Minneapolis Park & Recreation Board

2014

Water Resources Report

Environmental Stewardship
Water Resources Management
www.minneapolisparks.org
April 2016

Minneapolis
Park & Recreation Board

2014
WATER RESOURCES REPORT

Prepared by:

Minneapolis Park & Recreation Board
Environmental Stewardship
3800 Bryant Avenue South
Minneapolis, MN 55409-1029
612.230.6400
www.minneapolisparks.org

April 2016

Funding provided by:

Minneapolis Park & Recreation Board

City of Minneapolis
Public Works

Copyright © 2016 by the Minneapolis Park & Recreation Board
Material may be quoted with attribution.

TABLE OF CONTENTS

Page

Abbreviations i
Executive Summary iv

1. Monitoring Program Overview 1-1
2. Birch Pond 2-1
3. Brownie Lake 3-1
4. Lake Calhoun 4-1
5. Cedar Lake 5-1
6. Diamond Lake 6-1
7. Grass Lake 7-1
8. Lake Harriet 8-1
9. Lake Hiawatha 9-1
10. Lake of the Isles 10-1
11. Loring Pond 11-1
12. Lake Nokomis 12-1
13. Powderhorn Lake 13-1
14. Ryan Lake 14-1
15. Spring Lake 15-1
16. Webber Pond 16-1
17. Wirth Lake 17-1
18. Comparisons Among Lakes 18-1
19. Public Beach Monitoring 19-1
20. Exotic Aquatic Plant Management 20-1
21. Wetland Health Evaluation Program (WHEP) 21-1
22. National Pollutant Discharge Elimination System (NPDES) Monitoring 22-1
23. Nokomis 56th & 21st (BMP) Monitoring 23-1
24. Xerxes Avenue at Minnehaha Creek Monitoring Station 24-1
25. Golf Course Wetland Monitoring 25-1
26. Climatological Summary 26-1
27. Water Quality Education 27-1
28. Quality Assurance Assessment Report 28-1
29. Additional Sources of Water Quality Information 29-1
30. References 30-1

Appendix A – Box and Whisker Plot Record A-1
Appendix B – Lake Monitoring Data 2014 ..... B-1

LIST OF ABBREVIATIONS

% DO	Percent Dissolved Oxygen
µg	Microgram
µm	Micrometer
µmhos	Micromhos
µS	Micro Siemens
ACSP	Audubon Cooperative Sanctuary Program
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
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
m	Meter
MAX	Maximum
MCES	Metropolitan Council Environmental Services
MCWD	Minnehaha Creek Watershed District
MDL	Minimum Detection Limit
MDNR	Minnesota Department of Natural Resources
mg	Milligram
MIN	Minimum
mL	Milliliter
Mn	Manganese
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
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
OHW	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
VSS	Volatile Suspended Solids
WHEP	Wetland Health Evaluation Program
WOMP	Watershed Outlet Monitoring Program
WPA	Works Progress Administration
Zn	Zinc

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 contaminants and other water quality indicators. This report presents the results for the 2014 monitoring season. The report is primarily based on data collected by the MPRB Environmental Stewardship Section.

The MPRB monitors the water quality of Brownie, Calhoun, Cedar, Diamond, Grass, Harriet, Hiawatha, Isles, Loring, Nokomis, Powderhorn, Spring, Webber, and Wirth Lakes. Historical data from 1991-2014 are used to calculate trophic state index (TSI) trends and estimate the trophic status for each lake. Based on the trophic state report for 2014 the following observations are made:

Lakes with increasing water quality indicators	Lakes with stable trend	Lakes with decreasing water quality indicators
Lake Calhoun **Powderhorn Lake** **Wirth Lake**	**Brownie Lake** **Cedar Lake** **Lake Harriet** **Lake Hiawatha** **Lake of the Isles** **Loring Pond** **Lake Nokomis** **Spring Lake**	**Diamond Lake**

Water Quality Highlights

In 2014, the Minneapolis lakes experienced a cool wet first half of the year followed by drought conditions the second half of the year (from July through December) and near normal temperatures. The annual recorded rainfall total for 2014 was 35.40 inches, 0.40 inches above normal, and the average annual temperature was 43.3 ºF, 2.9 ºF below normal.

The water quality of Lakes Calhoun and Harriet continues to be strong for lakes in urban settings. Water quality indicators show better water quality than the early 1990s; however, the last decade of monitoring data have shown a possible trend towards slight degradation in water quality. Monitoring data should be used to track this nascent trend and to develop next generation plans for these lakes.

Powderhorn Lake received its eleventh barley straw treatment. Filamentous green and blue green algal growth in the summer impacted the aesthetics and clarity of the lake.

Wirth Lake continued its increasing water quality trend. Wirth Lake currently meets the Minnesota Pollution Control Agency (MPCA) guidelines for phosphorus, chlorophyll-*a*, and Secchi depth and has for most years since 2000.

The TSI value for Cedar Lake indicated poorer water quality in 2014. After a few good years following restoration efforts, water quality indicators have stabilized in recent years. However, the values are still better than pre-restoration years in the early 1990s.

Heavy rains led to flooding around Lake Nokomis in 2014, with lake levels 2.38 feet above the 10 year average elevation. Lake Nokomis completed a three year biomanipulation study in 2013, which aimed to reduce sediment disturbance by burrowing fish. While early results show a decline in burrowing fish populations and an above normal walleye population, the aquatic plant community is not responding quickly, as much of the littoral zone remains free of aquatic plants. It may take years to see potential benefits to biomanipulation. The TSI score in 2014 indicated improved water quality. MPRB will continue to monitor long term effects of this approach.

The water quality in Lake Hiawatha is controlled by the large inflow from Minnehaha Creek, with drought years leading to lower water quality. The heavy rains in 2014 also had a strong influence at Lake Hiawatha as inflow from Minnehaha Creek remained high from April through October. TSI scores for Hiawatha indicated good water quality in 2014.

The floating biohavens in Spring Lake entered its third full year of establishment in 2014. The biohavens appeared to be in poor condition after the winter and three islands have become detached. Qualitative monitoring during the summer showed there was now more growth of the volunteer plants than the original plantings.

In the fall of 2014, MPRB continued a project to remove hybrid and narrow-leaf cattail from Loring Pond and replant the shoreline with native vegetation. Loring's water level was allowed to fall below the outlet in order allow the cattails to be cut at the manipulated water surface. Water levels were then augmented with groundwater in November, flooding the cut shoots and preventing oxygen from reaching the rhizomes. Future years will show the effectiveness of this method to restore the shoreline around the pond.

The MPRB monitored 12 public beaches for *Escherichia coli* (*E. coli*, as recommended by the US Environmental Protection Agency). These bacteria are used as proxy indicators of pathogens in water. Most beaches had low season-long geometric means with the exception of Lake Hiawatha and Calhoun Thomas which were closed for part of 2014 due to exceeding the geometric mean guideline of 126 organisms per 100 mL of water. The Minnesota Pollution Control Agency single sample limit of 1,260 *E. coli* per 100 mL of water was exceeded only at Calhoun 32nd Beach once during the 2014 beach season.

Eurasian water milfoil harvesting was carried out on Calhoun, Cedar, Harriet, Nokomis, Lake of the Isles, and Wirth Lakes in 2014 to allow for improved recreational access. SCUBA divers were contracted to hand-harvest aquatic plants at Lake Nokomis and Wirth Lake in the beach areas.

MPRB, the Minnehaha Creek Watershed District, and the Friends of Lake Nokomis worked in partnership on early detection monitoring for invasive zebra mussels. Water quality staff only found zebra mussels on a sampling plate in Lake Hiawatha in 2014. The invasive mussel had previously been found in 2013 and was expected to arrive in Lake Hiawatha within a few years after their discovery in Lake Minnetonka, due to its direct connection with Minnehaha Creek. No zebra mussels were found in the other Minneapolis lakes in 2014.

The MPRB monitors storm sewers within Minneapolis to comply with the federal National Pollutant Discharge Elimination System (NPDES) permit. The purpose of this monitoring is to characterize the impacts of stormwater discharges to receiving waters and review the effectiveness of treatment best management practices (BMPs). The results of the 2014 data were typical for stormwater as compared to reports from other cities. The MPRB monitored 56th & 21st on the East side of Lake Nokomis. The Nokomis (56th & 21st) monitoring will be used with future data to determine the effectiveness of BMP street sweeping. Monitoring was also performed at Minnehaha Creek where it enters Minneapolis at Xerxes Avenue South.

Monitoring partners for 2014 included: the Bassett Creek Watershed Management Commission, The Friends of Lake Nokomis, Minneapolis Public Works, and the Minnehaha Creek Watershed District.

1. MONITORING PROGRAM OVERVIEW: 1991-2014

LAKE MONITORING

Background

The Environmental Stewardship 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, Calhoun, and Harriet. The monitoring program was expanded in 1992 to include Hiawatha, Nokomis, Diamond, Powderhorn, Loring, and Wirth Lakes. Spring and Grass Lakes was added on a limited basis in 1993 and 2002 respectively. Ryan Lake is occasionally monitored by the Met Council's CAMP program. **Figure 1-1** shows the location of waterbodies in Minneapolis. For purposes of this overview, these 14 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 14 Minneapolis lakes and their watersheds are located within the cities of Minneapolis, St. Louis Park, Richfield, Golden Valley, Robbinsdale, Brooklyn Center, and Edina. Residential housing is the predominant land use within all of the watersheds although industrial and commercial land uses are significant in several areas. The watershed associated with Loring Pond is predominantly parkland. All of 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 sedimentation and deposition of late Wisconsin glacial drift. Each glacial advance stripped the landscape of earlier 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.

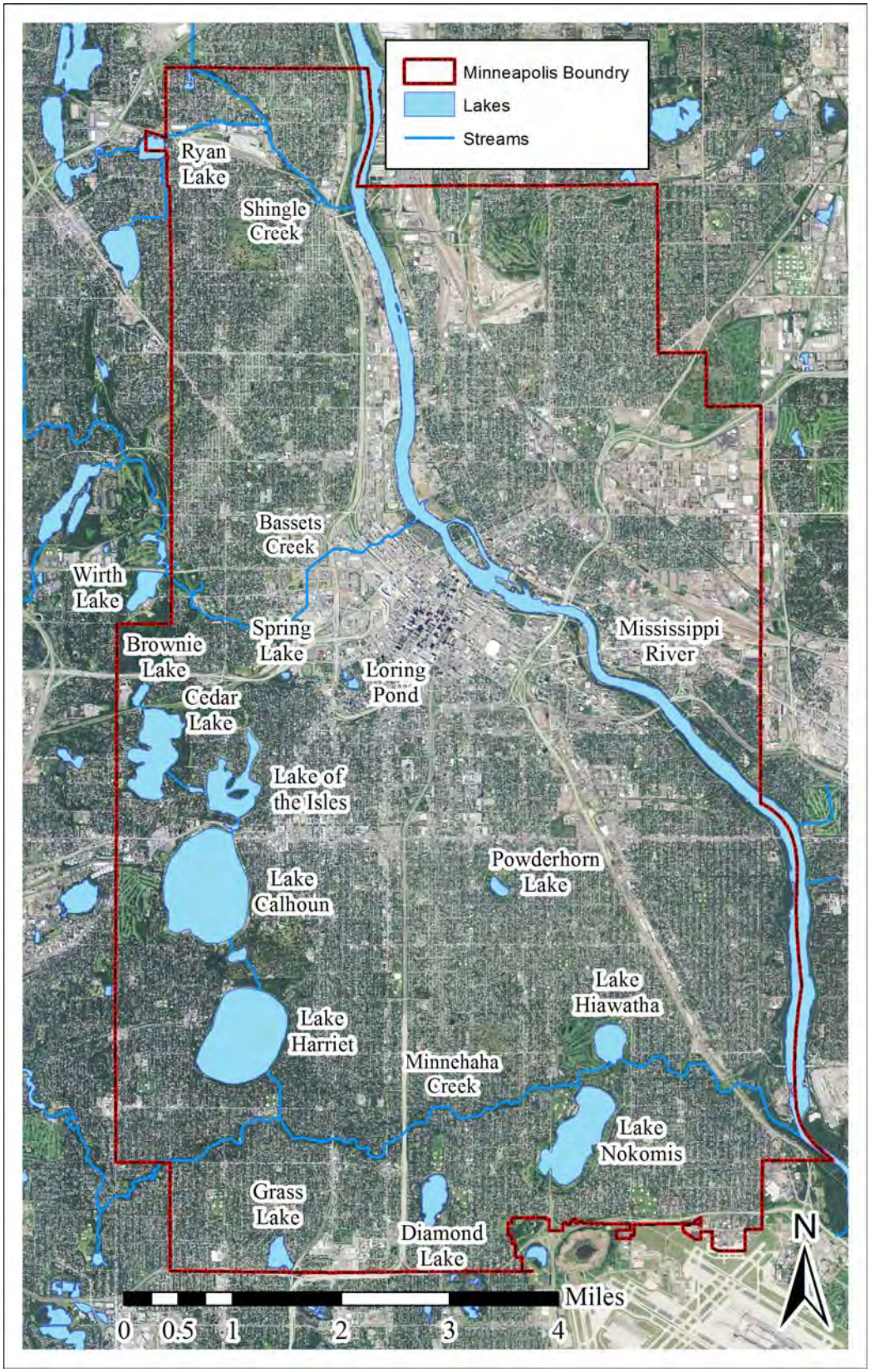


Figure 1-1. Location of waterbodies in Minneapolis.

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 of 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 (see **Table 1-1**) including shallow wetland systems (Diamond and Grass Lakes), protected meromictic lakes (Brownie and Spring Lakes), and more classic, deep dimictic lakes (Lake Harriet and Lake Calhoun).

Table 1-1. Minneapolis lakes morphometric data.

Lake	Surface Area (acres)	Mean Depth (m)	Max Depth (m)	% Littoral*	Volume (m^3)	Watershed Area (acres)	Watershed: Lake Area (ratio)	Residence Time (years)
Brownie	18	6.8	15.2	67%	$4.98x10^5$	369	20.5	2.0
Calhoun	421	10.6	27.4	31%	$1.80x10^7$	2,992	7.1	4.2
Cedar	170	6.1	15.5	37%	$4.26x10^6$	1,956	11.5	2.7
Diamond	41	0.9†	2.1†	100%	$7.15x10^4$	669‡	16.3	NA
Grass	27	0.6	1.5	NA	NA	386	14.3	NA
Harriet	353	8.7	25.0	25%	$1.25x10^7$	1,139	3.2	3.4
Hiawatha	54	4.1	7.0	26%	$8.95x10^5$	115,840	2145	0.03
Isles	103	2.7	9.4	89%	$1.11x10^6$	735	7.1	0.6
Loring	8	1.5	5.3	NA	$4.88x10^4$	24	3.0	NA
Nokomis	204	4.3	10.1	51%	$3.54x10^6$	869	4.3	4.0‡
Powderhorn	11	1.2	6.1	99%	$9.04x10^4$	286	26.0	0.2‡
Ryan	18	NA	10.7	50%	NA	5,510	306	NA
Spring	3	3.0	8.5	NA	$3.65x10^4$	45	15.0	NA
Wirth	39	4.3	7.9	61%	$6.70x10^5$	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 2014 schedule of physical and chemical parameters is shown in **Table 1-2**. Most lakes followed this schedule and were sampled once per month in February, April, and October and twice per month during the period of May through September. There were several exceptions to this schedule. Brownie, Grass and Spring Lake were each sampled once per month. Diamond and Grass were not sampled in winter because they were frozen to the bed.

Table 1-2. Schedule of sampled parameters for most lakes in 2014.

Parameter	Winter	March/April	May – Sept	October
Alkalinity	Once	Once	Once	Once
Chloride	Once	Once	Twice a Month	Once
Chlorophyll-*a*	Once	Once	Twice a Month	Once
Conductivity	Once	Once	Twice a Month	Once
Dissolved Oxygen	Once	Once	Twice a Month	Once
Escherichia Coli	Not sampled	Not Sampled	Once	Not Sampled
Hardness	Once	Once	Once	Once
pH	Once	Once	Twice a Month	Once
Phytoplankton	Once	Once	Twice a Month	Once
Secchi Transparency	Once	Once	Twice a Month	Once
Silica	Once	Once	Once a Month	Once
Temperature	Once	Once	Twice a Month	Once
TKN, NO_x	Once	Once	Once	Once
TP, SRP, TN	Once	Once	Twice a Month	Once
Turbidity	Once	Once	Twice a Month	Once
Zooplankton	Not sampled	Once	Once a Month	Once

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 shoreline landmarks and an electronic depth finder. Grass Lake samples were taken as grab samples from the shore or by wading if water levels were too low.

A Hydrolab Minisonde 5 Multiprobe was used to record temperature, pH, conductivity, dissolved oxygen, and turbidity profiles. These parameters were measured at 1-meter intervals from the surface to the lake bottom. The multiprobe was calibrated according to the manufacturer's guidelines prior to each sampling trip. Secchi disk transparency was determined with a black and white 20-cm diameter 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. Chlorophyll-*a* samples were stored in opaque bottles for analysis. Total phosphorus, soluble reactive phosphorus, total nitrogen, and chlorophyll-*a* concentrations were determined from the surface composite sample for all sampling trips. Phytoplankton samples were collected each sampling trip April through October for all lakes (**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

Brownie Lake, Diamond Lake, and Spring Lake). Zooplankton were collected using a 80-µm mesh Wisconsin vertical tow net retrieved at a rate of 1 m/s through the full water column. The 80-µm mesh Wisconsin bucket was rinsed with distilled water or ethanol from the outside. The sample was preserved 90% denatured histological ethanol to a mix of approximately 50% sample 50% ethanol.

Subsurface samples were collected with a 2-liter Wildco™ Kemmerer water sampler. Total phosphorus and soluble reactive phosphorus concentrations were determined every sampling trip at predetermined depths in each lake (**Table 1-3**). In spring, mid-summer, and fall deep subsurface chloride samples were also taken at most lakes. Each lake sample collection regime was determined based upon maximum depth, stratification characteristics, and the results of previous studies.

Table 1-3. Sampling depth profiles for the 2014 MPRB lakes monitoring program.

Lake	Sampling Depths in meters				
Brownie Lake	0-2 composite	6	12		
Lake Calhoun	0-2 composite	6	12	18	22
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	6		
Powderhorn Lake	0-2 composite	4	6		
Spring Lake	0-2 composite	4	6		
Wirth Lake	0-2 composite	4	7		

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 2014 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**.

Table 1-4. Methods and reporting limits used for parameter analysis in the 2014 Minneapolis lakes monitoring program.

Parameter	Method	Reporting Limit
Alkalinity	STANDARD METHODS 2320 B	2.00 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 (field)	0.1 µS/cm
Dissolved Oxygen	Hydrolab Minisonde 5a Multiprobe (field)	0.01 mg/L
Escherichia coli	Colilert Quanti-Tray, IRI	1 mpn
Hardness	STANDARD METHODS 2340 C	2.00 mg/L
Nitrate+Nitrite Nitrogen	STANDARD METHODS 4500-NO_3 E	0.030 mg/L
Silica	STANDARD METHODS 4500-Si O2-97	0.500 mg/L
Soluble Reactive Phosphorus	STANDARD METHODS 4500-P E.	0.003 mg/L
Sulfate	ASTM D516-90	15 mg/L
Temperature	Hydrolab Minisonde 5a Multiprobe (field)	0.01 °C
Total Dissolved Phosphorus	STANDARD METHODS 4500-P E.	10 µg/L
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 (field)	1 ntu
Transparency	Secchi disk depth measurement	0.01 m

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

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. Augmentation wells are used to maintain water levels at lakes and ponds, and if permitted are occasionally used for winter ice rinks. **Figure 1-2** is a map of the piezometric, irrigation, and augmentation well locations in Minneapolis.

The Minnesota Department of Natural Resources (MDNR) issues the permits and determines pumping limits for irrigation and augmentation wells. The MPRB is not allowed to exceed these limits. Annual fees and reports are sent to the MDNR. The MPRB staff records groundwater levels from piezometric wells throughout Minneapolis.

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.

Results & Discussion

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

Results from the 2014 lake augmentation well readings and annual usage can be found in each respective lake section (Powderhorn Lake and Loring Pond). All of the irrigation and augmentation wells used were below their MDNR allotted groundwater pumping volumes.

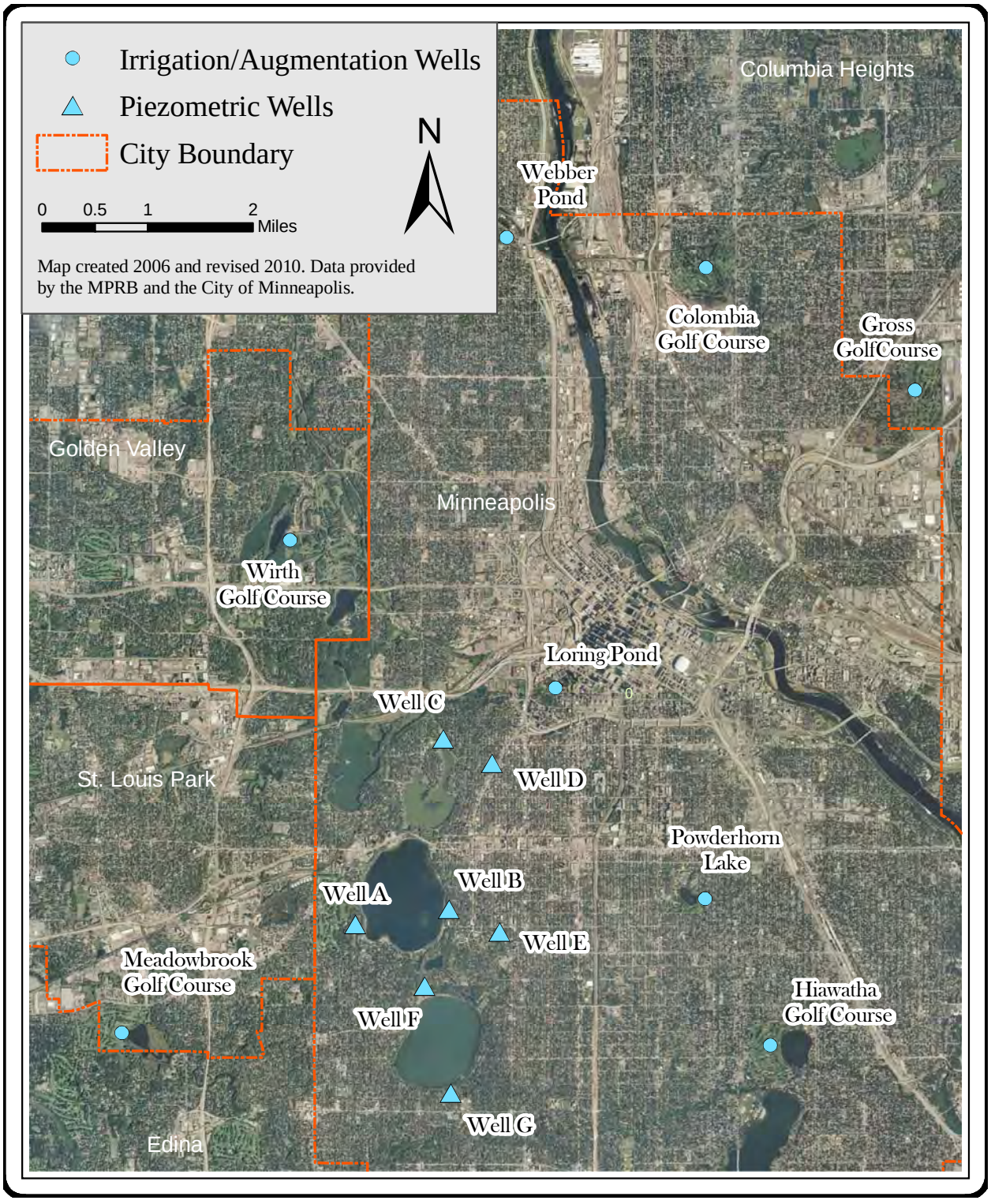


Figure 1-2. Map of piezometric and irrigation/augmentation well locations monitored by MPRB Environmental Operations.

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 2014, the MPRB monitored 13 city lakes according to the current schedule and protocols (**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 transparency (Secchi depth), chlorophyll-*a* (chl-*a*), and total phosphorus (TP).

> **Water transparency** 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 dependant on algal biomass or other factors that may limit light penetration (e.g. suspended solids, dissolved organic material).
>
> **Chlorophyll-*a*** is a pigment algae used to capture sunlight and is a measure of how much algal biomass is in the lake.
>
> **Phosphorus** is 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 (high algal growth).

Individual Secchi, chl-*a*, and TP TSI scores are calculated for the growing season (May-September) for each lake. The yearly 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, 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)*ln (Average growing season Secchi in meters)
Chl-a TSI=	9.81*ln (Average growing season chl-*a* in µg/L)
TP TSI=	14.42*ln (Average growing season TP in mg/L*1000) + 4.15
Annual TSI=	(Secchi TSI + chl-*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 41 and 77. 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.

One of the methods used to classify lakes involves using categories based on the TSI score. Lakes generally fall into one of three categories based on trophic status that include: eutrophic, mesotrophic, and oligotrophic (Horne and Goldman, 1994).

> **Oligotrophic** (TSI < 30) lakes are characterized by low nutrients, 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.

Lakes that have a TSI score greater than 70 are termed hypereutrophic and generally have very high algal biomass and low macrophyte densities due to light limitation by algae.

Lakes in the NCHF ecoregion frequently fall into the eutrophic category and the lowest trophic status lakes typically fall into the mesotrophic category. All the sampled lakes 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**.

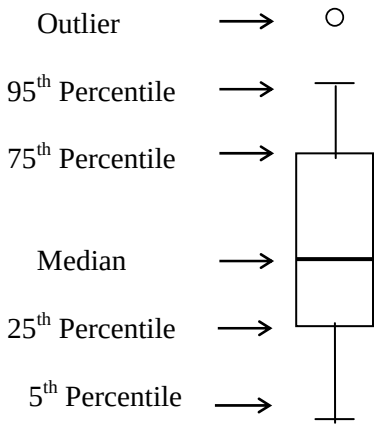
Changes in lake water quality can be tracked by analyzing long-term trends in TSI scores. The MPRB uses TSI scores to assess changes in water quality and evaluate the effectiveness of restoration and management activities on the trophic state of the lakes. Linear regression analysis is a common method 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 (as 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

Additional analysis of the three TSI parameters can include using box and whisker plots. The box and whisker plots for each lake are another way to determine trends and are valuable for assessing variability over the years. Box and whisker plots can be used to look at short-term (seasonal) and long-term trends at the same time. Box plots for the three trophic state parameters (transparency, surface chlorophyll-*a* levels and surface total phosphorus levels) were created for each lake and presented in individual lake sections.

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 of the boxes) represent the data from the 25th and 75th percentiles to the 5th and 95th percentiles, respectively. Any data falling above the 95th percentile or below the 5th percentile are marked as outliers. The horizontal line that cuts across the box represents the median value. In this report, all outliers in the box and whisker plots are represented by a circle.

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



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 well.

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 revised LAURI has five indices:

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

Data for the LAURI analysis is collected during the growing season from May to September and during regular lake monitoring activities.

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, aquatic plant, 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 Calhoun, Cedar, Harriet, Hiawatha, Nokomis, and Wirth Lakes. The scoring used the season long geometric mean from the beach monitoring program for each lake (**Table 1-5**). Lakes with more than one beach were averaged together. 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.

Table 1-5. Scoring for the public health portion of LAURI.

E. coli bacteria, (MPN/100mL) *	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

* The value used is the running geometric mean for the year, averaged for all the beaches on a lake.

Water Quality Index

Water clarity is easy to measure and easy to understand. This simple measure is a good integrator of various parameters affecting the eutrophication status of a lake. The average Secchi transparency reading from all the data collected during the growing season (May-September) is used. 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). Calhoun, Cedar, Harriet, and Wirth were considered deep lakes. Loring, Isles, Hiawatha, Nokomis, and Powderhorn are considered shallow lakes. Higher numbers indicate clearer water. LAURI scoring is shown below in **Table 1-6.**

Table 1-6. 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 - 3.0	6	
3.1 - 3.5	7	
3.6 - 4.0	8	
4.1 - 4.5	9	
> 4.6	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 (**Table 1-7**). 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 1-7. 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-med	3	25-50	4	7-8	4
2-4	6	Medium	6	50-75	7	9-11	6
5-6	8	Med-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 and quality of recreational access to the water. The recreational score considers the number of fishing docks, beaches, boat launches, intra lake connections, canoe racks and rentals, picnic areas, and concessions at a lake, **Table 1-8**. 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 1-8. Scoring for the recreational access portion of LAURI.

Recreational Op	#	Total # Ops + Aq Plnt Mgmt	Score
Fishing Dock		0	1
Beach		1	2
Boat Landing		2	3
Boat rental		3	4
Boat storage		4	5
Picnic area		5	6
Concessions		6	7
Aquatic Mgmt = yes	+ 4	7 - 8	8
Aquatic Mgmt = no	+ 0	8 - 9	9
TOTAL		> 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, **Table 1-9**. Lower numbers indicate worse aesthetics. The scores are averaged over the season. Aesthetics can be difficult to evaluate as they are strongly qualitative and dependent on individual experience.

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

Color	Score		**Odor**	Score		**Debris**	Score
Clear	10		None/Natural	10		None	10
lt. Brown or green	8		Musty - faint	8		Natural	9
Bright Green	5		Musty - strong	6		Foam	8
Milky White	4		Sewage/fishy/ garbage - faint	5		Piles of milfoil (>3)	7
Brown/Reddish/ Purple	2		Sewage/fishy/ garbage - strong	2		Trash: fixed (>3)	4
Gray/Black	0		Anaerobic/septic	0		Trash: floating (>3)	3
						Many dead fish (>5)	2
						Green scum	2
						Oil film	1
						Sewage Solids	0

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 sections and a comparison among lakes can be found in **Section 18** in **Tables 18-7** and **18-8**.

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. Aquatic plants 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. No macrophyte surveys were conducted in 2014; however, all lakes were assessed for curly-leaf pondweed prevalence during June.

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, 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.

Eurasian Watermilfoil Control 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. Eurasian watermilfoil also out-competes native species and may reduce the available habitat for sensitive species.

Currently, no environmentally safe method has been proven to rid lakes of milfoil, 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 Calhoun, 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 114 flatbed truck loads of milfoil in 2014 which is comparable to 630 cubic yards of aquatic plant material.

