0.00	0.65																							
27-0039	Cedar	10/11/2022	9:15		13	7.0	1.5	0.18	6.9	854	0.00	0.74																							
27-0039	Cedar	10/11/2022	9:14		14	7.0	1.8	0.22	6.9	859	0.02	0.87					0.607	0.602							175	8.87					15	15			
27-0039	Cedar	10/11/2022	9:12		15	7.0	2.5	0.30	6.8	862	0.01	0.93																							
27-0039	Cedar	10/11/2022	9:11		16	7.0	3.7	0.45	6.8	866	0.04	1.06																							
27-0022	Diamond	2/9/2022	9:25		0									132	6.58	2.95	0.594	0.074	2.96	3.30	0.034	2.07	150	140	470	6.11									
27-0022	Diamond	4/21/2022	9:31		0	6.0	91.6	11.39	8.0	1086			0.0	21.4	2.48	1.06	0.064	0.005	0.558	0.614	0.051	0.338	58	60	300	6.56									
27-0022	Diamond	5/11/2022	9:31		0	19.3	65.0	5.99	7.1	1050	1.38	3.32		11.4	3.88	0.970	0.101	0.015	0.740	1.01	0.015	0.125	60	64	270	6.97									
27-0022	Diamond	5/26/2022	8:59		0	13.7	63.0	6.53	7.5	808	0.57	99.26		3.04	2.17		0.120	0.036		0.662					210										
27-0022	Diamond	6/7/2022	9:20		0	20.7	55.8	4.99	7.3	820	0.08	1.94		13.2	3.75	0.663	0.113	0.033		0.774					265										
27-0022	Diamond	6/21/2022	10:03		0	26.6	104.9	8.40	8.8	875	0.47	1.50		5.91	2.67		0.121	0.044		0.681					240										
27-0022	Diamond	7/11/2022	9:33		0	23.9	10.0	0.84	6.8	883	0.21	2.41		18.5	4.93	0.993	0.206	0.018	1.51	1.62	0.015	0.328	66	68	95	2.50									
27-0022	Diamond	7/26/2022	9:05		0	21.3	10.1	0.89	6.9	1071	1.30	14.17		10.6	1.76		0.097	0.004		0.859					290										
27-0022	Diamond	8/9/2022	9:33		0	20.6	30.9	2.77	7.0	417	2.01	23.93		51.5	9.87	1.98	0.239	0.015		0.946					105		6								
27-0022	Diamond	8/24/2022	9:08		0	22.4	34.6	3.00	7.1	427	0.66	6.56		26.0	12.4		0.101	0.008		0.788					100										
27-0022	Diamond	9/19/2022	9:45		0	18.2	30.4	2.87	6.8	562	0.10	1.35		8.67	2.17	1.64	0.095	0.027		0.766					205										
27-0022	Diamond	9/27/2022	8:59		0	11.6	43.8	4.76	7.2	772	0.33	2.54		5.62	4.91		0.102	0.010		0.846					215										
27-0022	Diamond	10/12/2022	9:10		0	14.2	37.6	3.85	7.1	1000	0.05	1.69		10.9	6.05	1.15	0.076	0.016	1.58	1.86	0.279	0.840	84	86	360	2.50									
27-655	Grass	2/9/2022	8:55		0									126	19.9	14.9	0.347	0.012	4.47	5.27	0.037	3.05	210	192	110	5.40									
27-655	Grass	4/21/2022	9:04		0	5.6	95.3	12.00	8.4	464			0.1	52.8	7.61	3.12	0.123	0.005	1.35	1.41	0.035	0.125	52	48	105	5.80									
27-655	Grass	5/11/2022	9:00		0	19.3	90.5	8.34	7.6	458	0.74	9.59		21.6	9.28	1.17	0.101	0.008	0.930	0.960	0.015	0.258	63	64	95	5.87									
27-655	Grass	6/7/2022	8:50		0	21.7	80.9	7.11	8.1	391	1.55	20.63		29.9	8.61	2.40	0.170	0.006		1.64					105										
27-655	Grass	7/11/2022	9:00		0	25.4	99.6	8.20	9.6	404	0.99	3.60		25.7	4.43	5.86	0.184	0.083	0.250	0.250	0.015	0.360	55	56	225	5.08									
27-655	Grass	8/9/2022	8:57		0	21.7	45.0	3.95	8.6	294	1.22	6.12		8.36	4.15	0.787	0.054	0.008		0.676					55		218								
27-655	Grass	9/19/2022	9:12		0	18.6	32.1	3.00	7.4	415	4.97	21.11		51.3	15.5	2.17	0.336	0.030		1.63					95										
27-655	Grass	10/12/2022	8:40		0	13.8	37.6	3.88	7.1	449	7.67	24.96		59.4	21.5	2.35	0.188	0.009	1.74	2.39	0.326	0.595	69	66	110	2.50									
27-0016	Harriet	2/8/2022	9:00		0									7.69	0.609	0.839	0.095	0.062	0.846	0.979	0.070	0.646	125	148	140	8.42							<1.5		
27-0016	Harriet	2/8/2022	9:00		6												0.082	0.066																	
27-0016	Harriet	2/8/2022	9:00		12												0.124	0.106																	
27-0016	Harriet	2/8/2022	9:00		15												0.188	0.151																	
27-0016	Harriet	2/8/2022	9:00		20												0.221	0.189							140	8.27									
27-0016	Harriet	4/26/2022	9:11	1.20	0	5.1	104.3	13.43	8.4	666			399.6	37.8	8.07	0.531	0.103	0.034	0.802	0.945	0.205	0.409	119	144	145	7.46									
27-0016	Harriet	4/26/2022	9:11		1	5.1	104.0	13.39	8.4	666			243.0																						
27-0016	Harriet	4/26/2022	9:10		2	5.1	104.7	13.48	8.4	666			113.7																						
27-0016	Harriet	4/26/2022	9:09		3	5.1	105.6	13.59	8.4	666			108.1																						
27-0016	Harriet	4/26/2022	9:09		4	5.1	105.5	13.58	8.4	666			89.8																						
27-0016	Harriet	4/26/2022	9:08		5	5.1	106.0	13.64	8.4	666			81.1																						
27-0016	Harriet	4/26/2022	9:08		6	5.1	105.8	13.62	8.4	666			1.9				0.105	0.035																	
27-0016	Harriet	4/26/2022	9:07		7	5.1	105.2	13.53	8.4	666			0.7																						
27-0016	Harriet	4/26/2022	9:07		8	5.1	104.2	13.41	8.4	666			0.6																						
27-0016	Harriet	4/26/2022	9:06		9	5.1	104.1	13.39	8.4	666			0.6																						
27-0016	Harriet	4/26/2022	9:06		10	5.1	103.7	13.34	8.3	666			0.6																						
27-0016	Harriet	4/26/2022	9:05		11	5.1	103.9	13.37	8.3	666			0.7																						
27-0016	Harriet	4/26/2022	9:05		12	5.1	103.6	13.33	8.3	666			0.8				0.100	0.032																	
27-0016	Harriet	4/26/2022	9:04		13	5.1	103.0	13.26	8.3	667			0.0																						
27-0016	Harriet	4/26/2022	9:04		14	5.1	103.2	13.29	8.3	666			0.0																						
27-0016	Harriet	4/26/2022	9:03		15	5.1	103.5	13.32	8.3	667			0.0				0.099	0.034																	
27-0016	Harriet	4/26/2022	9:03		16	5.1	103.3	13.30	8.3	668			0.0																						
27-0016	Harriet	4/26/2022	9:02		17	5.1	103.3	13.31	8.3	667			0.0																						
27-0016	Harriet	4/26/2022	9:02		18	5.1	103.0	13.28	8.3	667			0.0																						
27-0016	Harriet	4/26/2022	9:01		19	5.1	103.2	13.30	8.2	667			0.0																						
27-0016	Harriet	4/26/2022	9:01		20	5.1	102.9	13.26	8.2	666			0.0				0.099	0.034							155	8.11									
27-0016	Harriet	4/26/2022	9:00		21	5.1	102.9	13.26	8.2	667			0.0																						
27-0016	Harriet	4/26/2022	9:00		22	5.1	102.9	13.26	8.2	667			0.0																						
27-0016	Harriet	5/13/2022	9:31	2.02	0	14.3	128.9	13.16	8.8	657	0.25	3.71		7.37	3.96	0.250	0.065	0.016	0.606	0.701	0.015	0.125	116	140	125	7.05									
27-0016	Harriet	5/13/2022	9:31		1	14.2	128.3	13.12	8.7	657	0.29	4.50																							
27-0016	Harriet	5/13/2022	9:30		2	14.0	125.6	12.93	8.7	658	0.17	2.93																							
27-0016	Harriet	5/13/2022	9:29		3	13.7	121.9	12.63	8.7	659	0.05	1.42																							
27-0016	Harriet	5/13/2022	9:29		4	12.3	120.1	12.82	8.6	662	0.10	2.69																							
27-0016	Harriet	5/13/2022	9:28		5	10.9	117.7	12.98	8.6	665	0.14	3.95																							
27-0016	Harriet	5/13/2022	9:27		6	10.0	115.4	12.99	8.5	667	0.06	3.74					0.060	0.019																	
27-0016	Harriet	5/13/2022	9:26		7	8.5	109.2	12.76	8.4	670	0.00	2.10																							
27-0016	Harriet	5/13/2022	9:25		8	8.0	107.6	12.71	8.4	671	0.00	1.72																							
27-0016	Harriet	5/13/2022	9:24		9	7.8	107.3	12.74	8.3	671	0.00	1.81																							
27-0016	Harriet	5/13/2022	9:23		10	7.5	106.7	12.76	8.3	671	0.00	1.43																							
27-0016	Harriet	5/13/2022	9:22		11	7.4	106.0	12.71	8.3	672	0.00	1.57																							
27-0016	Harriet	5/13/2022	9:21		12	7.3	104.9	12.62	8.3	672	0.00	1.53					0.061	0.031																	
27-0016	Harriet	5/13/2022	9:21		13	7.2	104.0	12.55	8.3	672	0.00	1.97																							
27-0016	Harriet	5/13/2022	9:20		14	7.1	103.8	12.53	8.3	672	0.00	1.34																							
27-0016	Harriet	5/13/2022	9:19		15	7.1	103.2	12.47	8.2	672	0.00	1.49					0.062	0.045																	
27-0016	Harriet	5/13/2022	9:18		16	7.1	102.8	12.44	8.2	672	0.00	1.14																							
27-0016	Harriet	5/13/2022	9:18		17	7.1	102.7	12.43	8.2	672	0.00	1.40																							
27-0016	Harriet	5/13/2022	9:17		18	7.0	102.7	12.42	8.2	672	0.00	1.23																							
27-0016	Harriet	5/13/2022	9:16		19	7.0	102.5	12.41	8.2	672	0.00	1.25																							
27-0016	Harriet	5/13/2022	9:15		20	7.0	102.0	12.36	8.2	673	0.00	1.20					0.064	0.036							145	7.22									

Lake ID	Lake Name	Date MM/DD/YYYY	Time HH:MM	Secchi meters	Depth meters	Temp °C	%DO	DO mg/L	pH units	SpCond µS/cm	Phycocyanin RFU	Chlorophyll-a RFU	TurbSC NTU	Chl-a mg/M3	Pheo-a mg/M3	Silica mg/L	TP mg/L	SRP mg/L	TKN mg/L	TN mg/L	NO3NO2 mg/L	NH3 mg/L	Alk mg/L	Hard mg/L	Cl mg/L	SO4 mg/L	E. Coli mpn/100 mL	DOC mg/L	Fe µg/L	DFe µg/L	Al µg/L	DAl µg/L	Microcystin µg/L	Cylindro. µg/L	Anatoxin-a µg/L
27-0016	Harriet	5/13/2022	9:14		21	7.0	101.4	12.29	8.2	673	0.00	1.08																							
27-0016	Harriet	5/13/2022	9:12		22	6.9	100.4	12.19	8.2	673	0.00	1.17																							
27-0016	Harriet	5/13/2022	9:11		23	6.9	100.0	12.13	8.2	673	0.00	1.20																							
27-0016	Harriet	5/13/2022	9:09		24	6.9	100.0	12.14	8.2	673	0.00	1.29																							
27-0016	Harriet	5/13/2022	9:08		25	6.9	99.9	12.12	8.2	673	0.00	1.22																							
27-0016	Harriet	5/27/2022	9:07	8.27	0	15.5	103.0	10.24	8.5	665	0.01	0.21		1.24	0.712		0.030	0.011		0.640					185										
27-0016	Harriet	5/27/2022	9:07		1	15.3	102.6	10.25	8.5	665	0.03	0.29																							
27-0016	Harriet	5/27/2022	9:05		2	15.3	102.3	10.23	8.5	665	0.04	0.40																							
27-0016	Harriet	5/27/2022	9:04		3	15.3	102.0	10.21	8.5	665	0.00	0.32																							
27-0016	Harriet	5/27/2022	9:03		4	15.2	101.2	10.14	8.5	665	0.01	0.26																							
27-0016	Harriet	5/27/2022	9:02		5	14.2	97.0	9.93	8.3	664	0.01	0.28																							
27-0016	Harriet	5/27/2022	9:01		6	11.2	96.6	10.58	8.2	662	0.01	0.31					0.041	0.019																	
27-0016	Harriet	5/27/2022	9:01		7	8.8	93.7	10.86	8.1	670	0.01	0.55																							
27-0016	Harriet	5/27/2022	9:00		8	8.3	89.5	10.49	8.0	674	0.01	0.59																							
27-0016	Harriet	5/27/2022	8:59		9	7.9	83.0	9.82	7.9	675	0.01	0.53																							
27-0016	Harriet	5/27/2022	8:58		10	7.7	77.1	9.18	7.8	676	0.02	0.41																							
27-0016	Harriet	5/27/2022	8:57		11	7.5	76.2	9.13	7.8	676	0.00	0.25																							
27-0016	Harriet	5/27/2022	8:56		12	7.4	73.3	8.80	7.8	676	0.00	0.21					0.087	0.065																	
27-0016	Harriet	5/27/2022	8:55		13	7.3	69.7	8.39	7.7	676	0.00	0.24																							
27-0016	Harriet	5/27/2022	8:54		14	7.1	60.0	7.24	7.6	677	0.00	0.23																							
27-0016	Harriet	5/27/2022	8:53		15	7.1	55.8	6.75	7.6	678	0.00	0.19					0.102	0.081																	
27-0016	Harriet	5/27/2022	8:52		16	7.1	50.1	6.06	7.5	679	0.00	0.20																							
27-0016	Harriet	5/27/2022	8:51		17	7.0	40.5	4.90	7.4	680	0.00	0.31																							
27-0016	Harriet	5/27/2022	8:50		18	7.0	35.7	4.33	7.4	681	0.00	0.31																							
27-0016	Harriet	5/27/2022	8:48		19	7.0	30.6	3.71	7.4	682	0.00	0.25																							
27-0016	Harriet	5/27/2022	8:46		20	7.0	18.2	2.20	7.3	683	0.00	0.28					0.169	0.130							180										
27-0016	Harriet	5/27/2022	8:45		21	7.0	15.5	1.88	7.3	684	0.00	0.37																							
27-0016	Harriet	5/27/2022	8:43		22	7.0	11.8	1.43	7.3	684	0.00	0.53																							
27-0016	Harriet	5/27/2022	8:43		23	7.0	4.3	0.52	7.2	686	0.03	0.57																							
27-0016	Harriet	5/27/2022	8:41		24	7.0	4.2	0.51	7.2	686	0.02	0.57																							
27-0016	Harriet	5/27/2022	8:39		25	7.0	5.8	0.71	7.2	686	0.05	0.69																							
27-0016	Harriet	6/8/2022	9:13	6.39	0	19.3	113.2	10.42	8.6	670	0.16	0.61		5.42	1.19	0.250	0.027	0.005		0.551					225										
27-0016	Harriet	6/8/2022	9:12		1	19.3	112.7	10.38	8.6	670	0.08	0.60																							
27-0016	Harriet	6/8/2022	9:11		2	19.2	111.8	10.31	8.6	670	0.11	0.57																							
27-0016	Harriet	6/8/2022	9:10		3	19.1	107.9	9.97	8.5	671	0.01	0.42																							
27-0016	Harriet	6/8/2022	9:09		4	18.4	97.2	9.11	8.4	671	0.00	0.28																							
27-0016	Harriet	6/8/2022	9:09		5	17.3	90.7	8.69	8.3	664	0.00	0.23																							
27-0016	Harriet	6/8/2022	9:08		6	14.7	83.9	8.51	8.1	672	0.00	0.32					0.035	0.013																	
27-0016	Harriet	6/8/2022	9:07		7	9.9	85.1	9.61	8.0	678	0.00	0.40																							
27-0016	Harriet	6/8/2022	9:06		8	8.9	78.5	9.09	7.9	682	0.00	0.57																							
27-0016	Harriet	6/8/2022	9:04		9	8.1	65.6	7.73	7.7	684	0.00	0.43																							
27-0016	Harriet	6/8/2022	9:03		10	7.8	60.4	7.17	7.6	684	0.00	0.21																							
27-0016	Harriet	6/8/2022	9:02		11	7.6	52.8	6.30	7.6	685	0.00	0.17																							
27-0016	Harriet	6/8/2022	9:01		12	7.5	46.7	5.59	7.5	686	0.00	0.15					0.121	0.097																	
27-0016	Harriet	6/8/2022	9:00		13	7.3	40.9	4.92	7.4	686	0.00	0.12																							
27-0016	Harriet	6/8/2022	8:59		14	7.3	34.3	4.13	7.4	687	0.00	0.09																							
27-0016	Harriet	6/8/2022	8:57		15	7.2	25.2	3.04	7.4	688	0.00	0.14					0.157	0.122																	
27-0016	Harriet	6/8/2022	8:56		16	7.1	16.3	1.97	7.3	690	0.00	0.13																							
27-0016	Harriet	6/8/2022	8:55		17	7.1	11.1	1.34	7.3	691	0.00	0.17																							
27-0016	Harriet	6/8/2022	8:54		18	7.1	6.2	0.74	7.3	692	0.00	0.17																							
27-0016	Harriet	6/8/2022	8:54		19	7.1	5.7	0.69	7.3	692	0.00	0.14																							
27-0016	Harriet	6/8/2022	8:53		20	7.1	4.0	0.48	7.3	693	0.00	0.25					0.258	0.201							230										
27-0016	Harriet	6/8/2022	8:53		21	7.1	3.8	0.46	7.3	693	0.00	0.19																							
27-0016	Harriet	6/8/2022	8:52		22	7.0	3.8	0.46	7.3	693	0.00	0.19																							
27-0016	Harriet	6/8/2022	8:52		23	7.1	3.9	0.48	7.3	694	0.00	0.20																							
27-0016	Harriet	6/8/2022	8:51		24	7.1	4.2	0.51	7.3	694	0.00	0.21																							
27-0016	Harriet	6/8/2022	8:51		25	7.0	5.6	0.68	7.3	698	2.42	5.43																							
27-0016	Harriet	6/28/2022	10:02	1.62	0	23.9	128.7	10.85	8.8	666	2.28	0.64		40.0	1.84		0.034	0.004		0.834					140										
27-0016	Harriet	6/28/2022	10:01		1	23.8	128.1	10.79	8.8	666	2.51	0.69																							
27-0016	Harriet	6/28/2022	10:01		2	23.8	125.7	10.60	8.8	666	2.47	0.70																							
27-0016	Harriet	6/28/2022	10:00		3	23.8	120.8	10.19	8.8	667	2.50	0.78																							
27-0016	Harriet	6/28/2022	9:59		4	23.5	97.0	8.23	8.6	670	1.88	0.55																							
27-0016	Harriet	6/28/2022	9:57		5	20.3	59.2	5.34	7.9	679	0.03	0.23																							
27-0016	Harriet	6/28/2022	9:56		6	14.6	60.2	6.11	7.8	682	0.03	0.19					0.020	0.005																	
27-0016	Harriet	6/28/2022	9:55		7	11.3	66.1	7.24	7.8	683	0.00	0.19																							
27-0016	Harriet	6/28/2022	9:53		8	9.6	62.6	7.13	7.8	685	0.03	0.14																							
27-0016	Harriet	6/28/2022	9:52		9	8.6	55.6	6.47	7.7	688	0.01	0.12																							
27-0016	Harriet	6/28/2022	9:09		10	8.0	26.3	3.11	7.4	690	0.00	0.12																							
27-0016	Harriet	6/28/2022	9:08		11	7.7	14.8	1.76	7.4	692	0.00	0.14																							
27-0016	Harriet	6/28/2022	9:07		12	7.6	11.9	1.41	7.4	692	0.00	0.11					0.196	0.170																	
27-0016	Harriet	6/28/2022	9:06		13	7.4	2.5	0.29	7.3	693	0.00	0.13																							
27-0016	Harriet	6/28/2022	9:03		14	7.3	0.8	0.10	7.3	693	0.00	0.17																							
27-0016	Harriet	6/28/2022	9:02		15	7.3	0.8	0.10	7.3	694	0.00	0.20					0.237	0.195																	
27-0016	Harriet	6/28/2022	9:01		16	7.3	0.9	0.11	7.3	694	0.00	0.17																							
27-0016	Harriet	6/28/2022	9:00		17	7.2	1.1	0.13	7.3	694	0.00	0.21																							
27-0016	Harriet	6/28/2022	8:59		18	7.2	1.2	0.15	7.3	695	0.00	0.22																							
27-0016	Harriet	6/28/2022	8:58		19	7.2	1.4	0.17	7.3	695	0.00	0.18																							
27-0016	Harriet	6/28/2022	8:57		20	7.2	1.5	0.19	7.3	695	0.02	0.22					0.285	0.237							152										
27-0016	Harriet	6/28/2022	8:55		21	7.2	1.8	0.22	7.3	695	0.00	0.25																							
27-0016	Harriet	6/28/2022	8:55		22	7.2	2.0	0.24	7.3	696	0.03	0.25																							
27-0016	Harriet	6/28/2022	8:54		23	7.1	2.3	0.28	7.3	697	0.05	0.27																							
27-0016	Harriet	6/28/2022	8:51		24	7.1	3.3	0.39	7.2	697	0.06	0.28																							
27-0016	Harriet	6/28/2022	8:51		25	7.1	4.3	0.52	7.2	702	0.21	0.45																							
27-0016	Harriet	7/14/2022	10:57	1.35	0	25.9	92.5	7.50	8.5	653	0.26	0.60		7.95	1.56	1.57	0.033	0.002	1.27	1.31	0.015	0.264	93	116	160	7.34									
27-0016	Harriet	7/14/2022	10:56		1	25.6	90.9	7.41	8.5	652	0.36	0.80																							
27-0016	Harriet	7/14/2022	10:55		2	25.2	86.3	7.09	8.5	653	0.42	0.93																							
27-0016	Harriet	7/14/2022	10:55		3	24.9	82.8	6.84	8.4	652	0.46	0.58																							
27-0016	Harriet	7/14/2022	10:53		4	24.1	31.3	2.62	7.8	663	0.63	0.59																							
27-0016	Harriet	7/14/2022	10:52		5	20.3	6.9	0.62	7.6	679	0.20	0.28																							
27-0016	Harriet	7/14/2022	10:50		6	14.9	33.5	3.38	7.6	680	0.09	0.17					0.024	0.002																	
27-0016	Harriet	7/14/2022	10:49		7	11.9	42.6	4.59	7.7	681	0.06	0.21																							
27-0016	Harriet	7/14/2022	10:48		8	9.6	35.5	4.04	7.6	688	0.00	0.10																							
27-0016	Harriet	7/14/2022	10:46		9	8.8	26.6	3.08	7.6	690	0.00	0.09																							
27-0016	Harriet	7/14/2022	10:44		10	8.1	3.2	0.38	7.5	693	0.00	0.12																							
27-0016	Harriet	7/14/2022	10:43		11	7.8	0.3	0.04	7.4	695	0.02	0.20																							
27-0016	Harriet	7/14/2022	10:43		12	7.6	0.3	0.04	7.4	696	0.08	0.23					0.226	0.177																	
27-0016	Harriet	7/14/2022	10:41		13	7.5	0.4	0.04	7.4	696	0.06	0.25																							
27-0016	Harriet	7/14/2022	10:40		14	7.4	0.4	0.05	7.4	697	0.08	0.25																							
27-0016	Harriet	7/14/2022	10:39		15	7.3	0.5	0.06	7.4	698	0.08	0.24					0.298	0.237																	
27-0016	Harriet	7/14/2022	10:37		16	7.3	0.5	0.06	7.4	698	0.03	0.24																							
27-0016	Harriet	7/14/2022	10:36		17	7.3	0.6	0.07	7.4	698	0.06	0.22																							

