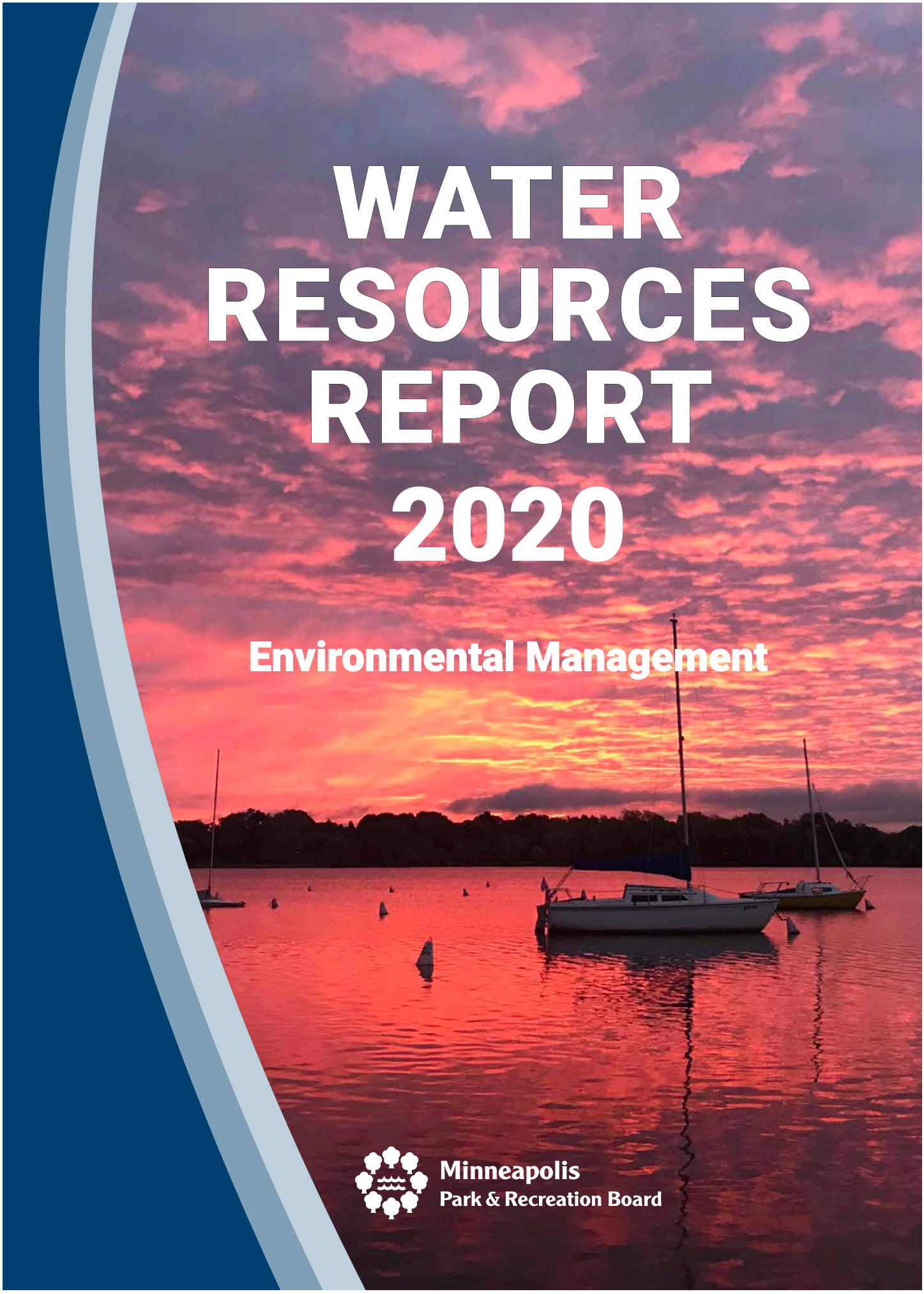
WATER RESOURCES REPORT 2020

Environmental Management



Minneapolis
Park & Recreation Board

Minneapolis
Park & Recreation Board

2020
WATER RESOURCES REPORT

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LIST OF ABBREVIATIONS

% DO	Percent Dissolved Oxygen
µg	Microgram
µm	Micrometer
µmhos	Micromhos
µS	Microsiemens
ACSP	Audubon Cooperative Sanctuary Program
AIS	Aquatic Invasive Species
Al	Aluminum
Alk	Alkalinity
alum	Aluminum sulfate
As	Arsenic
BCWMC	Bassett's Creek Watershed Management Commission
BMP	Best Management Practices
C	Celsius
CAMP	Citizen Assisted Monitoring Program
cBOD	5 day Carbonaceous Biochemical Oxygen Demand
Cd	Cadmium
CDS	Continuous Deflective Separation
cf	Cubic foot
cfs	Cubic foot per second
cfu	Colony forming unit
chl-*a*	Chlorophyll-*a*
Cl	Chloride
cm	Centimeter
COD	Chemical Oxygen Demand
Cond	Conductivity
Cu	Copper
CV	Coefficient of Variance
CWP	Center for Watershed Protection
DO	Dissolved Oxygen
E. coli	*Escherichia coli*
ERA	Environmental Resource Associates
EWM	Eurasian watermilfoil
F	Fahrenheit
F. coli	Fecal Coliform
Fe	Iron
FIN	Fishing in the Neighborhood Program
FOG	Fat Oil and Grease
ft	Foot
GIS	Geographical Information System
GPS	Global Positioning System
Hard	Hardness, Total as CaCO3

HPLC	High Pressure Liquid Chromatography
IBI	Index of Biological Integrity
ID	Insufficient Data
in/hr	Inches per hour
IRI	Instrumental Research, Inc.
IWMI	Interagency Water Monitoring Initiative
kg	Kilogram
L	Liter
LAURI	Lake Aesthetic and User Recreation Index
LCC	Lake Champlain Committee
m	Meter
MAX	Maximum
MCES	Metropolitan Council Environmental Services
MCWD	Minnehaha Creek Watershed District
MDH	Minnesota Department of Health
MDL	Minimum Detection Limit
mg	Milligram
MIN	Minimum
mL	Milliliter
Mn	Manganese
MNDNR	Minnesota Department of Natural Resources
MnDOT	Minnesota Department of Transportation
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
MRL	Minimum Reporting Limit
N/A	Not Applicable
n/c	Not Collected
NA	No Data Available
NB	No Swimming Beach
NCHF	North Central Hardwood Forests
ND	Not Detected
NDC	National Data Center
ng/L	Nanogram per Liter
ng/g	Nanogram per Gram
NH3	Ammonia, Un-ionized as N
Ni	Nickel
NO3/NO2	Nitrate+Nitrite
NOAA	National Oceanic and Atmospheric Administration
NOx	Nitrite+Nitrate, Total as N
NPDES	National Pollutant Discharge Elimination Systems
NS	Not Sampled

NTU	Nephelometric Turbidity Unit
NURP	Nationwide Urban Runoff Program
NWS	National Weather Service
OHWL	Ordinary High Water Level
OTP	Ortho Phosphorus
P	Phosphorus
Pb	Lead
PE	Performance Evaluation
PFC	Perflorinated Chemical
PFOA	Perflurorooctanoic Acid
PFOS	Perfluorooctane Sulfonate
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
RL	Reporting Limit
RPD	Relative Percent Difference
s	Second
Si	Reactive Silica
Sp. Cond.	Specific Conductivity
SRP	Soluble Reactive Phosphorus
STDEV	Standard Deviation
TCMA	Twin Cities Metropolitan Area
TDP	Total Dissolved Phosphorus
TDS	Total Dissolved Solids
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TOC	Total Organic Carbon
TP	Total Phosphorus
TRPD	Three Rivers Park District
TSI	Trophic State Index
TSS	Total Suspended Solids
US EPA	US Environmental Protection Agency
USGS	US Geological Survey
VMI	Visual Monitoring Index
VSS	Volatile Suspended Solids
WHEP	Wetland Health Evaluation Program
WOMP	Watershed Outlet Monitoring Program
WPA	Works Progress Administration
Zn	Zinc

TOC

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 2020 monitoring season. The report is based on data collected by the MPRB Environmental Management Section.

In 2020, 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. Spring Lake is monitored every other year and was not monitored in 2020. Historical data from 1991-2020 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 2020 the following observations were made:

Lakes with Improving Water Quality Indicators: 1991-2020	Bde Maka Ska Wirth Lake
Lakes with Stable: Trends 1991-2020	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: 1991-2020	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, our lake rankings are different.

Lakes with Improving Water Quality Indicators: 2011-2020	No lakes with improving trend
Lakes with Stable Trends: 2011-2020	Bde Maka Ska Brownie Lake Lake Harriet Lake Hiawatha Lake of the Isles Loring Pond Lake Nokomis Powderhorn Lake Spring Lake Wirth Lake
Lakes with Declining Water Quality Indicators: 2011-2020	Cedar Lake

Several lakes have seen poor water quality and higher TSI scores between 2017 and 2020. Extraordinarily high rainfall amounts received in our region over the last several years is a likely contributor to the change in trend from improvement towards stability in most lakes. Data from the most recent four years are the reason for the trend changes that have been detected. The Cedar Lake trend is now towards poorer water quality because of the scores calculated in 2017-20.

Despite the trend change, Bde Maka Ska, Cedar Lake, and Lake Harriet frequently meet the goals set for these lakes by the Clean Water Partnership 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, Lake Harriet, and Wirth Lake remain outstanding for lakes in urban settings. Indicators show better water quality in 2020 than the early 1990s when restoration efforts began. All three lakes currently have better water quality than Minnesota Pollution Control Agency (MPCA) guidelines for phosphorus, chlorophyll-*a*, and Secchi depth. Continued monitoring will assist in developing the next generation plans for Bde Maka Ska and Lake Harriet.

Most blue-green algae blooms occur during the hottest part of summer, but in 2020 an unusual severe blue-green algae bloom occurred in early spring on Cedar Lake, Lake of the Isles, and Lake Nokomis. The bloom caused each of these lakes to appear reddish or murky brown in color and decreased water clarity.

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 2017-20 led to poorer TSI scores at this lake, and in turn, have reversed its trend.

Lake Nokomis met MPCA site-specific standards for chlorophyll-*a* and phosphorus in 2020 but did not meet the standard for clarity. The MPRB received a grant from the Minnesota Environmental and Natural Resources Trust Fund for a project to study Lake Nokomis' carp population and to develop long-term management practices that improve water quality. The project was completed in 2019 and it was found that a large-scale carp removal is likely not feasible due to furrows and debris that remained from dredging. Several small to medium-scale removal techniques were trialed during the study. Creating a barrier for carp movement between Nokomis and the southern watershed is a high priority action in the plan. At high water levels, the Nokomis weir may play a more significant role in carp movement than during dry years.

Powderhorn Lake received its 17th barley straw treatment in 2020 in an ongoing project intended to reduce blue-green algae levels. The lake was impacted by blue-green algae and did not meet shallow lake standards for water clarity, chlorophyll-*a*, and total phosphorus in 2020.

In 2020, Lake Hiawatha met the site-specific standards set by the MPCA for chlorophyll-*a* and total phosphorus but did not meet the standard for clarity. The water quality in Lake Hiawatha is controlled by the large amount of inflow from Minnehaha Creek. TSI scores in Lake Hiawatha have remained stable over the past 25 years.

The MPRB monitored 12 public beaches for *Escherichia coli* in 2020. 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 Lake Hiawatha, Bde Maka Ska and Lake Harriet were closed for parts of the swimming season. The MPRB initiated a Visual Monitoring

Index for blue-green algae, education pieces related to healthy swimming practices and an online GIS based Lake Water Quality Map to better inform lake users of closures and issues that could impact human health.

The natural swimming pool at Webber Park, the first of its kind in North America, was open for the fourth full year in 2019. Due to COVID-19 concerns and for the safety of MPRB staff and guests, the pool was closed for the entire 2020 season. 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. Monitoring was limited in 2020 with the pool being sampled a total of four times. European standards suggest that 95% of samples should meet standards, and Webber NSP has made significant progress towards this goal. In 2020, 100% of *E. coli* samples, 80% of Enterococci samples, and 93% of Pseudomonas samples met standards. Low bacteria levels are likely attributed to numerous bird deterrents, secondary disinfection with UV light, and no human contact in the pool in 2020.

A variety of early detection tools, such as environmental DNA (eDNA) monitoring, veliger tows, settling plates, and boat launch surveys, were used to search for zebra mussels in Minneapolis lakes in 2020. Similar to previous years, zebra mussels were only detected at Lake Hiawatha and were not detected at any other Minneapolis lake.

Aquatic plant harvesting was carried out on Bde Maka Ska, Cedar, Harriet, Nokomis, Lake of the Isles, and Wirth Lakes in 2020 to allow for improved recreational access. MPRB Staff removed 179 flatbed truck loads of plants in 2020 which is equivalent to 611 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 2020 annual mean temperature was 47.8° F, which was 1.7° F above normal. Eight months had above normal temperatures and four months had below normal temperatures. The warmest month of the year was July, and the coolest month was January. The average monthly temperatures deviated more than 2° F from normal except in February, August, and September,

The 2020 annual recorded precipitation total was 29.83 inches, which was 0.78 inches below the 30-year normal. Eight months had below 30-year normal precipitation and four months had above 30-year normal precipitation. The wettest month of the year was June, and the driest month was September. The average monthly precipitation shows some significant monthly deviations from the 30-year normal: July through December were all drier than the 30-year normal; only January, March, May, and June were wetter than the 30-year normal.

The MPRB monitors stormsewers 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 2020, the COVID-19 pandemic disrupted the ability to carry out equipment installations. Work was altered, and grab samples were used to characterize stormwater at the Powderhorn Lake Inlets, and the 24th & Elm Infiltration Chamber. In partnership with the City of Minneapolis, a study of 16 stormwater ponds throughout the city was completed. The results of the 2020 stormwater data were typical for stormwater.

In 2020, monitoring was continued with multiple BMP projects. These included:

1) 24th & Elm Infiltration Chamber.

2) Powderhorn Lake watershed.
3) Sixteen Stormwater Ponds.

Monitoring partners for 2020 included: The Friends of Lake Nokomis, Hennepin County, Minneapolis Public Works, the Minnehaha Creek Watershed District, Minnesota Pollution Control Agency, and the Minnesota Department of Natural Resources.

TOC

1. MONITORING PROGRAM OVERVIEW:1991-2020

LAKE MONITORING

Background

The Environmental Management Section 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 CAMP program every two to three years and is monitored more extensively by the Commission every five years if the budget allows. **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.

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.

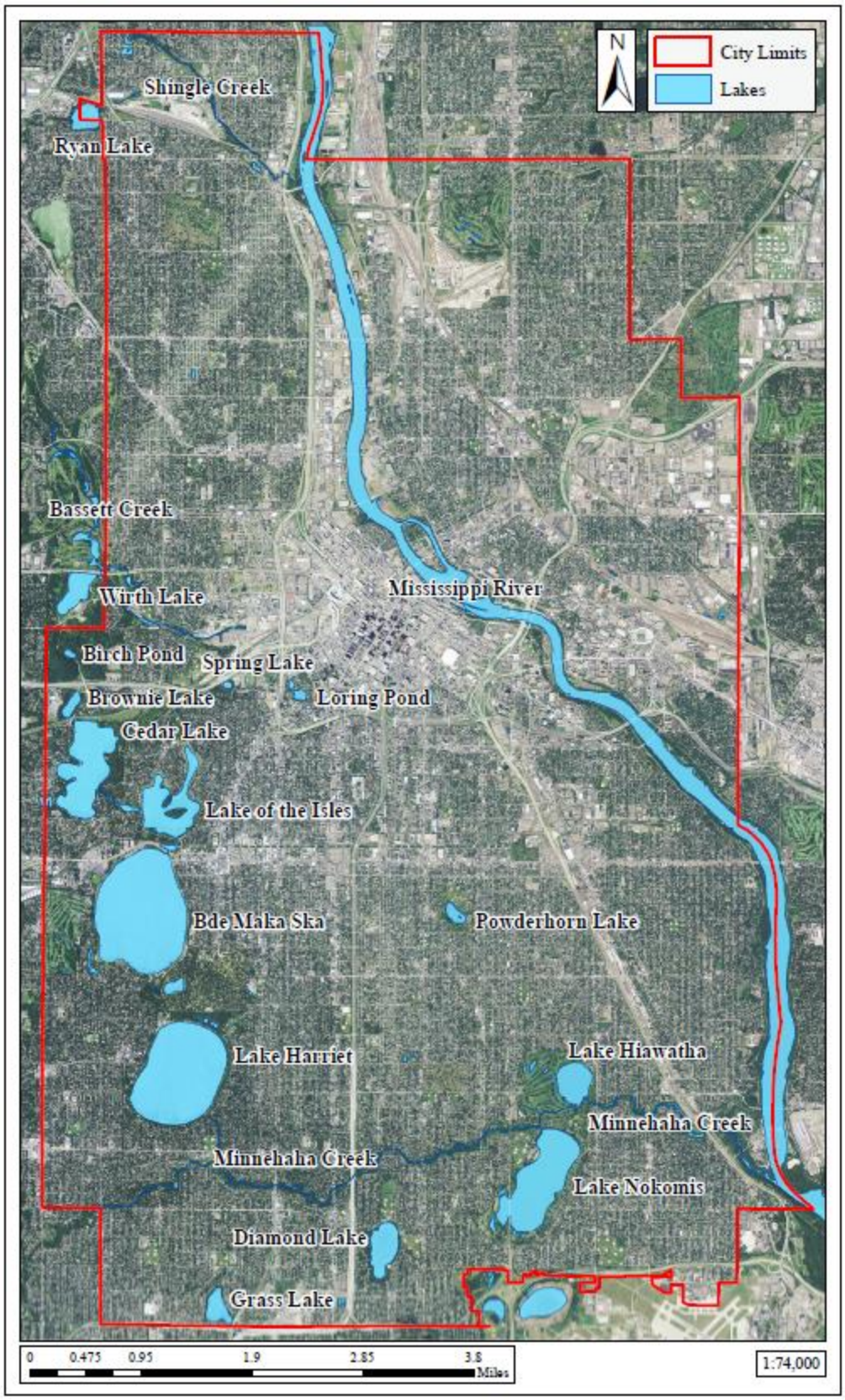


Figure 1-1. Location of waterbodies in Minneapolis.

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 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

† Based on long term average data.

‡Recent projects have altered these statistics.

NA= Information not available.

Methods

The 2020 lake monitoring 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. Brownie and Grass Lakes were only sampled once per month.

Table 1-2. Schedule of sampled parameters for most lakes in 2020.

Parameters	Sampling frequency
Chloride, Chlorophyll-*a*, Conductivity, Dissolved oxygen, pH, Phytoplankton, Secchi Transparency, Temperature, Total Phosphorus, Soluble Reactive Phosphorus, Total Nitrogen, Turbidity	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 point in each lake (sampling station). The sampling stations were determined from bathymetric maps and located using handheld GPS or parallax 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, and turbidity profiles. These parameters were measured at 1-meter intervals from the lake bottom to the surface. The multiprobes were calibrated according to the manufacturer's guidelines prior to each sampling trip. Water clarity was determined with 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-m 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 2020 MPRB lakes monitoring program.

Lake	Sample Depth (m)
Bde Maka Ska	0-2 composite, 6, 12, 18, 22
Brownie	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 sampling station for each lake once per month during the growing season, except at Diamond Lake and Spring 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 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 2020 contract laboratory for chemical analyses was Instrumental Research, Inc. (IRI). 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 sections and **Appendix B**.

Table 1-4. Methods and reporting limits used for parameter analysis in the 2020 Minneapolis lakes monitoring program.

Parameter	Method	Reporting Limit
Alkalinity	Standard Methods 2320 B	2.00 mg/L
Ammonia	USGS I-3520-85	0.250 mg/L
Chloride	Standard Methods 4500-Cl^- B	2.00 mg/L
Chlorophyll-*a*	Acetone extraction/spectrophotometric determination (pheophytin corrected) SM 10200 H	0.500 µg/L
Conductivity	Hydrolab Minisonde 5a Multiprobe & YSI EXO1 (field)	0.1 µS/cm
Dissolved oxygen	Hydrolab Minisonde 5a Multiprobe & YSI EXO1 (field)	0.01 mg/L
Escherichia coli	Colilert Quanti-Try, IRI	1 MPN/100 mL
Hardness	Standard Methods 2350 C	5.00 mg/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
Turbidity	Hydrolab Minisonde 5a Multiprobe & YSI EXO1 (field)	1 NTU
Transparency	Secchi disk	0.01 m

LAKE LEVELS

Background

Lake levels have been recorded by MPRB staff annually, 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 staff gages located at Bde Maka Ska, Diamond, Harriet, Hiawatha, Nokomis, Loring, Powderhorn, and Wirth, see **Figure 1-2**. The lake level reading for the Upper Chain of Lakes, Brownie, Cedar, Isles, and Bde Maka Ska, are all represented at the staff gage located at Bde Maka Ska.

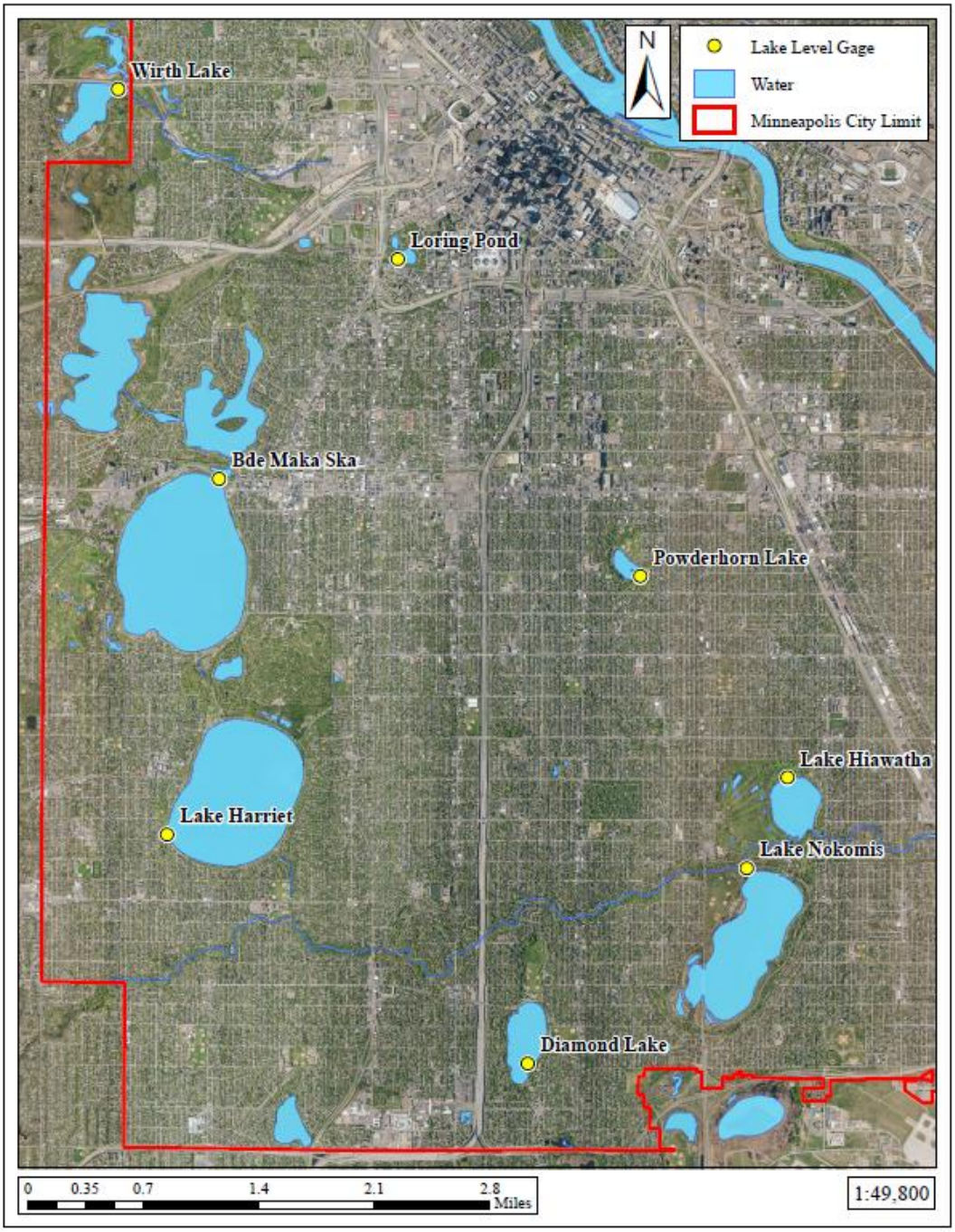


Figure 1-2. Minneapolis lake level monitoring locations.

Results & Discussion

Lake level data is converted to elevation (msl) and archived in a MS Excel spreadsheet. 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 staff gage, and water levels for Minneapolis lakes.

WELLS

Background

Groundwater levels are monitored by the MPRB staff at seven piezometric wells. Piezometric wells are drilled to specific depths in order to monitor hydraulic head, the groundwater pressure above a known datum. 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 are used to maintain water levels at lakes and ponds. **Figure 1-3** is a map of the piezometric, irrigation, and augmentation well locations in Minneapolis.

The Minnesota Department of Natural Resources (MNDNR) issues the permits and determines pumping limits for irrigation and augmentation wells. Annual fees and reports are sent to the MNDNR.

Methods

Piezometric well readings are taken with a Herron Instrument Water Level Meter. This water tape 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 Solinist dataloggers left in the wells. They are downloaded every two weeks along with a water tape reading taken at that time.

Results & Discussion

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

Results from the 2020 lake augmentation well readings and annual usage can be found in the Powderhorn Lake and Loring Pond sections. All the irrigation and augmentation wells used were below their MNDNR allotted groundwater pumping volumes.

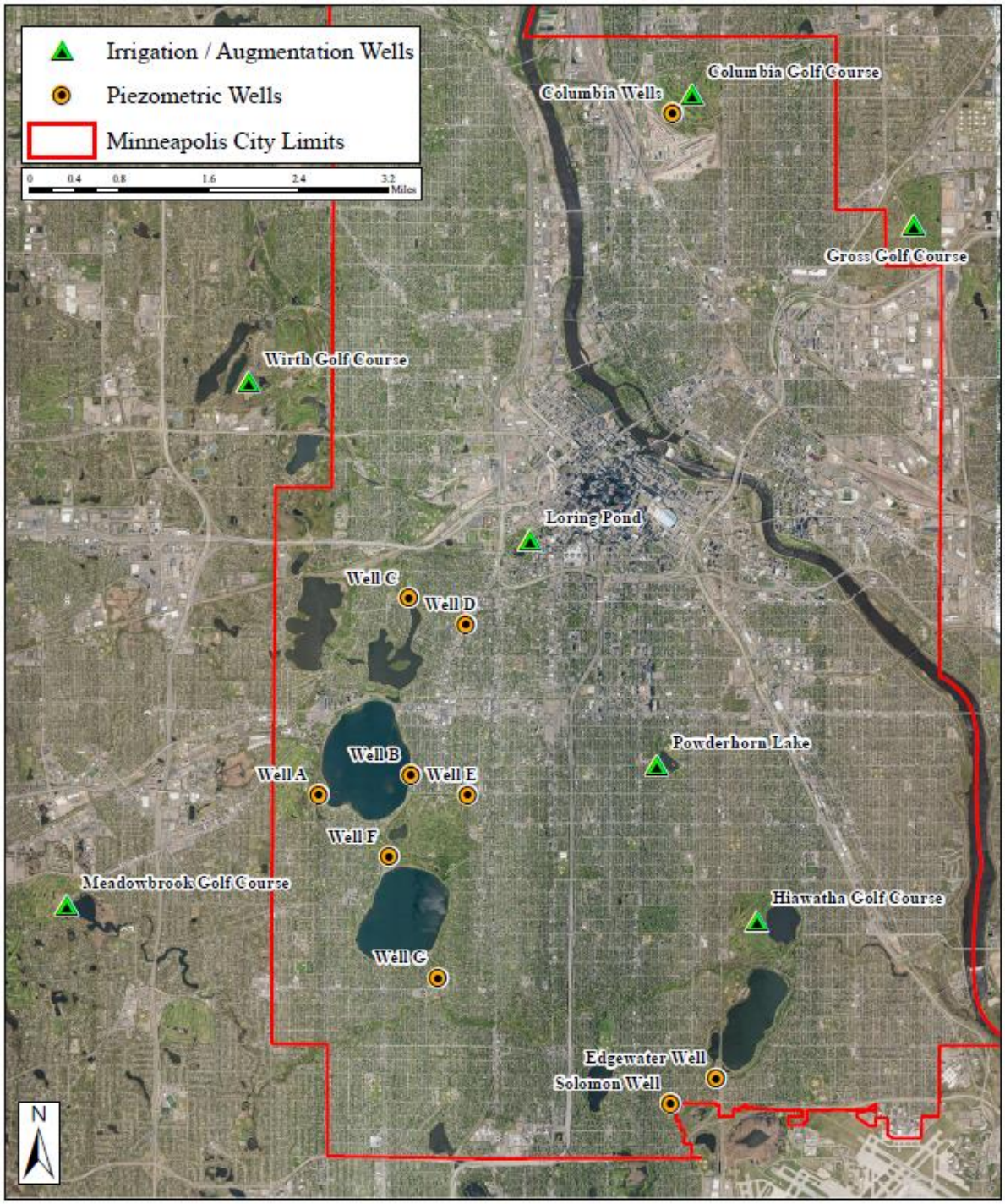


Figure 1-3. Map of piezometric and irrigation/augmentation well locations monitored by MPRB Environmental Management.

WATER QUALITY TRENDS (TSI)

Scientists have analyzed water quality parameters in Minneapolis lakes sporadically since 1927 and consistent bi-weekly monitoring began in 1991. In 2020, 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*** (chl-*a*) is a pigment algae use to capture sunlight and is a measure of how much algal biomass is in the lake.
>
> **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 algal blooms which is high algal growth.

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 soil type 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 a 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:

> **Oligotrophic** (30 > TSI < 40) lakes are characterized by low nutrients and contains oxygen throughout the water column, and clear water. Salmonid fisheries may dominate.
>
> **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 considered fertile and characterized by high algal biomass and may have macrophyte problems in some systems. Hypolimnetic anoxia occurs in stratified lakes and only warm water fisheries can be sustained.
>
> **Hypereutrophic** (TSI > 70) lakes are characterized by high nutrient concentrations, leading to frequent severe algal blooms and low macrophyte densities due to light limitation by algae.

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 sections 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 (found in each individual lake's section). 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. The slope indicates the general trend of the data. The *p*-value indicates the probability of the observed trend even if there isn't one. The use of a *p*-value of <0.05, meaning there is a 5% chance there isn't a trend even if one is observed, is frequently used to determine if a trend is statistically significant. 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 (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 section. 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 sections. 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 is marked as outliers. In this report, all outliers in the box and whisker plots are 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. MCPA 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. The red circle represents the mean value of data collected between June and September, 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.

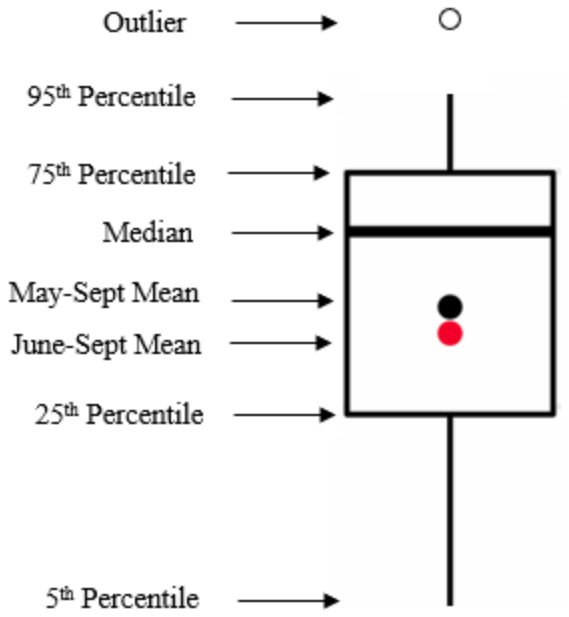


Figure 1-4. Legend for box and whisker plots.

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 a new index. The original Lake Aesthetic and User Recreation Index (LAURI) was the result of this development. It was designed to give recreational users a source of information about conditions affecting their use of city lakes. The goal was to have an easily understandable recreational indicator. 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 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. The revised LAURI has five indices:

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

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.

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 exist 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 1-6**. At lakes with more than one beach, beaches were averaged together. This metric was chosen because US 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.

Table 1-6. 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

Water Quality Index

Water clarity is easy to measure and understand. This simple measure is a good integrator of various parameters affecting the eutrophication status of a lake. The lakes are separated into deep lakes and shallow lakes using criteria developed by the Minnesota Pollution Control Agency (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 numbers 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

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 1-8**. 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 1-8. 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 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 1-9**. 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 invasive plant growth management.

Table 1-9. 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 is added to determine 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

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 1-10**. Lower numbers indicate worse aesthetics. Individual color, odor, and debris scores are averaged over the season. The final aesthetic score is 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 which was how it was previously calculated. This change was made based on feedback from lake users to better represent the impact of trash on lake aesthetics.

Table 1-10. 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 – strong	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

BLUE-GREEN ALGAE

Background

In 2020, Minneapolis Parks and Recreation Board staff began monitoring blue-green algae blooms. Blue-green algae is a naturally occurring phenomenon; however, frequency of occurrence and intensities of blooms have raised public concern. Blue-green algae blooms, otherwise known as harmful algal blooms (HABs), are caused by a photosynthetic microorganism called cyanobacteria. It is known that certain taxa of cyanobacteria have the capability to produce toxins called cyanotoxins (US EPA, 2017). If ingested these toxins can be harmful to wildlife, pets, and humans. See **Table 1-11** to see the possible level of exposure to algae toxins in relation to recreational water activities (https://www.pca.state.mn.us/water/blue-green-algae-and-harmful-algal-blooms).

Table 1-11. Possible level of exposure to algae toxins in relation to recreational water activities. 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

It has been long known that anthropogenic factors such as, urban, industrial, and agricultural activities have attributed to nutrient over-enrichment of water bodies, a process that cyanobacteria are well adapted and thrive from (Paerl & Otten, 2013). While the process of nutrient loading promotes cyanobacteria growth, warmer temperatures, more intense precipitation events, and longer stratification periods due to climate change will stimulate more intense and frequent future harmful algal bloom events (Paerl & Otten, 2013). There is much research regarding blue-green algae; however, it is not yet known why certain taxa of cyanobacteria produce toxins, and at what frequency they produce them. For more information on cyanotoxins and corresponding health effects visit https://www.epa.gov/cyanohabs/learn-about-cyanobacteria-and-cyanotoxins.

Methods

Currently, the 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. The MPCA recommends an advisory limit of 6 micrograms per liter (µg/L) for microcystin and 15 micrograms per liter (µg/L) for cylindrospermopsin as a standard for toxins in recreational water. In 2020, MPRB staff began a visual monitoring protocol for beaches, and response monitoring for reported blooms at lakes. This visual monitoring index occurred weekly during regularly scheduled beach monitoring program. If blue-greens were visually present a beach advisory was placed on the MPRB Lake Water Quality web app; a web application developed to notify the public on the status of Minneapolis beaches. This application also serves as an informational hub for the status of harmful algal blooms on lakes without beaches. Visit

https://minneapolisparks.maps.arcgis.com/apps/webappviewer/index.html?id=88319f73c7904adcbabccacdff38bbf1 to see the Lake Water Quality web app.

In Minneapolis lakes, blooms were regularly monitored throughout the open-water season. When blooms were reported MPRB staff would evaluate the intensity of blooms based on a visual monitoring index. If a bloom was considered severe the public was notified through media outlets, and lake-use advisory signs were placed at various locations around the reported lake. During severe blooms MPRB staff collected samples for cyanobacteria toxin testing. Blue-green algae bloom notification signs were left around a lake until sample value results were below the MPCA recommended limit. For more information on severe blue-green bloom events on specific lakes see **Chapter 5**, **Chapter 10**, and **Chapter 12**. For more information on blue-green monitoring at Minneapolis beaches see **Chapter 18**.

In addition to visual monitoring and response testing for toxins, MPRB is continuing to expand knowledge on blue-green algae blooms to better understand event occurrence in Minneapolis Lakes. It is not possible to know the algal conditions occurring around a lake at every location and point in time; however, there are certain conditions that can signal a toxic bloom event. In a study done on Minnesota lakes, Heiskary and Lindon (2009) found that 'moderate' to 'high risk' of toxins, specifically microcystin, likely occur when chlorophyll-*a* $\geq$ 30 Mg/m3, pH values $\geq$ 9.0, and Secchi readings $\leq$ 0.5 meters. Risk factors associated with cyanotoxins are based off criteria established by the World Health Organization (WHO). All three of these parameters are collected regularly during MPRB's lake sampling monitoring program. These toxin indicator parameters were evaluated for lakes with reported blooms during the 2020 season.

The MPRB have been collecting phytoplankton samples from Minneapolis Lakes since 2004. Cyanobacteria are routinely documented in these phytoplankton samples which identify species abundance and includes taxa that can produce cyanotoxins. This information helps MPRB staff to know which toxin needs to be tested when harmful bloom events occur. See **Chapter 17** for a comparison of cyanobacteria species and toxin indicator parameters for lakes with reported blooms in 2020.

Due to the public health concern of these events, MPRB staff will continue to monitor these events using the US EPA and MDH guidelines and notify the public on health concerns related to blue-green algae blooms. For more information on how to spot a bloom and what to do when a bloom is suspected visit:
https://www.minneapolisparks.org/park_care__improvements/water_resources/lake_water_resources/blue-green-algae/.

Winter Ice Cover

An interesting 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 migration and breeding patterns of birds, food supply of fish and animals, and water chemistry. Length of ice cover in our region is affected by local weather patterns as well as changes in regional and global cycles. Magnuson, et al (2001) found that northern hemisphere temperate climate ice records reflected changes in the strength of a low-pressure zone that builds over the Aleutian Islands (the Aleutian Low) and El Nino cycles (cycles of warming the surface waters of the tropical Pacific Ocean). Ice-out and -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 MDNR to include in their statewide long-term ice record.

However, 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 in the afternoon when ice may break up on a sunny day. Ice-off occurs when the lake is essentially ice free (<10% covered with ice).

AQUATIC PLANTS

Aquatic plants (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. All lakes were visually assessed with a meander survey in June of 2020 and a point intercept survey of Wirth Lake was conducted in August 2017.

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 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 significant 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 milfoil out of heavily used recreational areas in Lake Nokomis and Wirth Lake. For acreage see individual lake sections. MPRB Staff removed 179 flatbed truck loads of plants in 2020 which is equivalent to 984.5 cubic yards of aquatic plant material. See **Chapter 20** and **Chapter 21** 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, Harriet, Hiawatha, Isles, Loring, Nokomis, Powderhorn, and Wirth) except for April and October which were sampled once per month. Samples were collected once a month at Brownie, Diamond, and Grass Lakes. 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 for analysis into amber bottles, preserved with 25% glutaraldehyde (a preservative) back at the lab and sent to PhycoTech Incorporated laboratory for analysis. Analysis was completed using 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 sections. Common phytoplankton divisions and a common description are given in **Table 1-12**. Chlorophyll-*a* concentrations were used to estimate phytoplankton biomass in the lakes. Each lake section shows chlorophyll-*a* concentrations and the distribution of phytoplankton divisions throughout the sampling season.

Table 1-12. Phytoplankton divisions and brief descriptions.

Division	Description
Bacillariophyta	Diatoms
Chlorophyta	Green algae
Chrysophyta	Chrysophytes or Golden algae
Cryptophyta	Cryptomonads
Cyanophyta	Cyanobacteria or Blue-green algae
Euglenophyta	Euglenoids
Haptophyta	Haptophytes
Pyrrhophyta	Dinoflagellates
Xanthophyta	Yellow-green algae

Zooplankton

Zooplankton samples were collected monthly from most Minneapolis lakes, see **Table 1-2**. Diamond and Grass Lake were not sampled because of its shallow depth and Brownie Lake was not sampled due to lack of zooplankton in most 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 70% denatured histological ethanol to a final concentration of 30% sample and 70% preservative. 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 1-13**. Results are presented in the individual lake sections.

Table 1-13. 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 MDNR. This information is on the MDNR 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 causing a leakage of the bodily fluids and an influx of lake water into the fishes' body. There is little that the MDNR or the public can do to prevent this naturally occurring phenomenon.

Fish kills in Minneapolis lakes can also be attributed to carp edema virus (CEV), also 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 in Minnesota in Cottonwood Lake 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 Fahrenheit, 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 virus is greatest in juveniles, while adult fish may lie motionless on the bottom. There is little that the MDNR 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 to aid in determining the cause.

QUALITY ASSURANCE/QUALITY CONTROL

The contract laboratory 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.

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 2020, see the Quality Assurance Assessment Report in **Chapter 29**.

TOC

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**. 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 in comparison 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 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. Photo of the sailboat buoy field at Bde Maka Ska, taken from dock located at the boat launch in September of 2020.

The Minneapolis Chain of Lakes Regional Park is the most visited park in the State of Minnesota with over 8 million user visits in 2019 (Met Council, 2019). Met Council did not produce a park use estimate for 2020 due to COVID-19. 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 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, 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 is 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. Due to low water levels weed growth accelerated in the channels and a sodium arsenite treatment was done in 1959. Another pumping station and pipeline was 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.

Water quality on Bde Maka Ska has been monitored annually since 1991. Studies showed that water quality in Bde Maka Ska had degraded with human activity. 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 to 90 years. Total phosphorus 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. 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.

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 in 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 and since 2001 total phosphorus concentrations decreased and are less variable due to the alum treatment.

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 21** for additional details.

Table 2-1. Bde Maka Ska physical characteristics.

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.**

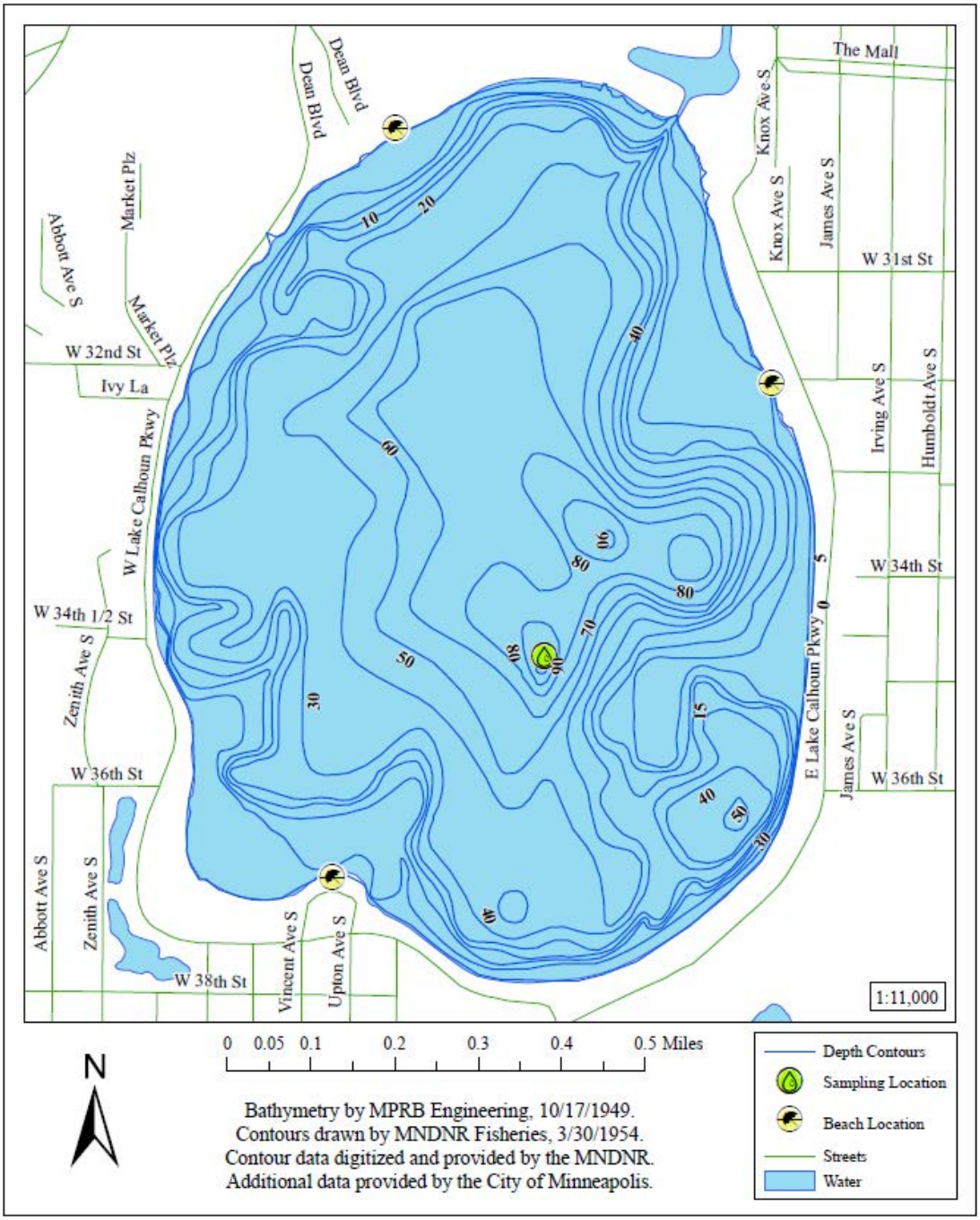


Figure 2-2. Bathymetric map with sampling locations at Bde Maka Ska.

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**. In 2019, the lake gage was missing between

April 22nd and June 17th and the lake levels were estimated using tape down measurements and a linear equation. Lake levels in the Upper Chain of Lakes remained below the OHWL for most of the year in 2020, only exceeding for a period in late May through July. Lake levels began to decline in August, and continued to decline through the fall, until freezing at 0.95 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.

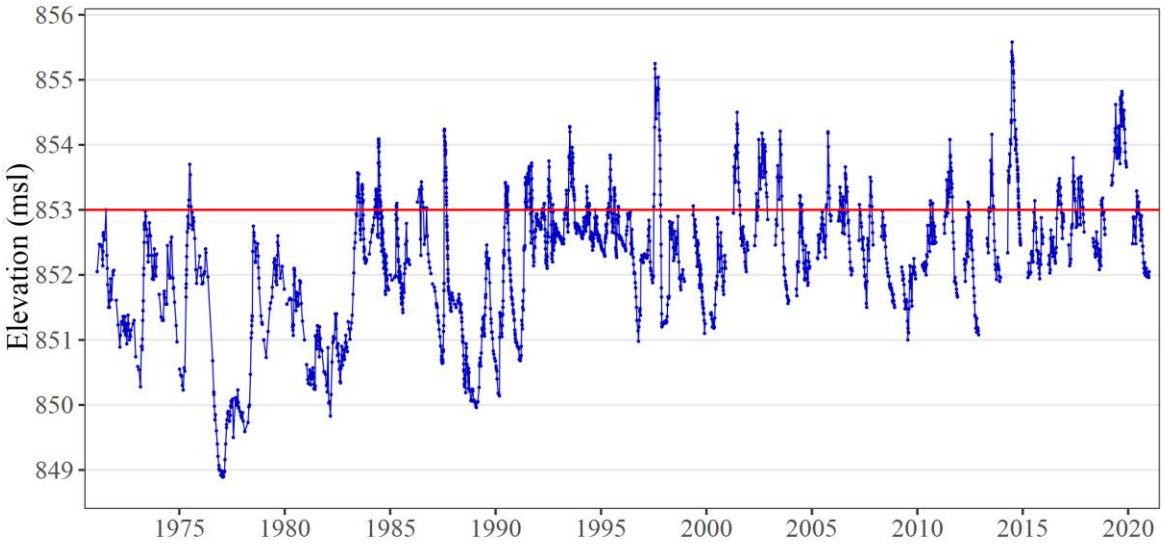


Figure 2-3. Lake levels for the Minneapolis Upper Chain of Lakes (Brownie, Cedar, Isles and Bde Maka Ska) from 1970 to 2020. Horizontal line represents the Ordinary High Water elevation (853 ft msl) for Bde Maka Ska.

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 2020 was 46. The lake is now mesotrophic having moderately clear water and increasing probability of hypolimnetic anoxia during summer.

The TSI score has remained relatively stable in recent years and is lower (better) than 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 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.

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 level in Bde Maka Ska is lower than in comparable lakes. See Minneapolis 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**.

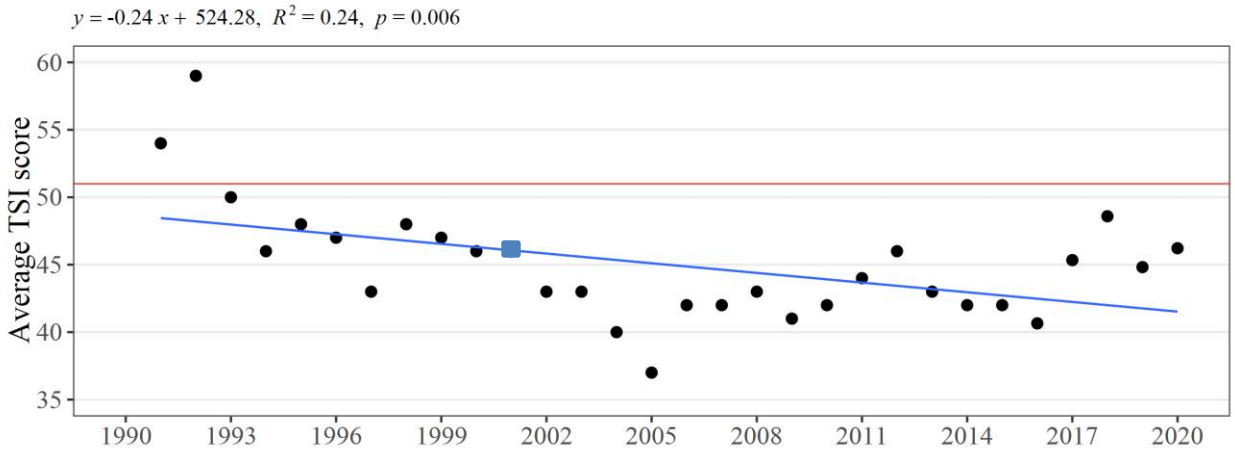


Figure 2-4. Bde Maka Ska TSI scores and linear regression from 1991-2020. The red line represents the CWP long-term TSI goal of below 51. The blue square highlights the 2001 alum treatment.

Table 2-2. Bde Maka Ska Secchi, chlorophyll-*a*, and total phosphorus TSI based on data collected between June and September 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	45	43-54	Within range
Chlorophyll-*a*	48	46-61	Within range
Total Phosphorus	46	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 deep lake standards, 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, 1991-2020, can be found in **Appendix A**.

Water clarity in 2020 was comparable to previous years, having a much smaller range of readings than 2019, with an average Secchi depth of 3.3 meters, see **Figure 2-5a**. Chlorophyll-*a* was comparable to previous years with an average concentration of 5.4 µg/L, see **Figure 2-5b**. Total phosphorus (TP) concentrations had a wide range in 2020 with the lowest concentrations occurring in spring and the highest concentrations occurring in the fall when the lake was not thermally stratified. The average TP concentration was similar to previous years at 23 µg/L, see **Figure 2-5c**. The lake met MPCA eutrophication standards in water clarity, chlorophyll-*a*, and total phosphorus in 2020. When comparing the boxplots in **Figure 2-5** to those in **Appendix A**, it appears that the 2001 alum treatment and BMP's in the watershed have had a profound effect on parameters measured in Bde Maka Ska, indicating an overall water quality improvement.

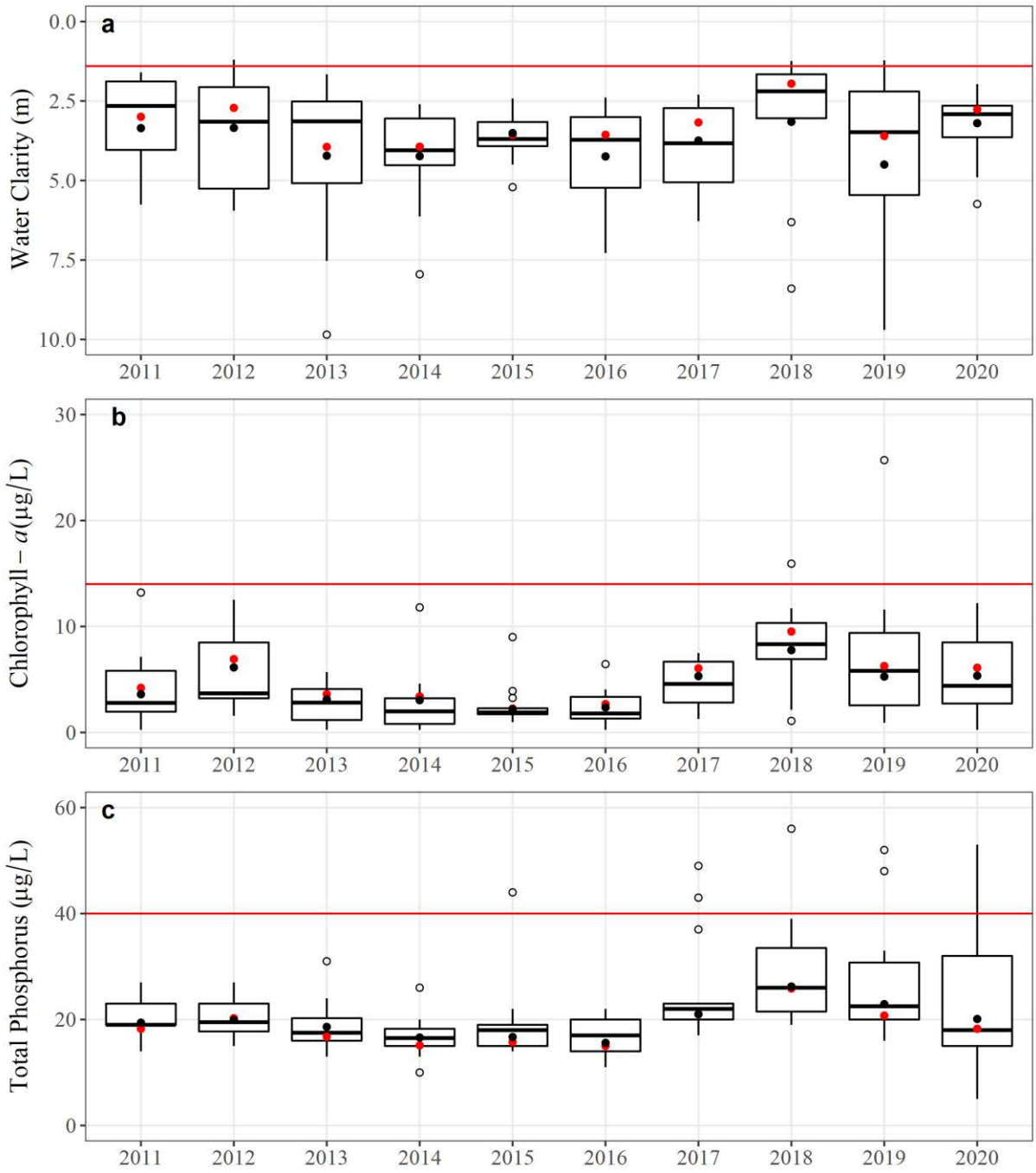


Figure 2-5. Bde Maka Ska box and whisker plots of water clarity (a), chlorophyll-*a* (b), and total phosphorus (c) from 2011-2020. Horizontal lines represent MPCA eutrophication standards for deep lakes, which applies to data collected between June and September. The red circles represent the mean value 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 1991-2020 can be found in Appendix A.

BEACH MONITORING

In 2020, 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 2-6**, *Escherichia coli* (*E. coli*) levels remained relatively low for most of the sampling season in 2020; however, concentrations increased in August. All three beaches at Bde Maka Ska experienced closures due to standard exceedances throughout the sampling season. Stormwater runoff, aquatic vegetation, and waterfowl waste may have contributed to high bacteria levels at all three of the beaches.

Bde Maka Ska 32nd Street Beach closed September 1st due to an exceedance of the 30-day geometric mean standard 126 MPN/100 mL. The beach remained closed for the remainder of the 2020 season. High concentrations of bacteria that led to this closure can be attributed to evidence of waterfowl activity and waste, as well as piles of aquatic vegetation.

Thomas Beach at Bde Maka Ska closed on August 11th due to an exceedance of the single sample *E. coli* standard of 1,260 MPN/100 mL. High concentrations of bacteria that led to this closure can be attributed to stormwater runoff from a recent rainfall event; a total of 1.6 inches was deposited 24 hours prior to sampling. Abundant aquatic vegetation along the beach may also have been a contributing factor to high bacteria. The beach was re-sampled on August 12th and re-opened on August 13th after results had shown that *E.coli* concentrations dropped below the single-sample threshold. Thomas Beach was closed again on September 1st due to an exceedance of the single sample *E. coli* standard. This closure could be attributed to abundant aquatic vegetation and stormwater runoff from a recent rainfall event; a total of 0.43 inches was deposited 24 hours prior to sampling. The beach was re-sampled on September 2nd and re-opened on September 3rd after results had shown that *E. coli* concentrations dropped below the single-sample threshold.

Bde Maka Ska Main Beach was closed on August 25th due to an exceedance of the 30-day geometric mean standard of 126 MPN/100 mL. The beach remained closed for the remainder of the 2020 season as bacteria levels did not return to acceptable standard concentrations. High *E. coli* concentrations may have been attributed to aquatic vegetation and evidence of waterfowl activity and waste.

As a result of an unusual early spring algae bloom on Minneapolis lakes in 2020, MPRB developed a blue-green algae index visual monitoring protocol. Visual indicators were noted as part of the protocol for the weekly beach sampling program. See **Chapter 18** for more information on beach and blue-green algae monitoring.

Table 2-3. Summary of *E. coli* (MPN per 100 mL) data for Bde Maka Ska beaches in 2020.

Statistical Calculations	Bde Maka Ska 32nd Beach	Bde Maka Ska Main Beach	Bde Maka Ska Thomas Beach
Number of Samples	13	13	13
Minimum	4	13	4
Maximum	1210	1267	2420
Median	36	69	27
Mean	186	231	394
Geometric Mean	44	76	48
Max 30-Day Geo Mean	151	183	121
Standard Deviation	374	360	869

Figure 2-6 illustrates the trend for *E.coli* levels for the sampling season of 2020. The graphs demonstrate how much of the season was above standard levels. The running 30-day geometric mean directly correlates to single-sample exceedances. 2020 was an unusual year for Bde Maka Ska with multiple *E.coli* samples higher than the standard.

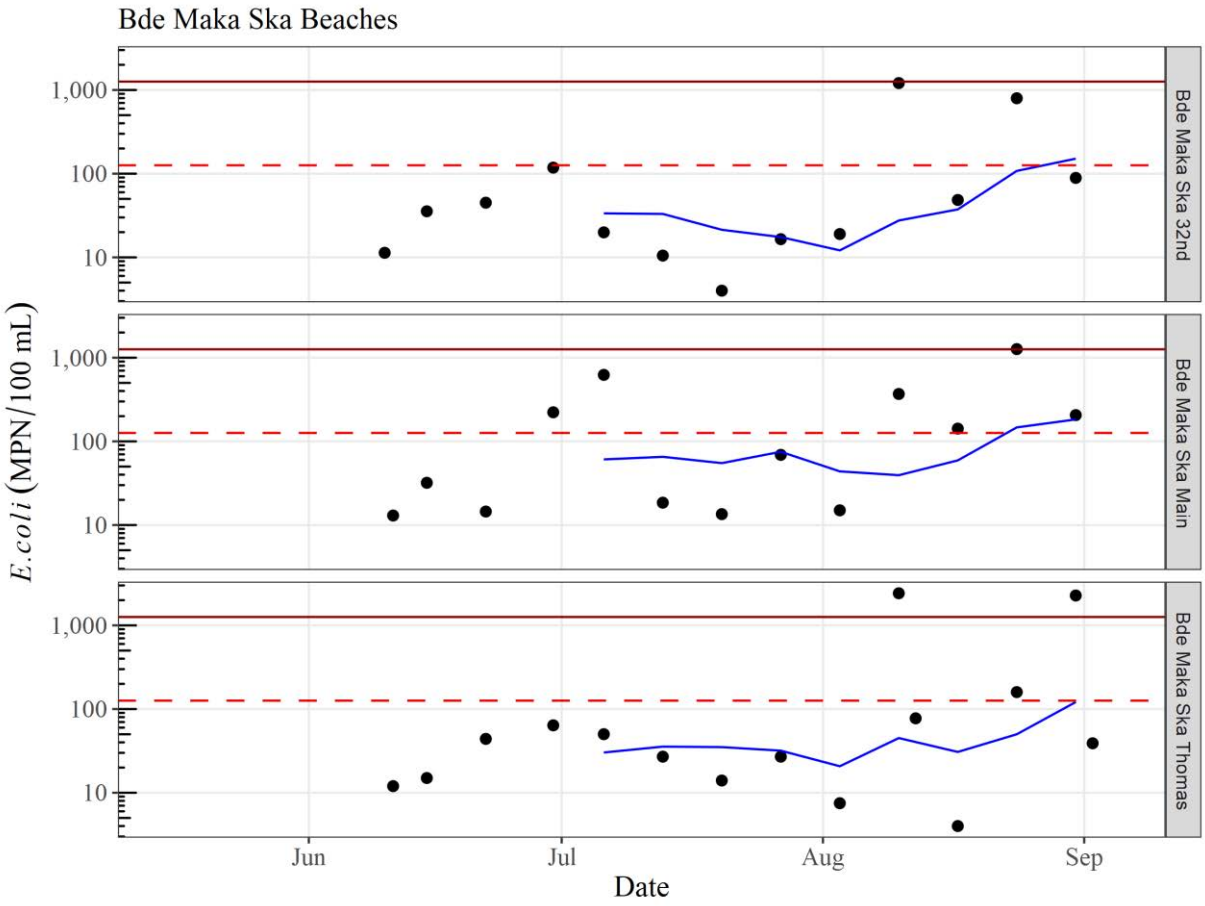


Figure 2-6. 2020 *E. coli* concentrations at Bde Maka Ska beaches. The blue line is the running 30-day geometric mean. The dashed horizontal line represents the *E. coli* standard for the 30-day geometric mean (126 MPN/100mL) and the solid horizontal line represents the single-sample maximum standard (1260 MPN/100mL). Note the log scale on the Y-axis.

Figure 2-7 shows *E. coli* monitoring data for Bde Maka Ska beaches from 2011 to 2020 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. The 2020 results show that *E. coli* levels were relatively consistent with previous years. The 32nd Street beach generally had higher *E. coli* concentrations compared to the other two beaches in previous years, but concentrations were higher on Main and Thomas beach in 2020.

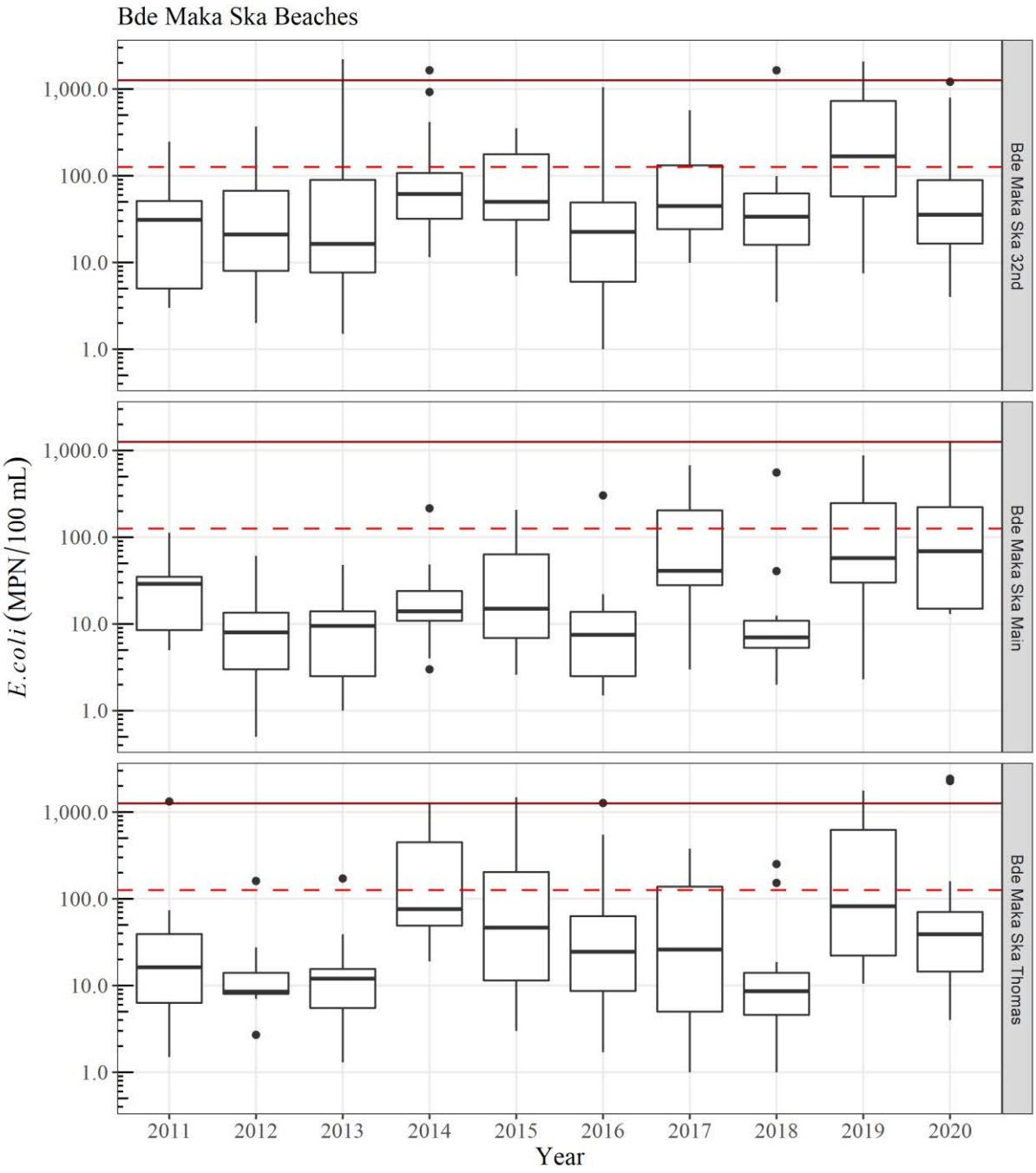


Figure 2-7. Box and whisker plots of *E. coli* concentrations (MPN per 100 mL) for Bde Maka Ska beaches from 2011-2020. The dashed horizontal line represents the *E. coli* standard for the 30-day geometric mean (126 MPN/100mL) and the solid horizontal line represents the single-sample maximum standard (1260 MPN/100mL). Note the log scale on the Y-axis.

LAKE AESTHETIC AND USER RECREATION INDEX (LAURI)

Figure 2-8 shows the 2020 LAURI for Bde Maka Ska. Bde Maka Ska was rated good in aesthetics and public health, and rated excellent in water clarity, habitat quality and recreational access. Details on LAURI can be found in **Chapter 1** and comparisons with other lakes can be found in **Chapter 17**.

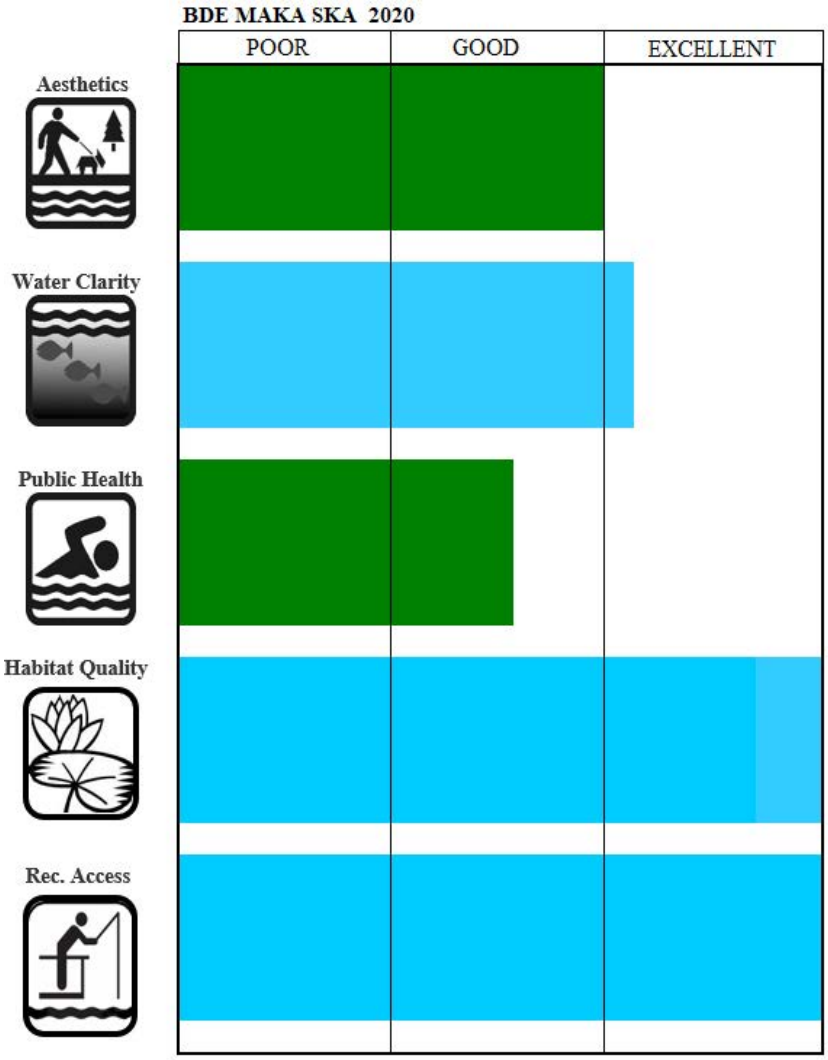


Figure 2-8. The 2020 LAURI for Bde Maka Ska.

WINTER ICE COVER

Ice came off Bde Maka Ska on March 29, 2020, 11 days earlier than the average ice-off date of April 9th. Lake ice fully covered the lake on December 28, 2020, 15 days later than the average ice-on date, see **Figures 2-9 and 2-10** 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 2-9**). The running average ice-off date has shifted to earlier dates, averaging around April 13th in the 1970's to April 6th 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.

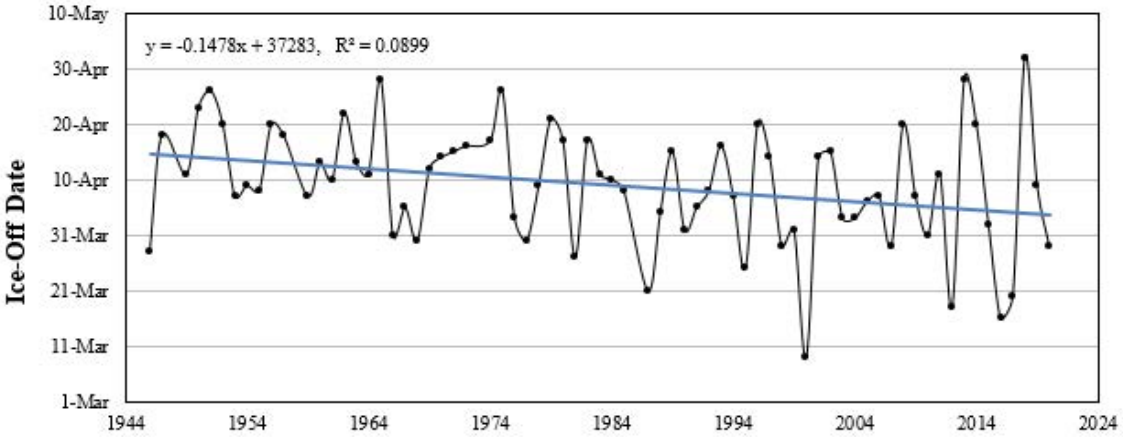


Figure 2-9. Bde Maka Ska ice-off dates and frequency of the occurrence of ice-off on particular dates for all the years of record. 70 recorded ice-off dates exist since 1946.

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 2-10**. Over the past 56 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.

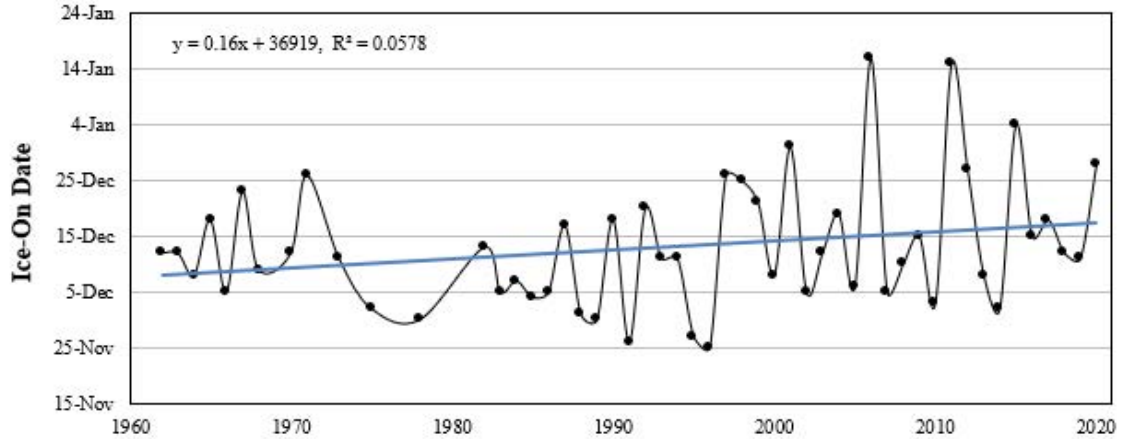


Figure 2-10. Bde Maka Ska ice-on dates and frequency of the occurrence of ice-on on particular dates for all the years of record. 50 recorded ice-on dates exist since 1962.

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 2020, 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 20**.

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 2-11** shows the water clarity, chlorophyll-*a* concentrations, and relative abundance of phytoplankton divisions during 2020. 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 mid-May at 5.7 meters and gradually decreased until early August when water clarity reached its shallowest reading at 2.0 meters. The Secchi reading slightly increased again in late August and remained at about 3.0 meters for the rest of the season, see **Figure 2-11a**. When chlorophyll-*a* concentrations were low the lake water was more transparent, see **Figure 2-11b**. Chlorophyll-*a* concentrations were highest in January at 12.2 µg/L when the phytoplankton community primarily consisted of blue-green algae (Cyanophyta). Concentrations of chlorophyll-*a* were lowest in late May at 0.25 µg/L and varied between 2 and 10 µg/L the rest of the season.

The phytoplankton community primarily consisted of blue-green algae (Cyanophyta) throughout 2020 with the highest percentage occurring in January along with the highest chlorophyll-*a* level, see **Figure 2-11c**. Diatoms (Bacillariophyta), green algae (Chlorophyta), and cryptomonads (Cryptophyta) had higher percentages in late April and were present in lower levels for the remainder of the season. Dinoflagellates (Pyrrhophyta) were present in low levels for most of the season but increased in mid-July consisting of about half of the phytoplankton community. Chrysophytes (Chrysophyta), euglenoids (Euglenophyta), and haptophytes (Haptophyta) were present in low levels for the entire 2020 season.

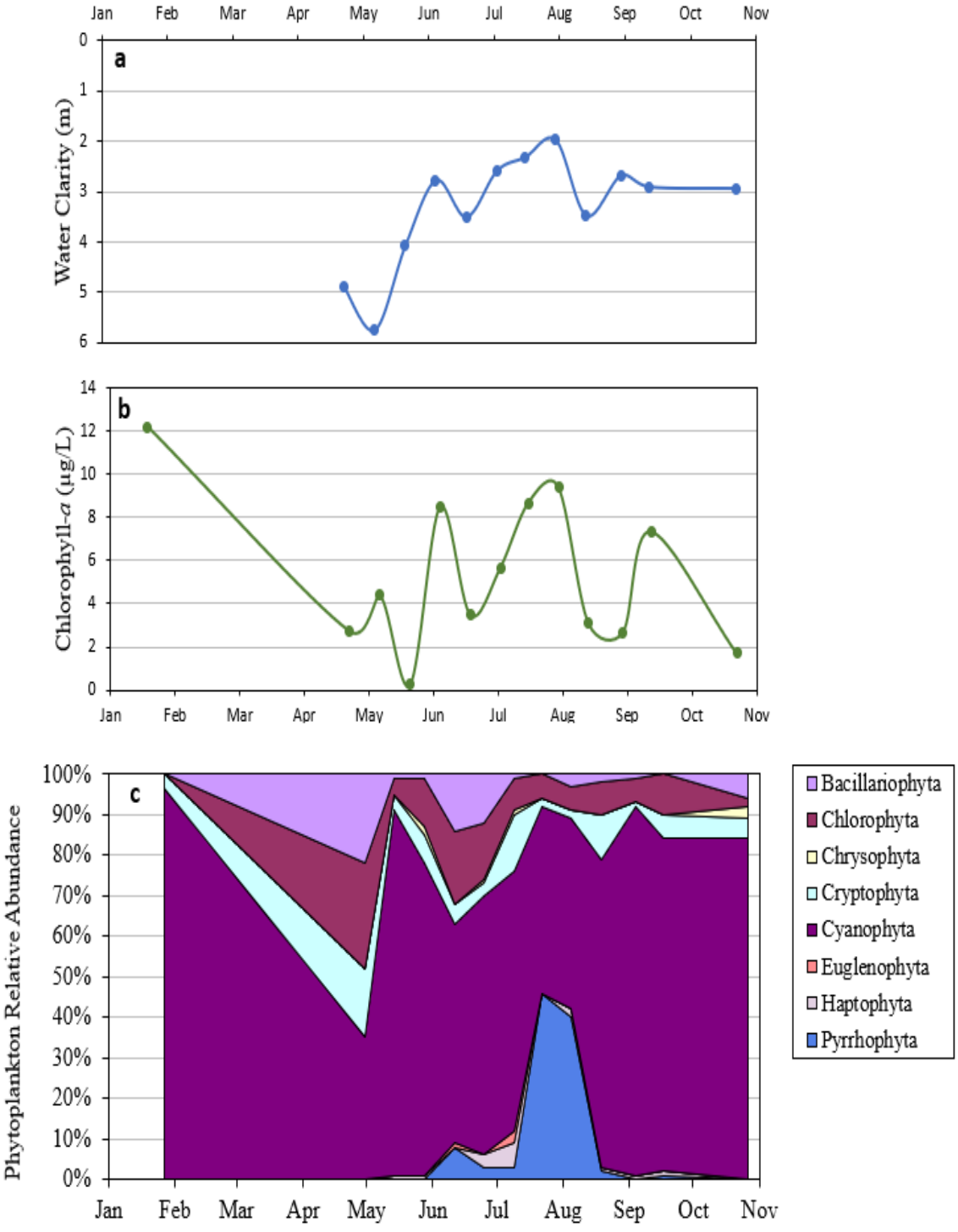


Figure 2-11. Water clarity (a), chlorophyll-a concentration (b), and relative abundance of phytoplankton (c) in Bde Maka Ska during 2020. Note that the Water Clarity axis is reversed, and only one sample for August is represented in Phytoplankton Relative Abundance (c).

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 2-12** shows the zooplankton distribution in Bde Maka Ska sampled throughout 2020. Rotifers were present throughout the year and were most abundant in July, at 200 organisms/L, and were present in high levels in April and May. Nauplii and juvenile copepods were most abundant in April and May and present in lower levels for the remainder of the season. Cladocerans were present throughout the year and were most abundant in May and July. Calanoids, cyclopoids, and protozoa were also present in low levels in 2020.

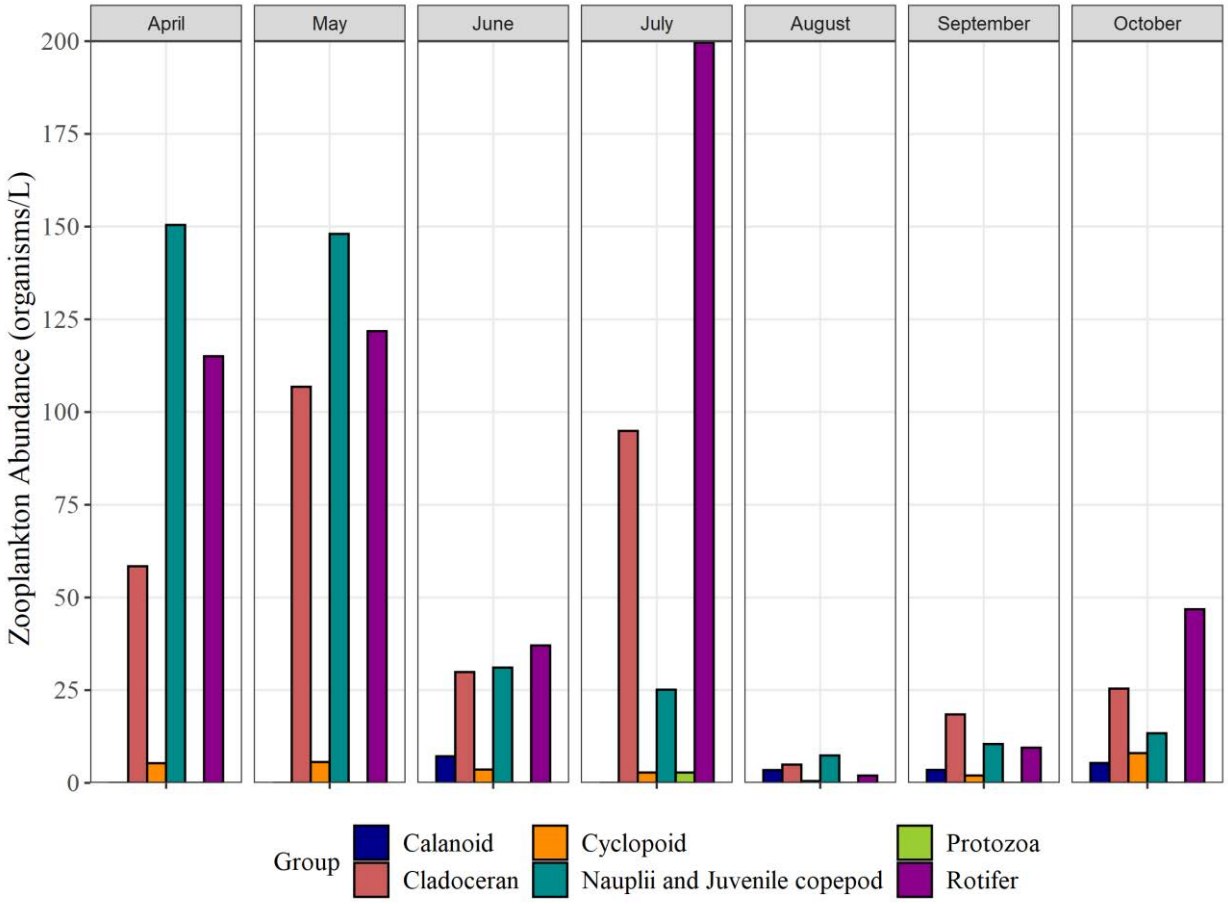


Figure 2-12. Zooplankton density in Bde Maka Ska during 2020.

EVENTS REPORT

On May 11, 2020, a citizen reported several large dead fish along the shoreline of Bde Maka Ska. MPRB staff identified the fish as carp and initially found twelve of them along the shoreline on the west side of the lake, at Main Beach and at Thomas Beach. An additional thirty dead carp were found on the north side of Bde Maka Ska a couple days after the initial report. An Incident Report was completed describing the fish kill event. Water quality data showed that oxygen levels in the lake were high and oxygen depletion was not the cause of the fish kill.

A Graduate Assistant at University of Minnesota Aquatic Invasive Species Research Center (MAISRC) funded by Legislative-Citizen Commission on Minnesota Resources (LCCMR), gathered samples from the fish kill event and studied the gill tissues using quantitative polymerase chain reaction (qPCR). The study concluded that carp edema virus (CEV) was the cause of mortality. CEV is a double-stranded DNA virus that is likely spread by diseased fish shedding the virus from gill and skin lesions. The virus typically occurs in the spring when water temperatures are between 43-50 degrees Fahrenheit and the surface water temperature at Bde Maka Ska during the fish kill was 50 degrees Fahrenheit. See the fish kill section in the **Chapter 1** for additional details.

FISH STOCKING

No fish were stocked into Bde Maka Ska in 2020, 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
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
2012	Muskellunge	123 fingerlings	24.6 pounds
2012	Walleye	12,684 yearlings	604.0 pounds

EMERGING CONTAMINANTS

Perflorinated chemicals (PFCs) are a class of chemicals that were produced by the 3M and DuPont corporations since the 1950s. 3M stopped producing PFCs in 2000 and DuPont ceased production of PFCs in 2015. PFCs are used worldwide in a variety of industrial and consumer products. The chemicals have a similar structure to long-chain carbon molecules except with fluorine atoms replacing carbon atoms in the chain. PFCs are ubiquitous throughout the environment at low levels and some PFCs have the ability to bioaccumulate in the tissues of plants and animals. Because PFCs can bioaccumulate and do not degrade under normal environmental conditions, they have been investigated for potential health risks.

In Minnesota, PFCs have been widely researched since 2005 when it was discovered that the chemicals were leaching into groundwater and into the Mississippi River from sources in Washington County. In 2007, PFC contamination was discovered in drinking water wells in the east Metro, sparking broad environmental testing. Environmental testing was expanded to include treatment plant influent and effluent, surface water, and fish from selected lakes and rivers. This wide-ranging round of investigation detected that PFCs are found throughout Minnesota and were not distributed uniformly.

In 2008, perfluorooctane sulfonate (PFOS) concentrations, a type of PFC, exceeded the water quality criteria in fish tissue and Bde Maka Ska was added to the Impaired Waters List to protect fish consumers. In 2020, the MPCA developed site-specific water quality criteria for application in Bde Maka Ska to reduce PFOS and associated per and polyfluoroalkyl substance (PFAS) contamination. In Bde Maka Ska the fish and recreational criteria is 0.05 ng/L and the fish tissue criteria is 0.37 ng/g. The intent of the criteria is to lower the PFOS concentration of the water so that fish are no longer affected. Fish can bioaccumulate the chemical to about 7,000 times the level in water, so the surface water standard is very low.

The MPCA and Interagency Fish Contaminant Monitoring Program have studied PFOS in several species of fish. **Table 2-5** shows the PFOS concentrations of fish in Bde Maka Ska from the past 10 years (https://www.pca.state.mn.us/sites/default/files/wq-s6-61b.pdf). In 2010, an industrial source of PFOS entering Bde Maka Ska was discovered; however, the industry responsible has reduced its PFOS use and has done extensive projects to ensure that PFOS do not leave the site. Since these projects began, PFOS levels in the Chain of Lakes has dropped significantly in both surface water and in fish.

Table 2-5. PFOS concentrations in Bde Maka Ska over the past 10 years based on MPCA Environmental Analysis and Outcomes studies. Note reduction of PFOS over time.

Year	PFOS Fish-tissue concentration (mean) ng/g (reporting limit used)	PFOS Fish-tissue concentration (highest species 90th percentile or max.) ng/g	PFOS Water concentration (mean) ng/L
2018	39.4 (3 species)	101 (walleye)	12.0
2016	99.2 (4 species)	146 (largemouth bass)	24.3
2013	129 (4 species)	243 (largemouth bass)	35.3

TOC

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 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**. Birch Pond is a closed basin, so there is no outlet.



Figure 3-1. Birch Pond in August of 2020.

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. Buckthorn (*Rhamnus cathartica* and *Rhamnus frangula*) is an invasive species that threatens native woodlands. Buckthorn was removed from the understory of the Birch Pond basin in 2006 as a part of vegetation restoration

efforts in preparation for the centennial anniversary of the Eloise Butler Wildflower Garden and Bird Sanctuary. Buckthorn was removed again in 2015 as part of the Wirth Vegetation Management project funded by the Outdoor Heritage Fund.

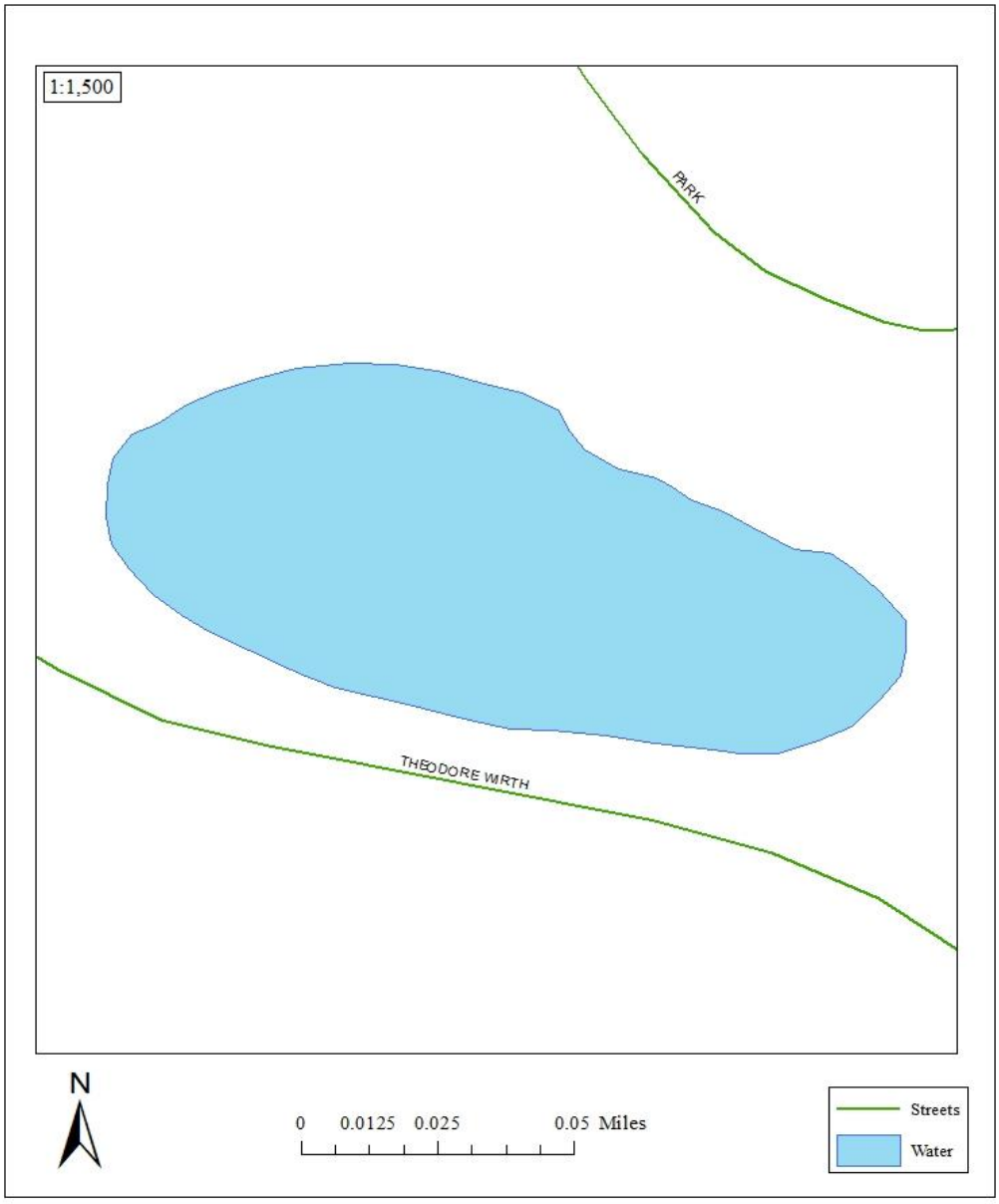


Figure 3-2. Map of Birch Pond.

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 set an Ordinary High Water Level (OHWL) of 846.3 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 2, 2020, two days earlier than the average ice-off. Ice came back to the pond November 30, 2020, five days later 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.

TOC

4. BROWNIE LAKE

HISTORY

Brownie Lake was acquired by Minneapolis Park and Recreation Board (MPRB) in 1908. The name of the lake predates MPRB which was established in 1883. An undated handwritten note documented with MPRB suggests that William McNair, who owned majority of the lake's surrounding land, had a 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%, transforming the lake formerly known as Hillside Harbor. 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 walking path on the southeast corner of Brownie Lake in August of 2020.

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 due to 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

characteristics 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**.

Brownie Lake has been consistently sampled every other year since 2002, and was sampled in 2020. 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 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 University, Mankato, and University of Iowa 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).

Table 4-1. Brownie Lake physical characteristics.

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.**

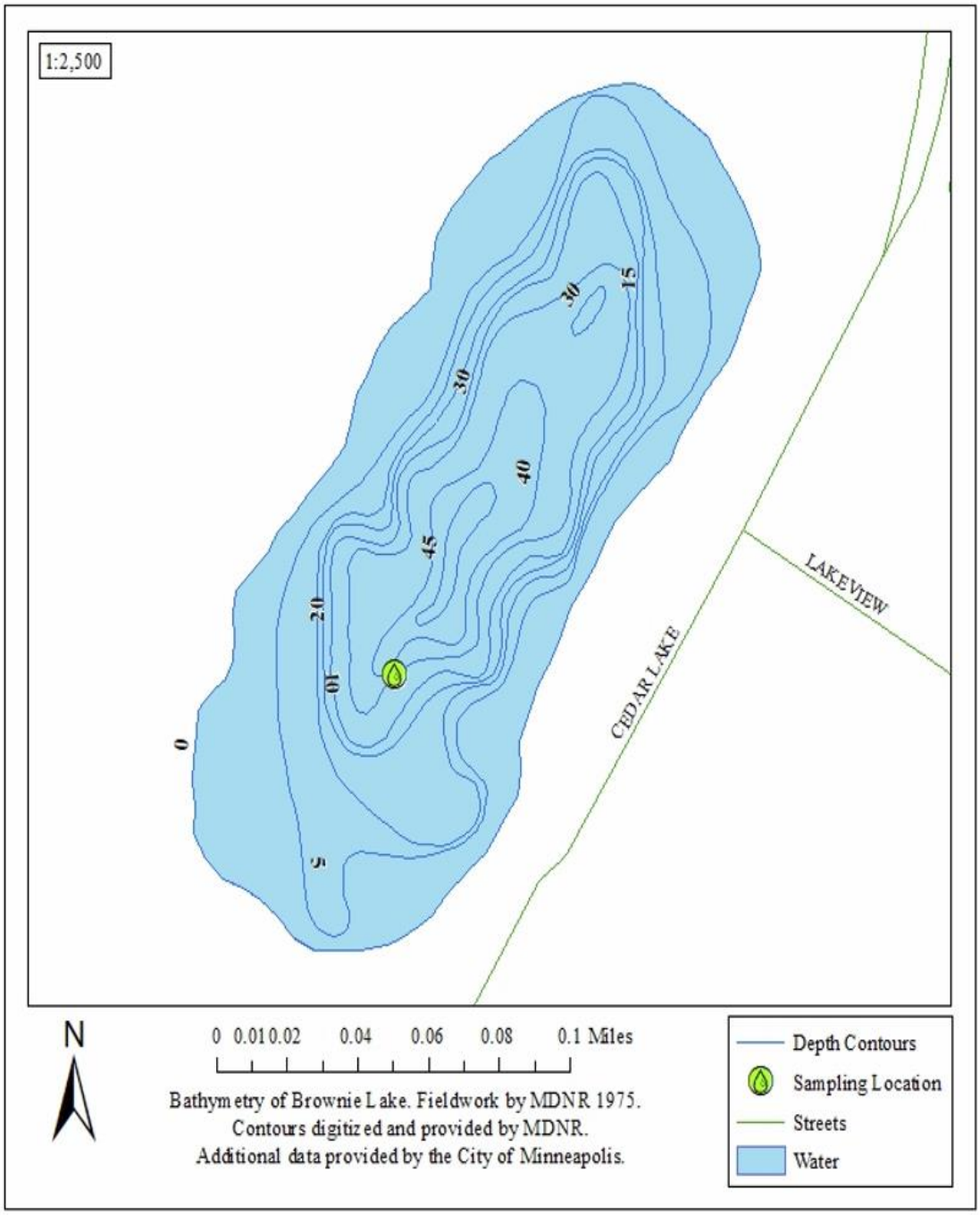


Figure 4-2. Bathymetric map of Brownie Lake. The green symbol represents the sampling location.

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 1993-2020 ($p > 0.05$). The TSI score for Brownie Lake in 2020 was 58. The lake is classified as eutrophic with 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 to be below 55 that was intended to be met within five to ten years of water quality project completion. TSI scores have not met the CWP goal every year except 2014.

Chlorophyll-*a* and phosphorus TSI scores for Brownie Lake are within the expected TSI range for lakes in the same ecoregion, see **Table 4-2**. The Secchi TSI score is above the TSI range for the ecoregion, meaning the water clarity in Brownie Lake is shallower than in comparable lakes. See Minneapolis 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**.

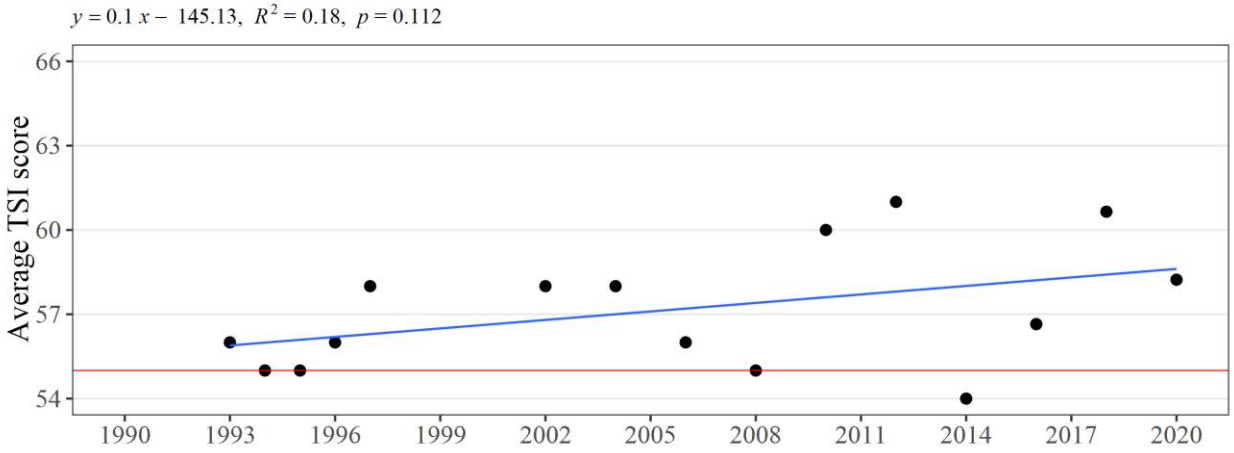


Figure 4-3. Brownie Lake TSI scores and linear regression from 1993-2020. The red line represents the CWP long-term TSI goal of below 55. The lake only met the goal in the year 2014.

Table 4-2. Brownie Lake Secchi, chlorophyll-*a*, and total phosphorus TSI based on data collected between June and September 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	59	43-54	Not within range, worse than expected
Chlorophyll-*a*	58	46-61	Within range
Total Phosphorus	59	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 deep lake standards, 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, 1993-2020, can be found in **Appendix A**.

Water clarity in Brownie Lake in 2020 was similar to previous years with an average Secchi depth of 1.1 meters, see **Figure 4-4a**. Algal biomass, as measured by chlorophyll-*a* concentration, was lower than 2018, and comparable to prior years with an average concentration of 14 µg/L, see **Figure 4-4b**. Total phosphorus was higher in 2020 with an average concentration of 47 µg/L, see **Figure 4-4c**. Brownie did not meet the MPCA eutrophication standards for any of the three parameters in 2020. 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.

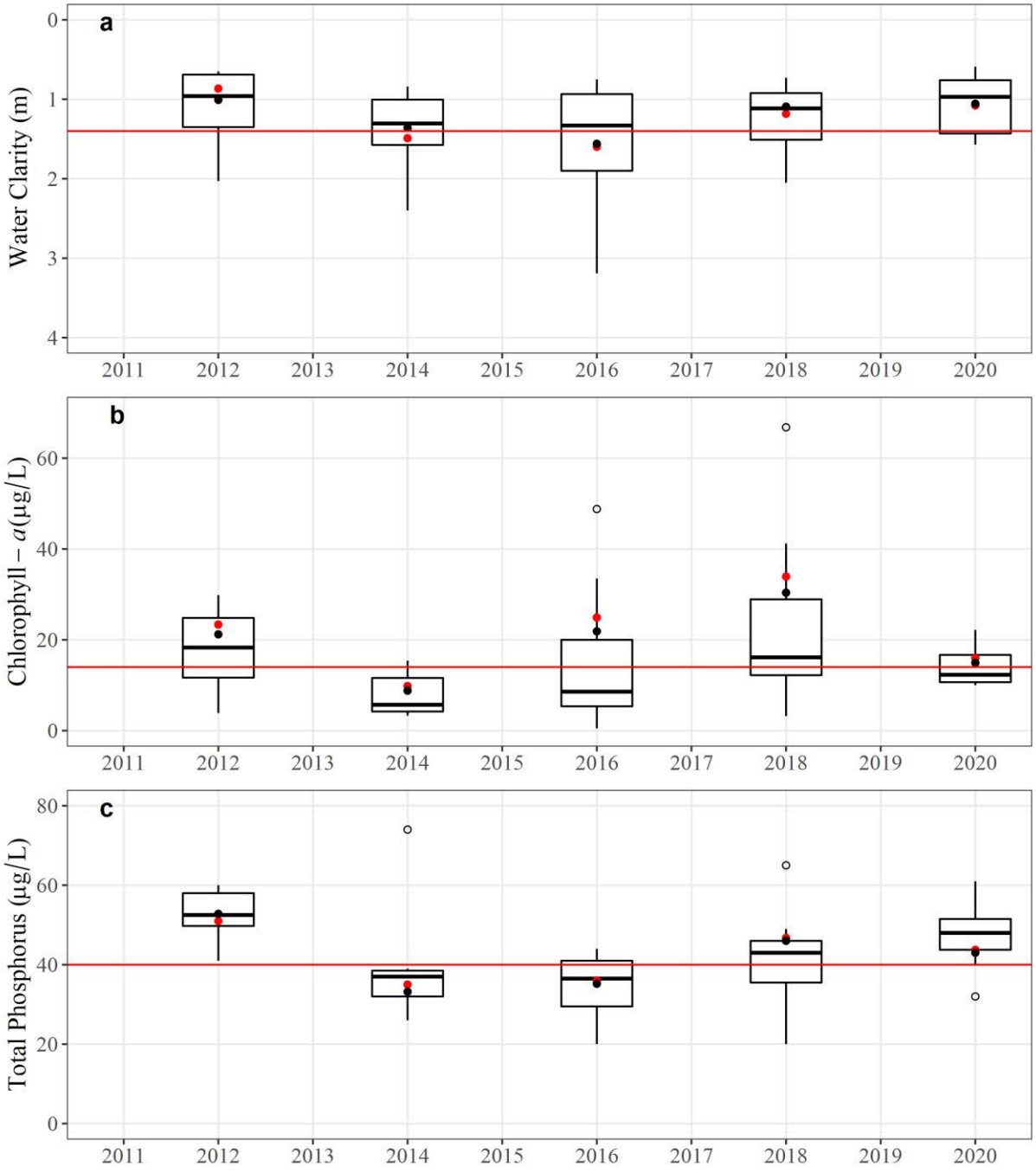


Figure 4-4. Brownie Lake box and whisker plots of water clarity (a), chlorophyll-*a* (b), and total phosphorus(c) from 2011-2020. Horizontal lines represent MPCA eutrophication standards for deep lakes, which applies to data collected between June and September. The red circles represent the mean value 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 1993-2020 can be found in Appendix A.

LAKE AESTHETIC AND USER RECREATION INDEX (LAURI)

Figure 4-5 shows the 2020 LAURI for Brownie Lake. Brownie Lake was rated excellent in aesthetics and good in habitat quality and recreational access. A lower macrophyte density and number of fish species led to a good rating for habitat quality. The lake scored poor in water clarity. 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**.

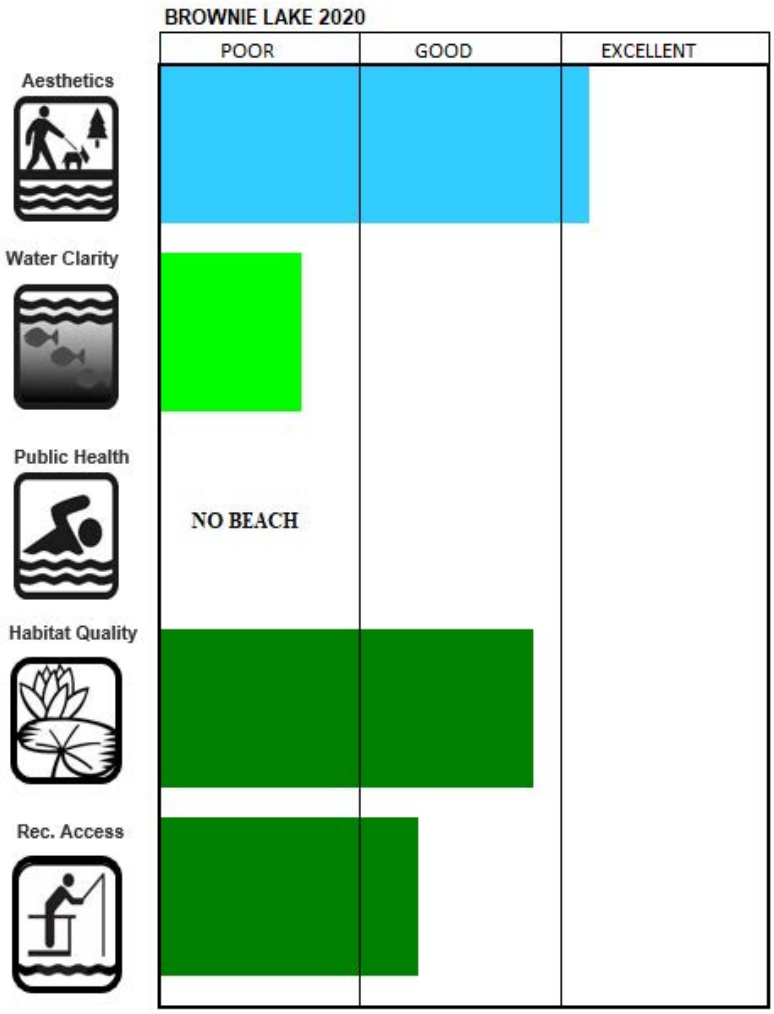


Figure 4-5. The 2020 LAURI for Brownie Lake.

WINTER ICE COVER

Ice came off Brownie Lake on March 28, 2020, six days earlier than the average ice-off. Ice came on the lake November 30, 2020, one day later 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 4-6** shows the water clarity, chlorophyll-*a* concentrations, and relative abundance of phytoplankton divisions during 2020. 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 2020 due to low zooplankton densities. In 2008, zooplankton tows yielded low concentrations compared to other Minneapolis lakes.

Water clarity primarily fluctuated between 0.5 meters and 1.5 meters in 2020. Water clarity was initially shallow in early spring and continued to increase into June, then Secchi readings gradually decreased again until late August when the shallowest reading was observed at 0.6 meters. Water clarity increased again in the fall with the deepest reading at 1.6 meters, see **Figure 4-6a**. Chlorophyll-*a* concentrations were lowest in late August at 10.0 µg/L and highest in early July at 22.2 µg/L. Dinoflagellates (Pyrrhophyta) dominated the phytoplankton population when chlorophyll-*a* concentrations were at the lowest and highest concentrations of the season, see **Figure 4-6b, c**.

Blue-green algae (Cyanophyta) dominated the phytoplankton population for most of 2020. Other phytoplankton that were abundant include diatoms (Bacillariophyta), green algae (Chlorophyta), cryptomonads (Cryptophyta), and dinoflagellates. Chrysophytes (Chrysophyta), euglenoids (Euglenophyta), and haptophytes (Haptophyta) were also present in low levels, see **Figure 4-6c**.

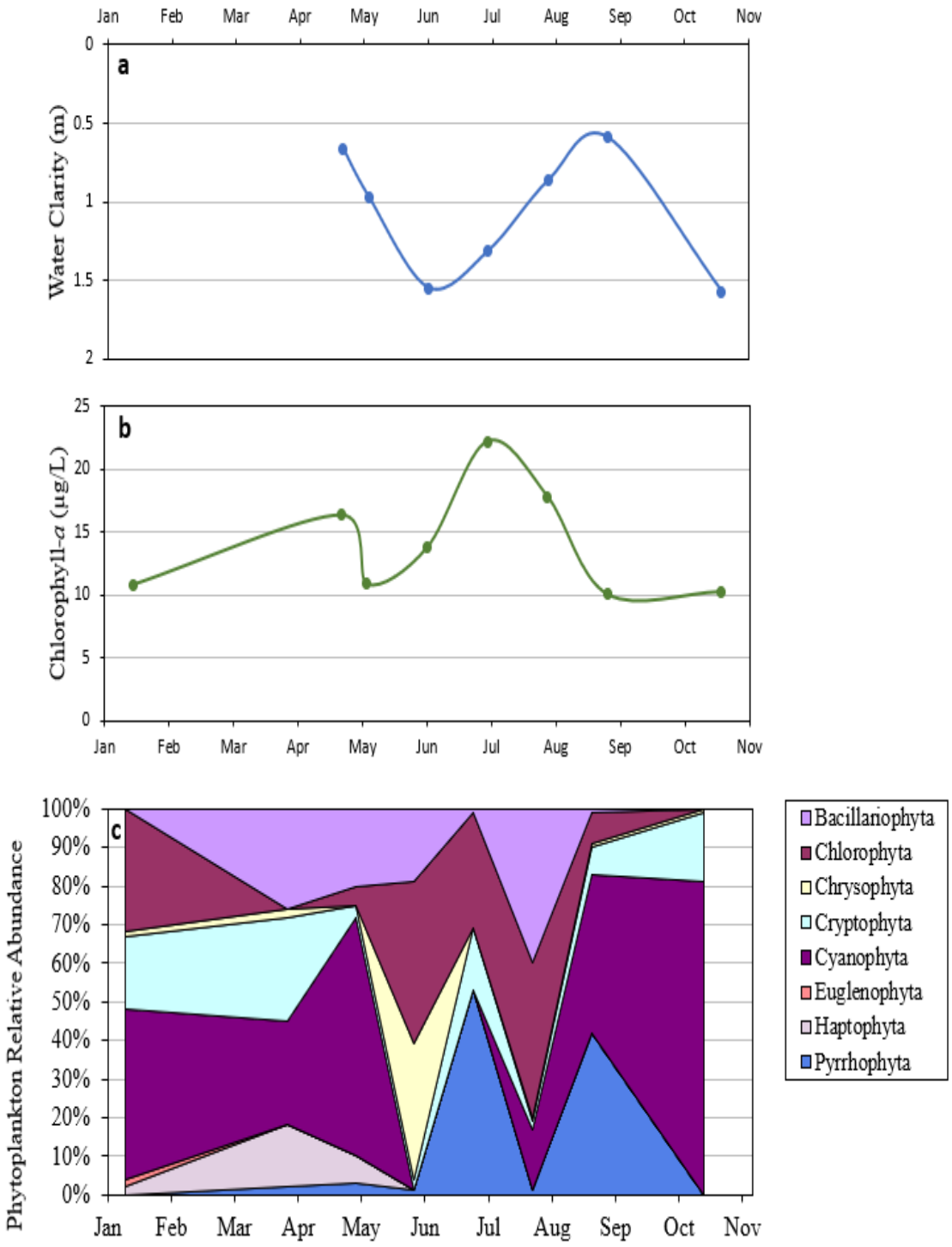


Figure 4-6. Water clarity (a), chlorophyll-*a* concentration (b), and relative abundance of phytoplankton (c) in Brownie Lake during 2020. Note that the water clarity axis is reversed.

TOC

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 acquired completely in 1955 and the last section of shoreline wasn't acquired until 1959. 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 (Smith, 2008). **Figure 5-1** shows a view of Cedar Lake from the shoreline.



Figure 5-1. View of Cedar Lake in August of 2020.

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 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 travels from Twin Lake in St. Louis Park down west 24th Street. When water flow is low, stormwater goes to Cedar Meadow wetland, and when stormwater flow is high a portion of the water flows directly into Cedar Lake.

Cedar Lake receives water from Brownie Lake and discharges water through 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.

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

Table 5-1. Cedar Lake physical characteristics.

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%	$1.50x10^8$	1,956	11.5	2.7

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

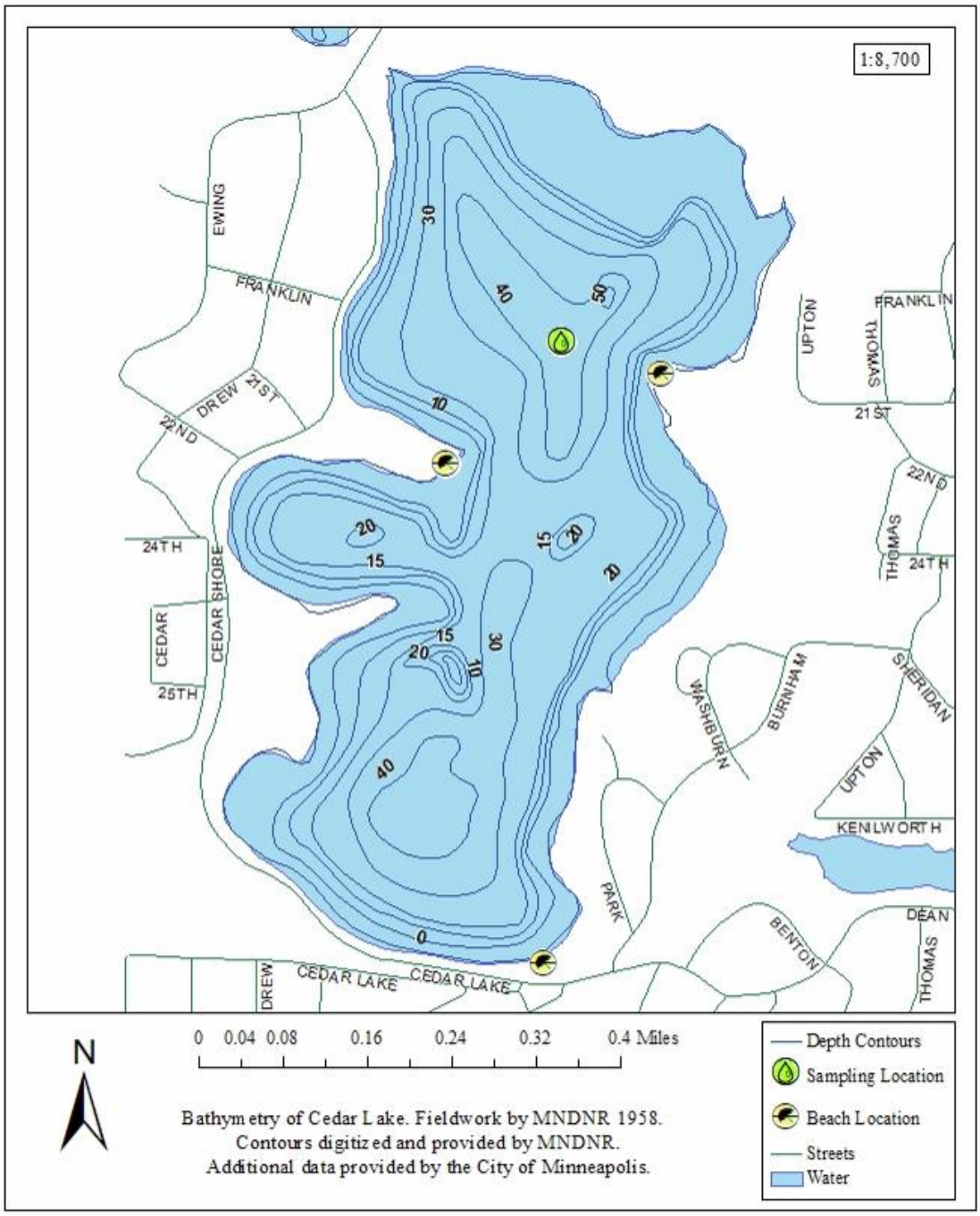


Figure 5-2. Bathymetric map with sampling locations at Cedar Lake.

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). As the Upper Chain of Lakes water bodies are connected via channels, the lake level 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 1991-2020 ($p > 0.05$). The TSI score for Cedar Lake in 2020 was 57. The lake is currently eutrophic with an anoxic hypolimnion and macrophyte problems.

The CWP Minneapolis Chain of Lakes Project developed a long-term TSI goal 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 and 2013. The most recent four consecutive years did not meet the CWP goal having much higher TSI scores than previous years and may indicate worsening water quality.

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**. The Secchi TSI score is above the TSI range for the ecoregion, meaning water clarity in Cedar Lake is shallower than in comparable lakes. See Minneapolis 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**.

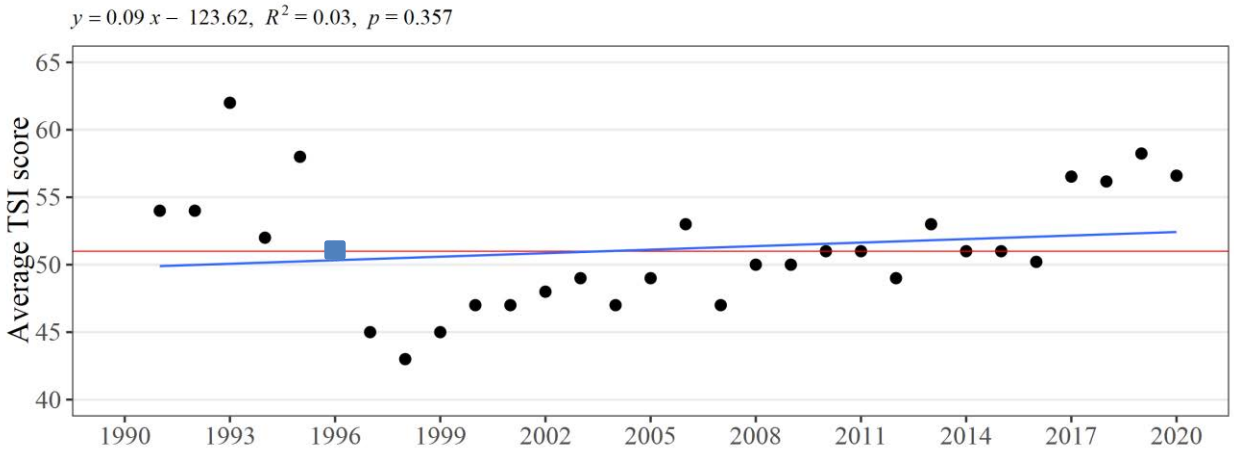


Figure 5-3. Cedar Lake TSI scores and linear regression from 1991-2020. The red line represents the CWP long-term TSI goal of below 51. The blue square highlights the 1996 alum treatment.

Table 5-2. Cedar Lake Secchi, chlorophyll-*a*, and total phosphorus TSI based on data collected between June and September 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	61	43-54	Not within range, worse than expected
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 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 deep lake standards, 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, 1991-2020, can be found in **Appendix A**.

Water clarity has gradually been declining since 2013 with 2020 having the lowest average of 1 meter, see **Figure 5-4a**. There was greater variability in water clarity in the past and can be seen in **Appendix A**. The 2020 chlorophyll-*a* levels were lower than 2019, but comparable to prior years with an average of 15.1 µg/L, see **Figure 5-4b**. Total phosphorus (TP) concentrations had a wide range in 2020 with the highest concentrations occurring in winter and lowest concentrations in early July. The average TP was higher than previous years at 46 µg/L, see **Figure 5-4c**. The lake met the MPCA eutrophication standards for chlorophyll-*a* and total phosphorus but did not meet the standard for water clarity in 2020.

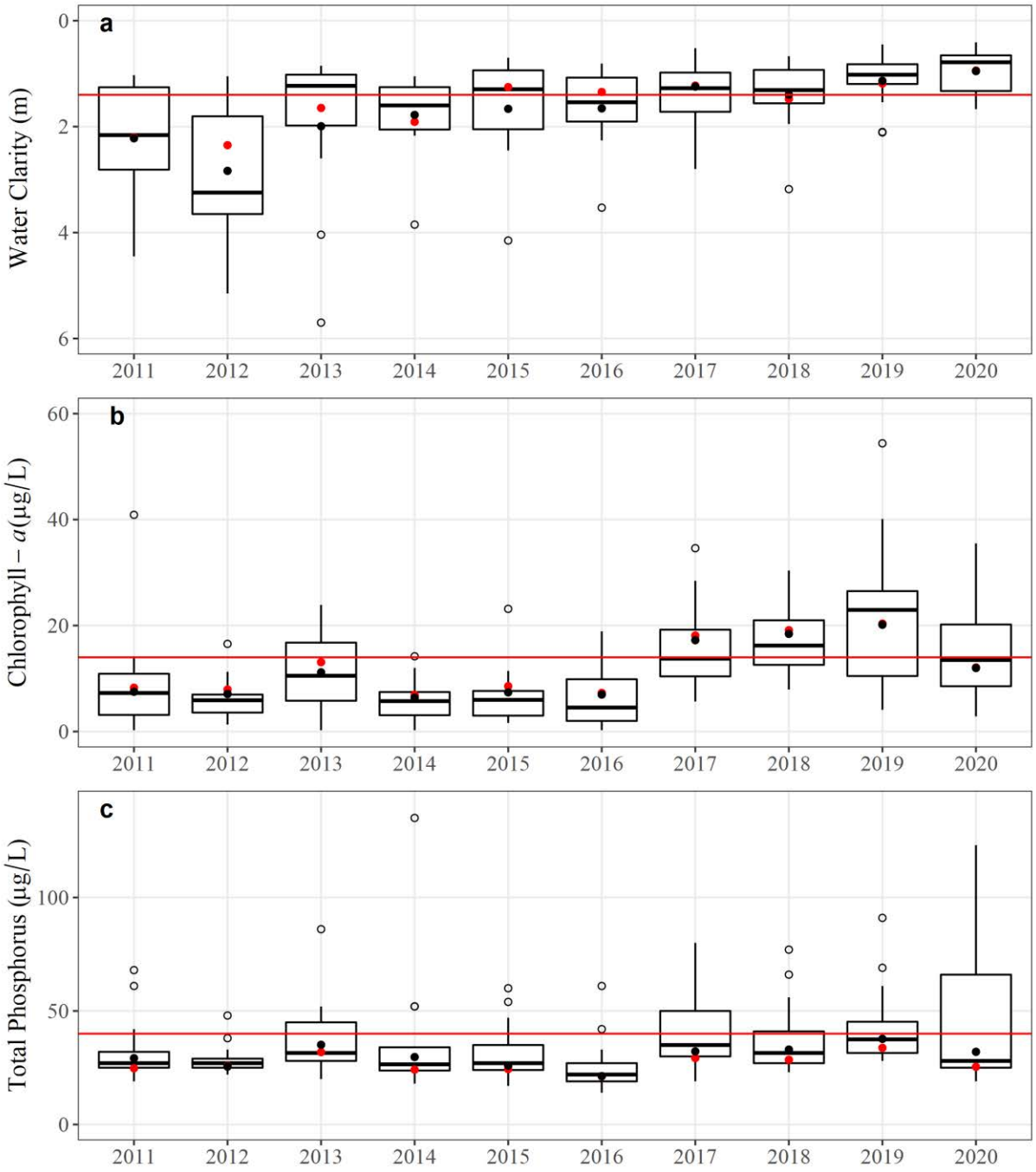


Figure 5-4. Cedar Lake box and whisker plots of water clarity (a), chlorophyll-*a* (b), and total phosphorus (c) from 2011-2020. Horizontal lines represent MPCA eutrophication standards for deep lakes, which applies to data collected between June and September. The red circles represent the mean value 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 1991-2020 can be found in Appendix A.

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 2020. All Cedar Lake beaches remained open for the entire 2020 swimming season. As shown in **Table 5-3** and **Figure 5-5,** the season-long geometric means for *E. coli* were low at all the Cedar Lake beaches. 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.

As a result of an unusual early spring algae bloom on Minneapolis lakes in 2020, MPRB developed a blue-green algae index visual monitoring protocol. Visual indicators were noted as part of the protocol for the weekly beach sampling program. See **Chapter 18** for more information on beach and blue-green algae monitoring.

Table 5-3. Summary of *E. coli* (MPN per 100 mL) data for Cedar Lake beaches in 2020.

Statistical Calculations	East Cedar	Cedar Main	Cedar Point
Number of Samples	13	13	13
Minimum	2	2	2
Maximum	66	494	113
Median	10	17	11
Mean	16	81	25
Geometric Mean	9	19	10
Max 30-Day Geo Mean	28	35	15
Standard Deviation	18	149	35

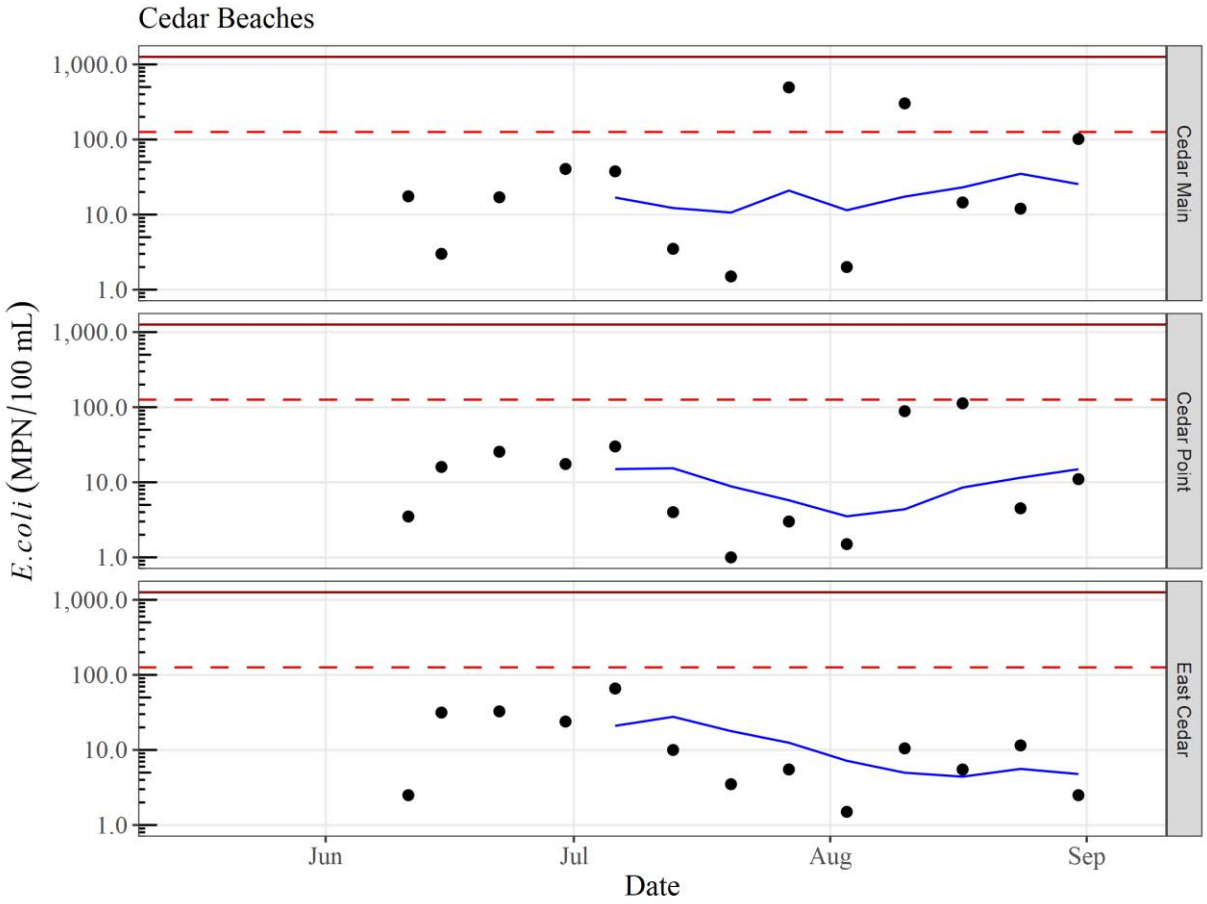


Figure 5-5. 2020 *E. coli* concentrations at the Cedar Lake beaches. Black circles are individual data points. Blue line is the running 30-day geometric mean. The dashed horizontal line represents the *E. coli* standard for the 30-day geometric mean (126 MPN/100mL) and the solid horizontal line represents the single-sample maximum standard (1260 MPN/100mL). Note the log scale on the Y-axis.

Figure 5-6 shows *E. coli* monitoring data for Cedar Lake beaches from 2011 to 2020 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 2020.

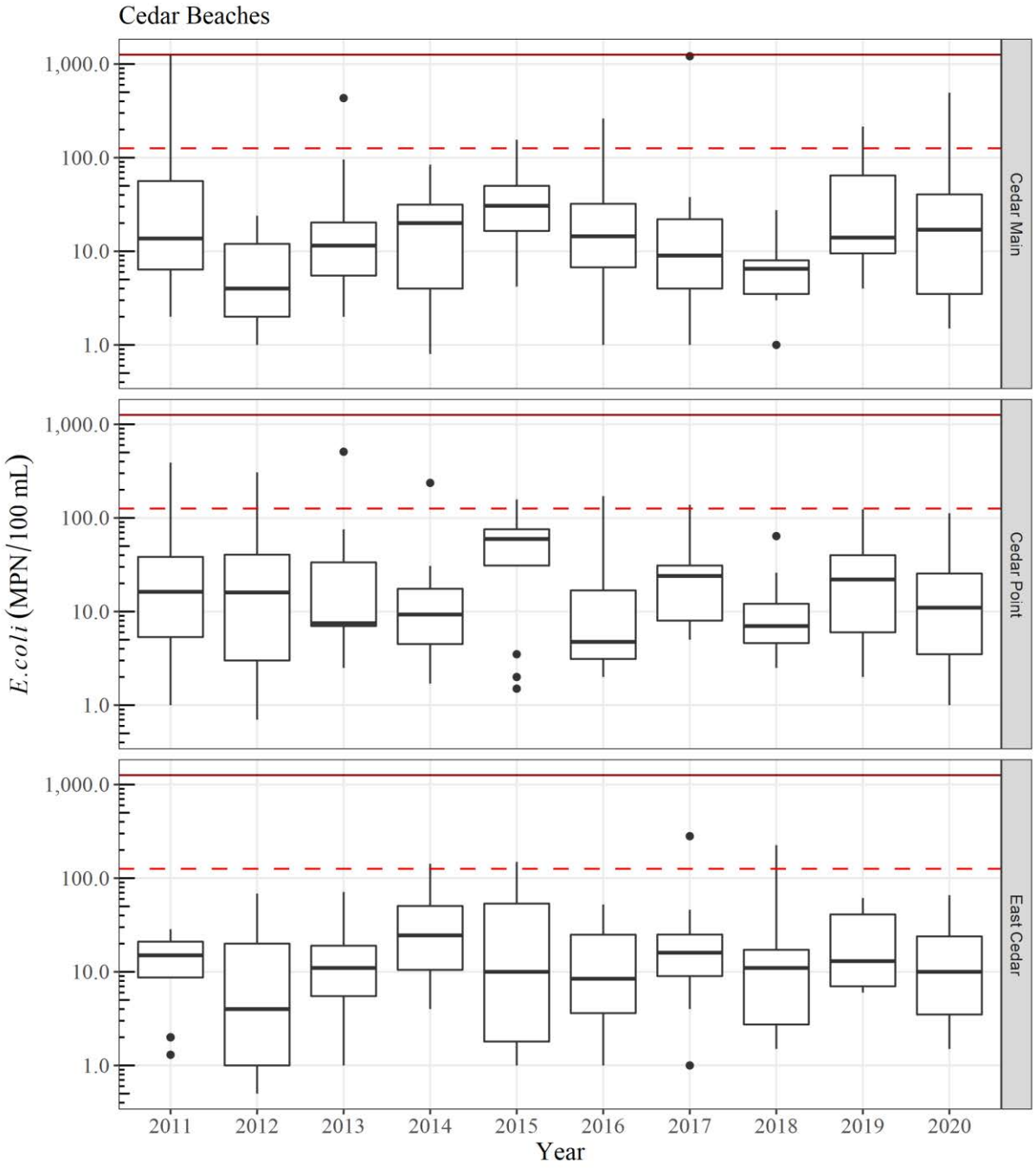


Figure 5-6. Box and whisker plots of *E. coli* concentrations (MPN/100 mL) for Cedar Lake beaches from 2011-2020. The dashed horizontal line represents the *E. coli* standard for the 30-day geometric mean (126 MPN/100mL) and the solid horizontal line represents the single-sample maximum standard (1260 MPN/100mL). Note the log scales on each y-axis.

LAKE AESTHETIC AND USER RECREATION INDEX (LAURI)

The 2020 LAURI for Cedar Lake is presented in **Figure 5-7**. Cedar Lake scored excellent in public health, habitat quality, and recreational access, good in aesthetics, and poor in water clarity. A severe algae bloom occurred on Cedar Lake in spring of 2020 decreasing the water clarity significantly. See **Chapter 1** for details on the LAURI index.

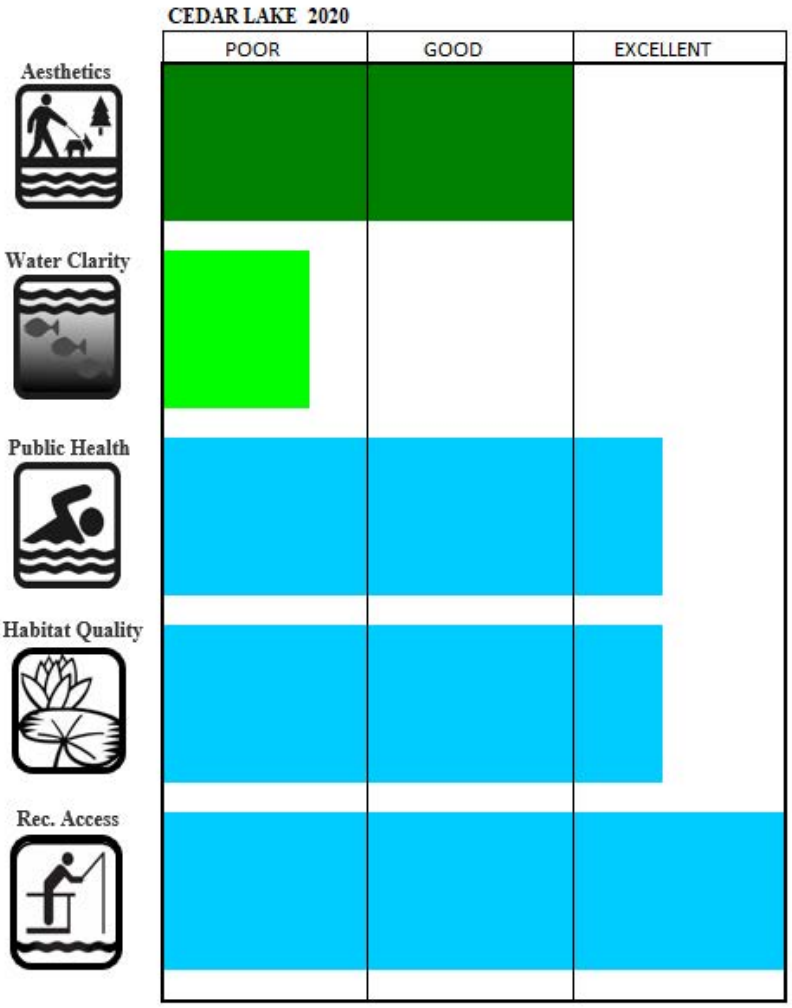


Figure 5-7. The 2020 LAURI for Cedar Lake.

WINTER ICE COVER

Ice came off Cedar Lake on March 28, 2020, nine days earlier than the average ice-off. Ice was back on the lake by December 1, 2020, three 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 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 2020, 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 20** 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 5-8** shows the water clarity, chlorophyll-*a* concentrations, and relative abundance of phytoplankton divisions during 2020. 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 0.4 and 1.7 meters in 2020. The shallowest Secchi reading occurred in early May when chlorophyll-*a* concentrations were high, and the deepest reading occurred in early June, see **Figure 5-8a**. Chlorophyll-*a* concentrations were highest in winter at 35.5 µg/L when the phytoplankton community primarily consisted of blue-green algae (Cyanophtya), see **Figure 5-8b, c**. Concentrations of chlorophyll-*a* were lowest in mid-August at 3.0 µg/L.

The phytoplankton community primarily consisted of blue-green algae (Cyanophyta) throughout the entire 2020 sampling season, see **Figure 5-8c**. The remainder of the phytoplankton community in Cedar Lake was a mix of diatoms (Bacillariophyta), green algae (Chlorophyta), chrysophytes (Chrysophyta), cryptomonads (Cryptophyta), haptophytes (Haptophyta), and dinoflagellates (Pyrrhophyta).

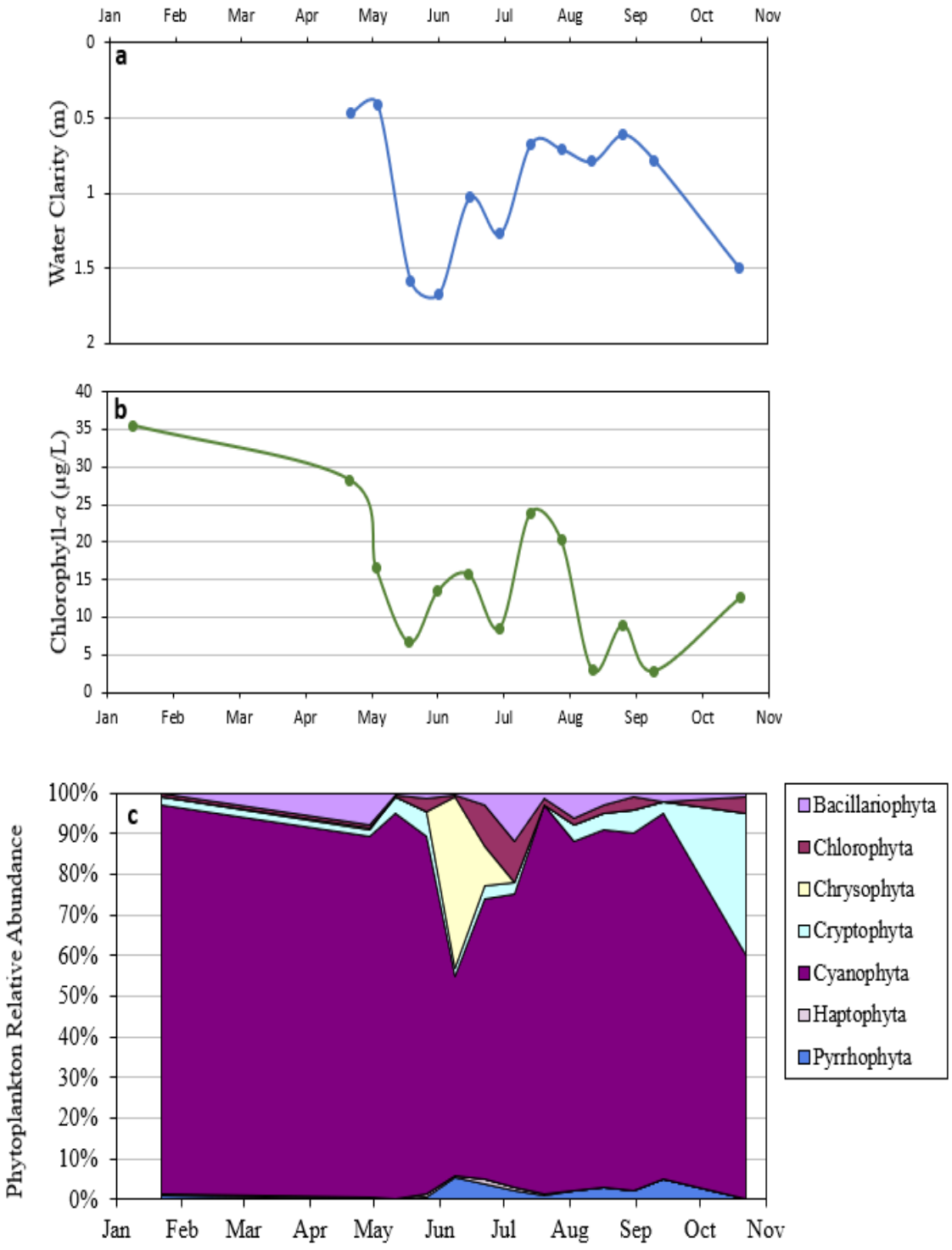


Figure 5-8. Water clarity (a), chlorophyll-a concentration (b), and relative abundance of phytoplankton (c) in Cedar Lake during 2020. Note that the water clarity axis is reversed.

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 5-9** shows the zooplankton distribution in Cedar Lake sampled throughout 2020. Rotifers, a group of small zooplankton, were present throughout the year and most abundant in May. Nauplii and juvenile copepods were also present through the year and were most abundant in May and April. Cladocerans were present in all samples and were abundant in June. Calanoids, cyclopoids, and protozoa were also present in low levels in 2020.

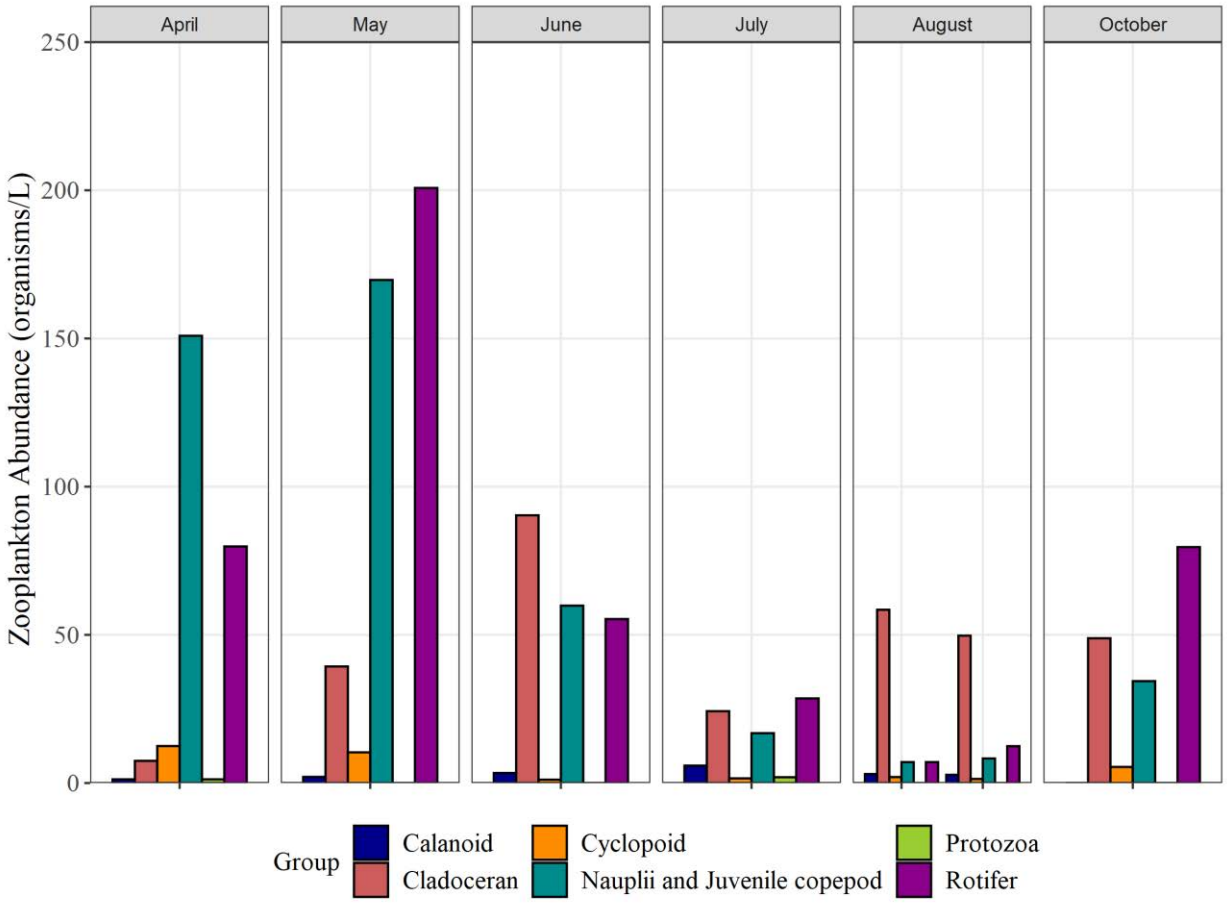


Figure 5-9. Zooplankton density in Cedar Lake during 2020.