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. Because the chlorophyll-*a* concentration can be easily measured in a water sample it is a common way to estimate the phytoplankton biomass in the water (Paerl and Sandgren, 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 (Calhoun, Cedar, Harriet, Hiawatha, Isles, Loring, Nokomis, Powderhorn, and Wirth) except for February, April, and October which were sampled once per month. Samples were collected once a month at Brownie, Grass and Spring Lakes. Surface water composite samples were collected for phytoplankton using a 2-m long, stoppered 2-inch diameter PVC tube. Before sampling the PVC tube was scrubbed with a brush and rinsed with lake water three times. Two such samples were mixed in a clean white plastic bucket that had also been scrubbed and rinsed with lake water. 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 (St. Joseph, MI) 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. Identification protocol is according to Weber (1971) and Prescott (1951). The results are presented by division (phylum) in the individual lake sections. Common phytoplankton divisions and a common description are given in **Table 1-10**.

Table 1-10. Phytoplankton divisions and brief descriptions.

Division	Description
Bacillariophyta	Diatoms
Chlorophyta	Green algae
Chrysophyta	Golden-brown algae
Cryptophyta	Cryptomonads
Cyanophyta	Blue-green algae
Euglenophyta	Euglenoids
Pyrrhophyta	Dinoflagellates
Xanthophyta	Yellow-brown algae

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.

Zooplankton

Zooplankton samples were collected monthly from most Minneapolis lakes (**Table 1-2)**. Diamond and Grass Lakes were not sampled because of their shallow depths. Brownie and Spring Lakes were not sampled due to lack of zooplankton in most years. Samples were collected using an 80-µm plankton net and a Wisconsin-type bucket. The net was raised from the bottom of the water column to the surface at a rate of one meter per second. The captured zooplankton were rinsed into a bottle using 90% denatured histological ethanol to a final concentration of 50% sample and 50% 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. Zooplankton were identified according to standard protocols and twelve taxonomic authorities (Edmondson, 1959). The zooplankton results were divided into groups for presentation as shown in **Table 1-11**. Results are presented in the individual lake sections.

Table 1-11. Major zooplankton groups and brief descriptions.

Major Group	Description
Calanoid	Phylum Arthropoda. Type of copepod. Generally herbivorous.
Cladoceran	Phylum Arthropoda. Eats algae. Commonly called "water flea."
Cyclopoid	Phylum Arthropoda. Type of copepod. Many are carnivorous.
Protozoan	Single celled organisms. Many are shelled amoeba.
Rotifer	"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* bacteria. 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 of this disease 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.

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. 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, 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 a independent verification of the calibration standards and as a quality control check for the analytical run and
- Blind samples (of unknown concentration) provided by the MPRB Environmental Operations staff.

For more details and QA/QC results for 2014, see the Quality Assurance Assessment Report in **Section 28**.

2. BIRCH POND

HISTORY

Birch Pond is a 6-acre water body on the east side of Theodore Wirth Parkway in Theodore Wirth Regional Park near the Eloise Butler Wildflower Garden and Bird Sanctuary, **Figure 2-1**. 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. It has no public boat access or fishing docks. Birch Pond is protected from winds by large hills and mature trees that surround it. Aesthetics and bird watching opportunities are Birch Pond's main recreational values.

Buckthorn (*Rhamnus cathartica* and *Rhamnus frangula*) 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 is an invasive species that threatens native woodlands.

The Minneapolis Park & Recreation Board (MPRB) currently does not include Birch Pond in its regular lake sampling program.

Figure 2-1. Birch Pond after 2006 buckthorn removal.

LAKE LEVEL

Lake level records for Birch Pond were historically kept by both the City of Minneapolis and the MPRB. More recently the MDNR has created an accurate bench mark and has set an Ordinary High Water Level (OHW) of 846.3 msl for Birch Pond. Lake levels in Birch pond have 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 gauge on Birch Pond.

Figure 2-2 shows historic water level records for Birch Pond compiled by the MPRB, the City of Minneapolis and the MDNR.

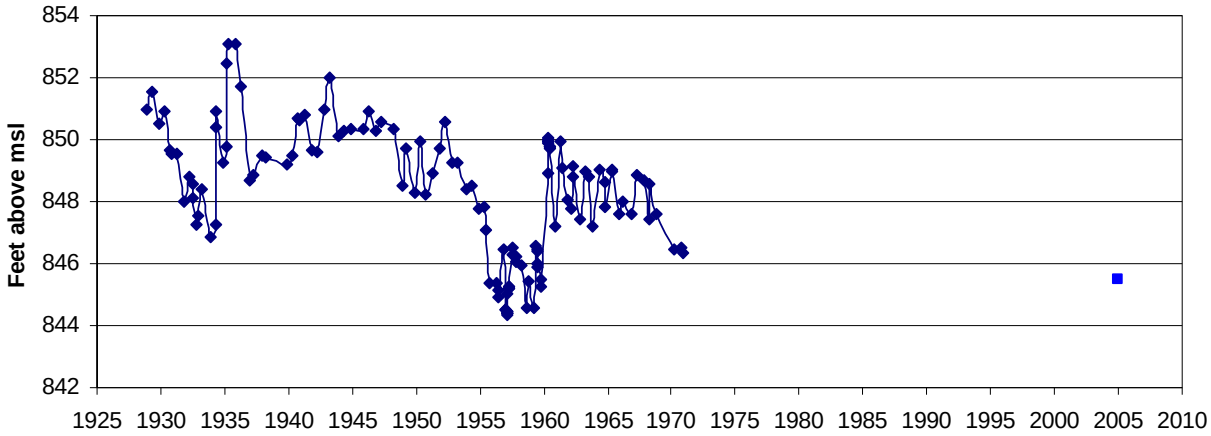


Figure 2-2. Historic level records for Birch Pond compiled by MPRB, City of Minneapolis and MDNR. Fluctuations are due to climate, season, and historic pumping.

WINTER ICE COVER

Ice came off Birch Pond on April 19, 2014 which was 15 days later than average and the second latest ice-off date recorded. Ice came back to the pond November 13, 2014, 12 days earlier than the average date for ice-on. See **Section 18** for additional ice monitoring data.

3. BROWNIE LAKE

HISTORY

Human activities drastically changed the shape and size of Brownie Lake over the past 150 years. Construction of a railroad embankment in 1883 caused a decrease in lake surface area of 34%, transforming the lake formerly known as Hillside Harbor. In 1916 the connection between Cedar and Brownie Lakes was completed further decreasing the surface area of the lake by another 56% by dropping the water level 3 m (~10 ft) and creating the lake that we see today (Wirth, 1945; Trembley, 2012). **Figure 3-1** shows a picture of Brownie Lake.

Figure 3-1. Kayakers on Brownie Lake

Structural changes to the lake have had implications to its water chemistry. Brownie Lake is permanently stratified (also called meromictic) 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. 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. Swain (1984) first theorized that the structural changes made to Brownie Lake caused its state of permanent stratification. Swain's 1984 study of a 117-cm lake sediment core found changes in the ratios of iron to manganese (Fe:Mn) and iron to phosphorus (Fe:P) at a layer in the sediment corresponding to approximately 1925. The change in the chemistry of the sediments indicates the onset of permanently anoxic bottom-water signifying to Swain that Brownie Lake had become meromictic. In the past, stormwater inputs from Interstate 394 (old U.S. Highway 12) added pollutants to Brownie Lake and has contributed to the stability of the chemocline.

Swain's lake-core analysis found further evidence of the influence that human activities had on Brownie Lake. Ragweed pollen first appeared at sediment core at depths that corresponding to 1850-1860, an indication of European-American settlement (Swain, 1984). Later, changes in the watershed led to increases in primary productivity, algal biomass, and sediment accumulation indicating eutrophication. As water clarity decreased over time benthic diatoms were replaced by planktonic forms and the zooplankton community shifted from large bodied *Daphnia* to the smaller *Bosmina* species (Swain, 1984).

Water levels in Brownie Lake have been manipulated at various times in its history. Groundwater was first used to augment lake levels in the Chain of Lakes (Brownie, Cedar, Isles and Calhoun) in 1933 and continued through 1938. During the 1950s, the Prudential Insurance Building began discharging 50 thousand gallons of cooling water per day into Brownie Lake. During this time-period, a link was created between Brownie Lake and Bassett's Creek that provided water to the Chain of Lakes during times of low water levels. In 1966, a pumping station was constructed at the Mississippi River to augment flow in Bassett's Creek. Water levels in the Chain of Lakes were regulated by pumping from the Mississippi River into Brownie Lake until 1990.

Brownie Lake is on an every other year sampling schedule, and was sampled in 2014. **Figure 3-2** shows the bathymetric map and **Table 3-1** shows the morphometric data for Brownie Lake.

Table 3-1. Brownie Lake morphometric data.

Surface Area (acres)	Mean Depth (m)	Max Depth (m)	Littoral Area*	Volume (m^3)	Watershed Area (acres)	Watershed: Lake Area (ratio)	Residence Time (years)
18	6.8	15.2	39%	4.98×10^5	369	20.5	2.0

* Littoral area defined as less than 15 feet deep.

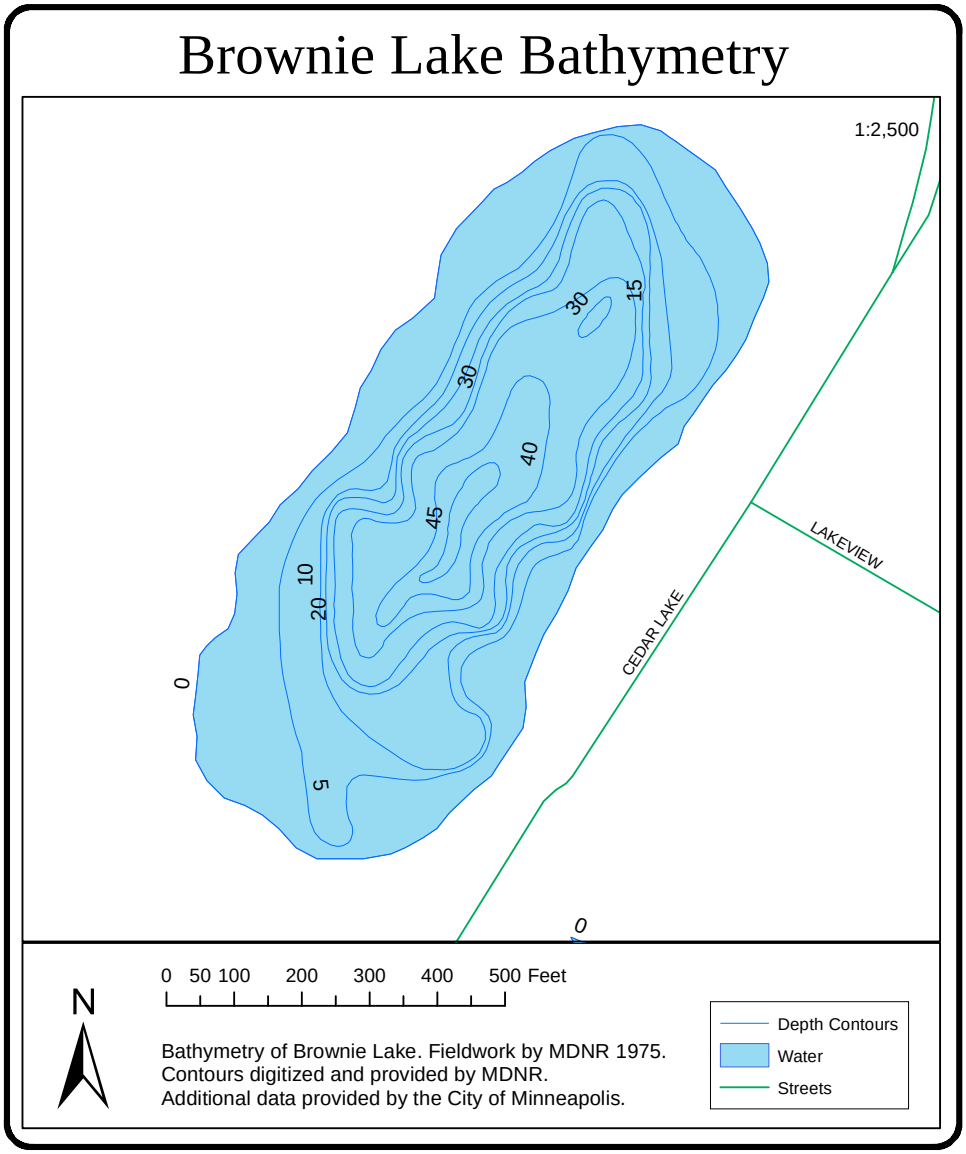


Figure 3-2. Bathymetric map of Brownie Lake.

LAKE LEVEL

The Ordinary High Water Level (OHW) for Brownie Lake, as determined by the MDNR, is 853 ft (msl). The OHW is defined as the elevation where high water levels can be maintained for a long enough a period of time to leave evidence of the water level on the landscape.

See **Section 4, Lake Calhoun** for more information on water levels in the Chain of Lakes.

WATER QUALITY TRENDS – TROPHIC STATE INDEX (TSI)

Figure 3-3 shows the Brownie Lake TSI scores and linear regression. The 2014 TSI score for Brownie Lake was 54 and the lowest score since 1993, when sampling began. There is not significant trend in TSI scores over the last 21 years ($p > 0.05$); however, Brownie is only sampled every-other year. Brownie Lake is scheduled to be sampled again in 2016. A detailed explanation of TSI can be found in **Section 1**.

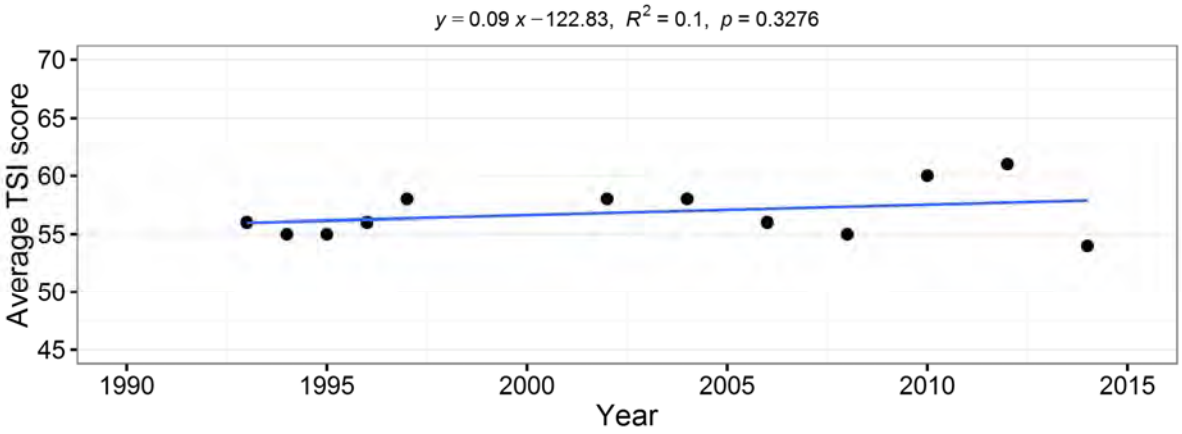


Figure 3-3. Brownie Lake TSI scores and regression analysis.

Brownie Lake falls near the 50th percentile category for lakes in this ecoregion, based on calculations from the Minnesota Lake Water Quality Assessment Data Base Summary (MPCA, 2004).

BOX AND WHISKER PLOTS

The box and whisker plots in **Figure 3-4** show the distribution of data for Secchi depth, chlorophyll-*a*, and total phosphorus sampling from 2005 to 2014. The horizontal line crossing the graph represents the MPCA eutrophication standard for deep lakes. Data for the entire period of record presented in box and whisker plot format is available in **Appendix A**. Long-term lake monitoring is necessary to evaluate the seasonal and year-to-year variations seen in each lake and predict trends. A detailed explanation of box and whisker plots can be found in **Section 1**.

Water transparency in Brownie Lake in 2014 was similar to previous years with an average Secchi depth of 1.4 meters. Algal biomass, as measured by chlorophyll-*a* concentration, and total phosphorus was lower than 2012 and similar to the mid-2000s. Brownie met the MPCA eutrophication standard for chlorophyll-*a* and total phosphorus, but not Secchi transparency. Due to Brownie Lake's permanent stratification, it may not be reasonable to compare Brownie Lake to the deep lake standard. A better measure of the health of Brownie Lake may be to look at long-term trends data, 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.

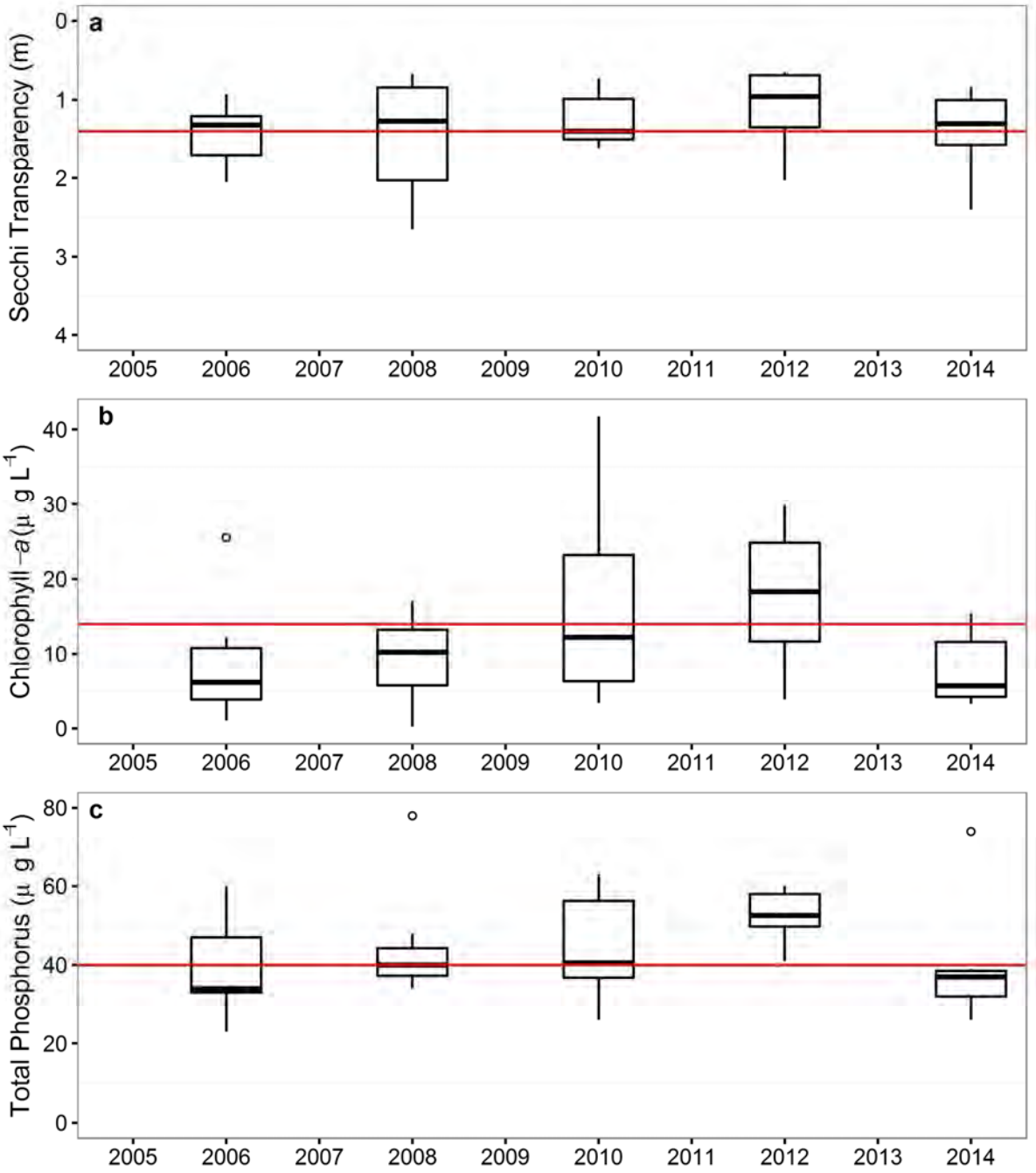


Figure 3-4. Brownie Lake box and whisker plots of TSI data for the past ten years. Horizontal lines represent MPCA eutrophication standard for deep lakes. Data for the entire period of record can be found in Appendix A.

WINTER ICE COVER

Ice came off Brownie Lake on April 14, 2014 which was 11 days later than average. Ice came on the lake November 18, 2014 which was ten days earlier than average. See **Section 1** for details on winter ice cover records and **Section 18** for a comparison with other MPRB lakes.

PHYTOPLANKTON

Phytoplankton and zooplankton are the microscopic plant and animal life that form the foundation of the food web in lakes. **Figure 3-5** shows the Secchi transparency, chlorophyll-*a* concentration, and relative abundance of phytoplankton divisions for the 2014 sampling season. No zooplankton samples were collected from Brownie in 2014 due to low zooplankton densities in the past. In 2008, zooplankton tows yielded low concentrations compared to other Minneapolis lakes.

Water transparency fluctuated between 0.8 meters to 2.4 meters, with the lowest transparency in early spring and greatest transparency in June (**Figure 3-5a**). The low Secchi depth in May was associated with low chlorophyll-*a* concentration and a large abundance of haptophytes and diatoms (Bacillariophyta, **Figures 3-5b, c)**. The highest chlorophyll-*a* values of the season occurred in July and September comprised of mainly green algae (Chlorophyta) and blue-green algae (Cyanophyta) respectively. Surprisingly, blue green algae, a group typically characteristic of warm stratified waters in the summer, were abundant in March and then again in September. Cryptomonads (Cryptophyta) were present throughout the year, but were at their greatest abundance in June.

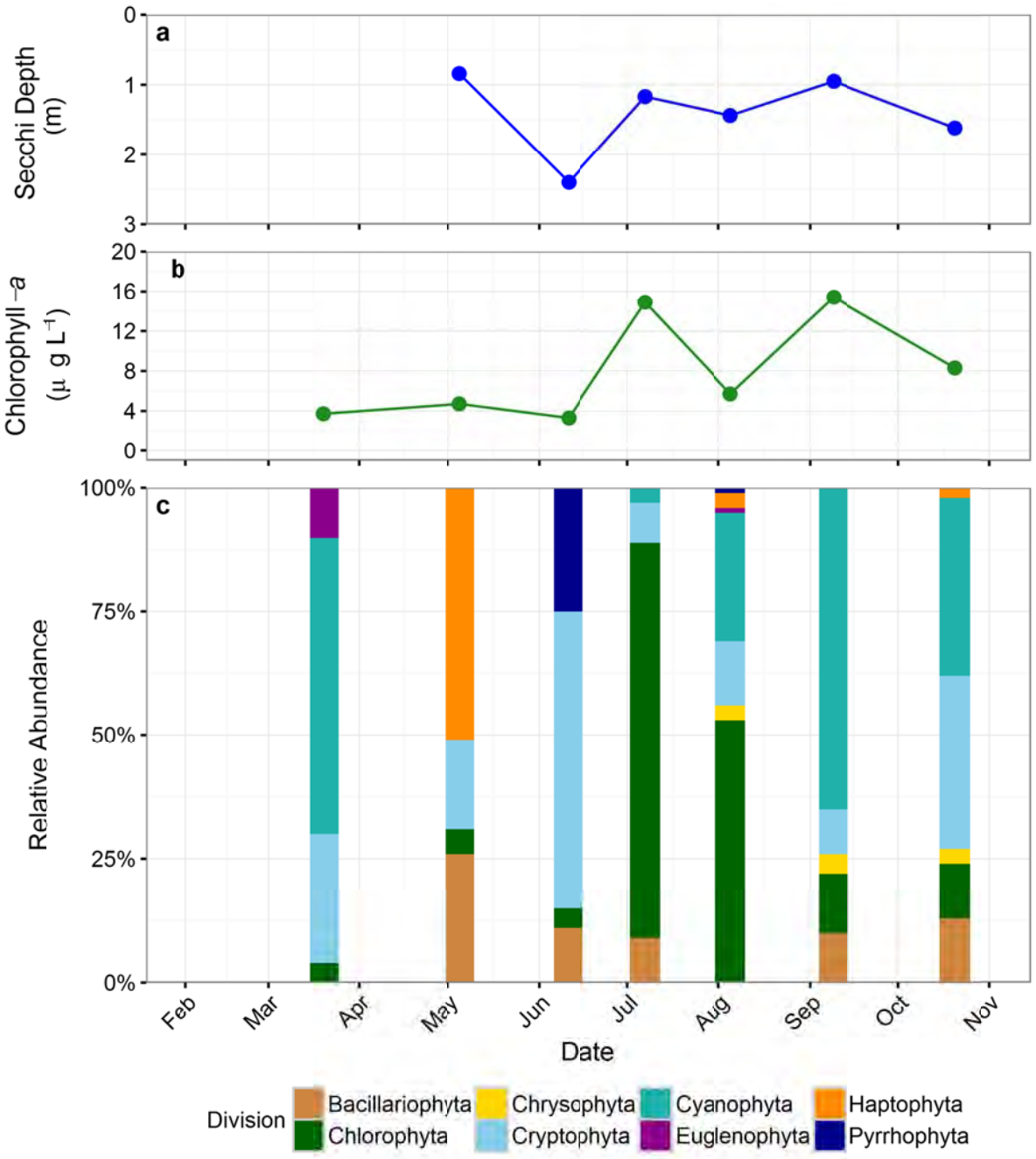


Figure 3-5. Secchi transparency (a), chlorophyll-*a* concentration (b), and relative abundance of phytoplankton (c) during the 2014 Brownie Lake sampling season. Note that the Secchi depth axis is reversed.

WATER QUALITY IMPROVEMENT PROJECTS

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.

In March 2012, the MPRB Board of Commissioners approved an Area Plan for Brownie Lake to improve the land and park amenities surrounding the lake, including path and bike trail improvements and a new canoe launch. Trail improvements, a pedestrian bridge, a new canoe launch, tree planting and landscaping were completed in 2014.

4. LAKE CALHOUN

HISTORY

Lake Calhoun is the largest lake in the Minneapolis Chain of Lakes (**Figure 4-1**). It receives water from Lake of the Isles and discharges water through a weir and open channel to Lake Harriet. The lake has a multitude of recreational opportunities including personal watercraft, sail boat buoy rentals, three public beaches, fishing, and picnicking. The Minneapolis Chain of Lakes Regional Park is the most visited park in the State of Minnesota with over 5 million user visits a year (Met Council, 2014).

Figure 4-1. View of downtown Minneapolis from Lake Calhoun at sunrise.

Previously known as Lake of the Loons, the lake was renamed after John Caldwell Calhoun. While Calhoun was Secretary of War under President Monroe he established a military post at Fort Snelling. The lake and adjacent property were acquired by the Minneapolis Park and Recreation Board (MPRB) between 1883 and 1907 at a cost of $130,000. Similar to other lakes in the Minneapolis Chain of Lakes Lake Calhoun was dredged and surrounding wetland areas were filled (~35 acres) 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.

An effort was made to connect Lake of the Isles and Lake Calhoun after wet years in the early 1900s increased interest in water related activities. A water connection between Isles and Calhoun was created in 1911 after the MRPB received numerous requests and petitions to join the lakes. A connection between Lake Calhoun and Lake Harriet was pondered but was never implemented due to a five foot elevation difference between the lakes. In 1967, a pipeline and pumping station were constructed between Lakes Calhoun and 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.

Studies have shown that water quality in Lake Calhoun has degraded with human activity. In 1973, Shapiro and Pfannkuch 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 construction and connection of storm sewers to Lake Calhoun (1910 to 1940) is also thought to have had a negative impact on water quality. A study by Klak (1933) showed that cyanobacteria were dominant by the early 1930s in Lake Calhoun, indicating possible nutrient enrichment.

In recent years, water quality restoration projects have improved water quality in Lake Calhoun. A detailed Clean Water Partnership diagnostic study conducted in 1991 determined that phosphorus input to the Chain of Lakes should be reduced to increase water quality. Best management practices (BMP) were then implemented for Calhoun and included: public education, increased street sweeping, improved storm-water 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 Lake Calhoun is at, or even slightly better than historic conditions. For example, Lake Calhoun's observed TP is similar to the TP level from 1750 and 1800 based on diatom reconstruction of sediment cores (Heiskary et al., 2004).

Lake Calhoun is a deep, dimictic, glacial kettle lake that typically remains stratified until late October. **Table 4-1** contains the morphometric data for Lake Calhoun. **Figure 4-2** shows the bathymetric map of Lake Calhoun.

Table 4-1. Lake Calhoun morphometric data.