Lake ID	Lake Name	Date MM/DD/YYYY	Time HH:MM	Secchi meters	Depth meters	Temp °C	%DO	DO mg/L	pH units	SpCond µS/cm	Phycocyanin RFU	Chlorophyll-a RFU	TurbSC NTU	Chl-a mg/M3	Pheo-a mg/M3	Silica mg/L	TP mg/L	SRP mg/L	TKN mg/L	TN mg/L	NO3NO2 mg/L	NH3 mg/L	Alk mg/L	Hard mg/L	Cl mg/L	SO4 mg/L	E. Coli mpn/100 mL	DOC mg/L	Fe µg/L	DFe µg/L	Al µg/L	DAl µg/L	Microcystin µg/L	Cylindro. µg/L	Anatoxin-a µg/L
27-0016	Harriet	7/14/2022	10:35		18	7.2	0.6	0.07	7.4	699	0.07	0.25																							
27-0016	Harriet	7/14/2022	10:33		19	7.2	0.8	0.09	7.4	699	0.02	0.24																							
27-0016	Harriet	7/14/2022	10:32		20	7.2	0.9	0.11	7.4	699	0.07	0.26					0.367	0.299							160	7.05									
27-0016	Harriet	7/14/2022	10:29		21	7.2	1.3	0.15	7.4	699	0.06	0.24																							
27-0016	Harriet	7/14/2022	10:28		22	7.2	1.5	0.18	7.4	699	0.03	0.25																							
27-0016	Harriet	7/14/2022	10:27		23	7.2	2.0	0.24	7.4	701	0.01	0.25																							
27-0016	Harriet	7/14/2022	10:26		24	7.2	2.7	0.32	7.3	701	0.05	0.27																							
27-0016	Harriet	7/27/2022	10:36	1.81	0	24.8	114.5	9.47	8.7	666	0.87	3.94		15.2	2.26		0.039	0.002		0.585					190										
27-0016	Harriet	7/27/2022	10:35		1	24.7	112.1	9.31	8.7	666	0.94	4.99																							
27-0016	Harriet	7/27/2022	10:34		2	24.5	100.2	8.35	8.6	667	0.87	2.96																							
27-0016	Harriet	7/27/2022	10:33		3	24.4	96.2	8.03	8.5	667	0.81	2.57																							
27-0016	Harriet	7/27/2022	10:32		4	24.4	92.6	7.73	8.5	668	0.77	1.72																							
27-0016	Harriet	7/27/2022	10:30		5	23.1	10.4	0.89	7.5	677	0.23	1.04																							
27-0016	Harriet	7/27/2022	10:28		6	15.7	1.2	0.12	7.3	688	0.00	0.40					0.044	0.004																	
27-0016	Harriet	7/27/2022	10:27		7	12.3	9.7	1.04	7.4	687	0.00	0.16																							
27-0016	Harriet	7/27/2022	10:25		8	10.0	11.8	1.32	7.4	690	0.00	0.16																							
27-0016	Harriet	7/27/2022	10:24		9	8.8	1.2	0.13	7.4	695	0.02	0.16																							
27-0016	Harriet	7/27/2022	10:22		10	8.3	0.5	0.06	7.4	697	0.06	0.21																							
27-0016	Harriet	7/27/2022	10:22		11	8.1	0.5	0.06	7.4	697	0.14	0.28																							
27-0016	Harriet	7/27/2022	10:21		12	7.8	0.5	0.06	7.4	699	0.04	0.28					0.268	0.189																	
27-0016	Harriet	7/27/2022	10:20		13	7.7	0.7	0.08	7.4	699	0.04	0.35																							
27-0016	Harriet	7/27/2022	10:19		14	7.5	0.7	0.08	7.3	700	0.02	0.24																							
27-0016	Harriet	7/27/2022	10:18		15	7.5	0.7	0.09	7.3	701	0.00	0.22					0.325	0.240																	
27-0016	Harriet	7/27/2022	10:17		16	7.3	0.8	0.09	7.3	702	0.00	0.20																							
27-0016	Harriet	7/27/2022	10:16		17	7.3	0.9	0.10	7.3	702	0.00	0.21																							
27-0016	Harriet	7/27/2022	10:15		18	7.3	1.0	0.12	7.3	702	0.00	0.21																							
27-0016	Harriet	7/27/2022	10:14		19	7.3	1.1	0.14	7.3	703	0.00	0.20																							
27-0016	Harriet	7/27/2022	10:14		20	7.3	1.2	0.15	7.3	704	0.00	0.19					0.411	0.326							195										
27-0016	Harriet	7/27/2022	10:13		21	7.3	1.3	0.16	7.3	704	0.00	0.21																							
27-0016	Harriet	7/27/2022	10:12		22	7.3	1.6	0.19	7.3	704	0.00	0.21																							
27-0016	Harriet	7/27/2022	10:11		23	7.3	1.9	0.23	7.3	704	0.00	0.19																							
27-0016	Harriet	7/27/2022	10:10		24	7.3	2.3	0.28	7.3	705	0.00	0.19																							
27-0016	Harriet	8/11/2022	9:21	1.41	0	25.0	114.2	9.42	8.7	664	0.27	1.10		6.51	0.554	1.03	0.024	0.005		0.586					155		0.5								
27-0016	Harriet	8/11/2022	9:21		1	25.0	113.6	9.37	8.7	664	0.29	1.19																							
27-0016	Harriet	8/11/2022	9:20		2	25.0	112.9	9.32	8.7	664	0.29	1.16																							
27-0016	Harriet	8/11/2022	9:19		3	24.7	113.6	9.43	8.7	662	0.40	1.39																							
27-0016	Harriet	8/11/2022	9:18		4	24.2	94.5	7.92	8.6	664	0.66	1.35																							
27-0016	Harriet	8/11/2022	9:15		5	23.0	33.7	2.89	7.9	673	0.62	1.25																							
27-0016	Harriet	8/11/2022	9:13		6	19.4	0.9	0.08	7.5	691	0.33	1.19					0.030	0.005																	
27-0016	Harriet	8/11/2022	9:12		7	13.5	0.5	0.05	7.4	696	0.33	0.87																							
27-0016	Harriet	8/11/2022	9:11		8	10.5	0.4	0.04	7.4	694	0.10	0.48																							
27-0016	Harriet	8/11/2022	9:11		9	9.0	0.3	0.04	7.4	695	0.00	0.29																							
27-0016	Harriet	8/11/2022	9:09		10	8.3	0.4	0.04	7.4	699	0.00	0.38																							
27-0016	Harriet	8/11/2022	9:08		11	8.0	0.4	0.05	7.4	700	0.00	0.22																							
27-0016	Harriet	8/11/2022	9:07		12	7.7	0.4	0.05	7.4	701	0.00	0.17					0.292	0.229																	
27-0016	Harriet	8/11/2022	9:06		13	7.6	0.5	0.05	7.4	702	0.00	0.20																							
27-0016	Harriet	8/11/2022	9:05		14	7.5	0.5	0.06	7.4	703	0.00	0.18																							
27-0016	Harriet	8/11/2022	9:04		15	7.4	0.5	0.07	7.3	704	0.00	0.14					0.366	0.307																	
27-0016	Harriet	8/11/2022	9:03		16	7.4	0.6	0.07	7.3	704	0.00	0.15																							
27-0016	Harriet	8/11/2022	9:03		17	7.3	0.7	0.08	7.3	706	0.00	0.17																							
27-0016	Harriet	8/11/2022	9:02		18	7.3	0.7	0.08	7.3	706	0.00	0.14																							
27-0016	Harriet	8/11/2022	9:01		19	7.3	0.7	0.09	7.3	707	0.00	0.14																							
27-0016	Harriet	8/11/2022	9:00		20	7.3	0.8	0.09	7.3	707	0.00	0.16					0.436	0.380							150										
27-0016	Harriet	8/11/2022	9:00		21	7.3	0.8	0.10	7.3	708	0.00	0.16																							
27-0016	Harriet	8/11/2022	8:58		22	7.3	1.0	0.12	7.3	708	0.00	0.14																							
27-0016	Harriet	8/11/2022	8:58		23	7.3	1.1	0.13	7.3	708	0.00	0.16																							
27-0016	Harriet	8/11/2022	8:56		24	7.3	1.3	0.15	7.3	710	0.00	0.19																							
27-0016	Harriet	8/11/2022	8:56		25	7.7	1.7	0.20	7.0	722	0.10	0.40																							
27-0016	Harriet	8/26/2022	9:43	2.27	0	24.4	110.1	9.19	8.7	664	0.12	0.64		6.46	0.250		0.017	0.005		0.250					160										
27-0016	Harriet	8/26/2022	9:42		1	24.4	110.0	9.18	8.7	664	0.13	0.92																							
27-0016	Harriet	8/26/2022	9:42		2	24.3	109.5	9.15	8.7	664	0.18	1.10																							
27-0016	Harriet	8/26/2022	9:41		3	24.2	108.3	9.06	8.7	664	0.17	1.11																							
27-0016	Harriet	8/26/2022	9:40		4	23.5	92.2	7.82	8.6	665	0.26	1.10																							
27-0016	Harriet	8/26/2022	9:39		5	22.8	56.8	4.88	8.2	665	0.25	0.56																							
27-0016	Harriet	8/26/2022	9:37		6	20.1	1.9	0.17	7.5	672	0.29	0.90					0.020	0.004																	
27-0016	Harriet	8/26/2022	9:36		7	14.5	2.1	0.22	7.4	691	0.37	1.32																							
27-0016	Harriet	8/26/2022	9:35		8	10.6	0.4	0.04	7.4	697	2.18	1.44																							
27-0016	Harriet	8/26/2022	9:34		9	9.0	0.3	0.03	7.4	701	0.32	0.78																							
27-0016	Harriet	8/26/2022	9:33		10	8.4	0.3	0.03	7.3	702	0.07	0.79																							
27-0016	Harriet	8/26/2022	9:32		11	8.0	0.2	0.03	7.3	701	0.00	0.33																							
27-0016	Harriet	8/26/2022	9:31		12	7.7	0.2	0.03	7.3	702	0.00	0.24					0.282	0.223																	
27-0016	Harriet	8/26/2022	9:30		13	7.6	0.3	0.04	7.3	704	0.00	0.19																							
27-0016	Harriet	8/26/2022	9:29		14	7.5	0.3	0.04	7.3	705	0.00	0.20																							
27-0016	Harriet	8/26/2022	9:28		15	7.5	0.4	0.05	7.3	706	0.00	0.17					0.379	0.335																	
27-0016	Harriet	8/26/2022	9:27		16	7.4	0.4	0.05	7.3	706	0.00	0.17																							
27-0016	Harriet	8/26/2022	9:26		17	7.4	0.4	0.05	7.3	707	0.00	0.19																							
27-0016	Harriet	8/26/2022	9:25		18	7.4	0.5	0.06	7.2	707	0.00	0.19																							
27-0016	Harriet	8/26/2022	9:24		19	7.4	0.6	0.08	7.2	708	0.00	0.19																							
27-0016	Harriet	8/26/2022	9:23		20	7.3	0.8	0.09	7.2	710	0.00	0.19					0.454	0.370							160										
27-0016	Harriet	8/26/2022	9:20		21	7.3	1.0	0.12	7.2	710	0.00	0.15																							
27-0016	Harriet	8/26/2022	9:19		22	7.3	1.2	0.15	7.2	710	0.00	0.18																							
27-0016	Harriet	8/26/2022	9:17		23	7.3	1.4	0.17	7.2	712	0.00	0.21																							
27-0016	Harriet	8/26/2022	9:16		24	7.3	2.0	0.24	7.2	713	0.00	0.25																							
27-0016	Harriet	8/26/2022	9:14		25	7.5	2.7	0.33	6.6	720	0.00	0.54																							
27-0016	Harriet	9/14/2022	9:13	3.49	0	22.1	100.4	8.75	8.6	668	0.09	0.69		10.3	1.25	1.28	0.018	0.002		0.535					145										
27-0016	Harriet	9/14/2022	9:12		1	22.1	100.2	8.72	8.6	668	0.05	0.76																							
27-0016	Harriet	9/14/2022	9:12		2	22.1	99.9	8.69	8.6	668	0.09	0.73																							
27-0016	Harriet	9/14/2022	9:11		3	22.1	99.4	8.65	8.6	668	0.09	0.88																							
27-0016	Harriet	9/14/2022	9:10		4	22.0	94.0	8.21	8.6	668	0.08	0.50																							
27-0016	Harriet	9/14/2022	9:08		5	21.8	89.8	7.86	8.6	668	0.00	0.48																							
27-0016	Harriet	9/14/2022	9:06		6	21.2	68.2	6.05	8.3	675	0.07	0.51					0.019	0.002																	
27-0016	Harriet	9/14/2022	9:06		7	15.6	6.7	0.67	7.4	685	0.35	1.60																							
27-0016	Harriet	9/14/2022	9:04		8	11.6	3.0	0.32	7.4	691	2.26	6.47																							
27-0016	Harriet	9/14/2022	9:03		9	9.7	0.5	0.06	7.3	698	6.15	3.68																							
27-0016	Harriet	9/14/2022	9:02		10	8.5	0.6	0.07	7.3	701	0.62	1.11																							
27-0016	Harriet	9/14/2022	9:01		11	8.0	0.5	0.06	7.2	703	0.12	0.38																							
27-0016	Harriet	9/14/2022	9:01		12	7.8	0.6	0.07	7.2	704	0.06	0.29					0.266	0.221																	

Lake ID	Lake Name	Date MM/DD/YYYY	Time HH:MM	Secchi meters	Depth meters	Temp °C	%DO	DO mg/L	pH units	SpCond µS/cm	Phycocyanin RFU	Chlorophyll-a RFU	TurbSC NTU	Chl-a mg/M3	Pheo-a mg/M3	Silica mg/L	TP mg/L	SRP mg/L	TKN mg/L	TN mg/L	NO3NO2 mg/L	NH3 mg/L	Alk mg/L	Hard mg/L	Cl mg/L	SO4 mg/L	E. Coli mpn/100 mL	DOC mg/L	Fe µg/L	DFe µg/L	Al µg/L	DAl µg/L	Microcystin µg/L	Cylindro. µg/L	Anatoxin-a µg/L
27-0016	Harriet	9/14/2022	9:00		13	7.6	0.6	0.08	7.2	705	0.00	0.24																							
27-0016	Harriet	9/14/2022	8:59		14	7.5	0.7	0.09	7.2	707	0.00	0.25																							
27-0016	Harriet	9/14/2022	8:59		15	7.5	0.8	0.09	7.2	708	0.00	0.20					0.359	0.341																	
27-0016	Harriet	9/14/2022	8:58		16	7.4	0.8	0.10	7.1	708	0.00	0.18																							
27-0016	Harriet	9/14/2022	8:58		17	7.4	0.9	0.11	7.1	709	0.00	0.17																							
27-0016	Harriet	9/14/2022	8:57		18	7.3	1.0	0.12	7.1	711	0.00	0.19																							
27-0016	Harriet	9/14/2022	8:56		19	7.3	1.1	0.13	7.1	711	0.00	0.17																							
27-0016	Harriet	9/14/2022	8:56		20	7.3	1.2	0.14	7.1	711	0.00	0.20					0.418	0.407							150										
27-0016	Harriet	9/14/2022	8:55		21	7.3	1.3	0.16	7.1	712	0.00	0.19																							
27-0016	Harriet	9/14/2022	8:54		22	7.3	1.7	0.21	7.2	712	0.00	0.19																							
27-0016	Harriet	9/14/2022	8:53		23	7.3	2.0	0.24	7.2	713	0.00	0.29																							
27-0016	Harriet	9/14/2022	8:53		24	7.3	2.2	0.27	7.2	715	0.20	0.88																							
27-0016	Harriet	9/14/2022	8:49		25	7.4	3.0	0.36	6.6	722	3.05	5.70																							
27-0016	Harriet	9/28/2022	10:22	2.38	0	17.6	91.7	8.74	8.5	677	0.09	0.79		5.29	0.250		0.021	0.003		0.531					150										
27-0016	Harriet	9/28/2022	10:21		1	17.6	91.4	8.72	8.5	677	0.11	0.74																							
27-0016	Harriet	9/28/2022	10:21		2	17.6	91.2	8.70	8.5	677	0.16	0.95																							
27-0016	Harriet	9/28/2022	10:20		3	17.5	90.6	8.64	8.5	677	0.20	0.97																							
27-0016	Harriet	9/28/2022	10:20		4	17.5	90.1	8.59	8.5	677	0.20	1.03																							
27-0016	Harriet	9/28/2022	10:19		5	17.5	89.1	8.51	8.5	677	0.16	1.07																							
27-0016	Harriet	9/28/2022	10:18		6	17.5	87.9	8.40	8.5	677	0.24	1.07					0.020	0.004																	
27-0016	Harriet	9/28/2022	10:17		7	17.4	79.6	7.62	8.4	678	0.17	1.15																							
27-0016	Harriet	9/28/2022	10:16		8	15.3	41.7	4.16	7.8	692	0.27	1.73																							
27-0016	Harriet	9/28/2022	10:15		9	10.8	0.8	0.09	7.4	696	9.72	8.28																							
27-0016	Harriet	9/28/2022	10:14		10	9.1	0.7	0.08	7.3	705	2.46	1.58																							
27-0016	Harriet	9/28/2022	10:12		11	8.1	0.7	0.08	7.2	709	0.42	0.55																							
27-0016	Harriet	9/28/2022	10:12		12	7.8	0.7	0.09	7.2	708	0.13	0.38					0.269	0.228																	
27-0016	Harriet	9/28/2022	10:11		13	7.6	0.8	0.09	7.2	710	0.06	0.32																							
27-0016	Harriet	9/28/2022	10:10		14	7.5	0.8	0.10	7.2	711	0.03	0.29																							
27-0016	Harriet	9/28/2022	10:10		15	7.5	0.9	0.11	7.2	712	0.01	0.26					0.388	0.345																	
27-0016	Harriet	9/28/2022	10:09		16	7.4	1.0	0.12	7.2	713	0.00	0.25																							
27-0016	Harriet	9/28/2022	10:09		17	7.4	1.1	0.13	7.2	714	0.00	0.25																							
27-0016	Harriet	9/28/2022	10:08		18	7.4	1.2	0.14	7.2	715	0.00	0.28																							
27-0016	Harriet	9/28/2022	10:07		19	7.4	1.4	0.16	7.2	716	0.00	0.25																							
27-0016	Harriet	9/28/2022	10:06		20	7.3	1.5	0.18	7.2	716	0.00	0.25					0.449	0.416							150										
27-0016	Harriet	9/28/2022	10:05		21	7.3	1.7	0.21	7.2	718	0.00	0.28																							
27-0016	Harriet	9/28/2022	10:05		22	7.3	1.9	0.23	7.1	719	0.01	0.30																							
27-0016	Harriet	9/28/2022	10:04		23	7.3	2.2	0.26	7.1	720	0.00	0.37																							
27-0016	Harriet	9/28/2022	10:03		24	7.3	2.9	0.35	7.1	724	0.11	0.45																							
27-0016	Harriet	9/28/2022	10:03		25	7.3	3.5	0.43	7.0	734	3.62	4.15																							
27-0016	Harriet	10/20/2022	10:58	1.92	0	10.6	72.4	8.05	8.0	686	0.07	1.24		27.4	2.71	1.82	0.046	0.009	0.653	0.906	0.186	0.424	113	166	150	8.06									
27-0016	Harriet	10/20/2022	10:58		1	10.5	71.9	8.00	8.0	686	0.19	1.79																							
27-0016	Harriet	10/20/2022	10:57		2	10.5	71.8	7.98	8.0	685	0.17	1.96																							
27-0016	Harriet	10/20/2022	10:56		3	10.5	71.5	7.96	8.0	686	0.17	1.43																							
27-0016	Harriet	10/20/2022	10:55		4	10.5	70.6	7.86	8.0	686	0.14	1.78																							
27-0016	Harriet	10/20/2022	10:54		5	10.5	70.4	7.83	8.0	686	0.16	1.79																							
27-0016	Harriet	10/20/2022	10:53		6	10.5	69.6	7.75	8.0	686	0.17	1.48					0.046	0.009																	
27-0016	Harriet	10/20/2022	10:52		7	10.5	69.2	7.71	8.0	686	0.15	1.78																							
27-0016	Harriet	10/20/2022	10:51		8	10.5	68.1	7.58	8.0	686	0.13	1.46																							
27-0016	Harriet	10/20/2022	10:51		9	10.5	66.3	7.38	7.9	686	0.17	2.11																							
27-0016	Harriet	10/20/2022	10:50		10	10.5	62.1	6.92	7.9	685	0.08	1.24																							
27-0016	Harriet	10/20/2022	10:49		11	10.2	43.8	4.91	7.7	688	0.00	0.64																							
27-0016	Harriet	10/20/2022	10:48		12	9.3	0.8	0.09	7.3	697	0.00	0.31					0.054	0.022																	
27-0016	Harriet	10/20/2022	10:47		13	7.9	0.8	0.09	7.2	708	0.00	0.28																							
27-0016	Harriet	10/20/2022	10:46		14	7.6	0.9	0.10	7.2	710	0.00	0.22																							
27-0016	Harriet	10/20/2022	10:45		15	7.5	0.9	0.11	7.2	712	0.00	0.20					0.380	0.372																	
27-0016	Harriet	10/20/2022	10:44		16	7.5	1.1	0.13	7.1	713	0.00	0.22																							
27-0016	Harriet	10/20/2022	10:43		17	7.4	1.2	0.14	7.1	714	0.00	0.29																							
27-0016	Harriet	10/20/2022	10:42		18	7.4	1.4	0.17	7.1	715	0.00	0.30																							
27-0016	Harriet	10/20/2022	10:41		19	7.4	1.5	0.18	7.1	716	0.00	0.29																							
27-0016	Harriet	10/20/2022	10:40		20	7.4	1.7	0.20	7.1	716	0.00	0.28					0.487	0.453							145	6.80									
27-0016	Harriet	10/20/2022	10:39		21	7.4	2.0	0.24	7.1	717	0.00	0.34																							
27-0016	Harriet	10/20/2022	10:38		22	7.4	2.5	0.30	7.1	718	0.00	0.39																							
27-0016	Harriet	10/20/2022	10:38		23	7.3	3.0	0.36	7.1	719	0.00	0.39																							
27-0016	Harriet	10/20/2022	10:37		24	7.3	3.8	0.46	7.1	720	0.11	0.50																							
27-0018	Hiawatha	2/10/2022	9:45		0									11.5	1.55	10.6	0.042	0.007	1.27	1.61	0.145	0.862	223	276	215	19.5									
27-0018	Hiawatha	2/10/2022	9:45		4												0.048	0.007							215	19.5									
27-0018	Hiawatha	4/26/2022	11:28	0.63	0	7.0	102.5	12.59	8.4	878			1.3	48.7	9.16	3.17	0.079	0.005	0.764	0.779	0.184	0.365	135	176	190	12.7									
27-0018	Hiawatha	4/26/2022	11:27		1	6.9	102.6	12.61	8.4	878			1.2																						
27-0018	Hiawatha	4/26/2022	11:27		2	6.8	102.1	12.57	8.4	878			1.0																						
27-0018	Hiawatha	4/26/2022	11:26		3	6.8	101.9	12.55	8.4	878			1.0																						
27-0018	Hiawatha	4/26/2022	11:26		4	6.8	101.5	12.51	8.4	879			0.9				0.085	0.005							195	11.1									
27-0018	Hiawatha	4/26/2022	11:25		5	6.7	99.4	12.28	8.3	880			0.8																						
27-0018	Hiawatha	4/26/2022	11:25		6	6.5	99.1	12.32	8.3	883			7.2																						
27-0018	Hiawatha	5/13/2022	11:28	0.62	0	18.7	84.6	7.89	7.9	724	0.54	7.53		22.2	7.04	1.32	0.121	0.011	0.978	1.04	0.081	0.277	120	152	140	10.5									
27-0018	Hiawatha	5/13/2022	11:27		1	18.6	83.5	7.79	7.8	724	0.58	7.90																							
27-0018	Hiawatha	5/13/2022	11:26		2	18.5	78.9	7.38	7.8	725	0.53	8.23																							
27-0018	Hiawatha	5/13/2022	11:25		3	15.5	59.0	5.87	7.7	718	0.10	5.15																							
27-0018	Hiawatha	5/13/2022	11:24		4	13.5	36.2	3.76	7.5	785	0.10	4.76					0.087	0.006							145	10.6									
27-0018	Hiawatha	5/13/2022	11:24		5	12.0	20.6	2.22	7.4	833	0.16	6.11																							
27-0018	Hiawatha	5/27/2022	11:31	1.62	0	16.8	77.1	7.47	7.8	791	0.20	2.35		10.6	5.00		0.076	0.015		0.735					155										
27-0018	Hiawatha	5/27/2022	11:31		1	15.3	65.7	6.56	7.7	792	0.44	5.82																							
27-0018	Hiawatha	5/27/2022	11:30		2	15.3	64.8	6.48	7.7	791	0.40	9.14																							
27-0018	Hiawatha	5/27/2022	11:28		3	15.2	60.4	6.05	7.6	799	0.27	10.14																							
27-0018	Hiawatha	5/27/2022	11:27		4	14.7	56.1	5.68	7.6	821	0.19	7.40					0.079	0.020							170										
27-0018	Hiawatha	5/27/2022	11:26		5	13.1	14.4	1.51	7.4	879	0.11	3.15																							
27-0018	Hiawatha	5/27/2022	11:24		6	8.7	2.3	0.27	7.2	1191	0.02	1.05																							
27-0018	Hiawatha	5/27/2022	11:23		7	5.9	2.8	0.34	7.0	2769	0.00	0.82																							
27-0018	Hiawatha	6/9/2022	10:51	2.89	0	20.9	81.6	7.28	7.7	819	0.28	1.18		11.8	1.35	2.44	0.083	0.019		0.898					185										
27-0018	Hiawatha	6/9/2022	10:49		1	20.2	77.5	7.00	7.7	828	0.32	1.10																							
27-0018	Hiawatha	6/9/2022	10:47		2	19.7	44.2	4.04	7.4	829	0.14	1.42																							
27-0018	Hiawatha	6/9/2022	10:45		3	18.9	15.4	1.43	7.2	831	0.10	1.11																							
27-0018	Hiawatha	6/9/2022	10:44		4	17.8	6.0	0.57	7.1	827	0.15	1.96					0.187	0.091							185										
27-0018	Hiawatha	6/28/2022	11:17	0.62	0	24.6	133.8	11.12	8.6	753	2.58	4.82		63.4	10.0		0.095	0.004		1.11					160										
27-0018	Hiawatha	6/28/2022	11:16		1	24.0	107.1	9.00	8.4	755	3.43	6.07																							
27-0018	Hiawatha	6/28/2022	11:15		2	23.3	39.9	3.40	7.7	763	1.31	3.85																							
27-0018	Hiawatha	6/28/2022	11:14		3	23.0	15.5	1.32	7.5	766	0.89	3.37																							
27-0018	Hiawatha	6/28/2022	11:12		4	19.4	3.9	0.36	7.0	867	0.10	1.18					0.245	0.043							155										
27-0018	Hiawatha	6/28/2022	11:12		5	14.6	5.3	0.54	7.2	985	0.11	1.28																							