EVENTS REPORT

Algae Bloom

Most blue-green algae blooms occur during the hottest part of the summer, but on April 11, 2020, an unusual spring bloom of blue-green algae was reported by a citizen. Algae are microscopic organisms that use the sun to make food. When algae grow very fast, it "blooms". A certain type of algae called blue-green algae can produce toxins that can make people or animals sick if they are ingested.

Plankton samples collected during winter showed that the blue-green algae bloom started under the ice. The species of algae that caused the bloom was initially identified as *Planktothrix prolifica*, but

after further analysis it is believed that the species was *Planktothrix aghardii*. Ongoing research is being done by others based on the phytoplankton samples collected by MPRB. *Planktothrix aghardii*, found in the winter and spring samples, grows well in cold water unlike most blue-green algae that prefer late summer temperatures. In a normal year, ice would melt off slowly and the algae would die off before it got a foothold in the lake. Rapid ice-out and cooler than average spring temperatures in 2020 led to conditions that allowed the algae to persist into spring.

Cedar Lake had murky brown water and very low water clarity, and the bloom was severe enough to form a scum that was visible on the north shoreline shown in **Figure 5-10**. The scum was a reddish-brown color and was initially investigated as a potential chemical spill; however, microscopic analysis by MPRB revealed that the scum was made up of strands of algae. Live samples of the algae were analyzed by MPRB's contract lab to confirm the species and identify whether it had the capability of producing toxins. The USGS was also requested to sample the algae in the lake.



Figure 5-10. Photo of algae bloom along North shoreline of Cedar Lake taken in early April.

MPRB made the decision to post a warning at Cedar Lake because the bloom was persisting into the swim season and people had begun to recreate in the water. As spring temperatures increased, so did the amount of recreation in the lake and park, increasing the potential that people would be exposed to blue-green algae. MPRB also tested the water for the presence of the most common algae toxin, microcystin. Microcystin was present at Cedar Lake but was below the EPA standard for body contact, 8 µg/L. Another algae toxin, anatoxin, was tested and not present in Cedar Lake. Because

algae toxins are not distributed evenly throughout the lake, and the bloom and scum were thick and persistent, posting advisory signs around the lake was warranted.

By early June, the lake water had lost its brown color and water clarity increased and MPRB removed the warning signage. MPRB re-tested the beaches for the presence of toxin. In this round of testing, no toxin was detected at Cedar Lake.

Fish Kill

In early May a citizen reported two dead fish along the shoreline of Cedar Lake. MPRB staff identified the fish as carp and found a total of five of them along the shoreline. Water quality data showed that water temperatures were too cold for spawning and oxygen levels in the lake were too high for oxygen depletion to be the cause of the fish kill.

A Graduate Assistant at University of Minnesota Aquatic Invasive Species Research Center (MAISRC) funded by Legislative-Citizen Commission on Minnesota Resources (LCCMR), gathered samples from the fish kill event and studied the gill tissues using quantitative polymerase chain reaction (qPCR). The study concluded that carp edema virus (CEV) was the cause of mortality. CEV is a double-stranded DNA virus that is likely spread by diseased fish shedding the virus from gill and skin lesions. The virus typically occurs in the spring when water temperatures are between 43-50 degrees Fahrenheit and the surface water temperature at Cedar Lake during the fish kill was 49 degrees Fahrenheit. See the fish kill section in **Chapter 1** for additional details.

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). No fish were stocked in Cedar Lake in 2020, see **Table 5-4**. Additional information and a definition of fry, fingerling, yearling, and adult fish sizes can be found in **Chapter 1**.

Table 5-4. 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
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
2012	Muskellunge	63 fingerlings	12.6 pounds
2011	Walleye	3,828 fingerlings	136.7 pounds

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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 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 August 2020.

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 of Diamond Lake and **Figure 6-2** shows a map of the lake. The lake is part of Minnehaha Creek Watershed and is predominantly surrounded by residential neighborhoods and parkland. City of Minneapolis installed stormsewers in 1940 and Diamond Lake currently has 11 stormwater outfalls, see **Appendix C**.

Construction of Interstate 35W during the 1960s added several miles of highway runoff to Diamond Lake. Water levels in Diamond Lake have fluctuated due to land-use changes in the surrounding watershed. Due to the installation of stormsewers, 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 to control water elevation and an outflow pipe that carried water from the northeast shore to Minnehaha Creek. In 1991, the MPRB placed a weir 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.

Water quality on Diamond Lake has been monitored annually since 1992. 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. In 2007, construction began on the 35W/HWY62 improvement project that again changed the drainage areas in the Diamond Lake watershed.

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.

Table 6-1. Diamond Lake physical characteristics.

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.**

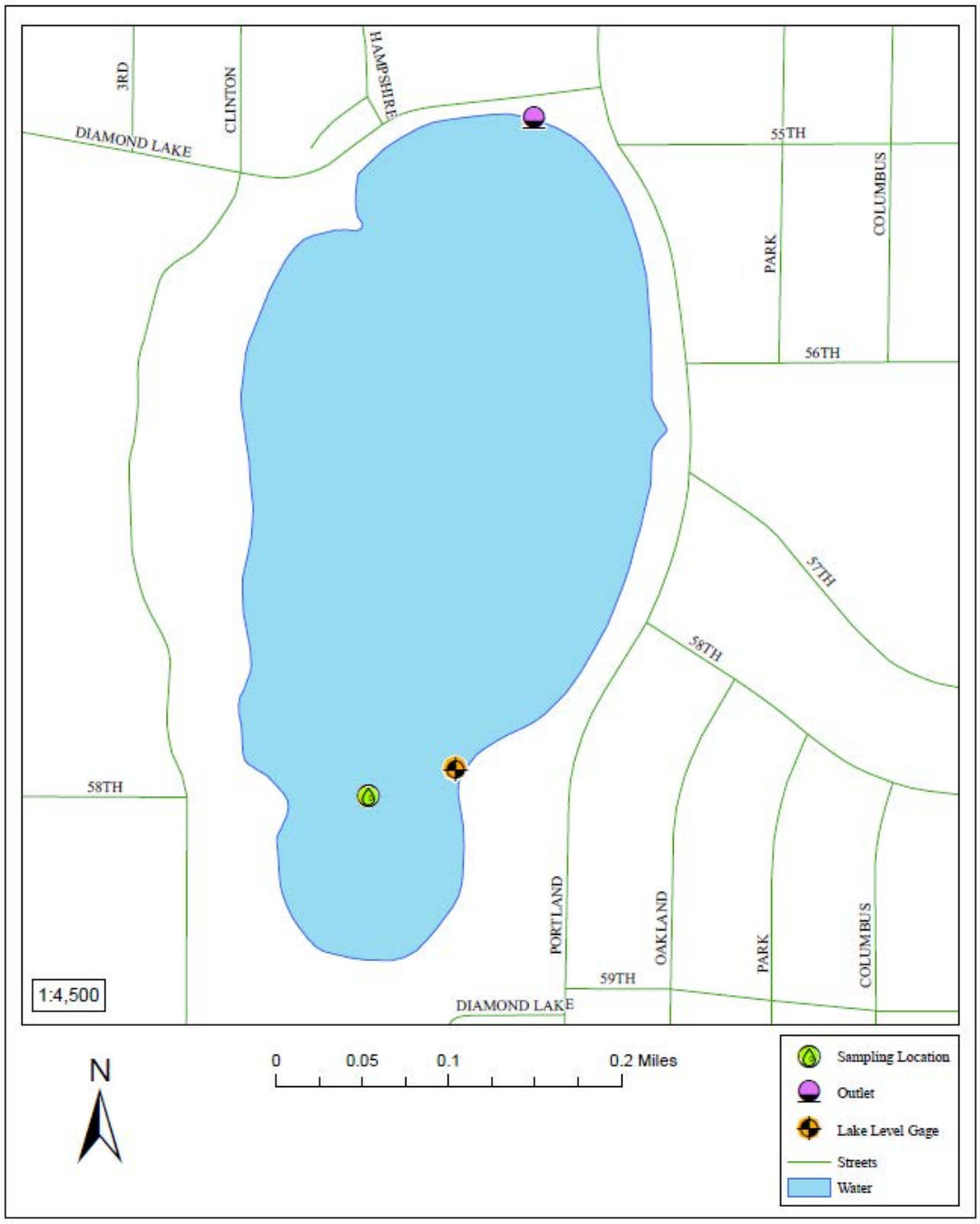


Figure 6-2. Diamond Lake map. The green circle represents the sampling location, purple circle represents the outlet, and the orange circle represents the lake level gage.

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 ft msl. The lake level for 2020 fluctuated above and below the OHWL. The lake froze below the OHWL in December of 2020.

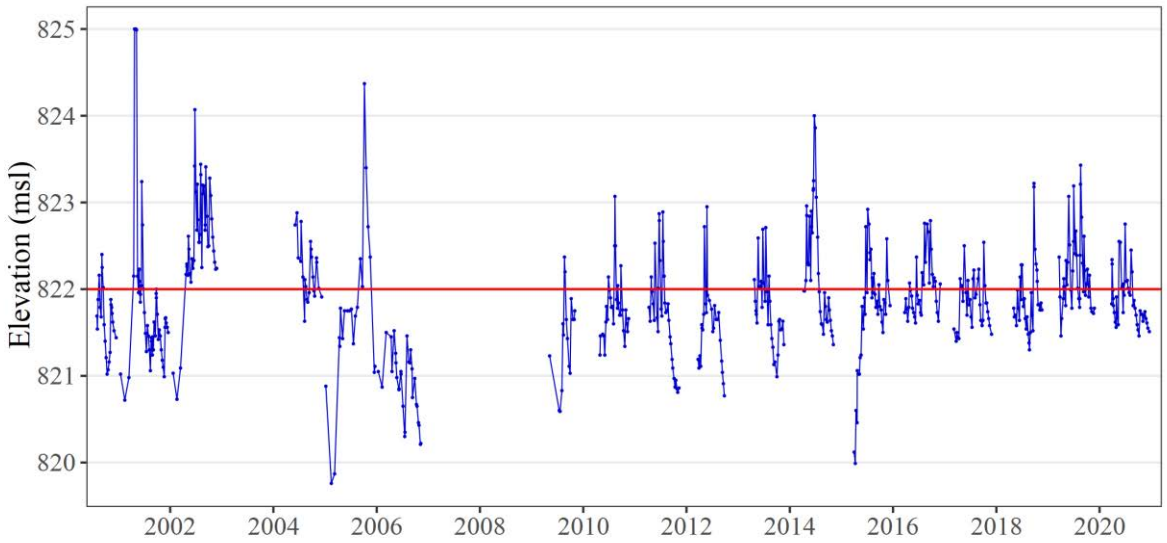


Figure 6-3. Lake levels for Diamond Lake from 2000-2020. Horizontal line represents the Ordinary High Water elevation (822 ft msl) for Diamond Lake.

WATER QUALITY TRENDS – TROPHIC STATE INDEX (TSI)

Figure 6-4 shows the TSI scores and linear regression from 1992–2020 at Diamond Lake. There is no significant trend in the TSI since 1992 ($p > 0.05$). The 2020 TSI score, calculated using chlorophyll-*a* and total phosphorus concentrations, for Diamond Lake was 58. 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**.

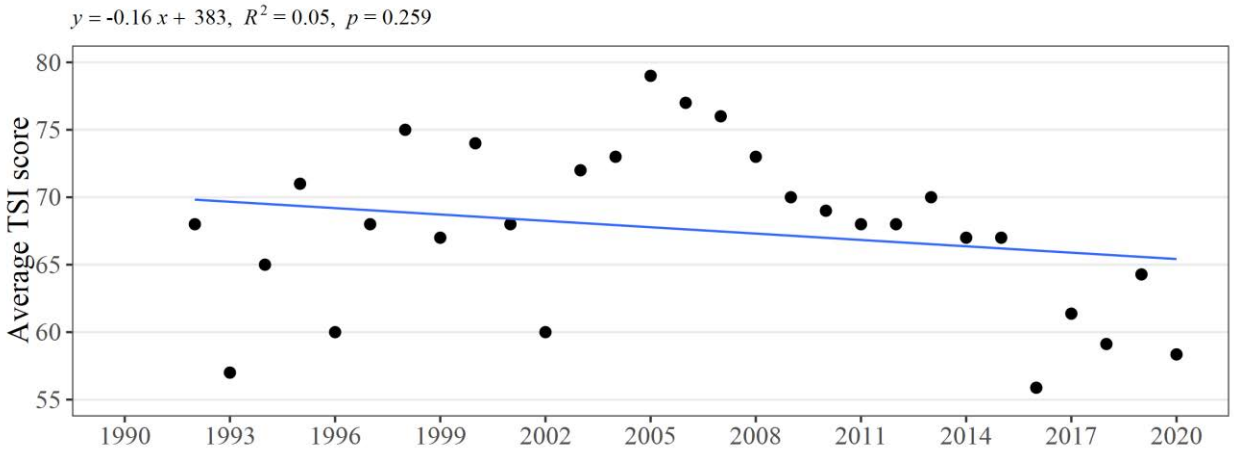


Figure 6-4. Diamond Lake TSI scores and linear regression from 1992 to 2020.

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, 1992-2020, can be found in **Appendix A**.

Diamond Lake has limited water clarity data due to its shallowness and high macrophyte density. No Secchi disk readings were taken in 2020. Chlorophyll-*a* concentrations in 2020 remained consistent with the previous four years, with an average of 17 µg/L. The last five years of chlorophyll-*a* concentrations have remained consistently lower than the five years prior, see **Figure 6-5a**. Similarly, total phosphorus (TP) concentrations were also lower between 2016 and 2020 compared to previous years with an average of 74 µg/L in 2020, see **Figure 6-5b**. Thick macrophyte growth, especially lily pads, filamentous algae, and star duckweed were noted during most sampling trips in 2020.

Generally, data from Diamond Lake is more variable and contains more variability 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.

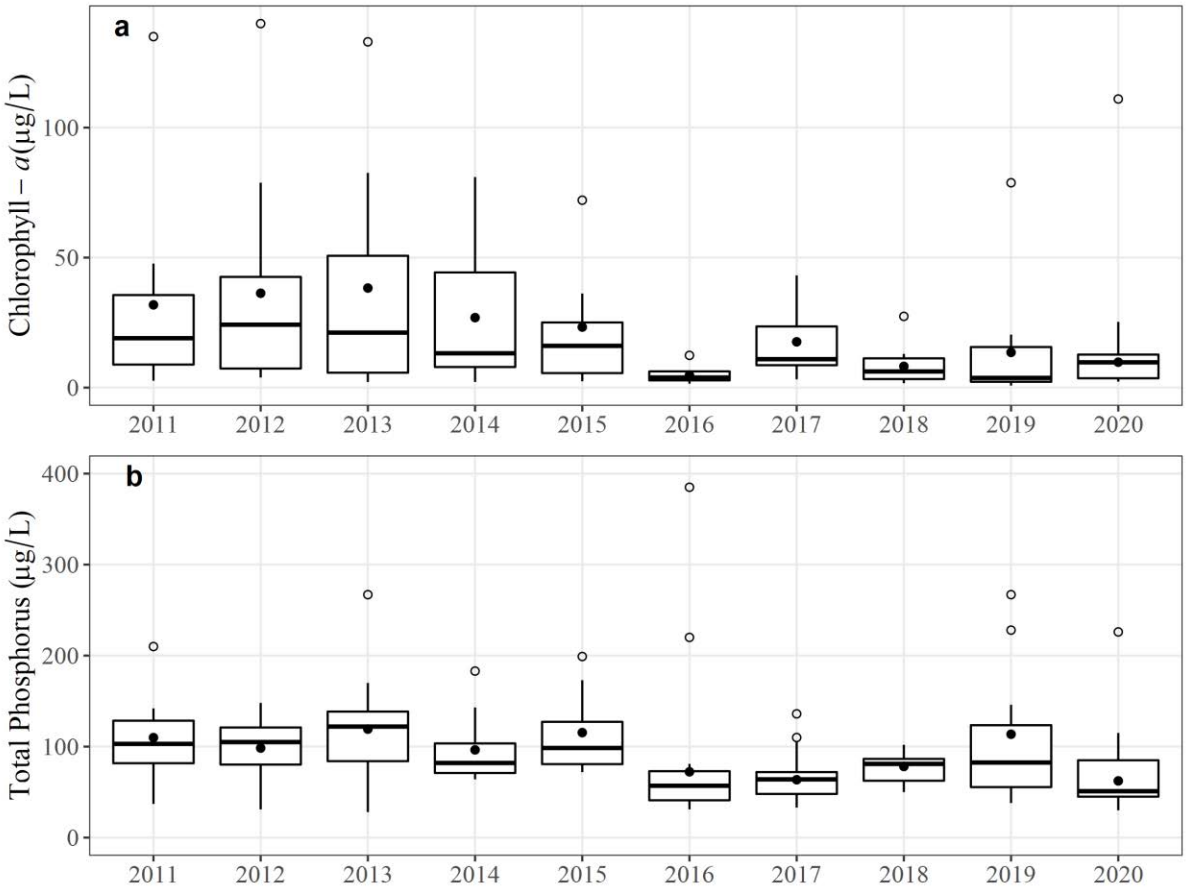


Figure 6-5. Box and whisker plots of Diamond Lake chlorophyll-*a* (a) and total phosphorus (b) from 2011-2020. The black circles represent the mean value of data collected during the growing season, May through September. Data from 1992-2020 can be found in Appendix A.

LAKE AESTHETIC AND USER RECREATION INDEX (LAURI)

Figure 6-6 shows the 2020 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**.

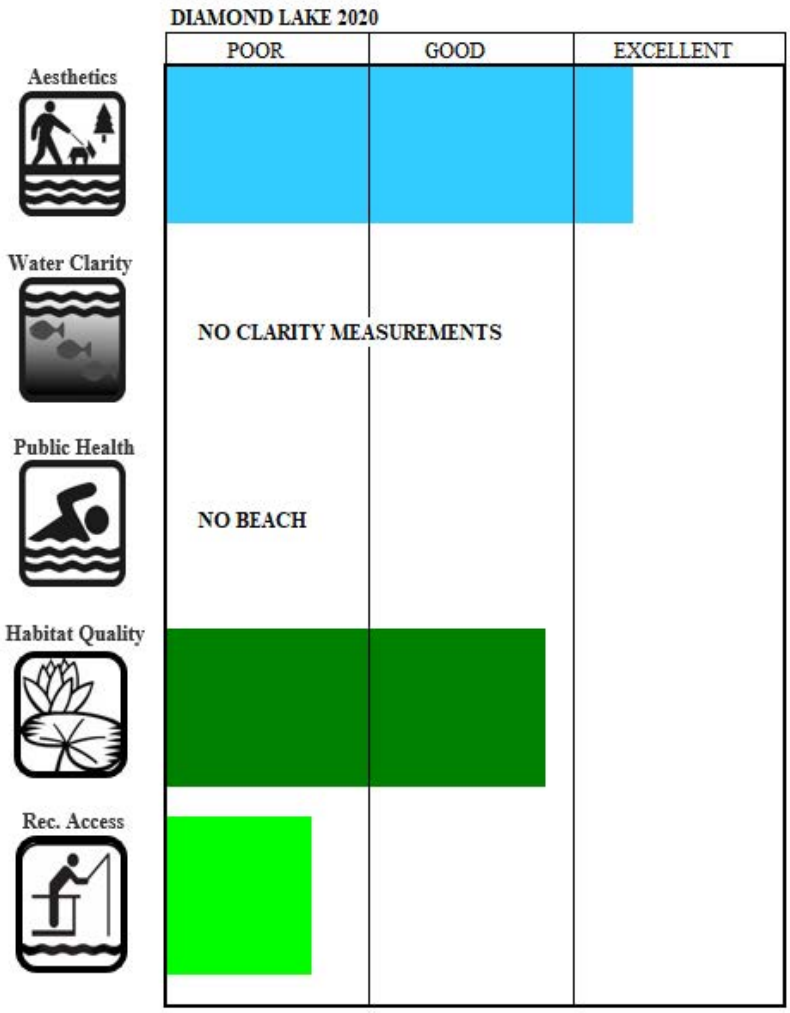


Figure 6-6. The 2020 LAURI for Diamond Lake.

WINTER ICE COVER

Ice came off Diamond Lake on March 24, 2020, 11 days earlier than the average ice-off. Ice came back on to Diamond Lake on December 15, 2020, 13 days after the average ice-on date, but five days before the latest ice on record of December, 20th. 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 6-7** shows the chlorophyll-*a* concentrations and relative abundance of phytoplankton divisions during 2020. 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 111 µg/L when the phytoplankton community primarily consisted of chrysophytes (Chrysophyta). Concentrations of chlorophyll-*a* remained below 25 µg/L for the remainder of the season and reached the lowest concentration in mid-September at 2.27 µg/L, see **Figure 6-7a, b**.

The phytoplankton community consisted of a mix of green algae (Chlorophyta), chrysophytes, cryptomonads, blue-green algae (Cyanophyta), and euglenoids (Euglenophyta). Diatoms (Bacillariophyta), haptophytes (Haptophyta), dinoflagellates (Pyrrhophyta) and yellow-green algae (Xanthophyta) were also present in low percentages in 2020, see **Figure 6-7b**.

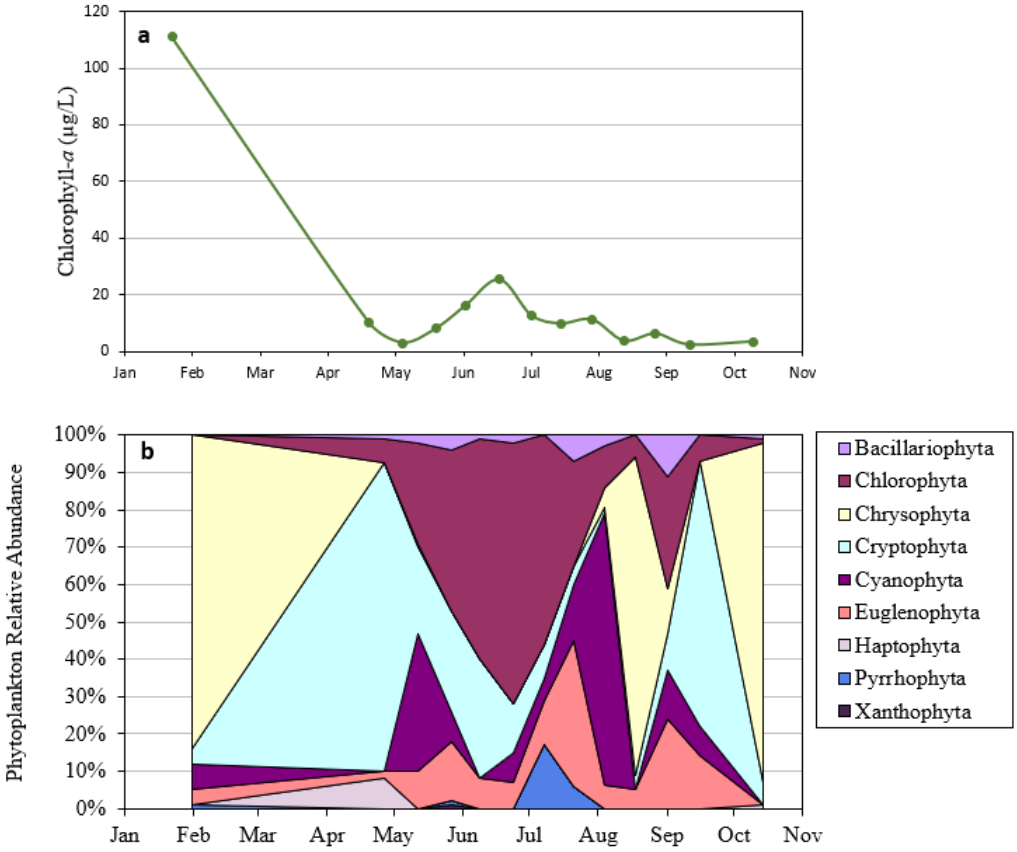


Figure 6-7. Chlorophyll-*a* concentration (a) and relative abundance of phytoplankton (b) in Diamond Lake during 2020.

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. 2020 was the sixteenth year that Diamond Lake was evaluated in the WHEP program. Diamond Lake scored moderate for

invertebrates and moderate for vegetation in 2020. Results of the wetland evaluation are presented in **Chapter 22**.

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 noted more empty shells and younger snails in recent years, which follows a general trend along the southeast shore since muskrats took up residence in 2010 or 2011.

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7. GRASS LAKE

HISTORY

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 National Wetlands Inventory classifies Grass Lake as a permanently flooded lacustrine/littoral system with an unconsolidated bed (L2UBH; **Figure 7-1**). Physical characteristics 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 sampled in 2020.



Figure 7-1. Grass Lake in July 2020.

Table 7-1. Grass Lake physical characteristics. 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

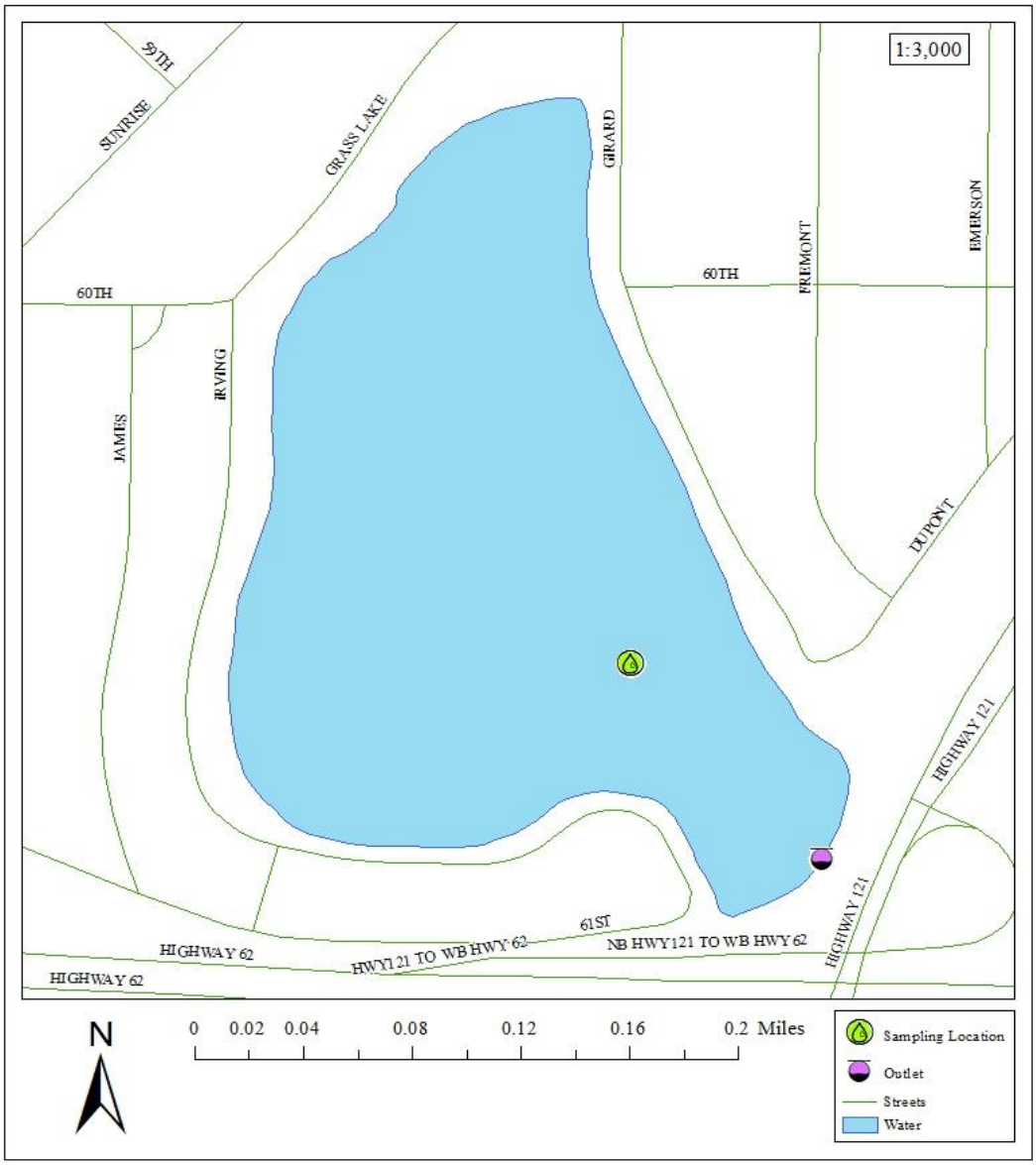


Figure 7-2. Grass Lake map. The green symbol represents the sampling location and the purple symbol represents the outlet.

WATER QUALITY TRENDS – TROPHIC STATE INDEX (TSI)

Figure 7-3 shows the TSI scores and linear regression from 2002-2020 at Grass Lake. There is not a significant trend in TSI scores over the last 18 years ($p > 0.5$); however, the lake is only sampled every-other year. The 2020 TSI score, calculated using chlorophyll-*a* and total phosphorus concentrations, for Grass Lake was 74. 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 has been inaccessible since 2008 due to a construction project. The very high TSI in 2003 could be an outlier, as subsequent years have clustered between a TSI score of 55 to 65 until 2018. Subsequently, the 2020 TSI was the highest score for Grass Lake since 2003. 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**.

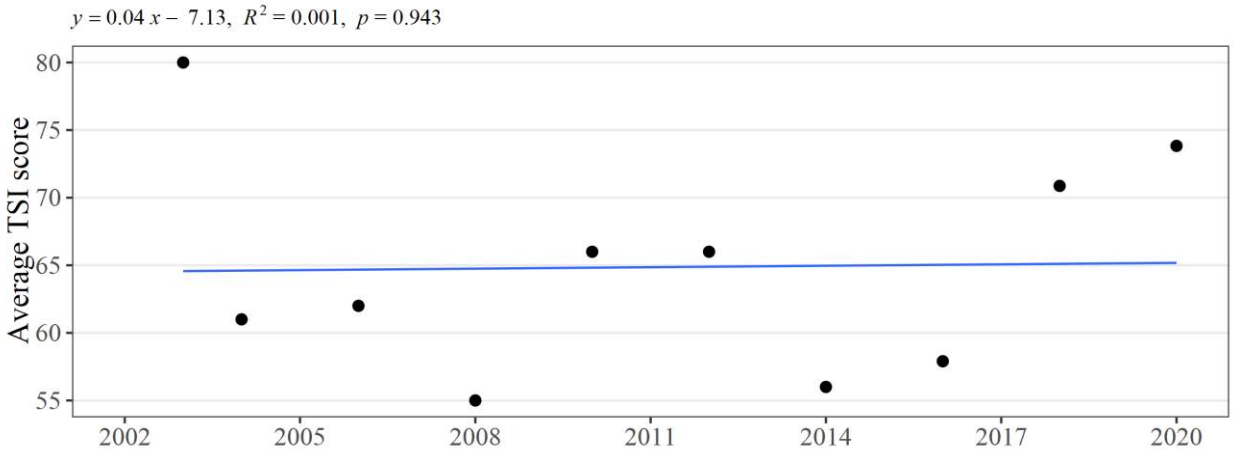


Figure 7-3. Grass Lake TSI scores and linear regression for monitored years from 2002 to 2020. Note: the sampling location changed in 2008 and again in 2016.

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, 2002-2020, 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 2020, chlorophyll-*a*, total phosphorus, and total nitrogen had more variability and higher concentrations than previous years. The average chlorophyll-*a* concentration was 57.1 µg/L. The average total phosphorus concentration was 251 µg/L. The average total nitrogen concentration was 1.45 mg/L.

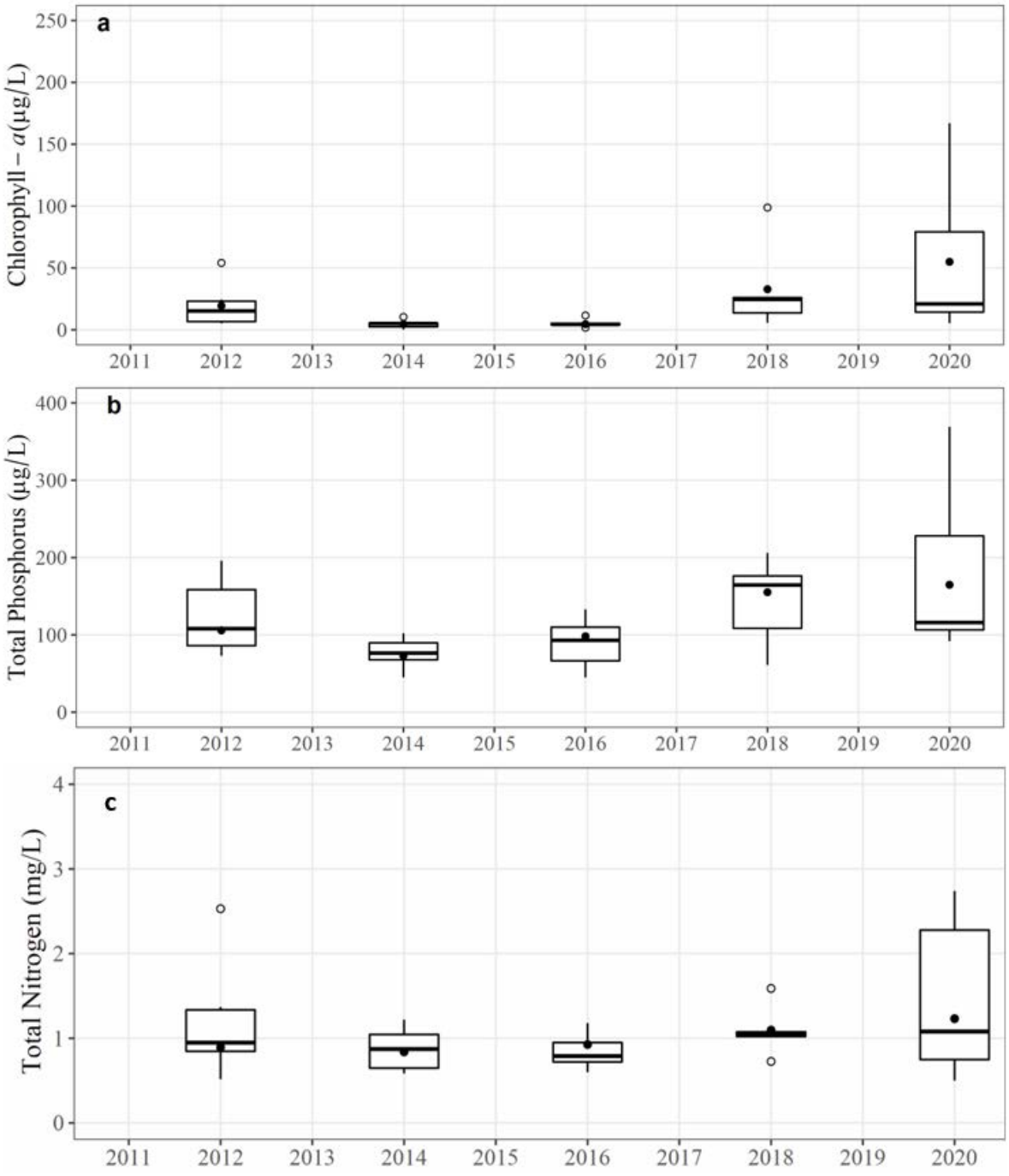


Figure 7-4. Grass Lake box and whisker plots of chlorophyll-*a* (a), total phosphorus (b), and total nitrogen (c) from 2011-2020. The black circles represent the mean value of data collected during the growing season, May through September. Data from 2002-2020 can be found in Appendix A.

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 March 24, 2020, nine days earlier than average for the lake since records began. Ice was back on Grass Lake on December 15, 2020, 13 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 7-5** shows the concentration of chlorophyll-*a* and the relative abundance of phytoplankton divisions during 2020. 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 164 µg/L when the phytoplankton community primarily consisted of chrysophytes (Chrysophyta), see **Figure 7-5a, b**. Concentrations of chlorophyll-*a* remained below 50 µg/L for most of 2020 until early September when the highest concentration was reached at 167 µg/L when the phytoplankton community primarily consisted of blue-green algae (Cyanophyta). The lowest chlorophyll-*a* concentration occurred in fall at 5.45 µg/L. The phytoplankton community changed drastically throughout the 2020 sampling season. Chrysophytes dominated the phytoplankton population in the winter, green algae (Chlorophytes) in spring, cryptomonads (Cryptophyta) in June, and blue-green algae for the remainder of the season. Diatoms (Bacillariophyta), euglenoids (Euglenophyta), and dinoflagellates (Pyrrhophyta) were also present in low levels.

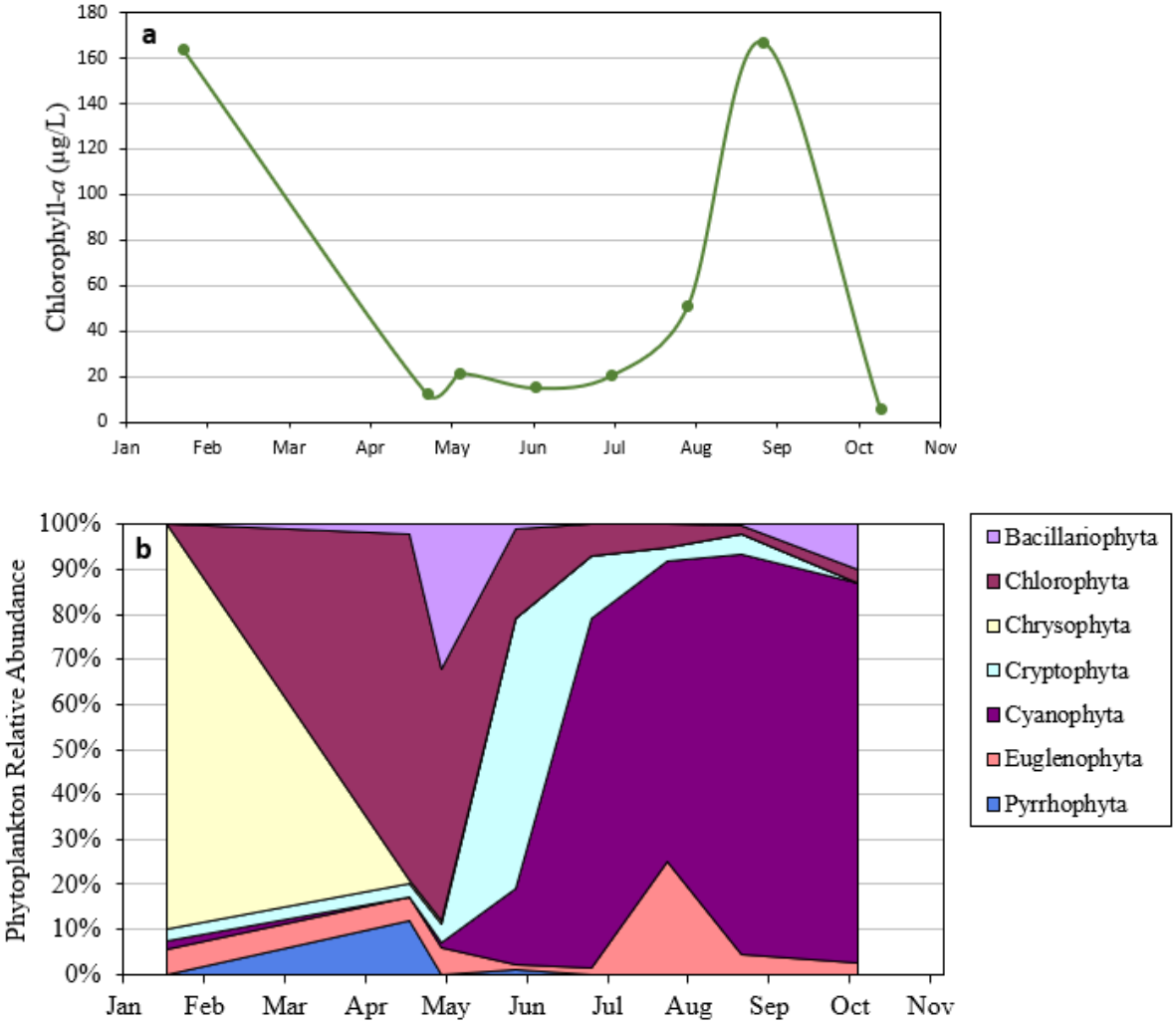


Figure 7-5. Chlorophyll-*a* concentration (a) and relative abundance of phytoplankton (b) in Grass Lake during 2020.

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 2020. Results of the wetland evaluation are presented in **Chapter 22**. Grass Lake received a moderate rating for both invertebrate and vegetation quality. 2020 was the sixth year that Grass Lake was evaluated in the WHEP program.

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8. LAKE HARRIET

HISTORY

Colonel W.S. King donated a majority of the lake 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. One of the original Dakota names for the lake is Bde Unma. Lake Harriet was 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. An open water channel allowing transportation 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 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 of Lake Harriet and **Figure 8-2** shows a bathymetric map. Lake Harriet is part of Minnehaha Creek Watershed and is surrounded by residential neighborhoods and has a 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. Bandshell on Lake Harriet in July 2020.

Lake Harriet receives water from Bde Maka Ska. In 1967, a pumping station and pipeline were constructed between Lake Harriet and Bde Maka Ska in order to control water levels in the upper Chain. 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 northeast 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. The outlet pipe contains a stop log weir with the elevation set at 846.78 feet above mean sea level (msl).

Water quality on Lake Harriet has been monitored annually since 1991. 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). Increases in stormsewer discharge since the 1920s led to increased phosphorus levels that peaked in the 1970s. 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 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. Not originally intended to do so, 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 to complete 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 21** for additional details. In 2020, the "Do not eat" order for Lake Harriet largemouth bass was removed due to new information and reduction in perfluorooctane sulfonate (PFOS), see **Chapter 1** for more information on PFOS.

Table 8-1. Lake Harriet physical characteristics.

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%	$4.41x10^8$	1,139	3.2	3.4

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

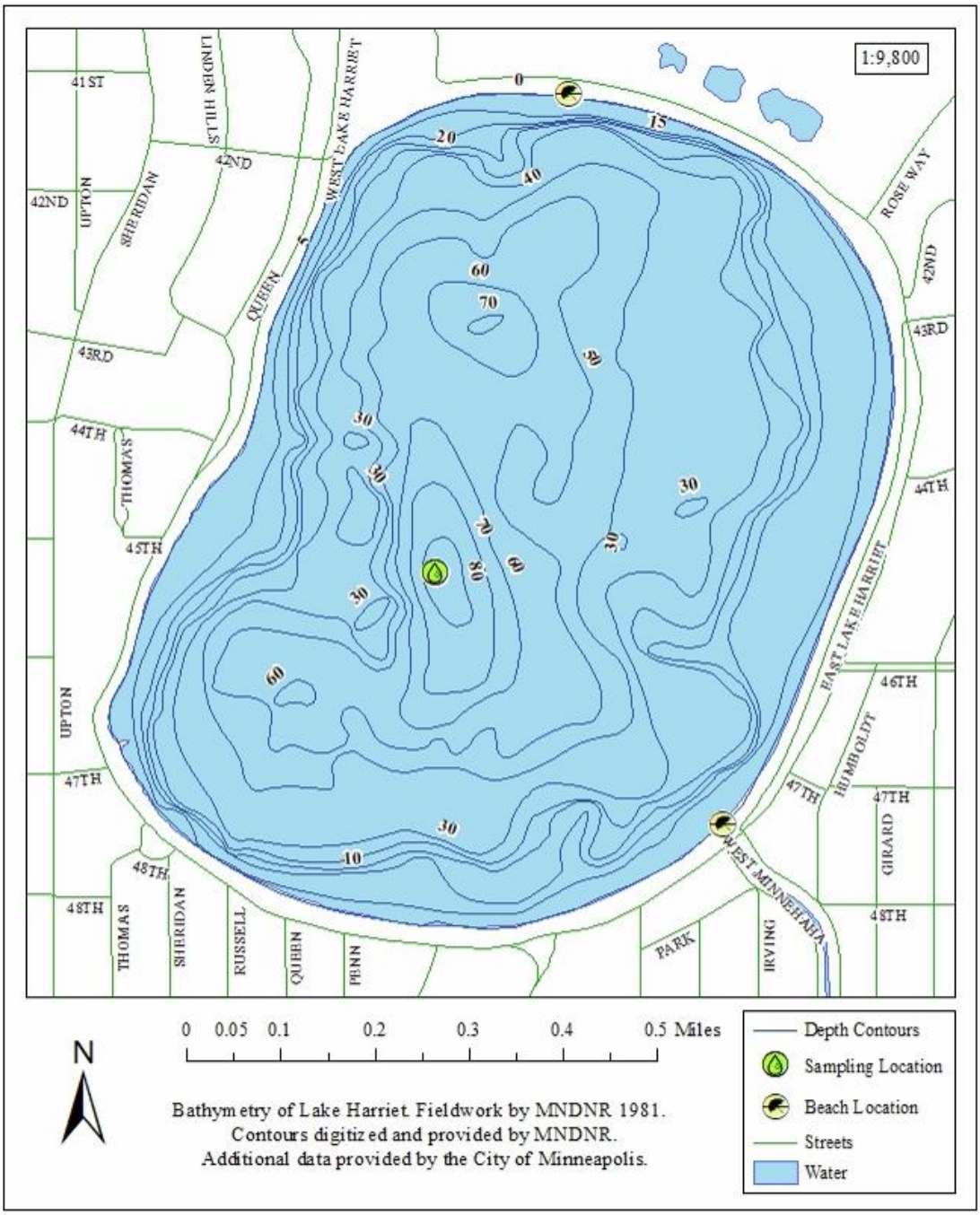


Figure 8-2. Bathymetric map and sampling locations at Lake Harriet.

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 for most of 2020 and froze below the OHW in December. See **Chapter 1** for details on lake level monitoring and **Chapter 17** for a comparison between other MPRB lake levels.

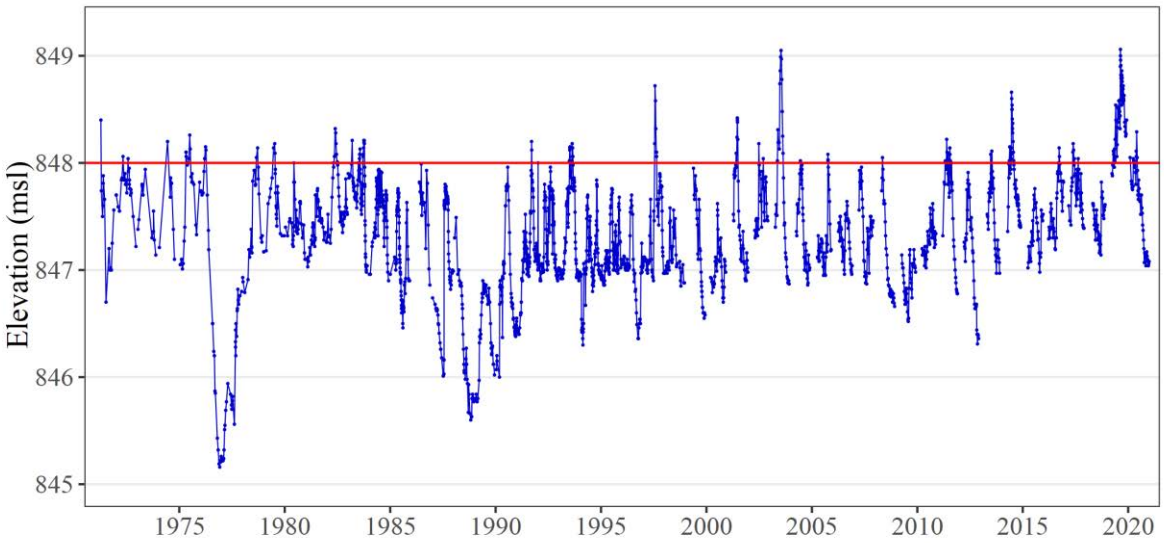


Figure 8-3. Lake levels for Lake Harriet from 1970 to 2020. Horizontal line represents the Ordinary High Water elevation (848 ft msl) for Lake Harriet.

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 1991-2020, 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 2020 was 42. The lake is currently mesotrophic having moderately clear water and increasing probability of hypolimnetic anoxia during summer.

The TSI score has remained relatively stable in recent years and is lower (better) than 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 TSI score met the CWP goal most years, except for 2006, 2008, 2018 and 2019.

Secchi, chlorophyll-*a*, and total phosphorus TSI scores for Lake Harriet are below the TSI range for the ecoregion, meaning water clarity is deeper and chlorophyll-*a* and total phosphorus levels in Lake Harriet are lower than in comparable lakes, see **Table 8-2**. For more information see Minneapolis 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**.

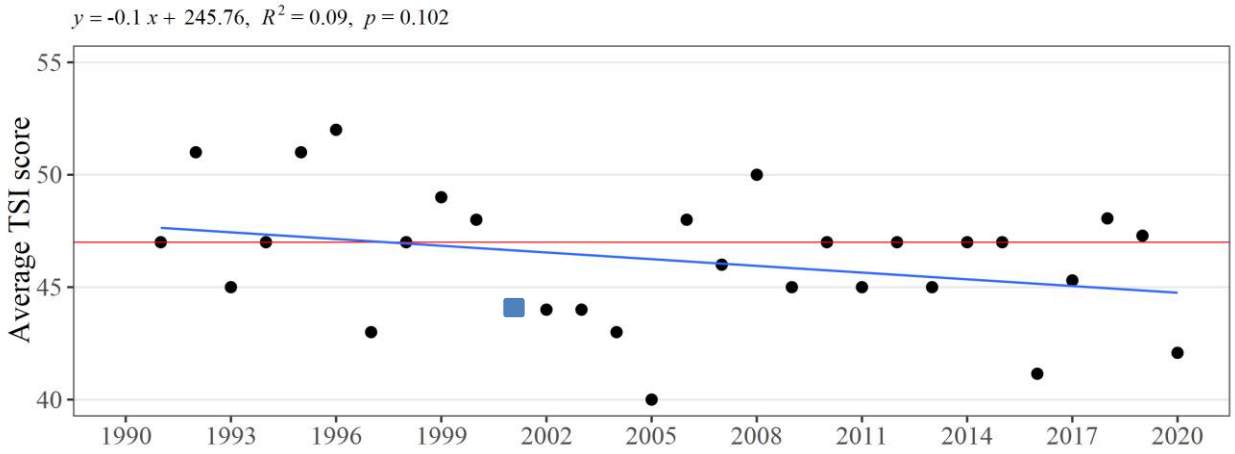


Figure 8-4. Lake Harriet TSI scores and linear regression from 1991-2020. The red line represents the CWP long-term TSI goal of below 47. The blue square highlights the 2001 alum treatment.

Table 8-2. Lake Harriet Secchi, chlorophyll-*a*, and total phosphorus TSI based on data collected between June and September 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	41	43-54	Not within range, better than expected
Chlorophyll-*a*	41	46-61	Not within range, better than expected
Total Phosphorus	47	49-61	Not within range, better than expected

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 deep lake standards, 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, 1991-2020, can be found in **Appendix A**.

The average Secchi disk reading for 2020 was 4.3 meters, which is comparable to 2016 and 2017 and deeper in relation to other years in the past decade, see **Figure 8-5a**. The 2020 chlorophyll-*a* concentrations were lower than 2018 and 2019 and comparable to previous years. The average chlorophyll-*a* concentration for 2020 was 4.3 µg/L, see **Figure 8-5b**. Total phosphorus (TP) concentrations were similar in comparison to previous years with an average of 30 µg/L. The highest concentration occurred while the lake was not thermally stratified in the fall, see **Figure 8-5c**. Lake Harriet met MPCA eutrophication standards for water clarity, chlorophyll-*a*, and total phosphorus in 2020.

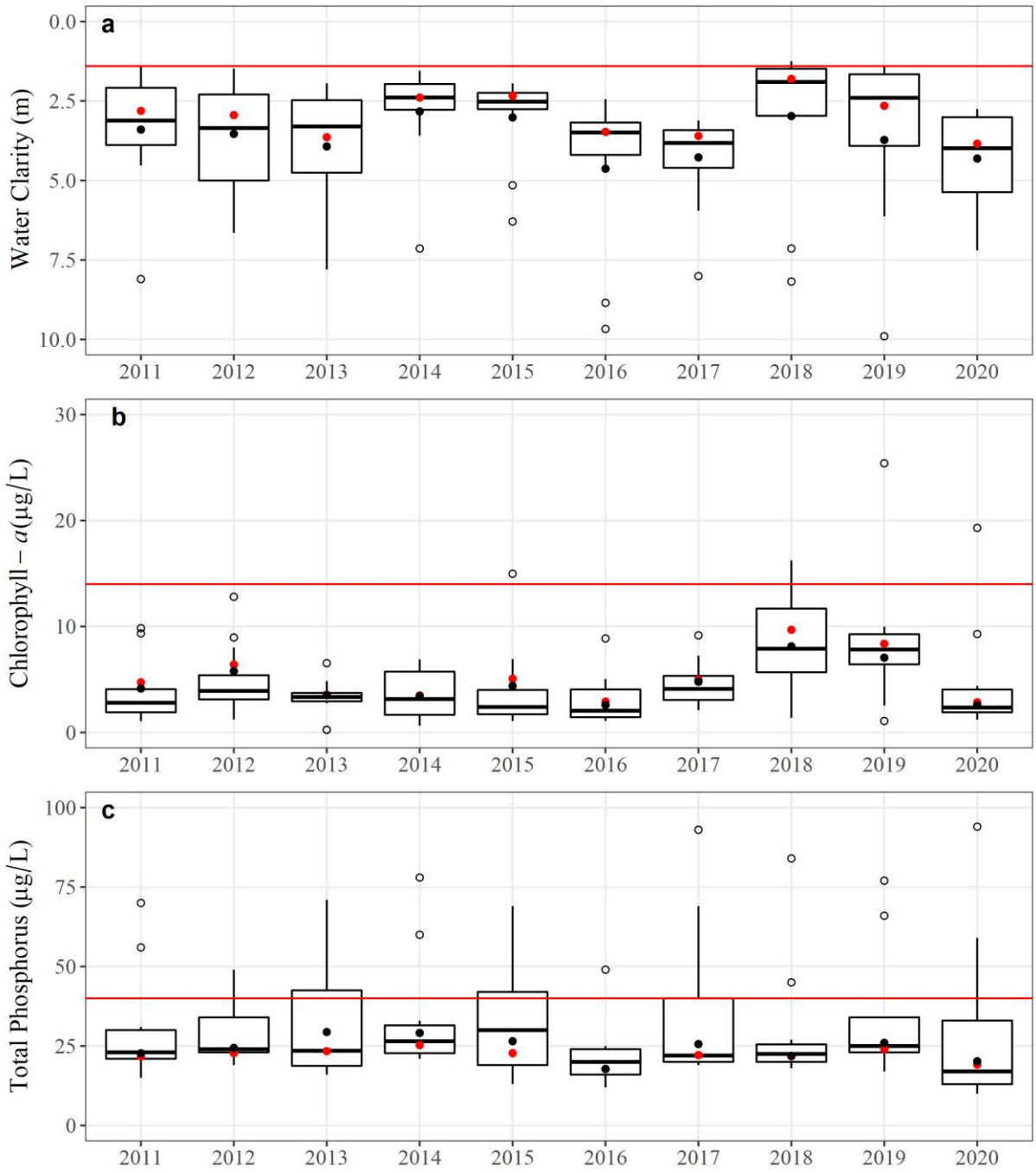


Figure 8-5. Lake Harriet box and whisker plots of water clarity (a), chlorophyll-*a* (b), and total phosphorus(c) from 2011 - 2020. Horizontal lines represent MPCA eutrophication standard for deep lakes, which applies to data collected between June and September. The red circles represent the mean value 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 - 2020 can be found in Appendix A.

BEACH MONITORING

Escherichia coli (*E. coli*) levels were sampled at two different locations on Lake Harriet: Harriet Main Beach and Harriet Southeast Beach. As shown in **Table 8-3** and **Figure 8-6**, *E. coli* counts were low at Harriet Main Beach and variable at Harriet Southeast Beach. Harriet Main Beach remained open for entire 2020 sampling season, while Harriet Southeast Beach closed three times. Harriet Southeast Beach first closed July 7th due to exceedance of the 30-day geomean (126 MPN/100 mL) standard and reopened on July 14th when *E. coli* levels dropped below the geomean standard. The beach closed again August 25th due to a single sample exceedance (>1260 MPN/100 mL) and reopened when *E. coli* levels dropped below the single sample threshold. Harriet Southeast Beach also closed on September 1st due to the exceedance of the 30-day geomean and remained closed through the end of the season. During all three beach closures a significant amount of aquatic vegetation and evidence of waterfowl and waste were noted, which likely contributed to the high bacteria levels.

As a result of an unusual early spring algae bloom on Minneapolis lakes in 2020, MPRB developed a blue-green algae index visual monitoring protocol. Visual indicators were noted as part of the protocol for the weekly beach sampling program. See **Chapter 18** for more information on beach and blue-green algae monitoring.

Table 8-3. Summary of *E. coli* (MPN per 100 mL) data for Lake Harriet beaches in 2020.

Statistical Calculations	Harriet Main	Harriet SE
Number of Samples	13	13
Minimum	3	4
Maximum	243	2420
Median	24	82
Mean	62	427
Geometric Mean	28	92
Max 30-Day Geo Mean	61	217
Standard Deviation	74	704

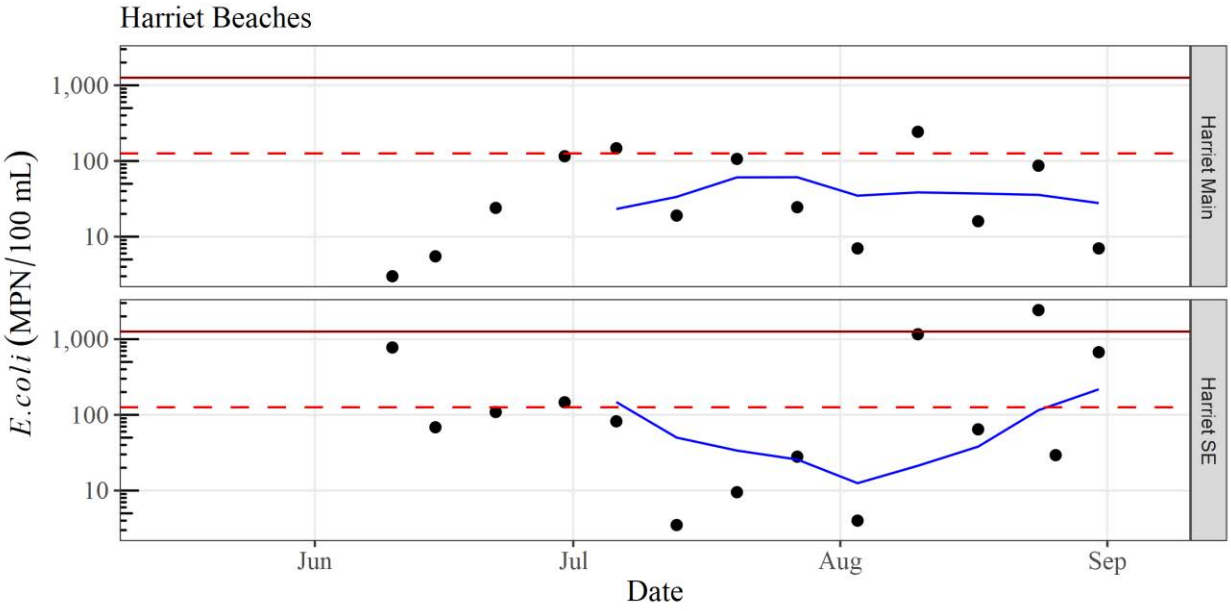


Figure 8-6. 2020 *E. coli* concentrations at the Lake Harriet beaches. Blue line is the running 30-day geometric mean. The dashed horizontal line represents the *E. coli* standard for the 30-day geometric mean (126 MPN/100mL) and the solid horizontal line represents the single-sample maximum standard (1260 MPN/100mL). Note the log scale on the Y-axis.

Figure 8-7 shows *E. coli* monitoring data for Lake Harriet beaches from 2011 to 2020 which is graphed by using box and whisker plots. The *E. coli* results from 2020 at Harriet Main Beach were typical compared to previous years, while the bacteria levels at Harriet Southeast Beach were higher than previous years. Harriet Southeast Beach also tends to have more variable *E. coli* concentrations than Harriet Main Beach.

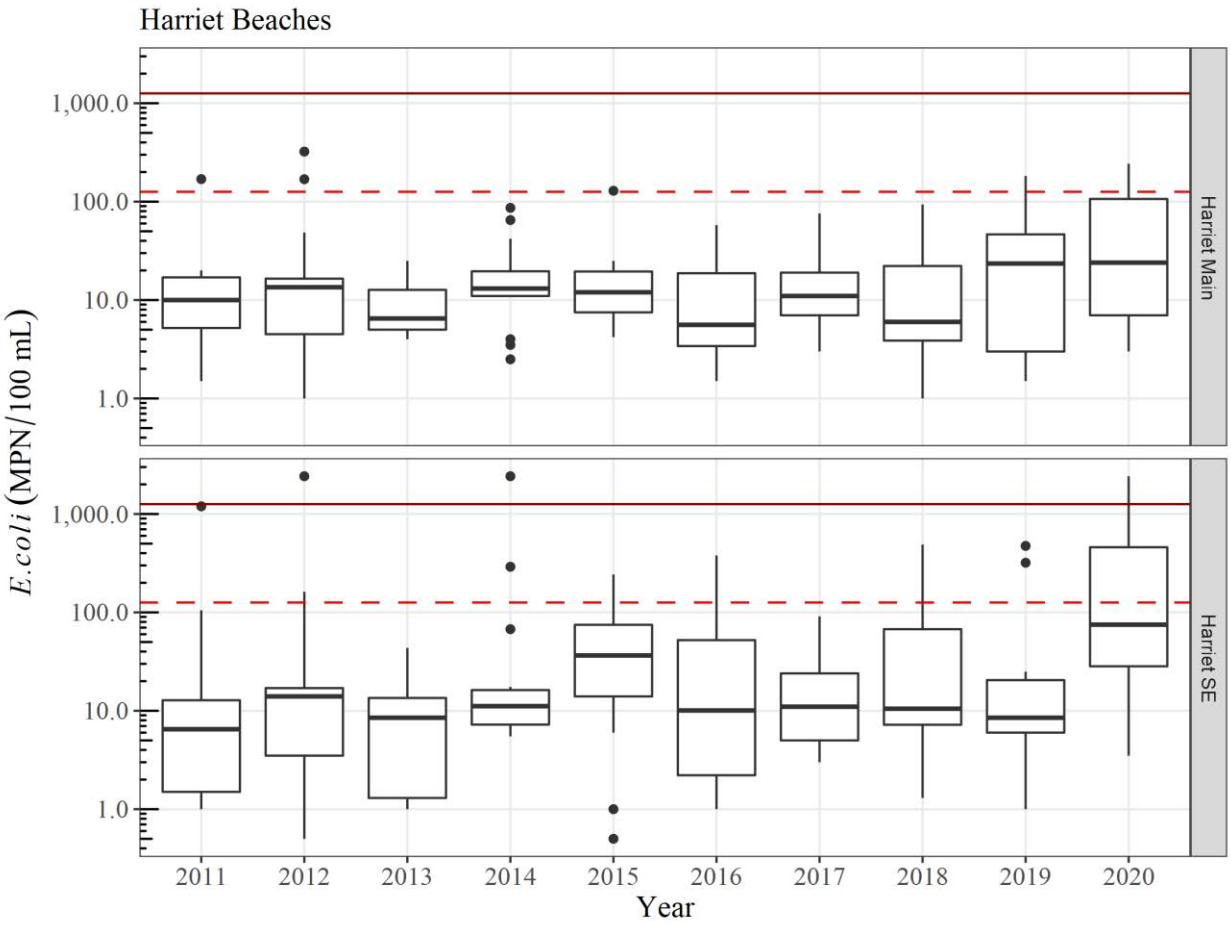


Figure 8-7. Box and whisker plots of *E. coli* concentrations (MPN/100 mL) for Lake Harriet beaches from 2011-2020. The dashed horizontal line represents the *E. coli* standard for the 30-day geometric mean (126 MPN/100mL) and the solid horizontal line represents the single-sample maximum standard (1260 MPN/100mL). Note the log scale on the Y-axis.

LAKE AESTHETIC AND USER RECREATION INDEX (LAURI)

Figure 8-8 shows the 2020 LAURI for Lake Harriet. Lake Harriet ranked excellent in aesthetics, water clarity, habitat quality, and recreational access and good in public health. Details on the LAURI can be found in **Chapter 1**.

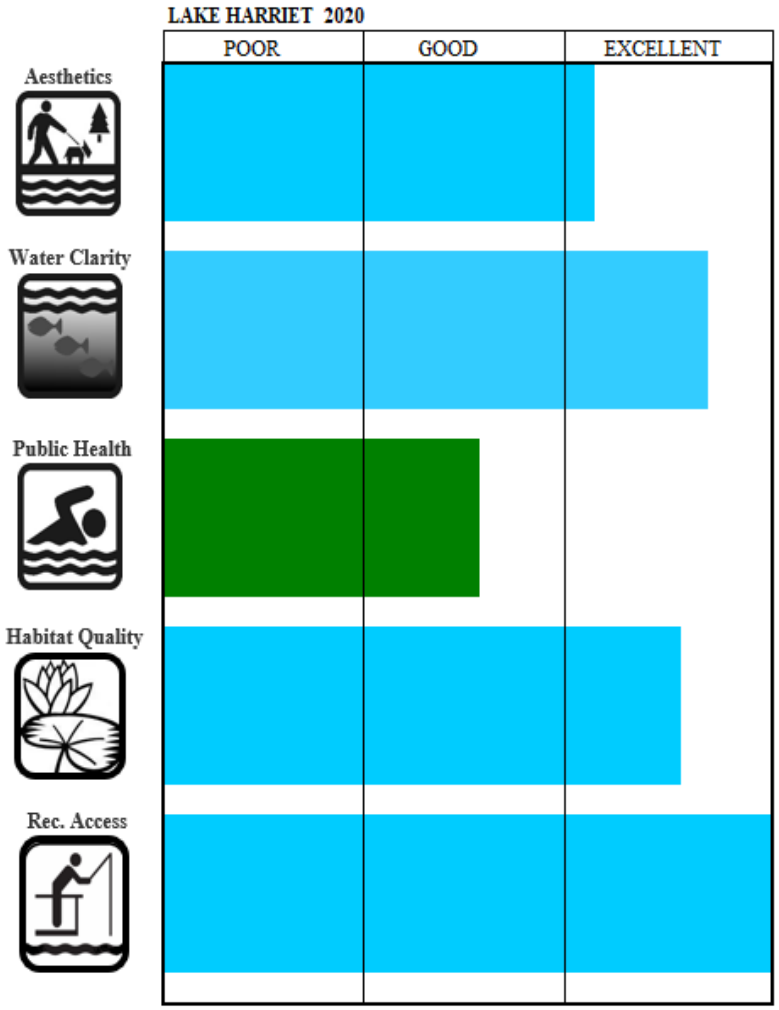


Figure 8-8. The 2020 LAURI for Lake Harriet.

WINTER ICE COVER

Ice came off on Lake Harriet March 29, 2020, six days earlier than the average ice-off date. Ice completely covered Lake Harriet for the season in December 28, 2020, 15 days later 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 2020 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 20**.

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 8-9** shows the water clarity, chlorophyll-*a* concentrations, and relative abundance of phytoplankton divisions during 2020. 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 mid-May at 7.2 meters when chlorophyll-*a* concentrations were low and shallowest in late August at 2.8 meters, see **Figure 8-9a**. Chlorophyll-*a* concentrations were highest in winter at 19.3 µg/L when the phytoplankton community primarily consisted of blue-green algae (Cyanophyta) and were lowest in late May at 1.2 µg/L, see **Figure 8-9b, c**. Concentrations of chlorophyll-*a* remained below 5 µg/L for most of the season until fall when concentrations increased to 9.29 µg/L when the phytoplankton community primarily consisted of diatoms (Bacillariophyta).

The phytoplankton community primarily consisted of blue-green algae in 2020 except for in mid-May and fall when cryptomonads (Cryptophyta) and diatoms dominated the population. The remainder of the phytoplankton community in Lake Harriet was a mix of green algae (Chlorophyta), chrysophytes (Chrysophyta), haptophytes (Haptophyta), and dinoflagellates (Pyrrhophyta), see **Figure 8-9c**.

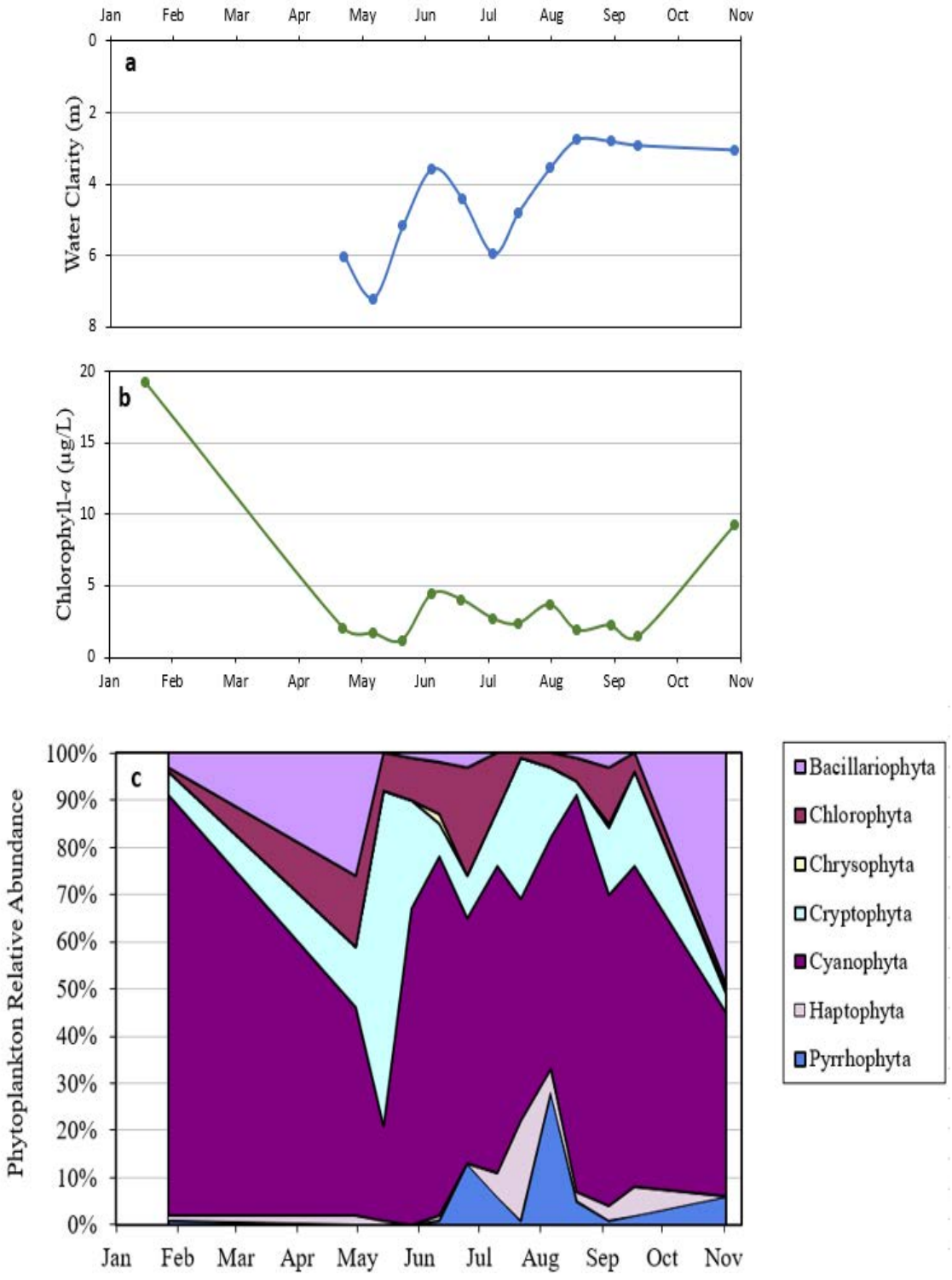


Figure 8-9. Water clarity (a), chlorophyll-*a* concentration (b), and relative abundance of phytoplankton (c) in Lake Harriet during 2020. Note that the water clarity axis is reversed.

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 8-10** shows the zooplankton distribution in Lake Harriet sampled throughout 2020. Rotifers, nauplii and juvenile copepods, and cladocerans were present in all samples and were most abundant in April and May. Calanoids, cyclopoids, and protozoa were also present in low levels in 2020.

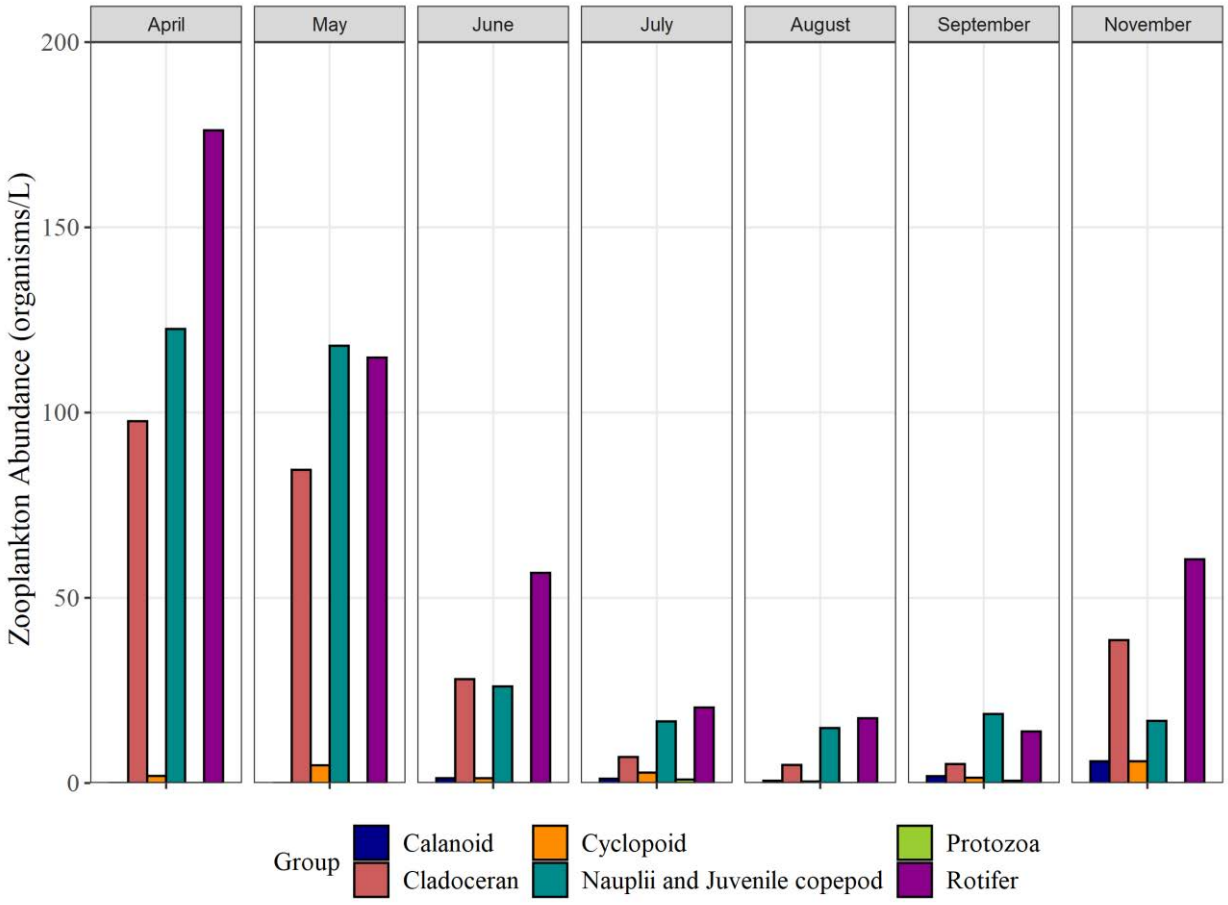


Figure 8-10. Zooplankton density in Lake Harriet during 2020.

EVENTS REPORT

On May 14, 2020, a MPRB Watercraft Inspector reported seven dead fish at the Lake Harriet boat launch and took photos. Water Quality staff reviewed the photos and identified the fish as sunfish. 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 that oxygen levels in the lake were high and oxygen depletion was not the cause of mortality. The surface water temperature

was 55 degrees Fahrenheit during the fish kill event and too cold for spawning to occur. Handling of the fish is the likely cause of the spread of *Columnaris* during the fish kill, as handling causes stress and fish are impacted by *Columnaris* when they are in a weakened state. See the fish kill section in **Chapter 1** for additional details.

FISH STOCKING

In 2020, 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
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
2012	Muskellunge	175 fingerlings	35.0 pounds
2012	Walleye	2,520 yearlings	120.0 pounds
2011	Walleye	3,244 fingerlings	115.9 pounds

TOC

9. LAKE HIAWATHA

HISTORY

Lake Hiawatha was acquired by the Minneapolis Park & Recreation Board (MPRB) in 1922. At that time, the lake was a shallow 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 health 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 July 2020.

Table 9-1 shows the physical characteristics of Lake Hiawatha and **Figure 9-2** shows the bathymetric map. Lake Hiawatha has an extremely large watershed due its connection with Minnehaha Creek. In addition to the creek, there are also seven stormwater outfalls surrounding the lake, see **Appendix C**. The watershed of the lake includes 115,840 acres. An immense volume of runoff from the very large watershed the reduces the residence time of the 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 which have residence times of up to four years. The short amount of time the water spends in the lake 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 2002, 2007 and 2009, residence time increased and algae growth was high.

The volume of water flowing to the lake has other repercussions for Lake Hiawatha. The large amount of runoff from the surrounding watershed accounts for approximately 88% of the phosphorus input to the lake. 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.

Lake Hiawatha water quality has been monitored annually since 1992. In 2013, zebra mussels (*Dreissena polymorpha*) were discovered on a sampling plate in the lake. Zebra mussels had been expected to arrive in Lake Hiawatha within a few years after their discovery in Lake Minnetonka, due to its direct connection with Minnehaha Creek. Since the establishment of zebra mussels in Lake Hiawatha water clarity is relatively higher, while chlorophyll-a concentrations are relatively lower. Fish populations, specifically northern pike and carp, remain abundant and continue to move between Minnehaha Creek and Lake Hiawatha. Colonies of bryozoans, forming gelatinous balls of various sizes, are also commonly found in Lake Hiawatha in late summer months.

Table 9-1. Lake Hiawatha physical characteristics.

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.**

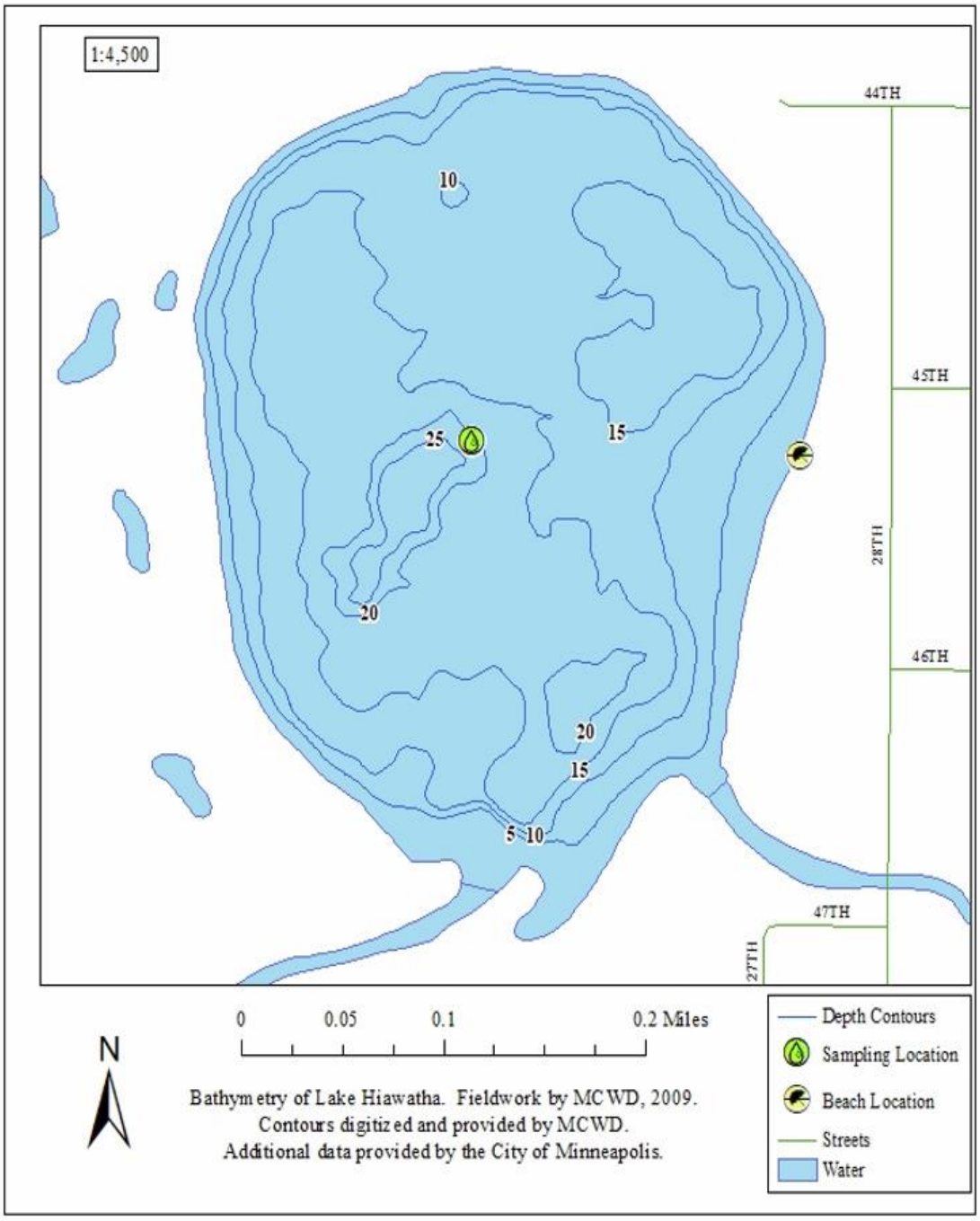


Figure 9-2. Bathymetric map and sampling location at Lake Hiawatha.

LAKE LEVEL

The lake levels for Lake Hiawatha are shown in **Figure 9-3**. Up to five feet of water level variation can be seen in Lake Hiawatha due to the influence of Minnehaha Creek and the dam at Gray's Bay in 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 fluctuated above and below the OHWL in 2020, freezing below the OHWL in December.

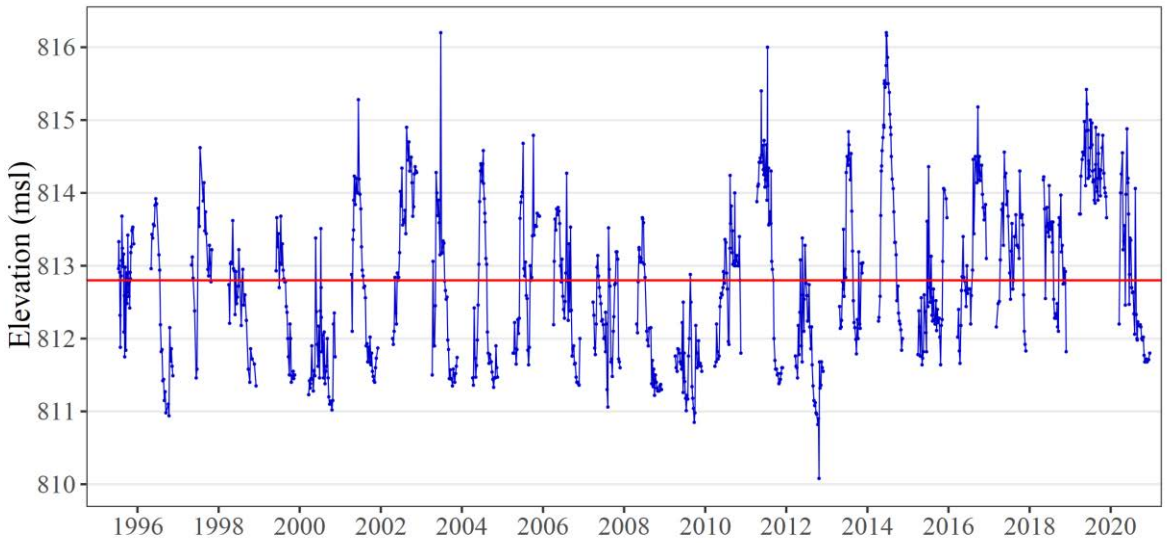


Figure 9-3. Lake levels for Lake Hiawatha from 1995-2020. Horizontal line represents the Ordinary High Water elevation (812.8 ft msl) for Lake Hiawatha.

WATER QUALITY TRENDS – TROPHIC STATE INDEX (TSI)

Figure 9-4 shows historical Lake Hiawatha TSI scores and trend line. There has been a decrease in TSI scores from 1992-2020, but there is no significant trend ($p > 0.05$). The high p-value indicates there is weak evidence that the TSI score is decreasing over time, but the lack of significant trend means the lake is neither improving or 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, and 2012 coincide with drought years where Minnehaha Creek was dry for at least a portion of the summer. The high flow from Minnehaha Creek over the last few years may be contributing to the lower TSI scores. The TSI score for Lake Hiawatha in 2020 was 58. The lake is currently eutrophic with an anoxic hypolimnion and possible macrophyte problems.

Chlorophyll-*a* and total phosphorus TSI scores for Lake Hiawatha are within the expected TSI range for lakes in the same ecoregion, see **Table 9-2**. The Secchi TSI score is above the TSI range for the ecoregion, meaning water clarity in Lake Hiawatha is shallower than in comparable lakes. See Minneapolis Pollution Control Agency (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**.

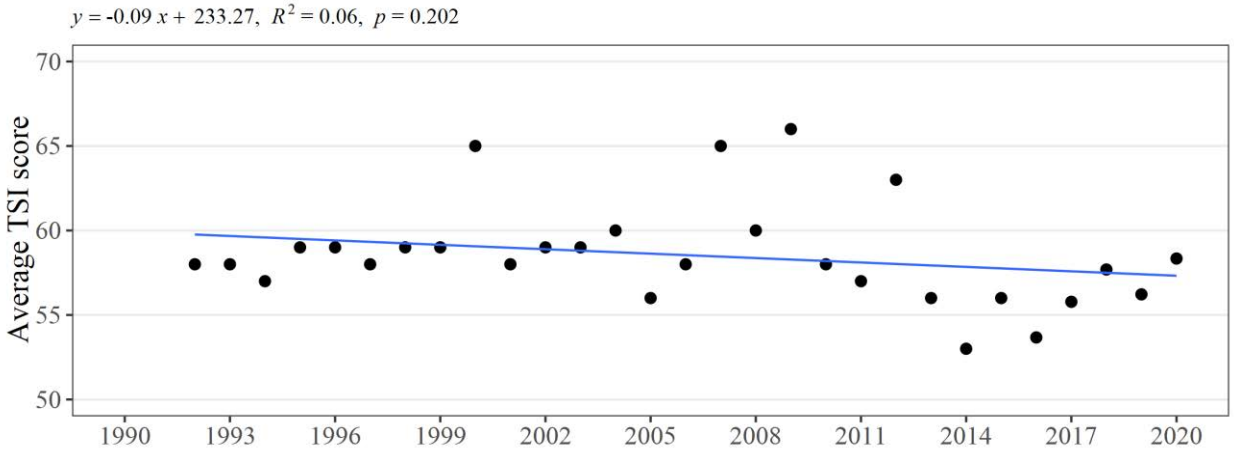


Figure 9-4. Lake Hiawatha TSI scores and liner regression from 1992-2020.

Table 9-2. Lake Hiawatha Secchi, chlorophyll-*a*, and total phosphorus TSI based on data collected between June and September 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	58	43-54	Not within range, worse than expected
Chlorophyll-*a*	60	46-61	Within range
Total Phosphorus	60	49-61	Within range

BOX AND WHISKER PLOTS

The box and whisker plots in **Figure 9-5** 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 site-specific standards, which applies to data collected between June and September. The US EPA approved a new 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, 1992-2020, can be found in **Appendix A**.

Water clarity in 2020 was slightly worse than previous years with an average depth of 1.2 meters, see **Figure 9-5a**. Chlorophyll-*a* was higher for the lake in 2020 with an average concentration of 15.3 µg/L. Concentrations of chlorophyll-*a* also had greater variability throughout the sampling season, see **Figure 9-5b**. Total phosphorus levels for 2020 remained relatively consistent with previous years with an average concentration of 49 µg/L, see **Figure 9-5c**. Hiawatha met the site-specific standards for total phosphorus in 2020 but did not meet the standards for water clarity and chlorophyll-*a*.

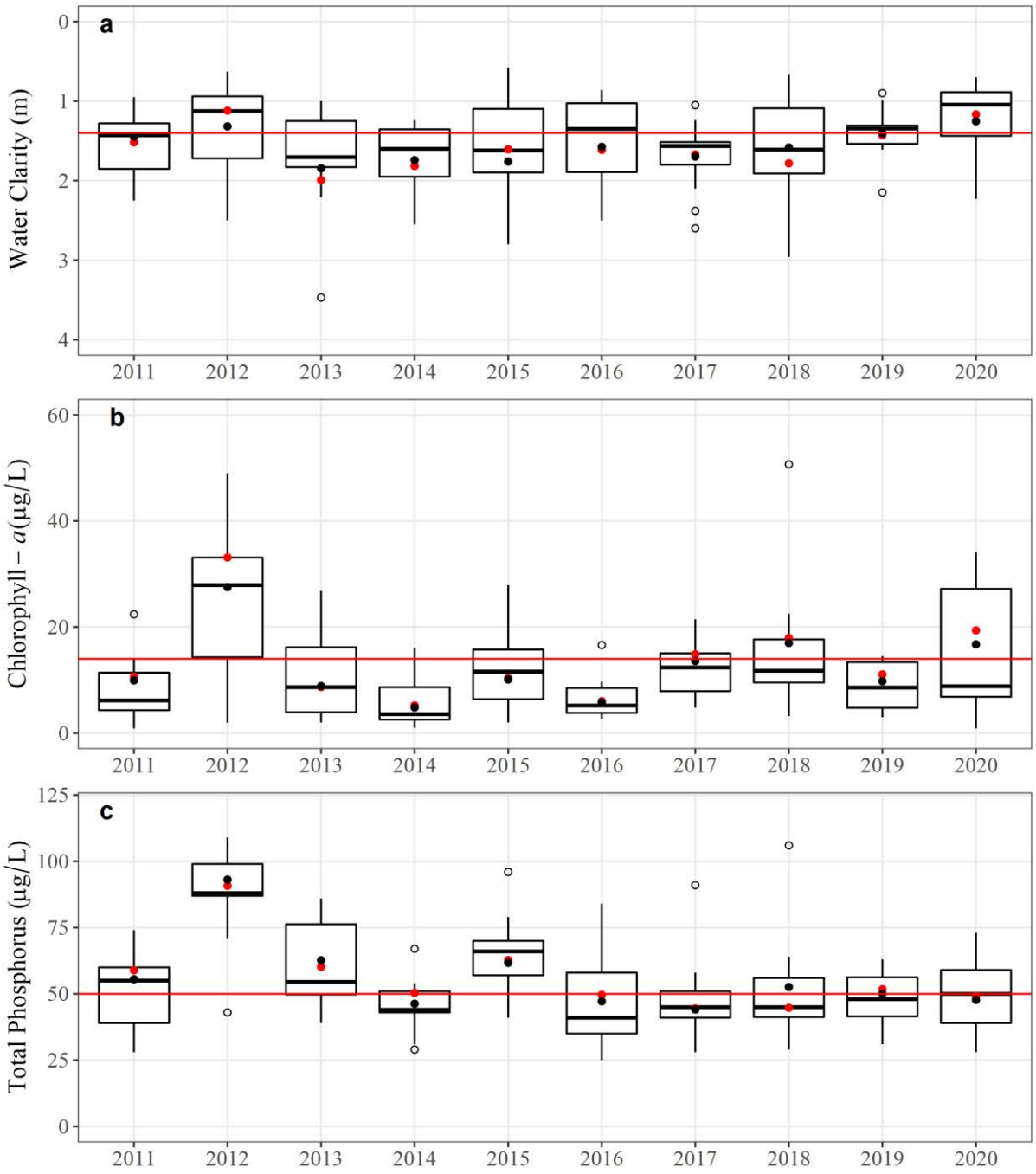


Figure 9-5. Lake Hiawatha box and whisker plots of water clarity (a), chlorophyll-*a* (b), and total phosphorus (c) from 2011-2020. Horizontal lines represent Lake Hiawatha site-specific eutrophication standards, which applies to data collected between June and September. The red circles represent the 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 1992-2020 can be found in Appendix A.

BEACH MONITORING

Bacteria levels, shown in **Table 9-3** and **Figure 9-6**, were monitored weekly from June through August at Hiawatha Beach in 2020. *Escherichia coli* (*E. coli*) levels at the beach were low at the beginning of the sampling season, and increased in late June and early July. Bacteria levels remained low the rest of July, significantly increased in early August, and decreased again in mid-August. Hiawatha Beach first closed on July 7th due to exceedance of the 30-day geomean standard of 126 MPN/100mL and reopened on August 4th when *E. coli* levels dropped below the 30-day geomean standard. The beach also closed on August 11th due to exceedance of the single sample *E. coli* standard of 1,260 MPN/100mL and reopened August 13th when bacteria levels decreased below the single sample standard. Hiawatha Beach closed again on September 1st due to exceedance of the 30-day geomean and remained closed the rest of the sampling season. The beach closure in July and September can be attributed to waterfowl waste, while stormwater runoff and erosion most likely contributed to the single sample exceedance in mid-August.

As a result of an unusual early spring algae bloom on Minneapolis lakes in 2020, MPRB developed a blue-green algae index visual monitoring protocol. Visual indicators were noted as part of the protocol for the weekly beach sampling program. See **Chapter 18** for more information on beach and blue-green algae monitoring.

Table 9-3. Summary of *E. coli* (MPN per 100 mL) data for the Lake Hiawatha Beach in 2020.

Statistical Calculations	Hiawatha
Number of Samples	13
Minimum	22
Maximum	2420
Median	117
Mean	425
Geometric Mean	149
Max 30-Day Geo Mean	230
Standard Deviation	695

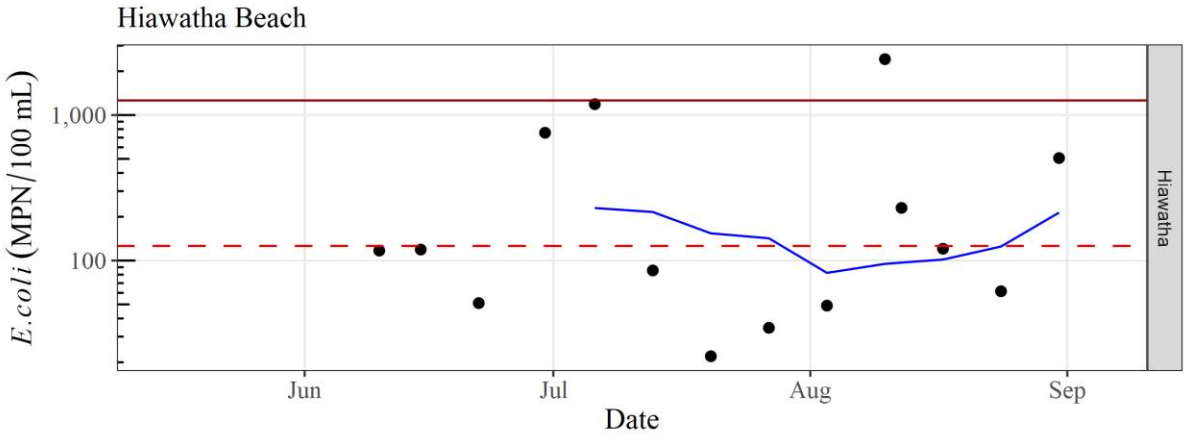


Figure 9-6. 2020 *E. coli* concentrations at Hiawatha Beach. Blue line is the running 30-day geometric mean. The dashed horizontal line represents the *E. coli* standard for the 30-day geometric mean (126 MPN/100mL) and the solid horizontal line represents the single-sample maximum standard (1260 MPN/100mL). Note the log scale on the Y-axis.

Figure 9-7 shows *E. coli* monitoring data for Hiawatha Beach from 2011 to 2020 which is graphed by using a box and whisker plot. The 2020 season had similar *E. coli* counts compared to previous years and some of the highest bacteria levels at any of the Minneapolis beaches. The highest bacteria levels occurred in early July and early August. 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 11 inlets around the lake likely increases bacteria concentrations in Lake Hiawatha.

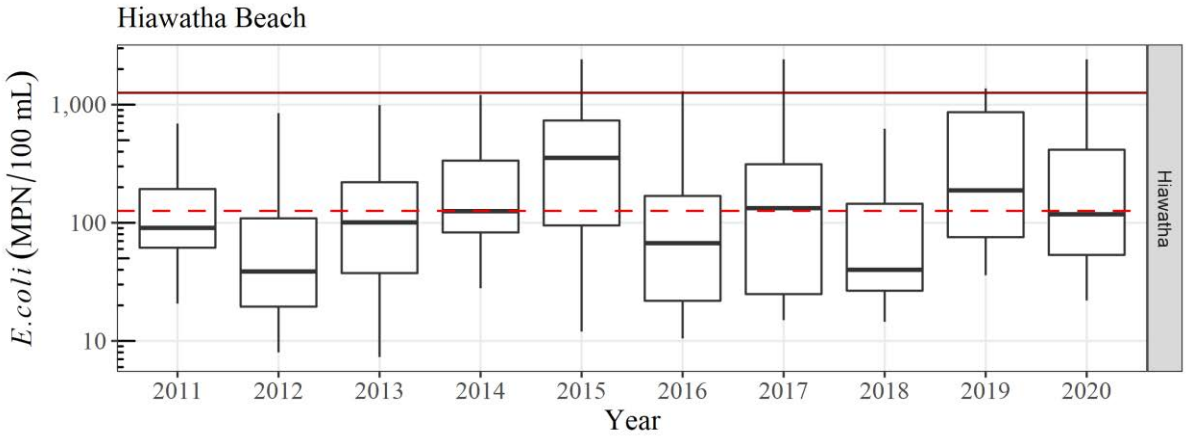


Figure 9-7. Box and whisker plots of *E. coli* concentrations (MPN/100 mL) for the Lake Hiawatha Beach from 2011 to 2020. Note the log scale on the Y-axis. The dashed horizontal line represents the *E. coli* standard for the 30-day geometric mean (126 MPN/100mL) and the solid horizontal line represents the single-sample maximum standard (1260 MPN/100mL).

LAKE AESTHETIC AND USER RECREATION INDEX (LAURI)

The LAURI for Lake Hiawatha is shown in **Figure 9-8**. In 2020, Lake Hiawatha scored good in aesthetics, water clarity, habitat quality, and recreational access but poor in public health. Lake Hiawatha had trash accumulation issues in 2020, but high water levels submerged the trash in spring, leading to a good score in aesthetics The lake collects trash flowing down Minnehaha Creek and from stormsewers, especially after large rainstorms. Details on the LAURI index can be found in **Chapter 1**.

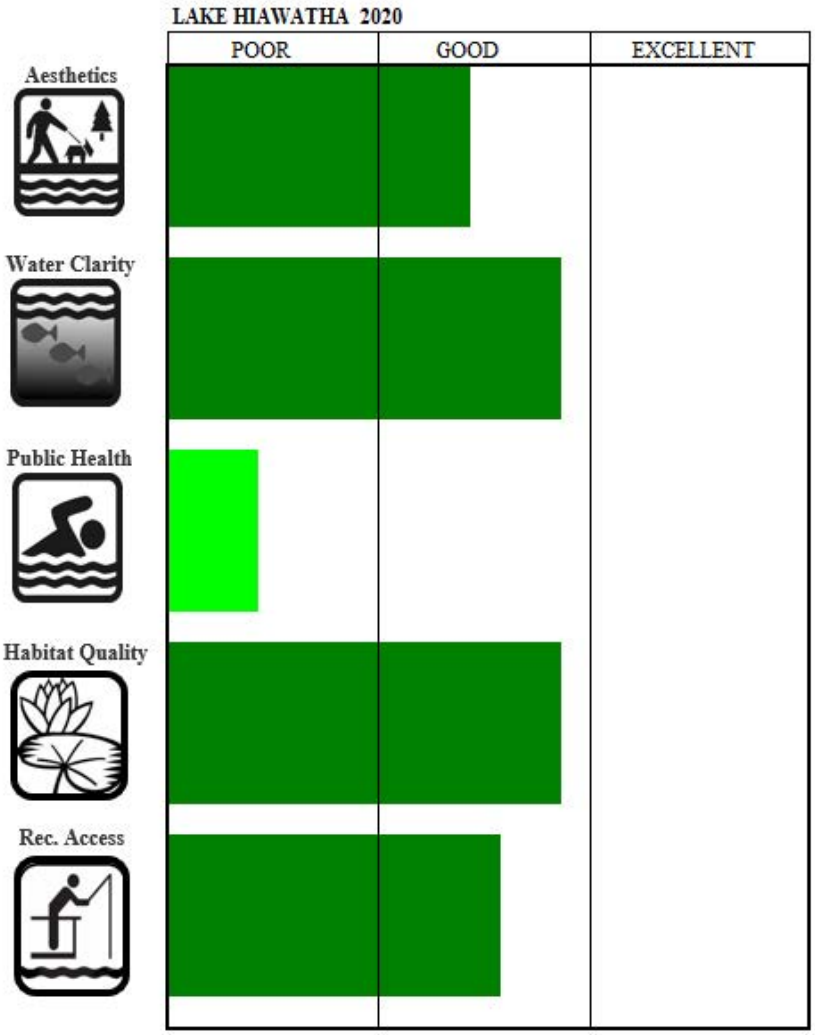


Figure 9-8. The 2020 LAURI for Lake Hiawatha.

WINTER ICE COVER

Ice came off Lake Hiawatha on March 28, 2020, seven days earlier than average. Ice returned to the lake for the winter on December 2, 2020, one day earlier than the average ice-on date. The flow from

Minnehaha Creek may result in 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 inlets. 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 9-9** shows the water clarity, chlorophyll-*a* concentrations, and relative abundance of phytoplankton divisions during 2020. 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 early May and increased in mid-May when water clarity reached its deepest reading at 2.2 meters, see **Figure 9-9a**. Water clarity gradually declined and reached its shallowest reading in late July at 0.7 meters and remained below 1.5 meters the remainder of the season. When chlorophyll-*a* concentrations were low the lake was clearer. Chlorophyll-*a* concentrations were lowest in mid-May at 0.9 µg/L when the phytoplankton community primarily consisted of diatoms (Bacillariophyta). Blue-green algae **(**Cyanophyta) dominated the phytoplankton population when chlorophyll-*a* concentrations were highest in late August at 34.1 µg/L, see **Figure 9-9b, c**.

The phytoplankton community primarily consisted of blue-green algae and cryptomonads (Cryptophyta) in 2020. Diatoms were also present in high percentages in the spring and fall. Green algae (Chlorophyta), chrysophytes (Chrysophyta), euglenoids (Euglenophyta), haptophytes (Haptophyta), and dinoflagellates (Pyrrhophyta) were present in low percentages in 2020, see **Figure 9-9c**.

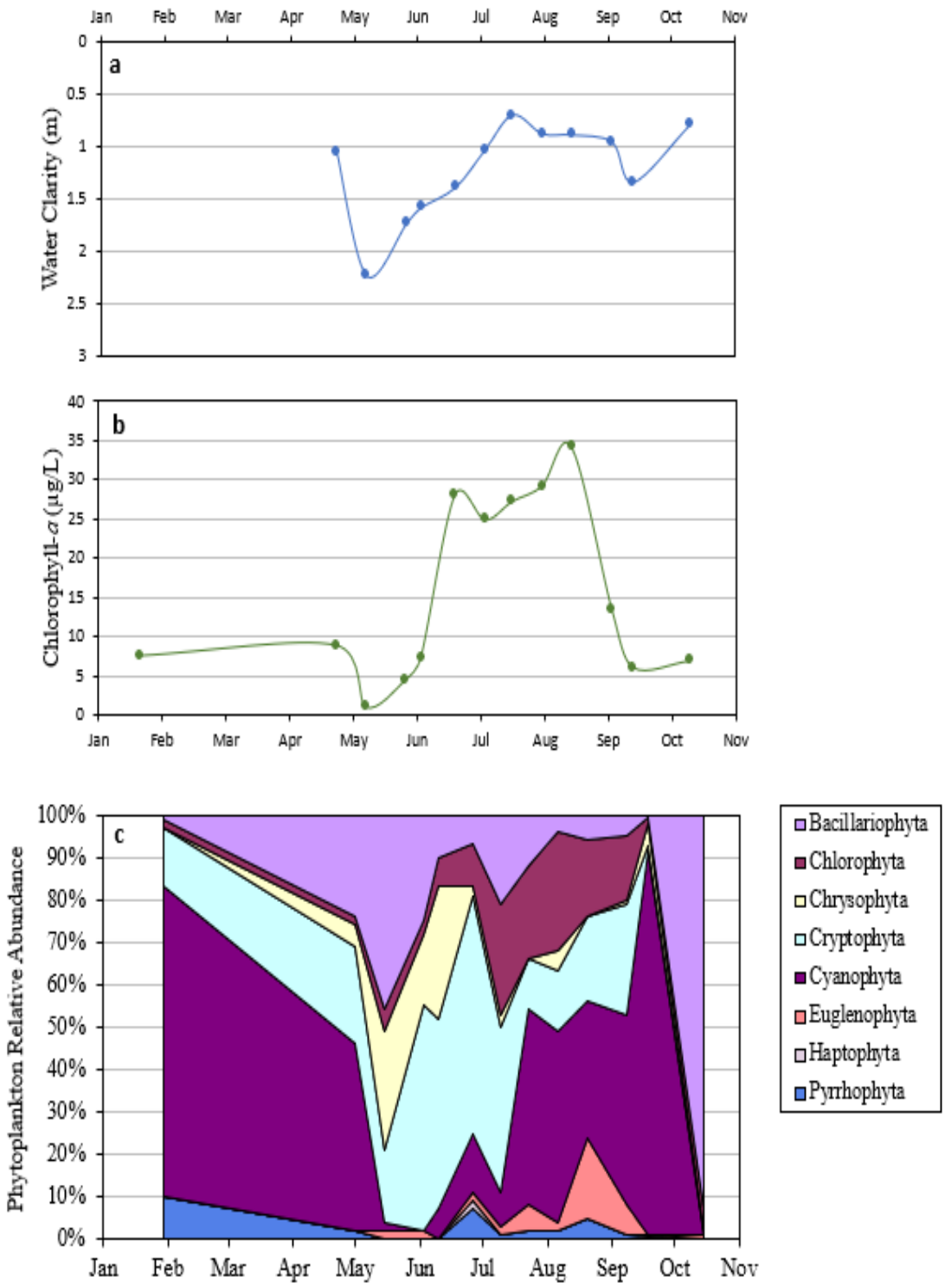


Figure 9-9. Water clarity (a), chlorophyll-*a* concentration (b), and relative abundance of phytoplankton (c) in Lake Hiawatha during 2020. Note that the water clarity axis is reversed.

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 9-10** shows the zooplankton distribution in Lake Hiawatha sampled throughout 2020. Rotifers were present in all samples and were most abundant in October. Cladocerans were present throughout the year and were most abundant in June and August. Nauplii and Juvenile copepods were also present in all samples and were most abundant in early May. Protozoa were present in higher concentrations in May and October. Calanoids, cyclopoids, and macroinvertebrates were present in low levels in 2020.

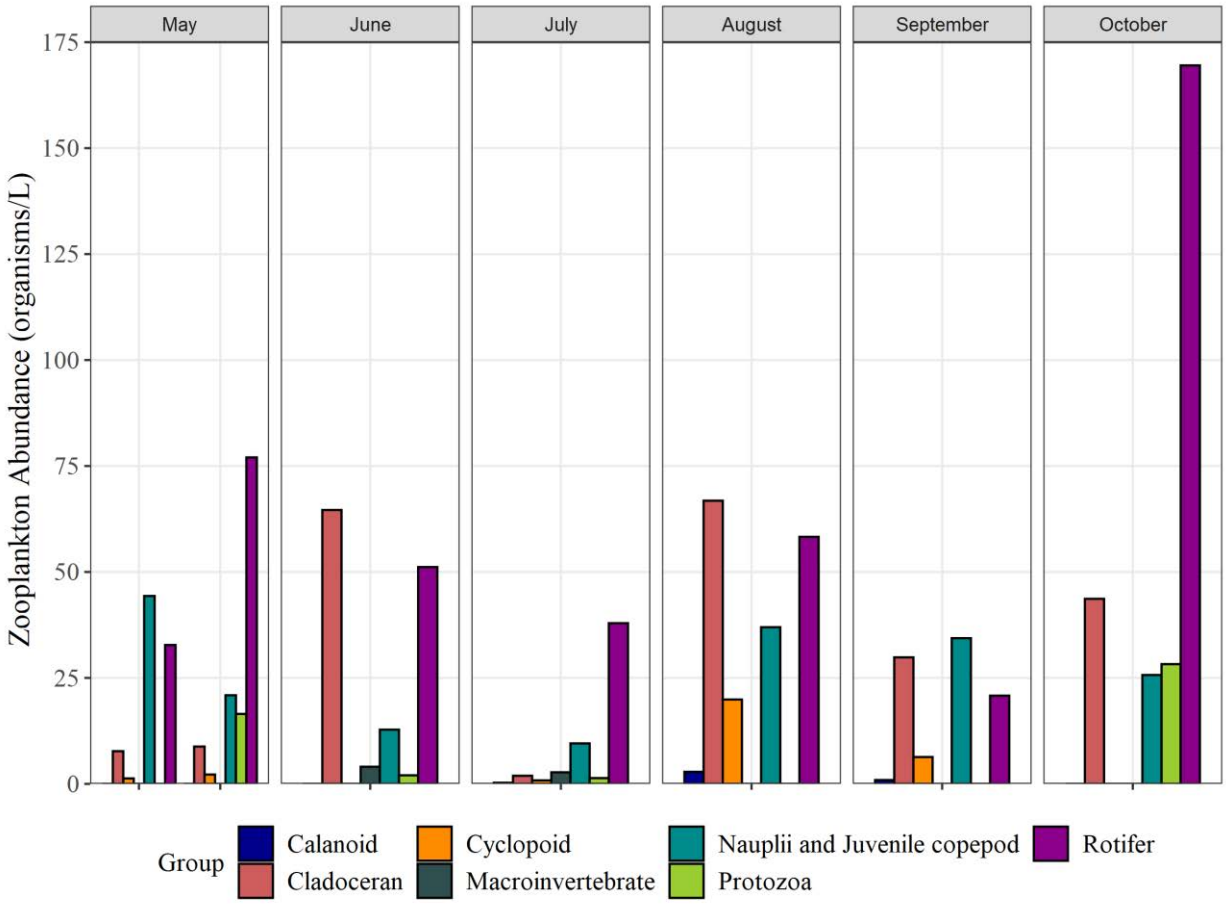


Figure 9-10. Zooplankton density in Lake Hiawatha during 2020.

EVENTS REPORT

Lake Hiawatha collects trash flowing down Minnehaha Creek and from stormsewers, especially after large rainstorms. Several projects have been implemented in recent years to remove trash from Lake Hiawatha. Sean Connaughty and 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 is not only weighed, but individual pieces of trash are 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 infrastructure was retrofitted in the city's stormwater system and several citizen level best management practices (BMPs) were recommended to mitigate trash upstream of Lake Hiawatha (Gordon et al., 2017). Trash removal is an ongoing project that will continue at Lake Hiawatha in the future to improve the water quality of the lake.

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

Year	Number of Sites	Number of Volunteers	Volunteer Hours	Trash (lbs)	Recyclables (lbs)	Metals (lbs)	Total (lbs)
2011	40	1,500					15,000
2012	40	1,500					>10,000
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				

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

TOC

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 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 summer.



Figure 10-1. Lake of the Isles in July 2020.

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 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. The shoreline at Lake of the Isles historically experienced erosion because the shoreline created by organic fill from dredging was unstable. The water level in the Chain of Lakes was decreased by six inches in 1935 in an attempt 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 again 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 of the wetlands outside of parkland were fully filled in for housing development and there were no wetlands 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 including the installation of grit chambers and CDS units in 1994, 1997, and 1999 for stormwater sediment removal, constructed wetland detention ponds for further treatment of incoming stormwater, and a whole lake alum treatment 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.

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.**

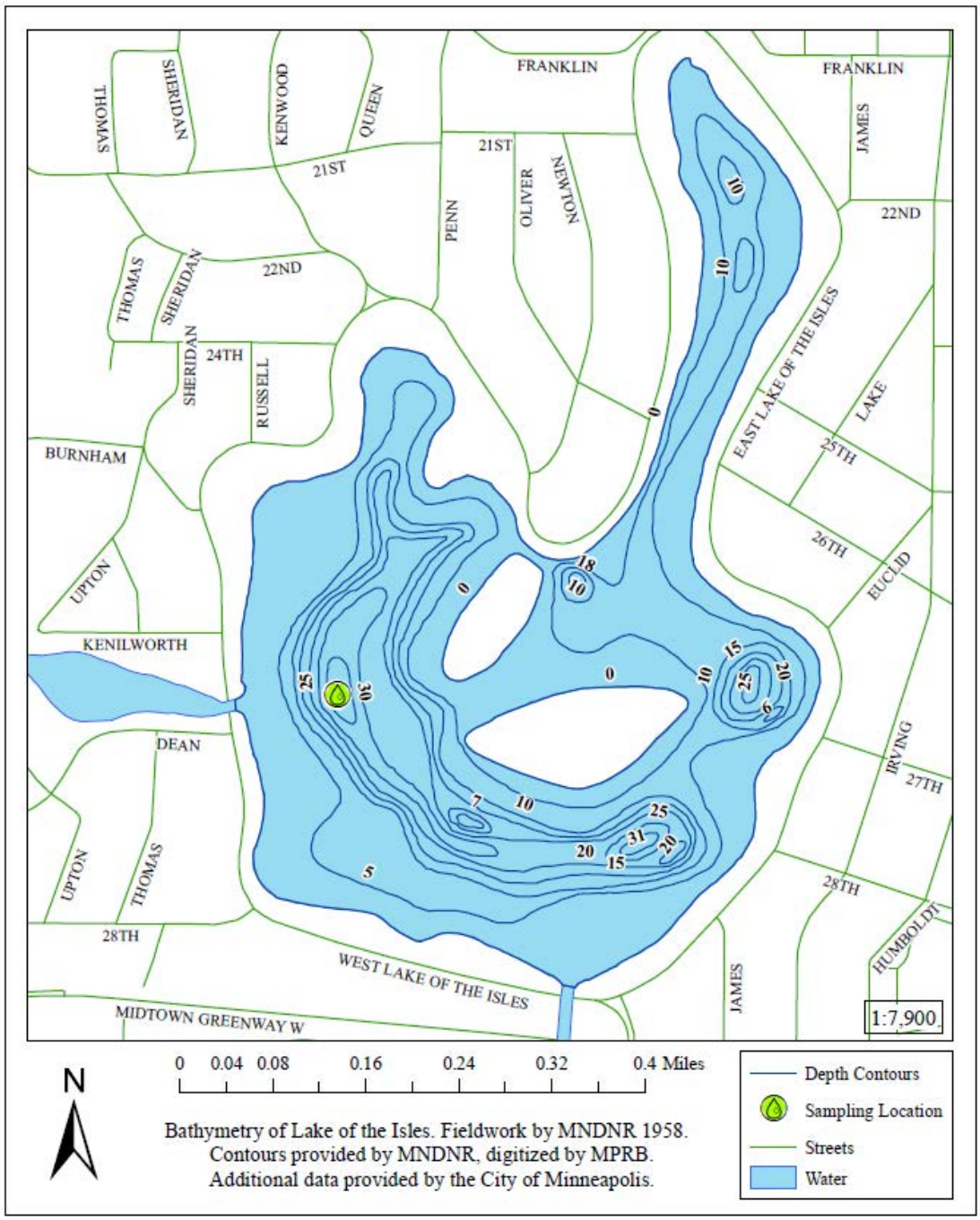


Figure 10-2. Bathymetric map and sampling location at Lake of the Isles.

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 a channel at 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 – 2020, 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 2020 was 59. The lake is currently eutrophic with an anoxic hypolimnion and macrophyte problems.

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. The TSI scores have fluctuated above and below the CWP goal ranging between 52 and 62.

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**. The Secchi TSI score is above the TSI range for the ecoregion, meaning the water clarity in Lake of the Isles is shallower than in comparable lakes. See Minneapolis 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**.

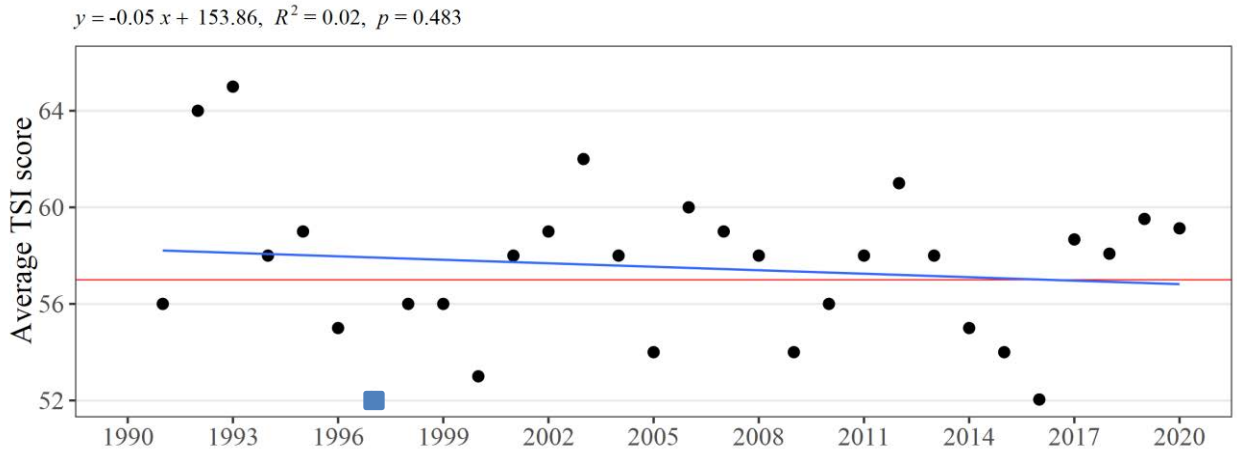


Figure 10-3. Lake of the Isles TSI scores and linear regression from 1991-2020. The red line represents the CWP long-term TSI goal of below 57. The blue square highlights the 1997 alum treatment.

Table 10-2. Lake of the Isles Secchi, chlorophyll-*a*, and total phosphorus TSI based on data collected between June and September 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	60	43-54	Not within range, worse than expected
Chlorophyll-*a*	61	46-61	Within range
Total Phosphorus	60	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 shallow lake standards, 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, 1991-2020, can be found in **Appendix A**.

Water clarity in 2020 was comparable to previous years with an average Secchi depth of 1.3 meters. There are two outliers observed in the water clarity data in 2020 occurring in late May and in the fall when the lake had deeper Secchi readings and lower chlorophyll-*a* concentrations, see **Figure 10-4a**. Chlorophyll-*a* was comparable to previous years with an average concentration of 18.6 µg/L in 2020, see **Figure 10-4b**. Total phosphorus levels were higher in 2020 compared to previous years with an average concentration of 56 µg/L, see **Figure 10-4c**. The lake met MPCA eutrophication standards for water clarity and total phosphorus but did not meet the standard for chlorophyll-*a* in 2020.

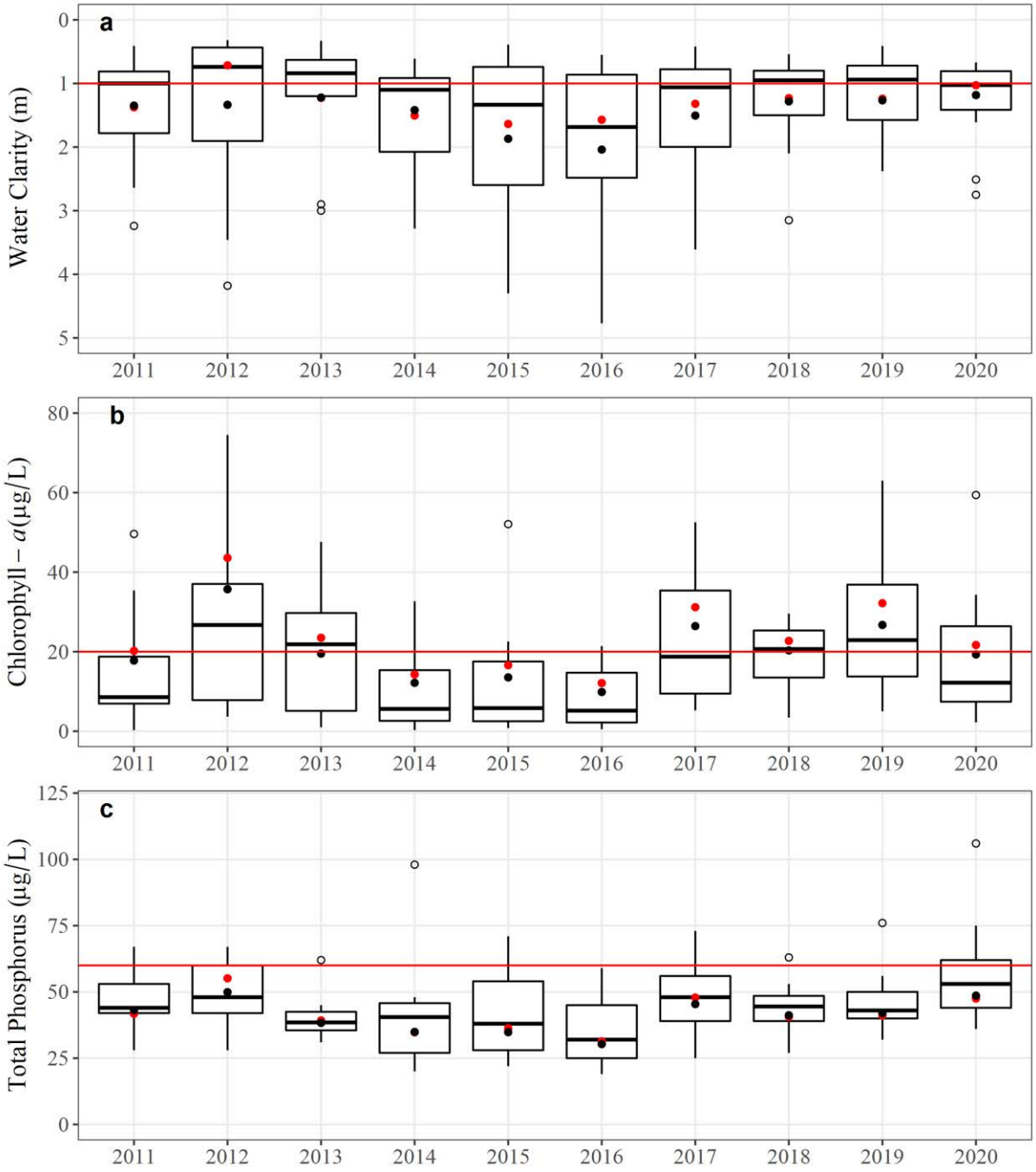


Figure 10-4. Lake of the Isles box and whisker plots of water clarity (a), chlorophyll-*a* (b), and total phosphorus (c) from 2011-2020. Horizontal lines represent MPCA eutrophication standard for shallow lakes, which applies to data collected between June and September. The red circles represent the 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 1991-2020 can be found in Appendix A.

LAKE AESTHETIC AND USER RECREATION INDEX (LAURI)

The LAURI for Lake of the Isles is shown in **Figure 10-5**. In 2020, Lake of the Isles scored excellent in aesthetics, habitat quality, and recreational access. The lake scored good in water clarity. An unusual early spring blue-green algae bloom decreased Secchi readings impacting the LAURI water clarity score. 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**.

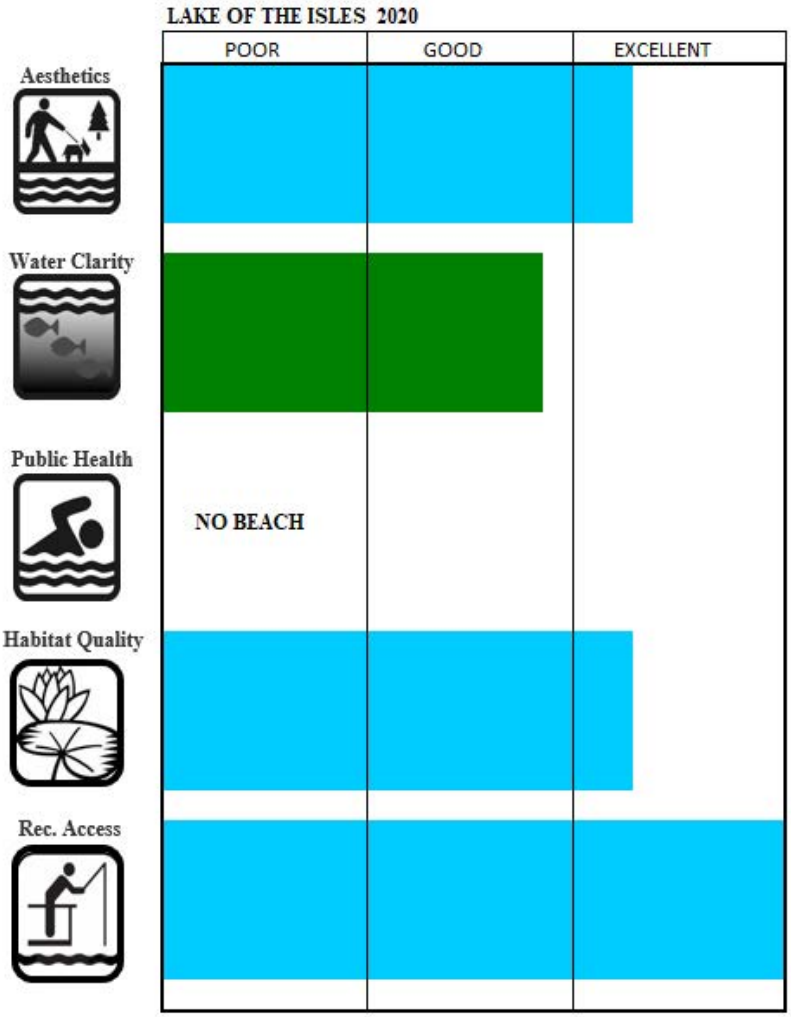


Figure 10-5. The LAURI for Lake of the Isles in 2020.

WINTER ICE COVER

Ice came off Lake of the Isles on March 28, 2020, which is eight days earlier than the average ice-off. Ice fully covered the lake on December 15, 2020, which is 14 days later 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 permits limit 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 2020 was 36 acres which is just over 39% of the littoral zone, the area shallower than 15 feet. See **Chapter 1** and **Chapter 20** 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 10-6** shows the water clarity, chlorophyll-*a* concentrations, and relative abundance of phytoplankton divisions during 2020. 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 remained shallower than 1.5 meters throughout most of the sampling season with the shallowest Secchi reading of 0.7 meters in early spring, see **Figure 10-6a**. Secchi readings increased in late May and again in fall when water clarity reached its deepest reading at 2.8 meters. Chlorophyll-*a* concentrations were highest in late July at 59.4 µg/L when the phytoplankton community primarily consisted of blue-green algae (Cyanophyta). Concentrations of chlorophyll-*a* were lowest in mid-September at 2.24 µg/L, see **Figure 10-6b**.

The phytoplankton community primarily consisted of blue-green algae in winter, spring, and between July and September in 2020, see **Figure 10-6c**. Other phytoplankton that were present in high percentages include Chrysophytes (Chrysophyta) in late May, dinoflagellates (Pyrrhophyta) in June, and cryptomonads (Cryptophyta) in fall. Diatoms (Bacillariophyta), green algae (Chlorophyta), euglenoids (Euglenophyta), and haptophytes (Haptophyta) were also present in low percentages.

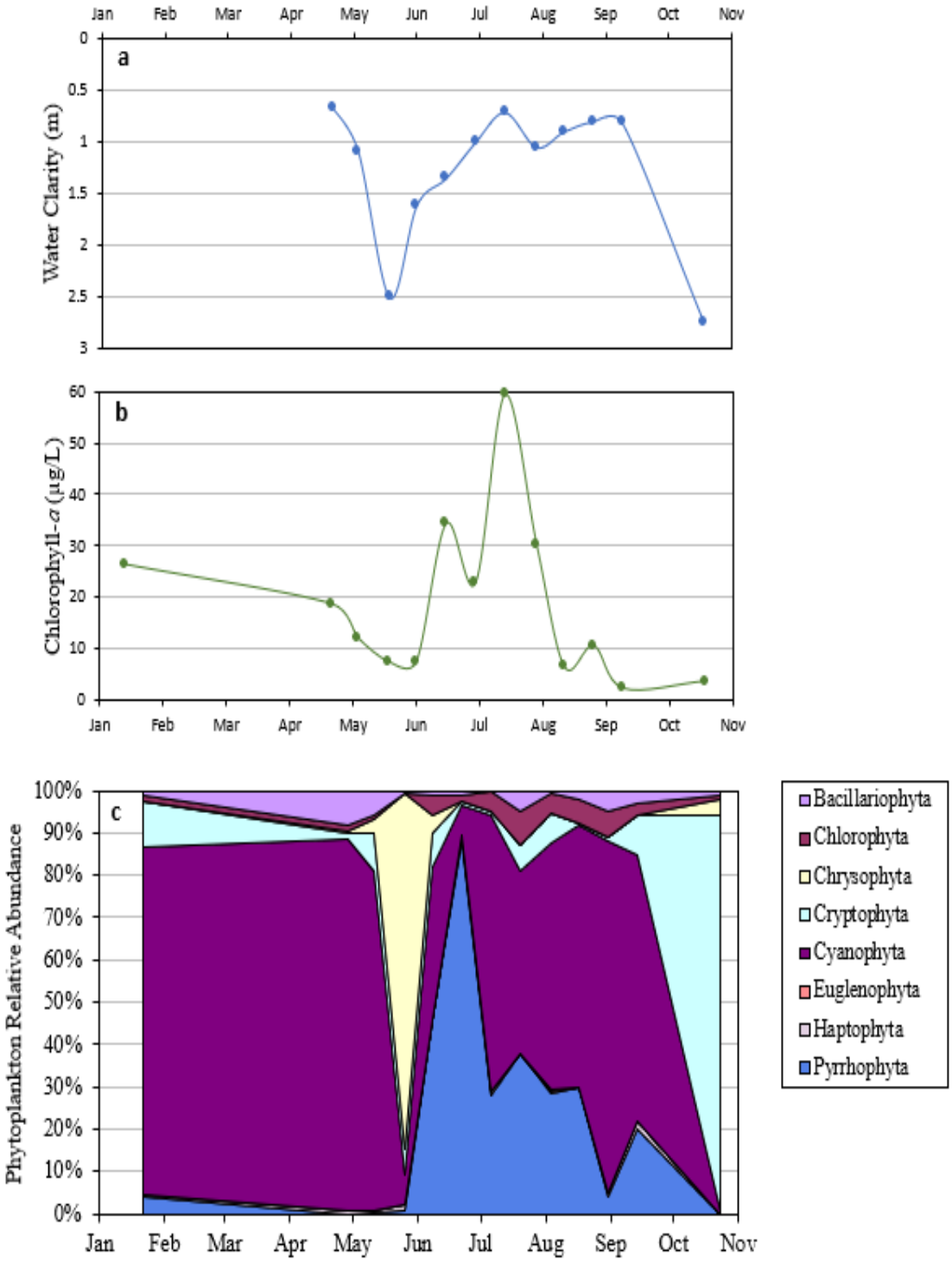


Figure 10-6. Water clarity (a), chlorophyll-*a* concentration (b), and relative abundance of phytoplankton (c) in Lake of the Isles during 2020. Note that the water clarity axis is reversed.

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 10-7** shows the zooplankton distribution in Lake of the Isles sampled throughout 2020. Cladocerans were present throughout the entire sampling season and were most abundant in May and October Rotifers and nauplii and juvenile copepods were also present throughout 2020 and were most abundant in May. Calanoid, cyclopoids, and protozoa were also present in low levels.

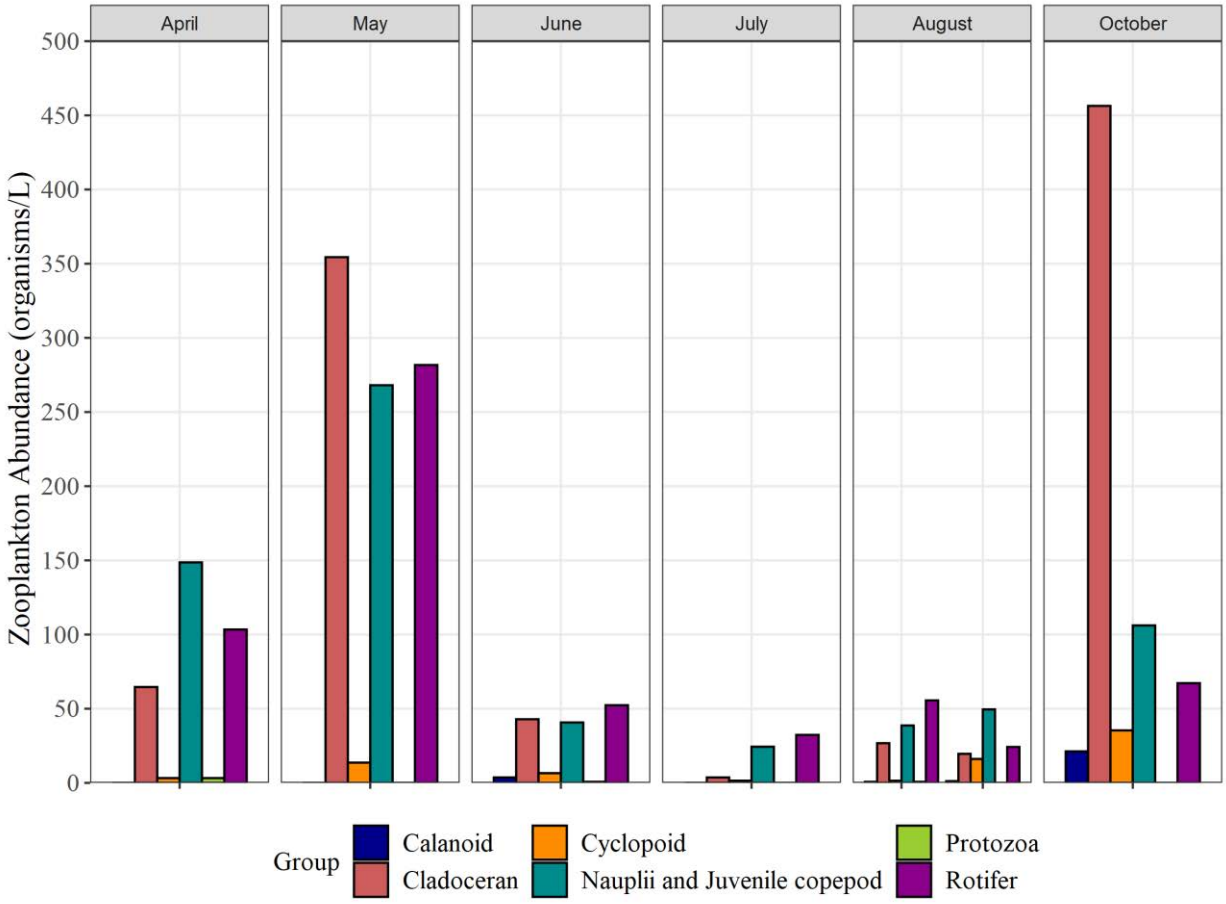


Figure 10-7. Zooplankton density in Lake of the Isles during 2020.

EVENTS REPORT

Algae Bloom

Most blue-green algae blooms occur during the hottest part of summer, but in 2020 an unusual early spring bloom of blue-green algae occurred on Lake of the Isles. Algae are microscopic organisms that use the sun to make food. When algae grow very fast, it creates "blooms". A certain type of algae called blue-green algae can make toxins that can make people or animals sick if they are ingested.

Plankton samples MPRB collected during winter showed that the blue-green algae bloom at Lake of the Isles started under the ice. The species of algae found in the winter and spring samples that caused the bloom grow well in cold water, unlike most blue-green algae that prefer warmer temperatures. In a normal year, ice would melt off slowly and the algae would die off before it got a foothold in the lake. Rapid ice-out and cooler than average spring temperatures in 2020 led to conditions that allowed the algae to persist into spring.

Lake of the Isles had murky brown water and very low water clarity as a result of the bloom. Live samples of the algae were collected at the canoe launch sites on the north and south sides of the lake and were analyzed by MPRB's contract lab to confirm the species and identify whether it had the capability of producing toxins.

MPRB made the decision to post a warning at Lake of the Isles because the bloom was persisting into the warmer weather season and people had begun to recreate in the water. As spring temperatures increased the potential that people would be exposed to a blue-green algal bloom increased as well with the higher amount of recreation in the lake and park. MPRB also tested the water for the presence of common algae toxins, microcystin and anatoxin. There were no toxins detected in the samples. Because algae toxins are not distributed evenly throughout the lakes, and the bloom was thick and persistent, posting signage around the lake was warranted.

By early June, lake water had lost its brown color and water clarity increased in Lake of the Isles, and MPRB removed the warning signage. MPRB re-tested the canoe launch sites for the presence of algae toxin. No toxin was detected at Lake of the Isles.

Fish Kill

On May 5, 2020, a citizen reported 12 dead fish along the east and south shoreline of Lake of the Isles. MPRB staff confirmed the fish kill finding five dead fish identified as carp. An Incident Report was completed describing the fish kill event. Water quality data showed that oxygen levels in the lake were high and oxygen depletion was not the cause of the fish kill.

A Graduate Assistant at University of Minnesota Aquatic Invasive Species Research Center (MAISRC) funded by Legislative-Citizen Commission on Minnesota Resources (LCCMR), gathered samples from the fish kill event and studied the gill tissues using quantitative polymerase chain reaction (qPCR). The study concluded that carp edema virus (CEV) was the cause of mortality. CEV is a double-stranded DNA virus that is likely spread by diseased fish shedding the virus from gill and skin lesions. The virus typically occurs in the spring when water temperatures are between 43-50 degrees Fahrenheit and the surface water temperature at Lake of the Isles during the fish kill was 52 degrees Fahrenheit. See the fish kill section in **Chapter 1** for additional details.

TOC

11. LORING POND

HISTORY

Loring Park was acquired in 1883 as the Central Park of Minneapolis. Loring Pond was named in 1890 in honor of Charles M. Loring the first president of the Board of Park Commissioners and is known as the Father of the Minneapolis Park System. The pond's current configuration 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 in order to create a bay that would hold open water. **Figure 11-1** shows a photo of Loring Pond.



Figure 11-1. Duckweed on Loring Pond in July 2020.

Loring Pond is a shallow system with an average depth of about five feet. **Table 11-1** shows the physical characteristics of Loring Pond. **Figure 11-2** is a map of the pond showing estimated bathymetry. Loring Pond is withing 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. The lake has a negative water balance; the lake loses more water than it receives. A groundwater augmentation well is used 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 in Loring Pond, see **Appendix C**.

Water quality on Loring Pond has been monitored annually since 1992 but was not sampled in 1997. 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 lake bottom was sealed, lined, and 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 northern and southern 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. See Water Quality Projects for more details on the work associated with the latest cattail removal and vegetation restoration project.

Table 11-1. Loring Pond physical characteristics.

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%	$1.72x10^6$	24	3.0

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

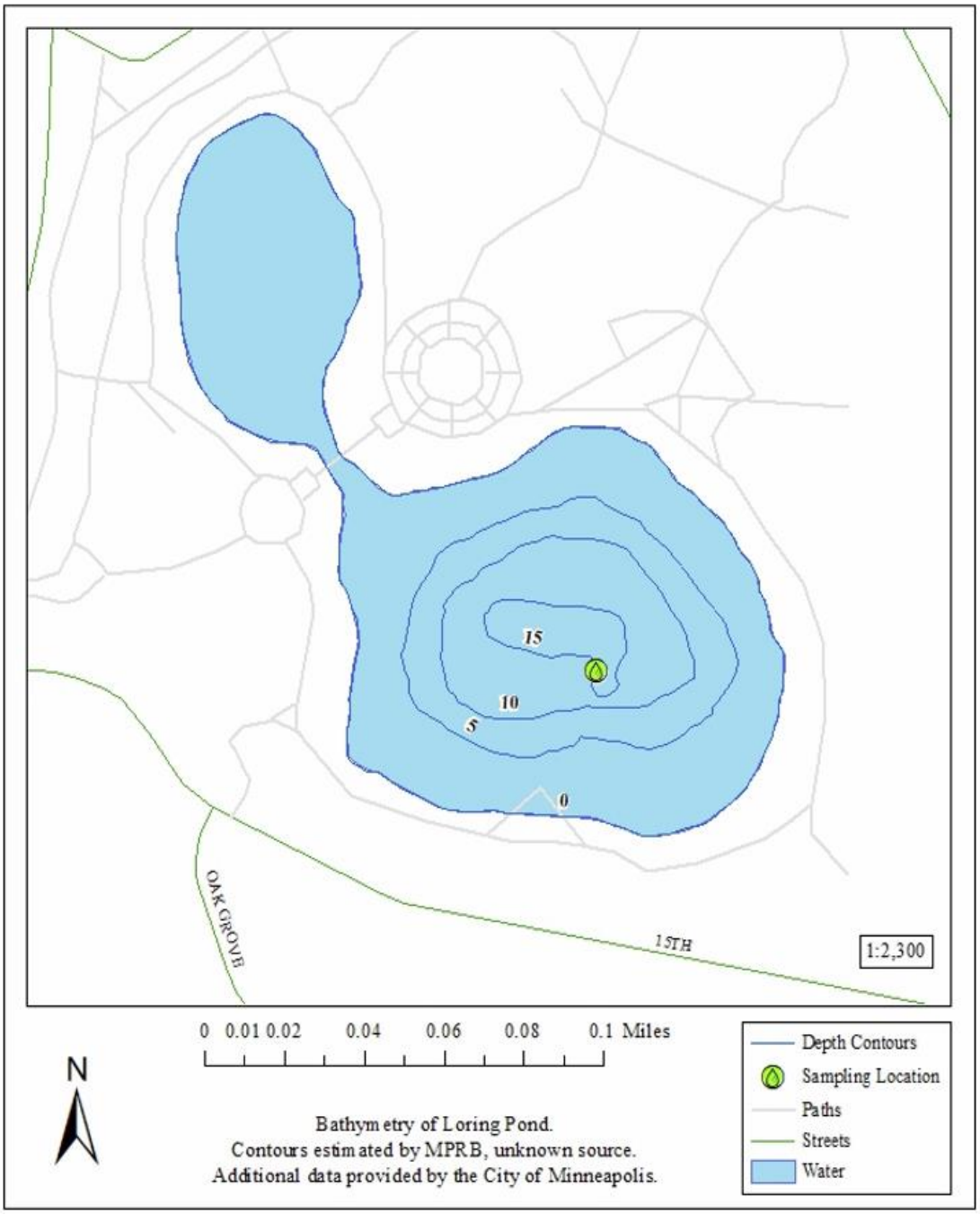


Figure 11-2. Map of Loring Pond showing approximate bathymetry contours and the sampling location.