Surface Area (acres)	Mean Depth (m)	Maximum Depth (m)	Littoral Area*	Volume (m^3)	Watershed Area (acres)	Watershed: Lake Area (ratio)	Residence Time (years)
421	10.6	27.4	27%	1.80×10^7	2,992	7.1	4.2

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

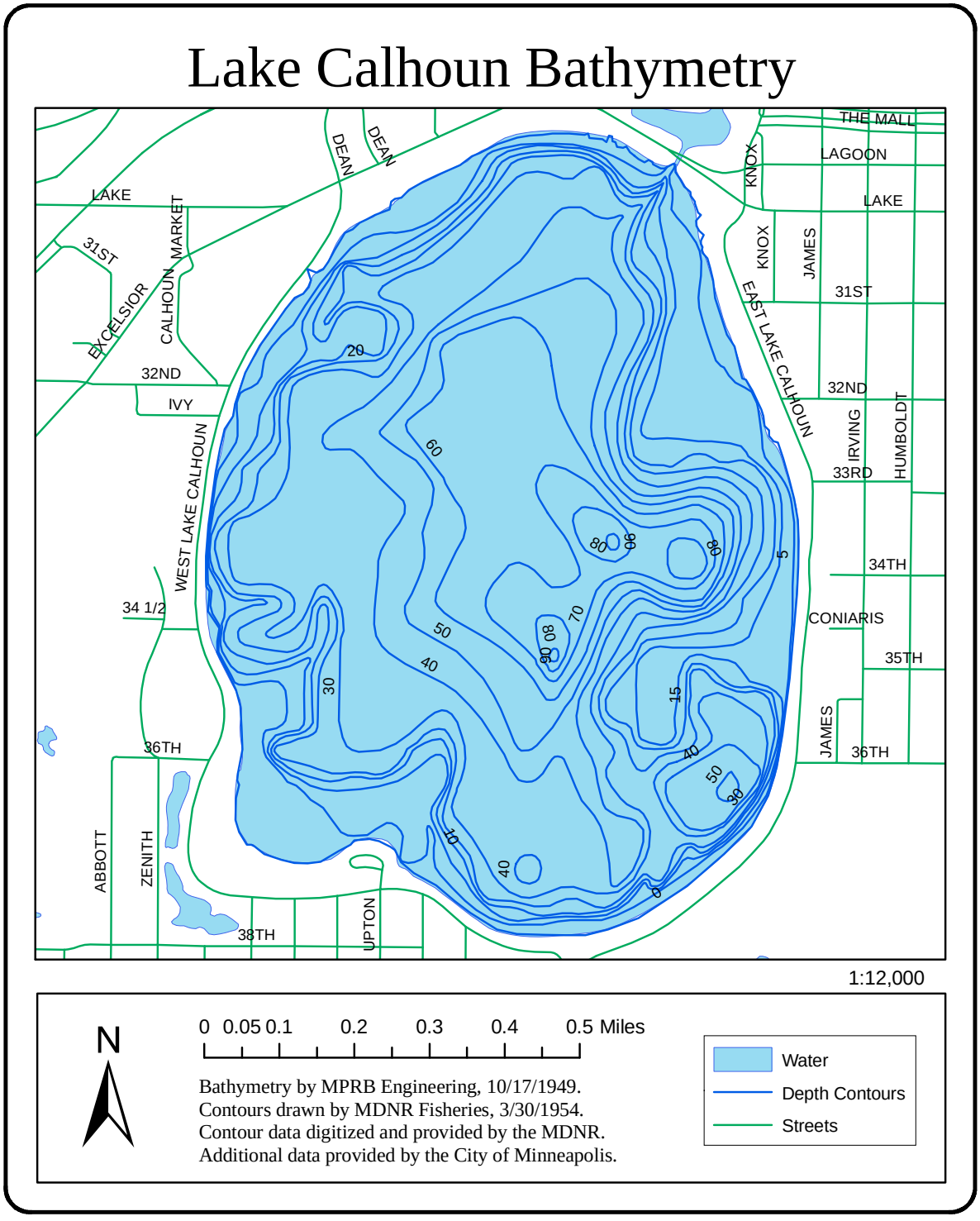


Figure 4-2. Bathymetric map of Lake Calhoun.

LAKE LEVEL

The lake level for the Upper Chain of Lakes (Brownie, Calhoun, Cedar, and Isles) is measured at Lake Calhoun. The four lakes are connected by channels and the gage at Lake Calhoun represents the level at each of the four lakes. The designated Ordinary High Water Level (OHW) for Lake Calhoun is 853 feet above mean sea level. The outlet elevation for Lake Calhoun is 851.85 ft above mean sea level. Lake levels for the Upper Chain of Lakes are shown in **Figure 4-3**. Heavy rains between April and June resulted in the highest water levels ever recorded in the Upper Chain of Lakes in 2014. Blockages in the channel leading to Harriet prevented water levels from returning to normal in the fall. In October, scuba divers were hired to remove debris from the drain in the open part of the channel and additional debris was removed around the open channel by MPRB staff. The lake level wasn't receding as expected and Minneapolis Public Works removed debris from fish grates in the pipe further downstream in November; those fish grates have since been removed in an effort to prevent future blockages. MPRB forestry staff removed trees impeding flow and maintenance staff continued to remove debris form the channel into December. Levels slowly lowered after all the blockages were removed, but were still above the Calhoun outlet elevation when ice formed on the lakes.

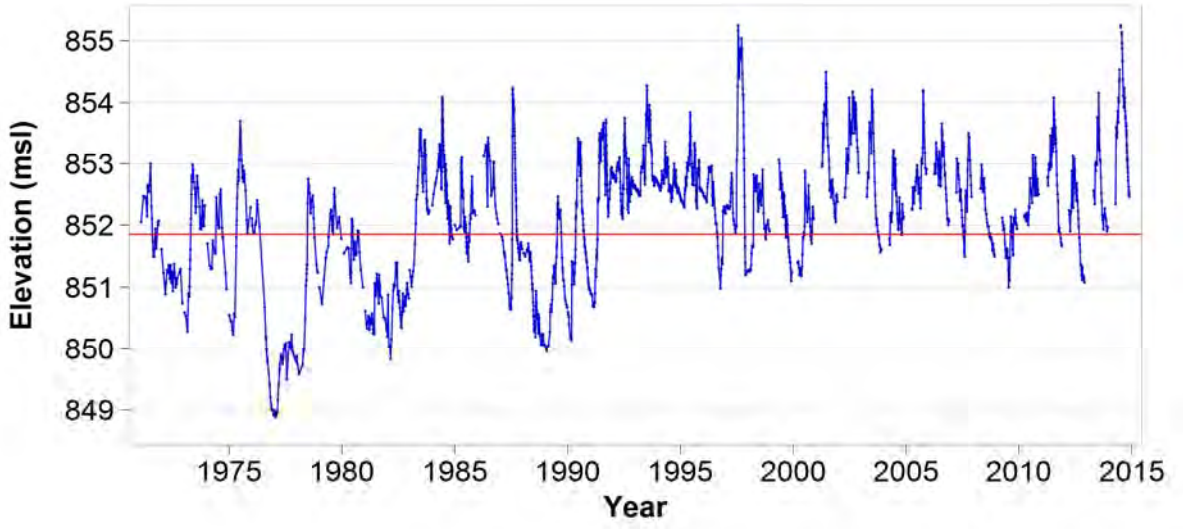


Figure 4-3. Lake levels for the Minneapolis Upper Chain of Lakes (Brownie, Cedar, Isles and Calhoun). Horizontal line represents Lake Calhoun outlet elevation (851.85 ft msl).

WATER QUALITY TRENDS – TROPHIC STATE INDEX (TSI)

Figure 4-4 shows historical Lake Calhoun TSI scores and trend line. There has been a significant decrease in TSI since 1991 ($p < 0.05$) with a TSI score of 42 in 2014. This decrease has followed multiple rehabilitation efforts since 1995. The lake is now mesotrophic with moderately clear water and some algae.

Recent lake conditions have remained relatively stable with a TSI score 10 to 15 units lower (better) than the early 1990s, before the lake and watershed improvement projects from the Clean Water Partnership. In comparison to other lakes in this ecoregion, Calhoun is in the top 5% of TSI scores based on calculations using the Minnesota Lake Water Quality Data Base Summary (MPCA, 2004). A detailed explanation of TSI can be found in **Section 1**.

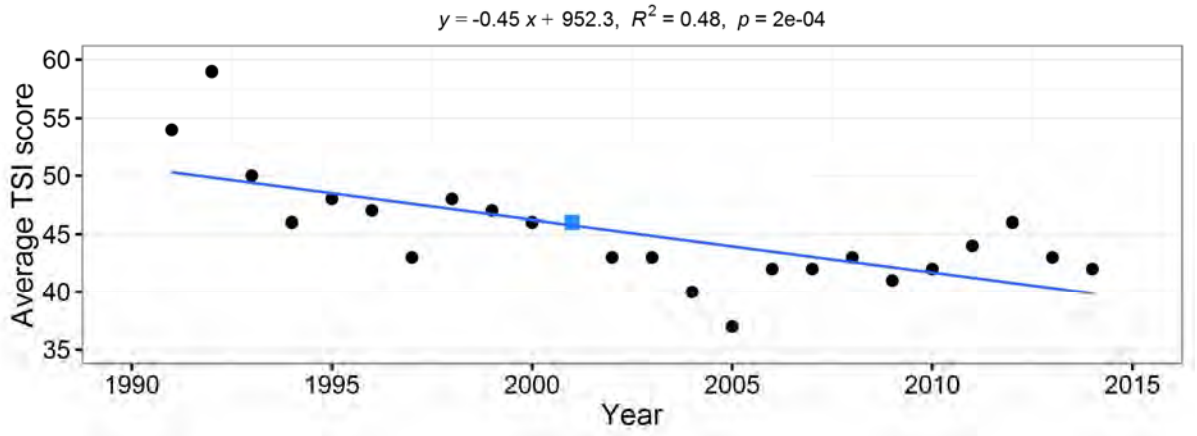


Figure 4-4. Lake Calhoun TSI scores and regression analysis. The blue square highlights the 2001 alum treatment.

BOX AND WHISKER PLOTS

The box and whisker plots in **Figure 4-5** show the data distribution for Secchi transparency, chlorophyll-*a*, and total phosphorus for the past 10 years. Horizontal lines on the graphs indicate the MPCA deep lake standards. A detailed explanation of box and whisker plots can be found in **Section 1**. Data from the entire period of record in box and whisker plot format can be found **Appendix A**.

Water transparency, chlorophyll-*a*, and total phosphorus in 2014 were similar to the previous 10 years and met the MPCA eutrophication standards for Secchi depth, chlorophyll-*a* and total phosphorous. When comparing the boxplots in **Figure 4-5** to those in **Appendix A**, it becomes obvious that the 2001 alum treatment had a profound effect on parameters measured in Lake Calhoun, indicating an overall water quality improvement.

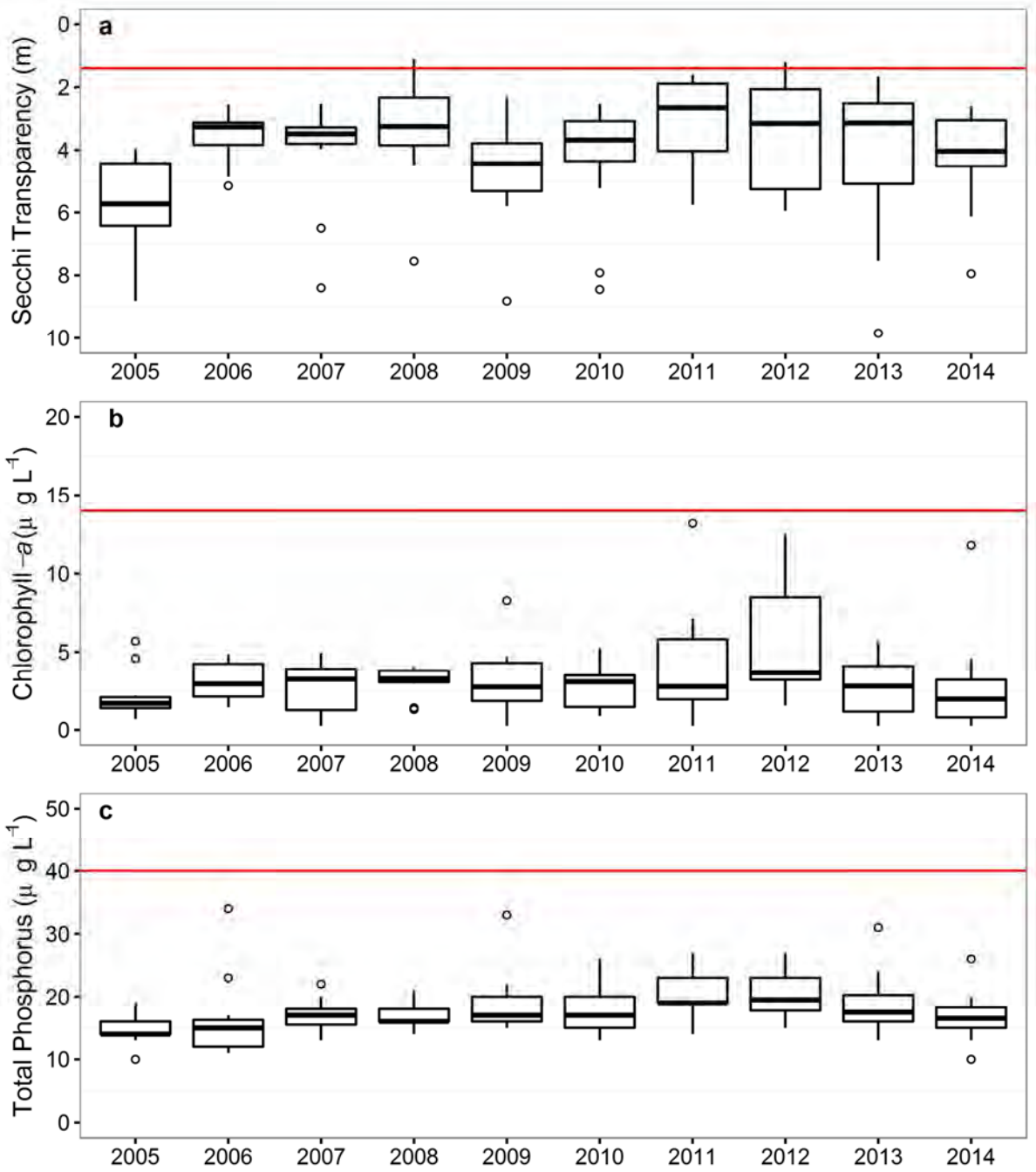


Figure 4-5. Lake Calhoun box and whisker plots of TSI data for the past 10 years. Horizontal lines represent MPCA eutrophication standard for deep lakes. See Appendix A for the entire period of record.

BEACH MONITORING

In 2014, bacteria levels were monitored at Lake Calhoun at three different locations: Calhoun 32nd Street Beach on the east side, Calhoun Main Beach on the north side, and Calhoun Thomas Beach on the south side. As shown in **Table 4-2**, the season long geometric means for *Escherichia coli* (*E. coli*) for Calhoun Main Beach was low, 32nd Street Beach was moderately low, and Thomas Beach was high. The high bacteria levels Calhoun 32nd and Thomas Beaches were most likely due to the abnormally high amounts of precipitation in the summer and led to both beaches being closed for part of the 2014 swimming season. See **Section 19** for more information on beach monitoring.

Table 4-2. Summary of *E. coli* (MPN per 100 mL) data for Lake Calhoun beaches in 2014.

Statistical Calculations	Calhoun 32nd	Calhoun Main	Calhoun Thomas
Number of Samples	15	13	15
Minimum	12	3	19
Maximum	1643	215	1252
Median	62	14	76
Mean	240	33	326
Geometric Mean	75	16	133
Max 30-Day Geo Mean	112	30	218
Standard Deviation	455	56	410

Figure 4-6 illustrates the box and whisker plots of *E. coli* sampling results (per 100 mL of lake water) for Lake Calhoun beaches from 2005 to 2014. The box and whisker plots show the scatter in the dataset over several years. The light red line represents the *E. coli* standard for the 30-day geometric mean (126 MPN/100mL), while the dark red line represents the single-sample maximum standard (1260 MPN/100mL). *E. coli* results were higher than previous years, especially at Thomas Beach in 2014.

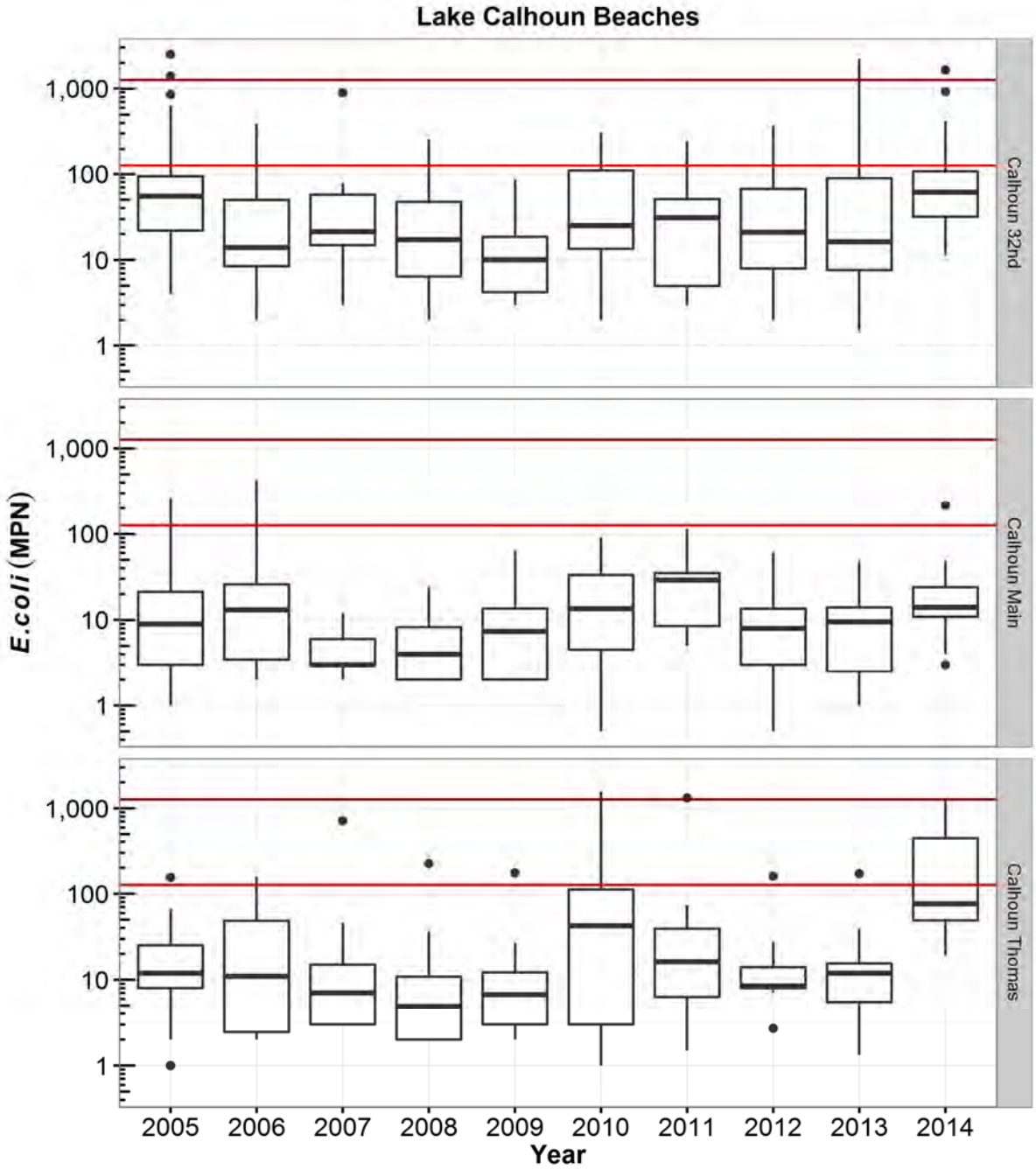


Figure 4-6. Box and whisker plots of *E. coli* results (per 100 mL) for Lake Calhoun beaches from data collected between 2005 and 2014. The horizontal lines represent the *E. coli* standard for the 30-day geometric mean (126 MPN/100mL) and the single-sample maximum standard (1260 MPN/100mL). Note the log scale on the Y-axis. From 2004-2009 *E. coli* concentrations were determined as colony forming units (CFU/100ml).

LAKE AESTHETIC AND USER RECREATION INDEX (LAURI)

Figure 4-7 shows the 2014 LAURI for Lake Calhoun. Lake Calhoun was rated excellent in aesthetics, habitat quality, clarity, and recreational access. Elevated *E. coli* levels at Thomas and 32nd St beaches after large rain events led to a good rating in public health. Details on LAURI can be found in **Section 1** and comparisons with other lakes can be found in **Section 18**.

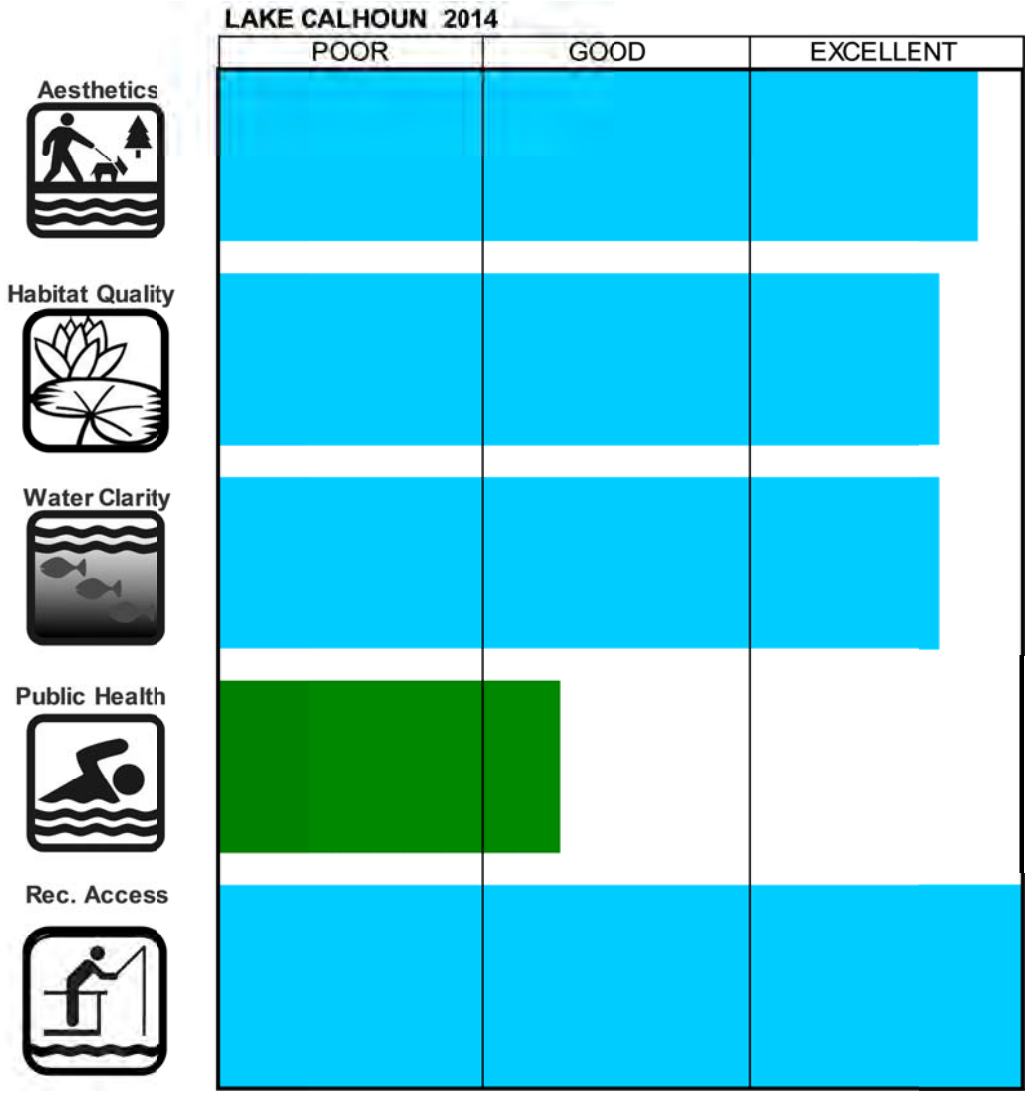


Figure 4-7. The 2014 LAURI for Lake Calhoun.

WINTER ICE COVER

Ice came off Lake Calhoun on April 20, 2014 which was 11 days later than average. Lake ice did not fully cover the lake until December 2, 2014 which was ten days earlier than the average. (See **Figures 4-8 and 4-9** below).

While there is a lot of fluctuation in the data, there is a significant trend towards an earlier ice-off ($p < 0.05$, **Figure 4-8**). The running average ice-off date has shifted to earlier dates, floating around April 13th in the 1970s to April 9th for the past 15 years. The histogram in **Figure 4-8** shows the majority of ice-off dates occurring in early to mid-April over the past 69 years, with a few years with early ice-off dates in March and lake ice-offs in late April.

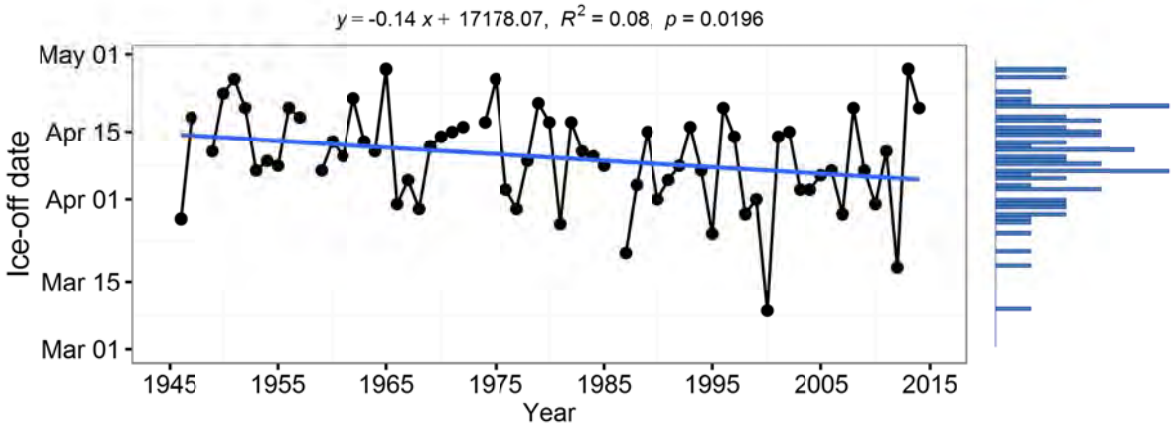


Figure 4-8. Lake Calhoun ice-off dates and frequency of the occurrence of ice-off on particular dates for all the years of record. 65 recorded ice-off dates exist over the past 69 years.

Fewer observations for in-on dates exist for Lake Calhoun. While there is no significant trend in ice-on date ($p > 0.05$), the three latest ice-on dates have occurred since 2001 (**Figure 4-9**). The histogram in **Figure 4-9** shows Lake Calhoun is typically frozen in early to mid-December over the past 53 years of observation, with a few ice-on dates in January. See **Section 1** for details on winter ice cover records and **Section 18** for a comparison with other lakes.

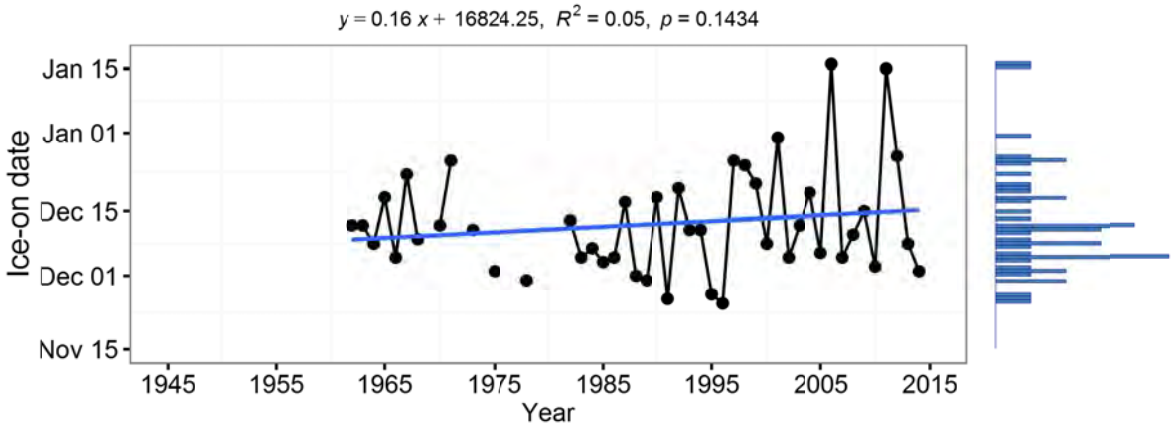


Figure 4-9. Lake Calhoun ice-on dates and frequency of the occurrence of ice-on on particular dates for all the years of record. 45 ice-on records exist.

EXOTIC AQUATIC PLANT MANAGEMENT

The Minnesota Department of Natural Resources (MDNR) requires a permit to remove or control Eurasian watermilfoil. These permits limit the area from which milfoil 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 areas where public recreational access is needed. In 2014, the permitted area on Lake Calhoun was 47 acres which is about 40% of the littoral zone (area 15 feet or shallower). For more information on aquatic plants see **Section 1** and **Section 20**.

PHYTOPLANKTON AND ZOOPLANKTON

Phytoplankton and zooplankton are the microscopic plant and animal life that form the basic food web of lake ecology. **Figures 4-10** shows the Secchi transparency, chlorophyll-*a* concentrations, and relative abundance of phytoplankton division during the 2014 sampling season.

Water clarity was greater than 2 meters for the entire sampling season in 2014, with the greatest transparency of 8 meters in the end of May (**Figure 4-10a**). Chlorophyll-*a* concentrations were low throughout the season as well (**Figure 4-10b**). The highest algal biomass occurred in early September (11.8 µg L^{-1}) and was characterized by blue green algae (Cyanophyta) and dinoflagelates (Pyrrhophyta, **Figure 4-10b, c**). The phytoplankton community of Lake Calhoun in was largely dominated by blue green algae for most of the year, even the winter sample, as seen in **Figure 4-10c**. Diatoms and Cryptomonads (Cryptophyta) were abundant in the spring and then again in late October. Both groups are high quality food for zooplankton. Dinoflagellates had a small bloom at the beginning of September.

Figure 4-11 shows the zooplankton distribution in Lake Calhoun sampled throughout 2014. Nauplii (juvenile stages of zooplankton) were found at their highest numbers in the spring sample, tapering off throughout the entire season to lower levels by November. Rotifers, which are a group of small zooplankton, became more abundant in July and continued to have the highest abundance through the fall. Cladocerans held greater density earlier in the season, tapering off as the weather cooled. Protozoa, cyclopoids, and calanoids were present in low concentrations throughout the entire season.