Lake ID	Lake Name	Date MM/DD/YYYY	Time HH:MM	Secchi meters	Depth meters	Temp °C	%DO	DO mg/L	pH units	SpCond µS/cm	Phycocyanin RFU	Chlorophyll-a RFU	TurbSC NTU	Chl-a mg/M3	Pheo-a mg/M3	Silica mg/L	TP mg/L	SRP mg/L	TKN mg/L	TN mg/L	NO3NO2 mg/L	NH3 mg/L	Alk mg/L	Hard mg/L	Cl mg/L	SO4 mg/L	E. Coli mpn/100 mL	DOC mg/L	Fe µg/L	DFe µg/L	Al µg/L	DAl µg/L	Microcystin µg/L	Cylindro. µg/L	Anatoxin-a µg/L
27-0018	Hiawatha	7/15/2022	11:03	0.76	0	26.0	114.6	9.29	8.5	671	2.31	9.44		23.6	7.76	2.69	0.111	0.004	1.21	1.74	0.015	0.253	130	168	185	8.14									
27-0018	Hiawatha	7/15/2022	11:02		1	25.6	101.7	8.30	8.5	671	2.30	10.60																							
27-0018	Hiawatha	7/15/2022	11:02		2	24.7	21.9	1.82	7.5	672	2.00	12.75																							
27-0018	Hiawatha	7/15/2022	11:00		3	23.4	2.5	0.21	7.4	694	0.97	4.86																							
27-0018	Hiawatha	7/15/2022	10:59		4	20.4	2.5	0.22	7.0	850	0.55	4.24					0.309	0.036							190	6.39									
27-0018	Hiawatha	7/15/2022	10:59		5	16.9	2.5	0.24	7.1	986	0.27	2.87																							
27-0018	Hiawatha	7/15/2022	10:58		6	11.5	2.3	0.25	7.2	1741	0.27	2.56																							
27-0018	Hiawatha	7/15/2022	10:58		7	10.1	2.3	0.26	7.1	2124	1.24	6.16																							
27-0018	Hiawatha	7/28/2022	10:20	0.38	0	24.1	88.5	7.42	8.1	686	6.52	18.10		98.3	17.1		0.156	0.004		1.37					130										
27-0018	Hiawatha	7/28/2022	10:19		1	24.0	80.1	6.73	8.0	687	6.75	23.13																							
27-0018	Hiawatha	7/28/2022	10:18		2	23.8	80.7	6.80	8.0	686	6.58	21.31																							
27-0018	Hiawatha	7/28/2022	10:17		3	23.7	84.8	7.16	8.0	685	6.50	21.29																							
27-0018	Hiawatha	7/28/2022	10:16		4	22.2	2.1	0.19	7.1	771	3.99	9.06					0.345	0.025							135										
27-0018	Hiawatha	7/28/2022	10:15		5	17.0	2.1	0.20	7.1	1099	2.21	5.97																							
27-0018	Hiawatha	7/28/2022	10:14		6	12.1	2.4	0.26	7.1	1793	1.44	5.26																							
27-0018	Hiawatha	7/28/2022	10:13		7	10.0	3.1	0.35	7.0	2268	3.01	7.96																							
27-0018	Hiawatha	8/11/2022	11:22	0.38	0	25.3	165.2	13.54	8.8	593	5.47	14.14		76.8	10.3	1.69	0.169	0.005		1.20					110		19								
27-0018	Hiawatha	8/11/2022	11:21		1	24.6	104.3	8.67	8.3	603	5.11	14.75																							
27-0018	Hiawatha	8/11/2022	11:20		2	24.0	7.6	0.64	7.4	612	3.28	9.87																							
27-0018	Hiawatha	8/11/2022	11:19		3	23.6	1.8	0.15	7.3	612	3.49	8.10																							
27-0018	Hiawatha	8/11/2022	11:18		4	22.5	2.1	0.18	7.2	636	2.67	4.95					0.165	0.012							115										
27-0018	Hiawatha	8/11/2022	11:17		5	18.3	2.2	0.21	7.0	1092	0.99	3.92																							
27-0018	Hiawatha	8/11/2022	11:16		6	12.9	2.2	0.24	7.0	1767	1.25	4.91																							
27-0018	Hiawatha	8/26/2022	11:58	0.40	0	24.2	141.4	11.84	8.8	527	5.50	11.52		92.4	2.88		0.125	0.005		1.25					160										
27-0018	Hiawatha	8/26/2022	11:57		1	23.6	90.7	7.69	8.4	538	5.43	9.20																							
27-0018	Hiawatha	8/26/2022	11:56		2	23.4	60.1	5.11	7.9	542	4.70	7.39																							
27-0018	Hiawatha	8/26/2022	11:55		3	23.0	17.0	1.46	7.4	552	3.68	5.44																							
27-0018	Hiawatha	8/26/2022	11:54		4	21.6	2.9	0.25	7.1	595	2.22	2.46					0.132	0.004							145										
27-0018	Hiawatha	8/26/2022	11:53		5	18.9	3.5	0.33	7.0	901	0.91	2.11																							
27-0018	Hiawatha	8/26/2022	11:51		6	14.0	4.3	0.45	6.9	1704	0.92	3.71																							
27-0018	Hiawatha	8/26/2022	11:50		7	11.4	8.0	0.86	6.8	2235	5.10	11.88																							
27-0018	Hiawatha	9/14/2022	11:22	0.33	0	22.0	98.9	8.63	8.2	532	7.59	9.71		123	12.9	3.24	0.137	0.002		1.38					100										
27-0018	Hiawatha	9/14/2022	11:21		1	21.9	79.3	6.94	7.9	535	7.85	9.82																							
27-0018	Hiawatha	9/14/2022	11:19		2	21.7	61.6	5.41	7.7	542	6.88	7.23																							
27-0018	Hiawatha	9/14/2022	11:18		3	21.6	45.5	4.00	7.5	538	7.24	6.85																							
27-0018	Hiawatha	9/14/2022	11:17		4	21.5	66.5	5.87	7.8	551	7.00	5.96					0.125	0.002							95										
27-0018	Hiawatha	9/14/2022	11:16		5	20.2	3.5	0.32	7.1	753	2.18	4.22																							
27-0018	Hiawatha	9/14/2022	11:15		6	15.0	12.9	1.30	6.9	1694	0.81	2.80																							
27-0018	Hiawatha	9/29/2022	9:41	0.40	0	16.4	73.5	7.18	7.7	569	7.20	5.77		80.1	8.77		0.134	0.003		1.72					110										
27-0018	Hiawatha	9/29/2022	9:40		1	16.4	73.1	7.15	7.7	569	7.79	6.29																							
27-0018	Hiawatha	9/29/2022	9:39		2	16.4	73.8	7.22	7.7	568	7.49	6.42																							
27-0018	Hiawatha	9/29/2022	9:39		3	16.4	74.5	7.28	7.7	568	7.57	6.30																							
27-0018	Hiawatha	9/29/2022	9:38		4	16.4	76.0	7.43	7.7	567	7.49	5.92					0.138	0.002							100										
27-0018	Hiawatha	9/29/2022	9:37		5	16.3	77.5	7.59	7.7	566	7.82	5.90																							
27-0018	Hiawatha	10/13/2022	9:52	0.27	0	14.2	80.3	8.22	7.7	590	14.68	6.08		73.9	6.27	6.39	0.143	0.003	1.78	2.00	0.237	0.605	123	154	125	9.20									
27-0018	Hiawatha	10/13/2022	9:51		1	14.2	79.9	8.17	7.7	590	14.43	6.27																							
27-0018	Hiawatha	10/13/2022	9:50		2	14.2	79.5	8.14	7.7	590	14.19	6.30																							
27-0018	Hiawatha	10/13/2022	9:50		3	14.2	79.2	8.11	7.6	591	13.99	5.93																							
27-0018	Hiawatha	10/13/2022	9:49		4	14.2	78.8	8.07	7.6	590	14.00	5.91					0.140	0.005							120	9.40									
27-0018	Hiawatha	10/13/2022	9:48		5	14.2	76.4	7.82	7.6	595	14.07	5.86																							
27-0018	Hiawatha	10/13/2022	9:47		6	14.2	71.9	7.37	7.5	614	14.08	6.97																							
27-0040	Isles	2/8/2022	11:45		0									1.18	0.774	1.01	0.041	0.025	0.891	0.946	0.107	0.408	126	144	160	9.60									
27-0040	Isles	2/8/2022	11:45		5												0.067	0.048																	
27-0040	Isles	2/8/2022	11:45		8												0.095	0.068							165	9.09									
27-0040	Isles	4/19/2022	11:13	1.39	0	5.5	105.7	13.46	8.5	712			3.3	30.2	6.58	0.663	0.060	0.005	0.619	0.656	0.015	0.125	106	120	155	7.13									
27-0040	Isles	4/19/2022	11:12		1	4.9	105.0	13.56	8.5	710			3.1																						
27-0040	Isles	4/19/2022	11:11		2	4.7	103.3	13.41	8.5	710			2.6																						
27-0040	Isles	4/19/2022	11:10		3	4.6	102.8	13.37	8.5	710			2.0																						
27-0040	Isles	4/19/2022	11:08		4	4.6	102.4	13.31	8.5	710			2.0																						
27-0040	Isles	4/19/2022	11:07		5	4.6	101.9	13.26	8.4	710			2.0				0.070	0.005																	
27-0040	Isles	4/19/2022	11:06		6	4.6	102.0	13.27	8.4	710			1.9																						
27-0040	Isles	4/19/2022	11:04		7	4.6	101.5	13.21	8.4	710			1.8																						
27-0040	Isles	4/19/2022	11:03		8	4.6	101.1	13.15	8.4	710			1.8				0.064	0.006							155	6.98									
27-0040	Isles	4/19/2022	11:02		9	4.6	101.2	13.17	8.3	711			1.7																						
27-0040	Isles	5/10/2022	10:23	1.54	0	15.2	103.4	10.37	8.2	710	0.20	3.41		13.6	3.54	0.250	0.044	0.008	0.680	0.711	0.015	0.125	105	120	165	7.29									
27-0040	Isles	5/10/2022	10:22		1	15.0	102.2	10.29	8.2	710	0.24	4.92																							
27-0040	Isles	5/10/2022	10:21		2	14.9	100.4	10.14	8.2	710	0.24	5.05																							
27-0040	Isles	5/10/2022	10:20		3	12.0	90.7	9.75	8.0	706	0.16	3.40																							
27-0040	Isles	5/10/2022	10:19		4	10.3	79.6	8.91	7.8	704	0.06	2.68																							
27-0040	Isles	5/10/2022	10:18		5	9.4	72.5	8.29	7.7	706	0.04	1.50					0.039	0.009																	
27-0040	Isles	5/10/2022	10:18		6	9.1	68.8	7.91	7.6	708	0.02	1.36																							
27-0040	Isles	5/10/2022	10:17		7	9.0	63.3	7.30	7.5	708	0.04	1.02																							
27-0040	Isles	5/10/2022	10:16		8	8.9	60.6	7.02	7.5	710	0.04	0.94					0.032	0.010							200	6.58									
27-0040	Isles	5/10/2022	10:15		9	8.8	50.2	5.83	7.4	712	0.02	1.11																							
27-0040	Isles	5/24/2022	10:34	3.84	0	17.9	113.0	10.71	8.6	692	0.00	0.83		2.07	1.10		0.042	0.007		0.750					152										
27-0040	Isles	5/24/2022	10:33		1	17.8	113.1	10.74	8.4	691	0.00	1.50																							
27-0040	Isles	5/24/2022	10:32		2	17.6	111.4	10.62	8.4	691	0.01	1.11																							
27-0040	Isles	5/24/2022	10:31		3	16.7	73.2	7.11	7.9	699	0.00	0.38																							
27-0040	Isles	5/24/2022	10:29		4	12.2	49.2	5.27	7.2	707	0.00	0.43																							
27-0040	Isles	5/24/2022	10:28		5	10.1	37.7	4.24	7.1	706	0.00	0.51					0.052	0.025																	
27-0040	Isles	5/24/2022	10:27		6	9.5	34.1	3.89	7.1	706	0.00	0.38																							
27-0040	Isles	5/24/2022	10:26		7	9.3	33.0	3.79	7.1	707	0.00	0.36																							
27-0040	Isles	5/24/2022	10:25		8	9.0	10.4	1.20	7.0	710	0.00	0.40					0.065	0.037							172										
27-0040	Isles	5/24/2022	10:24		9	9.0	4.0	0.46	7.0	710	0.00	0.38																							
27-0040	Isles	5/24/2022	10:23		10	8.7	3.0	0.35	7.0	714	0.03	0.79																							
27-0040	Isles	6/6/2022	10:51	3.45	0	20.5	114.1	10.25	8.7	683	0.01	0.65		2.32	1.04	0.250	0.041	0.007		0.628					180										
27-0040	Isles	6/6/2022	10:50		1	20.4	113.7	10.24	8.7	682	0.04	0.75																							
27-0040	Isles	6/6/2022	10:50		2	20.3	109.7	9.91	8.7	683	0.02	0.65																							
27-0040	Isles	6/6/2022	10:48		3	18.2	58.3	5.49	7.7	697	0.03	1.15																							
27-0040	Isles	6/6/2022	10:47		4	13.5	27.5	2.86	7.2	702	0.02	1.73																							
27-0040	Isles	6/6/2022	10:47		5	10.8	21.1	2.33	7.2	716	0.00	0.71					0.067	0.039																	
27-0040	Isles	6/6/2022	10:46		6	10.0	9.1	1.03	7.2	716	0.00	0.63																							
27-0040	Isles	6/6/2022	10:44		7	9.5	4.2	0.48	7.1	717	0.09	0.93																							
27-0040	Isles	6/6/2022	10:44		8	9.0	3.3	0.38	7.1	722	0.35	1.26					0.106	0.066							180										
27-0040	Isles	6/6/2022	10:43		9	8.7	4.2	0.48	7.1	732	0.07	0.79																							
27-0040	Isles	6/23/2022	9:38	1.64	0	26.0	131.4	10.65	9.0	684	0.30	2.40		13.8	1.29		0.050	0.004		0.749					155										
27-0040	Isles	6/23/2022	9:38		1	25.8	129.4	10.51	9.0	684	0.48	4.81																							
27-0040	Isles	6/23/2022	9:36		2	25.1	63.7	5.25	8.5	694	0.32	4.03																							
27-0040	Isles	6/23/2022	9:35		3	21.6	23.5	2.06	7.4	700	0.13	4.14																							
27-0040	Isles	6/23/2022	9:34		4	15.3	9.5	0.95	7.2	722	0.04	2.42																							
27-0040	Isles	6/23/2022	9:33		5	11.5	4.1	0.45	7.1	722	0.05	1.85					0.085	0.054																	
27-0040	Isles	6/23/2022	9:31		6	10.1	1.6	0.18	7.1	720	1.59	1.75																							
27-0040	Isles	6/23/2022	9:30		7	9.6	1.9	0.21	7.1	723	0.09	0.88																							
27-0040	Isles	6/23/2022	9:29		8	9.0	1.9	0.22	7.0	732	0.03	0.87					0.157	0.106							175										
27-0040	Isles	6/23/2022	9:28		9	8.9	2.5	0.29	6.6	775	0.00	0.46																							
27-0040	Isles	7/14/2022	8:20	2.40	0	25.6	99.5	8.11	8.7	697	0.39	2.73		12.7	1.62	0.952	0.033	0.002	1.05	1.21	0.015	0.125	88	108	175	6.58									

Lake ID	Lake Name	Date MM/DD/YYYY	Time HH:MM	Secchi meters	Depth meters	Temp °C	%DO	DO mg/L	pH units	SpCond µS/cm	Phycocyanin RFU	Chlorophyll-a RFU	TurbSC NTU	Chl-a mg/M3	Pheo-a mg/M3	Silica mg/L	TP mg/L	SRP mg/L	TKN mg/L	TN mg/L	NO3NO2 mg/L	NH3 mg/L	Alk mg/L	Hard mg/L	Cl mg/L	SO4 mg/L	E. Coli mpn/100 mL	DOC mg/L	Fe µg/L	DFe µg/L	Al µg/L	DAl µg/L	Microcystin µg/L	Cylindro. µg/L	Anatoxin-a µg/L
27-0040	Isles	7/14/2022	8:18		1	25.6	96.5	7.87	8.6	697	0.42	4.06																							
27-0040	Isles	7/14/2022	8:16		2	25.6	93.6	7.65	8.6	697	0.42	3.10																							
27-0040	Isles	7/14/2022	8:15		3	24.3	42.2	3.52	8.0	704	0.73	10.25																							
27-0040	Isles	7/14/2022	8:13		4	17.1	15.8	1.52	7.4	725	5.17	10.10																							
27-0040	Isles	7/14/2022	8:12		5	12.5	1.7	0.18	7.2	722	2.03	4.72					0.070	0.003																	
27-0040	Isles	7/14/2022	8:11		6	10.4	2.2	0.24	7.1	722	0.15	0.96																							
27-0040	Isles	7/14/2022	8:10		7	9.7	2.6	0.29	7.0	728	0.07	0.71																							
27-0040	Isles	7/14/2022	8:08		8	9.1	3.6	0.41	6.9	738	0.05	0.76					0.197	0.131							175	5.95									
27-0040	Isles	7/27/2022	8:20	1.15	0	24.5	91.8	7.64	8.4	710	1.44	5.08		24.3	3.61		0.042	0.002		0.874					170										
27-0040	Isles	7/27/2022	8:19		1	24.5	89.3	7.44	8.4	710	1.55	8.25																							
27-0040	Isles	7/27/2022	8:18		2	24.4	83.5	6.95	8.4	709	1.72	10.15																							
27-0040	Isles	7/27/2022	8:17		3	24.2	67.0	5.61	8.2	709	2.24	15.77																							
27-0040	Isles	7/27/2022	8:16		4	19.6	2.5	0.23	7.2	715	7.18	10.84																							
27-0040	Isles	7/27/2022	8:15		5	12.7	2.4	0.25	7.0	721	2.27	3.65					0.089	0.004																	
27-0040	Isles	7/27/2022	8:14		6	10.6	2.9	0.32	7.0	726	0.40	0.99																							
27-0040	Isles	7/27/2022	8:14		7	9.7	3.6	0.40	7.0	735	0.22	0.83																							
27-0040	Isles	7/27/2022	8:13		8	9.3	5.1	0.58	6.9	746	0.14	0.82					0.253	0.177							175										
27-0040	Isles	8/10/2022	8:42	0.65	0	25.1	134.9	11.11	8.9	710	1.93	4.27		29.3	3.76	1.32	0.042	0.006		1.08					195		3								
27-0040	Isles	8/10/2022	8:41		1	24.6	107.2	8.91	8.7	713	3.12	5.40																							
27-0040	Isles	8/10/2022	8:40		2	24.2	62.8	5.25	8.2	717	3.54	5.44																							
27-0040	Isles	8/10/2022	8:39		3	23.9	39.2	3.30	7.8	717	3.18	3.70																							
27-0040	Isles	8/10/2022	8:38		4	21.6	1.9	0.17	7.3	725	6.73	5.19																							
27-0040	Isles	8/10/2022	8:36		5	14.0	1.6	0.17	7.0	727	0.57	1.70					0.065	0.004																	
27-0040	Isles	8/10/2022	8:36		6	11.1	1.7	0.19	7.0	734	0.23	0.99																							
27-0040	Isles	8/10/2022	8:34		7	10.0	2.0	0.23	6.9	739	0.17	0.93																							
27-0040	Isles	8/10/2022	8:33		8	9.2	2.5	0.28	6.8	754	0.10	0.75					0.312	0.200							185										
27-0040	Isles	8/10/2022	8:32		9	8.8	3.5	0.41	6.7	771	0.13	0.86																							
27-0040	Isles	8/25/2022	8:49	1.25	0	24.3	97.4	8.14	8.6	700	0.59	2.78	4.3	18.6	3.20		0.033	0.004		0.766					180										
27-0040	Isles	8/25/2022	8:49		1	24.3	95.9	8.01	8.6	700	0.58	2.92																							
27-0040	Isles	8/25/2022	8:48		2	24.1	88.3	7.41	8.5	702	0.89	4.56																							
27-0040	Isles	8/25/2022	8:47		3	23.0	6.6	0.56	7.4	701	1.57	4.61																							
27-0040	Isles	8/25/2022	8:46		4	21.1	1.8	0.16	7.3	715	2.04	8.68																							
27-0040	Isles	8/25/2022	8:45		5	15.5	1.7	0.17	7.2	740	0.60	2.03					0.053	0.004																	
27-0040	Isles	8/25/2022	8:44		6	11.7	1.6	0.17	7.0	741	0.10	0.81																							
27-0040	Isles	8/25/2022	8:43		7	10.4	1.8	0.21	7.0	746	0.05	0.71																							
27-0040	Isles	8/25/2022	8:41		8	9.4	2.7	0.31	6.8	757	0.00	0.63					0.297	0.187							170										
27-0040	Isles	8/25/2022	8:40		9	9.0	6.1	0.71	6.7	778	0.06	0.74																							
27-0040	Isles	9/15/2022	9:57	1.10	0	21.8	92.8	8.14	8.4	708	0.32	2.14	2.5	18.9	3.49	1.51	0.038	0.005		0.939					180										
27-0040	Isles	9/15/2022	9:56		1	21.7	92.0	8.07	8.4	708	0.53	3.27																							
27-0040	Isles	9/15/2022	9:55		2	21.7	89.3	7.83	8.4	708	0.51	3.33																							
27-0040	Isles	9/15/2022	9:54		3	21.6	81.7	7.18	8.2	709	0.48	3.54																							
27-0040	Isles	9/15/2022	9:53		4	21.2	65.3	5.78	8.0	711	0.46	3.17																							
27-0040	Isles	9/15/2022	9:52		5	16.4	1.8	0.18	7.2	755	0.15	1.52					0.043	0.004																	
27-0040	Isles	9/15/2022	9:51		6	12.6	1.7	0.18	7.1	745	0.07	0.84																							
27-0040	Isles	9/15/2022	9:50		7	10.7	2.1	0.23	6.9	752	0.00	0.54																							
27-0040	Isles	9/15/2022	9:48		8	9.6	2.8	0.32	6.8	766	0.00	0.65					0.302	0.283							175										
27-0040	Isles	9/15/2022	9:48		9	9.0	4.5	0.51	6.7	790	0.06	0.76																							
27-0040	Isles	9/28/2022	8:49	1.47	0	16.4	68.1	6.65	7.8	727	0.31	3.17	1.7	11.9	3.05		0.041	0.003		0.937					160										
27-0040	Isles	9/28/2022	8:48		1	16.4	67.8	6.62	7.8	727	0.37	3.67																							
27-0040	Isles	9/28/2022	8:47		2	16.4	67.5	6.59	7.8	727	0.33	3.30																							
27-0040	Isles	9/28/2022	8:46		3	16.4	67.3	6.58	7.8	727	0.38	3.67																							
27-0040	Isles	9/28/2022	8:45		4	16.3	66.6	6.52	7.8	727	0.33	3.96																							
27-0040	Isles	9/28/2022	8:45		5	16.2	65.3	6.41	7.8	727	0.27	3.55					0.038	0.003																	
27-0040	Isles	9/28/2022	8:43		6	16.1	62.2	6.11	7.8	727	0.28	3.65																							
27-0040	Isles	9/28/2022	8:42		7	11.2	1.9	0.20	6.9	757	0.07	1.04																							
27-0040	Isles	9/28/2022	8:41		8	9.7	2.0	0.23	6.8	774	0.02	0.69					0.271	0.131							155										
27-0040	Isles	9/28/2022	8:40		9	9.1	3.0	0.35	6.7	798	0.12	1.13																							
27-0040	Isles	10/20/2022	9:17	1.82	0	8.5	75.0	8.76	7.8	749	0.05	3.73	0.5	10.6	3.76	0.839	0.045	0.014	0.903	1.05	0.267	0.477	115	158	175	7.00									
27-0040	Isles	10/20/2022	9:16		1	8.5	74.7	8.73	7.8	749	0.10	4.23																							
27-0040	Isles	10/20/2022	9:16		2	8.5	74.3	8.69	7.7	749	0.06	3.56																							
27-0040	Isles	10/20/2022	9:15		3	8.5	74.4	8.69	7.7	749	0.05	4.24																							
27-0040	Isles	10/20/2022	9:14		4	8.5	74.0	8.65	7.7	750	0.06	3.38																							
27-0040	Isles	10/20/2022	9:14		5	8.5	73.7	8.61	7.7	749	0.13	5.77					0.051	0.008																	
27-0040	Isles	10/20/2022	9:13		6	8.5	73.8	8.62	7.7	750	0.10	5.27																							
27-0040	Isles	10/20/2022	9:12		7	8.5	73.5	8.59	7.7	749	0.14	6.38																							
27-0040	Isles	10/20/2022	9:12		8	8.5	73.3	8.57	7.7	750	0.16	7.85					0.056	0.012							175	6.90									
27-0040	Isles	10/20/2022	9:11		8.9	8.5	72.9	8.52	7.8	750	0.09	4.80																							
27-0655	Loring	2/9/2022	10:50		0									6.97	4.20	21.3	0.080	0.034	1.16	1.17	0.038	0.635	203	328	225	31.2									
27-0655	Loring	2/9/2022	10:50		4												0.140	0.089							230	30.3									
27-0655	Loring	4/21/2022	11:13	0.92	0	6.6	112.5	13.80	8.6	840			1.2	19.0	5.29	9.40	0.082	0.005	0.712	0.811	0.015	0.125	146	244	170	22.0									
27-0655	Loring	4/21/2022	11:12		1	6.4	111.8	13.78	8.5	840			1.2																						
27-0655	Loring	4/21/2022	11:12		2	6.3	110.6	13.67	8.5	840			1.3																						
27-0655	Loring	4/21/2022	11:10		3	5.4	65.4	8.27	7.9	914			2.6																						
27-0655	Loring	4/21/2022	11:10		4	5.5	0.0	0.00	7.5	1178			9.0				0.165	0.005							200	24.9									
27-0655	Loring	5/11/2022	11:17	0.92	0	16.7	99.2	9.62	7.9	915	0.49	10.04		22.2	10.0	9.31	0.094	0.007	0.807	0.911	0.015	0.277	155	264	205	21.5									
27-0655	Loring	5/11/2022	11:17		1	16.8	99.4	9.63	7.9	915	0.49	9.67																							
27-0655	Loring	5/11/2022	11:15		2	16.7	95.5	9.27	7.8	915	0.51	9.86																							
27-0655	Loring	5/11/2022	11:15		3	16.6	92.2	8.96	7.8	916	0.42	8.53																							
27-0655	Loring	5/11/2022	11:14		4	16.3	74.7	7.31	7.6	919	0.44	8.46					0.100	0.008							185	20.8									
27-0655	Loring	5/26/2022	10:39	0.76	0	16.9	81.9	7.90	7.8	874	0.69	12.53		33.0	16.3		0.117	0.004		0.735					180										
27-0655	Loring	5/26/2022	10:39		1	16.9	81.6	7.88	7.8	874	0.62	12.31																							
27-0655	Loring	5/26/2022	10:38		2	16.9	81.1	7.83	7.8	874	0.70	14.73																							
27-0655	Loring	5/26/2022	10:37		3	16.9	79.9	7.71	7.8	874	0.68	12.46																							
27-0655	Loring	5/26/2022	10:36		4	16.8	68.3	6.62	7.6	874	0.93	13.99					0.120	0.004							175										
27-0655	Loring	6/7/2022	11:01	0.94	0	21.0	86.9	7.73	7.8	864	0.45	7.86		18.5	10.0	6.90	0.091	0.009		0.867					205										
27-0655	Loring	6/7/2022	11:00		1	21.0	86.6	7.70	7.8	864	0.37	9.99																							
27-0655	Loring	6/7/2022	11:00		2	21.0	85.2	7.58	7.8	864	0.42	10.20																							
27-0655	Loring	6/7/2022	10:59		3	20.9	78.1	6.96	7.7	864	0.37	7.89																							
27-0655	Loring	6/7/2022	10:59		4	20.8	71.2	6.36	7.6	865	0.50	9.86					0.099	0.012							215										
27-0655	Loring	6/21/2022	11:45	0.97	0	27.0	126.2	10.04	8.3	897	0.52	8.74		50.7	17.5		0.113	0.015		0.838					195										
27-0655	Loring	6/21/2022	11:44		1	26.8	117.6	9.38	8.2	898	0.77	11.63																							
27-0655	Loring	6/21/2022	11:42		2	26.5	102.9	8.25	8.1	899	0.39	8.46																							
27-0655	Loring	6/21/2022	11:41		3	26.4	86.9	6.99	7.9	899	0.29	6.20																							
27-0655	Loring	6/21/2022	11:39		4	25.5	23.4	1.92	7.4	906	0.84	9.99					0.109	0.019							180										
27-0655	Loring	7/11/2022	11:10	0.85	0	26.8	79.6	6.35	7.6	933	0.85	15.54		40.7	8.88	11.1	0.131	0.021	1.35	1.56	0.015	0.296	140	260	190	18.7									
27-0655	Loring	7/11/2022	11:09		1	26.7	66.2	5.29	7.5	933	0.77	17.04																							
27-0655	Loring	7/11/2022	11:08		2	26.6	52.7	4.22	7.4	933	0.64	13.21																							
27-0655	Loring	7/11/2022	11:07		3	26.4	49.0	3.93	7.3	936	0.34	8.31																							
27-0655	Loring	7/11/2022	11:07		4	25.6	43.2	3.52	7.2	988	0.49	15.95					0.111	0.024							200	19.0									
27-0655	Loring	7/26/2022	10:47	0.70	0	25.5	71.9	5.87	7.7	1001	1.51	17.82		60.6	12.6		0.131	0.012		0.874					220										
27-0655	Loring	7/26/2022	10:46		1	25.5	70.9	5.79	7.7	1001	1.49	18.95																							
27-0655	Loring	7/26/2022	10:45		2	25.4	69.0	5.64	7.7	1001	1.49	19.96																							