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. It is believed that the groundwater level in the area is below the desired lake level, and the lake loses water quickly in years with normal precipitation.

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. 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. See Water Quality Projects for more details.

The Ordinary High Water Level (OHWL), designated by the MNDNR, for Loring Pond is 818.0 feet above mean sea level (msl). Loring Pond remained above the OHWL for most of 2020, only going below the OHWL once during a period in July-August. Sustained high water levels in this lake can be attributed to added groundwater via the augmentation well. Loring Pond froze above the OHWL in December. See **Chapter 1** for details on lake level monitoring and **Chapter 17** for a comparison between other MPRB lake levels.

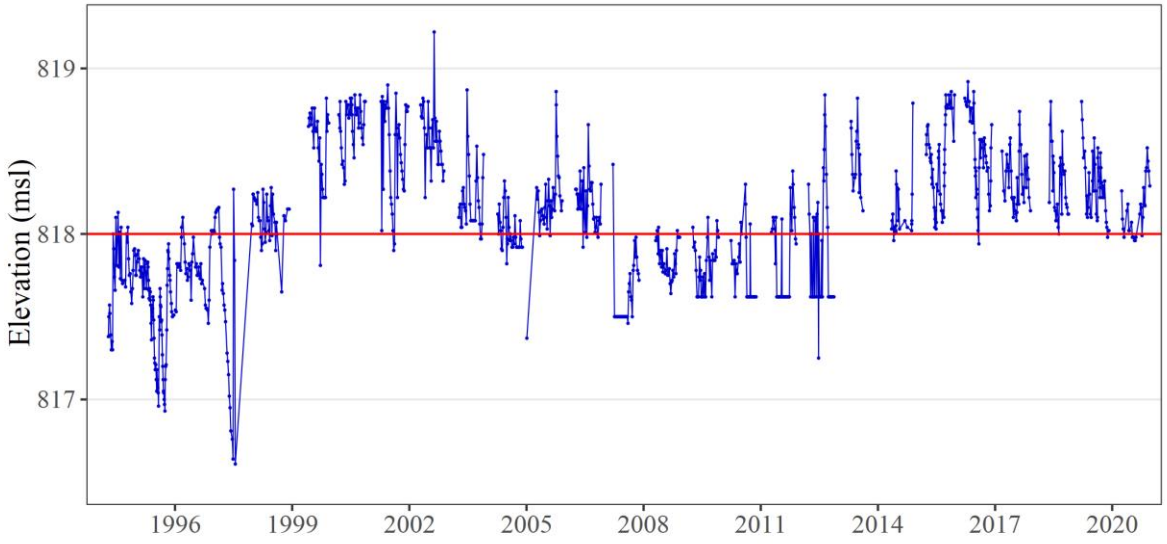


Figure 11-3. Lake levels for Loring Pond from 1995-2020. Water levels frequently dropped below the gage in the 2000s and water levels couldn't be accurately measured during that time. An auxiliary gage installed in 2013 is able be read at lower lake levels. Horizontal line represents the Ordinary High 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 issues the permits and determines pumping limits for augmentation wells. The MPRB har 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 for the temporary cattail removal project. In 2020, 10,670,160 gallons out of the 12 million permitted gallons were pumped into Loring Pond.

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

2016 Total	2017 Total	2018 Total	2019 Total	2020 Total
11,447,100 gal	5,310,240 gal	10,267,200 gal	1,959,600 gal	10,670,160 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 1992-2020 ($p > 0.05$). 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. Water levels were manipulated between 2013-2018 and in 2020. The water level was not manipulated in 2019 due to increased precipitation and a large amount of stormwater runoff entering Loring Pond. In 2016, a large amount of groundwater was pumped into the lake, which may have exchanged cleaner groundwater for more nutrient rich lake water leading to a better score. The TSI score for Loring Pond in 2020 was 68, classifying the pond as eutrophic.

Loring Pond is too small to be listed on MPCA's impaired waters list; however, 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 Minneapolis 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**.

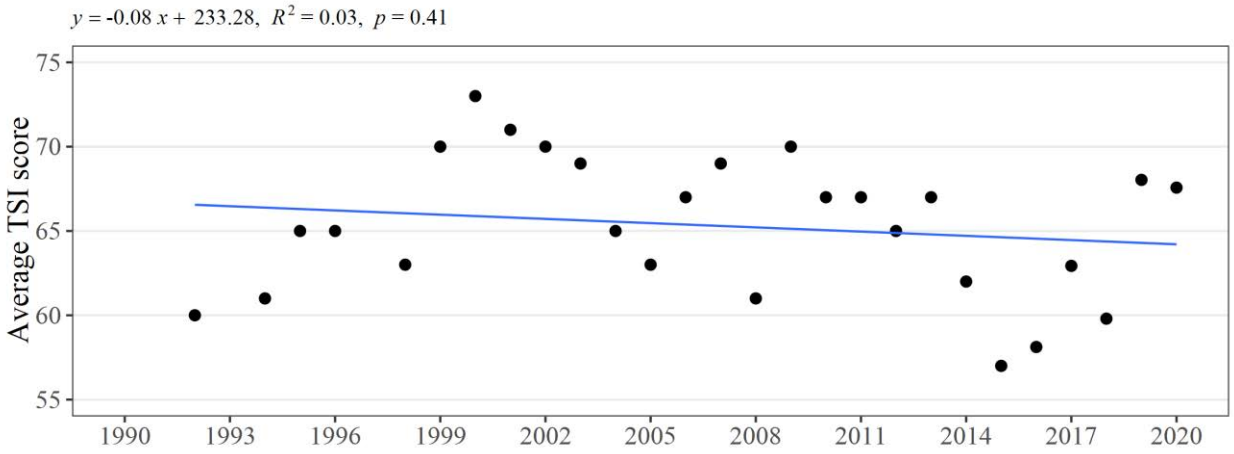


Figure 11-4. Loring Pond TSI data and linear regression from 1992 to 2020.

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 shallow lake standards, 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, 1992-2020, can be found in **Appendix A**.

The 303(d) assessment for impaired waters is limited to lakes of ten acres or greater (MPCA, 2014); therefore, Loring Pond is too small (7 acres) to be listed on MPCA's impaired waters list; however, it is still useful to compare Loring's data to the shallow lake standards to assess lake water quality. The water clarity was lower in 2020 compared to the previous years with an average of 0.8 meters, see **Figure 11-5a**. Chlorophyll-*a* was similar to 2019 and higher than prior years with an average concentration of 33 µg/L, see **Figure 11-5b**. Total phosphorus (TP) concentrations were comparable to previous years with an average of 116 µg/L, see **Figure 11-5c**. The pond is a small eutrophic lake and high productivity of plants and algae can be expected. Loring Pond is a small eutrophic lake and high productivity of plants and algae can be expected.

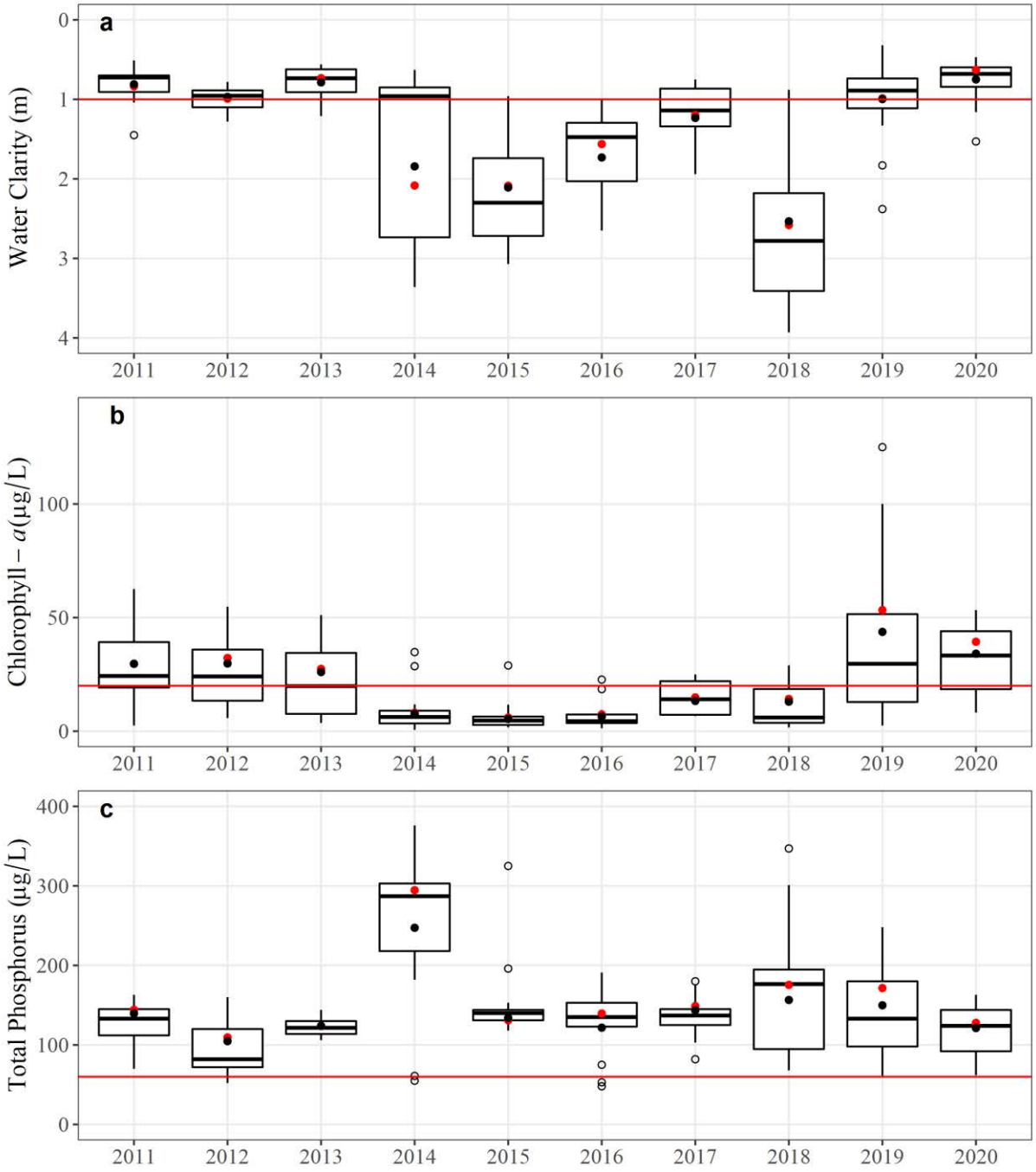


Figure 11-5. Loring Pond box and whisker plots of water clarity (a), chlorophyll-*a* (b), and total phosphorus (c) data from 2011-2020. Horizontal lines represent MPCA eutrophication standards for shallow lakes, which applies to data collected between June and September. The red circles represent the 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 1992-2020 can be found in Appendix A.

LAKE AESTHETIC AND USER RECREATION INDEX (LAURI)

The LAURI for Loring Pond is shown in **Figure 11-6**. In 2020, 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 potentially 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 index can be found in **Chapter 1**.

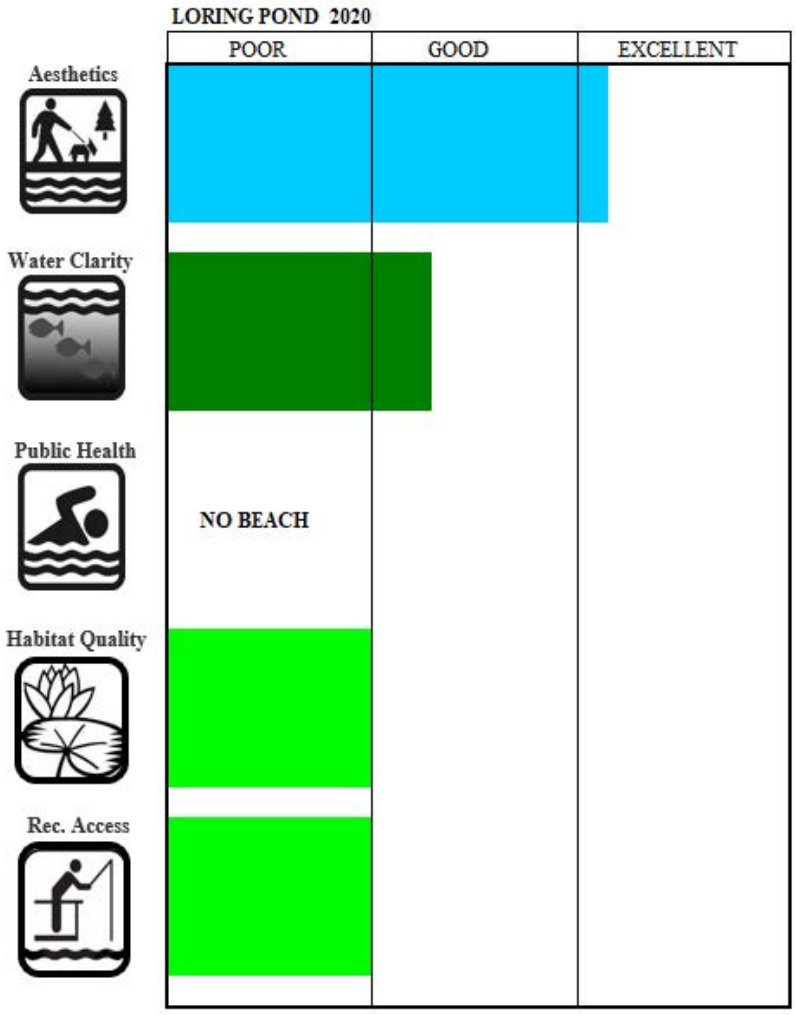


Figure 11-6. The 2020 LAURI for Loring Pond.

WINTER ICE COVER

Ice came off Loring Pond on March 25, 2020, eight days earlier than the average ice-off. Ice came on to the pond on December 1, 2020, which is 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 11-7** shows the water clarity, chlorophyll-*a* concentrations, and relative abundance of phytoplankton divisions during 2020. 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 in the spring and then remained between 0.5 and 1 meter for the remainder of the season, see **Figure 11-7a**. Water clarity was deepest in mid-May at 1.5 meters and shallowest in early September at 0.5 meters. When chlorophyll-*a* concentrations were low the lake was clearer. Chlorophyll-*a* concentrations were lowest in mid-May at 8.2 µg/L when the phytoplankton community primarily consisted of euglenoids (Euglenophyta). Dinoflagellates (Pyrrhophyta) dominated the phytoplankton population when chlorophyll-*a* concentrations were highest in late June at 53.3 µg/L, see **Figure 11-7b, c**.

The phytoplankton community in Loring Pond consisted of a mix of diatoms (Bacillariophyta), green algae (Chlorophyta), chrysophytes (Chrysophyta), euglenoids, and dinoflagellates. Cryptomonads (Cryptophyta), blue-green algae (Cyanophyta), haptophytes (Haptophyta), and yellow-green algae (Xanophyta) were also present in low percentages, see **Figure 11-7c**.

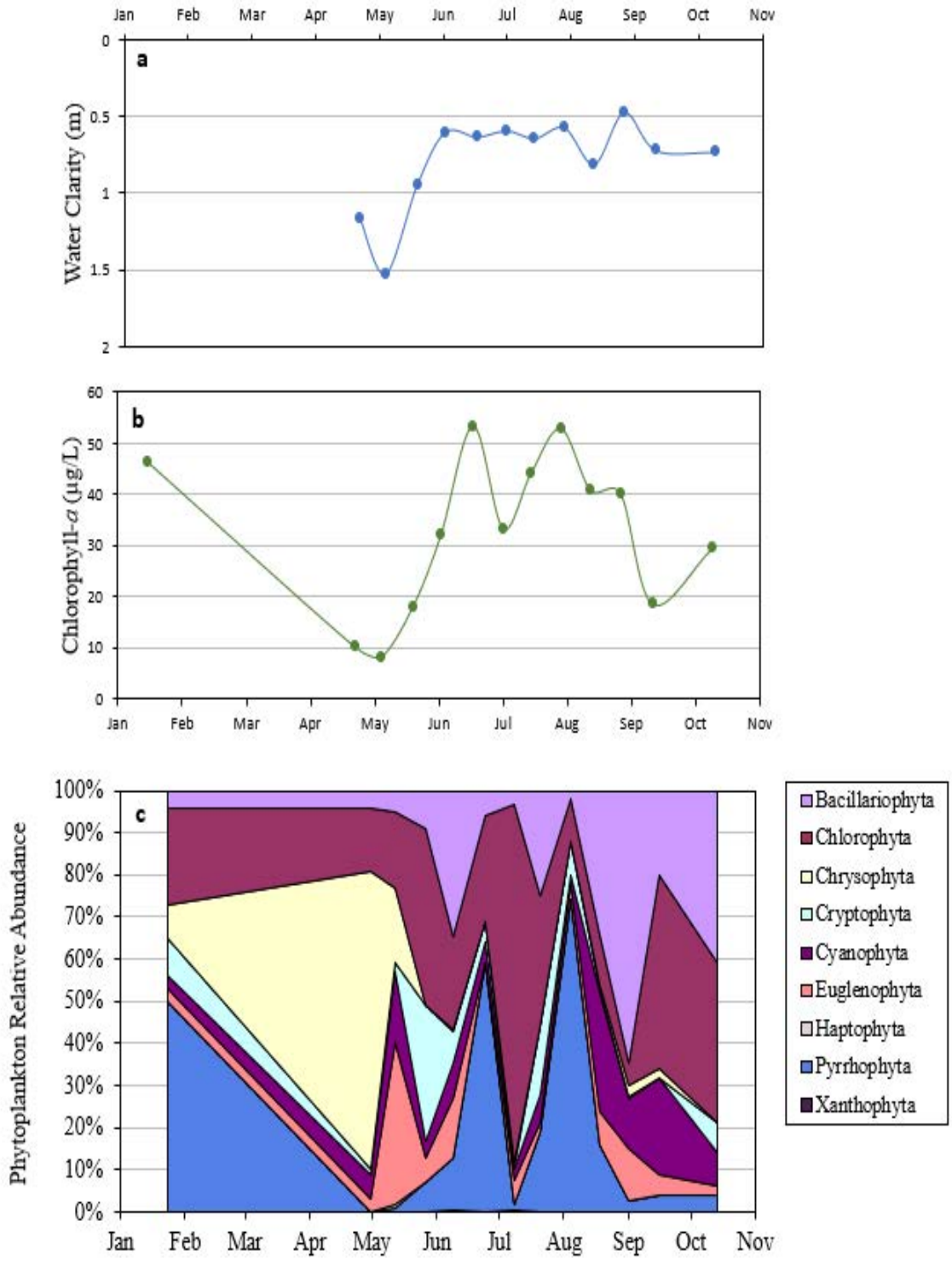


Figure 11-7. Water clarity (a), chlorophyll-*a* concentration (b), and relative abundance of phytoplankton (c) in Loring Pond during 2020. Note that the water clarity axis is reversed.

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 11-8** shows the zooplankton distribution in Loring Pond sampled throughout 2020. Rotifers were present throughout the year and were most abundant in the fall. Nauplii and juvenile copepods were also present throughout the sampling season and were most abundant in the spring. Cladocerans, cyclopoids, and protozoa were present in low levels in 2020.

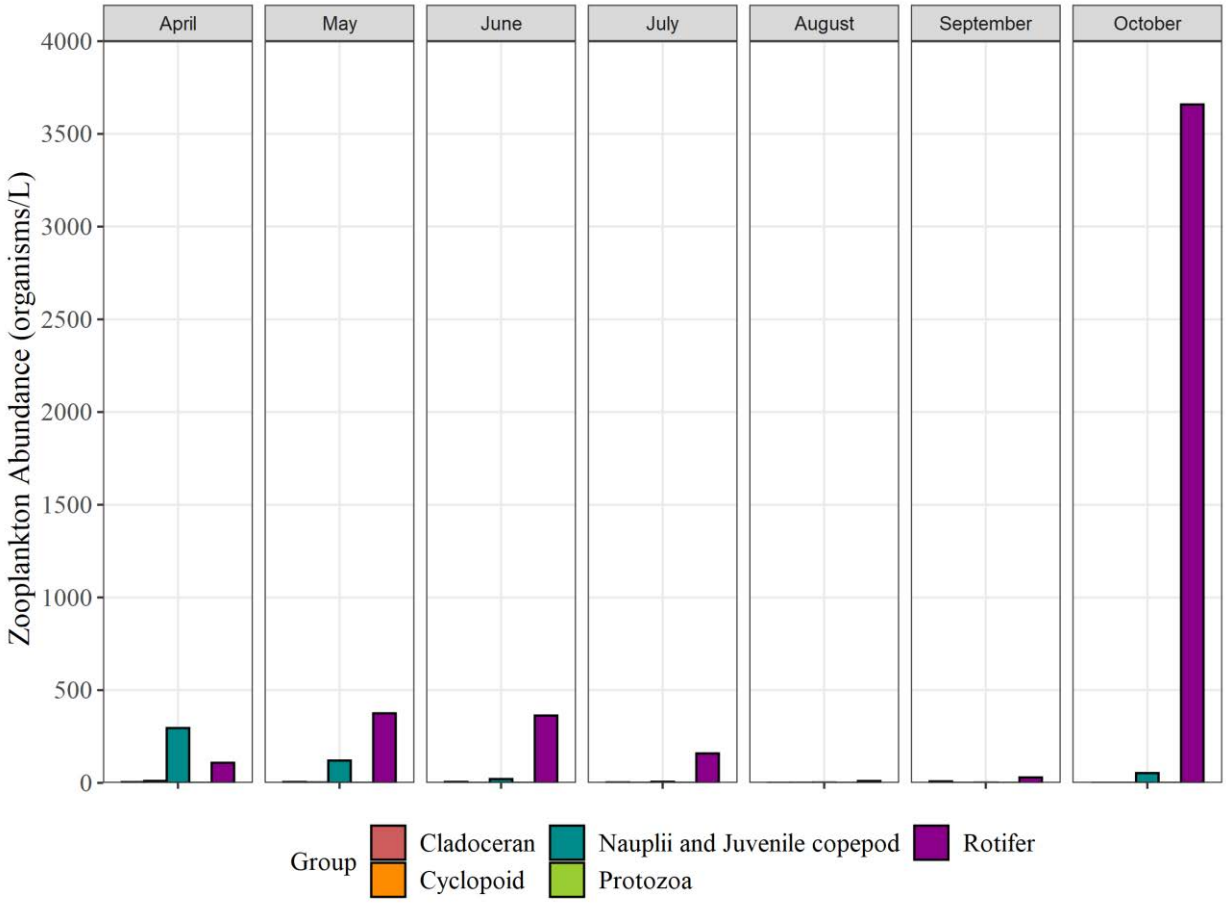


Figure 11-8. Zooplankton density in Loring Pond during 2020.

FISH STOCKING

No fish were stocked in Loring Pond in 2020, 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
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
2011	Black Crappie	79 adults	21.9 pounds
2011	Bluegill	329 adults	70.0 pounds
2011	Channel Catfish	28 adults	26.1 pounds

WATER QUALITY PROJECTS

Loring Pond Cattail Project

In the summer of 2012, MPRB contracted with Applied Ecological Services (AES) to begin a multi-year project to reduce the cattail monoculture in a select area on the **s**outh bay of Loring Pond. Working under MNDNR Aquatic Plant Permits, the 2012-2014 project included removal of hybrid and narrow-leaf cattail in a 15-foot area in front of the outlet structure, an area 25 feet in either direction from the center point of the dock, and a 100-foot long restoration area on the south shore. The 100-foot restoration area had cattails removed and the area planted with native aquatic emergent vegetation.

In the fall of 2014, the AES contract was expanded to include cutting as many cattails as possible beneath the water surface. It was anticipated that cutting cattails during this timeframe would cause the cattails to suffocate and either completely kill or reduce the cattail population for the 2015 growing season. AES found, during the fall 2014 project, that the north bay was predominantly a floating mat of cattails and there were floating cattail mats in the south bay as well. The floating cattail mats will float higher in the water when cattails are cut; therefore, it was impossible to keep the floating cattail mats below the water. The fall 2014 project also discovered that there were many cattails growing in shallow water and into park land shoreline, neither of which could be cut beneath the surface of the water.

Minnesota State Legislative action passed in 2014, "authorized [the MPRB] to remove all hybrid and narrow-leaved cattails by mechanical removal and chemical control at Loring Lake…and replant the shoreland with native species…" (2014 Minnesota Session Laws, Chapter 290, Sec. 60).

As a result of the Legislative action, the MPRB solicited Request for Proposals in early 2015 to implement a larger project to control cattails and replanting with native aquatic emergent vegetation

into both the south and north bays of the lake. The MPRB entered into a contract with AES for three years (2015-2018). Due to the complexity and high cost of removing the large cattail mat in the north bay, the project scope was changed. AES work in the north bay was only for cattail control during the 2015 growing season with removal of cattail stems from the floating mat during the winter of 2015-2016.

The fall 2014 below water cutting was found to be a very successful method to control cattails in open water areas. A second cutting was necessary in some areas, and this work was done by the contractor in August 2015 using brush saws, loppers, and hand pruners either from a boat or shore. Herbicide treatments were applied to the floating mats and to cattails that were growing in saturated shoreline soils in early September 2015. Work in the north bay included below water cutting and herbicide treatment of the floating mat during the 2015 growing season.

A good amount of native emergent plants that were part of the 1999 shoreline planting project were found to have survived once the cattails were removed. Most notably, large patches of sweet flag on the north end of the south bay remained intact.

In January 2016, AES cut dead cattail stems at ice level from the south and north bay floating mats. The cattail debris was hauled to a composting facility. In early March 2016, Forestry staff and a MPRB contractor used large equipment to attempt to break up and pull the floating mat out of the north bay. The equipment reach was approximately 20 feet and a very small amount of the north bay floating mat was removed. AES continued work on cattail control in the south bay during the 2016 growing season. Removing floating mats in late May 2016, pulling and cutting cattails and spot herbicide treatments were the cattail control activities on the south bay.

In July 2016, AES planted 5,000 plugs of a variety of native aquatic emergent plants into the south bay of the pond. AES and MPRB staff agreed that additional fencing should be placed around the plantings to protect them from Canada goose herbivory. This resulted in a double layer fence around the south bay planting area, which remained until 2020 when it was determined that the plants were well-established and no longer threatened by herbivory.

In 2017, AES continued the control of cattails by pulling, cutting, and select spot herbicide treatments. Additional maintenance of the 2013 and 2016 native aquatic emergent plantings in the south bay was also performed. In August 2017, MPRB staff amended the contract with AES to remove the upland buffer planting from the contract due to public concerns over herbicide treatments in parks. The amendment to the contract included an additional herbicide treatment of the north bay floating cattail mat, which was done in September 2017. The amendment also included removal of the floating cattail mat cattail stems when ice was on the lake in the winter of 2017-2018. Another amendment was made to the contract extending the end date of the contract from December 2018 to July of 2020.

In 2019 and 2020 the cattail project focused on the south bay of Loring Pond. The Park Board banned the use of glyphosate products beginning in 2019 and Clearcast was used for spot herbicide applications around the South Bay in September. In mid-July of 2020 AES hand pulled and cut cattails in the south bay. Also, Conservation Corps Minnesota (CCM) pulled out the fencing protecting the plantings surrounding the bay since the plants were well-established. The cattail project contract ended in July of 2020.

Loring Pond South Bay Duckweed Removal

The MPRB contracted with Waterfront Restorations, Inc. in 2018 to conduct a duckweed removal project. Over the course of three days, starting on July 17th, Waterfront used nets to skim and remove over 25 tons (wet weight) of duckweed off the surface of Loring Pond south bay. An estimated 80% of all the duckweed that was in the pond was removed. 20% remained in the peripheral emergent vegetation along the edges or in areas that have dense submerged weed growth that trapped the duckweed. After the completion of the removal from the south bay a boom was placed between the two bays to prevent duckweed growth from the north to float into the south bay.

Skimming removes duckweed off the surface of the pond, resulting in a temporary aesthetic improvement to the pond. Additional benefits can include increased light penetration which could enhance submerged plant growth, as well as removal of a small amount of phosphorus associated with the plant material that would otherwise remain in the pond.

MPRB staff monitored the results to gauge the effectiveness of this non-chemical experiment and how long the skimming process will last to determine a cost vs benefit analysis of the project. Only a week after the removal project, the duckweed had almost completely replaced itself.

Loring Pond South Bay Duckweed 2020

The abundance of duckweed generally increased throughout the sampling season in 2020. Duckweed was first seen in late May at 1-2%, ranged between 25-35% coverage for most of June and July, 100% coverage was noted one day in late July, and the lake was 60% covered throughout August. Duckweed coverage likely increased throughout the season due to lower water levels. Lake levels were below the OHWL between early July and early September when duckweed was present. The abundance of duckweed on Loring Pond decreased in September and through fall.

TOC

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 new parkland ended up settling, 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 July 2020. The silt fence was installed along the north shore to prevent erosion during the shoreline restoration project.

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 of 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. With increased development around the lake over the years, the impact of stormwater on water quality became a greater concern in the 2000s. There is a total of 16 stormwater outfalls surrounding Lake Nokomis, see **Appendix C**.

Table 12-1. Nokomis Lake physical characteristics.

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.**

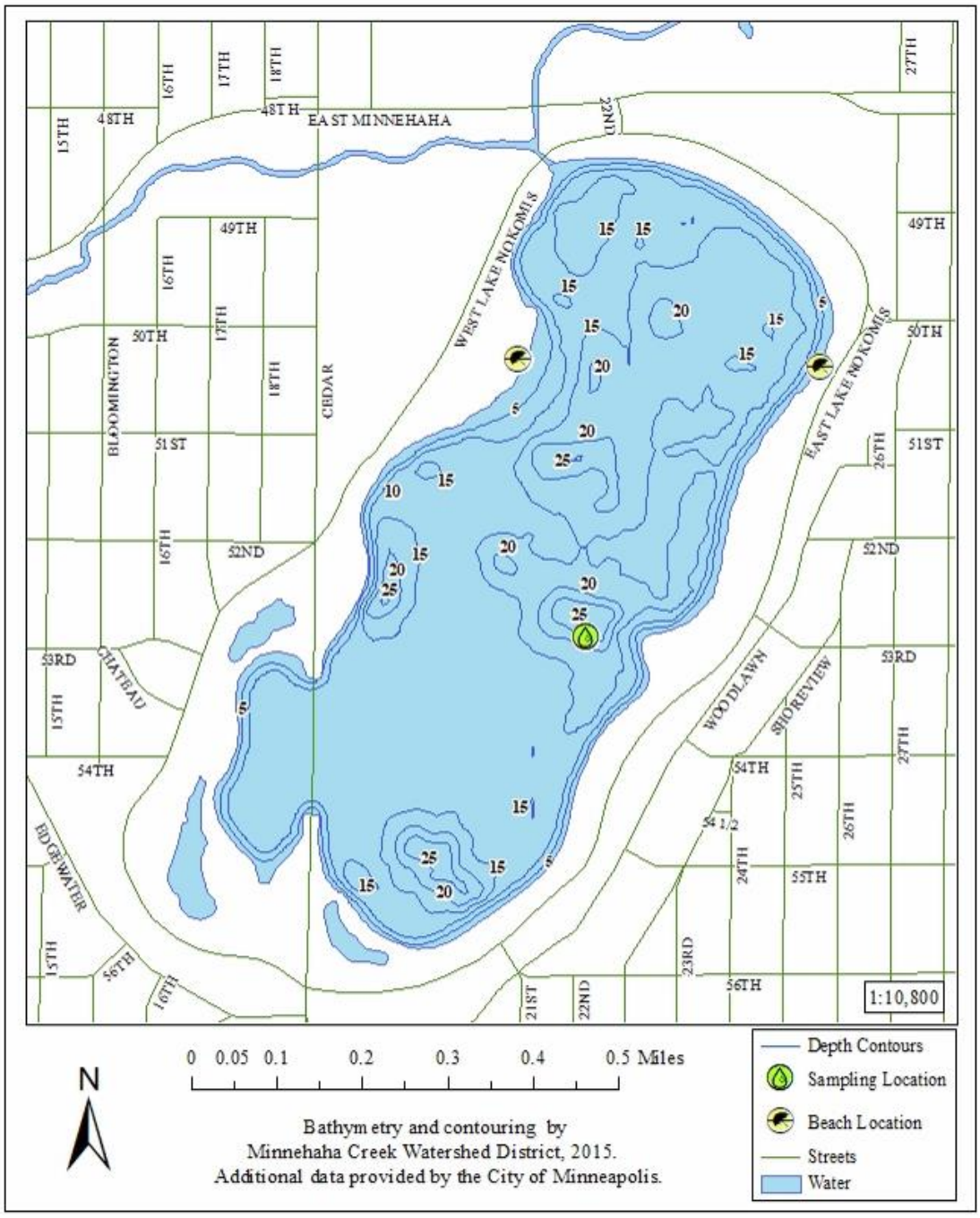


Figure 12-2. Bathymetric map of Lake Nokomis with sampling locations based on data collected by the Minnehaha Creek Watershed District.

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 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 **Figure 12-3 a-1.** A wooden weir was also constructed in 1937 in the bed of Minnehaha Creek downstream of the Nokomis outlet, 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. In the past, water was diverted to Nokomis from the creek in order to: fill the lake after dredging, 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 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 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.

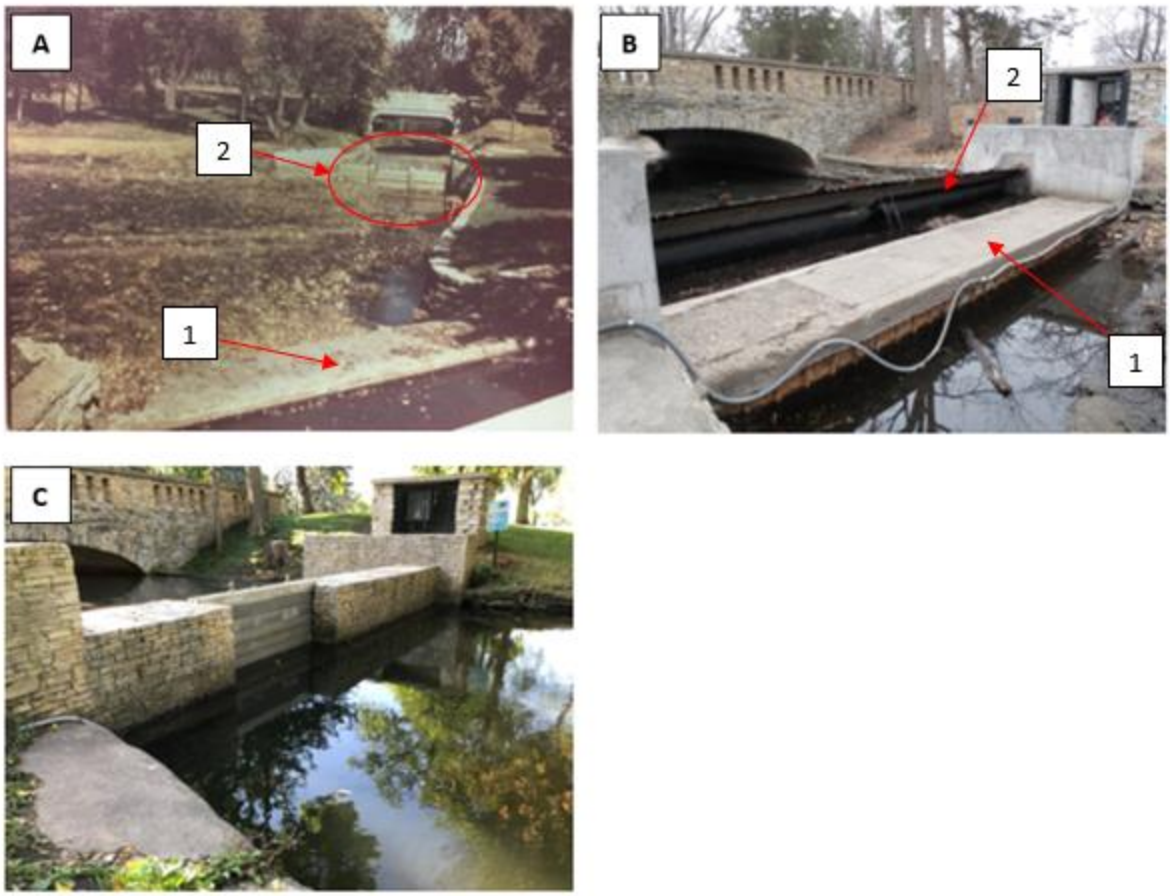


Figure 12-3. Historic weir structures at Lake Nokomis outlet including the original weir deck outlet structure (a-1), a wooden weir in Minnehaha Creek (a-2), inflatable weir (b-2), and stop log weir (c) that currently controls the outlet to the lake.

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. 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. A Blue Water Commission (BWC, 1998) study led to the creation of the Lake Nokomis stormwater wetlands in 1996, eight acres of cattail marsh on the southwest corner of the lake (Smith, 2008). Water quality on Lake Nokomis has been monitored annually since 1992. In 2011, a Total Maximum Daily Load (TMDL) study was done because Lake Nokomis was added to the EPA's 303d list of impaired waters in 2002 due to excess nutrients, and Minneapolis and Richfield were assigned phosphorus load reductions (MPCA and MCWD, 2011).

Numerous restoration projects have been implemented to improve water quality in the lake. Many projects undertaken were those recommended by the Blue Water Commission: Report and Recommendations for the Management of Lake Nokomis and Hiawatha (BWC, 1998). An attempt was made to remove carp from the lake during the winter of 2001-02 to limit internal phosphorus loading caused by the fish foraging in the sediment. Increased street sweeping, grit chambers, and stormwater wetlands were also implemented in 2001. In 2013, a flocculation treatment system was installed on the north side of Taft Lake to 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). A MCWD-led biomanipulation project aimed to reduce sediment disturbance by burrowing fish in Lake Nokomis and was completed in 2013. The project concluded that there was a change in the fish community away from burrowing species based on fish surveys. The project achieved some of its goals but there was less of an effect on phosphorus than was thought. It was then determined that the carp population should be re-evaluated. This led to the Carp Integrated Pest Management (IPM) Project, see the water quality project section, which took place between 2016 and 2019.

LAKE LEVEL

Weekly lake level measurements recorded at Lake Nokomis from 1999 through 2020 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 ft 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 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 have been high. Lake levels in 2020 fluctuated around the OHWL ranging between 814.9 and 816.3 ft msl. The lake froze 0.44 ft msl below the OHWL in December of 2020.

Persistent high groundwater levels in the Lake Nokomis area led to the formation of a multiagency technical team that is attempting to understand:

- Are surface water and groundwater levels near Lake Nokomis, particularly south and west of the lake, increasing?
- To what extent 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, The MNDNR The MCWD, The City of Minneapolis, and the Metropolitan Council Environmental Services (MCES). A City of Minneapolis website was created to disseminate information on the issue and the team's work to the public: http://www.minneapolismn.gov/publicworks/stormwater/nokomisgroundwater.

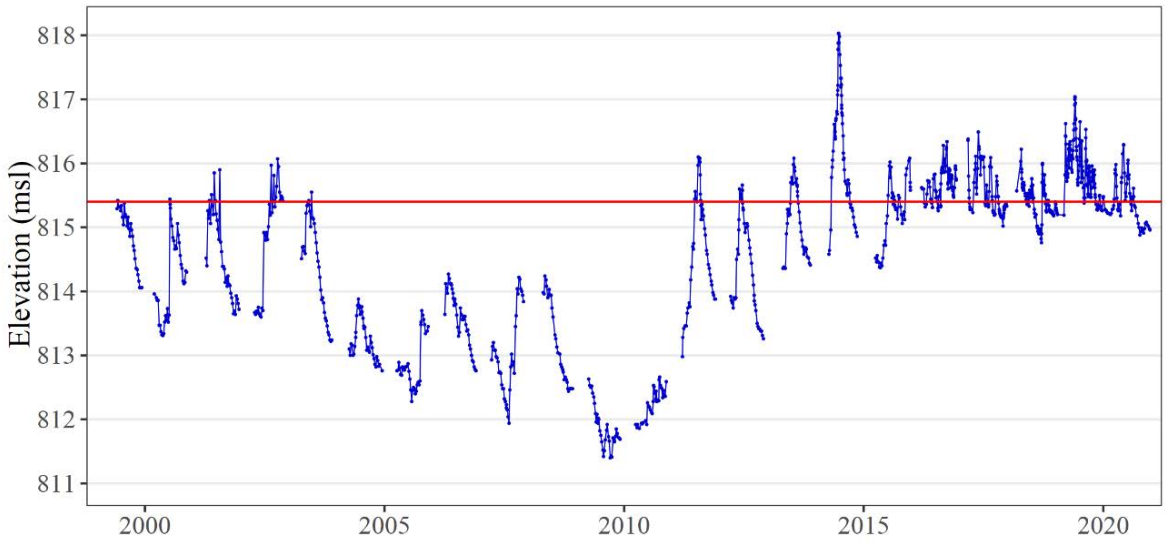


Figure 12-4. Lake levels for Lake Nokomis from 2000-2020. Horizontal line represents the Ordinary High Water elevation (815.4 ft msl) for Lake Nokomis.

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 2020 ($p > 0.05$). The TSI score for Lake Nokomis in 2020 was 60, classifying the lake as eutrophic having blue-green algae dominate the phytoplankton community and algal scums.

Chlorophyll-*a* and total phosphorus TSI scores for Lake Nokomis are within the expected TSI range for lakes in the same ecoregion, see **Table 12-2**. The Secchi TSI score is above the TSI range for the ecoregion, meaning the water clarity in Lake Nokomis shallower than in comparable lakes. See Minneapolis Pollution Control Agency (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**.

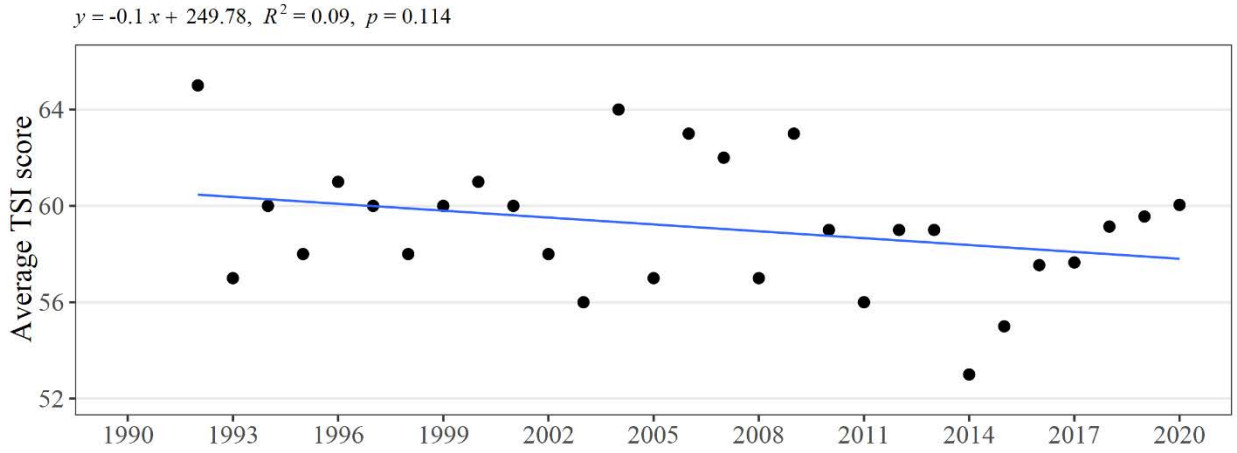


Figure 12-5. Lake Nokomis TSI scores and linear regression from 1992-2020.

Table 12-2. Lake Nokomis Secchi, chlorophyll-*a*, and total phosphorus TSI based on data collected between June and September 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	64	43-54	Not within range, worse than expected
Chlorophyll-*a*	61	46-61	Within range
Total Phosphorus	56	49-61	Within range

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 US EPA approved a new 50 µg/L total phosphorus standard for Lake Nokomis in 2013 (US EPA, 2013) because data showed that goals would 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, 1992-2020, can be found in **Appendix A**.

Water clarity has gradually been declining since 2014. 2020 had the shallowest water clarity over the past 10 years with an average Secchi depth of 0.8 meters. In June, Secchi depths reached 1.5 and 2.1 meters, which were outliers for the year, see **Figure 12-6a**. Chlorophyll-*a* levels were higher and more variable between 2018 and 2020 compared to previous years with an average concentration of 21.6 µg/L in 2020, see **Figure 12-6b**. Total phosphorus concentrations have become more variable in the past five years. The average total phosphorus in 2020 was 48 µg/L, see **Figure 12-6c**. Lake Nokomis met the site-specific standards for total phosphorus in 2020 but did not meet the standards for water clarity and chlorophyll-*a*.

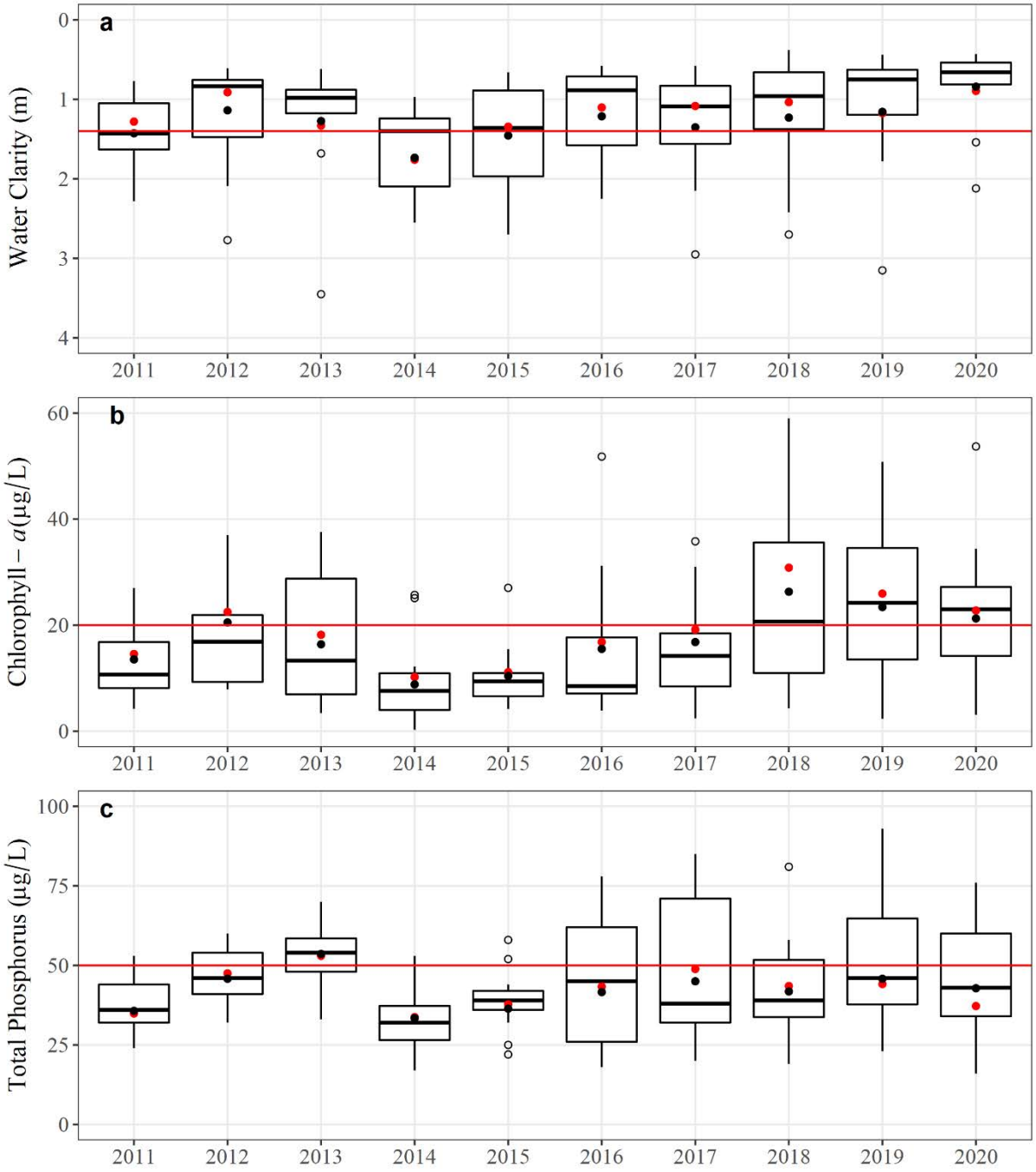


Figure 12-6. Lake Nokomis box and whisker plots of water clarity (a), chlorophyll-*a* (b), and total phosphorus (c) data from 2011-2020. Horizontal lines represent Lake Nokomis site-specific eutrophication standards, which applies to data collected between June and September. The red circles represent 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 1992-2020 can be found in Appendix A.

BEACH MONITORING

Bacteria levels were monitored at Nokomis Main Beach and Nokomis 50th Street Beach between June and August of 2020. As shown in **Table 12-3** and **Figure 12-7**, *Escherichia coli* (*E. coli*) levels were low for both beaches in 2020. There were no closures at either beach on Lake Nokomis during the 2020 beach season due to the exceedance of *E. coli* standards.

As a result of an unusual early spring algae bloom on Minneapolis lakes in 2020, MPRB developed a blue-green algae index visual monitoring protocol. Visual indicators were noted as part of the protocol for the weekly beach sampling program. See **Chapter 18** for more information on beach and blue-green algae monitoring.

Table 12-3. Summary of *E. coli* (MPN per 100 mL) data for Lake Nokomis beaches in 2020.

Statistical Calculations	Nokomis 50th	Nokomis Main
Number of Samples	13	13
Minimum	2	5
Maximum	586	887
Median	38	19
Mean	116	134
Geometric Mean	32	34
Max 30-Day Geo Mean	48	49
Standard Deviation	207	266

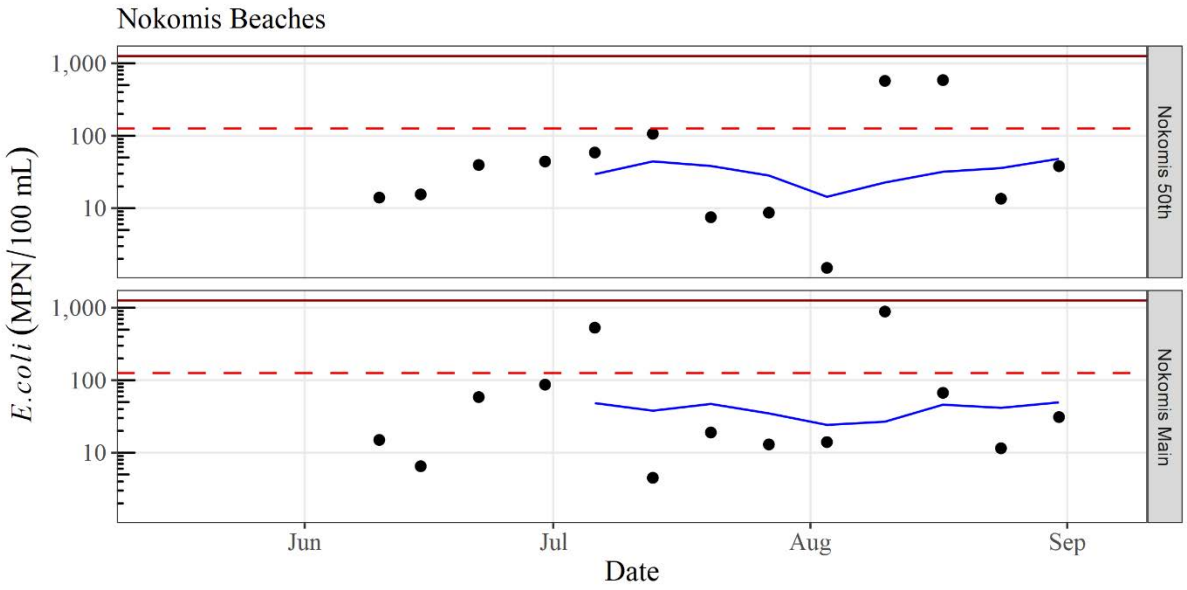


Figure 12-7. 2020 *E. coli* concentrations at the Lake Nokomis beaches. Blue line is the running 30-day geometric mean. The dashed horizontal line represents the *E. coli* standard for the 30-day geometric mean (126 MPN/100mL) and the solid horizontal line represents the single-sample maximum standard (1260 MPN/100mL). Note the log scale on the Y-axis.

Figure 12-8 shows *E. coli* monitoring data for Lake Nokomis beaches from 2011 to 2020 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. *E. coli* results had the highest outliers in 2020 at both Nokomis 50th Beach and Nokomis Main Beach compared to previous years.

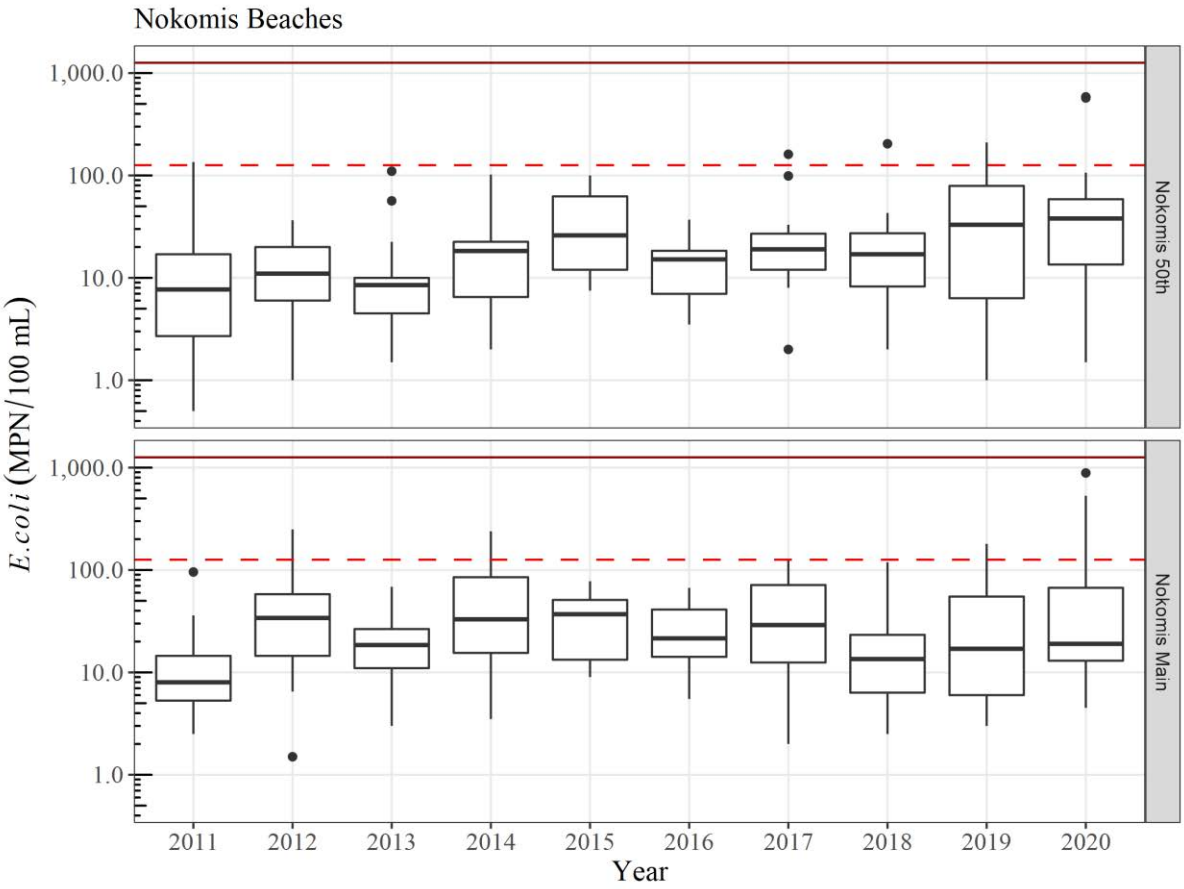


Figure 12-8. Box and whiskey plots of *E. coli* concentrations (MPN/100 mL) for Lake Nokomis beaches from 2011-2020. The dashed horizontal line represents the *E. coli* standard for the 30-day geometric mean (126 MPN/100mL) and the solid horizontal line represents the single-sample maximum standard (1260 MPN/100mL). Note the log scale on the Y-axis.

LAKE AESTHETIC AND USER RECREATION INDEX (LAURI)

Figure 12-9 shows the LAURI scores for Lake Nokomis. In 2020, the lake scored good in aesthetics, water clarity and habitat quality. Public health and recreational access was scored as excellent. The typically 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.

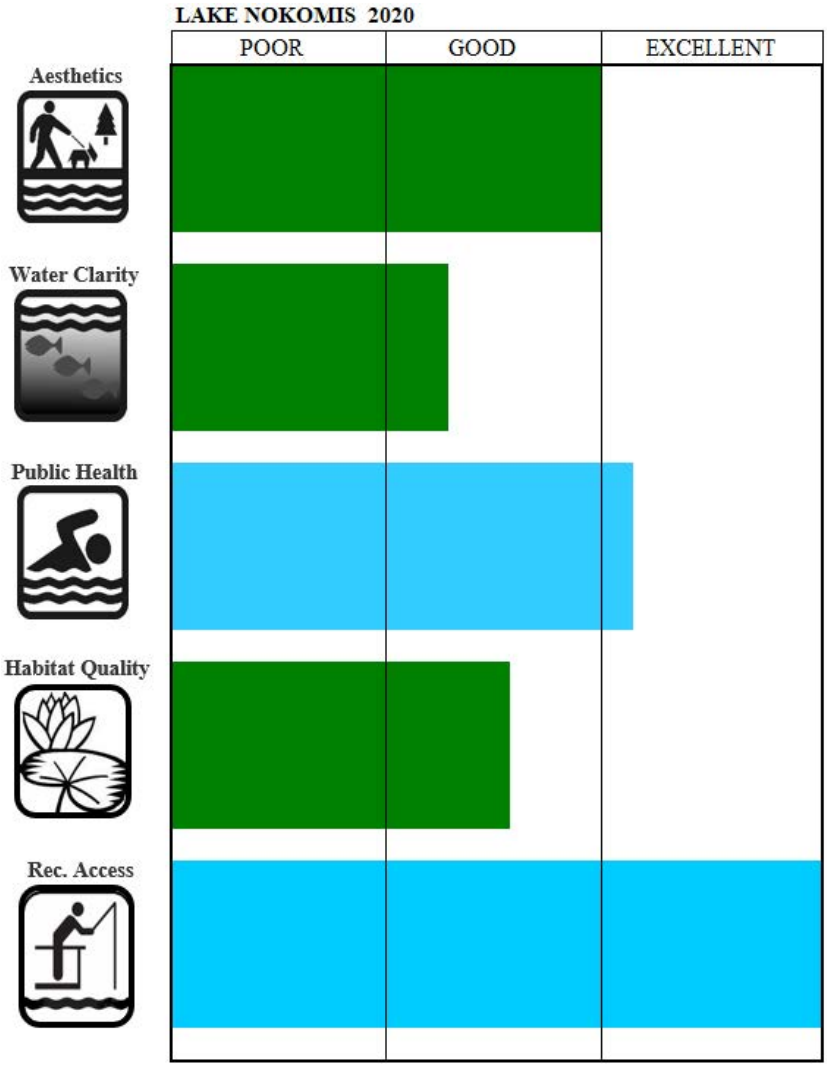


Figure 12-9. The 2020 LAURI Index scores for Lake Nokomis.

WINTER ICE COVER

Ice came off Lake Nokomis on March 29, 2020, six days earlier than the average ice-off. Ice came back onto the lake for the winter on December 2, 2020, which is 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 2020 was 15 acres, which is just under 15% of the littoral zone, the area shallower than 15 feet. Approximately 250 pounds of aquatic plants were removed from the beach areas at Lake Nokomis using contracted SCUBA divers. See **Chapter 1** and **Chapter 20** 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 12-10** shows the water clarity, chlorophyll-*a* concentrations, and relative abundance of phytoplankton divisions during 2020. 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 shallow in the spring and increased in early June when the clarity reached its deepest reading at 2.1 meters. Water clarity decreased throughout the season reaching its shallowest reading in mid-September at 0.4 meters, see **Figure 12-10a**. Chlorophyll-*a* concentrations were lowest in early June at 3.1 µg/L. Concentrations of chlorophyll-*a* were highest in late August at 53.7 µg/L when the phytoplankton community primarily consisted of blue-green algae (Cyanophyta), see **Figure 12-10a, c**.

The phytoplankton community in Lake Nokomis predominately consisted of blue-green algae. Diatoms (Bacillariophyta), green algae (Chlorophyta), chrysophytes (Chrysophyta), cryptomonads (Cryptophyta), euglenoids (Euglenophyta), haptophytes (Haptophyta), and dinoflagellates (Pyrrhophyta) were present in low percentages in 2020, see **Figure 12-10c**.

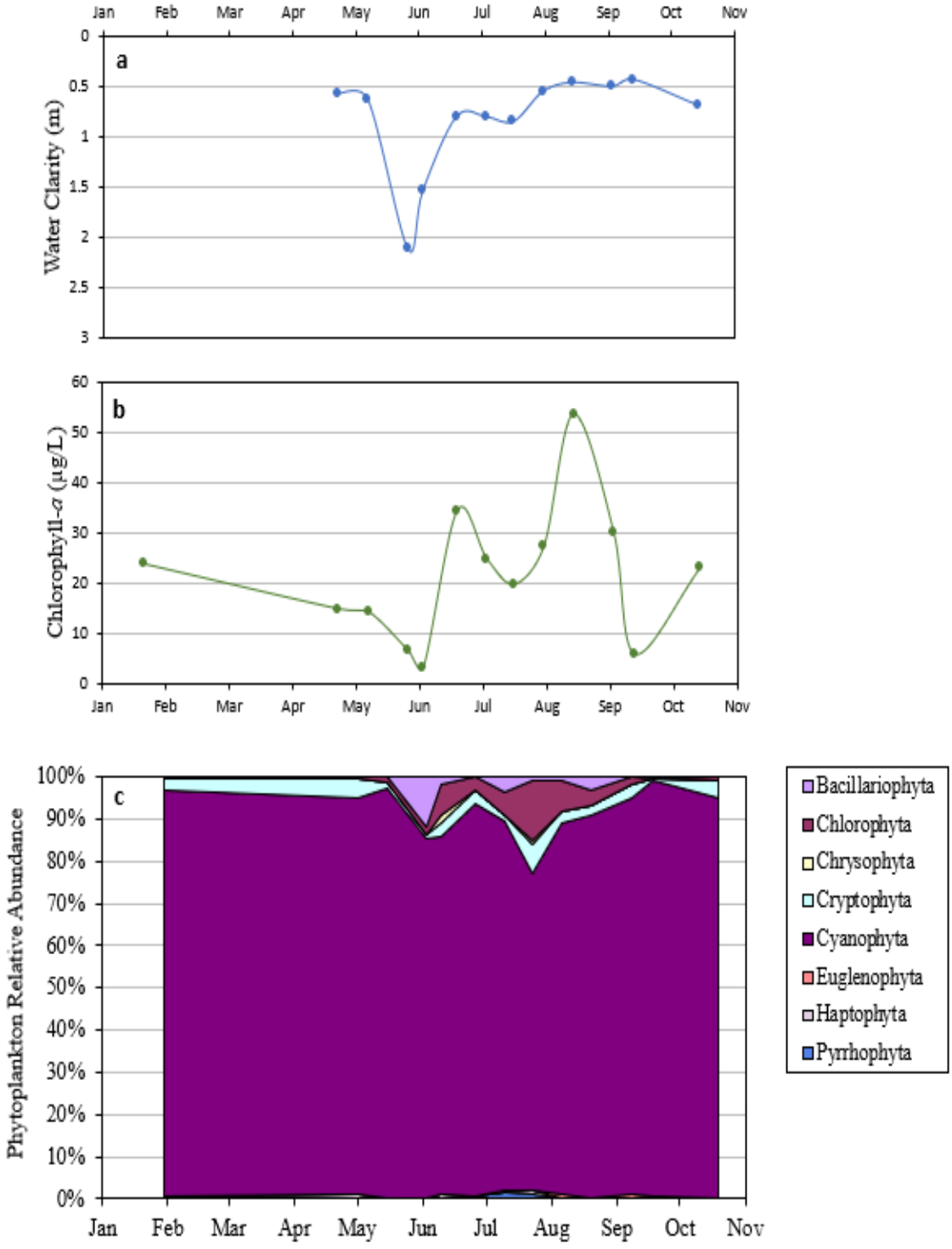


Figure 12-10. Water clarity (a), chlorophyll-*a* concentration (b), and relative abundance of phytoplankton (c) in Lake Nokomis during 2020. Note that the water clarity axis is reversed.

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 12-11** shows the zooplankton distribution in Lake Nokomis sampled throughout 2020. Rotifers were present throughout most of the year and were abundant in late May and June. Nauplii and juvenile copepods were present throughout the year and were most abundant in May. Cladocerans were also present throughout the sampling season and were most abundant in September. Calanoids, cyclopoids, and protozoa were present in low levels in 2020.

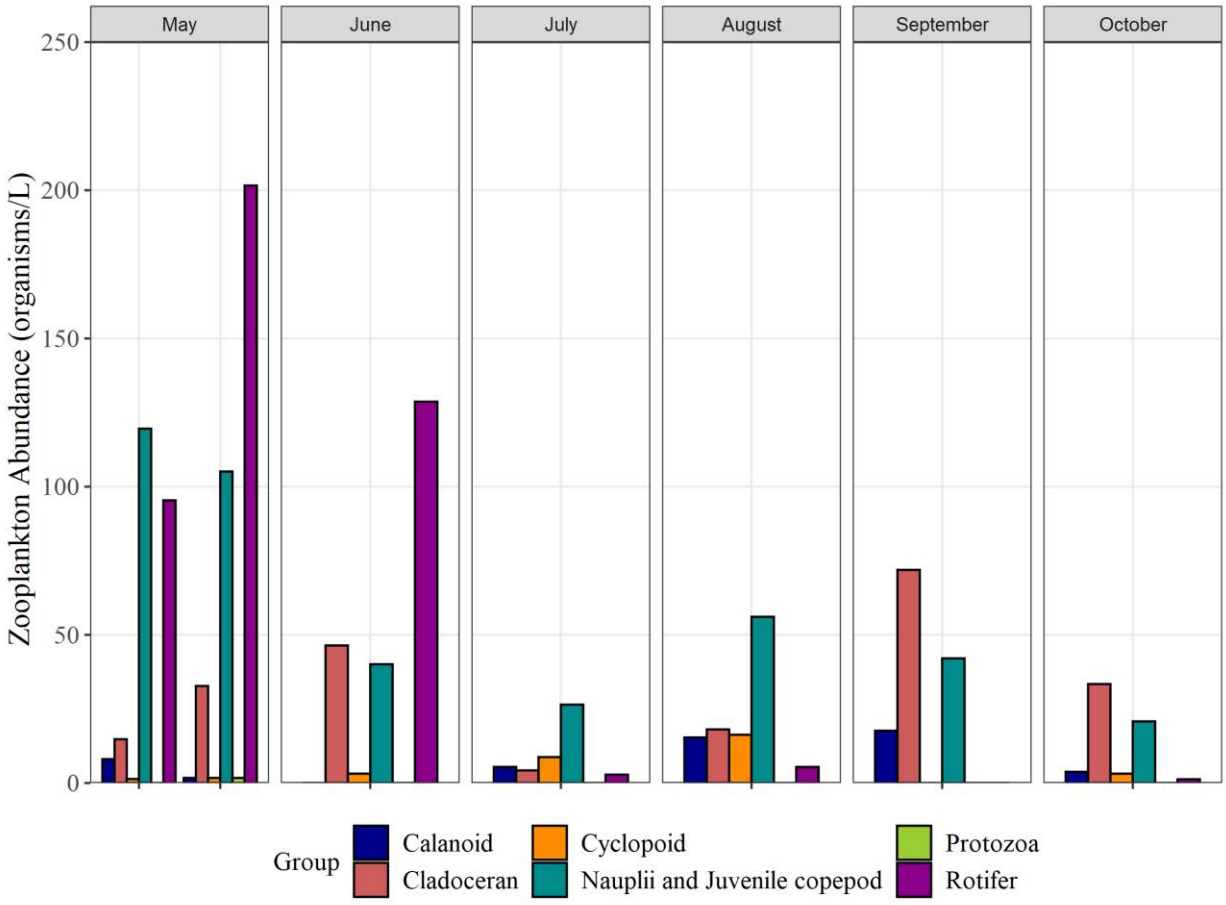


Figure 12-11. Zooplankton density in Lake Nokomis during 2020.

EVENTS REPORT

Algae Bloom

Most blue-green algae blooms occur during the hottest part of summer, but in 2020 an unusual early spring bloom of blue-green algae occurred on Lake Nokomis. Algae are microscopic organisms that use the sun to make food. When algae grow very fast, it creates "blooms". A certain type of algae called blue-green algae can make toxins that can make people or animals sick if they are ingested.

Plankton samples MPRB collected during winter showed that the blue-green algae bloom at Lake Nokomis started under the ice. The species of algae found in the winter and spring samples that caused the bloom grows well in cold water, unlike most blue-green algae that prefer late summer temperatures. In a normal year, ice would melt off slowly and the algae would die off before it got a foothold in the lake. Rapid ice-out and cooler than average spring temperatures in 2020 led to conditions that allowed the algae to persist into spring.

Lake Nokomis had murky brown water and very low water clarity as a result of the bloom. Live samples of the algae were analyzed by MPRB's contract lab to confirm the species and identify whether it had the capability of producing toxins.

MPRB made the decision to post a warning at Lake Nokomis because the bloom was persisting into the swim season and people had begun to recreate in the water. As spring temperatures increased the potential that people would be exposed to a blue-green algae bloom increased as well with the higher amount of recreation in the lake and park. MPRB tested the water for the presence of the most common algae toxin, microcystin. Microcystin was present at Lake Nokomis but was below the EPA standard for body contact. Another algae toxin, anatoxin, was tested for and was not present in the samples. Because algae toxins are not distributed evenly throughout the lake, and the bloom was thick and persistent, posting the lake was warranted.

By early June, lake water had lost its brown color, water clarity increased and MPRB removed the warning signage. MPRB re-tested the beaches for the presence of algae toxin. In this round of testing, no toxin was detected at Lake Nokomis.

Fish Kill

On June 10, 2020, MPRB Water Quality staff reported five dead sunfish and crappies at the outlet of Lake Nokomis. *Columnaris* disease, caused by the naturally occurring *Flexibacter columnaris* bacteria, was the suspected cause of mortality. *Columnaris* disease is usually associated with a stress condition such as high water temperature, low dissolved oxygen concentration, crowding, or handling. The surface water temperature was 72 degrees Fahrenheit during the fish kill event and within the range of spawning temperatures (65 to 80 degrees Fahrenheit). Crowding during spawning is likely the cause of the spread of *Columnaris* during the fish kill. An Incident Report was completed describing the fish kill event. See the fish kill section in **Chapter 1** for additional details.

FISH STOCKING

Table 12-4 shows the fish stocked into Lake Nokomis over the past decade. 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. Asterisk (*) indicates fish purchased and stocked by private citizens and sporting groups. Double asterisk (**) indicates fish purchased by the MNDNR for stocking.

Year	Species	Number and Size	Amount
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
2012	Tiger Muskellunge**	200 fingerlings	61.4 pounds
2012	Walleye*	2,000 yearlings	285.7 pounds
2011	Walleye	9,376 fingerlings	334.9 pounds

WATER QUALITY PROJECTS

Lake Nokomis Fish Management

As bottom-feeding fish, carp disturb lake beds where phosphorus has settled. Water quality is diminished by creating algae blooms that feed off the higher phosphorus levels. Carp can also eat and uproot vegetation, which can destroy a lake's aquatic plant community. Lakes with an overgrowth of carp typically have high phosphorus concentrations, low water clarity, and little to no aquatic plant growth.

The Blue Water Partnership identified carp as a water quality problem in Lake Nokomis. An attempt to remove carp was made by seining under the ice in the winter of 2000-2001 as one of several projects identified by the Blue Water Partnership report. Originally, the plan was to remove carp each winter for three years, but because of the difficulty in finding a suitable landing site, carp were only removed once, leaving many carp behind.

From 2010 to 2016, the Minnehaha Creek Watershed District (MCWD) conducted a biomanipulation project to remove other rough fish species, such as bullhead; and to stock predator fish that could eat fish linked to increased algae and turbidity. The results of the project indicated that walleye and other predatory fish manage the bluegill and plankton-consuming fish populations. For more information on the biomanipulation project, see MCWD's website https://www.minnehahacreek.org/project/lake-nokomis-biomanipulation-project.

After the biomanipulation project there was an improvement in water quality but not as significant as what was expected. At the time, it was assumed that there were few carp in Lake Nokomis, but there was no data to support the effectiveness of the 2001 carp removal, and MPRB staff were observing carp while lake sampling. Due to the number of observations of carp, MCWD contracted the U of M to electrofish for carp in 2014 and 2015 to determine how many carp were in Lake Nokomis. Based on those estimates, it was determined that Lake Nokomis' carp population had reached a point where water quality could be affected. The high levels of carp found led to the creation of a more comprehensive study.

In 2016, the MPRB was awarded funding from the Legislative Citizens Commission on Minnesota Resources (LCCCMR) for a project to study Lake Nokomis' carp population. The goals of the project were to collect data on fish and aquatic vegetation, start implementation of carp integrated pest management (IPM) strategies, and develop long-term carp management practices that improve water quality. MPRB and MCWD partnered with scientists at two local environmental consulting firms – WSB and Blue Water Science. During the project carp were quantitated through electrofishing and mark and recapture activities, movement patterns were monitored by radio tagging, age dating was done to help determine conditions for spawning, and a management plan was created. Multiple attempts were made to remove carp in the winter during aggregation but was unsuccessful due to unusually high water, presence of large debris on the lake bottom, and furrows that remained after dredging. The project area included the entire Lake Nokomis subwatershed as carp migrate and spawn through the system that includes Taft, Mother and Legion Lakes and several wetlands.

The carp project was completed in December 2019. There were three key findings as a result of this project. First, Lake Nokomis supports elevated carp biomass (>300 kg/ha) which leads to internal loading of phosphorus and negatively impacts water quality. Second, carp movement within the subwatershed was documented between Taft Lake, Solomon Wetland, and Lake Nokomis. Carp movement likely increased in recent years due to high water levels allowing carp to use daylit, piped, and newly opened connections. Lastly, the primary challenge for carp removal is high water, which made seining impossible. Non-standard techniques such as box netting or fish trapping at the Nokomis inlet stream at the south will likely need to be used for carp removal in the future.

Three management practices were suggested by WSB to improve the water quality of Lake Nokomis. Recommendations included installation of carp barriers at the Solomon Wetland inlet and outlet to prevent carp movement, and removal of adult carp biomass within Lake Nokomis below the 100 kg/ha ecological tipping point. It was also suggested that future studies could be done to determine the role of the Nokomis outlet weir with regard to carp movement. Future steps to improve the water quality at Lake Nokomis are suggested to be implemented in the following order: prevent carp recruitment, reduce carp biomass, education and outreach, and measure ecological response of management activities.

Groundwater observation wells

Property owners near Lake Nokomis have noted higher levels of groundwater and flooding in basements. Solomon Park and Lake Nokomis Park have also had extensive flooded areas for the last several years. Additionally, the City of Minneapolis has received comments and complaints over deteriorating private sewer laterals and groundwater impacting basements and foundations.

To better understand the area's groundwater system, 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. For more information on well data, see the MNDNR website https://www.dnr.state.mn.us/waters/cgm/index.html.

The water level data provided by this network of six observation wells will help the multi-agency team that has been working on the Nokomis area water concerns understand the area's groundwater system, learn how different aquifers may be interacting with each other and with surface waters, and how different bodies of water are interacting with each other.

For more information and updates, see the *City of Minneapolis project page*.

TOC

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 2020.

Powderhorn is a shallow lake with an island and one deeper hole at its southeastern end. **Table 13-1** contains physical characteristics and **Figure 13-2** is a bathymetric map of Powderhorn Lake. Computer modeling, using a Bathtub model, indicates the lake was historically eutrophic (MPRB, 1999). Powderhorn Lake is part of the Minnehaha Creek Watershed and the primary land-use is residential and mixed-use. Stormwater has worsened the water quality in Powderhorn Lake due to phosphorus input. There are six stormwater outfalls surrounding the lake with most of the watershed drained through the west side lot of the lake, see **Appendix C**.

Powderhorn Lake receives large amounts of stormwater runoff and water discharges to the Mississippi River. Historically, Powderhorn Lake had several issues with low water levels. In the early 1900s the lake level dropped several feet until the lake was dredged in 1924. The lake dropped

an additional three and half feet in 1963, the lowest water level on record, and city water was pumped into the lake raising the lake level by ten feet. It was thought that the digging of the trench for Interstate 35W was the cause of the low water level. A pump system was installed in 1996-1997 to maintain the water level of the lake. Between 2007 and 2014, after the invasive species *Egeria densa* was discovered in Powderhorn Lake, MPRB did not intentionally run the inflow or outflow pump during the growing season to prevent good growing conditions and spreading of the invasive species. Since 2015, the inflow pump has not been used to pump water into Powderhorn Lake due to high lake levels, but the outflow pump has been used to lower the lake level.

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. 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. Powderhorn Lake has been stocked by the MNDNR as a Fishing in the Neighborhood (FiN) lake since 1980.

Water quality on Powderhorn Lake has been monitored annually since 1992. 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 Works Progress Administration (WPA) stone wall that was initially constructed in 1940, removing concrete sluiceways, and installing a permanent summer aerator. An alum treatment was conducted in May 2003 to attempt to limit phosphorus availability.

Historically, Powderhorn Lake had less than foot of water clarity due to blue-green algae blooms. MPRB started treating the lake with barley straw in 2004 in an attempt to control the blue-green algal growth. Between 2005 and 2013 fewer blue-green algae blooms occurred, but other types of growth such as filamentous algae and duckweed grew heavily. Aquatic plants were abundant, and the water clarity improved, but there have been few aquatic plants present in recent years. Blue-green algae blooms began again in 2015. 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.

Restoration efforts shifted in 2007 when 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. The invasive plant has not been identified in the lake since the herbicide treatment and was removed from the infested waters list for this species in 2014. The MNDNR based the decision to remove Powderhorn 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.

Minneapolis Pollution Control Agency (MPCA) removed Powderhorn Lake from the US EPA 303(d) list of impaired waters 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.

Table 13-1. Powderhorn Lake physical characteristics.

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%	$3.19x10^6$	286	26.0	0.2

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

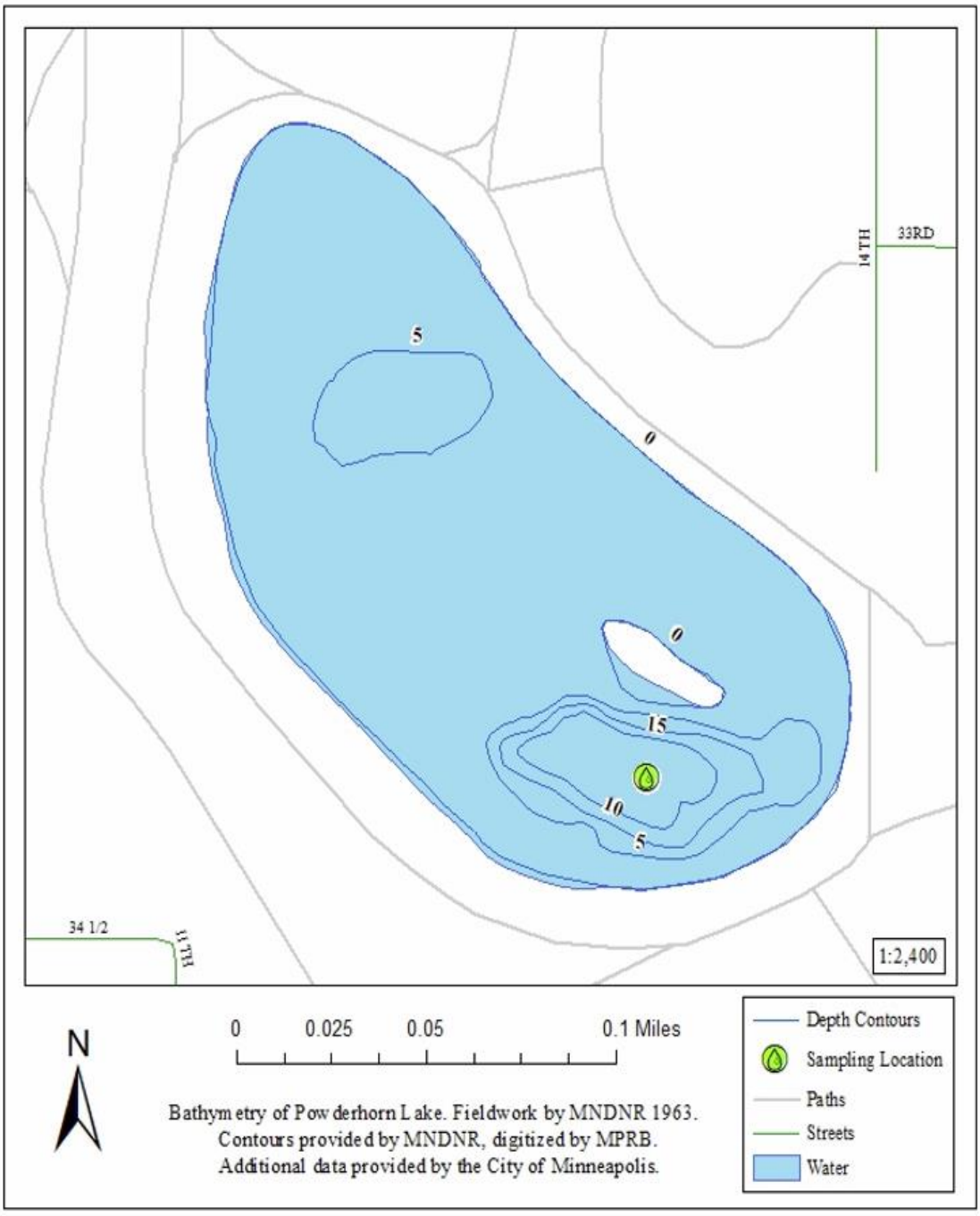


Figure 13-2. Bathymetric map of Powderhorn Lake and sampling location.

LAKE LEVEL

Powderhorn Lake levels over the last 20 years are shown in **Figure 13-3**. The outlet pump was used for the fifth straight year in 2020 to prevent flooding. In total, 17.4 million gallons were pumped out of the lake in 2020. **Table 13-3** 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. The permit from the Minnesota Department of Natural Resources (MNDNR) to pump water out of Powderhorn was amended in 2019 to allow up to 49 million gallons per year for level maintenance.

During low water, lake levels can be augmented with a groundwater well. Augmentation pumping was not done in 2020 and has not been utilized since 2015 due to recent years of high levels of precipitation maintaining higher lake levels. There is no MNDNR designated Ordinary High Water Level (OHWL) for Powderhorn Lake. See **Chapter 1** for details on lake level monitoring and **Chapter 17** for a comparison between other MPRB lake levels.

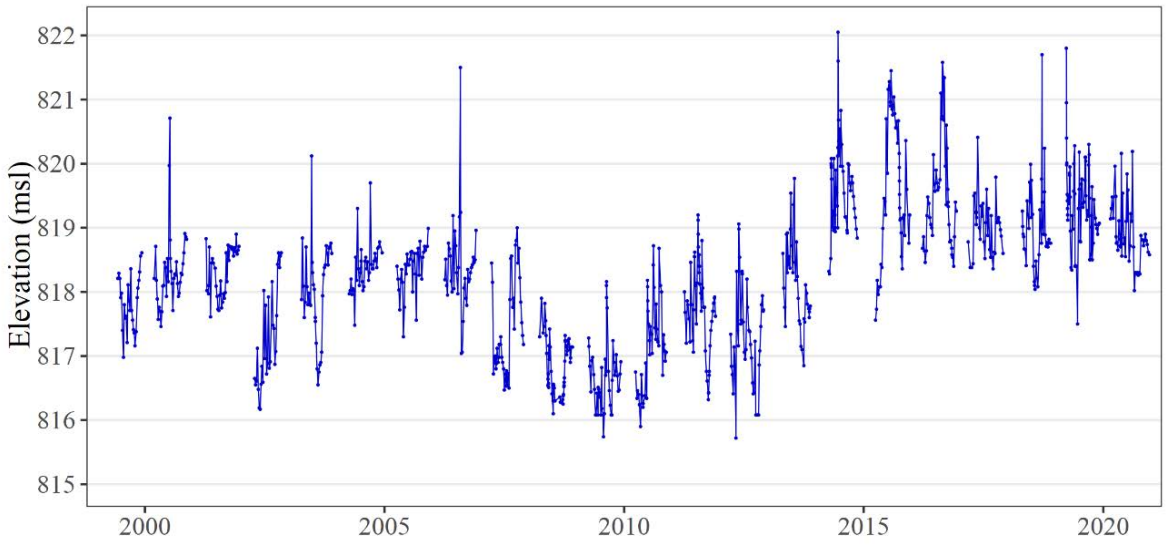


Figure 13-3. Powderhorn Lake levels from 2000-2020.

AUGMENTATION WELL

The MPRB holds a MNDNR permit to pump groundwater from a well into Powderhorn Lake for water level maintenance. The MNDNR issues a permit to appropriate groundwater and determines pumping volume limits for appropriate groundwater resource use. All monthly pumping data are reported to the MNDNR annually in the MDNR Permitting and Reporting System (MPARS). In the past, up to 26 million gallons per year was permitted to be pumped into Powderhorn Lake. State law changed, and this amount was reduced to 10 million gallons per year in 2006. MPRB staff records groundwater usage monthly when the groundwater pump is operational. No groundwater has been pumped into Powderhorn Lake since 2015. **Table 13-2** shows the annual water use over the past 5 years. See **Chapter 1** for detailed information on MPRB augmentation wells.

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

2016	2017	2018	2019	2020
0 gal	0 gal	0 gal	0 gal	0 gal

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, see **Table 13-3**. The pump is operated by Minneapolis Public Works, but MPRB staff determine when the pump needs to be turned on and off and maintain records for permitting. The MNDNR issues permits and determines the pumping volume limit. All monthly pumping data are reported to the MNDNR annually in the MDNR Permitting and Reporting System (MPARS). In 2015, a permit allowed 3.5 million gallons to be pumped. Additionally, 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.

Table 13-3. Powderhorn Lake yearly outlet pumping volume in gallons.

2016	2017	2018	2019	2020
18,004,800 gal	19,258,800 gal	14,163,600 gal	38,194,200 gal	17,430,600 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 2020 ($p > 0.05$). 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 lower water quality; however, TSI scores were lower in 2018 and 2019 likely due to the absence of severe blue-green algal blooms. The

TSI score for Powderhorn Lake in 2020 was 74, classifying the lake as hypereutrophic having dense algae.

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 13-4**. 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**.

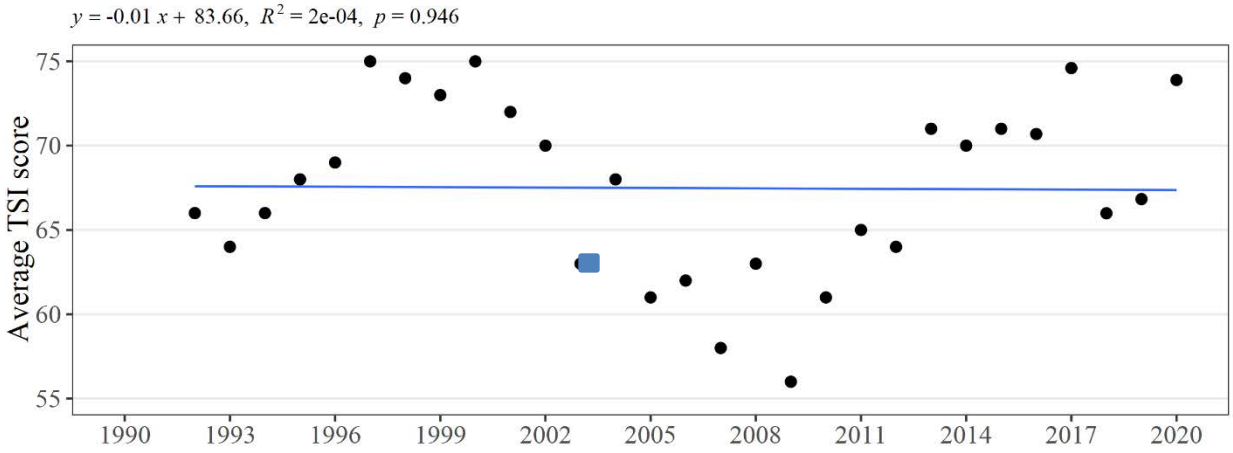


Figure 13-4. Powderhorn Lake TSI scores and linear regression from 1992-2020. The blue square highlights the 2003 alum treatment.

Table 13-4. Powderhorn Lake Secchi, chlorophyll-*a*, and total phosphorus TSI based on data collected between June and September 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	74	43-54	Not within range, worse than expected
Chlorophyll-*a*	72	46-61	Not within range, worse than expected
Total Phosphorus	79	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 shallow lake standards, 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, 1992-2020, can be found in **Appendix A**.

Water clarity in 2020 was comparable to previous years, having a smaller range than the previous four years, with an average of 0.5 meters, see **Figure 13-5a**. Chlorophyll-*a* concentrations in 2020 were similar to 2017 having higher concentrations and more variability. The average chlorophyll-*a* concentration in 2020 was 58.9 µg/L, see **Figure 13-5b**. Total phosphorus was also similar to 2017 having high concentrations, with an average of 170 µg/L, see **Figure 13-5c**. The lake exceeded MPCA eutrophication standards for water clarity, chlorophyll-*a*, and total phosphorus in 2020. Since 2009 all three parameters worsened with no perceived explanation.

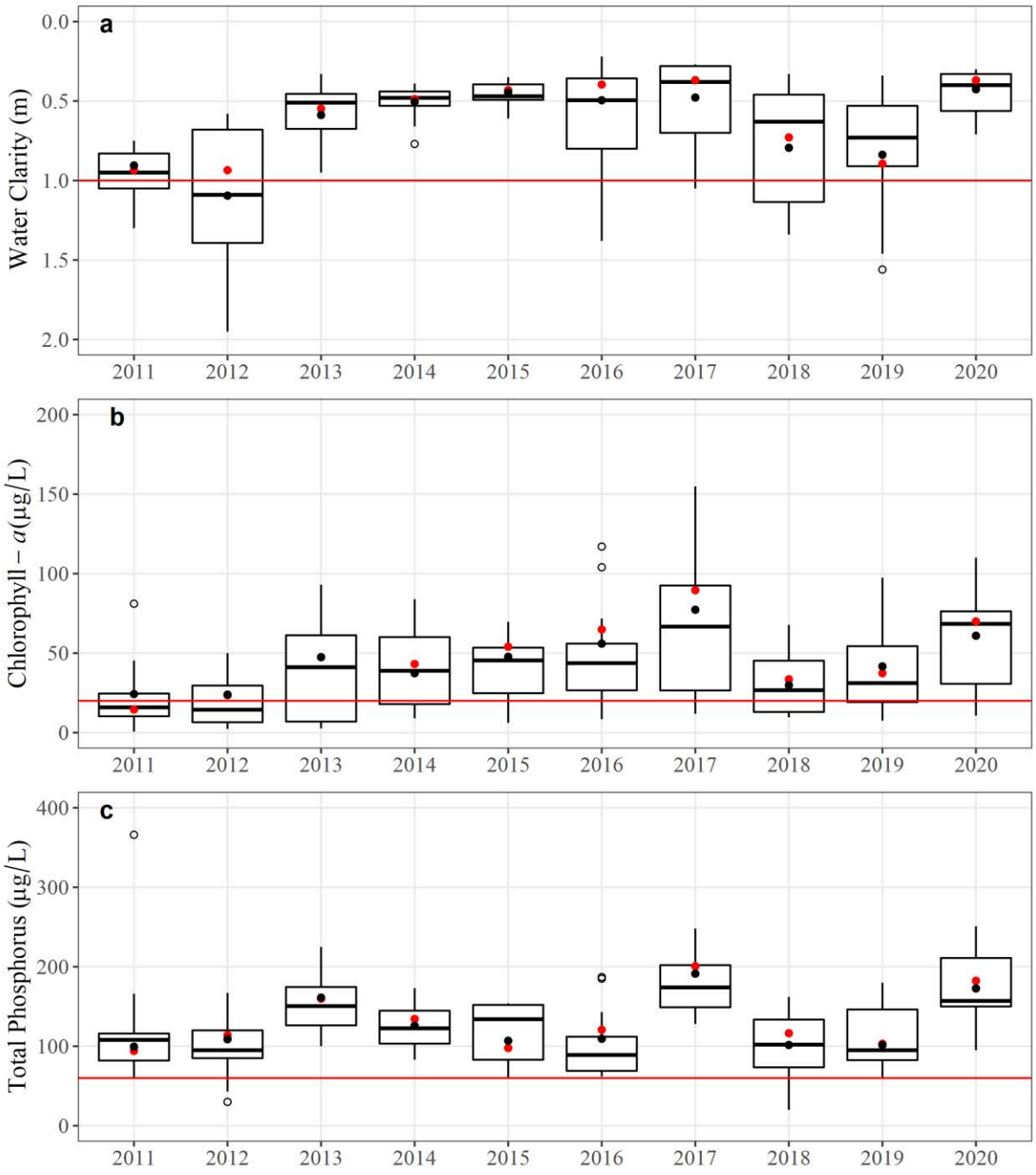


Figure 13-5. Powderhorn Lake box and whisker plots of water clarity (a), chlorophyll-*a* (b), and total phosphorus (c) from 2011 to 2020. Horizontal lines represent MPCA eutrophication standard for shallow lakes, which applies to data collected between June and September. The red circles represent the 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 1992-2020 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. Since 2009, total nitrogen levels have been slowly increasing, with 2018-2020 having slightly lower concentrations, see **Figure 13-6**. It is unknown why nitrogen levels decreased, or why nitrogen levels appear to be increasing again. 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.

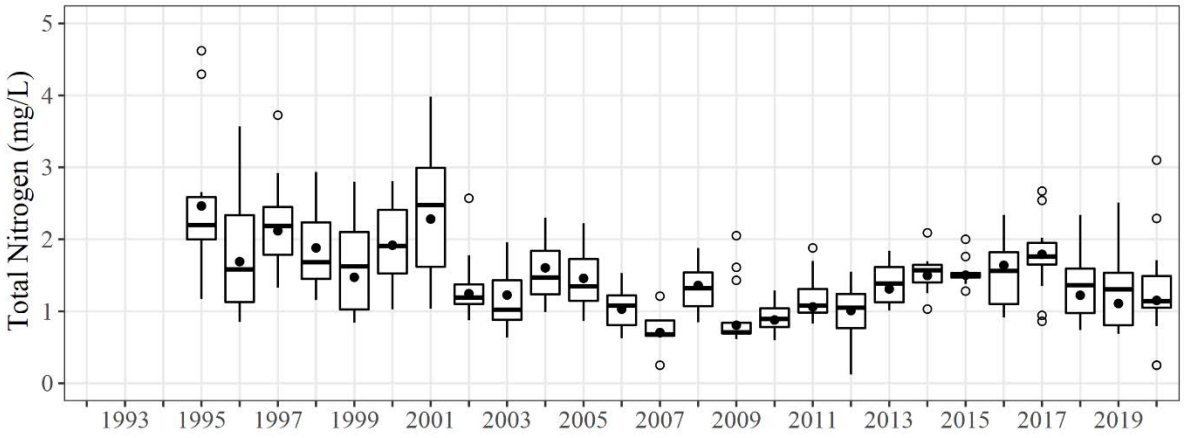


Figure 13-6. Powderhorn Lake box and whisker plot of total nitrogen from 1994-2020. The black circles represent the mean value of data collected during the growing season, May through September.

LAKE AESTHETIC AND USER RECREATION INDEX (LAURI)

The LAURI for Powderhorn Lake is shown in **Figure 13-7**. In 2020, Powderhorn Lake scored good in aesthetics. Powderhorn Lake scored poor in water clarity, habitat quality and recreational access opportunities. Water clarity was poor in 2020 due to a severe blue-green algae bloom. The habitat quality for Powderhorn Lake received a score of poor as the lake does not contain a macrophyte community currently. There were no aquatic plant species identified during a meander survey in 2015 and subsequently in 2019. Powderhorn Lake does not have a swimming beach and therefore was not scored for public health. See **Chapter 1** for details on the LAURI.

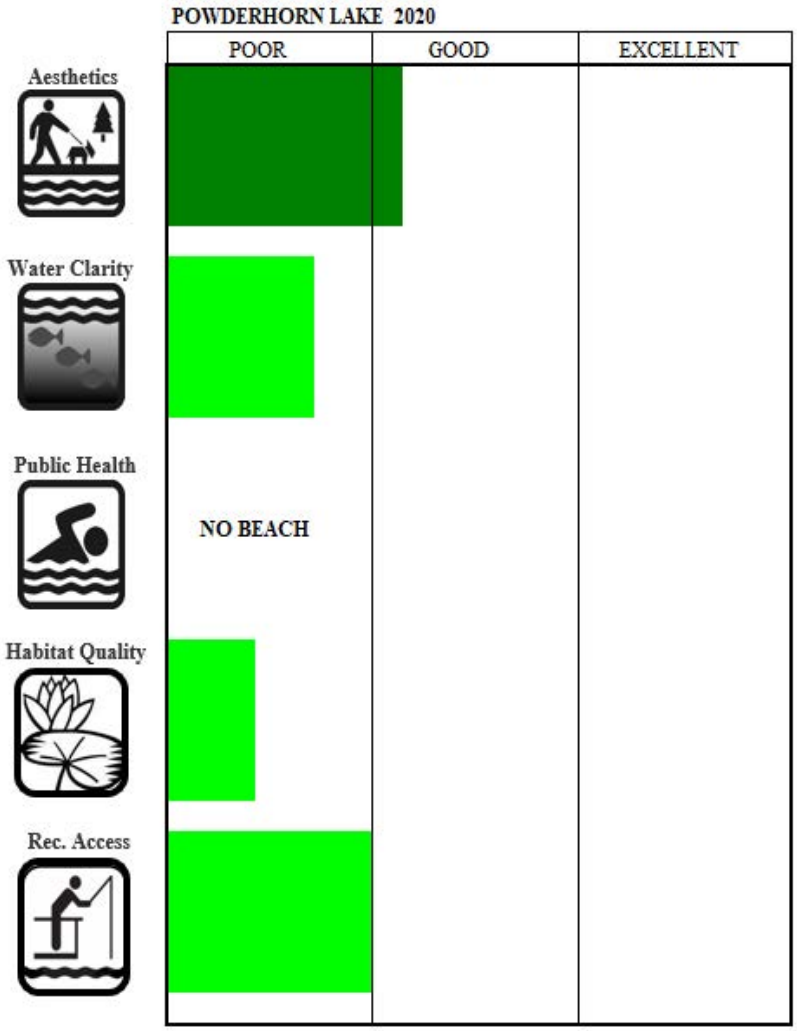


Figure 13-7. The 2020 LAURI for Powderhorn Lake.

WINTER ICE COVER

Ice came off Powderhorn Lake on March 27, 2020, eight days later than the average ice-off date. Ice came back onto the lake on December 1, 2020, two 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 13-8** shows the water clarity, chlorophyll-*a* concentrations, and relative abundance of phytoplankton divisions during 2020. 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 2020 remaining below 0.75 meters for the entire sampling season. Water clarity was deepest in the spring at 0.7 meters and shallowest in early August at 0.3 meters when chlorophyll-*a* levels were high, see **Figure 13-8a, b**. Chlorophyll-*a* concentrations were highest in late July at 110 µg/L when the phytoplankton community primarily consisted of blue-green algae (Cyanophyta). Cryptomonads (Cryptophyta) dominated the phytoplankton population when chlorophyll-*a* concentrations were lowest in fall at 10.7 µg/L, see **Figure 13-8b, c**.

The phytoplankton community in Powderhorn Lake primarily consisted of green algae (Chlorophtya) early in the year and blue-green algae later in the year. Diatoms (Bacillariophyta) dominated the population in early May and cryptomonads dominated the population in the fall. Euglenoids (Euglenophyta) and dinoflagellates (Pyrrhophyta) were present in low levels in 2020, see **Figure 13-8c**.

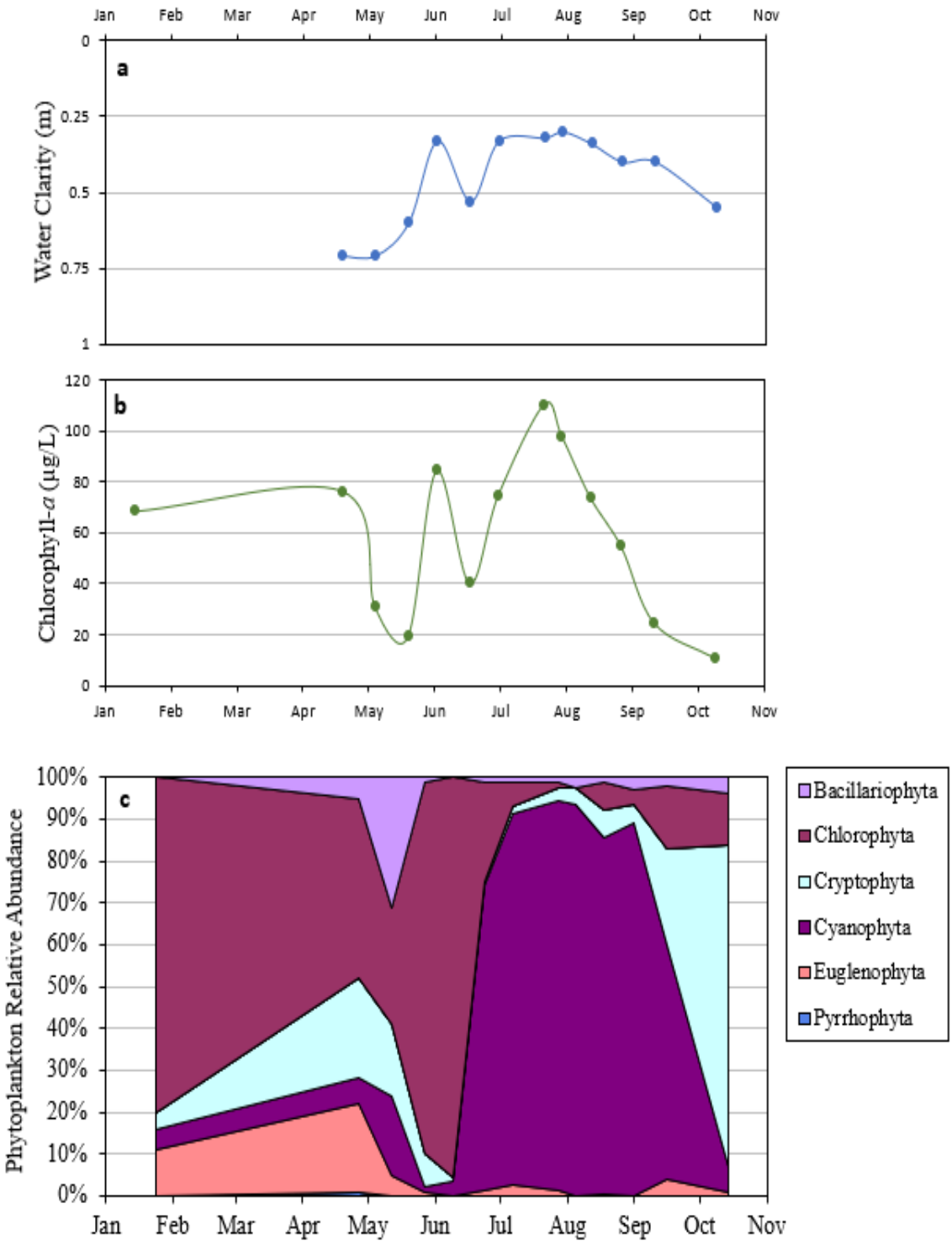


Figure 13-8. Water clarity (a), chlorophyll-*a* concentration (b), and relative abundance of phytoplankton (c) in Powderhorn Lake during 2020. Note that the water clarity axis is reversed.

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 13-9** shows the zooplankton distribution in Powderhorn Lake sampled throughout 2020. Rotifers were present throughout the year and were most abundant in June. Nauplii and juvenile copepods were also present throughout the year and were abundant in May. Cladocerans were most abundant in June, August and October. Cyclopoids and protozoa were present in low levels in 2020.

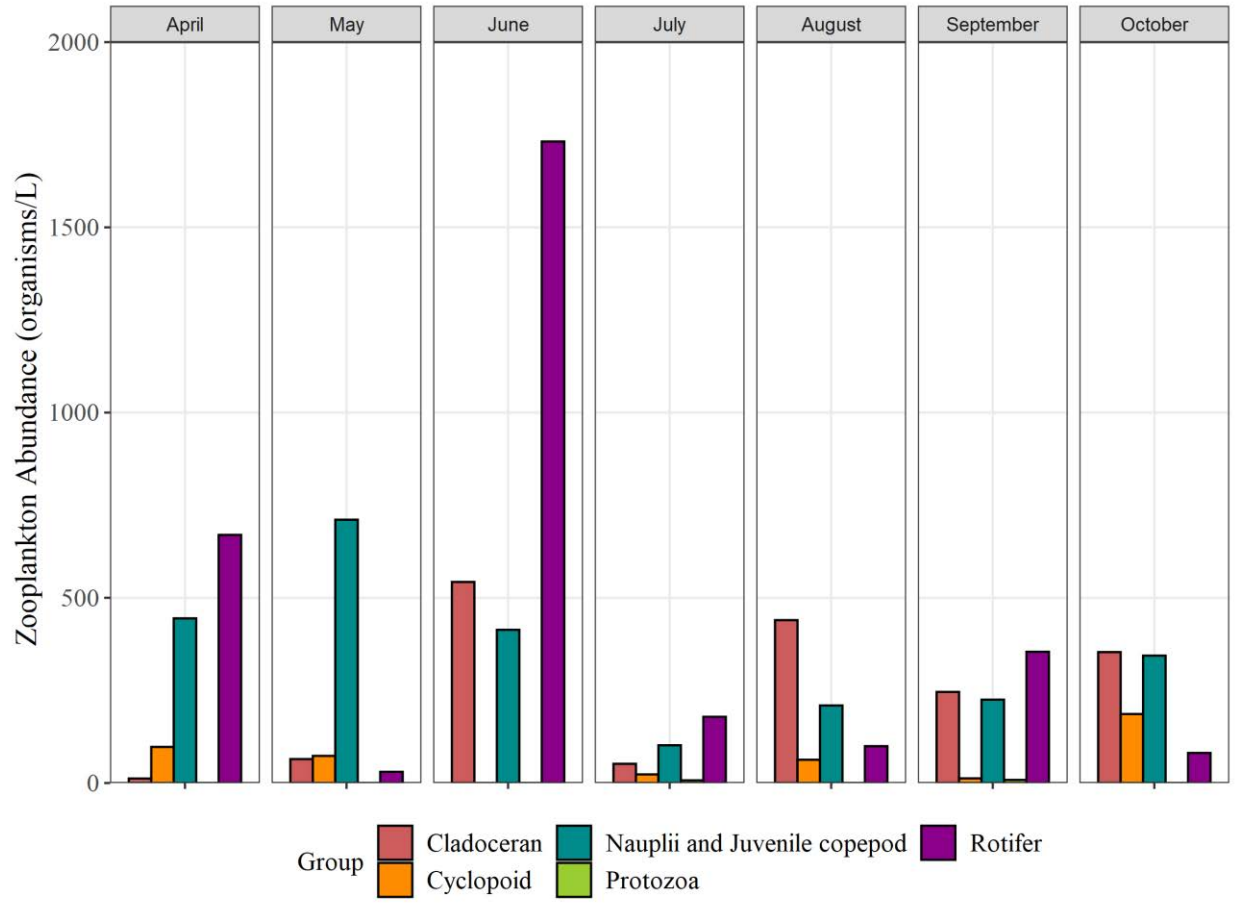


Figure 13-9. Zooplankton density in Powderhorn Lake during 2020.

FISH STOCKING

Table 13-5 shows fish stocked into Powderhorn Lake over the past decade. No fish were stocked into Powderhorn Lake in 2020. Additional fish stocking information can be found in **Chapter 1**.

Table 13-5. 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
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
2012	Bluegill	711 adults	151.4 pounds
2012	Channel Catfish	35 adults	69.0 pounds
2011	Bluegill	277 adults	63.4 pounds
2011	Channel Catfish	116 adults	237.2 pounds
2011	Largemouth Bass	13 adults	13.7 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 negative 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.

After water quality improved enough to meet state standards between 2005 and 2009, there has been an increase in nuisance blue-green algae in recent years and an increase in TSI score. Nutrients such as nitrogen and phosphorus drive algae growth. Nutrients enter the lake from two sources - internal load and external load. Internal loads may come from sediment release or fish effects, while external loads primarily arise from pollution originating from human activity and surface runoff.

One idea that may explain the trend could be that barley straw was increasing dissolved organic carbon (DOC) concentrations and preventing light penetration in Powderhorn Lake. A decrease in light can prevent plant growth, meaning that only algae may have been available to use nutrients in the water. To determine the impact of barley straw on DOC concentrations, Powderhorn DOC concentrations were compared to DOC concentrations of seven other lakes in Minneapolis. The University of Minnesota (UMN) collected DOC data on Bde Maka Ska, Harriet, Hiawatha, Nokomis, Cedar, Isles, and Wirth Lake in 2016 and 2017. MPRB collected DOC data on Powderhorn Lake between 2018 and 2020. **Table 13-6** shows that Lake Hiawatha had the highest mean DOC and was the only lake that was significantly similar to Powderhorn Lake. Lake Hiawatha does not receive barley straw treatments but has a higher mean DOC concentration than Powderhorn Lake. Also, the mean DOC concentration in Powderhorn Lake did not change significantly between 2018 at 7.73 mg/L and 2020 at 7.09 mg/L although barley straw treatments occurred every year; therefore, barley straw treatments are likely not the reason for declining water quality in Powderhorn Lake.

Table 13-6. DOC levels in Minneapolis lakes compared to DOC levels in Powderhorn Lake. Bde Maka Ska, Harriet, Hiawatha, Nokomis, Cedar, Isles and Wirth Lake data was collected in 2016 and 2017 and Powderhorn data was collected between 2018 and 2020.

Lake	Mean DOC (mg/L)	Difference Compared to Powderhorn Lake	% Difference Compared to Powderhorn Lake
Bde Maka Ska	5.17	1.92	30
Harriet	6.26	0.83	12
Hiawatha	7.16	0.07	1
Nokomis	6.40	0.69	10
Cedar	5.77	1.32	21
Isles	5.55	1.54	24
Wirth	4.53	2.56	44
Powderhorn	7.09	—	—

Another theory was that although the summer aeration system is intended to keep oxygen in the water column, it may be mixing phosphorus from the sediment into the water column. To illustrate, the average percent dissolved oxygen in Lake Nokomis, which is not aerated, was 92% at 2-meters of depth in 2020, while aerated Powderhorn Lake averaged 68% at the same time. To test whether the aeration system was increasing phosphorus concentrations, the summer aeration system was turned off for 2019 and was turned on for most of 2020.

Table 13-7 and Figure 13-10 shows Secchi readings, chlorophyll-*a*, and total phosphorus concentrations in Powderhorn Lake between 2017 and 2020**.** After leaving the aeration system off, the average TSI score for Powderhorn Lake decreased to 67 in 2019 from 75 in 2017, meaning the water quality improved. Total phosphorus measurements had the most significant change between 2017 and 2019. The decrease in TSI score, in both 2018 and 2019, may be due to decreased phosphorus inputs from limiting the amount of time the aeration system was on. Sediment acts as a sink where phosphorus can be stored, and it is likely that the aeration system did not provide enough oxygen to the water column to hold phosphorus in the sediment. Nuisance blue-green algal blooms did not occur in either 2018 or 2019, making the Secchi readings deeper and decreasing the chlorophyll-*a* concentrations, which also contributed to the improved TSI score. In 2020 the aeration system was turned on in early May and turned off in mid-October. The TSI score increased to 74, meaning the water quality declined. Severe blue-green algae blooms occurred in Powderhorn Lake in 2020 causing the water clarity to be shallower and increasing the chlorophyll-*a* concentrations. There is likely no significant change between Secchi readings, chlorophyll-*a*, and total phosphorus between 2017 and 2020 because the summer aeration system was turned on for most of the year.

Table 13-7. Average Secchi disk readings, chlorophyll-a, and total phosphorus on Powderhorn Lake between 2017 and 2020. *Note that the aeration system was turned on for a limited amount of time during the 2018 and 2019 sampling season.

Parameter	2017 Average	2018 Average*	2019 Average*	2020 Average	P-value Comparing 2017 and 2020
Secchi Disk	0.52	0.77	0.81	0.46	0.57
Chlorophyll-*a*	69.2	31.7	39.2	58.9	0.50
Total Phosphorus	0.18	0.10	0.11	0.17	0.66

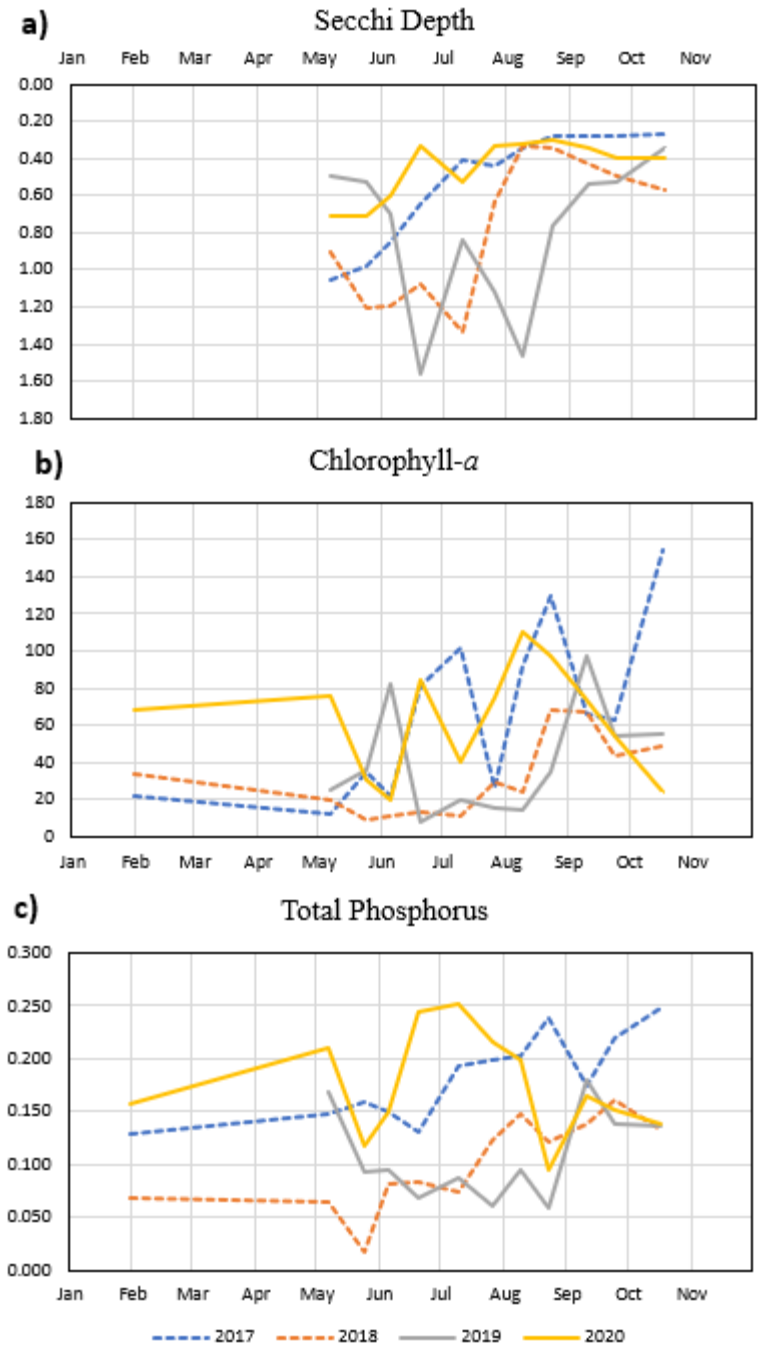


Figure 13-10. Secchi disk readings (a), chlorophyll-a (b), and total phosphorus concentrations (c) in Powderhorn Lake between 2017 and 2020. Note that the Secchi depth axis is reversed and that the aeration system was turned on for a limited amount of time during the 2018 and 2019 sampling season.

The last theory was that better water quality years, with higher Secchi disk readings and less blue-green algae, were correlated with low water years. In a drought, low water levels could create conditions where light penetrated to the bottom of the lake and facilitated plant growth. Increased plant growth could decrease algae by competing for the same nutrients. Additionally, increased plant growth could stabilize sediment, slightly decreasing internal phosphorus load. This theory is harder to test. Option one would be to wait for several consecutive years of drought and lower water artificially with the outflow pump, which would require a DNR permit. Option two would be to test whether lower water alone was the limiting factor by separating low water from low phosphorus inputs due to drought. Option two would likely only be permitted if a robust experiment could be carried out.

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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. In the spring of 2006, a small rain garden was constructed, and in 2018, canoe racks were installed. 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 from the fishing pier at Ryan Lake in August 2020.

Ryan Lake is a deep, mesotrophic lake that has relatively good water quality. **Table 14-1** shows the physical characteristics of Ryan Lake and **Figure 14-2** shows a bathymetric map of the lake. Ryan Lake is part of 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 but has not been monitored by CAMP since 2015. Over the years, the Ryan Lake CAMP score has fluctuated between a "B" and "D", with a most recent score of a "B" in

2012. 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 listed on the Minnesota Pollution Control Agency (MPCA)'s list of impaired waters (303(d) list) for excess nutrients. A TMDL and an implementation plan were approved in 2007 along with the Twin Lake chain of lakes. 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. 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/water/tmdl/twin-and-ryan-lakes-excess-nutrients-tmdl-project). Ryan lake has experienced several winter fish kills due to low dissolved oxygen levels.

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 chain of lakes. 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.

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.**

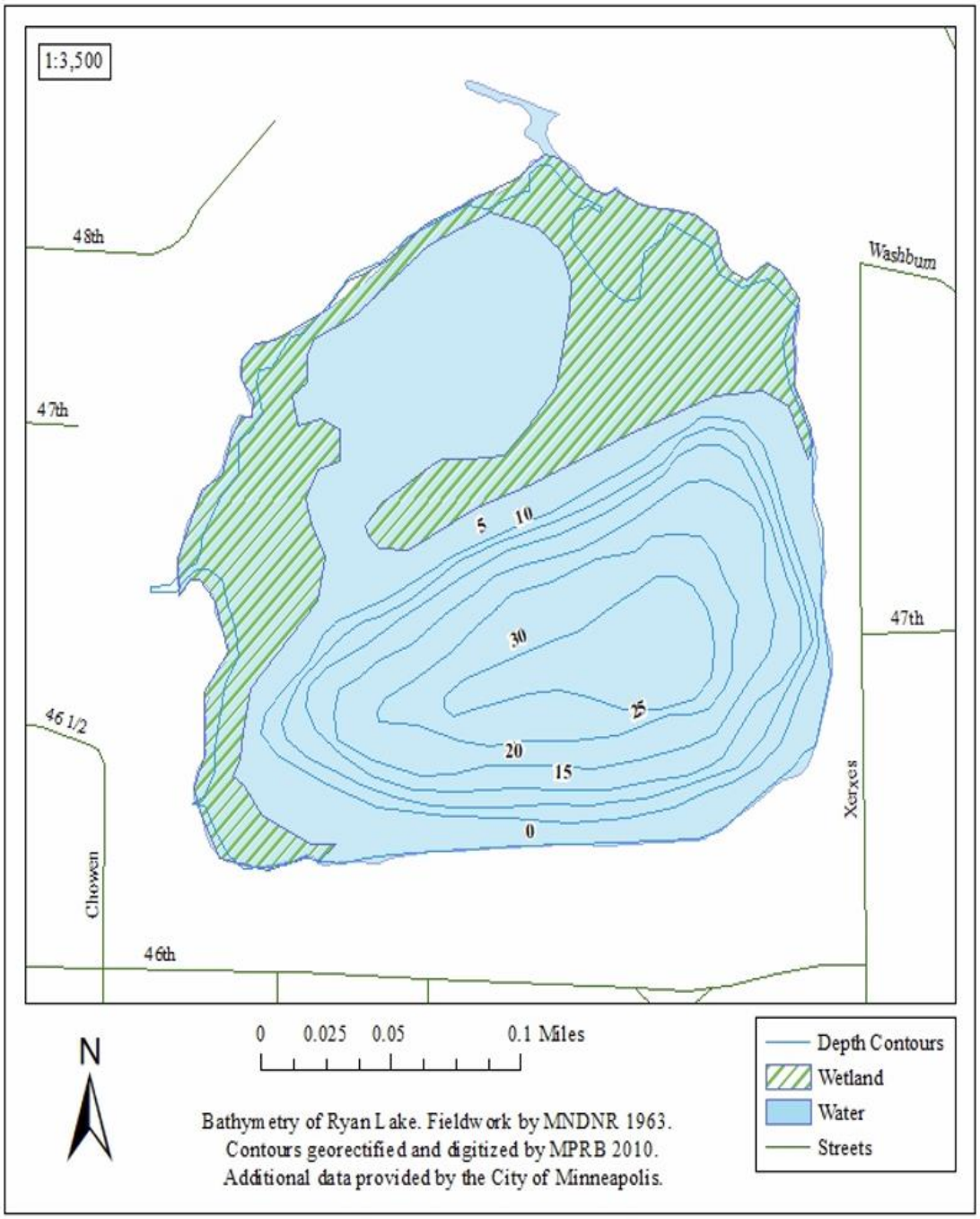


Figure 14-2. Bathymetric map of Ryan Lake.

WINTER ICE COVER

Ice came off of Ryan Lake on March 28, 2020, seven days earlier than the average. Ice came back on Ryan Lake on December 15, 2020, eight days later 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.

FISH STOCKING

Table 14-2 shows fish stocked into Ryan Lake over the past decade. No fish were stocked into Ryan Lake in 2020. 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
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
2011	Black Crappie	20 adults	9.1 pounds
2011	Bluegill	20 adults	5.0 pounds
2011	Largemouth Bass	6 adults	6.3 pounds

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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 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 lumberyard. A photograph of Spring Lake is presented below in **Figure 15-1**.



Figure 15-1. Duckweed on Spring Lake in August 2020.

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 also 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 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 is normally monitored every other year and was not monitored in 2020. The lake was sampled each year from 2011-2015 to assess potential water quality effects of several artificial islands that were installed.

Table 15-1. Spring Lake physical characteristics.

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	1.29x106	45	15.0	820.46

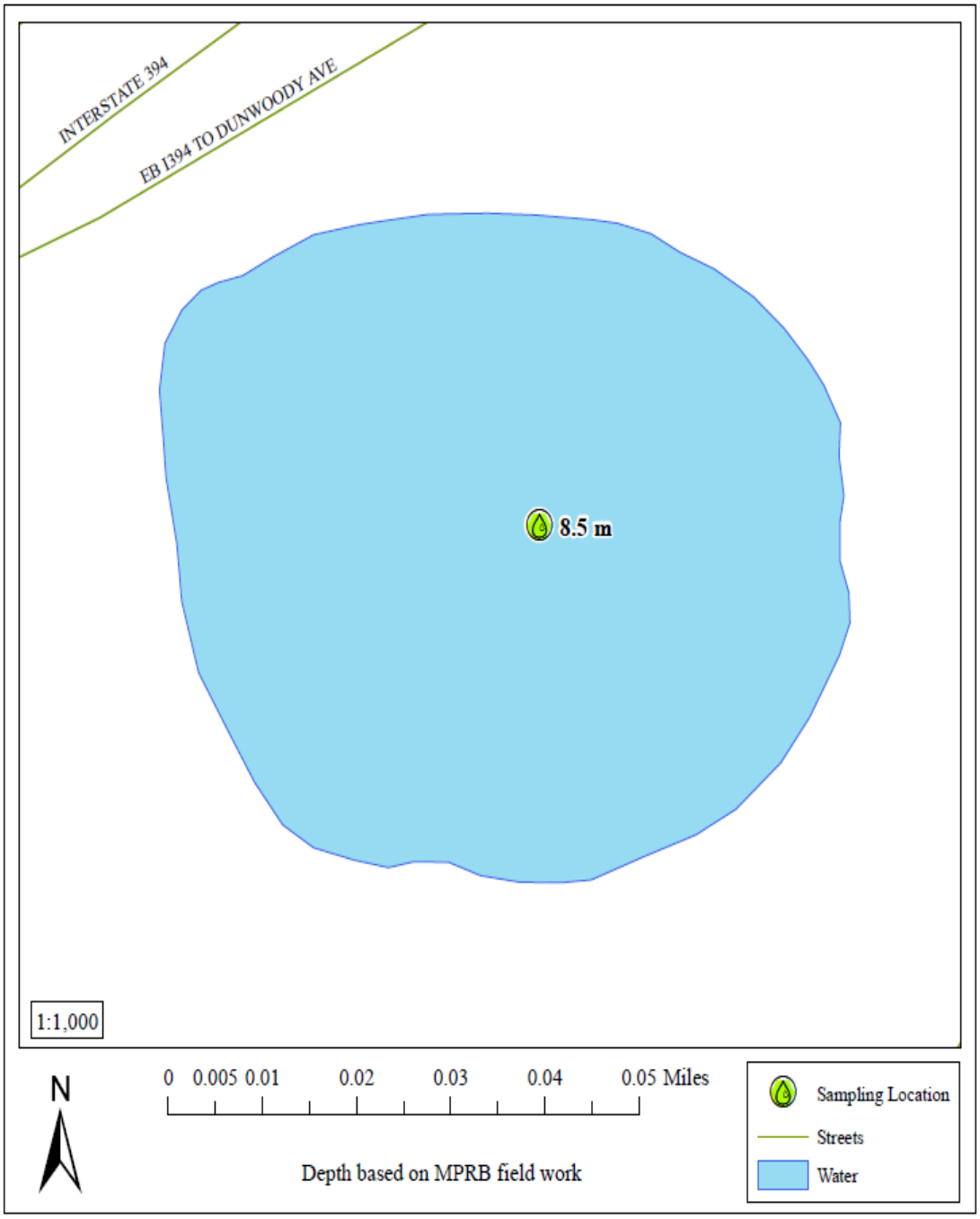


Figure 15-2. Map showing the location of Spring Lake and the water quality sampling station.

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 1995-2019 ($p > 0.05$). 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 2019 was 83, 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 Minneapolis 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**.

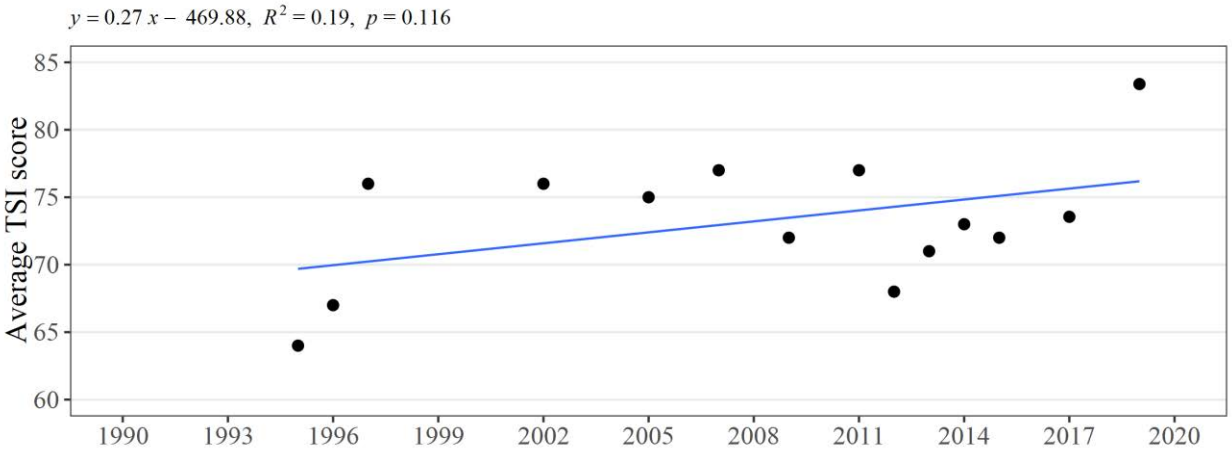


Figure 15-3. Spring Lake TSI scores and linear regression from 1995-2019.

Table 15-2. Spring Lake Secchi, chlorophyll-*a*, and total phosphorus TSI based on data collected between June and September 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	63	43-54	Not within range, worse than expected
Chlorophyll-*a*	80	46-61	Not within range, worse than expected
Total Phosphorus	105	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 2010 to 2019, based on data from the entire sampling season. Red horizontal lines on the graphs indicate the MPCA shallow lake standards, which applies to data collected between June and September. The 303(d) assessment for impaired waters is limited to lakes of ten acres or greater (MPCA, 2014). Spring Lake is too small (3 acres) to be listed on MPCA's impaired waters list; however, it is still useful to compare Spring's data to the state standards to determine 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, 1994-2019, can be found in **Appendix A**.

Water clarity in 2019 was slightly worse compared to previous years with an average Secchi depth of 0.7 meters. Chlorophyll-*a* concentrations ranged between 2.72 and 350 µg/L with higher concentrations in spring, August, and fall. Historically, total phosphorus concentrations have been high in Spring Lake. In 2019, phosphorus levels had an average of 1,188 µg/L, which is elevated in comparison to previous years and far exceeds the MPCA standard. The average phosphorus level in Spring Lake has doubled since 2017, with the highest concentration occurring in August of 2019. 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 2019 due to excessive algae growth caused by high concentrations of phosphorus. As the algae die and decompose, the process consumes dissolved oxygen.

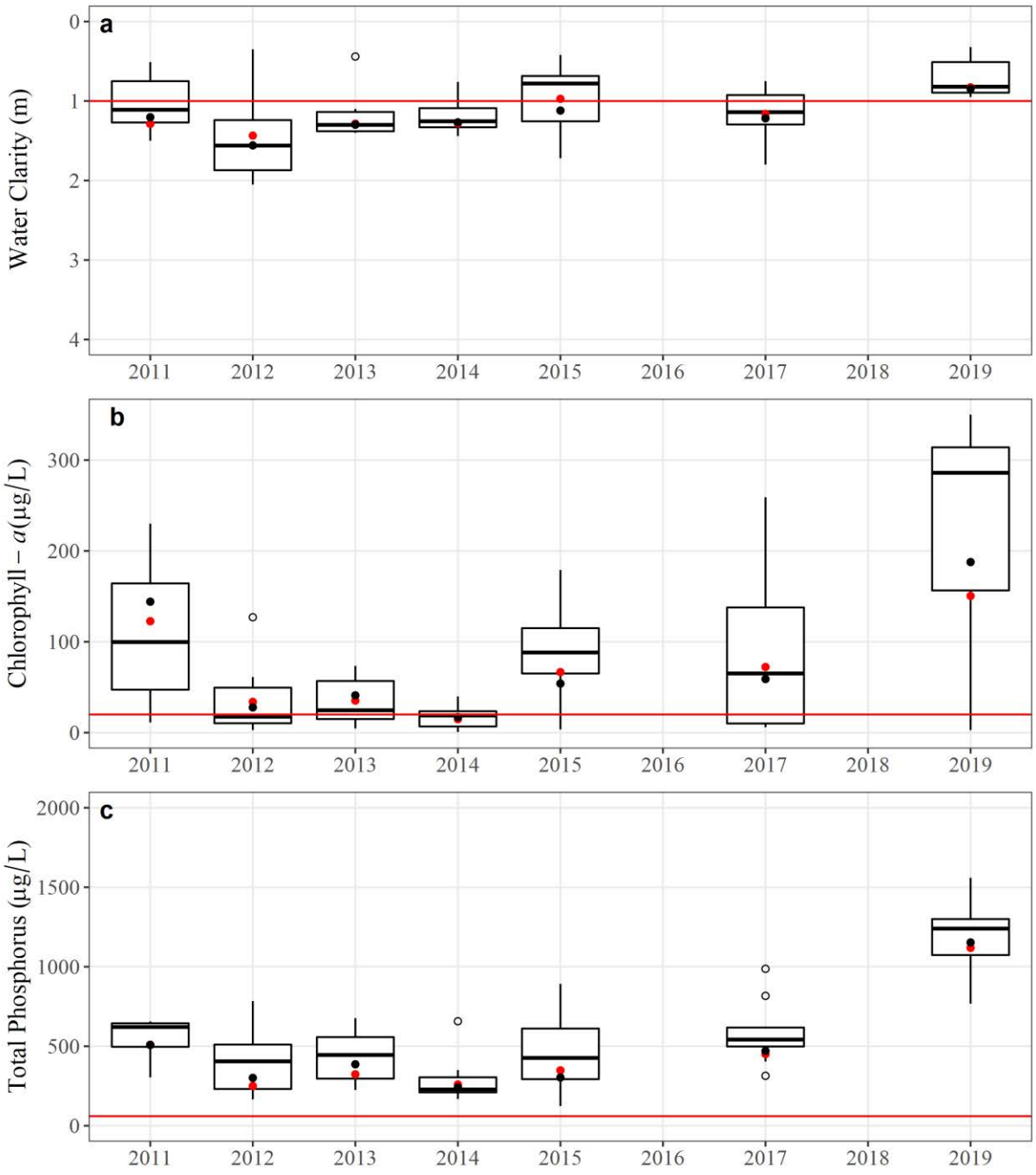


Figure 15-4. Spring Lake box and whisker plots of water clarity (a), chlorophyll-*a* (b), and total phosphorus (c), from 2010-2019. Horizontal lines represent MPCA eutrophication standard for shallow lakes, which applies to data collected between June and September. The red circles represent the mean 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 1994-2019 can be found in Appendix A.

WINTER ICE COVER

The ice came off Spring Lake on March 25, 2020, seven days earlier than the average ice-off. Ice covered Spring Lake on November 30, 2020, 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 15-5** shows the water clarity, chlorophyll-*a* concentrations, and relative abundance of phytoplankton divisions for Spring Lake in 2019. Although zooplankton weren't sampled, observations of surface water noted bright red zooplankton on several occasions. Certain zooplankton can produce a substance similar to hemoglobin that they use to store oxygen when living in low-oxygen environments, making them appear red.

Water clarity was relatively correlated to chlorophyll-*a* concentrations for Spring lake in 2019. As chlorophyll-*a* concentration decreased water clarity increased. The water was less clear in April at 0.3 meters and was the clearest in June at 1.0 meter. Water clarity declined in July, increased again in late summer, and declined in the fall. Similarly, chlorophyll-*a* concentrations were highest in the spring at 350 µg/L primarily consisting of green algae (Chlorophyta) and declined to 2.72 µg/L in June. Concentrations continued to increase until August, decreased in September and increased again in fall, see **Figure 15-5a, b**.

The phytoplankton community in Spring Lake primarily consisted of green algae and cryptomonads (Cryptophyta) in 2019. Green algae dominated the population in April and May. Cryptomonads dominated the population the rest of 2019 with relative abundances greater than 90% from August through October. Diatoms (Bacillariophyta), blue-green algae (Cyanophyta), euglenoids (Euglenophyta) and dinoflagellates (Pyrrhophyta) were also present in small numbers, see **Figure 15-5c**. In past sampled years, Spring Lake has had a diverse phytoplankton community; however, the community has consisted of mostly *C. erosa* since 2011. *Lemna* cover in recent years may be affecting the phytoplankton community composition, since *C. erosa* can survive in low light conditions.

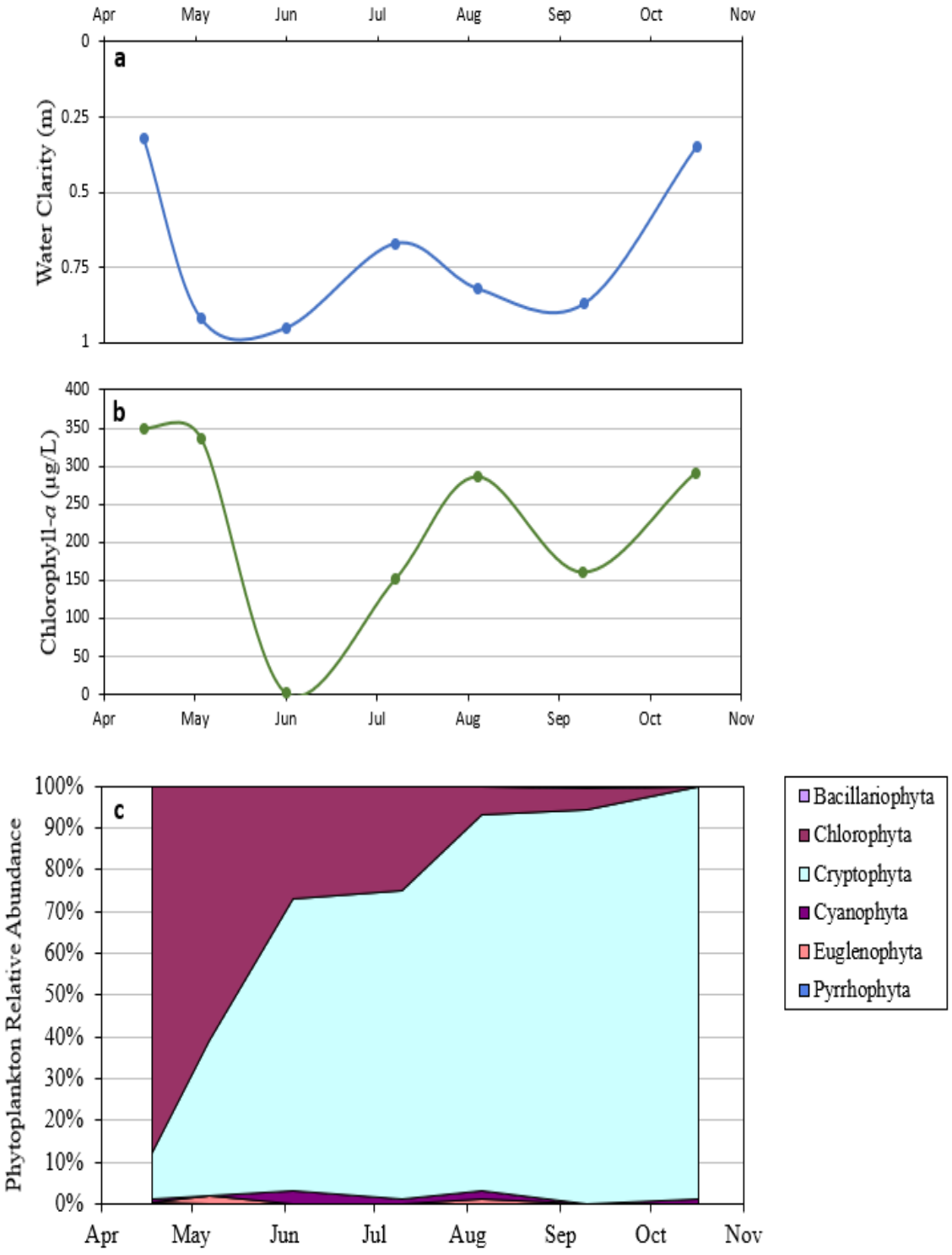


Figure 15-5. Water clarity (a), chlorophyll-*a* concentration (b), and relative abundance of phytoplankton (c) in Spring Lake during 2019. Note that the water clarity axis is reversed.

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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 lakes in the MPRB, 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 August 2020.

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 of Wirth Lake and **Figure 16-2** shows a bathymetric map. Wirth Lake is part of Basset 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. Water quality on Wirth Lake has been monitored annually since 1992. 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 summer aerator was installed and operated

from the early 1980s until 1991 before being abandoned as unnecessary. 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.

Table 16-1. Wirth Lake physical characteristics.

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%	$2.37x10^7$	348	9.4

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

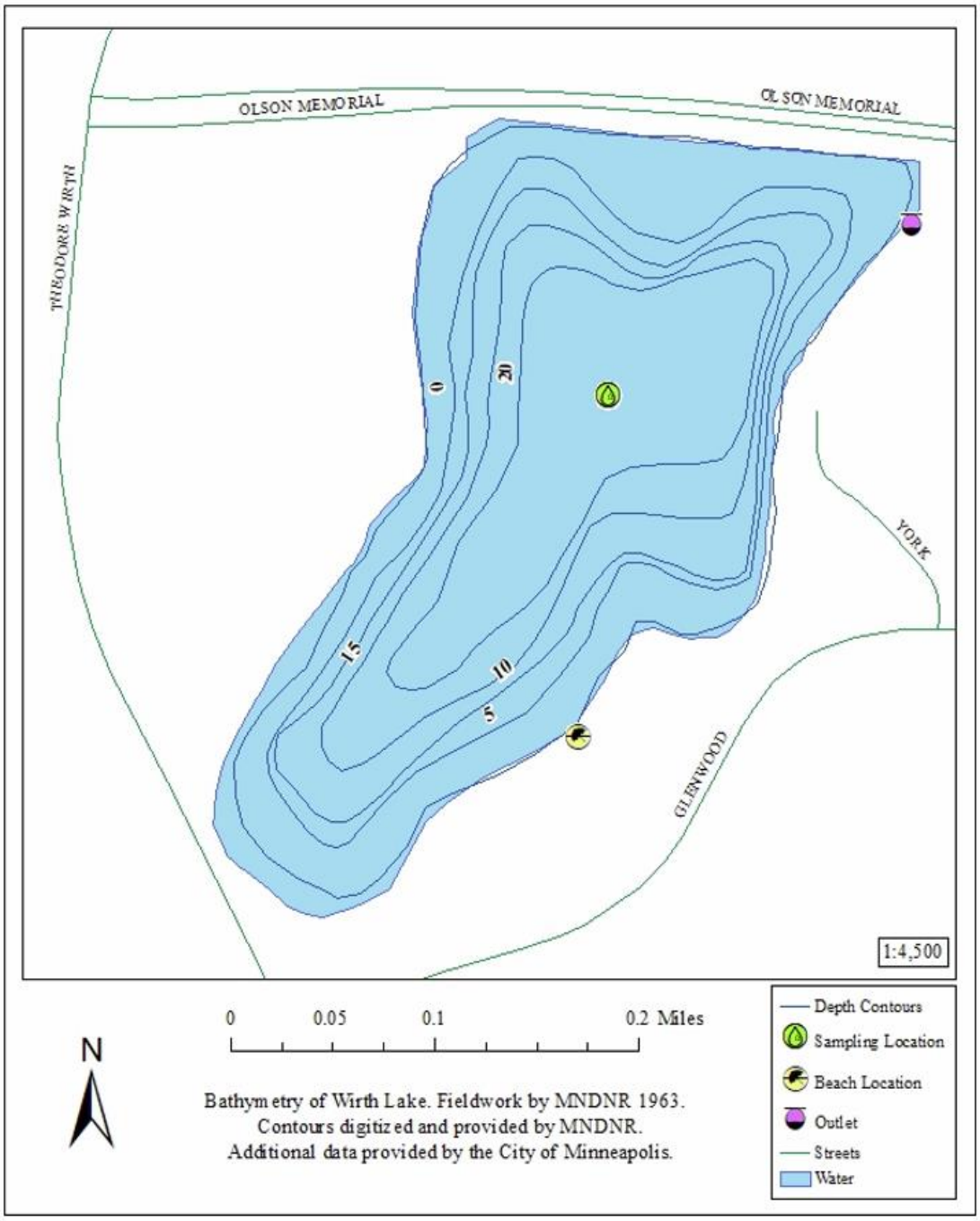


Figure 16-2. Bathymetric map of Wirth Lake. The green circle represents the sampling location, yellow circle represents the beach location, and purple circle represents the outlet.