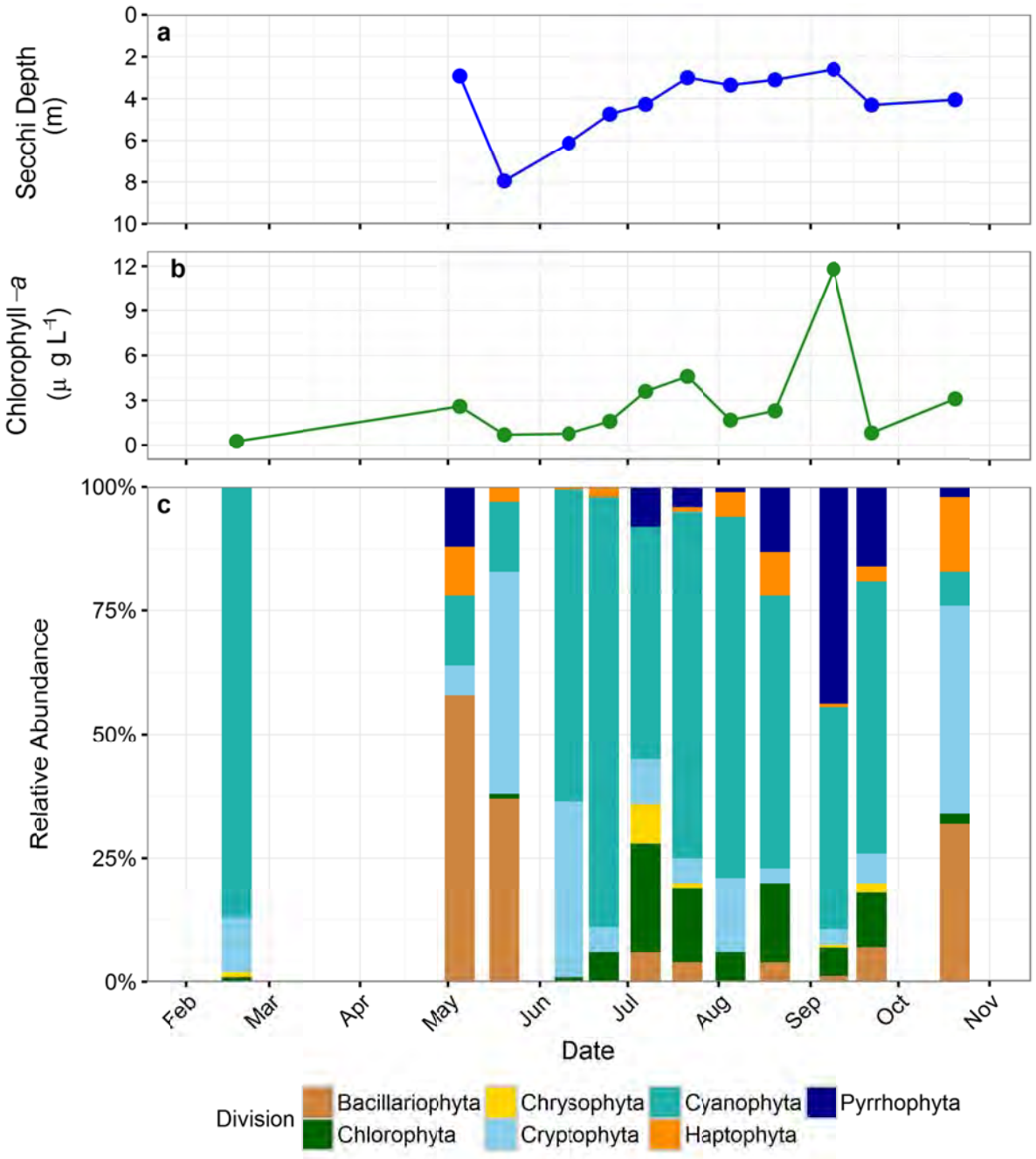


Figure 4-10. Secchi transparency (a), chlorophyll-*a* concentration (b), and relative abundance of phytoplankton (c) during the 2014 Lake Calhoun sampling season. Note that the Secchi depth axis is reversed.

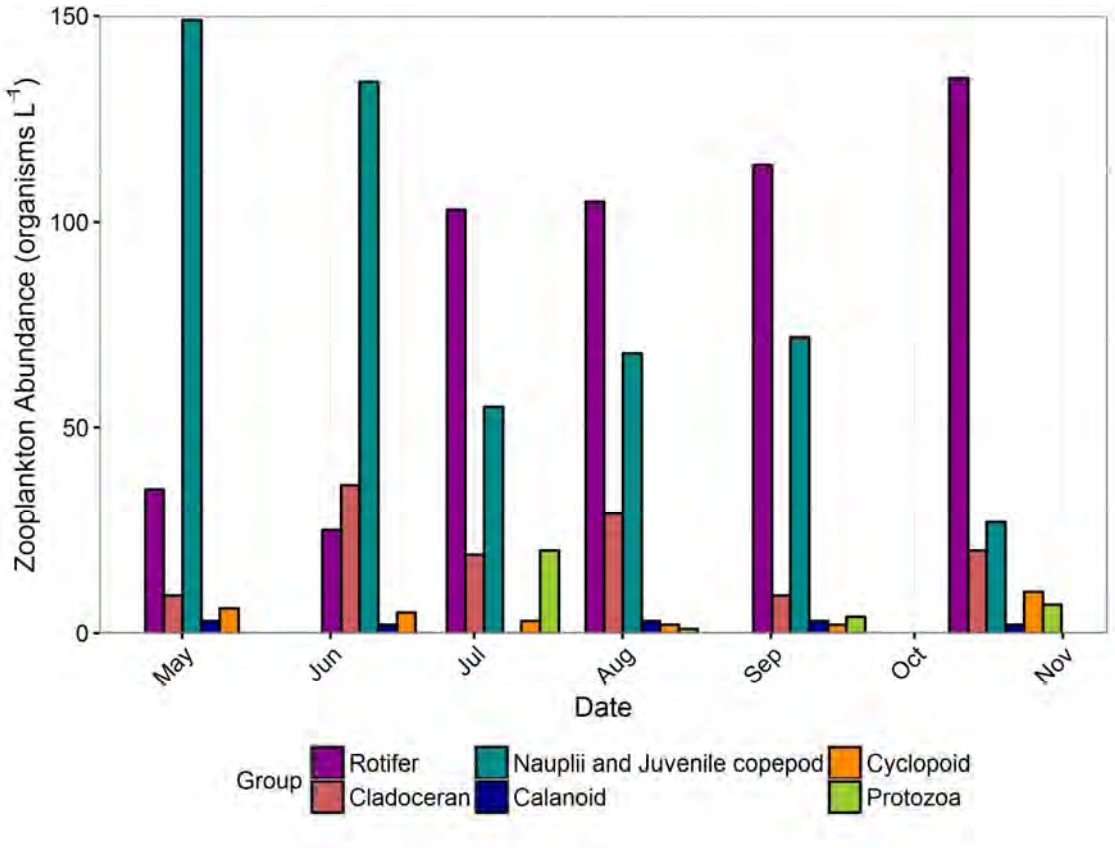


Figure 4-11. Lake Calhoun 2014 zooplankton density.

FISH STOCKING

Additional information and a definition of fry, fingerling, yearling and adult fish can be found in **Section 1**.

Lake Calhoun was stocked by the MDNR in:

1999 with 71 adult Muskellunge, 125 fingerling Muskellunge.

2000 with 107 adult Muskellunge, 1,590 yearling Walleye.

2001 with 12,654 fingerling Walleye.

2002 with 500 fingerling Tiger Muskellunge.

2003 with 5,545 fingerling Walleye.

2005 with 500 fingerling Tiger Muskellunge.

2006 with 2,356 fingerling Walleye.

2007 with 500 fingerling Tiger Muskellunge.

2009 with 480 fingerling Tiger Muskellunge, 9,991 fingerling Walleye, 248 yearling Walleye.

2010 with 127 fingerling Muskellunge.

2012 with 123 fingerling Muskellunge, 12,684 yearling Walleye.

5. CEDAR LAKE

HISTORY

Like the other lakes in the Chain of Lakes, Cedar Lake was altered from its natural state when it was dredged between 1911 and 1917. Channels connecting Cedar Lake to Lake of the Isles and to Brownie Lake were created in 1913 and 1916. The Lake of the Isles connection caused the water level in Cedar Lake to drop six 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. **Figure 5-1** shows a recent photograph of Cedar Lake.

Clean Water Partnership projects were implemented to improve water quality at Cedar Lake. Constructed wetlands (1995) and an aluminum sulfate (alum) treatment (1996) were best management practices (BMPs) implemented to improve water quality in the lake. The 1996 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).

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). **Figure 5-2** shows a bathymetric map of Cedar Lake. **Table 5-1** shows the Cedar Lake morphometric data.

Figure 5-1. View of Cedar Lake from Main Beach in 2012.

Table 5-1. Cedar Lake morphometric data.

Surface Area (acres)	Mean Depth (m)	Max Depth (m)	Littoral Area*	Volume (m^3)	Watershed Area (acres)	Watershed: Lake Area (ratio)	Residence Time (years)
170	6.1	15.5	37%	4.26×10^6	1,956	11.5	2.7

* Littoral area defined as less than 15 feet deep.

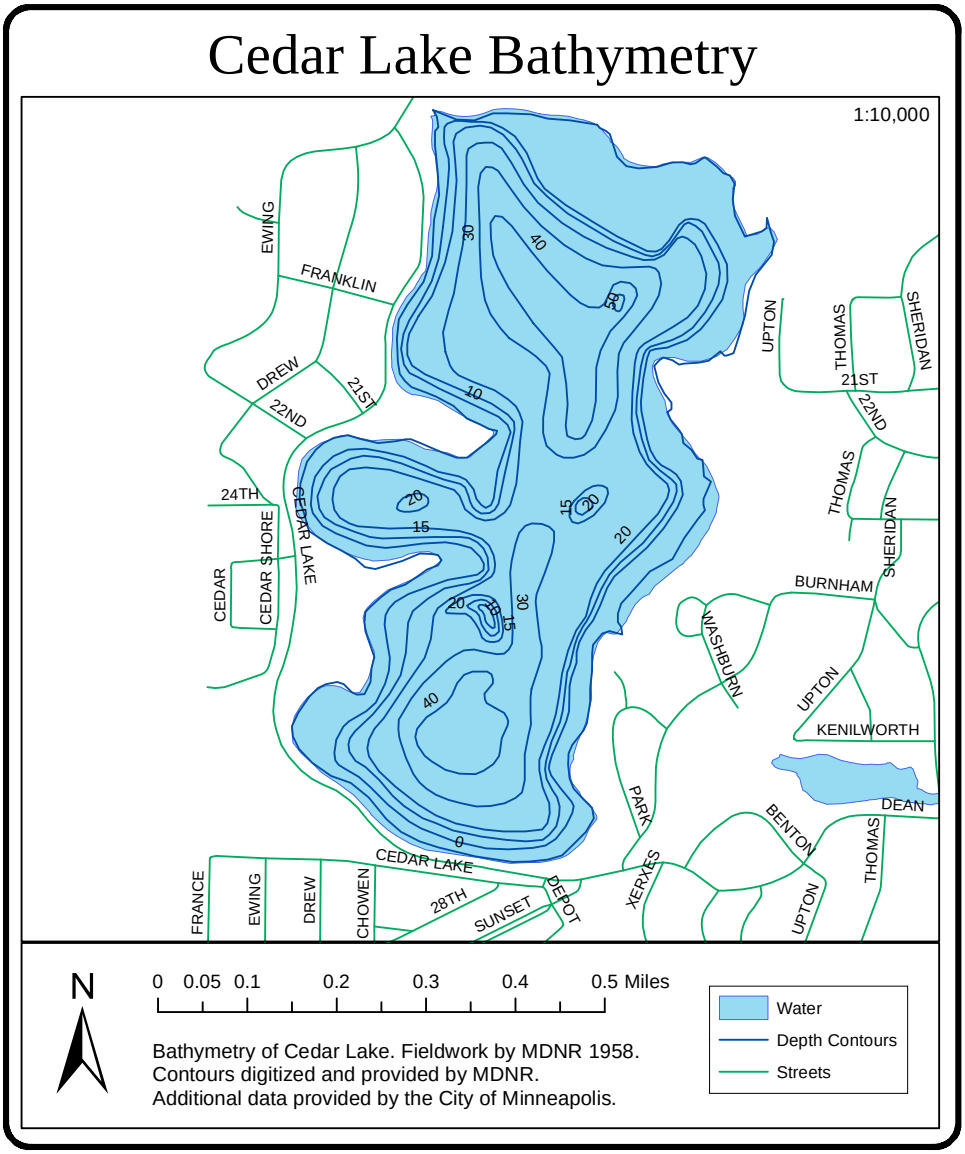


Figure 5-2. Bathymetric map of Cedar Lake.

LAKE LEVEL

The designated Ordinary High Water Level (OHW) for Cedar Lake is 853 feet above msl. **Section 4, Lake Calhoun** includes more information on historic Chain of Lakes water level information.

WATER QUALITY TRENDS – TROPHIC STATE INDEX (TSI)

The 2014 TSI score for Cedar Lake was 51, putting Cedar in the top 25% of TSI scores compared to other lakes in the ecoregion (based on calculations from the Minnesota Pollution Control Agency, using the Minnesota Lake Water Quality Data Base Summary, 2004). The TSI scores for all monitored years with a linear regression are shown in **Figure 5-3**. Restoration efforts begun in 1994 have helped improve water quality in the lake. Although there was an initial decrease in TSI after restoration projects, there has been no significant trend in TSI from 1991-2014 ($p > 0.05$). Cedar Lake is currently mesotrophic with moderately clear water and some algae. A detailed explanation of TSI can be found in **Section 1**.

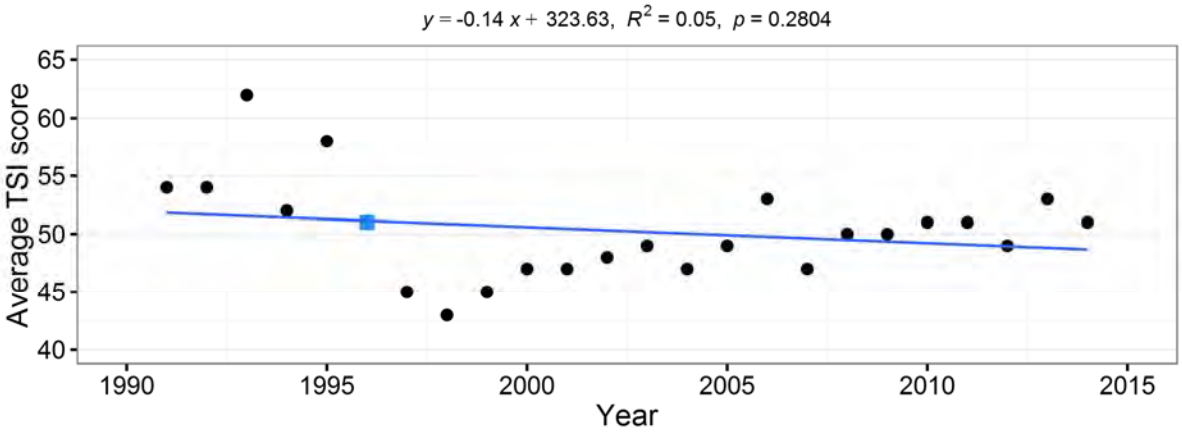


Figure 5-3. Cedar Lake TSI scores and regression analysis from 1991-2014. The alum treatment year is indicated with a blue square.

BOX AND WHISKER PLOTS

The box and whisker plots in **Figure 5-4** show the data distribution for Secchi transparency, chlorophyll-*a*, and total phosphorus for Cedar Lake for the past decade. Horizontal lines on the graphs indicate the MPCA deep lake standards. A detailed explanation of box and whisker plots can be found in **Section 1**. Data in box and whisker plot format for the entire period of record can be found in **Appendix A**.

Cedar Lake water transparency in 2014 was similar to 2013 and slightly worse than most of the past decade; however, chlorophyll-*a* and total phosphorus levels were lower than 2013 and consistent with levels from 2007-2012. Cedar met the MPCA eutrophication standard for Secchi depth, chlorophyll-*a*, and total phosphorus in 2014.

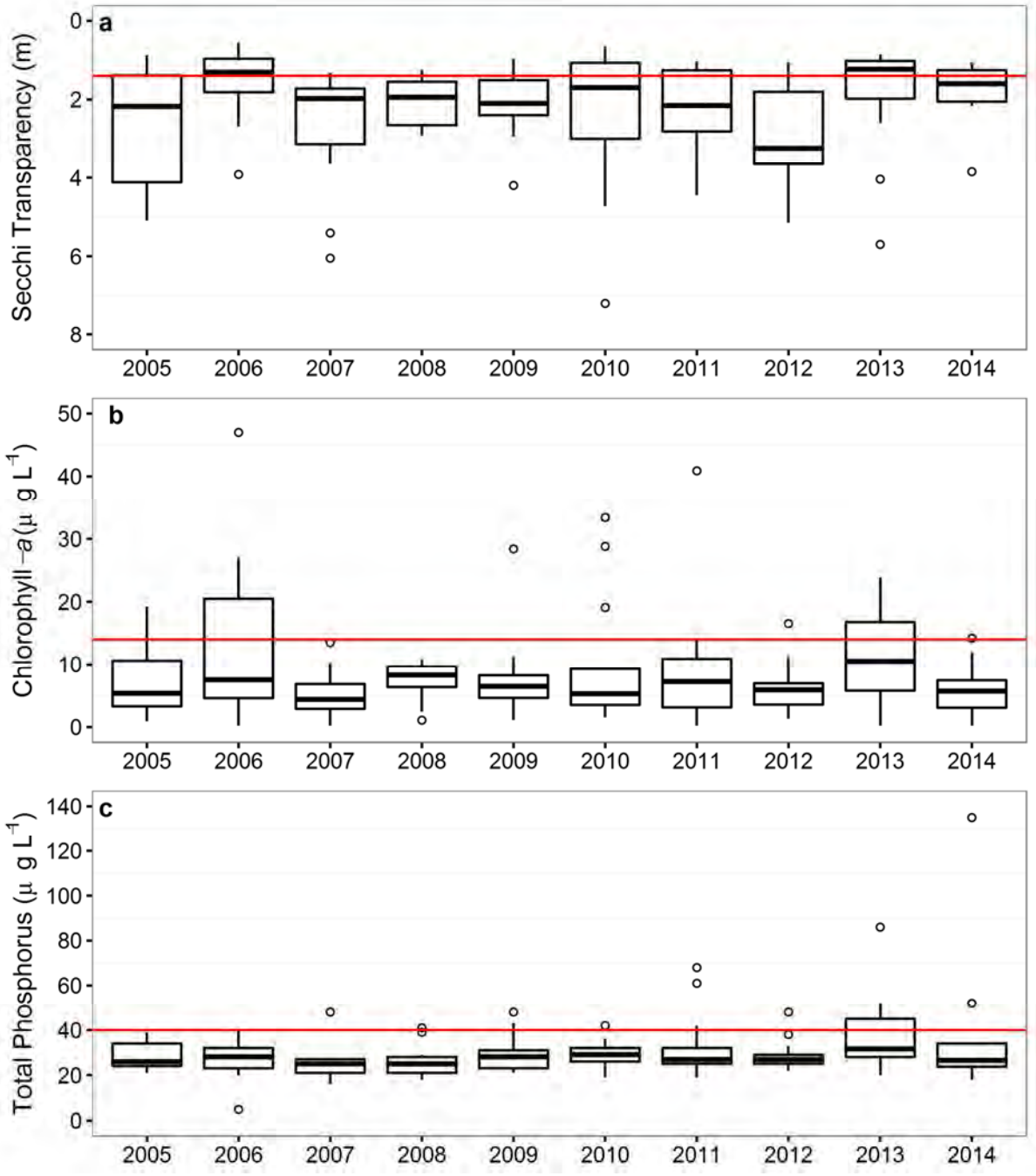


Figure 5-4. Box and whisker plot data for Cedar Lake for the past decade. Horizontal lines represent MPCA eutrophication standard for deep lakes. See Appendix A for the entire period of record.

BEACH MONITORING

Escherichia coli (*E. coli*) levels were sampled at three different locations around Cedar Lake: Cedar Main Beach, Cedar Point Beach, and East Cedar Beach (Hidden). All Cedar Lake beaches remained open for the entire season. As shown in **Table 5-2,** the season-long geometric means for *E. coli* were relatively low at all of the Cedar Lake beaches. East Cedar Beach was opened as a supervised public beach for the first time in 2007 and typically has had some of the lowest *E. coli* count values for all MPRB beaches. East Cedar and Cedar Main both had one high sample over the course of the season, but it was not high enough to exceed the single-sample standard of 1260 MPN/100 mL.

Table 5-2. Summary of 2014 *E. coli* results (MPN per 100 mL) for Cedar Lake beaches.

Statistical Calculations	East Cedar	Cedar Main	Cedar Point
Number of Samples	13	13	13
Minimum	4	1	2
Maximum	143	84	237
Median	25	20	9
Mean	41	28	29
Geometric Mean	24	13	11
Max 30-Day Geo Mean	77	20	30
Standard Deviation	43	29	63

Figure 5-5 shows box and whisker plots of *E. coli* sampling results for 2005 - 2014. The light red line represents the *E. coli* standard for the 30-day geometric mean (126 MPN/100mL), while the dark red line represents the single-sample maximum standard (1260 MPN/100mL). Additional information on beach monitoring can be found in **Section 19**.

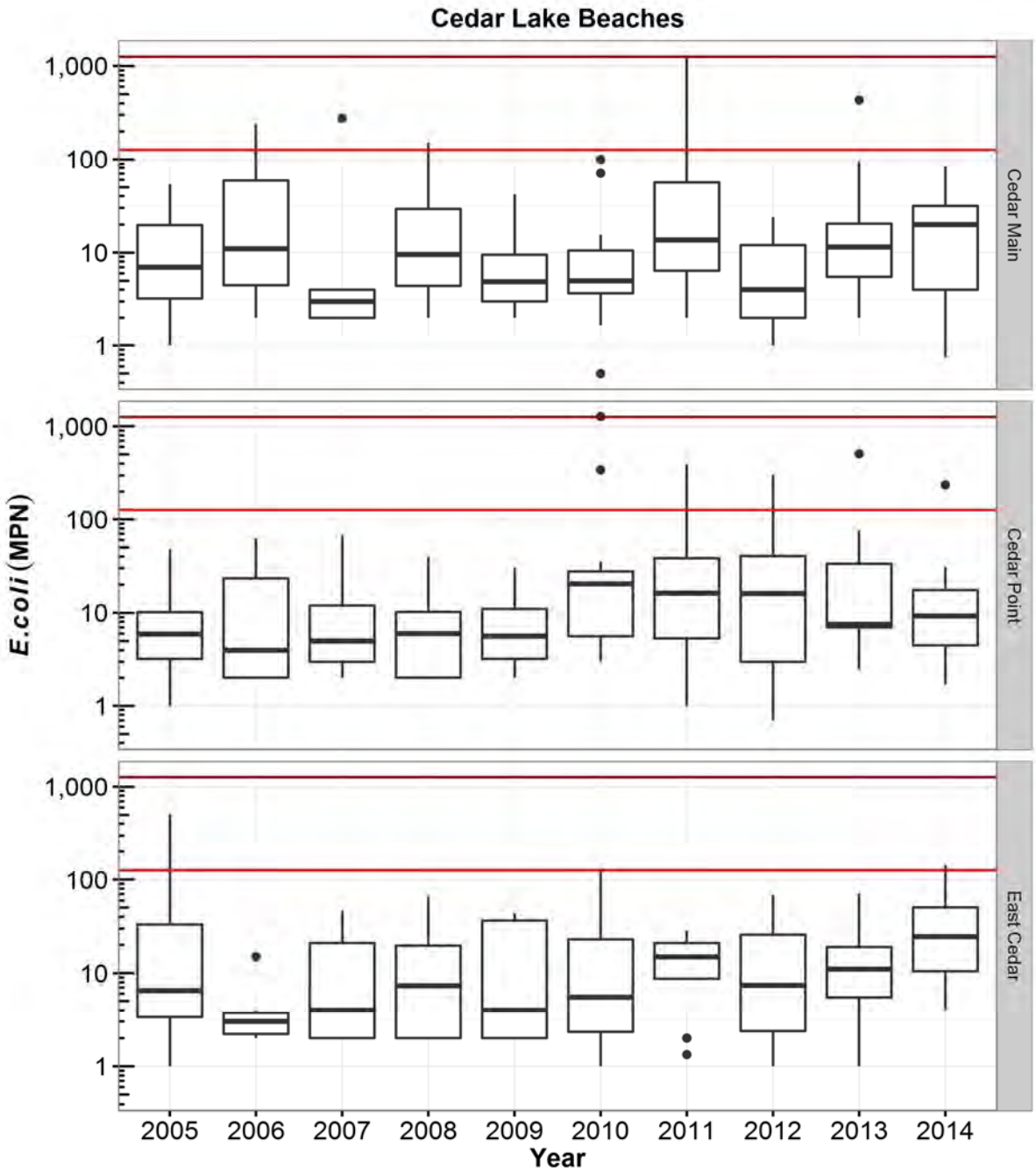


Figure 5-5. Box and whisker plots of *E. coli* results (per 100 mL) for Cedar Lake beaches for 2005 -2014. The horizontal lines represent the *E. coli* standard for the 30-day geometric mean (126 MPN/100mL) and the single-sample maximum standard (1260 MPN/100mL). Note the log scales on each y-axis. From 2005-2009 *E. coli* concentrations were determined as colony forming units (CFU/100ml).

LAKE AESTHETIC AND USER RECREATION INDEX (LAURI)

The 2014 LAURI for Cedar Lake is presented in **Figure 5-6**. Cedar Lake scored "excellent" in aesthetics, habitat quality, public health, and recreational access and "good" in water clarity. See **Section 1** for details on the LAURI index.

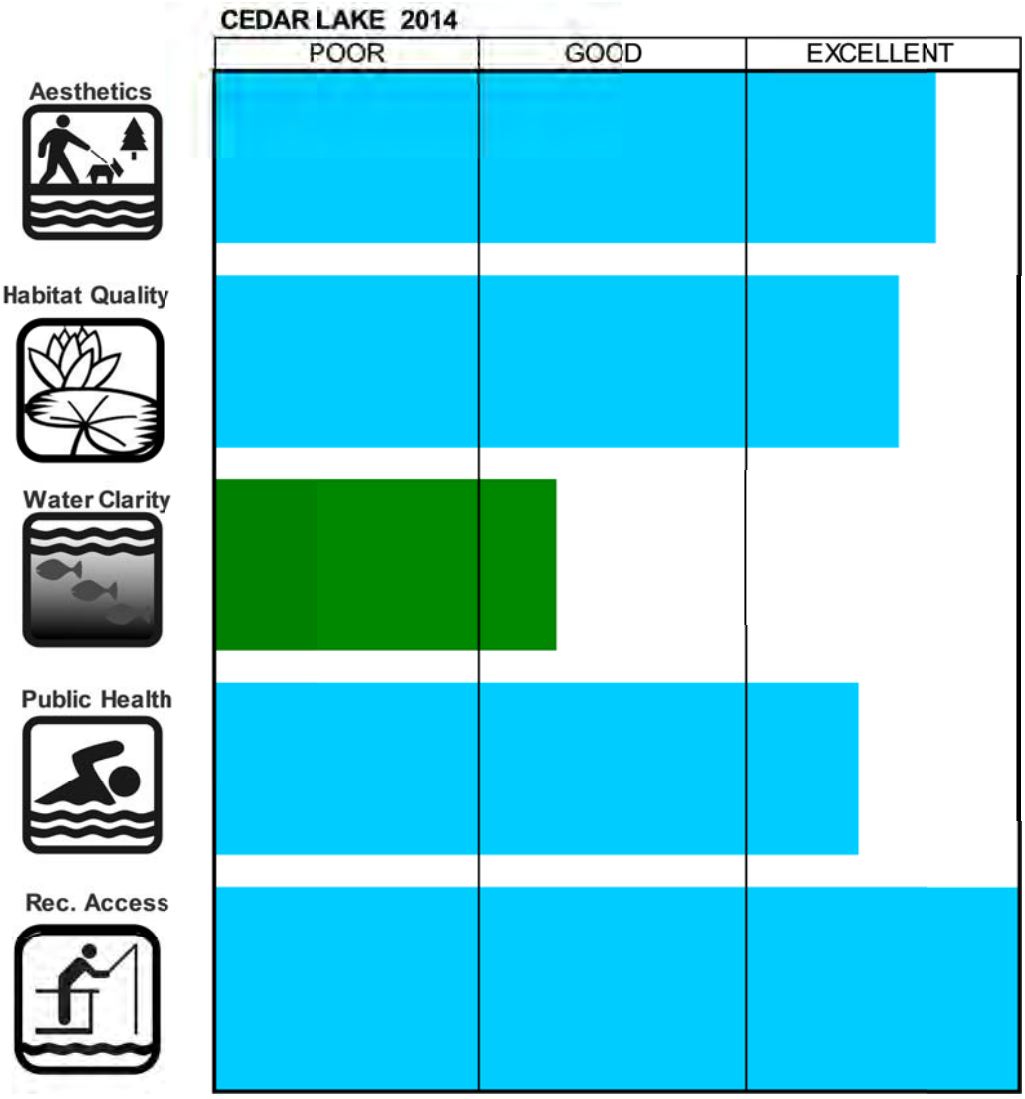


Figure 5-6. The 2014 LAURI for Cedar Lake.

WINTER ICE COVER

Ice came off Cedar Lake on April 19, 2014, which was 13 days later than average. Ice was back on the lake by November 21, 2014, which is 12 days before the average ice-on date for the lake. See **Section 1** for details on winter ice-cover records and **Section 18** for a comparison with other lakes.

EXOTIC AQUATIC PLANT MANAGEMENT

The MDNR requires a permit to remove or control Eurasian watermilfoil. The permit limits the area from which milfoil 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 shallow areas where recreational access was necessary. In 2014, the permitted area on Cedar Lake was 19 acres which is approximately 25% of the littoral zone of the lake (area shallower than 15 feet). See **Section 1** for details on aquatic plants.

PHYTOPLANKTON AND ZOOPLANKTON

Phytoplankton and zooplankton are the microscopic plant and animal life that form the foundation of the food web in lakes. **Figure 5-7** shows the Secchi transparency, chlorophyll-*a* concentrations, and relative abundance of phytoplankton division during the 2014 sampling season. **Figure 5-8** shows the zooplankton distribution over 2014.

Secchi depth at the beginning of the season was low (1-1.4 m), but chlorophyll-*a* concentrations were also low (< 5.5 µg L^{-1}), indicating non algal turbidity may have influenced water transparency in the early spring (**Figure 5-7a, b**). These early spring samples were mostly comprised of a spring diatom (Bacillariophyta) bloom, cryptophytes (Cryptophyta), and haptophytes (Haptophyta, **Figure 5-6c**). There was a brief time in early June when water transparency approached 4 meters, but the remainder of the season Secchi depth fluctuated between 1-2 meters once blue green algae (Cyanobacteria) became more abundant (**Figure 5-7a-c**). The March sample was characterized by a majority of chrysophytes (Chrysophyta), which are typically found in cold water, but were at a low abundance the remainder of season if they were present in a sample.

Zooplankton samples were taken once per month between April and October during the 2014 sampling season and results are displayed in **Figure 5-8**. Concentrations of juvenile zooplankton and nauplii were abundant early in the season and again in August. Rotifers, which are a group of small zooplankton, spiked in June and September. Cladocerans were present throughout the season, but were most abundant in October. Calanoids and cyclopoids were present at low levels throughout the sampling season.