Lake ID	Lake Name	Date MM/DD/YYYY	Time HH:MM	Secchi meters	Depth meters	Temp °C	%DO	DO mg/L	pH units	SpCond µS/cm	Phycocyanin RFU	Chlorophyll-a RFU	TurbSC NTU	Chl-a mg/M3	Pheo-a mg/M3	Silica mg/L	TP mg/L	SRP mg/L	TKN mg/L	TN mg/L	NO3NO2 mg/L	NH3 mg/L	Alk mg/L	Hard mg/L	Cl mg/L	SO4 mg/L	E. Coli mpn/100 mL	DOC mg/L	Fe µg/L	DFe µg/L	Al µg/L	DAl µg/L	Microcystin µg/L	Cylindro. µg/L	Anatoxin-a µg/L
27-0655	Loring	7/26/2022	10:44		3	25.4	65.9	5.39	7.6	1001	1.47	21.43																							
27-0655	Loring	7/26/2022	10:42		4	25.3	50.7	4.15	7.5	1002	3.18	40.46					0.127	0.009							220										
27-0655	Loring	8/9/2022	11:17	0.55	0	25.1	95.2	7.83	7.9	1011	1.22	11.38		64.9	16.9	14.8	0.117	0.004		0.961					235		687								
27-0655	Loring	8/9/2022	11:16		1	24.8	89.1	7.37	7.8	1011	1.30	20.83																							
27-0655	Loring	8/9/2022	11:15		2	24.7	75.1	6.23	7.7	1011	1.30	22.66																							
27-0655	Loring	8/9/2022	11:14		3	24.6	68.4	5.68	7.7	1011	1.38	23.54																							
27-0655	Loring	8/9/2022	11:13		4	24.5	57.5	4.78	7.5	1013	1.78	34.77					0.118	0.005							240										
27-0655	Loring	8/24/2022	10:59	0.53	0	24.6	108.9	9.04	8.1	1017	2.18	23.04		43.3	13.5		0.094	0.010		0.919					230										
27-0655	Loring	8/24/2022	10:58		1	24.5	103.7	8.63	8.0	1017	2.13	24.23																							
27-0655	Loring	8/24/2022	10:57		2	24.4	99.0	8.25	8.0	1017	2.54	32.52																							
27-0655	Loring	8/24/2022	10:56		3	24.4	93.3	7.78	7.9	1018	2.73	33.64																							
27-0655	Loring	8/24/2022	10:55		4	24.3	88.5	7.38	7.8	1019	3.06	32.03					0.095	0.012							242										
27-0655	Loring	9/19/2022	11:42	0.61	0	21.9	47.8	4.18	7.5	1047	0.29	3.85		24.8	12.5	17.7	0.085	0.012		0.989					245										
27-0655	Loring	9/19/2022	11:41		1	21.6	43.2	3.79	7.4	1047	0.22	3.33																							
27-0655	Loring	9/19/2022	11:41		2	21.6	43.2	3.79	7.4	1047	0.28	4.29																							
27-0655	Loring	9/19/2022	11:40		3	21.6	42.6	3.75	7.4	1047	0.20	3.63																							
27-0655	Loring	9/19/2022	11:38		4	21.5	39.6	3.49	7.4	1049	0.29	4.57					0.086	0.017							235										
27-0655	Loring	9/27/2022	10:43	1.02	0	16.9	88.2	8.51	7.9	1068	0.94	5.19		39.4	12.1		0.077	0.002		0.981					240										
27-0655	Loring	9/27/2022	10:43		1	16.9	87.2	8.43	7.9	1068	0.88	6.49																							
27-0655	Loring	9/27/2022	10:42		2	16.8	86.6	8.37	7.9	1068	0.77	6.04																							
27-0655	Loring	9/27/2022	10:42		3	16.8	85.4	8.26	7.9	1068	0.77	6.10																							
27-0655	Loring	9/27/2022	10:40		4	16.8	24.4	2.37	7.4	1067	0.61	4.76					0.077	0.002							250										
27-0655	Loring	10/12/2022	12:14	0.79	0	15.4	121.0	12.04	8.3	1101	1.73	12.67		39.1	11.8	14.9	0.083	0.005	0.938	1.14	0.173	0.328	182	320	250	28.4									
27-0655	Loring	10/12/2022	12:13		1	15.0	99.0	9.95	8.0	1106	1.03	11.05																							
27-0655	Loring	10/12/2022	12:11		2	14.2	67.6	6.91	7.6	1107	0.60	9.51																							
27-0655	Loring	10/12/2022	12:10		3	14.3	55.7	5.69	7.5	1131	0.39	7.75																							
27-0655	Loring	10/12/2022	12:09		4	14.2	51.9	5.31	7.4	1120	0.67	8.56					0.085	0.006							250	30.1									
27-0019	Nokomis	2/10/2022	8:50		0									1.20	0.250	12.1	0.041	0.020	1.47	1.56	0.142	0.760	138	136	145	6.19							<1.5		
27-0019	Nokomis	2/10/2022	8:50		4												0.041	0.019																	
27-0019	Nokomis	2/10/2022	8:50		7												0.048	0.018							150	6.01									
27-0019	Nokomis	4/26/2022	10:25	1.50	0	6.4	95.7	11.92	8.4	625			0.0	6.45	1.40	7.95	0.042	0.006	1.06	1.17	0.221	0.562	116	120	130	5.63		7.20			100	100	<1.5		
27-0019	Nokomis	4/26/2022	10:25		1	6.5	96.0	11.95	8.4	625			0.0																						
27-0019	Nokomis	4/26/2022	10:24		2	6.5	96.3	11.99	8.4	625			0.0																						
27-0019	Nokomis	4/26/2022	10:24		3	6.5	96.0	11.95	8.3	625			0.0																						
27-0019	Nokomis	4/26/2022	10:23		4	6.4	95.3	11.86	8.3	625			0.0				0.041	0.005													100	100			
27-0019	Nokomis	4/26/2022	10:22		5	6.4	95.3	11.87	8.3	625			0.0																						
27-0019	Nokomis	4/26/2022	10:22		6	6.4	95.7	11.91	8.3	625			0.0																						
27-0019	Nokomis	4/26/2022	10:21		7	6.4	95.5	11.89	8.2	625			0.0				0.047	0.004							135	5.40					100	100			
27-0019	Nokomis	4/26/2022	10:21		8	6.4	95.4	11.88	8.2	624			0.0																						
27-0019	Nokomis	5/13/2022	10:39	1.48	0	16.9	117.6	11.38	8.5	618	0.01	2.25		9.61	2.50	2.33	0.058	0.005	1.08	1.17	0.134	0.321	111	116	120	6.46		8.10			100	100			
27-0019	Nokomis	5/13/2022	10:38		1	16.8	117.4	11.37	8.5	617	0.08	2.78																							
27-0019	Nokomis	5/13/2022	10:38		2	16.8	116.8	11.32	8.5	617	0.15	6.52																							
27-0019	Nokomis	5/13/2022	10:37		3	16.4	114.2	11.15	8.4	616	0.15	6.43																							
27-0019	Nokomis	5/13/2022	10:36		4	14.0	100.5	10.34	8.3	624	0.19	8.54					0.044	0.004													100	100			
27-0019	Nokomis	5/13/2022	10:36		5	13.7	97.8	10.12	8.2	625	0.21	10.05																							
27-0019	Nokomis	5/13/2022	10:35		6	13.3	93.1	9.72	8.2	627	0.23	10.49																							
27-0019	Nokomis	5/13/2022	10:34		7	12.4	78.3	8.33	8.0	632	0.11	8.95					0.046	0.004							115	5.66					100	100			
27-0019	Nokomis	5/13/2022	10:32		8	11.1	44.8	4.92	7.6	641	0.06	3.98																							
27-0019	Nokomis	5/27/2022	10:33	4.43	0	16.8	90.4	8.76	8.2	621	0.06	0.35		1.03	0.748		0.029	0.006		0.934					180										
27-0019	Nokomis	5/27/2022	10:32		1	16.3	86.0	8.42	8.2	621	0.03	0.28																							
27-0019	Nokomis	5/27/2022	10:31		2	16.2	85.4	8.38	8.2	621	0.01	0.34																							
27-0019	Nokomis	5/27/2022	10:30		3	16.1	86.3	8.48	8.2	621	0.01	0.40																							
27-0019	Nokomis	5/27/2022	10:29		4	16.1	86.2	8.48	8.2	621	0.02	0.33					0.028	0.005																	
27-0019	Nokomis	5/27/2022	10:28		5	16.0	83.3	8.20	8.2	621	0.04	0.46																							
27-0019	Nokomis	5/27/2022	10:25		6	14.0	27.7	2.85	7.4	643	0.03	0.70																							
27-0019	Nokomis	5/27/2022	10:24		7	12.3	3.5	0.37	7.3	646	0.03	0.82					0.045	0.007							170										
27-0019	Nokomis	5/27/2022	10:23		8	11.1	3.9	0.43	7.2	665	0.02	0.69																							
27-0019	Nokomis	6/9/2022	9:44	2.93	0	20.9	112.1	9.99	8.3	632	0.15	1.01		5.19	1.37	1.12	0.032	0.002		0.959					155										
27-0019	Nokomis	6/9/2022	9:43		1	20.5	111.1	9.98	8.3	631	0.15	1.52																							
27-0019	Nokomis	6/9/2022	9:42		2	20.4	107.8	9.71	8.3	631	0.19	1.69																							
27-0019	Nokomis	6/9/2022	9:41		3	19.8	87.5	7.97	8.0	633	0.26	2.20																							
27-0019	Nokomis	6/9/2022	9:41		4	19.2	57.5	5.30	7.6	636	0.08	1.77					0.035	0.002																	
27-0019	Nokomis	6/9/2022	9:39		5	18.8	26.3	2.45	7.4	642	0.10	1.37																							
27-0019	Nokomis	6/9/2022	9:38		6	18.4	25.3	2.37	7.3	639	0.06	1.22																							
27-0019	Nokomis	6/9/2022	9:37		7	17.3	2.0	0.19	7.2	636	0.27	1.93					0.050	0.009							135										
27-0019	Nokomis	6/9/2022	9:36		8	15.7	2.1	0.21	7.1	658	0.07	1.01																							
27-0019	Nokomis	6/24/2022	10:20	0.79	0	25.5	108.3	8.86	8.3	623	1.03	2.86		22.1	3.12		0.050	0.007		0.905					185										
27-0019	Nokomis	6/24/2022	10:19		1	25.4	106.9	8.75	8.3	623	1.58	4.87																							
27-0019	Nokomis	6/24/2022	10:18		2	25.4	105.0	8.60	8.3	623	1.46	5.13																							
27-0019	Nokomis	6/24/2022	10:17		3	25.3	98.8	8.10	8.2	624	1.44	5.60																							
27-0019	Nokomis	6/24/2022	10:16		4	24.2	42.7	3.57	7.5	635	1.02	4.56					0.051	0.006																	
27-0019	Nokomis	6/24/2022	10:15		5	22.2	2.2	0.19	7.3	646	0.46	3.11																							
27-0019	Nokomis	6/24/2022	10:14		6	19.1	2.3	0.22	7.3	655	0.17	1.20																							
27-0019	Nokomis	6/24/2022	10:13		7	17.2	2.7	0.26	7.2	658	0.13	0.86					0.113	0.043							185										
27-0019	Nokomis	6/24/2022	10:11		8	15.3	3.9	0.38	7.1	690	0.13	1.07																							
27-0019	Nokomis	7/15/2022	9:54	0.80	0	26.0	113.8	9.22	8.6	618	2.88	1.64		33.3	4.16	5.53	0.074	0.004	1.53	1.56	0.015	0.285	97	104	195	5.08		7.80			15	15			
27-0019	Nokomis	7/15/2022	9:53		1	25.8	110.8	9.01	8.6	618	2.96	1.95																							
27-0019	Nokomis	7/15/2022	9:50		2	25.8	104.1	8.47	8.6	618	2.84	2.18																							
27-0019	Nokomis	7/15/2022	9:48		3	25.1	42.5	3.50	7.7	623	2.37	2.04																							
27-0019	Nokomis	7/15/2022	9:46		4	24.3	1.6	0.13	7.4	638	0.67	0.91					0.099	0.005													15	15			
27-0019	Nokomis	7/15/2022	9:44		5	23.6	1.8	0.15	7.5	650	0.18	0.59																							
27-0019	Nokomis	7/15/2022	9:43		6	20.5	1.9	0.17	7.5	662	0.04	0.35																							
27-0019	Nokomis	7/15/2022	9:42		7	17.4	1.8	0.17	7.4	684	0.03	0.35					0.308	0.080							185	2.50					15	15			
27-0019	Nokomis	7/28/2022	9:26	0.46	0	24.2	99.6	8.34	8.5	616	9.50	1.98		85.6	9.83		0.086	0.004		1.12					130										
27-0019	Nokomis	7/28/2022	9:24		1	24.2	98.6	8.26	8.5	615	9.98	2.12																							
27-0019	Nokomis	7/28/2022	9:22		2	24.2	97.2	8.15	8.5	615	9.29	2.25																							
27-0019	Nokomis	7/28/2022	9:21		3	24.2	95.3	7.98	8.5	615	9.33	2.28																							
27-0019	Nokomis	7/28/2022	9:19		4	24.1	93.1	7.80	8.5	616	9.41	2.23					0.089	0.003																	
27-0019	Nokomis	7/28/2022	9:18		5	24.1	91.6	7.68	8.4	616	9.46	2.21																							
27-0019	Nokomis	7/28/2022	9:17		6	23.9	85.4	7.19	8.4	617	9.33	2.19																							
27-0019	Nokomis	7/28/2022	9:15		7	17.3	2.4	0.23	7.1	732	2.13	0.97					0.084	0.003							130										
27-0019	Nokomis	8/11/2022	10:28	0.30	0	25.8	180.9	14.70	9.1	577	8.53	3.19		72.8	2.66	8.22	0.088	0.005		1.13					155		0.5								
27-0019	Nokomis	8/11/2022	10:27		1	25.1	89.2	7.34	8.3	599	10.86	2.73																							
27-0019	Nokomis	8/11/2022	10:25		2	24.7	66.2	5.49	8.0	603	10.30	2.77																							
27-0019	Nokomis	8/11/2022	10:24		3	24.3	17.9	1.50	7.6	612	8.27	2.12																							
27-0019	Nokomis	8/11/2022	10:23		4	24.1	1.9	0.16	7.5	615	8.56	2.05					0.100	0.005																	
27-0019	Nokomis	8/11/2022	10:22		5	24.1	2.0	0.17	7.5	616	8.71	2.02																							
27-0019	Nokomis	8/11/2022	10:21		6	24.0	2.3	0.19	7.4	614	8.56	1.93																							
27-0019	Nokomis	8/11/2022	10:21		7	20.3	4.4	0.40	7.1	737	3.87	1.33					0.131	0.005							140										
27-0019	Nokomis	8/26/2022	11:04	0.42	0	25.0	125	10.31	8.9	590	5.35	2.08		58.0	4.13		0.096	0.008		1.40					170										
27-0019	Nokomis	8/26/2022	11:03		1	24.1	114.5	9.60	8.8	590	7.32	2.69																							
27-0019	Nokomis	8/26/2022	11:02		2	23.9	80.3	6.77	8.5	592	6.16	2.45																							
27-0019	Nokomis	8/26/2022	11:00		3	23.2	1.3	0.11	7.5	613	4.02	1.37																							
27-0019	Nokomis	8/26/2022	10:59		4	23.1	1.5	0.13	7.5	617	3.58	1.19					0.134	0.019																	