LAKE LEVEL

The lake levels for Wirth Lake from 1971 to 2020 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 new outlets installed in 1978 and in 1996 on water level fluctuations can be seen in the graph below. Since the installation of the 1996 outlet fewer high flow events have backed up water from Bassett Creek into the lake. The outlet to Bassett Creek was renovated and a new lake gage was installed in August 2013. Lake levels remained below the OHWL in 2020. See **Chapter 1** for details on lake level monitoring and **Chapter 17** for a comparison between other MPRB lake levels.

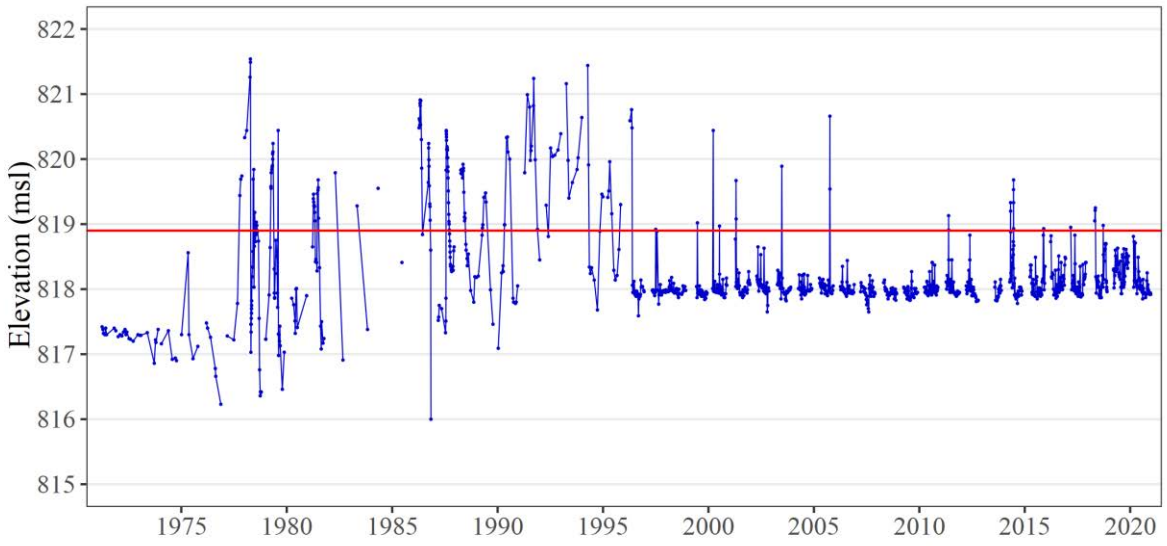


Figure 16-3. Lake levels for Wirth Lake from 1970–2020. Horizontal line represents the Ordinary High Water elevation (818.9 ft. msl) for Wirth Lake.

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 1992-2020 ($p < 0.05$). The TSI score for Wirth Lake in 2020 was 47, classifying the lake as mesotrophic 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 is below the TSI range for the ecoregion, meaning the phosphorus level in Wirth Lake is lower than in comparable lakes. See Minneapolis Pollution Control Agency (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**.

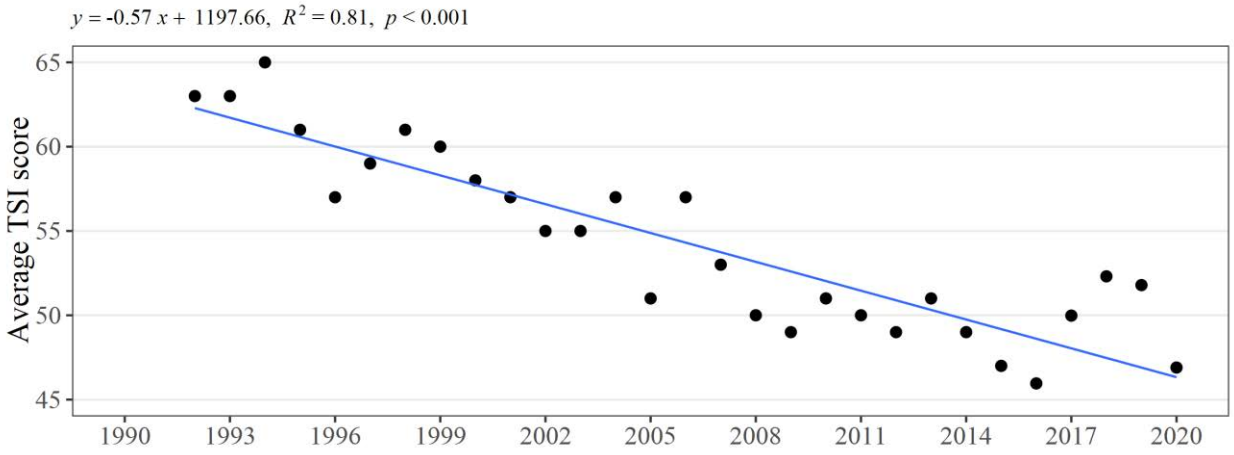


Figure 16-4. Wirth Lake TSI scores and linear regression from 1992-2020.

Table 16-2. Wirth Lake Secchi, chlorophyll-*a*, and total phosphorus TSI based on data collected between June and September 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	44	43-54	Within range
Chlorophyll-*a*	50	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 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 deep lake standards, 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, 1992-2020, can be found in **Appendix A**.

Water clarity in 2020 was similar in comparison to the previous 10 years with an average Secchi depth of 2.8 meters, see **Figure 16-5a**. Chlorophyll-*a* concentrations were lower than 2017-2019 and comparable to prior years with an average concentration of 7 µg/L. Higher concentrations of chlorophyll-*a* were observed in winter, late July and early August, see **Figure 16-5b**. Total phosphorus concentrations in 2020 were slightly lower than previous years with an average of 25 µg/L. The higher concentrations of phosphorus occurred in winter and fall, see **Figure 16-5c**. The lake met MPCA eutrophication standards for water clarity, chlorophyll-*a*, and total phosphorus in 2020. When comparing the boxplots in **Figure 16-5** to those in **Appendix A**, it appears the separation of Bassett Creek from Wirth Lake and upstream water quality improvements in the lake's watershed may be responsible for continued improvement in Wirth Lake.

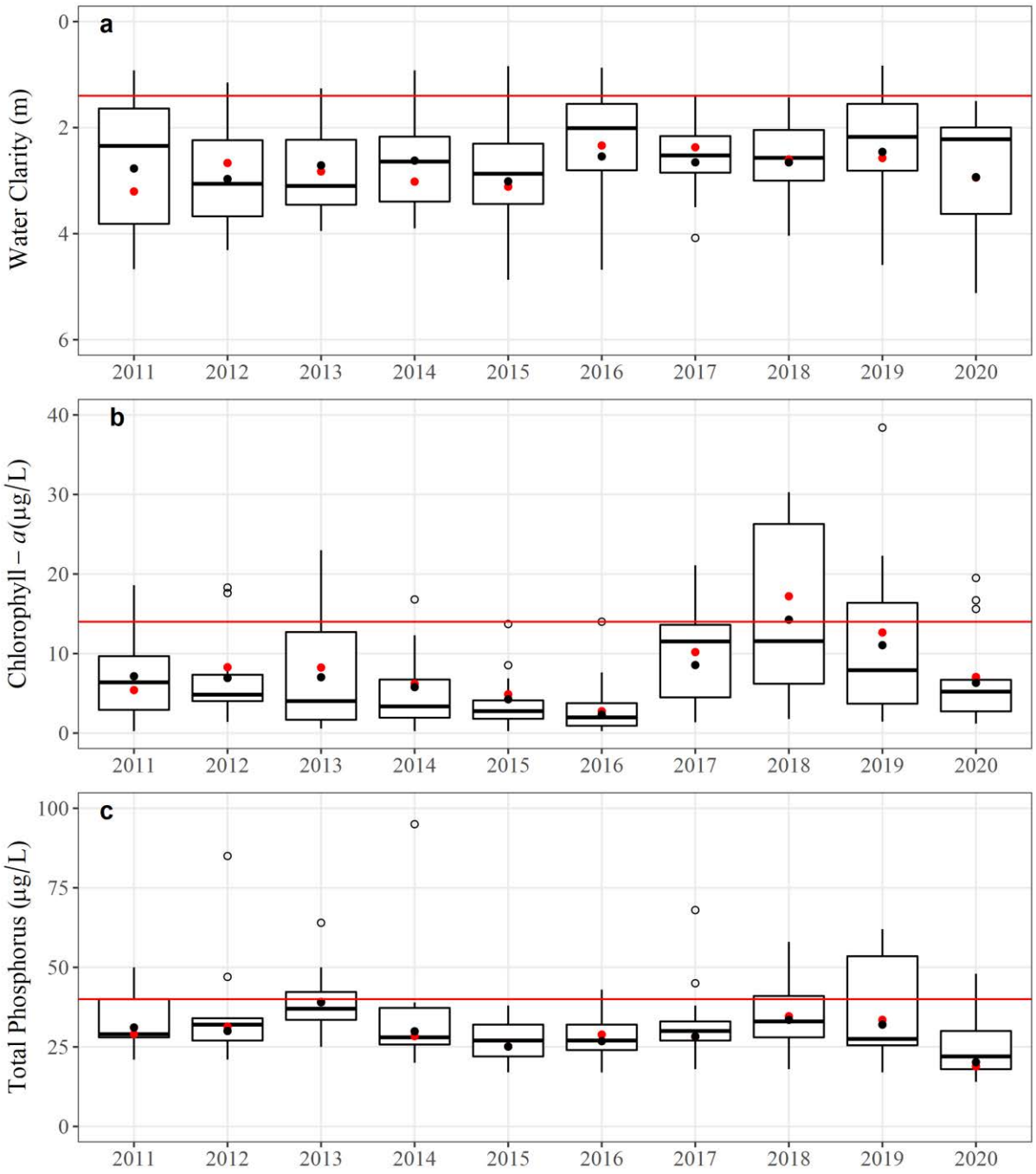


Figure 16-5. Wirth Lake box and whisker plots of water clarity (a), chlorophyll-*a* (b), and total phosphorus (c) data from 2011-2020. Horizontal lines represent MPCA eutrophication standard for deep lakes, which applies to data collected between June and September. The red circles represent the mean 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 1992-2020 can be found in Appendix A.

BEACH MONITORING

Table 16-3 and **Figure 16-6** show *Escherichia coli* (*E. coli*) levels that were monitored weekly from June through August at Wirth Beach in 2020. *E. coli* concentrations were relatively low throughout the beach season, with higher concentrations in mid-July and throughout August. Wirth Beach remained open for the entire 2020 sampling season.

As a result of an unusual early spring algae bloom on Minneapolis lakes in 2020, MPRB developed a blue-green algae index visual monitoring protocol. Visual indicators were noted as part of the protocol for the weekly beach sampling program. See **Chapter 18** for more information on beach and blue-green algae monitoring.

Table 16-3. Summary of *E. coli* (MPN per 100 mL) data for Wirth Beach in 2020.

Statistical Calculations	Wirth
Number of Samples	13
Minimum	1
Maximum	591
Median	8
Mean	143
Geometric Mean	22
Max 30-Day Geo Mean	109
Standard Deviation	195

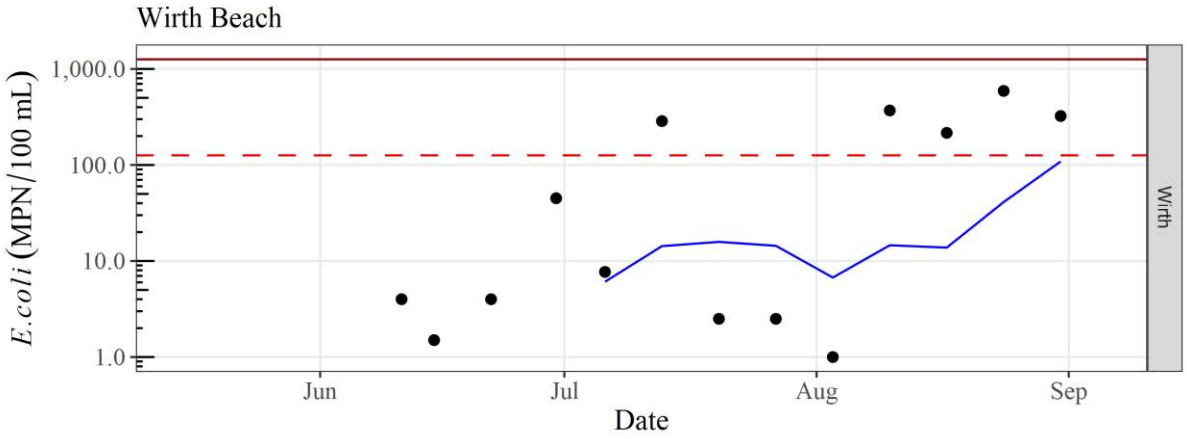


Figure 16-6. 2020 *E. coli* concentrations at Wirth Beach. Blue line is the running 30-day geometric mean. The dashed horizontal line represents the *E. coli* standard for the 30-day geometric mean (126 MPN/100mL) and the solid horizontal line represents the single-sample maximum standard (1260 MPN/100mL). Note the log scale on the Y-axis.

Figure 16-7 shows *E. coli* monitoring data for Wirth Beach from 2011 to 2020 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 2020 *E. coli* results were typical for Wirth Beach.

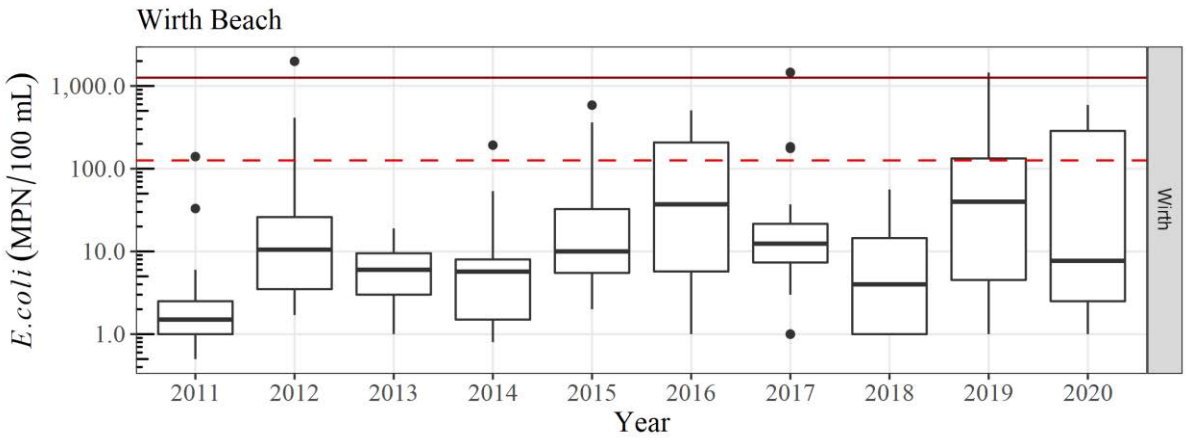


Figure 16-7. Box and whisker plot of *E. coli* concentrations (MPN/100 mL) for Wirth Beach from 2011–2020. The dashed horizontal line represents the *E. coli* standard for the 30-day geometric mean (126 MPN/100mL) and the solid horizontal line represents the single-sample maximum standard (1260 MPN/100mL). Note the log scale on the Y-axis.

LAKE AESTHETIC AND USER RECREATION INDEX (LAURI)

The 2020 LAURI for Wirth Lake is shown in **Figure 16-8**. Wirth Lake scored excellent for aesthetics, public health, habitat quality and recreational access opportunities and good for water clarity. Details on the updated LAURI can be found in **Chapter 1**.

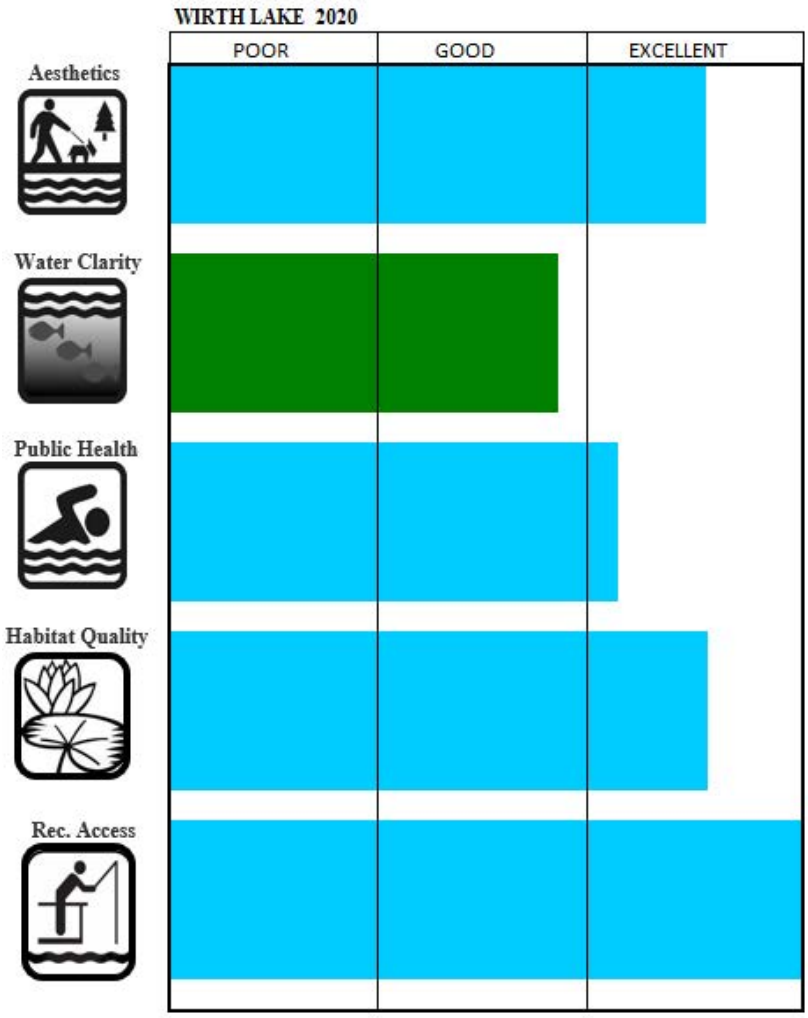


Figure 16-8. Wirth Lake LAURI for 2020.

WINTER ICE COVER

Ice came off Wirth Lake on March 28, 2020, seven days earlier than average ice-off. Ice came onto the lake for the winter on December 1, 2020, one day later 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 2020 was 2.3 acres which is 21% 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 5,680 pounds of aquatic plants were removed from Wirth Lake in 2020. See **Chapter 1** and **Chapter 20** 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 16-9** shows the water clarity, chlorophyll-*a* concentrations, and relative abundance of phytoplankton divisions during 2020. 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 about 2 meters and gradually increased until late June when water clarity reached its deepest reading at 5.1 meters when the phytoplankton community primarily consisted of green algae (Chlorophyta), see **Figure 16-9a, c**. Water clarity then decreased gradually until early September reaching its shallowest reading at 1.5 meters when blue-green algae (Cyanophyta) dominated the phytoplankton population. Chlorophyll-*a* concentrations were highest in winter at 19.5 µg/L when the phytoplankton community primarily consisted of cryptomonads (Cryptophyta). Blue-green algae dominated the phytoplankton population when chlorophyll-*a* concentrations were lowest in mid-September at 1.2 µg/L, see **Figure 16-9b, c**.

The phytoplankton community varied greatly over the course of 2020. Cryptomonads dominated the population in winter, spring, and fall. Dinoflagellates (Pyrrhophyta) dominated the population in late May and early July. Green algae dominated the population throughout June. Blue-green algae dominated the population between July and September. Diatoms (Bacillariophyta), chrysophytes (Chrysophyta), euglenoids (Euglenophyta), and haptophytes (Haptophyta) were present in low levels in 2020, see **Figure 16-9c**.

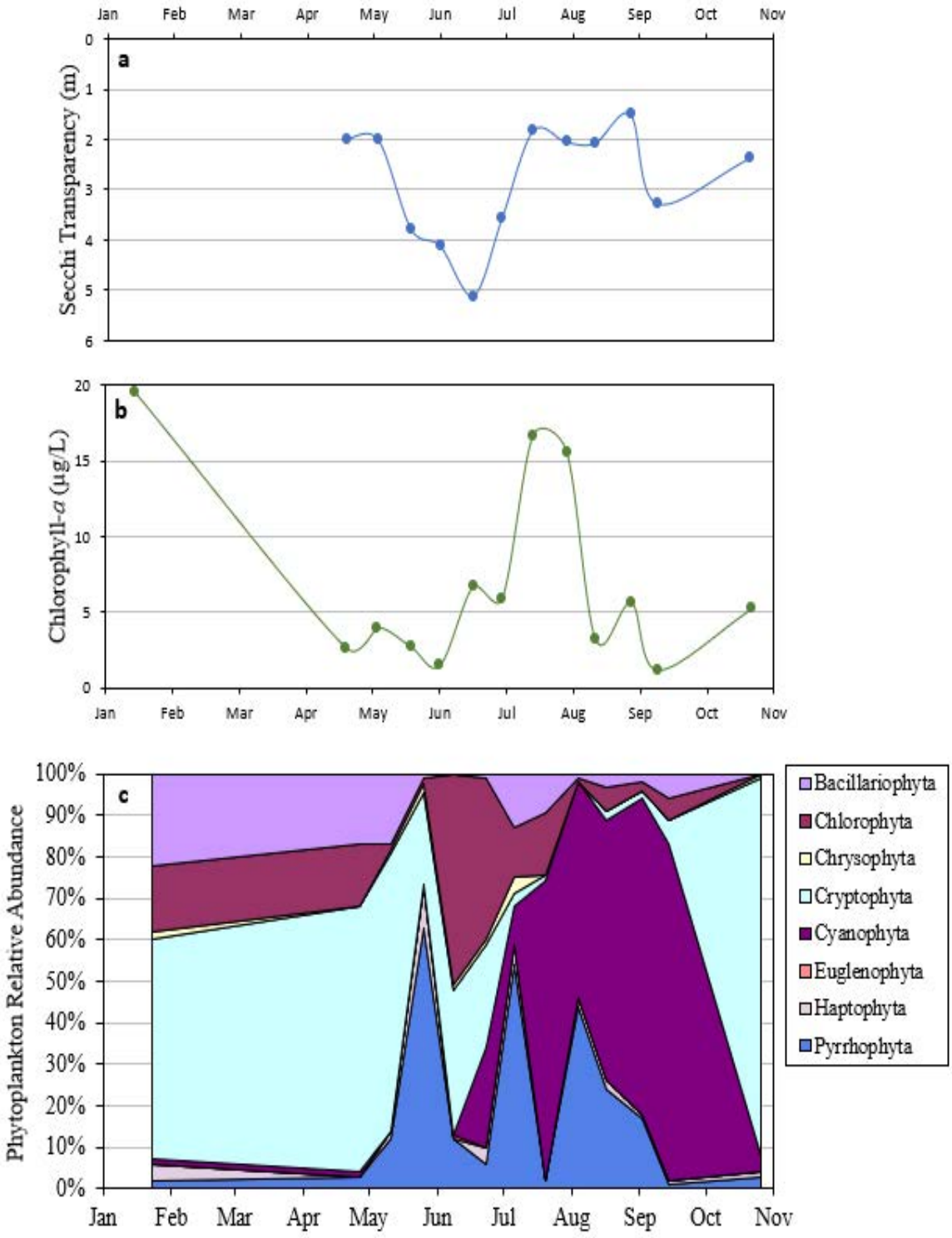


Figure 16-9. Water clarity (a), chlorophyll-*a* concentration (b), and relative abundance of phytoplankton (c) in Wirth Lake during 2020. Note that the water clarity axis is reversed.

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 16-10** shows the zooplankton distribution in Wirth Lake sampled throughout 2020. Nauplii and juvenile copepods were present throughout the year and were most abundant in April and May. Cladocerans were also present all year and were most abundant in May. Rotifers were present in higher concentrations in August. Calanoids, cyclopoids, and protozoa were present in low levels in 2020.

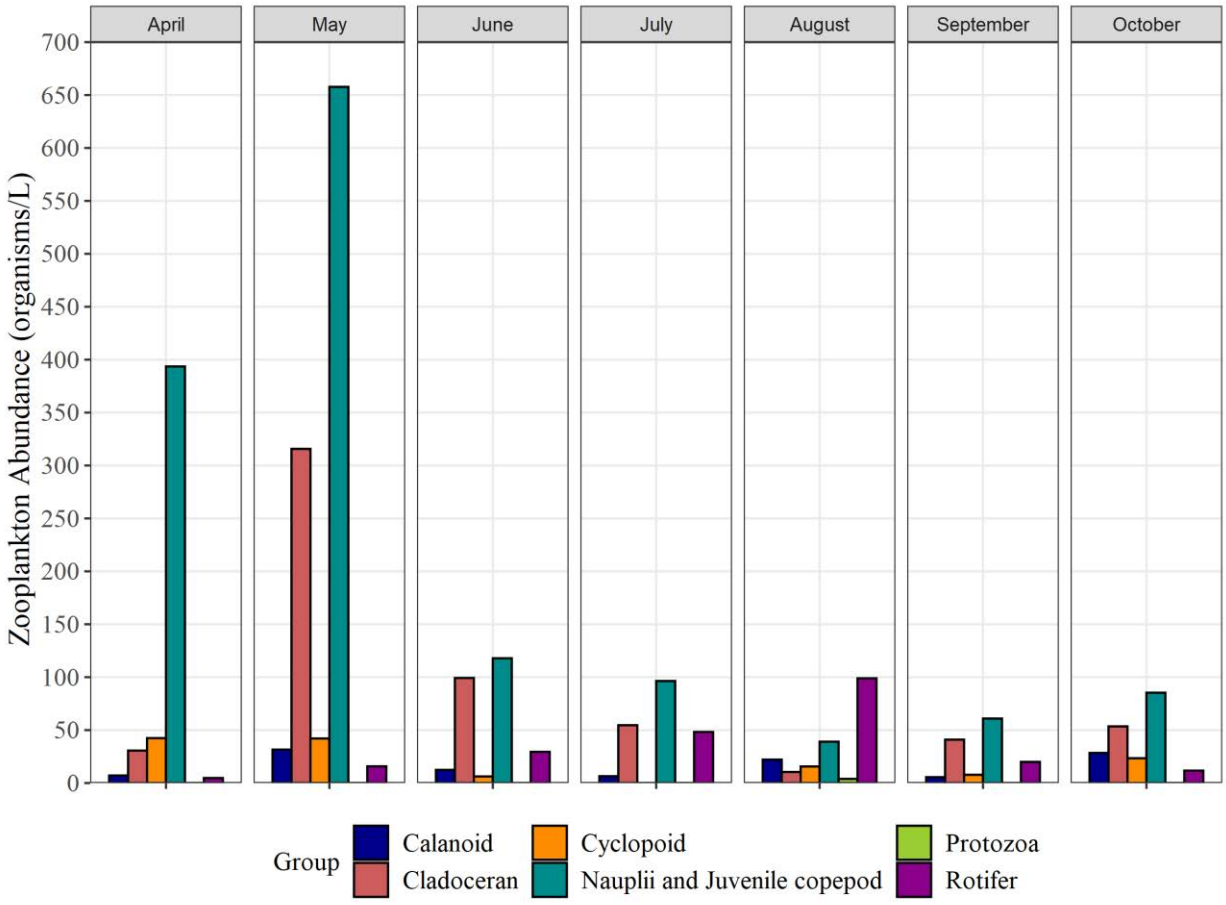


Figure 16-10. Zooplankton density in Wirth Lake during 2020.

FISH STOCKING

Table 16-4 shows fish stocked into Wirth Lake over the past decade. 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
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
2011	Walleye	2,772 fingerlings	99.0 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. Results of the wetland evaluation are presented in **Chapter 22**. In 2019, a carnivorous, aquatic plant species Bladderwort (*Utricularia*) was first identified at the wetland by the WHEP volunteers. The plant was surveyed again with a significantly larger population in 2020. Bladderwort is an indicator species of high water quality. 2020 was the seventh year that the Wirth Beach wetland was evaluated in the WHEP program. Wirth Beach wetland scored excellent for invertebrates and excellent for vegetation in 2020.



Figure 16-11. Bladderwort flowering in August 2020.

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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 of the Minneapolis lakes.

Table 17-1. Minneapolis lakes physical characteristics.

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
† Based on long-term data. ‡ Recent projects within the watersheds have altered these statistics.

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 4 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 2020, MPRB scientists monitored 12 of the city's most heavily used lakes. The data collected were used to calculate a Trophic State Index (TSI) score for each of the lakes. Lower TSI scores indicate high 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, Harriet, and Wirth are mesotrophic having moderately clear water and increasing probability of hypolimnetic anoxia during the summer. Brownie, Cedar, Hiawatha, and Isles are eutrophic having an anoxic hypolimnion and possible macrophyte problems. Nokomis and Loring are also eutrophic with high algal productivity. Blue-green algae also dominates the phytoplankton community on Lake Nokomis causing algal scum to appear on the lake periodically. Powderhorn Lake is hypereutrophic with high nutrient concentrations and the potential for severe algal blooms. Spring Lake was also classified as hypereutrophic in 2019 but was not sampled in 2020. 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 2011. 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 regression 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 in water quality.

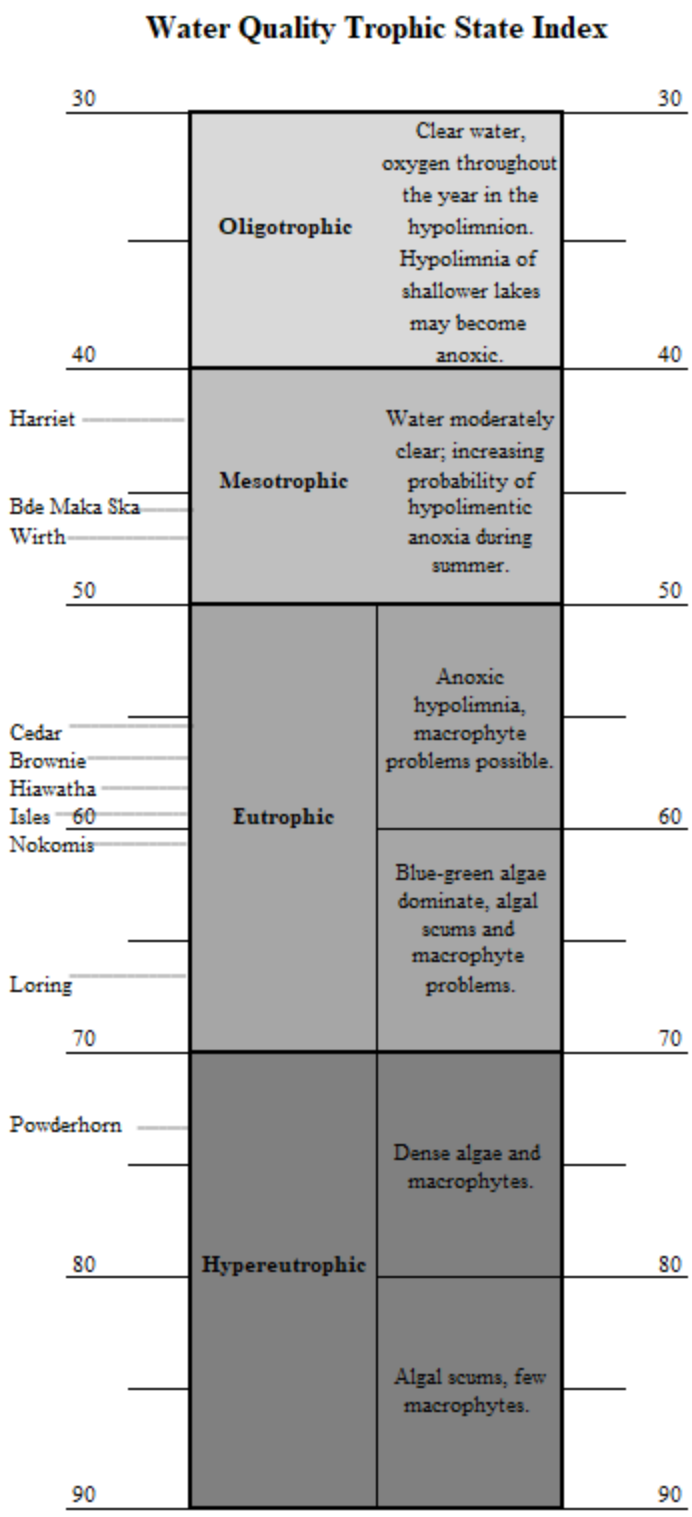


Figure 17-1. 2020 lake trophic state comparison. The hypolimnion is the lower layer of water in a stratified lake, typically cooler than the water above. In general, the deeper lakes have lower TSI scores and are higher up on this graphic.

Table 17-2. Water quality trends in Minneapolis lakes from 1991-2020

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 2011-2020

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

There has been a significant improvement in water quality indicators in Bde Maka Ska since the early 1990s (linear regression, $p < 0.05$); however, TSI scores have stabilized since 2006. The TSI score at Bde Maka Ska between 2017 and 2020 was higher than the previous few years due to higher chlorophyll-*a* and total phosphorus concentrations but were still below the early 1990s scores. The 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 between 2017 and 2019 was slightly above the previous few years due to increased chlorophyll-*a* and total phosphorus concentrations and improved again in 2020.

Most of the Minneapolis lakes have no directional trend in water quality indicators since the early 1990s. The water quality in Brownie Lake has been relatively stable, with no significant trend since 1993. Brownie Lake is monitored every other year and was monitored in 2020. 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 2020 have been the highest they have been since the early 1990s due to higher chlorophyll-*a* and total phosphorus concentrations. Lake Harriet experienced a few years with lower TSI scores following a littoral alum treatment in the mid-2000s and the TSI scores remained relatively stable for several years, with lower TSI scores in 2016 and 2020. The TSI trend in Lake Harriet was not significant in 2020 (linear regression, $p > 0.05$).

Previously, Lake Nokomis had seen a significant improvement in water quality following a biomanipulation project in 2010; however, with higher algal concentrations in recent years, TSI scores have stabilized and there is no statistically significant trend (linear regression, $p > 0.05$). Lake Hiawatha is heavily influenced by the inflow from Minnehaha Creek and the lake has poorer water quality during drought years. Above average spring and summer precipitation in the last few years have led to low TSI scores in Lake Hiawatha compared to the 2000's. The water quality in Lake of the Isles varies from year to year, with higher TSI scores between 2017 and 2020 compared to the previous few years due to increased chlorophyll-*a* concentrations, but there is no significant trend in any direction since 1991 (linear regression, $p > 0.05$). Loring Pond experienced decreased water quality immediately following a dredging project in 1997; however, conditions have slowly returned to levels similar to pre-1997. The TSI scores at Loring Pond in 2019 and 2020 were higher than previous years due to higher chlorophyll-*a* concentrations. 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 had poor water quality between 2013 and 2017 and again in 2020, with blue-green algae blooms leading to low water clarity. TSI scores were lower in 2018 and 2019 because severe algal blooms did not occur, and chlorophyll-*a* concentrations decreased. Water quality in Spring Lake is variable, but there is no significant trend in any direction since 1994. Spring Lake is also monitored every other year and was not monitored in 2020. The TSI score increased in 2019 due to higher chlorophyll-*a* and 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 lakes. There are no lakes in Minneapolis with significant decline in water quality indicators since the early 1990s; however, water quality trends over the past 10 years indicate that Cedar Lake water quality is declining as seen in increasing TSI scores in recent years.

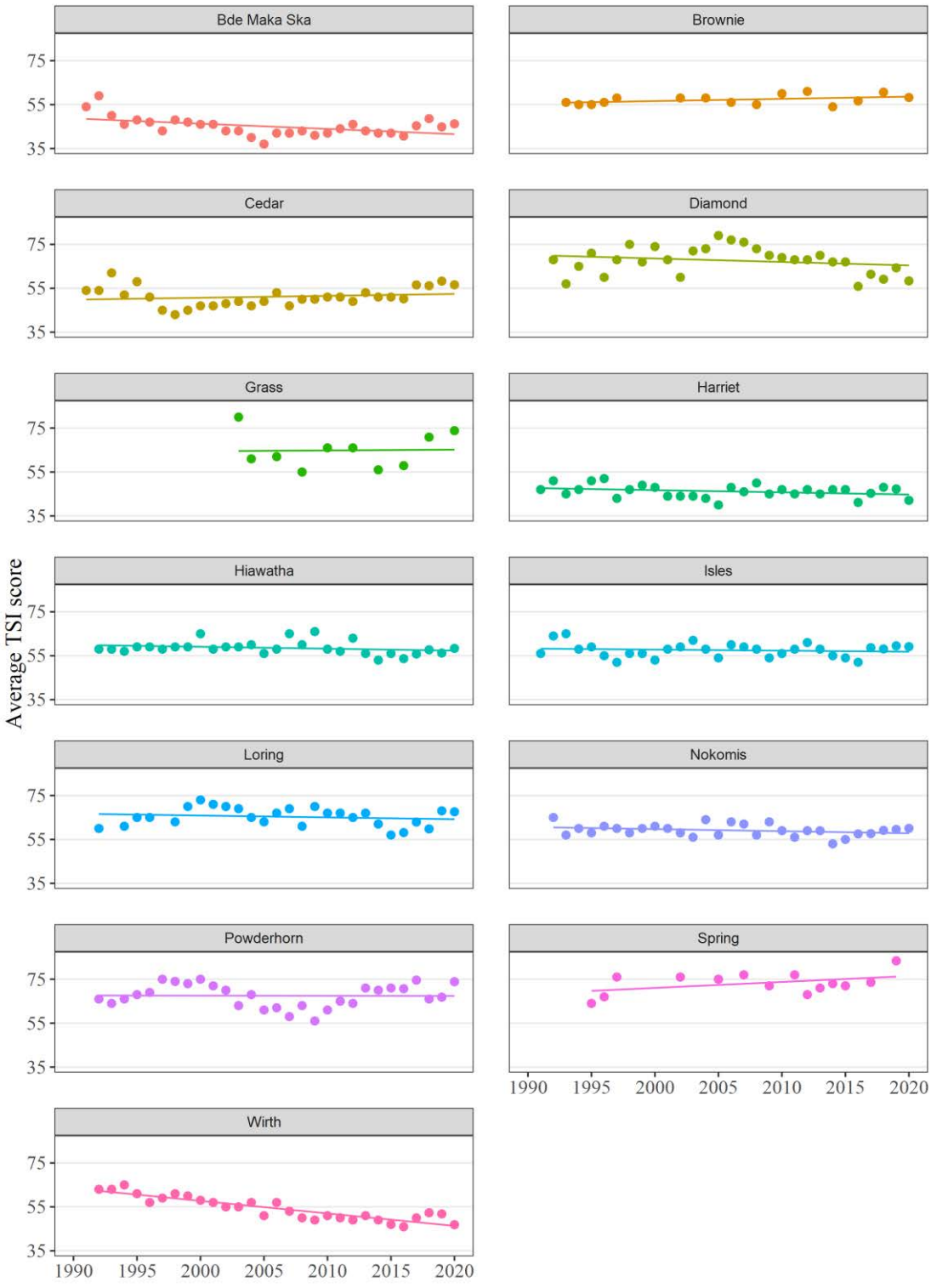


Figure 17-2. TSI scores and regression analysis for selected Minneapolis lakes 1991–2020. Lower TSI scores indicate high water clarity, low levels of algae in the water column, and/or low phosphorus concentrations. A negative slope indicates improving water quality, while a positive slope indicates declining water quality. Only Bde Maka Ska and Wirth have statistically significant trends ($p < 0.05$).

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 2020, total annual precipitation was 29.83 inches. See **Chapter 27** for more information on annual precipitation. In 2020, almost all lake level averages were below their corresponding 10-year averages as can be seen in **Tables 17-4** and **17-5**. The exception being Loring Pond and Powderhorn Lake, both lakes where levels can be altered via augmentation wells. Historical lake levels can be found in the individual lake chapters.

Table 17-4. Average annual lake levels in feet above msl for 2011-2020.

Lake	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Chain[§]	852.9	852.1	852.7	853.8	852.4	852.7	853.0	852.6	854.2	852.6
Diamond	821.8	821.6	821.7	822.2	822.4	822.9	821.8	821.9	822.2	821.9
Harriet	847.6	847.1	847.5	847.8	847.4	847.6	847.7	847.5	848.5	847.6
Hiawatha	813.4	811.8	813.1	814.1	812.5	813.3	813.3	813.2	814.4	812.7
Loring*	817.8	818.0	817.9	814.9	818.5	818.5	818.3	818.3	818.3	818.2
Nokomis	814.7	814.5	815.1	816.4	815.2	815.7	815.5	815.4	815.9	815.4
Powderhorn*	817.8	817.4	818.2	819.7	819.6	819.6	819.0	819.0	819.4	818.9
Wirth	818.1	818.0	818.1	818.5	818.3	818.3	818.1	818.3	818.3	818.1

[§] 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 17-5. Selected statistics for lakes with level data based on data from 2011-2020.

Lake	10 year average (ft msl)	2020 average (ft msl)	2020 comparison to 10 year average (ft)	Standard deviation around 10 year average (ft)
Chain	852.9	852.6	-0.3	0.9
Diamond	822.0	821.9	-0.2	0.5
Harriet	847.6	847.6	0.0	0.5
Hiawatha	813.2	812.7	-0.5	1.2
Loring	817.9	818.2	0.3	0.3
Nokomis	815.4	815.4	0.0	0.7
Powderhorn	818.8	818.9	0.1	1.1
Wirth	818.2	818.1	-0.1	0.3

Groundwater continued to be pumped into Loring Pond throughout 2020 to keep water levels near the top of the outlet structure to prevent cattail regrowth. Large storms have caused the outlet to surcharge to the pond periodically in the last 10 years and can be seen in the lake level graph in Loring's individual lake chapter.

Powderhorn Lake is another lake that can be augmented by a groundwater well; however, it was not used in 2020. The outlet pump was turned on and 17.4 million gallons were pumped out of the lake in 2020 to prevent flooding. The lake was 0.1 feet above its 10-year average in 2020, see **Table 17-5**. 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 17-3** for Minneapolis lake levels for 2020.

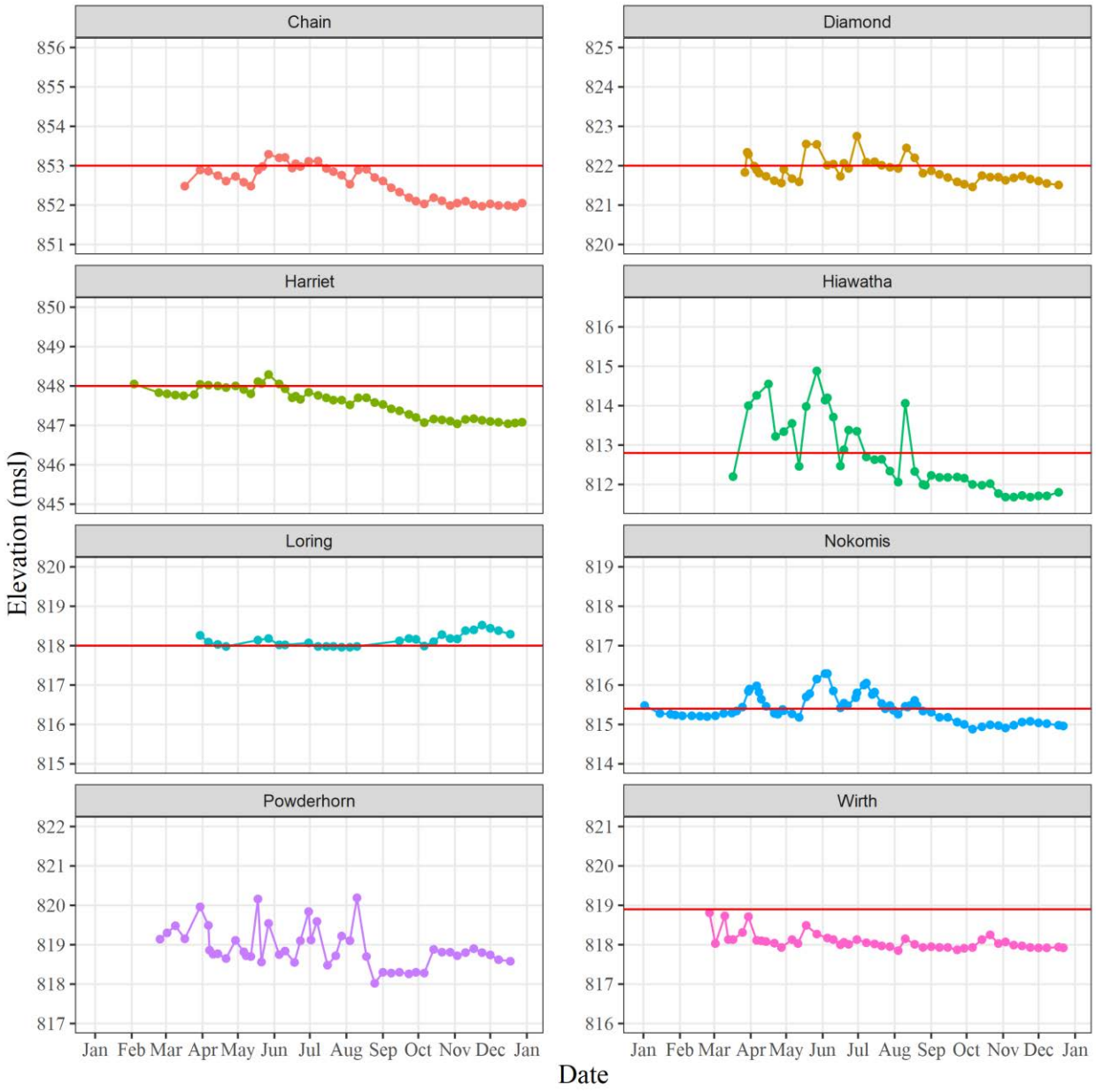


Figure 17-3. Lake levels for the Minneapolis Lakes in 2020. Horizontal lines represent ordinary high water elevation (OHWL). Note the MNDNR has not designated an OHWL for Powderhorn Lake.

Lake Hiawatha levels are influenced by the inflow of Minnehaha Creek which changes depending on the operation of the Lake Minnetonka outlet dam. The dam at Gray's Bay opened March 17, 2020, with 50 cubic feet per second (cfs) of discharge. Flow to the creek from the dam fluctuated between 50 and 250 cfs until October. The dam was closed on October 5, 2020 when Lake Minnetonka reached the drawdown level of 928.6 ft, but was opened again on October 12, 2020, at 20 cfs, when precipitation increased the lake level above 928.6 ft. The dam was closed for the rest of the year on October 19, 2020. The 2020 average Hiawatha lake level was 0.5 feet below the 10-year average for the lake.

Following a six-year streak of high water, lake levels for Nokomis varied around the OHWL elevation in 2020. The lake saw higher water levels, just above the OHWL, during the summer months, and lower levels falling below the OHWL the rest of the year. The MPRB operates a fixed crest weir at the outlet of Lake Nokomis to Minnehaha Creek which allows the lake to overflow during periods of high water, yet still prevents the creek from flowing into the lake. The weir was open for 284 days between January and December in 2020. Of the 284 days the weir was open, there were 184 days when water was flowing out of Lake Nokomis. Wier operations are based on a DNR-approved operation plan and done in consultation with Minnehaha Creek Watershed District (MCWD), per the plan.

Lake Aesthetic and User Recreation Index (LAURI)

The LAURI was developed 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 LAURI index was updated in 2009 to include measures of habitat quality and recreational access. The scoring for the aesthetic index was further refined in 2017 to use the lowest of the three scores, rather than an average of the three which was how it was previously calculated. The scores have been used by 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 17-6** shows the LAURI scores of each lake for 2020. The LAURI parameters for all the lakes together are presented in **Figure 17-4.** The Citywide LAURI scored excellent for recreational access, and good for aesthetics, water clarity, public health, and habitat quality. Blue-green algae blooms occurred on several MPRB lakes in 2020 and likely contributed to lowering the aesthetics score from excellent to good.

Table 17-6. 2020 sub-scores and classifications for each LAURI category.

Lake	Aesthetics	Water Clarity	Public Health Index	Habitat Quality	Recreation Access
Bde Maka Ska	6.5	7.0	5.0	10.0	10.0
Cedar	6.5	2.0	8.0	8.3	10.0
Harriet	7.1	9.0	5.0	8.5	10.0
Hiawatha*	4.5	6.0	1.0	6.3	5.0
Isles*	7.5	6.0	N/A	7.5	10.0
Loring*	7.1	4.0	N/A	3.0	3.0
Nokomis*	6.6	4.0	7.0	5.3	10.0
Powderhorn*	3.3	2.0	N/A	1.0	3.0
Wirth	8.5	6.0	7.0	8.5	10.0

LEGEND

Excellent	Good	Poor

* Denotes shallow lake.
N/A = 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. Larger lakes had better recreational access scores due to more opportunities to access the water through boating.

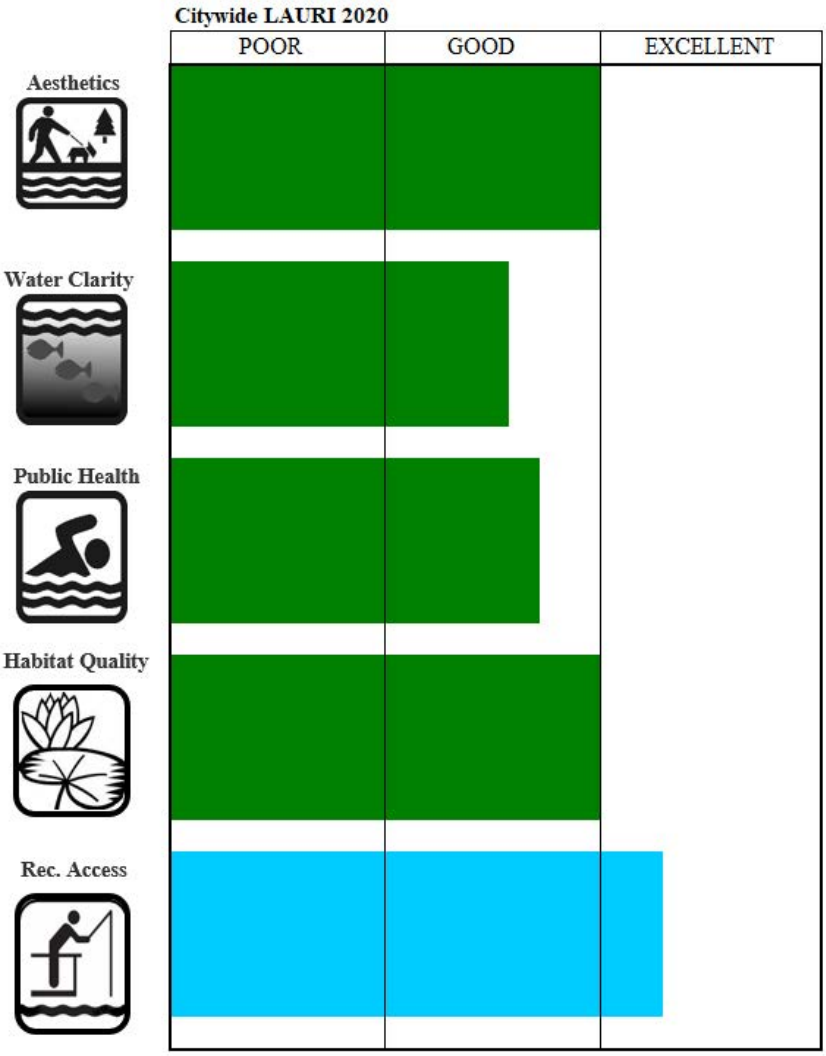


Figure 17-4. 2020 Average LAURI for Minneapolis. Includes: Bde Maka Ska, Cedar, Harriet, Hiawatha, Isles, Loring, Nokomis, Powderhorn, and Wirth Lake.

BLUE-GREEN ALGAE

Cyanobacteria, the microorganism that makes up blue-green algae blooms, have always occurred naturally in the environment. As awareness of cyanobacteria and their capability to produce toxins have raised concern for public health, MPRB has focused on monitoring for blue-green algae blooms and identifying indicators that determine when a bloom event could be potentially harmful. It is important to note that light availability, warm water temperature, nutrient loading, pH changes, and alteration of water flow are all driving factors that contribute to blue-green algae blooms (Paerl & Otten, 2013). Peak bloom times, times when toxins may be most prevalent, typically occur in July and August when temperatures are high, ≥ 68° Fahrenheit, and water is nutrient-rich, but blooms can occur at any time of year.

To establish the risk of cyanotoxins presence based on other environmental factors, a toxin indicator threshold was devised. Based on research conducted by Heiskary and Lindon (2009), Secchi reading, pH, and chlorophyll-*a* are defined as correlated references to toxin presence. The threshold for each of these parameters are pH values ≥ 9.00, Secchi readings ≤ 0.5, and chlorophyll-*a* values ≥ 30 Mg/m3. The study

found that when chlorophyll-*a* concentrations exceed 30 Mg/m3 during blooms, the frequency of algal toxins to reach 'moderate' to 'high risk' intensity increases by about 30%. The study also found that over 90% of pH values that were greater than 9.00 were associated with severe nuisance blooms. A list of events in which one or more parameter exceeded the threshold in 2020 is shown in **Table 17-7** for Cedar, Nokomis, and Lake of the Isles.

Table 17-7. Toxin indicator parameters, Secchi, pH and chlorophyll-*a*, that exceeded the threshold for moderate to high risk cyanotoxins in 2020.

Lake	Date M/DD/YY	Secchi meters	pH units	Chl-*a* Mg/m3
Cedar	1/22/2020	NA	7.72	35.5
Cedar	4/29/2020	0.47	8.56	28.3
Cedar	5/11/2020	0.41	9.21	16.5
Isles	6/22/2020	1.35	8.9	34.30
Isles	7/20/2020	0.71	8.82	59.4
Isles	8/4/2020	1.05	8.1	30.1
Nokomis	5/1/2020	0.57	9.16	14.7
Nokomis	5/15/2020	0.63	9.08	14.2
Nokomis	6/26/2020	0.8	8.59	34.40
Nokomis	8/20/2020	0.46	8.44	53.7
Nokomis	9/8/2020	0.50	8.2	30.1
Nokomis	9/18/2020	0.43	8.14	5.70

NA= Information not available

Cedar, Nokomis, and Lake of the Isles were the only Minneapolis lakes evaluated due to severe, early spring bloom events that occurred in these lakes in 2020. Being that chlorophyll-*a* is a measurement of the total algal biomass it serves as an indicator for blue-green presence, and therefore cyanotoxin presence. Chlorophyll-*a* exceeded the threshold the most compared to pH and Secchi, reflecting periods of reported blooms. In general, chlorophyll-*a* values exceeded the thresholds between June and August. These are periods when water temperatures are warmest and the water column is vertically stratified, which are optimal conditions for most genera of cyanobacteria. Threshold exceedances for Cedar Lake correlate directly to reported severe bloom conditions that occurred in early spring.

The toxin indicator data was collected during regularly scheduled lake monitoring and provides a snapshot of the status of the lake during that time. It is important to note that this data is taken from mid-lake locations, where blooms have been identified, but not to the severity of near-shore bloom events. In most lakes, near shore algae blooms are known to be more severe and intense, forming scums on the surface that can yield higher toxin concentrations (Heiskary & Lindon, 2009). For more information on specific bloom events see the Events Report section in individual lakes chapters for these lakes.

Figure 17-5 shows bar graphs of prevalent cyanobacteria species in Cedar, Nokomis, and Lake of the Isles for 2020. Data includes species of cyanobacteria with a total yearly abundance of ≥ 20 percent of the phytoplankton community. This information helps determine which species of cyanobacteria were most abundant throughout the year and which species were most prevalent during reported blooms. This data also helps assess which toxins to be aware of for future testing. Species specific information in the following section is derived from the World Health Organization (WHO) guide to Toxic Cyanobacteria in Water (WHO, 2021).

In 2020, all three lakes had an abundance of blue-green algae between January and May. The species of algae that caused the bloom was initially identified as *Planktothrix prolifica*, but after further analysis it is believed that the species was *Planktothrix aghardii*, which may be different strains of the same species rather than two different species. Ongoing research is being done by others based on the phytoplankton samples collected by MPRB. Due to this species possessing the accessory pigment, phycoerythrin, blooms tend to be pink or red in color. *Planktothrix* species are generally planktonic and can be found evenly distributed throughout the water column. This species is also more adapted to blooming in colder temperatures, it can even be found blooming under the ice during the winter season. The genus *Planktothrix* can produce the following toxins: microcystin, anatoxin, and saxitoxin.

Another dominant species across all three lakes in 2020 was *Raphidiopsis raciborskii (R.raciborskii)*, previously known as *Cylindrospermopsis raciborskii*. A filamentous species, *R.raciborskii* tends to prefer warmer conditions, above 68° F (Paerl & Otten, 2013). Since this species contains the pigment phycocyanin, blooms for this species are typically green in color and are commonly described as having a pea-soup appearance. In Cedar Lake, *R.raciborskii* peaked in late-July, and in Nokomis and Lake of the Isles the species reached peak abundance in late-August. *R.raciborskii* forms dense, suspended water blooms and typically thrive in eutrophic, turbid, warm, and shallow waters.

Aphanizomenon flos-aquae (Aph.flos-aquae) was also present in all three lakes in 2020 and is most abundant in June and July. *Aph.flos-aquae* flourishes in waters during thermal stratification and when there are low levels of available nitrogen. This species forms dense surface aggregations that generally dominate eutrophic, stagnant waters, and occurs mainly in temperate zones. Due to the species possessing the pigment-protein phycocyanin, blooms tend to be blue or green in color. This species is morphologically distinguished by forming accumulations of fibrous, straight filaments. *Aph.flos-aquae* and *R.raciborskii* both have the capability to produce the toxin cylindrospermopsin.

Planktothrix agardhii, Planktothrix rubescens, and *Planktothrix prolifica* may be ecotypes rather than different species. *P. agardhii,* also known for having red pigmentated blooms, appear as long, slender, straight filaments that can form dense surface scums. *P.agardhii* is commonly found in shallow and turbid lakes where it can tolerate continuous mixing of the water column. This species takes advantage of the ability to thrive in low light conditions, making it more adapted to winter blooms. In 2020, this species continually increased in the fall in Cedar and Nokomis Lake, as temperatures began to decline. *P.agardhii* has the capability to produce the toxin microcystin.

The genus *Dolichospermum* was found at various times of the year for these three lakes and has more species variation. *Dolichospermum* are found in mesotrophic to eutrophic, stratified, shallow lakes. This species is planktonic, forming blooms on the surface, and creating scums. Species of *Dolichospermum* have the capability to produce microcystin, anatoxin-s, and saxitoxins.

This information can help MPRB staff better test for cyanotoxins and assess risk to the recreating public. Understanding the preferred lake conditions, time of year, and appearance of the lake when blue-green algae is present helps staff determine when and where in the lake to collect samples. Environmental indicators associated with toxins are assessed and help determine the risk of cyanotoxin presence during the swim season.

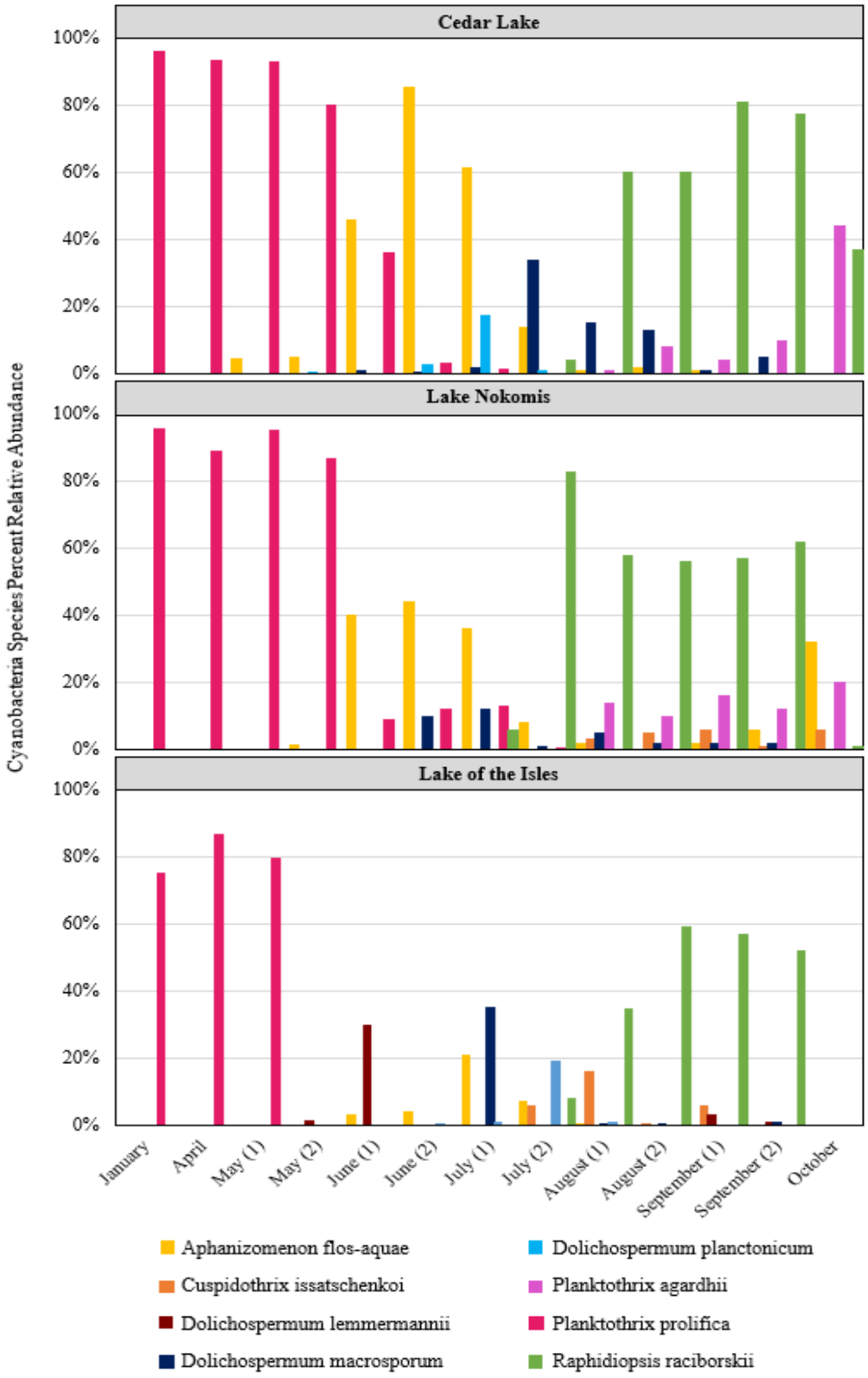


Figure 17-5. Bar graphs for percent relative abundance of cyanobacteria species prevalent in Cedar, Nokomis, and Lake of the Isles in 2020.

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 March 24th, with the last lake opening on April 2nd, as show in **Table 17-8**. The date that ice completely covered the lake, shown in **Table 17-9**, ranges from November 13th to December 28th, with an average ice-on date of December 2nd. **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, like Bde Maka Ska, Lake Harriet, Lake Nokomis, and Lake Hiawatha, ice-free periods have increased slightly over time. Some lakes, like Brownie and Wirth, have remained relatively stable in ice-free periods. While for other lakes, like Birch Pond and Ryan Lake, there is a decreasing trend in ice-free periods. 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 **Section 1** and individual lake sections.

Table 17-8. Statistics related to ice-off dates.

Lake	2020	Earliest Ice-Off	Year Occurred	Latest Ice-Off	Year Occurred	Mean	Median	Years of Record
Bde Maka Ska	3/29	3/9	2000	5/2	2018	4/9	4/9	71
Birch	4/2	3/8	2000	4/30	2018	4/4	4/4	35
Brownie	3/28	3/9	2000	4/30	2018	4/3	4/3	39
Cedar	3/28	3/9	2000	5/1	2018	4/6	4/6	47
Diamond	3/24	3/6	2000	4/27	2018	4/1	4/2	28
Grass	3/24	3/14	2016	4/27	2018	4/2	4/1	15
Harriet	3/29	3/9	2000	5/2	2018	4/6	4/7	53
Hiawatha	3/28	3/8	2000	4/26	2013, 2018	4/4	4/3	46
Isles	3/28	3/8	2000	5/1	2018	4/5	4/5	51
Loring	3/25	3/6	2000	4/26	2018	4/2	4/3	40
Nokomis	3/29	3/8	2000	5/1	2018	4/4	4/4	49
Powderhorn	3/27	3/8	2000	4/29	2018	4/4	4/3	41
Ryan	3/28	3/15	2016	4/30	2018	4/4	4/3	17
Spring	3/25	3/6	2000	4/26	2018	4/1	4/1	30
Wirth	3/28	3/7	2000	4/30	2018	4/2	4/3	44

Table 17-9. Statistics related to ice-on dates.

Lake	First ice-on date 2020	Final ice-on date 2020	Earliest Ice-On	Year Occurred	Latest Ice-On	Year Occurred	Mean	Median	Years of Record
Bde Maka Ska	12/28	12/28	11/25	1996	1/16	2006-07	12/13	12/11	51
Birch	11/13	11/30	11/1	1991	12/16	1998	11/25	11/29	35
Brownie	11/17	11/30	11/5	1991	12/21	2015	11/29	11/30	39
Cedar	12/1	12/1	11/18	1989	12/21	1998, 1999, 2001, 2015	12/4	12/4	39
Diamond	11/17	12/15	11/13	2014	12/20	2001	12/2	12/3	26
Grass	11/30	12/15	11/13	2014	12/15	2020	12/2	12/4	15
Harriet	12/28	12/28	11/25	1996	1/16	2006-07	12/13	12/11	48
Hiawatha	12/2	12/2	11/1	1991	1/31	2006-07	12/3	12/3	40
Isles	12/1	12/15	11/5	1991	1/2	2006-07	12/1	12/2	46
Loring	11/17	12/1	11/1	1991	12/21	1999, 2001, 2015	12/1	12/2	36
Nokomis	12/2	12/2	11/1	1991	1/17	2011-12	12/2	12/2	41
Powderhorn	12/1	12/1	11/1	1991	12/21	2015	11/29	12/1	36
Ryan	11/17	12/15	11/17	2014	1/16	2006-07	12/7	12/2	14
Spring	11/17	11/30	11/10	1995	12/20	2001	11/29	11/30	30
Wirth	12/1	12/1	11/5	1991	12/21	2001, 2015	11/30	12/2	40

Table 17-10. Average length in days of ice cover for each decade between 1962 and 2020.

Lake	1962-1969	1970-1979	1980-1989	1990-1999	2000-2009	2010-2019	2020
Bde Maka Ska	118.6	125.6	119.7	117.7	110.0	109.4	109
Birch	118.5	NA	NA	134.9	129.4	130.0	146
Brownie	118.5	NA	146.0	132.5	122.8	124.1	123
Cedar	124.0	130.0	142.0	125.3	117.1	121.7	117
Diamond	118.5	NA	NA	NA	122.1	121.7	113
Harriet	117.6	121.3	120.0	117.6	109.6	109.2	109
Hiawatha	130.0	NA	125.5	131.4	111.6	116.4	117
Isles	126.0	129.5	131.8	134.8	117.2	120.5	117
Loring	124.0	NA	131.0	132.1	115.0	121.7	114
Nokomis	132.3	NA	132.7	131.9	119.7	115.9	118
Powderhorn	136.3	NA	133.0	132.4	121.1	123.4	116
Spring	118.5	NA	NA	127.7	119.7	124.4	114
Wirth	118.5	NA	131.5	131.7	119.9	119.6	117

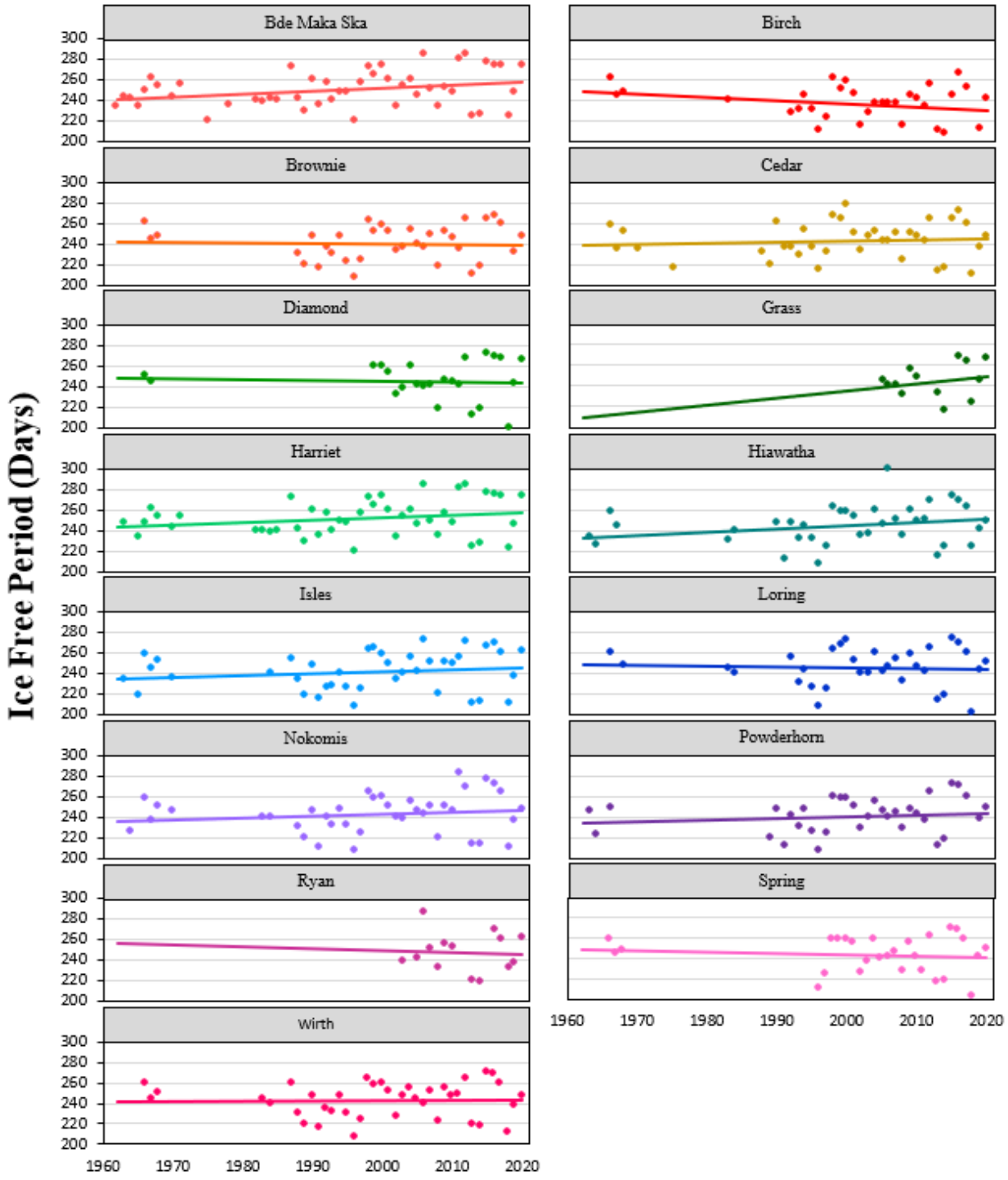


Figure 17-6. Ice free period (days) on Minneapolis lakes between 1962 and 2020.

TOC

18. PUBLIC BEACH 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. From 2004 to the present MPRB Environmental Management staff monitored the beaches for *E. coli* alone as recommended by the US Environmental Protection Agency (US EPA). US 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 5 samples equally spaced over a 30-day period should not exceed 126 organisms per 100 mL of water (US EPA, 1986). MPRB followed this set of guidelines for the 2004 and 2005 beach seasons. Epidemiological testing allowed the Minnesota Pollution Control Agency (MPCA) to develop an inland lake standard of 1,260 organisms per 100 mL which MPRB has followed since 2006.

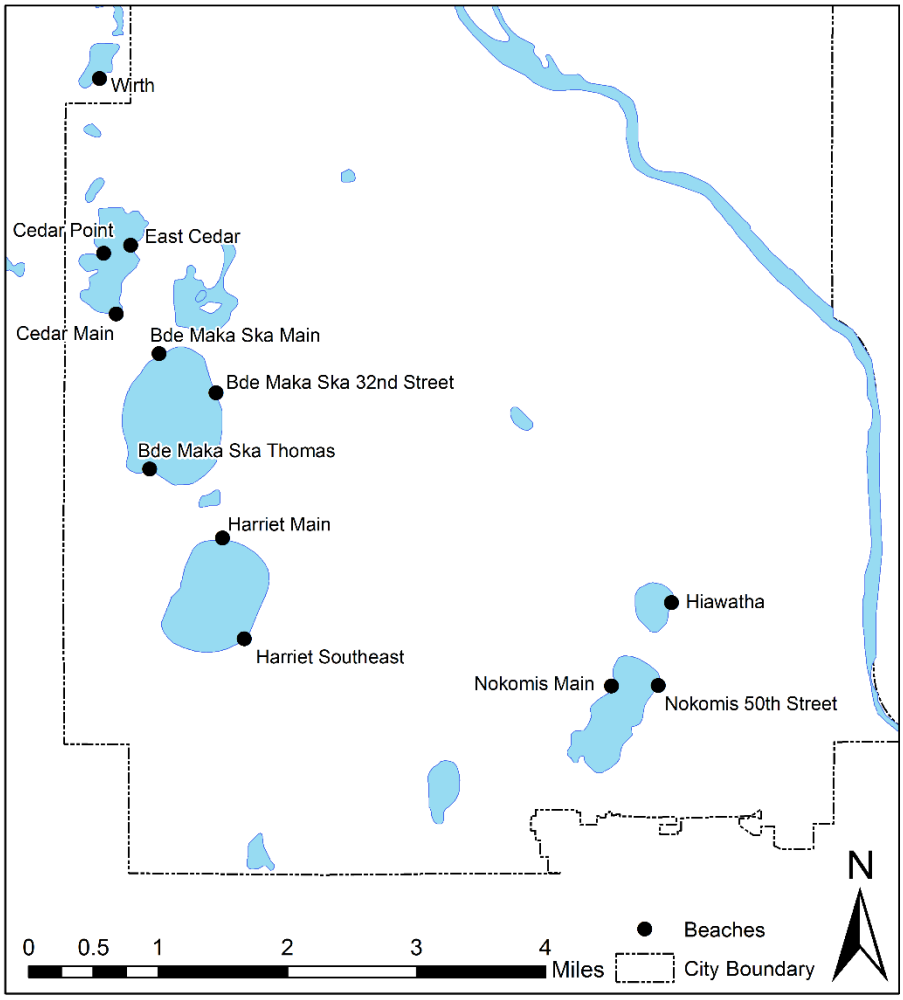


Figure 18-1. Map of MPRB public beaches monitored in 2020.

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 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
- organic debris
- leaking diapers, bather defecation
- polluted stormwater runoff
- sewage spills near the beach
- sewer line break discharges
- stream inflows
- shoreline bank erosion
- 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 are capable of supporting *E. coli* in significant numbers. Bacteria from the dried mats grew upon re-hydration even after 6 months. Other pathogens like *Shigella*, *Salmonella*, *Campylobacter*, and a shiga toxin-producing strain of *E. coli* (STEC) have also been found to be associated with a common filamentous algae species, *Cladophora* (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.* Whitman and Nevers (2003) have shown 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 stream. *E. coli* was common in stream banks and wetted sediments acting 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 biological, e.g. nutrients and protection from predation, and physical, e.g. particulate matter, periodic wetting and drying, and protection from solar irradiation, factors enhance bacteria survival while providing a growth-promoting environmental niche. 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 interpretation of *E. coli* levels at beaches less straightforward, as multiple sources may cause elevated bacteria levels, and it is not well understood how many pathogens also become naturalized.

2020 Program Changes

As a result of an unusual early spring algae bloom on Minneapolis lakes in 2020, MPRB developed a blue-green algae Visual Monitoring Index to assess the lakes. This index was added to the weekly beach bacteria monitoring program. Often referred to as algae, blue-green algae are not algae at all, but types of bacteria called cyanobacteria that are normally present in bodies of water throughout the world. This type of bacteria thrives in warm, nutrient-rich water. When water temperatures begin to rise the blue-green algae can grow quickly forming "blooms", although blooms can be present at any time of year if conditions for growth are right. Blue-green algae can be a public health concern since certain varieties of blue-green algae can produce toxins that are linked to illness in humans and animals (MPCA, 2021; https://www.pca.state.mn.us/water/blue-green-algae-and-harmful-algal-blooms).

MPRB developed an online GIS-based Lake Water Quality Map in 2020 to better communicate beach closures and notifications to lake and beach users. This map, shown in **Figure 18-2**, replaced the weekly updates on the MPRB website and the beach hotline. Information could be communicated visually and in real time. Beach status, water temperatures, and water clarity data were updated weekly with graphics indicating if beaches were open or closed based on *E coli* monitoring results. Blue-green algae observations were added to the Lake Water Quality Map later in the season and displayed information for all Minneapolis lakes, including those without beaches. The map is found on the MPRB website bit.ly/mplsbeaches. Locations were marked with a yellow halo indicated a "watch" for the presence of blue-green algae in the 2020 version of the map.

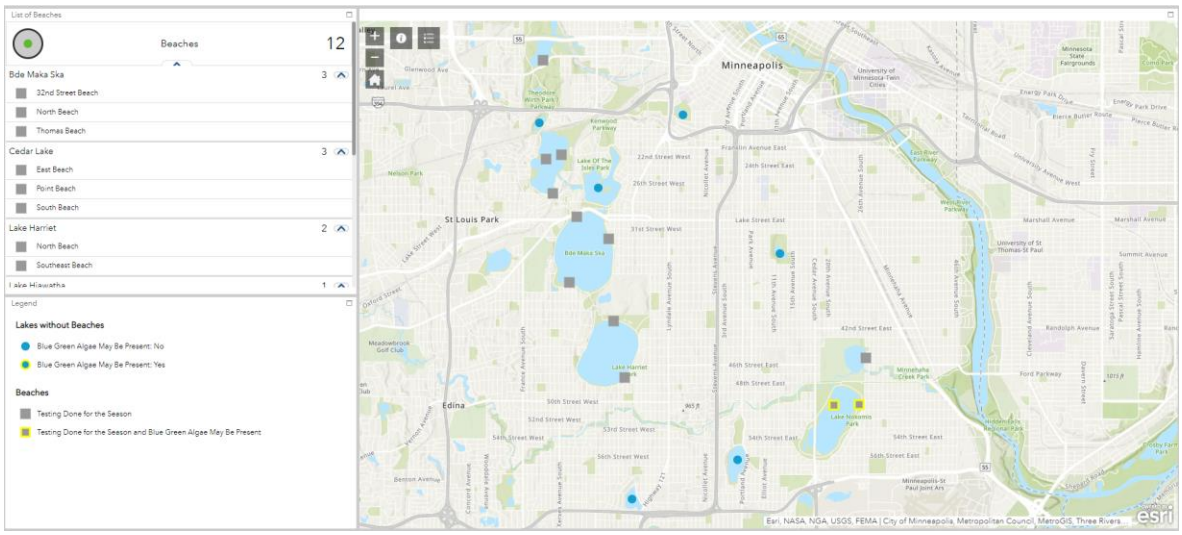


Figure 18-2. Example of the MPRB Lake Water Quality Map showing the water quality status of the beaches and lakes monitored by MPRB Water Resources staff in October of 2020.

MPRB developed a new healthy swimming sign, shown in **Figure 18-3**, that was posted at each of the beaches in 2020. This sign was created as a response to the Lake Nokomis *E.coli* O145:H28 outbreak in 2019, and emphasizes the MDH's recommendations of showering before and after swimming, cleaning hands often, waiting 48 hours after rainfall before swimming, avoiding swallowing lake water and not swimming when sick. The sign directs visitors to the new online Lake Water Quality Map for more information and water quality status. Encouraging these healthy swim behaviors can reduce the risk of water borne illness exposure for all beach users.



Figure 18-3. Swim Healthy Stay Safe sign created in 2020 to encourage healthy swimming behaviors.

METHODS

Samples were collected at Minneapolis beaches beginning 6/10/2020. Typically, Nokomis Main and Wirth beaches would be sampled both early and late in the season to allow for early and late season weekend swims. The Minneapolis swim season was impacted due to issues related to the COVID-19 pandemic. MPRB staff worked with the MDH to determine the safety protocols necessary to open beaches to the public. Delayed hiring of lifeguards during this process slowed the openings and required that several beaches remain unguarded through the season. The decision was made at the start of June to move forward with the full beach monitoring program at all 12 beaches. Although the sampling field work was impacted throughout the summer by staff reductions, roads closures, and altered work schedules due to the pandemic and social unrest, samples were collected from all MPRB beaches every Monday during the beach season (6/10/20 through 9/4/20). Beaches monitored in the 2020 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. The samples were then transported in an ice water bath to Instrumental Research Incorporated's lab (IRI). IRI used a Colilert-Quanti Tray to determine the most probable number (MPN) of *E. coli* colonies in the samples. Field duplicates were also collected every sampling day on a rotating schedule. Water and air temperatures were measured using a digital thermometer. Rain data was collected at the MPRB South Side Service Center using a tipping bucket rain gage.

Other parameters collected in the field when samples were taken included:

- air and water temperature
- current weather
- LAURI parameters of beach (For additional information on the LAURI see **Chapter 1**)
- number of adults, children, and children in diapers not in the water
- number of geese, ducks, and gulls on the beach
- number of swimmers in the water broken down by adults, children, and children in diapers
- water quality parameters (when permitted)
- comments (anything unusual, visible fecal material).

Additional data compiled in the office were:

- amount of previous day's rainfall
- wind speed and direction
- duration of rain event
- hours since last rain event

- intensity of rain event
- lake level
- beach attendance.

Blue-Green Algae Visual Monitoring Index

A blue-green algae Visual Monitoring Index (VMI) was implemented in 2020 as part of the weekly data collection at each of the MPRB beaches. The VMI was based on criteria developed by the Vermont Department of Environmental Conservation and the Lake Champlain Committee (https://www.lakechamplaincommittee.org/get-involved/volunteers/cyanobacteriamonitors/cyanobacteria-bloom-intensity#c4807). Blue-green algae blooms, otherwise known as harmful algal blooms, are caused by a photosynthetic microorganism called cyanobacteria. The VMI can often be referred to as blue-green algae, cyanobacteria or harmful algae bloom visual monitoring index. Images of the VMI criteria were taken by the Lake Champlain Committee (LCC) and MPRB staff. The 2020 results served as a base set of information to begin building a more robust monitoring program.

The VMI is as follows:

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 narrow band on shore, open water not discolored
3: full bloom visible

Category 1a: Generally safe with no cyanobacteria observed and clear water. Any organisms floating in 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 18-4**.

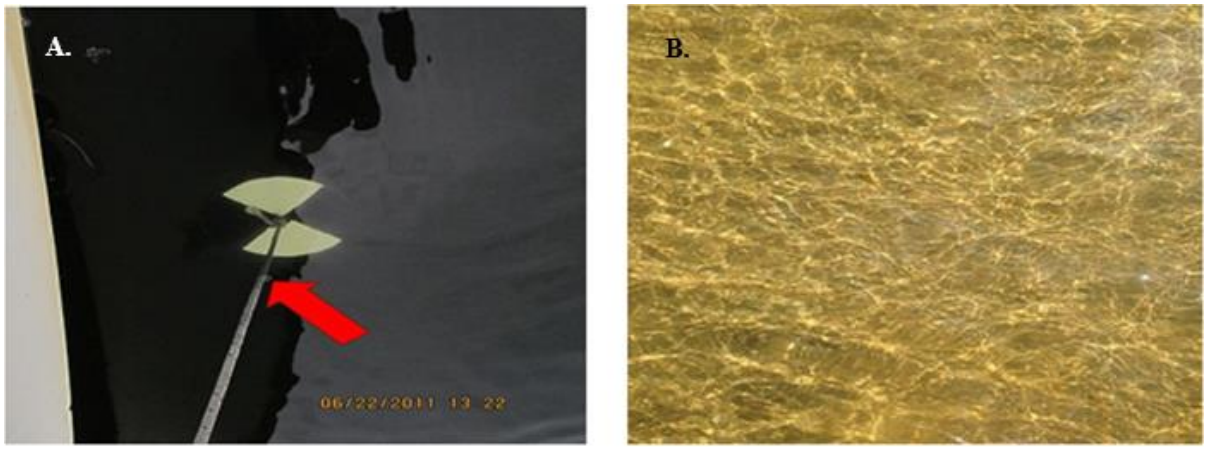


Figure 18-4. Images from the LCC of Category 1a: Generally Safe with no cyanobacteria observed in images A and B where clear water is shown by the visible Secchi disc and lake bottom.

Category 1b: Generally safe, with no cyanobacteria observed but conditions are brown and turbid. **Figure 18-5** shows brown turbid low visibility through water column but do not indicate a presence of cyanobacteria.

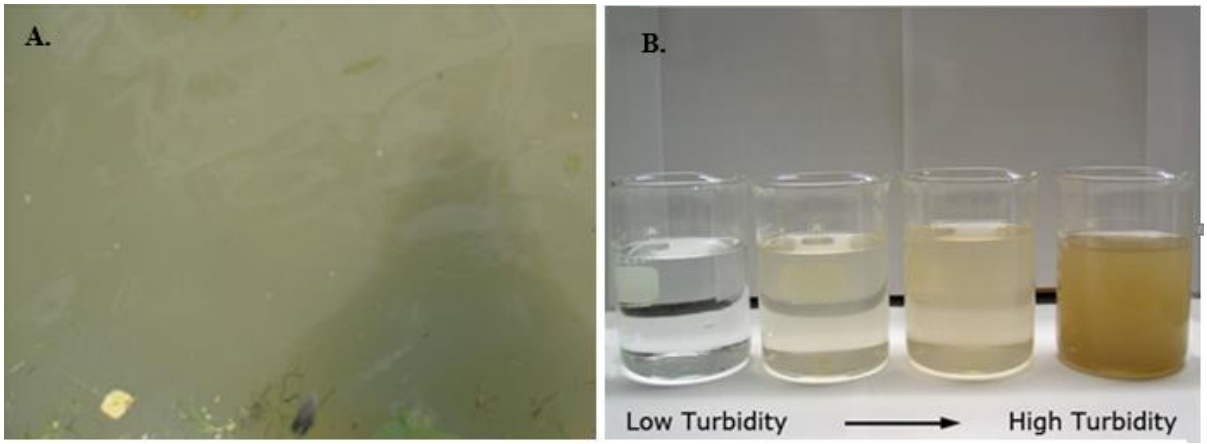


Figure 18-5. Images taken by LCC of Category 1b where conditions are generally safe with no cyanobacteria observed however the conditions are brown and turbid. Image A shows brown/turbid conditions in the field while B is a comparison of low to high turbidity in the lab.

Category 1c: Generally safe with no cyanobacteria observed but other phenomena present. Other material, as shown in **Figure 18-6** may include:

- filamentous green algae that appear stringy, with long strands or attached to the bottom of the lake
- pollen
- duckweed



Figure 18-6. Images from the LCC of Category 1c: Generally safe with 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: Generally safe with 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 18-7**, 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 18-7. Image from LCC of Category 1d jar test: Generally safe with 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 18-8**. Some cyanobacteria are observed in the water but not a uniform layer.

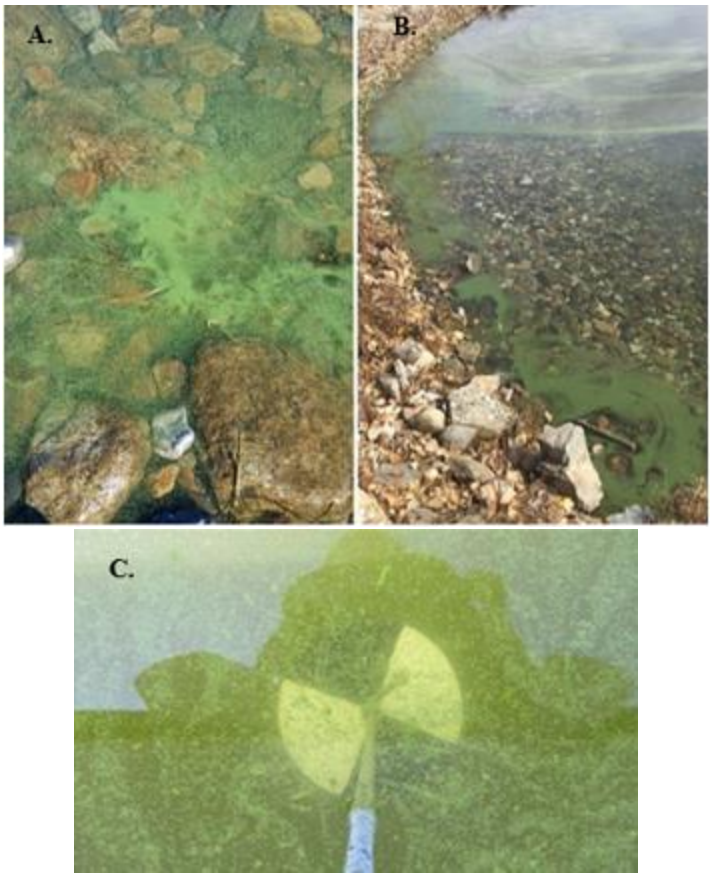


Figure 18-8. Images from LCC of Category 2: Low alert, cyanobacteria observed, but at less than "bloom" levels as seen by the bands of cyanobacteria present at the shoreline (A and B) and reduced clarity but not green structure covering the Secchi disc in open water (C).

Category 3: High alert, cyanobacteria bloom observed in progress. Extensive surface scum on the water and color may range from green to electric blue. Usually, the scum on the water is accompanied by a thick accumulation at shoreline. Open water appears green to turquoise as shown in **Figure 18-9**.

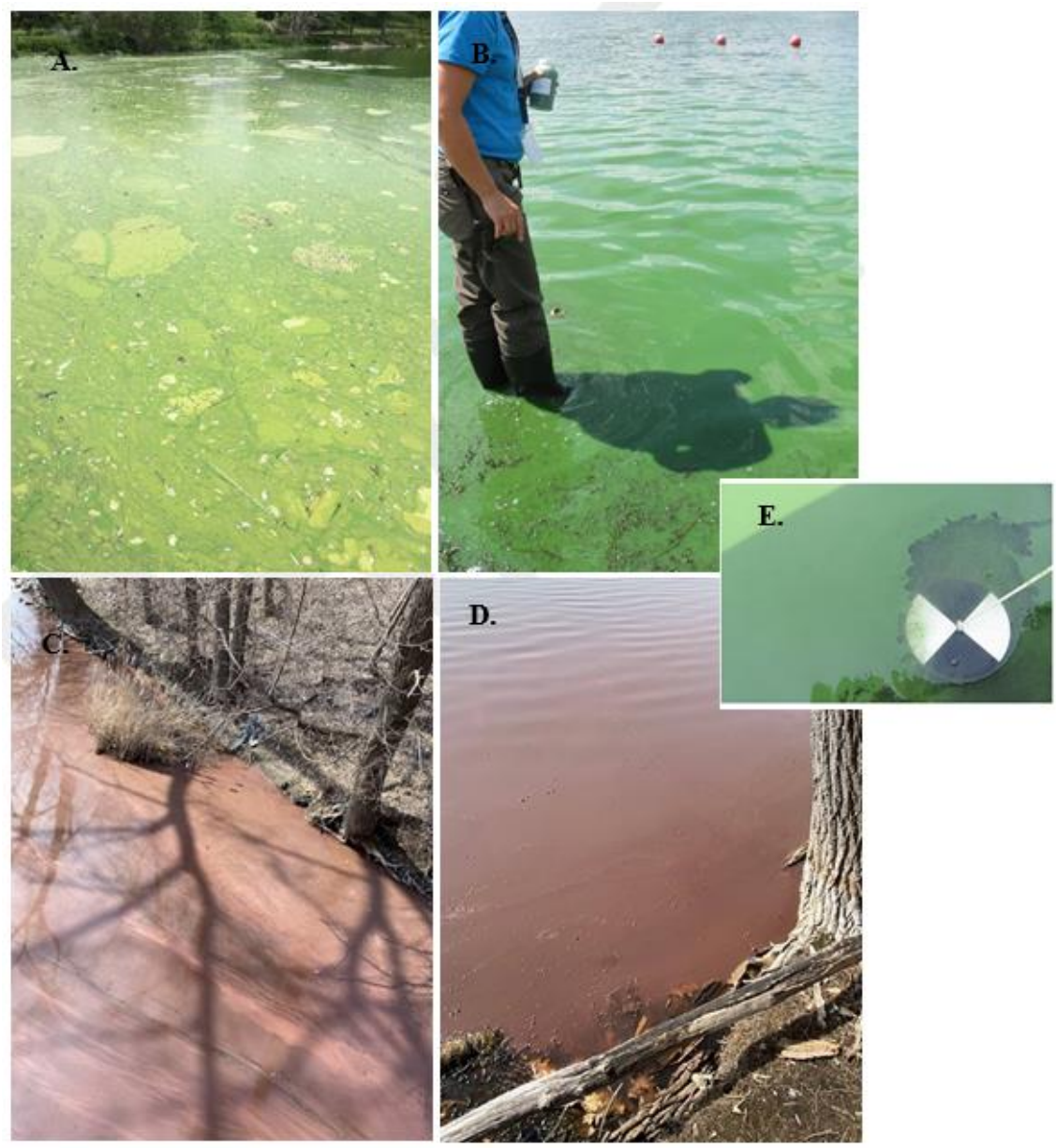


Figure 18-9. Images of examples of Category 3 taken by MPRB staff: High alert, cyanobacteria bloom observed in progress. A continuous layer of cyanobacteria observed at the surface and not stringy as seen in images A, B, C and D. Thick surface scum present as seen covering the Secchi disc in image E.

Results of the VMI were posted on the online MPRB Lake Water Quality Map to indicate the potential for blue-green/cyanobacteria blooms that could become a health hazard. The map was updated when Level 1d or 2 conditions were observed. The map indicated "be on the lookout for blue-green algae" and a yellow halo around the beach symbol. Additional information and a link to the Minnesota Pollution Control Agency web site was posted in the map to give the public the most up to date information on blue-green algae. If a site had indicated a Level 3, or full bloom, the beach would have been posted on the map as closed and beach closure signs would have been put in place at the beach.

RESULTS & DISCUSSION

Specific lake and beach results are discussed in each of the lake sections. Refer to **Chapter 17** for comparison of data between lakes for blue-green monitoring and events.

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 2020 beach monitoring season (6/10/20 through 9/4/20). Most beaches had low season-long geometric means but there were several closures during 2020.

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 2020.

Statistical Calculations	Bde Maka Ska			Cedar			Harriet		Hiawatha	Nokomis		Wirth
	32nd	Main	Thomas	East	Main	Point	Main	SE		50th	Main	
Number of Samples	13	13	13	13	13	13	13	13	13	13	13	13
Minimum	4	13	4	2	2	1	3	4	22	2	5	1
Maximum	1210	1267	2420	66	494	113	243	2420	2420	586	887	591
Median	36	69	27	10	17	11	24	82	117	38	19	8
Mean	186	231	394	16	81	25	62	427	425	116	134	143
Geometric Mean	44	76	48	9	19	10	28	92	149	32	34	22
Max 30-Day Geo Mean	151	183	121	28	35	15	61	217	230	48	49	109
Standard Deviation	374	360	869	18	149	35	74	704	695	207	266	195

2020 Beach Closures

Bde Maka Ska 32nd Street Beach closed September 1st and remained closed through the last week of the 2020 season due to an exceedance of the 30-day geometric mean standard 126 MPN/100 mL. Higher concentrations of bacteria that led to this closure could be attributed to evidence of waterfowl activity and waste, as well as piles of aquatic vegetation along the shore. Thomas Beach at Bde Maka Ska closed on August 11th due to an exceedance of the single sample *E. coli* standard of 1,260 MPN/100 mL. High concentrations of bacteria that led to this closure could be attributed to stormwater runoff from a recent rainfall event; a total of 1.6 inches was deposited 24 hours prior to sampling. The beach was re-sampled on August 12th and re-opened on August 13th after results had shown that *E.coli* concentrations dropped below the single-sample threshold. Thomas Beach was closed again on September 1st due to an exceedance of the single sample *E. coli* standard. The beach was re-sampled on September 2nd and re-opened on September 3rd after results had shown that *E. coli* concentrations dropped below the single-sample threshold. Bde Maka Ska Main Beach was closed on August 25th due to an exceedance of the 30-day geometric mean standard of 126 MPN/100 mL. The beach remained closed for the rest of the 2020 season as bacteria levels did not return to acceptable standard concentrations.

Harriet Main beach remained open for the entire 2020 sampling season, while Harriet Southeast beach closed three times. Harriet Southeast beach first closed July 7th due to exceedance of the 30-day geomean (126 MPN/100 mL) standard and reopened on July 14th when *E. coli* levels dropped below the geomean standard. The beach closed again August 25th due to a single sample exceedance (>1260 MPN/100 mL) and reopened when *E. coli* levels dropped below the single sample threshold. Harriet Southeast beach also closed on September 1st due to the exceedance of the 30-day geomean and remained closed through the end of the season. Throughout the 2020 season the Harriet Southeast beach had signs of heavy waterfowl use; however, spotting the geese and ducks during sampling was rare. Piles of aquatic plants washed up on shore, waterfowl waste and erosion of beach sand after rainfall events could have contributed to the higher bacteria levels that closed the Southeast beach.

Hiawatha beach first closed on July 7th due to exceedance of the 30-day geomean standard of 126 MPN/100mL and reopened on August 4th when *E. coli* levels dropped below the 30-day geomean standard. The beach also closed on August 11th due to exceedance of the single sample *E. coli* standard of 1,260 MPN/100mL and reopened August 13th when bacteria levels decreased below the single sample standard. Hiawatha beach closed again on September 1st due to exceedance of the 30-day geomean and remained closed the rest of the sampling season. High numbers of waterfowl overnighting on Hiawatha Beach are the most likely cause of high bacteria levels.

High *E. coli* concentrations at beaches may be attributed to stormwater runoff from rainfall events, large amounts of aquatic vegetation accumulating in the beach areas, erosion of beach sand and shoreline from large rain events, and waterfowl activity and waste. In general, rain and large amounts of birds near the beach are likely the most influential causes of elevated *E. coli* levels in Minneapolis lakes. Large numbers of waterfowl were documented on and near many of the beaches that experienced closures including Lake Hiawatha, Lake Harriet Southeast, and Bde Maka Ska. Although the MPRB conducts a resident Canada Goose removal program, there remained large groups of 40+ birds that appeared to overnight on some of the beaches, especially during migration.

Rainfall events wash the bacteria off hard surfaces and send it through the stormsewer system to the lakes. Surface runoff from larger events can erode beach sand and shoreline soils washing accumulated bacteria into the lake. **Table 18-2** shows the number of storms during the beach season, 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 season. Rain data was collected at the MPRB South Side 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 2016–2020 beach seasons (entire months of June, July and August). A storm is defined as being greater than 0.10 inches and separated from other rain by 8 hours.

Year	2016	2017	2018	2019	2020
Number of storms	21	21	18	26	20
Maximum rain single event (in)	2.52	1.49	1.27	2.58	2.18
Average rain per event (in)	0.71	0.61	0.56	0.64	0.57
Total rain in inches	14.92	12.78	10.16	17.20	11.11

It is difficult to assess the quality of water the same day of sample collection since laboratory testing requires 24 hours to complete. The lag time between sample collection and receipt of test results can sometimes result in posting errors. 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. The 24-hour delay may occasionally result in these posting errors based on the single-sample exceedance of the MPCA inland lake standard of 1,260 organisms per 100 mL of water which represents levels at a single point in time. It is important to note that the MPCA single-sample standard is a very high *E. coli* level trigger and is not typically sustained over long periods. Closures based on the US EPA geometric mean standard of not to exceed 126 organisms per 100 mL of water were not affected by the lag time issue as this standard reflects the compounding effect of five *E. coli* samples collected equally spaced over a 30-day period.

Beach management decisions are made using the best available methods and data. MPRB Environmental Water Resources staff seeks out the latest *E. coli* and beach pathogen research as well as technology for a rapid *E. coli* test to eliminate unnecessary closures. In the past, staff members have also participated in a Metro-Wide Beach Regulators group to enhance consistency among the different organizations operating beaches in the Metro.

In the US 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).

Blue-Green Visual Monitoring

Results from the blue-green VMI can be seen in **Table 18-3**. Beaches that received a 1d or 2 rating were marked in the MPRB Lake Water Quality Map with a yellow halo indicating a watch condition for the presence of blue-green algae. The watch designation was used when conditions did not warrant beach closure conditions but indicated the need for increased awareness. It is important to note that blooms and accumulation can move throughout the lake, including shallow to deeper areas, so it is unrealistic to place signs in every location along the lake and close specific locations since conditions are constantly changing. Lake users are encouraged during watch conditions and stay out of the water if a bloom is observed. Category 3 level, or warning level conditions of an ongoing bloom, did not happen during the timeframe of the VMI which began on June 30th and continued through the 2020 beach monitoring season which ended on August 31, 2020.

Table 18-3. Results of the VMI taken weekly during beach monitoring from June 30th to August 31st, 2020. Beaches that received a 1d or 2 rating were marked in the MPRB lake water quality map with a yellow halo indicating a watch condition for the presence of blue-green algae. The shaded cells show when watch conditions were recorded at MPRB beaches.

Beach Location	6/30	7/6	7/13	7/20	7/27	8/3	8/10	8/17	8/24	8/31
Hiawatha	1b	1b	1b	1b	**1d**	**1d**	1b	1b	**2**	**2**
Nokomis 50th	**1d**	1c	1b	1b	**2**	**1d**	**2**	**1d**	**2**	**2**
Nokomis Main	**1d**	1c	1b	1b	**2**	**1d**	**2**	**2**	**2**	**2**
Harriet SE	1a	1a	1c	1a	1a	1a	1a	1a	1a	1b
Harriet Main	1a	1a	1a	1a	1a	1a	1a	1a	1a	1a
Bde Maka Ska - Thomas	1a	1c	1c	1a	1a	1a	1a	1a	1a	1a
Bde Maka Ska - 32nd	1a	1a	1c	**1d**	**1d**	1c	**1d**	1a	1a	1a
Bde Maka Ska - Main	1a	1a	1c	**1d**	1a	1c	**1d**	1a	1a	1a
Cedar - East Hidden	1b	1b	1b	**2**	**2**	**2**	**2**	**2**	**2**	**2**
Cedar - Main	1c	1b	1b	**2**	**2**	**2**	**2**	**2**	**2**	**2**
Cedar - Point	1b	1b	1b	**2**	**2**	**2**	**2**	**2**	**2**	**2**
Wirth	1c	1a	1a	1a	1a	1a	1a	1a	1a	1a

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: full bloom visible *no MPRB beaches were observed to have a level 3 rating in 2020*

Visual indications of blue-green algae were observed at Hiawatha Beach at the end of July and through mid-August which prompted a watch ring for the beach beginning on July 27th. The algae levels increased to Category 2 during the last two weeks of August and into the fall.

Both Lake Nokomis beaches were observed to have blue-green remnants from an unusual spring algal bloom early in the beach monitoring season, warranting a 1d Category rating and watch indication on the lake water quality map on June 30th. Winter blue-green algae blooms under the ice on Lake Nokomis are not uncommon; however, the rapid ice-out and cooler than average spring temperatures in 2020 led to conditions that allowed the algae to continue growing into spring. The blue-green algae subsided for the first three weeks of July until an increased growth at the end of the month again indicated a level 1d rating that lasted through the rest of the beach monitoring season and into the late fall. The Lake Nokomis beaches were marked with a blue-green watch on the Lake Water Quality Map for most of the beach season.

Increases in visible blue-green algae warranted a Category 1d ranking at Bde Maka Ska's 32nd and Main beaches from the end of July through mid-August, with the first week of August having a slight decrease in visual algae. The Lake Water Quality Map indicated a watch on all Bde Maka Ska beaches, including Thomas, for potential blue-green algae blooms during this period. None of the Bde Maka Ska beaches were observed to reach Category 2 levels.

All the Cedar Lake beaches had decreased water clarity at the beginning of the beach season and reached a Category 2 rating on July 20th that remained in place through the rest of the beach season and into the Fall. Watches for blue-green algae were flagged on the Lake Water Quality Map for all three beaches from July 20th through the rest of the beach season.

TOC

19. 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 19-1. Lower Pool at Webber Natural Swimming Pool in June 2019.

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, 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. Therefore, 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. A UV disinfection system was added in 2019, prior to the swim season, as part of the sanitation process of the pool. The UV disinfection system is a UV light that, when operating, inactivates 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 opened in July 2015 and was only open for swimming on the weekends. Due to COVID-19 concerns and for the safety of staff and guests, Webber NSP was closed for the entire 2020 season.

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 US Environmental Protection Agency (USEPA). Knowledge gained from the *E. coli* 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, US EPA Beach Act STV standards (EPA, 2012), and WHO standards until US EPA or State of Minnesota approved standards are available for natural swimming pools. 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 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 Statistical Threshold Values (EPA STV) would be used as a "not to exceed standard" for the Webber NSP, see **Table 19-1**. 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*, and by using this more restrictive standard, it is expected that public health will be preserved. Because of the type of NSP built at Webber Park, the FLL standard should be the primary standards used to measure the pool in order to be most protective of public health and the EPA STV values used secondarily as a "not to exceed" level. Since there is no EPA standard set for *Pseudomonas aeruginosa*, a WHO guideline from 2000 (WHO, 2000) will be used as a "not to exceed" for this organism.

Table 19-1. MPRB 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 will remain open and regular maintenance will continue. If FLL standards are exceeded once, the pool will be resampled after appropriate additional maintenance. If the FLL standard is still exceeded, the pool will close until the standard is met again. If the EPA STV or WHO value is exceeded, the pool will be closed. After appropriate maintenance, the pool will be 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. Since Webber NSP is not technologically heated, and is only heated by the sun, these bacteria will not be part of the regular sampling program at this time.

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. Any city potable water used must first be run through a phosphate filter to limit the phosphorus concentration in the pool water in order to limit algae growth.

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 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 and does not need the use of chemicals to eliminate harmful microorganisms.

METHODS

Environmental Management staff monitors 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. Monitoring was limited in 2020 because the pool was closed due to COVID-19. Bacteria samples were collected once a month from June through September to ensure the NSP system continued to work properly.

MPRB Maintenance staff records the water transparency by lowering a black and white 20-cm diameter Secchi disk into the deep diving well of the pool three times per day. Probes were installed in the pumphouse to monitor water temperature, pH, oxidative reduction potential (ORP), and conductivity. The pumphouse flooded May 14, 2020, causing all the probes to malfunction. A Hydrolab MS5 was used to measure the pH, temperature and conductivity monthly. The probes were replaced in late-October. A YSI Pro30 has also been used to measure the conductivity due to a probe malfunction that occurred in June of 2018; this same method has been carried out for the 2020 sampling season.

Grab samples were taken from each basin (upper pool, lower pool, and regeneration basin) for total phosphorus, soluble reactive phosphorus, total nitrogen, nitrate/nitrate, ammonia, alkalinity, hardness, chlorophyll-*a*, and phytoplankton enumeration. Both chlorophyll-*a* and phytoplankton samples were stored in opaque bottles for analysis with the phytoplankton samples preserved with 2.5 mls 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 m/s. 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.

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) and can be found in **Table 19-2**. The contract laboratory for chemical analyses was Instrumental Research, Inc. (IRI). PhycoTech, Inc. analyzed all phytoplankton and zooplankton samples.

Table 19-2. List of physical, chemical and biological parameters along with the method used in 2020.

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 transparency	Upper pool & Lower pool	Secchi Disk
Water temperature	Fine filter tank & Regeneration basin	Hydrolab MS5
pH value	Fine filter tank & Regeneration basin	Hydrolab MS5
Conductivity	Fine filter tank & Regeneration basin	Hydrolab MS 5 and YSI
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/nitrate	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 2340 C.
Chlorophyll -*a*	Upper pool, Lower pool, & Regeneration basin	SM 10200 H
Phytoplankton/zooplankton	Upper pool, Lower pool, & Regeneration basin	Phyto - rapid assessment and biomass estimate Zoop - horizontal tow 80 µm

RESULTS & DISCUSSION

Bacteria

E. coli concentrations were low throughout the entire 2020 sampling season. All *E. coli* samples met the FLL standard of 100 MPN per 100 mL and EPA STV threshold of 410 MPN per 100 mL, see **Figure 19-2a**. *E.coli*, although present in the environment, is commonly found in the lower intestines of warm-blooded organisms. The presence of *E.coli* is indicative of fecal pollution. High concentrations of *E.coli* may be indicative of waterfowl activity. Waterfowl spread *E.coli* strains via the environment or through passing strains enterically. Low *E. coli* concentrations in 2020 are likely attributed to the pool being closed and no human contact in the NSP. Enterococci concentrations were relatively low for most of the year. Levels exceeded the FLL standard of 50 MPN per 100 mL three times with 80% of the samples meeting the standard in 2020, see **Figure 19-2b**. The source of the elevated enterococci is unknown, but birds are possible source. Numerous anti-bird devices are used around Webber pool; however, the pool is located along a major flyway and it is difficult to deter every bird, especially at night. *Pseudomonas aeruginosa* concentrations were low for most of the year. Levels exceeded the FLL standard of 10 MPN per 100 mL once in September with 93% of the samples meeting the standard in 2020, see **Figure 19-2C**. *Pseudomonas* is a common bacterium in soils and excess sediment in the pool is typically thought to be the cause of elevated concentrations.

Water Chemistry

Temperature, pH, and conductivity were measured at two locations: water from the fine filter tank (System 1) and water leaving the regeneration basin (System 2). Due to the probe malfunction there are four readings collected in 2020 and no ORP (Oxidation Reduction Potential) data. Conductivity was also measured in the upper and lower pool using a YSI Pro30. Water temperature was above the FLL recommendation of less than 25 °C (77 °F) in July for both System 1 and System 2. The FLL states that the water temperatures in the pool above 28 °C (82.4°F) can be tolerated for up to five days, see **Figure 19-3a**. 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 2020 sampling season, see **Figure 19-3b**. Specific conductivity was within the FLL recommended range (200-1000 $\mu S\ cm^{-1}$) the entire season, see **Figure 19-3c**.

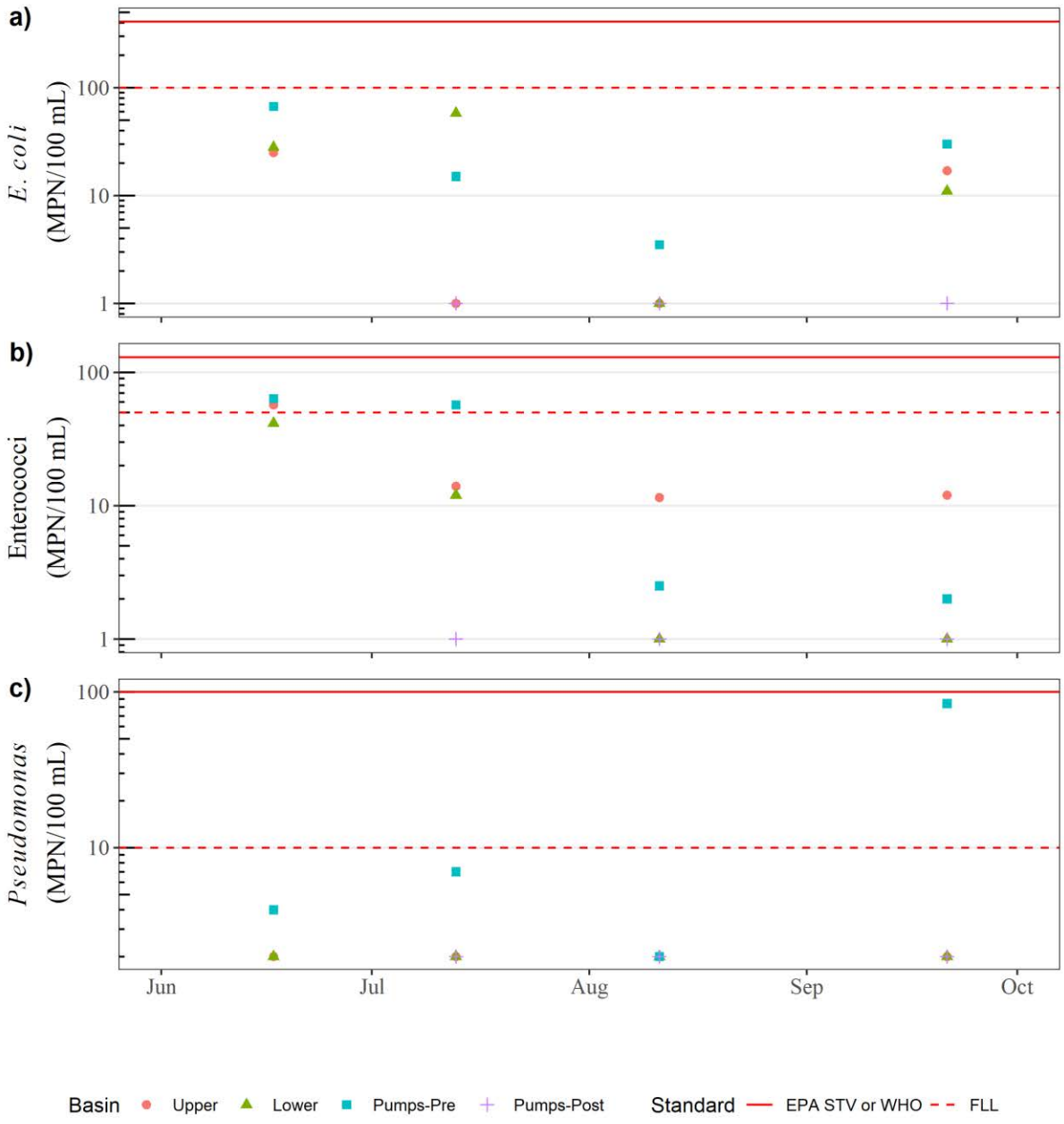


Figure 19-2. Webber pool *E. coli* (a), Enterococci (b) and *Pseudomonas aeruginosa* (c) concentrations in 2020. The dashed horizontal lines represent the FLL standard and solid horizontal lines represent either the EPA STV threshold for *E. coli* and Enterococci or the WHO guideline for *Pseudomonas*. Note the log scales on each y-axis.

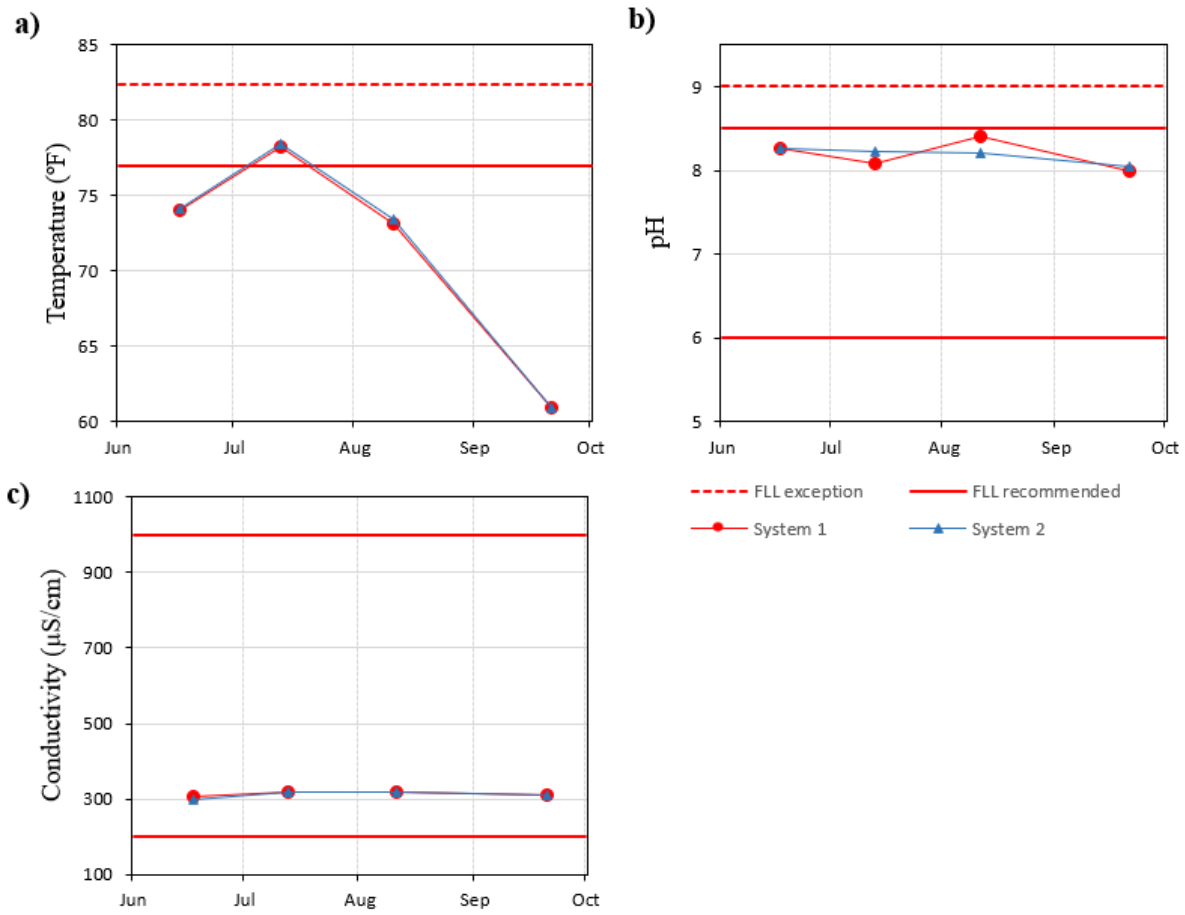


Figure 19-3. Webber pool temperature (a), pH (b), and conductivity (c) in 2020. The horizontal lines represent the FLL recommended values and the dashed horizontal lines represent acceptable levels as an exception according to the FLL.

Chlorophyll-*a* values in 2020 were initially high in the regeneration basin before the UV system was turned on and decreased throughout the season, see **Figure 19-4a**. Chlorophyll-*a* values were relatively low in both the upper and lower pools throughout 2020; however, concentrations of chlorophyll-*a* slightly increased in the upper pool in July. Chlorophyll-*a* concentrations were likely low in 2020 due to the UV disinfection system because UV radiation has the ability to destroy pigments in the photosynthetic apparatus, which can decrease plant growth.

Total phosphorus levels were initially above the FLL recommendation at over 0.010 mg/L due to the pool being filled using the city water supply which contains high levels of polyphosphate as an anti-corrosion agent. Phosphorus concentrations fell within the FLL recommended value (< 0.010 mg/L) the rest of the season, see **Figure 19-4b**. Nitrate/nitrite concentrations were low throughout the entire season remaining at 0.030 mg/L in 2020, well within the FLL recommendation of less than 30 mg/L, see **Figure 19-4c**. Alkalinity was also well below the FLL recommended value of 200 mg/L throughout 2020, ranging between 75 and 78 mg/L in all three basins, see **Figure 19-4d**. Hardness exceeded the FLL recommended value of 100 mg/L for the entire sampling season in all three basins indicating that the water was high in mineral content, see **Figure 19-4e**.

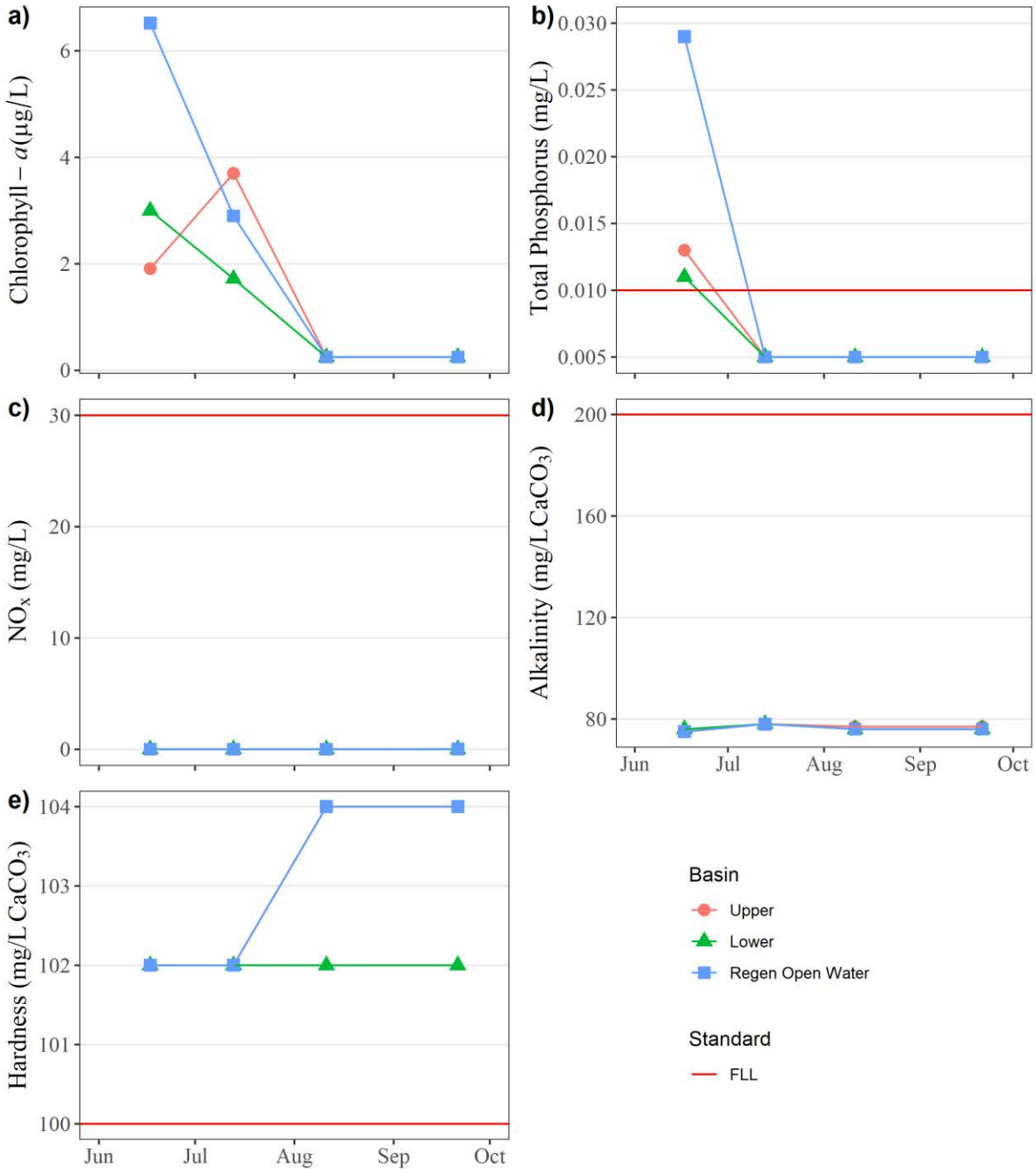


Figure 19-4. Webber pool chlorophyll-*a* (a), total phosphorus (b), nitrate/nitrite (c), alkalinity (d) and hardness (e) in 2020. The horizontal lines represent the FLL recommended values.

Phytoplankton

Phytoplankton are microscopic plants that are an integral part of natural swimming pools because it forms the base of the aquatic food web. They also consume phosphorus and turn it into plant biomass, which can be filtered out of the water and produce oxygen for pool animals. Phytoplankton biovolume by division is displayed in **Figure 19-5**. 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), chrysophytes (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 2020 primarily consisting of green algae. This sample exceedance can be attributed to high concentrations of filamentous algae that were observed upon sampling.

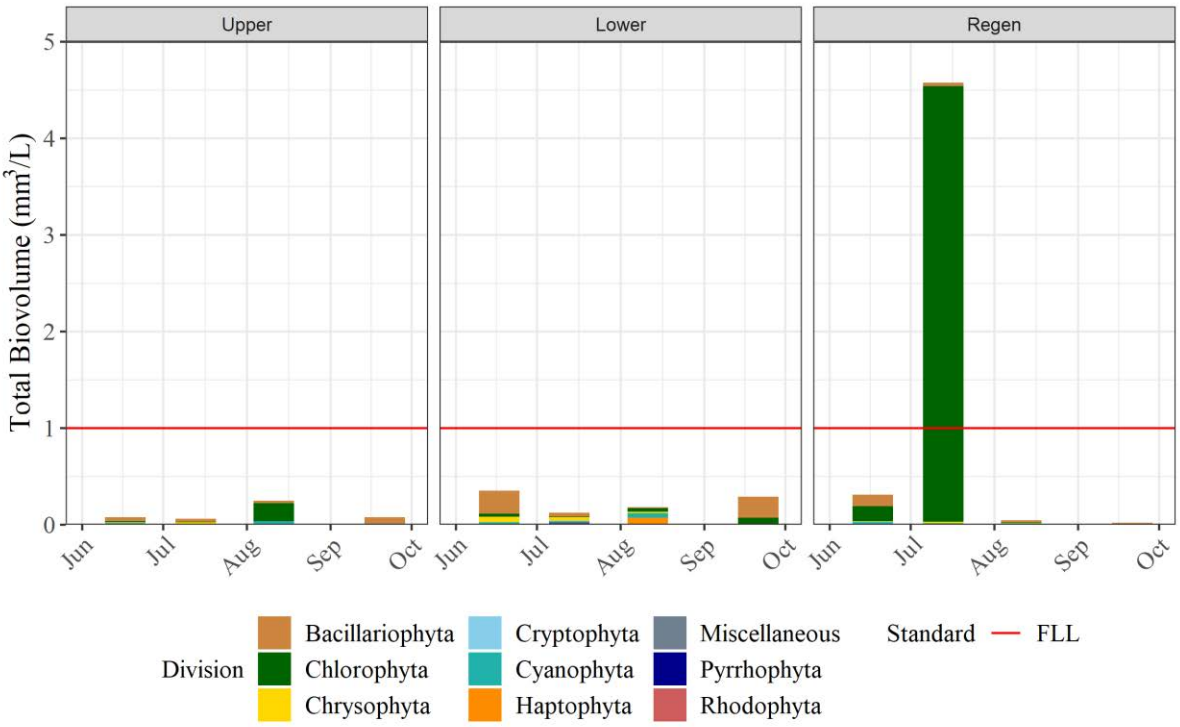


Figure 19-5. Webber pool phytoplankton biomass in 2020. The horizontal line represents the FLL recommended maximum value.

Zooplankton

Zooplankton are tiny animals that feed on phytoplankton and are also vital for natural swimming pools because they act as a live filtering system within the pool. All three basins had low concentrations of zooplankton in 2020, see **Figure 19-6**. The zooplankton community is important for filtering bacteria in the pool water. Copepods have been found to have the greatest filtration capacity (64.8 ml/ind/day), followed by cladocerans (33.3 ml/ind/day) and rotifers (8.5 ml/ind/day) (Eydeler et al. 2010). The majority of the zooplankton in the pool basins were cladocerans, nauplii and juvenile copepods, and rotifers, with lower levels of cyclopoids. In the regeneration basin there were primarily nauplii and juveniles copepods and rotifers throughout the year with high levels of protozoa in June and low levels of cladocerans in September.

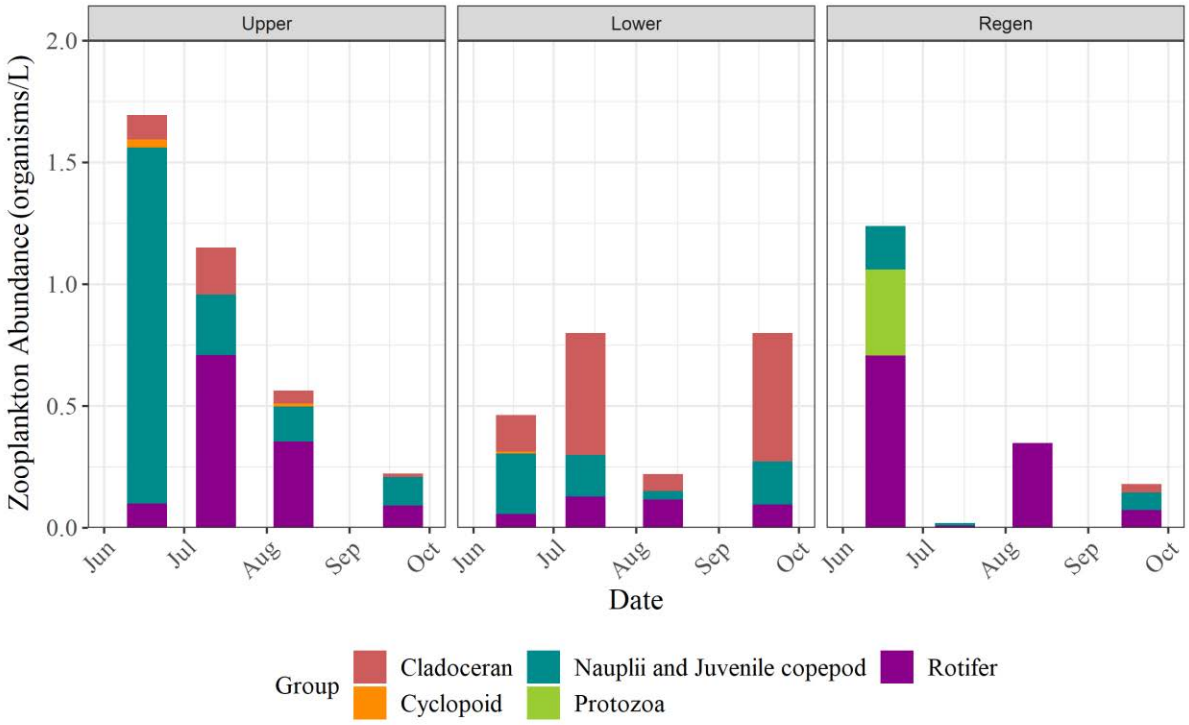


Figure 19-6. Webber pool zooplankton abundance in 2020.

TOC

20. AQUATIC PLANT HARVESTING PROGRAM

The Minneapolis Park and Recreation Board (MPRB) primarily uses mechanical harvesting to maintain recreational access to city lakes. Only the top two meters of the aquatic plants are removed, temporarily allowing for problem-free boating and swimming. The Minnesota Department of Natural Resources (MNDNR) permits determine the limit of allowable harvest area for each lake.

Harvesting using MPRB-owned mechanical harvesters, like the one depicted in **Figure 20-1**, was completed on Bde Maka Ska, Cedar, Harriet, and Isles in 2020. The results of 2020's harvesting activities are listed in **Table 20-1**. MPRB staff removed 179 flatbed truck loads of plants in 2020 which is equivalent to 984.5 cubic yards of aquatic plant material. The 2018 and 2019 harvesting programs resulted in 159 and 140 truckloads of plant material, respectively.

In addition to operating the harvesters, MPRB contracted out harvesting work on Wirth and Nokomis to specialized lake service companies who removed milfoil and other aquatic plants from high traffic recreational areas by hand via SCUBA. **Figure 20-2** depicts hand removal of aquatic plants.

MPRB harvests zebra mussel-infested lakes after uninfested lakes to reduce the risk of unintentionally infesting waterbodies. MPRB currently owns two harvesting machines and arranges for one to stay on Lake Harriet all summer while the second rotates among Bde Maka Ska, Isles, and Cedar. The non-Harriet 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 20-1. Aquatic plant harvesting machine in operation at Lake Harriet.

Table 20-1. 2020 harvesting data.

	Bde Maka Ska	Cedar	Isles	Harriet	Nokomis	Wirth
Acres of permitted harvesting	55	13	36	44	15	2.3
% of littoral zone* permitted to harvest	48%	19%	39%	50%	15%	21%
Amount of aquatic plants harvested (lbs)	234,099	8,214	36,963	455,877	250	5,680

**The littoral zone is the area in which submerged plants can grow. It extends to about 15-feet of depth depending on water clarity.*



Figure 20-2. Hand removal of aquatic plants at Wirth Lake via SCUBA diving.

EURASIAN WATERMILFOIL (*MYRIOPHYLLUM SPICATUM*)

Macrophyte surveys by Shapiro (1974) documented aquatic plants growing to only about 15 feet of depth 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. Wirth Lake only had a shallow ring of aquatic plants growing out to a depth of 3 feet. Intact and robust native plant communities are better able to withstand invasive species. Therefore, the lack of plant growth throughout the littoral zones of 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. 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.

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 and dies off 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 low levels of growth by harsh Minnesota winters. The 1974 Shapiro macrophyte surveys documented curly-leaf pondweed in Bde Maka Ska, Lake Harriet, Lake of the Isles, and Lake Nokomis. The surveys carried out by Shapiro were in late-July which was likely too late in the season to capture the full extent of curly-leaf pondweed in the Minneapolis lakes.

TOC

21. 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. Over time, MPRB has developed a comprehensive AIS program that encompasses a variety of prevention, early detection, response, and management activities. The following chapter is a summary of MPRB's 2020 AIS activities.

INFESTATION STATUS

As of December 2020, 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 21-1**. 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 in 2017. 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 in 2018. Continued searching will take place at several Minneapolis lakes in the future to track zebra mussel populations.

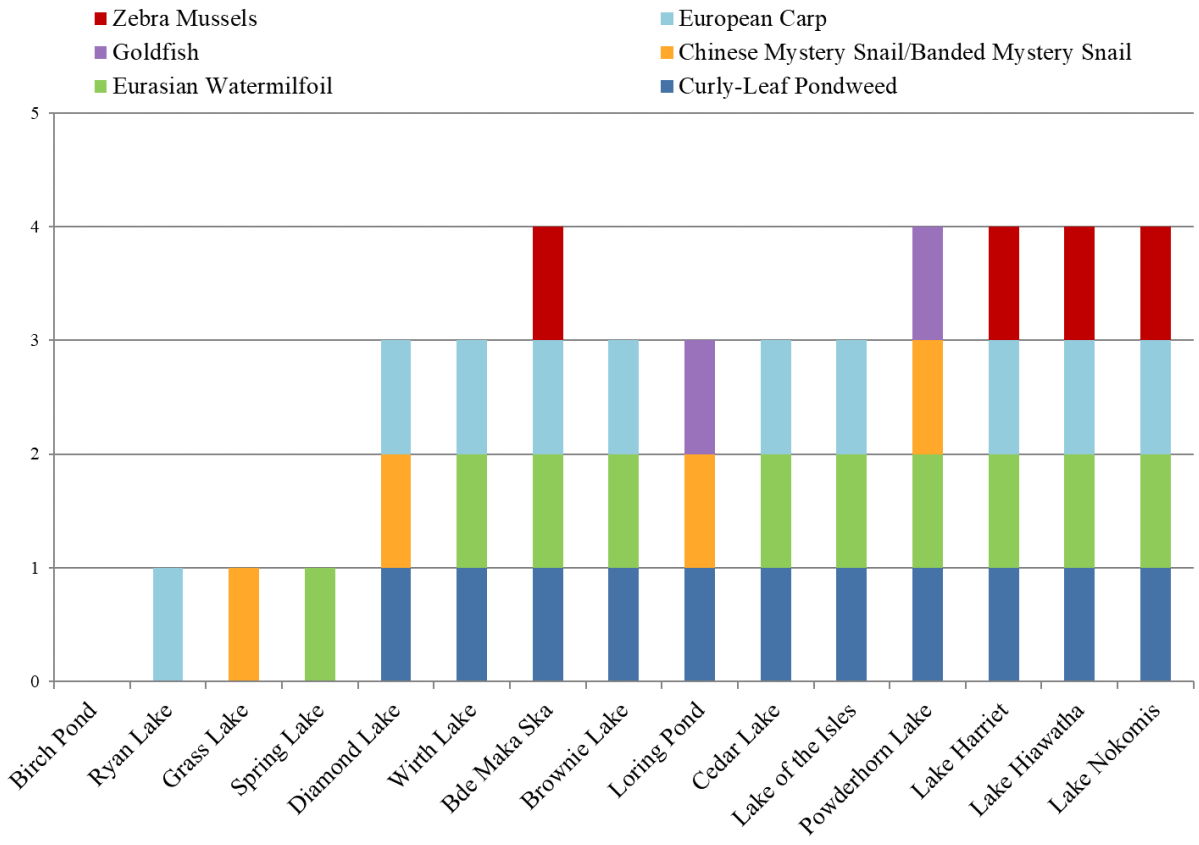


Figure 21-1. Aquatic invasive species found in MPRB lakes according to data collected by MNDNR, WHEP, and MPRB. Birch Pond, Ryan Lake, and Grass Lake have not been fully surveyed for invasive species. Zebra mussels have not been confirmed present in Lake Nokomis, though the lake is designated as infested due to its connection with Minnehaha Creek.

PREVENTION

Watercraft Education and Inspection Program

The MPRB Watercraft Inspection and Education program completed its eighth year in 2020. MPRB watercraft inspectors conducted 10,137 inspections and assisted 12,391 non-boater patrons in 2020. This is the highest number of inspections that have ever been performed in the history of the program. A total of 5,304 inspections were conducted in 2019 and 7,611 inspections were conducted in 2018. It seems that high numbers of people turned to boating as a safe, socially distanced activity during the COVID-19 pandemic. Detailed reports related to the 2020 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 generally 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 178 entering watercraft and 844 exiting watercraft in 2020. 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 178 entering watercraft that were in violation of AIS laws in 2020, 192 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 123 of the 192 incoming AIS violations. Water and mud accounted for 26 and 43 of the 192 incoming AIS violations, respectively. 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.

For the first time in the program's history, no zebra mussel violations occurred in 2020. This means that zebra mussels were never found during a watercraft inspection in 2020. It is not likely that the lack of zebra mussel violations was due to lazy or inattentive inspectors; other AIS violations (plants, animals, mud, water) were detected in 2020. Also, over one third of the 2020 watercraft inspectors had prior experience as inspectors before joining the team in 2020. This is was a very high "employee return rate" for the inspection program and indicated an experienced team. Instead of lazy or inattentive inspectors, the watercraft that visited Minneapolis lakes in 2020 simply appeared to have lacked zebra mussels. The number of zebra mussel violations in previous years has ranged from two in 2017 to 18 in 2014. Zebra mussel violations have occurred 71 times in the history of the program. Of those 71 violations, 34 were at Lake Harriet, 19 were at Lake Nokomis, and 18 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 to this question give insight into how boaters (and AIS) move around Minnesota. According to the 2020 data, 5,875 boaters (58% of 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 were Lake Minnetonka (236 boaters), the Mississippi River (166 boaters), the St. Croix River (103 boaters), Bush Lake (73 boaters), Minnehaha Creek (63 boaters), and Mille Lacs Lake (61 boaters). Boaters came in lesser quantities from lakes all over the state.

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 2020, MPRB staff performed inspections on 59 watercraft that had previously been in starry stonewort-infested waterbodies and 129 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, 20 SCUBA permits were issued in 2020. 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, Bde Maka Ska was designated as infested with zebra mussels by the MNDNR in 2018. In response, MPRB staff adjusted internal workflow procedures to minimize the potential for new introductions. The biggest threat was introducing Bde Maka Ska's zebra mussel population into the upper chain of lakes (Brownie Lake, Cedar Lake, Lake of the Isles). To prevent this, MPRB Water Quality staff and aquatic plant harvesting staff followed protocols in 2019 and 2020 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 21-2**, 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 or stream bottom. The plates are checked for zebra mussel growth 2-4 times per month and are placed back into the water without being cleaned.



Figure 21-2. 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 2020: 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 2020. As shown in **Figure 21-3**, the Lake Hiawatha sampling plate was covered with several thousand zebra mussels by the end of the open water season. Lake Hiawatha has been heavily infested with zebra mussels for several years, due to its connectivity with Minnehaha Creek.



Figure 21-3. Lake Hiawatha zebra mussel sampling plate covered with several thousand zebra mussels in September 2020.

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. **Table 21-1** summarizes the results of the zebra mussel veliger sampling that occurred in 2020.

Table 21-1. 2020 zebra mussel veliger sampling schedule and results.

	Late-June	Late-July	Early-August	Late-August	Early-September
Bde Maka Ska	X	X	X	X	X
Harriet	X	X	X	X	X
Nokomis	X	X	X	X	X
Cedar		X		X	X
Isles		X		X	X
Wirth		X		X	X
Hiawatha		P		P	X

X = Sampling occurred; Samples tested negative for zebra mussel veligers
P = Sampling occurred; Samples tested positive for zebra mussel veligers
Blank cell = Sampling did not occur

As depicted above, zebra mussel veligers were only found in Lake Hiawatha.

Buoy Inspections

Similar to zebra mussel settling plates, beach buoys and sailboat buoys serve as suitable zebra mussel substrate. MPRB watercraft inspectors inspected all the beach buoys from Cedar Lake, Lake Hiawatha, Bde Maka Ska, Lake Harriet, and Lake Nokomis after they were removed from the lakes in the fall. Zebra mussels were only found on the Lake Hiawatha beach buoys. A Lake Hiawatha beach buoy with two attached zebra mussels is shown in **Figure 21-4**.



Figure 21-4. 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 97% 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 2020.

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 21-5**, 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, so they used the surveys to look for a variety of plant and animal AIS. No unexpected AIS were observed during the surveys in 2020.



Figure 21-5. 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 storm sewer discharges and from the movement of zebra mussels from Minnehaha Creek to the lake. The MPRB and Minnehaha Creek Watershed District work together using an established Operating Plan based on lake and creek levels, precipitation, and amount of water released from Grays Bay Dam to manage the weir.

Environmental DNA (eDNA) Monitoring

MPRB staff conducted environmental DNA (eDNA) monitoring at seven lakes in August 2020. Five or ten sample sites were identified per lake and were distributed among inlets, outlets, boat launches, fishing piers, and other noteworthy locations. All the samples from a single lake were passed through the same 10µm nylon filter, creating a composite sample for that lake. **Table 21-2** summarizes the eDNA monitoring that occurred in 2020.

Table 21-2. 2020 eDNA sampling schedule and results.