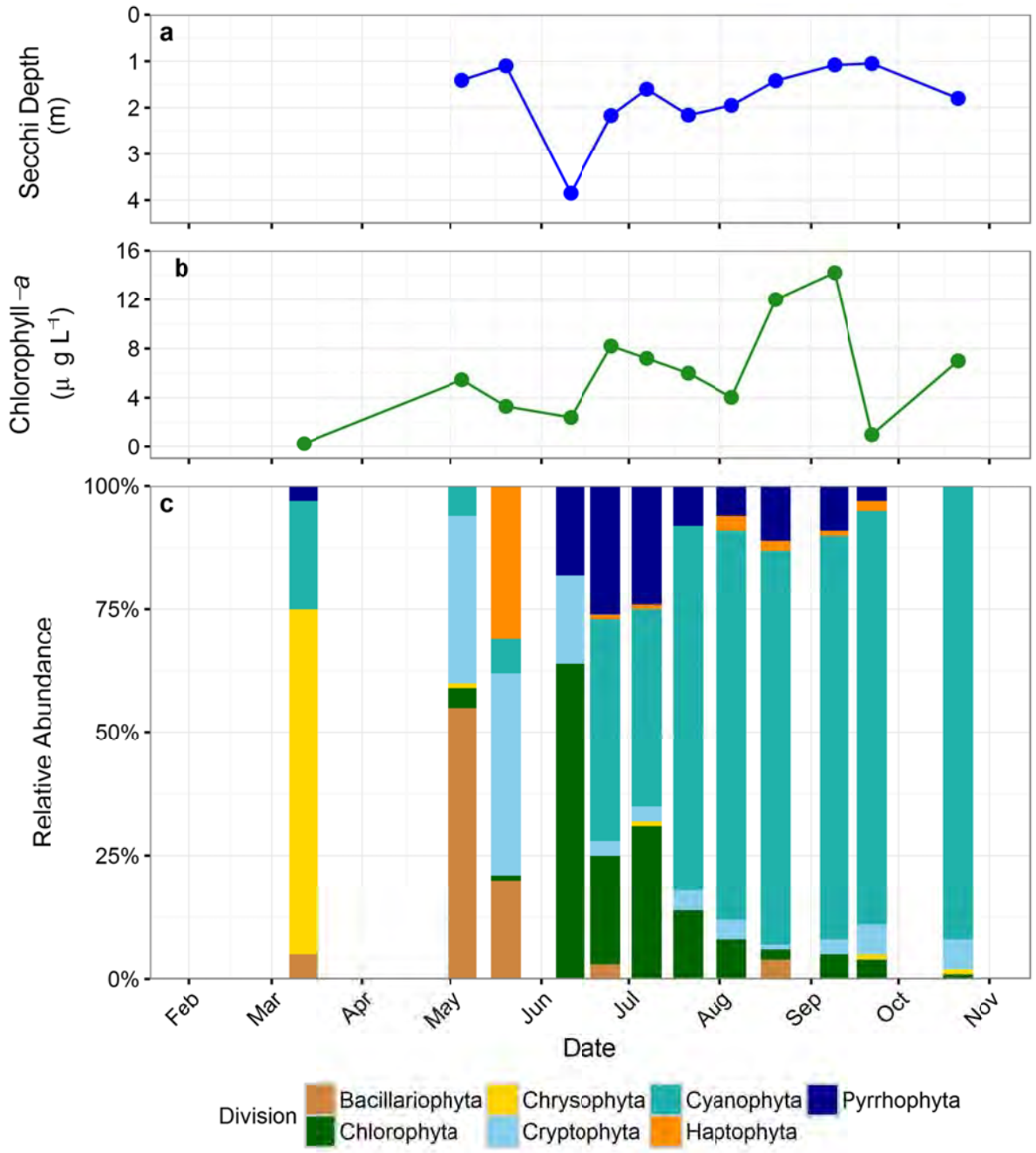


Figure 5-7. Secchi transparency (a), chlorophyll-*a* concentration (b), and relative abundance of phytoplankton (c) during the 2014 Cedar Lake sampling season. Note that the Secchi depth axis is reversed.

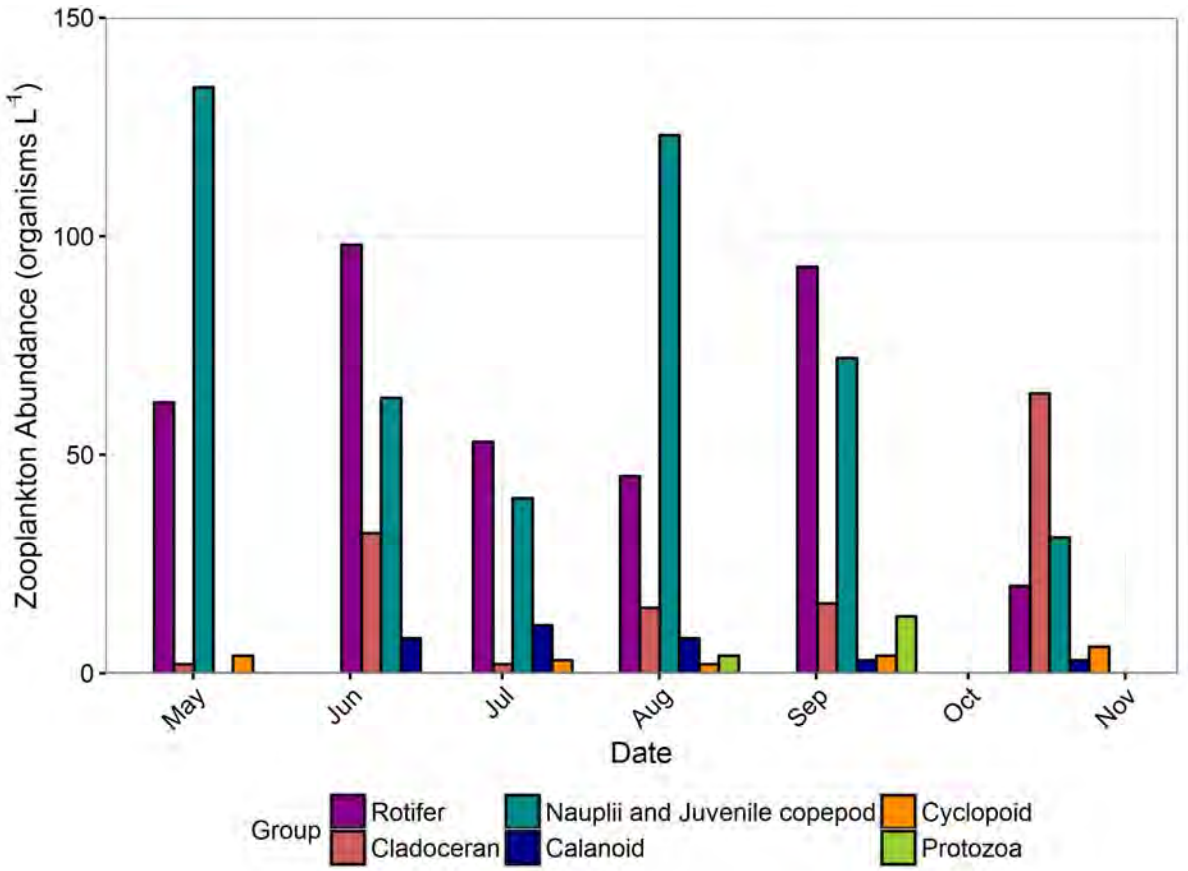


Figure 5-8. 2014 Cedar Lake zooplankton distribution.

FISH STOCKING

Additional information and a definition of fry, fingerling, yearling, and adult fish sizes can be found in **Section 1**.

Cedar Lake was stocked by MDNR in:

1998 with 299 fingerling Muskellunge.
2001 with 200 fingerling Tiger Muskellunge.
2004 with 200 fingerling Tiger Muskellunge.
2005 with 1,168 fingerling Walleye.
2007 with 160 fingerling Tiger Muskellunge and 2,022 fingerling Walleye.
2009 with 2,835 fingerling Walleye and 115 yearling Walleye.
2010 with 67 fingerling Muskellunge.
2011 with 3,828 fingerling Walleye.
2012 with 63 fingerling Muskellunge.
2013 with 3.640 fingerling Walleye.

6. DIAMOND LAKE

HISTORY

Diamond Lake is a small shallow water body predominantly surrounded by residential neighborhoods and parkland **(Figure 6-1)**. The National Wetlands Inventory classifies Diamond Lake as a lacustrine/limnetic system with an unconsolidated bed and is permanently flooded (L1UBH). The fringe of Diamond Lake is classified as palustrine semipermanently flooded wetland with emergent vegetation (PEMF; USFWS, 2012).

Diamond Lake and surrounding park areas were donated to the 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.

Water levels in Diamond Lake have fluctuated due to land use changes in the surrounding watershed. In 1940, the City of Minneapolis installed storm sewers and 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. Construction of Interstate 35W during the 1960s added several miles of highway runoff to Diamond Lake. In 1991, the MPRB placed a weir at 822.0 ft msl (112.2 feet above city datum) allowing for higher water than the previous outlet which was 820.1 ft msl (110.3 feet above city datum). The increase in water elevation was made to encourage establishment of aquatic plants and to restore important wildlife habitat in Diamond Lake.

Figure 6-1. Diamond Lake in Fall 2013.

In 1953, the Minnesota Department of Natural Resources (MDNR) 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 (MDNR, 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 changed the drainage areas in the Diamond Lake watershed. **Figure 6-2** shows a map for Diamond Lake. **Table 6-1** shows morphometric data for Diamond Lake.

Table 6-1. Diamond Lake morphometric data.

Surface Area (acres)	Mean Depth (m)	Max Depth (m)	Littoral Area*	Volume (m^3)	Watershed Area (acres)	Watershed: Lake Area (ratio)	Ordinary High Water Level (msl)
41	0.9	2.1	100%	$7.15x10^4$	669	16.3	822.32

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

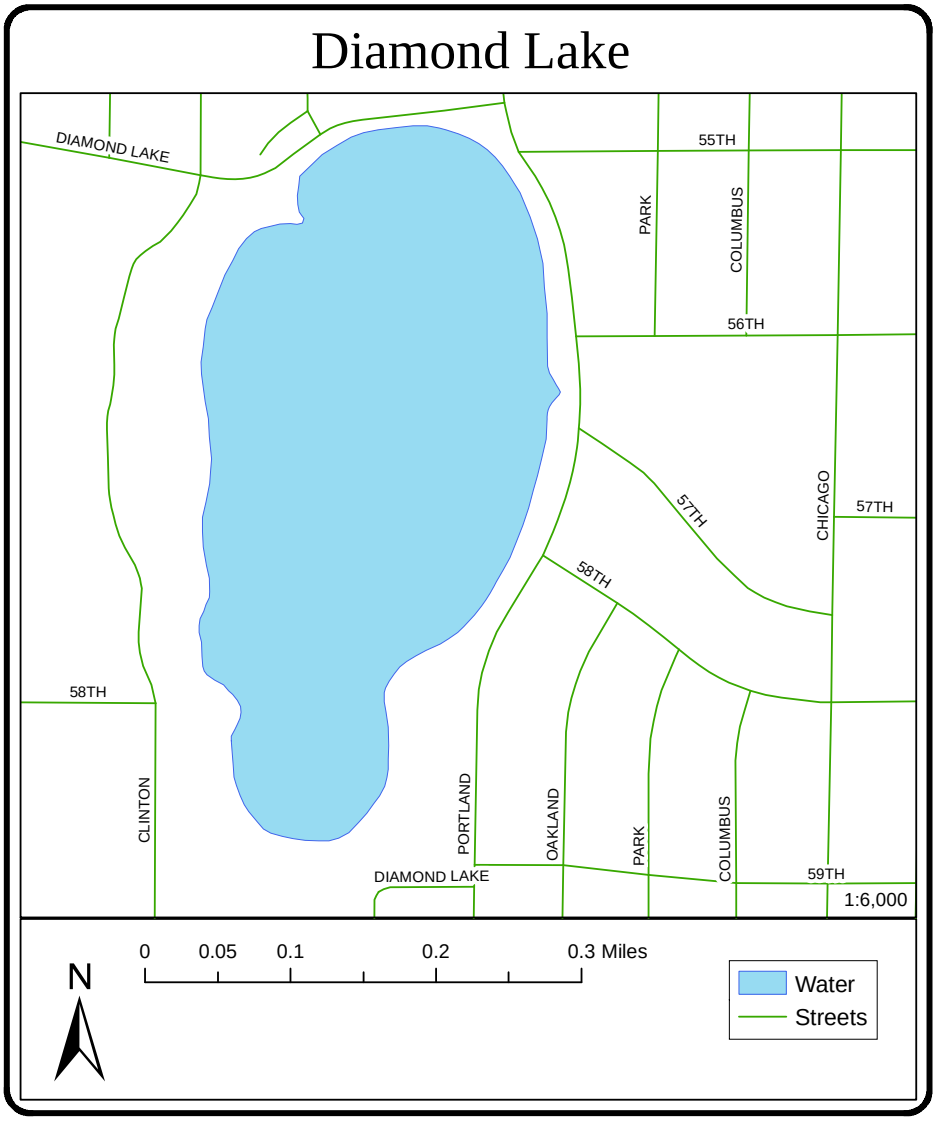


Figure 6-2. Diamond Lake map.

LAKE LEVEL

The lake level for Diamond Lake is measured at a gage near the Diamond Lake Lutheran Church and results are shown in in **Figure 6-3**. The designated Ordinary High Water Level (OHW) for Diamond Lake is 822.32 feet above mean sea level. Similar to previous years, lake levels were high early in the season after snowmelt and large rains and dropped during the late summer drought.

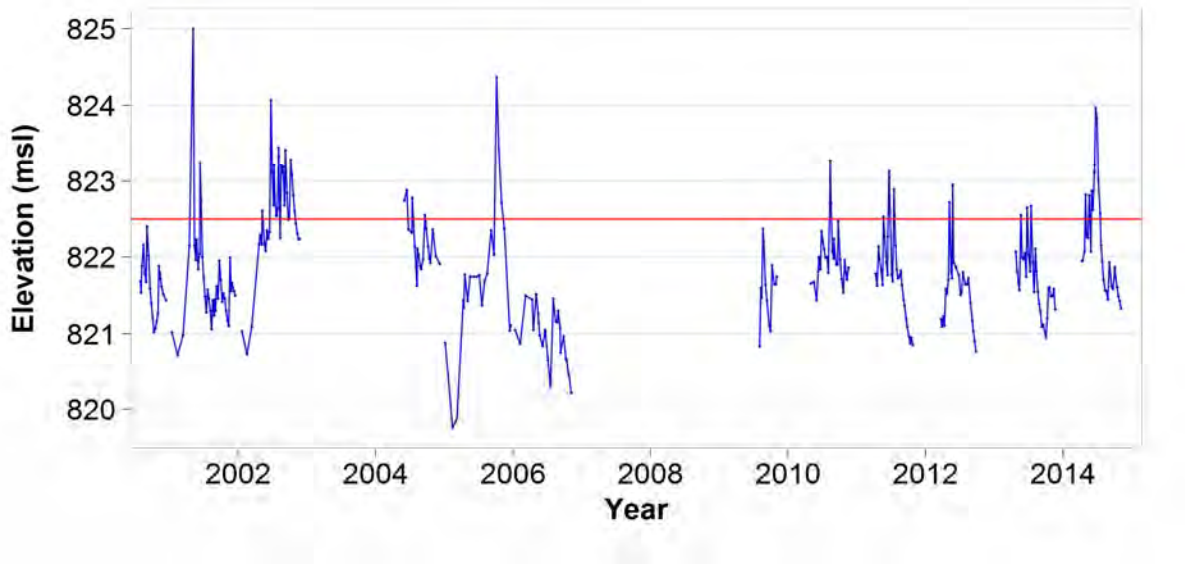


Figure 6-3. Diamond Lake levels from 2000 to the present. Horizontal line represents Diamond Lake outlet elevation (822.5 ft msl).

WATER QUALITY TRENDS – TROPHIC STATE INDEX (TSI)

The 2014 TSI score for Diamond Lake was 67. **Figure 6-4** shows the TSI scores and trend from 1992–2014 at Diamond Lake. A detailed explanation of TSI can be found in **Section 1**.

Carlson's TSI Index would classify Diamond Lake as eutrophic. However, Carlson's 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. Secchi depth was not used in TSI calculations of Diamond Lake, since the lake is often either clear to the bottom or the Secchi disk is obscured by dense aquatic plant growth. 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. There is no significant trend in the TSI score for Diamond Lake from 1992-2014 ($p > 0.05$); however, there is a significant decrease in TSI score from 2004-2014 ($p < 0.05$) indicated by the red line in **Figure 6-4**. This phenomenon could be due to the change in sampling location or to improvements due to water quality infrastructure constructed for the 35W/HWY62 project. More data must be collected to determine whether this trend accurately depict a new direction for water quality at Diamond Lake.

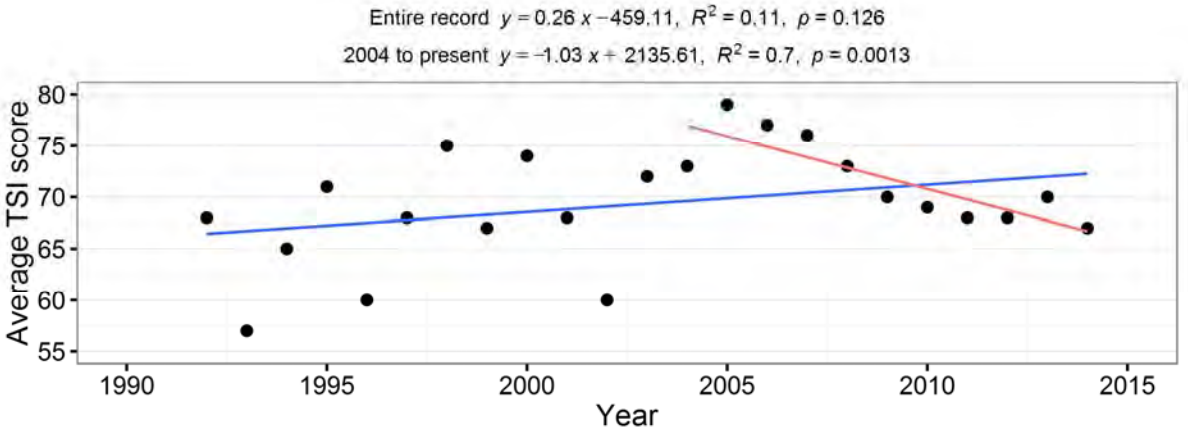


Figure 6-4. Diamond Lake TSI scores and regression analysis from 1992 to 2014. The linear regression line for the entire record is colored blue, while the linear regression line since 2004 is colored red.

BOX AND WHISKER PLOTS

The box and whisker plots in **Figure 6-5** show the data distribution for chlorophyll-*a* and total phosphorus levels in Diamond Lake over the past ten years. Data from the entire period of record in box and whisker plot format can be found in **Appendix A**. A detailed explanation of box and whisker plots can be found in **Section 1**.

Diamond Lake has limited Secchi transparency data due to its shallowness and high macrophyte density. During 2014, only three Secchi disk readings were taken; otherwise, the lake was either clear to the bed or obscured by thick aquatic plant growth.

Chlorophyll-*a* and total phosphorus levels began to decrease in 2008. This phenomenon could be due to construction activities from the 35W/HWY 62 project and subsequent slope stabilization and constructed best management practices. Continued monitoring will help to determine if the trend will continue or whether the changes in nutrient levels are part of the natural fluctuations of the wetland. Generally data from Diamond Lake is more variable and contains more scatter than deeper lakes. Increased scatter in the Diamond Lake data could be influenced by seasonal water level changes and stormwater influx.

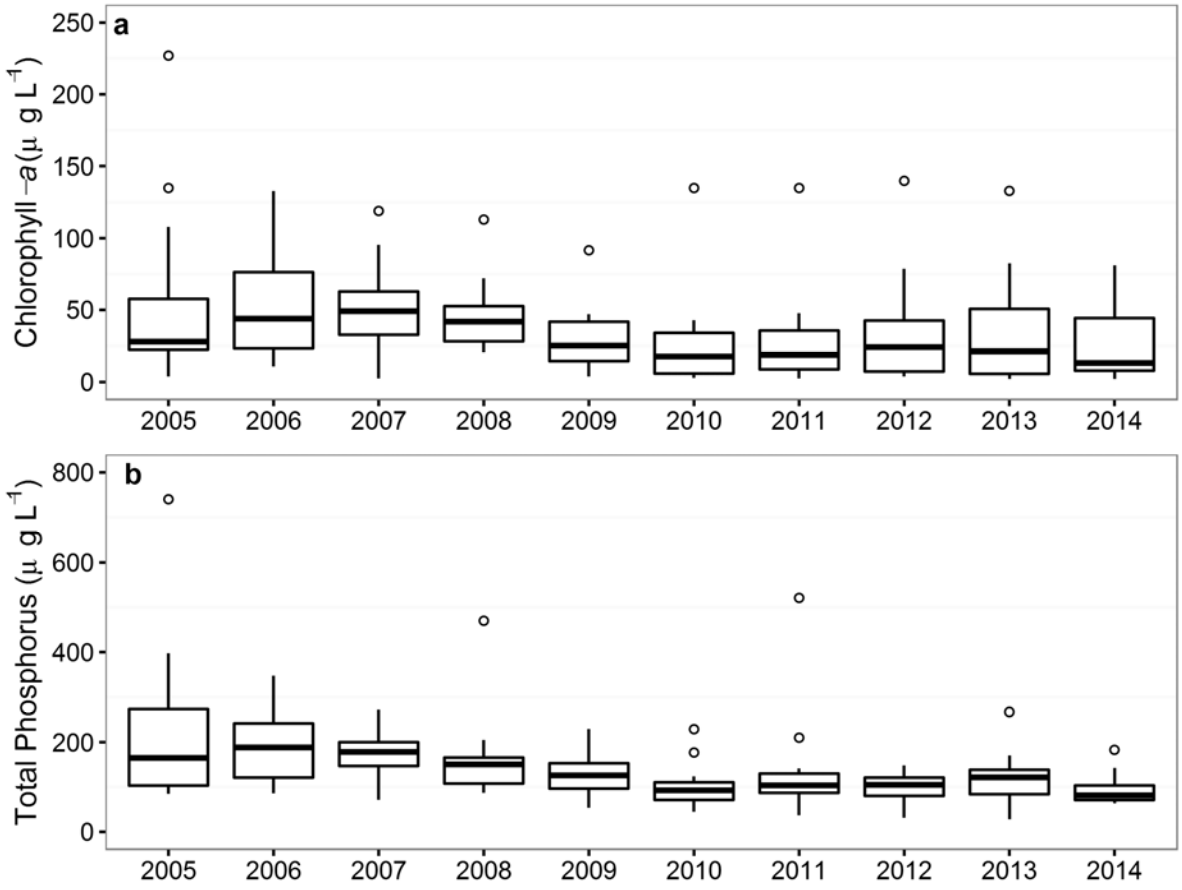


Figure 6-5. Box and whisker plots of Diamond Lake data from 2005-2014. See Appendix A for the entire period of record.

WINTER ICE COVER

In the spring, ice came off of Diamond Lake on April 10, 2014, four days later than average. Ice came on to Diamond Lake on November 13, 2014, seventeen days before the average ice-on date. See **Section 1** for details on winter ice cover records and **Section 18** for a comparison with other lakes.

PHYTOPLANKTON

Phytoplankton are the microscopic plant life that form the foundation of the food web in lakes. In **Figure 6-6** shows the chlorophyll-*a* concentrations and relative abundance of phytoplankton division during the 2014 sampling season in Diamond Lake. Zooplankton are not sampled at Diamond Lake.

Chlorophyll-*a* was low (< 20 µg L^{-1}) for much of the spring and comprised of diatoms (Bacillariophyta) and cryptomonads (Cryptophyta). In July the phytoplankton community shifted to green algae (Chlorophyta) and chlorophyll-*a* concentrations exceeded 80 µg L^{-1}. There was another peak in algal biomass near the end of August when euglenoids (Euglenophyta) and green algae comprised much of the phytoplankton community (**Figure 6-6a, b**). Unlike most of the other MPRB lakes, euglenoids were present at high levels in the late summer. Euglenoids are commonly found in

waters rich in nutrients and organic matter around sediments and macrophytes. Also unlike most other Minneapolis lakes, blue-green algae (Cyanophyta) were only present at low levels throughout the summer. Diamond Lake contains high levels of dense plant growth and the phytoplankton collected may partially reflect the community of organisms living attached to plants as well as the free-floating algae community found in most of the other sampled lakes.

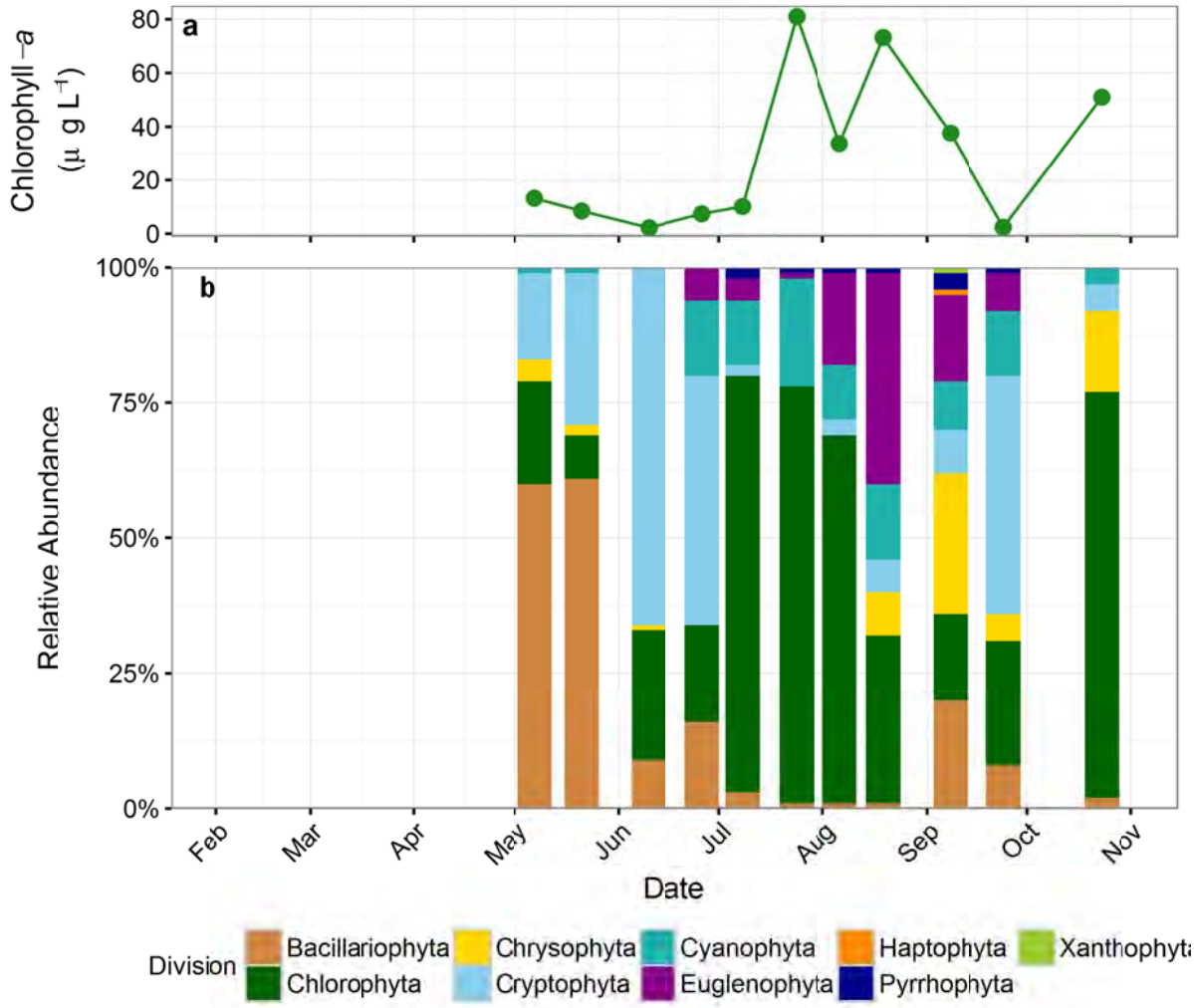


Figure 6-6. Chlorophyll-*a* concentration (a) and relative abundance of phytoplankton (b) during the 2014 Diamond Lake sampling season. Note that the Secchi depth axis is reversed.

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. Results of the wetland evaluation are presented in **Section 21**. 2014 was the ninth year that Diamond Lake was evaluated in the WHEP program.

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 area is known for bird-watching. Land surrounding the lake is not connected to the Minneapolis Park system and is shown below in **Figure 7-1**.

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 2014. Morphometric data for the lake is presented in **Table 7-1**. **Figure 7-2** shows a map of Grass Lake.

Figure 7-1. Photograph of Grass Lake.

Table 7-1. Grass Lake morphometric data. OHW= Ordinary High Water Level.