Lake ID	Lake Name	Date MM/DD/YYYY	Time HH:MM	Secchi meters	Depth meters	Temp °C	%DO	DO mg/L	pH units	SpCond µS/cm	Phycocyanin RFU	Chlorophyll-a RFU	TurbSC NTU	Chl-a mg/M3	Pheo-a mg/M3	Silica mg/L	TP mg/L	SRP mg/L	TKN mg/L	TN mg/L	NO3NO2 mg/L	NH3 mg/L	Alk mg/L	Hard mg/L	Cl mg/L	SO4 mg/L	E. Coli mpn/100 mL	DOC mg/L	Fe µg/L	DFe µg/L	Al µg/L	DAl µg/L	Microcystin µg/L	Cylindro. µg/L	Anatoxin-a µg/L
27-0019	Nokomis	8/26/2022	10:58		5	23.0	1.6	0.13	7.4	618	3.39	1.20																							
27-0019	Nokomis	8/26/2022	10:57		6	22.9	1.8	0.15	7.4	618	2.87	1.11																							
27-0019	Nokomis	8/26/2022	10:55		7	21.6	2.2	0.19	7.1	668	1.39	0.71					0.230	0.055							155										
27-0019	Nokomis	9/14/2022	10:28	0.35	0	22.3	123.9	10.76	8.9	602	9.91	2.99		100	2.15	8.79	0.104	0.002		1.62					140										
27-0019	Nokomis	9/14/2022	10:27		1	22.0	94.1	8.21	8.6	604	10.52	3.08																							
27-0019	Nokomis	9/14/2022	10:26		2	21.9	83.7	7.32	8.5	604	9.98	2.94																							
27-0019	Nokomis	9/14/2022	10:25		3	21.8	67.6	5.92	8.2	605	9.73	2.76																							
27-0019	Nokomis	9/14/2022	10:24		4	21.7	36.5	3.21	7.7	608	9.00	2.56					0.111	0.004																	
27-0019	Nokomis	9/14/2022	10:21		5	21.7	20.2	1.77	7.6	611	8.30	2.31																							
27-0019	Nokomis	9/14/2022	10:20		6	21.7	21.5	1.89	7.5	610	8.32	2.47																							
27-0019	Nokomis	9/14/2022	10:19		7	21.6	31.2	2.74	7.6	608	9.22	2.57					0.126	0.002							170										
27-0019	Nokomis	9/29/2022	8:51	0.34	0	16.7	68.9	6.69	8.1	622	11.93	2.76		67.3	4.84		0.115	0.003		1.63					135										
27-0019	Nokomis	9/29/2022	8:51		1	16.7	68.7	6.67	8.1	622	11.22	2.68																							
27-0019	Nokomis	9/29/2022	8:50		2	16.7	68.8	6.68	8.1	622	10.88	2.80																							
27-0019	Nokomis	9/29/2022	8:48		3	16.7	69.1	6.70	8.1	622	10.84	2.41																							
27-0019	Nokomis	9/29/2022	8:47		4	16.7	70.3	6.82	8.1	622	10.58	2.81					0.133	0.004																	
27-0019	Nokomis	9/29/2022	8:46		5	16.6	71.6	6.96	8.1	622	10.84	2.80																							
27-0019	Nokomis	9/29/2022	8:45		6	16.6	72.1	7.02	8.1	622	10.91	2.82																							
27-0019	Nokomis	9/29/2022	8:44		7	16.5	73.0	7.11	8.2	622	10.98	2.84					0.131	0.003							130										
27-0019	Nokomis	10/13/2022	8:47	0.50	0	14.4	68.4	6.97	7.9	641	11.82	2.12		53.1	3.59	10.5	0.114	0.002	1.56	1.94	0.290	0.573	104	111	145	2.50		8.50			15	15			
27-0019	Nokomis	10/13/2022	8:46		1	14.4	68.5	6.99	7.9	641	11.14	1.97																							
27-0019	Nokomis	10/13/2022	8:45		2	14.4	68.2	6.96	7.9	641	10.96	2.12																							
27-0019	Nokomis	10/13/2022	8:44		3	14.4	67.8	6.92	7.9	641	10.76	2.03																							
27-0019	Nokomis	10/13/2022	8:43		4	14.4	67.6	6.90	7.9	641	10.65	2.09					0.117	0.005													15	15			
27-0019	Nokomis	10/13/2022	8:43		5	14.4	67.4	6.88	7.9	641	10.71	2.21																							
27-0019	Nokomis	10/13/2022	8:42		6	14.3	67.4	6.88	7.9	641	10.68	2.05																							
27-0019	Nokomis	10/13/2022	8:41		7	14.2	67.3	6.89	7.8	641	10.72	2.15					0.127	0.004							157	2.50					15	15			
27-0014	Powderhorn	2/9/2022	10:00		0									7.87	4.03	1.04	0.063	0.015	1.26	1.34	0.069	0.646	50	49	137	7.43			311	231			<1.5		
27-0014	Powderhorn	2/9/2022	10:00		4												0.068	0.027																	
27-0014	Powderhorn	2/9/2022	10:00		6												0.237	0.049							255	7.50									
27-0014	Powderhorn	4/21/2022	10:12	0.70	0	6.1	90.5	11.25	7.8	748			2.0	18.6	7.88	1.94	0.126	0.013	1.35	1.61	0.080	0.430	44	41	215	7.11		7.80	542	284			<1.5		
27-0014	Powderhorn	4/21/2022	10:11		1	5.9	89.6	11.20	7.8	734			1.8																						
27-0014	Powderhorn	4/21/2022	10:11		2	5.8	89.3	11.17	7.8	728			1.4																						
27-0014	Powderhorn	4/21/2022	10:10		3	5.8	87.8	11.00	7.8	732			0.7																						
27-0014	Powderhorn	4/21/2022	10:09		4	5.5	77.1	9.73	7.7	801			0.0				0.126	0.015											497	283					
27-0014	Powderhorn	4/21/2022	10:08		5	5.3	56.7	7.19	7.6	895			0.0																						
27-0014	Powderhorn	4/21/2022	10:06		6	4.9	0.0	0.00	7.2	2088			0.0				0.206	0.038							280	7.38			907	516					
27-0014	Powderhorn	5/11/2022	10:03	0.77	0	15.8	114.1	11.27	7.8	749	0.85	10.85		35.6	24.8	0.795	0.117	0.013	1.25	1.39	0.149	0.343	40	84	215	6.49		8.50	540	283			<1.5		
27-0014	Powderhorn	5/11/2022	10:03		1	15.8	114.0	11.26	7.8	749	0.80	12.66																							
27-0014	Powderhorn	5/11/2022	10:03		2	15.8	113.8	11.24	7.8	749	0.80	11.55																							
27-0014	Powderhorn	5/11/2022	10:02		3	15.8	113.7	11.24	7.8	749	0.91	12.34																							
27-0014	Powderhorn	5/11/2022	10:02		4	15.8	113.5	11.22	7.8	749	0.88	13.45					0.124	0.013											553	299					
27-0014	Powderhorn	5/11/2022	10:01		5	15.8	112.2	11.10	7.7	749	0.89	13.43																							
27-0014	Powderhorn	5/11/2022	10:01		6	15.8	111.8	11.05	7.7	749	1.06	13.61					0.119	0.013							200	6.61			516	273					
27-0014	Powderhorn	5/26/2022	9:48	0.67	0	17.1	78.6	7.57	7.1	648	1.49	16.73		30.6	17.3		0.130	0.004		0.809					175								<1.5		
27-0014	Powderhorn	5/26/2022	9:47		1	17.1	78.4	7.55	7.1	648	1.40	16.28																							
27-0014	Powderhorn	5/26/2022	9:45		2	17.1	78.7	7.58	7.1	648	1.46	14.24																							
27-0014	Powderhorn	5/26/2022	9:44		3	17.1	79.0	7.62	7.1	648	1.51	15.41																							
27-0014	Powderhorn	5/26/2022	9:43		4	17.0	79.7	7.68	7.1	648	1.46	15.87					0.128	0.004																	
27-0014	Powderhorn	5/26/2022	9:42		5	17.0	79.5	7.66	7.2	648	1.52	16.95																							
27-0014	Powderhorn	5/26/2022	9:41		6	17.0	80.9	7.80	7.3	648	1.50	16.82					0.127	0.004							185										
27-0014	Powderhorn	6/7/2022	10:01	0.40	0	20.9	74.8	6.66	7.1	631	1.44	18.99		40.5	24.2	2.56	0.158	0.006		1.26					210				538	59			<1.5		
27-0014	Powderhorn	6/7/2022	10:01		1	20.9	74.9	6.67	7.1	631	1.53	25.21																							
27-0014	Powderhorn	6/7/2022	10:00		2	20.9	74.9	6.67	7.1	631	1.57	20.59																							
27-0014	Powderhorn	6/7/2022	10:00		3	20.9	74.8	6.66	7.1	631	1.54	22.66																							
27-0014	Powderhorn	6/7/2022	9:59		4	20.9	74.6	6.64	7.2	631	1.65	26.54					0.162	0.008											509	65					
27-0014	Powderhorn	6/7/2022	9:59		5	20.9	74.9	6.67	7.2	631	1.57	23.06																							
27-0014	Powderhorn	6/7/2022	9:59		6	20.9	76.1	6.78	7.3	631	1.58	18.99					0.168	0.007							185				386	60					
27-0014	Powderhorn	6/21/2022	10:50	0.41	0	26.5	107.5	8.62	7.6	643	2.32	22.90		46.5	23.3		0.190	0.007		1.20					185								<1.5		
27-0014	Powderhorn	6/21/2022	10:49		1	26.5	107.4	8.62	7.6	643	2.29	25.10																							
27-0014	Powderhorn	6/21/2022	10:48		2	26.5	104.3	8.37	7.6	643	2.31	24.27																							
27-0014	Powderhorn	6/21/2022	10:48		3	26.5	99.6	8.00	7.5	643	2.24	25.04																							
27-0014	Powderhorn	6/21/2022	10:46		4	26.3	86.1	6.94	7.3	643	2.77	28.42					0.203	0.007																	
27-0014	Powderhorn	6/21/2022	10:46		5	26.2	82.1	6.63	7.3	644	2.34	27.69																							
27-0014	Powderhorn	6/21/2022	10:44		6	26.0	64.7	5.24	7.2	644	4.17	38.57					0.216	0.007							185										
27-0014	Powderhorn	7/11/2022	10:50	0.35	0	26.5	107.5	8.62	7.6	643	2.32	22.90		58.9	28.7	3.06	0.197	0.018	1.76	2.01	0.015	0.285	43	46	180	6.19		7.70	461	125			<1.5	<0.5	<1.5
27-0014	Powderhorn	7/11/2022	10:49		1	26.5	107.4	8.62	7.6	643	2.29	25.10																							
27-0014	Powderhorn	7/11/2022	10:48		2	26.5	104.3	8.37	7.6	643	2.31	24.27																							
27-0014	Powderhorn	7/11/2022	10:48		3	26.5	99.6	8.00	7.5	643	2.24	25.04																							
27-0014	Powderhorn	7/11/2022	10:46		4	26.3	86.1	6.94	7.3	643	2.77	28.42					0.203	0.019											442	124					
27-0014	Powderhorn	7/11/2022	10:46		5	26.2	82.1	6.63	7.3	644	2.34	27.69																							
27-0014	Powderhorn	7/11/2022	10:43		6	26.0	74.7	6.04	7.5	644	3.84	41.51					0.205	0.020							180	6.32			621	125					
27-0014	Powderhorn	7/26/2022	9:49	0.30	0	25.6	55.9	4.55	7.1	667	2.52	10.08		45.8	23.8		0.245	0.037		1.64					215								6.02	<0.5	<0.15
27-0014	Powderhorn	7/26/2022	9:48		1	25.7	55.6	4.53	7.1	667	2.29	9.99																							
27-0014	Powderhorn	7/26/2022	9:48		2	25.7	55.5	4.53	7.1	667	2.31	12.73																							
27-0014	Powderhorn	7/26/2022	9:46		3	25.7	55.2	4.50	7.1	667	2.28	10.44																							
27-0014	Powderhorn	7/26/2022	9:45		4	25.6	54.8	4.47	7.1	667	2.34	14.35					0.267	0.049																	
27-0014	Powderhorn	7/26/2022	9:45		5	25.6	53.6	4.38	7.0	667	2.31	11.71																							
27-0014	Powderhorn	7/26/2022	9:44		6	25.6	53.6	4.38	7.0	667	2.39	12.52					0.264	0.050							205										
27-0014	Powderhorn	8/9/2022	10:18	0.32	0	24.7	69.2	5.74	7.2	628	2.53	5.15		77.4	27.4	3.43	0.258	0.037		1.91					190		387		685	143			2.22	<0.5	<0.15
27-0014	Powderhorn	8/9/2022	10:17		1	24.7	68.9	5.71	7.2	628	1.68	5.22																							
27-0014	Powderhorn	8/9/2022	10:16		2	24.7	68.6	5.69	7.2	628	1.98	6.26																							
27-0014	Powderhorn	8/9/2022	10:15		3	24.7	68.7	5.70	7.2	628	1.70	5.56																							
27-0014	Powderhorn	8/9/2022	10:15		4	24.7	68.6	5.69	7.2	628	1.81	6.69					0.255	0.041											603	133					
27-0014	Powderhorn	8/9/2022	10:14		5	24.7	69.0	5.72	7.3	628	1.65	6.02																							
27-0014	Powderhorn	8/9/2022	10:13		6	24.6	68.3	5.68	7.3	628	1.17	6.43					0.249	0.041							180				783	151					
27-0014	Powderhorn	8/24/2022	9:58	0.39	0	24.3	69.6	5.82	7.2	580	3.52	10.48		69.7	27.9		0.225	0.023		1.81					170								4.63	<0.5	<0.15
27-0014	Powderhorn	8/24/2022	9:57		1	24.3	69.4	5.80	7.2	580	3.31	9.90																							
27-0014	Powderhorn	8/24/2022	9:56		2	24.3	69.2	5.79	7.2	580	3.16	9.36																							
27-0014	Powderhorn	8/24/2022	9:55		3	24.3	68.0	5.69	7.2	580	3.06	10.76																							
27-0014	Powderhorn	8/24/2022	9:54		4	24.3	68.3	5.71	7.2	580	3.06	11.66					0.235	0.027																	
27-0014	Powderhorn	8/24/2022	9:53		5	24.2	65.1	5.45	7.2	580	2.96	12.11																							
27-0014	Powderhorn	8/24/2022	9:52		6	24.2	68.7	5.75	7.2	580	2.86	11.51					0.236	0.027							170										
27-0014	Powderhorn	9/19/2022	10:33	0.41	0	21.6	111.8	9.84	8.4	571	5.26	8.18		86.7	13.9	2.86	0.166	0.006		1.62					173				402	142.5			0.471	0.157	<0.15
27-0014	Powderhorn	9/19/2022	10:32		1	21.6	111.3	9.80	8.3	571	4.88	7.81																							
27-0014	Powderhorn	9/19/2022	10:31		2	21.6	111.3	9.80	8.4	571	4.83	8.29																							
27-0014	Powderhorn	9/19/2022	10:30		3	21.6	111.1	9.78	8.3	571	4.78	11.69																							
27-0014	Powderhorn	9/19/2022	10:30		4	21.6	110.9	9.76	8.3	571	4.73	8.75					0.165	0.006											372	135					
27-0014	Powderhorn	9/19/2022	10:29		5	21.6	110.3	9.71	8.3	571	4.77	10.03																							
27-0014	Powderhorn	9/19/2022	10:28		6	21.5	106.5	9.39	8.2	571	4.20	9.93					0.162	0.007							175				423	130					
27-0014	Powderhorn	9/27/2022	9:45	0.34	0	16.9	104.0	10.07	8.7	568	7.68	8.64		114	16.7		0.189	0.002		1.70					175								0.469	<0.05	<0.15

Lake ID	Lake Name	Date MM/DD/YYYY	Time HH:MM	Secchi meters	Depth meters	Temp °C	%DO	DO mg/L	pH units	SpCond µS/cm	Phycocyanin RFU	Chlorophyll-a RFU	TurbSC NTU	Chl-a mg/M3	Pheo-a mg/M3	Silica mg/L	TP mg/L	SRP mg/L	TKN mg/L	TN mg/L	NO3NO2 mg/L	NH3 mg/L	Alk mg/L	Hard mg/L	Cl mg/L	SO4 mg/L	E. Coli mpn/100 mL	DOC mg/L	Fe µg/L	DFe µg/L	Al µg/L	DAl µg/L	Microcystin µg/L	Cylindro. µg/L	Anatoxin-a µg/L
27-0014	Powderhorn	9/27/2022	9:44		1	16.9	103.5	10.01	8.7	568	7.66	8.31																							
27-0014	Powderhorn	9/27/2022	9:44		2	16.9	103.4	10.00	8.7	568	7.43	9.37																							
27-0014	Powderhorn	9/27/2022	9:43		3	16.9	103.4	10.01	8.7	568	7.54	8.19																							
27-0014	Powderhorn	9/27/2022	9:42		4	16.9	103.3	9.99	8.7	568	7.50	9.21					0.191	0.004																	
27-0014	Powderhorn	9/27/2022	9:42		5	16.8	102.8	9.96	8.7	568	7.06	8.86																							
27-0014	Powderhorn	9/27/2022	9:41		6	16.7	101.8	9.88	8.7	568	7.01	9.45					0.191	0.004							170										
27-0014	Powderhorn	10/12/2022	9:50	0.40	0	15.2	102.8	10.31	8.7	575	4.70	7.80		61.8	9.98	2.75	0.154	0.008	1.40	1.85	0.333	0.413	45	46	165	6.27		12.0	398	161			0.442		
27-0014	Powderhorn	10/12/2022	9:50		1	15.1	102.1	10.25	8.7	575	4.80	6.63																							
27-0014	Powderhorn	10/12/2022	9:49		2	15.1	101.7	10.21	8.7	575	4.71	7.50																							
27-0014	Powderhorn	10/12/2022	9:48		3	15.1	101.3	10.18	8.7	575	4.69	8.86																							
27-0014	Powderhorn	10/12/2022	9:48		4	15.1	100.9	10.14	8.6	575	4.70	7.62					0.164	0.007											360	167					
27-0014	Powderhorn	10/12/2022	9:47		5	15.0	100.4	10.10	8.6	575	4.66	9.04																							
27-0014	Powderhorn	10/12/2022	9:47		6	15.0	100.3	10.09	8.6	574	7.65	14.82					0.158	0.006							175	6.32			407	257					
27-0037	Wirth	2/9/2022	11:25		0									1.64	0.763	11.0	0.027	0.016	0.626	0.696	0.075	0.283	191	292	200	13.8									
27-0037	Wirth	2/9/2022	11:25		4												0.029	0.014																	
27-0037	Wirth	2/9/2022	11:25		7												0.031	0.018							200	16.4									
27-0037	Wirth	4/19/2022	13:03	1.51	0	6.1	94.4	11.82	8.1	891			2.2	17.3	3.22	9.16	0.052	0.005	0.503	0.562	0.056	0.125	196	290	162	13.7									
27-0037	Wirth	4/19/2022	13:02		1	5.5	93.0	11.83	8.0	890			2.2																						
27-0037	Wirth	4/19/2022	13:01		2	5.2	90.5	11.61	7.9	889			2.0																						
27-0037	Wirth	4/19/2022	13:00		3	5.1	89.4	11.47	7.9	889			1.9																						
27-0037	Wirth	4/19/2022	12:59		4	5.1	88.0	11.32	7.8	890			1.8				0.045	0.005																	
27-0037	Wirth	4/19/2022	12:57		5	5.0	87.4	11.25	7.7	889			1.6																						
27-0037	Wirth	4/19/2022	12:56		6	5.1	87.1	11.19	7.6	891			1.4																						
27-0037	Wirth	4/19/2022	12:55		7	5.1	86.5	11.10	7.4	887			1.1				0.037	0.005							165	14.2									
27-0037	Wirth	5/11/2022	12:03	1.86	0	16.8	111.5	10.79	8.2	893	0.05	1.84		4.97	1.65	4.62	0.031	0.007	0.250	0.546	0.015	0.125	186	276	175	14.4									
27-0037	Wirth	5/11/2022	12:02		1	16.5	111.8	10.88	8.2	890	0.06	2.43																							
27-0037	Wirth	5/11/2022	12:01		2	15.1	112.6	11.30	8.1	890	0.13	3.48																							
27-0037	Wirth	5/11/2022	12:00		3	11.1	135.9	14.90	8.3	876	0.38	9.18																							
27-0037	Wirth	5/11/2022	11:59		4	9.6	129.3	14.70	8.3	884	1.36	24.36					0.038	0.007																	
27-0037	Wirth	5/11/2022	11:58		5	8.6	63.6	7.41	7.7	898	0.52	10.10																							
27-0037	Wirth	5/11/2022	11:56		6	7.7	27.7	3.29	7.4	911	0.31	3.73																							
27-0037	Wirth	5/11/2022	11:54		7	7.4	6.9	0.83	7.3	925	0.22	2.96					0.047	0.008							165	13.5									
27-0037	Wirth	5/26/2022	11:38	3.74	0	16.1	96.8	9.50	8.0	855	0.01	0.81		2.78	1.50		0.045	0.004		0.250					160										
27-0037	Wirth	5/26/2022	11:37		1	16.1	96.4	9.46	8.0	855	0.01	1.05																							
27-0037	Wirth	5/26/2022	11:36		2	16.1	95.9	9.42	8.0	856	0.00	1.08																							
27-0037	Wirth	5/26/2022	11:35		3	15.6	99.5	9.87	8.0	862	0.05	1.24																							
27-0037	Wirth	5/26/2022	11:34		4	11.9	112.3	12.09	8.1	885	0.00	1.05					0.037	0.006																	
27-0037	Wirth	5/26/2022	11:33		5	9.4	35.2	4.02	7.4	898	0.04	1.66																							
27-0037	Wirth	5/26/2022	11:31		6	8.2	3.4	0.39	7.3	917	0.37	3.22																							
27-0037	Wirth	5/26/2022	11:30		7	7.6	5.3	0.64	7.2	956	0.88	1.24					0.083	0.008							175										
27-0037	Wirth	6/8/2022	10:41	4.12	0	21.0	131.7	11.72	8.3	823	0.00	0.29		1.79	0.613	1.16	0.020	0.004		0.250					225										
27-0037	Wirth	6/8/2022	10:40		1	20.5	130.7	11.74	8.3	823	0.00	0.43																							
27-0037	Wirth	6/8/2022	10:39		2	20.3	124.2	11.19	8.2	828	0.00	0.63																							
27-0037	Wirth	6/8/2022	10:38		3	18.2	113.7	10.71	7.9	858	0.00	0.98																							
27-0037	Wirth	6/8/2022	10:37		4	13.4	106.5	11.09	8.0	893	0.46	13.02					0.052	0.004																	
27-0037	Wirth	6/8/2022	10:35		5	10.4	6.6	0.73	7.3	907	0.67	13.85																							
27-0037	Wirth	6/8/2022	10:34		6	9.0	3.2	0.37	7.3	924	2.98	10.48																							
27-0037	Wirth	6/8/2022	10:33		7	7.9	3.0	0.35	7.2	968	0.96	1.82					0.101	0.004							205										
27-0037	Wirth	6/22/2022	9:38	4.95	0	26.1	127.2	10.29	8.5	787	0.04	0.29		1.28	0.662		0.015	0.005		0.250					170										
27-0037	Wirth	6/22/2022	9:37		1	26.0	126.2	10.22	8.5	786	0.07	0.34																							
27-0037	Wirth	6/22/2022	9:37		2	25.8	123.9	10.07	8.3	788	0.02	0.65																							
27-0037	Wirth	6/22/2022	9:36		3	21.0	124.7	11.10	7.8	852	0.11	4.15																							
27-0037	Wirth	6/22/2022	9:35		4	15.6	107.0	10.62	7.8	891	0.08	3.89					0.028	0.003																	
27-0037	Wirth	6/22/2022	9:34		5	11.8	78.2	8.44	7.6	909	0.51	16.76																							
27-0037	Wirth	6/22/2022	9:32		6	9.6	5.1	0.58	7.2	928	7.94	32.68																							
27-0037	Wirth	6/22/2022	9:31		7	8.2	5.4	0.63	7.1	1000	0.70	3.58					0.168	0.005							180										
27-0037	Wirth	7/11/2022	11:59	3.24	0	26.5	121.6	9.75	8.6	768	0.03	0.40		4.49	1.23	0.911	0.015	0.002	0.707	0.713	0.015	0.125	108	216	195	13.2									
27-0037	Wirth	7/11/2022	11:58		1	26.5	122.7	9.85	8.6	768	0.04	0.63																							
27-0037	Wirth	7/11/2022	11:57		2	26.3	124.6	10.04	8.5	767	0.03	0.84																							
27-0037	Wirth	7/11/2022	11:56		3	23.8	144.9	12.21	8.2	821	0.84	10.01																							
27-0037	Wirth	7/11/2022	11:56		4	19.1	138.9	12.83	8.0	878	0.34	7.12					0.048	0.004																	
27-0037	Wirth	7/11/2022	11:55		5	14.0	106.3	10.93	8.0	901	1.82	19.15																							
27-0037	Wirth	7/11/2022	11:53		6	10.4	3.5	0.39	7.2	930	6.91	19.08																							
27-0037	Wirth	7/11/2022	11:52		7	8.7	4.6	0.53	7.0	997	0.44	2.16					0.153	0.004							165	9.33									
27-0037	Wirth	7/26/2022	11:37	3.29	0	25.2	101.8	8.37	8.5	787	0.26	0.66		8.89	1.52		0.020	0.002		0.526					210										
27-0037	Wirth	7/26/2022	11:36		1	25.2	101.1	8.31	8.5	787	0.26	0.67																							
27-0037	Wirth	7/26/2022	11:36		2	25.2	99.4	8.17	8.5	787	0.26	0.68																							
27-0037	Wirth	7/26/2022	11:35		3	25.0	85.3	7.04	8.5	787	0.23	0.75																							
27-0037	Wirth	7/26/2022	11:34		4	20.0	74.4	6.74	7.7	894	1.58	2.50					0.023	0.002																	
27-0037	Wirth	7/26/2022	11:32		5	15.6	2.8	0.28	7.4	915	6.84	22.52																							
27-0037	Wirth	7/26/2022	11:32		6	10.8	3.2	0.35	7.3	953	1.54	4.13																							
27-0037	Wirth	7/26/2022	11:31		7	9.0	4.7	0.54	7.1	1068	0.32	1.44					0.129	0.022							200										
27-0037	Wirth	8/9/2022	12:05	3.40	0	25.0	94.3	7.77	8.4	788	0.07	0.00		10.1	1.14	2.85	0.027	0.002		0.250					215		1								
27-0037	Wirth	8/9/2022	12:04		1	24.9	93.7	7.74	8.4	788	0.08	0.00																							
27-0037	Wirth	8/9/2022	12:03		2	24.7	92.3	7.65	8.4	788	0.11	0.00																							
27-0037	Wirth	8/9/2022	12:01		3	24.0	21.6	1.82	7.7	793	0.03	0.00																							
27-0037	Wirth	8/9/2022	12:00		4	21.4	5.7	0.50	7.4	888	0.31	1.84					0.029	0.002																	
27-0037	Wirth	8/9/2022	11:59		5	16.9	4.3	0.42	7.4	906	2.71	4.16																							
27-0037	Wirth	8/9/2022	11:58		6	11.7	3.0	0.33	7.2	953	0.73	0.32																							
27-0037	Wirth	8/9/2022	11:57		7	9.6	4.3	0.49	7.0	1088	0.28	0.00					0.346	0.026							220										
27-0037	Wirth	8/23/2022	11:52	2.56	0	24.8	123.4	10.22	8.6	771	0.15	0.80		6.25	0.250		0.017	0.005		0.250					170										
27-0037	Wirth	8/23/2022	11:52		1	24.2	120.5	10.07	8.6	772	0.14	1.08																							
27-0037	Wirth	8/23/2022	11:50		2	23.8	87.4	7.38	8.3	778	0.37	2.24																							
27-0037	Wirth	8/23/2022	11:48		3	23.0	30.9	2.64	7.6	800	0.55	2.84																							
27-0037	Wirth	8/23/2022	11:47		4	21.3	42.7	3.78	7.7	859	3.83	6.36					0.029	0.002																	
27-0037	Wirth	8/23/2022	11:45		5	17.8	2.0	0.19	7.4	909	14.00	35.28																							
27-0037	Wirth	8/23/2022	11:44		6	12.1	1.2	0.13	7.1	960	1.58	1.94																							
27-0037	Wirth	8/23/2022	11:43		7	9.8	1.3	0.15	7.0	1085	2.34	1.63					0.378	0.046							180										
27-0037	Wirth	9/13/2022	9:30	2.30	0	21.7	94.4	8.29	8.4	780	0.51	0.62		11.8	0.993	4.75	0.028	0.003		0.250					175										
27-0037	Wirth	9/13/2022	9:29		1	21.7	92.6	8.13	8.3	780	0.51	0.58																							
27-0037	Wirth	9/13/2022	9:29		2	21.6	85.3	7.49	8.3	779	0.50	0.62																							
27-0037	Wirth	9/13/2022	9:28		3	21.3	44.2	3.91	7.7	793	0.37	0.78																							
27-0037	Wirth	9/13/2022	9:27		4	20.9	9.9	0.88	7.4	844	2.81	1.82					0.030	0.002																	
27-0037	Wirth	9/13/2022	9:27		5	17.7	2.1	0.20	7.1	910	3.33	6.71																							
27-0037	Wirth	9/13/2022	9:26		6	13.8	2.0	0.21	7.0	975	2.38	3.61																							
27-0037	Wirth	9/13/2022	9:24		7	10.8	17.1	1.89	6.8	1113	1.55	1.50					0.525	0.049							180										
27-0037	Wirth	9/26/2022	11:55	1.75	0	18.1	72.4	6.83	8.0	804	0.21	0.38		11.9	1.13		0.029	0.002		0.250					190										
27-0037	Wirth	9/26/2022	11:54		1	18.1	72.5	6.84	8.0	804	0.30	0.49																							
27-0037	Wirth	9/26/2022	11:53		2	18.1	71.8	6.77	8.0	805	0.38	0.56																							
27-0037	Wirth	9/26/2022	11:51		3	18.1	71.8	6.77	8.0	804	0.35	0.53																							
27-0037	Wirth	9/26/2022	11:51		4	18.0	71.6	6.75	8.0	804	0.37	0.53					0.029	0.002																	
27-0037	Wirth	9/26/2022	11:49		5	17.6	24.2	2.30	7.4	844	1.27	1.80																							
27-0037	Wirth	9/26/2022	11:47		6	14.1	2.7	0.28	7.1	974	1.27	2.03																							
27-0037	Wirth	9/26/2022	11:46		7	10.7	2.9	0.32	6.9	1119	0.68	1.13					0.480	0.023							205										
27-0037	Wirth	10/11/2022	10:43	1.75	0	15.1	81.2	8.16	8.0	821	0.31	0.74		10.6	0.824	6.79	0.029	0.004	0.528	0.857	0.264	0.264	146	240	180	11.8									

Lake ID	**Lake Name**	**Date** MM/DD/YYYY	**Time** HH:MM	**Secchi** meters	**Depth** meters	**Temp** °C	**%DO**	**DO** mg/L	**pH** units	**SpCond** µS/cm	**Phycocyanin** RFU	**Chlorophyll-a** RFU	**TurbSC** NTU	**Chl-a** mg/M3	**Pheo-a** mg/M3	**Silica** mg/L	**TP** mg/L	**SRP** mg/L	**TKN** mg/L	**TN** mg/L	**NO3NO2** mg/L	**NH3** mg/L	**Alk** mg/L	**Hard** mg/L	**Cl** mg/L	**SO4** mg/L	**E. Coli** mpn/100 mL	**DOC** mg/L	**Fe** µg/L	**DFe** µg/L	**Al** µg/L	**DAl** µg/L	**Microcystin** µg/L	**Cylindro.** µg/L	**Anatoxin-a** µg/L
27-0037	Wirth	10/11/2022	10:42		1	15.0	81.2	8.16	8.0	820	0.44	0.81																							
27-0037	Wirth	10/11/2022	10:41		2	15.0	80.6	8.11	8.0	820	0.60	0.92																							
27-0037	Wirth	10/11/2022	10:41		3	15.0	79.0	7.95	8.0	820	0.51	0.81																							
27-0037	Wirth	10/11/2022	10:40		4	14.9	70.6	7.12	7.9	821	0.44	0.71					0.027	0.005																	
27-0037	Wirth	10/11/2022	10:39		5	14.6	40.1	4.07	7.6	828	0.17	0.36																							
27-0037	Wirth	10/11/2022	10:38		6	13.9	3.0	0.31	7.2	905	0.93	4.24																							
27-0037	Wirth	10/11/2022	10:37		7	11.2	3.9	0.42	6.9	1130	0.84	2.12					0.120	0.034							185	9.71									

Appendix C

This section contains a table showing the lake and number of stormwater outfalls and maps showing stormwater outfall and lake outlet locations.