Date	Lake	# of Sites	Total Volume of Filtered Water (mL)	Result
8/17/2020	Cedar	5	5,031 mL	*X*
8/17/2020	Isles	5	5,060 mL	*X*
8/17/2020	Wirth	5	4,865 mL	*X*
8/19/2020	Bde Maka Ska	10	9,939 mL	*X*
8/19/2020	Harriet	10	9,997 mL	*X*
8/20/2020	Nokomis	10	10,164 mL	*X*
8/20/2020	Hiawatha	5	3,423 mL	*P*

P = Sampling occurred; Samples tested positive for zebra mussel DNA
X = Sampling occurred; Samples tested negative for zebra mussel and quagga mussel DNA

As shown in **Figure 21-6**, all samples were filtered by MPRB staff at the Southside Operations Center and sent to Pisces Molecular Lab in Boulder, Colorado for analysis. The samples were analyzed for zebra mussel and quagga mussel DNA using quantitative polymerase chain reaction (qPCR). The only samples that tested positive for zebra mussel DNA were those collected from Lake Hiawatha. No samples tested positive for quagga mussel DNA.



Figure 21-6. MPRB employee processing a water sample for eDNA analysis.

Lake Nokomis Zebra Mussel Survey

Staff from MPRB, Blue Water Science, and the Minnesota Department of Natural Resources (DNR) conducted surveys for zebra mussels at Lake Nokomis on September 15th. Blue Water Science and DNR staff SCUBA dived during the survey while MPRB staff checked rocks and other substrate along the shoreline using waders. In total, 10.6 hours of searching was conducted in 2020 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, were used to search for zebra mussels in Bde Maka Ska in 2019 and 2020. No evidence of additional zebra mussels was observed in 2019 and 2020. There does not appear to be a well-established population of zebra mussels in Bde Maka Ska at this time. Additional searching is planned to occur in 2021.

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, were used to search for zebra mussels in Lake Harriet in 2018-2020. No evidence of additional zebra mussels was observed in any of those years. There does not appear to be a well-established population of zebra mussels in Lake Harriet at this time. Additional searching is planned to occur in 2021.

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 mechanical harvesters, 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.

Lastly, staff continued to monitor the status of the riparian AIS *Phragmites australis* (common reed) on MPRB property in 2020. Populations of invasive *Phragmites* exist on the south side of Lake of the Isles and the south side of Bde Maka Ska. To manage invasive *Phragmites*, the University of Minnesota recommends a glyphosate and/or imazapyr herbicide treatment in the fall paired with a winter mowing. They have also stated that mechanical control (e.g. mowing, cutting, or digging up the plants) alone without herbicide treatment would likely not be effective. MPRB has not pursued chemical or mechanical management of the invasive *Phragmites* at this time.

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22. Wetland Health Evaluation Project (WHEP)



Figure 22-1. WHEP's Muckstars! volunteering in Robert's Bird Sanctuary

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 22-1**, to collect and analyze wetland 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 monitor wetlands within the park system each year since 2002. Every summer, several wetlands are monitored within Minneapolis depending on the needs of the MPRB. The wetlands monitored during 2020 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.

The COVID-19 pandemic greatly impacted the work of the WHEP program in 2020. The regular monitoring program of over 100 volunteers at 30 wetlands was cancelled however, Hennepin County staff member Ann Journey was able to work with a smaller crew of four volunteers to conduct the monitoring at all the Minneapolis wetland sites.

For more information see the Minnesota WHEP website at www.mnwhep.org or the Hennepin County WHEP website https://www.hennepin.us/your-government/get-involved/wetland-health-evaluation-program.

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. In 2016, Hennepin County WHEP stopped using bottle traps, which were previously used in addition to two dipnet samples for invertebrate surveys, to align with MPCA protocols.

The information 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.

Vegetation IBI metrics (identification to genus level)

- 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

Invertebrate IBI Metrics (identification to family level)

- Number and type of leeches in net and bottle trap samples
- Proportion of Water Boatmen (*Corixidae*) in a bottle trap in relation to the total number of aquatic beetles and all bugs in the sample
- Number of types of dragonflies and damselfly nymphs in dip-net samples
- Total number of mayflies, plus the number and type of caddis flies, plus presence of fingernail clams and dragonflies
- Number of types of snails
- Number of taxa above, plus the number of crustaceans, plus the presence of *Chaoborus*

Ratings developed for the invertebrate and vegetation IBI are shown below in **Table 22-1**. 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. The scoring summary for invertebrates was adjusted in 2016 due to the elimination of bottle traps.

Due to the COVID-19 pandemic monitoring on the Minneapolis sites was conducted on a smaller scale. A COVID-19 monitoring protocol was developed for the safety of the volunteers. The team that conducted the WHEP monitoring in 2020 were a very experienced crew lead by Hennepin County staff.

Table 22-1. Ratings for the invertebrate and vegetation IBIs.

Invertebrate Index of Biotic Integrity		Vegetation Index of Biotic Integrity	
Sum of invertebrate metric scores	**Interpretation**	**Sum of vegetation metric scores**	**Interpretation**
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 2020, WHEP-trained volunteers, as seen in **Figure 22-2** monitored six wetlands within the MPRB system. Roberts Bird Sanctuary was monitored for the eighteenth time serving as a reference wetland for the Minneapolis WHEP program. IBI scores for other monitored wetlands can be compared to scores for the reference wetland to determine the effects of inter-annual variation or regional changes (drought, wet periods, plant diseases, etc.) on wetland heath.



Figure 22-2. WHEP volunteers at work in Wirth Beach Wetland (A) and Webber Pond (B).

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 ten acres in size. The WHEP team accesses the monitoring location near a tamarack stand from the boardwalk. **Table 22-2** shows the results for all eighteen years of monitoring at the Roberts Bird Sanctuary. In 2020, the wetland received a poor rating for invertebrate quality and moderate for vegetation quality. The team noted that sampling was challenging due to the impact of years of consecutive high-water conditions. Due to COVID-19, a smaller crew of 4 were only able to sort 5 dip nets, compared with a typical size crew of 12 making 8 dip net efforts. A continued decrease in invertebrate numbers from 2019 could be attributed to these sampling challenges. Precipitation amounts decreased throughout the summer, and work was done to improve flow at the Cemetery Creek outlet to Lake Harriet helping to reduce the flooding in the Sanctuary. Subsequent years of monitoring will give a better picture of the impacts of flooding on invertebrates and sampling conditions in Roberts. Notable points from the 2020 monitoring included large numbers of waterfowl and small frogs and toads.

Table 22-2. WHEP scores at the Roberts Bird Sanctuary Site.

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

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 **Chapter 6**. Diamond Lake has been monitored sixteen times in the WHEP Program. This site is located in an urban setting with a large urban 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 22-3**. In 2020, the Diamond Lake Wetland Fringe rated moderate for both invertebrate and vegetation quality.

Sustained high water levels in Diamond, due to four consecutive years of higher than average precipitation, appears to be shifting Diamond to a more "lake-like" ecosystem. Nesting bluegills, tadpoles, red-winged black birds, barn swallows, robins, mallards and muskrats were noted by the sampling team.

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 2020. They were documented by WHEP volunteers in 2008 – 2013 and 2015 – 2019. WHEP volunteers noted more empty shells and younger snails in recent years, which follows a general trend along the southeast shore since muskrats took up residence in 2010 or 2011.

Table 22-3. WHEP scores at Diamond Lake.

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

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 bird-watching. The lake has typically been monitored every other year since 2002 as part of MPRB's lake sampling water quality program **Chapter 7**. 2020 was the sixth year that Grass Lake was evaluated in the WHEP program, as presented below in **Table 22-4**. In 2020, Grass Lake received a moderate rating for both invertebrate and vegetation quality.

Banded and/or Chinese mystery snails (*Vivaparus georgianus* and/or *Cipangopaludina chinensis*) were noted and have been historically found during WHEP monitoring at Grass Lake Wetland. Other species observed in 2020 included: egrets, red-winged blackbirds, mallards, muskrats, and turtles. Neighbors noted that there is a springtime egret rookery located along the lake.

Table 22-4. WHEP scores at Grass Lake Wetland.

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



Figure 22-3. WHEP volunteer searching for invertebrates.

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 wetland was historically filled with debris from the old Wirth Beach House. Debris was removed and the wetland was replanted in 2011. The previous vegetation type of the wetland was a mix of cattail and purple loosestrife.

The scores and ratings from all seven years that the Wirth Beach Restored Wetland has been included in the WHEP monitoring program are shown in **Table 22-5**. Wirth Beach Restored Wetland received an excellent rating for both invertebrate and vegetation quality in 2020. During the plant survey conducted in July of 2019 the WHEP team discovered bladderwort (*Utricularia sp.*) for the first time. Bladderwort is one of only a few carnivorous aquatic plant species in Minnesota. The plant has small bladders, or stomachs, along its branches that are used to trap and digest microscopic prey. The bladderwort population increased in 2020 with a sea of yellow flowers observed. This discovery is notable, because bladderwort is considered an indicator of good water quality. True to the bladderworts status as an indicator species, the 2020 WHEP team discovered a wider variety of invertebrate species accompanying the growing bladderwort population.

Table 22-5. WHEP scores at Wirth Beach Restored Wetland.

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



Figure 22-4. Bladderwort flower found at Wirth Beach Restored Wetland.

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, 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 the only other water added is run through a phosphate filter to limit phosphors in the system.

Due to the impacts of COVID-19, Webber Pool remained closed in 2020. The pool was filled in the spring and constant flow was maintained through the system while rehabilitation of the regeneration basin was completed. **Table 22-6** shows the scores and ratings from all five years that the Webber Regeneration Basin has been included in the WHEP monitoring program. The Regeneration Basin received an excellent rating for invertebrate quality and a moderate for vegetation quality in 2020. The WHEP team noted a more stream like invertebrate community developing. Notable species included water striders, tadpoles and lots of frogs.

Table 22-6. 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

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 five years that the Webber Stormwater Pond has been included in the WHEP monitoring program is shown in **Table 22-7**. Webber Stormwater Pond received an excellent rating for invertebrate quality and moderate for vegetation quality in 2020. Many tadpoles, frogs, toads, turtles and bird species were noted. Invasive rusty crayfish have been seen at this site in the past but are not established and were not seen in 2020.

Table 22-7. 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

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23. Pond Screening and Monitoring

BACKGROUND

In 2020, the COVID-19 pandemic disrupted the ability to carry out field-based work and equipment installations. Due to social distancing guidelines, a pond screening study was designed for the NPDES stormwater monitoring program. In 2020 the City of Minneapolis conducted a stormwater pond study that included chemical monitoring, bathymetric surveys, and oxygen/temperature water column profiles. A Minneapolis Park and Recreation Board (MPRB) pond screening study was carried out to augment the data collected for the Minneapolis screening study.

The purpose of the screening study was to determine if any of a group of 16 existing ponds should be prioritized for retrofit projects that would increase their nutrient removal benefit. Most of the 16 ponds were designed originally for flood control. Ponds could be prioritized for projects if they had a high potential of Harmful Algal Blooms (HABs), evidence of high phosphorus return from the sediment, or evidence of sediment resuspension. For screening purposes, Chl-a was considered an indicator of moderate or greater likelihood for HABs presence when the Chl-*a* concentration was greater than 30 ug/L (Heiskary and Lindon, 2009). HABs in neighborhood ponds could be a potential health hazard. High total phosphorus values in pond water could be caused by anoxic conditions due to sediment-bound phosphorus being released to the water column. Ponds with high phosphorus may prioritized for dredging or other retrofit to gain a water quality benefit for downstream water bodies. Sediment resuspension or bioturbation in a pond could be potentially determined by high TSS, VSS, or metals values. Resuspension of sediment may indicate that the pond could be retrofit or maintained differently for increased water quality benefit.

There is also a desire in the City of Minneapolis for ponds to be greenspace or habitat. Chloride content above the Minnesota Pollution Control Agency (MPCA) 5-day chronic threshold of 230 mg/L can impair aquatic life and is an indication that a pond would be poor habitat. The Canadian Environmental Quality Guidelines have a stricter chronic chloride concentration threshold of 120 mg/L which is used to protect sensitive species (Canadian Environmental Quality Guidelines, Canadian Council of Minister of the Environment, 2011). If pond chloride concentrations were below the MPCA chronic threshold, the pond could be considered as potentially suitable aquatic habitat. If chloride values were measured below the Canadian standard, pond habitat could be considered good for aquatic life.

The MPRB study screened stormwater ponds during dry conditions, that is not directly after a rain event. Data could then be used to decide which watersheds and ponds to maintain, retrofit to improve their pollutant removal performance, and potentially prioritize as wildlife habitat.

The MPRB monitored a total of 16 ponds, **Table 23-1**. The ponds are listed in the order that they were sampled. All the ponds had a grab sample taken once a month and samples were analyzed for Chl-*a*, chloride (Cl), and total phosphorus (TP). Six of the ponds had grab samples taken every two weeks and had the NPDES chemistry suite analyzed along with Chl-*a*, Cl, and TP. **Figure 23-1** shows the location of each pond in the City of Minneapolis. The NPDES chemical methods, reporting limits, and holding times are presented in **Table 23-2**.

Table 23-1. Pond names, construction date, watershed area, majority land use, and year last dredged.

Pond Number	Pond Name	Construction Date	Watershed Area (acres)	Predominant Land Use	Last Dredged
1	**Mead Pond***	2000	223	Right of Way/Industrial	Never
2	**MPRB Hiawatha Outlet Pond E***	NA	206	Golf Course	2012-2013
3	**West, Park & 44th***	2002	109	Parkland	Never
4	**Columbus Wet***	2004	56	Singe Family/Duplex	2014
5	**Logan Pond***	2003	103	Singe Family/Duplex	2017
6	**Camden Pond***	NA	235	Parkland	Never
7	**East, Park Ave & 43rd**	2002	14	Singe Family/Duplex	Never
8	**25th Ave NE**	2011	4	Parkland	Never
9	**Winter St Basin**	2012	17	Industrial	Rebuilt 2016
10	**Currie**	1999	2	Industrial	2017
11	**Heritage Park #1**	2004	16	Multifamily	2014
12 & 13	**Heritage Park #2 & #3**	2004	86	Singe Family/Duplex	2014
14	**Heritage Park #4**	2004	106	Singe Family/Duplex	2014
15	**Heritage Park #5**	2004	116	Singe Family/Duplex	2014
16	**Central**	2003	28	Golf Course	Never

*Pond samples included full NPDES water chemistry analysis.

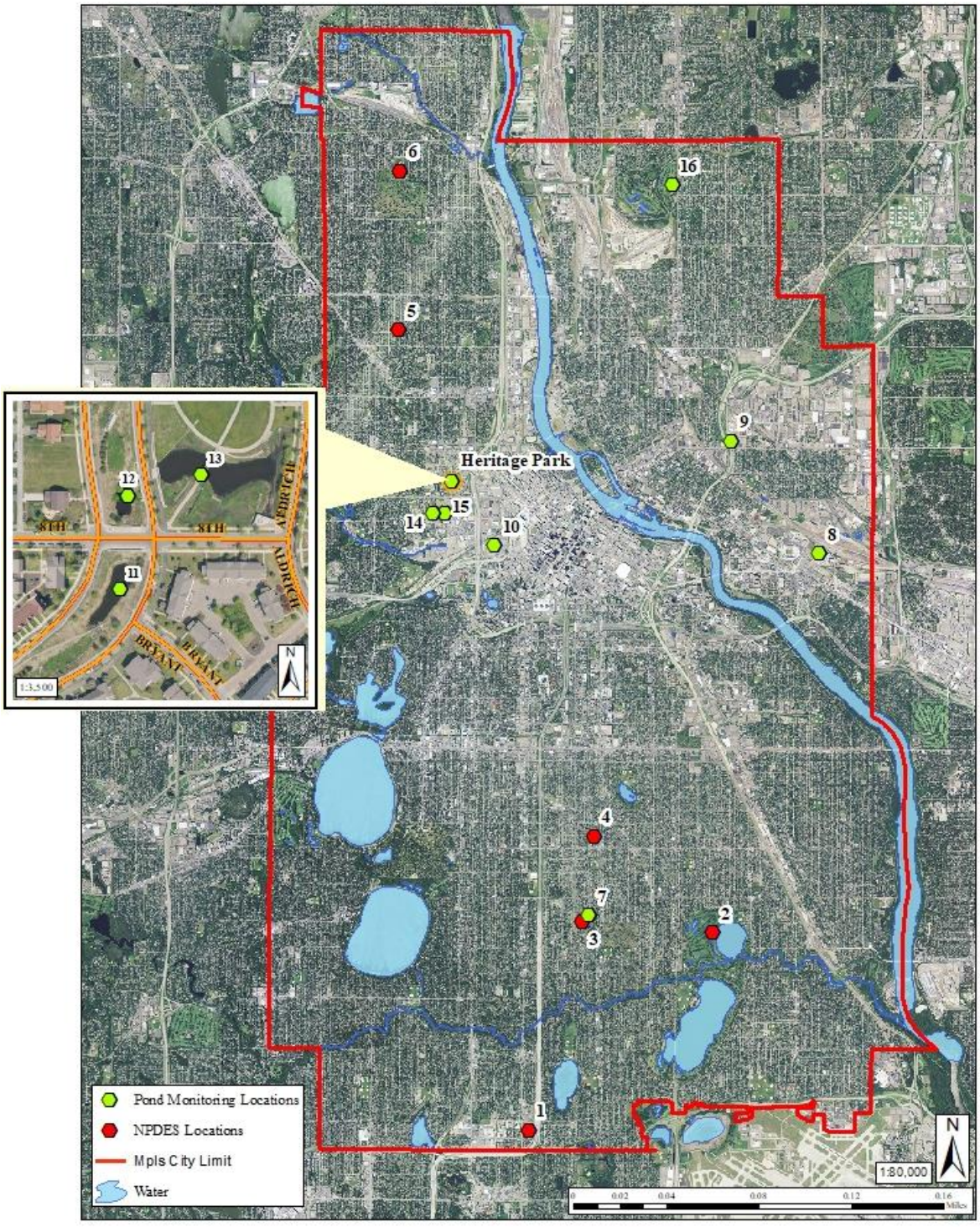


Figure 23-1. Map of the ponds and sampling locations in the City of Minneapolis. The numbers correspond with the ponds listed in Table 23-1.

Table 23-2. Analysis method, reporting limit, and holding times for parameters used by Instrumental Research, Inc. and Pace Laboratories.

Parameter	Method	Reporting Limit	Holding Times
Chlorophyll-*a*	SM 10200 H	0.5 µg/L	24-48 hrs. unfiltered, 28 days filtered in dark
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
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	0.050 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

[‡]Metals and DOC were analyzed by Pace Laboratories.

Figure 23-2 through **Figure 23-13** show an aerial picture of each pond with a yellow diamond at the sampling location. The corresponding pond name and number is in the figure description. The ponds in the study were largely constructed for flood control and were chosen for study if Minneapolis staff believed that the ponds had potential to be retrofit for additional water quality benefit.



Figure 23-2. - Mead Pond (Pond #1) and sampling location.



Figure 23-3. MPRB Hiawatha Outlet Pond (Pond #2) and sampling location.



Figure 23-4. West, Park Ave & 44th Pond (Pond #3) and the sampling location.

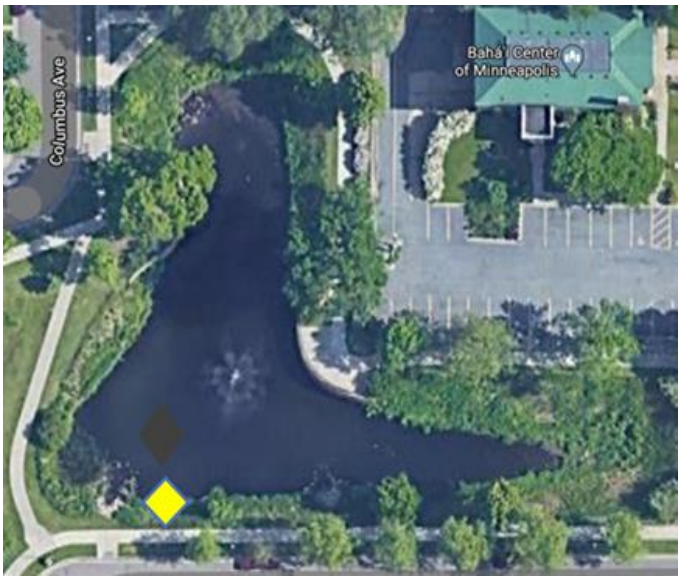


Figure 23-5. Columbus Wet Pond (Pond #4) and sampling location. Note the aerator in the middle of the pond.



Figure 23-6. Logan Pond (Pond #5) and sampling location.



Figure 23-7. Camden Pond (Pond #6) and sampling location.



Figure 23-8. East, Park Avenue & 43rd Pond (Pond #7) sampling location.



Figure 23-9. 25th Avenue NE Pond (Pond #8) and sampling location.



Figure 23-10. Winter Street Pretreatment Basin Pond (Pond #9) and sampling location.



Figure 23-11. Currie Pond (Pond #10) and sampling location.



Figure 23-12. Heritage Park 1 Pond (Pond #11), Heritage Park 2 Pond (Pond #12), Heritage Park 3 Pond (Pond #13), Heritage Park 4 Pond (Pond #14), Heritage Park 5 Pond (Pond #15) and their sampling locations. Water flow in the northern ponds is from 11 to 13. In the south, water in Pond 14 flows to Pond 15.



Figure 23-13. Central Pond (Pond #16) and sampling location.

METHODS

Sample Collection

Samples were collected from all ponds by MPRB personnel and followed recommended COVID-19 social distancing practices. A modified pool skimmer pole with a water clamp was used to secure the sample bottle. The sample was collected with the pool skimmer pole extended out 15-20 feet from the shore where the sample was collected, **Figure 23-14**. One person rinsed the bottle and took the sample with the pool skimmer and one person uncapped/capped the sample bottle. All sample bottles were rinsed with the pond water one time prior to collecting submitted samples. Samples were collected sub-surface with the bottle initially facing down, plunged into the water and inverted 6-inches subsurface to fill the sample bottle so as to not collect surface material. The sample bottle was then given to the other person via the pool skimmer pole to cap.

Samples were only collected from ponds at least 8 hours, or more, after any precipitation. Analysis of the ponds were to represent steady state non-storm conditions.

From May through October, monthly grab samples were collected at sixteen ponds for Chl-*a*, TP, and Cl, as shown in **Table 23-3**. Six of the ponds had Chl-a, TP, Cl, and the additional NPDES chemical parameters collected every two weeks **Table 23-4**. Pheophytin data were disregarded since the Chl-*a* data are Pheophytin corrected. The NPDES parameters are COD, DOC, Chloride, Hardness, Total Copper, Total Lead, Total Zinc, Nitrate/Nitrite, Total Nitrogen Total Phosphorus, Total Dissolved Phosphorus, Total Dissolved Solids, Total Suspended Solids, and Volatile Suspended Solids.

Field blanks accompanied all sampling trips. All Chl-*a* samples were collected in opaque 2-L bottles, chemistry samples were collected in 2-L Nalgene bottles and *Escherichia coli* (*E. coli*) were collected in 100 mL sterile vials. All samples were immediately stored and transported on ice in a cooler prior to delivery to the laboratory for analysis.

Field notes included air temperature, wind and weather conditions, water color, smell/odors, duckweed, algae presence, pond conditions, trash, percent algae, percent duckweed, and any waterfowl present.



Figure 23-14. Grab sample being collected with a pool skimmer at Mead Pond.

RESULTS & DISCUSSION

Pond Chl-*a*, TP, and Cl

Table 23-3 shows the chlorophyll-a, total phosphorus, and chloride data for all grab samples taken at each of the ponds. Chl-*a* data are pheophytin corrected. **Table 23-4** shows comparison statistics for these parameters.

Table 23-5 shows the geometric mean, arithmetic mean and maximum values for the ponds, as compared to average 2001-2017 FLUX event mean for NPDES representative land use stormwater sites and the Minneapolis lakes Diamond and Grass 2020 data.

Table 23-3. Chlorophyll-a, total phosphorus, and chloride data for all grab samples taken at each of the ponds. Underlined red data failed the laboratory blind monthly performance standard.

Pond #	Site Location	Date Sampled	Time	Sample Type	Chl-*a* ug/L	TP mg/L	Cl mg/L
1	Mead Pond	5/21/2020	9:25	Grab	15	0.052	110
1	Mead Pond	6/16/2020	8:45	Grab	20	0.083	160
1	Mead Pond	7/1/2020	8:50	Grab	10	0.095	65
1	Mead Pond	7/13/2020	12:30	Grab	21	0.069	57
1	Mead Pond	7/29/2020	8:30	Grab	16	0.078	50
1	Mead Pond	8/11/2020	9:55	Grab	7	0.087	37
1	Mead Pond	8/25/2020	11:00	Grab	29	0.058	37
1	Mead Pond	9/11/2020	9:00	Grab	21	0.078	28
1	Mead Pond	9/22/2020	8:30	Grab	7	0.105	40
1	Mead Pond	10/2/2020	8:20	Grab	9	0.082	53
1	Mead Pond	10/29/2020	9:35	Grab	6	0.095	87
2	Hiawatha Outlet Pond E	5/21/2020	9:50	Grab	12	0.104	85
2	Hiawatha Outlet Pond E	6/16/2020	9:10	Grab	9	0.108	115
2	Hiawatha Outlet Pond E	7/1/2020	9:15	Grab	29	0.187	80
2	Hiawatha Outlet Pond E	7/13/2020	12:55	Grab	13	0.187	102
2	Hiawatha Outlet Pond E	7/29/2020	8:55	Grab	4	0.122	102
2	Hiawatha Outlet Pond E	8/11/2020	10:15	Grab	11	0.126	92
2	Hiawatha Outlet Pond E	8/25/2020	11:20	Grab	7	0.149	105
2	Hiawatha Outlet Pond E	9/11/2020	9:25	Grab	6	0.138	102
2	Hiawatha Outlet Pond E	9/22/2020	8:50	Grab	4	0.099	105
2	Hiawatha Outlet Pond E	10/2/2020	8:45	Grab	2	0.106	100
2	Hiawatha Outlet Pond E	10/29/2020	10:00	Grab	2	0.120	102
3	West, Park & 44th	5/21/2020	9:05	Grab	17	0.087	70
3	West, Park & 44th	6/16/2020	8:25	Grab	8	0.126	40
3	West, Park & 44th	7/1/2020	8:30	Grab	5	0.170	24
3	West, Park & 44th	7/13/2020	13:15	Grab	50	0.245	24
3	West, Park & 44th	7/29/2020	9:10	Grab	31	0.269	18
3	West, Park & 44th	8/11/2020	10:35	Grab	17	0.176	13
3	West, Park & 44th	8/25/2020	11:40	Grab	21	0.104	12
3	West, Park & 44th	9/11/2020	8:45	Grab	23	0.140	10
3	West, Park & 44th	9/22/2020	9:10	Grab	7	0.105	11
3	West, Park & 44th	10/2/2020	9:00	Grab	74	0.106	11
3	West, Park & 44th	10/29/2020	10:15	Grab	22	0.125	20
4	Columbus Wet	5/21/2020	10:10	Grab	4	0.161	15
4	Columbus Wet	6/16/2020	9:35	Grab	28	0.334	20
4	Columbus Wet	7/1/2020	9:35	Grab	9	0.200	2
4	Columbus Wet	7/13/2020	13:35	Grab	19	0.467	9
4	Columbus Wet	7/29/2020	9:30	Grab	27	0.292	5
4	Columbus Wet	8/11/2020	10:45	Grab	6	0.179	1
4	Columbus Wet	8/25/2020	11:50	Grab	16	0.260	10
4	Columbus Wet	9/11/2020	9:45	Grab	7	0.149	10
4	Columbus Wet	9/22/2020	9:20	Grab	4	0.082	11
4	Columbus Wet	10/2/2020	9:05	Grab	3	0.153	19
4	Columbus Wet	10/29/2020	10:20	Grab	31	0.370	25

Table 23-3. (continued) The 2020 pond chemistry results are presented. Underlined red data failed the laboratory blind monthly performance standard.

Pond #	Site Location	Date Sampled	Time	Sample Type	Chl-*a* ug/L	TP mg/L	Cl mg/L
5	**Logan Pond**	5/21/2020	10:50	Grab	3	0.109	155
5	**Logan Pond**	6/16/2020	10:15	Grab	5	0.266	115
5	**Logan Pond**	7/1/2020	10:15	Grab	27	0.210	45
5	**Logan Pond**	7/13/2020	14:15	Grab	48	0.159	43
5	**Logan Pond**	7/29/2020	10:20	Grab	13	0.238	27
5	**Logan Pond**	8/11/2020	11:15	Grab	25	0.303	15
5	**Logan Pond**	8/25/2020	12:30	Grab	16	0.223	13
5	**Logan Pond**	9/11/2020	10:20	Grab	35	0.242	14
5	**Logan Pond**	9/22/2020	9:50	Grab	8	0.126	20
5	**Logan Pond**	10/2/2020	9:40	Grab	16	0.259	23
5	**Logan Pond**	10/29/2020	10:55	Grab	31	0.249	26
6	**Camden Pond**	5/21/2020	11:20	Grab	73	0.096	70
6	**Camden Pond**	6/16/2020	10:45	Grab	47	0.176	60
6	**Camden Pond**	7/1/2020	10:35	Grab	75	0.200	45
6	**Camden Pond**	7/13/2020	14:45	Grab	62	0.121	50
6	**Camden Pond**	7/29/2020	10:35	Grab	146	0.260	66
6	**Camden Pond**	8/11/2020	11:30	Grab	159	0.262	32
6	**Camden Pond**	8/25/2020	12:50	Grab	175	0.209	22
6	**Camden Pond**	9/11/2020	13:00	Grab	83	0.253	20
6	**Camden Pond**	9/22/2020	10:05	Grab	70	0.255	22
6	**Camden Pond**	10/2/2020	9:50	Grab	135	0.229	20
6	**Camden Pond**	10/29/2020	11:10	Grab	59	0.261	20
7	**East, Park Ave & 43rd**	5/22/2020	9:25	Grab	4	0.137	55
7	**East, Park Ave & 43rd**	6/17/2020	8:55	Grab	3	0.060	50
7	**East, Park Ave & 43rd**	7/8/2020	8:00	Grab	5	0.055	27
7	**East, Park Ave & 43rd**	8/19/2020	8:55	Grab	30	0.079	11
7	**East, Park Ave & 43rd**	9/9/2020	9:25	Grab	18	0.070	11
7	**East, Park Ave & 43rd**	10/13/2020	9:50	Grab	7	0.228	10
8	**25th Ave NE**	5/22/2020	9:55	Grab	4	0.028	340
8	**25th Ave NE**	6/17/2020	9:25	Grab	1	0.020	405
8	**25th Ave NE**	7/8/2020	8:40	Grab	37	0.059	390
8	**25th Ave NE**	8/19/2020	9:30	Grab	12	0.045	390
8	**25th Ave NE**	9/9/2020	9:50	Grab	145	0.284	410
8	**25th Ave NE**	10/13/2020	10:25	Grab	13	0.038	430
9	**Winter St Basin**	5/22/2020	10:15	Grab	31	0.200	70
9	**Winter St Basin**	6/17/2020	9:45	Grab	373	0.905	280
9	**Winter St Basin**	7/8/2020	9:00	Grab	6	0.121	4
9	**Winter St Basin**	8/19/2020	9:45	Grab	8	0.216	11
9	**Winter St Basin**	9/9/2020	10:05	Grab	15	0.059	3
9	**Winter St Basin**	10/13/2020	10:40	Grab	1	0.054	5

Table 23-3. (continued) The 2020 pond chemistry results are presented. Underlined red data failed the laboratory blind monthly performance standard.

Pond #	Site Location	Date Sampled	Time	Sample Type	Chl-*a* ug/L	TP mg/L	Cl mg/L
10	**Currie**	5/22/2020	13:15	Grab	6	0.031	300
10	**Currie**	6/17/2020	10:50	Grab	6	0.156	450
10	**Currie**	7/8/2020	10:10	Grab	37	0.146	260
10	**Currie**	8/19/2020	11:20	Grab	52	0.287	160
10	**Currie**	9/9/2020	11:10	Grab	148	0.898	145
10	**Currie**	10/13/2020	11:35	Grab	5	0.106	115
11	**Heritage Park #1**	5/22/2020	10:35	Grab	5	0.149	50
11	**Heritage Park #1**	6/17/2020	10:00	Grab	19	0.132	50
11	**Heritage Park #1**	7/8/2020	9:20	Grab	196	0.438	24
11	**Heritage Park #1**	8/19/2020	10:05	Grab	36	0.231	13
11	**Heritage Park #1**	9/9/2020	10:20	Grab	5	0.110	25
11	**Heritage Park #1**	10/13/2020	10:55	Grab	6	0.135	32
12	**Heritage Park #2**	5/22/2020	10:45	Grab	9	0.140	65
12	**Heritage Park #2**	6/17/2020	10:10	Grab	29	0.284	65
12	**Heritage Park #2**	7/8/2020	9:25	Grab	15	0.237	34
12	**Heritage Park #2**	8/19/2020	10:10	Grab	18	0.175	18
12	**Heritage Park #2**	9/9/2020	10:30	Grab	2	0.125	21
12	**Heritage Park #2**	10/13/2020	11:00	Grab	3	0.149	25
13	**Heritage Park #3**	5/22/2020	10:50	Grab	29	0.115	40
13	**Heritage Park #3**	6/17/2020	10:15	Grab	25	0.256	65
13	**Heritage Park #3**	7/8/2020	9:30	Grab	31	0.322	17
13	**Heritage Park #3**	8/19/2020	10:20	Grab	22	0.164	16
13	**Heritage Park #3**	9/9/2020	10:35	Grab	11	0.208	21
13	**Heritage Park #3**	10/13/2020	11:05	Grab	4	0.189	19
14	**Heritage Park #4**	5/22/2020	11:00	Grab	3	0.357	165
14	**Heritage Park #4**	6/17/2020	10:25	Grab	68	0.456	155
14	**Heritage Park #4**	7/8/2020	9:40	Grab	10	0.416	33
14	**Heritage Park #4**	8/19/2020	10:55	Grab	8	0.250	36
14	**Heritage Park #4**	9/9/2020	10:45	Grab	60	0.377	29
14	**Heritage Park #4**	10/13/2020	11:15	Grab	4	0.301	17
15	**Heritage Park #5**	5/22/2020	11:15	Grab	51	0.133	155
15	**Heritage Park #5**	6/17/2020	10:35	Grab	22	0.192	110
15	**Heritage Park #5**	7/8/2020	9:50	Grab	60	0.145	68
15	**Heritage Park #5**	8/19/2020	11:05	Grab	25	0.113	46
15	**Heritage Park #5**	9/9/2020	10:50	Grab	87	0.464	50
15	**Heritage Park #5**	10/13/2020	11:20	Grab	47	0.277	50
16	**Central**	5/22/2020	13:50	Grab	2	0.221	205
16	**Central**	6/17/2020	13:30	Grab	2	0.342	320
16	**Central**	7/8/2020	10:30	Grab	17	0.405	120
16	**Central**	8/19/2020	11:45	Grab	11	0.197	25
16	**Central**	9/9/2020	11:40	Grab	14	0.287	50
16	**Central**	10/13/2020	12:00	Grab	129	0.262	54

Table 23-4. 2020 pond comparison statistics of Chl-*a*, TP, and Cl. When statistical analysis was performed on the data sets and values below the reporting limit were present, half of the reporting limit was used in the calculations.

Pond #	Site Location	Statistical Function	Chl-a ug/L	TP mg/L	Cl mg/L
1	**Mead Pond**	MEAN (geometric)	13	0.079	58
1	**Mead Pond**	MEAN (arithmetic)	14	0.080	66
1	**Mead Pond**	MAX	29	0.105	160
1	**Mead Pond**	MIN	6	0.052	28
1	**Mead Pond**	MEDIAN	15	0.082	53
1	**Mead Pond**	STDEV	7	0.016	39
1	**Mead Pond**	NUMBER	11	11	11
1	**Mead Pond**	COV	0.513	0.199	0.598
2	**Hiawatha Outlet Pond E**	MEAN (geometric)	7	0.129	99
2	**Hiawatha Outlet Pond E**	MEAN (arithmetic)	9	0.132	99
2	**Hiawatha Outlet Pond E**	MAX	29	0.187	115
2	**Hiawatha Outlet Pond E**	MIN	2	0.099	80
2	**Hiawatha Outlet Pond E**	MEDIAN	7	0.122	102
2	**Hiawatha Outlet Pond E**	STDEV	8	0.031	10
2	**Hiawatha Outlet Pond E**	NUMBER	11	11	11
2	**Hiawatha Outlet Pond E**	COV	0.872	0.238	0.099
3	**West, Park & 44th**	MEAN (geometric)	19	0.141	19
3	**West, Park & 44th**	MEAN (arithmetic)	25	0.150	23
3	**West, Park & 44th**	MAX	74	0.269	70
3	**West, Park & 44th**	MIN	5	0.087	10
3	**West, Park & 44th**	MEDIAN	21	0.126	18
3	**West, Park & 44th**	STDEV	21	0.060	18
3	**West, Park & 44th**	NUMBER	11	11	11
3	**West, Park & 44th**	COV	0.830	0.398	0.781
4	**Columbus Wet**	MEAN (geometric)	10	0.216	8
4	**Columbus Wet**	MEAN (arithmetic)	14	0.241	12
4	**Columbus Wet**	MAX	31	0.467	25
4	**Columbus Wet**	MIN	3	0.082	1
4	**Columbus Wet**	MEDIAN	9	0.200	10
4	**Columbus Wet**	STDEV	11	0.115	8
4	**Columbus Wet**	NUMBER	11	11	11
4	**Columbus Wet**	COV	0.758	0.478	0.658
5	**Logan Pond**	MEAN (geometric)	16	0.207	32
5	**Logan Pond**	MEAN (arithmetic)	21	0.217	45
5	**Logan Pond**	MAX	48	0.303	155
5	**Logan Pond**	MIN	3	0.109	13
5	**Logan Pond**	MEDIAN	16	0.238	26
5	**Logan Pond**	STDEV	14	0.061	47
5	**Logan Pond**	NUMBER	11	11	11
5	**Logan Pond**	COV	0.681	0.281	1.03
	NPDES 2001-2017*	Ave. Event Mean	NA	0.433	299
	Diamond, 2020	MEAN (geometric)	9	0.063	123
	Grass, 2020	MEAN (geometric)	30	0.185	44

*Average FLUX Event Mean Stormwater Concentration 2001-2017 for four land use categories. NA=not available.

Table 23-4. (continued) The 2020 pond data showing comparison statistics. When statistical analysis was performed on the data sets and values below the reporting limit were present, half of the reporting limit was used in the calculations.

Pond #	Site Location	Statistical Function	Chl-a ug/L	TP mg/L	Cl mg/L
6	**Camden Pond**	MEAN (geometric)	89	0.202	34
6	**Camden Pond**	MEAN (arithmetic)	98	0.211	39
6	**Camden Pond**	MAX	175	0.262	70
6	**Camden Pond**	MIN	47	0.096	20
6	**Camden Pond**	MEDIAN	75	0.229	32
6	**Camden Pond**	STDEV	46	0.058	20
6	**Camden Pond**	NUMBER	11	11	11
6	**Camden Pond**	COV	0.465	0.277	1
7	**East, Park Ave & 43rd**	MEAN (geometric)	8	0.091	21
7	**East, Park Ave & 43rd**	MEAN (arithmetic)	11	0.105	27
7	**East, Park Ave & 43rd**	MAX	30	0.228	55
7	**East, Park Ave & 43rd**	MIN	3	0.055	10
7	**East, Park Ave & 43rd**	MEDIAN	6	0.075	19
7	**East, Park Ave & 43rd**	STDEV	11	0.067	21
7	**East, Park Ave & 43rd**	NUMBER	6	6	6
7	**East, Park Ave & 43rd**	COV	0.964	0.640	0.757
8	**25th Ave NE**	MEAN (geometric)	12	0.050	393
8	**25th Ave NE**	MEAN (arithmetic)	35	0.079	394
8	**25th Ave NE**	MAX	145	0.284	430
8	**25th Ave NE**	MIN	1	0.020	340
8	**25th Ave NE**	MEDIAN	13	0.042	397
8	**25th Ave NE**	STDEV	55	0.101	30
8	**25th Ave NE**	NUMBER	8	8	8
8	**25th Ave NE**	COV	1.57	1.28	0.077
9	**Winter St Basin**	MEAN (geometric)	15	0.157	16
9	**Winter St Basin**	MEAN (arithmetic)	72	0.259	62
9	**Winter St Basin**	MAX	373	0.905	280
9	**Winter St Basin**	MIN	1	0.054	3
9	**Winter St Basin**	MEDIAN	12	0.160	8
9	**Winter St Basin**	STDEV	148	0.324	110
9	**Winter St Basin**	NUMBER	6	6	6
9	**Winter St Basin**	COV	2.04	1.25	1.77
10	**Currie**	MEAN (geometric)	20	0.163	213
10	**Currie**	MEAN (arithmetic)	42	0.270	238
10	**Currie**	MAX	148	0.898	450
10	**Currie**	MIN	5	0.031	115
10	**Currie**	MEDIAN	22	0.151	210
10	**Currie**	STDEV	55	0.319	126
10	**Currie**	NUMBER	6	6	6
10	**Currie**	COV	1.31	1.18	0.528
	NPDES 2001-2017*	Ave. Event Mean	NA	0.433	299
	Diamond, 2020	MEAN (geometric)	9	0.063	123
	Grass, 2020	MEAN (geometric)	30	0.185	44

*Average FLUX Event Mean Stormwater Concentration 2001-2017 for four land use categories. NA=not available.

Table 23-4. (continued) The 2020 pond data showing comparison statistics. When statistical analysis was performed on the data sets and values below the reporting limit were present, half of the reporting limit was used in the calculations.

Pond #	Site Location	Statistical Function	Chl-a ug/L	TP mg/L	Cl mg/L
11	**Heritage Park #1**	MEAN (geometric)	17	0.176	29
11	**Heritage Park #1**	MEAN (arithmetic)	45	0.199	32
11	**Heritage Park #1**	MAX	196	0.438	50
11	**Heritage Park #1**	MIN	5	0.110	13
11	**Heritage Park #1**	MEDIAN	13	0.142	28
11	**Heritage Park #1**	STDEV	75	0.124	15
11	**Heritage Park #1**	NUMBER	6	6	6
11	**Heritage Park #1**	COV	1.68	0.623	0.466
12	**Heritage Park #2**	MEAN (geometric)	9	0.177	33
12	**Heritage Park #2**	MEAN (arithmetic)	13	0.185	38
12	**Heritage Park #2**	MAX	29	0.284	65
12	**Heritage Park #2**	MIN	2	0.125	18
12	**Heritage Park #2**	MEDIAN	12	0.162	29
12	**Heritage Park #2**	STDEV	10	0.062	22
12	**Heritage Park #2**	NUMBER	6	6	6
12	**Heritage Park #2**	COV	0.792	0.338	0.568
13	**Heritage Park #3**	MEAN (geometric)	17	0.198	26
13	**Heritage Park #3**	MEAN (arithmetic)	20	0.209	30
13	**Heritage Park #3**	MAX	31	0.322	65
13	**Heritage Park #3**	MIN	4	0.115	16
13	**Heritage Park #3**	MEDIAN	23	0.199	20
13	**Heritage Park #3**	STDEV	11	0.073	19
13	**Heritage Park #3**	NUMBER	6	6	6
13	**Heritage Park #3**	COV	0.530	0.347	0.655
14	**Heritage Park #4**	MEAN (geometric)	44	0.194	71
14	**Heritage Park #4**	MEAN (arithmetic)	49	0.221	80
14	**Heritage Park #4**	MAX	87	0.464	155
14	**Heritage Park #4**	MIN	22	0.113	46
14	**Heritage Park #4**	MEDIAN	49	0.169	59
14	**Heritage Park #4**	STDEV	24	0.133	44
14	**Heritage Park #4**	NUMBER	6	6	6
14	**Heritage Park #4**	COV	0.493	0.602	0.549
15	**Heritage Park #5**	MEAN (geometric)	13	0.353	50
15	**Heritage Park #5**	MEAN (arithmetic)	26	0.360	72
15	**Heritage Park #5**	MAX	68	0.456	165
15	**Heritage Park #5**	MIN	3	0.250	17
15	**Heritage Park #5**	MEDIAN	9	0.367	34
15	**Heritage Park #5**	STDEV	30	0.075	68
15	**Heritage Park #5**	NUMBER	6	6	6
15	**Heritage Park #5**	COV	1.21	0.209	0.940
16	**Central**	MEAN (geometric)	5	0.277	90
16	**Central**	MEAN (arithmetic)	12	0.286	129
16	**Central**	MAX	48	0.405	320
16	**Central**	MIN	1	0.197	25
16	**Central**	MEDIAN	6	0.275	87
16	**Central**	STDEV	18	0.078	114
16	**Central**	NUMBER	6	6	6
16	**Central**	COV	1.50	0.272	0.884
	NPDES 2001-2017*	Ave. Event Mean	NA	0.433	299
	Diamond, 2020	MEAN (geometric)	9	0.063	123
	Grass, 2020	MEAN (geometric)	30	0.185	44

*Average FLUX Event Mean Stormwater Concentration 2001-2017 for four land use categories. NA=not available.

Table 23-4 shows comparison statistics for each pond for Chl-*a*, TP, and Cl. For comparison, similar data from NPDES representative land use sites as well as smaller Minneapolis Lakes Diamond and Grass are also shown. All of the ponds TP and Cl geometric means are significantly lower than the NPDES stormwater geometric means. The exception was at Heritage Park #5 Pond where the geometric mean of 0.353 mg/L TP at this pond was comparable to levels measured in stormwater (0.433 mg/L TP).

Most of the ponds had similar or lower Chl-*a* than found in stormwater-influenced Grass Lake (30 mg/L). Exceptions were Camden Pond, at 89 ug/L Chl-*a* and Heritage Park #4 Pond, 44 ug/L Chl-*a* which were higher. The geometric mean of TP in the ponds was generally similar or lower than at Grass Lake (0.185 mg/ TP). Heritage Park #5, where the geometric mean of TP was 0.353 mg/L was an exception. The geometric mean of Cl at the ponds was generally lower than chloride levels at Diamond Lake (123 mg/L Cl). Two ponds, 25th Ave NE (393 mg/L Cl) and Currie (213 mg/L Cl) had higher Cl than at Diamond Lake, which is listed as impaired for chloride.

Table 23-5. The 2020 pond data showing limited comparison statistics for Chl-*a*, TP, and Cl. When statistical analysis was performed on the data sets and values below the reporting limit were present, half of the reporting limit was used in the calculations.

Pond #	Site Location	Statistical Function	Chl-a ug/L	TP mg/L	Cl mg/L
1	**Mead Pond**	MEAN (geometric)	13	0.079	58
1	**Mead Pond**	MEAN (arithmetic)	14	0.080	66
1	**Mead Pond**	MAX	29	0.105	160
2	**Hiawatha Outlet Pond E**	MEAN (geometric)	7	0.129	99
2	**Hiawatha Outlet Pond E**	MEAN (arithmetic)	9	0.132	99
2	**Hiawatha Outlet Pond E**	MAX	29	0.187	115
3	**West, Park & 44th**	MEAN (geometric)	19	0.141	19
3	**West, Park & 44th**	MEAN (arithmetic)	25	0.150	23
3	**West, Park & 44th**	MAX	74	0.269	70
4	**Columbus Wet**	MEAN (geometric)	10	0.216	8
4	**Columbus Wet**	MEAN (arithmetic)	14	0.241	12
4	**Columbus Wet**	MAX	31	0.467	25
5	**Logan Pond**	MEAN (geometric)	16	0.207	32
5	**Logan Pond**	MEAN (arithmetic)	21	0.217	45
5	**Logan Pond**	MAX	48	0.303	155
6	**Camden Pond**	MEAN (geometric)	89	0.202	34
6	**Camden Pond**	MEAN (arithmetic)	98	0.211	39
6	**Camden Pond**	MAX	175	0.262	70
7	**East, Park Ave & 43rd**	MEAN (geometric)	8	0.091	21
7	**East, Park Ave & 43rd**	MEAN (arithmetic)	11	0.105	27
7	**East, Park Ave & 43rd**	MAX	30	0.228	55
8	**25th Ave NE**	MEAN (geometric)	12	0.050	393
8	**25th Ave NE**	MEAN (arithmetic)	35	0.079	394
8	**25th Ave NE**	MAX	145	0.284	430
	NPDES 2001-2017*	Ave. Event Mean	NA	0.433	299
	Diamond, 2020	MEAN (geometric)	9	0.063	123
	Grass, 2020	MEAN (geometric)	30	0.185	44

*Average FLUX Event Mean Stormwater Concentration 2001-2017 for four land use categories.
NA=not available.

Table 23-5. (continued) The 2020 pond data showing limited comparison statistics. When statistical analysis was performed on the data sets and values below the reporting limit were present, half of the reporting limit was used in the calculations.

Pond #	Site Location	Statistical Function	Chl-a ug/L	TP mg/L	Cl mg/L
9	**Winter St Basin**	MEAN (geometric)	15	0.157	16
9	**Winter St Basin**	MEAN (arithmetic)	72	0.259	62
9	**Winter St Basin**	MAX	373	0.905	280
10	**Currie**	MEAN (geometric)	20	0.163	213
10	**Currie**	MEAN (arithmetic)	42	0.270	238
10	**Currie**	MAX	148	0.898	450
11	**Heritage Park #1**	MEAN (geometric)	17	0.176	29
11	**Heritage Park #1**	MEAN (arithmetic)	45	0.199	32
11	**Heritage Park #1**	MAX	196	0.438	50
12	**Heritage Park #2**	MEAN (geometric)	9	0.177	33
12	**Heritage Park #2**	MEAN (arithmetic)	13	0.185	38
12	**Heritage Park #2**	MAX	29	0.284	65
13	**Heritage Park #3**	MEAN (geometric)	17	0.198	26
13	**Heritage Park #3**	MEAN (arithmetic)	20	0.209	30
13	**Heritage Park #3**	MAX	31	0.322	65
14	**Heritage Park #4**	MEAN (geometric)	44	0.194	71
14	**Heritage Park #4**	MEAN (arithmetic)	49	0.221	80
14	**Heritage Park #4**	MAX	87	0.464	155
15	**Heritage Park #5**	MEAN (geometric)	13	0.353	50
15	**Heritage Park #5**	MEAN (arithmetic)	26	0.360	72
15	**Heritage Park #5**	MAX	68	0.456	165
16	**Central**	MEAN (geometric)	11	0.277	90
16	**Central**	MEAN (arithmetic)	29	0.286	129
16	**Central**	MAX	129	0.405	320
	NPDES 2001-2017*	Ave. Event Mean	NA	0.433	299
	Diamond, 2020	MEAN (geometric)	9	0.063	123
	Grass, 2020	MEAN (geometric)	30	0.185	44

*Average FLUX Event Mean Stormwater Concentration 2001-2017 for four land use categories. NA=not available.

Table 23-5 shows the geometric and arithmetic means and the maximum values for Chl-*a*, TP and Cl, as well as showing for comparison the NPDES representative land use average event mean FLUX stormwater data and smaller Minneapolis lakes: Diamond and Grass. The highest pond values of Chl-*a* were found at Camden, Winter St. Basin, Currie, Heritage Park #1, Heritage Park #4, Heritage Park #5, and Central Ponds. The maximum TP values were all over 0.200 mg/L, except at Mead (0.105 mg/L TP), and Hiawatha Outlet (0.187 mg/L TP). The maximum Cl values were all below the MPCA 5-day chronic standard of 230 mg/L, except at 25th Ave NE (430 mg/L Cl), Winter St. Basin (280 mg/L Cl), Currie (450 mg/L Cl), and Central (320 mg/L Cl).

Table 23-6 shows the NPDES chemistry data for all of the samples. TSS values were generally low with a few samples as high as 60 mg/L at Columbus and Logan Ponds. Some of the COD values were high at 50-100 mg/L. Camden Pond had a higher COD of around 70-100 mg/L. All metals samples were generally low.

Table 23-7 shows the NPDES comparison statistics along with data from the NPDES representative

land sites and several Minneapolis lakes. TSS geometric mean in the ponds is much lower than what is found in stormwater. In the ponds, most of the suspended solids are volatile and organic. DOC in the ponds is comparable to what is found in Minneapolis lakes. All metals measured in the ponds were half or less than what was found in stormwater.

Table 23-6. The 2020 ponds NPDES chemistry results are presented. Underlined red data failed the laboratory blind monthly performance standard.

Site Location	Date Sampled	Time	Sample Type	TP mg/L	TDP 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	Chl-*a* ug/L	Pheo ug/L	Cu ug/L	Pb ug/L	Zn ug/L	DOC mg/L
Columbus Wet	5/21/2020	10:10	Grab	0.161	0.102	0.933	0.031	15	26	3	3	85	<20.0	4	2	10	1	<20.0	5
Columbus Wet	6/16/2020	9:35	Grab	0.334	0.062	1.63	<0.030	20	54	12	8	140	62	28	13	6	3	<20.0	15
Columbus Wet	7/1/2020	9:35	Grab	0.200	0.104	1.16	0.095	2	26	5	3	50	9	9	6	7	2	<20.0	5
Columbus Wet	7/13/2020	13:35	Grab	0.467	0.073	2.02	<0.030	9	44	69	42	108	99	19	8	7	5	<20.0	12
Columbus Wet	7/29/2020	9:30	Grab	0.292	0.020	1.60	0.214	5	32	17	14	80	42	27	19	8	2	<20.0	8
Columbus Wet	8/11/2020	10:45	Grab	0.179	0.113	1.21	0.067	1	18	11	6	60	22	6	4	8	2	<20.0	4
Columbus Wet	8/25/2020	11:50	Grab	0.260	0.045	1.84	<0.030	10	66	65	23	127	61	16	11	11	13	46	9
Columbus Wet	9/11/2020	9:45	Grab	0.149	0.058	1.30	0.065	10	60	6	4	105	32	7	2	6	1	<20.0	9
Columbus Wet	9/22/2020	9:20	Grab	0.082	0.055	1.29	0.035	11	60	2	<2.00	115	32	4	1	6	1	<20.0	9
Columbus Wet	10/2/2020	9:05	Grab	0.153	0.092	3.02	0.686	19	72	2	2	158	32	3	3	5	2	<20.0	10
Columbus Wet	10/29/2020	10:20	Grab	0.370	0.144	1.42	0.035	25	60	17	12	170	49	31	39	9	2	<20.0	11
Camden Pond	5/21/2020	11:20	Grab	0.096	0.021	1.32	<0.030	70	106	14	13	248	35	73	2	6	1	<20.0	7
Camden Pond	6/16/2020	10:45	Grab	0.176	0.026	1.48	<0.030	60	94	31	20	237	19	47	4	6	1	<20.0	10
Camden Pond	7/1/2020	10:35	Grab	0.200	0.021	1.59	0.005	45	74	23	21	195	45	75	4	7	0.4	<20.0	10
Camden Pond	7/13/2020	14:45	Grab	0.121	0.025	1.80	<0.030	50	76	30	27	220	71	62	7	4	0.3	<20.0	12
Camden Pond	7/29/2020	10:35	Grab	0.260	0.024	3.15	<0.030	66	66	48	42	385	84	146	7	3	0.4	<20.0	10
Camden Pond	8/11/2020	11:30	Grab	0.262	0.033	3.43	<0.030	32	54	31	28	170	92	159	4	3	1	<20.0	10
Camden Pond	8/25/2020	12:50	Grab	0.209	0.033	2.49	<0.030	22	62	28	24	160	93	175	6	4	0.5	<20.0	11
Camden Pond	9/11/2020	13:00	Grab	0.253	0.033	3.17	<0.030	20	75	21	20	160	89	83	57	7	0.3	<20.0	12
Camden Pond	9/22/2020	10:05	Grab	0.255	0.026	4.22	<0.030	22	80	42	40	153	98	70	21	3	0.3	<20.0	12
Camden Pond	10/2/2020	9:50	Grab	0.229	0.023	3.48	<0.030	20	82	37	36	170	100	135	16	8	0.4	<20.0	13
Camden Pond	10/29/2020	11:10	Grab	0.261	0.027	3.07	<0.030	20	90	31	28	188	93	59	13	6	0.3	<20.0	12
Logan Pond	5/21/2020	10:50	Grab	0.109	0.043	0.982	0.055	155	96	2	2	395	22	3	<0.500	5	1	<20.0	8
Logan Pond	6/16/2020	10:15	Grab	0.266	0.063	0.922	<0.030	115	106	20	8	352	48	5	3	5	2	<20.0	13
Logan Pond	7/1/2020	10:15	Grab	0.210	0.093	1.10	0.005	45	60	10	7	197	25	27	8	7	1	<20.0	9
Logan Pond	7/13/2020	14:15	Grab	0.159	0.088	2.50	0.316	43	68	59	29	215	79	48	12	7	3	<20.0	15
Logan Pond	7/29/2020	10:20	Grab	0.238	0.031	1.60	0.211	27	56	26	14	153	52	13	11	4	1	<20.0	10
Logan Pond	8/11/2020	11:15	Grab	0.303	0.083	1.83	0.107	15	42	7	4	115	72	25	19	6	4	<20.0	8
Logan Pond	8/25/2020	12:30	Grab	0.223	0.102	1.02	<0.030	13	58	13	7	125	35	16	11	4	2	<20.0	11
Logan Pond	9/11/2020	10:20	Grab	0.242	0.065	1.46	<0.030	14	58	12	9	120	46	35	22	3	1	<20.0	9
Logan Pond	9/22/2020	9:50	Grab	0.126	0.030	0.901	<0.030	20	70	9	7	122	29	8	6	5	1	<20.0	8
Logan Pond	10/2/2020	9:40	Grab	0.259	0.038	1.38	<0.030	23	74	23	14	157	56	16	6	6	2	<20.0	9
Logan Pond	10/29/2020	10:55	Grab	0.249	0.110	1.12	<0.030	26	70	10	7	180	46	31	10	7	1	<20.0	11

Table 23-6. (continued) The 2020 pond NPDES chemistry results are presented. Underlined red data failed the laboratory blind monthly performance standard.

Site Location	Date Sampled	Time	Sample Type	TP mg/L	TDP 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	Chl-*a* ug/L	Pheo ug/L	Cu ug/L	Pb ug/L	Zn ug/L	DOC mg/L
Mead Pond	5/21/2020	9:25	Grab	0.052	0.015	<0.500	0.038	110	32	5	3	222	<20.0	15	3	6	0.4	<20.0	4
Mead Pond	6/16/2020	8:45	Grab	0.083	0.015	0.726	<0.030	160	64	9	7	363	45	20	6	7	1	<20.0	7
Mead Pond	7/1/2020	8:50	Grab	0.095	0.039	0.859	0.162	65	34	5	3	175	9	10	5	4	0.1	<20.0	4
Mead Pond	7/13/2020	12:30	Grab	0.069	0.014	0.685	0.115	57	38	6	5	178	25	21	6	5	0.3	<20.0	NA
Mead Pond	7/29/2020	8:30	Grab	0.078	0.015	0.811	0.051	50	46	7	6	158	35	16	6	5	0.3	<20.0	7
Mead Pond	8/11/2020	9:55	Grab	0.087	0.028	0.860	0.123	37	32	9	5	125	29	7	4	4	1	<20.0	4
Mead Pond	8/25/2020	11:00	Grab	0.058	0.009	0.554	<0.030	37	50	8	5	157	12	29	7	5	0.4	<20.0	5
Mead Pond	9/11/2020	9:00	Grab	0.078	0.018	0.530	<0.030	28	56	7	5	133	25	21	8	4	0.4	<20.0	7
Mead Pond	9/22/2020	8:30	Grab	0.105	0.026	0.548	<0.030	40	68	6	4	164	29	7	3	5	0.4	<20.0	8
Mead Pond	10/2/2020	8:20	Grab	0.082	0.020	0.586	<0.030	53	78	7	5	188	29	9	4	6	0.5	<20.0	8
Mead Pond	10/29/2020	9:35	Grab	0.095	0.034	0.697	0.070	87	66	7	3	260	42	6	3	9	1	<20.0	7
Hiawatha Outlet Pond	5/21/2020	9:50	Grab	0.104	0.011	2.98	0.584	85	332	10	5	512	<20.0	12	2	5	<0.10	<20.0	7
Hiawatha Outlet Pond	6/16/2020	9:10	Grab	0.108	0.016	2.36	0.346	115	352	8	3	637	25	9	4	5	<0.10	<20.0	6
Hiawatha Outlet Pond	7/1/2020	9:15	Grab	0.187	0.022	1.82	0.271	80	292	14	8	470	25	29	13	6	2	<20.0	7
Hiawatha Outlet Pond	7/13/2020	12:55	Grab	0.187	0.010	1.98	0.299	102	348	14	6	552	15	13	4	4	0.3	<20.0	6
Hiawatha Outlet Pond	7/29/2020	8:55	Grab	0.122	0.007	2.00	1.189	102	340	13	6	595	19	4	4	3	<0.10	<20.0	6
Hiawatha Outlet Pond	8/11/2020	10:15	Grab	0.126	0.025	1.76	0.380	92	320	10	5	528	18	11	8	7	0.1	<20.0	6
Hiawatha Outlet Pond	8/25/2020	11:20	Grab	0.149	0.025	1.68	0.232	105	308	10	3	523	12	7	4	3	<0.10	<20.0	6
Hiawatha Outlet Pond	9/11/2020	9:25	Grab	0.138	0.023	2.11	0.105	102	320	8	3	518	22	6	3	4	<0.10	<20.0	6
Hiawatha Outlet Pond	9/22/2020	8:50	Grab	0.099	0.016	1.85	0.703	105	356	8	3	565	15	4	2	5	0.1	<20.0	6
Hiawatha Outlet Pond	10/2/2020	8:45	Grab	0.106	0.024	1.92	0.192	100	296	5	3	493	12	2	1	5	0.4	<20.0	6
Hiawatha Outlet Pond	10/29/2020	10:00	Grab	0.120	0.012	2.20	0.160	102	304	5	2	535	19	2	2	5	<0.10	<20.0	5
West, Park & 44th	5/21/2020	9:05	Grab	0.087	0.022	0.681	<0.030	70	30	5	3	165	22	17	3	7	0.3	<20.0	6
West, Park & 44th	6/16/2020	8:25	Grab	0.126	0.060	0.726	<0.030	40	42	3	3	149	42	8	3	6	1	<20.0	8
West, Park & 44th	7/1/2020	8:30	Grab	0.170	0.111	0.945	0.067	24	36	4	3	85	12	5	2	9	1	<20.0	6
West, Park & 44th	7/13/2020	13:15	Grab	0.245	0.045	1.99	<0.030	24	42	29	24	121	54	50	5	5	1	<20.0	7
West, Park & 44th	7/29/2020	9:10	Grab	0.269	0.015	1.41	0.254	18	36	29	22	98	55	31	6	5	0.5	<20.0	7
West, Park & 44th	8/11/2020	10:35	Grab	0.176	0.065	1.03	0.030	13	32	9	6	95	32	17	12	6	2	<20.0	6
West, Park & 44th	8/25/2020	11:40	Grab	0.104	0.029	0.799	<0.030	12	42	12	8	93	28	21	8	5	1	<20.0	7
West, Park & 44th	9/11/2020	8:45	Grab	0.140	0.042	1.02	<0.030	10	50	8	7	100	39	23	5	6	4	<20.0	8
West, Park & 44th	9/22/2020	9:10	Grab	0.105	0.036	1.29	0.077	11	54	10	6	90	29	7	3	6	1	<20.0	8
West, Park & 44th	10/2/2020	9:00	Grab	0.106	0.028	1.31	<0.030	11	62	13	8	108	32	74	33	6	1	<20.0	8
West, Park & 44th	10/29/2020	10:15	Grab	0.125	0.055	0.725	0.031	20	64	4	3	135	35	22	6	7	0.4	<20.0	9

Table 23-7. The 2020 pond NPDES data showing comparison statistics. When statistical analysis was performed on the data sets and values below the reporting limit were present, half of the reporting limit was used in the calculations.

Site Location	Statistical Function	TP mg/L	TDP 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	Chl-*a* ug/L	Pheo ug/L	Cu ug/L	Pb ug/L	Zn ug/L	DOC mg/L
Columbus Wet	MEAN (geometric)	0.216	0.071	1.51	0.052	8	43	10	6	102	33	10	6	7	2	11	8
Columbus Wet	MEAN (arithmetic)	0.241	0.079	1.58	0.116	12	47	19	11	109	41	14	10	8	3	13	9
Columbus Wet	MAX	0.467	0.144	3.02	0.686	25	72	69	42	170	99	31	39	11	13	46	15
Columbus Wet	MIN	0.082	0.020	0.933	0.015	1	18	2	1	50	9	3	1	5	1	10	4
Columbus Wet	MEDIAN	0.200	0.073	1.42	0.035	10	54	11	6	108	32	9	6	7	2	10	9
Columbus Wet	STDEV	0.115	0.036	0.571	0.198	8	19	24	12	38	26	11	11	2	3	11	3
Columbus Wet	NUMBER	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Columbus Wet	COV	0.478	0.449	0.361	1.71	0.658	0.397	1.28	1.13	0.353	0.641	0.758	1.13	0.248	1.18	0.811	0.371
Camden Pond	MEAN (geometric)	0.202	0.026	2.48	0.014	34	77	29	26	200	67	89	8	5	0.4	10	11
Camden Pond	MEAN (arithmetic)	0.211	0.027	2.65	0.014	39	78	30	27	208	74	98	13	5	0.5	10	11
Camden Pond	MAX	0.262	0.033	4.22	0.015	70	106	48	42	385	100	175	57	8	1	10	13
Camden Pond	MIN	0.096	0.021	1.32	0.005	20	54	14	13	153	19	47	2	3	0.3	10	7
Camden Pond	MEDIAN	0.229	0.026	3.07	0.015	32	76	31	27	188	89	75	7	6	0.4	10	11
Camden Pond	STDEV	0.058	0.005	0.973	0.003	20	15	9	9	67	28	46	16	2	0.2	0.00	2
Camden Pond	NUMBER	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Camden Pond	COV	0.277	0.172	0.367	0.214	1	0.190	0.309	0.335	0.323	0.382	0.465	1	0.323	0.470	0.000	0.159
Logan Pond	MEAN (geometric)	0.207	0.061	1.28	0.031	32	67	13	8	177	43	16	7	5	1	10	10
Logan Pond	MEAN (arithmetic)	0.217	0.068	1.35	0.071	45	69	17	10	194	46	21	10	5	2	10	10
Logan Pond	MAX	0.303	0.110	2.50	0.316	155	106	59	29	395	79	48	22	7	4	10	15
Logan Pond	MIN	0.109	0.030	0.901	0.005	13	42	2	2	115	22	3	0.250	3	1	10	8
Logan Pond	MEDIAN	0.238	0.065	1.12	0.015	26	68	12	7	157	46	16	10	5	1	10	9
Logan Pond	STDEV	0.061	0.029	0.487	0.102	47	18	16	7	95	18	14	6	1	1	0.000	2
Logan Pond	NUMBER	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Logan Pond	COV	0.281	0.432	0.361	1.43	1.03	0.265	0.892	0.739	0.492	0.398	0.681	0.651	0.248	0.653	0.000	0.220
NPDES 2001-2017*	MEAN (arithmetic) Event Mean	0.433	0.140	NA	0.570	299	49	118	37	568	NA	NA	NA	23	22	114	NA
Diamond, 2020	MEAN (arithmetic)	0.074	NA	0.560	0.060	163	74	NA	NA	NA	NA	17	4	NA	NA	NA	NA
Grass, 2020	MEAN (arithmetic)	0.251	NA	1.45	0.060	52	100	NA	NA	NA	NA	57	12	NA	NA	NA	NA
Powderhorn, 2018-2020	MEAN (geometric)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	7
Chain (Bde, Harriet, Isles, Cedar) 2016-2017	MEAN (geometric)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	6

*Average Event Mean Stormwater Concentration 2001-2017 for four land use categories. NA=data not available.

Table 23-7. (continued) The 2020 pond NPDES data showing comparison statistics. When statistical analysis was performed on the data sets and values below the reporting limit were present, half of the reporting limit was used in the calculations.

Site Location	Statistical Function	TP mg/L	TDP 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	Chl-*a* ug/L	Pheo ug/L	Cu ug/L	Pb ug/L	Zn ug/L	DOC mg/L
Mead Pond	MEAN (geometric)	0.079	0.020	0.617	0.038	58	49	7	4	184	23	13	5	5	0.4	10	6
Mead Pond	MEAN (arithmetic)	0.080	0.021	0.646	0.058	66	51	7	5	193	26	14	5	5	0.4	10	6
Mead Pond	MAX	0.105	0.039	0.860	0.162	160	78	9	7	363	45	29	8	9	1	10	8
Mead Pond	MIN	0.052	0.009	0.250	0.015	28	32	5	3	125	9	6	3	4	0.1	10	4
Mead Pond	MEDIAN	0.082	0.018	0.685	0.038	53	50	7	5	175	29	15	5	5	0.4	10	7
Mead Pond	STDEV	0.016	0.009	0.179	0.053	39	16	1	1	68	12	7	2	1	0.3	0.000	2
Mead Pond	NUMBER	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	10
Mead Pond	COV	0.199	0.435	0.277	0.920	0.598	0.317	0.211	0.276	0.352	0.459	0.513	0.378	0.260	0.568	0.000	0.254
Hiawatha Outlet Pond E	MEAN (geometric)	0.129	0.016	2.03	0.322	99	324	9	4	537	17	7	3	5	0.1	10	6
Hiawatha Outlet Pond E	MEAN (arithmetic)	0.132	0.017	2.06	0.406	99	324	10	4	539	18	9	4	5	0.3	10	6
Hiawatha Outlet Pond E	MAX	0.187	0.025	2.98	1.189	115	356	14	8	637	25	29	13	7	2	10	7
Hiawatha Outlet Pond E	MIN	0.099	0.007	1.68	0.105	80	292	5	2	470	10	2	1	3	0.1	10	5
Hiawatha Outlet Pond E	MEDIAN	0.122	0.016	1.98	0.299	102	320	10	3	528	18	7	4	5	0.1	10	6
Hiawatha Outlet Pond E	STDEV	0.031	0.007	0.365	0.315	10	23	3	2	47	5	8	3	1	0.5	0.000	1
Hiawatha Outlet Pond E	NUMBER	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Hiawatha Outlet Pond E	COV	0.238	0.385	0.177	0.777	0.099	0.070	0.342	0.416	0.087	0.294	0.872	0.791	0.254	1.78	0.000	0.090
West, Park & 44th	MEAN (geometric)	0.141	0.040	1.03	0.029	19	43	9	6	110	32	19	6	6	1	10	7
West, Park & 44th	MEAN (arithmetic)	0.150	0.046	1.08	0.050	23	45	11	8	113	34	25	8	6	1	10	7
West, Park & 44th	MAX	0.269	0.111	1.99	0.254	70	64	29	24	165	55	74	33	9	4	10	9
West, Park & 44th	MIN	0.087	0.015	0.681	0.015	10	30	3	3	85	12	5	2	5	0.3	10	6
West, Park & 44th	MEDIAN	0.126	0.042	1.02	0.015	18	42	9	6	100	32	21	5	6	1	10	7
West, Park & 44th	STDEV	0.060	0.027	0.393	0.071	18	12	9	7	27	13	21	9	1	1	0.000	1
West, Park & 44th	NUMBER	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
West, Park & 44th	COV	0.398	0.576	0.362	1.43	0.781	0.260	0.815	0.892	0.236	0.370	0.830	1.12	0.202	0.979	0.000	0.130
NPDES 2001-2017*	MEAN (arithmetic) Event Mean	0.433	0.140	NA	0.570	299	49	118	37	568	NA	NA	NA	23	22	114	NA
Diamond, 2020	MEAN (arithmetic)	0.074	NA	0.560	0.060	163	74	NA	NA	NA	NA	17	4	NA	NA	NA	NA
Grass, 2020	MEAN (arithmetic)	0.251	NA	1.45	0.060	52	100	NA	NA	NA	NA	57	12	NA	NA	NA	NA
Powderhorn, 2018-2020	MEAN (geometric)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	7
Chain (Bde, Harriet, Isles, Cedar) 2016-2017	MEAN (geometric)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	6

*Average Event Mean Stormwater Concentration 2001-2017 for four land use categories. NA=data not available.

Pond Comparison of Chl-a to TP and Cl

As part of the pond screening all the ponds were monitored for Chl-*a* to TP and Cl. **Figure 23-15** through **Figure 23-31** show a comparison of Chl-*a* to TP and Cl, on two Y-axes. Chl-*a* is a measurement of algal biomass. Chl-*a* levels above 30 ug/L can indicate a greater likelihood of HABs (Heiskary and Lindon, 2009). TP level could be an indicator that the pond is sequestering phosphorus or exporting phosphorus downstream. The MPCA chronic 5-day Cl threshold standard concentration for receiving waters is 230 mg/L. High Cl values over 230 mg/L can indicate an impaired ecological habitat in the ponds and a potentially negative downstream environmental impact.

Columbus Wet Pond

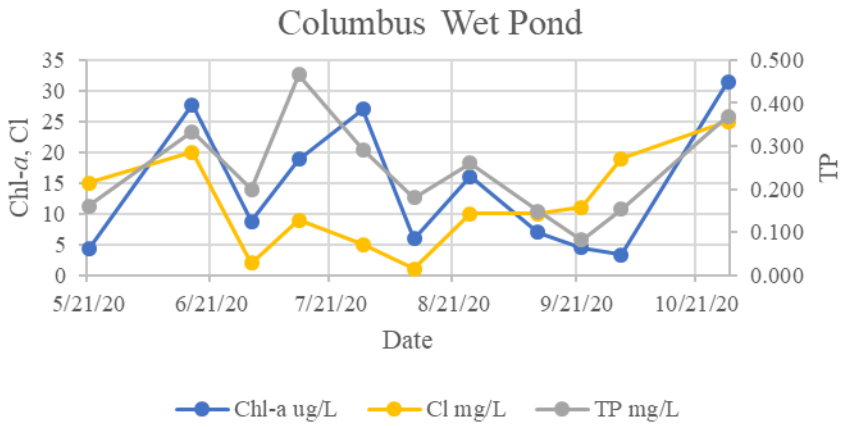


Figure 23-15. 2020 Columbus Pond (Pond 1) showing Chl-*a*, Cl and TP.

The Columbus Pond data shows that Chl-*a* does correlate well with TP, indicating TP may be a driver of Chl-*a*. Except for the last October sample the Chl-*a* values were below the 30 ug/L threshold where HABs can be a threat. The chloride values were well below the MPCA 5-day chronic threshold of 230 mg/L. This pond may be a good candidate for a retrofit for TP reduction.

Camden Pond

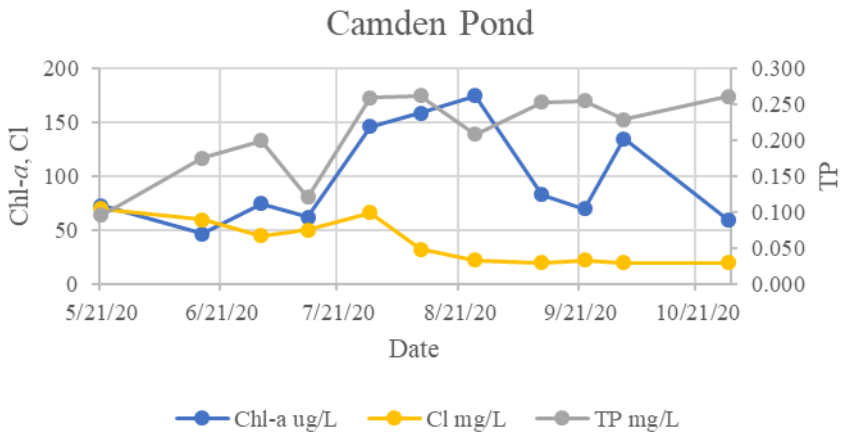


Figure 23-16. 2020 Camden Pond (Pond 2) showing Chl-*a*, Cl and TP.

The Camden Pond data shows that Chl-*a* correlates roughly with TP, indicating TP may be a driver of Chl-*a*. The Chl-*a* values were consistently above the 30 ug/L threshold where HABs can be of concern. This pond may be a good retrofit candidate for Chl-*a* reduction. The chloride values were always below the MPCA 5-day chronic threshold of 230 mg/L.

Logan Pond

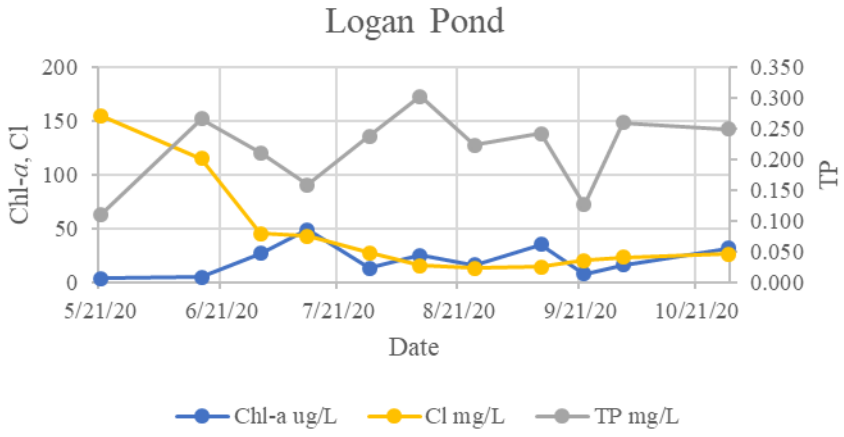


Figure 23-17. 2020 Logan Pond (Pond 3) showing Chl-*a*, Cl and TP.

The Logan Pond data shows that Chl-*a* does not appear to correlate well with TP, indicating TP is likely not a driver of Chl-*a*. The Chl-*a* values were only briefly above the 30 ug/L threshold where HABs can be of concern. The chloride values were higher in the spring but always below the MPCA 5-day chronic threshold of 230 mg/L. This pond may also be a good retrofit candidate for TP reduction.

Mead Pond

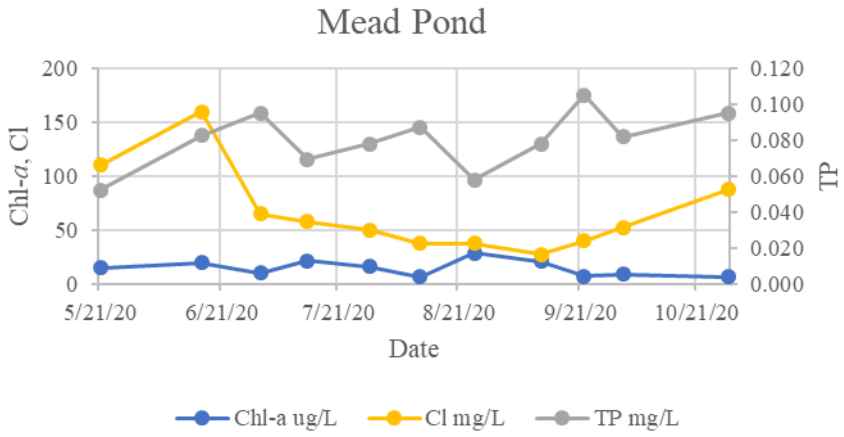


Figure 23-18. 2020 Mead Pond (Pond 4) showing Chl-*a*, Cl and TP.

The Mead Pond data shows that Chl-*a* appears to correlate roughly with TP, indicating TP may be a driver of Chl-*a*. The Chl-*a* values were not above the 30 ug/L threshold where HABs can be of concern. The chloride values were higher in the spring but always below the MPCA 5-day chronic threshold of 230 mg/L.

Hiawatha Outlet Pond

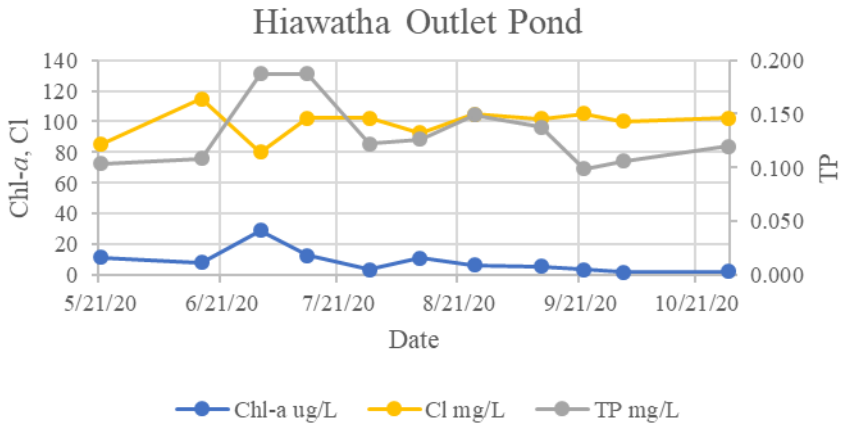


Figure 23-19. 2020 Hiawatha Outlet Pond (Pond 5) showing Chl-*a*, Cl and TP.

The Hiawatha Outlet Pond data shows that Chl-*a* appears to correlate roughly with TP, indicating TP may be a driver of Chl-*a*. The Chl-*a* values were relatively low and not above the 30 ug/L threshold where HABs can be of concern. The chloride values were always below the MPCA 5-day chronic threshold of 230 mg/L. This pond has a pumped outlet and is part of a network of ponds that drains the Hiawatha Golf Course.

West, Park & 44th Pond

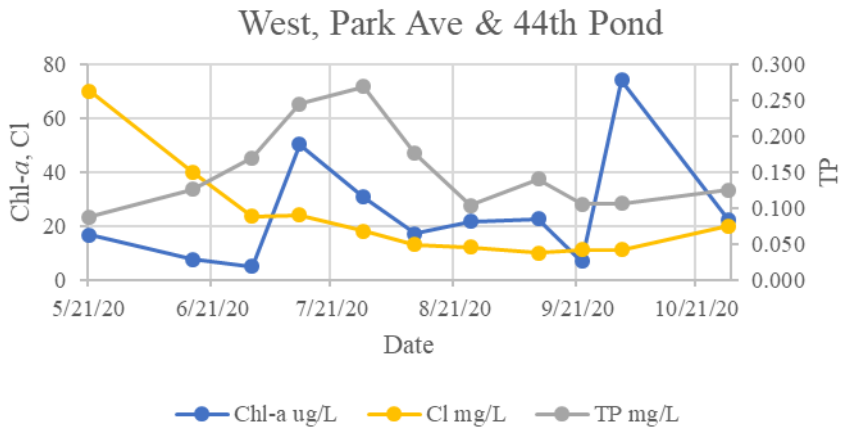


Figure 23-20. 2020 West, Park & 44th Pond (Pond 6) showing Chl-*a*, Cl and TP.

The West, Park & 44th Pond data shows that Chl-*a* appears to correlate with TP, indicating TP may be a driver of Chl-*a*. In the July and October samples, Chl-*a* values were above the 30 ug/L threshold where HABs can be of concern. The chloride values were always below the MPCA 5-day chronic threshold of 230 mg/L.

East, Park Ave & 43rd Pond

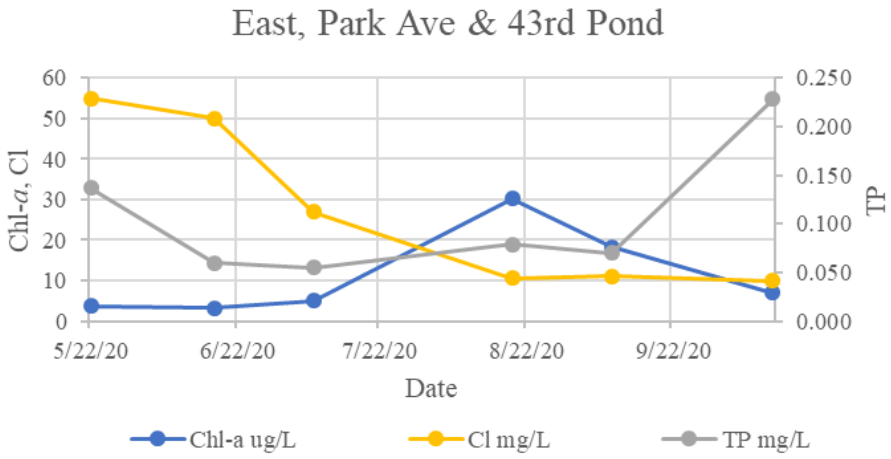


Figure 23-21. 2020 East, Park Ave. & 43rd Pond (Pond 7) showing Chl-*a*, Cl and TP.

The East, Park & 43rd Pond data shows that Chl-*a* does not correlate with TP, indicating TP is not a driver of Chl-*a*. The Chl-*a* values had a single value in late August of 30 ug/L which is the threshold where above this HABs can be of concern. The Chl-*a* values were below 30 ug/L the rest of the year. The chloride values were higher in spring but always below the MPCA 5-day chronic threshold of 230 mg/L.

25th Ave NE Pond

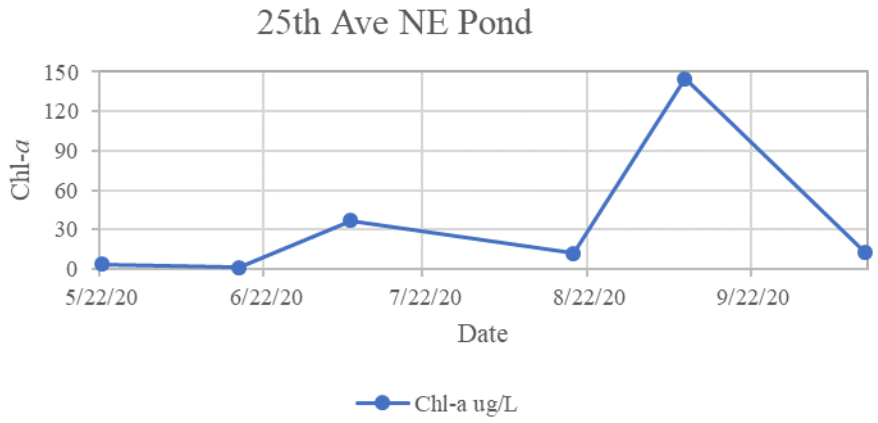


Figure 23-22. Graph of the 2020 25th Ave NE (Pond 8) showing Chl-*a*.

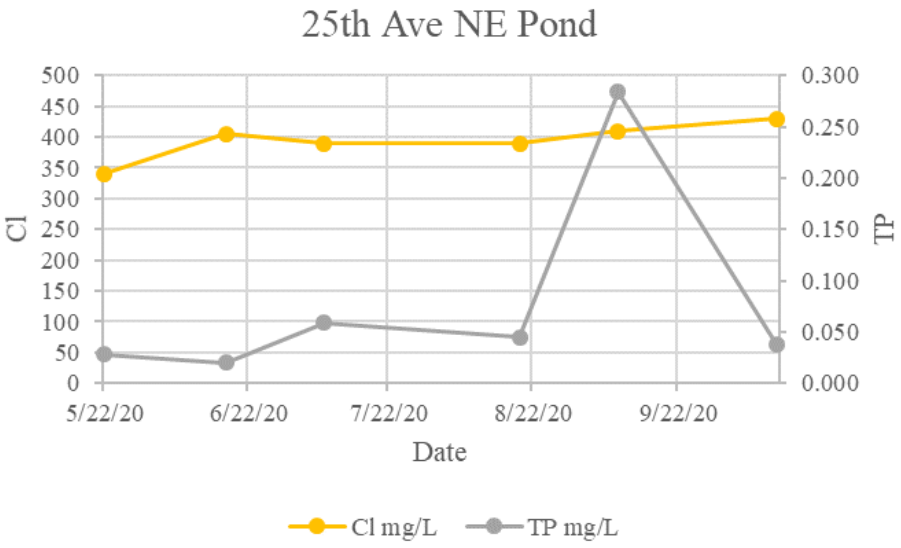


Figure 23-23. Graph of the 2020 25th Ave NE (Pond 8) showing Cl and TP.

The 25th Ave NE Pond Chl-*a* data are graphed separately to show definition. Chl-*a* does correlate with TP, indicating TP may be a driver of Chl-*a*. Two Chl-*a* values in early July and September were above 30 ug/L which is the threshold where above this HABs can be of concern. The Chl-*a* values were below 30 ug/L the rest of the year. This pond was unique in that the chloride values were always high around 400 mg/L and above the MPCA 5-day chronic threshold of 230 mg/L. This pond is a good candidate for Cl reduction.

Winter St. Basin Pond

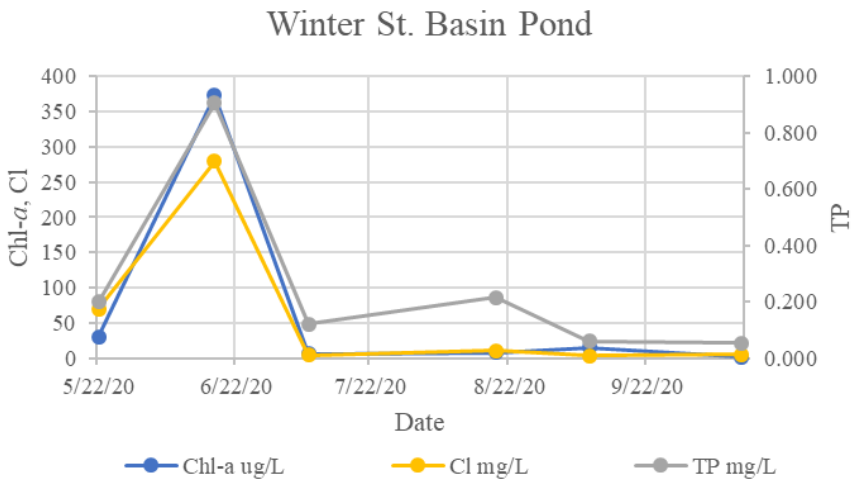


Figure 23-24. Graph of the 2020 Winter St. Basin Pond (Pond 9) showing Chl-*a*, Cl and TP.

The Winter St. Basin Pond data shows that Chl-*a* does correlate with TP, indicating TP may be a driver of Chl-*a*. All the data parameters can be seen increasing in the June 17th sample. The field notes show this June sample was brown opaque and smelled odiferous. The two Chl-*a* values in the spring were above 30 ug/L which is the threshold where above this HABs can be of concern. The Chl-*a* values were below 30 ug/L the rest of the year. The chloride values were only higher in the single June sample where it was above the MPCA 5-day chronic threshold of 230 mg/L. Other than this sample, chloride was always below the MPCA threshold. This BMP is also an infiltration basin with little open water and likely not a good candidate for pond screening or retrofit.

Currie Pond

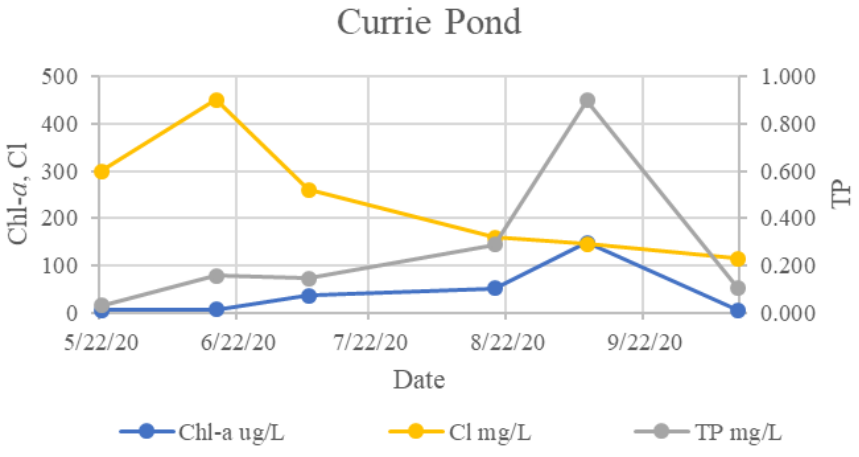


Figure 23-25. Graph of the 2020 Currie Pond (Pond 10) showing Chl-*a*, Cl and TP.

The Currie Pond data shows that Chl-*a* does correlate with TP, indicating TP may be a driver of Chl-

a. The Chl-*a* June, July, and August values were above 30 ug/L which is the threshold where above HABs can be of concern. The Chl-*a* values were only below 30 ug/L in the spring and fall. The MPCA 5-day chronic chloride threshold is 230 mg/L. The chloride values were above 230 mg/L in May, June and July. The chloride values were quite high in June at 450 mg/L. This pond may be a good retrofit candidate for TP and Chl-*a* reduction.

Heritage Park Pond #1

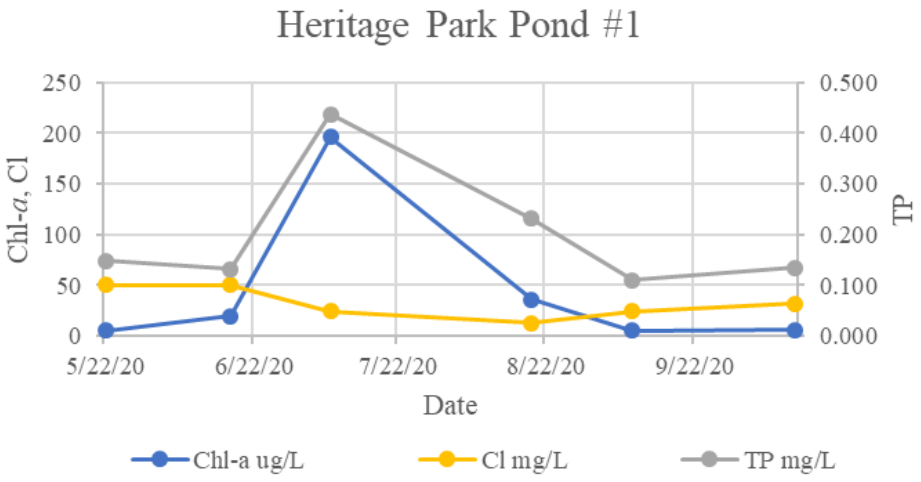


Figure 23-26. Graph of the 2020 Heritage Park Pond #1 (Pond 11) showing Chl-*a*, Cl and TP.

The Heritage Park Pond #1 data shows that Chl-*a* does correlate with TP, indicating TP may be a driver of Chl-*a*. The Chl-*a* July value was 196 mg/L and well above 30 ug/L which is the threshold where above this HABs can be of concern. The Chl-*a* values were only over 30 ug/L in July and August, and below the threshold the rest of the year. The MPCA 5-day chronic chloride threshold is 230 mg/L. The chloride values at Heritage Park Pond #1 were never above 230 mg/L.

Heritage Park Pond #2

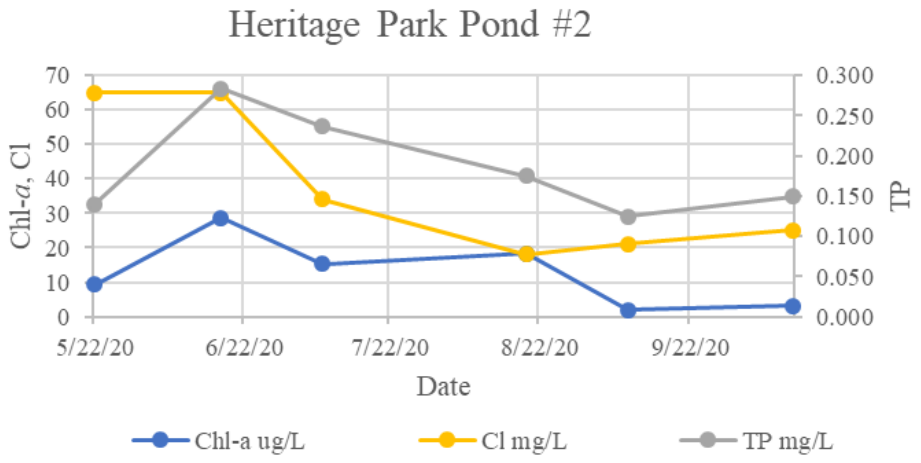


Figure 23-27. Graph of the 2020 Heritage Park Pond #2 (Pond 12) showing Chl-*a*, Cl and TP.

The Heritage Park Pond #2 data shows that Chl-*a* does correlate with TP, indicating TP may be a driver of Chl-*a*. The Chl-*a* values were never above 30 ug/L which is the threshold where above this HABs can be of concern. The MPCA 5-day chronic chloride threshold is 230 mg/L. The chloride values were never over 230 mg/L.

Heritage Park Pond #3

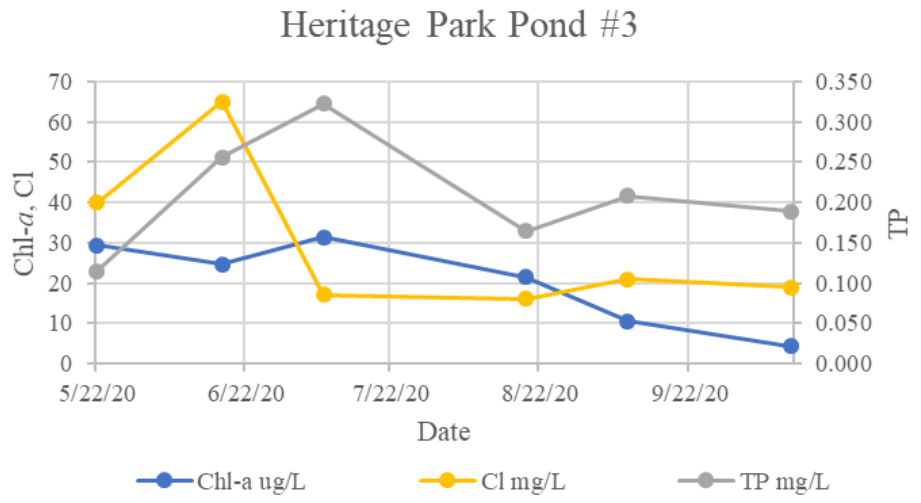


Figure 23-28. Graph of the 2020 Heritage Park Pond #3 (Pond 13) showing Chl-*a*, Cl and TP.

The Heritage Park Pond #3 data shows that Chl-*a* does correlate with TP, indicating TP may be a driver of Chl-*a*. Only the Chl-*a* July value of 31 ug/L was above 30 ug/L, which is the threshold where above this HABs can be of concern. The MPCA 5-day chronic chloride threshold is 230 mg/L. The chloride values were never above 230 mg/L. Heritage Park Ponds #2 and #3 are hydrologically

connected and often function as one pond.

Heritage Park Pond #4

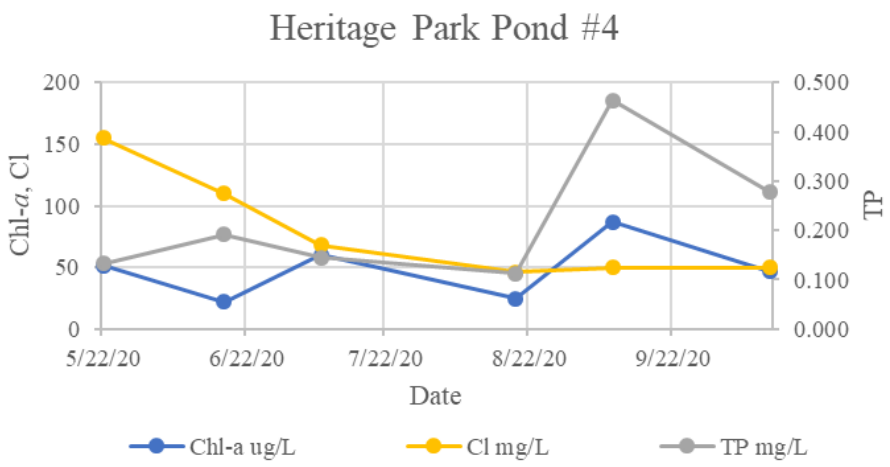


Figure 23-29. Graph of the 2020 Heritage Park Pond #4 (Pond 14) showing Chl-*a*, Cl and TP.

The Heritage Park Pond #4 data shows that Chl-*a* does correlate with TP, indicating TP may be a driver of Chl-*a*. The Chl-*a* threshold is 30 ug/L where above this HABs can be of concern. In June and September, the Chl-*a* values were 68 ug/L and 60 ug/L respectively. The MPCA 5-day chronic chloride threshold is 230 mg/L. The chloride values were never over 230 mg/L. This pond may be a good retrofit candidate for TP and Chl-*a* reduction.

Heritage Park Pond #5

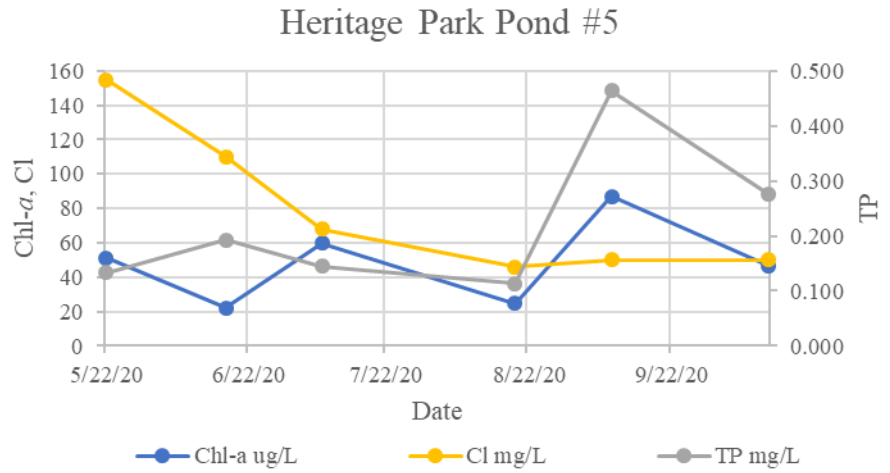


Figure 23-30. Graph of the 2020 Heritage Park Pond #5 (Pond 15) showing Chl-*a*, Cl and TP.

The Heritage Park Pond #5 data shows that Chl-*a* does correlate with TP, indicating TP may be a driver of Chl-*a*. The Chl-*a* threshold is 30 ug/L where above this HABs can be of concern. Many of

the Chl-*a* samples were above 30 ug/L except the June and August samples. The MPCA 5-day chronic chloride threshold is 230 mg/L. The chloride values were never over 230 mg/L. This pond may be a good retrofit candidate for TP and Chl-*a* reduction.

Central Pond

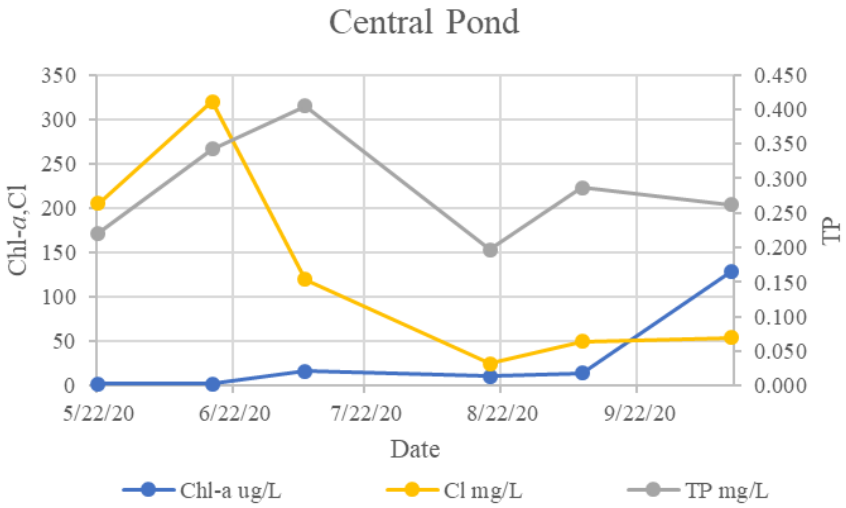


Figure 23-31. Graph of the 2020 Central Pond (Pond 16) showing Chl-*a*, Cl and TP.

The Central Pond data shows that Chl-*a* does not correlate with TP, indicating TP may not be a driver of Chl-*a*. The Chl-*a* threshold is 30 ug/L where above this HABs can be of concern. All the Chl-*a* samples were below 30 ug/L except the last October sample where Chl-*a* was 129 ug/L. The MPCA 5-day chronic chloride threshold is 230 mg/L. Only the June chloride sample of 320 mg/L was over the MPCA 230 mg/L threshold. This pond may be a good retrofit candidate for TP reduction.

Most of the ponds Chl-*a* data correlated well with TP which is not surprising. The exceptions were E. Park & 43rd, Logan, and Central where there was no Chl-*a* correlation with TP. The Central Pond was dyed green in 2020 to inhibit Chl-*a* growth which likely effected the Chl-*a* results. The Cl values at most of the ponds were below the MPCA 5-day chronic Cl threshold of 230 mg/L. These included the Columbus, Camden. Logan Mead, Hiawatha Outlet, West Park & 44th, East Park & 43rd, Heritage Park 1, 2, 3, 4, and 5 Ponds. The ponds with Cl samples above than the MPCA 5-day chronic Cl threshold were Winter St. Infiltration Basin, Currie, Central, and 25th Ave NE Ponds. The 25th Ave NE Pond was the only pond that consistently had Cl values over the MPCA 5-day Cl chronic threshold.

Ponds with Chl-*a* over 30 ug/L

Figure 23-32 shows fourteen ponds that had values greater than 30 ug/L Chl-*a* graphed on a log-scale. The red line highlights the 30 ug/L threshold where conditions above this level indicate that HABs can be of concern.

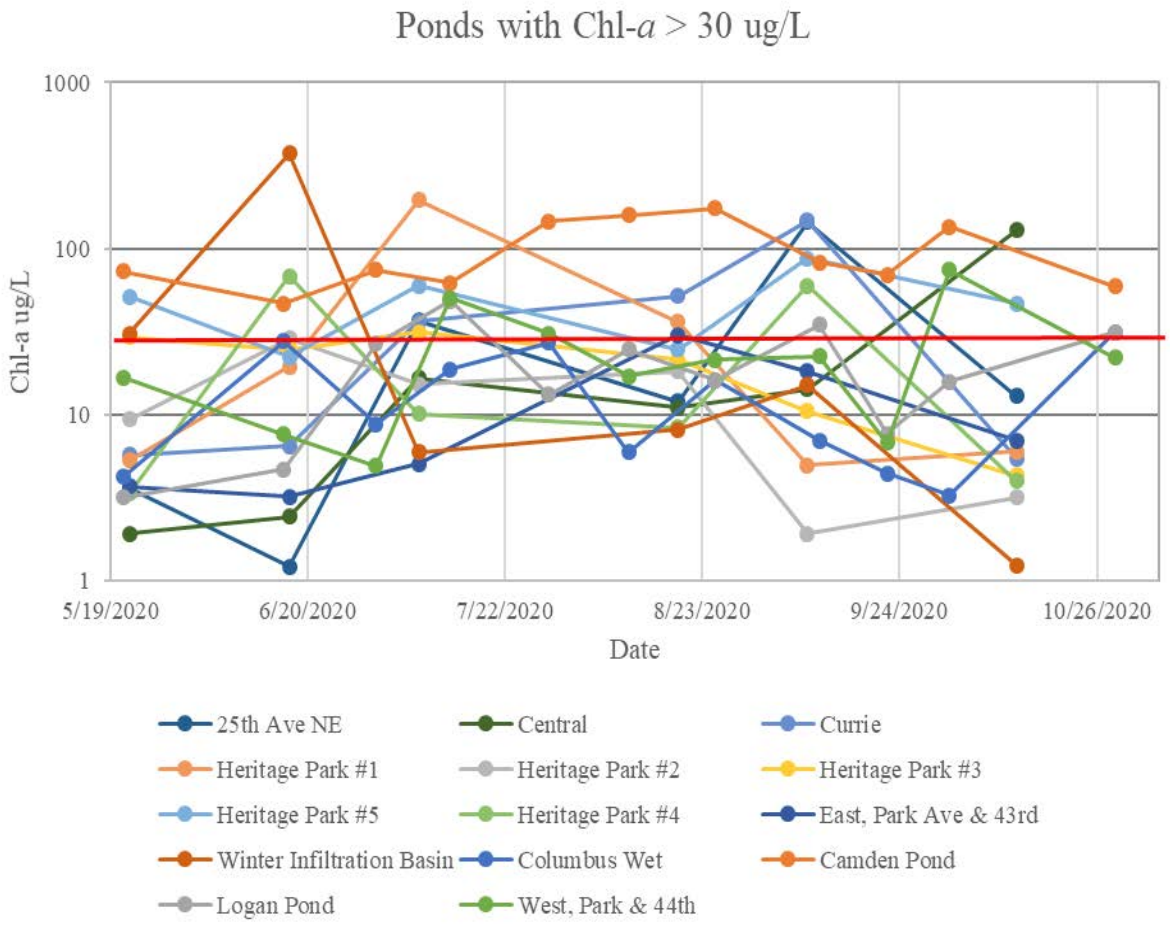


Figure 23-32. Ponds on a log-scale with Chl-*a* over 30 ug/L. The red line at 30 ug/L demonstrates the threshold where HABs are likely to occur.

In **Figure 23-32** Winter St. Basin Pond is the outlier in mid-June with Chl-*a* at approximately 375 mg/L. Chl-*a* at Camden Pond was consistently over 30 ug/L with readings lower in the spring at around 75 ug/L but between 150 to 175 ug/L in June and July. Most of the ponds intermittently exceeded the 30 ug/L Chl-*a* threshold.

Ponds with Cl over 230 mg/L and 120 mg/L

Figure 23-33 shows eight of the ponds graphed for Cl that were either over 230 mg/L or 120 mg/L. The red line in the Cl graph is the 230 mg/L chronic 5-day MPCA threshold. The green line in the Cl graph is the 120 mg/L Canadian chronic threshold for ecological impacts.

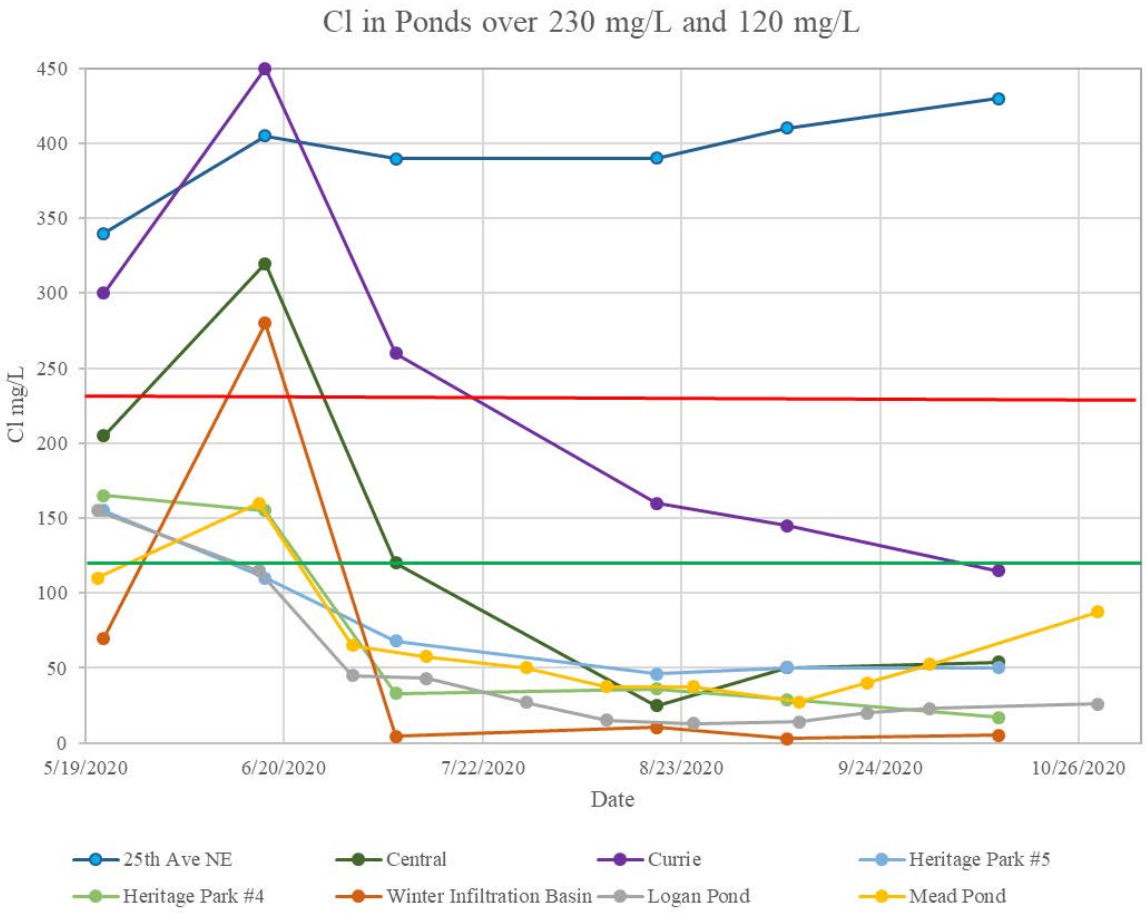


Figure 23-33. Graph of the 2020 ponds with higher Cl. The red line is the 230 mg/L MPCA 5-day chronic threshold, and the green line is the 120 mg/L Canadian chronic threshold.

Cl was consistently high at the 25th Ave NE Pond and always over the 230 mg/L MPCA 5-day chronic threshold. Cl levels at Currie, Central, and Winter St. Basin Ponds were all over the 230 mg/L standard in mid-June. The ponds that did not exceed the MPCA 230 mg/L threshold but did exceed the 120 mg/L Canadian chronic threshold were the Heritage Park 4 and 5, Logan, and Mead Ponds. With the exception of the 25th Ave NE Pond these ponds show increased Cl levels in the spring, likely from snowmelt chloride application runoff, and then a flushing throughout the year to lower levels.

Ponds with higher TP

Figure 23-34 shows the ponds graphed that had higher TP. Phosphorus is usually a limiting nutrient in aquatic ecosystems. Phosphorus can be from stormwater inputs, resuspension and disturbance of sediments, or internal release in ponds from the sediment. Higher TP values can drive phytoplankton production and then increase Chl-*a*.

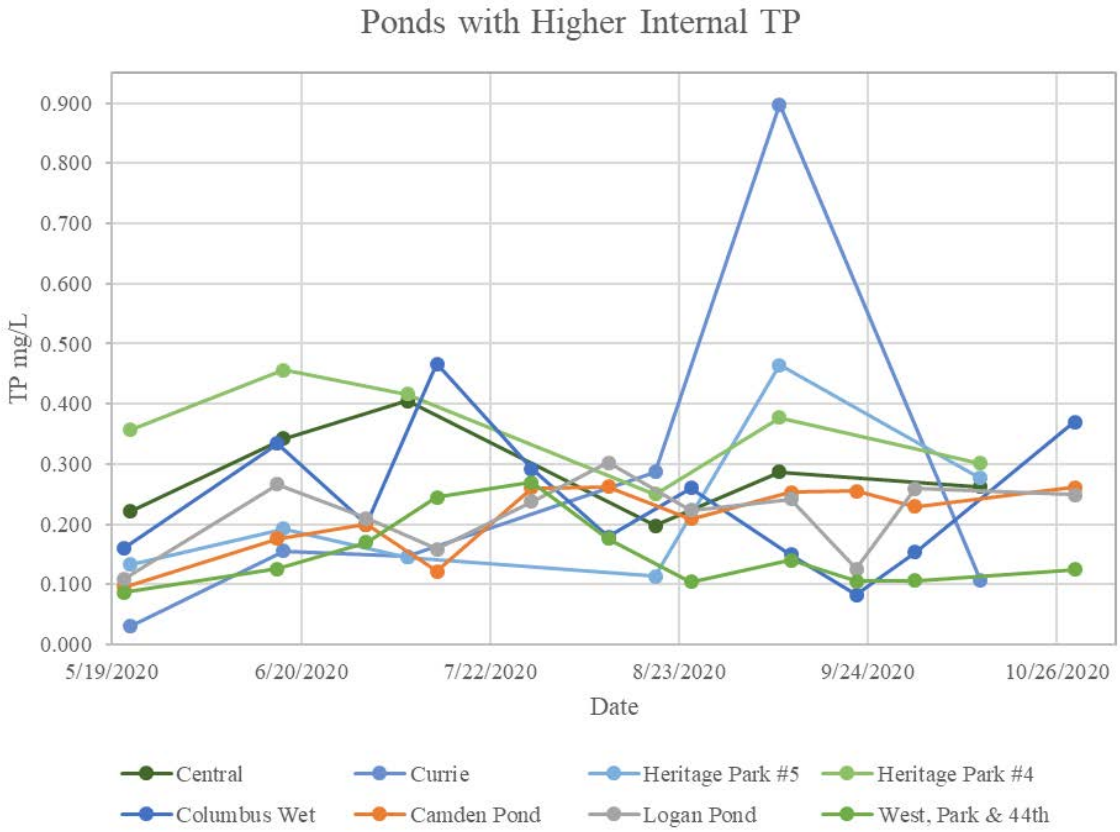


Figure 23-34. Ponds with higher internal TP.

Eight of the ponds that had higher internal TP were compared and appear to show the possibility of internal loading. All eight ponds had exceedances of 0.250 mg/L, which is quite high for a waterbody. TP can be a limiting nutrient for phytoplankton. Pond retrofits should focus on limiting phosphorus availability. High concentrations of TP can lead to increased phytoplankton and Chl-*a* concentrations.

TP increased to approximately 0.900 mg/L at Currie in early September, which is quite high. The Winter St. Basin Pond TP data are not presented in the graph since it is not a pond but an infiltrations basin with a very small ponding area. With the exception of the Currie Pond, the TP at seven of the eight ponds was below 0.500 mg/L all year. The data from the ponds with higher internal TP illustrate the bimodal tendency in many of the ponds, with both a mid-summer and fall rise in TP.

WENCK Pond 2020 Monitoring Data

The WENCK pond data collected in 2020 are presented in **Figure 23-35** and **Figure 23-36** showing the dissolved oxygen (DO) and temperature profiles. Oxygen and temperature profiles can indicate stratification and anoxic conditions at the pond bottom. Fourteen of the ponds WENCK studied

overlapped with the sixteen ponds that MPRB studied. The MPRB did not study the Shingle Creek North and South Ponds and the graphics used are from the WENCK study.

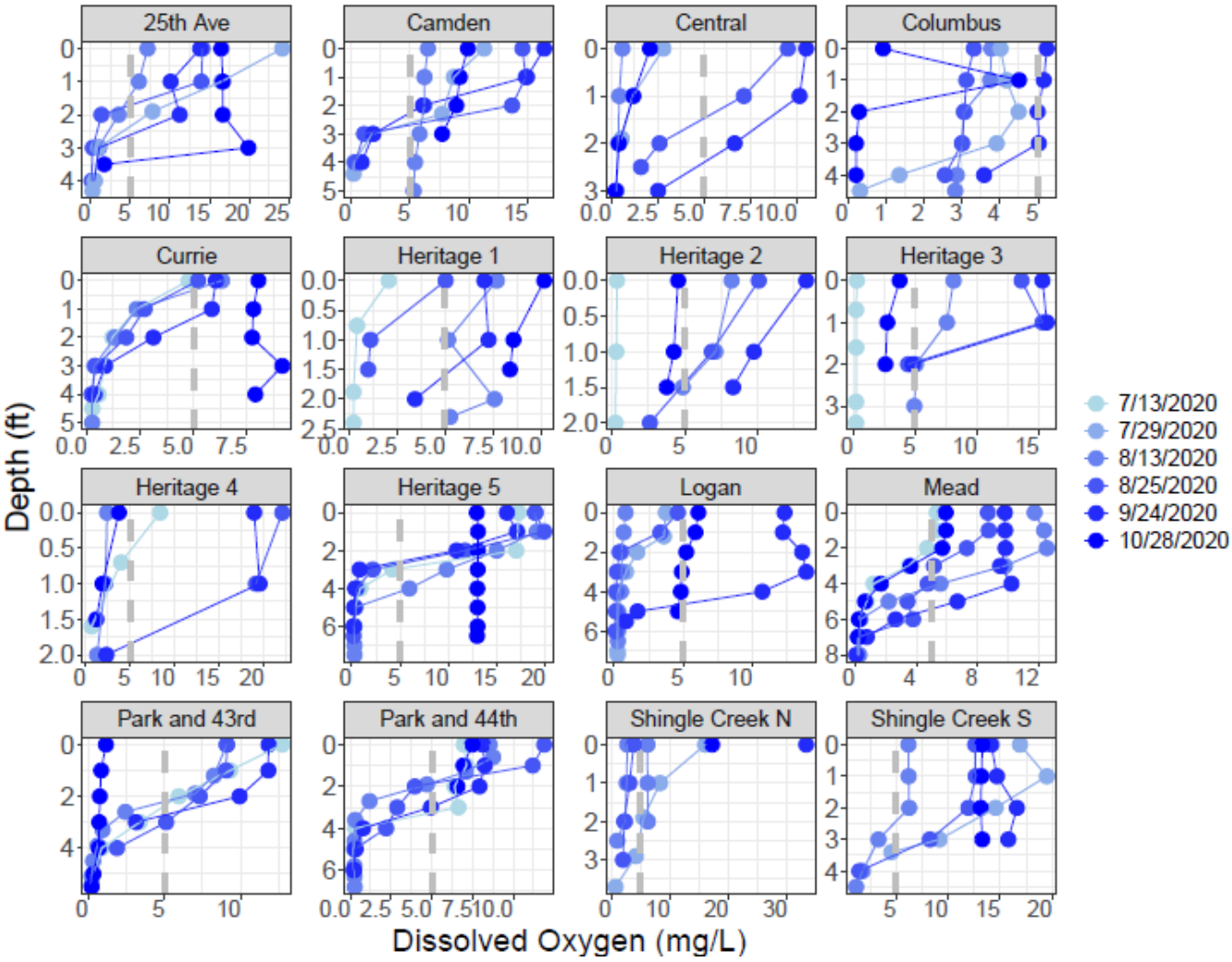


Figure 23-35. WENCK data and graph of the dissolved oxygen (DO) profiles of 14 of the 16 MPRB ponds. The Shingle Creek North and South Ponds were not part of the MPRB study. The grey dashed line shows the 5 mg/L mark.

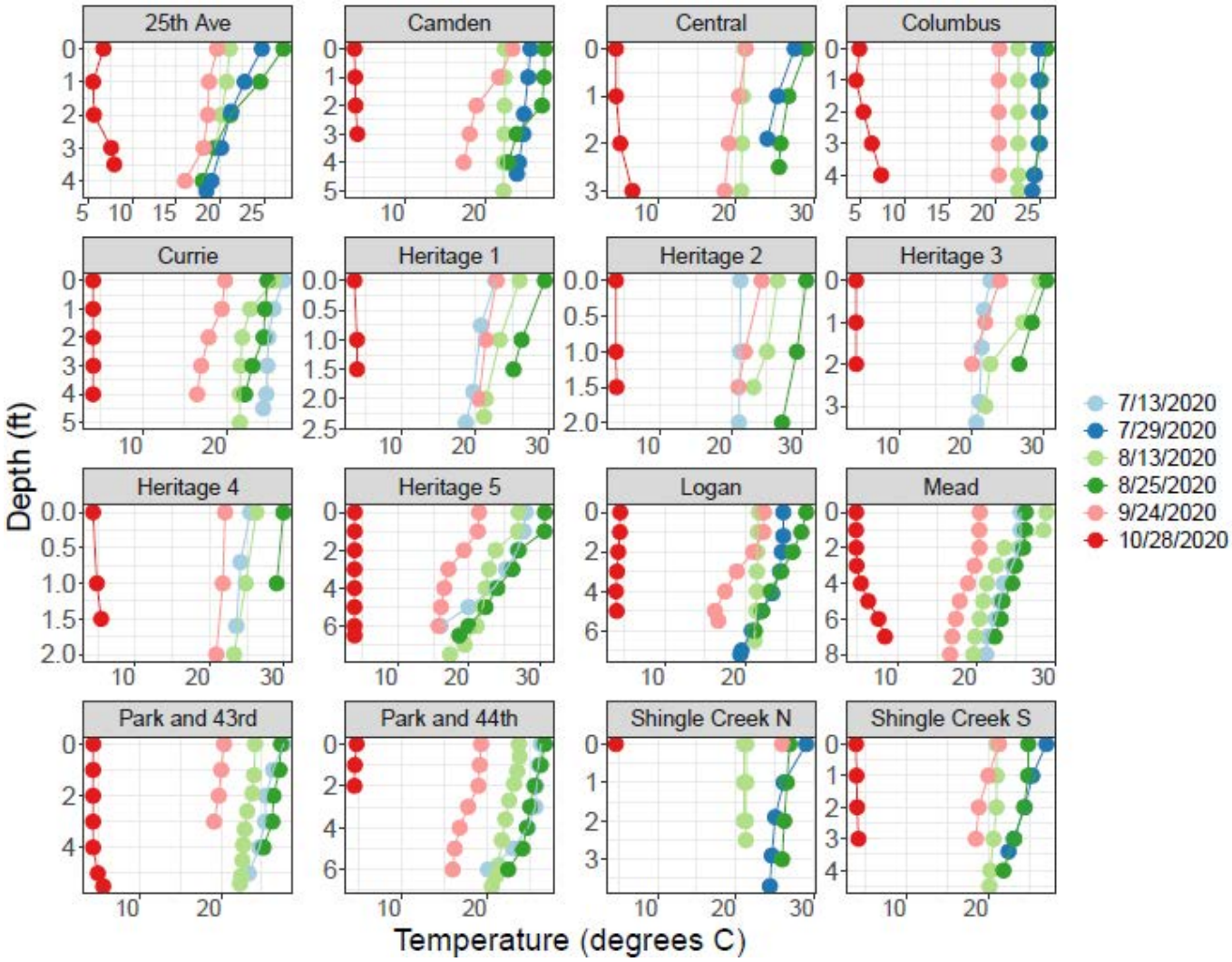


Figure 23-36. WENCK data and graph of the temperature profiles of 14 of the 16 ponds. The Shingle Creek North and South Ponds were not part of the MPRB study.

Figure 23-35 and **Figure 23-36** show that many of the ponds DO appears stratified, but the temperature is not stratified. The ponds appear to be mixing because the temperature is consistent top to bottom, but the pond sediments likely have a high oxygen demand which quickly sets up a dissolved oxygen stratification in many of the ponds. Specifically, 25th Ave NE, Mead, Park & 43rd & Park & 44th ponds have stratified DO and the bottom samples are anoxic all year. The Currie, Heritage Park 5, and Logan Pond bottom samples are anoxic, except later in the year in September and October. The Central and Columbus Ponds bottom samples are anoxic in July and Sept. The Heritage Park Ponds 1-4 bottom samples are all anoxic in mid-July. When the bottom pond water is anaerobic the pond sediments can release phosphorus internally back to the pond water column where it can facilitate unwanted algae growth and increase Chl-*a* concentrations possibly leading to HABs.

CONCLUSION

The pond screening looked for:

1) Pond Chl-*a* values greater than 30 ug/L when HABs can be of concern.

2) High pond TP values, usually greater than 0.250 mg/L or higher, and what the source could be. Higher TP pond values can be associated with internal release from the pond sediments. The Wenck pond data show anoxic conditions at the pond bottom where iron-bound phosphorus can be released. Some of the ponds had limited TSS, VSS and metals data that could shed light on bioturbation or resuspension of pond sediments.

3) Pond chloride values that either exceeded the MPCA 5-day chronic standard of 230 mg/L or the Canadian chronic aquatic standard of 120 mg/L.

Chlorophyll-*a*

Fourteen of the ponds had Chl-*a* measurements above the 30 ug/L threshold where HABs can occur. HABs are made up of a phytoplankton organism called cyanobacteria which has the capability to produce toxins. Cyanotoxins were not monitored in 2020. These toxins can be a health concern to humans or animals. Human body contact does not usually occur in stormwater ponds, but it can occur in downstream waterbodies.

HABs are not a concern at Winter St. Infiltration Basin since it is an infiltration basin and does not maintain much standing water. The Chl-*a* at Camden Pond is the most concerning since recorded concentrations had the potential to produce a sustained HAB event.

There are two main HAB concerns with stormwater ponds. First, the possible seeding of downstream water bodies with phytoplankton HAB resting cells. The other concern is the possibility, if a HAB event were to occur, that the HAB could become aerosolized by the wind. If a HAB was to be aerosolized by the wind, it could pose a risk burden to the local surrounding community. Many of the stormwater ponds are in lower income and minority communities and reducing HABs could be part of environmental justice issues.

Ponds that should be investigated for high Chl-*a* and HAB potential are:

- Camden
- Heritage Park #4
- Heritage Park #5
- Currie
- West, Park & 44th

Chloride

Chloride is also present in stormwater in significant concentrations, particularly snowmelt. Novotney et.al. (2009) showed that 77% of the chloride is not flushed through but retained in the Twin Cities Metropolitan Area (TCMA) watershed, and pre-settlement background levels were roughly 3 mg/L. The Minnesota Cl standard for aquatic life is 230 mg/L. The Canadian Water Quality Guidelines for the Protection of Aquatic Life recommend that long term chloride concentrations for freshwater be less than 120 mg/L (Canadian Environmental Quality Guidelines, Canadian Council of Minister of

the Environment, 2011).

The Cl of many of the ponds increases in mid-June and then decreases throughout rest of the summer. The 25th Ave NE Pond had very high Cl levels all season of around 400 mg/L. It is unknown where the Cl is coming from at the 25th Ave NE Pond since most of the surrounding watershed is owned by the University of Minnesota. Spring is when most aquatic life is emerging, growing, and vulnerable to damage due to high levels of chloride. Chloride in ponds originates from the surrounding watershed. These watersheds should be investigated for Cl reduction strategies. Ponds cannot be retrofit to remove dissolved chloride.

- 25th Ave NE pond should be investigated for consistently high chloride levels..

Total Phosphorus

Most of the ponds in this study are flood control ponds that may be able to have a stormwater benefit. Stormwater ponds are specifically designed to settle material and sediment bound TP from incoming stormwater. Sometimes this phosphorus is resuspended or internally released from pond sediments. Total phosphorus is a target pollutant for removal because it can be a driver of Chl-*a* in waterbodies. An MPCA study of 98 stormwater ponds showed that nearly 40% had a summer median TP concentration exceeding average stormwater runoff concentrations of 0.380 mg/L (Vinicius, et.al., 2020). The MPCA study concludes stormwater ponds are highly susceptible to internal phosphorus release which can add to eutrophication of downstream waterbodies. One mechanism of the internal release of phosphorus in stormwater ponds occurs when the sediment water interface becomes anaerobic, allowing iron-bound phosphorus to be released. Resuspension or bioturbation may be another source. If the pond mixes intermittently the sediment released phosphorus will become bio-available to phytoplankton near the surface.

The TP data show a mix of results. Some ponds showed TP increases in both the spring and fall. Most of the pond's TP levels remained below 0.400 mg/L. Not all ponds with high TP translated into high Chl-*a*. This relationship appears complicated by multiple factors. It is interesting to note that Camden Pond which had consistently high Chl-*a* values had no TP values above 0.300 mg/L. There appears to sometimes be a correlation with high TP and high Chl-*a*, but not always.

Ponds that should be investigated for potential high internal loading of TP are:

- Heritage Park #4
- Heritage Park #5
- Central
- Columbus
- Currie
- Logan

Ponds tested for NPDES parameters

The ponds monitored in 2020 for the full NPDES chemistry suite show that Chl-*a* appears to correlate well with TSS and VSS at all the ponds, except Columbus. When looking at the possibility of resuspension in the ponds, a significant portion of the TSS appears to be VSS. Almost half or more of the TSS is VSS. The majority of the VSS is likely phytoplankton or fine organic colloidal material in the ponds that does not settle well. The metals values are also very low which would indicate that sediment is not being resuspended and bioturbation is not occurring in the ponds with these data.

Future Work and Retrofits

Dredging may be needed at Mead, West Park & 44th, East Park & 43rd, Camden, and Central Ponds. They have been in service for 20 years and never been dredged. As-built bathymetric construction maps should ideally be compared to current bathymetry to help determine if dredging is needed. Organic sediments consume oxygen from the water column and may create anoxic conditions above sediments where iron-bound phosphorus may be released back to the pond. Dredging may enhance their efficacy of future stormwater pollutant settling and removal. It should be noted that dredging with other improvements should help create aerobic conditions to keep iron-bound phosphorus in the pond sediments.

Aeration may also be added to keep the ponds mixed and aerobic. The Columbus Pond has a small aeration system for odor control, but it appears to be undersized to create aerobic conditions at the bottom or inhibit Chl-*a* production. Oxygenated water at the pond bottom would prevent the iron-bound phosphorus release from sediments. Phosphorus release can increase Chl-*a* creating conditions for algae to grow.

Most of the ponds were developed for flood control and not as green space or for wildlife habitat. The City would like to investigate the possibility of enhancing pond wildlife habitat. High chloride levels can have a negative effect on aquatic life. Chloride levels were only consistently high at the 25th Ave NE Pond with levels around 400 mg/L. Cl in spring, greater than 230 mg/L, at Currie, Central, and Winter St. Infiltration Basin may also negatively affect the spring emerging aquatic life and chloride should be mitigated to lower levels if ponds are expected to function as habitat.

If duckweed is growing or planted in a pond it could be harvested as a final nutrient sink for removal. Logan Pond has extensive duckweed mats that could be harvested. There are smaller commercially available remote-controlled vehicles that could help facilitate duckweed management. Harvested duckweed should be quantified and tested for the nutrients removed from the pond.

The addition of biodegradable colored dyes or herbicides e.g. Aquashade, to ponds has been shown to inhibit the production of Chl-*a*. Dyes and herbicides would need to be continually added as they would be flushed out with the short residence time of stormwater ponds. Central Pond is on Columbia Golf Course and was dyed blueish-green most of the season to inhibit algae. Central Pond had Chl-*a* below 30 ug/L all season except for the October sample where it was approximately 130 ug/L. This may be a useful seasonal short-term tool for the prevention of HABs.

Alum injection systems, for pond inlet stormwater, could be investigated where the stormwater aluminum bound phosphorus can then settle in the pond and later be dredged out and removed. These systems exist but also require a high degree of maintenance. Treating pond influent with alum to bind, settle, and limit phosphorus may also inhibit the formation of Chl-*a* and potentially HABs.

Future Monitoring

Flow-weighted sampling at pond inlets and outlets would help to determine both the external load to the ponds and give a more complete picture of nutrient removal. This sampling could be done prior to and after a retrofit project to calculate the nutrient removal benefit of specific projects.

Regular pond profiles of DO and temperature should be done to determine if the pond is stratified or mixing and if the pond bottom is anaerobic. If the pond bottom becomes anaerobic it can release phosphorus from the sediment back to the water column.

If HABs in stormwater ponds are of concern, Chl-*a* along with HAB cyanotoxins could also be tested. This would provide evidence of not just conditions for potential HABs, but credible evidence of cyanotoxins presence and their concentrations. These data would support a more complete risk assessment. Ponds with Chl-*a* greater than 30 ug/L should also have a phytoplankton sample taken to determine the dominant species. Different types of algae may require different management strategies.

TOC

24. Fat Oil and Grease (FOG), and 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 permit requires quarterly grab samples for NPDES chemistry, pH, *E. coli*, and a pilot project to monitor fat, oils, and grease (FOG). The purpose of this monitoring is to characterize the seasonality of runoff for parameters that cannot be collected with flow-weighted composite monitoring (e.g. pH, *E. coli*, FOG). Criteria for snowmelt sample collection was a winter snowpack melt. Criteria for spring, summer, and fall grab sample collection was precipitation greater than 0.10" separated by at least 8 hours from other rain events.

The NPDES permit requires quarterly grab stormwater event monitoring to be attempted, but it is not always possible to carry out. Rain events must occur when staff are working, and the laboratory is open to receive samples. Ideally, annual quarterly grab monitoring includes two snowmelt grab samples, and a one each of a spring, summer and fall grab sample. Quarterly grab monitoring includes a pH, *E. coli*, NPDES water chemistry sample, and a Fat Oil and Grease (FOG) sample. The water chemistry samples are analyzed for the 14 chemistry parameters included in the NPDES permit. The pH, *E. coli*, and FOG sample data cannot be collected from regular composite sampling and can only be collected from a grab sample.

Grab sampling characterizes a point in time of a snowmelt or rain event. The first snowmelt event usually has higher pollutant concentration than subsequent snowmelt events. The chemical concentrations can change over time and throughout the hydrograph as the rising limb usually mobilizes fine particles and FOG material on hard surfaces first. Chemical concentrations can vary not only throughout the individual hydrograph but also from storm to storm, largely driven by the time since the last precipitation. It can be helpful to think of pollution in a watershed as behaving like dust. It accumulates over time and then washes off in a melt or rain event. The longer the time between wash off (snowmelt or rain) the more material (pollutants) accumulates.

As part of the NPDES permit, a study of quarterly FOG grab samples were conducted along with regular grab sample monitoring with the intent to sample six sites. The latest NPDES permit it was determined 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. FOG in stormwater can come from a variety of sources such as: vehicles, industry, food waste and gas stations. Elevated levels of hydrocarbons can be harmful to aquatic plants and animals. It is important to minimize FOG in stormwater through best practices in industry, public education about vehicle maintenance, and the prevention of improper waste disposal.

In 2018 quarterly grabs were collected at the representative land use sites. Following snowmelt, grab samples could not be collected from the Pershing land use site since auto-monitoring equipment was housed in a box on top of the manhole. 61st and Lyndale had extensive road construction 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). It had been intended to continue sampling at the 61st and Lyndale site, but the site was again inaccessible due to 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 (N, SE, S, and W) and 61st & Lyndale. The Powderhorn Inlet N site was deemed inaccessible and dropped from sampling after several attempts. 61st and Lyndale was only sampled one time in July, and a full year of sampling at this site will be attempted again.

METHODS

Grab Sampling

The sample bottle was either attached to a modified pool skimmer pole a clean white 5-gallon bucket was lowered into the stormsewer to collect an aliquot and poured off if flow was not adequate to collect with the bottle method. If the protocol required rinsing, one rinse was done, if rinsing was not protocol samples were collected without rinsing.

The pH grab sample was analyzed in the field by a hand-held Oakton pH meter that had a two-point calibration prior to field use that day. The pH probe was rinsed with the grab sample water and the pH measurement taken directly from the aliquot.

The *E. coli* samples were collected in sterile 100 mL bottes and not rinsed. These samples were immediately stored directly on ice in a cooler.

Standard FOG sampling protocol was followed, and FOG samples were collected in an unrinsed amber glass bottle. Rinsing could introduce additional FOG material which would stick to the inside glass container walls and produce artificially high results.

NPDES water chemistry samples were collected in a 2-liter Nalgene bottle that was rinsed once with the stormwater prior to filling.

A 2-liter field blank of DI water accompanied all samples while in the field. All samples were stored and transported on ice to the laboratory within holding times.

Samples could only be collected when enough flow was present to collect a sample. Snowmelt and precipitation needed to produce at least over 1" of stage in the pipe to be sampled. Precipitation events needed to be greater than 1/10" to produce enough runoff.

In 2020, quarterly grab samples were attempted on 2/24/20, 10/22/20 and 11/9/20 but no samples could be collected due to limited flow of less than 1".

All FOG, NPDES water chemistry, and *E. coli* samples were analyzed at Instrumental Research Incorporated (IRI) Laboratory in Fridley, Minnesota. All metals and DOC samples were analyzed by Pace Laboratory in Minneapolis, MN.

Table 24-1 shows all the NPDES chemistry parameters tested 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). Pace Laboratory analyzed all metals and DOC samples.

Table 24-1. The list of required NPDES permit chemistry parameters to be monitored.

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	NO_3NO_2	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

[‡]Metals and DOC were analyzed by Pace Laboratories.

Figure 24-1 shows the location of the 61st & Lyndale, industrial land use site, within the City of Minneapolis, MN. **Figure 24-2** show the location of the Powderhorn Lake SE, S, and W Inlets, and **Figure 24-3** show the location of the 24th Ave. SE & Elm St. SE infiltration basin N and S Inlets.



Figure 24-1. Aerial photo of the 2020 61st & Lyndale stormwater quarterly grab monitoring sites.



Figure 24-2. Aerial photo of the 2020 Powderhorn quarterly grab monitoring sites.

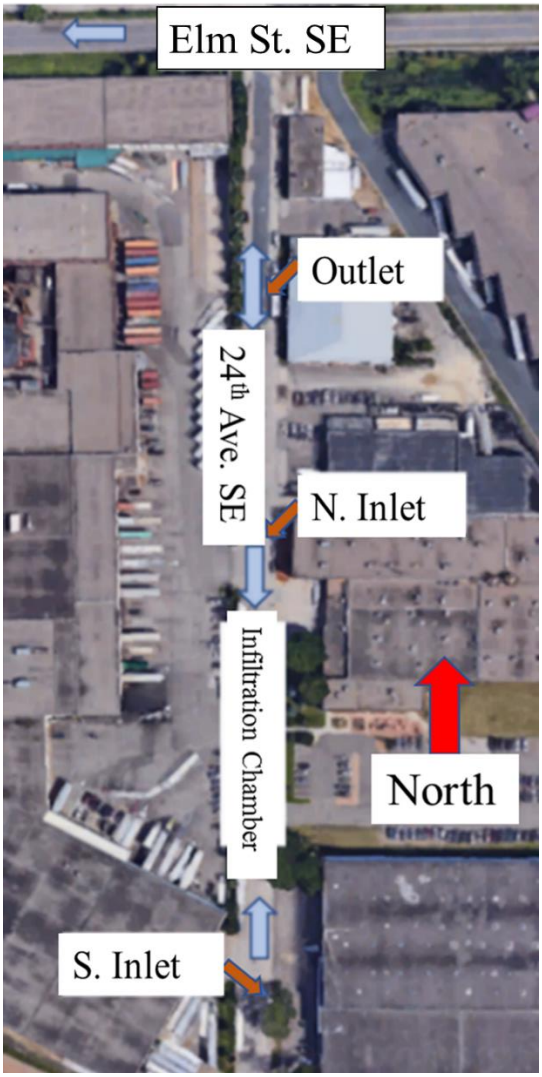


Figure 24-3. Aerial photo of 24th Ave. SE & Elm St. SE Infiltration Chamber and its two inlets and outlet. Blue arrows show the direction of flow.

Table 24-3 shows the land use and drainage area for the sampled sites at the Powderhorn inlets and 61st & Lyndale. **Table 24-4** shows the 24th Ave. SE & Elm St. SE and Winter Infiltration basins land use and drainage area.

Table 24-3. The 2020 Powderhorn Inlets and 61st & Lyndale sites monitored for NPDES chemistry, *E. coli*, pH, and FOG.

Site ID	Powderhorn Inlet Southeast	Powderhorn Inlet South	Powderhorn Inlet West	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	Multi–Family, Residential, Mixed Use	Residential, Mixed Use	Residential, Mixed Use	Commercial/Industrial
Drainage Area	68.8 acres	81.2 acres	99.4 acres	34.9 acres

Table 24-4. The 2020 24th Ave. SE & Elm St. SE sites monitored for NPDES chemistry, *E. coli*, pH, and FOG.

Site ID	24th Ave. SE & Elm St. SE Infiltration Basin North Inlet	24th Ave. SE & Elm St. SE Infiltration Basin South Inlet
Location	24th Ave SE	24th Ave SE
Land Use	Light Industrial	Light Industrial
Drainage Area	3.9 acres	10.3 acres

FIELD QUALITY ASSURANCE SAMPLES

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 2020. 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 that month all the data for that parameter were flagged for the entire month.

Field measurements were recorded on a Field Measurement Form in the 2020 Field Log Book. Electronic data from the laboratory were forwarded to the MPRB in preformatted 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 data reported below the reporting limit, the reporting limit value was divided in half for use in statistical calculations.

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 29,** Quality Assurance Assessment Report for details.

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

Snowmelt usually has the highest geometric mean concentrations for most chemical parameters. This is as expected as snowmelt is the release of 4-5 months of deposition and debris from the watershed. Snowmelt usually has the lowest geometric mean for *E. coli*. The *E. coli* concentrations are temperature dependent because bacteria do not survive well in cold conditions.