Surface Area (acres)	Mean Depth (m)	Maximum Depth (m)	Watershed Area (acres)	Watershed: Lake Area (ratio)	OHW (msl)
27	0.6	1.5	386	14.3	830.9

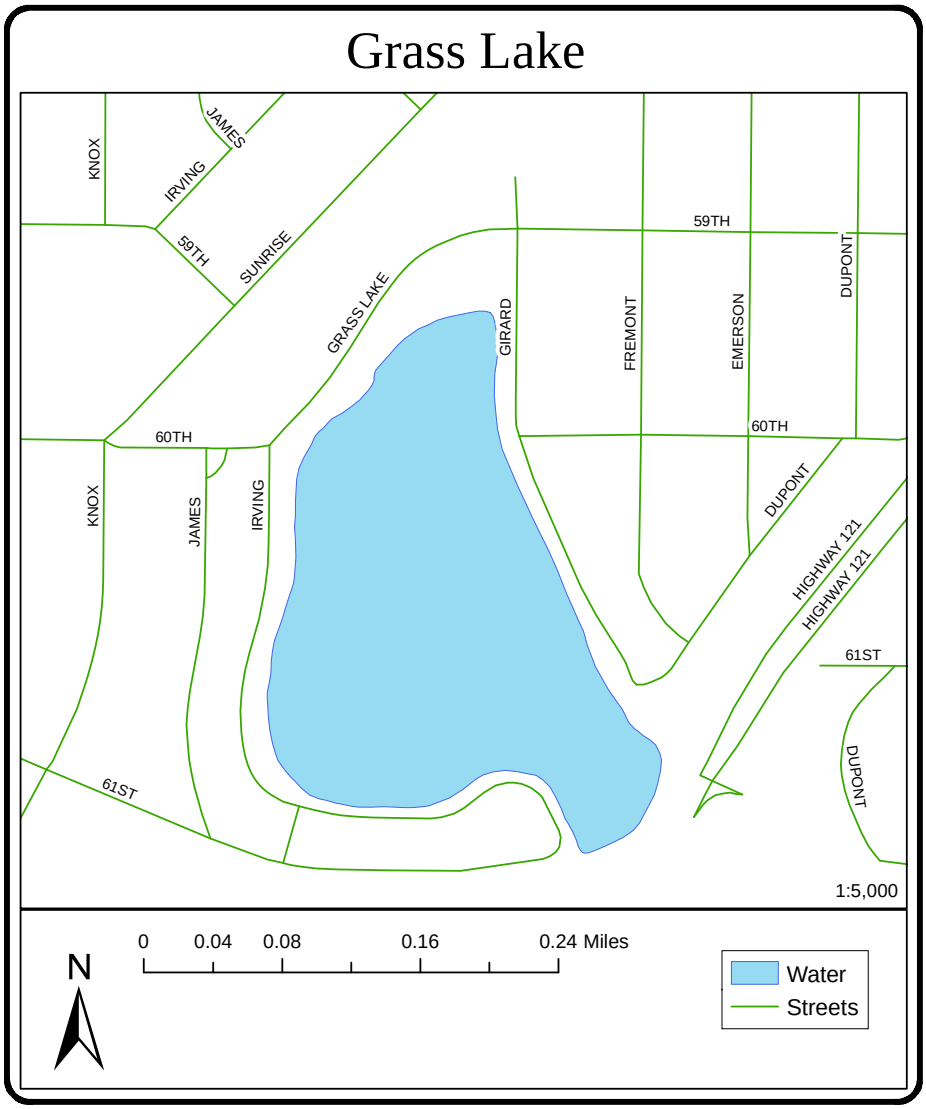


Figure 7-2. Grass Lake map.

WATER QUALITY TRENDS – TROPHIC STATE INDEX (TSI)

The TSI Index is also meant to examine lakes without non-algal turbidity and with low macrophyte populations. Grass Lake is a predominantly a Type 5 wetland containing extensive macrophytes and is too shallow to measure the Secchi depth; therefore, Secchi depth was not used in TSI calculations for Grass Lake. A detailed explanation of TSI can be found in **Section 1**.

The 2014 Grass Lake TSI score was 56 and **Figure 7-3** shows the Grass Lake TSI scores for 2002-2014. This data includes samples from two different locations, potentially biasing the results. The original sample location has been inaccessible since 2008 due to a construction project. There is not significant trend in TSI scores over the last 13 years ($p > 0.05$); however, Grass is only sampled every-other year. Grass Lake is scheduled to be sampled again in 2016. It appears as though 2003 was an outlier, as subsequent years have clustered between a TSI score of 55 to 65. Additional years of monitoring will be needed to discern a trend from natural variation seen in Grass Lake.

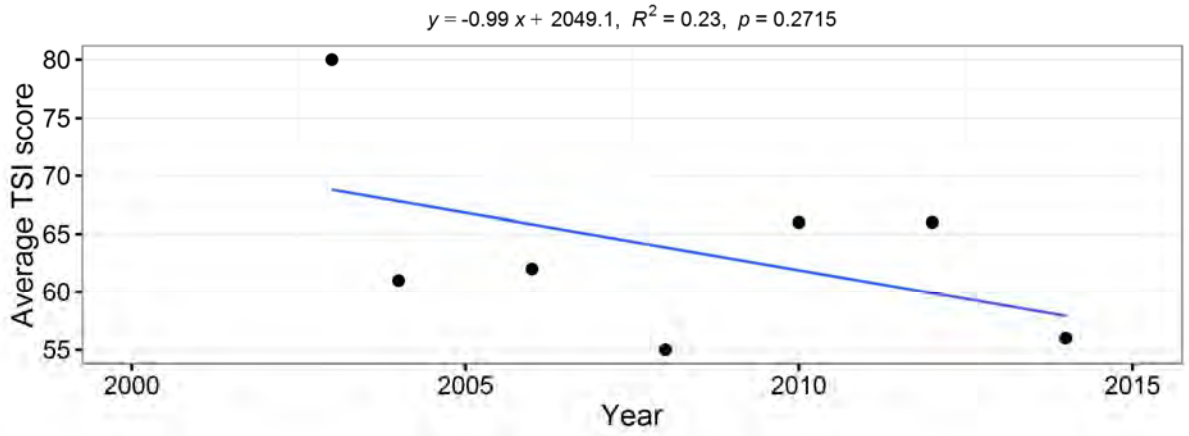


Figure 7-3. Grass Lake TSI scores for monitored years from 2002 to 2014. The trend should be viewed with caution since only 7 data points have been calculated and the sampling location changed in 2008.

BOX AND WHISKER PLOTS

Figure 7-4 shows box and whisker plots of the Grass Lake data from 2005 to 2014. A detailed explanation of box and whisker plots can be found in **Section 1**. Data from the entire period of record in box and whisker format can be found in **Appendix A**.

Secchi readings are not taken due to the shallowness of the wetland and the sampling location. 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.

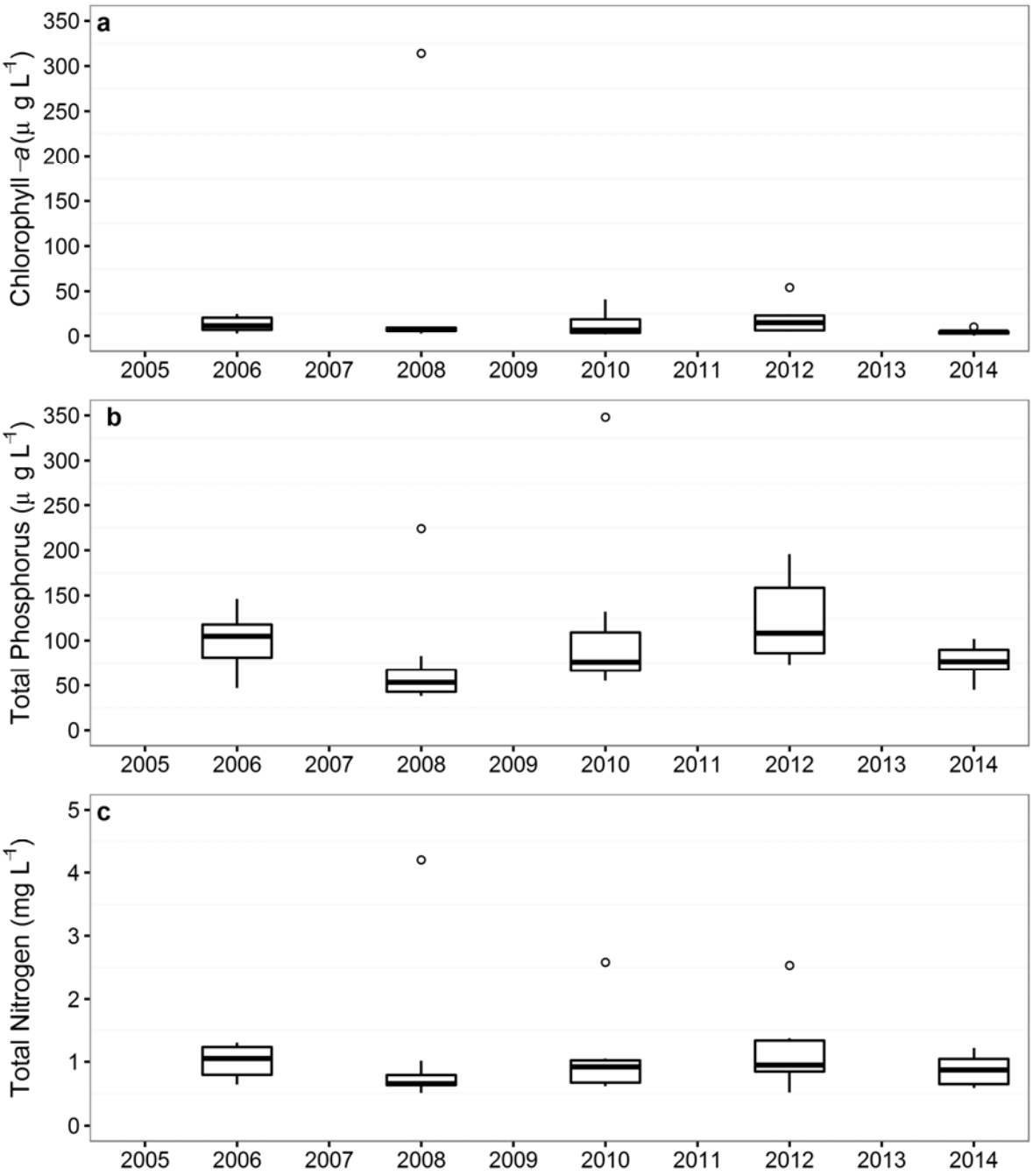


Figure 7-4. Plots of chlorophyll-*a*, total phosphorus, and total nitrogen data for Grass Lake.

WINTER ICE COVER

Ice came off Grass Lake on April 11, 2014, seven days later than average. Ice was back on Grass Lake on November 13, 2014, 16 days earlier than average. See **Section 1** for details on winter ice cover records and **Section 18** for a comparison with other lakes.

PHYTOPLANKTON

Phytoplankton are the microscopic plant life that forms the foundation of the food web in lakes. **Figure 7-5** shows the concentration of chlorophyll-*a* and the relative abundance of phytoplankton divisions in Grass Lake for the 2014 sampling season. Chlorophyll-*a* levels were low (< 10.5 µg L^{-1}) throughout the open water season (**Figure 7-5a**). Cryptomonads (Cryptophyta), green algae (Chlorophyta), and diatoms (Bacillariophyta) dominated the phytoplankton assemblage, while blue-green algae were at low abundance throughout the season (**Figure 7-5b**). The Grass Lake phytoplankton community is similar to Diamond Lake, which is the other shallow wetland sampled this year.

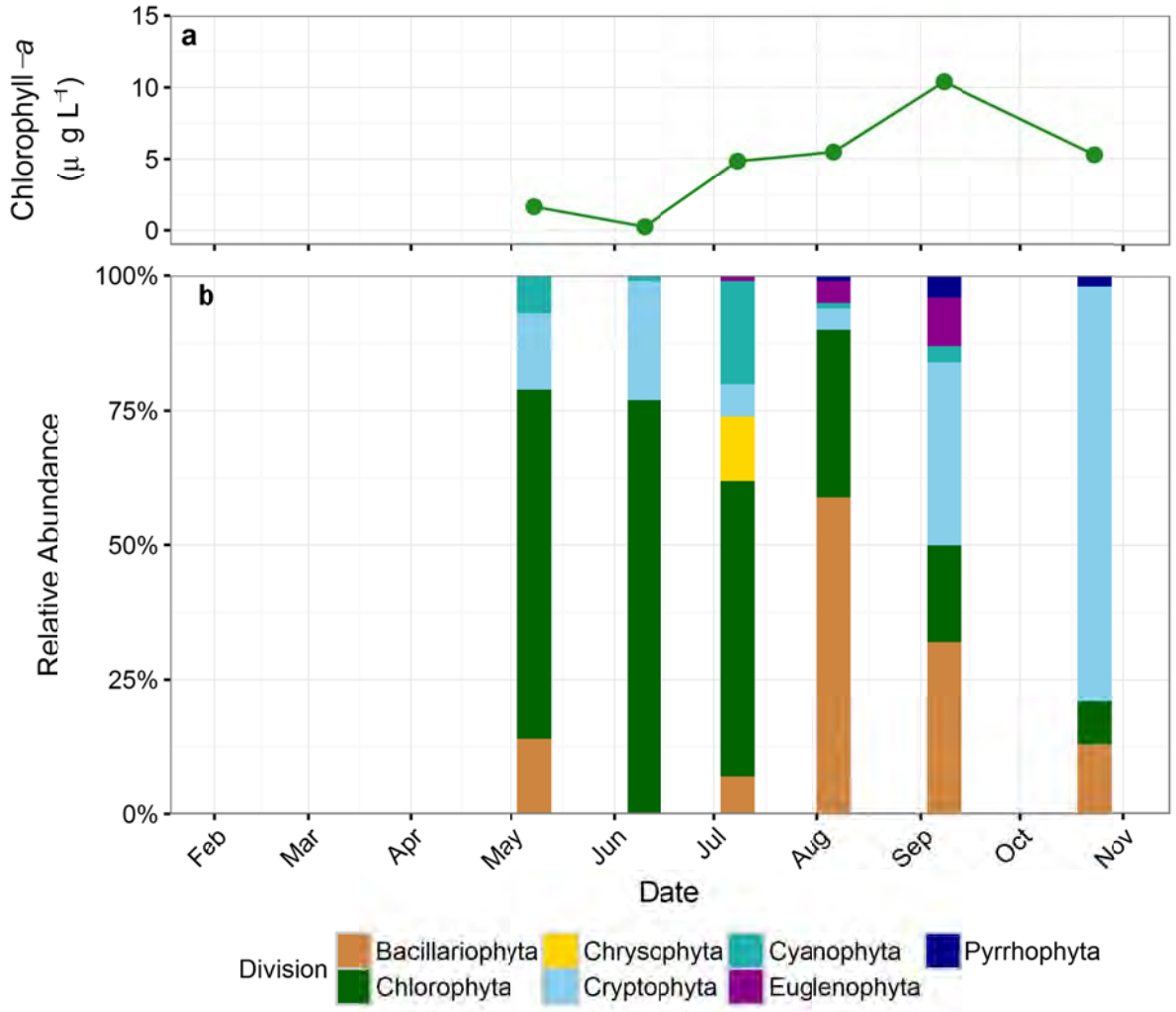


Figure 7-5. Chlorophyll-*a* concentration (a) and relative abundance of phytoplankton (b) during the 2014 Grass Lake sampling season.

8. Lake Harriet

HISTORY

Lake Harriet is named after Harriet Lovejoy Leavenworth, the wife of Colonel Leavenworth. Colonel W.S. King donated a majority of the lake (360 acres) and surrounding areas (55 acres) to the Minneapolis Park & Recreation Board (MPRB) in 1885. The MPRB acquired the remainder of the surrounding land between 1883-1898 and 1921.

Lake Harriet is a deep kettle lake that generally remains strongly stratified through October. The lake offers many recreational activities including sailing, swimming, and fishing. Park patrons enjoy concerts at the bandshell and the many gardens surrounding the lake. In 2006, both of the MDNR-funded floating docks in Lake Harriet were extended. The lake is shown below in **Figure 8-1**. **Figure 8-2** shows a bathymetric map and **Table 8-1** shows the morphometric data for Lake Harriet.

Figure 8-1. Lake Harriet Bandshell at sunset

There has been less dredging and filling at Lake Harriet compared to the other MPRB lakes. A marshland on the northeast corner of the lake was filled to make room for the parkway. The wetland at the north end of the lake that is now Robert's Bird Sanctuary was deemed too expensive to fill. A proposed channel connecting Lake Harriet with Lake Calhoun was never constructed due to the 5-foot elevation difference between the upper Chain of Lakes and Harriet. Today, after several modifications to the inlet and outlet, there is a 4-foot difference between the two lakes.

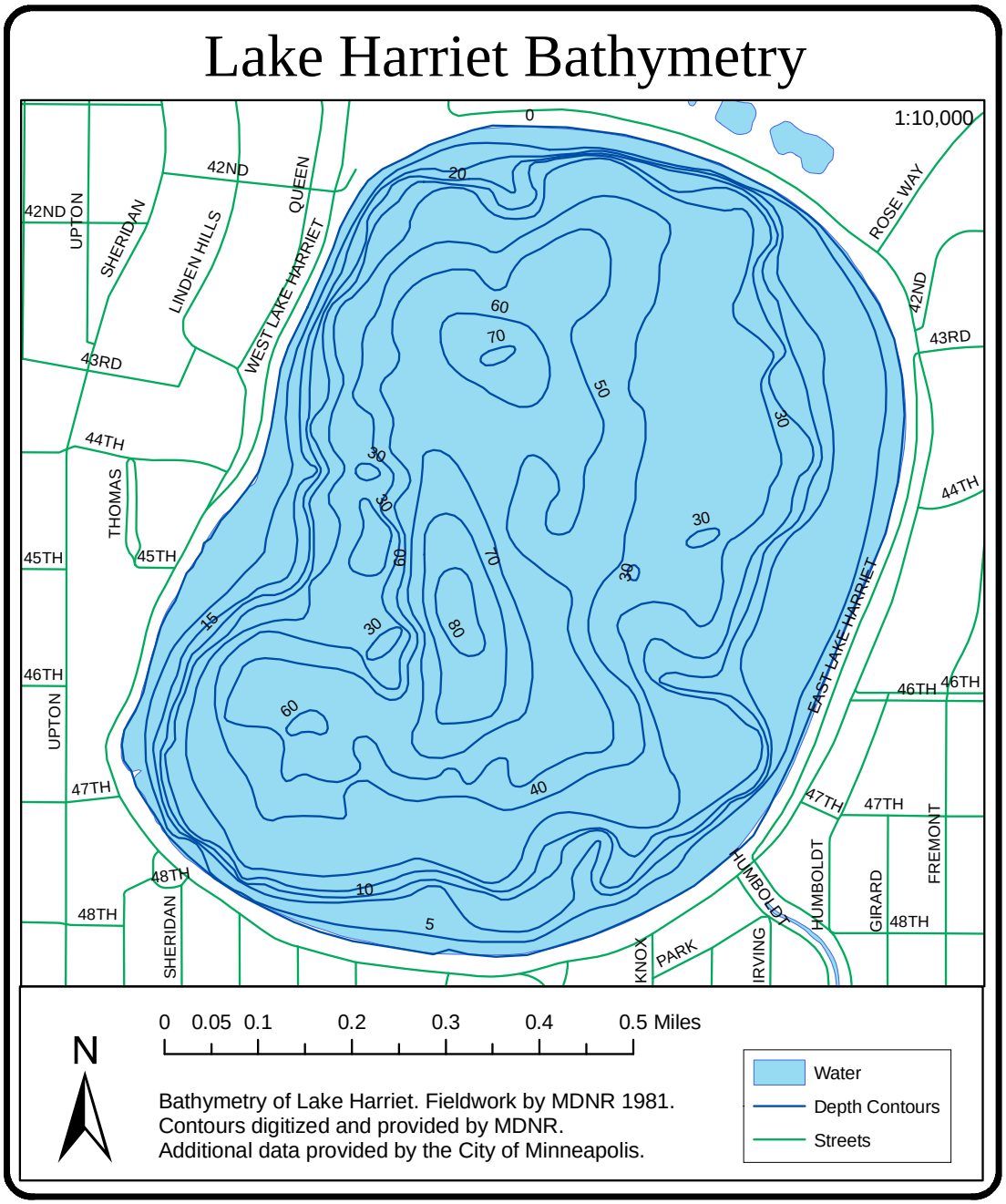


Figure 8-2. Bathymetric map of Lake Harriet.

Table 8-1. Lake Harriet morphometric data.

Surface Area (acres)	Mean Depth (m)	Max Depth (m)	Littoral Area*	Volume (m^3)	Watershed Area (acres)	Watershed: Lake Area (ratio)	Residence Time (years)
353	8.7	25.0	25%	1.25×10^7	1,139	3.2	3.4

* Littoral area defined as less than 15 feet deep.

In 1967, a pumping station and pipeline were constructed between Lakes Harriet and Calhoun 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. Lake Harriet discharges to Minnehaha Creek through a submerged pipe located at the southern edge of the lake.

Brugam and Speziale (1983) analyzed deep 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, 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 diagnostic study conducted in 1991 determined that phosphorus input to the Chain of Lakes should be reduced to improve water quality. BMPs implemented 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 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 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.

LAKE LEVEL

The lake level for Lake Harriet is recorded weekly and is shown in **Figure 8-3**. After high water levels in the spring, water levels fell throughout the late-summer drought.

The ordinary high water level (OHW) determined by the MDNR for Lake Harriet is 846.82 ft msl. The designated OHW is the highest regularly sustained water level that has made a physical imprint on the land, marked by either a transition in vegetation or a physical characteristic.

See **Section 18** for a comparison between other MPRB lake levels.

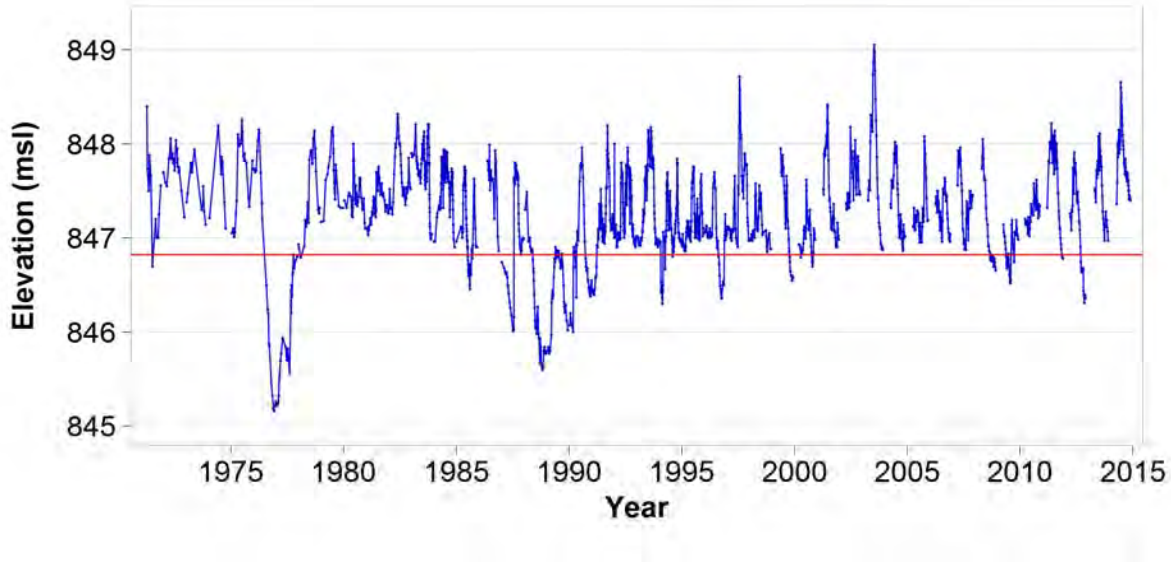


Figure 8-3. Lake levels for Lake Harriet from 1971 to the present.

WATER QUALITY TRENDS – TROPHIC STATE INDEX (TSI)

The TSI scores for Lake Harriet are improving as shown by the linear regression in **Figure 8-4**. A detailed explanation of TSI can be found in **Section 1**.

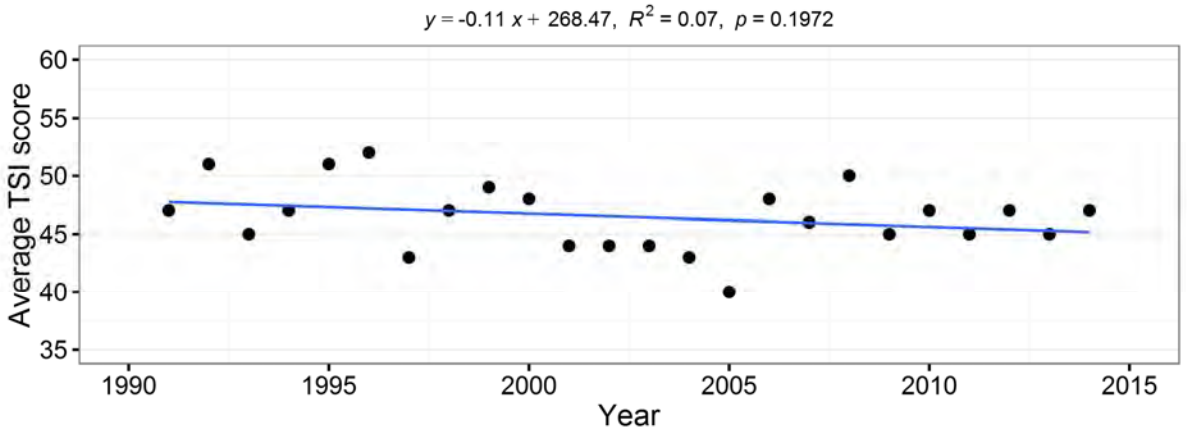


Figure 8-4. Lake Harriet TSI scores and regression analysis 1991-2014.

Lake Harriet's 2014 TSI score was 47 and classified the lake as mesotrophic with moderately clear water and some algae. There is no significant trend in TSI scores from 1991-2014 ($p > 0.05$) and scores have stayed between 45 and 50 for the last nine years. The lake remains in the top 25% of TSI scores in this ecoregion (based on calculations from the Minnesota Pollution Control Agency, using the Minnesota Lake Water Quality Data Base Summary, 2004).

BOX AND WHISKER PLOTS

The box and whisker plots in **Figure 8-5** show the data distribution for Secchi, chlorophyll-*a*, and total phosphorus sampling for the past ten years. MPCA deep lake standards are indicated by a horizontal line across the box plot graphs. A further detailed explanation of box and whisker plots can be found in **Section 1**. **Appendix A** contains box plots of data for all of the years of record.

Water clarity in Lake Harriet was a little lower in 2014 compared with the past five years. However, chlorophyll-*a* and total phosphorus were both similar to previous years. Harriet met the MPCA eutrophication standard for Secchi depth, chlorophyll-*a*, and total phosphorus in 2014.

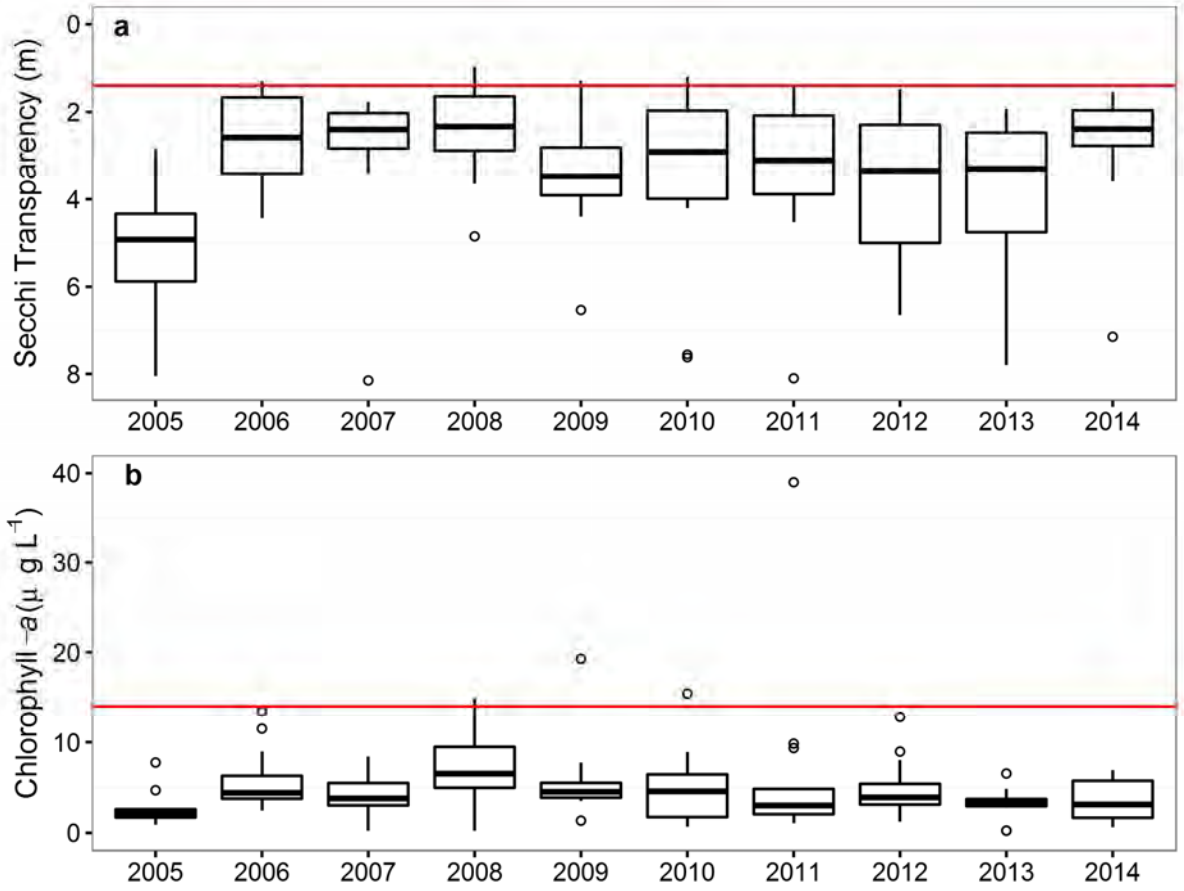


Figure 8-5. Lake Harriet box and whisker plots of TSI data for the past 10 years. Horizontal lines represent MPCA eutrophication standard for deep lakes. See Appendix A for the entire period of record.

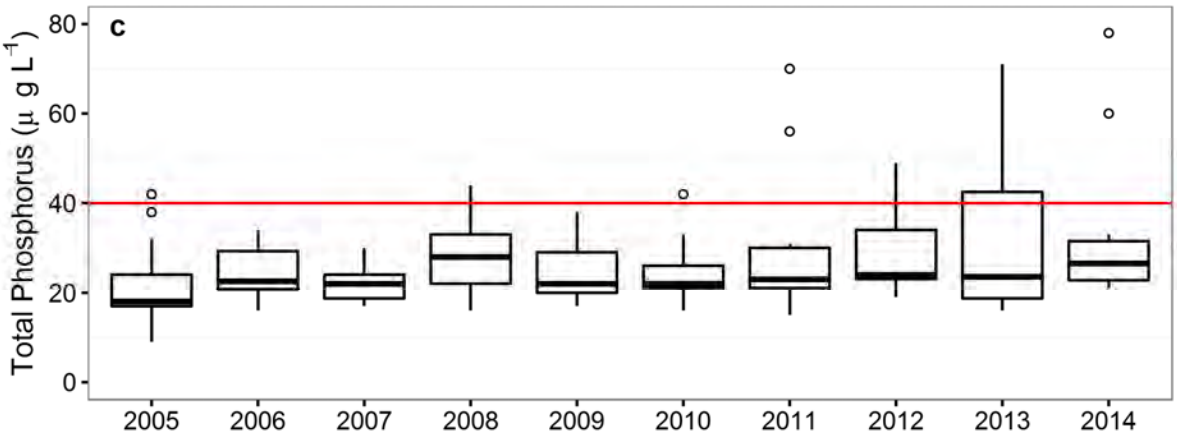


Figure 8-5. Continued. Lake Harriet box and whisker plots of TSI data for the past 10 years. Horizontal lines represent MPCA eutrophication standard for deep lakes. See Appendix A for the entire period of record.