Table C-1. Number of stormwater outfalls for all MPRB lakes.

Lake	Number of Stormwater Outfalls
Bde Maka Ska	28
Birch Pond	1
Brownie Lake	4
Cedar Lake	10
Diamond Lake	11
Grass Lake	12
Lake Harriet	24
Lake Hiawatha	7
Lake of the Isles	22
Loring Pond	0
Lake Nokomis	16
Powderhorn Lake	6
Ryan Lake	3
Spring Lake	3
Wirth Lake	5

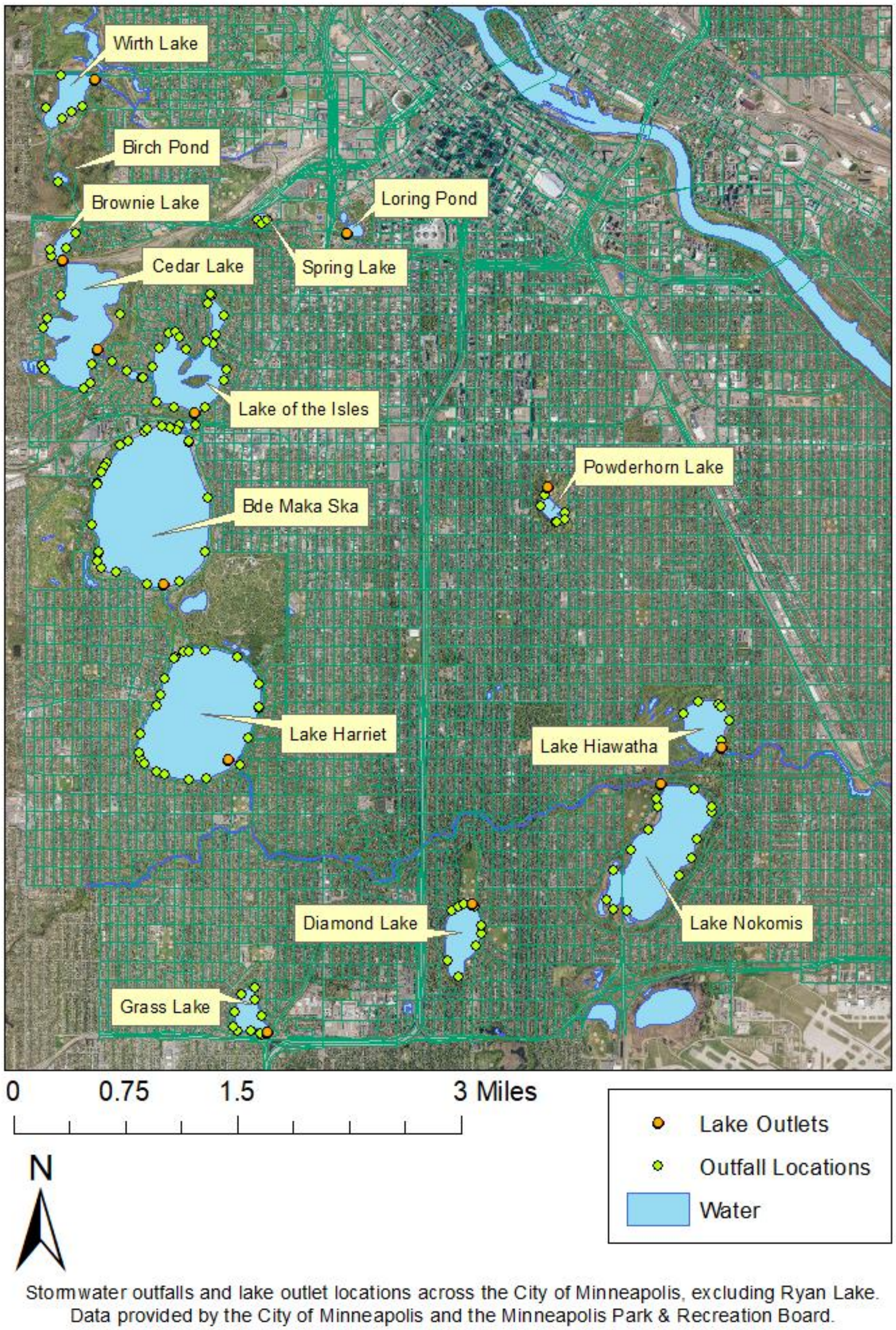


Figure C-1. Map of stormwater outfalls and lake outlet locations across the city of Minneapolis, excluding Ryan Lake.

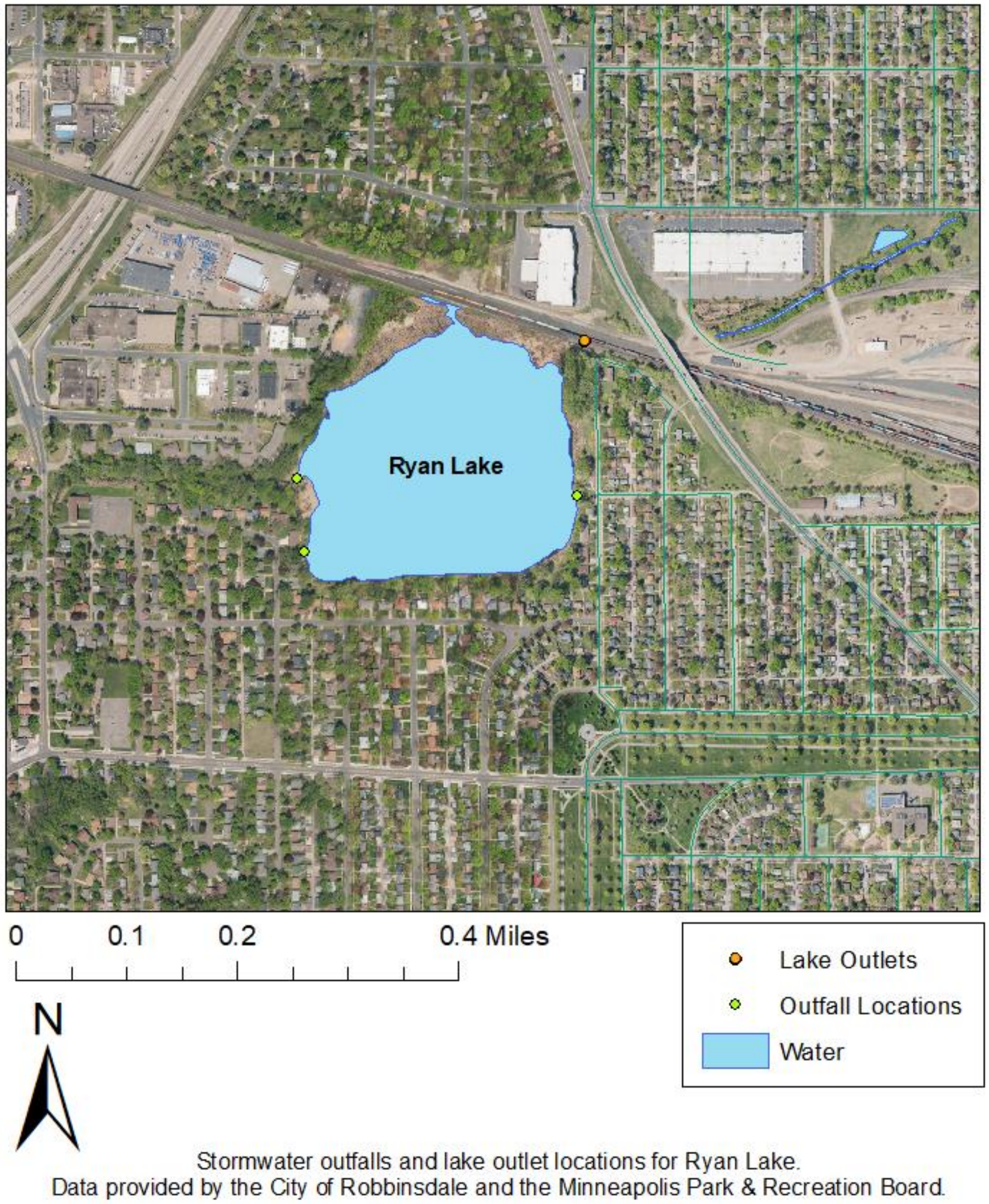


Figure C-2. Map of stormwater outfalls and lake outlet locations for Ryan Lake.

Appendix D

This section contains blue-green algae and cyanotoxin data for 2022.

Lake	Site	Beach	Date	VMI	Sample Type	Microcystin µg/L	Cylindrospermopsin µg/L	Anatoxin-*a* µg/L
Bde Maka Ska	Lake		2/8/2022	1a	Composite	<1.5		
Bde Maka Ska	Beach	Bde Maka Ska Thomas	5/23/2022	1c	Grab	<1.5		
Bde Maka Ska	Beach	Bde Maka Ska 32nd	5/23/2022	1a	Grab	2.33		
Bde Maka Ska	Beach	Bde Maka Ska Main	5/23/2022	1a	Grab	<1.5		
Bde Maka Ska	Beach	Bde Maka Ska Thomas	5/31/2022	1a	Grab	<1.5		
Bde Maka Ska	Beach	Bde Maka Ska 32nd	5/31/2022	1a	Grab	<1.5		
Bde Maka Ska	Beach	Bde Maka Ska Main	5/31/2022	1a	Grab	<1.5		
Bde Maka Ska	Lake		5/24/2022	1a				
Bde Maka Ska	Beach	Bde Maka Ska Thomas	6/6/2022	1a	Grab	<1.5		
Bde Maka Ska	Beach	Bde Maka Ska 32nd	6/6/2022	1a	Grab	<1.5		
Bde Maka Ska	Beach	Bde Maka Ska Main	6/6/2022	1a	Grab	<1.5		
Bde Maka Ska	Lake		6/6/2022	1a				
Bde Maka Ska	Beach	Bde Maka Ska Thomas	6/14/2022	1a	Grab	<1.5		
Bde Maka Ska	Beach	Bde Maka Ska 32nd	6/14/2022	1a	Grab	<1.5		
Bde Maka Ska	Beach	Bde Maka Ska Main	6/14/2022	1a	Grab	<1.5		
Bde Maka Ska	Beach	Bde Maka Ska Thomas	6/21/2022	1d	Grab	<1.5		
Bde Maka Ska	Beach	Bde Maka Ska 32nd	6/21/2022	1a	Grab	<1.5		
Bde Maka Ska	Beach	Bde Maka Ska Main	6/21/2022	1a	Grab	<1.5		
Bde Maka Ska	Beach	Bde Maka Ska Thomas	6/27/2022	1a	Grab	<1.5		
Bde Maka Ska	Beach	Bde Maka Ska 32nd	6/27/2022	2	Grab	<1.5		
Bde Maka Ska	Beach	Bde Maka Ska Main	6/27/2022	2	Grab	<1.5		
Bde Maka Ska	Lake		6/23/2022	1a				
Bde Maka Ska	Beach	Bde Maka Ska Thomas	7/5/2022	1a	Grab	<1.5	<0.5	<1.5
Bde Maka Ska	Beach	Bde Maka Ska 32nd	7/5/2022	1a	Grab	<1.5	<0.5	<1.5
Bde Maka Ska	Beach	Bde Maka Ska Main	7/5/2022	1a	Grab	<1.5	<0.5	<1.5
Bde Maka Ska	Beach	Bde Maka Ska Thomas	7/11/2022	1a	Grab	<1.5	<0.5	<1.5
Bde Maka Ska	Beach	Bde Maka Ska 32nd	7/11/2022	1a	Grab	<1.5	<0.5	<1.5
Bde Maka Ska	Beach	Bde Maka Ska Main	7/11/2022	1a	Grab	<1.5	<0.5	<1.5
Bde Maka Ska	Lake		7/14/2022	1d				
Bde Maka Ska	Beach	Bde Maka Ska Thomas	7/18/2022	1a	Grab	<0.15	<0.05	<0.15
Bde Maka Ska	Beach	Bde Maka Ska 32nd	7/18/2022	1a	Grab	<0.15	<0.05	<0.15
Bde Maka Ska	Beach	Bde Maka Ska Main	7/18/2022	1a	Grab	<0.15	<0.05	<0.15
Bde Maka Ska	Beach	Bde Maka Ska 32nd	7/20/2022	1a				

Lake	Site	Beach	Date	VMI	Sample Type	Microcystin µg/L	Cylindrospermopsin µg/L	Anatoxin-*a* µg/L
Bde Maka Ska	Beach	Bde Maka Ska Thomas	7/25/2022	1a	Grab	<0.15	<0.05	<0.15
Bde Maka Ska	Beach	Bde Maka Ska 32nd	7/25/2022	1a	Grab	<0.15	<0.05	<0.15
Bde Maka Ska	Beach	Bde Maka Ska Main	7/25/2022	1a	Grab	<0.15	<0.05	<0.15
Bde Maka Ska	Lake		7/27/2022	1a				
Bde Maka Ska	Beach	Bde Maka Ska Thomas	8/1/2022	1a	Grab	<0.15	<0.05	<0.15
Bde Maka Ska	Beach	Bde Maka Ska 32nd	8/1/2022	1a	Grab	<0.15	<0.05	<0.15
Bde Maka Ska	Beach	Bde Maka Ska Main	8/1/2022	1a	Grab	<0.15	<0.05	<0.15
Bde Maka Ska	Beach	Bde Maka Ska Thomas	8/8/2022	1a	Grab	<0.15	<0.05	<0.15
Bde Maka Ska	Beach	Bde Maka Ska 32nd	8/8/2022	1a	Grab	<0.15	<0.05	<0.15
Bde Maka Ska	Beach	Bde Maka Ska Main	8/8/2022	1a	Grab	0.179	<0.05	0.256
Bde Maka Ska	Lake		8/10/2022	1a				
Bde Maka Ska	Beach	Bde Maka Ska Thomas	8/15/2022	1a	Grab	<0.15	<0.05	<0.15
Bde Maka Ska	Beach	Bde Maka Ska 32nd	8/15/2022	1a	Grab	<0.15	<0.05	<0.15
Bde Maka Ska	Beach	Bde Maka Ska Main	8/15/2022	1a	Grab	<0.15	<0.05	<0.15
Bde Maka Ska	Beach	Bde Maka Ska Thomas	8/22/2022	1a	Grab	<0.15	<0.05	<0.15
Bde Maka Ska	Beach	Bde Maka Ska 32nd	8/22/2022	1a	Grab	0.178	<0.05	<0.15
Bde Maka Ska	Beach	Bde Maka Ska Main	8/22/2022	1a	Grab	0.162	<0.05	<0.15
Bde Maka Ska	Beach	Bde Maka Ska 32nd	8/24/2022	1a				
Bde Maka Ska	Lake		8/25/2022	1a				
Bde Maka Ska	Beach	Bde Maka Ska Thomas	8/29/2022	1a	Grab	0.322	<0.05	<0.15
Bde Maka Ska	Beach	Bde Maka Ska 32nd	8/29/2022	1a	Grab	<0.15	0.062	<0.15
Bde Maka Ska	Beach	Bde Maka Ska Main	8/29/2022	1a	Grab	<0.15	<0.05	<0.15
Bde Maka Ska	Lake		9/15/2022	1a				
Bde Maka Ska	Lake		9/28/2022	1a				
Bde Maka Ska	Lake		10/20/2022	1a				
Brownie	Lake		6/6/2022	1a				
Brownie	Lake		7/13/2022	1a				
Brownie	Lake		8/8/2022	1a				
Brownie	Lake		9/12/2022	1d				
Brownie	Lake		10/11/2022	1a				
Cedar	Lake		2/8/2022	1a	Composite	<1.5		
Cedar	Lake		4/19/2022	1a	Composite	<1.5		
Cedar	Beach	Cedar East Hidden	5/23/2022	1a	Grab	<1.5		

Lake	Site	Beach	Date	VMI	Sample Type	Microcystin µg/L	Cylindrospermopsin µg/L	Anatoxin-*a* µg/L
Cedar	Beach	Cedar Main	5/23/2022	1a	Grab	<1.5		
Cedar	Beach	Cedar Point	5/23/2022	1a	Grab	<1.5		
Cedar	Beach	Cedar East Hidden	5/31/2022	1b	Grab	<1.5		
Cedar	Beach	Cedar Main	5/31/2022	1c	Grab	<1.5		
Cedar	Beach	Cedar Point	5/31/2022	1a	Grab	<1.5		
Cedar	Lake		5/24/2022	1a				
Cedar	Beach	Cedar East Hidden	6/6/2022	1b	Grab	<1.5		
Cedar	Beach	Cedar Main	6/6/2022					
Cedar	Beach	Cedar Point	6/6/2022	1d	Grab	<1.5		
Cedar	Lake		6/6/2022	1a				
Cedar	Beach	Cedar East Hidden	6/14/2022	1a	Grab	<1.5		
Cedar	Beach	Cedar Main	6/14/2022	1d	Grab	<1.5		
Cedar	Beach	Cedar Point	6/14/2022	1a	Grab	<1.5		
Cedar	Beach	Cedar East Hidden	6/21/2022	1a	Grab	<1.5		
Cedar	Beach	Cedar Main	6/21/2022	1d	Grab	<1.5		
Cedar	Beach	Cedar Point	6/21/2022	1d	Grab	<1.5		
Cedar	Beach	Cedar East Hidden	6/27/2022	1a	Grab	<1.5		
Cedar	Beach	Cedar Main	6/27/2022	1a	Grab	<1.5		
Cedar	Beach	Cedar Point	6/27/2022	1a	Grab	<1.5		
Cedar	Lake		6/23/2022	1a				
Cedar	Beach	Cedar East Hidden	7/5/2022	1a	Grab	<1.5	<0.5	<1.5
Cedar	Beach	Cedar Main	7/5/2022	1a	Grab	<1.5	<0.5	<1.5
Cedar	Beach	Cedar Point	7/5/2022	1a	Grab	<1.5	<0.5	<1.5
Cedar	Beach	Cedar East Hidden	7/11/2022	1a	Grab	<1.5	<0.5	<1.5
Cedar	Beach	Cedar Main	7/11/2022	1a	Grab	<1.5	<0.5	<1.5
Cedar	Beach	Cedar Point	7/11/2022	1a	Grab	<1.5	<0.5	<1.5
Cedar	Beach	Cedar Point	7/13/2022	1a				
Cedar	Lake		7/13/2022	1a				
Cedar	Beach	Cedar East Hidden	7/18/2022	1a	Grab	<0.15	<0.05	<0.15
Cedar	Beach	Cedar Main	7/18/2022	1a	Grab	<0.15	<0.05	<0.15
Cedar	Beach	Cedar Point	7/18/2022	1a	Grab	<0.15	<0.05	<0.15
Cedar	Beach	Cedar Main	7/20/2022	1a				
Cedar	Beach	Cedar East Hidden	7/25/2022	1a	Grab	<0.15	<0.05	<0.15

Lake	Site	Beach	Date	VMI	Sample Type	Microcystin µg/L	Cylindrospermopsin µg/L	Anatoxin-*a* µg/L
Cedar	Beach	Cedar Main	7/25/2022	1a	Grab	<0.15	<0.05	<0.15
Cedar	Beach	Cedar Point	7/25/2022	1a	Grab	<0.15	<0.05	<0.15
Cedar	Lake		7/25/2022	1a				
Cedar	Beach	Cedar East Hidden	8/1/2022	1a	Grab	0.181	<0.05	<0.15
Cedar	Beach	Cedar Main	8/1/2022	1a	Grab	<0.15	<0.05	<0.15
Cedar	Beach	Cedar Point	8/1/2022	1a	Grab	<0.15	<0.05	<0.15
Cedar	Beach	Cedar East Hidden	8/8/2022	1a	Grab	<0.15	<0.05	<0.15
Cedar	Beach	Cedar Main	8/8/2022	1a	Grab	<0.15	<0.05	<0.15
Cedar	Beach	Cedar Point	8/8/2022	1a	Grab	<0.15	<0.05	<0.15
Cedar	Lake		8/8/2022	1a				
Cedar	Beach	Cedar East Hidden	8/15/2022	1a	Grab	<0.15	<0.05	<0.15
Cedar	Beach	Cedar Main	8/15/2022	1a	Grab	<0.15	<0.05	<0.15
Cedar	Beach	Cedar Point	8/15/2022	1a	Grab	<0.15	<0.05	<0.15
Cedar	Beach	Cedar East Hidden	8/22/2022	1a	Grab	<0.15	<0.05	0.171
Cedar	Beach	Cedar Main	8/22/2022	1a	Grab	<0.15	<0.05	0.241
Cedar	Beach	Cedar Point	8/22/2022	1a	Grab	<0.15	<0.05	0.168
Cedar	Lake		8/23/2022	1a				
Cedar	Beach	Cedar East Hidden	8/29/2022	1b	Grab	0.202	<0.05	0.280
Cedar	Beach	Cedar Main	8/29/2022	1b	Grab	0.237	<0.05	<0.15
Cedar	Beach	Cedar Point	8/29/2022	1b	Grab	0.153	<0.05	<0.15
Cedar	Lake		9/12/2022	1d				
Cedar	Lake		9/26/2022	1a				
Cedar	Lake		10/11/2022	1a				
Diamond	Lake		5/26/2022	1a				
Diamond	Lake		6/7/2022	1a				
Diamond	Lake		6/21/2022	1c				
Diamond	Lake		7/11/2022	1c				
Diamond	Lake		7/26/2022	1c				
Diamond	Lake		8/9/2022	1c				
Diamond	Lake		8/24/2022	1c				
Diamond	Lake		9/19/2022	1c				
Diamond	Lake		9/27/2022	1c				
Diamond	Lake		10/12/2022	1a				

Lake	Site	Beach	Date	VMI	Sample Type	Microcystin µg/L	Cylindrospermopsin µg/L	Anatoxin-*a* µg/L
Grass	Lake		6/7/2022	1b				
Grass	Lake		7/11/2022	1c				
Grass	Lake		8/9/2022	1c				
Grass	Lake		9/19/2022	1d				
Grass	Lake		10/12/2022	1a				
Harriet	Lake		2/8/2022	1a	Composite	<1.5		
Harriet	Beach	Harriet SE	5/23/2022	1a	Grab	<1.5		
Harriet	Beach	Harriet Main	5/23/2022	1a	Grab	<1.5		
Harriet	Beach	Harriet SE	5/31/2022	1a	Grab	<1.5		
Harriet	Beach	Harriet Main	5/31/2022	1a	Grab	<1.5		
Harriet	Lake		5/27/2022	1d				
Harriet	Beach	Harriet SE	6/6/2022	1a	Grab	<1.5		
Harriet	Beach	Harriet Main	6/6/2022	1d	Grab	<1.5		
Harriet	Lake		6/8/2022	1d				
Harriet	Beach	Harriet SE	6/14/2022	1d	Grab	<1.5		
Harriet	Beach	Harriet Main	6/14/2022	1a	Grab	<0.15		
Harriet	Beach	Harriet SE	6/21/2022	1d	Grab	<1.5		
Harriet	Beach	Harriet Main	6/21/2022	1d	Grab	<0.15		
Harriet	Beach	Harriet SE	6/27/2022	1d	Grab	<1.5		
Harriet	Beach	Harriet Main	6/27/2022	1d	Grab	<0.15		
Harriet	Lake		6/28/2022	1d				
Harriet	Beach	Harriet SE	7/5/2022	1d	Grab	<1.5	<0.5	<1.5
Harriet	Beach	Harriet Main	7/5/2022	2	Grab	<1.5	<0.5	<1.5
Harriet	Beach	Harriet SE	7/11/2022	1d	Grab	<1.5	<0.5	<1.5
Harriet	Beach	Harriet Main	7/11/2022	1d	Grab	<1.5	<0.5	<1.5
Harriet	Lake		7/14/2022	1a				
Harriet	Beach	Harriet SE	7/18/2022	1a	Grab	<0.15	<0.05	<0.15
Harriet	Beach	Harriet Main	7/18/2022	1a	Grab	<0.15	<0.05	<0.15
Harriet	Beach	Harriet SE	7/25/2022	1d	Grab	0.299	<0.05	<0.15
Harriet	Beach	Harriet Main	7/25/2022	2	Grab	0.235	<0.05	<0.15
Harriet	Lake		7/27/2022	1a				
Harriet	Beach	Harriet SE	8/1/2022	1a	Grab	0.524	<0.05	<0.15
Harriet	Beach	Harriet Main	8/1/2022	1a	Grab	0.238	<0.05	<0.15