Table 24-5 shows the 2020 quarterly NPDES chemistry grab sample results. Snowmelt has more pollutants than the summer grab samples, but lower *E. coli*. It should be noted that all of the Powderhorn (SE, S, and W) Inlet snowmelt samples have significantly more pollutants than the other sites sampled. Specifically, the Powderhorn (SE, S, and W) Inlet snowmelt phosphorus and metals samples are high in comparison to the other sites sampled. All the sites monitored had pH quarterly grab samples ranged between 6.9 and 8.3.

Table 24-5. The 2020 quarterly stormwater grab sample chemistry collected, NA=data not available.

Site Location	Date Sampled	Time	Sample Type	TP mg/L	TDP mg/L	TN mg/L	NO3NO2 mg/L	Cl mg/L	Hardness mg/L	pH Units	TSS mg/L	VSS mg/L	TDS mg/L	COD mg/L	FOG mg/L	E. Coli MPN	Cu ug/L	Pb ug/L	Zn ug/L	DOC mg/L
24th & Elm In N	3/3/2020	13:30	Grab	0.339	0.175	1.55	0.237	160	40	7.4	23	12	432	46	<5.00	<1	13	3	64	11
24th & Elm In N	3/4/2020	12:20	Grab	0.382	0.192	1.52	0.306	170	48	7.3	38	13	415	62	<5.00	<1	21	12	76	9
24th & Elm In N	7/14/2020	8:20	Grab	0.195	0.083	2.75	1.42	16	64	7.0	22	10	148	85	<5.00	3270	12	3	63	16
24th & Elm In N	7/21/2020	9:40	Grab	0.164	0.016	1.59	0.706	8	40	6.6	64	16	117	61	<5.00	6131	15	5	69	8
24th & Elm In S	3/3/2020	13:20	Grab	0.459	0.297	2.33	0.216	260	36	7.6	22	13	537	48	<5.00	4	10	2	44	11
24th & Elm in S	3/4/2020	12:10	Grab	0.400	0.287	1.79	0.184	200	32	7.1	11	6	410	25	<5.00	<1	11	1	35	9
24th & Elm In S	7/14/2020	8:10	Grab	0.197	0.065	2.41	0.698	8	36	7.1	57	21	199	101	<5.00	441	16	4	91	16
24th & Elm In S	7/21/2020	9:30	Grab	0.170	0.055	1.61	0.480	<2.00	16	6.9	11	6	58	32	<5.00	24196	6	0	<20.0	6
24th & Elm Out	7/14/2020	8:30	Grab	0.163	0.046	4.72	2.88	190	150	7.1	72	17	548	117	7	272	19	8	129	16
61st & Lyndale	7/7/2020	9:30	Grab	0.076	0.019	2.46	0.701	72	70	8.0	226	52	255	185	6	294	40	19	155	17
61st & Lyndale	7/21/2020	8:35	Grab	0.224	0.018	1.66	0.328	16	44	8.4	152	30	108	107	<5.00	2620	18	8	113	10
Powderhorn In S	2/24/2020	13:42	Grab	1.00	0.419	5.14	0.250	750	50	8.0	128	65	1360	197	31	133	41	28	236	24
Powderhorn In S	3/3/2020	12:40	Grab	1.30	0.473	5.17	0.169	550	64	7.6	338	196	1112	326	14	2420	46	38	245	27
Powderhorn In S	7/7/2020	10:05	Grab	0.099	0.083	1.13	0.319	<2.00	14	8.0	29	12	53	22	3	41	18	11	34	4
Powderhorn In S	7/21/2020	9:00	Grab	0.203	0.067	1.63	0.604	<2.00	20	6.6	28	12	50	49	<5.00	9330	13	8	34	7
Powderhorn In SE	3/3/2020	12:50	Grab	1.08	0.592	3.57	0.151	450	72	NA	75	39	950	167	6	2420	26	14	116	43
Powderhorn In SE	3/4/2020	11:45	Grab	0.806	0.582	3.57	0.143	450	72	NA	24	14	868	108	6	121	18	8	74	27
Powderhorn In SE	7/7/2020	9:55	Grab	0.152	0.119	1.41	0.561	<2.00	18	6.6	20	10	40	26	5	>24200	20	7	30	6
Powderhorn In SE	7/21/2020	8:50	Grab	0.173	0.080	1.44	0.534	2	14	6.6	19	9	30	42	<5.00	7701	8	3	24	6
Powderhorn In W	2/24/2020	14:15	Grab	1.04	0.324	3.93	0.250	800	70	8.3	175	104	1434	412	109	517	38	20	174	25
Powderhorn In W	3/3/2020	12:20	Grab	1.79	0.512	5.33	0.142	450	80	7.4	430	206	1068	470	13	866	70	135	396	26
Powderhorn In W	7/7/2020	10:10	Grab	0.149	0.039	1.21	<0.030	<2.00	14	7.2	33	14	43	33	4	>24200	14	18	30	4
Powderhorn In W	7/21/2020	9:10	Grab	0.236	0.028	1.69	0.455	2	22	6.4	30	17	42	66	<5.00	98040	10	10	47	8

For historical consideration of the FOG project **Table 24-6** shows the 2018 and **Table 24-7** shows the 2019 FOG data. In 2018 none of the FOG data were reported greater than 15 mg/L. In 2019, the only data where FOG samples were reported greater than 15 mg/L were from 61st & Lyndale snowmelt. All other FOG samples were below 15 mg/L.

Table 24-6. Shows the 2018 FOG event dates and grab samples collected.

Site Location & Date Sampled	1/10/2018	1/19/2018	1/26/2018	3/19/2018	3/26/2018	7/12/2018	7/13/2018	10/1/2018
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			

Table 24-7. Shows the 2019 FOG event dates and grab samples collected. Data in bold are over 15 mg/L.

Site Location & Date Sampled	3/12/2019	3/13/2019	3/19/2019	3/20/2019	5/8/2019	6/27/2019	8/26/2019	9/12/2019
14th & Park	9	10						
22nd & Aldrich	Attempted⸸	7						
61st & Lyndale	**21**	**19**						
Pershing			<5.00	<5.00				
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 In Out								
Winter Basin In S					<5.00	<5.00	6	6
Winter Basin In W					5	5	5	<5.00

⸸Attempted refers to sampling that was attempted but could not be collected.

All 2020 Fat Oil and Grease (FOG) samples are shown in **Table 24-8.** Two snowmelt samples from Powderhorn Inlet South and Inlet West collected on 2/24/20 were over the 15 mg/L MPCA threshold. All other FOG grab samples were below 15 mg/L.

Table 24-8. 2020 FOG event dates and grab samples collected. Bold data are FOG samples were greater than 15 mg/L.

Site Location & Date Sampled	2/24/2020	3/3/2020	3/4/2020	7/7/2020	7/14/2020	7/21/2020
61st & Lyndale				6		<5.00
24th & Elm In N	Attempted⸸	<5.00	<5.00		<5.00	<5.00
24th & Elm In S	Attempted⸸	<5.00	<5.00		<5.00	<5.00
Powderhorn In N	Attempted⸸	Attempted⸸				
Powderhorn In SE	Attempted⸸	6	6	5		<5.00
Powderhorn In S	**31**	14		3		<5.00
Powderhorn In W	**109**	13		4		<5.00

⸸Attempted refers to sampling that was attempted but could not be collected.

CONCLUSION

In 2020, an attempt was made to monitor six sites quarterly for NPDES water chemistry, *E. coli*, pH, and FOG. In 2020 the six sites were chosen were 24th Ave. SE & Elm St. SE Inlets (N and S) and Powderhorn Inlets (N. SE, S, and W). In 2020 the Powderhorn Inlet N site could not be grab sampled for snowmelt due to the pipe flow path relationship to the manhole being inaccessible, so it was abandoned as a quarterly grab sample site. In 2020 following snowmelt it was decided to add back 61st & Lyndale to the quarterly grab monitoring since the 2019 snowmelt FOG samples had come back greater than 15 mg/L at this site.

Grab samples of stormwater represent chemistry at a point in time. Following sampling protocol, some parameters can only be characterized by a grab sample, e.g. pH, *E. coli*, and FOG. The 2020 quarterly grab sampling data show that snowmelt has high values for all chemical parameters when compared to runoff at other times of the year. Snowmelt chemistry values were also high at the Powderhorn Inlet (S and W) sites, specifically the phosphorus, solids, metals, and FOG data.

The pH ranged between seven and eight. The *E. coli* levels were low in the snowmelt and higher in the warmer months since *E. coli* are temperature-dependent organisms.

In 2020, two February FOG snowmelt grabs from Powderhorn Inlet South and West were the only samples above 15 mg/L. All other FOG samples collected in 2020 were below the 15 mg/L threshold.

Snowmelt is a unique event that contributes pollution from 4-5 frozen months into the watershed at once. As seen in the data, snowmelt samples are extremely polluted from material deposited in the watershed over the winter, and it is common to see an oily sheen on a snowmelt grab sample. In adherence to the NPDES permit the MPRB will continue to attempt to monitor 6 sites quarterly for NPDES water chemistry, *E. coli*, pH, and FOG. The stormwater pipe has been replaced at 61st & Lyndale and is now accessible and since it had a 2019 snowmelt FOG sample greater than 15 mg/L it will continue to be part of the quarterly grab sampling sites.

TOC

25. POWDERHORN LAKE INLET MONITORING

BACKGROUND

The City of Minneapolis and Minneapolis Park and Recreation Board undertook a restoration plan for Powderhorn Lake in 1999, due to poor lake conditions. Part of the restoration plan included the installation of Continuous Deflective Separators (CDS) to remove trash and solids from the stormwater to Powderhorn Lake. In 2001, five CDS grit chambers were installed at the outlets to the larger watersheds flowing to Powderhorn Lake to remove solids from stormwater inflow **Figure 25-3**. A drawing of a CDS unit is shown in **Figure 25-1**. The Powderhorn Lake watersheds are shown in **Figure 25-2**.

Despite this and other restoration work, the lake was listed as impaired and placed on the Environmental Protection Agency (EPA) 303d list based on eutrophication and biological indicators in 2001. Powderhorn Lake later trended towards better water quality and was subsequently delisted in 2012 after meeting state standards for several years. Powderhorn was relisted on the EPA 303d list as impaired for nutrients in 2018 after relapsing to poor water quality.

The purpose of monitoring the stormwater inlets into Powderhorn Lake is to measure the external nutrient load of the main tributaries to the lake. Information collected will help create a plan to decrease the amount of external nutrients impacting Powderhorn Lake. In 2020, the COVID-19 pandemic disrupted the ability to carry out equipment installations and only grab samples were collected at the Powderhorn inlets.

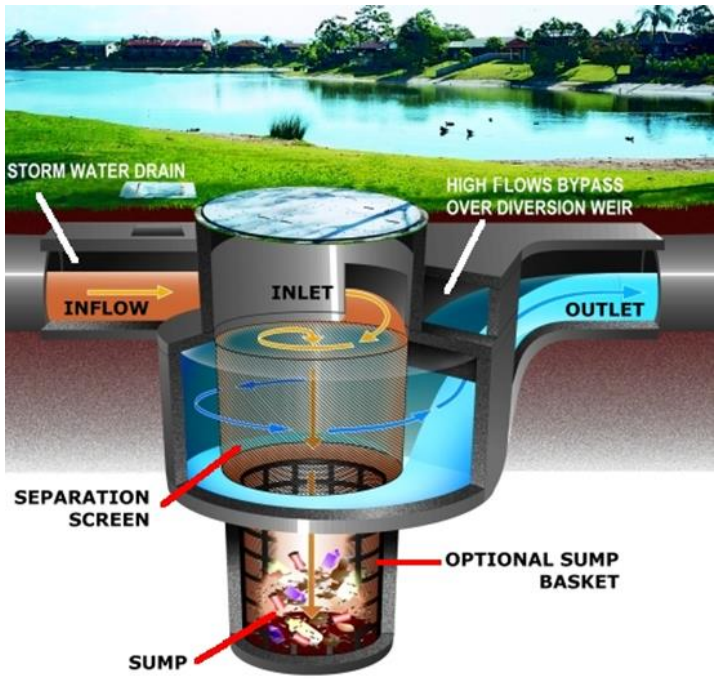


Figure 25-1. Cross section showing components of a CDS grit chamber unit.

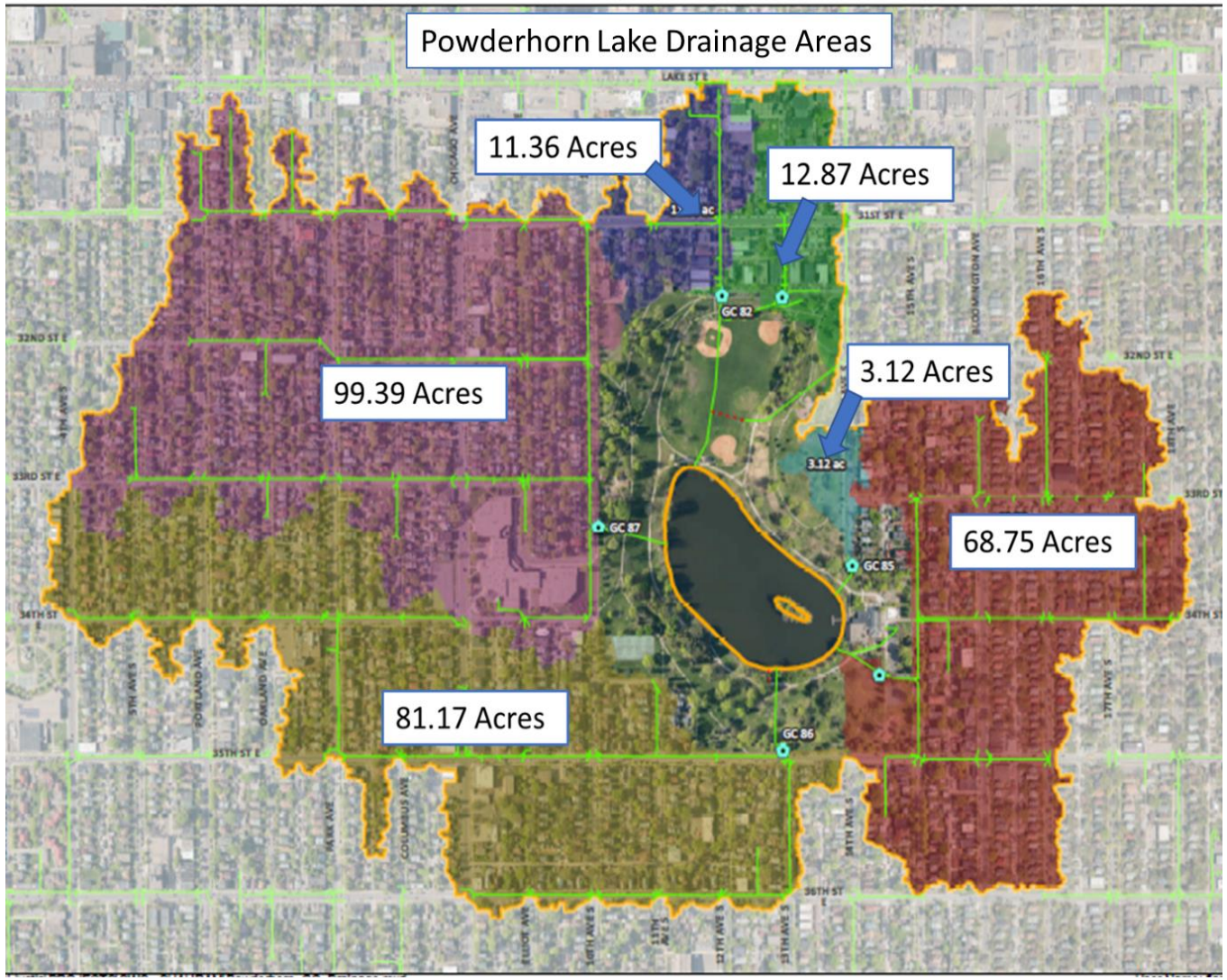


Figure 25-2. Powderhorn Lake individual watershed drainage areas with acreage. All inlets have CDS units except the small 3.12 acre area which has a sump.

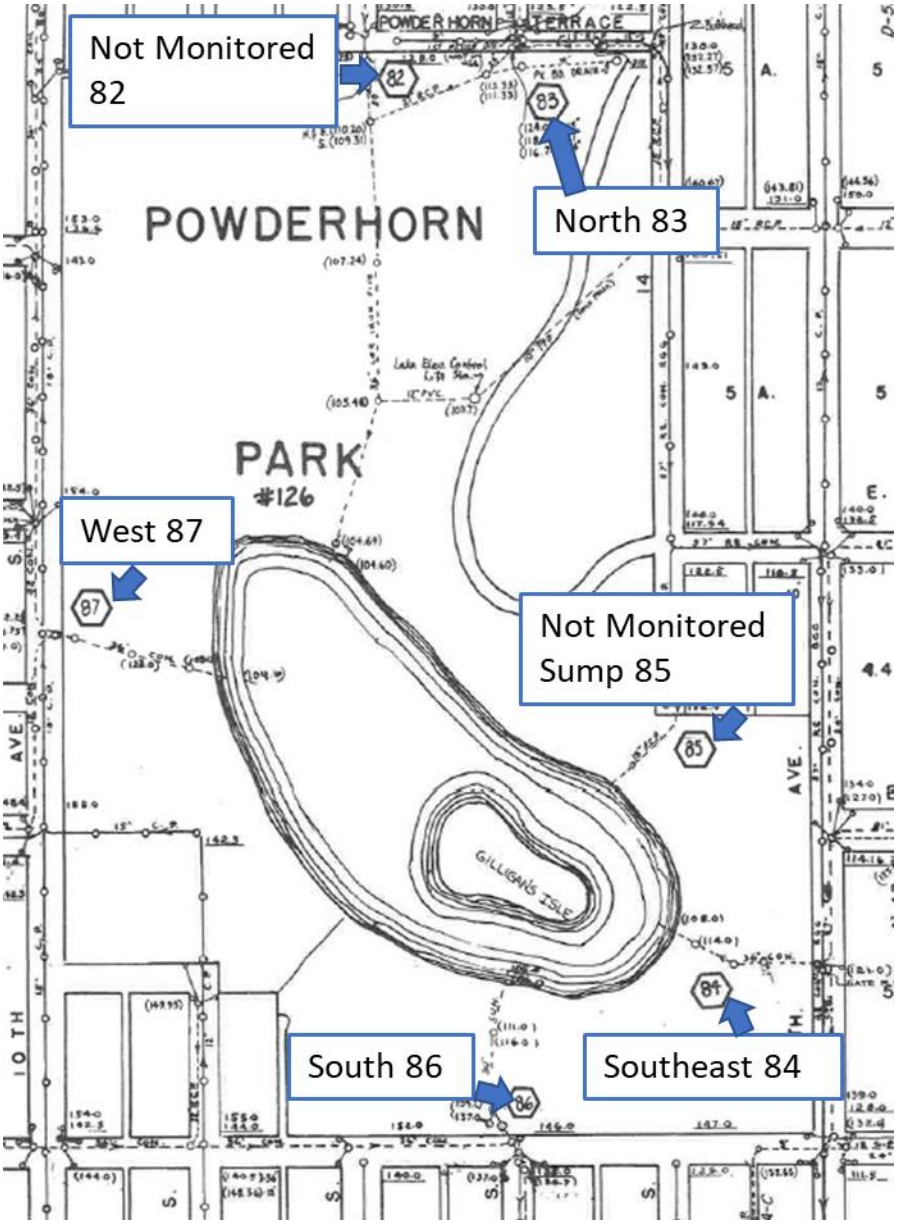


Figure 25-3. Stormsewer map of CDS grit chambers 82-87 surrounding Powderhorn Park.

There are five CDS grit chambers and one sump structure installed in stormwater pipes leading to Powderhorn Lake. A sump is a pit, usually in a catch basin, that traps solids. **Table 25-1** shows the Powderhorn CDS grit chamber assigned numbers, location, and drainage areas for each CDS 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 the watershed is only 3.1 acres which is about 1% of the watershed and it is unlikely that this watershed contributes a significant portion of nutrient loading to Powderhorn Lake.

Table 25-1. A list of the Best Management Practices (BMP's) surrounding Powderhorn Lake, their associated drainage areas.

Monitoring ID Name	BMP Type	Grit_ID	Drainage (Acres)	Location
Not Monitored	CDS Hydrodynamic Separator	82	11.4	12th Ave S and Powderhorn Terrace
Inlet North	CDS Hydrodynamic Separator	83	12.9	13th Ave S and Powderhorn Terrace
Inlet Southease	CDS Hydrodynamic Separator	84	68.8	3421 15th Ave S
Not Monitored	Sump Manhole	85	3.1	3329 14th Ave S
Inlet South	CDS Hydrodynamic Separator	86	81.2	13th Ave S and East 35th Street
Inlet West	CDS Hydrodynamic Separator	87	99.4	3318 10th Ave S back of sidewalk oppisite of house #3318

METHODS

Site Installation

In 2020, the COVID-19 pandemic prevented installation of equipment and auto-monitoring of the Powderhorn Inlet sites. The sites continued to be part of the NPDES quarterly grab sample schedule.

The Inlet South and Inlet West had significant sedimentation upstream of the CDS overflow weirs. It is believed that this is caused by the CDS screens becoming plugged and water backing up the inlet pipes where settling occurred. If the pandemic has subsided to the point where safe monitoring can be done, it is planned that auto-monitoring equipment will be installed spring of 2021.

Sample Collection

Auto-monitoring with flow-paced composite sampling was not done in 2020. Only quarterly grab sampling was done at the Inlet South, Inlet Southeast, and Inlet West for chemistry, *E. coli*, pH, and Fat Oil and Grease (FOG) analysis.

Sample collection was done with either a modified pool skimmer pole or a white bucket tied to a rope. The 2-Lsample bottle was rinsed prior to sample collection for water chemistry, pH aliquots poured off for analysis in the field. The pH data were collected by a handheld Oakton pH meter that had a two-point calibration with 7 and 10 pH standards in the office. Following protocol, the *E. coli* sample bottles were not rinsed prior to sample collection. *E. coli* samples were collected in single-use sterile bottles. FOG samples were collected in non-rinsed1-L bottle for analysis.

RESULTS & DISCUSSION

Sample Collection

In 2020, Powderhorn Inlet samples were collected from storms ranging from 0.32" to 0.88''. Samples were collected from two snowmelt events and two individual storms at the Inlet South, Inlet Southeast, and Inlet West sites. **Table 25-2** shows the grab sample storms collected and the precipitation measured by a rain gauge at MPRB's service center at 3800 Bryant Ave. S. Minneapolis, MN. A precipitation event was defined as a storm greater than 0.10" and separated by eight hours or more from other precipitation.

Table 25-2. 2020 Precipitation and grab samples collected at the Powderhorn Lake inlets.

Start Date	Start Time	End Date	End Time	Rain (inches)	Duration (hours)	Intensity (in/hr)	Hours since last Rain.	Powderhorn In S	Powderhorn In SE	Powderhorn In W
2/24/2020	13:42	Snowmelt						X	NS	X
3/3/2020	12:40	Snowmelt						X	X	X
3/4/2020	11:45	Snowmelt						NS	X	NS
7/7/2020	7:45	7/7/2020	8:30	0.70	0.75	0.93	176	X	X	X
7/21/2020	6:30	7/21/2020	8:30	0.32	2	0.16	59	X	X	X

NS indicates storms that were not sampled.

When grab samples were collected at the South Inlet and West Inlet water appeared to be backed up to the height of the overflow weir, approximately two feet high, indicating that the CDS unit is partially plugged. A plugged CDS screen appears to cause stormwater to back up the inlet pipe which settles out solids upstream, **Figure 25-4**. Untreated stormwater flows by the overflow weir directly to the lake. The water impounded in the upstream pipe then appears to have slowly drained down between storms through the CDS unit screen.



Figure 25-4. A 2019 photograph of the upstream Powderhorn Inlet South offset AV probe and intake strainer after removing 8" of sand and debris.

Table 25-3 shows the 2020 grab sample chemistry data for samples collected at the Powderhorn inlets. Data underlined failed the blind monthly laboratory standard for the corresponding test and month. When the laboratory cannot recover the blind standard at ± 20%, all the data are marked for that month. These data were deemed usable but should be used with caution.

The snowmelt samples had significant amounts of pollutants. The July grab samples had very high *E. coli* values. The Powderhorn West Inlet March snowmelt metals were high. The March lead concentrations at this inlet was high, at 135 ug/L, and should be investigated for a possible source. There are no stormwater standards, but the lead drinking water action standard is 15 ug/L. The source of the lead is currently unknown, but one possibility may be exterior lead paint coming from the older residential buildings.

Table 25-3. 2020 Powderhorn Inlet Stormwater grab sample chemistry data. Data that are underlined in red had a blind performance standard failure for that month, for that parameter. NA = data not available.

Site Location	Date Sampled	Time	Sample Type	TP mg/L	TDP mg/L	TN mg/L	NO3NO2 mg/L	Cl mg/L	Hardness mg/L	pH Units	TSS mg/L	VSS mg/L	TDS mg/L	COD mg/L	FOG mg/L	E. Coli MPN	Cu ug/L	Pb ug/L	Zn ug/L	DOC mg/L
Powderhorn In S	**2/24/2020**	13:42	Grab	1.00	0.419	5.14	0.250	750	50	8.0	128	65	1360	197	31	133	41	28	236	24
Powderhorn In S	**3/3/2020**	12:40	Grab	1.30	0.473	5.17	0.169	550	64	7.6	338	196	1112	326	14	2420	46	38	245	27
Powderhorn In S	**7/7/2020**	10:05	Grab	0.099	0.083	1.13	0.319	<2.00	14	8.0	29	12	53	22	3	41	18	11	34	4
Powderhorn In S	**7/21/2020**	9:00	Grab	0.203	0.067	1.63	0.604	<2.00	20	6.6	28	12	50	49	<5.00	9330	13	8	34	7
Powderhorn In SE	**3/3/2020**	12:50	Grab	1.08	0.592	3.57	0.151	450	72	NA	75	39	950	167	6	2420	26	14	116	43
Powderhorn In SE	**3/4/2020**	11:45	Grab	0.806	0.582	3.57	0.143	450	72	NA	24	14	868	108	6	121	18	8	74	27
Powderhorn In SE	**7/7/2020**	9:55	Grab	0.152	0.119	1.41	0.561	<2.00	18	6.6	20	10	40	26	5	>24200	20	7	30	6
Powderhorn In SE	**7/21/2020**	8:50	Grab	0.173	0.080	1.44	0.534	2	14	6.6	19	9	30	42	<5.00	7701	8	3	24	6
Powderhorn In W	**2/24/2020**	14:15	Grab	1.04	0.324	3.93	0.250	800	70	8.3	175	104	1434	412	109	517	38	20	174	25
Powderhorn In W	**3/3/2020**	12:20	Grab	1.79	0.512	5.33	0.142	450	80	7.4	430	206	1068	470	13	866	70	135	396	26
Powderhorn In W	**7/7/2020**	10:10	Grab	0.149	0.039	1.21	<0.030	<2.00	14	7.2	33	14	43	33	4	>24200	14	18	30	4
Powderhorn In W	**7/21/2020**	9:10	Grab	0.236	0.028	1.69	0.455	2	22	6.4	30	17	42	66	<5.00	98040	10	10	47	8

CONCLUSION

Snowmelt likely contributes a significant amount of the nutrient load to Powderhorn Lake. Further monitoring will be needed to determine annual loads.

The 2021 monitoring plan is to install monitoring equipment at the South Inlet, SE Inlet, N Inlet, and West Inlet sites. The West Inlet is the largest watershed at 99 acres, and the South Inlet is the second largest at 81 acres. It is planned to move monitoring equipment locations at the South and West inlets to pipes downstream of the CDS units. If the monitoring equipment cannot be moved at these two sites, upstream monitoring will continue with an enhanced upstream pipe and CDS unit cleaning.

To determine the external pollutant load from the watershed, monitoring data from the inlets is needed. When collected, these data will provide information that can be used to determine the external pollutant load to Powderhorn Lake. The data could assist in a creation of a lake diagnostic study and inform a plan to mitigate the external pollutant load to the lake, ideally leading to improving in-lake conditions.

TOC

26. MONITORING FOR THE AUDUBON COOPERATIVE SANCTUARY PROGRAM FOR GOLF

BACKGROUND

The Audubon Cooperative Sanctuary Program for Golf (ACSPG) is described as an education and certification program that helps golf courses protect the environment and preserve natural areas, https://audubonintenational.org/acsp/. By helping enhance the valuable natural areas and wildlife habitats that golf courses provide, improving efficiency, and minimizing potentially harmful impacts of golf course operations, the program serves an important environmental role. 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

Environmental Management assists the Minneapolis Park and Recreation Board (MPRB) golf courses in collecting both water and vegetation data required for their annual certification by the ACSPG. The ACSPG has a water quality and aquatic plant monitoring component as part of their final certification. Each golf course integrates these data into their final certification application.

Theodore Wirth and Meadowbrook Golf Courses have requested annual monitoring since 2001. Columbia, Hiawatha and Gross Golf Courses have included environmental monitoring to their programs since 2009. The ACSPG certification with plant and water chemistry data collected are proposed to help lead to improved land/water stewardship. The data and reports are shared annually with the golf courses to renew certification and implement improvements to plant diversity and water quality.

Golf Course Foremen assisted Water Resources staff in choosing representative water bodies on each MPRB course. A meander survey of aquatic and wetland vegetation was conducted at each sample site. The ACSPG suggests the monitoring of basic physical water quality parameters such as, temperature (°C), conductivity, pH, and dissolved oxygen (DO). These parameters were measured with either a YSI multiprobe or Hydrolab Minisonde 5 Multiprobe. The ACSPG also suggest the chemical parameters to be monitored as total phosphorus (TP), nitrate/nitrite (NO2/NO3), and ammonia (NH3). Water samples collected were taken to Instrumental Research, Inc. in Fridley, MN for laboratory analysis of the chemical parameters. Standard MPRB sampling and QA/QC procedures were followed. This report details the last two years of data and older data can be found in previous Annual Water Resources reports at https://www.minneapolisparks.org/park_care__improvements/water_resources/ .

COLUMBIA GOLF COURSE

Three ponds on the Columbia Golf Course were chosen for monitoring and are shown in **Figure 26-1** and **Figure 26-2**. 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 low area before entering a stormsewer that drains to the Mississippi River. Columbia Golf Course has been monitored for Audubon since 2009. On August 20th, 2020, aquatic, terrestrial, and wetland plants in the ponds and surrounding buffer zones were surveyed.



Figure 26-1. Columbia Golf Course Ponds: Hole 4 Pond, Driving Range Pond, and Outlet Pond.

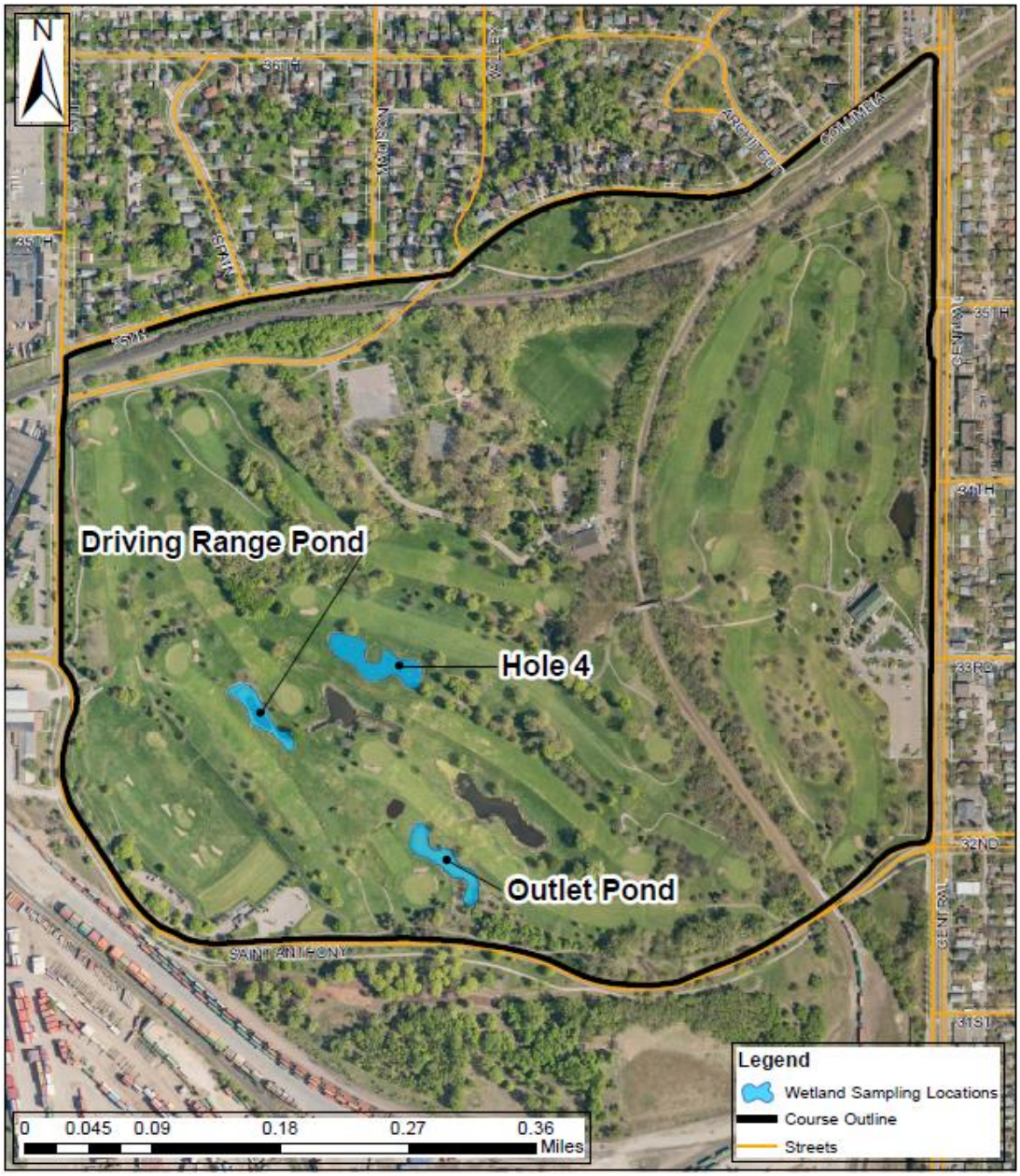


Figure 26-2. Ariel photograph of Columbia Golf course and the sampling locations. .

All plant species identified at the Columbia Golf Course are presented in **Table 26-1**. The most prevalent species in the last five years include: cattails, thistle, smartweed, stinging nettle, and blue vervain.

Table 26-1. Dominant plants within and surrounding the Columbia Golf Course Ponds.

Columbia Golf Course		**Hole 4 Pond**		**Driving Range Pond**		**Outlet Pond**	
Terrestrial and Wetland Species		Aug-19	Aug-20	Aug-19	Aug-20	Aug-19	Aug-20
Scientific Name	**Common Name**						
Ambrosia artemisiifolia	**Common Ragweed**	**X**	**X**			**X**	
Arctium minus	**Burdock**	**X**					
Asclepias incarnata	**Marsh Milkweed**	**X**					
Asclepias syriaca	**Common Milkweed**			**X**	**X**		
Chenopodium album	**Lamb's Quarters**	**X**					
Cirsium spp	**Thistle**	**X**	**X**		**X**		
Fraxinus Pennsylvanica	**Green Ash**			**X**	**X**		
Poa pratensis	**Kentucky Bluegrass**	**X**	**X**			**X**	**X**
Polygonum pensylvanicum	**Smartweed**	**X**	**X**	**X**	**X**	**X**	**X**
Rumex crispus	**Curled Dock**					**X**	**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**	
Sonchus arvensis	**Sow Thistle**			**X**	**X**		
Typha spp	**Cattail**	**X**	**X**	**X**	**X**	**X**	**X**
Ulmaceaespp	**Elm**			**X**		**X**	
Urtica dioica	**Stinging Nettle**	**X**	**X**		**X**	**X**	**X**
Verbena hastata	**Blue Vervain**	**X**	**X**	**X**	**X**	**X**	**X**
Vitus riparia	**Riverbank Grape**	**X**	**X**				
Aquatic Species		**Hole 4 Pond**		**Driving Range Pond**		**Outlet Pond**	
Scientific Name	**Common Name**	Aug-19	Aug-20	Aug-19	Aug-20	Aug-19	Aug-20
Filamentous algae	**Filamentous algae**	**X**	**X**			**X**	**X**
Lemna minor	**Lesser Duckweed**		**X**		**X**	**X**	**X**
Potamogeton spp	**Narrow Leaf Pondweed**	**X**					
Potamogeton pectinatus	**Sago Pondweed**	**X**					
Zosterella dubia	**Water Stargrass**		**X**				

The 2019 and 2020 water quality monitoring results from the Hydrolab and water chemistry, at Columbia Golf Course are shown in **Table 26-2**. Hole 4 Pond receives water from a groundwater well that is aerated in the pond by a fountain; therefore, the dissolved oxygen concentration in Hole 4 Pond remains relatively high, despite the slight increase in NH3 nutrient levels over the past two years. The Driving Range Pond historically has had low levels of dissolved oxygen potentially due to eutrophication caused by organic material and nutrients draining into it. The Driving Range Pond has low levels of dissolved oxygen and high concentrations of TP and NH_3. In 2020, the dissolved oxygen in the Outlet Pond increased slightly where TP and NH3 both decreased compared to the previous year. Definitive conclusions cannot be drawn from a single sample taken once a year but may provide a general overview.

Table 26-2. Water quality monitoring results for Columbia Golf Course for 2019 and 2020.

Columbia	Date	Time	Temp °C	DO% Sat	DO mg/L	pH Units	SpCond µS/cm	Turb NTU	TP mg/L	NH3 mg/L	NO3/NO2 mg/L
Hole 4 Pond	8/15/2019	10:16	23.2	98	8.21	8.0	1188	0	0.027	0.303	0.763
Hole 4 Pond	8/20/2020	9:40	20.4	92	8.03	8.4	1291	7	0.016	0.758	0.070
Driving Range Pond	8/15/2019	10:31	21.9	5	0.41	6.9	1095	54	0.889	1.95	<0.030
Driving Range Pond	8/20/2020	9:56	22.4	9	0.78	8.0	1859	33	0.783	3.55	<0.030
Outlet Pond	8/15/2019	10:36	20.1	27	2.43	7.1	1550	83	0.822	3.04	<0.030
Outlet Pond	8/20/2020	10:06	20.9	44	3.81	7.8	1659	4	0.057	0.680	0.578

GROSS NATIONAL GOLF COURSE

Three ponds and a low area site were chosen on Gross National Golf Course. Photographs are presented in **Figure 26-3** of the ponds, and a map in **Figure 26-4**. Pond 7 is one of the oldest water bodies on the golf course and may be a remnant of a natural wetland. Pond 7 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 of the golf course is pumped to Pond 14. Pond 14 then drains to Pond 12. The low area originally contained shallow standing water. The low area was originally chosen as an additional vegetation survey site since site since water was pumped to and it contained different vegetation than most of the golf course, but the low area has been dry without standing water or wetland vegetation the last few years. Monitoring at this low area site will be been abandoned in future years. So no photo is available. Gross Golf Course has been monitored for Audubon since 2009. On August 18th, 2020, the multiprobe water, water chemistry, aquatic, terrestrial, and wetland plants in the ponds and surrounding buffer zones were surveyed.

Pond 7



Pond 12



Pond 14



Figure 26-3. Photographs of Gross National Golf Course Ponds 7, 12, and 14. Note, the low area is not photographed.



Figure 26-4. Aerial photograph of Gross golf course and the sampled locations.

All species identified from Gross Golf Course are presented in **Table 26-3**. Reed canary grass, Kentucky bluegrass, Canadian thistle, and sow thistle were the most prevalent species surveyed in the past two years. Algae were also present in Ponds 12 and 14. In 2017, much of the vegetation surrounding the water bodies was cut down and continues to be mowed to the water's edge. A reduction of species could be attributed to the lack of vegetation. Purple loosestrife was identified at Pond 7 in 2019, after not being identified at this location since 2014. Purple loosestrife was not seen in 2020. No aquatic species have been identified in the Low Area as as it does not contain standing water.

Table 26-3. Dominant plants at the Gross National Golf Course sample sites.

Gross Golf Course		Pond 7		Pond 12		Pond 14		Low Area	
Terrestrial and Wetland Species		Aug-19	Aug-20	Aug-19	Aug-20	Aug-19	Aug-20	Aug-19	Aug-20
Scientific Name	Common Name								
Cirsium avense	Canadian Thistle	X	X		X		X	X	X
Cyperus odoratus	Flat sedge	X		X					
Glechoma hederacea	Groundy Ivy (Creeping Charlie)		X						
Impatiens capensis	Spotted Touch-Me-Not (Jewelweed)								X
Lycopus americanus	American bugleweed								
Lythrum salicaria	Purple Loosestrife	X							
Persicaria spp.	Smartweed/Lady's Thumb	X			X	X			
Phalaris arundinacea	Reed Canary Grass	X	X	X				X	X
Plantago major	Common Plantain		X						
Poa pratensis	Kentucky Bluegrass	X	X	X	X			X	X
Scirpus fluviatilis	River Bulrush		X	X	X				
Scirpus validus	Soft stem Bulrush					X			
Sonchus ssp	Sow Thistle		X				X	X	X
Setaria veridis	Foxtail		X				X		X
Urtica dioica	Stinging Nettle								X
Aquatic Species		Pond 7		Pond 12		Pond 14		Low Area	
Scientific Name	Common Name	Aug-19	Aug-20	Aug-19	Aug-20	Aug-19	Aug-20	Aug-19	Aug-20
Filamentous algae	Filamentous algae			X	X	X	X		
Lemna minor	Lesser Duckweed	X		X	X	X			
Potamogeton spp	Pondweed 1				X				
Potamogeton pectinatus	Sago Pondweed				X		X		
Spirodela polyrhiza	Big Duckweed			X					

Water quality monitoring results for Gross Golf Course are shown in **Table 26-4**. Dissolved oxygen levels showed an increase. Ponds 7 and 14 show stable but high TP, and Pond 14 shows a decrease in TP. In 2020 all ponds were aerated with fountains. The fountains increase dissolved oxygen levels in these ponds. Ammonia and nitrates/nitrites show a drop in Pond 12 but an increase in Ponds 7 and 14. The phosphorous levels in Pond 7 remain relatively high. Definitive conclusions cannot be drawn from a single sample once a year but can provide general information.

Table 26-4. Water quality monitoring results for Gross National Golf Course for 2019 and 2020.

Gross	Date	Time	Temp °C	DO% Sat	DO mg/L	pH Units	SpCond µS/cm	Turb NTU	TP mg/L	NH3 mg/L	NO3/NO2 mg/L
Pond 7	8/15/2019	9:18	22.7	67	5.71	7.9	439	1	0.908	0.486	0.251
Pond 7	8/18/2020	14:17	24.9	87	7.06	8.1	503	18	0.964	0.571	0.470
Pond 12	8/15/2019	9:36	22.9	72	6.06	8.1	462	5	0.202	0.400	0.203
Pond 12	8/18/2020	14:26	24.4	103	8.47	8.2	485	0	0.212	<0.250	<0.030
Pond 14	8/15/2019	9:27	23.6	92	7.62	8.7	469	22	0.469	0.357	<0.030
Pond 14	8/18/2020	14:35	27.6	110	8.54	8.1	452	0	0.139	0.492	0.186

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 **Figure 26-5** and **Figure 26-6.** During storm events, stormwater from neighborhood streets drain to Pond 1. The golf course parking lot is also drained to Pond 1. The ponds drain, in sequence, from Pond 1, to Pond 2, and then to Pond 3. Stormwater and groundwater, carried by drain tile between Ponds 1-3, are the two sources of pond 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 and is pumped into Lake Hiawatha. Hiawatha Golf Course has been monitored for Audubon since 2009. On August 14th, 2020, the multiprobe measurements, water chemistry, aquatic, terrestrial, and wetland plants in the ponds and surrounding buffer zones were surveyed.



Figure 26-5. Hiawatha Golf Course Ponds 1 – 4.

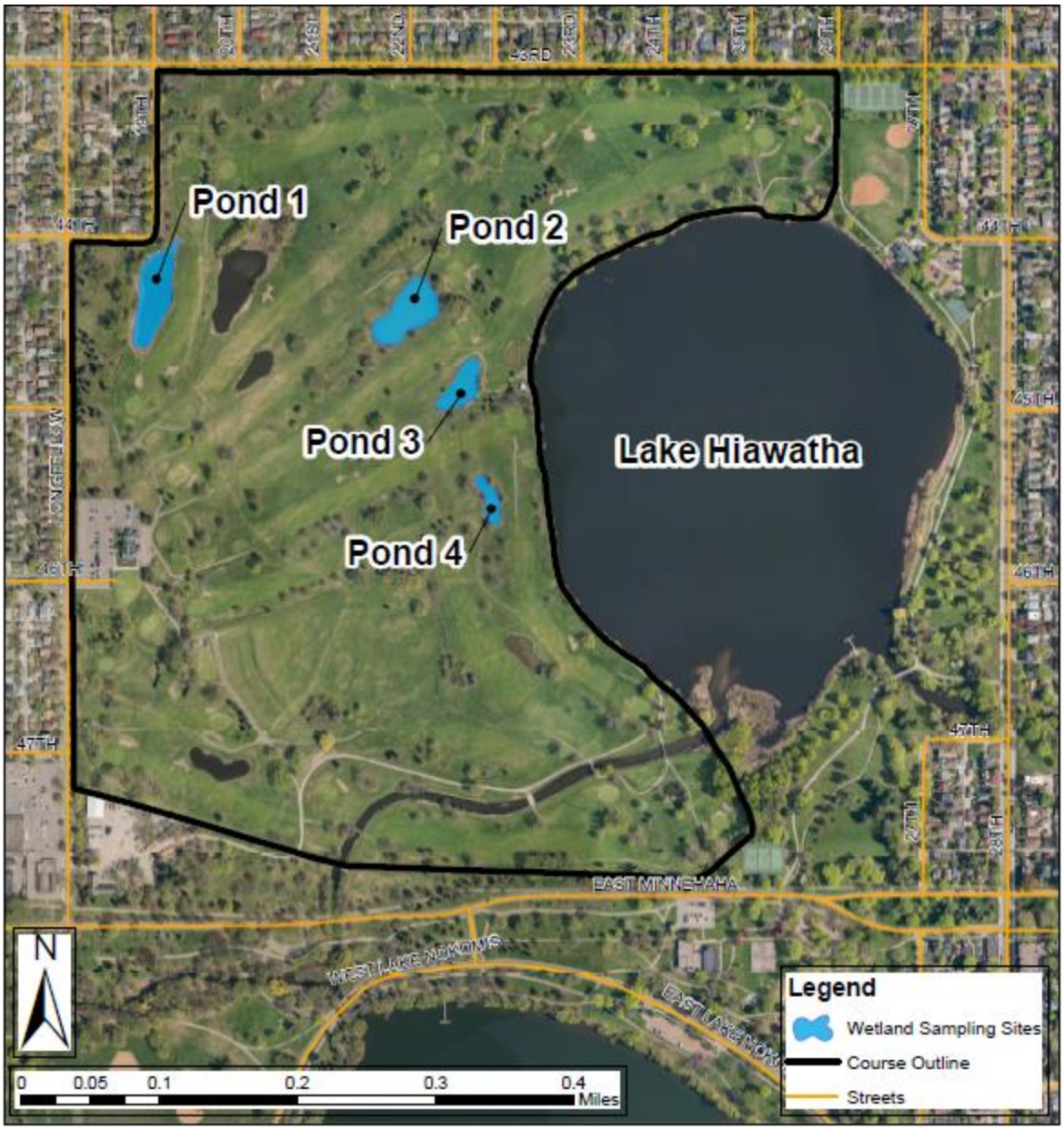


Figure 26-6. Aerial photograph of Hiawatha Golf Course and the sampling locations.

All species identified from Hiawatha Golf Course are presented in **Table 26-5.** Kentucky bluegrass, Reed canary grass, Jewelweed, Smartweed, Sow thistle, and Stinging nettle were the most prevalent species surveyed in the past two years.

Table 26-5. Dominant plants within and surrounding the Hiawatha Golf Course sample sites.

Hiawatha Golf Course		Pond 1		Pond 2		Pond 3		Pond 4	
Terrestrial and Wetland Species		Aug-19	Aug-20	Aug-19	Aug-20	Aug-19	Aug-20	Aug-19	Aug-20
Scientific Name	Common Name								
Acer spp	Maple (saplings)	X	X					X	
Alliaria petiolata	Garlic Mustard						X		X
Ambrosia artemisiifolia	Common Ragweed	X	X	X	X	X		X	
Ambrosia trifida	Giant Ragweed		X	X		X	X	X	
Arctium minus	Burdock								X
Aster spp	Aster				X		X		
Carex spp	Sedge	X	X						
Cirsium spp	Thistle	X	X	X	X	X	X	X	
Impatiens capensis	Spotted Touch-Me-Not (Jewelweed)	X	X			X	X	X	X
Eupatorium perfoliatum	Common Boneset	X	X						
Fraxinus pennsylvanica	Green Ash							X	
Gleditsia triacanthos	Honey Locust			X	X				
Larix laricina	Tamarack					X			
Lycopus americanus	American Water Horehound		X		X				
Phalaris arundinacea	Reed Canary Grass			X	X	X	X	X	
Poa pratensis	Kentucky Bluegrass	X	X	X	X	X	X	X	
Polygonum hydropier	Smartweed	X	X		X		X		
Populus deltoides	Cottonwood			X					
Rumex crispus	Curled Dock	X	X		X	X	X	X	
Salix spp	Sandbar Willow	X	X		X			X	X
Scirpus cyperinus	Woolgrass		X						
Scirpus validus	Softstem Bulrush						X		
Solanum dulcamara	Bittersweet Nightshade		X						
Solidago spp	Goldenrod		X		X				
Sonchus oleraceous	Common Sow Thistle	X	X	X	X		X	X	
Typha spp	Cattail	X	X						
Unknown	Annual Weeds					X	X	X	
Urtica diotica	Stinging Nettle	X	X			X	X		X
Verbena hastata	Blue Vervain	X	X			X	X		
Aquatic Species		Pond 1		Pond 2		Pond 3		Pond 4	
Scientific Name	Common Name	Aug-19	Aug-20	Aug-19	Aug-20	Aug-19	Aug-20	Aug-19	Aug-20
Ceratophyllum demersum	Coontail					X			
Filamentous Algae	Filamentous Algae			X					
Lemna minor	Lesser Duckweed							X	X
Potamogeton pectinatus	Sago Pondweed			X					

Water quality monitoring results for Hiawatha Golf Course are shown in **Table 26-6**. In 2019, Ponds 1 and 2 continued to have relatively high dissolved oxygen. Pond 3 has some oxygen and Pond 4 has low oxygen levels. Ponds 1, 2, and 3 show a moderate amount of phosphorus, and Pond 4 shows a

higher level of phosphorus levels. Ponds 1, 3, and 4 show an increase in NH3 levels. Pond 1 shows a decrease in nitrate/nitrite levels, but Pond 3 shows an increase.

High nutrients can lead to eutrophication causing undesirable low oxygen and algal growth. Definitive conclusions cannot be drawn from a single sample once a year but can provide general information.

Table 26-6. Water quality monitoring results for Hiawatha Golf Course for 2019 and 2020.

Hiawatha	Date	Time	Temp °C	DO% Sat	DO mg/L	pH Units	SpCond µS/cm	Turb NTU	TP mg/L	NH3 mg/L	NO3/NO2 mg/L
Pond 1	8/16/2019	12:20	22.4	86	7.30	7.6	276	5	0.099	<0.250	0.167
Pond 1	8/14/2020	9:20	23.9	103	8.47	8.2	1	13	0.197	0.426	<0.030
Pond 2	8/16/2019	12:27	20.3	83	7.32	7.3	706	10	0.115	0.488	0.389
Pond 2	8/14/2020	9:29	20.3	95	8.42	7.8	815	4	0.070	0.482	0.205
Pond 3	8/16/2019	12:40	20.5	54	4.73	7.2	728	17	0.174	0.951	0.315
Pond 3	8/14/2020	9:45	21.7	40	3.39	7.6	846	25	0.167	1.14	0.728
Pond 4	8/16/2019	12:53	21.0	29	2.52	7.1	607	29	0.318	1.43	0.143
Pond 4	8/14/2020	9:50	19.2	9	0.81	7.3	853	74	0.376	2.43	0.135

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 26-7** and a map in **Figure 26-8**. 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 neighborhood. Wetland L is an isolated pond. Minnehaha Creek flows through Meadowbrook Lake. Meadowbrook Golf Course has been monitored for Audubon since 2000. On August 12th, 2020, multiprobe measurements, water chemistry, aquatic, terrestrial, and wetland plants in the ponds and surrounding buffer zones were surveyed.



Figure 26-7. Meadowbrook Golf Course water quality and vegetation monitoring locations.

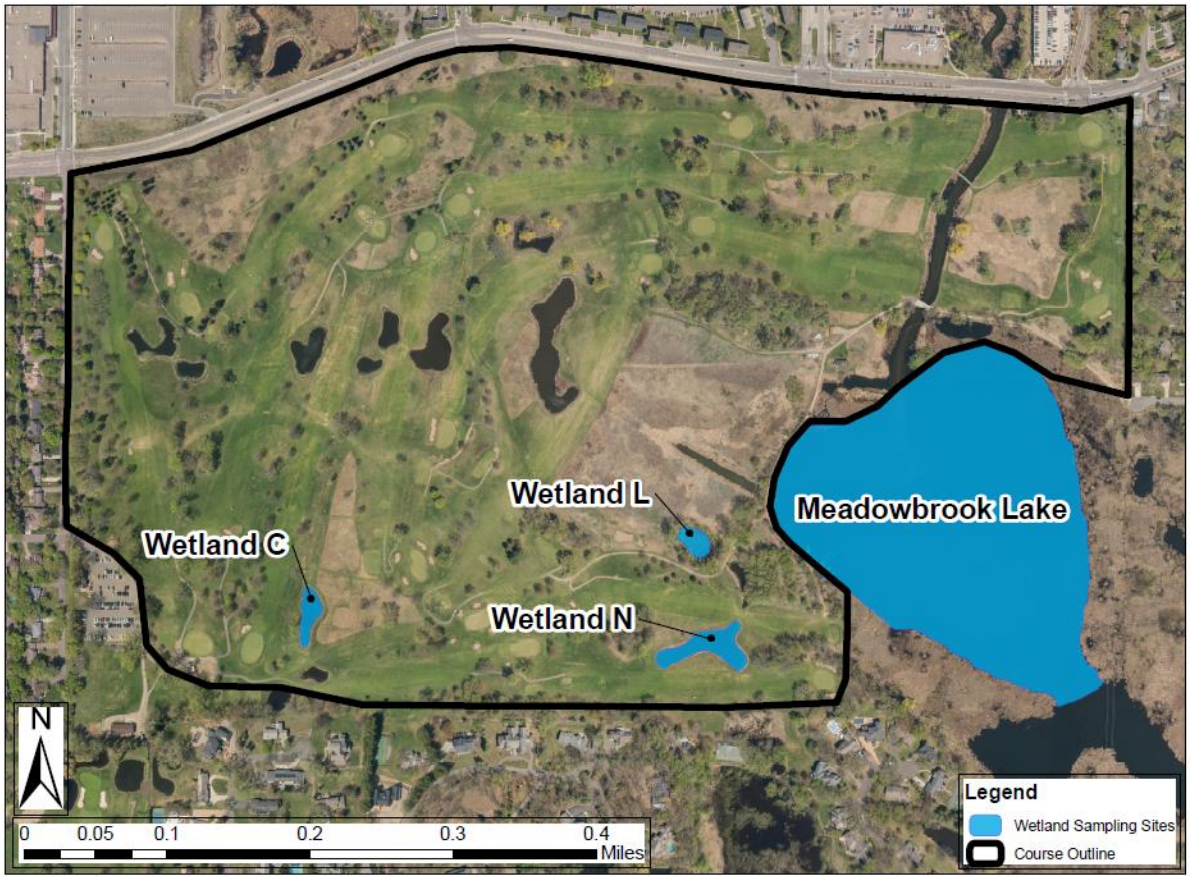


Figure 26-8. Meadowbrook Golf Course water quality and vegetation monitoring locations.

All species identified from Meadowbrook Golf Course are presented in **Table 26-7.** Reed canary grass, Kentucky bluegrass, Smartweed, Canadian goldenrod, Sow thistle, and cattails were the most prevalent species surveyed in the past two years.

Wetland L has not been accessed since 2015 due to a lack of mowing following the flooding in 2014. The area is surrounded by 50 yards of 4-foot-tall grass and wet soils, hence has been inaccessible for monitoring. Wetland L was not monitored in 2020.

Table 26-7. Dominant buffer zone plants surrounding the Meadowbrook Golf Course sample site.

Meadowbrook Golf Course		Wetland C		Wetland N		Wetland L		Meadowbrook Lake	
Terrestrial and Wetland Species		Aug-19	Aug-20	Aug-19	Aug-20	Aug-19	Aug-20	Aug-19	Aug-20
Scientific Name	Common Name								
Ambrosia trifida	Giant Ragweed	X	X						
Arctium minus	Burdock	X	X	X					X
Asclepias incarnata	Marsh Milkweed			X					
Asclepias syriaca	Common Milkweed	X	X						
Carex spp	Sedge spp				X				
Carex meadii	Mead's Sedge			X					
Cirsium avense	Canadian Thistle	X	X	X	X				
Fraxinus pennsylvanica	Green Ash	X	X						
Harkelia virginiana	Virginia Stick-Seed (Beggars Lice)		X						
Impatiens capensis	Spotted Touch-Me-Not (Jewelweed)	X	X		X				
Lycopus americanus	American Water Horehound (American Bugleweed)		X		X				
Persicaria spp.	Smartweed / Lady's Thumb	X	X	X	X				
Phalaris arundinacea	Reed Canary Grass	X	X	X	X			X	X
Poa pratensis	Kentucky Bluegrass	X	X	X	X				
Populus deltoides	Eastern Cottonwood							X	X
Rhamnus cathartica	Buckthorn							X	X
Rudbeckia hirta	Black eyed susan		X						
Salix exigua	Sandbar Willow	X	X						
Scirpus atrovirens	Green Bulrush		X						
Solanum dulcamara	Bittersweet Nightshade		X						
Solidago canadensis	Canada Goldenrod		X		X				
Sonchus oleraceus	Common Sow-thistle	X	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
Urtica dioica	Stinging Nettle		X	X					X
Verbascum thapsus	Mullein								
Verbena hastata	Blue Vervain	X	X	X	X				
Vicia cracca	Cow Vetch	X							
Vitus riparia	Riverbank Grape							X	X

Table 26-7 (continued). Dominant buffer zone plants surrounding the Meadowbrook Golf Course sample site.

Meadowbrook Golf Course									
Aquatic Species		**Wetland C**		**Wetland N**		**Wetland L**		**Meadowbrook Lake**	
Scientific Name	**Common Name**	Aug-19	Aug-20	Aug-19	Aug-20	Aug-19	Aug-20	Aug-19	Aug-20
Lemna minor	**Lesser Duckweed**	**X**	**X**	**X**	**X**			**X**	**X**
Nymphaea odorata	**White Water Lily**							**X**	**X**
Spirodela polyrhiza	**Big Duckweed**							**X**	**X**
Wolffia columbiana	**Watermeal**	**X**	**X**	**X**	**X**			**X**	**X**
Ceratophyllum demersum	**Coontail**			**X**				**X**	**X**
Elodea canadensis	**Canadian Waterweed**								**X**
Filamentous algae	**Filamentous Algae**							**X**	
Myriophyllum spicatum	**Eurasian Watermilfoil**								**X**
Utricularia vulgaris	**Common Bladderwort**								**X**

Water quality monitoring results for Meadowbrook Golf Course are shown in **Table 26-8**. Meadowbrook Lake has a moderate amount of dissolved oxygen the others are low in oxygen. 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. Wetlands C and N show a moderate level of phosphorus and NH3. Meadowbrook Lake and Wetland N show an increase in nitrate/nitrite levels.

Wetland L was not sampled in 2020 due to wet soils and inaccessibility. Definitive conclusions cannot be drawn from a single sample once a year but may help provide a general overview.

Table 26-8. Water quality monitoring results for Meadowbrook Golf Course for 2019 and 2020. NS=not sampled.

Meadowbrook	**Date**	**Time**	**Temp °C**	**DO% Sat**	**DO mg/L**	**pH Units**	**SpCond µS/cm**	**Turb NTU**	**TP mg/L**	**NH3 mg/L**	**NO3/NO2 mg/L**
Meadowbrook Lake	8/13/2019	9:25	23.3	67	5.61	7.7	447	0	0.033	0.346	<0.030
Meadowbrook Lake	8/12/2020	9:29	22.0	48	4.07	7.9	415	0	0.068	<0.250	0.145
Wetland C	8/13/2019	9:00	20.2	3	0.22	6.9	410	22	1.11	0.843	<0.030
Wetland C	8/12/2020	8:55	19.8	9	0.82	8.3	258	6	0.401	0.591	0.016
Wetland L	8/13/2019	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Wetland L	8/12/2020	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Wetland N	8/13/2019	9:15	19.3	21	1.90	7.0	60	3000	0.889	1.48	<0.030
Wetland N	8/12/2020	9:19	20.7	13	1.18	8.0	340	12	0.464	0.910	0.118

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 affects stream water quality. The Par 3 Wetland is unconnected to Bassett Creek and is located adjacent to a recently developed housing complex and accepts stormwater from this region. The Par 3 Wetland had an increase in the volume in stormwater runoff due to residential development to the north of it in the early 2000s. In 2018, construction was being done on the culvert upstream of the bridge at the Bassett Inlet. **Figure 26-9** and **Figure 26-10** show photographs and the map location of the monitoring sites on the golf course. Theodore Wirth Golf Course has been monitored for Audubon since 2000. On August 13th, 2020, multiprobe measurements, water chemistry, aquatic, terrestrial, and wetland plants in the ponds and surrounding buffer zones were surveyed. The Courage Kenny Center site is a small pond that drains to Basset Creek from the Courage Kenny Center. It is located on the West side of the golf course. This site was monitored for the first time in 2020 at the request of the Wirth Golf Course Foreman.

Basset Creek Inlet



Basset Creek Outlet



Par 3 Wetland



Figure 26-9. Theodore Wirth Golf Course water quality and vegetation monitoring locations. The Courage Kenny Center location is not pictured.



Figure 26-10. Theodore Wirth Golf Course water quality and vegetation monitoring locations.

All species identified from Theodore Wirth Golf Course are presented in **Table 26-9.** The most prevalent species at this location in the last two years included: Common ragweed, Kentucky bluegrass, Canadian thistle, Virginia stick weed, sweet clover, sow thistle, and blue vervain.

Table 26-9. Aquatic vegetation monitoring results for the Theodore Wirth Golf Course.

Theodore Wirth Golf Course		Bassett Creek Inlet		Bassett Creek Outlet		Par 3 Wetland		Courage Kenney Center
Scientific Name	Common Name	Aug-19	Aug-20	Aug-19	Aug-20	Aug-19	Aug-20	Aug-20
Terrestrial and Wetland Species								
Acer negundo	Box Elder						X	
Alliaria petiolata	Garlic Mustard				X			X
Ambrosia artemisiifolia	Common Ragweed	X	X	X	X		X	
Ambrosia trifada	Giant Ragweed		X		X			
Andropogon gerardii	Big Bluestem		X					
Arctium minus	Burdock				X			
Asclepias incarnata	Marsh Milkweed		X					
Asclepias syriaca L.	Common Milkweed	X	X	X	X			
Bidens spp	Beggars Tick		X					
Cirsium avense	Canadian Thistle	X	X			X	X	
Daucus carota	Queen Anne's Lace		X		X			
Eupatorium perfoliatum	Common Boneset				X			
Glechoma hederacea	Ground Ivy (Creeping Charlie)						X	X
Hackelia viginiana	Virginia Stickseed		X		X		X	X
Impatiens pallida	Pale Jewelweed		X				X	
Lathyrus latifolius	Everlasting Pea		X					
Linaria vulgaris	Butter and Eggs				X			
Lotus corniculatus	Birdsfoot Trefoil		X		X			
Lycopus americanus	American Water Horehound		X				X	
Lythrum salicaria	Purple Loosestrife		X					
Mentha arvensis	Wild Mint		X					
Nepeta cataria	Catnip		X					
Panicum virgatum	Switchgrass				X			
Melilotus officinalis	Sweet Clover		X		X		X	
Monarda fistulosa	Wild Bergamot		X					
Parthenocissus quinquefolia	Virginia Creeper							X
Phalaris arundinacea	Reed Canary Grass	X		X		X		
Plantago major	Common Plantain		X		X		X	
Poa pratensis	Kentucky Bluegrass	X	X			X	X	
Polygonum amphibium	Water Smartweed					X		
Polygonum persicaria	Lady's Thumb		X		X		X	
Rhamnus cathartica	Buckthorn			X				

Table 26-9 (continued). Aquatic vegetation monitoring results for the Theodore Wirth Golf Course.

Theodore Wirth Golf Course		Bassett Creek Inlet		Bassett Creek Outlet		Par 3 Wetland		Courage Kenney Center
Terrestrial and Wetland Species		Aug-19	Aug-20	Aug-19	Aug-20	Aug-19	Aug-20	Aug-20
Scientific Name	Common Name							
Ribes spp	Currant				X			
Rudbecia laciniata	Green Headed Coneflower		X					
Rudbeckia hirta	Black Eyed Susan	X		X	X			
Rumex crispus	Curled Dock	X	X					
Salix exigua	Sandbar Willow	X				X		
Scirpus cespitosus	Green Bullrush		X					
Seteria gracilis	Foxtail Bristlegrass		X		X		X	
Solanum dulcamara	Bittersweet Nightshade		X		X		X	
Solidago canadensis	Canada Goldenrod		X					
Solidago spp.	Goldenrod		X					
Sonchus arvensis	Sow Thistle	X	X		X		X	
Trifolium pratense	Red Clover		X					X
Trifolium repens	White Clover		X		X		X	X
Typha angustifolia	Narrow Leaved Cattail					X		
Typha latifolia	Broad Leaved Cattail					X		
Typha X glauca	Hybrid Cattail					X	X	
Urtica dioica	Stinging Nettle		X					
Verbascum thapsus	Common Mullein				X			
Verbena hastata	Blue Vervain	X	X		X		X	
Vitus riparia	Riverbank Grape	X		X				
Aquatic Species		Bassett Creek Inlet		Bassett Creek Outlet		Par 3 Wetland		Courage Kenney Center
Scientific Name	Common Name	Aug-19	Aug-20	Aug-19	Aug-20	Aug-19	Aug-20	Aug-20
Lemna minor	Lesser Duckweed			X		X		
Lemna trisulca	Star Duckweed					X		
Potamogeton natans	Floating Pondweed			X				
Spirodela polyrhiza	Big Duckweed			X		X		
Wolffia columbiana	Watermeal					X		
Ceratophyllum demersum	Coontail					X		
Potamogeton berchtoldii	Narrow-Leaf Pondweed			X				
Potamogeton nodusus	Long-Leaf Pondweed			X				
Potamogeton pectinatus	Sago Pondweed		X			X		

Water quality monitoring results for Theodore Wirth Golf Course are shown in **Table 26-10.** The Bassett Creek Inlet showed consistently high concentrations of dissolved oxygen as it entered

Theodore Wirth Golf Course. The Bassett Creek Outlet had a lower amount of dissolved oxygen (DO). This may be due to the slight temperature increase as the creek flows through Theodore Wirth Golf Course. The generally decreasing nutrient concentrations of phosphorus and nitrogen in Bassett Creek as it flows through Theodore Wirth Golf Course may indicate some improvement in water quality chemistry of the creek.

The Par 3 Wetland historically contained low amounts of dissolved oxygen, which is typical of a wetland with an abundance of organic decomposition. Nutrient concentration in the wetland has remained consistent with previous years.

At the request of Theodore Wirth Golf Course staff, the outlet from the Courage Kenny Center to Theodore Wirth Golf Course was monitored for the first time in 2020. At the Courage Kenny Center site, the water quality generally had lower nutrients and higher dissolved oxygen when compared to the other Wirth sites. The Courage Kenny Center input appeared to have very little negative effect on the Basset Creek Outlet. The Basset Creek Outlet dissolved oxygen and TP were lower than the Basset Creek Inlet. In 2020 the Basset Creek Outlet nitrogen was lower than the Basset Creek Inlet. The Par 3 wetland had a lower dissolved oxygen and higher TP than other sites monitored at Theodore Wirth Golf Course, but levels were typical of a wetland. The Courage Kenny Center site had a relatively high dissolved oxygen and appears low in nutrients. The Courage Kenny Center had a relatively high conductivity indicating it may be dominated by groundwater.

Table 26-10. Water quality monitoring results for Theodore Wirth Golf Course for 2019 and 2020.

Theodore Wirth	Date	Time	Temp °C	DO% Sat	DO mg/L	pH Units	SpCond µS/cm	Turb NTU	TP mg/L	NH3 mg/L	NO3/NO2 mg/L
Basset Creek Inlet	8/13/2019	10:38	20.9	87	7.59	7.9	805	1	0.072	<0.250	0.184
Basset Creek Inlet	8/13/2020	9:55	21.0	83	7.20	8.0	562	10	0.119	0.370	0.346
Basset Creek Outlet	8/13/2019	10:58	22.2	23	1.96	7.5	772	0	0.072	<0.250	0.162
Basset Creek Outlet	8/13/2020	10:40	21.9	54	4.61	8.1	577	2	0.099	<0.250	0.161
Par 3 Wetland	8/13/2019	10:17	21.4	3	0.23	7.1	464	16	0.155	<0.250	<0.030
Par 3 Wetland	8/13/2020	9:36	22.9	22	1.81	8.0	488	12	0.167	0.370	0.201
Courage Kenny Center	8/13/2020	10:13	23.4	78	6.52	7.9	1127	1	0.028	0.370	0.050

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27. CLIMATOLOGICAL SUMMARY

NATIONAL WEATHER SERVICE DATA

Annual climate data is tracked and reported due to its year to year variability and significant impact on water resources. **Table 27-1** and **Figure 27-1** shows the Minneapolis National Weather Service (NWS) total monthly precipitation and monthly average temperature for the year 2020. These NWS data are gathered at the Minneapolis/St. Paul Airport (MSP). These data are annual from January – December and not water year from October – September. Normal is defined by MSP airport NWS data from 1981 – 2010, where 30-year normal annual precipitation is 30.61 inches and 30-year normal annual temperature is 46.1°Farenheight (F).

The climate of Minneapolis, Minnesota is classified as humid continental. It has hot summers and cold winters. In 2020, there was a cool spring, a warm summer, cool fall, and significantly warm onset of winter. The 2020 annual mean temperature was 47.8° F, which was 1.7° F above normal, **Table 27-1**. Eight months had above normal temperatures and four months had below normal temperatures. The warmest month of the year was July and the coolest month was January. The average monthly temperatures deviated more than 2° F from normal except in February, August, and September, **Figure 27-1**.

Overall, 2020 was a dry year. Spring had above average precipitation, but starting in July, monthly precipitation was below the 30-year normal for the rest of the year. The 2020 annual recorded precipitation total was 29.83 inches, which was 0.78 inches below the 30-year normal, **Table 27-1**. Eight months had below 30-year normal precipitation and four months had above 30-year normal precipitation. The wettest month of the year was June and the driest month was September. The average monthly precipitation shows some significant monthly deviations from the 30-year normal: July through December were all drier than the 30-year normal; only January, March, May, and June were wetter than the 30-year normal, **Figure 27-1**.

Table 27-1. Minneapolis precipitation mean temperature and deviation from the 30-year normal as recorded by the National Weather Service/NOAA (MSP Airport).

2020	Total Precipitation (inches)	Normal Comparison:	Mean Temp. (F)	Normal Comparison:
January	0.97	0.07" above normal	20.6	5.0 F above normal
February	0.58	0.19" below normal	21.1	0.3 F above normal
March	2.41	0.52" above normal	37.7	4.9 F above normal
April	1.80	0.86" below normal	45.1	2.4 F below normal
May	4.85	1.49" above normal	58.7	0.4 F below normal
June	6.72	2.47" above normal	72.9	4.1 F above normal
July	3.19	0.85" below normal	76.0	2.2 F above normal
August	3.98	0.32" below normal	73.1	1.9 F above normal
September	0.88	2.20" below normal	61.3	0.7 F below normal
October	2.40	0.03" below normal	43.6	5.3 F below normal
November	1.29	0.48" below normal	38.6	4.9 F above normal
December	0.76	0.40" below normal	25.3	5.6 F above normal
Annual Data	**29.83**	**0.78" below normal**	**47.8**	**1.7 F above normal**

All NWS data were obtained from National Oceanic and Atmospheric Administration (NOAA) monthly publications. The NWS 30-year normal (1981-2010) annual precipitation and temperature were obtained from NOAA website at (https://w2.weather.gov/climate/index.php?wfo=mpx).

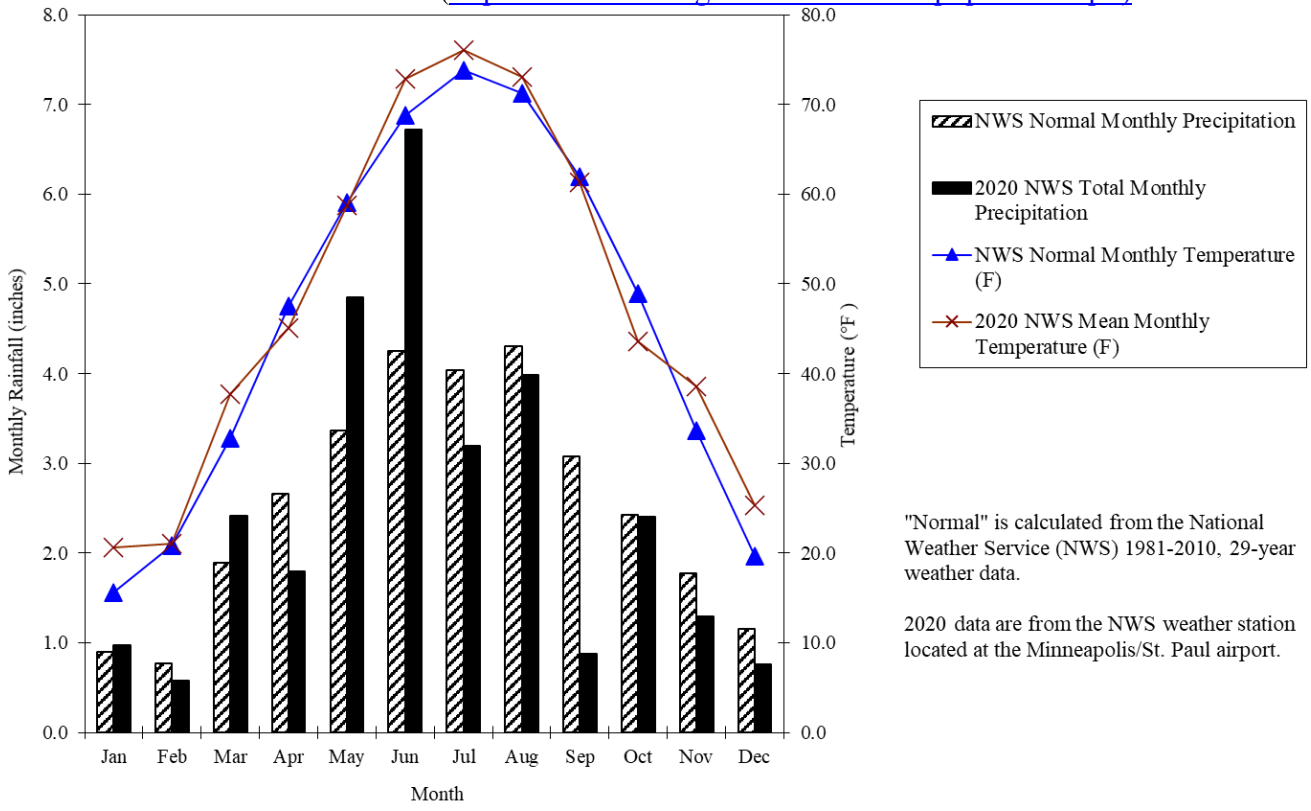


Figure 27-1. Comparison showing the NWS 30-year normal with 2020 temperature and precipitation data.

TWIN CITIES RAIN GAUGE COMPARISON

To better understand the local spatial pattern of precipitation, monthly NWS rainfall data were compared to the MPRB weather station. The MPRB operates a heated tipping bucket rain gauge and weather station in southwest Minneapolis, located on the roof of the Southside Operations Center (SSSC) at 3800 Bryant Ave. South, Minneapolis, MN. The NWS heated tipping bucket rain gauge is located at the Minneapolis/St. Paul Airport (MSP) airport. It should be noted that heated tipping bucket rain gauges lose a small amount of frozen precipitation due to sublimation before it can be measured.

The monthly precipitation and the differences between the MPRB and NWS can be seen in **Table 27-2**. These data illustrate the spatial variability of precipitation across the landscape.

Table 27-2. Monthly precipitation totals for 2020 recorded at both the NWS (MSP Airport) and MPRB (SSSC) rain gauges. Months with a * represent the NWS and MPRB heated rain gauges and the water equivalent.

Month	NWS (inches)	MPRB (inches)	Difference (inches)
Jan*	0.97	0.31	0.66
Feb*	0.58	0.31	0.27
March*	2.41	2.21	0.20
April	1.80	1.3	0.50
May	4.85	4.17	0.68
June	6.72	3.98	2.74
July	3.19	3.07	0.12
August	3.98	4.06	0.08
September	0.88	0.66	0.22
October	2.40	1.63	0.77
November*	1.29	0.76	0.53
December*	0.76	0.27	0.49
Totals	**29.83**	**22.73**	**7.10**

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28. WATER QUALITY EDUCATION

ACTIVITIES

In 2020, Minneapolis Park & Recreation Board (MPRB) staff provided water quality education programs throughout the City. Water quality education programs were unique in 2020 due to the covid-19 pandemic. Environmental Management Naturalist staff were still able to offer program opportunities 31 times in neighborhood and regional parks. Additionally, educational sign prompts (offered in both Spanish and English) were placed in 9 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 can be seen in **Figure 28-1**. Socially distanced, in-person water quality educational displays focused on neighborhood watersheds and how human activities impact local water bodies. 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.

MINNEHAHA PARK

A moveable water quality education exhibit was deployed at Minnehaha Park near the pavilion that houses the popular restaurant, Sea Salt Eatery. The spinning cubes 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.

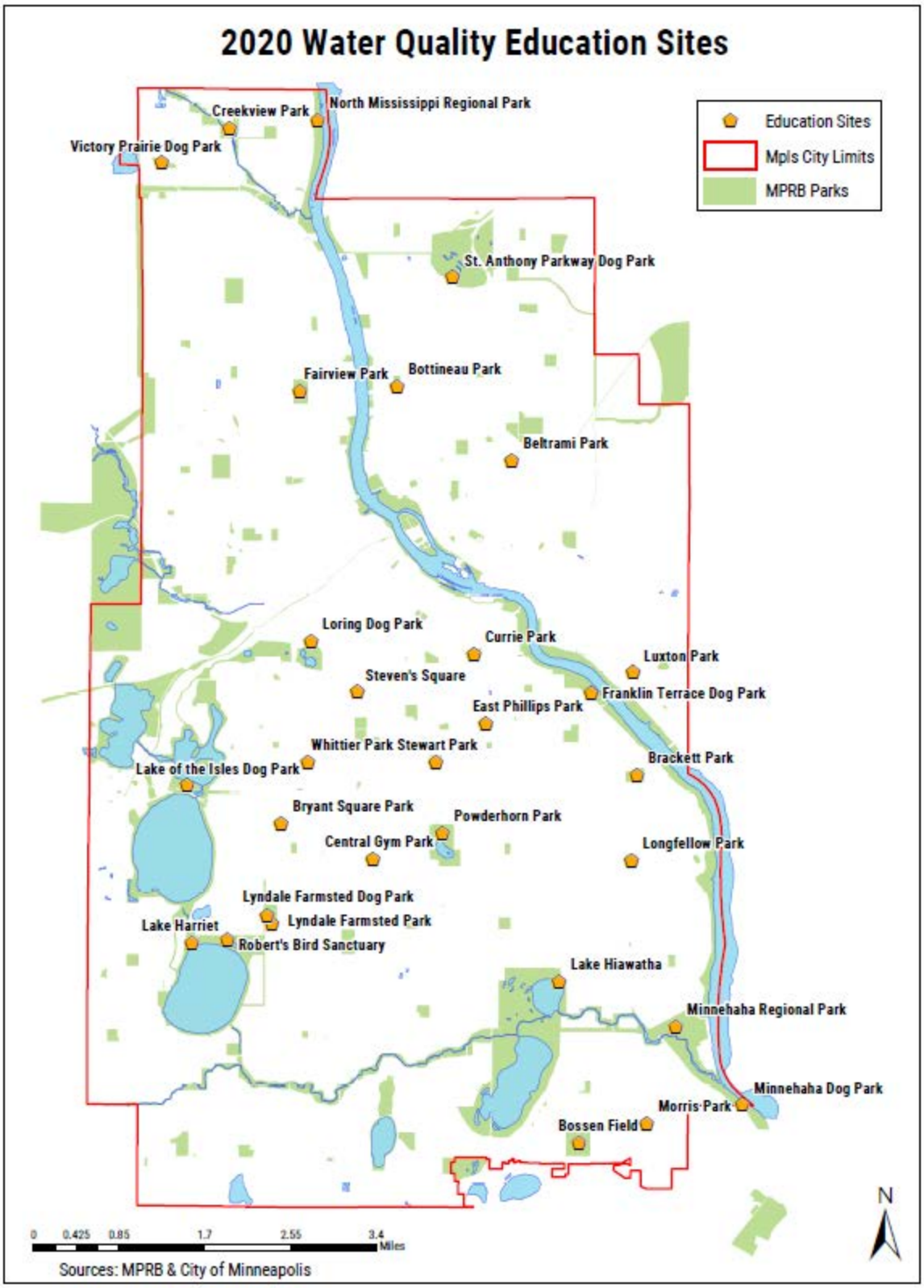


Figure 28-1. Map and list of water quality education sites in 2020.

WATER QUALITY WATER TRAIL

A Water Trail, a designed series of buoys to follow like a trail on the water, for Lake Nokomis is planned to include water quality education materials. A set of 10 Stand Up Paddleboard (SUP) yoga poses were designed to be added to the buoys holding water quality messages, see **Figure 28-2** for one example. These Water Trail marking buoys will be deployed in the summer of 2021 for SUP paddlers (or other boaters) to explore the lake and learn more about protecting the water quality of Lake Nokomis.



Figure 28-2. White buoy with yoga illustration on top and water quality message about the impacts of litter below.

SPANISH LANGUAGE PUBLICATIONS

A series of weekly newsletter articles were published in La Matraca News, as seen in **Figure 28-3**. This newsletter featured topics on how storm drains work, raking fall leaves, picking up litter, reducing salt use in winter, picking up dog waste, and not feeding waterfowl. These articles appeared in Spanish and were accompanied with a photo and a list of park sites for readers to visit and learn more about water quality.



"NO SE PUEDE CHIFLAR Y COMER PINOLE" EDICIÓN 560 — DICIEMBRE 11, 2020 11

Locales

¿Qué es mejor que la sal para limpiar el hielo? ¡Muchas cosas!

Por James A. Emery
Educador en Calidad del Agua en Minneapolis Park and Recreation Board

Toda la sal que depositamos en nuestros caminos de entrada y aceras llega a los desagües pluviales y tiene un impacto terrible en nuestros lagos y arroyos. Esa es una buena razón para usar menos sal, pero otra buena razón es que la sal no hace un buen trabajo limpiando los pasillos de nieve y hielo.

La sal derrite el hielo al reducir el punto de congelación del agua, pero ese proceso deja de funcionar a temperaturas por debajo de los 15 grados Fahrenheit. Si compra y usa más sal, no servirá de nada; simplemente estará tirando su dinero por el desagüe pluvial y pagando para envenenar nuestras aguas. Se acerca el invierno y hay formas de limpiar la nieve y el hielo que son tan o más efectivas que usar sal.

¡PALEAR!

Es el deporte de invierno no oficial del estado de Minnesota. Palear nieve es un gran ejercicio, una forma divertida de estar al aire libre en un día de invierno y es una forma mucho más eficiente de quitar la nieve que rociando sal.

Vierta chocolate caliente para terminar el trabajo, en su taza, es decir, no en la acera.

ARENA

Además de proporcionar una gran tracción para zapatos y neumáticos, la arena absorbe la luz solar que ayuda a derretir el hielo y la nieve.

ARENA PARA GATOS

La arena para gatos está diseñada para ser absorbente, por lo que es muy eficaz para absorber el agua que hace que la superficie del hielo sea resbaladiza. Es mucho más amigable para las patas de sus mascotas que la sal, y no matará su césped en la primavera.

Si debe usar sal para superficies potencialmente peligrosas, como escalones, recuerde que solo un poco de sal hará el trabajo y que usar más sal no será más efectivo.

Piense en formas de reducir, si no eliminar, la sal. Hacer tu parte para cuidar nuestras aguas durante todo el año te ayudará a disfrutar de estos largos meses de invierno. ■

Figure 28-3. A screenshot of the La Matraca online News feature about using salt responsibly.

AQUATIC INVASIVE SPECIES EDUCATION

The MPRB continued its extensive Aquatic Invasive Species (AIS) Inspection 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 boats entering and leaving the lakes are inspected for AIS. In addition to providing boat inspections, staff are an information source for the park visitors. Staff directly interacted with 12,391 park visitors in 2020. Adjacent to the AIS booths are sandwich boards, **Figure 28-4**, 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 28-4. Aquatic Invasive Species and water quality education at boat launches.

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 2020, 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 our water quality. **Figure 28-5** shows an example of one of these signs, all of which were offered in both Spanish and English.



Figure 28-5. An example of the signs posted in Minneapolis Dog Parks.

DO NOT 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 2020, our yellow duck ambassadors continued their focus on persuading park patrons to not feed the ducks. An oversized buoy in the shape of a rubber duck floated along the Lake Harriet shoreline, adjacent to the seasonal restaurant Bread & Pickle. 60 rubber duck table-toppers with ' please do not feed the ducks' messaging were installed in the following locations: picnic tables at Bread & Pickle at Lake Harriet, Sea Salt Eatery in Minnehaha Regional Park, the former Refectory site at Bde Maka Ska, Sand Castle at Lake Nokomis, and along the fishing rail at Powderhorn Lake, where ducks were provided in both English and Spanish. See **Figure 28-6** for examples of our rubber duck ambassadors.



Figure 28-6. Photos showing a tabletop duck and the Lake Harriet rubber duck buoy of the Don't Feed the Ducks Campaign.

EARTH DAY WATERSHED CLEAN-UP

Since 2008, The MPRB Earth Day Clean-up event has inspired more than 20,000 residents to remove more than 160,000 pounds of garbage from Minneapolis Parks. In the spirit of continuing to create a positive impact in our parks, the 2020 Clean-Up was modified to a 'Do-It-Yourself' mode. More than 4,400 people were reached by MPRB Facebook posts, and more than 600 people participated with the hashtag #MplsDIYEarthDay. This support of so many people throughout the City of Minneapolis showed us all what we can do #AloneTogether, and created a way for us to share photos of folks picking up in our parks! Two of such photos are included in **Figure 28-7**.



Figure 28-7. Photos from the 2020 Earth Day Watershed Clean-up

MISSISSIPPI RIVER GREEN TEAM

For 2020, the Mississippi River Green Team, a conservation-based teen crew, was unable to engage in their typical environmental work throughout the summer. Instead, a crew of 8 returning, second-year youth staff and one supervisor, spent the fall working in the natural areas of North Mississippi Regional Park. See four of our youth staff mustering trail side to receive instructions for the day in **Figure 28-8.** Typical workdays included invasive species removal, weed wrenching, planting, watering, and mulching.

The Mississippi River Green Team is made possible through a partnership between the Minneapolis Park & Recreation Board and the Mississippi Watershed Management Organization.



Figure 28-8. Mississippi River Green Team youth staff at North Mississippi Regional Park.

FROG & TOAD SURVEYS



Figure 28-9. Wood frog (*Rana sylvestris*). *Photograph by J. Winkelman*.

The presence and abundance of frogs and toads is a useful indicator of water and habitat quality, as well as for tracking short and long-term environmental changes. Long-term surveys by natural resource agencies have resulted in standardized methods of collecting data. The Minnesota Department of Natural Resources (MNDNR) conducted statewide citizen science monitoring using the Minnesota Frog & Toad Calling Survey (MFTCS), to contribute to the nation-wide North American Amphibian Monitoring Program (NAAMP). Note: MFTCS and NAAMP monitoring programs were discontinued in 2017 and 2015 respectively.

Frog and toad calling surveys have been conducted in Theodore Wirth Park by citizen science volunteers since 2015 to evaluate frog and toad presence in areas where buckthorn was removed during a multi-year habitat improvement project. The baseline 2015 survey was conducted before any habitat enhancement took place.

Purpose

1) Identify frog and toad species found in Theodore Wirth Park.
2) Evaluate the impact of habitat improvement efforts in 2016—the removal of invasive buckthorn—on the presence and abundance of frogs and toads, for at least five years.
3) Create a long-term volunteer monitoring program. Note: Volunteers were recruited to assist in conducting surveys but the goal of creating an ongoing program was dropped after considering logistics, liability, and later, COVID-19 restrictions.

Methods

Survey methods for this study were adapted from the MFTCS survey protocols are described in **Table 28-1**. Modifying the MFTCS protocol for this study enabled the documentation of species presence at a number of locations in the park and was done in a way that can still be compared with the statewide survey data. At each site, species presence and abundance, based on strength of calling

index of 1-3, was recorded for each of three runs. Note: the 2020 season only conducted two of the three runs because of COVID-19 restrictions. In some cases, a '1' may also indicate a species was seen but not heard, to capture the information that is present and recorded on data sheets as 'P' for present. Variability among observers was reduced by having the same lead observer and asking all assistant volunteers to practice the USGS frog calling identification, which can be found at the web address; https://www.pwrc.usgs.gov/frogquiz/index.cfm?fuseaction=main.lookupNAAMP calling quiz.

Table 28-1. Comparison between two survey protocols, showing how MFTCS was adapted for the Theodore Wirth Park Study.

	Theodore Wirth Survey	**MFTCS**
Sampling Locations	Selected to align with survey goals. Most are less than a half mile apart.	Randomly assigned. Minimum of a half mile apart.
Data Collection	Water temperature recorded at all sites, where safely accessible.	Measuring water temperature optional; one reading per run used for all sites.
	Additional observations recorded at each location. A field was added to each site for notes about habitat, phenology, etc.	Comments limited to one field for all sites and dedicated to how sampling was done (e.g., tried to silence frogs at site X)
	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.	Records only species heard during the 5-minute listening period. Optional to note in comments species heard outside of the listening period.
	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 only species heard during the 5-minute listening period. Optional to note in comments species seen and not heard.
	Distinguishes between species heard at the sampling site and those heard in the distance, which could be from a nearby site since some are less than a half mile apart. This is particularly relevant for Woodland Pothole on Wayzata Blvd and Birch Pond, two EBWG sites, and two sites near Regency Hospital. Species heard far in the distance, possibly at another site, denoted by parentheses around the numeric calling index – for example, (3).	Records all species heard during the 5-minute listening period – regardless of distances. Sites are located a minimum distance apart, which prevents data from more than one site being included in the data.

Site Descriptions

Woodland Pothole near Wayzata Blvd. One of the more interior wooded pothole wetlands in this section of the park, fish-free, possibly spring-fed since water found in all years, though water levels changed. Evidence of a stormwater overflow was not seen. This site is lower than the surrounding landscape and as a result quieter. It is naturally darker as surrounding city lights do not penetrate the woodland buffer. Fireflies were particularly abundant at certain times.

Birch Pond. A large, open, permanent water body surrounded by woods with emergent vegetation around the edges. Theodore Wirth Pkwy runs along the southwest length of the pond; stormwater pipes flow into the pond from at least two locations. Lights from the road shine onto the water, and their brightness increased after buckthorn removal. Traffic and road noise interfered with observer's ability to hear frog calls and contributed to loss of frogs via roadkill..

Spring near Eloise Butler Wildflower Garden. A wooded, more remote site probably most comparable to the woodland pothole near Wayzata Blvd. It is a fish-free, vernal pond, mostly rain-fed from the surrounding area with some spring overflow. It is typically dry by early summer as seen

during Run Three. Moist soil remains near the spring, and is colder due to the source, but frogs call from across the path and do not appear to use the spring itself for breeding. This site is protected from ambient light and traffic noise from the surrounding area.

Dike near Eloise Butler Wildflower Garden. An open, permanent, wetland with emergent vegetation around the edges and in summer, duckweed; stormwater pipes add runoff. Until 2020, frogs and toads heard were coming from the EBWG spring area and further away, such as Wirth Lake and Birch Pond, and not the adjacent wetland. The presence of fish and lack of calling from the area caused it to be dropped from the survey in 2019. However, in 2020, volunteers were literally stopped in their tracks by the choruses and abundance of toads on the dike road, so it was added back. This is a well-lit and very noisy site—from trains, planes, cars, motorcycles, and volleyball at Wirth Beach. Also, the presence of fish in the waters adjacent to the dike could explain the absence of amphibians.

Woodland Pothole near Regency Hospital. A wooded, fish-free pothole wetland bordering a paved utility area for HVAC and parking of Regency Hospital. Supports hydrophilic vegetation. Transitioned from open water in 2015 and filled with emergent vegetation after 2016. Ambient light, noise from car doors slamming and HVAC; and runoff from the hospital parking characterize this location.

Golf Course Pond near Regency Hospital. Habitat improvements were not conducted near this location; however, it was included to round out the characterization of species in the park and ease of sampling. This permanent pond is slightly larger than Birch Pond, adjacent to the golf course with two sides on relatively flat ground. The north and northwest sides are steep slopes, one wooded and one an open field where trees are likely cut to preserve the view from homes at the top of the slope. Listening took place from the latter. Open water, often with duckweed, and emergent vegetation around the edges was present.

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. Within protocol parameters, moonlight was avoided, and surveys were conducted during or as close to rain events as possible.

Of 14 species found in Minnesota, seven were identified in Wirth Park-between 2015-2020 as shown in **Table 28-2**. Spring peepers were mistakenly recorded in the early years, but later corrected to be the distinct “watch” calls of treefrogs.

Gray treefrogs, chorus frogs and toads were found at all sites in most years and were the most abundant species. Gray treefrogs and toads were often found on the road heading to a breeding site. There is a large seasonal migration of treefrogs across Theodore Wirth Pkwy to Birch Pond. Toads were seen moving towards the permanent wetlands near Glenwood Ave and Theodore Wirth Pkwy. Amphibians killed on the road coincided with seasonal migrations toward water.

Cope's gray treefrogs were found at four sites, overlapping with gray treefrogs. Cope’s are found in woodland and field edges and were most abundant at the golf course pond near Regency Hospital, which has both species.

Wood frogs were rarely found; only during 2018 surveys at two sites, the woodland pothole near Wayzata Blvd and at Eloise Butler Wildflower Garden near the spring. Wood frogs breed for a short, intense period requiring an ideal combination of ice-out and warm spring rains, meaning breeding may occur between March and May. In 2018, the timing of the first survey coincided with a very late spring. Alternately, their presence may be a response to habitat improvement efforts. They were

found in the most interior wooded sites where the understory was dramatically opened up when buckthorn was removed. While rare, their presence was detected the first full year after the habitat work. In subsequent years, buckthorn has regrown rapidly from the seed bank, filling back in the understory.

Leopard frogs were rarely found in the first five years. Two of three observations were found outside of the 5-minute listening window—once 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. 2020 was a banner year for leopard frogs, heard at Birch Pond, the golf course pond, and for the first time at the EBWG sites, being particularly abundant near the dike.

American bullfrogs—an invasive, non-native species—were found breeding at the golf course pond near Regency Hospital. This find was reported to Erica Hoagland, DNR Region 3 Nongame Wildlife Specialist, July 10, 2017 who communicated "…this is an important update. [this new data will be] added to our database to update the status of Bullfrogs at Theodore Wirth". The only other record for bullfrogs at Wirth Park was from 2006 about a half mile northeast of where it was found in 2017.

Table 28-2. Species richness found at Theodore Wirth Park in years surveyed, 2015-20 (presence shown by "x").

Species	Total number of species	2015*	2016	2017	2018	2019	2020
American Toad (Anaxyrus americanus)[1]	1	x	x	x	x	x	x
Canadian Toad (Anaxyrus hemiophrys)[1]							
Great Plains Toad (Anaxyrus cognatus)[1]							
Eastern Cricket Frog (Acris crepitans)							
Gray Treefrog (Hyla versicolor)	1	x	x	x	x	x	x
Cope's Gray Treefrog (Hyla chrysoscelis)	1	x	x	x	x	x	x
Spring Peeper (Pseudacris crucifer)							
Boreal Chorus Frog (Pseudacris maculata)	1	x	x	x	x	x	x
American Bullfrog (Lithobates catesbeianus)[2]	1			x [3]			
Green Frog (Lithobates clamitans)[2]							
Mink Frog (Lithobates septentrionalis)[2]							
Northern Leopard Frog (Lithobates pipiens)[2]	1	x	x				x
Pickerel Frog (Lithobates palustris)[2]							
Wood Frog (Lithobates sylvaticus) [2]	1				x		
Species richness:	7	5	5	5	5	4	5

*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]Reported to MNDNR.

Conclusions and Recommendations

Trends are observational but nonetheless revealing, raising questions, and directing activities that can protect and maintain habitat quality and amphibian fauna in Theodore Wirth Park.

Half the frog and toad species found in Minnesota, 7 of 14, were heard in Wirth Park and five species are either out of range or extremely rare as seen in **Table 28-2**. Spring peepers and green frogs were expected to be found and probably were in the past, but no longer; they are known to be sensitive to development and habitat fragmentation. The American bullfrog, not native to this area, was found breeding in Wirth Park. Bullfrogs are associated with the decline of many species, including leopard and green frogs; removing bullfrogs can be used as a method to potentially increase the relative abundance of native species.

Green, leopard and bullfrogs overwinter in water that does not freeze solid. So, when found they would be in or near permanent, deeper water—such as Birch Pond, EBWG near the dike, golf course pond, Wirth Lake, and Twin lake. Care should be taken that bullfrogs are not introduced to other areas as may most likely happen through angling or pet releases.

Wood frogs are rare but may respond to habitat improvements that open the understory; however, the benefits must be maintained. Interior woodland sites in the vicinity of fish-free, ephemeral ponds should be prioritized for future and ongoing buckthorn removal, while wood frogs are still present. These habitat enhancements could also create conditions suitable for spring peepers.

The world-wide decline of amphibians is of great concern. Theodore Wirth Park still has seven breeding species, one introduced, and this survey reveals actions that can be taken to protect and maintain these populations. The sites sampled could all benefit from one or more of these actions:

- Maintain benefits of invasive plant removal. Prioritize woodland areas described above.
- Prevent bullfrogs from reaching other sites.
- Reduce roadkill during seasonal migrations. Prioritize critical times and locations. Apply best practices in road design or redesign.
- Reduce or direct light away from breeding ponds.
- Protect water quality from runoff using structural and nonstructural practices e.g., reduce salt use, keep grass clippings out.
- Maintain intact vegetative buffers as wide as possible, 30m are recommended in some studies. Reduce ambient noise from machinery, people, and traffic.
- Engage the public in frog conservation. Volunteer assistants were delighted to learn about amphibian resources in the parks.

TOC

29. QUALITY ASSURANCE ASSESSMENT REPORT

BACKGROUND

Environmental monitoring and management require the collection of highly reliable 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, 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 2020 for the Minneapolis Chain of Lakes monitoring, 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 (MPRB, 2021).

QA/QC definitions, as presented by T.A. Dillaha, et al. (1988) and Standard Methods for the Examination of Water and Wastewater (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 (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 29-1**. The QAQC plan follows the recommendations of Standard Methods for the Examination of Water and Wastewater (2005).

Table 29-1. 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	Each sampling trip
Field Duplicate	Duplicate of lake and beach sampling procedures	Estimating lab batch and sampling procedure precision	Each sampling trip
Blind QA/QC Audit Standard	Synthetic sample to mimic a natural sample	Estimating overall batch precision and lab bias	Once/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	Identifying signal drift and contamination of samples	One/lab batch (10% of samples)
Laboratory Reagent Blank	Reagent-grade de-ionized water plus reagents	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	Twice during 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 sample (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. In 2020, both metals and DOC analysis were performed by PACE Laboratories located in Minneapolis, MN.

This program was designed to clearly establish which data were: 1) usable, 2) of questionable usability and needed to be flagged, or 3) 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 forth target frequencies for all QAQC 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 29-2**.
B. Experienced individuals trained technicians before they could conduct analyses by themselves and their supervisors routinely reviewed their performance.

Table 29-2. IRI analytical laboratory and PACE laboratory reporting limits (RL), the performance evaluation (PE) percent recovery acceptance limits, and relative percent difference (RPD) allowed with duplicates. NA = Not Applicable. MPN = most probable number.

Parameter	Abbreviation	IRI RL	PACE RL	PE % Rec Limits	Duplicate RPD Limits
Alkalinity, Total	Alk	2.0 mg/L	NA	80-120	±10%
Ammonia, Un-ionized as N	NH_3	0.250 mg/L	NA	80-120	±10%
Chemical Oxygen Demand	COD	20.0 mg/L	NA	80-120	±10%
Chloride, Total	Cl	2.0 mg/L	NA	80-120	±10%
Chlorophyll-*a*	Chl-*a*	0.5 µg/L	NA	NA	±10%
Conductivity	Cond	10 µmhos/cm	NA	80-120	±10%
Copper, Total	Cu	NA	1 µg/L	80-120	±10%
Dissolved Organic Carbon	DOC	NA	1.5 mg/L	80-120	±10%
Escherichia coli	*E. coli*	1 MPN per 100ml	NA	NA	NA
Fat, Oil, and Grease	FOG	5.0 mg/L	NA	80-120	±10%
Hardness, Total as $CaCO_3$	Hard	5.0 mg/L	NA	80-120	±10%
Kjeldahl Nitrogen, Total	TKN	0.500 mg/L	NA	80-120	±10%
Lead, Total	Pb	NA	0.1 µg/L	80-120	±10%
Nitrite+Nitrate	NOx or NO_2NO_3	0.030 mg/L	NA	80-120	±10%
Nitrogen, Total (persulfate)	TN	0.500 mg/L	NA	80-120	±10%
pH	pH	1.00 Std Units	NA	80-120	±10%
Phosphorus, Dissolved	TDP	0.010 mg/L	NA	80-120	±10%
Phosphorus, Total	TP	0.010 mg/L	NA	80-120	±10%
Silica, Reactive	Si	0.500 mg/L	NA	NA	±10%
Solids, Total Dissolved	TDS	5.0 mg/L	NA	80-120	±10%
Solids, Total Suspended	TSS	1.0 mg/L	NA	80-120	±10%
Solids, Volatile Suspended	VSS	2.0 mg/L	NA	80-120	±10%
Soluble Reactive Phosphorus	SRP	0.003 mg/L	NA	80-120	±10%
Sulfate	SO_4	5.0 mg/L	NA	80-120	±10%
Zinc, Total	Zn	NA	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 below. 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) $= \frac{\Sigma|x_1 - x_2|}{n}$

Standard Deviation (estimated) $s = \sqrt{\frac{\Sigma(x - x\ sample\ mean)^2}{n-1}}$

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 29-2** 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 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 29-2** 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 a total of four data points flagged in 2020, the January COD, July COD and DOC, and the October COD samples.

Completeness

The data collected in 2020 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 2020 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).

Comparability

Between Years

The 2020 lakes data were deemed to be comparable to previous years' data. In reviewing box and whisker plots of total phosphorus, Secchi transparency, and chlorophyll-*a* data, reported values appeared to be consistent with values reported at the same times during the 2016 - 2019 monitoring seasons. The 2020 monitoring season was roughly comparable to the 2019 monitoring season, but the chlorophyll-*a* (Chl-*a*), TP, and total nitrogen (TN) for Grass Lake had a larger range in 2020 compared to previous years.

Between Laboratories

To determine data comparability between laboratories lake samples were split in the field and shared with IRI, Minnehaha Creek Watershed District (MCWD), and Three Rivers Park District (TRPD). MCWD used PACE Laboratory, Minneapolis, MN as their laboratory 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 acceptable range. In **Table 29-3** the SRP values reported at reporting limits did not have CV's calculated if more than two laboratories were at reporting limits.

The MPRB shared round-robin format split samples with the participating laboratories from the sampling event on June 23rd and September 2nd, 2020. The results from all agency split samples are summarized in **Table 29-3** and in **Figures 29-1** through **29-5**. The 2020 lake split data set were deemed to be generally comparable to data analyzed by TRPD and MCWD. **Table 29-3** shows the coefficient of variation was greater than 20% for three Chlorophyll-*a* (Chl-*a*), five Total Phosphorus (TP), six Soluble Reactive Phosphorus (SRP), and two Total Nitrogen (TN) samples, all highlighted in red. Split data can only be compared when there are three samples analyzed by three different laboratories. Only then can an outlier be seen.

It should be noted the MCWD laboratory PACE changed the reporting limits in June and September for Chl-*a* from 2 ug/L to 1.3 ug/L, SRP from 0.002 mg/L to 0.003 mg/L, and Cl from 6 mg/L to 1.2 mg/L respectively. This change had no discernable effect on the split results.

Table 29-3. Summary of 2020 split sample results reported by IRI/MRPB, MCWD, and TRPD. CV = Coefficient of Variation. Split failures are highlighted in red. ND = no data.

ID	Parameter	Units	Depth	Lake	MPRB	MCWD	TRPD	CV
1	Chla	mg/M^3	0-2	Long	15.00	19.90	18.10	14%
2	Chla	mg/M^3	0-2	Wirth	6.70	2.60	2.50	61%
3	Chla	mg/M^3	0	WT-S	19.80	25.80	23.70	13%
4	Chla	mg/M^3	0	MUR	1.53	3.50	3.00	38%
5	Chla	mg/M^3	0-2	Wirth	5.60	17.50	20.10	54%
6	TP	mg/l	0-2	Long	0.036	0.036	0.026	18%
7	TP	mg/l	8	Long	0.571	0.550	0.560	2%
8	TP	mg/l	0	RARA	0.066	0.079	0.063	12%
9	TP	mg/l	0-2	Wirth	0.015	0.015	0.010	24%
10	TP	mg/l	7	Wirth	0.332	0.270	0.215	22%
11	TP	mg/l	0	WT-S	0.049	0.036	0.031	24%
12	TP	mg/l	6	WT-S	0.040	0.074	0.033	45%
13	TP	mg/l	0	MUR	0.017	0.020	0.017	9%
14	TP	mg/l	4	MUR	0.097	0.370	0.082	88%
15	TP	mg/l	0	PHEWA	0.116	0.130	0.132	7%
16	TP	mg/l	0-2	Wirth	0.024	0.025	0.019	13%
17	TP	mg/l	7	Wirth	0.847	0.750	0.932	11%
18	SRP	mg/l	0-2	Long	0.004	0.002	0.012	89%
19	SRP	mg/l	8	Long	0.138	0.120	0.162	15%
20	SRP	mg/l	0	RARA	0.027	0.003	0.006	108%
21	SRP	mg/l	0-2	Wirth	0.005	0.002	0.004	42%
22	SRP	mg/l	7	Wirth	0.009	0.017	0.052	88%
23	SRP	mg/l	0	WT-S	0.004	0.002	0.014	96%
24	SRP	mg/l	6	WT-S	0.004	0.002	0.016	104%
25	SRP	mg/l	0	MUR	0.004	ND	0.005	16%
26	SRP	mg/l	4	MUR	0.005	ND	0.015	69%
27	SRP	mg/l	0	PHEWA	0.014	0.015	0.019	16%
28	SRP	mg/l	0-2	Wirth	0.004	ND	0.012	72%
29	SRP	mg/l	7	Wirth	0.009	0.006	0.196	155%
30	TN	mg/l	0	WT-S	0.704	1.100	1.120	24%
31	TN	mg/l	0	MUR	0.500	0.640	0.600	12%
32	TN	mg/l	0-2	Wirth	0.500	0.002	0.270	97%
33	TN	mg/l	0-2	Long	0.726	1.2	0.860	26%
34	TN	mg/l	0-2	Wirth	0.551	0.760	0.620	17%

Table 29-3 (continued). Summary of 2020 split sample results reported by IRI/MRPB, MCWD, and TRPD. CV = Coefficient of Variation. Split failures are highlighted in red. ND = no data.

ID	Parameter	Units	Depth	Lake	MPRB	MCWD	TRPD	CV
35	Cl	mg/l	0-2	Long	45	ND	54	13%
36	Cl	mg/l	8	Long	45	ND	54	13%
37	Cl	mg/l	0-2	Wirth	140	ND	137	2%
38	Cl	mg/l	7	Wirth	210	200	215	4%
39	Cl	mg/l	0	WT-S	15	ND	14	5%
40	Cl	mg/l	6	WT-S	16	15	14	7%
41	Cl	mg/l	0	MUR	2	ND	10	94%
42	Cl	mg/l	4	MUR	2	ND	10	94%
43	Cl	mg/l	0-2	Wirth	145	111	138	14%
44	Cl	mg/l	7	Wirth	230	171	242	18%

The split samples for chlorophyll-*a* were moderately comparable as seen in **Figure 29-1**. All laboratories used a spectrophotometer. There were two samples with wide scatter and outliers could not be determined.

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 36%. It should be noted that IRI is low in 3 of the 5 samples.

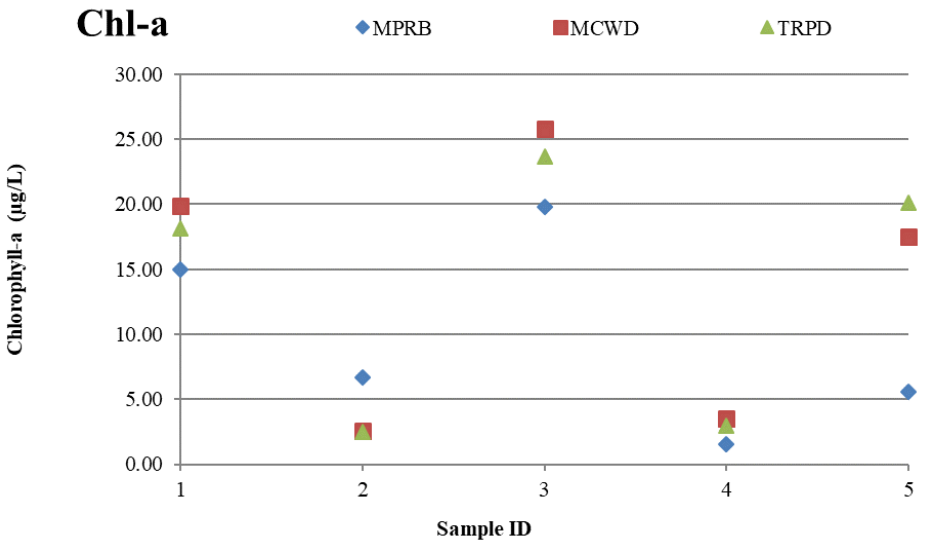


Figure 29-1. Plot of Chlorophyll-*a* split sample results reported for 2020. See Table 29-3 to reference ID numbers with sample descriptions and results.

Total phosphorus splits had low comparability as seen in **Figure 29-2**. Sample number 14 was from MCWD and was the outlier. Sample 17 had significant scatter. Phosphorus is an important and limiting aquatic nutrient and accuracy for this element is critical. The average CV for TP was 23%. This low comparability and higher CV is a statistical anomaly since many of the phosphorus samples have low-level concentrations.

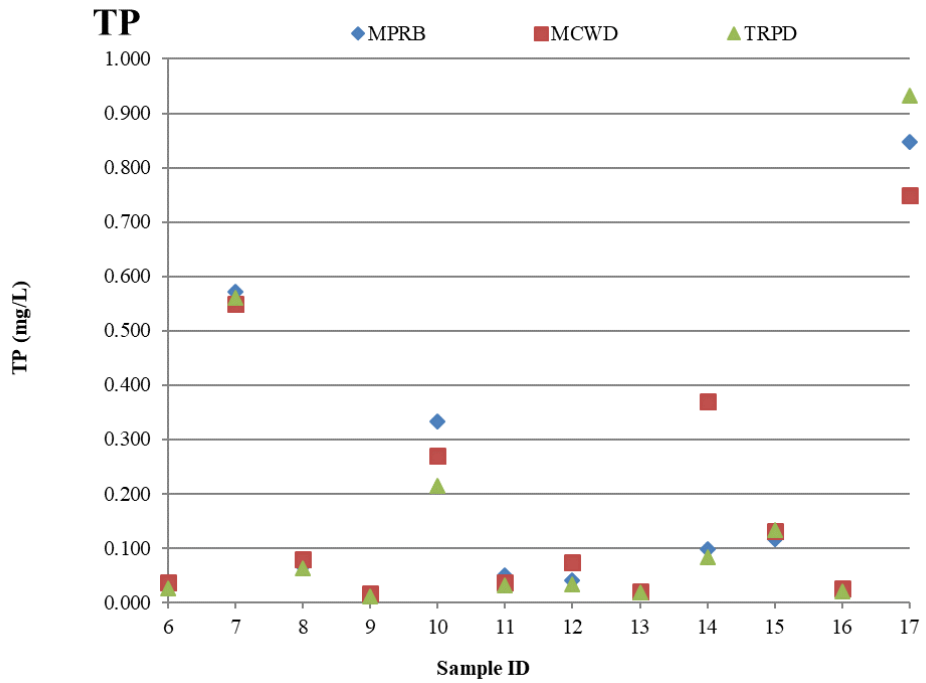


Figure 29-2. Scatter plot of Total Phosphorus split sample results reported for 2020. See Table 29-3 to reference ID numbers with descriptions and results.

Four concentrations of the submitted SRP split samples were near lab reporting limits as seen in **Figure 29-3**. There were three outliers, sample ID numbers 20, 22 and 29. Number 20 was analyzed by MPRB and 22 and 29 were analyzed by TRPD. Sample 19 had significant scatter. IRI and MCWD (PACE) had a reporting limit of 0.003 mg/L, while TRPD has a reporting limit of 0.006 mg/L. 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. The average CV for SRP was 72%.

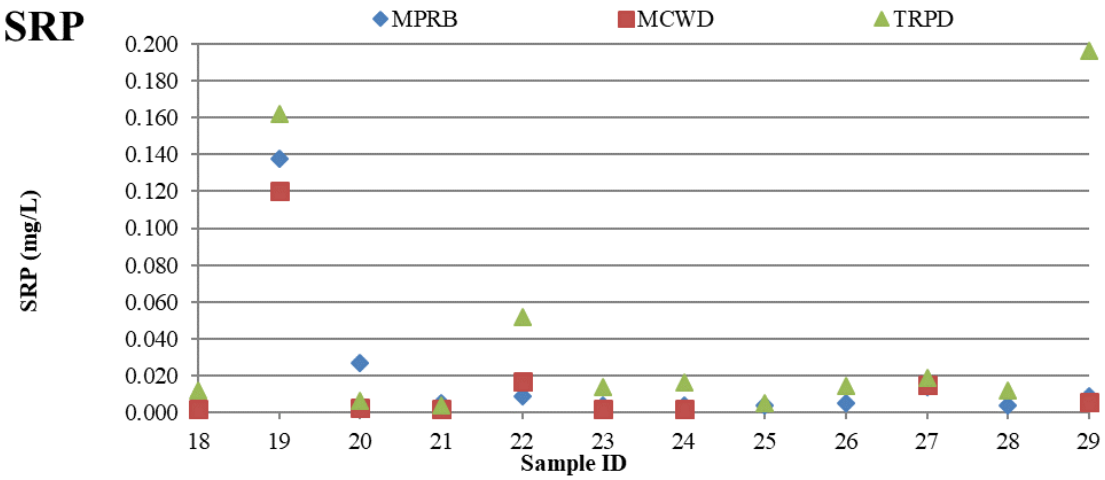


Figure 29-3. Scatter plot of Soluble Reactive Phosphorus split sample results reported for 2020. See Table 29-3 to reference sample ID numbers with descriptions and results.

Total nitrogen (TN) splits were completed by IRI, TRPD, and MCWD as seen in **Figure 29-4**. There were three significant outliers for TN seen in sample numbers 30, 33, and 34. Sample number 32 had significant scatter and an outlier could not be determined. TRPD and IRI perform a persulfate digestion and MCWD (PACE) performs a sum of the nitrogen species TKN and NO_3NO_2. The average CV for TN was 35%.

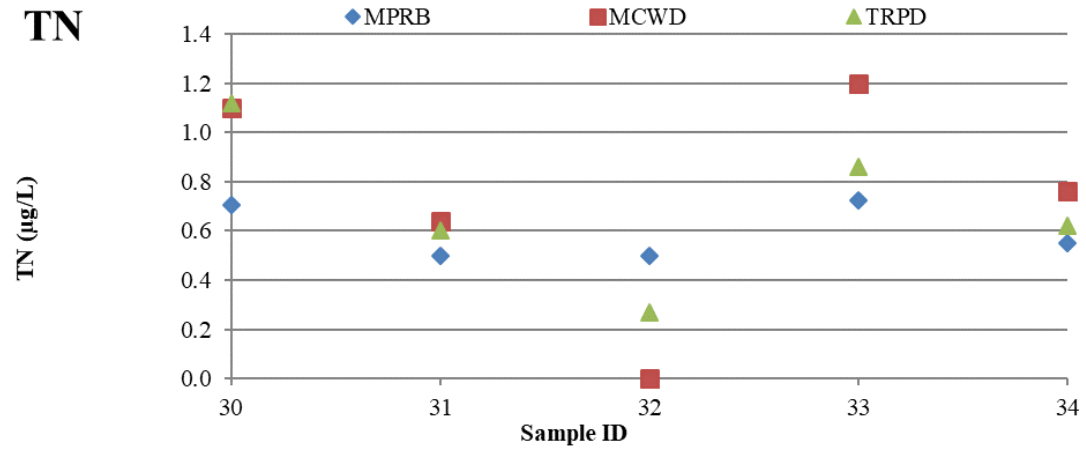


Figure 29-4. Scatter plot of Total Nitrogen split sample results reported for 2020. See Table 29-3 to reference ID numbers with descriptions and results.

Chloride splits were completed by IRI, TRPD, and MCWD as seen in **Figure 29-5**. There were two outliers, sample ID numbers 43 and 44 analyzed by MCWD. Chloride is an extremely stable test and there is generally little variability between laboratories. The average CV for chloride was 20%.

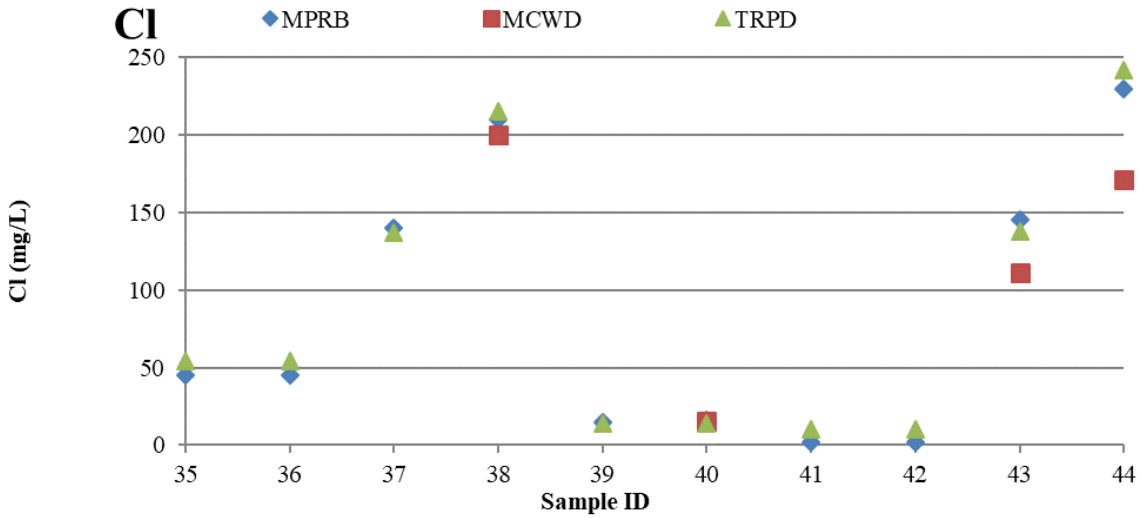


Figure 29-5. Scatter plot of Chloride split sample results reported for 2020. See Table 29-3 to reference ID numbers with descriptions and results.

The comparability of the inter-laboratory split sample within each of the parameters differed considerably. In 2020, MCWD failed to request some of the SRP and Cl analysis which complicated splits. **Table 29-4** details the variability within parameters and lists the determined level of comparability for each. The comparability between years was determined by comparing 2020 values to previous year's data. 2020 had similar comparability between labs to 2019. The TP and SRP appeared to have more outliers than usual. The Cl should not have any outliers since this test is very stable. The final CV calculated for SRP should not be used if many are below or near detection limit values.

Table 29-4. 2020 comparability of parameters analyzed as a part of the inter-laboratory split sample program and compared to previous years' data. Values listed are the range and mean for the coefficient of variation between labs.

Parameter	2020 CV Range	2020 CV Mean %	Comparability Between labs
Chlorophyll-*a*	13-61%	36%	Medium
Total Phosphorus	2%-88%	23%	Medium
Soluble Reactive Phosphorus	15%-155%	72%	Low
Total Nitrogen	12%-97%	35%	Medium
Chloride	2%-94%	20%	Medium

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 29-5** summarizes the results from field duplicate samples in 2020. 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 and 0.004 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 particles in the epilimnion. Further investigation should consider any potential cause.

Table 29-5. 2020 summary of field duplicate sample results and acceptability for IRI Laboratory.

Parameter	Units	Average Relative % Difference	Average Range	Standard Deviation	Acceptable
Chlorophyll-a	µg/L	8.9	23.7	21.0	Yes
Silica	mg/L	4.3	1.69	1.49	Yes
Total Phosphorus	mg/L	10.5	0.41	0.36	Yes
Soluble Reactive Phosphorus	mg/L	11.4	0.15	0.13	Yes
Total Kjeldahl Nitrogen	mg/L	4.5	0.21	0.19	Yes
Total Nitrogen	mg/L	4.4	0.64	0.57	Yes
NO_2NO_3	mg/L	0.4	0.01	0.01	Yes
Alkalinity	mg/L	1.2	6.00	5.32	Yes
Hardness	mg/L	3.8	10.0	8.87	Yes
Chloride	mg/L	2.6	68	60	Yes
Sulfate	mg/L	5.1	4.39	3.9	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 performance evaluation samples. Performance evaluation standards were purchased from ERA. 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 29-6** and **Figures 29-6** through **29-9** summarize the performance evaluation sample results for each parameter. Of the 2020 performance parameters

tested, the January COD, May TP, July COD and DOC, along with the October COD samples fell outside the recovery limits and all data were flagged for those parameters for each month. All other performance evaluation samples fell within acceptance limits.

Table 29-6. Performance evaluation samples analyzed by IRI in 2020. Recovery in red were outside performance standard limits.

Sample ID	Parameter	Date	Calculated Value	IRI Value	% Recovery
1	Alkalinity	1/23/2020	80	79	99%
2	Alkalinity	5/14/2020	106	106	100%
3	Alkalinity	6/22/2020	43	43	100%
4	Alkalinity	7/7/2020	45	44	97%
5	Alkalinity	8/17/2020	45	43	96%
6	Alkalinity	9/2/2020	42	37	89%
7	Alkalinity	10/22/2020	32	29	90%
8	Chloride	1/23/2020	95	79	83%
9	Chloride	5/14/2020	63	55	87%
10	Chloride	6/22/2020	104	95	91%
11	Chloride	7/7/2020	64.9	62	96%
12	Chloride	8/17/2020	78.6	74	94%
13	Chloride	9/2/2020	50.1	48	96%
14	Chloride	10/22/2020	46.5	44	95%
15	Chemical Oxygen Demand	1/23/2020	62.8	85.0	135%
16	Chemical Oxygen Demand	5/14/2020	56.8	51.5	91%
17	Chemical Oxygen Demand	6/22/2020	56.8	51.4	90%
18	Chemical Oxygen Demand	7/7/2020	28.4	18.5	65%
19	Chemical Oxygen Demand	8/17/2020	56.8	55.3	97%
20	Chemical Oxygen Demand	9/2/2020	56.8	58.8	104%
21	Chemical Oxygen Demand	10/22/2020	56.8	31.9	56%

Table 29-6. (continued) Performance evaluation samples analyzed by IRI in 2020. Recovery in red were outside performance standard limits.

Sample ID	Parameter	Date	Calculated Value	IRI Value	% Recovery
22	Copper	1/23/2020	221	227	103%
23	Copper	5/14/2020	672	743	111%
24	Copper	6/22/2020	672	749	111%
25	Copper	7/7/2020	672	698	104%
26	Copper	8/17/2020	672	615	92%
27	Copper	9/2/2020	672	646	96%
28	Copper	10/22/2020	672	690	103%
29	Dissolved Organic Carbon	5/14/2020	2.80	3.3	118%
30	Dissolved Organic Carbon	6/22/2020	2.80	3.3	118%
31	Dissolved Organic Carbon	7/7/2020	2.80	3.4	121%
32	Dissolved Organic Carbon	8/17/2020	5.64	6.5	115%
33	Dissolved Organic Carbon	9/2/2020	5.64	6.4	113%
34	Dissolved Organic Carbon	10/22/2020	5.64	5.8	103%
35	A Ecoli - Quarterly	6/22/2020	345 (86.5-859)	348	100%
36	A Ecoli - Quarterly	8/17/2020	348 (151-560)	276	100%
37	A Ecoli - Quarterly	9/2/2020	2171 (1140-4440)	1986	100%
38	B Ecoli - Quarterly	6/22/2020	<1	<1	100%
39	B Ecoli - Quarterly	8/17/2020	<1	<1	100%
40	B Ecoli - Quarterly	9/2/2020	<1	<1	100%

Table 29-6. (continued) Performance evaluation samples analyzed by IRI in 2020.

Sample ID	Parameter	Date	Calculated Value	IRI Value	% Recovery
41	Fat Oil Grease	5/14/2020	97.5	97.4	100%
42	Fat Oil Grease	9/2/2020	92.5	80.4	87%
43	Ammonia	1/23/2020	3.18	3.21	101%
44	Ammonia	5/14/2020	3.30	3.30	100%
45	Ammonia	6/22/2020	3.30	3.02	92%
46	Ammonia	7/7/2020	3.30	3.29	100%
47	Ammonia	8/17/2020	3.30	3.22	98%
48	Ammonia	9/2/2020	3.30	3.32	101%
49	Ammonia	10/22/2020	3.30	3.36	102%
50	Nitrate/Nitrite	1/23/2020	1.51	1.45	96%
51	Nitrate/Nitrite	5/14/2020	4.72	4.63	98%
52	Nitrate/Nitrite	6/22/2020	4.72	4.64	98%
53	Nitrate/Nitrite	7/7/2020	4.72	4.55	96%
54	Nitrate/Nitrite	8/17/2020	4.72	3.84	81%
55	Nitrate/Nitrite	9/2/2020	4.72	4.09	87%
56	Nitrate/Nitrite	10/22/2020	4.72	3.97	84%
57	Lead	1/23/2020	23.9	25.5	107%
58	Lead	5/14/2020	16.8	18.3	109%
59	Lead	6/22/2020	16.8	17.6	105%
60	Lead	7/7/2020	16.8	16.9	101%
61	Lead	8/17/2020	16.8	16.7	99%
62	Lead	9/2/2020	16.8	16.6	99%
63	Lead	10/22/2020	16.8	17.3	103%
64	Sulfate	1/23/2020	18.6	16.0	86%
65	Sulfate	5/14/2020	17.6	14.5	82%
66	Sulfate	6/22/2020	15.4	12.6	82%
67	Sulfate	7/7/2020	36.8	35.6	97%
68	Sulfate	8/17/2020	13.6	11.4	84%
69	Sulfate	9/2/2020	27.1	24.3	90%
70	Sulfate	10/22/2020	40.7	39.3	97%

Table 29-6. (continued) Performance evaluation samples analyzed by IRI in 2020.

Sample ID	Parameter	Date	Calculated Value	IRI Value	% Recovery
71	Soluble Reactive Phosphorus	1/23/2020	0.0129	0.012	93%
72	Soluble Reactive Phosphorus	5/14/2020	0.0088	0.009	102%
73	Soluble Reactive Phosphorus	6/22/2020	0.0088	0.010	114%
74	Soluble Reactive Phosphorus	7/7/2020	0.0088	0.009	102%
75	Soluble Reactive Phosphorus	8/17/2020	0.0088	0.009	102%
76	Soluble Reactive Phosphorus	9/2/2020	0.0088	0.009	102%
77	Soluble Reactive Phosphorus	10/22/2020	0.0088	0.010	114%
78	Total Dissolved Phosphorus	1/23/2020	0.0129	0.015	116%
79	Total Dissolved Phosphorus	5/14/2020	0.0088	0.008	91%
80	Total Dissolved Phosphorus	6/22/2020	0.0088	0.008	91%
81	Total Dissolved Phosphorus	7/7/2020	0.0088	0.009	102%
82	Total Dissolved Phosphorus	8/17/2020	0.0088	0.009	102%
83	Total Dissolved Phosphorus	9/2/2020	0.0088	0.008	91%
84	Total Dissolved Phosphorus	10/22/2020	0.0088	0.009	102%

Table 29-6. (continued) Performance evaluation samples analyzed by IRI in 2020.

Sample ID	Parameter	Date	Calculated Value	IRI Value	% Recovery
85	Total Dissolved Solids	1/23/2020	360	360	100%
86	Total Dissolved Solids	5/14/2020	370	363	98%
87	Total Dissolved Solids	6/22/2020	294	289	98%
88	Total Dissolved Solids	7/7/2020	279	273	98%
89	Total Dissolved Solids	8/17/2020	259	253	98%
90	Total Dissolved Solids	9/2/2020	220	213	97%
91	Total Dissolved Solids	10/22/2020	221	218	99%
92	Total Kjeldahl Nitrogen	1/23/2020	3.16	3.10	98%
93	Total Kjeldahl Nitrogen	5/14/2020	2.92	2.72	93%
94	Total Kjeldahl Nitrogen	6/22/2020	2.92	2.91	100%
95	Total Kjeldahl Nitrogen	7/7/2020	2.92	3.03	104%
96	Total Kjeldahl Nitrogen	8/17/2020	2.92	2.84	97%
97	Total Kjeldahl Nitrogen	9/2/2020	2.92	2.74	94%
98	Total Kjeldahl Nitrogen	10/22/2020	2.92	3.26	112%

Table 29-6. (continued) Performance evaluation samples analyzed by IRI in 2020. Recovery in red were outside performance standard limits.

Sample ID	Parameter	Date	Calculated Value	IRI Value	% Recovery
99	Total Nitrogen	1/23/2020	3.16	2.89	91%
100	Total Nitrogen	5/14/2020	2.92	3.41	117%
101	Total Nitrogen	6/22/2020	2.92	2.87	98%
102	Total Nitrogen	7/7/2020	2.92	2.84	97%
103	Total Nitrogen	8/17/2020	2.92	2.84	97%
104	Total Nitrogen	9/2/2020	2.92	2.84	97%
105	Total Nitrogen	10/22/2020	2.92	3.11	107%
106	Total Hardness	1/23/2020	315	316	100%
107	Total Hardness	5/14/2020	250	232	93%
108	Total Hardness	6/22/2020	130	120	92%
109	Total Hardness	7/7/2020	250	228	91%
110	Total Hardness	8/17/2020	340	328	96%
111	Total Hardness	9/2/2020	185	172	93%
112	Total Hardness	10/22/2020	338	320	95%
113	Total Phosphorus 01	1/23/2020	0.035	0.034	98%
114	Total Phosphorus 01	5/14/2020	0.019	0.023	121%
115	Total Phosphorus 01	6/22/2020	0.019	0.019	100%
116	Total Phosphorus 01	7/7/2020	0.019	0.021	111%
117	Total Phosphorus 01	8/17/2020	0.019	0.018	95%
118	Total Phosphorus 01	9/2/2020	0.019	0.017	89%
119	Total Phosphorus 01	10/22/2020	0.019	0.021	111%

Table 29-6. (continued) Performance evaluation samples analyzed by IRI in 2020.

Sample ID	Parameter	Date	Calculated Value	IRI Value	% Recovery
120	Total Phosphorus 02	1/23/2020	1.732	1.750	101%
121	Total Phosphorus 02	5/14/2020	0.952	0.980	103%
122	Total Phosphorus 02	6/22/2020	0.952	1.032	108%
123	Total Phosphorus 02	7/7/2020	0.952	1.005	106%
124	Total Phosphorus 02	8/17/2020	0.952	0.840	88%
125	Total Phosphorus 02	9/2/2020	0.952	0.930	98%
126	Total Phosphorus 02	10/22/2020	0.952	0.918	96%
127	Total Suspended Solids	1/23/2020	57	58	102%
128	Total Suspended Solids	5/14/2020	97	91	94%
129	Total Suspended Solids	6/22/2020	91	83	92%
130	Total Suspended Solids	7/7/2020	97	85	88%
131	Total Suspended Solids	8/17/2020	87	88	101%
132	Total Suspended Solids	9/2/2020	89	81	91%
133	Total Suspended Solids	10/22/2020	88	83	94%

Table 29-6. (continued) Performance evaluation samples analyzed by IRI in 2020.

Sample ID	Parameter	Date	Calculated Value	IRI Value	% Recovery
134	Zinc	1/23/2020	708	723	102%
135	Zinc	5/14/2020	664	706	106%
136	Zinc	6/22/2020	664	767	116%
137	Zinc	7/7/2020	664	656	99%
138	Zinc	8/17/2020	664	716	108%
139	Zinc	9/2/2020	664	698	105%
140	Zinc	10/22/2020	664	726	109%

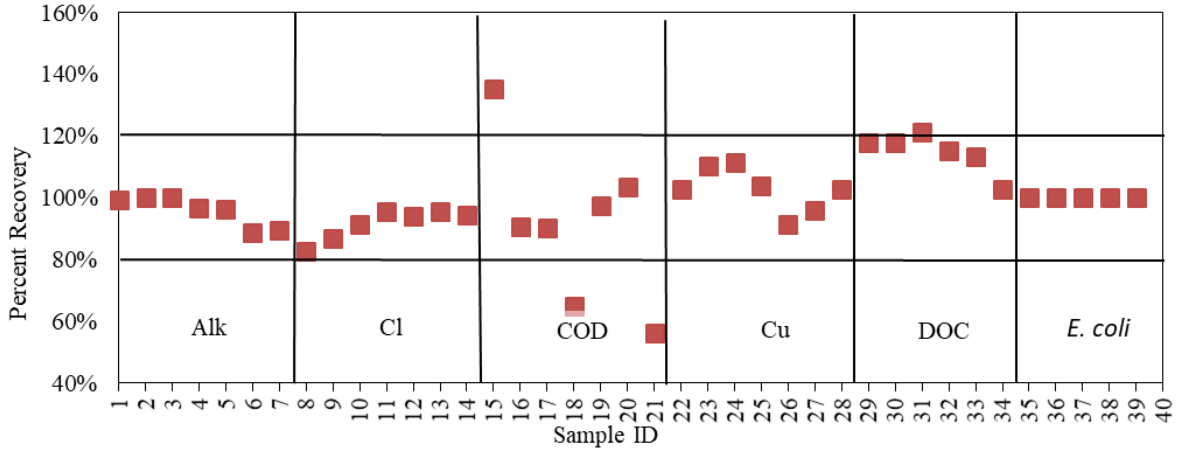


Figure 29-6. Scatter plot of reported percent recoveries for performance evaluation samples in 2020. See Table 29-6 to reference ID numbers with descriptions and results.

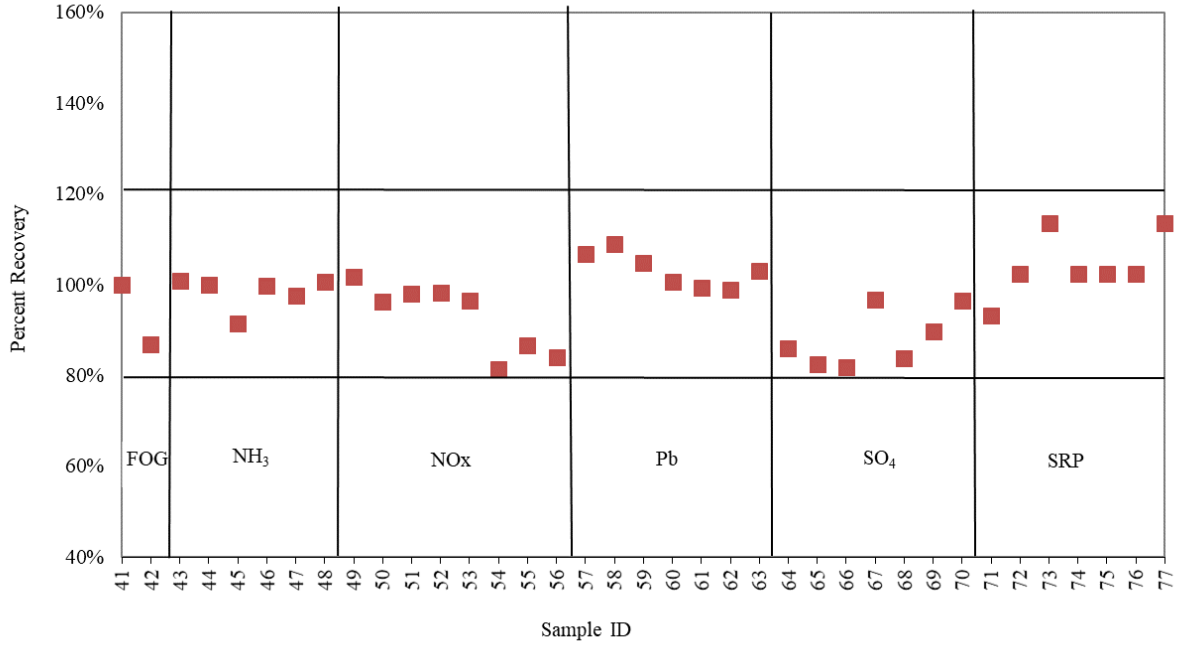


Figure 29-7. Scatter plot of reported percent recoveries for performance evaluation samples in 2020. See Table 29-6 to reference ID numbers with descriptions and results.

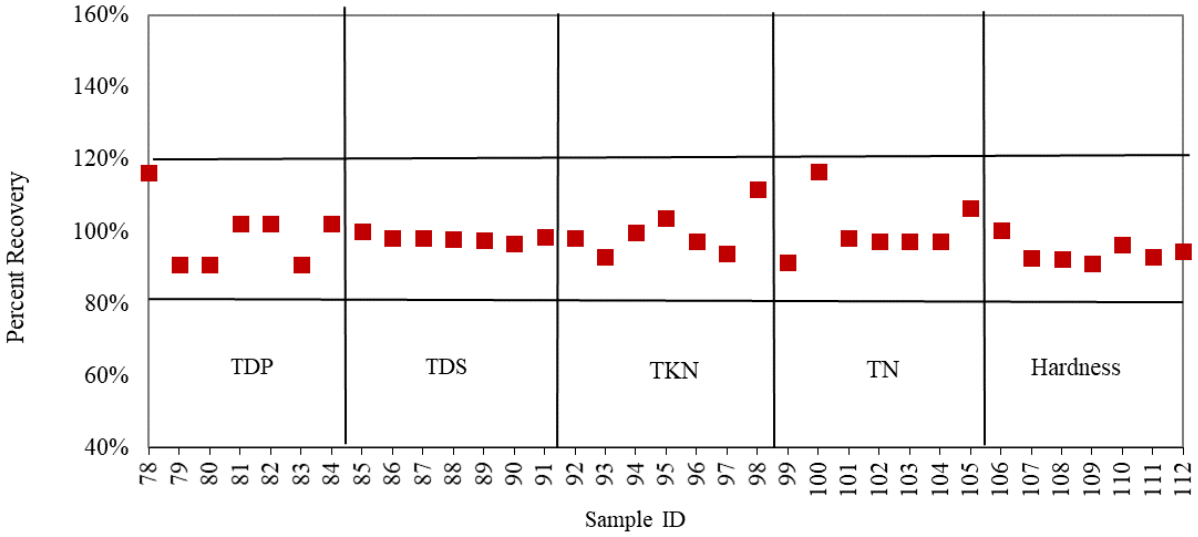


Figure 29-8. Scatter plot of reported percent recoveries for performance evaluation samples in 2020. See Table 29-6 to reference ID numbers with descriptions and results.

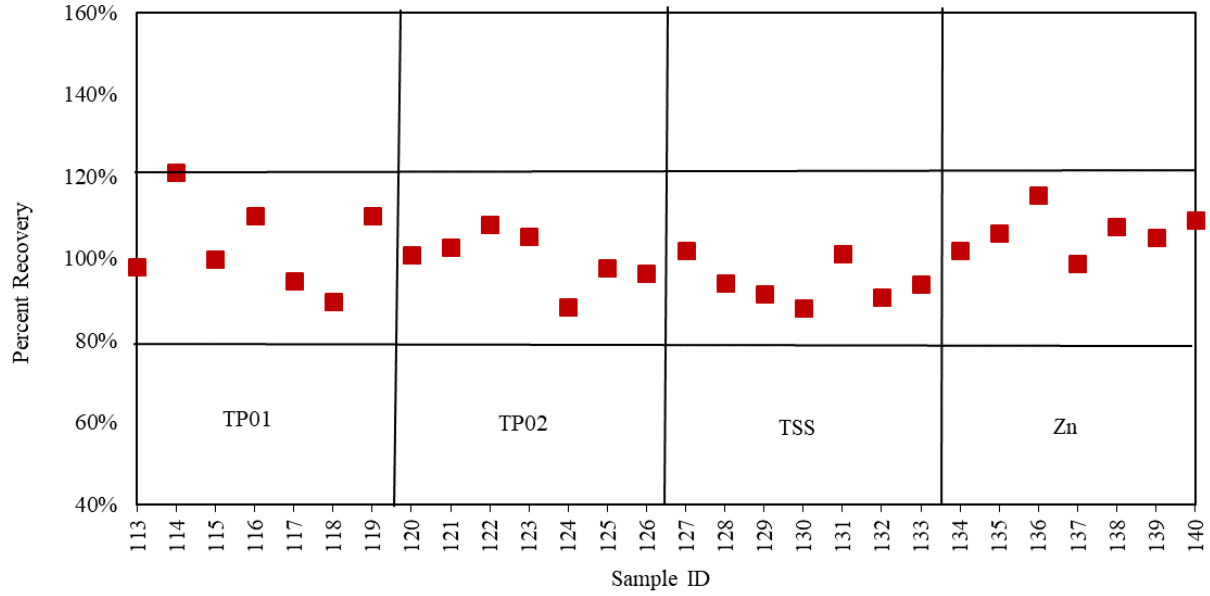


Figure 29-9. Scatter plot of reported percent recoveries for performance evaluation samples in 2020. See Table 29-6 to reference ID numbers with descriptions and results.

Most of the performance evaluation standards were acceptable for all months. Alkalinity, chloride, hardness, TDS, 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 IRI (MPRB laboratory) 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.