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 8-2** and **Figure 8-6**, *E. coli* counts were very low for the most of beach season. Harriet SE had high *E. coli* numbers on the first sample of the year (6/2/2014); however, numbers had already dropped to 11 MPN/100 ml two days later and remained relatively low the rest of the season. Neither Lake Harriet beach closed in 2014 since the high sample at Harriet SE occurred before the beaches were open for the season.

Table 8-2. Summary of *E. coli* results (per 100 mL) for Lake Harriet beaches in 2014.

Statistical Calculations	Harriet Main	Harriet SE
Number of Samples	13	14
Minimum	3	6
Maximum	86	2420
Median	13	11
Mean	23	206
Geometric Mean	14	21
Max 30-Day Geo Mean	18	47
Standard Deviation	26	642

Figure 8-6 illustrates the box and whisker plots of *E. coli* sampling results (per 100 mL) for Lake Harriet beaches for the past ten years. Results from 2014 at Harriet Main Beach were slightly higher than recent years, while Harriet Southeast Beach was similar to previous years with less variability. The light red line represents the *E. coli* standard for the 30-day geometric mean (126 MPN/100mL), while the dark red line represents the single-sample maximum standard (1260 MPN/100mL). Further details on MPRB beach monitoring can be found in **Section 19**.

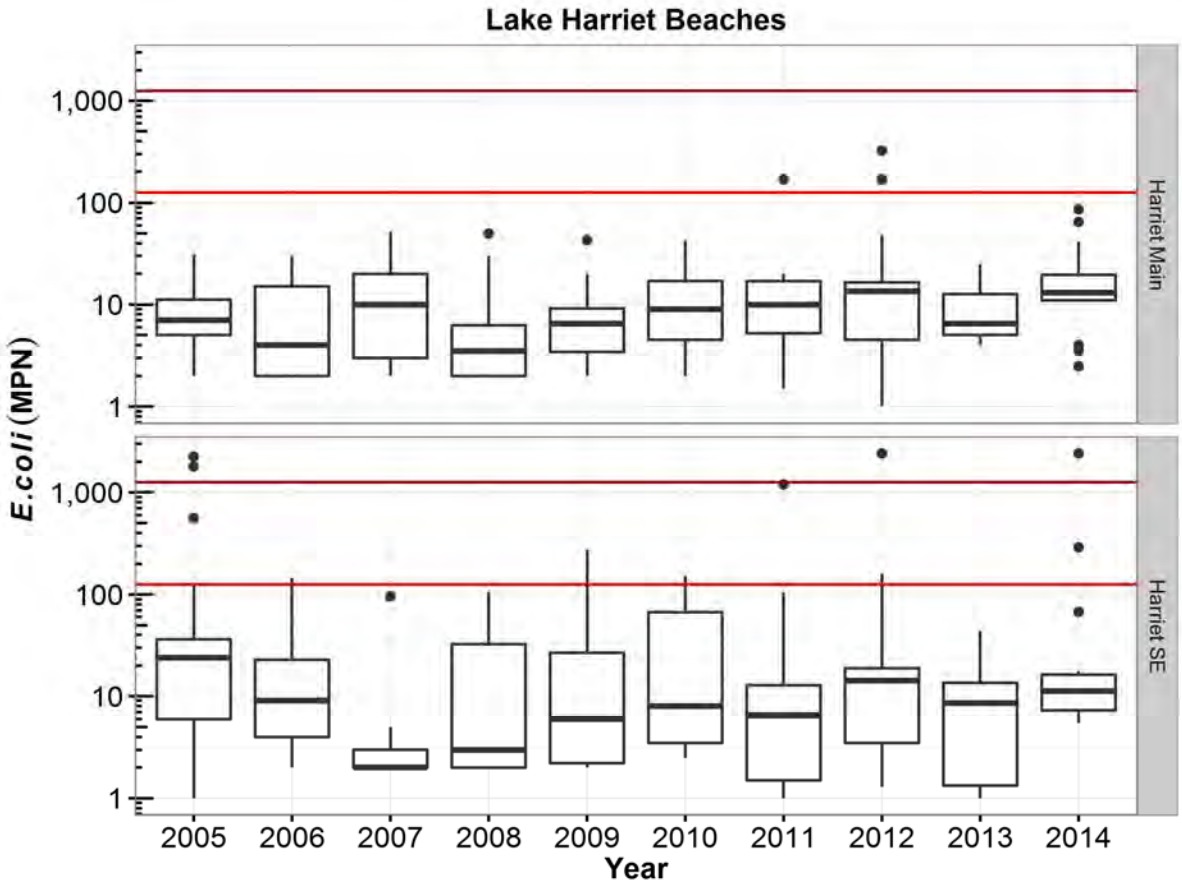


Figure 8-6. Box and whisker plots of *E. coli* results (per 100 mL) for Lake Harriet beaches, 2005-2014. The horizontal lines represent the E. coli standard for the 30-day geometric mean (126 MPN/100mL) and the single-sample maximum standard (1260 MPN/100mL). Note the log scale on the Y-axis. From 2005-2009 E. coli concentrations were determined as colony forming units (CFU/100ml).

LAKE AESTHETIC AND USER RECREATION INDEX (LAURI)

Figure 8-7 shows the LAURI for Lake Harriet. Lake Harriet ranked "excellent" in aesthetics, habitat quality, water clarity, public health, and recreational access in 2014. Details on the LAURI can be found in **Section 1**.

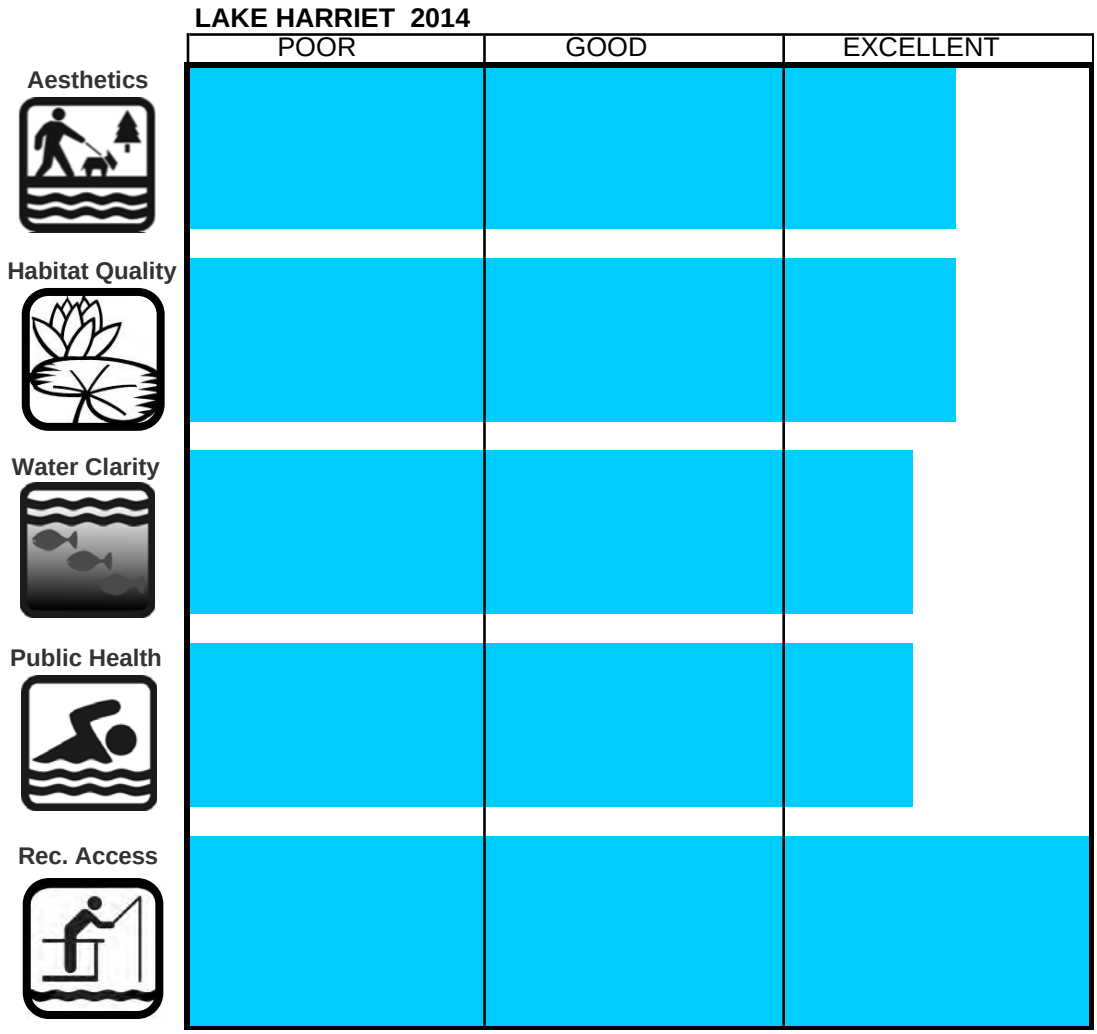


Figure 8-7. The 2014 LAURI for Lake Harriet.

WINTER ICE COVER

Ice went out on Lake Harriet on April 19, 2014 which was 12 days later than average. Ice did not completely cover Lake Harriet for the season again until December 2, 2014 which was ten days earlier than the average ice-on date. See **Section 1** for details on winter ice cover records and **Section 18** for a comparison with other lakes.

EXOTIC AQUATIC PLANT MANAGEMENT

The MDNR requires a permit to remove or control Eurasian watermilfoil. These permits limit the area milfoil 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 Eurasian water milfoil harvest on Lake Harriet was 40 acres, which is 45% of the littoral zone of the lake (area shallower than 15 feet). More information on aquatic plants can be found in **Section 1** and **Section 20**.

PHYTOPLANKTON AND ZOOPLANKTON

Phytoplankton and zooplankton are the microscopic plants and animals that form the foundation of the food web in lakes. **Figure 8-8** shows the Secchi transparency, chlorophyll-*a* concentrations, and relative abundance of phytoplankton division during the 2014 sampling season.

Secchi depth was greater than 1.5 m for the entire open water season in 2014 at Lake Harriet (**Figure 8-8a**). Chlorophyll-*a* concentrations were low (< 8 µg L^{-1}) throughout the season (**Figure 8-8b**). Water transparency was relatively low in the beginning of May when there was a spring diatom (Bacillariophyta) bloom and a peak in chlorophyll-*a* levels. This was followed by the clearest water of the year with a Secchi depth of 7.1 m and low chlorophyll-*a* levels (0.7 µg L^{-1}). Blue green algae (Cyanophyta) comprised the majority of the phytoplankton community the remainder of the season and Secchi depths ranged from 1.6-3.6 m. In eutrophic lakes, blue-green algae are often indicators of poor water quality; however, blue-green algae can dominate even in lakes with good water quality due to their ability to scavenge nutrients and out-compete other groups. Cryptomonads (Cryptophyta) also bloomed early and remained a minor part of the phytoplankton community through October. Cryptomonads are relatively small (3-50 µm long) members of the phytoplankton community and are common in cold waters. Dinoflaggelates (Pyrrhophyta) were present from late May through the fall and were most abundant in late June and early July (**Figure 8-8c**).

Zooplankton abundance in Lake Harriet during the 2014 sampling season is shown in **Figure 8-9**. Nauplii and juvenile zooplankton were present in all the samples, but peaked in the May and August samples. Rotifers were present in high numbers throughout the season as well, with the highest concentrations occurring in June and September. Cladocerans were present in low numbers until October, when they were the most abundant group. Cyclopoids, calanoids, and protozoa were only present in low numbers.

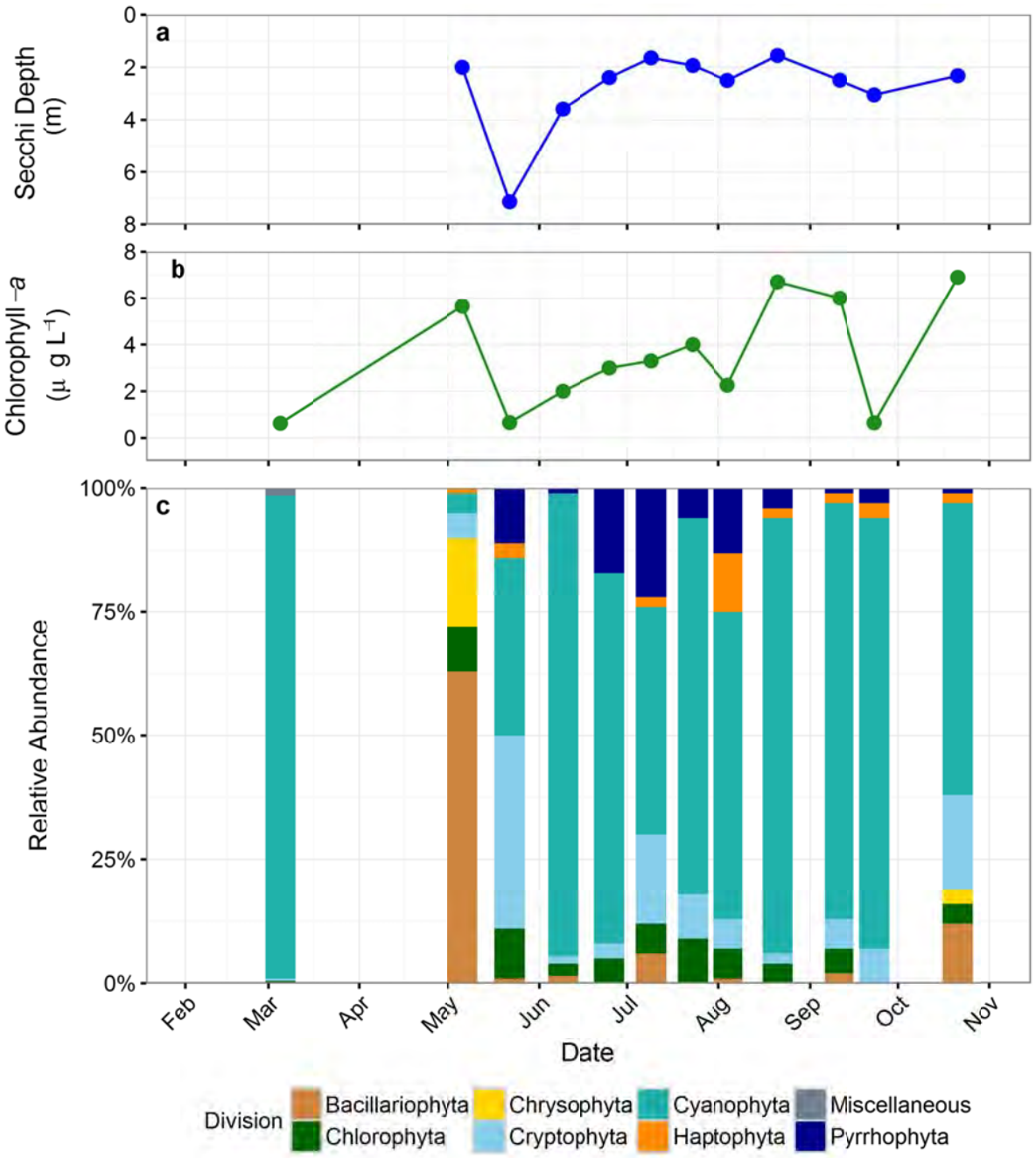


Figure 8-8. Relative abundance of phytoplankton during 2014 for Lake Harriet.

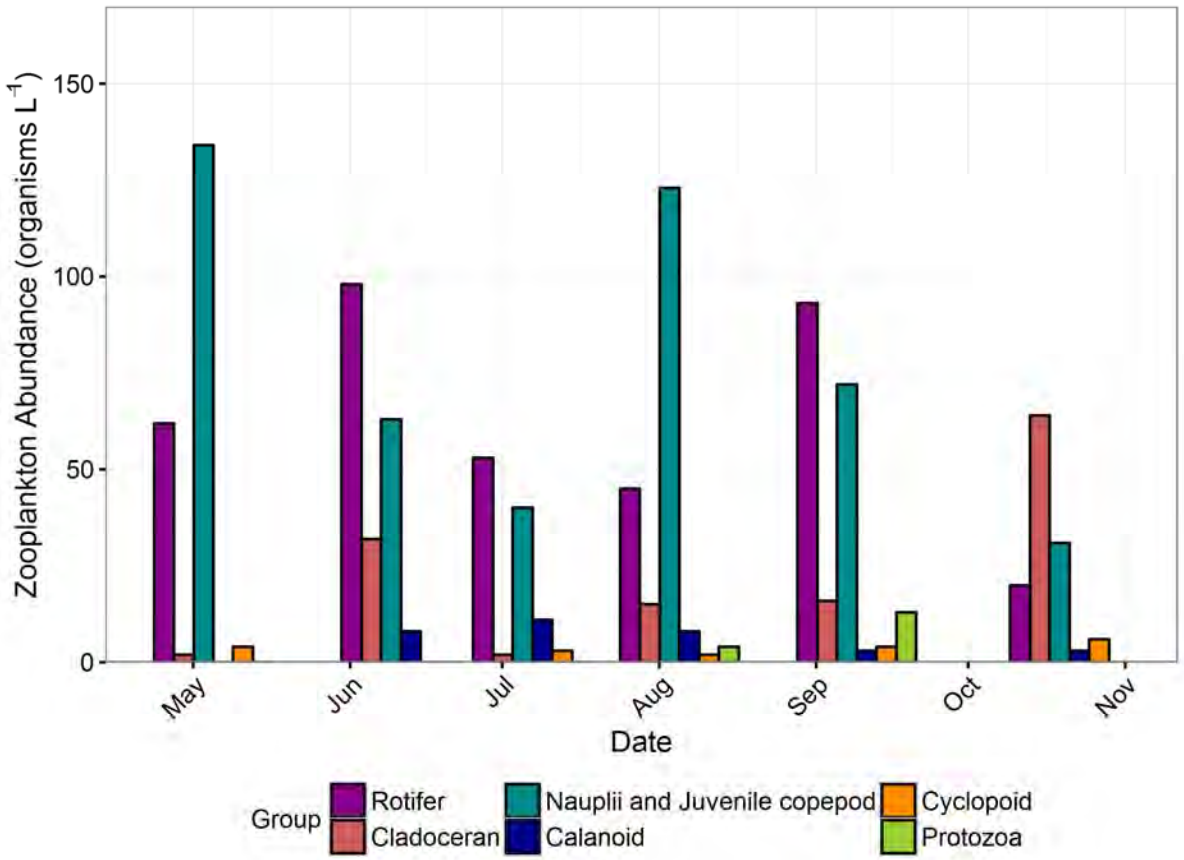


Figure 8-9. Zooplankton distribution in Lake Harriet for 2014.

FISH STOCKING

Additional information and a definition of fry, fingerling, yearling and adult size fish can be found in **Section 1**.

Lake Harriet was stocked by MDNR in:

1998 with 250 fingerling Muskellunge, 1,365 fingerling Walleye.

1999 with 824 fingerling Walleye, 50 yearling Walleye.

2000 with 175 fingerling Muskellunge, 142 adult Walleye, 499 adult Walleye.

2001 with 2,273 fingerling Walleye.

2002 with 175 fingerling Muskellunge, 312 fingerling Walleye, 698 yearling Walleye.

2003 with 554 fingerling Walleye, 33 yearling Walleye.

2004 with 175 fingerling Muskellunge, 3,447 fingerling Walleye.

2005 with 140 yearling Walleye.

2006 with 175 fingerling Muskellunge, 1,919 fingerling Walleye, 33 adult Walleye.

2007 with 136 adult Walleye, 50 fingerling Walleye, and 428 yearling Walleye.

2008 with 117 adult Walleye, 3,234 fingerling Walleye, and 175 fingerling Muskellunge.

2009 with 110 yearling Walleye, and 2,482 fingerling Walleye.

2010 with 179 fingerling Muskellunge, and 2862 fingerling Walleye.

2011 with 3,244 fingerling Walleye.

2012 with 175 fingerling Muskellunge, and 2,520 yearling Walleye.

2013 with 2,890 fingerling Walleye.

2014 with 2,545 fingerling Walleys.

9. LAKE HIAWATHA

HISTORY

Lake Hiawatha was acquired by the Minneapolis Park & Recreation Board (MPRB) in 1923 at a cost of $555,000. At that time the lake was a shallow wetland named Rice Lake for the stands of wild rice that grew in its shallow waters. Lake Hiawatha was renamed after Henry Wadsworth Longfellow's poem "Song of Hiawatha" in 1925. 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 and relocated to construct Hiawatha Golf Course. Today Lake Hiawatha is part of the Lake Nokomis–Lake Hiawatha Regional Park.

Figure 9-1. Lake Hiawatha in Autumn.

Figure 9-2 shows the bathymetric map of Lake Hiawatha. Lake Hiawatha has an extremely large watershed due its connection with Minnehaha Creek. The watershed of the lake includes 115,840 acres and the large volume of runoff associated with this area (~97% of the water and ~88% of the phosphorus input to the lake) reduces the residence time of the water in the lake to an average of 11 days or less. Flushing time in Lake Hiawatha is short compared to most other lakes in Minneapolis that have residence times up to four years (**Table 18-1**). The limited amount of time the water spends in the lake affects the biology of the system. The most obvious effect is a generally less than expected level of algae in the water based on the amount of phosphorus present. The converse of this occurs during seasons with low creek flow (for example 2002, 2007, and 2009) which increased the residence time in the lake and allows excess algae to build up. **Table 9-1** shows the morphometric data for Lake Hiawatha.

Flow contributed from the creek and from storm sewer connections have other physical repercussions for Lake Hiawatha. A delta has formed at the point where Minnehaha Creek meets the lake. The water level in Lake Hiawatha varies widely due to fluctuations in the flow of Minnehaha Creek. Additionally, the creek and stormwater inflow can have a destabilizing effect on the thermal stratification of the lake during the summer months.

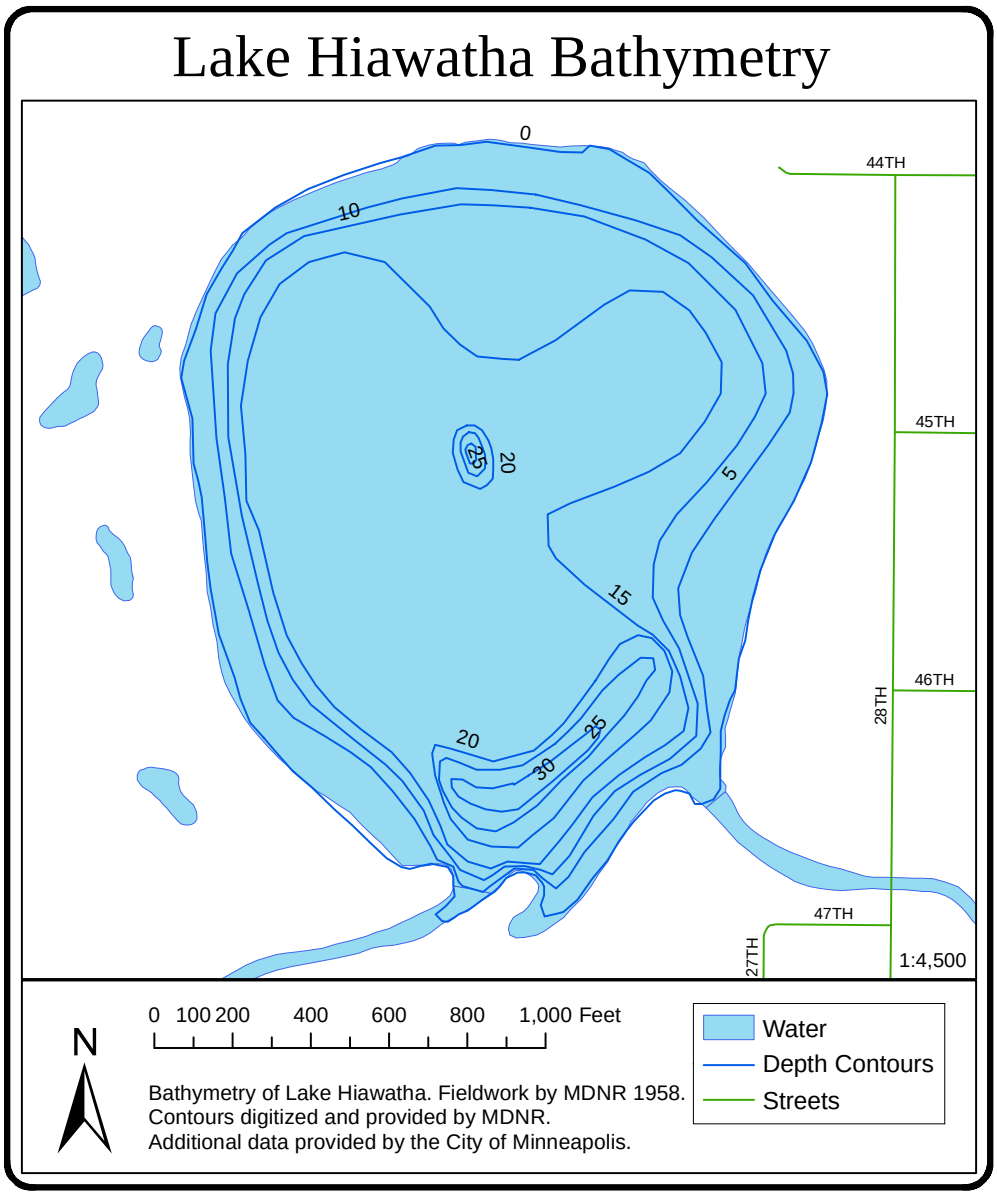


Figure 9-2. Bathymetric map of Lake Hiawatha based on MDNR data.

Table 9-1. Lake Hiawatha morphometric data.

Surface Area (acres)	Mean Depth (m)	Max Depth (m)	Littoral Area*	Volume (m^3)	Watershed Area (acres)	Watershed: Lake Area (ratio)	Residence Time (years)
54	4.1	7.0	49%	$8.95x10^5$	115,840	2145	0.03

*Littoral area defined as less than 15 feet deep.

LAKE LEVEL

Lake levels for Lake Hiawatha are recorded weekly during the open water season. The lake levels for Lake Hiawatha from 1996 to the present are shown in **Figure 9-3**. Up to four feet of water level bounce can be seen in Lake Hiawatha due to the influence of Minnehaha Creek and the dam at Grey's Bay in Lake Minnetonka. Heavy rains between April and June resulted in the highest water levels ever recorded in Lake Hiawatha in 2014. Levels slowly lowered as flow from Minnehaha Creek slowed and the level dropped below the ordinary high water level (OHW) when ice formed on the lakes. The OHW as determined by the MDNR is 812.8 ft msl.

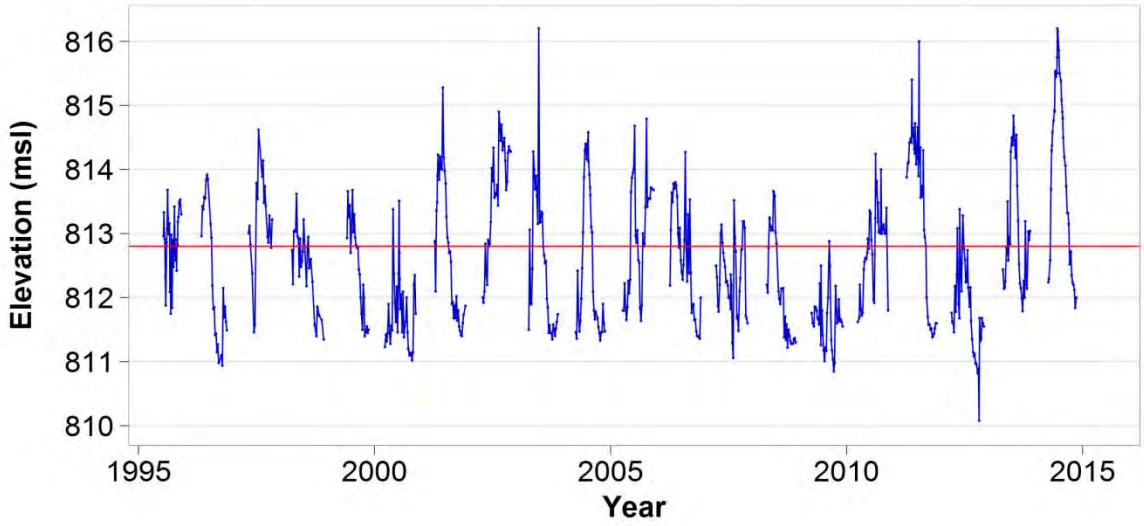


Figure 9-3. Lake levels for Lake Hiawatha 1995-2014. Horizontal line represents Lake Hiawatha outlet elevation (812.8 ft msl).

WATER QUALITY TRENDS – TROPHIC STATE INDEX (TSI)

Figure 9-4 shows the Lake Hiawatha linear regression of TSI scores over time. A detailed explanation of TSI can be found in **Section 1**. 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. With all years taken into consideration, Lake Hiawatha has no significant trend in TSI score from 1992 to 2014 ($p > 0.05$) shown in **Figure 9-4.** The 2014 TSI score for Lake Hiawatha was 52. Currently Lake Hiawatha has a TSI score that is average for lakes in the Central Hardwood Forest ecoregion (MPCA, 2004).