Lake	Site	Beach	Date	VMI	Sample Type	Microcystin µg/L	Cylindrospermopsin µg/L	Anatoxin-*a* µg/L
Harriet	Beach	Harriet SE	8/8/2022	1a	Grab	1.18	<0.05	<0.15
Harriet	Beach	Harriet Main	8/8/2022	1a	Grab	1.07	<0.05	<0.15
Harriet	Lake		8/11/2022	1a				
Harriet	Beach	Harriet SE	8/15/2022	1a	Grab	0.555	0.055	<0.15
Harriet	Beach	Harriet Main	8/15/2022	1a	Grab	0.944	0.091	<0.15
Harriet	Beach	Harriet SE	8/22/2022	1a	Grab	0.433	<0.05	<0.15
Harriet	Beach	Harriet Main	8/22/2022	1a	Grab	0.339	<0.05	<0.15
Harriet	Lake		8/26/2022	1a				
Harriet	Beach	Harriet SE	8/29/2022	1a	Grab	0.493	<0.05	<0.15
Harriet	Beach	Harriet Main	8/29/2022	1a	Grab	0.670	<0.05	<0.15
Harriet	Lake		9/14/2022	1d				
Harriet	Lake		9/28/2022	1d				
Harriet	Lake		10/20/2022	1a				
Hiawatha	Beach	Hiawatha	5/23/2022	1a	Grab	<1.5		
Hiawatha	Beach	Hiawatha	5/31/2022	1b	Grab	<1.5		
Hiawatha	Lake		5/27/2022	2				
Hiawatha	Beach	Hiawatha	6/6/2022	1d	Grab	<1.5		
Hiawatha	Lake		6/9/2022	1d				
Hiawatha	Beach	Hiawatha	6/14/2022	1d	Grab	<1.5		
Hiawatha	Beach	Hiawatha	6/21/2022	2	Grab	<1.5		
Hiawatha	Beach	Hiawatha	6/27/2022	1d	Grab	<1.5		
Hiawatha	Lake		6/28/2022	1d				
Hiawatha	Beach	Hiawatha	7/5/2022	1b	Grab	0.355	<0.5	<1.5
Hiawatha	Beach	Hiawatha	7/11/2022	1b	Grab	0.190	<0.5	<1.5
Hiawatha	Lake		7/15/2022	1b				
Hiawatha	Beach	Hiawatha	7/18/2022	1b	Grab	0.190	<0.05	<0.15
Hiawatha	Beach	Hiawatha	7/25/2022	1b	Grab	0.203	<0.05	<0.15
Hiawatha	Lake		7/28/2022	1b				
Hiawatha	Beach	Hiawatha	8/1/2022	1b	Grab	0.592	<0.05	0.182
Hiawatha	Beach	Hiawatha	8/8/2022	1b	Grab	0.544	<0.05	1.12
Hiawatha	Beach	Hiawatha	8/10/2022	1b				
Hiawatha	Lake		8/11/2022	1b				
Hiawatha	Beach	Hiawatha	8/15/2022	1b	Grab	1.47	<0.05	<0.15

Lake	Site	Beach	Date	VMI	Sample Type	Microcystin µg/L	Cylindrospermopsin µg/L	Anatoxin-*a* µg/L
Hiawatha	Beach	Hiawatha	8/22/2022	1b	Grab	1.39	<0.05	0.166
Hiawatha	Lake		8/26/2022	1b				
Hiawatha	Beach	Hiawatha	8/29/2022	1b	Grab	1.73	<0.05	<0.15
Hiawatha	Lake		9/14/2022	1d				
Hiawatha	Lake		9/29/2022	3				
Hiawatha	Lake		10/13/2022	3				
Isles	Lake		5/24/2022	1a				
Isles	Lake		6/6/2022	1a				
Isles	Lake		6/23/2022	1d				
Isles	Lake		7/14/2022	1a				
Isles	Lake		7/27/2022	1a				
Isles	Lake		8/10/2022	1b				
Isles	Lake		8/25/2022	1a				
Isles	Lake		9/15/2022	1a				
Isles	Lake		9/28/2022	1d				
Isles	Lake		10/20/2022	1d				
Loring	Lake		5/26/2022	1b				
Loring	Lake		6/7/2022	1b				
Loring	Lake		6/21/2022	1a				
Loring	Lake		7/11/2022	1a				
Loring	Lake		7/26/2022	1c				
Loring	Lake		8/9/2022	1b				
Loring	Lake		8/24/2022	1b				
Loring	Lake		9/19/2022	1b				
Loring	Lake		9/27/2022	1a				
Loring	Lake		10/12/2022	1a				
Nokomis	Lake		2/10/2022	1a	Composite	<1.5		
Nokomis	Lake		4/26/2022	1b	Composite	<1.5		
Nokomis	Beach	Nokomis 50th	5/23/2022	1a	Grab	<1.5		<1.5
Nokomis	Beach	Nokomis Main	5/23/2022	1a	Grab	<1.5		<1.5
Nokomis	Beach	Nokomis 50th	5/31/2022	1a	Grab	<1.5		<1.5
Nokomis	Beach	Nokomis Main	5/31/2022	1a	Grab	<1.5		<1.5
Nokomis	Lake		5/27/2022	1a				

Lake	Site	Beach	Date	VMI	Sample Type	Microcystin µg/L	Cylindrospermopsin µg/L	Anatoxin-*a* µg/L
Nokomis	Beach	Nokomis 50th	6/6/2022	1a	Grab	<1.5		<1.5
Nokomis	Beach	Nokomis Main	6/6/2022	1d	Grab	<1.5		<1.5
Nokomis	Lake		6/9/2022	1d				
Nokomis	Beach	Nokomis 50th	6/14/2022	1a	Grab	<1.5		<1.5
Nokomis	Beach	Nokomis Main	6/14/2022	1a	Grab	<1.5		<1.5
Nokomis	Beach	Nokomis 50th	6/21/2022	1d	Grab	<1.5		<1.5
Nokomis	Beach	Nokomis Main	6/21/2022	1d	Grab	<1.5		<1.5
Nokomis	Beach	Nokomis 50th	6/27/2022	1d	Grab	<1.5		<1.5
Nokomis	Beach	Nokomis Main	6/27/2022	2	Grab	<1.5		<1.5
Nokomis	Lake		6/24/2022	1d				
Nokomis	Beach	Nokomis 50th	7/5/2022	1d	Grab	0.291	<0.5	<1.5
Nokomis	Beach	Nokomis Main	7/5/2022	2	Grab	1.75	<0.5	<1.5
Nokomis	Beach	Nokomis 50th	7/11/2022	1d	Grab	0.537	<0.5	<1.5
Nokomis	Beach	Nokomis Main	7/11/2022	1b	Grab	0.498	<0.5	<1.5
Nokomis	Lake		7/15/2022	1b				
Nokomis	Beach	Nokomis 50th	7/18/2022	1b	Grab	1.79	<0.05	<0.15
Nokomis	Beach	Nokomis Main	7/18/2022	1d	Grab	0.817	<0.05	<0.15
Nokomis	Beach	Nokomis 50th	7/25/2022	3	Grab	2.40	<0.05	0.201
Nokomis	Beach	Nokomis Main	7/25/2022	3	Grab	2.76	<0.05	0.152
Nokomis	Lake		7/28/2022	3				
Nokomis	Beach	Nokomis 50th	8/1/2022	3	Grab	2.09	<0.05	0.152
Nokomis	Beach	Nokomis Main	8/1/2022	3	Grab	1.96	<0.05	0.160
Nokomis	Beach	Nokomis 50th	8/8/2022	3	Grab	2.03	<0.05	0.174
Nokomis	Beach	Nokomis Main	8/8/2022	3	Grab	2.09	<0.05	0.202
Nokomis	Lake		8/11/2022	3				
Nokomis	Beach	Nokomis 50th	8/15/2022	3	Grab	3.22	<0.05	<0.15
Nokomis	Beach	Nokomis Main	8/15/2022	3	Grab	3.69	0.070	<0.15
Nokomis	Beach	Nokomis 50th	8/22/2022	3	Grab	5.00	<0.05	<0.15
Nokomis	Beach	Nokomis Main	8/22/2022	3	Grab	3.68	<0.05	0.154
Nokomis	Lake		8/26/2022	3				
Nokomis	Beach	Nokomis 50th	8/29/2022	3	Grab	6.79	<0.05	0.207
Nokomis	Beach	Nokomis Main	8/29/2022	3	Grab	7.93	<0.05	0.200
Nokomis	Beach	Nokomis 50th	9/6/2022	3	Grab	9.26		

Lake	Site	Beach	Date	VMI	Sample Type	Microcystin µg/L	Cylindrospermopsin µg/L	Anatoxin-*a* µg/L
Nokomis	Beach	Nokomis Main	9/6/2022	3	Grab	6.67		
Nokomis	Beach	Nokomis 50th	9/12/2022	3	Grab	18.2		
Nokomis	Beach	Nokomis Main	9/12/2022	3	Grab	22.8		
Nokomis	Beach	Nokomis 50th	9/19/2022	3	Grab	8.80		
Nokomis	Beach	Nokomis Main	9/19/2022	3	Grab	14.0		
Nokomis	Lake		9/14/2022	3				
Nokomis	Beach	Nokomis 50th	9/27/2022	3	Grab	1.60		
Nokomis	Beach	Nokomis Main	9/27/2022	3	Grab	1.50		
Nokomis	Lake		9/29/2022	3				
Nokomis	Lake		10/13/2022	3				
Powderhorn	Lake		2/9/2022	1a	Composite	<1.5		
Powderhorn	Lake		4/21/2022	1b	Composite	<1.5		
Powderhorn	Lake		5/11/2022	1b	Composite	<1.5		
Powderhorn	Lake		5/26/2022	1b	Composite	<1.5		
Powderhorn	Lake		6/7/2022	1b	Composite	<1.5		
Powderhorn	Lake		6/21/2022	1b	Composite	<1.5		
Powderhorn	Lake		7/11/2022	2	Composite	<1.5	<0.5	<1.5
Powderhorn	Lake		7/26/2022	2	Composite	5.00	<0.05	<0.15
Powderhorn	Lake		7/26/2022	2	Composite	6.02		
Powderhorn	Lake		8/9/2022	2	Composite	2.22	<0.05	<0.15
Powderhorn	Lake		8/9/2022	2	Composite	2.11		
Powderhorn	Lake		8/24/2022	3	Grab	4.63	<0.05	<0.15
Powderhorn	Lake		8/24/2022	3	Grab	4.26		
Powderhorn	Lake		9/19/2022	3	Grab	0.471	0.157	<0.15
Powderhorn	Lake		9/19/2022	3	Grab	<1.5		
Powderhorn	Lake		9/27/2022	3	Grab	0.469	<0.05	<0.15
Powderhorn	Lake		9/27/2022	3	Grab	<1.5		
Powderhorn	Lake		10/12/2022	3		0.442		
Wirth	Beach	Wirth	5/23/2022	1a	Grab	<1.5		
Wirth	Beach	Wirth	5/31/2022	1b	Grab	<1.5		
Wirth	Lake		5/26/2022	1a				
Wirth	Beach	Wirth	6/6/2022	1a	Grab	<1.5		
Wirth	Lake		6/8/2022	1a				

Lake	Site	Beach	Date	VMI	Sample Type	Microcystin µg/L	Cylindrospermopsin µg/L	Anatoxin-*a* µg/L
Wirth	Beach	Wirth	6/14/2022	1a	Grab	<1.5		
Wirth	Beach	Wirth	6/21/2022	1a	Grab	<1.5		
Wirth	Beach	Wirth	6/27/2022	1a	Grab	<1.5		
Wirth	Lake		6/22/2022	1a				
Wirth	Beach	Wirth	7/5/2022	1a	Grab	<1.5	<0.5	<1.5
Wirth	Beach	Wirth	7/11/2022	1a	Grab	<1.5	<0.5	<1.5
Wirth	Lake		7/11/2022	1a				
Wirth	Beach	Wirth	7/18/2022	1a	Grab	<0.15	<0.05	<0.15
Wirth	Beach	Wirth	7/25/2022	1a	Grab	<0.15	<0.05	<0.15
Wirth	Lake		7/26/2022	1a				
Wirth	Beach	Wirth	8/1/2022	1a	Grab	<0.15	<0.05	<0.15
Wirth	Beach	Wirth	8/8/2022	1a	Grab	<0.15	<0.05	<0.15
Wirth	Lake		8/9/2022	1a				
Wirth	Beach	Wirth	8/15/2022	1a	Grab	0.221	0.111	<0.15
Wirth	Beach	Wirth	8/22/2022	1a	Grab	0.315	<0.05	<0.15
Wirth	Lake		8/23/2022	1a				
Wirth	Beach	Wirth	8/29/2022	1d	Grab	0.166	<0.05	<0.15
Wirth	Lake		9/13/2022	1d				
Wirth	Lake		9/26/2022	1a				
Wirth	Lake		10/11/2022	1a				

Appendix E

This section contains the Frog and Toad monitoring data for 2022:
Winkelman, Jenny. (2022). **Frog and Toad Calling Surveys: Minneapolis Stormwater Ponds: 2015 - 2022**

BACKGROUND AND OBJECTIVES

The presence and abundance of frogs and toads are a useful indicator of water and habitat quality, as well as short and long-term environmental changes. Standard protocols using calling surveys during peak breeding activity have been used to determine distribution and population trends by natural resource agencies nation-wide. The Minnesota Department of Natural Resources (DNR) Nongame Wildlife Program worked with citizen scientists to monitor frog and toad populations statewide from 1994-2017 using Minnesota Frog & Toad Calling Surveys (MFTCS)[1]. Out of concern for declining amphibian populations, The North American Amphibian Monitoring Program (NAAMP), coordinated by the United States Geological Survey (USGS), expanded and collaborated with states' efforts to collect data from 1997-2015[2].

Frog and toad calling surveys were initiated in Theodore Wirth Park in 2015 to evaluate frog and toad presence in areas where buckthorn was removed during a multi-year habitat improvement project. The 2015 survey was conducted before any habitat enhancement took place to serve as a baseline. Moving forward, there is interest in continuing the surveys as a citizen science monitoring project executed by volunteers.

Partial funding for this project was provided from the Outdoor Heritage Fund as appropriated by the Minnesota State Legislature and recommended by the Lessard-Sams Outdoor Heritage Council (LSOHC) to restore, protect, and enhance Minnesota's wetlands, prairies, forests, and habitat for fish, game, and wildlife.

The original purpose of this survey was to:

1) Identify frog and toad species found in Theodore Wirth Park.
2) Evaluate the impact of habitat improvement efforts in 2016 on the presence and abundance of frogs and toads, over the next five years. (Habitat improvement efforts focused on removing the understory of invasive buckthorn.)
3) Create a long-term volunteer monitoring program.

The third objective, that of creating an ongoing volunteer monitoring activity, was dropped after considering logistics, liability, and later, Covid 19 restrictions.

[1] Minnesota Frog & Toad Calling Survey (MFTCS) Last accessed February 28, 2023.
[2] North American Amphibian Monitoring Program Last accessed February 28, 2023.

METHODS

Sampling locations were selected in areas targeted for manual buckthorn removal in 2016. Sites chosen reflect different habitat types and are described and mapped in Appendix E1. Key characteristics are compared in Table 3.

Survey methods for this study were adapted from the MFTCS survey protocols[3,4]. The relative proximity of sites sampled and objectives of this survey required modifications. However, the raw data was recorded in a way that can still be compared with MFTCS data. A side by side comparison of the MFTCS and modifications made for this study appear in Appendix E2.

Sampling surveys (runs) were conducted within established time frames and air and water temperatures. Runs were intended to capture calls from frog and toad species breeding in early spring, mid to late spring and summer. At each site, species presence and chorus strength were recorded, based on volume of calling (calling index of 1-3). The calling index is based on hearing one or two (index 1), a few (2) or many (3). In some cases, a "1" is used to indicate a species was seen but not heard, to capture the information that it is present (recorded on data sheets as a "P" for present). Observer bias was reduced in this study by using the same, experienced observer for all surveys. All assistants were given an opportunity to learn Minnesota frog calls online using the USGS NAAMP frog calling look up and public quiz[5]. Frog recordings were also listened to between sites to further familiarize and finetune their identification skills.

An early survey was added in March 2020 to capture the explosive breeding of wood frogs. However, no species were heard. Breeding is short-lived and it is difficult to time early surveys because Ice-out and spring rains vary between sites and years (ranging from March to May). In 2020, the third survey run did not take place, as a result of citywide restrictions imposed due to civil unrest and the pandemic.

Calculations and Limitations

Frequency calculations are based on presence and absence (not chorus strength) for eight years of sampling (2015 to 2022). Calling surveys enable gathering useful comparable information over a large area but are not perfect. Calling surveys are influenced by abiotic factors—especially temperature and precipitation—as well as day of year, time of day, weather, moon phase, drought, distance to and noise from roads, and whether the habitat is natural or built. Calling surveys can miss detecting populations (such as when not heard due to the volume of other sounds and choruses), especially rare species[6].

Repeating surveys (three runs) and assigning calling indexes (1-3) was used to determine species presence, seasonal changes in species composition, and the timing of peak breeding of each species. Observations from different runs are used to show variation of activity between species and not intended as multiple observations of a species (and therefore, not subject to averaging)[7]. Also, chorus strength is not a reliable indicator of abundance. The association between calling index and abundance varies among species and has not been rigorously quantified[8]. For example, all males present may not be calling at the time of the survey and some may call at other times of the day.

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3 2002 Anderson, Y. and R. Baker. Minnesota Frog and Toad Calling Survey, 1996-2002. MN Department of Natural Resources.

4 Mossman et al., 1998

5 USGS Frog Quiz. Last accessed February 25, 2023

6 Weir et al. 2009

7 Mossman et al., 1998

8 Corn et al., 2011

FINDINGS

Findings vary by habitat, weather and time of year. Timing is critical and was geared towards finding the most species at peak breeding times. That is to say, within protocol parameters, moonlight was avoided and surveys were conducted during or as close to rain events as possible.

Findings by Species

Of the 14 frog and toad species known in Minnesota, seven were heard in Wirth Park-between 2015–2022 (Table 1). Spring peepers were mistakenly recorded in the early years, but later corrected to be the distinct "watch" calls of treefrogs[9], which made more sense given how late in the season they were heard, well after spring peepers would no longer be calling. In 2022, MPRB naturalists communicated that they thought they heard spring peepers calling in early spring during the day from the wetland across from Wirth Beach, but this has not been verified.

Key findings:

- The calling phenology of species found in Wirth Park is depicted in Figure 1. Early spring breeders are: chorus frogs, wood frogs, and northern leopard frogs. Mid to late spring breeders are toads, and both species of gray treefrogs. The only exclusively summer breeder heard was the American bullfrog. Peak breeding activity is influenced by abiotic factors such as when ice melts, temperatures warm, and the amount and timing of rain. In addition, some species such as treefrogs call intermittently even when not breeding.

- Boreal chorus frogs and gray treefrogs were heard at all sites in most years and, overall, were the most common species parkwide (Figure 2). Both were heard in full chorus at multiple locations, Table 2).

- Toads were also common parkwide (Figure 2). During peak breeding, dozens were seen at a time on land next to and heading to breeding wetlands. Yet, none were heard during sampling in 2022, which was characterized by high temperatures and lack of spring rain following a dry 2021. Based on other observations that year, toad breeding was significantly truncated and occurred earlier than in other years, suggesting that breeding took place between sampling windows (pers.comm., J. Winkelman, 2022).

- Cope's gray treefrogs were found at four sites, overlapping with gray treefrogs. The two species are indistinguishable except by their breeding call and number of chromosomes. Cope's gray treefrogs are found in more open areas and along the edges of woodlands and fields. They were only heard in full chorus at the golf course pond near Regency Hospital, which is most open site.

- Northern leopard frogs were found rarely in the first five years. Two of three observations were found outside of the 5-minute listening window—at Birch Pond heard while returning to the vehicle, and in 2015 froglets were seen hopping near the woodland pothole near Regency Hospital. The latter indicates they are in the area, but not necessarily breeding in the pothole.

  In comparison, 2020 was a banner year for leopard frogs and they continue to be heard. In 2020 their calls were detected at Birch Pond, the golf course pond, and for the first time at both EBWG sites. They were particularly abundant near the dike, the only place they were heard in full chorus (Table 2). Pandemic restrictions and civil unrest dramatically reduced traffic and recreation at the park, which may be why leopard frogs were audible, especially near Wirth Beach, where in typical years the

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[9] Tekiela, S. 2003. CD recording. Reptiles & Amphibians of Minnesota Field Guide. Adventure Publications. 172 pp.

combination of lights, traffic, whistles from sand court volleyball may reduce breeding activity and/or drown out low, snoring call of the leopard frog.

Table 1. Frog and toad species found at Theodore Wirth Park from 2015–22 and compared to species known in Minnesota (presence shown by "+").

Species	MN Status	Found in MN	Found in Wirth Park	*Years Sampled in Wirth Park*							
				2015*	2016	2017	2018	2019	2020	2021	2022
American Toad (*Anaxyrus americanus*)[1]		+	+	+	+	+	+	+	+	+	
Canadian Toad (*Anaxyrus hemiophrys*)[1]		+									
Great Plains Toad (*Anaxyrus cognatus*)[1]	Special concern	+									
Gray Treefrog (*Hyla versicolor*)		+	+	+	+	+	+	+	+	+	+
Cope's Gray Treefrog (*Hyla chrysoscelis*)		+	+	+	+	+	+	+	+	+	+
Spring Peeper (*Pseudacris crucifer*)		+									
Boreal/Western Chorus Frog (*Pseudacris maculata*)		+	+	+	+	+	+	+	+	+	+
Wood Frog (*Lithobates sylvaticus*) [2]		+	+				+				
Northern Leopard Frog (*Lithobates pipiens*)[2]		+	+	+	+				+	+	+
American Bullfrog (*Lithobates catesbeianus*)[2, 3]	Not native in most of MN	+	+			+					
Green Frog (*Lithobates clamitans*)[2]		+									
Mink Frog (*Lithobates septentrionalis*)[2]		+									
Pickerel Frog (*Lithobates palustris*)[2]		+									
Northern Cricket Frog (*Acris crepitans*)	Endangered	+									
Species richness (no. of species):		14	7	5	5	5	5	4	5	5	4

Includes all species seen or heard at each site, including outside of the 5-minute sampling.
* Baseline survey conducted before any habitat enhancement activities began.
[1] The genus *Anaxyrus* was formerly called *Bufo*.
[2] The genus *Lithobates* was formerly called *Rana*.
[3] Introduced. Native range limited to two southeastern-most counties in Minnesota.

Figure 1. General calling phenology of species by survey Period (2015-22).

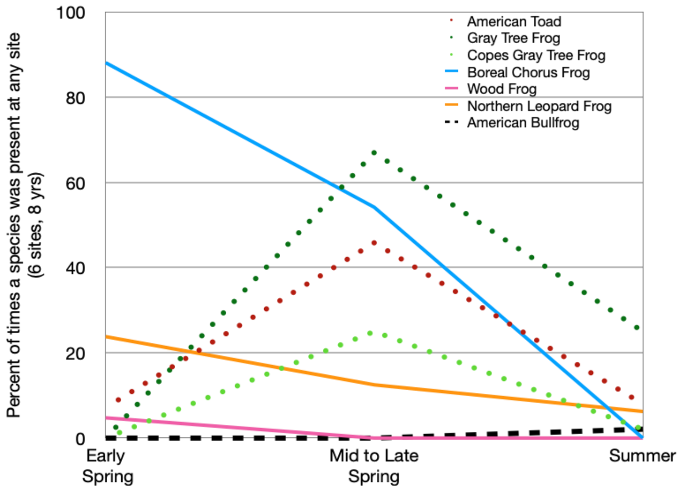

Figure 2. Occurrence of frog and toad species parkwide in eight years, 2015-22.

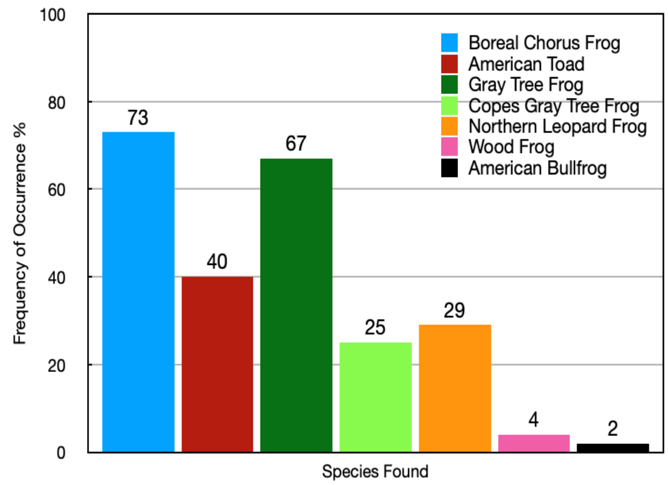

Table 2. Occurrence of frog and toad species found and number of times a full chorus was heard at specific sites in Theodore Wirth Park during surveys from 2015–22 (based on presence and absence in 8 years; full chorus indicated by calling index of 3).

Species	**Frequency of Occurrence % (no. years full chorus heard)**					
	Woodland pothole - Wayzata	Birch Pond	Spring near EBWG	Dike near EBWG	Woodland pothole - Regency	Golf course pond - Regency
American Toad (*Anaxyrus americanus*)[1]	**38**	**75** (1)	**50**	**50** (2)	–	**63** (4)
Gray Treefrog (*Hyla versicolor*)	**63** (3)	**100**(6)	**50**	**63**	**25** (1)	**100** (4)
Cope's Gray Treefrog (*Hyla chrysoscelis*)	–	**38**	–	**13**	**13**	**88** (3)
Boreal/Western Chorus Frog (*Pseudacris maculata*)	**100** (7)	**75** (5)	**100** (5)	**75** (1)	**100** (1)	**63**

Wood Frog (*Lithobates sylvaticus*) [2]	**13**	**–**	**13**	**–**	**–**	**–**
Northern Leopard Frog (*Lithobates pipiens*)[2]	**–**[3]	**50**	**38**	**38** (1)	**–**	**50**
American Bullfrog *(Lithobates catesbeianus)*[2, 4]	**–**	**–**	**–**	**–**	**–**	**13**
Species richness (no.of species):	4	5	5	5	5	6

Includes all species seen or heard at each site, including outside of the 5-minute sampling.
[1]The genus *Anaxyrus* was formerly called *Bufo*.
[2] The genus *Lithobates* was formerly called *Rana*.
[3] Froglets seen dispersing towards and within 100 ft of this pond; breeding frogs not heard here.
[4] Introduced. Native rangers limited to Fillmore and Houston counties, the two southeastern-most counties in Minnesota.