The January COD, May TP, July COD and DOC, and October COD blind monthly performance samples were flagged as failing for that month.

Analysis of Equipment Blanks and Field Blanks

Equipment blanks were run for lake water sampling equipment. First, a regular set of equipment blanks were done in which lakes equipment was scrubbed and rinsed before running DI water through each piece of equipment (composite tube, bucket and Kemmerer). Results from this initial set of blanks showed that SRP concentrations were over the reporting limit for both infested and non-infested equipment. An additional set of equipment blanks was done in which a sample was collected from each individual piece of equipment. Results showed that all samples including the field blank were above the reporting limit. Possible causes that could have impacted results were that (1) the QC sample which had a higher SRP concentration than the field blank was ran first and (2) the TP standard was nearing the expiration date. After the lab created a new standard, the second set of equipment blank samples were run again, and results indicated all equipment was below the reporting limit except for both the infested and non-infested brushes. The brushes may have been contaminated, so the surface samples for SRP were flagged since the brush is used to clean the composite tube and bucket prior to rinsing with lake water. The MPRB has continued to do additional work with the potentially contaminated brushes. The brushes were acid washed a second time and all infested and non-infested equipment blanks values were reported below SRP reporting limits. Final results from stormwater and lake equipment blanks for 2020 yielded non-detects for all parameters and equipment except the brushes used to clean lake surface monitoring equipment.

The 2020 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 29-7 lists the overall completeness, representativeness, comparability, and precision determined for the 2020 data by parameter. All additional parameters not analyzed by IRI and collected in the field (dissolved oxygen, temperature, conductivity, pH, and Secchi transparency) were deemed to be fully usable. These measurements followed standard methods and protocols for collection and daily equipment calibration.

The 2020 data designated as questionable usability 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 29-7** are for months that either failed a blind monthly performance standard parameter or the comparability of a split sample parameter was of concern. No parameters in 2020 failed performance standards for every month. 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 29-7. Summary of 2020 data usability by parameter. Fully denotes that acceptance criteria were met, questionably denotes that some of the data were of questionable usability.

Parameter	Completeness (<5% missing data)	Representativeness (representative of natural samples)	Comparability (splits, 2020 data)	Precision (lab field dups, performance)
Alkalinity	fully	fully	fully	fully
Ammonia	fully	fully	fully	fully
COD	fully	fully	fully	questionably
Conductivity	fully	fully	fully	fully
Chloride	fully	fully	fully	questionably
Chlorophyll-*a*	fully	fully	questionably	questionably
Copper	fully	fully	fully	fully
Dissolved Organic Carbon	fully	fully	fully	fully
E. coli	fully	fully	fully	fully
Hardness	fully	fully	fully	fully
Iron	fully	fully	fully	fully
Lead	fully	fully	fully	fully
Nitrate+Nitrite	fully	fully	fully	fully
pH	fully	fully	fully	fully
Silica	fully	fully	fully	fully
Soluble/Reactive Phosphorus	fully	fully	questionably	fully
Sulfate	fully	fully	fully	fully
Total Dissolved Phosphorus	fully	fully	fully	fully
Total Dissolved Solids	fully	fully	fully	fully
Total Kjeldahl Nitrogen	fully	fully	fully	fully
Total Nitrogen	fully	fully	questionably	fully
Total Phosphorus	fully	fully	questionably	fully
Total Suspended Solids	fully	fully	fully	fully
Volatile Suspended Solids	fully	fully	fully	fully
Zinc	fully	fully	fully	fully

TOC

30. Additional Sources of Water Quality Information

Minneapolis Park and Recreation Board

Water Quality Homepage
https://www.minneapolisparks.org/park_care__improvements/water_resources
612.230.6400

City of Minneapolis

Storm and Surface Water Management Website
http://www.ci.minneapolis.mn.us/stormwater/

Minneapolis Surface Water Management Plan
http://www.minneapolismn.gov/publicworks/stormwater/stormwater_local-surface

Results Minneapolis
Lake water quality
https://minneapolisparks.maps.arcgis.com/apps/webappviewer/index.html?id=88319f73c7904adcbabccacdff38bbf1

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

Minnesota Pollution Control Agency
Information on environmental monitoring, clean-up, and more.
https://www.pca.state.mn.us/

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 Extension Service
http://www.extension.umn.edu/

Minnesota Sea Grant
http://www.seagrant.umn.edu

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

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/status/1047486167749484544

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

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31. REFERENCES

Balaban, N.H. (Ed.). (1989). Geologic atlas Hennepin County, Minnesota. *Minnesota Geologic Survey Atlas C-4*.

Bannerman, R.T., R. Dodds, Hornewer, N.J., & Owens, D.W. (1993). Sources of pollutants in Wisconsin stormwater. *Water Science Technology*. 28(3-5), 241-259.

Barr Engineering Company. (2010). Wirth Lake Excess Nutrients Total Maximum Daily Load Report. Prepared for the Minnesota Pollution Control Agency

Blue Water Commission. (1998). Report and recommendations for the management of Lake Nokomis and Lake Hiawatha.

Borman, S., Korth, R., & Temte, J. (1997). Through the Looking Glass…A Field Guide to Aquatic Plants. Wisconsin Lakes Partnership. Stevens Point, WI. 248 pages.

Brugam, R.B., Speziale, B.J. (1983). Human Disturbance and the paleolimnological record of change in the zooplankton community of Lake Harriet, Minnesota. *Ecology*. 64(3), 578-591.

Burns & McDonnell Engineering Company, Inc (2019). City of Minneapolis, Department of Public Works Minnehaha Creek Bacterial Source Identification Study Final Report.

Byappanahalli, Muruleedhara, Fowler, M., Shively, D., & Whitman, R. (2003). Ubiquity and persistence of *Escherichia coli* in a midwestern coastal stream. *Applied and Environmental Microbiology*. 69(8), 4549-4555.

Byappanahalli, M. N., Sawdey M., Ishii S., Shively, D., Ferguson J., Whitman, R., & Sadowsky M. (2009). Seasonal stability of *Cladophora*-associated *Salmonella* in Lake Michigan watersheds. *Water Research*. 43(3), 806-814.

Carlson, R.E. (1977). A trophic state index for lakes. *Limnology and Oceangraphy*. 22, 361-369.

Center for Watershed Protection (CWP) and the Maryland Department of the Environment. (2000). 2000 Maryland stormwater design manual, Volumes I & II. http://www.mde.state.md.us/Programs/WaterPrograms/SedimentandStormwater/stormwater_design/index.asp

City of Minneapolis, Public Works Department. (1992, November 16). NPDES permit application for discharges from municipal separate storm sewer systems, Part 2. Minneapolis, MN.

Dillaha, T.A., Eddleton, C.D., McClellan, P.W., & Mostaghimi, S. (1988). Quality control/quality assurance for water quality monitoring. American Society of Civil Engineers Meeting presentation 88-2648, Chicago, IL.

European Union. (2006). Directive 2006/7/EC of the European Parliament and the council of 15 February 2006 concerning the management of bathing water quality and repealing Directive 75/160/EEC

Eydeler, I. & Spieker, J. (2010). Keimelimination durch zooplankton. *Archiv des Badewesens*. 1-9.

Fairless, B.J., & D.I. Bates. (1989). Estimating the quality of environmental data. *Pollution Engineering.* March, 108-111.

Fassett, N. C. (1957). A Manual of Aquatic Plants. The University of Wisconsin Press. Madison, WI. 405 pages.

Fink, D.F. (1994). A Guide to Aquatic Plants: Identification and Management. Minnesota Department of Natural Resources. Ecological and Water Resources Division. St. Paul, MN. 52 pages.

FLL. (2011). Recommendations for Planning, Construction, Servicing and Operation of Outdoor Swimming Pools with Biological Water Purification (Swimming and Bathing Ponds); Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau e. V. (FLL; Landscaping and Landscape Development Research Society) Friedensplatz 4, 2nd edition (german version 2011), download edition, 2013; 1st edition (as "Recommendations for Planning, Construction, Servicing and Operation of Public Swimming and Bathing Ponds), 2006

Genthner, F.J., Friedman, S.D., James, J.B., & Yates, D.F. (2005). Use of composite data sets for source-tracking enterococci in the water column and shoreline interstitial waters on Pensacola Beach, Florida. *Marine Pollution Bulletin,* 50, 724-732.

Gernes, M. (2002). *Vegetation Method for Wetland Evaluation*

Gordon, R., C. Larson, W. Leksell, & Y. Shi. (2017). Stormwater infrastructure retrofits and recommended best-management-practices to mitigate trash upstream of Lake Hiawatha. *University of Minnesota*.

Ha Kim, J. & Grant, S.B. (2004). Public mis-notification of coastal water quality: A probabilistic evaluation of posting errors at Huntington Beach, California. *Environmental Science and Technology,* 38(9), 2497-2504.

Havel, J.G., K.E. Kovalenko, S.M. Thomaz, S. Amalfitano, & L.B. Kats. (2015). Aquatic invasive species: challenges for the future. *Hydrobiologia*. 750, 147-170.

Heiskary, S.A., E.B. Swain, & M.B. Edlund. (2004). Reconstructing historical water quality in Minnesota lakes from fossil diatoms. Environmental Bulletin Number 4. St. Paul, MN: Minnesota Pollution Control Agency, Environmental Outcomes Division.

Heiskary, S.A., & Lindon, M. (2009). Microcystin in Minnesota Lakes. *LakeLine*. 29. 25-30.

Huser, B.J. (2005). Phosphorus sorption by sediments in eutrophic and acidic lakes. (Unpublished doctoral dissertation) University of Minnesota, Minneapolis.

Ishii, Satoshi, W.B. Ksoll, R.E. Hicks, & M.J. Sadowski. (2005). Presence and growth of naturalized *Escherichia coli* in temperate soils from Lake Superior watersheds. *Applied and Environmental Microbiology.* 72(1), 612-621.

Ishii, Satoshi, D.L. Hanson, R.E. Hicks, & M.J. Sadowski. (2007). Beach sand and sediments are temporal sinks and sources of *Esherichia coli* in Lake Superior. *Environmental Science and Technology*. 41(7), 2203-2209.

Klak, G.E. (1933). A comparative study of summer phytoplankton from 22 bodies of water in the vicinity of Minneapolis and St. Paul, MN. Unpublished master's thesis, University of Minnesota, Minneapolis.

Lee, J.T., & J.R. Jontz. (1997). An overview of the monitoring plan and water quality of Minneapolis lakes. 1991-1996. In: E. Derby, J. Lee and D. Pilger (Eds.) Minneapolis Lakes and Parks—Special Session Proceedings, 1997. Sixteenth Annual North American Lake Management Society International Symposium, Minneapolis, MN.

Lambrecht, N., Wittkop, C., Sergei, K., Mojtaba, F., & Swanner, E.D. (2018). Geochemical characterization of two ferruginous meromictic lakes in the Upper Midwest, USA. *Journal of Geophysical Research: Biogeosciences*. 10.1029/2018JG004587.

Madsen, J. (1999). Point Intercept and Line Intercept Methods for Aquatic Plant Management. APCRP Technical Notes Collection (TN APCRP-MI-02). U.S. Army Engineer Center, Vicksburg, M.S., U.S.A

Magnuson, J. J., D. M. Robertson, B. J. Benson, R. H. Wynne, D. M. Livingstone, T. Arai, R. A. Assel, R. G. Barry, V. Card, E. Kuusisto, N. G. Granin, T. D. Prowse, K. M. Stewart and V. S. Vuglinski (2000) Historical trends in lake and river ice cover in the Northern Hemisphere. *Science,* 289, 1743-1746.

Metropolitan Council. (2015). ANNUAL USE ESTIMATE OF THE METROPOLITAN REGIONAL PARKS SYSTEM FOR 2014. St. Paul, MN. https://metrocouncil.org/Parks/Publications-And-Resources/PARK-USE-REPORTS/2014-Annual-Use-Estimate-of-the-Regional-Parks-Sys.aspx

Metropolitan Council. (n.d.). Citizen-Assisted Monitoring Program (CAMP). St. Paul, MN. Retrieved September 9, 2021, from https://metrocouncil.org/Wastewater-Water/Services/Water-Quality-Management/Lake-Monitoring-Analysis/Citizen-Assisted-Monitoring-Program.aspx

MPRB. (1999). Powderhorn Lake Restoration Project. MPRB documents, 80pp.

MPRB. (2001). Stormwater monitoring program manual. Minneapolis, MN: Minneapolis Park and Recreation Board, Environmental Operations Section, Water Quality.

MPRB. (2004). Minneapolis lakes recreation/aesthetic indicator development. Minneapolis, MN: Minneapolis Park and Recreation Board, Environmental Operations Section, Water Quality.

Minnehaha Creek Watershed District (2012). Taft-Legion Volume and Load Reduction Project. Retrieved November 23, 2021, from https://www.minnehahacreek.org/project/taft-legion-volume-and-load-reduction-project

Minnehaha Creek Watershed District. (2013). Lake Nokomis Water Quality Improvement Project: Implementation of Biomanipulation Study. Author: Kelly Dooley.

Minnesota Department of Health (MDH). (2017). Waterborne Illness Surveillance Statistics. Retrieved February 20, 2018, from http://www.health.state.mn.us/divs/idepc/dtopics/waterborne/statistics.html#illness

Minnesota Department of Natural Resources. (1953). Diamond Lake survey report.

Minnesota Department of Natural Resources. (n.d.). Aquatic Invasive Species in Minnesota. Retrieved March 3, 2015, from http://www.dnr.state.mn.us/invasives/aquatic/index.html

Minnesota Department of Natural Resources (MNDNR). (1993). Guidelines for Ordinary High Water Level (OHWL) Determinations. Retrieved January 5, 2020, from https://files.dnr.state.mn.us/waters/surfacewater_section/hydrographics/ohwl.pdf

Minnesota Pollution Control Agency (MPCA). (2000). Protecting water quality in urban areas: Best management practices for dealing with stormwater runoff from urban, suburban and developing areas of Minnesota. St. Paul, MN: Author.

Minnesota Pollution Control Agency (MPCA). (2004). Lake water quality assessment data base summary. St. Paul, MN: Author.

Minnesota Pollution Control Agency and Minnehaha Creek Watershed District. (2011). Minnehaha Creek Watershed Lakes TMDL: Lake Nokomis, Parley Lake, Lake Virginia, and Wassermann Lake. Prepared by Emmons & Olivier Resources, Inc.

Minnesota Pollution Control Agency. (2013) Minnesota Stormwater Manual. St. Paul, MN https://stormwater.pca.state.mn.us/index.php/Summary_of_sate_of_Minnesota_water_quality_guidelines_for_stormwater_harvesting_and_reuse_systems_for_Irrigation

Minnesota Pollution Control Agency. (2014). Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 305(b) Report and 303(d) List. Retrieved from http://www.pca.state.mn.us/index.php/view-document.html?gid=16988

Minnesota Pollution Control Agency (n.d.). Surface Water Data. Retrieved October 5, 2021, from https://webapp.pca.state.mn.us/wqd/surface-water

Minnesota Pollution Control Agency (n.d.). Twin and Ryan Lakes – Excess Nutrients: TMDL Project. Retrieved September 9, 2021, from https://www.pca.state.mn.us/water/tmdl/twin-and-ryan-lakes-excess-nutrients-tmdl-project

North American Lake Management Society (n.d.). Trophic State Equations. Retrieved October 5, 2021, from https://www.nalms.org/secchidipin/monitoring-methods/trophic-state-equations/

Novotny, E. V., A. Sander, O. Mohseni, H. Stefan, (2009). Chloride ion transport and mass balance in a metropolitan area using road salt. *Water Resources Research*, *45*(12), 2009.

Paerl, H. W. (1998). Growth and reproductive strategies of freshwater Blue-green algae (Cyanobacteria). In C.D. Sandgren (Ed.) *Growth and Reproductive Strategies of Freshwater Phytoplankton* (pp. 261-315). Cambridge, MA: Cambridge University Press.

Paerl, H.W., & Otten, T.G. (2013). Harmful Cyanobacterial Blooms: Causes, Consequences, and Controls. *Environmental Microbiology*, 65, 995-1010.

Perleberg, D., P. Radomski, S. Simon, K. Carlson, and J. Knopik. 2016. Minnesota Lake Plant Survey Manual, for use by MNDNR Fisheries Section and EWR Lake Habitat Program. Minnesota

Department of Natural Resources. Ecological and Water Resources Division. Brainerd, MN. 128 pages including Appendices A-E.

Pulscher, M.L. (1997). History of Minneapolis parks and lakes. In: Minneapolis Lakes and Parks - Special Session Proceedings. Sixteenth Annual North American Lakes Management Society International Symposium. Minneapolis, MN.

Sayer, C.D. (2001). Problems with the application of diatom-total phosphorous transfer functions: examples from a shallow English lake. *Freshwater Biology*. 46(6), 743-757.

Shapiro, J., & H. O. Pfannkuch. (1973). The Minneapolis chain of lakes, a study of urban drainage and its effects. Interim Rept. No. 9, Limnological Research Center, Univ. Minnesota, Minneapolis, 250 p.

Shapiro, J. (1975). Report to the City of Minneapolis Park and Recreation Board on the Condition of Lakes in Minneapolis, 1974. Limnological Research Center, Interim Report No 12. Minneapolis, MN.

Shingle Creek Watershed Management (n.d.). Commissions. Plymouth, MN. Retrieved September 9, 2021, from http://www.shinglecreek.org/commissions.html

Smith, D.C. (2008). City of Parks: The Story of Minneapolis Parks. University of Minnesota Press.

Shingle Creek Watershed Management Commission. (2014). Twin and Ryan Lakes Nutrient TMDL Five Year Review. Prepared by Wenk Associates Inc.

Standard Methods for the Examination of Water and Wastewater. (2005). Joint Editorial Board, American Public Health Association, American Water Works Association, Water Environment Fed., 21st ed. Washington, DC.

Trembley, N. G. (2012). The Changing Face of Cedar Lake: 1900–1918. (Unpublished master's thesis). University of Minnesota, Minneapolis, 131 p.

US Army Corps of Engineers and PCA. (2014). FLUX32 [computer model] Retrieved from https://www.pca.state.mn.us/wplmn/flux32

US EPA. (1979). Methods for chemical analysis of water and waste, US EPA Environmental Monitoring and Support Laboratory. Cincinnati, OH.

US EPA. (1980). Interim guidelines and specifications for preparing quality assurance project plans. QAMS-005/80. Office of Research and Development, Washington, D.C.

US EPA. (1985). Working protocol for sampling, sample analysis, and QA/QC for the EPA long-term surface water monitoring program. Corvallis, OR: Environmental Research Laboratory.

US EPA. (1986). Ambient water quality criteria for bacteria – 1986 (EPA Publication No. EPA440/5-84-002). Washington, DC: Office of Water.

US EPA. (1996). Protecting natural wetlands: A guide to stormwater best management practices (EPA Publication No. EPA-843-B-96-001). Washington, DC: Office of Water.

US EPA. (2005). The EMPACT beaches project: Results from a study on microbiological monitoring in recreational waters (EPA Publication No. EPA 600/R-04/023). Washington, DC: Office of Research and Development.

US EPA. (2012). Recreational Water Quality Criteria.

US EPA, Minnesota Pollution Control Agency and Minnehaha Creek Watershed District. (2013). Minnehaha Creek E. Coli Bacteria / Lake Hiawatha Nutrients Total Maximum Daily Load. Prepared by Tetra Tech.

US EPA. (2017). Recommended Human Health Recreational Ambient Water Quality Criteria or Swimming Advisories for Microcystin and Cylindrospermopsin. (EPA Publication No. EPA-HQ-OW-2016-0715). Washington, DC: Office of Water.

U. S. Fish and Wildlife Service. Publication date (2012). National Wetlands Inventory website. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. http://www.fws.gov/wetlands/

Vinicius J. T., T Olsen, P. Natarajan, B. Janke, J. Gulliver, J. Finlay H. Stefan. Internal loading in stormwater ponds as a phosphorus source to downstream waters. (2020). *Limnology and Oceanography Letters* 5, 2020, 322-330

Wedepohl, R.E., D.R. Knauer, G.B. Wolbert, H. Olem, P.J. Garrison, and K. Kepford. 1990. *Monitoring Lake and Reservoir Restoration*. EPA 440/4-90-007. Prep. by N. Am. Lake Manage. Soc. for U.S.E.P.A.

Wenck Associates, Inc. (2019). Twin Lake Carp Management Project Summary Final Report. http://www.shinglecreek.org/uploads/5/7/7/6/57762663/twin_lake_carp_final_report.pdf

Whitman, Richard L., Byappanahalli, M.N., Nevers, M.B., Pawlik, H., & Shively, D.A. (2003). Occurrence of *Escherichia coli* and Enterococci in Cladophora (Chlorophyta) in nearshore water and beach sand of Lake Michigan. *Applied and Environmental Microbiology,* 69(8), 4714-4719.

Whitman, Richard L., & M. B. Nevers. (2003). Foreshore sand as a source of *Escherichia coli* in nearshore water of a Lake Michigan beach. *Applied and Environmental Microbiology*, 69(9), 5555-5562.

Winfield, Mollie D., & E. A. Groisman. (2003). Role of nonhost environments in the lifestyles of *Salmonella* and *Escherichia coli*. *Applied and Environmental Microbiology*, 69(7), 3687-3694.

Wirth, Theodore. (1945). Minneapolis Park System, 1883-1944. Minneapolis: Board of Park Commissioners.

WHO, 2021. Toxic Cyanobacteria in Water – A Guide to Their Public Health Consequences, Monitoring and Management Edited by Ingrid Chorus and Martin Welker © 2021 WHO.

WHO, 2000. Monitoring Bathing Waters - A Practical Guide to the Design and Implementation of Assessments and Monitoring Programmes Edited by Jamie Bartram and Gareth Rees © 2000 WHO.

ISBN 0-419-24390-1Zumberge, J.H. (1952). The lakes of Minnesota: Their origin and classification. St. Paul, MN: The University of Minnesota Press.

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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.

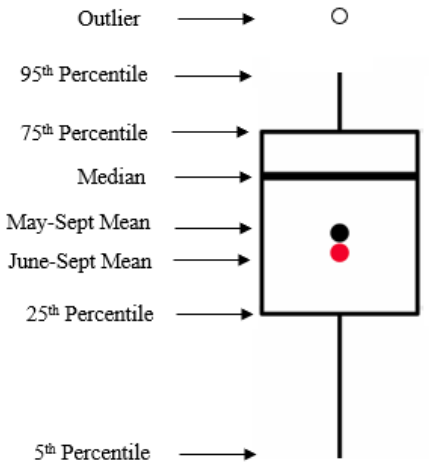
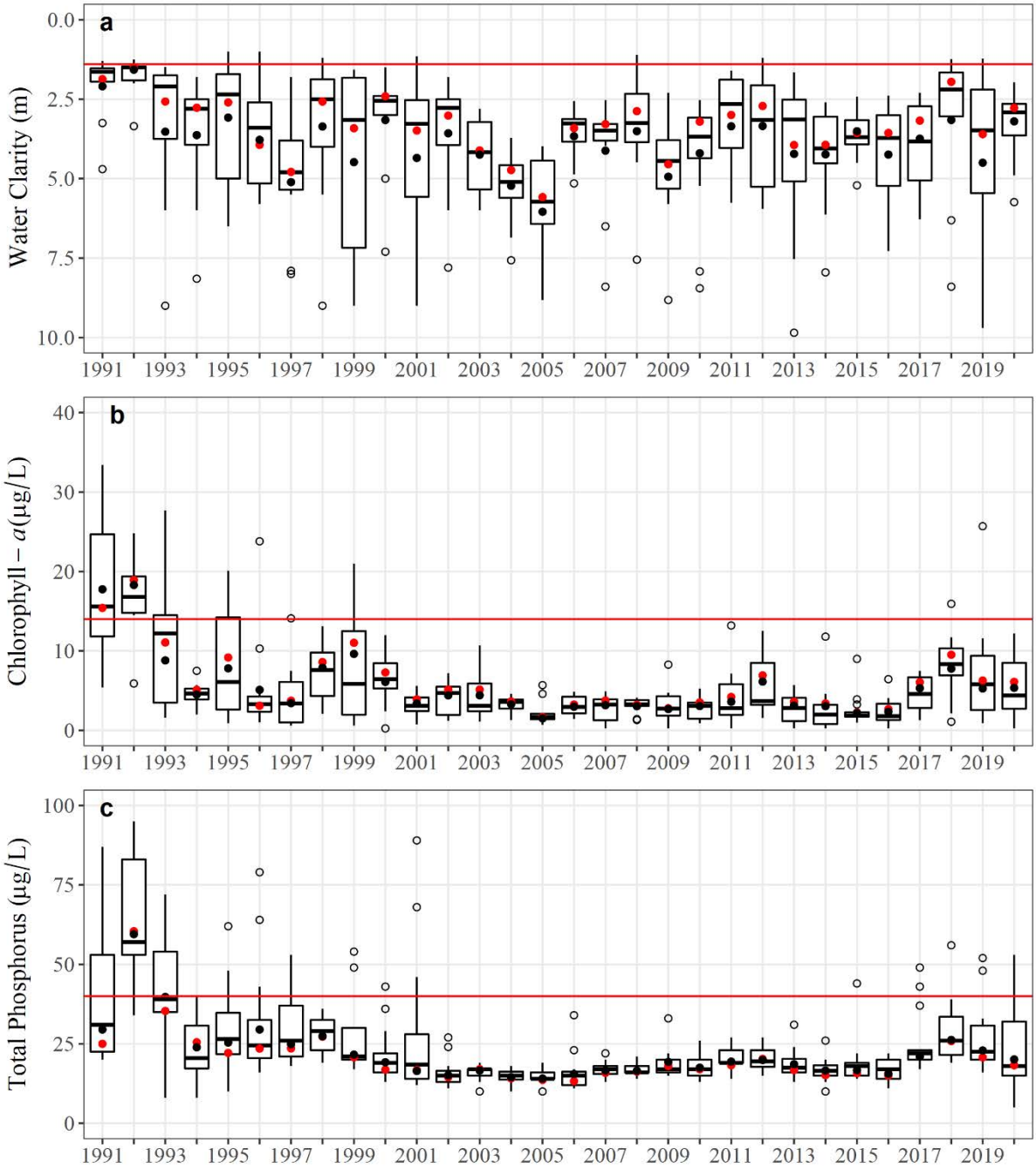
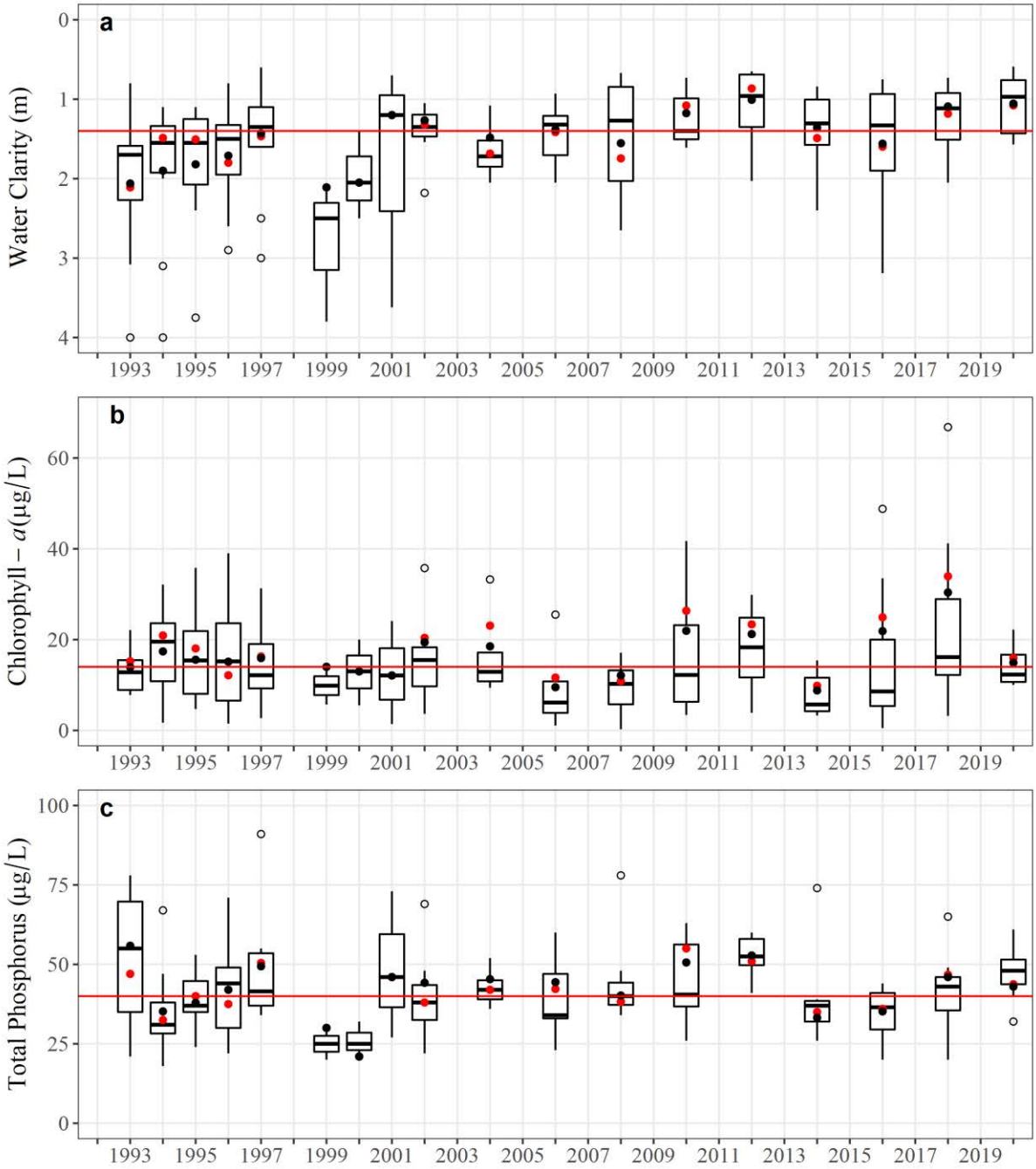


Figure A-1. Legend for box and whisker plots.

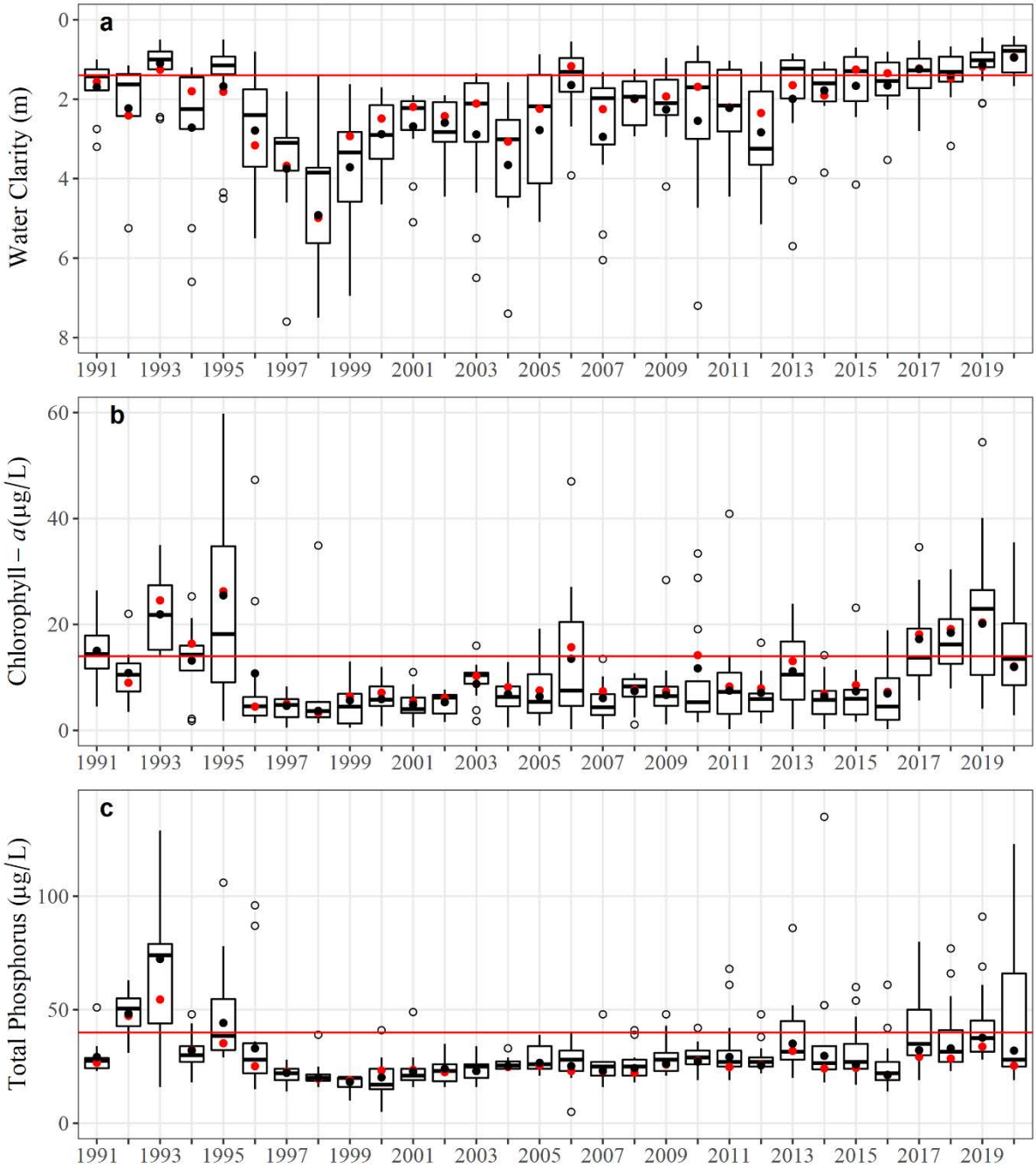
Bde Maka Ska 1991-2020



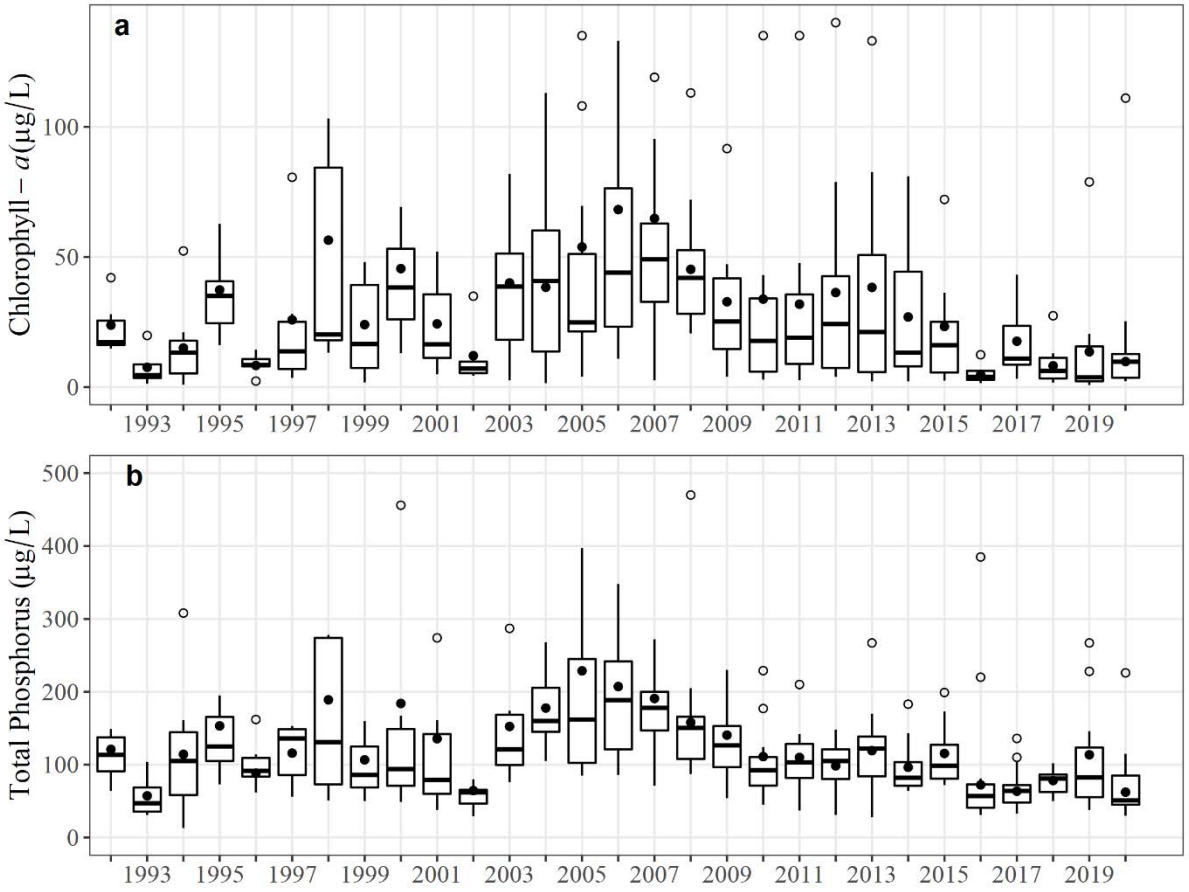
Brownie Lake 1993-2020



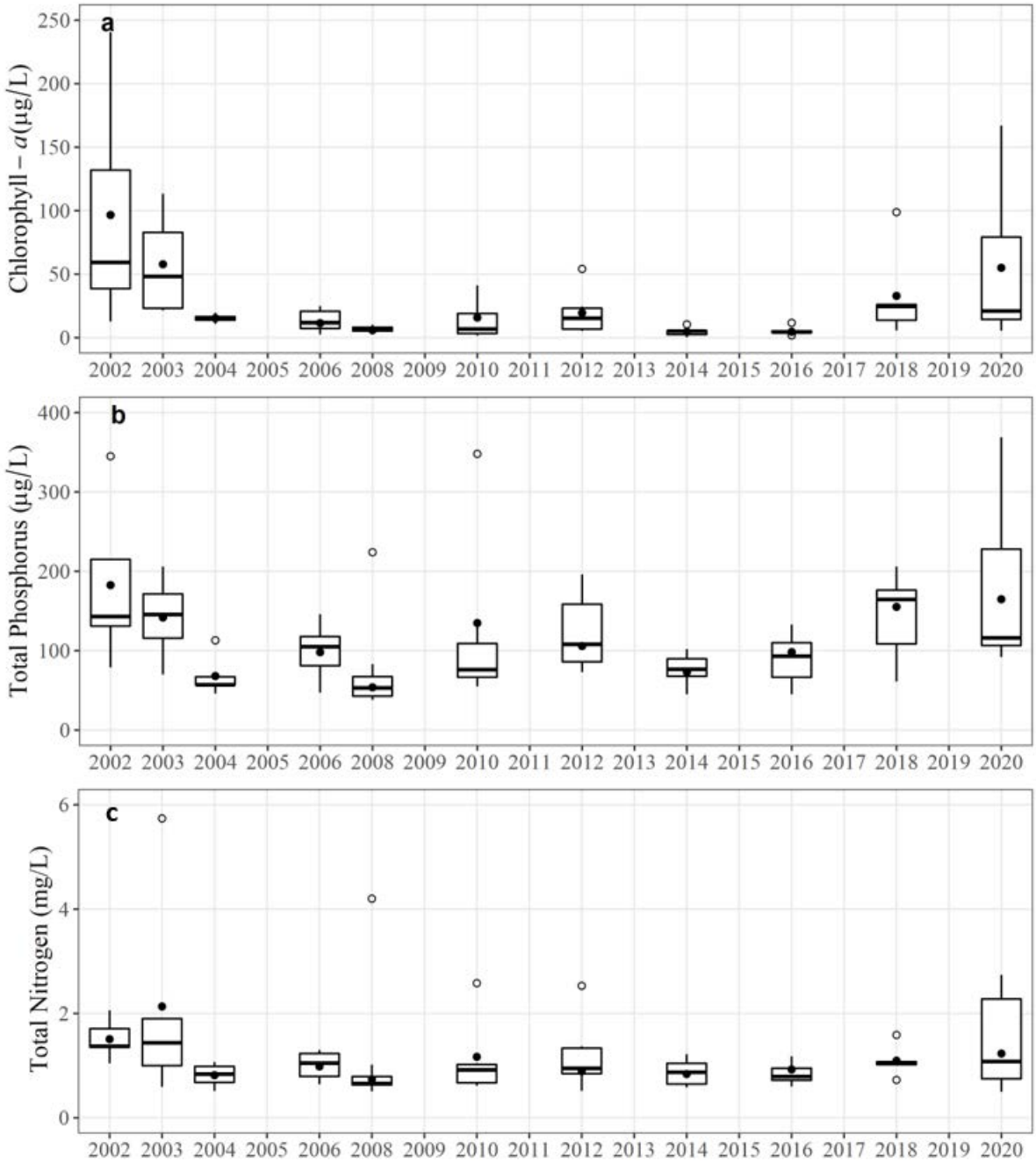
Cedar Lake 1991-2020



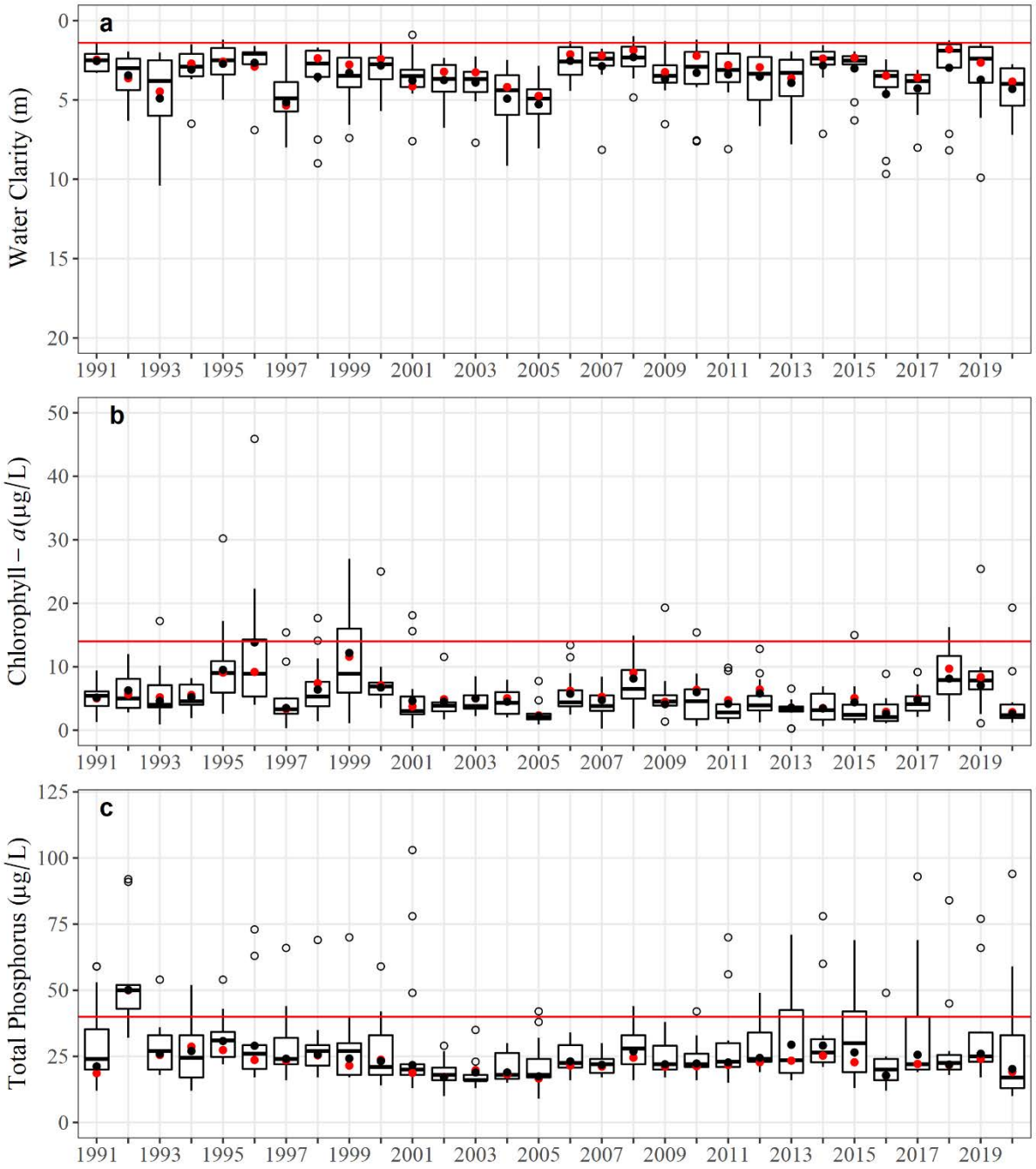
Diamond Lake 1992-2020



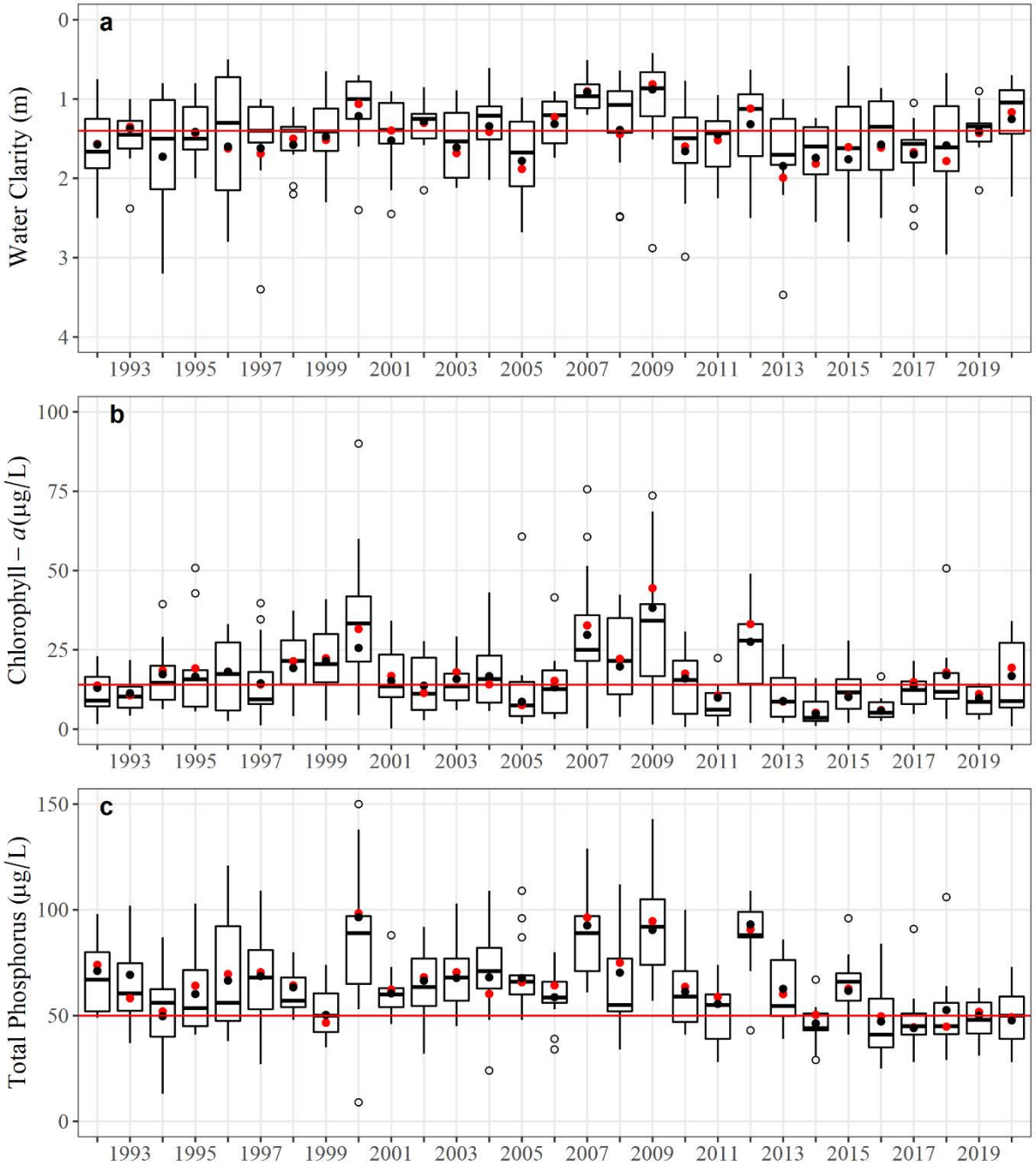
Grass Lake 2002-2020



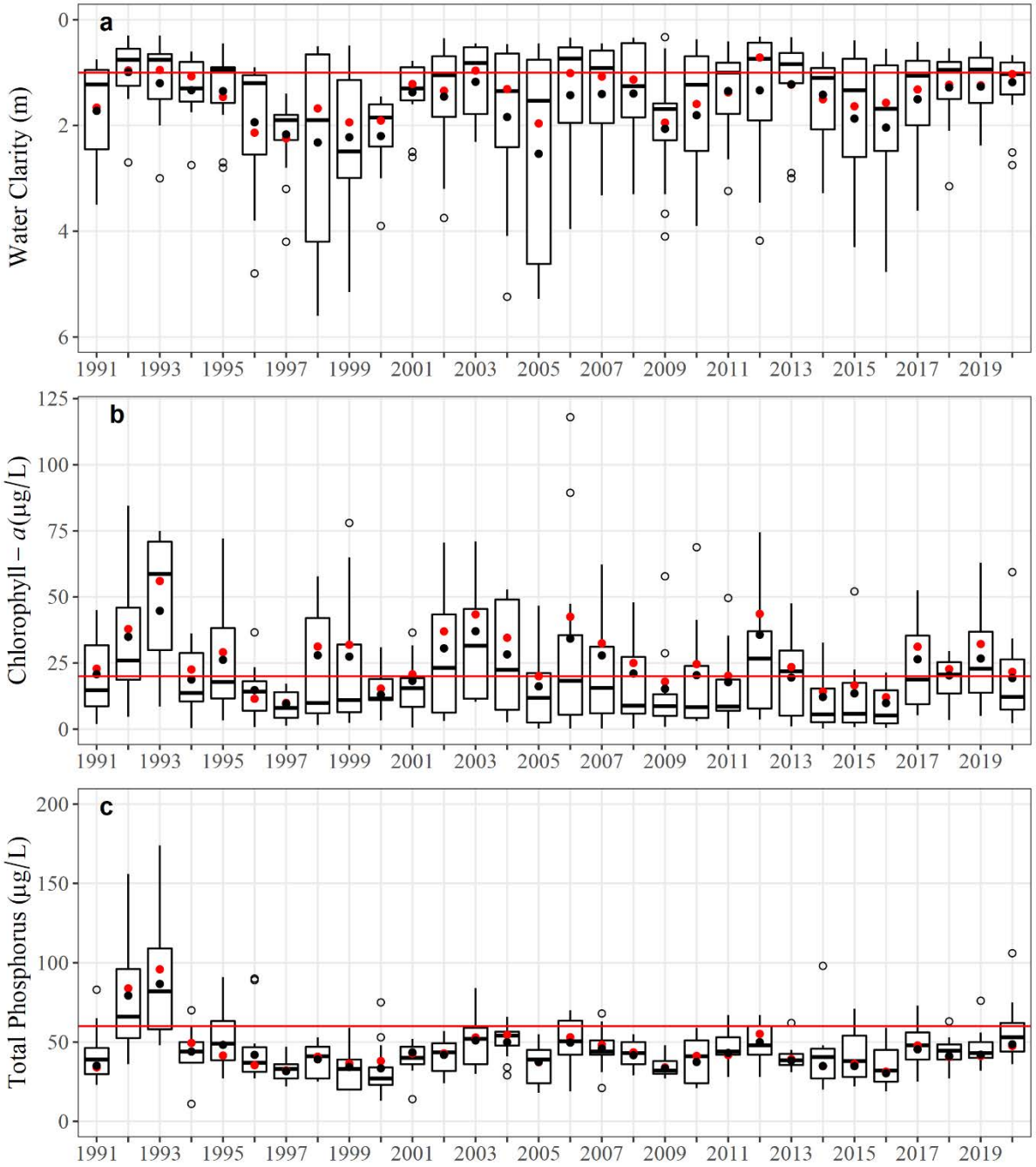
Lake Harriet 1991-2020



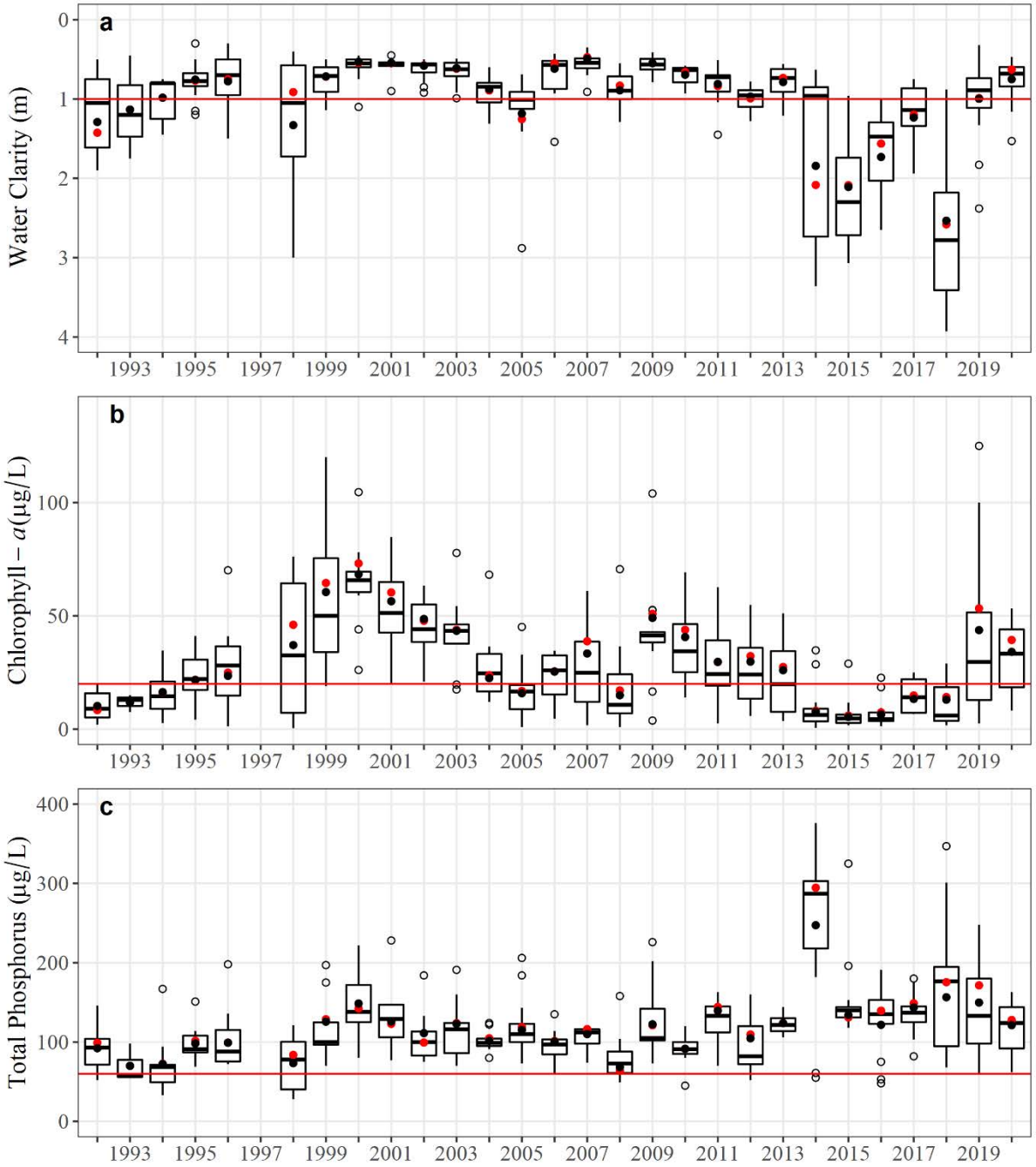
Lake Hiawatha 1992-2020



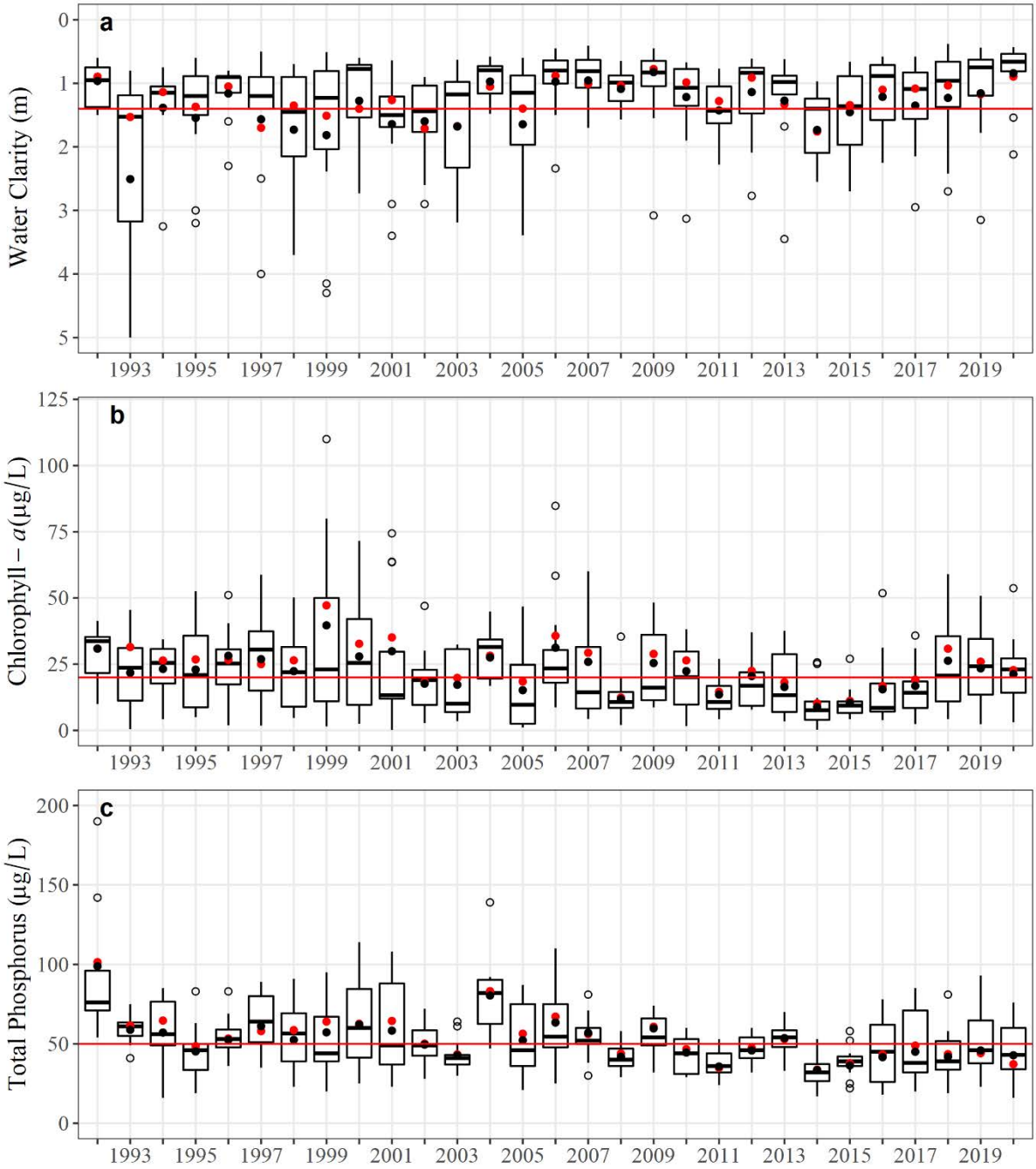
Lake of the Isles 1991-2020



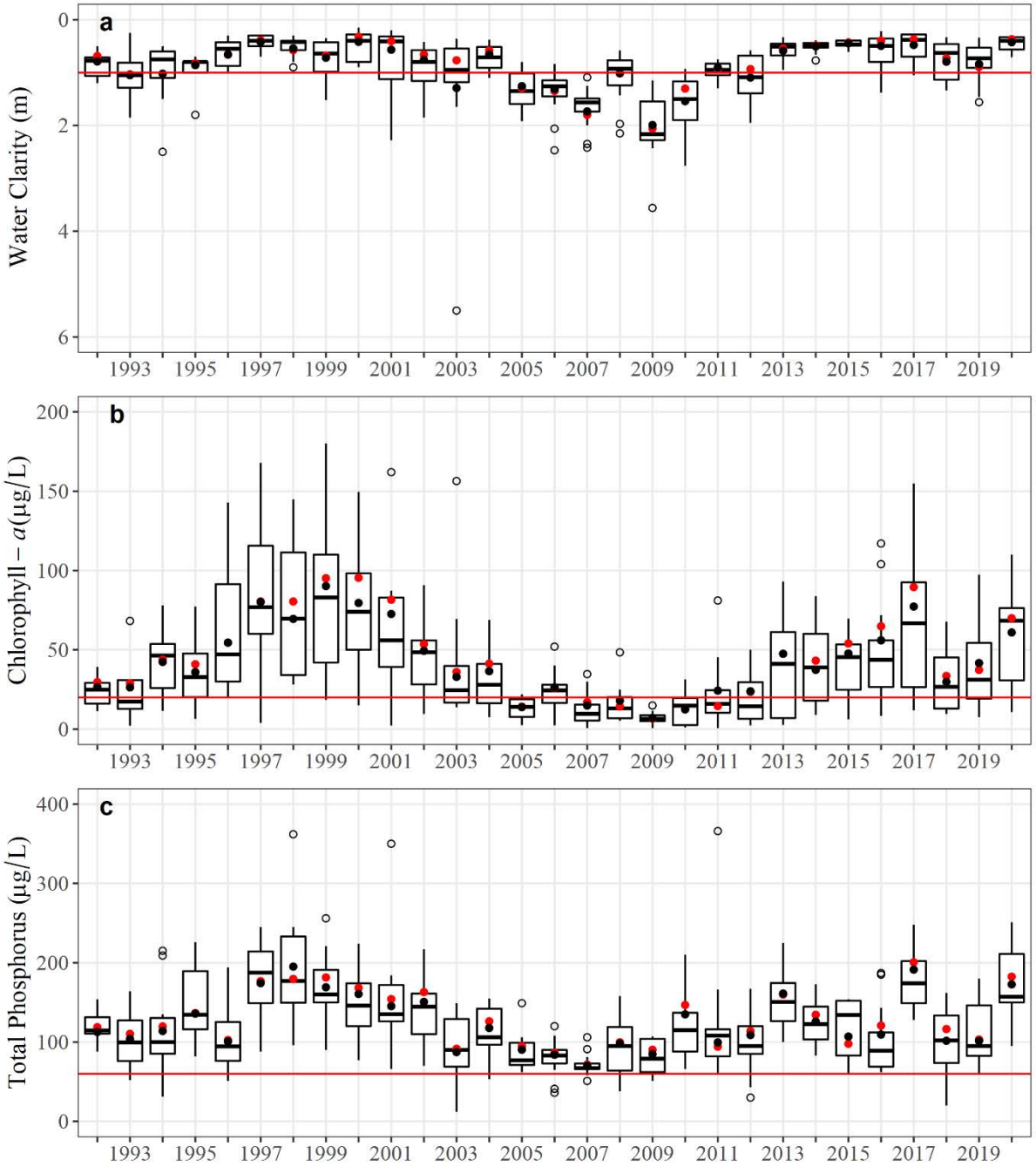
Loring Pond 1992-2020 Note: Loring was not sampled in 1997.



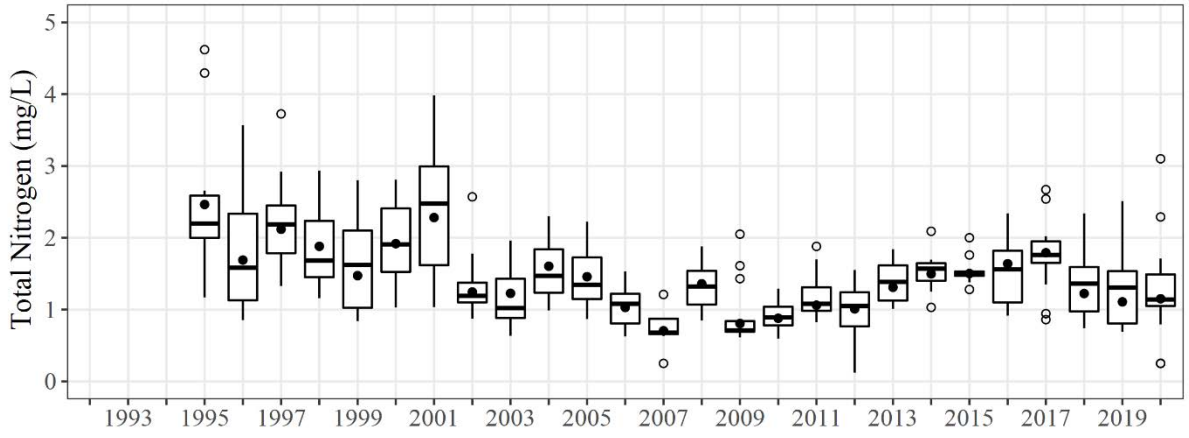
Lake Nokomis 1992-2020



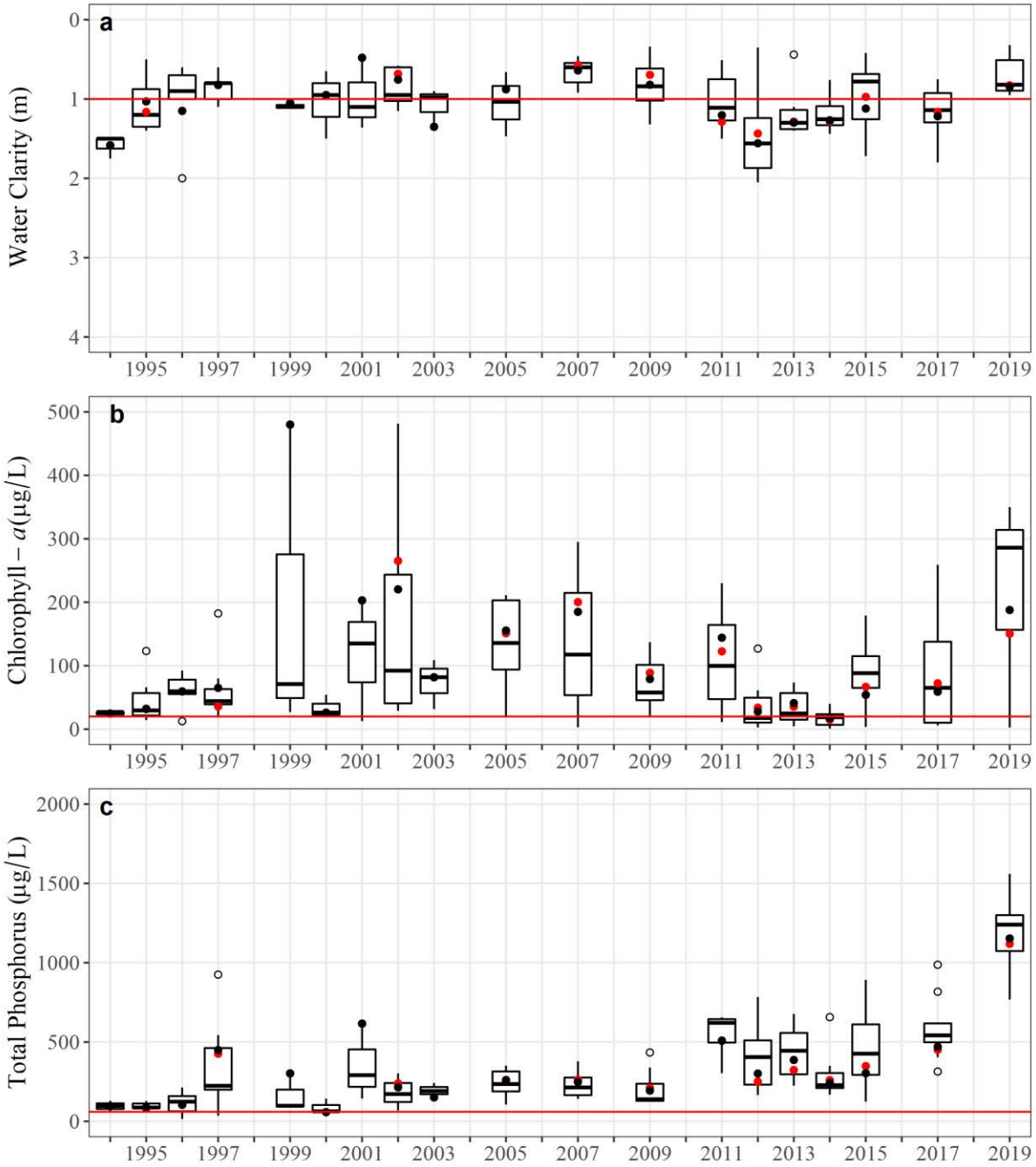
Powderhorn Lake 1992-2020



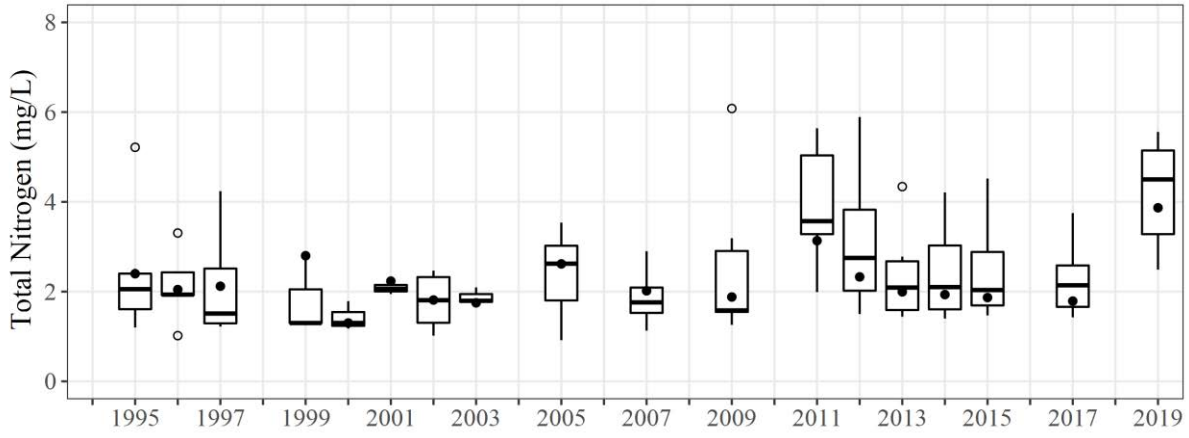
Powderhorn Lake Total Nitrogen 1994-2020



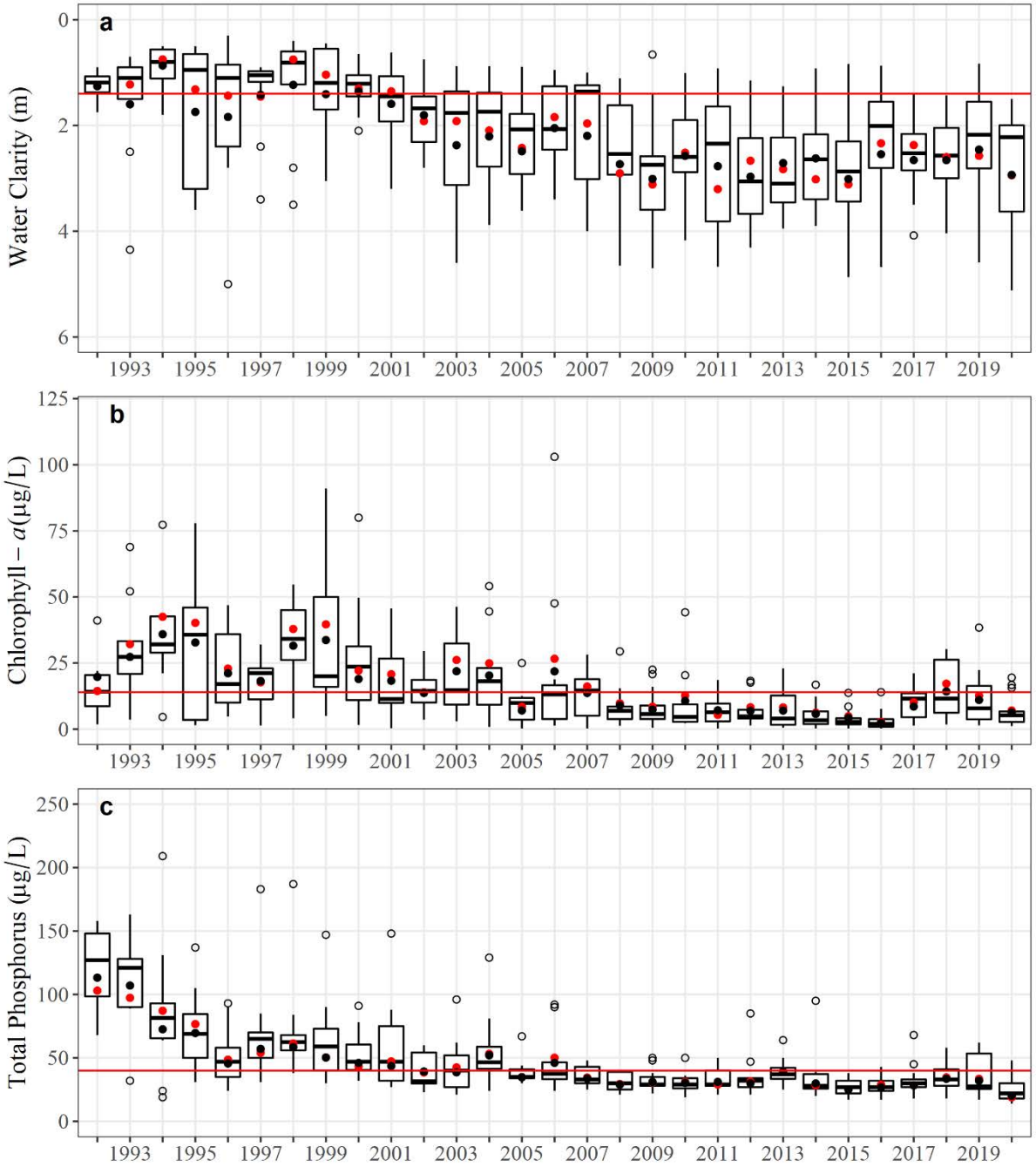
Spring Lake 1994-2019



Spring Lake 1994- 2019 Total Nitrogen



Wirth Lake 1992-2020



Wirth Lake 1994-2020 Total Nitrogen

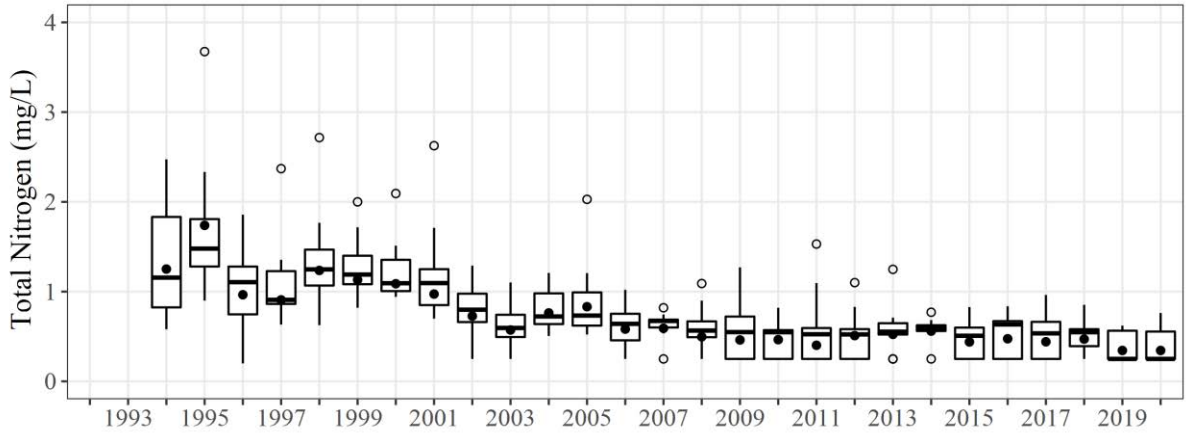


Table A-1. Box and whisker plot outliers removed

Lake	Date	Parameter	Units	Outlier Value
Bde Maka Ska	10/20/1999	Chl-*a*	µg/L	41
Bde Maka Ska	3/21/2000	Chl-*a*	µg/L	82
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
Bde Maka Ska	5/25/1999	TN	mg/L	4.2
Bde Maka Ska	9/27/1999	TN	mg/L	2.3
Brownie	8/27/1996	TN	mg/L	3.5
Cedar	7/25/1995	TN	mg/L	2.924
Cedar	9/27/1999	TN	mg/L	2.8
Diamond	2/17/2016	Chl-*a*	µg/L	614
Diamond	7/21/2005	TP	µg/L	0.74
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	9.8
Grass	9/10/2003	Chl-*a*	µg/L	417.9
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
Harriet	5/11/1995	TN	mg/L	3.135
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	8.876
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

TOC

Appendix B

This section contains lake monitoring data for 2020.

Lake ID	Lake Name	Date MM/DD/YY	Time HH:MM :SS	Secchi meters	Depth meters	Temp °C	%DO	DO mg/L	pH units	SpCond µS/cm	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/10 0mL	DOC mg/L
27-0031	Bde Maka Ska	01/27/20	10:43		0	0.2	92.9	13.25	8.53	697.8	40.9	12.2	2.24	0.879	0.039	0.002	0.588	0.694	0.087	0.351	135	160	140	7.94		
27-0031	Bde Maka Ska	01/27/20	10:43		1	1.88	95.2	12.95	8.45	704	0															
27-0031	Bde Maka Ska	01/27/20	10:42		2	2.08	94.4	12.77	8.41	702.3	0															
27-0031	Bde Maka Ska	01/27/20	10:41		3	2.07	94.5	12.79	8.4	704.1	0															
27-0031	Bde Maka Ska	01/27/20	10:40		4	2.11	91.6	12.38	8.34	704.2	0															
27-0031	Bde Maka Ska	01/27/20	10:39		5	2.19	83.9	11.32	8.22	705.7	0															
27-0031	Bde Maka Ska	01/27/20	10:38		6	2.2	77.1	10.4	8.12	709.5	0				0.027	0.006										
27-0031	Bde Maka Ska	01/27/20	10:38		7	2.23	76	10.24	8.09	716.7	0															
27-0031	Bde Maka Ska	01/27/20	10:37		8	2.27	74	9.96	8.05	721.9	0															
27-0031	Bde Maka Ska	01/27/20	10:36		9	2.33	69.7	9.37	8	729.1	0															
27-0031	Bde Maka Ska	01/27/20	10:35		10	2.37	66.6	8.93	7.96	733.7	0															
27-0031	Bde Maka Ska	01/27/20	10:35		11	2.46	65.5	8.77	7.94	735.7	0															
27-0031	Bde Maka Ska	01/27/20	10:34		12	2.48	62.5	8.36	7.91	744.6	0				0.052	0.028										
27-0031	Bde Maka Ska	01/27/20	10:33		13	2.49	61.3	8.2	7.88	754.6	0															
27-0031	Bde Maka Ska	01/27/20	10:33		14	2.49	59	7.9	7.85	770.2	0															
27-0031	Bde Maka Ska	01/27/20	10:32		15	2.5	55.1	7.37	7.8	791	2															
27-0031	Bde Maka Ska	01/27/20	10:31		16	2.5	52.3	6.99	7.76	807.8	0															
27-0031	Bde Maka Ska	01/27/20	10:31		17	2.53	52.4	7	7.73	830.1	1															
27-0031	Bde Maka Ska	01/27/20	10:30		18	2.56	53.5	7.14	7.73	846.8	0				0.064	0.044										
27-0031	Bde Maka Ska	01/27/20	10:29		19	2.59	50.6	6.75	7.7	875.2	0															
27-0031	Bde Maka Ska	01/27/20	10:28		20	2.76	10.3	1.37	7.55	909.7	0															
27-0031	Bde Maka Ska	01/27/20	10:27		21	2.85	1.7	0.23	7.53	923.7	0															
27-0031	Bde Maka Ska	01/27/20	10:27		22	2.94	0	0	7.55	930.1	0				0.163	0.120							180	11.0		
27-0031	Bde Maka Ska	01/27/20	10:26		23	3.05	0	0	7.5	949	2															
27-0031	Bde Maka Ska	01/27/20	10:25		24	3.13	0	0	7.42	968.1	21.2															
27-0031	Bde Maka Ska	01/27/20	10:24		24.6	3.37	0	0	7.2	972.3	0															
27-0031	Bde Maka Ska	04/30/20	9:19	4.9	0	10.34	99.5	10.89	8.31	756.4		2.73	2.48	<0.500	<0.010	0.005	0.635	0.758	0.115	0.282	140	164	145	10.0		
27-0031	Bde Maka Ska	04/30/20	9:18		1	10.31	99.6	10.91	8.31	756.1																
27-0031	Bde Maka Ska	04/30/20	9:18		2	10.19	99.7	10.95	8.3	756.6																
27-0031	Bde Maka Ska	04/30/20	9:17		3	10.12	99.4	10.94	8.3	756.3																
27-0031	Bde Maka Ska	04/30/20	9:17		4	9.55	98.3	10.96	8.26	753.4																
27-0031	Bde Maka Ska	04/30/20	9:16		5	8.63	98.3	11.21	8.25	756.3																
27-0031	Bde Maka Ska	04/30/20	9:16		6	8.06	97.7	11.29	8.24	754.8					0.031	0.006										
27-0031	Bde Maka Ska	04/30/20	9:15		7	7.98	96.1	11.13	8.23	753.8																
27-0031	Bde Maka Ska	04/30/20	9:15		8	7.6	95	11.1	8.21	753.9																
27-0031	Bde Maka Ska	04/30/20	9:14		9	7.55	94.7	11.08	8.21	754																
27-0031	Bde Maka Ska	04/30/20	9:14		10	7.31	93.1	10.96	8.19	754.1																
27-0031	Bde Maka Ska	04/30/20	9:13		11	7.04	92	10.91	8.18	754.1																
27-0031	Bde Maka Ska	04/30/20	9:13		12	6.93	91.9	10.93	8.17	754.2					0.052	0.008										
27-0031	Bde Maka Ska	04/30/20	9:12		13	6.91	91.8	10.92	8.17	753.7																
27-0031	Bde Maka Ska	04/30/20	9:12		14	6.85	91.2	10.86	8.16	754.3																
27-0031	Bde Maka Ska	04/30/20	9:11		15	6.8	90.1	10.75	8.16	765																
27-0031	Bde Maka Ska	04/30/20	9:10		16	6.61	88.5	10.6	8.13	754.7																
27-0031	Bde Maka Ska	04/30/20	9:10		17	6.6	88	10.55	8.13	753.8																
27-0031	Bde Maka Ska	04/30/20	9:09		18	6.61	88	10.54	8.13	773.7					0.028	0.011										
27-0031	Bde Maka Ska	04/30/20	9:09		19	6.56	87.8	10.54	8.13	764.8																
27-0031	Bde Maka Ska	04/30/20	9:08		20	6.54	87.4	10.5	8.12	755.1																
27-0031	Bde Maka Ska	04/30/20	9:08		21	6.55	86.9	10.43	8.1	754.6																
27-0031	Bde Maka Ska	04/30/20	9:07		22	6.5	85.9	10.32	8.1	754.5					0.031	0.011							150	9.04		
27-0031	Bde Maka Ska	04/30/20	9:06		23	6.64	7.6	0.9	7.42	766																
27-0031	Bde Maka Ska	05/14/20	10:09	5.74	0	12.49	105.7	10.96	8.76	749.6	0	4.4	<0.500	<0.500	0.037	0.004	0.778	0.889	0.102	0.343	141	164	150	9.52		
27-0031	Bde Maka Ska	05/14/20	10:08		1	12.39	106.2	11.03	8.77	749.5	0															
27-0031	Bde Maka Ska	05/14/20	10:07		2	12.23	106.9	11.14	8.76	749.7	0															
27-0031	Bde Maka Ska	05/14/20	10:06		3	12.01	104.8	10.98	8.73	748.6	0															
27-0031	Bde Maka Ska	05/14/20	10:05		4	11.6	102.4	10.83	8.7	747.5	0															
27-0031	Bde Maka Ska	05/14/20	10:05		5	11.41	100.2	10.65	8.67	748.1	0															
27-0031	Bde Maka Ska	05/14/20	10:04		6	11.38	99.9	10.62	8.64	747.9	0				0.036	0.006										
27-0031	Bde Maka Ska	05/14/20	10:03		7	11.29	97.3	10.37	8.57	748.5	0															

Lake ID	Lake Name	Date MM/DD/YY	Time HH:MM :SS	Secchi meters	Depth meters	Temp °C	%DO	DO mg/L	pH units	SpCond µS/cm	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/10 0mL	DOC mg/L
27-0031	Bde Maka Ska	05/14/20	10:02		8	9.8	84	9.26	8.36	743.1	0															
27-0031	Bde Maka Ska	05/14/20	10:01		9	8.29	73.6	8.42	8.28	743.8	0															
27-0031	Bde Maka Ska	05/14/20	10:00		10	7.58	67.7	7.88	8.25	744.9	0															
27-0031	Bde Maka Ska	05/14/20	9:59		11	7.41	69.7	8.15	8.25	744.5	0															
27-0031	Bde Maka Ska	05/14/20	9:58		12	7.16	70.6	8.3	8.24	743.4	0				0.051	0.032										
27-0031	Bde Maka Ska	05/14/20	9:57		13	6.98	66.2	7.81	8.22	744.9	0															
27-0031	Bde Maka Ska	05/14/20	9:56		14	6.93	64.7	7.65	8.22	744.8	0															
27-0031	Bde Maka Ska	05/14/20	9:54		15	6.91	63.8	7.54	8.21	744.8	0															
27-0031	Bde Maka Ska	05/14/20	9:53		16	6.91	63.3	7.49	8.21	744.9	0															
27-0031	Bde Maka Ska	05/14/20	9:52		17	6.89	62.2	7.36	8.2	744.9	0															
27-0031	Bde Maka Ska	05/14/20	9:51		18	6.83	59	7	8.19	745.7	0				0.067	0.048										
27-0031	Bde Maka Ska	05/14/20	9:49		19	6.85	58.5	6.93	8.19	745.3	0															
27-0031	Bde Maka Ska	05/14/20	9:48		20	6.8	56.2	6.67	8.17	746.1	0															
27-0031	Bde Maka Ska	05/14/20	9:47		21	6.84	56.3	6.67	8.17	745.9	0															
27-0031	Bde Maka Ska	05/14/20	9:45		22	6.8	56.3	6.68	8.13	746.7	0				0.084	0.057							145	9.14		
27-0031	Bde Maka Ska	05/14/20	9:43		23	6.89	56.4	6.68	8.06	745.4	0															
27-0031	Bde Maka Ska	05/14/20	9:42		24	6.91	54.4	6.43	8.03	745.8	0															
27-0031	Bde Maka Ska	05/14/20	9:42		25	6.87	51.3	6.08	7.94	746.7	263.4															
27-0031	Bde Maka Ska	05/28/20	9:11	4.06	0	20.41	114.9	10.12	8.55	723	0	<0.500	<0.500		0.018	0.005		<0.500					130			
27-0031	Bde Maka Ska	05/28/20	9:10		1	20.43	115.2	10.15	8.54	722.4	0															
27-0031	Bde Maka Ska	05/28/20	9:09		2	20.36	115.7	10.21	8.54	723.7	0															
27-0031	Bde Maka Ska	05/28/20	9:09		3	20.1	116	10.28	8.52	722.8	0															
27-0031	Bde Maka Ska	05/28/20	9:08		4	14.36	103.6	10.36	8.34	747.2	0															
27-0031	Bde Maka Ska	05/28/20	9:07		5	13.32	98.3	10.05	8.28	746.4	0															
27-0031	Bde Maka Ska	05/28/20	9:06		6	12.39	91.1	9.51	8.19	747.6	0				0.029	0.003										
27-0031	Bde Maka Ska	05/28/20	9:05		7	12.04	84.6	8.9	8.1	748.8	0															
27-0031	Bde Maka Ska	05/28/20	9:04		8	10.5	68.2	7.44	7.88	753.4	0															
27-0031	Bde Maka Ska	05/28/20	9:03		9	9.1	56.4	6.36	7.74	754.1	0															
27-0031	Bde Maka Ska	05/28/20	9:02		10	8.6	50.8	5.79	7.68	755.8	0															
27-0031	Bde Maka Ska	05/28/20	9:02		11	7.98	43.4	5.03	7.63	756.2	0															
27-0031	Bde Maka Ska	05/28/20	9:01		12	7.45	47.8	5.6	7.65	755.7	0				0.079	0.058										
27-0031	Bde Maka Ska	05/28/20	9:00		13	6.9	41.6	4.94	7.6	755.2	0															
27-0031	Bde Maka Ska	05/28/20	8:59		14	6.86	39.7	4.72	7.59	755.4	0															
27-0031	Bde Maka Ska	05/28/20	8:58		15	6.83	38.5	4.59	7.58	755.4	0															
27-0031	Bde Maka Ska	05/28/20	8:57		16	6.82	38	4.53	7.57	755.6	0															
27-0031	Bde Maka Ska	05/28/20	8:56		17	6.79	34.3	4.09	7.55	756.1	0.3															
27-0031	Bde Maka Ska	05/28/20	8:55		18	6.78	33.8	4.03	7.54	756.2	0.3				0.117	0.100										
27-0031	Bde Maka Ska	05/28/20	8:54		19	6.78	33.3	3.97	7.53	756.3	0.3															
27-0031	Bde Maka Ska	05/28/20	8:53		20	6.78	32.4	3.87	7.52	756.2	402															
27-0031	Bde Maka Ska	05/28/20	8:52		21	6.79	19.8	2.37	7.5	756.5	19.2															
27-0031	Bde Maka Ska	05/28/20	8:51		22	6.79	16.1	1.91	7.39	756.5	3.2				0.113	0.091							135			
27-0031	Bde Maka Ska	05/28/20	8:51		23	6.8	0	0	7.02	729.8	2.3															
27-0031	Bde Maka Ska	05/28/20	8:42		24	6.82	18.1	2.16	7.13	820.9	17.9															
27-0031	Bde Maka Ska	05/28/20	8:41		25	7.54	0.2	0.02	6.87	821.9	1.6															
27-0031	Bde Maka Ska	06/11/20	8:46	2.77	0	21.44	103.7	8.95	8.75	726.9	2.2	8.50	1.86	0.585	0.032	0.003		<0.500					145			
27-0031	Bde Maka Ska	06/11/20	8:45		1	21.45	103.3	8.91	8.76	726.8	1.5															
27-0031	Bde Maka Ska	06/11/20	8:44		2	21.44	103.6	8.94	8.74	726.8	1.1															
27-0031	Bde Maka Ska	06/11/20	8:43		3	21.41	103.3	8.92	8.73	726.9	0.1															
27-0031	Bde Maka Ska	06/11/20	8:42		4	21.13	102.1	8.86	8.71	728.2	0															
27-0031	Bde Maka Ska	06/11/20	8:41		5	15.92	104.9	10.13	8.37	748.2	0															
27-0031	Bde Maka Ska	06/11/20	8:41		6	13.26	84.4	8.63	8.11	749	0				0.027	0.003										
27-0031	Bde Maka Ska	06/11/20	8:40		7	12.14	69.1	7.25	7.93	751.6	0															
27-0031	Bde Maka Ska	06/11/20	8:38		8	10.63	53.1	5.76	7.77	755.4	0															
27-0031	Bde Maka Ska	06/11/20	8:38		9	9.94	44.8	4.94	7.7	756.2	0															
27-0031	Bde Maka Ska	06/11/20	8:37		10	8.82	36.1	4.1	7.65	757.9	0															
27-0031	Bde Maka Ska	06/11/20	8:36		11	8.23	32.8	3.77	7.63	757.6	0															
27-0031	Bde Maka Ska	06/11/20	8:35		12	7.79	33.4	3.88	7.63	757	0				0.071	0.053										
27-0031	Bde Maka Ska	06/11/20	8:35		13	7.47	31.7	3.71	7.62	757.5	0															

Lake ID	Lake Name	Date MM/DD/YY	Time HH:MM :SS	Secchi meters	Depth meters	Temp °C	%DO	DO mg/L	pH units	SpCond µS/cm	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/10 0mL	DOC mg/L
27-0031	Bde Maka Ska	06/11/20	8:34		14	7.26	29	3.42	7.6	757.4	0															
27-0031	Bde Maka Ska	06/11/20	8:33		15	7.01	25.1	2.97	7.58	757.9	0															
27-0031	Bde Maka Ska	06/11/20	8:32		16	6.98	23.1	2.74	7.57	757.8	0															
27-0031	Bde Maka Ska	06/11/20	8:32		17	6.96	22.7	2.69	7.57	758.2	0															
27-0031	Bde Maka Ska	06/11/20	8:31		18	6.94	21.7	2.58	7.55	758.2	0				0.125	0.104										
27-0031	Bde Maka Ska	06/11/20	8:30		19	6.93	20.4	2.43	7.54	758.6	0															
27-0031	Bde Maka Ska	06/11/20	8:29		20	6.91	19.9	2.37	7.53	758.7	0															
27-0031	Bde Maka Ska	06/11/20	8:28		21	6.91	18.6	2.21	7.51	758.5	0															
27-0031	Bde Maka Ska	06/11/20	8:27		22	6.91	17.7	2.1	7.5	758.7	0				0.146	0.131							150			
27-0031	Bde Maka Ska	06/11/20	8:27		22.6	6.93	16.2	1.93	7.49	759.5	0															
27-0031	Bde Maka Ska	06/25/20	8:49	3.5	0	22.97	119.6	10.02	8.69	722.3	0.3	3.50	<0.500		0.019	0.003		<0.500					140			
27-0031	Bde Maka Ska	06/25/20	8:48		1	22.9	119.5	10.03	8.69	722.4	0.3															
27-0031	Bde Maka Ska	06/25/20	8:47		2	22.57	117.1	9.88	8.67	722.7	0.2															
27-0031	Bde Maka Ska	06/25/20	8:47		3	22.38	115.4	9.78	8.64	723.5	0.2															
27-0031	Bde Maka Ska	06/25/20	8:45		4	22.08	105.5	8.99	8.45	725.1	0.1															
27-0031	Bde Maka Ska	06/25/20	8:44		5	20.29	70	6.17	8.05	741.8	0															
27-0031	Bde Maka Ska	06/25/20	8:43		6	15.83	66.3	6.42	7.73	751.4	0				0.018	0.003										
27-0031	Bde Maka Ska	06/25/20	8:42		7	11.96	52.7	5.55	7.65	750.8	0															
27-0031	Bde Maka Ska	06/25/20	8:41		8	10.57	43.1	4.69	7.61	757	0															
27-0031	Bde Maka Ska	06/25/20	8:40		9	9.43	30.2	3.37	7.57	758.7	0															
27-0031	Bde Maka Ska	06/25/20	8:39		10	8.68	18.1	2.06	7.55	758.8	0															
27-0031	Bde Maka Ska	06/25/20	8:38		11	8.38	22.2	2.54	7.57	758.5	0															
27-0031	Bde Maka Ska	06/25/20	8:38		12	8.06	22.2	2.56	7.57	758.5	0				0.086	0.062										
27-0031	Bde Maka Ska	06/25/20	8:37		13	7.72	27.1	3.15	7.58	757	0															
27-0031	Bde Maka Ska	06/25/20	8:36		14	7.45	19.1	2.24	7.56	757.1	0															
27-0031	Bde Maka Ska	06/25/20	8:35		15	7.21	14.9	1.75	7.54	758.4	0															
27-0031	Bde Maka Ska	06/25/20	8:34		16	7.08	15.1	1.78	7.55	758.4	0															
27-0031	Bde Maka Ska	06/25/20	8:33		17	7.01	7	0.83	7.54	759.8	0															
27-0031	Bde Maka Ska	06/25/20	8:31		18	6.91	0.8	0.09	7.54	760.3	0				0.177	0.147										
27-0031	Bde Maka Ska	06/25/20	8:30		19	6.87	0	0	7.56	760.8	0															
27-0031	Bde Maka Ska	06/25/20	8:29		20	6.86	0	0	7.57	761.2	0															
27-0031	Bde Maka Ska	06/25/20	8:28		21	6.89	0	0	7.59	761.8	0															
27-0031	Bde Maka Ska	06/25/20	8:26		22	6.87	0	0	7.62	762.3	0				0.194	0.168							140			
27-0031	Bde Maka Ska	06/25/20	8:25		23	6.82	0	0	7.62	763.9	0															
27-0031	Bde Maka Ska	06/25/20	8:24		24	6.86	0	0	7.66	767.4	0.6															
27-0031	Bde Maka Ska	06/25/20	8:23		24.8	7.38	0	0	7.66	772.5	62.5															
27-0031	Bde Maka Ska	07/09/20	9:40	2.58	0	27.88	115.9	8.82	8.63	703.1	0.5	5.67	1.50	1.198	0.014	0.002	<0.500	<0.500	<0.030	0.433	113	132	145	13.1		
27-0031	Bde Maka Ska	07/09/20	9:39		1	27.9	115.7	8.81	8.62	702.7	0.4															
27-0031	Bde Maka Ska	07/09/20	9:38		2	27.88	116	8.83	8.59	702.7	0.4															
27-0031	Bde Maka Ska	07/09/20	9:37		3	27.63	113.8	8.7	8.52	704.8	0.2															
27-0031	Bde Maka Ska	07/09/20	9:36		4	25.36	119.3	9.51	8.38	719.7	0.1															
27-0031	Bde Maka Ska	07/09/20	9:34		5	21.49	74.7	6.4	7.98	742.5	0															
27-0031	Bde Maka Ska	07/09/20	9:33		6	16.48	21	1.99	7.52	760.5	0				0.013	0.002										
27-0031	Bde Maka Ska	07/09/20	9:31		7	12.31	22.8	2.37	7.52	763.7	0															
27-0031	Bde Maka Ska	07/09/20	9:30		8	10.31	10.1	1.1	7.49	765.3	0															
27-0031	Bde Maka Ska	07/09/20	9:28		9	9.74	6.8	0.75	7.47	766.3	0															
27-0031	Bde Maka Ska	07/09/20	9:28		10	9.15	2.2	0.25	7.47	767.1	0															
27-0031	Bde Maka Ska	07/09/20	9:27		11	8.72	0	0	7.48	767	0															
27-0031	Bde Maka Ska	07/09/20	9:26		12	8.19	10.5	1.2	7.49	765.3	0				0.083	0.071										
27-0031	Bde Maka Ska	07/09/20	9:25		13	7.52	7.5	0.88	7.49	765.4	0															
27-0031	Bde Maka Ska	07/09/20	9:24		14	7.27	0	0	7.49	767.1	0															
27-0031	Bde Maka Ska	07/09/20	9:23		15	7.16	0	0	7.5	768.3	0															
27-0031	Bde Maka Ska	07/09/20	9:22		16	7.1	0	0	7.51	768.9	0															
27-0031	Bde Maka Ska	07/09/20	9:21		17	7.06	0	0	7.51	769	0															
27-0031	Bde Maka Ska	07/09/20	9:20		18	7.03	0	0	7.51	769.4	0				0.174	0.155										
27-0031	Bde Maka Ska	07/09/20	9:19		19	7.04	0	0	7.53	769.3	0															
27-0031	Bde Maka Ska	07/09/20	9:18		20	7.05	0	0	7.54	769	0															
27-0031	Bde Maka Ska	07/09/20	9:17		21	7.04	0	0	7.55	769	0															

Lake ID	Lake Name	Date MM/DD/YY	Time HH:MM :SS	Secchi meters	Depth meters	Temp °C	%DO	DO mg/L	pH units	SpCond µS/cm	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/10 0mL	DOC mg/L
27-0031	Bde Maka Ska	07/09/20	9:16		22	7	0	0	7.57	769.9	0				0.206	0.190							150	9.77		
27-0031	Bde Maka Ska	07/09/20	9:15		23	7	0	0	7.59	769.8	0															
27-0031	Bde Maka Ska	07/09/20	9:14		24	6.98	0	0	7.63	770.5	0															
27-0031	Bde Maka Ska	07/09/20	9:13		24.9	7.26	0	0	7.65	766.5	0															
27-0031	Bde Maka Ska	07/22/20	8:40	2.31	0	25.43	108.4	8.71	8.52	697	3.2	8.68	1.04		0.017	0.003		<0.500					135			
27-0031	Bde Maka Ska	07/22/20	8:39		1	25.46	108.6	8.72	8.5	696.9	3															
27-0031	Bde Maka Ska	07/22/20	8:38		2	25.44	108.5	8.71	8.49	696.9	0.3															
27-0031	Bde Maka Ska	07/22/20	8:37		3	25.45	109	8.75	8.46	697	0.1															
27-0031	Bde Maka Ska	07/22/20	8:36		4	25.38	111.1	8.93	8.37	697	0															
27-0031	Bde Maka Ska	07/22/20	8:35		5	23.62	28.4	2.36	7.6	727.1	0															
27-0031	Bde Maka Ska	07/22/20	8:34		6	18.49	2.8	0.26	7.5	755.9	0				0.011	0.004										
27-0031	Bde Maka Ska	07/22/20	8:33		7	14.45	0	0	7.47	764.8	0															
27-0031	Bde Maka Ska	07/22/20	8:32		8	11.17	0.6	0.06	7.47	764.6	0															
27-0031	Bde Maka Ska	07/22/20	8:31		9	10.12	1.8	0.19	7.47	765.3	0															
27-0031	Bde Maka Ska	07/22/20	8:30		10	9.26	2.2	0.24	7.47	766.2	0															
27-0031	Bde Maka Ska	07/22/20	8:29		11	8.61	1.5	0.17	7.48	767.1	0															
27-0031	Bde Maka Ska	07/22/20	8:28		12	8.03	0.9	0.11	7.48	765.8	0				0.114	0.084										
27-0031	Bde Maka Ska	07/22/20	8:28		13	7.78	0.8	0.09	7.49	766	0															
27-0031	Bde Maka Ska	07/22/20	8:27		14	7.56	0.4	0.04	7.5	767.1	0															
27-0031	Bde Maka Ska	07/22/20	8:26		15	7.45	0.2	0.02	7.5	767.1	0															
27-0031	Bde Maka Ska	07/22/20	8:24		16	7.3	0.1	0.02	7.52	767.7	0															
27-0031	Bde Maka Ska	07/22/20	8:23		17	7.14	0	0	7.53	768.7	0															
27-0031	Bde Maka Ska	07/22/20	8:22		18	7.06	0	0	7.54	769.5	0				0.215	0.199										
27-0031	Bde Maka Ska	07/22/20	8:21		19	7.02	0	0	7.56	770.1	0															
27-0031	Bde Maka Ska	07/22/20	8:19		20	7	0	0	7.59	770.3	0															
27-0031	Bde Maka Ska	07/22/20	8:18		21	6.99	0	0	7.61	770.6	0															
27-0031	Bde Maka Ska	07/22/20	8:17		22	6.99	0	0	7.65	770.8	0				0.241	0.219							145			
27-0031	Bde Maka Ska	07/22/20	8:16		23	7.04	0	0	7.7	770.1	19.7															
27-0031	Bde Maka Ska	07/22/20	8:14		24	7	0	0	7.78	770.6	84.3															
27-0031	Bde Maka Ska	07/22/20	8:13		24.2	6.98	0	0	7.9	771.6	0															
27-0031	Bde Maka Ska	08/05/20	10:26	1.97	0	24.25	116.6	9.58	8.6	690	4.2	9.4	2.0	2.6	0.019	0.004		<0.500					145		<1	
27-0031	Bde Maka Ska	08/05/20	10:26		1	24.26	116.4	9.56	8.59	689.8	3.9															
27-0031	Bde Maka Ska	08/05/20	10:25		2	24.19	117.2	9.64	8.59	689.5	2.8															
27-0031	Bde Maka Ska	08/05/20	10:24		3	24.11	116.3	9.58	8.55	690	2.4															
27-0031	Bde Maka Ska	08/05/20	10:23		4	23.99	117.2	9.67	8.47	690.5	3.2															
27-0031	Bde Maka Ska	08/05/20	10:21		5	23.71	110.9	9.2	8.09	692.9	2.9															
27-0031	Bde Maka Ska	08/05/20	10:20		6	18.95	0.8	0.07	7.47	765.3	0.4				0.017	0.002										
27-0031	Bde Maka Ska	08/05/20	10:19		7	14.33	0	0	7.43	770.3	1.4															
27-0031	Bde Maka Ska	08/05/20	10:18		8	11.2	2.1	0.22	7.42	772.3	1.2															
27-0031	Bde Maka Ska	08/05/20	10:17		9	9.78	1.8	0.2	7.41	771.1	0.7															
27-0031	Bde Maka Ska	08/05/20	10:16		10	9.13	1	0.11	7.41	772.5	0.3															
27-0031	Bde Maka Ska	08/05/20	10:14		11	8.76	1.3	0.15	7.42	772.8	0															
27-0031	Bde Maka Ska	08/05/20	10:13		12	8.38	0.9	0.11	7.43	769.6	0				0.086	0.066										
27-0031	Bde Maka Ska	08/05/20	10:12		13	7.94	0	0	7.43	768.7	0.4															
27-0031	Bde Maka Ska	08/05/20	10:11		14	7.38	0	0	7.42	771.2	2.4															
27-0031	Bde Maka Ska	08/05/20	10:10		15	7.25	0	0	7.41	771.6	80.8															
27-0031	Bde Maka Ska	08/05/20	10:09		16	7.15	0	0	7.4	773.2	4.2															
27-0031	Bde Maka Ska	08/05/20	10:08		17	7.1	0	0	7.4	875.3	346.8															
27-0031	Bde Maka Ska	08/05/20	10:06		18	7.09	0	0	7.38	879.3	247.3				0.231	0.210										
27-0031	Bde Maka Ska	08/05/20	10:05		19	7.07	0	0	7.34	881.1	141.4															
27-0031	Bde Maka Ska	08/05/20	10:04		20	7.09	0	0	7.35	880.3	40.1															
27-0031	Bde Maka Ska	08/05/20	10:02		21	7.07	0	0	7.35	880.2	37.8															
27-0031	Bde Maka Ska	08/05/20	10:01		22	7.1	0	0	7.34	880.4	36				0.293	0.257							153			
27-0031	Bde Maka Ska	08/05/20	10:00		23	7	0	0	7.35	883.3	31.7															
27-0031	Bde Maka Ska	08/05/20	9:59		24	7.02	0	0	7.33	882.6	27.7															
27-0031	Bde Maka Ska	08/05/20	9:58		24.7	7.69	0	0	7.29	854.9	5.4															
27-0031	Bde Maka Ska	08/19/20	8:38	3.47	0	24.13	107.6	8.87	8.46	678.2	0.3	3.10	1.18		0.015	0.004		<0.500					130			
27-0031	Bde Maka Ska	08/19/20	8:37		1	24.14	107.8	8.88	8.43	678.4	0.3															

Lake ID	Lake Name	Date MM/DD/YY	Time HH:MM :SS	Secchi meters	Depth meters	Temp °C	%DO	DO mg/L	pH units	SpCond µS/cm	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/10 0mL	DOC mg/L
27-0031	Bde Maka Ska	08/19/20	8:35		2	24	105.7	8.73	8.4	678.4	0.3															
27-0031	Bde Maka Ska	08/19/20	8:34		3	23.78	102.7	8.52	8.36	679	0.3															
27-0031	Bde Maka Ska	08/19/20	8:33		4	23.62	98.8	8.22	8.28	679.6	0.3															
27-0031	Bde Maka Ska	08/19/20	8:31		5	23.4	86.9	7.26	8.11	681.5	0.4															
27-0031	Bde Maka Ska	08/19/20	8:29		6	22.2	41.3	3.53	7.56	695.6	0.6				0.016	0.003										
27-0031	Bde Maka Ska	08/19/20	8:27		7	16.67	3.3	0.32	7.42	766	0.6															
27-0031	Bde Maka Ska	08/19/20	8:26		8	11.72	4.8	0.51	7.42	774	0.6															
27-0031	Bde Maka Ska	08/19/20	8:25		9	10.29	3.1	0.34	7.41	769.5	0.4															
27-0031	Bde Maka Ska	08/19/20	8:23		10	9.49	0	0	7.4	769.1	0															
27-0031	Bde Maka Ska	08/19/20	8:22		11	9.04	5.4	0.61	7.39	770.4	0															
27-0031	Bde Maka Ska	08/19/20	8:21		12	8.58	7	0.81	7.4	770.9	0				0.079	0.039										
27-0031	Bde Maka Ska	08/19/20	8:20		13	8.02	1.9	0.23	7.4	768.4	0															
27-0031	Bde Maka Ska	08/19/20	8:19		14	7.6	2	0.23	7.39	769.5	0															
27-0031	Bde Maka Ska	08/19/20	8:18		15	7.32	1.8	0.21	7.38	771.2	0															
27-0031	Bde Maka Ska	08/19/20	8:16		16	7.22	1.8	0.21	7.37	772.1	0															
27-0031	Bde Maka Ska	08/19/20	8:15		17	7.15	1.7	0.2	7.37	773.4	0															
27-0031	Bde Maka Ska	08/19/20	8:13		18	7.1	1.7	0.2	7.36	773.6	0				0.244	0.202										
27-0031	Bde Maka Ska	08/19/20	8:11		19	7.08	1.4	0.17	7.35	774.1	0															
27-0031	Bde Maka Ska	08/19/20	8:10		20	7.08	1.3	0.16	7.34	774.1	0															
27-0031	Bde Maka Ska	08/19/20	8:08		21	7.06	1.5	0.18	7.36	774.3	0															
27-0031	Bde Maka Ska	08/19/20	8:06		22	7.06	1.3	0.16	7.36	774.2	0				0.266	0.228							135			
27-0031	Bde Maka Ska	08/19/20	8:04		23	7.05	1.3	0.15	7.35	774.5	0															
27-0031	Bde Maka Ska	08/19/20	8:02		24	7.06	1.1	0.13	7.3	775.4	0															
27-0031	Bde Maka Ska	08/19/20	8:01		25	8.38	1.3	0.15	7.02	772.6	1.9															
27-0031	Bde Maka Ska	09/04/20	8:34	2.67	0	21.53	92.6	8.01	8.44	692.6	40.9	2.7	0.96	2.8	0.015	0.003		<0.500					145			
27-0031	Bde Maka Ska	09/04/20	8:34		1	21.54	92.7	8.02	8.44	692.4	46															
27-0031	Bde Maka Ska	09/04/20	8:32		2	21.53	92.8	8.02	8.42	692.7	0.7															
27-0031	Bde Maka Ska	09/04/20	8:31		3	21.51	92.6	8.01	8.4	692.7	0.6															
27-0031	Bde Maka Ska	09/04/20	8:29		4	21.5	92.8	8.03	8.36	692.8	0.5															
27-0031	Bde Maka Ska	09/04/20	8:28		5	21.5	92.5	8.01	8.33	692.8	0.5															
27-0031	Bde Maka Ska	09/04/20	8:26		6	21.42	93	8.06	8.19	693	0.5				0.015	0.003										
27-0031	Bde Maka Ska	09/04/20	8:24		7	18.24	2.6	0.24	7.46	766.8	0.5															
27-0031	Bde Maka Ska	09/04/20	8:22		8	12.38	0.2	0.02	7.45	776.9	0.6															
27-0031	Bde Maka Ska	09/04/20	8:19		9	10.82	1.6	0.17	7.44	777.7	0.7															
27-0031	Bde Maka Ska	09/04/20	8:18		10	9.73	2.2	0.24	7.44	777.8	0.7															
27-0031	Bde Maka Ska	09/04/20	8:14		11	9.16	1.8	0.21	7.42	779.9	0															
27-0031	Bde Maka Ska	09/04/20	8:13		12	8.54	1.3	0.15	7.44	777.2	0				0.098	0.065										
27-0031	Bde Maka Ska	09/04/20	8:12		13	8.04	0.6	0.07	7.44	777	0															
27-0031	Bde Maka Ska	09/04/20	8:10		14	7.78	0.4	0.04	7.44	777.7	0															
27-0031	Bde Maka Ska	09/04/20	8:08		15	7.42	0	0	7.44	778.9	0															
27-0031	Bde Maka Ska	09/04/20	8:06		16	7.33	0	0	7.45	779.8	0															
27-0031	Bde Maka Ska	09/04/20	8:05		17	7.23	0	0	7.46	781.6	0															
27-0031	Bde Maka Ska	09/04/20	8:03		18	7.19	0	0	7.51	783	0				0.253	0.245										
27-0031	Bde Maka Ska	09/04/20	8:01		19	7.22	0	0	7.57	781.3	0															
27-0031	Bde Maka Ska	09/04/20	8:00		20	7.34	0.1	0.01	7.67	779.3	0															
27-0031	Bde Maka Ska	09/04/20	7:59		21	7.36	0	0	7.79	778.1	0															
27-0031	Bde Maka Ska	09/04/20	7:55		22	7.16	0	0	7.55	782.2	0				0.278	0.270							140			
27-0031	Bde Maka Ska	09/04/20	7:53		23	7.11	0	0	7.58	784.4	0															
27-0031	Bde Maka Ska	09/04/20	7:51		24	7.1	0	0	7.7	784.9	0															
27-0031	Bde Maka Ska	09/04/20	7:51		25	7.11	0	0	7.72	785	0															
27-0031	Bde Maka Ska	09/17/20	8:27	2.90	0	18.232	87	8.19	8.45	694.6	0.88	7.35	6.99		0.015	0.003		<0.500					130			
27-0031	Bde Maka Ska	09/17/20	8:26		1	18.234	86.7	8.16	8.46	694.7	0.92															
27-0031	Bde Maka Ska	09/17/20	8:25		2	18.235	86.4	8.12	8.48	694.7	0.87															
27-0031	Bde Maka Ska	09/17/20	8:24		3	18.232	85.8	8.07	8.51	694.7	0.92															
27-0031	Bde Maka Ska	09/17/20	8:23		4	18.228	85.4	8.03	8.53	694.6	0.81															
27-0031	Bde Maka Ska	09/17/20	8:22		5	18.221	84.7	7.97	8.59	694.7	0.75															
27-0031	Bde Maka Ska	09/17/20	8:21		6	18.177	81.1	7.63	8.53	694.2	0.92				0.018	0.009										
27-0031	Bde Maka Ska	09/17/20	8:20		7	17.346	49.1	4.7	8.12	703.1	1.13															

Lake ID	Lake Name	Date MM/DD/YY	Time HH:MM :SS	Secchi meters	Depth meters	Temp °C	%DO	DO mg/L	pH units	SpCond µS/cm	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/10 0mL	DOC mg/L
27-0031	Bde Maka Ska	09/17/20	8:19		8	13.495	0	0	7.74	775.8	1.1															
27-0031	Bde Maka Ska	09/17/20	8:17		9	10.551	0	0	7.69	778.8	1.78															
27-0031	Bde Maka Ska	09/17/20	8:16		10	9.462	0	0	7.64	783.1	1.61															
27-0031	Bde Maka Ska	09/17/20	8:15		11	8.984	0	0	7.63	779.9	1.32															
27-0031	Bde Maka Ska	09/17/20	8:14		12	8.439	0	0	7.62	779.6	0.74				0.109	0.076										
27-0031	Bde Maka Ska	09/17/20	8:13		13	8.026	0	0	7.59	779.9	0.62															
27-0031	Bde Maka Ska	09/17/20	8:13		14	7.715	0	0	7.58	783.2	0.76															
27-0031	Bde Maka Ska	09/17/20	8:12		15	7.602	0	0	7.61	784.3	0.77															
27-0031	Bde Maka Ska	09/17/20	8:11		16	7.492	0	0	7.56	785.9	1.09															
27-0031	Bde Maka Ska	09/17/20	8:10		17	7.39	0	0	7.53	787.3	1.15															
27-0031	Bde Maka Ska	09/17/20	8:09		18	7.356	0	0	7.54	788.1	1				0.282	0.252										
27-0031	Bde Maka Ska	09/17/20	8:08		19	7.343	0	0	7.54	788.3	0.7															
27-0031	Bde Maka Ska	09/17/20	8:06		20	7.31	0	0	7.54	789.6	0.97															
27-0031	Bde Maka Ska	09/17/20	8:03		21	7.295	0	0	7.49	790.2	0.84															
27-0031	Bde Maka Ska	09/17/20	8:02		22	7.281	0	0	7.42	791.3	3.33				0.333	0.324							135			
27-0031	Bde Maka Ska	09/17/20	8:01		23	7.296	0	0	7.42	791.3	3.29															
27-0031	Bde Maka Ska	09/17/20	7:59		24	7.277	0	0	7.44	797.4	5.37															
27-0031	Bde Maka Ska	09/17/20	7:56		25	7.351	0.1	0.01	7.28	820.3	2.33															
27-0031	Bde Maka Ska	10/27/20	10:29	2.93	0	7.632	56.8	6.78	7.78	725.5	1.26	1.70	<0.500	2.63	0.053	0.020	0.633	0.703	0.030	0.509	133	152	135	9.55		
27-0031	Bde Maka Ska	10/27/20	10:28		1	7.643	56.6	6.75	7.78	725.6	1.28															
27-0031	Bde Maka Ska	10/27/20	10:26		2	7.645	56.5	6.73	7.78	725.6	1.37															
27-0031	Bde Maka Ska	10/27/20	10:25		3	7.644	56.3	6.71	7.78	725.6	1.4															
27-0031	Bde Maka Ska	10/27/20	10:25		4	7.646	56.2	6.7	7.78	725.7	1.33															
27-0031	Bde Maka Ska	10/27/20	10:24		5	7.642	55.7	6.65	7.77	725.6	1.27															
27-0031	Bde Maka Ska	10/27/20	10:23		6	7.648	55.4	6.61	7.77	725.8	1.22				0.063	0.020										
27-0031	Bde Maka Ska	10/27/20	10:22		7	7.646	55.2	6.58	7.77	725.7	1.32															
27-0031	Bde Maka Ska	10/27/20	10:21		8	7.645	55.4	6.6	7.77	725.8	1.35															
27-0031	Bde Maka Ska	10/27/20	10:21		9	7.64	55.4	6.6	7.77	725.7	1.25															
27-0031	Bde Maka Ska	10/27/20	10:20		10	7.643	55.2	6.58	7.77	725.7	1.25															
27-0031	Bde Maka Ska	10/27/20	10:19		11	7.647	55	6.56	7.76	725.6	1.32															
27-0031	Bde Maka Ska	10/27/20	10:18		12	7.644	54	6.43	7.76	726.3	1.31				0.057	0.019										
27-0031	Bde Maka Ska	10/27/20	10:16		13	7.643	54.4	6.49	7.76	726	1.23															
27-0031	Bde Maka Ska	10/27/20	10:15		14	7.638	54.5	6.49	7.75	726	1.32															
27-0031	Bde Maka Ska	10/27/20	10:14		15	7.64	54.6	6.51	7.75	725.8	1.3															
27-0031	Bde Maka Ska	10/27/20	10:13		16	7.645	53.9	6.42	7.74	726	1.27															
27-0031	Bde Maka Ska	10/27/20	10:11		17	7.656	52.8	6.29	7.71	726	1.27															
27-0031	Bde Maka Ska	10/27/20	10:08		18	7.674	37	4.41	7.57	738.5	1.92				0.108	0.072										
27-0031	Bde Maka Ska	10/27/20	10:06		19	7.666	29.6	3.53	7.52	744.2	2.88															
27-0031	Bde Maka Ska	10/27/20	10:05		20	7.651	25.1	2.99	7.5	748.7	3.64															
27-0031	Bde Maka Ska	10/27/20	10:04		21	7.62	23.1	2.75	7.47	750.1	4.05															
27-0031	Bde Maka Ska	10/27/20	10:04		22	7.508	20.9	2.5	7.43	752.5	45.75				0.157	0.126							135	8.62		
27-0031	Bde Maka Ska	10/27/20	10:02		23	7.349	2.1	0.25	7.31	777	7.02															
27-0038	Brownie	01/23/20	10:46		0	0.54	11.4	1.59	7.41	1088	4	10.8	3.72	11.40	0.061	0.006	0.935	1.161	0.121	0.600	196.0	288	340	20.63		
27-0038	Brownie	01/23/20	10:45		1	5.34	2	0.24	7.24	1692	7.7															
27-0038	Brownie	01/23/20	10:45		2	6.98	2	0.23	7.19	2095	5.1															
27-0038	Brownie	01/23/20	10:44		3	7.49	1.9	0.23	7.14	2435	5.5															
27-0038	Brownie	01/23/20	10:40		4	6.57	2	0.24	6.84	3707	10.6															
27-0038	Brownie	01/23/20	10:43		5	7.47	2	0.23	7.02	2923	5.9															
27-0038	Brownie	01/23/20	10:38		6	6.53	2	0.24	6.89	3819	8.8				0.720	0.005										
27-0038	Brownie	01/23/20	10:43		7	7.38	2	0.24	6.93	3401	5.4															
27-0038	Brownie	01/23/20	10:39		8	6.52	2	0.23	6.87	3781	13.1															
27-0038	Brownie	01/23/20	10:41		9	7.11	2	0.23	6.88	3577	7.9															
27-0038	Brownie	01/23/20	10:37		10	6.66	2.1	0.25	6.96	3925	17.1															
27-0038	Brownie	01/23/20	10:41		11	6.84	2	0.24	6.87	3659	9.1															
27-0038	Brownie	01/23/20	10:38		12	6.6	2	0.24	6.91	3866	18.9				4.206	0.018							1050	6.74		
27-0038	Brownie	01/23/20	10:37		13	6.66	2.2	0.25	6.97	4008	19.3															
27-0038	Brownie	01/23/20	10:35		14	6.69	2.1	0.25	7.03	3342	333															
27-0038	Brownie	04/29/20	9:09	0.66	0	13.01	107.4	10.98	8.3	1530		16.3	4.97	5.18	0.051	0.003	<0.500	0.574	0.045	<0.250	151	252	360	18.9		

Lake ID	Lake Name	Date MM/DD/YY	Time HH:MM :SS	Secchi meters	Depth meters	Temp °C	%DO	DO mg/L	pH units	SpCond µS/cm	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/10 0mL	DOC mg/L
27-0038	Brownie	04/29/20	9:09		1	13.02	114.1	11.67	8.29	1530																
27-0038	Brownie	04/29/20	9:08		2	12.02	148	15.46	8.14	1906																
27-0038	Brownie	04/29/20	9:07		3	9.88	3	0.33	7.14	2832																
27-0038	Brownie	04/29/20	9:07		4	7.24	0	0	6.88	3373																
27-0038	Brownie	04/29/20	9:05		5	6.96	0	0	6.78	3534																
27-0038	Brownie	04/29/20	9:04		6	6.82	0	0	6.73	3624					1.667	0.100										
27-0038	Brownie	04/29/20	9:04		7	6.68	0	0	6.67	3714																
27-0038	Brownie	04/29/20	9:04		8	6.65	0	0	6.65	3809																
27-0038	Brownie	04/29/20	9:03		9	6.69	0	0	6.68	3891																
27-0038	Brownie	04/29/20	9:02		10	6.78	0	0	6.7	4003																
27-0038	Brownie	04/29/20	9:01		11	6.78	0	0	6.72	4036																
27-0038	Brownie	04/29/20	9:01		12	6.84	0	0	6.74	4066					3.284	0.101							1075	9.39		
27-0038	Brownie	05/11/20	10:11	0.97	0	13.37	110.3	11.36	8.74	1630	52.4	10.9	3.31	5.13	0.040	0.003	<0.500	0.566	<0.030	<0.250	172	264	410	22.3		
27-0038	Brownie	05/11/20	10:10		1	13.22	109.4	11.3	8.73	1631	26.7															
27-0038	Brownie	05/11/20	10:09		2	13.04	108	11.2	8.65	1624	24.6															
27-0038	Brownie	05/11/20	10:08		3	10.39	0	0	7.38	2945	81.6															
27-0038	Brownie	05/11/20	10:07		4	7.8	0	0	7.21	3362	3.6															
27-0038	Brownie	05/11/20	10:06		5	7.14	0	0	7.12	3525	3.5															
27-0038	Brownie	05/11/20	10:04		6	6.97	0	0	7.04	3611	4.4				1.740	0.013										
27-0038	Brownie	05/11/20	10:02		7	6.89	0	0	6.98	3681	5.3															
27-0038	Brownie	05/11/20	10:01		8	6.86	0	0	6.95	3756	6															
27-0038	Brownie	05/11/20	10:00		9	6.84	0	0	6.95	3826	6.5															
27-0038	Brownie	05/11/20	9:59		10	6.91	0	0	6.96	3928	7															
27-0038	Brownie	05/11/20	9:58		11	6.98	0	0	6.95	3990	7.6															
27-0038	Brownie	05/11/20	9:57		12	6.99	0	0	6.92	4026	8.3				3.058	0.013							1100	8.28		
27-0038	Brownie	05/11/20	9:56		13	7.07	0	0	6.88	4038	8.5															
27-0038	Brownie	06/08/20	9:26	1.55	0	24.28	117.1	9.51	8.37	1140	4.7	13.76	4.03	0.993	0.045	0.004		0.504					280			
27-0038	Brownie	06/08/20	9:24		1	23.49	107.8	8.89	8.15	1154	5.6															
27-0038	Brownie	06/08/20	9:23		2	21.05	81	6.99	7.65	1267	6.5															
27-0038	Brownie	06/08/20	9:22		3	15.54	7.4	0.72	7.21	1923	7															
27-0038	Brownie	06/08/20	9:22		4	9.54	0	0	6.81	3309	7.5															
27-0038	Brownie	06/08/20	9:21		5	7.61	0	0	6.71	3514	6.4															
27-0038	Brownie	06/08/20	9:20		6	6.99	0	0	6.65	3605	6.8				1.704	0.016										
27-0038	Brownie	06/08/20	9:19		7	6.81	0	0	6.6	3688	7.7															
27-0038	Brownie	06/08/20	9:18		8	6.81	0	0	6.56	3775	8.8															
27-0038	Brownie	06/08/20	9:17		9	6.76	0	0	6.57	3856	9.5															
27-0038	Brownie	06/08/20	9:16		10	6.99	0	0	6.57	3946	10.2															
27-0038	Brownie	06/08/20	9:15		11	6.85	0	0	6.55	4013	10.8															
27-0038	Brownie	06/08/20	9:14		12	7.05	0	0	6.53	4003	11.3				3.178	0.018							1090			
27-0038	Brownie	06/08/20	9:13		13	7.18	0	0	6.5	4010	11.9															
27-0038	Brownie	06/08/20	9:12		13.9	7.01	0	0	6.48	4058	12															
27-0038	Brownie	07/06/20	11:58	1.31	0	28.4	124.8	9.47	8.19	1072	8.9	22.2	2.15	3.85	0.053	0.004	0.929	1.010	<0.030	0.478	102	164	250	14.7		
27-0038	Brownie	07/06/20	11:57		1	28.18	113.1	8.62	7.87	1060	9.7															
27-0038	Brownie	07/06/20	11:56		2	23.75	56.1	4.63	7.29	1354	10.7															
27-0038	Brownie	07/06/20	11:55		3	18.27	5	0.46	7.05	1770	11.3															
27-0038	Brownie	07/06/20	11:54		4	10.97	1.8	0.19	6.74	3251	8.3															
27-0038	Brownie	07/06/20	11:53		5	8.58	0	0	6.67	3458	6.6															
27-0038	Brownie	07/06/20	11:53		6	7.46	0	0	6.62	3548	6.3				1.446	0.016										
27-0038	Brownie	07/06/20	11:52		7	7.02	0	0	6.58	3631	6.8															
27-0038	Brownie	07/06/20	11:51		8	6.98	0	0	6.54	3690	7.3															
27-0038	Brownie	07/06/20	11:49		9	6.96	0	0	6.56	3795	8.3															
27-0038	Brownie	07/06/20	11:48		10	7.11	0	0	6.58	3866	9															
27-0038	Brownie	07/06/20	11:47		11	7.32	0	0	6.6	3893	9.7															
27-0038	Brownie	07/06/20	11:46		12	7.49	0	0	6.61	3901	10.6				3.466	0.020							1150	7.4		
27-0038	Brownie	07/06/20	11:45		12.9	8.61	0	0	6.67	3833	11.6															
27-0038	Brownie	08/03/20	11:30	0.86	0	25.16	102.6	8.31	7.81	1213	5.7	17.8	3.6	1.1	0.032	0.003		<0.500					275			
27-0038	Brownie	08/03/20	11:30		1	24.49	100.4	8.23	7.77	1204	5.9															
27-0038	Brownie	08/03/20	11:28		2	24.2	81.9	6.75	7.47	1215	6.7															

Lake ID	Lake Name	Date MM/DD/YY	Time HH:MM :SS	Secchi meters	Depth meters	Temp °C	%DO	DO mg/L	pH units	SpCond µS/cm	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/10 0mL	DOC mg/L
27-0038	Brownie	08/03/20	11:27		3	20.16	4.9	0.43	6.98	1942	7.8															
27-0038	Brownie	08/03/20	11:26		4	12.09	0.2	0.02	6.75	3354	7.7															
27-0038	Brownie	08/03/20	11:25		5	8.91	0.2	0.02	6.69	3566	6.2															
27-0038	Brownie	08/03/20	11:24		6	7.46	0	0	6.66	3666	6.3				1.888	0.012										
27-0038	Brownie	08/03/20	11:23		7	6.95	0	0	6.64	3748	6.7															
27-0038	Brownie	08/03/20	11:22		8	6.85	0	0	6.63	3807	7.2															
27-0038	Brownie	08/03/20	11:21		9	6.81	0	0	6.65	3897	7.8															
27-0038	Brownie	08/03/20	11:20		10	6.86	0	0	6.71	4005	7.9															
27-0038	Brownie	08/03/20	11:17		11	7.14	1.1	0.13	6.8	4022	7.8															
27-0038	Brownie	08/03/20	11:16		12	7.4	3.3	0.38	6.87	3999	7.8				3.566	0.012							1050			
27-0038	Brownie	08/03/20	11:14		12.8	8.31	7.8	0.89	7.08	3971	21.4															
27-0038	Brownie	08/31/20	10:14	0.59	0	23.86	96.4	7.86	7.78	1133	50	10.0	5.3	4.5	0.045	0.003		0.780					270			
27-0038	Brownie	08/31/20	10:14		1	23.7	97.3	7.95	7.74	1125	10.1															
27-0038	Brownie	08/31/20	10:13		2	23.37	93.5	7.69	7.57	1085	10.8															
27-0038	Brownie	08/31/20	10:11		3	20.6	2.8	0.24	7.14	1589	11.3															
27-0038	Brownie	08/31/20	10:10		4	15.12	0	0	6.88	2973	8.3															
27-0038	Brownie	08/31/20	10:08		5	10.76	2.1	0.22	6.78	3521	5.1															
27-0038	Brownie	08/31/20	10:07		6	7.47	0	0	6.72	3687	5				1.601	0.004										
27-0038	Brownie	08/31/20	10:05		7	7.07	0	0	6.75	3752	5.4															
27-0038	Brownie	08/31/20	10:04		8	6.9	0	0	6.76	3814	5.8															
27-0038	Brownie	08/31/20	10:03		9	6.85	0	0	6.79	3874	6															
27-0038	Brownie	08/31/20	10:01		10	6.87	0	0	6.84	3974	6.4															
27-0038	Brownie	08/31/20	10:00		11	6.9	0	0	6.88	4002	6.6															
27-0038	Brownie	08/31/20	9:59		12	7.06	0	0	6.93	4009	7.3				3.430	0.008							1100			
27-0038	Brownie	08/31/20	9:58		13	7.19	0	0	6.99	4022	8.1															
27-0038	Brownie	10/23/20	10:41	1.57	0	7.28	22.7	2.72	7.42	1394.8	2.28	10.3	3.87	7.69	0.051	0.004	1.21	1.44	0.062	0.619	150.0	212	330	13.5		
27-0038	Brownie	10/23/20	10:40		1	7.286	22.3	2.67	7.41	1395.1	2.26															
27-0038	Brownie	10/23/20	10:39		2	7.294	21.6	2.59	7.39	1394.8	2.51															
27-0038	Brownie	10/23/20	10:39		3	7.281	20.5	2.46	7.48	1397.6	2.24															
27-0038	Brownie	10/23/20	10:37		4	9.641	0	0	6.92	3039.9	4.96															
27-0038	Brownie	10/23/20	10:34		5	10.264	0	0	6.9	3521.1	2.94															
27-0038	Brownie	10/23/20	10:32		6	8.686	0	0	6.82	3646.3	2.74				1.686	0.083										
27-0038	Brownie	10/23/20	10:31		7	7.556	0	0	6.81	3747	2.8															
27-0038	Brownie	10/23/20	10:30		8	7.229	0	0	6.82	3824.8	2.91															
27-0038	Brownie	10/23/20	10:28		9	7.131	0	0	6.84	3911.5	3.27															
27-0038	Brownie	10/23/20	10:27		10	7.122	0	0	6.84	3972.2	3.48															
27-0038	Brownie	10/23/20	10:26		11	7.148	0.1	0.01	6.89	3996.6	3.6															
27-0038	Brownie	10/23/20	10:24		12	7.188	0.7	0.09	6.91	4021.4	4.09				3.550	0.059							1050	6.61		
27-0038	Brownie	10/23/20	10:23		13	7.242	1.6	0.19	6.93	4043.5	6.64															
27-0039	Cedar	01/22/20	10:25		0	0.24	87.1	12.32	7.72	766.4	6.4	35.5	3.60	8.21	0.123	0.003	1.17	1.58	0.227	0.492	161	184	145	10.3		
27-0039	Cedar	01/22/20	10:23		1	2.34	84	11.22	7.69	761.2	4.6															
27-0039	Cedar	01/22/20	10:22		2	2.39	82	10.93	7.67	760.7	4.1															
27-0039	Cedar	01/22/20	10:22		3	2.43	72.4	9.64	7.64	761.7	3.5															
27-0039	Cedar	01/22/20	10:21		4	2.46	70.3	9.36	7.62	765.2	3.5															
27-0039	Cedar	01/22/20	10:19		5	2.45	70.1	9.33	7.62	767.5	3.3				0.076	0.006										
27-0039	Cedar	01/22/20	10:18		6	2.5	56.6	7.53	7.59	778.4	3															
27-0039	Cedar	01/22/20	10:17		7	2.5	48.4	6.43	7.59	784.6	3															
27-0039	Cedar	01/22/20	10:16		8	2.54	42.3	5.61	7.57	794.1	3															
27-0039	Cedar	01/22/20	10:15		9	2.61	35.8	4.75	7.57	799.6	3.1															
27-0039	Cedar	01/22/20	10:14		10	2.62	32.8	4.34	7.57	809	3.3				0.093	0.046										
27-0039	Cedar	01/22/20	10:12		11	2.65	27.3	3.61	7.58	814.3	3.6															
27-0039	Cedar	01/22/20	10:11		12	2.73	12.2	1.61	7.57	820.4	4.8															
27-0039	Cedar	01/22/20	10:10		13	2.78	17.4	2.29	7.59	822.9	6.2															
27-0039	Cedar	01/22/20	10:08		14	2.89	2.1	0.28	7.61	831	10.9				0.180	0.090							150	10.8		
27-0039	Cedar	01/22/20	10:07		15	2.99	2.1	0.28	7.61	839.5	13.7															
27-0039	Cedar	01/22/20	10:05		9.3	3.09	2.8	0.36	7.67	841.3	28.4															
27-0039	Cedar	04/29/20	9:37	0.47	0	9.54	109	12.11	8.56	784.8		28.3	5.10	6.87	0.095	0.003	0.760	0.849	<0.030	0.271	166	196	135	12.0		
27-0039	Cedar	04/29/20	9:37		1	9.53	109	12.12	8.57	785.4																

Lake ID	Lake Name	Date MM/DD/YY	Time HH:MM :SS	Secchi meters	Depth meters	Temp °C	%DO	DO mg/L	pH units	SpCond µS/cm	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/10 0mL	DOC mg/L
27-0039	Cedar	04/29/20	9:36		2	9.5	108.9	12.1	8.55	784.9																
27-0039	Cedar	04/29/20	9:36		3	9.49	108.1	12.03	8.55	785.1																
27-0039	Cedar	04/29/20	9:35		4	8.97	104.8	11.81	8.46	787																
27-0039	Cedar	04/29/20	9:34		5	8.4	99.2	11.32	8.35	790.2					0.094	<0.003										
27-0039	Cedar	04/29/20	9:34		6	8.05	91.5	10.54	8.25	787.9																
27-0039	Cedar	04/29/20	9:32		7	7.11	81.8	9.64	8.09	787.6																
27-0039	Cedar	04/29/20	9:31		8	6.81	78.6	9.34	8.05	787.4																
27-0039	Cedar	04/29/20	9:30		9	6.48	70	8.38	7.96	789.7																
27-0039	Cedar	04/29/20	9:29		10	6.46	69.7	8.35	7.95	789.8					0.062	0.004										
27-0039	Cedar	04/29/20	9:28		11	6.45	68.3	8.18	7.95	789.7																
27-0039	Cedar	04/29/20	9:28		12	6.38	66.9	8.03	7.93	790.3																
27-0039	Cedar	04/29/20	9:27		13	6.25	58.2	7.01	7.87	792.9																
27-0039	Cedar	04/29/20	9:26		14	6.25	58.2	7	7.88	792.1					0.075	0.009							140	12.4		
27-0039	Cedar	05/11/20	10:38	0.41	0	12.13	113.2	12.02	9.21	781.9	8.6	16.5	1.32	8.35	0.082	0.003	1.010	1.178	<0.030	0.470	165	192	135	13.13		
27-0039	Cedar	05/11/20	10:38		1	12.06	113.4	12.06	9.2	780.9	8.1															
27-0039	Cedar	05/11/20	10:37		2	11.93	112.9	12.04	9.19	780.9	6.6															
27-0039	Cedar	05/11/20	10:36		3	11.89	110.6	11.81	9.17	781	5.2															
27-0039	Cedar	05/11/20	10:35		4	11.08	82.9	9.01	8.61	787.3	2.5															
27-0039	Cedar	05/11/20	10:35		5	8.97	69.6	7.95	8.34	789.3	1.5				0.067	0.003										
27-0039	Cedar	05/11/20	10:34		6	7.65	63.5	7.49	8.28	789.8	1.3															
27-0039	Cedar	05/11/20	10:33		7	7.16	65.5	7.83	8.27	787.9	1.3															
27-0039	Cedar	05/11/20	10:33		8	6.95	59.2	7.11	8.23	788.2	1.4															
27-0039	Cedar	05/11/20	10:32		9	6.86	55.2	6.65	8.2	788.6	1.4															
27-0039	Cedar	05/11/20	10:31		10	6.78	52.2	6.29	8.17	789.1	1.6				0.051	0.011										
27-0039	Cedar	05/11/20	10:30		11	6.71	44.2	5.34	8.12	789.5	1.9															
27-0039	Cedar	05/11/20	10:29		12	6.57	35.4	4.29	8.08	791.2	2.5															
27-0039	Cedar	05/11/20	10:28		13	6.49	22.6	2.74	8.04	792.9	3.4															
27-0039	Cedar	05/11/20	10:27		14	6.44	12.7	1.54	8.04	793	3.8				0.098	0.044							130	12.34		
27-0039	Cedar	05/11/20	10:26		15	6.51	9.4	1.15	8.09	796.2	11.3															
27-0039	Cedar	05/26/20	10:07	1.58	0	21.17	111.5	9.64	8.65	764.2	5.8	6.66	2.80		0.035	0.003		0.544					120			
27-0039	Cedar	05/26/20	10:06		1	21.01	110.7	9.6	8.63	763.4	6.4															
27-0039	Cedar	05/26/20	10:04		2	16.94	104.8	9.87	8.62	771	7.1															
27-0039	Cedar	05/26/20	10:03		3	13.61	95.1	9.62	8.67	769.6	7.3															
27-0039	Cedar	05/26/20	10:01		4	12.69	59.7	6.17	8.18	781.4	4															
27-0039	Cedar	05/26/20	10:00		5	11.6	38.5	4.07	7.88	789.2	2.3				0.052	0.003										
27-0039	Cedar	05/26/20	9:59		6	9.24	26.1	2.92	7.62	794.8	2.2															
27-0039	Cedar	05/26/20	9:58		7	7.86	26.3	3.04	7.59	792.6	1.5															
27-0039	Cedar	05/26/20	9:58		8	7.09	25.1	2.96	7.59	792.7	1.5															
27-0039	Cedar	05/26/20	9:56		9	6.73	13.4	1.59	7.55	794	0.8															
27-0039	Cedar	05/26/20	9:55		10	6.58	0	0	7.52	796	6.3				0.071	0.024										
27-0039	Cedar	05/26/20	9:54		11	6.53	0	0	7.52	796.9	7.3															
27-0039	Cedar	05/26/20	9:53		12	6.45	0	0	7.55	800.8	8.9															
27-0039	Cedar	05/26/20	9:52		13	6.41	0	0	7.57	803.3	11.3															
27-0039	Cedar	05/26/20	9:50		14	6.36	0	0	7.58	809.2	16				0.147	0.057							135			
27-0039	Cedar	05/26/20	9:49		15	6.37	0	0	7.56	813	19.6															
27-0039	Cedar	05/26/20	9:47		16	6.46	0	0	7.5	817.3	34.9															
27-0039	Cedar	06/08/20	10:03	1.67	0	23.65	119.6	9.84	8.66	753	1.9	13.5	1.46	4.88	0.033	0.003		<0.500					140			
27-0039	Cedar	06/08/20	10:02		1	23.62	119.7	9.85	8.67	753.2	1.7															
27-0039	Cedar	06/08/20	10:01		2	23.61	119.3	9.83	8.65	753.2	1.8															
27-0039	Cedar	06/08/20	10:00		3	23.44	119.2	9.85	8.63	753.7	1.8															
27-0039	Cedar	06/08/20	9:59		4	14.86	56.1	5.51	7.98	788	1.9															
27-0039	Cedar	06/08/20	9:59		5	12.18	0.6	0.06	7.52	792	1.4				0.064	0.003										
27-0039	Cedar	06/08/20	9:58		6	10.35	0	0	7.45	797.8	0.7															
27-0039	Cedar	06/08/20	9:57		7	8.02	0	0	7.41	796.3	0.6															
27-0039	Cedar	06/08/20	9:56		8	7.31	0	0	7.42	796.7	1															
27-0039	Cedar	06/08/20	9:55		9	6.87	0	0	7.41	799.6	1.3															
27-0039	Cedar	06/08/20	9:55		10	6.68	0	0	7.38	803.8	16.5				0.088	0.031										
27-0039	Cedar	06/08/20	9:54		11	6.55	0	0	7.36	807.2	27.4															