- Wood frogs were rarely found, only in 2018 and then, only at two locations. Both locations are seasonally wet in moist woodlands, and farthest from the noise and light of roads and human activity (the pothole wetland near Wayzata Blvd and the wetland near the EBWG spring). Wood frogs are explosive breeders (namely they breed for a short, intense period) and the ideal combination of ice-out and warm spring rains triggering breeding may occur between March and May). In 2018, the timing of the first survey in 2018 coincided with a very late spring. Wood frogs breed earlier than other species, often with ice still on the edges of ponds, and before the established windows of sampling. Their absence may be a “false absence” due to their rareness or because they are missed during sampling.

- Another possibility is that their presence may have been detected because of habitat improvement efforts. While rare, their presence was detected only one year after the understory was dramatically opened up when buckthorn was removed and only in the most interior wooded sites. Buckthorn rapidly regrew and filled in the understory in subsequent years. In 2021, additional buckthorn control using goats in the vicinity of the pothole wetland near Wayzata Blvd. It remains to be seen, or heard, whether wood frogs are found here again.
- American bullfrogs—an invasive, non-native species—were found breeding in 2017 at the golf course pond near Regency Hospital. It was reported to the DNR who responded "…this is an important update. [this new data will be] added to our database to update the status of Bullfrogs at Theodore Wirth" (pers.comm., Erica Hoagland, Region 3 Nongame Wildlife Specialist, July 10, 201). The only other record for bullfrogs at Wirth Park was from 2006 about a half mile NE of where it was found in 2017.

- Gray treefrogs and toads were often seen hopping across or killed on roads that separate their breeding sites from their nonbreeding, upland habitat[10]. Treefrogs seasonally migrate across Theodore Wirth Pkwy to breed in Birch Pond. In addition, toads were often seen crossing stretches of Glenwood Ave and Theodore Wirth Pkwy to reach adjacent wetlands during breeding season (Figure 3). Amphibian migrations are most susceptible to road mortality when crossing roads to breed and to a lesser extent, when tadpoles emerge from water and disperse on land, and when moving to overwintering locations.

Figure 3. Known locations of frog and toad migrations across roadways and a trail in Wirth Park.

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[10] Toad migration across landscapes resulted in noticeable road kill were noticed in at least two other locations in Minneapolis: along William Berry Pkwy between Jo Pond and William Berry Woods, and on Cedar Lake Pkwy between Cedar Meadows and Cedar Lake (J. Winkelman, pers. comm., 2022).

Findings by Site

All sites were naturally formed, some receive stormwater discharge, but none were built as stormwater ponds. Detailed descriptions of each site appear in Appendix E1 and key features of each site are compared in Table 3. Groundwater is high in the park and particularly important to the hydrology of the three intermittently flooded wetlands.

Woodland Pothole near Wayzata Blvd. One of the more interior wooded pothole wetlands in Wirth Park, fish-free, standing water disappears in drought years, though water levels often fluctuate, and soils remain saturated. Located low in the surrounding landscape, it is quieter and darker due to the surrounding woods, despite the proximity to highway noise and city lights. Fireflies are very abundant on some nights.

- Four species were heard overall (Table 4); this is one of only two sites where wood frogs found and the only location where leopard frogs were not heard nor seen).
- Boreal chorus frogs, an early season breeder, were dominant (100% frequency of occurrence and in full chorus in seven years: Table 2). Gray treefrogs were also very common and heard in full chorus three times. Full chorus at this site can be deafening and at times it does not quiet down even when intentionally disturbed by shouting and clapping.
- No Cope's gray treefrogs were heard, which is consistent with their habitat preference for more open and edge areas.
- Buckthorn removal (2016) rendered this site nearly unrecognizable. The dramatic opening of the understory may be why wood frogs were found breeding here in 2018 (if they moved into the site in 2017, they would be found breeding the following year). However, buckthorn grew back rapidly and by 2019 it was over 5 ft tall. Wood frogs may have been detected because of the late spring and delayed calling. In 2021, goats were used to graze the regrowth of buckthorn and significantly reopen the understory. If there was any frog response to habitat improvement, it was negated by drought conditions in 2021 and 2022. Drought resulted in this pond having no standing water by mid-spring of 2022, for the first time in eight years.
- This habitat and species composition most resembles the wooded, intermittent pond near EBWG spring.

Table 3. Comparison of key site characteristics where calling surveys were conducted in Wirth Park (additional details in Appendix E1)						
	Woodland pothole - Wayzata	Birch Pond	Spring near EBWG	Dike near EBWG	Woodland pothole - Regency	Golf course pond - Regency
Permanently or intermittently flooded	Intermittent (rarely is there no standing water)	Permanent	Intermittent (first to dry up)	Permanent	Intermittent	Permanent
Surrounding landscape	Wooded	Mixed	Wooded	Open	Wooded	Open
Location relative to built environment	Interior	Near road	Interior	Near road	Near parking lot	Interior
Type of Disturbance	NA	Traffic, lights	NA	Traffic, lights, volleyball noise	Parking lot, lights, HVAC	NA
Receives stormwater discharge	No	Yes	No	Yes	No (indirectly runoff from parking lot)	No (indirectly runoff from golf course)

Table 4. Frog and toad species found at specific sites in Theodore Wirth Park during surveys from 2015–22 (presence shown by "+").							
Species	Found in Wirth Park	**Locations sampled in Wirth Park**					
		Woodland pothole - Wayzata	Birch Pond	Spring - EBWG	Dike - EBWG	Woodland pothole - Regency	Golf course pond - Regency
American Toad (*Anaxyrus americanus*)[1]	**+**	+	+	+	+		+
Gray Treefrog (*Hyla versicolor*)	**+**	+	+	+	+	+	+
Cope's Gray Treefrog (*Hyla chrysoscelis*)	**+**		+		+	+	+
Boreal/Western Chorus Frog (*Pseudacris maculata*)	**+**	+	+	+	+	+	+
Wood Frog (*Lithobates sylvaticus*) [2]	**+**	+		+			
Northern Leopard Frog	**+**		+	+	+	+[2]	+

(*Lithobates pipiens*)[2]							
American Bullfrog *(Lithobates catesbeianus)*[2, 4]	**+**						+
Species richness (no.of species):	**7**	4	5	5	5	4	6

Includes all species seen or heard at each site, including outside of the 5-minute sampling.
[1]The genus *Anaxyrus* was formerly called *Bufo*.
[2] The genus *Lithobates* was formerly called *Rana*.
[3] Froglets seen dispersing towards and within 100 ft of this pond; breeding frogs not heard here.
[4] Introduced. Native range limited to two southeastern-most counties in Minnesota.

Birch Pond. A large open, permanent water body surrounded by woods ringed with emergent vegetation and surrounded by woods. Streetlights shine onto the water. Traffic and road noise was constant, sometimes interfering with observers' hearing.

- Five species were heard (Table 4) and all were fairly common at 38-100% (Table 2).
- Consistently, this is an important and active breeding area for gray treefrogs in mid-late spring. They called in full chorus in six of eight years (Table 2), which can be deafening. During peak times gray treefrogs were seen hopping in large numbers across the parkway; the constant traffic frequently resulted in them being run over (Figure 3).
- Cope's gray treefrogs were also found but not as frequently as their counterparts. Their distribution often overlaps with gray tree frogs and increases at woodland edges and in open areas. Boreal chorus frogs were consistently heard, and in five years in full chorus (Table 2). They called mostly from the far side of the pond, and it was not possible to tell if the calls came strictly from Birch Pond or carried from the wooded pothole area.
- Leopard frogs may be under-documented due to their low, rumbling call, the din of other species in full chorus, and the noise from traffic, and whistles from Wirth Beach. Leopard frogs are able to overwinter here and are more often found in habitats with fish.
- Buckthorn removal in 2016 dramatically increased illumination of the pond by streetlights and traffic noise coming from Theodore Wirth Pkwy.

Spring near Eloise Butler Wildflower Garden (EBWG). A wooded, more remote site probably most comparable to the woodland pothole near Wayzata Blvd. It is a fish-free, vernal pond and the first site to dry out (typically dry by early summer). Moist soil remains near the spring, which is measurably colder, but frogs mostly call from across the path and do not appear to use the spring itself for breeding. This site is protected by woods and topography from nearby lights and traffic noise. Fireflies are abundant.

- Five species heard; one of only two sites where wood frogs found (Table 4).
- Boreal chorus frogs were the most common, found in all years and in full chorus in five years. Because it dries up so quickly, it makes sense that it is used mostly by early season breeders (Figure 1).

- Wood frogs were found breeding here only in 2018. Buckthorn removal (2016) may be a driver (if wood frogs moved into the site in 2017, they would be found breeding the following year). Wood frog presence may also be explained by the late spring in 2018 or a combination of factors
- Leopard frogs heard after 2020 may be an overflow from the abundance found nearby at the dike road.
- Gray treefrogs and toads were heard about half the time. Since the pond dries up so quickly, it is questionable whether their breeding successfully produces adults.
- This location is most similar to the wooded potholes near Wayzata Blvd and Regency Hospital (the latter is the most disturbed by human activity and lights).

Dike near Eloise Butler Wildflower Garden (EBWG). An open permanent, wetland ringed by emergent vegetation in summer, covered with duckweed.

This is a well-lit and very noisy site—from trains, planes, cars, motorcycles and volleyball at Wirth Beach.

- Five species have been heard (Table 4). Boreal and chorus frog calls recorded came from the direction of the spring area and possibly even farther further away, such as Wirth Lake and Birch Pond.
- Until 2020, few amphibians were heard at this site. Due to the presence of fish and lack of calling, this site was nearly dropped from the survey in 2019. However, in 2020, observers were literally stopped in their tracks by the chorus and abundance of toads. At least 34 individuals were counted congregating and moving across the dike road, some in amplexus.
- Also in 2020, the low, snoring chorus of leopard frogs in 2020 was the loudest, most abundant than elsewhere, lasted early to late spring, and earned a calling index of 3 (Table 4).
- No other sites have documented the abundance and activity of breeding toads and leopard frogs found here. Toad roadkill often found in this area is further evidence (Figure 3).
- A conspicuous difference between conditions in 2020 and preceding years was the absence of volleyball activity at Wirth Beach due to pandemic restrictions. Citywide curfews due to civil unrest further reduced the amount of activity and traffic in this area. Loud voices, referee whistles, traffic, and bright lights until at least 10 PM, typical of this area and may be influencing breeding activity, in addition to making it hard to hear the calls.
- Buckthorn removal in 2016 did not visually transform the site, which is open, as in other locations. Still, the observed increase in leopard frogs—considered grassland frogs of open fields and meadows—may be associated with habitat diversity created by opening up the understory.

Woodland Pothole near Regency Hospital. This pothole wetland is bordered by a paved HVAC and parking area of Regency Hospital and separated by a high chain link fence. Noise from dumpsters, doors cars and HVAC is ongoing, and the pond is lit by lights from the parking lot.

Ambient light, noise from car doors slamming and HVAC; and runoff from the hospital parking characterize this location.

- Four species were heard; five species found. Leopard froglets were only seen on the path, once, in early summer (2015; Chart 4).

- Loudest choruses were heard before habitat improvements were conducted (gray treefrogs and toads).
- Boreal chorus frogs were consistently present and most abundant in 2020.
- Both gray and Cope's treefrogs were found in 2018. As wood frogs, Cope's gray treefrogs may be responding to a more open understory resulting from habitat improvements (if they moved into the site in 2017, they would be found breeding the following year). They could have moved in from the nearby golf course pond.
- Buckthorn removal (2016) dramatically opened up the understory and increased the amount of light reaching the pond. The pothole transitioned from open water and duckweed in 2015 and filled with emergent vegetation after 2016. The pothole supports hydrophilic plants but does not always have standing water by summer. While buckthorn rapidly grew back, the emergent vegetation persists.
- This site could be improved by reducing artificial light and runoff from the adjacent parking lot.

Golf Course Pond near Regency Hospital. Habitat improvements were not conducted at this location; however, it was included to round out the characterization of species in the park and ease of sampling. A permanent pond with a prairie/grassland and woodland surrounding about half the pond and open flat golf course the rest. Listening took place from the top of the slope above the grassland (near the Regency Hospital parking lot). Open water (often with duckweed), emergent vegetation and wet shrubs around the edges was present.

- Six species were heard, more than at any other site (Tables 1, 2). The only species heard in the park but not at this location were wood frogs.
- Significantly, in 2017, American bullfrogs were found breeding here. Bullfrogs found outside of Fillmore and Houston counties (the two southeastern-most counties in Minnesota are considered introduced). Bullfrogs are highly territorial and because they have been associated with the decline and displacement of other species are also considered invasive[11]. The sighting was reported to the DNR, who noted only one other record of it in Wirth in 2006. Bullfrogs are the only summer breeding species found during these surveys (Figure 1).
- Mid-season breeders were most common; full choruses of toads and both species of treefrogs were heard (Figure 1, Table 2). Gray and Cope's treefrogs were most abundant and their calling strength and frequency were nearly equal. Cope's gray treefrogs occurred more than at any other sites reflecting its preference for open and edge habitat.
- In summer, toads were also commonly seen on the trail, and on the mowed lawn near the well-lit parking lot.
- Leopard frogs were heard regularly and seen on a number of occasions. Observations may be limited due to the clamor of other species and the distance from the pond. Also adult frogs were seen in summer on the top of the steep grassland; and froglets, probably dispersing from the pond, were found hopping on the path about 100ft from the woodland pothole site.

[11] Virginia Herpetological Society. American Bullfrog-Interspecific Behaviors/Exclusions. Last accessed on Feb 1, 2023

DISCUSSION and NEXT STEPS

Half the frog and toad species found in Minnesota were heard in Theodore Wirth Park, 2015-2022 (7 of 14; five species are either out of range or extremely rare; Table 1). Spring peepers and green frogs were expected to be found and probably were in the past. Recent anecdotes[12] of spring peepers calling in the afternoon near EBWG and the dike, warrant additional effort. The American bullfrog was found breeding in Wirth Park and required reporting to the DNR. They are not native to this area and were probably introduced through angling or pet releases. They are also considered invasive. Bullfrogs are highly territorial and are associated with the decline of many species, including leopard and green frogs; their removal has been used to increase the relative abundance of native species[13]. The breeding population seems limited at this time but may warrant future attention. Care should be taken to avoid their expansion into other areas.

Habitat fragmentation, noise, and artificial lights—all found in Wirth Park—are among many variables associated with amphibian declines[14,15]. Contaminants in runoff and increasing salinization of surface and groundwater from chlorides used as de-icers in winter are also a concern. Tolerance to chloride varies by species and life stage, so even if adult frogs and toads can breed, their eggs, and tadpoles may not survive[16].

Monitoring data cannot be used to determine how breeding behavior and use of breeding sites responded to buckthorn removal, due to its rapid regrowth to full density and the many variables at play. The value of removing highly invasive buckthorn is justified in other ways and may benefit amphibian habitat as well. However, improvements need to be maintained and the seedbank depleted for benefits to persist.

Wood frogs were rare but may respond to habitat improvements that open the understory; however, observations were limited to a single year before buckthorn regrew, followed by drought. Perhaps by using goats, the understory will remain open and in years with average precipitation, wood frogs and possibly spring peepers will respond.

Interior woodland sites in the vicinity of fish-free, ephemeral ponds are important breeding habitats and should be prioritized for habitat improvements including buckthorn removal. In some locations, such as Birch Pond and the pothole wetland near the hospital, buckthorn screens breeding ponds from artificial light and acts as a noise buffer. In these locations, buckthorn removal alone is not enough, the understory should be replaced with less invasive, native plants

Drought conditions in 2021 and 2022 dried up the ephemeral ponds more quickly. As a result, eggs and tadpoles of early spring breeders may not have survived. Midseason breeders called earlier and less overall but may have been missed because their breeding season was truncated. If they did lay eggs in the temporary ponds, they probably did not survive when the pond dried up. Toas were not heard at all during surveys in 2022.

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[12] MPRB Naturalists, 2022

[13] VA Herpetological Society. American Bullfrog-Interspecific Behaviors/Exclusions. http://www.virginiaherpetologicalsociety.com/amphibians/frogsandtoads/american-bullfrog/american_bullfrog.php Last accessed on Feb 1, 2021.

[14] Hall 2016

[15] Kingsbury and Gibson 2011

[16] Snodgrass and Ownby 2015

As climate changes, the presence and composition of frogs and toads in Wirth Park. Some effects, such as hotter, drier weather may reduce groundwater in the park to the extent that temporary ponds only exist briefly in years with ample precipitation, and temperatures may rise in breeding ponds changing phenology and breeding success. Chlorides may increase in water as it becomes more concentrated. Developing stages may not grow up to become breeding adults.

The world-wide decline of amphibians is of great concern. As amphibians decline elsewhere, Theodore Wirth Regional Park is a kind of urban oasis surrounded by development. There are still seven breeding species (one introduced) in the park and actions can be taken to help protect and maintain habitat quality and amphibian fauna. Wildlife in the park could all benefit from one or more of these actions:

- Maintain benefits of removing buckthorn and prioritize interior woodland areas with temporary ponds. When buckthorn provides indirect benefits, such as buffering noise and screening artificial lights, replace it structurally using native plants or another type of barrier.
- Reduce roadkill during seasonal migrations. Prioritize critical times and locations (Figure 3). Remove barriers, slow traffic, warn drivers, and reconnect upland and breeding habitat using best practices in road design.
- Reduce and direct artificial light away from breeding ponds.
- Protect water quality from runoff using structural and nonstructural practices (such as intercepting runoff and reducing use of chloride deicers in the vicinity of wetlands).
- Maintain intact vegetative buffers as wide as possible (30 m recommended in some studies[17]).
- Reduce ambient noise from machinery, people, traffic.
- Prevent bullfrogs from reaching other sites.
- Educate and engage the public in frog conservation. Volunteer assistants are enthusiastic and delighted to learn about amphibian resources in the parks.

Recommended Monitoring

- Continue annual surveys
- Extend efforts to find wood frogs (early surveys) and spring peepers (coordinate with MPRB staff at EBWG and sample earlier in the day during the early spring breeding).
- Prioritize and characterize temporal ponds in the park. Most, but not all, appear in the NWI, and some characterizations have changed.
- Determine the extent of bullfrog colonization in the park.

[17] Gibbs et al. 2007

LIST OF ABBREVIATIONS

DNR	Refers to Minnesota Department of Natural Resources
EBWG	Eloise Butler Wildlflower Garden
MFTCS	Minnesota Frog and Toad Calling Surveys
MN PWI	Minnesota Public Waters Inventory
MPRB	Minneapolis Park & Recreation Board
NAAMP	North American Amphibian Monitoring Program
NWI	National Wetlands Inventory
USGS	United States Geological Survey

GLOSSARY

Anuran	Amphibian without a tail (frogs and toads)
Chorus strength	Also called "calling index"
Calling index	Also called "chorus strength". Rating on a scale of 1–3 where 1=one or two, 2=a few, and 3=many
Explosive breeding	Concentration of intense breeding activity into short periods of times
Run	Sampling window

APPENDIX E1 - Map, Description of Park Habitat, and Locations Sampled

Map of Sampling Sites

The sites sampled appear in the following map and are described in more detail below.
Map of survey locations sampled for frog and toad calling, from 2015-22 in Theodore Wirth Regional Park

Park Habitat

The Theodore Wirth Regional Park Master Plan[18] characterizes the park as

> *… having by very high groundwater levels and a number of springs, particularly surrounding Wirth Lake and near Eloise Butler Wildflower Garden. Ground water in Wirth Park is high in dissolved minerals. Groundwater may also contain chloride above background levels due to the highly urban nature of surrounding land.*
>
> *…small kettle wetlands exist in the southeast Wirth woodland and "Back 40" woodland areas. These wetlands are typically less than 1/8 of an acre and are fully within the park boundary. Many vernal pools are homes to birds and amphibians. Little change has occurred in these wetlands though some natural surface trails pass nearby and allow visitors views of the water.*

Description of Locations Sampled

Woodland Pothole Wetland near Wayzata Boulevard

- Low lying "pothole" or "kettle" wetland formed by ice blocks buried in glacial deposits.
- Temporarily to seasonally flooded. Water levels vary greatly from season to season. Can have some standing water throughout the season. In dry years, soils remain saturated but no standing water.
- No emergent vegetation; at times is covered by duckweed.
- Surrounded by hills and mature deciduous woodland. Dense buckthorn understory at beginning of the survey.
- < 0.25 acres
- No fish.
- Interestingly, this wetland is not listed in the National Wetland Inventory. (Similar nearby kettles are considered PFO1A)

Birch Pond (MN PWI #27065300[19])

- Permanently flooded pond with unconsolidated bottom. Part of the surrounding wetland is seasonally flooded (for over 30 days) and part is temporarily flooded (NWI classification: PUBH, PEM1C and PEM1A)
- Submersed and floating-leaved plants, ringed by emergent vegetation.
- Surrounded by hills and mature deciduous woodland. Dense buckthorn understory at beginning of the survey. Theodore WIrth Parkway borders the southwest side.4.61 acres
- Fish
- Stormwater discharges into the pond from at least two locations.

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18 Theodore Wirth Regional Park Master Plan 2015. Minneapolis Park and Recreation Board February 18, 2015. Last accessed on March 1, 2023.

19 Identifier currently used by DNR; previously Identified as MN PWI # 27-653 in Master Plan.

- Partially illuminated by streetlights on the parkway. Lights from the road shine onto the water, and their brightness increased after buckthorn removal.
- Frequent traffic kills breeding treefrogs migrating to the pond. Dead painted turtles have also found on road (pers. comm. J. Winkelman, 2022).
- Noise from and whistles from Wirth Beach volleyball courts are very loud and interfere with observer's hearing.

Spring and temporary wetland near EBWG
- Temporarily flooded. Area near spring retains saturated soils, but the north of spring dries up before summer (NWI classification PFO1A).
- Surrounded by hills and mature deciduous woodland. Adjacent to EBWG. Dense buckthorn understory at beginning of the survey. Very close to permanent shallow marsh across Glenwood from Wirth Lake.
- 1.83 acres
- No fish

Dike near EBWG
- Permanent shallow marsh across Glenwood Avenue from Wirth Lake. There is a flowing connection under the dike connecting two wetlands (NWI classification PABH, PEM1F and PEM1C).
- Emergent vegetation and floating-leaved plants, often covered with a thick blanket of duckweed. .
- Mostly open. Partially bordered by hills and mature deciduous woodland. Adjacent to EBWG. in wooded areas dense buckthorn understory at beginning of the survey. Glenwood Avenue runs along the north side.
- 3.65 acres
- Strongly illuminated by road, parking lot and sand volleyball court lights. Traffic and whistles from beach volleyball games are extremely loud.

Woodland Pothole near Regency Hospital
- Low lying "pothole" or "kettle" wetland formed by ice blocks buried in glacial deposits (NWI classification is PEM1C).
- Persistent emergent vegetation. In 2015, there was open water in summer; emergent vegetation has since filled in, and now only seasonally flooded (more than 30 days).
- Bordered on three sides by hills and mature deciduous woodland. Dense buckthorn understory at beginning of the survey.
- Hospital parking lot adjacent to and drains towards wetland.
- 0.24 acres
- No fish.
- Strongly illuminated by parking lot lights and noise from hospital HVAC is loud.

Golf Course Pond near Regency Hospital (aka "Ski Jump Pond" (MN PWI #27-648[20])
- Permanent flooded pond with unconsolidated bottom (NWI classification is PABH, PFO1A, PEM1C)
- Emergent vegetation, and shrubs. Part of the wetland is seasonally flooded (for over 30 days) and part is temporarily flooded.
- Mostly open, bordered by an open area of golf course and steep slopes, which are vegetated with prairie on one side and mature deciduous woodland on another.
- Located west of the Par 3 golf course, not actively used for recreation.
- 5.27 acres

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[20] Referred to as MN PWI #27-648 in Master Plan; however, considered unnamed and not listed on DNR website.

APPENDIX E2 - Comparison of Differences between MFTCS and the Protocol Used in this Survey

	MFTCS	This Survey
Sampling Locations	Randomly assigned and cover a large region. Minimum of 0.5 miles apart.	Not randomly assigned. Limited to Theodore Wirth Regional Park. Locations chosen to align with survey goals Most sites are less 0.5 miles apart.
Data Collection	Measuring water temperature optional; one reading per run used for all sites regardless of location or water source.	Water temperature recorded at all sites, when present and safely accessible.
	Comments limited to one field for all sites and dedicated to how sampling was done (eg., tried to silence frogs at site X).	Additional observations recorded at each location. A field was added to each site for notes about habitat, phenology, weather, etc.
	Records only species heard during the 5-minute listening period. It is optional to note in comments species heard outside of the listening period.	Records frogs and toads **heard** outside of the 5-minute listening period. "P", for present, was used instead of the numeric calling index to distinguish this type of observation from MFTCS protocol in raw data.
	Records only species heard during the 5- minute listening period. Optional to note in comments species seen and not heard.	Records frogs and toads **seen** at a site outside of the 5-minute listening period. P, for present, was used instead of the numeric calling index to distinguish this type of observation from MFTCS protocol.
	Records all species heard during the 5-minute listening period—regardless of distance. Sites are located at least 0.5 miles apart, which prevents hearing calls from another site.	Distinguishes between species heard at the waterbody being sampling site and those heard in the distance (which could be from a nearby sampling site since some are less than a 0.5 mile apart). Calling index for species heard in the distance is denoted by parentheses around the rating, for example (3). Note this is not foolproof as it can be hard to discern whether calls are from an adjacent site or on the far side of the location being sampled.

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