Lake ID	Lake Name	Date MM/DD/YY	Time HH:MM :SS	Secchi meters	Depth meters	Temp °C	%DO	DO mg/L	pH units	SpCond µS/cm	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/10 0mL	DOC mg/L
27-0039	Cedar	06/08/20	9:54		12	6.48	0	0	7.29	811.9	822															
27-0039	Cedar	06/08/20	9:51		13	6.4	0	0	7.29	817.2	7.8															
27-0039	Cedar	06/08/20	9:50		14.6	6.34	0	0	7.24	825	820				0.229	0.147							140			
27-0039	Cedar	06/22/20	8:52	1.03	0	23.35	121.5	10.07	8.5	734	4.9	15.7	2.34		0.028	0.003		<0.500					125			
27-0039	Cedar	06/22/20	8:51		1	23.36	121.6	10.08	8.49	733.3	4.8															
27-0039	Cedar	06/22/20	8:50		2	23.32	120.8	10.02	8.43	733	4.8															
27-0039	Cedar	06/22/20	8:49		3	22.25	81.4	6.89	8.19	746.3	4.7															
27-0039	Cedar	06/22/20	8:47		4	18.7	6.1	0.55	7.58	772.7	3.2															
27-0039	Cedar	06/22/20	8:46		5	12.04	1.3	0.13	7.47	792.6	2.2				0.045	0.003										
27-0039	Cedar	06/22/20	8:45		6	9.78	0	0	7.41	795.5	1.9															
27-0039	Cedar	06/22/20	8:44		7	8.38	0	0	7.39	798.1	1.9															
27-0039	Cedar	06/22/20	8:44		8	7.45	0	0	7.41	796.6	2.3															
27-0039	Cedar	06/22/20	8:43		9	6.99	0	0	7.4	797.1	2.6															
27-0039	Cedar	06/22/20	8:42		10	6.77	0	0	7.38	801.1	3.3				0.130	0.065										
27-0039	Cedar	06/22/20	8:41		11	6.61	0	0	7.36	805.2	3.8															
27-0039	Cedar	06/22/20	8:40		12	6.53	0	0	7.34	807.8	4.5															
27-0039	Cedar	06/22/20	8:39		13	6.48	0	0	7.33	810.5	5.1															
27-0039	Cedar	06/22/20	8:38		14	6.54	0	0	7.3	812.6	6.4				0.300	0.238							110			
27-0039	Cedar	06/22/20	8:37		15	6.34	0	0	7.25	825.7	7.5															
27-0039	Cedar	06/22/20	8:36		15.7	7.25	0	0	7.15	843.3	63.5															
27-0039	Cedar	07/06/20	12:26	1.27	0	29.38	118	8.81	8.45	701	5	8.545	0.801	4.954	0.0185	0.002	0.8695	0.937	<0.030	0.3965	131	160	133	11.35		
27-0039	Cedar	07/06/20	12:26		1	28.98	127.8	9.61	8.5	702.9	4.9															
27-0039	Cedar	07/06/20	12:25		2	27.66	134	10.31	8.38	708.5	5.2															
27-0039	Cedar	07/06/20	12:24		3	24.38	111.3	9.09	8.19	720.3	5.4															
27-0039	Cedar	07/06/20	12:23		4	20.57	12.1	1.06	7.52	750.9	4.9															
27-0039	Cedar	07/06/20	12:22		5	13.59	1.5	0.15	7.37	787.3	2.8				0.029	0.0025										
27-0039	Cedar	07/06/20	12:21		6	10.19	0	0	7.34	790.7	2.5															
27-0039	Cedar	07/06/20	12:20		7	8.5	0	0	7.31	795.7	2.7															
27-0039	Cedar	07/06/20	12:19		8	7.53	0	0	7.3	795	3															
27-0039	Cedar	07/06/20	12:18		9	6.97	0	0	7.29	796.7	3.7															
27-0039	Cedar	07/06/20	12:17		10	6.71	0	0	7.26	802.2	4.5				0.1665	0.12										
27-0039	Cedar	07/06/20	12:16		11	6.55	0	0	7.24	806.3	5.2															
27-0039	Cedar	07/06/20	12:15		12	6.48	0	0	7.21	810.4	5.8															
27-0039	Cedar	07/06/20	12:15		13	6.39	0	0	7.19	817.5	6.3															
27-0039	Cedar	07/06/20	12:13		14	6.4	0	0	7.18	819.1	6.5				0.4095	0.345							123	11		
27-0039	Cedar	07/06/20	12:13		15	6.62	0	0	7.17	820.5	6.8															
27-0039	Cedar	07/06/20	12:12		15.9	6.49	0	0	7.21	821.3	6.6															
27-0039	Cedar	07/20/20	9:43	0.67	0	26.55	151.1	11.88	8.78	685	20.1	23.9	<0.500		0.024	0.003		0.604					130			
27-0039	Cedar	07/20/20	9:42		1	26.37	150.6	11.89	8.76	685	39.8															
27-0039	Cedar	07/20/20	9:40		2	26	142.9	11.36	8.65	685.2	5.7															
27-0039	Cedar	07/20/20	9:38		3	25.33	68.3	5.53	7.82	704.4	4.4															
27-0039	Cedar	07/20/20	9:37		4	21.06	1.8	0.15	7.54	761.7	3.6															
27-0039	Cedar	07/20/20	9:36		5	13.76	1.5	0.16	7.48	801.9	2.7				0.036	0.004										
27-0039	Cedar	07/20/20	9:35		6	10.5	0.8	0.09	7.45	809.2	2.4															
27-0039	Cedar	07/20/20	9:31		7	8.34	0	0	7.42	812.7	2.3															
27-0039	Cedar	07/20/20	9:30		8	7.64	0	0	7.41	815.1	2.6															
27-0039	Cedar	07/20/20	9:29		9	7.19	0	0	7.41	815.7	2.9															
27-0039	Cedar	07/20/20	9:27		10	6.86	0	0	7.4	819.6	3.5				0.194	0.180										
27-0039	Cedar	07/20/20	9:26		11	6.78	0	0	7.4	821.4	4															
27-0039	Cedar	07/20/20	9:25		12	6.69	0	0	7.41	823.6	4.5															
27-0039	Cedar	07/20/20	9:23		13	6.91	0	0	7.41	822.3	5.3															
27-0039	Cedar	07/20/20	9:22		14	6.41	0	0	7.43	838.3	6.9				0.427	0.331							140			
27-0039	Cedar	07/20/20	9:21		15	6.29	0	0	7.47	848.5	6.7															
27-0039	Cedar	07/20/20	9:19		15.8	7.6	0	0	7.59	839.8	849															
27-0039	Cedar	08/03/20	11:59	0.71	0	25.61	106.7	8.59	8.45	689.2	6.2	20.2	1.2	5.7	0.021	0.003		0.62					130		<1	
27-0039	Cedar	08/03/20	11:59		1	24.88	106.7	8.7	8.43	688.7	4.7															
27-0039	Cedar	08/03/20	11:58		2	24.66	97.4	7.97	8.28	690.3	4.2															
27-0039	Cedar	08/03/20	11:57		3	24.34	91.8	7.56	8.04	693.6	3.4															

Lake ID	Lake Name	Date MM/DD/YY	Time HH:MM :SS	Secchi meters	Depth meters	Temp °C	%DO	DO mg/L	pH units	SpCond µS/cm	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/10 0mL	DOC mg/L
27-0039	Cedar	08/03/20	11:56		4	21.05	0	0	7.43	759.3	2.6															
27-0039	Cedar	08/03/20	11:54		5	13.74	1.6	0.17	7.34	809.2	2.3				0.033	0.002										
27-0039	Cedar	08/03/20	11:53		6	10.39	0	0	7.31	816.7	1.9															
27-0039	Cedar	08/03/20	11:52		7	8.72	0	0	7.31	818.9	1.9															
27-0039	Cedar	08/03/20	11:51		8	7.8	0	0	7.3	819.2	2.2															
27-0039	Cedar	08/03/20	11:50		9	7.13	0	0	7.3	821.9	2.6															
27-0039	Cedar	08/03/20	11:49		10	6.86	0	0	7.29	828	2.9				0.220	0.169										
27-0039	Cedar	08/03/20	11:48		11	6.77	0	0	7.29	829	3.3															
27-0039	Cedar	08/03/20	11:47		12	6.64	0	0	7.29	832.8	3.6															
27-0039	Cedar	08/03/20	11:46		13	6.49	0	0	7.3	841.2	3.8															
27-0039	Cedar	08/03/20	11:45		14	6.31	0	0	7.31	855.2	5.3				0.485	0.405							140			
27-0039	Cedar	08/03/20	11:44		15	6.42	0	0	7.38	862.3	4.8															
27-0039	Cedar	08/17/20	9:08	0.79	0	24.19	122.7	10.11	8.6	674.8	42.4	3.0	1.440		0.026	0.004		<0.500					125			
27-0039	Cedar	08/17/20	9:07		1	24.18	122.8	10.12	8.55	674.9	159.3															
27-0039	Cedar	08/17/20	9:06		2	24.13	118.9	9.81	8.4	674.6	160.7															
27-0039	Cedar	08/17/20	9:04		3	23.36	68.6	5.74	7.92	677.6	148.1															
27-0039	Cedar	08/17/20	9:03		4	22.08	8	0.69	7.54	698	5															
27-0039	Cedar	08/17/20	9:01		5	16.48	0	0	7.41	801.5	10.2				0.036	0.003										
27-0039	Cedar	08/17/20	9:00		6	11.51	0.5	0.05	7.37	814.3	3.8															
27-0039	Cedar	08/17/20	8:59		7	9.41	2.1	0.23	7.34	821.1	3.8															
27-0039	Cedar	08/17/20	8:57		8	8.06	1.7	0.19	7.35	819.6	3.7															
27-0039	Cedar	08/17/20	8:56		9	7.43	0.9	0.11	7.35	822.3	4.8															
27-0039	Cedar	08/17/20	8:55		10	6.93	0.3	0.03	7.32	829	41.2				0.278	0.228										
27-0039	Cedar	08/17/20	8:54		11	6.8	0.2	0.03	7.32	831.6	3.8															
27-0039	Cedar	08/17/20	8:52		12	6.67	0	0	7.31	833.4	6.4															
27-0039	Cedar	08/17/20	8:51		13	6.5	0	0	7.3	840.4	7.3															
27-0039	Cedar	08/17/20	8:49		14	6.4	0.1	0.01	7.32	846.6	8.3				0.480	0.426							140			
27-0039	Cedar	08/17/20	8:47		15	6.34	0.1	0.02	7.37	852.2	8.3															
27-0039	Cedar	08/17/20	8:45		16	6.96	0	0	7.49	855.1	666															
27-0039	Cedar	08/31/20	10:45	0.61	0	24.12	96.8	7.86	8.37	675.4	33.3	9.0	3.27	5.8	0.027	0.004		0.937					145			
27-0039	Cedar	08/31/20	10:45		1	24.07	96.3	7.83	8.33	675.6	25.4															
27-0039	Cedar	08/31/20	10:44		2	24.04	94.5	7.69	8.27	676.7	27															
27-0039	Cedar	08/31/20	10:42		3	23.84	88.6	7.23	8.03	678.3	5.5															
27-0039	Cedar	08/31/20	10:41		4	22.56	2.8	0.23	7.53	699.2	4.8															
27-0039	Cedar	08/31/20	10:40		5	16.68	0	0	7.4	803.5	4.9				0.032	0.002										
27-0039	Cedar	08/31/20	10:38		6	11.63	0	0	7.33	820.2	5.2															
27-0039	Cedar	08/31/20	10:37		7	9.41	1.4	0.15	7.31	822.6	5															
27-0039	Cedar	08/31/20	10:36		8	8.21	1.2	0.14	7.31	824	5.3															
27-0039	Cedar	08/31/20	10:35		9	7.59	0.5	0.06	7.29	828	5.4															
27-0039	Cedar	08/31/20	10:34		10	7.16	0	0	7.28	830.1	6.1				0.248	0.220										
27-0039	Cedar	08/31/20	10:32		11	6.95	0	0	7.27	832.4	8.7															
27-0039	Cedar	08/31/20	10:31		12	6.8	0	0	7.27	836.1	10.9															
27-0039	Cedar	08/31/20	10:30		13	6.62	0	0	7.26	843.9	5.5															
27-0039	Cedar	08/31/20	10:29		14	6.46	0	0	7.27	850.9	48.7				0.477	0.441							150			
27-0039	Cedar	08/31/20	10:29		15	6.52	0	0	7.29	850	76.1															
27-0039	Cedar	09/14/20	9:40	0.78	0	17.922	89.5	8.47	8.62	693.8	4.02	2.86	2.204		0.025	<0.003		0.849					125			
27-0039	Cedar	09/14/20	9:38		1	17.642	79.5	7.57	8.55	694.2	3.94															
27-0039	Cedar	09/14/20	9:36		2	17.513	79	7.54	8.63	695.6	3.99															
27-0039	Cedar	09/14/20	9:34		3	17.49	75.6	7.22	8.69	696.4	4.27															
27-0039	Cedar	09/14/20	9:31		4	17.412	65	6.21	8.76	697.7	3.78															
27-0039	Cedar	09/14/20	9:30		5	15.518	3.2	0.32	8.3	797.5	3.34				0.024	<0.003										
27-0039	Cedar	09/14/20	9:28		6	11.564	0	0	8.06	829.4	2.4															
27-0039	Cedar	09/14/20	9:26		7	9.248	0	0	7.98	834.4	1.91															
27-0039	Cedar	09/14/20	9:24		8	8.176	0	0	7.94	839.8	1.93															
27-0039	Cedar	09/14/20	9:23		9	7.507	0	0	7.9	844.2	1.67															
27-0039	Cedar	09/14/20	9:21		10	7.153	0	0	7.89	849.1	1.73				0.304	0.264										
27-0039	Cedar	09/14/20	9:19		11	6.962	0	0	7.88	851.7	1.85															
27-0039	Cedar	09/14/20	9:18		12	6.793	0	0	7.86	859.2	2.01															

Lake ID	Lake Name	Date MM/DD/YY	Time HH:MM :SS	Secchi meters	Depth meters	Temp °C	%DO	DO mg/L	pH units	SpCond µS/cm	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/10 0mL	DOC mg/L
27-0039	Cedar	09/14/20	9:15		13	6.675	0	0	7.84	864.1	2.2															
27-0039	Cedar	09/14/20	9:14		14	6.614	0	0	7.83	868.6	2.87				0.504	0.461							130			
27-0039	Cedar	09/14/20	9:11		15	6.551	0	0	7.81	872.8	6.51															
27-0039	Cedar	09/14/20	9:08		16	6.493	0	0	7.7	890.3	27.24															
27-0039	Cedar	09/14/20	9:06		16.5	6.762	0	0	7.34	917.9	1.62															
27-0039	Cedar	10/23/20	11:16	1.50	0	8.453	34.6	4.04	7.68	741.7	2.32	12.6	2.25	7.74	0.066	0.005	1.10	1.24	0.033	0.630	155	176	130	10.91		
27-0039	Cedar	10/23/20	11:16		1	8.45	34.8	4.07	7.68	741.8	2.52															
27-0039	Cedar	10/23/20	11:14		2	8.455	34.1	3.99	7.66	741.9	2.37															
27-0039	Cedar	10/23/20	11:13		3	8.455	33.8	3.95	7.66	741.8	2.55															
27-0039	Cedar	10/23/20	11:13		4	8.454	33.6	3.93	7.66	741.8	2.3															
27-0039	Cedar	10/23/20	11:12		5	8.451	33.2	3.87	7.65	741.9	2.39				0.069	0.004										
27-0039	Cedar	10/23/20	11:11		6	8.404	34.8	4.07	7.65	741.4	2.38															
27-0039	Cedar	10/23/20	11:10		7	8.397	33.6	3.94	7.63	742.4	2.24															
27-0039	Cedar	10/23/20	11:10		8	8.368	34.7	4.07	7.63	740.9	2.48															
27-0039	Cedar	10/23/20	11:09		9	8.353	34.1	4	7.6	740.8	2.33															
27-0039	Cedar	10/23/20	11:07		10	8.281	28.3	3.32	7.5	747.7	2.35				0.070	0.009										
27-0039	Cedar	10/23/20	11:05		11	7.295	0	0	7.24	852.9	1.87															
27-0039	Cedar	10/23/20	11:03		12	7.042	0	0	7.21	856.7	2.01															
27-0039	Cedar	10/23/20	11:03		13	6.834	0	0	7.18	863.4	2.06															
27-0039	Cedar	10/23/20	11:02		14	6.765	0	0	7.17	867	2.36				0.502	0.461							135	10.68		
27-0039	Cedar	10/23/20	11:02		15	6.72	0	0	7.16	869.7	2.92															
27-0022	Diamond	01/31/20	9:26		0	0.01	7.6	1.08	7.33	1655	0.5	111	9.64	6.21	0.226	0.024	1.420	1.735	0.056	0.449	107.0	112	450	8.43		
27-0022	Diamond	04/27/20	13:52		0	19.31	135	12.11	8.27	1211		10.3	7.81	<0.500	0.068	0.005	0.694	0.736	<0.030	0.282	70.0	72.0	330	7.60		
27-0022	Diamond	05/12/20	9:53		0	12.43	105	11.06	8.84	1155	0	2.9	0.92	<0.500	0.063	0.015	0.516	0.589	<0.030	0.512	66.0	80	310	8.38		
27-0022	Diamond	05/27/20	8:39		0	22.29	83.8	7.1	7.86	732.2	0.7	8.03	2.02		0.101	0.015		<0.500					185			
27-0022	Diamond	06/09/20	9:00		0	25.67	78.5	6.19	8.06	703.6	0.3	16.1	9.30	1.20	0.115	0.023		0.575					190			
27-0022	Diamond	06/24/20	8:22		0	21.52	61.8	5.32	8.12	721.1	0.3	25.30	6.13		0.085	0.020		0.501					170			
27-0022	Diamond	07/08/20	8:24		0	27.34	55.4	4.27	7.68	532.5	0.7	12.7	3.16	1.50	0.051	0.005	0.820	0.836	<0.030	0.377	52.0	48.0	125	<5.00		
27-0022	Diamond	07/21/20	11:20		0	24.13	59.3	4.86	7.66	416.5	2	9.72	3.89		0.051	0.005		<0.500					95			
27-0022	Diamond	08/04/20	12:00		0	22.96	143.4	12.13	8.3	352.9	0.9	11.1	3.5	1.7	0.045	0.007		<0.500					70		9	
27-0022	Diamond	08/18/20	8:35		0	20.92	29.2	2.57	7.74	229.3	0	3.60	2.92		0.042	0.006		<0.500					40			
27-0022	Diamond	09/01/20	9:18		0	19.56	26.5	2.37	8.17	282.1	0	6.1	<0.500	1.4	0.030	0.003		<0.500					50			
27-0022	Diamond	09/16/20	9:12		0	17.12	84.7	8.01	8.44	299.8	16.7	2.27	<0.5		0.040	0.015		0.605					46			
27-0022	Diamond	10/14/20	9:57		0	12.537	35.5	3.77	7.94	353.2	0.73	3.33	1.66	1.05	0.045	0.005	<0.500	0.517	<0.030	<0.250	65.0	56	67	5.86		
27-655	Grass	01/31/20	9:46		0	0.44	1	0.15	7.25	655.7	10.3	164	19.0	12.2	0.761	0.037	2.30	2.74	0.060	1.690	213	204.0	75	8.59		
27-655	Grass	04/30/20	11:39		0	14.01	106.7	10.76	8.36	444.5		12.4	9.27	0.789	0.092	0.012	0.524	0.577	<0.030	0.495	105	92.0	80	6.31		
27-655	Grass	05/12/20	9:26		0	12.59	149.7	15.75	9.95	399	0.3	21.4	5.02	0.866	0.113	0.009	0.734	0.806	<0.030	0.265	73.5	74.0	60	7.61		
27-655	Grass	06/09/20	8:24		0	23.9	112.3	9.16	10.16	280.4	0.2	15.0	3.62	2.015	0.100	0.028		0.500					100			
27-655	Grass	07/07/20	8:32		0	27.97	80.8	6.19	8.99	193	5.6	20.5	6.18	2.679	0.126	0.038	1.049	1.059	<0.030	0.388	50	46.0	15	<5.00		
27-655	Grass	08/04/20	11:21		0	21.61	198.6	8.43	73.8	6.41	7.7	50.9	8.5	2.1	0.116	0.018		1.10					26			
27-655	Grass	09/01/20	8:45		0	20.58	43.7	3.84	8.38	231.4	62.6	167	42.5	7.99	0.369	0.014		2.69					29			
27-655	Grass	10/14/20	9:23		0	12.348	54.7	5.84	7.52	290.7	16.47	5.45	1.95	4.47	0.330	0.007	1.84	2.14	<0.030	0.509	95	86.0	33	5.25		
27-0016	Harriet	01/27/20	12:16		0	0.37	102.1	14.49	8.76	649.4	0	19.30	1.27	0.707	0.059	0.011	0.966	1.090	0.070	0.405	131	148	120	7.48		
27-0016	Harriet	01/27/20	12:15		1	1.86	92.3	12.56	8.49	655.2	0															
27-0016	Harriet	01/27/20	12:14		2	1.94	92	12.49	8.47	653.5	0															
27-0016	Harriet	01/27/20	12:14		3	1.96	92.4	12.54	8.46	654.2	0															
27-0016	Harriet	01/27/20	12:13		4	2.01	91.6	12.42	8.45	651.7	0															
27-0016	Harriet	01/27/20	12:12		5	2.02	90.8	12.31	8.43	652.2	0															
27-0016	Harriet	01/27/20	12:11		6	2.1	89.3	12.08	8.4	651.6	0				0.039	0.014										
27-0016	Harriet	01/27/20	12:10		7	2.16	87.4	11.79	8.35	650.5	0															
27-0016	Harriet	01/27/20	12:10		8	2.27	84.4	11.36	8.3	650.5	0															
27-0016	Harriet	01/27/20	12:09		9	2.35	83.8	11.26	8.27	652.4	0															
27-0016	Harriet	01/27/20	12:08		10	2.41	80.2	10.76	8.2	653.3	0															
27-0016	Harriet	01/27/20	12:07		11	2.44	75.3	10.09	8.11	653.9	0															
27-0016	Harriet	01/27/20	12:06		12	2.51	67.7	9.05	8.01	657.8	0				0.053	0.032										
27-0016	Harriet	01/27/20	12:05		13	2.53	48.8	6.52	7.84	660.4	0															
27-0016	Harriet	01/27/20	12:05		14	2.59	40.5	5.41	7.78	664.8	0															
27-0016	Harriet	01/27/20	12:04		15	2.63	29.7	3.96	7.71	671.1	0				0.109	0.080										

Lake ID	Lake Name	Date MM/DD/YY	Time HH:MM :SS	Secchi meters	Depth meters	Temp °C	%DO	DO mg/L	pH units	SpCond µS/cm	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/10 0mL	DOC mg/L
27-0016	Harriet	01/27/20	12:02		16	2.72	8.9	1.18	7.63	678	0															
27-0016	Harriet	01/27/20	12:01		17	2.76	0	0	7.63	682.7	0															
27-0016	Harriet	01/27/20	12:00		18	2.77	0	0	7.63	686	0															
27-0016	Harriet	01/27/20	11:59		19	2.8	1	0.13	7.63	690.6	0															
27-0016	Harriet	01/27/20	11:58		20	2.86	0	0	7.62	700.4	0				0.246	0.189							130	6.89		
27-0016	Harriet	01/27/20	11:57		21	2.9	1.1	0.15	7.61	711	0															
27-0016	Harriet	01/27/20	11:56		22	2.9	0	0	7.61	732.3	0															
27-0016	Harriet	01/27/20	11:55		23	2.92	0	0	7.61	739.7	0															
27-0016	Harriet	01/27/20	11:54		24	2.97	0	0	7.6	745.7	0.7															
27-0016	Harriet	01/27/20	11:53		24.8	3.09	0.2	0.03	7.54	763.8	3.9															
27-0016	Harriet	04/30/20	10:25	6.03	0	10.23	99.7	10.95	8.46	662.1		2.06	<0.500	<0.500	0.030	0.009	0.590	0.661	0.345	0.045	130	148	120	8.23		
27-0016	Harriet	04/30/20	10:24		1	10.07	98.8	10.88	8.48	661.9																
27-0016	Harriet	04/30/20	10:23		2	9.98	98.5	10.88	8.48	662																
27-0016	Harriet	04/30/20	10:22		3	9.53	98.9	11.04	8.48	663.9																
27-0016	Harriet	04/30/20	10:22		4	9.29	97.9	10.99	8.47	663.5																
27-0016	Harriet	04/30/20	10:21		5	8.84	96.6	10.97	8.45	663.4																
27-0016	Harriet	04/30/20	10:21		6	8.37	96.4	11.07	8.45	664.4					0.066	0.011										
27-0016	Harriet	04/30/20	10:21		7	8.3	95.1	10.94	8.44	663.9																
27-0016	Harriet	04/30/20	10:20		8	7.72	93	10.84	8.41	662.9																
27-0016	Harriet	04/30/20	10:19		9	7.4	91.6	10.77	8.4	663.4																
27-0016	Harriet	04/30/20	10:19		10	7.22	89.7	10.57	8.39	663.6																
27-0016	Harriet	04/30/20	10:19		11	6.73	87.7	10.48	8.35	663																
27-0016	Harriet	04/30/20	10:18		12	6.64	87.3	10.46	8.34	663.1					0.045	0.014										
27-0016	Harriet	04/30/20	10:18		13	6.6	86	10.31	8.33	663.1																
27-0016	Harriet	04/30/20	10:17		14	6.33	85.1	10.27	8.31	663.2																
27-0016	Harriet	04/30/20	10:17		15	6.33	84.7	10.22	8.31	663					0.039	0.015										
27-0016	Harriet	04/30/20	10:16		16	6.28	83.8	10.13	8.29	663.3																
27-0016	Harriet	04/30/20	10:16		17	6.25	83.3	10.07	8.28	663.2																
27-0016	Harriet	04/30/20	10:16		18	6.22	83.1	10.05	8.28	663.5																
27-0016	Harriet	04/30/20	10:15		19	6.19	82.5	10	8.28	663.6																
27-0016	Harriet	04/30/20	10:15		20	6.23	82.4	9.97	8.27	663					0.039	0.018							120	7.47		
27-0016	Harriet	04/30/20	10:14		21	6.21	81.7	9.89	8.26	663.3																
27-0016	Harriet	04/30/20	10:14		22	6.17	81.8	9.91	8.26	663.9																
27-0016	Harriet	04/30/20	10:13		23	6.16	81.7	9.9	8.26	663.9																
27-0016	Harriet	04/30/20	10:13		24	6.24	78.3	9.47	8.23	665																
27-0016	Harriet	04/30/20	10:12		25	6.19	76.2	9.23	8.18	663.6																
27-0016	Harriet	05/14/20	11:38	7.2	0	12.66	105.7	10.92	8.81	660.1	0	1.7	<0.500	<0.500	0.032	0.007	0.622	0.711	0.030	0.311	130	148	120	8.13		
27-0016	Harriet	05/14/20	11:37		1	12.53	105.8	10.95	8.83	660.9	0															
27-0016	Harriet	05/14/20	11:37		2	12.29	106.2	11.06	8.81	661.2	0															
27-0016	Harriet	05/14/20	11:36		3	11.9	103.2	10.84	8.78	660.7	0															
27-0016	Harriet	05/14/20	11:35		4	11.89	102.8	10.81	8.77	660.4	0															
27-0016	Harriet	05/14/20	11:34		5	11.79	102.1	10.75	8.75	660.2	0															
27-0016	Harriet	05/14/20	11:33		6	11.5	98	10.39	8.67	659.3	0				0.035	0.011										
27-0016	Harriet	05/14/20	11:33		7	10.94	96	10.31	8.61	655.7	0															
27-0016	Harriet	05/14/20	11:32		8	9.1	83.5	9.36	8.44	655.1	0															
27-0016	Harriet	05/14/20	11:31		9	7.78	75.8	8.78	8.36	656.3	0															
27-0016	Harriet	05/14/20	11:30		10	7.38	74.2	8.68	8.32	656.3	0															
27-0016	Harriet	05/14/20	11:29		11	6.97	65.4	7.72	8.24	656.7	0															
27-0016	Harriet	05/14/20	11:27		12	6.91	62.8	7.43	8.21	658.7	0				0.058	0.045										
27-0016	Harriet	05/14/20	11:26		13	6.83	62.1	7.36	8.19	657.2	0															
27-0016	Harriet	05/14/20	11:25		14	6.67	57.7	6.86	8.14	657.4	0															
27-0016	Harriet	05/14/20	11:23		15	6.61	53.9	6.42	8.1	657.7	0				0.081	0.064										
27-0016	Harriet	05/14/20	11:22		16	6.58	52.3	6.24	8.08	658.4	0															
27-0016	Harriet	05/14/20	11:21		17	6.58	51.8	6.18	8.06	658.1	0															
27-0016	Harriet	05/14/20	11:20		18	6.53	49.2	5.88	8.04	658.4	0															
27-0016	Harriet	05/14/20	11:19		19	6.52	47.4	5.66	8.01	658.4	0															
27-0016	Harriet	05/14/20	11:18		20	6.5	45.8	5.47	7.98	659.2	0				0.096	0.080							125	7.95		
27-0016	Harriet	05/14/20	11:17		21	6.49	37.4	4.47	7.91	661.9	0															

Lake ID	Lake Name	Date MM/DD/YY	Time HH:MM :SS	Secchi meters	Depth meters	Temp °C	%DO	DO mg/L	pH units	SpCond µS/cm	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/10 0mL	DOC mg/L
27-0016	Harriet	05/14/20	11:16		22	6.45	34.7	4.15	7.89	660.6	0															
27-0016	Harriet	05/14/20	11:15		23	6.43	32.2	3.86	7.87	661.1	0															
27-0016	Harriet	05/14/20	11:13		24	6.47	32.3	3.86	7.84	661.8	0															
27-0016	Harriet	05/14/20	11:12		25	6.44	30.4	3.65	7.8	661.8	0															
27-0016	Harriet	05/28/20	10:35	5.17	0	20.03	111.1	9.87	8.56	643.9	0	1.20	0.720		0.017	0.003		<0.500					110			
27-0016	Harriet	05/28/20	10:34		1	20.04	111.4	9.89	8.56	643.7	0															
27-0016	Harriet	05/28/20	10:34		2	19.84	111.3	9.93	8.56	644.9	0															
27-0016	Harriet	05/28/20	10:33		3	16.27	115	11.03	8.56	655.3	0															
27-0016	Harriet	05/28/20	10:32		4	14.68	109.9	10.91	8.51	656	0															
27-0016	Harriet	05/28/20	10:31		5	13.77	99.7	10.1	8.39	658.2	0															
27-0016	Harriet	05/28/20	10:30		6	12.73	90	9.33	8.26	659.8	0				0.022	0.003										
27-0016	Harriet	05/28/20	10:29		7	12.07	82.3	8.66	8.16	660.1	0															
27-0016	Harriet	05/28/20	10:29		8	10.66	74.2	8.07	8.06	663.6	0															
27-0016	Harriet	05/28/20	10:28		9	8.66	59.5	6.78	7.89	672.3	0															
27-0016	Harriet	05/28/20	10:27		10	7.43	46.3	5.44	7.76	666.5	0															
27-0016	Harriet	05/28/20	10:26		11	7.32	44	5.18	7.74	665.8	0															
27-0016	Harriet	05/28/20	10:25		12	7.11	41.8	4.95	7.72	667	0				0.104	0.088										
27-0016	Harriet	05/28/20	10:24		13	6.95	40.5	4.81	7.71	667	0															
27-0016	Harriet	05/28/20	10:23		14	6.78	37.3	4.45	7.68	666.4	0															
27-0016	Harriet	05/28/20	10:23		15	6.71	31.3	3.75	7.63	666.5	0				0.119	0.103										
27-0016	Harriet	05/28/20	10:21		16	6.68	29.6	3.54	7.62	666.8	0															
27-0016	Harriet	05/28/20	10:20		17	6.6	24.4	2.93	7.58	668.6	0															
27-0016	Harriet	05/28/20	10:19		18	6.59	22.1	2.65	7.57	667.6	0															
27-0016	Harriet	05/28/20	10:18		19	6.54	18.3	2.2	7.54	668.4	0															
27-0016	Harriet	05/28/20	10:17		20	6.52	17.3	2.08	7.53	668.2	0				0.169	0.148							115			
27-0016	Harriet	05/28/20	10:16		21	6.62	16.4	1.96	7.52	666.8	0															
27-0016	Harriet	05/28/20	10:15		22	6.52	15.9	1.91	7.5	668.8	0															
27-0016	Harriet	05/28/20	10:14		23	6.55	15.1	1.82	7.49	668.3	0															
27-0016	Harriet	05/28/20	10:14		24	6.62	13.9	1.66	7.48	668	0															
27-0016	Harriet	05/28/20	10:11		25	7.15	11.4	1.35	7.45	660.2	5.5															
27-0016	Harriet	06/11/20	11:41	3.57	0	21.62	100.4	8.64	8.44	656.1	0.1	4.40	0.94	0.534	0.033	0.004		<0.500					120			
27-0016	Harriet	06/11/20	11:40		1	21.61	100.9	8.68	8.44	656.2	0.1															
27-0016	Harriet	06/11/20	11:40		2	21.6	100.7	8.66	8.46	656.2	0.1															
27-0016	Harriet	06/11/20	11:39		3	21.58	100.5	8.65	8.44	656.1	0															
27-0016	Harriet	06/11/20	11:38		4	21.55	100.5	8.65	8.43	656.5	0															
27-0016	Harriet	06/11/20	11:37		5	17.97	124.9	11.55	8.44	657.9	0															
27-0016	Harriet	06/11/20	11:36		6	13.5	83.7	8.51	7.99	661	0				0.028	0.004										
27-0016	Harriet	06/11/20	11:36		7	12.54	74.9	7.78	7.9	662.2	0															
27-0016	Harriet	06/11/20	11:35		8	11.7	64.9	6.87	7.81	664.3	0															
27-0016	Harriet	06/11/20	11:34		9	9.25	43.2	4.85	7.58	668.6	0															
27-0016	Harriet	06/11/20	11:33		10	7.97	31.9	3.69	7.52	669.4	0															
27-0016	Harriet	06/11/20	11:32		11	7.6	29.5	3.45	7.51	669.3	0															
27-0016	Harriet	06/11/20	11:31		12	7.52	26.4	3.09	7.49	669.1	0				0.139	0.121										
27-0016	Harriet	06/11/20	11:30		13	7.11	15.9	1.89	7.42	670.1	0															
27-0016	Harriet	06/11/20	11:30		14	6.91	15	1.78	7.41	670.4	0															
27-0016	Harriet	06/11/20	11:27		15	6.8	7.2	0.86	7.38	670.9	0				0.180	0.167										
27-0016	Harriet	06/11/20	11:29		16	6.82	9.6	1.14	7.4	671	0															
27-0016	Harriet	06/11/20	11:26		17	6.68	1.8	0.21	7.36	671.4	0															
27-0016	Harriet	06/11/20	11:26		18	6.66	0	0	7.34	671.7	0															
27-0016	Harriet	06/11/20	11:25		19	6.61	0	0	7.33	672.5	0															
27-0016	Harriet	06/11/20	11:24		20	6.6	0	0	7.3	672.2	0				0.219	0.204							125			
27-0016	Harriet	06/11/20	11:23		21	6.6	0	0	7.28	672.5	0															
27-0016	Harriet	06/11/20	11:22		22	6.64	0	0	7.25	672.1	271.3															
27-0016	Harriet	06/11/20	11:21		23	6.6	0	0	7.24	672.9	380.8															
27-0016	Harriet	06/11/20	11:21		24	6.6	0	0	7.22	672.9	3.2															
27-0016	Harriet	06/25/20	11:18	4.4	0	23.37	118.4	9.85	8.63	659.7	0	4.05	<0.500		0.017	0.004		<0.500					120			
27-0016	Harriet	06/25/20	11:18		1	23.08	117.7	9.84	8.61	658.9	0															
27-0016	Harriet	06/25/20	11:17		2	22.74	116.8	9.83	8.6	658.6	0															

Lake ID	Lake Name	Date MM/DD/YY	Time HH:MM :SS	Secchi meters	Depth meters	Temp °C	%DO	DO mg/L	pH units	SpCond µS/cm	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/10 0mL	DOC mg/L
27-0016	Harriet	06/25/20	11:16		3	22.46	112.5	9.52	8.56	659.9	0															
27-0016	Harriet	06/25/20	11:15		4	22.28	110.5	9.38	8.48	659.7	0															
27-0016	Harriet	06/25/20	11:14		5	20.93	90	7.84	8.19	661.6	0															
27-0016	Harriet	06/25/20	11:13		6	16.23	96.5	9.26	7.96	662.4	0				0.022	<0.003										
27-0016	Harriet	06/25/20	11:12		7	12.09	57.4	6.03	7.67	666.3	0															
27-0016	Harriet	06/25/20	11:11		8	10.54	46.6	5.08	7.62	668.9	0															
27-0016	Harriet	06/25/20	11:11		9	9.29	35.9	4.03	7.58	671.3	0															
27-0016	Harriet	06/25/20	11:10		10	8.81	28.1	3.18	7.55	671.8	0															
27-0016	Harriet	06/25/20	11:08		11	7.75	17	1.98	7.5	672.2	0															
27-0016	Harriet	06/25/20	11:07		12	7.28	1.4	0.16	7.47	673.5	0				0.163	0.130										
27-0016	Harriet	06/25/20	11:06		13	7.02	0	0	7.47	672.8	0															
27-0016	Harriet	06/25/20	11:05		14	6.9	0	0	7.48	672.3	0															
27-0016	Harriet	06/25/20	11:05		15	6.79	0	0	7.47	673.7	0				0.219	0.198										
27-0016	Harriet	06/25/20	11:04		16	6.75	0	0	7.46	674.7	0															
27-0016	Harriet	06/25/20	11:02		17	6.74	0	0	7.47	675.2	0															
27-0016	Harriet	06/25/20	11:01		18	6.73	0	0	7.46	674.7	0															
27-0016	Harriet	06/25/20	11:00		19	6.65	0	0	7.45	675.7	0															
27-0016	Harriet	06/25/20	10:59		20	6.66	0	0	7.49	676.4	0				0.282	0.255							117			
27-0016	Harriet	06/25/20	10:58		21	6.63	0	0	7.5	676.6	0															
27-0016	Harriet	06/25/20	10:57		22	6.74	0	0	7.52	675.1	0															
27-0016	Harriet	06/25/20	10:56		23	6.73	0	0	7.53	676.6	0															
27-0016	Harriet	06/25/20	10:55		24	6.68	0	0	7.55	677	0															
27-0016	Harriet	06/25/20	10:54		24.9	6.77	0.5	0.07	7.55	680.2	0															
27-0016	Harriet	07/10/20	9:04	5.96	0	27.19	104.3	8.08	8.62	652.7	0	2.72	0.53	1.147	0.012	0.003	0.634	0.667	<0.030	<0.250	117	132	125	10.74		
27-0016	Harriet	07/10/20	9:03		1	27.19	104.7	8.12	8.61	652.4	0															
27-0016	Harriet	07/10/20	9:02		2	27.13	104.6	8.12	8.6	653.3	0															
27-0016	Harriet	07/10/20	9:01		3	27.03	104.4	8.11	8.57	653.9	0															
27-0016	Harriet	07/10/20	9:00		4	26.85	101.3	7.9	8.43	653.6	0															
27-0016	Harriet	07/10/20	8:59		5	22.15	62.7	5.33	7.91	667.7	0															
27-0016	Harriet	07/10/20	8:58		6	18.15	56.5	5.21	7.72	669.2	0				0.012	0.004										
27-0016	Harriet	07/10/20	8:57		7	13.65	49.5	5.02	7.65	669.5	0															
27-0016	Harriet	07/10/20	8:56		8	11.05	34.5	3.72	7.58	672.4	0															
27-0016	Harriet	07/10/20	8:54		9	9.54	19.4	2.16	7.53	674.1	0															
27-0016	Harriet	07/10/20	8:53		10	8.37	0.7	0.08	7.5	677.1	0															
27-0016	Harriet	07/10/20	8:52		11	7.82	0	0	7.48	676.7	0															
27-0016	Harriet	07/10/20	8:51		12	7.37	0	0	7.49	677.2	0				0.179	0.175										
27-0016	Harriet	07/10/20	8:49		13	7.2	0	0	7.49	677.5	0															
27-0016	Harriet	07/10/20	8:47		14	7.03	0	0	7.49	678.4	0															
27-0016	Harriet	07/10/20	8:46		15	6.97	0	0	7.5	678.3	0				0.241	0.219										
27-0016	Harriet	07/10/20	8:45		16	6.94	0	0	7.5	678.4	0															
27-0016	Harriet	07/10/20	8:44		17	6.9	0	0	7.51	678.8	0															
27-0016	Harriet	07/10/20	8:43		18	6.86	0	0	7.52	679.1	0															
27-0016	Harriet	07/10/20	8:42		19	6.82	0	0	7.52	680	0															
27-0016	Harriet	07/10/20	8:41		20	6.81	0	0	7.54	679.8	0				0.284	0.269							125	8.68		
27-0016	Harriet	07/10/20	8:40		21	6.83	0	0	7.56	679.4	0															
27-0016	Harriet	07/10/20	8:39		22	6.8	0	0	7.57	680.2	0															
27-0016	Harriet	07/10/20	8:38		23	6.94	0	0	7.59	678.7	0															
27-0016	Harriet	07/10/20	8:37		24	6.81	0	0	7.64	680.4	0															
27-0016	Harriet	07/10/20	8:36		25	6.92	0	0	7.69	678.1	0															
27-0016	Harriet	07/22/20	11:08	4.8	0	25.28	101.6	8.18	8.46	655	0	2.35	0.589		0.041	0.003		<0.500					125			
27-0016	Harriet	07/22/20	11:07		1	25.27	101.7	8.19	8.46	655.5	0															
27-0016	Harriet	07/22/20	11:06		2	25.29	101.8	8.19	8.45	655.5	0															
27-0016	Harriet	07/22/20	11:05		3	25.26	101.7	8.19	8.43	655.9	0															
27-0016	Harriet	07/22/20	11:02		4	25.26	100.7	8.11	8.38	655.9	0															
27-0016	Harriet	07/22/20	11:01		5	25.05	99.2	8.02	8.2	657.3	0															
27-0016	Harriet	07/22/20	11:00		6	19.62	37.1	3.32	7.5	671	0				0.013	0.003										
27-0016	Harriet	07/22/20	10:59		7	14.26	30.3	3.04	7.46	671.6	0															
27-0016	Harriet	07/22/20	10:58		8	11.79	22.4	2.38	7.43	673.9	0															

Lake ID	Lake Name	Date MM/DD/YY	Time HH:MM :SS	Secchi meters	Depth meters	Temp °C	%DO	DO mg/L	pH units	SpCond µS/cm	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/10 0mL	DOC mg/L
27-0016	Harriet	07/22/20	10:57		9	9.98	8.2	0.91	7.41	673.8	0															
27-0016	Harriet	07/22/20	10:56		10	8.84	1.7	0.19	7.39	678.1	0															
27-0016	Harriet	07/22/20	10:54		11	8.32	0	0	7.39	678.7	0															
27-0016	Harriet	07/22/20	10:53		12	7.79	0	0	7.38	679	0.1				0.181	0.167										
27-0016	Harriet	07/22/20	10:52		13	7.38	0	0	7.37	678.9	0.4															
27-0016	Harriet	07/22/20	10:51		14	7.21	0	0	7.36	679.6	0.5															
27-0016	Harriet	07/22/20	10:50		15	7.07	0	0	7.36	680	0.5				0.268	0.248										
27-0016	Harriet	07/22/20	10:49		16	6.98	0	0	7.35	680.6	0.3															
27-0016	Harriet	07/22/20	10:48		17	6.9	0	0	7.34	681.8	0.2															
27-0016	Harriet	07/22/20	10:47		18	6.89	0	0	7.34	681.7	0.2															
27-0016	Harriet	07/22/20	10:46		19	6.86	0	0	7.34	682.3	0.3															
27-0016	Harriet	07/22/20	10:45		20	6.86	0	0	7.36	681.7	0.7				0.336	0.320							125			
27-0016	Harriet	07/22/20	10:44		21	6.85	0	0	7.36	682	0															
27-0016	Harriet	07/22/20	10:43		22	6.83	0	0	7.37	682.7	0															
27-0016	Harriet	07/22/20	10:41		23	6.83	0	0	7.38	682.9	0															
27-0016	Harriet	07/22/20	10:40		24	6.9	0	0	7.38	682.6	0															
27-0016	Harriet	07/22/20	10:38		24.6	7.16	0	0	7.31	681.3	447															
27-0016	Harriet	08/06/20	8:18	3.55	0	23.98	109.3	9.02	8.57	651.7	0.4	3.7	1.5	2.0	0.010	0.003		<0.500					125		<1	
27-0016	Harriet	08/06/20	8:17		1	24.08	109.5	9.02	8.56	652	0.4															
27-0016	Harriet	08/06/20	8:14		2	24.06	109.2	9.01	8.53	652.1	0.2															
27-0016	Harriet	08/06/20	8:12		3	24.06	109	8.98	8.51	651.8	0.1															
27-0016	Harriet	08/06/20	8:10		4	23.99	109.8	9.07	8.44	652.2	0.1															
27-0016	Harriet	08/06/20	8:09		5	23.95	110.4	9.12	8.32	652	0															
27-0016	Harriet	08/06/20	8:07		6	21.73	24.8	2.14	7.6	666.2	0				0.010	0.003										
27-0016	Harriet	08/06/20	8:04		7	15.54	4	0.39	7.49	675.9	0															
27-0016	Harriet	08/06/20	8:02		8	12.44	0.4	0.04	7.52	675.6	0															
27-0016	Harriet	08/06/20	8:01		9	10.1	0.3	0.03	7.53	676.2	0															
27-0016	Harriet	08/06/20	7:58		10	8.91	2.1	0.24	7.55	678.3	0															
27-0016	Harriet	08/06/20	7:55		11	8.2	1.8	0.21	7.55	679.4	0.2															
27-0016	Harriet	08/06/20	7:54		12	7.82	1.5	0.17	7.55	679.4	0.4				0.190	0.185										
27-0016	Harriet	08/06/20	7:53		13	7.37	0.8	0.09	7.55	679.9	0.6															
27-0016	Harriet	08/06/20	7:52		14	7.12	0.3	0.04	7.55	680.5	0.7															
27-0016	Harriet	08/06/20	7:52		15	7.05	0.5	0.06	7.54	681.5	0.3				0.294	0.288										
27-0016	Harriet	08/06/20	7:51		16	6.98	0.5	0.06	7.55	681.9	0.1															
27-0016	Harriet	08/06/20	7:49		17	6.96	0.2	0.03	7.56	682.2	0															
27-0016	Harriet	08/06/20	7:48		18	6.91	0.2	0.02	7.57	683	0															
27-0016	Harriet	08/06/20	7:47		19	6.87	0.6	0.08	7.59	683.8	0															
27-0016	Harriet	08/06/20	7:46		20	6.85	0.3	0.03	7.6	684.2	0				0.780	0.359							130			
27-0016	Harriet	08/06/20	7:45		21	6.84	0.8	0.09	7.62	684.3	0															
27-0016	Harriet	08/06/20	7:44		22	6.88	1	0.12	7.67	685.6	0															
27-0016	Harriet	08/06/20	7:43		23	6.85	0.7	0.09	7.72	685.7	0															
27-0016	Harriet	08/06/20	7:42		24	6.89	0	0	7.77	686.6	0															
27-0016	Harriet	08/06/20	7:40		24.8	7.42	0	0	7.89	738.4	5.2															
27-0016	Harriet	08/19/20	11:26	2.75	0	24.2	118.6	9.77	8.58	640.5	0.8	1.90	0.520		0.013	0.003		<0.500					120			
27-0016	Harriet	08/19/20	11:25		1	24.2	118.7	9.77	8.56	640.4	0.8															
27-0016	Harriet	08/19/20	11:24		2	24.16	118.9	9.8	8.54	640.5	0.7															
27-0016	Harriet	08/19/20	11:22		3	24.08	118	9.73	8.48	640.5	0.6															
27-0016	Harriet	08/19/20	11:21		4	23.95	118.1	9.77	8.4	640.5	0.6															
27-0016	Harriet	08/19/20	11:20		5	23.56	100	8.33	8.17	643.5	0.5															
27-0016	Harriet	08/19/20	11:18		6	22.33	40.2	3.43	7.71	651.7	0.4				0.015	0.002										
27-0016	Harriet	08/19/20	11:16		7	19.5	4.2	0.38	7.55	667.4	0.2															
27-0016	Harriet	08/19/20	11:15		8	13.54	1.3	0.13	7.55	678.7	0.2															
27-0016	Harriet	08/19/20	11:14		9	11	1.9	0.2	7.56	678.4	0.4															
27-0016	Harriet	08/19/20	11:12		10	9.61	1	0.11	7.56	680.3	0.6															
27-0016	Harriet	08/19/20	11:11		11	8.53	0	0	7.56	682.2	0.7															
27-0016	Harriet	08/19/20	11:10		12	7.81	0	0	7.57	681.4	0.8				0.244	0.211										
27-0016	Harriet	08/19/20	11:09		13	7.38	0	0	7.57	683.2	0.8															
27-0016	Harriet	08/19/20	11:08		14	7.3	0	0	7.57	683.5	0.5															

Lake ID	Lake Name	Date MM/DD/YY	Time HH:MM :SS	Secchi meters	Depth meters	Temp °C	%DO	DO mg/L	pH units	SpCond µS/cm	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/10 0mL	DOC mg/L
27-0016	Harriet	08/19/20	11:07		15	7.09	0	0	7.57	685.2	0.4				0.341	0.309										
27-0016	Harriet	08/19/20	11:06		16	7.04	0	0	7.55	686	0.4															
27-0016	Harriet	08/19/20	11:05		17	6.99	0	0	7.53	686.2	0.4															
27-0016	Harriet	08/19/20	11:03		18	6.96	0	0	7.51	686.8	0.3															
27-0016	Harriet	08/19/20	11:02		19	6.93	0	0	7.51	687.3	0.3															
27-0016	Harriet	08/19/20	11:00		20	6.92	0	0	7.51	687.3	0.3				0.840	0.384							120			
27-0016	Harriet	08/19/20	10:58		21	6.91	0	0	7.54	687.5	0.1															
27-0016	Harriet	08/19/20	10:57		22	6.91	0	0	7.56	687.6	0.1															
27-0016	Harriet	08/19/20	10:55		23	6.91	0	0	7.57	687.7	0.1															
27-0016	Harriet	08/19/20	10:54		24	6.9	0	0	7.6	688	0.1															
27-0016	Harriet	08/19/20	10:52		25	6.9	0	0	7.63	688.2	0															
27-0016	Harriet	09/04/20	10:29	2.80	0	21.89	92.9	7.98	8.44	648.3	0.4	2.2	0.8	2.1	0.014	0.003		<0.500					130			
27-0016	Harriet	09/04/20	10:28		1	21.91	92.8	7.97	8.44	648.1	0.3															
27-0016	Harriet	09/04/20	10:27		2	21.87	92.8	7.98	8.42	648	0.3															
27-0016	Harriet	09/04/20	10:25		3	21.85	92.5	7.95	8.39	647.8	0.3															
27-0016	Harriet	09/04/20	10:24		4	21.77	92.5	7.97	8.36	648.4	0.3															
27-0016	Harriet	09/04/20	10:23		5	21.81	92.4	7.95	8.31	647.9	0.3															
27-0016	Harriet	09/04/20	10:21		6	21.79	92.5	7.96	8.19	647.6	0.4				0.014	0.003										
27-0016	Harriet	09/04/20	10:19		7	20.76	44.7	3.93	7.7	664.3	0.5															
27-0016	Harriet	09/04/20	10:18		8	13.87	0	0	7.51	689.4	0.3															
27-0016	Harriet	09/04/20	10:16		9	11	0	0	7.51	686.7	0.4															
27-0016	Harriet	09/04/20	10:14		10	9.66	0	0	7.5	688.6	0.6															
27-0016	Harriet	09/04/20	10:13		11	8.39	0.1	0.02	7.5	689.1	0.6															
27-0016	Harriet	09/04/20	10:11		12	8.03	0.5	0.06	7.5	689	0.3				0.250	0.229										
27-0016	Harriet	09/04/20	10:10		13	7.64	0.4	0.05	7.48	689.7	0.2															
27-0016	Harriet	09/04/20	10:09		14	7.41	0.8	0.09	7.48	690.9	0.2															
27-0016	Harriet	09/04/20	10:07		15	7.26	0.7	0.09	7.49	691.1	0.3				0.354	0.321										
27-0016	Harriet	09/04/20	10:05		16	7.21	0.8	0.09	7.49	691.6	0.6															
27-0016	Harriet	09/04/20	10:04		17	7.15	0.8	0.09	7.49	692.7	0															
27-0016	Harriet	09/04/20	10:03		18	7.11	0.6	0.07	7.49	694.2	0															
27-0016	Harriet	09/04/20	10:02		19	7.08	0.6	0.07	7.5	693.9	0															
27-0016	Harriet	09/04/20	10:00		20	7.07	0.5	0.05	7.52	693.8	0				0.429	0.387							130			
27-0016	Harriet	09/04/20	9:59		21	7.06	0	0	7.53	694.3	0															
27-0016	Harriet	09/04/20	9:57		22	7.07	0	0	7.58	694.2	0															
27-0016	Harriet	09/04/20	9:55		23	7.12	2.2	0.26	7.65	693.1	0															
27-0016	Harriet	09/04/20	9:54		24	7.12	1.5	0.18	7.68	695.4	0															
27-0016	Harriet	09/04/20	9:52		25	7.19	1.8	0.22	7.74	692.9	0															
27-0016	Harriet	09/17/20	9:42	2.91	0	18.45	91.4	8.56	8.67	645.8	0.67	1.44	0.801		0.013	0.007		0.548					115			
27-0016	Harriet	09/17/20	9:41		1	18.452	91	8.52	8.69	645.8	0.66															
27-0016	Harriet	09/17/20	9:40		2	18.45	90.7	8.49	8.71	645.7	0.65															
27-0016	Harriet	09/17/20	9:39		3	18.457	90.3	8.45	8.73	645.7	0.65															
27-0016	Harriet	09/17/20	9:37		4	18.449	89.4	8.37	8.78	645.6	0.68															
27-0016	Harriet	09/17/20	9:36		5	18.438	88.8	8.31	8.83	645.8	0.69															
27-0016	Harriet	09/17/20	9:36		6	18.442	87.4	8.19	8.86	645.8	0.69				0.015	0.002										
27-0016	Harriet	09/17/20	9:34		7	18.259	70.3	6.61	8.92	647.2	0.69															
27-0016	Harriet	09/17/20	9:33		8	15.804	1.4	0.14	8.68	669.9	1.14															
27-0016	Harriet	09/17/20	9:32		9	10.884	0	0	8.55	690.3	1.41															
27-0016	Harriet	09/17/20	9:31		10	9.235	0	0	8.55	689.7	2.13															
27-0016	Harriet	09/17/20	9:29		11	8.647	0	0	8.52	687.9	3.04															
27-0016	Harriet	09/17/20	9:29		12	8.076	0	0	8.54	691.5	1.41				0.261	0.221										
27-0016	Harriet	09/17/20	9:27		13	7.718	0	0	8.57	694.6	1.01															
27-0016	Harriet	09/17/20	9:26		14	7.539	0	0	8.57	695	0.93															
27-0016	Harriet	09/17/20	9:25		15	7.476	0	0	8.48	696	0.99				0.329	0.340										
27-0016	Harriet	09/17/20	9:24		16	7.339	0	0	8.49	697.9	0.95															
27-0016	Harriet	09/17/20	9:23		17	7.292	0	0	8.51	698.9	0.9															
27-0016	Harriet	09/17/20	9:22		18	7.268	0	0	8.52	700.2	0.92															
27-0016	Harriet	09/17/20	9:20		19	7.244	0	0	8.48	700.7	1.3															
27-0016	Harriet	09/17/20	9:18		20	7.233	0	0	7.95	701.1	0.91				0.452	0.426							110			

Lake ID	Lake Name	Date MM/DD/YY	Time HH:MM :SS	Secchi meters	Depth meters	Temp °C	%DO	DO mg/L	pH units	SpCond µS/cm	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/10 0mL	DOC mg/L
27-0016	Harriet	09/17/20	9:17		21	7.225	0	0	7.9	701.4	0.96															
27-0016	Harriet	09/17/20	9:15		22	7.227	0	0	7.88	701.4	1.5															
27-0016	Harriet	09/17/20	9:14		23	7.225	0	0	7.82	701.8	1.17															
27-0016	Harriet	09/17/20	9:12		24	7.238	0	0	7.75	709.7	2.31															
27-0016	Harriet	09/17/20	9:10		25	7.223	0.3	0.03	7.42	736	1.86															
27-0016	Harriet	11/02/20	11:45	3.04	0	6.753	68.5	8.34	7.98	664.7	1.21	9.29	1.36	1.351	0.094	0.059	0.747	0.801	0.045	<0.250	130	140	110	7.94		
27-0016	Harriet	11/02/20	11:44		1	6.744	68.2	8.32	7.98	664.7	1.22															
27-0016	Harriet	11/02/20	11:44		2	6.728	68.1	8.31	7.98	664.8	1.26															
27-0016	Harriet	11/02/20	11:42		3	6.722	67.6	8.25	7.98	664.8	1.21															
27-0016	Harriet	11/02/20	11:38		4	6.717	67.7	8.26	7.97	664.8	1.24															
27-0016	Harriet	11/02/20	11:36		5	6.7	67.2	8.2	7.97	664.8	1.52															
27-0016	Harriet	11/02/20	11:34		6	6.678	66.9	8.17	7.96	664.9	1.19				0.096	0.063										
27-0016	Harriet	11/02/20	11:32		7	6.689	66.8	8.16	7.96	664.7	1.22															
27-0016	Harriet	11/02/20	11:31		8	6.672	66.7	8.14	7.96	664.8	1.37															
27-0016	Harriet	11/02/20	11:29		9	6.658	66.5	8.13	7.95	664.9	1.21															
27-0016	Harriet	11/02/20	11:27		10	6.663	66.4	8.12	7.95	664.9	1.27															
27-0016	Harriet	11/02/20	11:21		11	6.663	66.4	8.11	7.94	664.9	1.33															
27-0016	Harriet	11/02/20	11:19		12	6.659	66.3	8.1	7.94	664.9	1.16				0.090	0.059										
27-0016	Harriet	11/02/20	11:13		13	6.654	66.2	8.09	7.93	664.8	1.15															
27-0016	Harriet	11/02/20	11:06		14	6.656	66.2	8.08	7.93	664.9	1.13															
27-0016	Harriet	11/02/20	11:04		15	6.648	66.1	8.08	7.93	665	1.26				0.097	0.060										
27-0016	Harriet	11/02/20	11:03		16	6.652	66	8.07	7.94	665	1.1															
27-0016	Harriet	11/02/20	10:58		17	6.649	65.9	8.06	7.94	665.1	1.33															
27-0016	Harriet	11/02/20	10:57		18	6.651	65.9	8.05	7.93	665	1.21															
27-0016	Harriet	11/02/20	10:53		19	6.646	65.8	8.04	8.09	665	1.4															
27-0016	Harriet	11/02/20	10:51		20	6.645	65.8	8.04	7.88	665.2	1.41				0.089	0.059							115	6.18		
27-0016	Harriet	11/02/20	10:48		21	6.639	65.7	8.03	7.86	664.9	1.11															
27-0016	Harriet	11/02/20	10:44		22	6.637	65.4	7.99	7.82	665.1	1.16															
27-0016	Harriet	11/02/20	10:43		23	6.639	65	7.95	7.79	665	1.16															
27-0016	Harriet	11/02/20	10:41		24	6.584	63.1	7.73	7.71	665.4	1.66															
27-0016	Harriet	11/02/20	10:37		25	6.699	0.6	0.07	6.97	701.9	1.6															
27-0018	Hiawatha	01/30/20	11:04		0	0.03	79	11.36	8.08	837.1	0	7.5	1.09	10.9	0.040	0.004	0.935	1.020	0.230	0.697	200	236	155	10.1		
27-0018	Hiawatha	01/30/20	11:04		1	0.28	80.5	11.48	8.09	901.2	0															
27-0018	Hiawatha	01/30/20	11:03		2	0.46	76.2	10.81	8.05	926.6	0															
27-0018	Hiawatha	01/30/20	11:02		3	0.67	69.9	9.87	8.04	938.9	0															
27-0018	Hiawatha	01/30/20	11:01		4	1.33	51.6	7.15	8.03	985.5	0.8				0.048	0.005							165	9.83		
27-0018	Hiawatha	01/30/20	11:00		5	1.53	41.3	5.69	8.06	1030	2.3															
27-0018	Hiawatha	01/30/20	10:59		6	1.49	38.2	5.27	8.11	1082	4.7															
27-0018	Hiawatha	01/30/20	10:58		6.9	1.44	38.5	5.31	8.1	1085	0															
27-0018	Hiawatha	05/01/20	9:50	1.06	0	13.73	91.8	9.28	8.6	564.5	0.8	8.8	4.46	1.96	0.050	0.004	0.517	0.623	0.093	0.260	148	160	80	7.37		
27-0018	Hiawatha	05/01/20	9:49		1	13.7	90.9	9.19	8.61	565.1	0.8															
27-0018	Hiawatha	05/01/20	9:48		2	13.46	86.2	8.76	8.55	571.1	0.8															
27-0018	Hiawatha	05/01/20	9:47		3	13.2	83.4	8.52	8.53	567.5	0.8															
27-0018	Hiawatha	05/01/20	9:47		4	12.52	77.5	8.04	8.47	555.4	0.7				0.042	0.005							85	7.22		
27-0018	Hiawatha	05/01/20	9:45		5	11.49	56.8	6.03	8.35	545.4	0.4															
27-0018	Hiawatha	05/01/20	9:44		6	8.88	47.5	5.36	8.29	588.5	0.1															
27-0018	Hiawatha	05/01/20	9:43		7	7.29	0	0	8.01	1212	0.3															
27-0018	Hiawatha	05/15/20	10:14	2.23	0	14.11	104.4	10.5	8.58	616.4	0	0.90	<0.500	1.096	0.032	0.004	0.525	0.533	<0.030	0.290	166	188	90	7.77		
27-0018	Hiawatha	05/15/20	10:14		1	14.06	104.4	10.52	8.58	616.5	0															
27-0018	Hiawatha	05/15/20	10:13		2	13.91	104.2	10.53	8.57	617.4	0															
27-0018	Hiawatha	05/15/20	10:12		3	13.5	97.4	9.93	8.48	618.2	0															
27-0018	Hiawatha	05/15/20	10:11		4	12.7	81.4	8.45	8.3	619.9	0.2				0.034	0.004							90	7.85		
27-0018	Hiawatha	05/15/20	10:10		5	12.21	71.1	7.47	8.19	627.3	0.5															
27-0018	Hiawatha	05/15/20	10:09		6	11.57	59.1	6.3	8.07	656.5	1															
27-0018	Hiawatha	05/15/20	10:09		7	7.81	4.1	0.47	7.65	1441	1.3															
27-0018	Hiawatha	06/03/20	10:13	1.73	0	22.79	87.2	7.32	7.93	480.1	2	4.47	<0.500		0.045	0.005		0.529					50			
27-0018	Hiawatha	06/03/20	10:13		1	22.66	85.7	7.22	7.91	479.5	2.1															
27-0018	Hiawatha	06/03/20	10:10		2	22.14	80.1	6.81	7.87	479.3	2.2															

Lake ID	Lake Name	Date MM/DD/YY	Time HH:MM :SS	Secchi meters	Depth meters	Temp °C	%DO	DO mg/L	pH units	SpCond µS/cm	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/10 0mL	DOC mg/L
27-0018	Hiawatha	06/03/20	10:09		3	21.99	76.3	6.51	7.84	480.3	2.3															
27-0018	Hiawatha	06/03/20	10:08		4	21.55	66.3	5.7	7.78	483	2.5				0.043	0.009							50			
27-0018	Hiawatha	06/03/20	10:07		5	20.47	55.7	4.89	7.74	491.7	2.3															
27-0018	Hiawatha	06/03/20	10:06		6	16.7	7.9	0.75	7.51	552.9	1.8															
27-0018	Hiawatha	06/03/20	10:04		7	11.45	0	0	7.52	760.5	1.2															
27-0018	Hiawatha	06/03/20	10:02		8	8.7	0	0	7.46	1251	1.5															
27-0018	Hiawatha	06/10/20	9:56	1.58	0	23.55	66.4	5.43	7.81	497.6	0.3	7.30	1.98	3.19	0.053	0.019		0.552					70			
27-0018	Hiawatha	06/10/20	9:55		1	23.56	66.3	5.43	7.82	497.8	0.2															
27-0018	Hiawatha	06/10/20	9:55		2	23.55	66.6	5.45	7.81	498.1	0.2															
27-0018	Hiawatha	06/10/20	9:54		3	23.48	67	5.49	7.82	498.9	0.3															
27-0018	Hiawatha	06/10/20	9:53		3.5	23.53	67.6	5.53	7.82	498.3	2.4				0.059	0.020							70			
27-0018	Hiawatha	06/26/20	12:02	1.39	0	23.77	119	9.79	8.28	603.1	1.1	28.00	7.60		0.059	0.004		0.596					95			
27-0018	Hiawatha	06/26/20	12:01		1	23.73	117.9	9.7	8.25	603.7	1.1															
27-0018	Hiawatha	06/26/20	12:00		2	22.64	75.3	6.33	7.83	601.4	1.1															
27-0018	Hiawatha	06/26/20	11:59		3	22.28	42.9	3.62	7.67	599.6	1.2															
27-0018	Hiawatha	06/26/20	11:58		4	21.84	20	1.71	7.64	602.1	1.4				0.042	0.005							90			
27-0018	Hiawatha	06/26/20	11:58		5	21.14	11.9	1.03	7.68	604.1	0.9															
27-0018	Hiawatha	06/26/20	11:57		6	18.7	1.2	0.11	7.73	634.6	0.4															
27-0018	Hiawatha	06/26/20	11:56		6.9	10.67	0	0	7.69	1169	2.7															
27-0018	Hiawatha	07/10/20	11:15	1.03	0	27.25	90.1	6.98	7.96	550.3	2.6	24.8	8.77	5.03	0.059	0.005	0.896	0.931	<0.030	0.714	125	148	80	10.32		
27-0018	Hiawatha	07/10/20	11:14		1	26.61	79.4	6.23	7.86	553	2.6															
27-0018	Hiawatha	07/10/20	11:14		2	26.55	76.8	6.03	7.79	553	2.4															
27-0018	Hiawatha	07/10/20	11:13		3	26.02	57.7	4.57	7.58	551.1	2.3															
27-0018	Hiawatha	07/10/20	11:12		4	23.73	1.1	0.09	7.36	527.5	2.3				0.045	0.010							81	7.95		
27-0018	Hiawatha	07/10/20	11:11		5	21.2	0	0	7.44	593	1.2															
27-0018	Hiawatha	07/10/20	11:11		6	18.18	0.9	0.08	7.55	660	0.8															
27-0018	Hiawatha	07/10/20	11:10		7	13.18	9.1	0.93	7.36	1172	2.6															
27-0018	Hiawatha	07/23/20	10:42	0.7	0	24.24	67.5	5.57	7.77	552.7	4.7	27.19	9.51		0.038	0.005		0.517					92			
27-0018	Hiawatha	07/23/20	10:41		1	23.72	68.1	5.67	7.79	549.8	4.6															
27-0018	Hiawatha	07/23/20	10:40		2	23.64	53.2	4.44	7.74	550.7	4.7															
27-0018	Hiawatha	07/23/20	10:38		3	23.5	55.1	4.61	7.77	555.5	5															
27-0018	Hiawatha	07/23/20	10:37		4	23.13	60	5.05	7.78	564.3	5.6				0.040	0.005							92			
27-0018	Hiawatha	07/23/20	10:36		5	22.69	14.5	1.23	7.67	570	9.1															
27-0018	Hiawatha	07/23/20	10:35		6	16.91	1.2	0.11	7.77	790.7	14															
27-0018	Hiawatha	07/23/20	10:34		6.8	13.6	1.7	0.18	7.81	1153	39.4															
27-0018	Hiawatha	08/06/20	12:03	0.88	0	23.27	110.6	9.25	8.07	599.2	3.2	29.2	6.5	6.3	0.028	0.006		0.601					95		25	
27-0018	Hiawatha	08/06/20	12:02		1	23.24	110.9	9.29	8.04	599.2	3.2															
27-0018	Hiawatha	08/06/20	12:01		2	23.18	106.9	8.96	7.94	598.5	3.1															
27-0018	Hiawatha	08/06/20	12:01		3	22.89	37.3	3.15	7.65	606	3.1															
27-0018	Hiawatha	08/06/20	11:59		4	22.46	78.1	6.64	7.79	615.4	3.1				0.029	0.006							95			
27-0018	Hiawatha	08/06/20	11:59		5	22.11	41.6	3.56	7.68	619.3	3.6															
27-0018	Hiawatha	08/06/20	11:58		6	17	2.2	0.21	7.54	817.7	4															
27-0018	Hiawatha	08/06/20	11:56		6.8	13.55	1.3	0.13	7.51	1173	5.1															
27-0018	Hiawatha	08/20/20	11:53	0.89	0	23.58	128.5	10.64	8.42	531.1	2.6	34.1	5.80		0.062	0.004		<0.500					90			
27-0018	Hiawatha	08/20/20	11:52		1	23.45	127	10.54	8.35	532.4	2.3															
27-0018	Hiawatha	08/20/20	11:51		2	23.19	105.4	8.79	8.18	533.3	2.3															
27-0018	Hiawatha	08/20/20	11:51		3	22.84	51.2	4.3	7.96	546.8	2.3															
27-0018	Hiawatha	08/20/20	11:50		4	22.52	4.6	0.39	7.97	518.1	2.1				0.070	0.005							90			
27-0018	Hiawatha	09/08/20	11:36	0.96	0	18.97	69.2	6.35	7.9	642.2	41.4	13.3	6.68	8.4	0.060	0.004		0.759					110			
27-0018	Hiawatha	09/08/20	11:35		1	18.97	69.1	6.34	7.92	642.2	40.1															
27-0018	Hiawatha	09/08/20	11:34		2	18.9	69.3	6.37	7.93	642.6	3.2															
27-0018	Hiawatha	09/08/20	11:33		3	18.76	72.8	6.71	7.98	642.9	4.1															
27-0018	Hiawatha	09/08/20	11:31		4	18.27	74.2	6.9	8.01	644.8	6				0.060	0.003							110			
27-0018	Hiawatha	09/08/20	11:30		5	18.15	72.8	6.79	8.04	645.1	9.7															
27-0018	Hiawatha	09/08/20	11:29		6	18.16	58.3	5.44	8.02	687.7	18															
27-0018	Hiawatha	09/18/20	10:22	1.34	0	16.77	94.7	9.14	7.94	629	2.3	5.96	3.77		0.039	0.004		0.774					95			
27-0018	Hiawatha	09/18/20	10:22		1	16.77	94	9.08	7.94	629.1	2.2															
27-0018	Hiawatha	09/18/20	10:21		2	16.72	94.3	9.11	7.91	627.8	2.2															

Lake ID	Lake Name	Date MM/DD/YY	Time HH:MM :SS	Secchi meters	Depth meters	Temp °C	%DO	DO mg/L	pH units	SpCond µS/cm	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/10 0mL	DOC mg/L
27-0018	Hiawatha	09/18/20	10:21		3	16.48	90.3	8.77	7.88	626.4	2.2															
27-0018	Hiawatha	09/18/20	10:20		4	16.08	78.9	7.73	7.85	625.1	2.5				0.034	0.005							100			
27-0018	Hiawatha	09/18/20	10:19		5	15.98	58.4	5.73	7.85	624.2	2.7															
27-0018	Hiawatha	09/18/20	10:18		6	15.76	3.3	0.33	7.94	670.6	2.5															
27-0018	Hiawatha	09/18/20	10:18		7	15.4	3.7	0.37	8.03	702.7	2.6															
27-0018	Hiawatha	10/15/20	9:10	0.79	0	12.767	67.4	7.13	8.16	549.3	2.46	6.8	5.81	4.9	0.073	0.005	0.577	0.675	0.078	<0.250	155	178	70	9.12		
27-0018	Hiawatha	10/15/20	9:09		1	12.806	66.7	7.05	8.16	549.8	2.61															
27-0018	Hiawatha	10/15/20	9:09		2	12.74	66.4	7.03	8.15	550.1	3.5															
27-0018	Hiawatha	10/15/20	9:08		3	12.657	65.7	6.97	8.14	550	3.78															
27-0018	Hiawatha	10/15/20	9:07		4	12.788	4.7	0.5	7.74	559.6	12.34				0.074	0.005							65	8.85		
27-0040	Isles	01/22/20	11:39		0	0.23	36	5.1	7.65	696	2.9	26.4	5.45	4.55	0.106	0.012	1.17	1.46	0.145	0.600	141	164	130	7.70		
27-0040	Isles	01/22/20	11:38		1	2.89	43.9	5.77	7.65	694.2	2.7															
27-0040	Isles	01/22/20	11:37		2	2.69	45.5	6.01	7.65	718.1	2.7															
27-0040	Isles	01/22/20	11:35		3	2.8	38.6	5.08	7.65	725.9	2.5															
27-0040	Isles	01/22/20	11:32		4	2.98	16.5	2.17	7.67	731.1	2.8															
27-0040	Isles	01/22/20	11:30		5	3.01	33.9	4.44	7.71	737.4	3.1				0.094	0.042										
27-0040	Isles	01/22/20	11:29		6	2.95	40.5	5.31	7.73	745.9	3.4															
27-0040	Isles	01/22/20	11:27		7	3.01	26.6	3.49	7.75	749.6	3															
27-0040	Isles	01/22/20	11:25		8	3.11	21.7	2.84	7.78	753.2	4				0.105	0.037							145	9.21		
27-0040	Isles	01/22/20	11:24		9	3.21	15.5	2.02	7.82	756.6	15.4															
27-0040	Isles	01/22/20	11:22		10	3.4	2.7	0.35	7.81	778.5	133.5															
27-0040	Isles	04/29/20	10:07	0.67	0	11.45	103.1	10.96	8.51	713.9		18.7	4.92	1.61	0.075	0.003	0.723	0.814	<0.030	0.260	131	156	140	8.86		
27-0040	Isles	04/29/20	10:06		1	11.47	103.2	10.96	8.52	713.6																
27-0040	Isles	04/29/20	10:06		2	11.43	102.6	10.91	8.51	713.9																
27-0040	Isles	04/29/20	10:05		3	11.35	101.8	10.84	8.49	713.5																
27-0040	Isles	04/29/20	10:04		4	8.61	78.9	8.96	8	717																
27-0040	Isles	04/29/20	10:03		5	8.24	71.9	8.25	7.9	715.9					0.068	0.004										
27-0040	Isles	04/29/20	10:02		6	8.05	66	7.6	7.84	715.7																
27-0040	Isles	04/29/20	10:01		7	7.97	64	7.38	7.82	715.9																
27-0040	Isles	04/29/20	10:00		8	7.89	60.9	7.04	7.79	715.8					0.060	0.005							140	8.73		
27-0040	Isles	04/29/20	9:59		9	7.7	45.3	5.27	7.7	716.3																
27-0040	Isles	05/11/20	11:05	1.09	0	12.82	98	10.25	8.87	718.1	4.4	12.2	1.21	1.096	0.062	0.003	<0.500	0.522	<0.030	0.322	130	148	140	8.83		
27-0040	Isles	05/11/20	11:04		1	12.73	97.8	10.25	8.89	717.9	3.5															
27-0040	Isles	05/11/20	11:04		2	12.65	98	10.28	8.87	717.6	2.7															
27-0040	Isles	05/11/20	11:03		3	12.56	96.6	10.15	8.84	717.4	2.3															
27-0040	Isles	05/11/20	11:02		4	12.46	93.9	9.9	8.73	717.4	1.4															
27-0040	Isles	05/11/20	11:00		5	9.88	35.8	4	8.04	720.4	0.1				0.067	0.003										
27-0040	Isles	05/11/20	10:59		6	8.71	33	3.8	8.04	717.7	0															
27-0040	Isles	05/11/20	10:58		7	8.36	30.3	3.52	8.05	718.1	0															
27-0040	Isles	05/11/20	10:57		8	7.9	8.5	1	8.04	721.4	1.1				0.056	0.019							135	8.41		
27-0040	Isles	05/11/20	10:56		9	7.67	0	0	8.09	729.2	3.6															
27-0040	Isles	05/26/20	9:20	2.51	0	21.03	153.8	13.33	8.89	706.1	1.2	7.41	0.75		0.044	0.004		0.522					127			
27-0040	Isles	05/26/20	9:19		1	20.91	149.5	12.99	8.85	666.4	1.3															
27-0040	Isles	05/26/20	9:17		2	17.21	92.4	8.65	8.09	692.4	1.5															
27-0040	Isles	05/26/20	9:14		3	14.82	102.9	10.13	8.33	696.1	1.7															
27-0040	Isles	05/26/20	9:13		4	13.76	68.7	6.92	7.89	697.9	0.4															
27-0040	Isles	05/26/20	9:11		5	12.45	34.9	3.63	7.6	708.1	0				0.047	0.003										
27-0040	Isles	05/26/20	9:09		6	9.82	0	0	7.4	719.2	0.2															
27-0040	Isles	05/26/20	9:08		7	8.6	0	0	7.39	719.5	0.8															
27-0040	Isles	05/26/20	9:07		8	8.3	0	0	7.39	721.4	1.4				0.092	0.059							130			
27-0040	Isles	05/26/20	9:05		9	7.9	0	0	7.28	727.4	28.5															
27-0040	Isles	05/26/20	9:03		10	8.03	0	0	7.15	738.2	26															
27-0040	Isles	06/08/20	11:04	1.61	0	24.14	119	9.71	8.74	643.4	0.4	7.50	1.21	0.585	0.039	0.004		0.500					135			
27-0040	Isles	06/08/20	11:03		1	24.02	119.7	9.78	8.73	642.9	0.5															
27-0040	Isles	06/08/20	11:02		2	23.91	119.7	9.8	8.72	643.2	0.7															
27-0040	Isles	06/08/20	11:01		3	19.33	83.9	7.51	7.88	694.6	0.9															
27-0040	Isles	06/08/20	11:01		4	15.26	77.3	7.53	7.88	699.6	1.1															
27-0040	Isles	06/08/20	11:00		5	12.51	2.5	0.25	7.33	712.2	0.8				0.081	0.011										

Lake ID	Lake Name	Date MM/DD/YY	Time HH:MM :SS	Secchi meters	Depth meters	Temp °C	%DO	DO mg/L	pH units	SpCond µS/cm	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/10 0mL	DOC mg/L
27-0040	Isles	06/08/20	10:59		6	10.59	0	0	7.28	722.1	0.9															
27-0040	Isles	06/08/20	10:59		7	9.24	0	0	7.24	724.4	1.5															
27-0040	Isles	06/08/20	10:58		8	8.76	0	0	7.22	724.1	2				0.128	0.065							145			
27-0040	Isles	06/08/20	10:57		8.9	8.32	0	0	7.09	726.9	1.9															
27-0040	Isles	06/22/20	9:27	1.35	0	23.41	126.9	10.52	8.9	631.7	4.2	34.30	2.350		0.065	0.007		<0.500					115			
27-0040	Isles	06/22/20	9:26		1	23.37	127.1	10.54	8.89	631.9	2.9															
27-0040	Isles	06/22/20	9:25		2	23.34	121.5	10.08	8.8	632.1	2.9															
27-0040	Isles	06/22/20	9:24		3	21.78	25.4	2.17	7.59	651.1	2.9															
27-0040	Isles	06/22/20	9:23		4	18.92	0.2	0.02	7.44	671.8	3															
27-0040	Isles	06/22/20	9:22		5	12.85	1.2	0.13	7.37	709.2	3.4				0.057	0.020										
27-0040	Isles	06/22/20	9:22		6	10.63	0	0	7.35	718.4	3.4															
27-0040	Isles	06/22/20	9:21		7	9.36	0	0	7.29	723	3.1															
27-0040	Isles	06/22/20	9:20		8	8.42	0	0	7.26	727.3	3				0.181	0.106							140			
27-0040	Isles	06/22/20	9:18		9	8.42	0	0	7.18	729.8	3.7															
27-0040	Isles	06/22/20	9:17		9.7	9.55	0	0	7.19	723	435															
27-0040	Isles	07/06/20	13:12	1	0	30.05	175.6	12.97	8.88	2.5	6.3	22.7	0.58	2.42	0.044	0.003	0.983	1.010	<0.030	0.613	89	104	115	9.31		
27-0040	Isles	07/06/20	13:11		1	29.32	191.7	14.33	8.92	596.6	6.5															
27-0040	Isles	07/06/20	13:10		2	27.23	87.1	6.76	7.96	629.2	6.5															
27-0040	Isles	07/06/20	13:09		3	22.55	0	0	7.43	655.4	4															
27-0040	Isles	07/06/20	13:08		4	19.48	0	0	7.28	671.6	4.5															
27-0040	Isles	07/06/20	13:08		5	13.99	2.3	0.24	7.19	709.6	3.6				0.060	0.011										
27-0040	Isles	07/06/20	13:07		6	10.75	0	0	7.14	717.9	2.9															
27-0040	Isles	07/06/20	13:06		7	9.79	0	0	7.11	718.6	2.8															
27-0040	Isles	07/06/20	13:05		8	9.08	0	0	7.08	725.3	2.9				0.164	0.148							145	8.94		
27-0040	Isles	07/06/20	13:05		9	8.37	0	0	7.08	737.4	3.1															
27-0040	Isles	07/20/20	10:54	0.71	0	26.65	116.5	9.15	8.82	601.2	6.3	59.4	4.88		0.055	0.005		2.060					120			
27-0040	Isles	07/20/20	10:53		1	26.14	95.9	7.6	8.63	603.2	6															
27-0040	Isles	07/20/20	10:52		2	25.89	60.7	4.84	8.16	611.3	4.8															
27-0040	Isles	07/20/20	10:51		3	24.37	3.5	0.29	7.65	636.3	3.2															
27-0040	Isles	07/20/20	10:50		4	18.87	0	0	7.52	699.4	2.8															
27-0040	Isles	07/20/20	10:48		5	13.54	1.7	0.18	7.46	732	2.3				0.064	0.049										
27-0040	Isles	07/20/20	10:47		6	11.05	0.9	0.1	7.45	738.8	2.5															
27-0040	Isles	07/20/20	10:46		7	9.88	0	0	7.47	744.6	2.8															
27-0040	Isles	07/20/20	10:45		8	9.08	1.1	0.12	7.43	749.5	3.3				0.239	0.189							135			
27-0040	Isles	07/20/20	10:44		9	8.97	0	0	7.44	769	4															
27-0040	Isles	08/04/20	8:42	1.05	0	24.28	60.9	5.02	8.1	615.6	3	30.1	4.0	3.5	0.049	0.003		0.908					130		<1	
27-0040	Isles	08/04/20	8:41		1	24.21	61.4	5.07	8.04	616.1	2.5															
27-0040	Isles	08/04/20	8:41		2	24.05	62.1	5.14	7.94	617	2.3															
27-0040	Isles	08/04/20	8:40		3	23.48	38.9	3.25	7.7	624.7	1.9															
27-0040	Isles	08/04/20	8:39		4	18.1	0.7	0.07	7.46	710.4	1.5															
27-0040	Isles	08/04/20	8:38		5	13.26	0.5	0.06	7.43	743.1	1.2				0.058	0.017										
27-0040	Isles	08/04/20	8:36		6	11.14	0.8	0.08	7.46	744.9	1.2															
27-0040	Isles	08/04/20	8:35		7	9.97	2.3	0.26	7.48	749.4	1.4															
27-0040	Isles	08/04/20	8:35		8	9	1.7	0.19	7.5	761.2	1.9				0.269	0.226							140			
27-0040	Isles	08/04/20	8:34		8.9	8.83	0	0	7.56	785.1	2.4															
27-0040	Isles	08/17/20	10:28	0.9	0	24.27	111.9	9.21	8.54	602.9	4.4	6.5	6.43		0.053	0.006		<0.500					115			
27-0040	Isles	08/17/20	10:27		1	24.26	111	9.14	8.5	602.8	4.3															
27-0040	Isles	08/17/20	10:26		2	24.18	108.4	8.94	8.4	600.8	4.2															
27-0040	Isles	08/17/20	10:23		3	23.34	19.9	1.66	7.52	610.2	3.9															
27-0040	Isles	08/17/20	10:22		4	20.33	0	0	7.38	686	3.6															
27-0040	Isles	08/17/20	10:20		5	14.34	0.7	0.07	7.31	734.5	2.6				0.035	0.004										
27-0040	Isles	08/17/20	10:19		6	11.94	2.2	0.23	7.31	745.3	2.5															
27-0040	Isles	08/17/20	10:17		7	10.25	0.4	0.05	7.26	753.1	2.6															
27-0040	Isles	08/17/20	10:16		8	9.41	0	0	7.25	762.9	2.8				0.297	0.250							135			
27-0040	Isles	08/17/20	10:13		9	8.84	0	0	7.28	778.3	3.1															
27-0040	Isles	08/31/20	11:33	0.80	0	24.22	87.7	7.11	8.31	609.2	5	10.6	5.01	2.3	0.039	0.003		0.887					120			
27-0040	Isles	08/31/20	11:32		1	24.14	86.2	7	8.28	609.5	5															
27-0040	Isles	08/31/20	11:31		2	23.94	80.1	6.53	8.14	608.7	4.7															

Lake ID	Lake Name	Date MM/DD/YY	Time HH:MM :SS	Secchi meters	Depth meters	Temp °C	%DO	DO mg/L	pH units	SpCond µS/cm	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/10 0mL	DOC mg/L
27-0040	Isles	08/31/20	11:30		3	23.67	71.8	5.88	7.9	608.3	4.4															
27-0040	Isles	08/31/20	11:29		4	19.56	2.6	0.23	7.45	695.3	4.1															
27-0040	Isles	08/31/20	11:28		5	15.64	0	0	7.39	739.4	2.9				0.058	<0.003										
27-0040	Isles	08/31/20	11:27		6	11.82	1.5	0.16	7.35	751.7	2.5															
27-0040	Isles	08/31/20	11:26		7	10.36	0.6	0.06	7.34	761	2.5															
27-0040	Isles	08/31/20	11:25		8	9.5	0.9	0.1	7.32	770.4	2.7				0.386	0.300							135			
27-0040	Isles	08/31/20	11:24		9	8.95	2.3	0.25	7.29	790.2	3.1															
27-0040	Isles	09/14/20	10:21	0.81	0	17.691	96.6	9.19	8.7	624.3	2.89	2.24	1.23		0.036	<0.003		0.834					110			
27-0040	Isles	09/14/20	10:19		1	17.621	94.9	9.04	8.66	624.3	2.87															
27-0040	Isles	09/14/20	10:16		2	17.341	82.9	7.94	8.55	625.2	2.71															
27-0040	Isles	09/14/20	10:13		3	16.875	67.4	6.52	8.3	623.4	2.73															
27-0040	Isles	09/14/20	10:12		4	16.682	58.7	5.7	8.22	625.5	2.5															
27-0040	Isles	09/14/20	10:10		5	15.717	0	0	7.88	653.6	2.21				0.036	<0.003										
27-0040	Isles	09/14/20	10:07		6	11.868	0	0	7.67	762.3	2.13															
27-0040	Isles	09/14/20	10:05		7	10.331	0	0	7.64	770.3	2.12															
27-0040	Isles	09/14/20	10:04		8	9.36	0	0	7.58	790.3	2.98				0.358	0.284							125			
27-0040	Isles	09/14/20	10:02		9	8.824	0	0	7.56	818.7	3.89															
27-0040	Isles	09/14/20	10:00		9.4	9.361	2.2	0.26	7.37	830.8	24.36															
27-0040	Isles	10/23/20	11:52	2.75	0	6.592	53.9	6.6	7.73	660.1	0.85	3.68	1.92	1.91	0.056	0.018	1.03	1.29	0.075	<0.250	127	140	115	8.14		
27-0040	Isles	10/23/20	11:52		1	6.61	53.5	6.55	7.72	660.1	0.89															
27-0040	Isles	10/23/20	11:51		2	6.612	53.4	6.54	7.72	660.1	0.85															
27-0040	Isles	10/23/20	11:50		3	6.612	53.3	6.52	7.71	660	0.91															
27-0040	Isles	10/23/20	11:50		4	6.594	53.1	6.5	7.7	660.3	0.9															
27-0040	Isles	10/23/20	11:49		5	6.602	52.9	6.47	7.69	660.1	0.85				0.052	0.021										
27-0040	Isles	10/23/20	11:48		6	6.596	52.7	6.45	7.68	660	0.84															
27-0040	Isles	10/23/20	11:48		7	6.488	52	6.38	7.66	660.3	0.92															
27-0040	Isles	10/23/20	11:47		8	6.434	49.8	6.12	7.64	660.1	0.9				0.061	0.021							120	8.32		
27-0040	Isles	10/23/20	11:47		9	6.411	41.8	5.13	7.59	660	48.76															
27-655	Loring	01/24/20	11:39		0	0.28	20.7	2.95	7.81	762.8	0	46.2	15.3	9.93	0.142	0.038	1.47	1.59	0.038	0.686	181	228	130	9.05		
27-655	Loring	01/24/20	11:38		1	3.42	16.2	2.11	7.78	763.8	0															
27-655	Loring	01/24/20	11:36		2	3.72	13.1	1.7	7.77	765.8	0															
27-655	Loring	01/24/20	11:33		3	4.03	5.7	0.73	7.75	772.2	0															
27-655	Loring	01/24/20	11:31		4	4.37	0	0	7.75	779.3	4.8				0.122	0.071							130	8.35		
27-655	Loring	04/30/20	12:31	1.16	0	15.24	113.9	11.17	8.62	639.2		10.2	4.52	4.77	0.062	0.005	0.539	0.601	<0.030	<0.250	138	172	110	7.67		
27-655	Loring	04/30/20	12:31		1	13.53	112.8	11.49	8.63	635.1																
27-655	Loring	04/30/20	12:30		2	11.43	123.9	13.23	8.66	650.5																
27-655	Loring	04/30/20	12:27		3	7.6	0	0	7.33	711.7																
27-655	Loring	04/30/20	12:27		4	6.7	2.5	0.29	7.14	819.1					0.287	0.112							120	7.90		
27-655	Loring	05/12/20	11:24	1.53	0	14.37	117.7	11.89	8.9	626.3	2.3	8.2	0.82	6.664	0.062	<0.003	<0.500	0.511	<0.030	0.363	131	160	110	7.93		
27-655	Loring	05/12/20	11:23		1	13.85	114.8	11.73	8.87	626	3															
27-655	Loring	05/12/20	11:23		2	12.83	97.6	10.2	8.72	624.7	4.8															
27-655	Loring	05/12/20	11:22		3	9.9	5.9	0.66	7.68	712.3	10.1															
27-655	Loring	05/12/20	11:21		4	7.27	10	1.19	7.45	838.6	29.4				0.319	0.137							115	7.77		
27-655	Loring	05/27/20	11:08	0.94	0	21.27	100.1	8.65	8.13	629.3	5.6	18.10	7.72		0.128	0.043		0.551					105			
27-655	Loring	05/27/20	11:05		1	20.64	81.1	7.1	7.9	632	4.7															
27-655	Loring	05/27/20	11:04		2	20.41	76.5	6.73	7.82	654.5	4.9															
27-655	Loring	05/27/20	11:03		3	19.66	56.4	5.03	7.68	654.7	4.6															
27-655	Loring	05/27/20	11:02		4	18.55	0	0	7.4	659.5	4.1				0.179	0.081							110			
27-655	Loring	06/09/20	10:46	0.6	0	24.88	91.2	7.3	7.92	635.7	4.3	32.1	10.70	7.48	0.147	0.048		0.575					110			
27-655	Loring	06/09/20	10:45		1	24.44	71.7	5.79	7.71	636.7	4.3															
27-655	Loring	06/09/20	10:45		2	24.37	68.8	5.56	7.67	636.2	4.3															
27-655	Loring	06/09/20	10:44		3	24.19	61.6	5	7.58	636.4	4.7															
27-655	Loring	06/09/20	10:43		4	21.97	0	0	7.23	640.9	7.7				0.151	0.058							110			
27-655	Loring	06/24/20	10:05	0.63	0	23.27	71.6	5.96	7.7	653	3.7	53.30	11.36		0.163	0.060		0.559					125			
27-655	Loring	06/24/20	10:05		1	22.91	57.2	4.79	7.61	652.7	3.5															
27-655	Loring	06/24/20	10:04		2	22.84	50.3	4.22	7.57	652.6	3.8															
27-655	Loring	06/24/20	10:03		3	22.7	38.8	3.27	7.5	653.3	3.1															
27-655	Loring	06/24/20	10:02		3.9	22.19	44.3	3.76	7.45	702.6	10.5				0.124	0.063							120			

Lake ID	Lake Name	Date MM/DD/YY	Time HH:MM :SS	Secchi meters	Depth meters	Temp °C	%DO	DO mg/L	pH units	SpCond µS/cm	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/10 0mL	DOC mg/L
27-655	Loring	07/08/20	9:11	0.59	0	27.69	23.1	1.77	7.44	691.5	2.6	33.3	13.17	12.59	0.119	0.062	1.016	1.076	<0.030	0.411	139	176	115	10.10		
27-655	Loring	07/08/20	9:10		1	27.72	22.1	1.69	7.43	691	2.6															
27-655	Loring	07/08/20	9:10		2	27.71	21.1	1.61	7.43	691.2	2.4															
27-655	Loring	07/08/20	9:09		3	27.69	20	1.53	7.45	691.3	2.2															
27-655	Loring	07/08/20	9:08		3.4	27.72	19.5	1.49	7.46	690.9	2				0.118	0.062							120	9.69		
27-655	Loring	07/21/20	12:08	0.64	0	26.71	51.1	3.99	7.58	707.7	3.2	44.0	12.6		0.101	0.057		0.560					120			
27-655	Loring	07/21/20	12:07		1	26.46	34.7	2.73	7.53	708.2	2.8															
27-655	Loring	07/21/20	12:06		2	26.41	33.4	2.62	7.56	707.9	2.7															
27-655	Loring	07/21/20	12:05		3	26.34	23.6	1.86	7.57	707.7	2.9															
27-655	Loring	07/21/20	12:04		3.9	26.18	17.8	1.4	7.63	708.7	4				0.099	0.068							120			
27-655	Loring	08/04/20	12:52	0.57	0	25.12	142.2	11.54	8.05	727.2	4.6	52.8	12.3	19.5	0.156	0.047		0.661					120		6	
27-655	Loring	08/04/20	12:52		1	24.48	70.9	5.82	7.68	729.9	3.4															
27-655	Loring	08/04/20	12:51		2	24.22	49.6	4.1	7.61	730.3	3.3															
27-655	Loring	08/04/20	12:50		3	24.12	40.4	3.34	7.6	730.1	3.1															
27-655	Loring	08/04/20	12:49		3.9	24	27.6	2.29	7.63	729.8	2.1				0.085	0.046							120			
27-655	Loring	08/18/20	10:09	0.81	0	23.88	71.3	5.91	7.7	743.5	43.2	40.7	18.9		0.144	0.010		<0.500					125			
27-655	Loring	08/18/20	10:08		1	23.88	71.9	5.96	7.7	743.5	4.5															
27-655	Loring	08/18/20	10:06		2	23.88	71.6	5.94	7.7	743.5	4.1															
27-655	Loring	08/18/20	10:05		3	23.88	68.7	5.7	7.69	743.3	5.1															
27-655	Loring	08/18/20	10:04		4	23.74	49.6	4.13	7.67	743.7	15.5				0.175	0.017							125			
27-655	Loring	09/01/20	10:57	0.47	0	23.9	56.6	4.65	7.75	751.6	5.7	40.1	19.7	17.6	0.124	0.003		1.030					130			
27-655	Loring	09/01/20	10:56		1	23.88	55.8	4.59	7.75	751.7	5.7															
27-655	Loring	09/01/20	10:55		2	23.88	53.8	4.42	7.78	751.5	5.6															
27-655	Loring	09/01/20	10:55		3	23.84	53.6	4.41	7.81	751.4	5.5															
27-655	Loring	09/01/20	10:54		4	23.79	51.1	4.21	7.83	751.4	5.9				0.134	0.004							135			
27-655	Loring	09/16/20	10:40	0.72	0	18.17	110.2	10.17	7.92	812.8	3.6	18.5	11.4		0.068	<0.003		0.751					130			
27-655	Loring	09/16/20	10:39		1	18.09	106.2	9.82	7.9	812.9	3.6															
27-655	Loring	09/16/20	10:39		2	18.05	104.6	9.68	7.9	813.2	3.6															
27-655	Loring	09/16/20	10:38		3	18.02	103.6	9.59	7.92	812.4	3.6															
27-655	Loring	09/16/20	10:37		4	17.27	69.8	6.57	8.02	851.6	5				0.068	<0.003							130			
27-655	Loring	10/14/20	11:37	0.73	0	14.353	88.8	9.06	8.14	836.5	3.98	29.5	14.8	13.31	0.092	0.005	0.73	0.83	0.063	0.564	192	252	140	12.89		
27-655	Loring	10/14/20	11:37		1	14.345	88.2	9	8.13	835	4.07															
27-655	Loring	10/14/20	11:36		2	14.33	88	8.98	8.12	835.2	4.18															
27-655	Loring	10/14/20	11:35		3	14.311	86.7	8.85	8.07	836.2	3.9															
27-655	Loring	10/14/20	11:33		4	14.191	74.7	7.65	7.86	871.9	4.53				0.092	0.004							140	12.67		
27-0018	Nokomis	01/30/20	10:14		0	0.34	113.5	16.18	8.81	596.4	5.8	23.7	<0.500	13.4	0.076	0.003	0.761	0.796	<0.030	0.362	131	128	100	5.11		
27-0018	Nokomis	01/30/20	10:14		1	2.27	102	13.79	8.44	594.6	5.9															
27-0018	Nokomis	01/30/20	10:13		2	2.64	74.5	9.96	7.92	598	3.3															
27-0018	Nokomis	01/30/20	10:12		3	3.01	35.3	4.68	7.66	604.4	0.5															
27-0018	Nokomis	01/30/20	10:11		4	3.44	11.1	1.46	7.56	630	0				0.054	0.003										
27-0018	Nokomis	01/30/20	10:10		5	3.68	0.6	0.07	7.53	645.2	0.2															
27-0018	Nokomis	01/30/20	10:08		6	3.79	0	0	7.55	651.4	1.8															
27-0018	Nokomis	01/30/20	10:07		7	3.92	0	0	7.57	659.8	2.1				0.083	0.006							105	4.65		
27-0018	Nokomis	01/30/20	10:06		7.9	3.96	0	0	7.59	665.2	3.7															
27-0018	Nokomis	05/01/20	9:04	0.57	0	12.44	117	12.16	9.16	611.2	12.8	14.7	26.2	10.0	0.076	0.004	0.930	1.03	<0.030	0.271	132	136	110	6.08		
27-0018	Nokomis	05/01/20	9:03		1	12.42	117	12.16	9.15	611.4	12.7															
27-0018	Nokomis	05/01/20	9:02		2	11.51	106.7	11.33	9.01	610.5	12.5															
27-0018	Nokomis	05/01/20	9:01		3	11.14	97.5	10.44	8.86	610.5	11.8															
27-0018	Nokomis	05/01/20	9:00		4	10.67	94.2	10.2	8.75	611.5	11.6				0.068	0.003										
27-0018	Nokomis	05/01/20	8:58		5	10.1	72	7.9	8.41	614.1	9.9															
27-0018	Nokomis	05/01/20	8:58		6	9.97	70.1	7.72	8.34	614.9	8.6															
27-0018	Nokomis	05/01/20	8:57		7	9.95	69.3	7.63	8.3	615.2	9.1				0.081	0.004							110	5.58		
27-0018	Nokomis	05/01/20	8:56		8	9.89	59.2	6.52	8.18	619.2	88															
27-0018	Nokomis	05/15/20	9:20	0.63	0	13.9	115.3	11.65	9.08	613	12.3	14.2	1.63	11.62	0.060	0.003	0.943	1.030	<0.030	0.259	135	128	105	5.96		
27-0018	Nokomis	05/15/20	9:19		1	13.87	115	11.63	9.08	613	12															
27-0018	Nokomis	05/15/20	9:18		2	13.8	115.1	11.66	9.07	613	11.6															
27-0018	Nokomis	05/15/20	9:17		3	13.7	111.5	11.32	9.03	612.2	12															
27-0018	Nokomis	05/15/20	9:17		4	12.77	96.2	9.97	8.86	613.5	12.6				0.075	0.003										

Lake ID	Lake Name	Date MM/DD/YY	Time HH:MM :SS	Secchi meters	Depth meters	Temp °C	%DO	DO mg/L	pH units	SpCond µS/cm	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/10 0mL	DOC mg/L
27-0018	Nokomis	05/15/20	9:16		5	12.38	80.9	8.46	8.68	615.6	14.3															
27-0018	Nokomis	05/15/20	9:15		6	12.31	76.9	8.06	8.61	616.3	17.2															
27-0018	Nokomis	05/15/20	9:14		7	12.27	72.1	7.55	8.5	616.8	13.3				0.081	0.004							120	6.18		
27-0018	Nokomis	05/15/20	9:12		8	12.13	55.9	5.88	8.25	619.2	21.1															
27-0018	Nokomis	05/15/20	9:11		9	12.21	46.3	4.86	8.15	621.1	522															
27-0018	Nokomis	06/03/20	9:20	2.12	0	22.2	111.8	9.49	8.71	619.1	9.2	6.32	<0.500		0.034	0.003		<0.500					110			
27-0018	Nokomis	06/03/20	9:19		1	21.76	106.8	9.14	8.68	619.5	6.9															
27-0018	Nokomis	06/03/20	9:18		2	21.51	109.6	9.43	8.7	617.5	8.7															
27-0018	Nokomis	06/03/20	9:17		3	19.79	119.2	10.61	8.76	614.3	13.2															
27-0018	Nokomis	06/03/20	9:16		4	16.61	130.4	12.38	8.55	613.1	27.4				0.083	0.004										
27-0018	Nokomis	06/03/20	9:14		5	13.67	9.7	0.98	7.46	624.8	33.1															
27-0018	Nokomis	06/03/20	9:12		6	13.67	3.1	0.31	7.44	624.4	34.6															
27-0018	Nokomis	06/03/20	9:11		7	13.51	0	0	7.41	625	30.4				0.200	0.003							105			
27-0018	Nokomis	06/03/20	9:09		8	13.44	0	0	7.4	629.2	100.5															
27-0018	Nokomis	06/10/20	8:59	1.54	0	22.7	95	7.9	8.56	622.9	4.2	3.10	2.5	9.01	0.035	0.004		0.522					110			
27-0018	Nokomis	06/10/20	8:59		1	22.74	94.9	7.88	8.56	622.5	5.1															
27-0018	Nokomis	06/10/20	8:58		2	22.71	94.7	7.87	8.56	623.1	7															
27-0018	Nokomis	06/10/20	8:57		3	22.66	94.2	7.84	8.54	623.5	9.5															
27-0018	Nokomis	06/10/20	8:57		4	22.41	73.7	6.16	8.32	624.1	16.2				0.036	0.003										
27-0018	Nokomis	06/10/20	8:56		5	14.9	1.9	0.18	7.39	635.7	27.6															
27-0018	Nokomis	06/10/20	8:55		5.9	14.21	0.9	0.09	7.38	634.2	31				0.223	0.003							110			
27-0018	Nokomis	06/26/20	10:18	0.8	0	24.6	160.5	12.99	8.59	592.8	9.1	34.40	1.37		0.040	0.004		0.813					105			
27-0018	Nokomis	06/26/20	10:18		1	24.44	156.6	12.71	8.54	593.5	8.7															
27-0018	Nokomis	06/26/20	10:17		2	22.83	113.7	9.52	8.32	607.7	7.6															
27-0018	Nokomis	06/26/20	10:16		3	22.35	61.4	5.18	7.85	616.4	5.6															
27-0018	Nokomis	06/26/20	10:14		4	21.17	0	0	7.56	634	2.3				0.057	0.004										
27-0018	Nokomis	06/26/20	10:13		5	19.42	0	0	7.42	659.3	2															
27-0018	Nokomis	06/26/20	10:12		6	14.86	1.2	0.12	7.29	648.4	1.8															
27-0018	Nokomis	06/26/20	10:11		7	13.57	2.5	0.25	7.25	659.6	1.7				0.270	0.069							100			
27-0018	Nokomis	06/26/20	10:10		7.8	13.11	0	0	7.22	692.8	2.2															
27-0018	Nokomis	07/10/20	10:19	0.8	0	27.27	101.2	7.84	8.52	581.2	4.9	24.8	1.4	7.1	0.034	0.003	1.115	1.210	<0.030	<0.250	109	108	105	5.61		
27-0018	Nokomis	07/10/20	10:18		1	27.22	101.3	7.85	8.51	581.2	4.6															
27-0018	Nokomis	07/10/20	10:17		2	27.12	96.5	7.5	8.46	581.4	4.1															
27-0018	Nokomis	07/10/20	10:16		3	26.9	97	7.56	8.43	581.1	3.6															
27-0018	Nokomis	07/10/20	10:14		4	21.78	0	0	7.34	632.6	0.8				0.081	0.032										
27-0018	Nokomis	07/10/20	10:12		5	20.04	0	0	7.21	656.1	0.2															
27-0018	Nokomis	07/10/20	10:11		6	19.19	0.2	0.02	7.17	657.9	0.1															
27-0018	Nokomis	07/10/20	10:10		7	15	0	0	7.04	669.1	0.1				0.290	0.069							115	<5.00		
27-0018	Nokomis	07/10/20	10:08		8	13.06	0	0	6.89	733.3	0.5															
27-0018	Nokomis	07/23/20	8:52	0.85	0	24.43	84.3	6.92	8.34	582.4	6.1	19.6	1.83		0.016	0.003		0.575					105			
27-0018	Nokomis	07/23/20	8:50		1	24.41	88.3	7.26	8.34	581.4	6.3															
27-0018	Nokomis	07/23/20	8:48		2	24.37	91.4	7.51	8.27	580.9	6.5															
27-0018	Nokomis	07/23/20	8:47		3	24.35	91	7.48	8.16	580.8	6															
27-0018	Nokomis	07/23/20	8:46		4	23.34	1.4	0.11	7.38	624.8	17.4				0.013	0.004										
27-0018	Nokomis	07/23/20	8:44		5	20.17	0	0	7.19	677.6	5.4															
27-0018	Nokomis	07/23/20	8:42		6	18.08	0	0	7.15	673.1	2.1															
27-0018	Nokomis	07/23/20	8:41		7	15.01	0.4	0.04	7.06	704	3.1				0.708	0.047							110			
27-0018	Nokomis	07/23/20	8:39		7.6	13.73	1.5	0.15	7.08	746.4	112.8															
27-0018	Nokomis	08/06/20	10:18	0.55	0	24.13	87	7.16	8.07	581.1	63.9	27.2	2.7	8.9	0.020	0.005		0.803					105		2	
27-0018	Nokomis	08/06/20	10:17		1	23.9	81.3	6.72	8.02	580.9	54.9															
27-0018	Nokomis	08/06/20	10:16		2	23.78	80	6.63	7.96	581.2	7.8															
27-0018	Nokomis	08/06/20	10:15		3	23.76	80	6.63	7.9	580.9	7.6															
27-0018	Nokomis	08/06/20	10:14		4	23.66	21.1	1.76	7.57	587.1	7.3				0.031	0.004										
27-0018	Nokomis	08/06/20	10:13		5	22.08	0	0	7.38	665.1	7															
27-0018	Nokomis	08/06/20	10:12		6	17.98	1.9	0.18	7.28	691.1	4.9															
27-0018	Nokomis	08/06/20	10:10		6.9	15.5	0.9	0.09	7.31	725.4	6.1				0.202	0.038							110			
27-0018	Nokomis	08/20/20	9:25	0.46	0	24.1	125.5	10.29	8.44	558.9	13.2	53.7	2.98		0.043	0.003		0.575					110			
27-0018	Nokomis	08/20/20	9:24		1	24.03	122.7	10.11	8.34	558.3	11															

Lake ID	Lake Name	Date MM/DD/YY	Time HH:MM :SS	Secchi meters	Depth meters	Temp °C	%DO	DO mg/L	pH units	SpCond µS/cm	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/10 0mL	DOC mg/L
27-0018	Nokomis	08/20/20	9:23		2	23.84	92.3	7.6	8.11	564.7	10.8															
27-0018	Nokomis	08/20/20	9:22		3	23.65	99.5	8.22	8.04	563.7	10.7															
27-0018	Nokomis	08/20/20	9:21		4	23.56	83	6.87	7.87	566.6	10.6				0.048	0.003										
27-0018	Nokomis	08/20/20	9:20		5	23.28	10.2	0.85	7.65	578.6	11															
27-0018	Nokomis	08/20/20	9:19		6	21.55	0	0	7.49	612.5	13.7															
27-0018	Nokomis	08/20/20	9:18		7	16.13	1.5	0.14	7.29	748.5	16.1				0.765	0.035							110			
27-0018	Nokomis	08/20/20	9:16		8	14.99	1.5	0.15	7.45	778.8	15.7															
27-0018	Nokomis	09/08/20	9:46	0.50	0	20.05	79.9	7.17	8.2	561.3	46	30.1	6.32	10.1	0.059	0.004		1.216					105			
27-0018	Nokomis	09/08/20	9:45		1	20.06	80	7.18	8.2	561.4	12.8															
27-0018	Nokomis	09/08/20	9:43		2	20.06	79.9	7.17	8.2	561.2	12.8															
27-0018	Nokomis	09/08/20	9:41		3	20.06	79.2	7.11	8.2	561.1	12.4															
27-0018	Nokomis	09/08/20	9:38		4	20	79.2	7.12	8.19	561.6	12.3				0.071	0.004										
27-0018	Nokomis	09/08/20	9:37		5	20.01	77.2	6.94	8.16	563.4	12.1															
27-0018	Nokomis	09/08/20	9:36		6	19.98	76.6	6.89	8.15	563.5	12															
27-0018	Nokomis	09/08/20	9:33		7	19.81	66.1	5.96	8.1	576.9	11.6				0.116	0.010							105			
27-0018	Nokomis	09/18/20	9:35	0.43	0	17.86	83.4	7.88	8.14	572.2	9.8	5.70	2.85		0.054	0.008		1.571					95			
27-0018	Nokomis	09/18/20	9:34		1	17.86	83.4	7.87	8.12	572.1	9.8															
27-0018	Nokomis	09/18/20	9:34		2	17.82	80.2	7.58	8.09	572.4	9.9															
27-0018	Nokomis	09/18/20	9:33		3	17.81	81.8	7.73	8.11	572.4	10.2															
27-0018	Nokomis	09/18/20	9:32		4	17.79	83.1	7.86	8.11	572.2	9.7				0.071	0.004										
27-0018	Nokomis	09/18/20	9:32		5	17.79	87.7	8.29	8.14	571.3	9.7															
27-0018	Nokomis	09/18/20	9:31		6	17.75	89.3	8.45	8.16	571	9.6															
27-0018	Nokomis	09/18/20	9:30		7	17.55	89.2	8.47	8.2	572.4	25.4				0.067	0.005							105			
27-0018	Nokomis	10/19/20	11:20	0.69	0	10.458	63.3	7.06	8.07	596.3	6.38	22.98	3.85	12.54	0.070	0.003	1.365	1.710	0.239	0.630	127	125	100	5.61		
27-0018	Nokomis	10/19/20	11:19		1	10.448	63.3	7.06	8.07	596.2	6.34															
27-0018	Nokomis	10/19/20	11:19		2	10.468	62.8	6.99	8.07	596.4	6.16															
27-0018	Nokomis	10/19/20	11:18		3	10.466	62.4	6.96	8.08	596.3	6.66															
27-0018	Nokomis	10/19/20	11:16		4	10.464	62	6.91	8.08	596.4	6.41				0.07	0.003										
27-0018	Nokomis	10/19/20	11:14		5	10.459	61.8	6.89	8.09	596.4	6.61															
27-0018	Nokomis	10/19/20	11:12		6	10.461	61.5	6.86	8.12	596.5	6.99															
27-0018	Nokomis	10/19/20	11:10		7	10.459	61.6	6.86	8.15	596.5	6.97				0.078	0.003							105	5.28		
27-0014	Powderhorn	01/24/20	10:34		0	0.42	71.2	10.09	7.35	322.4	0.5	68.35	17.78	1.62	0.16	0.01	1.01	1.49	0.36	0.65	49.50	34.00	75	3.68		
27-0014	Powderhorn	01/24/20	10:33		1	2.51	26.7	3.57	7.14	327.5	0.3															
27-0014	Powderhorn	01/24/20	10:31		2	3.44	1.2	0.15	7.11	388.6	1.6															
27-0014	Powderhorn	01/24/20	10:30		3	3.5	0	0	7.05	562	2.1															
27-0014	Powderhorn	01/24/20	10:28		4	3.66	0	0	7.02	696.5	4.3				0.202	0.060										
27-0014	Powderhorn	01/24/20	10:27		5	3.84	0	0	6.98	817.1	8.5															
27-0014	Powderhorn	01/24/20	10:26		6	4.13	0.4	0.05	6.88	893.2	22.1				0.268	0.081							220	4.830		
27-0014	Powderhorn	01/24/20	10:25		6.5	4.66	0.1	0.02	6.72	1040	65															
27-0014	Powderhorn	04/27/20	14:31	0.71	0	18.49	170.3	15.55	9.39	628.8		76.3	17.9	1.147	0.211	0.005	1.02	1.14	<0.030	0.239	39.0	36.0	160	<5.00		7.4
27-0014	Powderhorn	04/27/20	14:30		1	16.43	166.2	15.84	9.44	625.3																
27-0014	Powderhorn	04/27/20	14:29		2	9.84	76.5	8.45	7.01	622.3																
27-0014	Powderhorn	04/27/20	14:28		3	8.51	37.2	4.24	6.78	634.6																
27-0014	Powderhorn	04/27/20	14:27		4	8.29	26.3	3.01	6.72	640.1					0.131	0.011										
27-0014	Powderhorn	04/27/20	14:25		5	7.51	0	0	6.42	758.4																
27-0014	Powderhorn	04/27/20	14:24		6	5.76	9	1.1	5.99	1611					0.703	0.359							300	5.65		
27-0014	Powderhorn	05/12/20	10:34	0.71	0	13.77	99.4	10.19	8.74	584.7	2.6	30.7	5.51	0.687	0.118	0.003	1.000	1.050	<0.030	0.311	39.5	32.0	145	5.78		6.7
27-0014	Powderhorn	05/12/20	10:34		1	13.16	97	10.07	8.56	583.7	3															
27-0014	Powderhorn	05/12/20	10:33		2	12.93	91.7	9.57	8.15	584.1	3.7															
27-0014	Powderhorn	05/12/20	10:31		3	11.71	17.5	1.88	7.63	601.5	5.4															
27-0014	Powderhorn	05/12/20	10:31		4	8.4	0	0	7.5	661.4	1.5				0.208	0.005										
27-0014	Powderhorn	05/12/20	10:30		5	7.31	0	0	7.37	809.2	2															
27-0014	Powderhorn	05/12/20	10:29		6	6.21	0	0	7.02	1573	6.1				1.054	0.430							290	6.01		
27-0014	Powderhorn	05/12/20	10:29		7	5.97	0	0	7.01	1640	15															
27-0014	Powderhorn	05/27/20	9:37	0.6	0	19.75	71.6	6.38	7.17	486.3	8.2	19.30	7.97		0.150	0.039		0.794					110			
27-0014	Powderhorn	05/27/20	9:36		1	19.75	71.5	6.37	7.17	486	8.1															
27-0014	Powderhorn	05/27/20	9:35		2	19.75	71.7	6.39	7.17	486	7.9															
27-0014	Powderhorn	05/27/20	9:35		3	19.75	71.4	6.36	7.18	486.6	7.8															

Lake ID	Lake Name	Date MM/DD/YY	Time HH:MM :SS	Secchi meters	Depth meters	Temp °C	%DO	DO mg/L	pH units	SpCond µS/cm	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/10 0mL	DOC mg/L
27-0014	Powderhorn	05/27/20	9:33		4	19.75	71.3	6.36	7.18	489.1	8				0.189	0.038										
27-0014	Powderhorn	05/27/20	9:32		5	19.74	71.1	6.34	7.19	488.2	8.6															
27-0014	Powderhorn	05/27/20	9:30		6	19.72	70.1	6.25	7.2	486	13.1				0.176	0.053							110			
27-0014	Powderhorn	05/27/20	9:29		7	19.68	62.3	5.56	7.19	483	132.8															
27-0014	Powderhorn	06/09/20	9:47	0.33	0	24.91	101.8	8.14	7.72	474.3	13.4	84.4	18.7	4.978	0.245	0.046		1.08					120			
27-0014	Powderhorn	06/09/20	9:46		1	24.9	102.4	8.19	7.73	474.5	13.4															
27-0014	Powderhorn	06/09/20	9:46		2	24.91	101.8	8.15	7.72	474.5	13.3															
27-0014	Powderhorn	06/09/20	9:45		3	24.91	101.4	8.12	7.73	474.5	13.3															
27-0014	Powderhorn	06/09/20	9:44		4	24.86	101.4	8.12	7.74	472.4	13.1				0.267	0.047										
27-0014	Powderhorn	06/09/20	9:43		5	24.84	98	7.85	7.71	473.9	13.2															
27-0014	Powderhorn	06/09/20	9:43		5.9	24.81	93.7	7.51	7.7	475	13.7				0.291	0.049							130			
27-0014	Powderhorn	06/24/20	9:11	0.53	0	23.51	40.8	3.38	7.16	464.6	9	40.10	17.18		0.251	0.063		1.470					100			
27-0014	Powderhorn	06/24/20	9:10		1	23.52	40.5	3.36	7.18	464.5	8.7															
27-0014	Powderhorn	06/24/20	9:09		2	23.52	40.8	3.38	7.23	464.7	8.6															
27-0014	Powderhorn	06/24/20	9:08		3	23.47	41	3.4	7.29	464.9	10.2															
27-0014	Powderhorn	06/24/20	9:07		4	23.46	41.1	3.41	7.36	464.8	6.8				0.231	0.065										
27-0014	Powderhorn	06/24/20	9:06		5	23.51	41	3.4	7.45	464.5	6															
27-0014	Powderhorn	06/24/20	9:05		5.9	23.44	41.7	3.46	7.55	465	6.8				0.208	0.068							100			
27-0014	Powderhorn	07/07/20	11:01	0.33	0	27.99	93.5	7.15	7.49	384.1	29.8	74.5	11.3	5.744	0.216	0.040	2.27	2.290	<0.030	0.962	34.0	32.0	95	5.10		
27-0014	Powderhorn	07/07/20	11:01		1	28.02	94.8	7.25	7.5	385.2	29.6															
27-0014	Powderhorn	07/07/20	11:00		2	28.01	94.4	7.22	7.52	385	29.7															
27-0014	Powderhorn	07/07/20	11:00		3	28.01	94	7.19	7.54	384.8	29.8															
27-0014	Powderhorn	07/07/20	10:59		4	27.98	93.8	7.17	7.55	384.6	30.9				0.157	0.044										
27-0014	Powderhorn	07/07/20	10:58		5	27.92	92.3	7.07	7.59	382.4	31.2															
27-0014	Powderhorn	07/07/20	10:57		6	27.87	91	6.98	7.67	382	43.5				0.150	0.043							90	5.17		
27-0014	Powderhorn	07/07/20	10:56		6.3	27.86	90.9	6.97	7.76	379.7	30.9															
27-0014	Powderhorn	07/28/20	8:50	0.32	0	26.27	62.4	4.92	7.43	353.3	31.7	110	29.8		0.198	0.019		<0.500					85			
27-0014	Powderhorn	07/28/20	8:48		1	26.26	61.6	4.85	7.48	353.2	31.7															
27-0014	Powderhorn	07/28/20	8:47		2	26.25	62.5	4.92	7.56	353.4	34.8															
27-0014	Powderhorn	07/28/20	8:45		3	26.23	62.3	4.91	7.65	353.2	19.3															
27-0014	Powderhorn	07/28/20	8:44		4	26.22	63.4	5	7.73	353.7	29.2				0.110	0.019										
27-0014	Powderhorn	07/28/20	8:43		5	26.21	63.4	5.01	7.87	353.5	29.9															
27-0014	Powderhorn	07/28/20	8:42		6	26.19	66.7	5.27	8.01	353.9	28.7				0.110	0.021							85			
27-0014	Powderhorn	08/05/20	8:42	0.30	0	24.52	68.5	5.61	7.7	356	24.4	97.7	39.1	8.3	0.095	0.008		1.140					80		76	
27-0014	Powderhorn	08/05/20	8:41		1	24.53	67.7	5.54	7.73	356.1	23.3															
27-0014	Powderhorn	08/05/20	8:40		2	24.53	67.9	5.56	7.84	355.8	32.6															
27-0014	Powderhorn	08/05/20	8:40		3	24.52	68	5.56	7.87	355.9	35.1															
27-0014	Powderhorn	08/05/20	8:39		4	24.53	67.9	5.56	7.94	356.8	30.4				0.068	0.007										
27-0014	Powderhorn	08/05/20	8:38		5	24.53	67.2	5.5	8.06	356.3	26.6															
27-0014	Powderhorn	08/05/20	8:37		5.9	24.45	67.7	5.54	8.18	356.3	16.1				0.092	0.007							80			
27-0014	Powderhorn	08/18/20	9:19	0.34	0	24.15	98.4	8.14	7.82	306.3	51.3	74	23.9		0.164	0.007		<0.500					65			
27-0014	Powderhorn	08/18/20	9:18		1	24.15	98.9	8.18	7.84	306.4	30.9															
27-0014	Powderhorn	08/18/20	9:17		2	24.15	98.8	8.16	7.89	306.3	46.1															
27-0014	Powderhorn	08/18/20	9:16		3	24.14	98.1	8.11	7.92	306.1	29.9															
27-0014	Powderhorn	08/18/20	9:15		4	24.14	98.4	8.14	7.98	306.5	28.8				0.166	0.004										
27-0014	Powderhorn	08/18/20	9:14		5	24.11	97.5	8.06	8.03	305.8	30.1															
27-0014	Powderhorn	08/18/20	9:12		6	24.11	94.8	7.84	8.12	306	25.7				0.164	0.004							70			
27-0014	Powderhorn	08/18/20	9:11		6.4	24.05	95	7.86	8.2	306.4	28.7															
27-0014	Powderhorn	09/01/20	10:00	0.40	0	24.09	72.4	5.94	7.58	299.8	18.1	54.5	26.7	6.5	0.152	0.0035		1.473					78			
27-0014	Powderhorn	09/01/20	9:59		1	24.08	72.6	5.96	7.62	299.6	18															
27-0014	Powderhorn	09/01/20	9:59		2	24.08	72.6	5.96	7.65	299.5	18.4															
27-0014	Powderhorn	09/01/20	9:58		3	24.07	72.1	5.92	7.7	299.8	17.4															
27-0014	Powderhorn	09/01/20	9:56		4	24.09	72.2	5.92	7.8	299.5	17.1				0.154	0.0035										
27-0014	Powderhorn	09/01/20	9:55		5	24.06	72.4	5.95	7.88	299.6	17															
27-0014	Powderhorn	09/01/20	9:54		6	24	72.3	5.94	7.99	301.3	33.9				0.151	0.003							78			
27-0014	Powderhorn	09/16/20	9:54	0.40	0	18.54	63	5.78	7.77	301.7	11.8	24.6	19.5		0.138	0.006		1.706					55			
27-0014	Powderhorn	09/16/20	9:54		1	18.53	63.1	5.79	7.79	301.7	11.8															
27-0014	Powderhorn	09/16/20	9:54		2	18.53	63	5.79	7.8	301.5	11.7															

Lake ID	Lake Name	Date MM/DD/YY	Time HH:MM :SS	Secchi meters	Depth meters	Temp °C	%DO	DO mg/L	pH units	SpCond µS/cm	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/10 0mL	DOC mg/L
27-0014	Powderhorn	09/16/20	9:53		3	18.53	62.7	5.76	7.84	301.7	11.6															
27-0014	Powderhorn	09/16/20	9:53		4	18.52	62.4	5.73	7.89	301.8	11.6				0.151	0.007										
27-0014	Powderhorn	09/16/20	9:53		5	18.52	62.4	5.73	7.93	301.6	11.3															
27-0014	Powderhorn	09/16/20	9:52		6	18.52	62.4	5.73	7.99	301.8	9.6				0.156	0.007							60			
27-0014	Powderhorn	10/14/20	10:34	0.55	0	14.504	37.5	3.82	7.31	296.1	6.19	10.7	5.2	5.131	0.155	0.027	2.22	3.10	1.006	1.160	38.0	34.0	55	8.67		7.8
27-0014	Powderhorn	10/14/20	10:34		1	14.502	37.6	3.83	7.33	296.2	6.12															
27-0014	Powderhorn	10/14/20	10:33		2	14.502	37.5	3.82	7.35	296.1	5.98															
27-0014	Powderhorn	10/14/20	10:29		3	14.502	38	3.87	7.49	296.2	6.16															
27-0014	Powderhorn	10/14/20	10:28		4	14.503	38.4	3.91	7.58	296.1	6.08				0.155	0.032										
27-0014	Powderhorn	10/14/20	10:27		5	14.503	38.8	3.96	7.65	296.1	6.17															
27-0014	Powderhorn	10/14/20	10:26		6	14.501	40	4.07	7.76	296.2	6.09				0.163	0.032							55	8.90		
27-0037	Wirth	01/23/20	11:40		0	0.25	53.7	7.59	7.44	891.3	0	19.5	4.44	11.4	0.048	0.006	0.585	0.761	0.152	0.319	210	288	150	12.1		
27-0037	Wirth	01/23/20	11:39		1	2.8	39.8	5.25	7.43	898.2	0															
27-0037	Wirth	01/23/20	11:38		2	3.01	27.3	3.58	7.41	897.3	0															
27-0037	Wirth	01/23/20	11:38		3	3.04	21.8	2.86	7.41	904.2	0															
27-0037	Wirth	01/23/20	11:37		4	3.06	10.7	1.4	7.4	935.2	0				0.029	0.008										
27-0037	Wirth	01/23/20	11:36		5	3.15	3	0.39	7.38	980.4	0															
27-0037	Wirth	01/23/20	11:36		6	3.39	1.9	0.25	7.36	1062	0.7															
27-0037	Wirth	01/23/20	11:35		7	3.83	2	0.25	7.2	1368	5				0.049	0.020							170	16.7		
27-0037	Wirth	01/23/20	11:34		8	4.5	2	0.25	6.98	2660	26.9															
27-0037	Wirth	04/27/20	11:39	1.99	0	14.56	109.3	10.83	8.19	919		2.64	2.30	7.379	0.035	0.003	<0.500	<0.500	<0.030	<0.250	228.5	308.0	150	16.1		
27-0037	Wirth	04/27/20	11:39		1	14.23	110.4	11.03	8.2	920.6																
27-0037	Wirth	04/27/20	11:38		2	10.91	118.5	12.76	8.21	911.1																
27-0037	Wirth	04/27/20	11:38		3	9.41	115.5	12.88	8.23	906.4																
27-0037	Wirth	04/27/20	11:37		4	8.19	104.1	11.95	8.14	907.7					0.0385	0.003										
27-0037	Wirth	04/27/20	11:35		5	7.11	39.9	4.71	7.63	926																
27-0037	Wirth	04/27/20	11:34		6	6.05	0	0	7.35	1093																
27-0037	Wirth	04/27/20	11:34		7	4.99	0	0	7.16	1585					0.159	0.007							180	14.4		
27-0037	Wirth	04/27/20	11:33		8	4.85	0	0	7.09	1867																
27-0037	Wirth	05/11/20	12:08	2	0	12.89	102.5	10.69	8.55	896.7	0.2	4.00	<0.500	6.77	0.030	0.003	<0.500	0.555	<0.030	0.343	220	308	150	15.65		
27-0037	Wirth	05/11/20	12:07		1	12.83	102.1	10.66	8.54	896.4	0.6															
27-0037	Wirth	05/11/20	12:06		2	12.77	102.1	10.68	8.52	896.6	1.5															
27-0037	Wirth	05/11/20	12:06		3	12.7	101.2	10.6	8.5	895.8	2.2															
27-0037	Wirth	05/11/20	12:05		4	11.87	93.4	9.97	8.36	898.2	4				0.035	0.003										
27-0037	Wirth	05/11/20	12:04		5	8.44	60.9	7.05	7.97	912.5	8.4															
27-0037	Wirth	05/11/20	12:03		6	6.44	0	0	7.62	1157	18.4															
27-0037	Wirth	05/11/20	12:02		7	5.73	8.7	1.08	7.5	1531	13.4				0.723	0.014							230	11.86		
27-0037	Wirth	05/26/20	11:13	3.8	0	21.24	127.3	10.99	8.4	847.1	1.6	2.73	1.06		0.021	0.003		<0.500					140			
27-0037	Wirth	05/26/20	11:12		1	21.03	126.7	10.98	8.4	849.8	1.9															
27-0037	Wirth	05/26/20	11:11		2	16.41	129.4	12.32	8.38	860.2	2.7															
27-0037	Wirth	05/26/20	11:10		3	14.72	101.8	10.05	8.26	863.2	4.1															
27-0037	Wirth	05/26/20	11:09		4	13.25	67	6.83	7.93	879.2	6.3				0.026	0.003										
27-0037	Wirth	05/26/20	11:08		5	10.68	16.3	1.76	7.57	920.9	11.2															
27-0037	Wirth	05/26/20	11:06		6	7.49	0	0	7.3	1086	18.5															
27-0037	Wirth	05/26/20	11:05		7	5.94	0	0	7.11	1573	18.7				0.758	0.010							265			
27-0037	Wirth	05/26/20	11:04		8	7.39	0	0	7.01	1672	32.5															
27-0037	Wirth	06/08/20	12:12	4.12	0	24.33	119.9	9.74	8.2	804	0.3	1.50	1.09	2.17	0.022	0.004		<0.500					130			
27-0037	Wirth	06/08/20	12:12		1	24.28	119.9	9.75	8.2	805.1	0.4															
27-0037	Wirth	06/08/20	12:11		2	24.2	120.1	9.78	8.2	804.8	0.8															
27-0037	Wirth	06/08/20	12:11		3	19.59	142.8	12.71	8.1	861.3	1.3															
27-0037	Wirth	06/08/20	12:10		4	15.53	81.3	7.87	7.82	882.9	2.3				0.030	0.004										
27-0037	Wirth	06/08/20	12:10		5	12.29	40.9	4.25	7.44	923.4	3.6															
27-0037	Wirth	06/08/20	12:09		6	9.44	12.8	1.42	7.19	1034	8.1															
27-0037	Wirth	06/08/20	12:08		6.9	6.76	0	0	6.82	1538	19.2				0.361	0.006							190			
27-0037	Wirth	06/23/20	8:50	5.12	0	22.84	115.2	9.66	8.35	770.7	1	6.70	1.20		0.015	0.005		<0.500					140			
27-0037	Wirth	06/23/20	8:49		1	22.85	115.5	9.68	8.34	771.1	1.3															
27-0037	Wirth	06/23/20	8:48		2	22.85	115	9.64	8.32	770.3	1.6															
27-0037	Wirth	06/23/20	8:46		3	21.87	62.5	5.33	7.72	820.3	2.9															

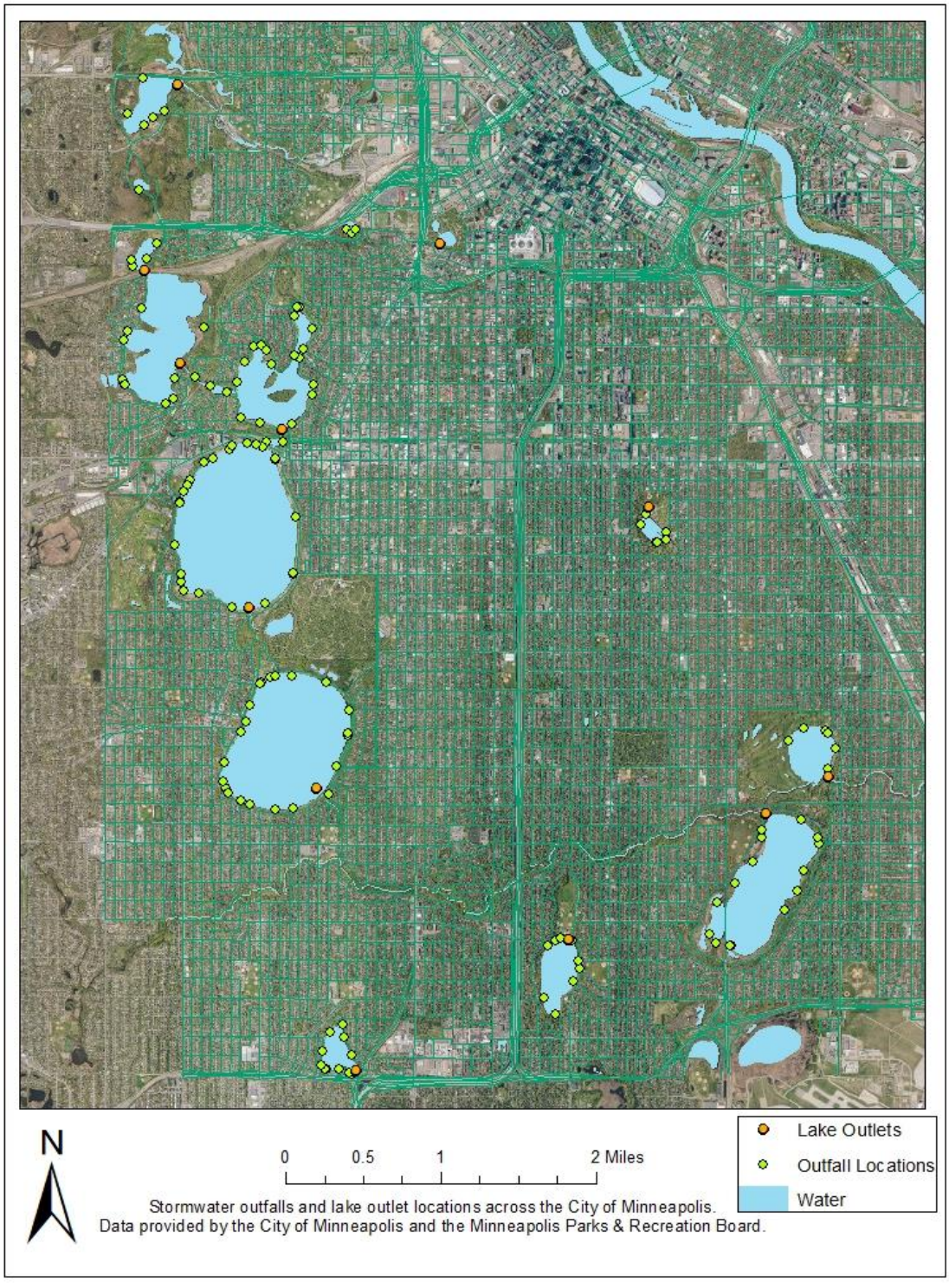
Lake ID	Lake Name	Date MM/DD/YY	Time HH:MM :SS	Secchi meters	Depth meters	Temp °C	%DO	DO mg/L	pH units	SpCond µS/cm	TurbSC NTU	Chl-a mg/M3	Pheo-a mg/M3	Silica mg/L	TP mg/L	SRP mg/L	TKN mg/L	TN mg/L	NO3NO2 mg/L	NH3 mg/L	Alk mg/L	Hard mg/L	Cl mg/L	SO4 mg/L	E. Coli mpn/10 0mL	DOC mg/L
27-0037	Wirth	06/23/20	8:45		4	17.44	67.7	6.32	7.77	889.6	4.8				0.021	0.005										
27-0037	Wirth	06/23/20	8:44		5	13.47	114.9	11.67	7.81	936.5	7.3															
27-0037	Wirth	06/23/20	8:43		6	10.1	0	0	7.27	1112	11.4															
27-0037	Wirth	06/23/20	8:41		6.8	7.62	0	0	6.95	1495	24.6				0.332	0.009							210			
27-0037	Wirth	07/06/20	10:54	3.57	0	28.39	151.6	11.52	8.75	707.1	1.2	5.89	1.06	<0.500	0.016	0.003	0.579	0.584	<0.030	0.209	121	204	140	14.7		
27-0037	Wirth	07/06/20	10:53		1	28.31	149.4	11.37	8.71	706.6	1.4															
27-0037	Wirth	07/06/20	10:52		2	26.53	171.7	13.49	8.47	750	1.8															
27-0037	Wirth	07/06/20	10:50		3	23.41	164.7	13.71	8.19	810.3	3.4															
27-0037	Wirth	07/06/20	10:49		4	19.39	105.2	9.46	7.84	873.3	3.8				0.022	0.003										
27-0037	Wirth	07/06/20	10:48		5	14.73	97.4	9.66	7.74	935.3	4															
27-0037	Wirth	07/06/20	10:46		6	11.32	0	0	7.44	1067	9.1															
27-0037	Wirth	07/06/20	10:45		7	8.29	0	0	7.26	1461	25.6				0.177	0.031							205	9.8		
27-0037	Wirth	07/20/20	13:02	1.83	0	27.25	149	11.58	8.59	726	6.1	16.7	1.61		0.014	0.005		<0.500					140			
27-0037	Wirth	07/20/20	13:02		1	26.55	146	11.48	8.57	727.8	7.3															
27-0037	Wirth	07/20/20	13:01		2	26.22	143.4	11.35	8.51	728.5	9															
27-0037	Wirth	07/20/20	13:00		3	24.47	150.4	12.29	7.96	813.2	11.7															
27-0037	Wirth	07/20/20	12:59		4	19.83	12.3	1.1	7.42	913.3	6.3				0.040	0.004										
27-0037	Wirth	07/20/20	12:58		5	15.73	1.3	0.12	7.42	969.2	8.5															
27-0037	Wirth	07/20/20	12:57		6	11.23	3	0.32	7.31	1123	20.6															
27-0037	Wirth	07/20/20	12:56		7	8.67	0.9	0.1	7.11	1531	21				0.952	0.031							240			
27-0037	Wirth	07/20/20	12:56		7.7	9.09	9	1.01	7.07	1700	6															
27-0037	Wirth	08/04/20	9:38	2.05	0	24.11	107.3	8.87	8.35	732.1	2.8	15.6	2.5	4.5	0.018	0.003		<0.500					140		4	
27-0037	Wirth	08/04/20	9:37		1	24.02	107.4	8.89	8.29	732.6	3.1															
27-0037	Wirth	08/04/20	9:37		2	23.89	106	8.8	8.14	732.6	3.8															
27-0037	Wirth	08/04/20	9:36		3	23.68	56.3	4.7	7.67	749.8	4.9															
27-0037	Wirth	08/04/20	9:34		4	19.97	0.8	0.07	7.52	911.5	8				0.021	0.002										
27-0037	Wirth	08/04/20	9:34		5	15.85	1.8	0.18	7.5	967.9	9.8															
27-0037	Wirth	08/04/20	9:33		6	11.32	0	0	7.49	1145	14.2															
27-0037	Wirth	08/04/20	9:32		7	8.72	0	0	7.41	1567	16				0.507	0.040							215			
27-0037	Wirth	08/17/20	12:32	2.07	0	24.44	111.1	9.11	8.4	699.7	5.3	3.2	1.40		0.024	0.006		<0.500					130			
27-0037	Wirth	08/17/20	12:31		1	24.45	114	9.35	8.38	699.9	5.9															
27-0037	Wirth	08/17/20	12:30		2	24.35	119.9	9.85	8.36	698.1	6.8															
27-0037	Wirth	08/17/20	12:28		3	23.12	9	0.75	7.51	733.9	9.6															
27-0037	Wirth	08/17/20	12:27		4	21.41	6.3	0.55	7.41	852.8	12				0.037	0.004										
27-0037	Wirth	08/17/20	12:25		5	16.18	0	0	7.29	973.7	12.4															
27-0037	Wirth	08/17/20	12:23		6	12.02	1.3	0.14	7.23	1110	13.1															
27-0037	Wirth	08/17/20	12:20		7	8.98	0	0	7.07	1531	16.6				0.713	0.014							225			
27-0037	Wirth	08/17/20	12:18		8	8.69	0	0	7.08	1616	0															
27-0037	Wirth	09/02/20	8:46	1.50	0	22.47	78	6.55	8.1	727.6	5.1	5.6	2.14	6.4	0.024	0.004		0.551					145			
27-0037	Wirth	09/02/20	8:45		1	22.51	78.2	6.56	8.09	726.6	5.4															
27-0037	Wirth	09/02/20	8:44		2	22.43	77.6	6.53	8.04	727.8	6.6															
27-0037	Wirth	09/02/20	8:42		3	22.33	75.7	6.38	7.92	728.2	9.4															
27-0037	Wirth	09/02/20	8:41		4	21	3.2	0.28	7.51	867.5	12.7				0.031	0.003										
27-0037	Wirth	09/02/20	8:40		5	16.38	0	0	7.4	977	12.2															
27-0037	Wirth	09/02/20	8:38		6	12.39	1.3	0.13	7.34	1121	13.4															
27-0037	Wirth	09/02/20	8:37		7	9.65	0.3	0.03	7.16	1513	14.7				0.847	0.009							230			
27-0037	Wirth	09/02/20	8:36		7.5	8.76	0	0	7.22	1598	15.2															
27-0037	Wirth	09/14/20	11:15	3.28	0	18.133	98.3	9.26	8.43	748.6	0.58	1.20	1.08		0.018	<0.003		<0.500					130			
27-0037	Wirth	09/14/20	11:14		1	17.975	96.2	9.09	8.43	748.6	0.64															
27-0037	Wirth	09/14/20	11:12		2	17.465	75.7	7.23	8.21	751.8	1.21															
27-0037	Wirth	09/14/20	11:11		3	17.293	40.6	3.89	7.99	758.9	1.38															
27-0037	Wirth	09/14/20	11:08		4	16.876	5	0.48	7.85	800.2	1.08				0.024	<0.003										
27-0037	Wirth	09/14/20	11:08		5	15.853	0.3	0.03	7.65	974.2	7.72															
27-0037	Wirth	09/14/20	11:07		6	11.453	0	0	7.55	1259.8	8.48															
27-0037	Wirth	09/14/20	11:05		7	9.678	0	0	7.2	1524.6	8.57				1.725	0.012							210			
27-0037	Wirth	09/14/20	11:04		7.7	8.829	0.5	0.06	6.81	1750.4	4.78															
27-0037	Wirth	10/26/20	9:57	2.37	0	6.23	57	7.03	7.8	822.1	0.83	5.21	1.38	9.2	0.042	0.009	0.577	0.669	<0.030	<0.250	178	256	145	11.81		
27-0037	Wirth	10/26/20	9:56		1	6.257	56.8	7.01	7.79	822	0.85															

Lake ID	Lake Name	Date MM/DD/YY	Time HH:MM :SS	Secchi meters	Depth meters	Temp °C	%DO	DO mg/L	pH units	SpCond µS/cm	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/100mL	DOC mg/L
27-0037	Wirth	10/26/20	9:56		2	6.244	56.6	6.98	7.8	822	0.8															
27-0037	Wirth	10/26/20	9:55		3	6.243	56.6	6.98	7.8	822.1	0.87															
27-0037	Wirth	10/26/20	9:51		4	6.234	56.1	6.93	7.82	821.8	0.8				0.044	0.009										
27-0037	Wirth	10/26/20	9:50		5	6.206	55.5	6.86	7.81	821.9	0.88															
27-0037	Wirth	10/26/20	9:49		6	6.158	54.4	6.73	7.79	822	0.79															
27-0037	Wirth	10/26/20	9:49		7	6.057	51.9	6.44	7.76	823.9	0.86				0.037	0.009							140	12.19		

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Appendix C

This section contains a map showing stormwater outfalls and lake outlet locations.



Stormwater outfalls and lake outlet locations across the City of Minneapolis.
Data provided by the City of Minneapolis and the Minneapolis Parks & Recreation Board.

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