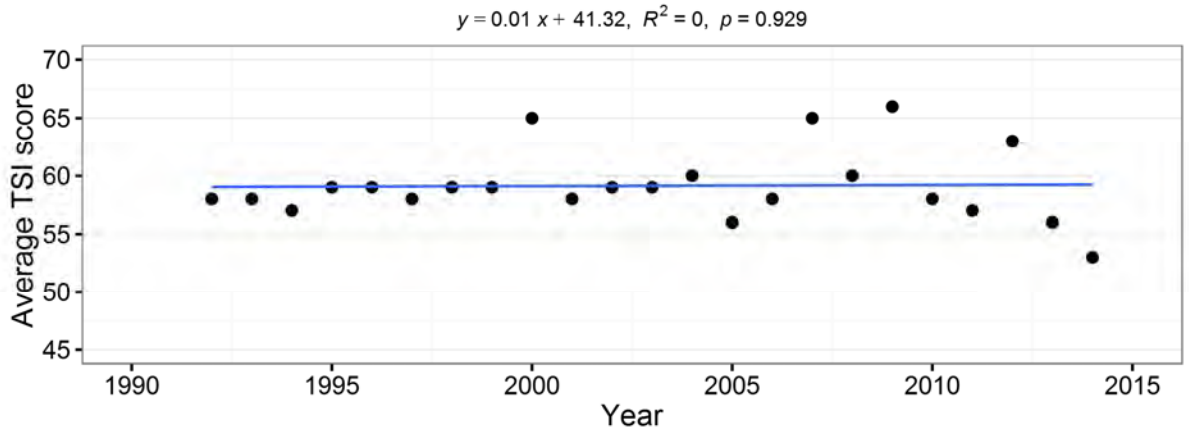


Figure 9-4. Lake Hiawatha TSI scores and regression analysis.

BOX AND WHISKER PLOTS

The box and whisker plots in **Figure 9-5** show the variation between years for the Secchi, chlorophyll-*a*, and total phosphorus data for the past ten years. Lake Hiawatha site specific standards are indicated by a horizontal line on the box plot graphs. The EPA approved a new 50 µg L^{-1} TP standard for Lake Hiawatha in 2013. A detailed explanation of box and whisker plots can be found in **Section 1**. Data collected since 1992 in box and whisker format is available **Appendix A**. Long-term lake monitoring is necessary to evaluate the seasonal and year-to-year variations seen in each lake and predict trends.

In most years, the Lake Hiawatha system is stable due to short residence times and the strong influence of Minnehaha Creek. In 2014, Hiawatha met the new site specific standards set by the MPCA for Secchi depth, chlorophyll-*a*, and total phosphorus. Water transparency in 2014 was similar to the previous four years and one of the clearest on record. Both chlorophyll-*a* and total phosphorus levels were lower than previous years and the lowest recorded since 1992. This could be explained by the abnormally high precipitation in 2014. Continued monitoring will help evaluate effects of climate variability on the water quality in Lake Hiawatha.

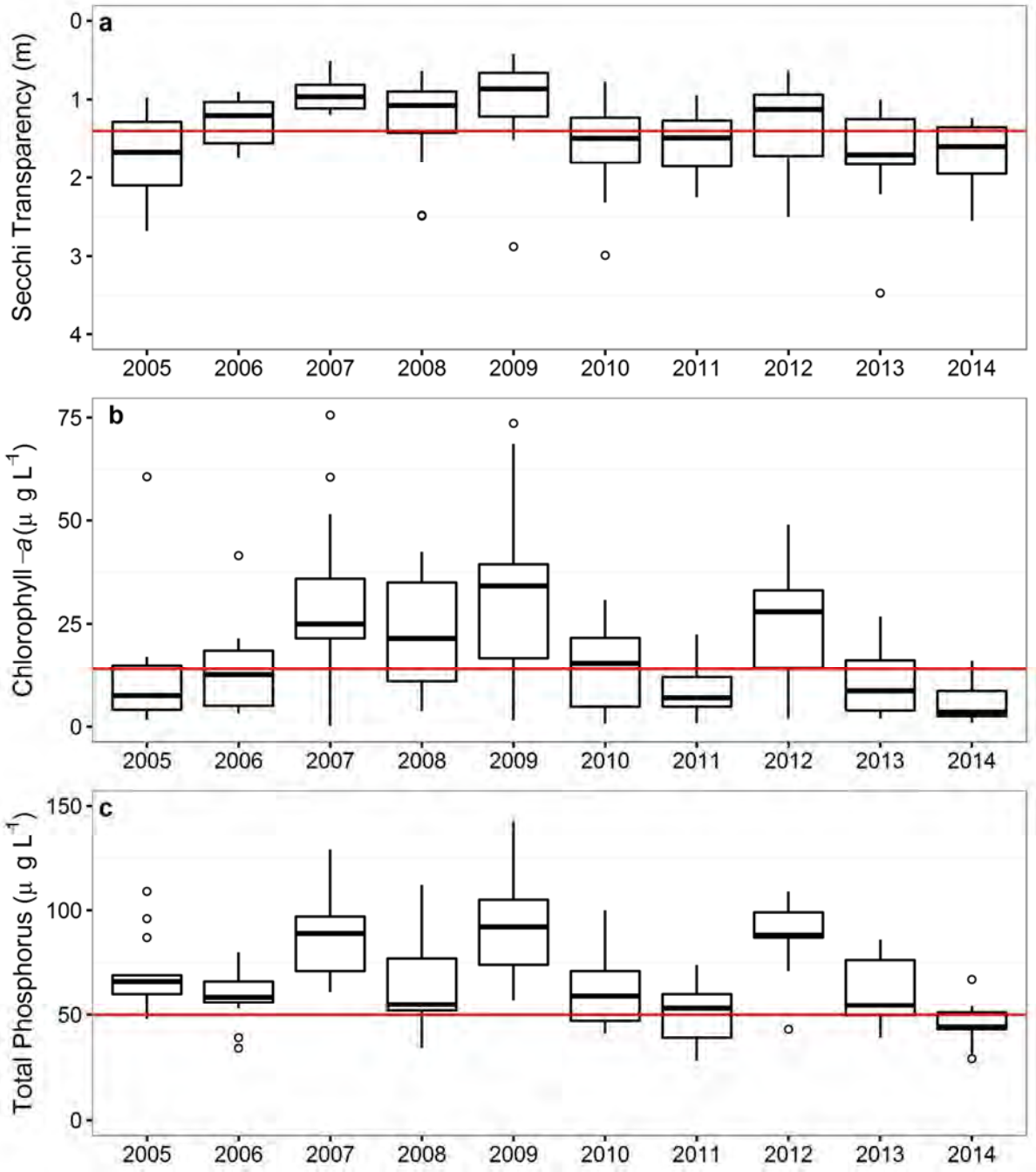


Figure 9-5. Ten years of box and whisker plots of Lake Hiawatha TSI data. Horizontal lines represent Lake Hiawatha site specific eutrophication standards. See Appendix A for the entire period of record.

BEACH MONITORING

The public beach at Lake Hiawatha was officially closed from 2004 to 2006 because of budgetary constraints and the history of *E. coli* bacteria issues at the beach. Due to concern about bacteria levels, monitoring continued while the beach was closed. Because of the beach's popularity with the public and its continued heavy use, the MPRB re-opened the beach in 2007.

Table 9-2. Summary of 2014 *E. coli* (MPN per 100 mL) results for Lake Hiawatha.

Statistical Calculations	Hiawatha
Number of Samples	15
Minimum	28
Maximum	1210
Median	125
Mean	288
Geometric Mean	157
Max 30-Day Geo Mean	322
Standard Deviation	346

The 30-day geometric mean standard of 126 MPN/100 mL was exceed in early August of 2014 and remained over the standard for the rest of the swimming season (**Figure 9-6)**. **Table 9-2** shows the basic statistics on the 2014 bacteria sampling at Lake Hiawatha. Further details on MPRB beach monitoring can be found in **Section 19**.

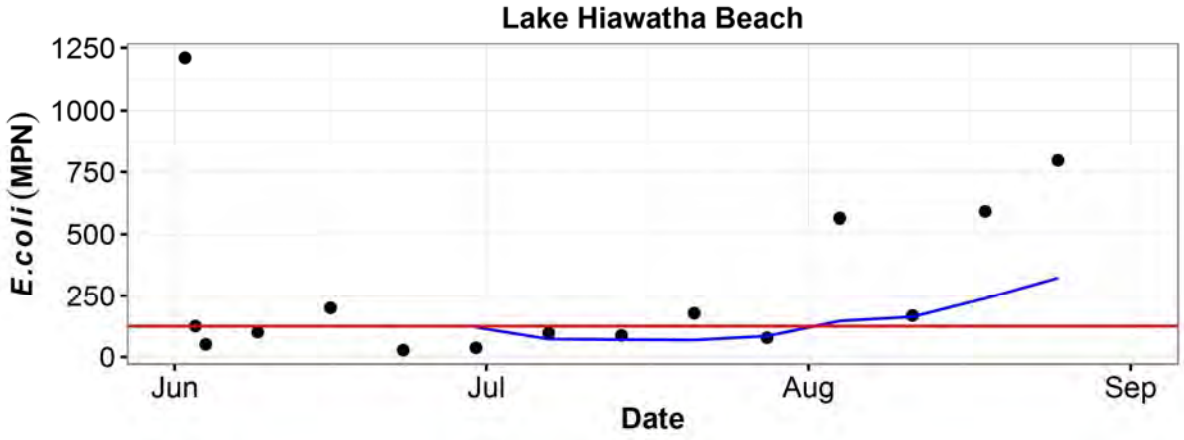


Figure 9-6. 2014 *E. coli* concentrations at Hiawatha Beach. Blue line is the running 30-day geometric means and the horizontal red line represents the 30-day geometric mean standard of 126 colonies per 100 mL.

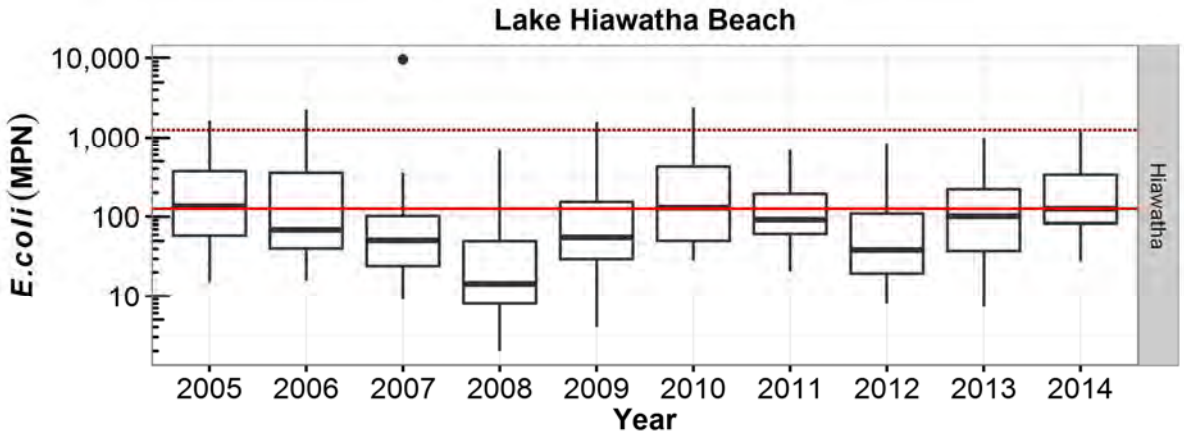


Figure 9-7. Box and whisker plot of *E. coli* results (per 100 mL) for the Lake Hiawatha site, 2005 to 2014. Note the log scale on the Y-axis. The horizontal lines represent the *E. coli* standard for the 30-day geometric mean (126 MPN/100mL) and the single-sample maximum standard (1260 MPN/100mL). From 2004-2009 E. coli concentrations were determined as colony forming units (CFU/100ml).

Figure 9-7 shows box and whisker plots of *E. coli* sampling results (per 100 mL) for the past ten years. The 2014 season had average *E. coli* counts compared to previous years. The majority of the elevated bacteria levels occurred in August. The range of results at Lake Hiawatha is larger than at the other lakes in Minneapolis due to the large influence Minnehaha Creek has on the lake's water quality.

LAKE AESTHETIC AND USER RECREATION INDEX (LAURI)

The LAURI for Lake Hiawatha is shown in **Figure 9-8**. In 2014, Lake Hiawatha scored "excellent" in aesthetics and water clarity. The lake scored "good" in habitat quality and recreational access and "poor" on public health. Lake Hiawatha scored "excellent" in aesthetics due to low water odor and light brown/green water color; however, it collects trash flowing down Minnehaha Creek, especially after large rainstorms. The trash gets deposited along the still shoreline of the lake where it usually remains for the rest of the summer. Details on the LAURI index can be found in **Section 1**.

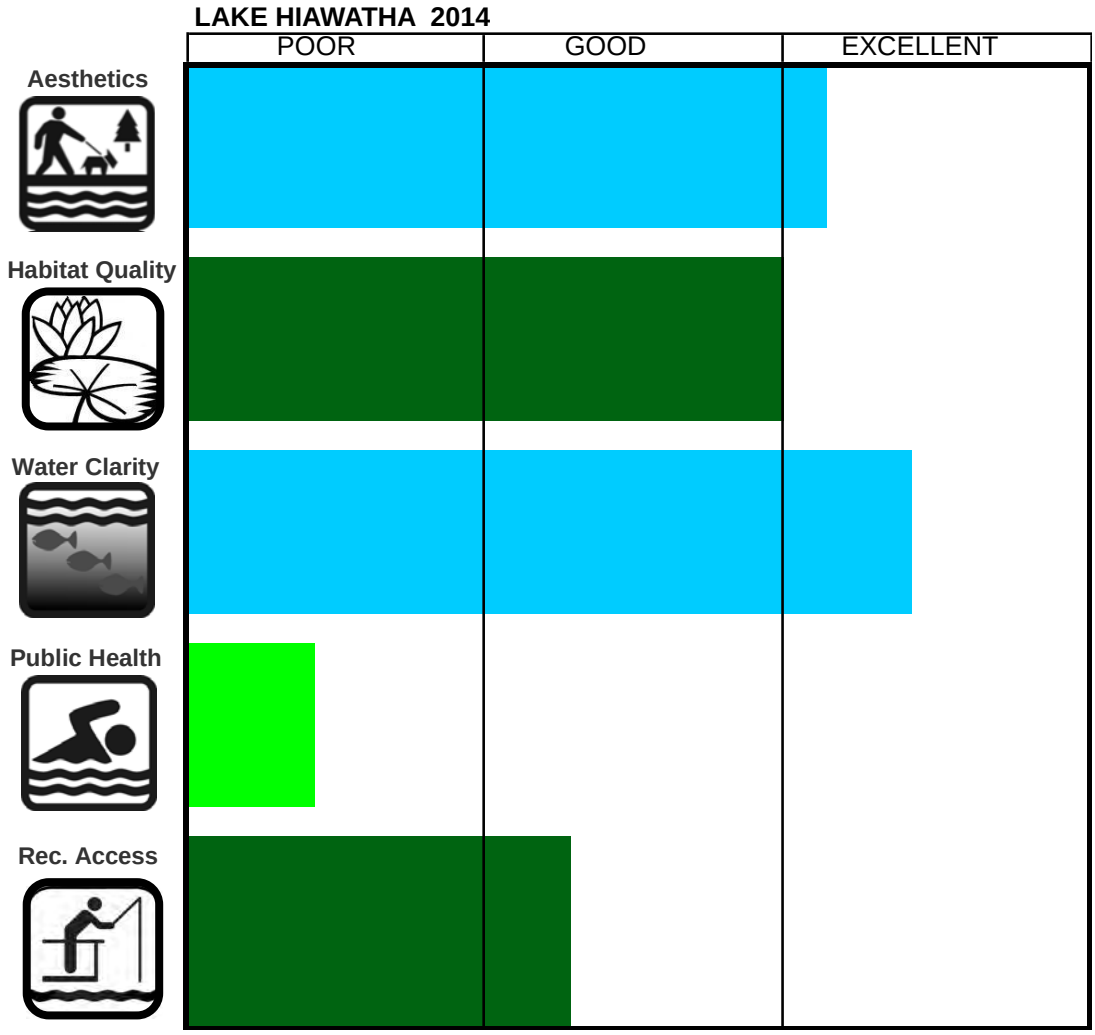


Figure 9-8. The 2014 LAURI for Lake Hiawatha.

WINTER ICE COVER

Ice came off Lake Hiawatha on April 14, 2014, ten days later than average. Ice returned to the lake for the winter on November 25, 2014, seven days earlier than the average ice-on date. See **Section 1** for details on winter ice cover records and **Section 18** for a comparison with other lakes.

PHYTOPLANKTON AND ZOOPLANKTON

Phytoplankton and zooplankton are the microscopic plant and animal life that form the foundation of the food web. The Secchi transparency, chlorophyll-*a* concentrations, and relative abundance of phytoplankton division during the 2014 sampling season composition is shown in **Figure 9-9**. Secchi depth consistently increased from May thru early July while chlorophyll-*a* concentrations were low (< 5 µg L^{-1}). The remainder of the season was characterized by decreasing clarity and increasing chlorophyll-*a* (**Figure 9-9a, b**). This could be attributed to the high precipitation between April and June and high flows from Minnehaha Creek leading to a quick flushing of the lake. The phytoplankton community in Lake Hiawatha is typically dominated by blue-green algae

(Cyanophyta) for the majority sampling season; however, blue-green algae did not bloom in 2014. Instead, diatoms (Bacillariophyta), cryptomonads, and chrysophytes represented most of the algal biomass (**Figure 9-9c**). Cryptomonads and chrysophytes both contain chlorophyll-*a* for photosynthesis but some species are also able to utilize organic matter to acquire carbon.

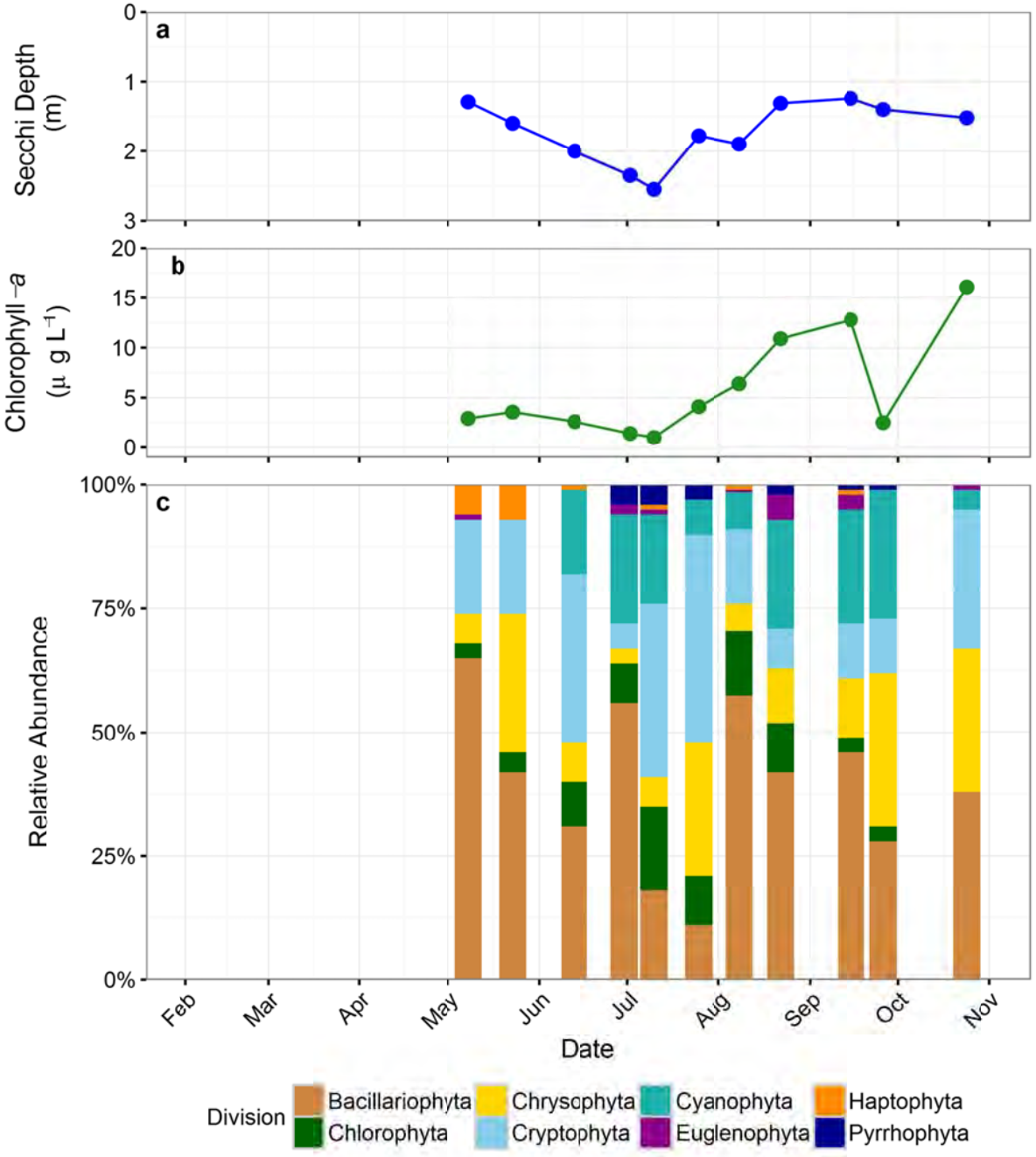


Figure 9-9. Secchi transparency (a), chlorophyll-*a* concentration (b), and relative abundance of phytoplankton (c) during the 2014 Lake Hiawatha sampling season. Note that the Secchi depth axis is reversed.

Figure 9-10 shows the zooplankton distribution in Lake Hiawatha during the 2014 sampling season. Cladocerans, rotifers and juveniles were the dominating zooplankton groups present throughout the sampling season. Like most of the Minneapolis lakes, juvenile zooplankton were at the highest concentrations in early spring. There was an overall low abundance of zooplankton in August.

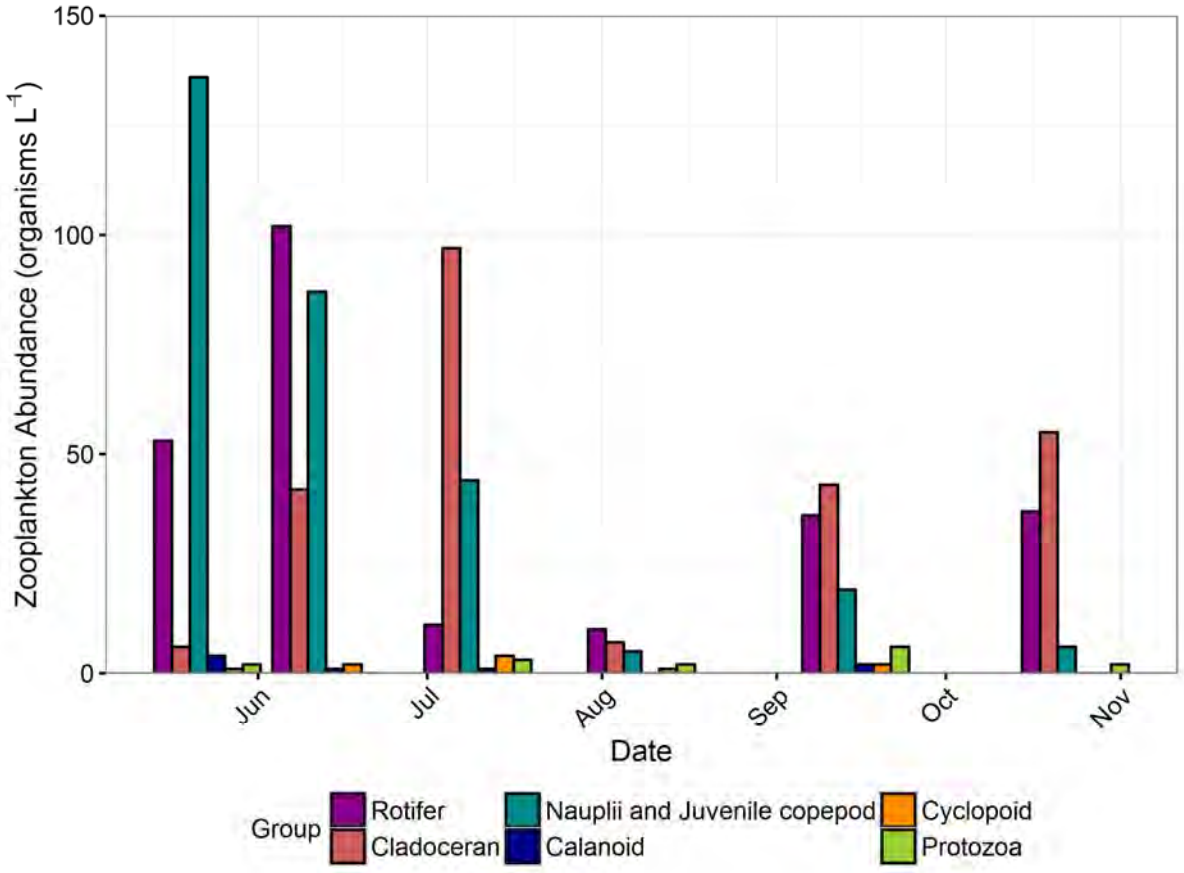


Figure 9-10. Lake Hiawatha zooplankton distribution during the 2014 sampling season.

EVENTS REPORT

On July 28 2010, zebra mussels (*Dreissena polymorpha*) were confirmed as present in Lake Minnetonka and at the headwaters of Minnehaha Creek by MDNR ecologists. The MDNR declared Lake Minnetonka, Minnehaha Creek and all public waters with creek connections to be infested with zebra mussels, including Lake Hiawatha.

In response, MPRB has been installing zebra mussel sampling plates in five lakes since 2010. In 2011, Water Resources staff began using a separate set of equipment only to be used on infested lakes as a precaution to not spread zebra mussels. Since 2012, the MPRB has operated an Aquatic Invasive Species (AIS) Inspection Program at boat launches on Lake Calhoun, Lake Harriet, and Lake Nokomis to prevent the spread of zebra mussels.

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. In August 2013, Water Resources staff discovered and the Minnesota DNR confirmed the finding of zebra mussels on a sampling plate in Lake Hiawatha. Since, staff has continued to monitor the sampling plate and conduct annual shoreline survey to determine the extent of infestation. **Figure 9-11** shows the results of the rapid shoreline survey in 2014. Future surveys and lake monitoring will indicate whether zebra mussels are altering the ecology of the lake.

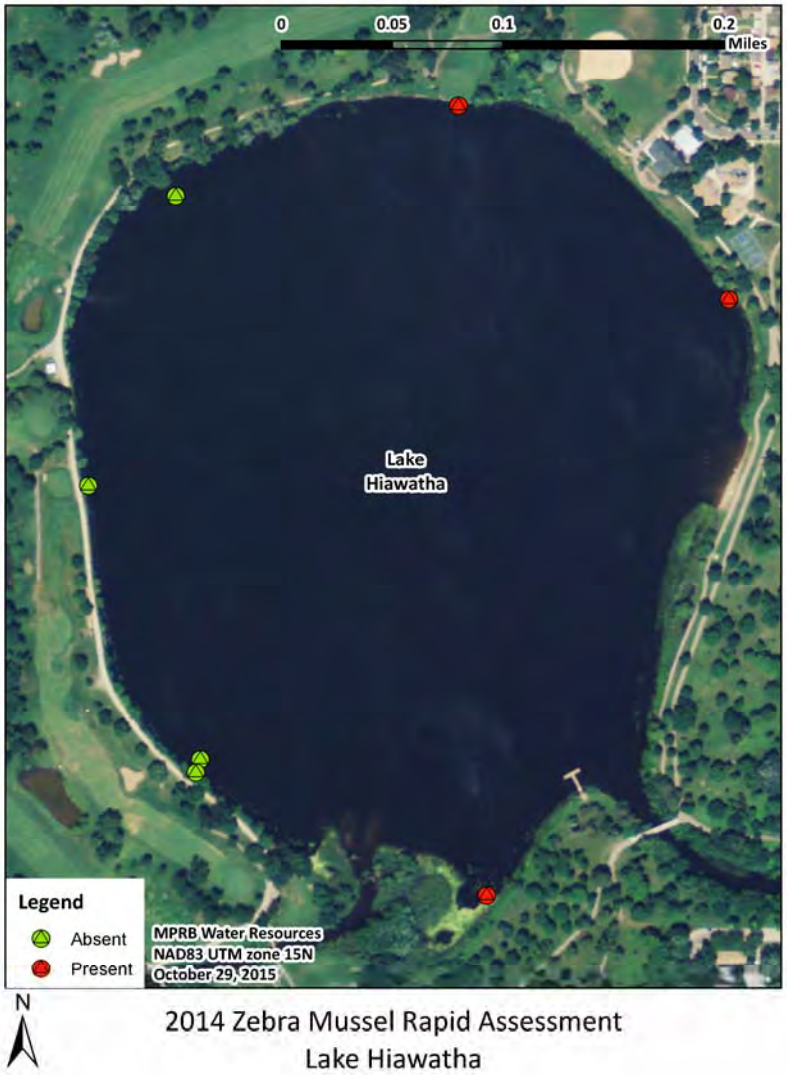


Figure 9-11. Results of zebra mussel shoreline surveys from 2014.

10. LAKE OF THE ISLES

HISTORY

Lake of the Isles was named for the four islands that were present in the lake prior to alteration of the park. The original park property consisted of 100 acres of water, 67 acres of wetland, and 33 acres of land. The park was acquired by the Minneapolis Park and Recreation Board in 1886 through purchase, donation, and condemnation. One of the islands had already been eliminated in 1884 by the Chicago Milwaukee and Saint Paul Railway when tracks were laid on fill between Lake Calhoun and 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, to deepen the North Arm to a uniform depth, and to replace the marshy east side of the lake with an upland shoreline. The connection of Isles to Calhoun was completed in 1911 and was celebrated by citywide festivities. Lake of the Isles is part of the Chain of Lakes Regional Park which receives over 5 million visitors year and the most visited park in Minnesota (Metropolitan Council, 2014).

The lake was part of the Clean Water Partnership project for the Chain of Lakes and was the focus of multiple restoration activities including grit chambers (1994, 1997, 1999) for stormwater sediment removal, constructed wetland detention ponds for further treatment of incoming stormwater, and a whole lake alum treatment (1997) to limit the internal loading of phosphorus.

Lake of the Isles is a shallow lake with dense stands of macrophytes in some areas. The lake is polymictic as it becomes thermally stratified and periodically mixes due to wind throughout the summer. **Figure 10-1** shows Lake of the Isles in fall. **Table 10-1** shows the Lake of the Isles morphometric data. **Figure 10-2** shows the Lake of the Isles bathymetry.

Figure 10-1. Lake of the Isles.

Table 10-1. Lake of the Isles morphometric data.

Surface Area (acres)	Mean Depth (m)	Max Depth (m)	Littoral Area*	Volume (m^3)	Watershed Area (acres)	Watershed: Lake Area (ratio)	Residence Time (years)
103	2.7	9.4	89%	$1.11x10^6$	735	7.1	0.6

*Littoral area defined as less than 15 feet deep.

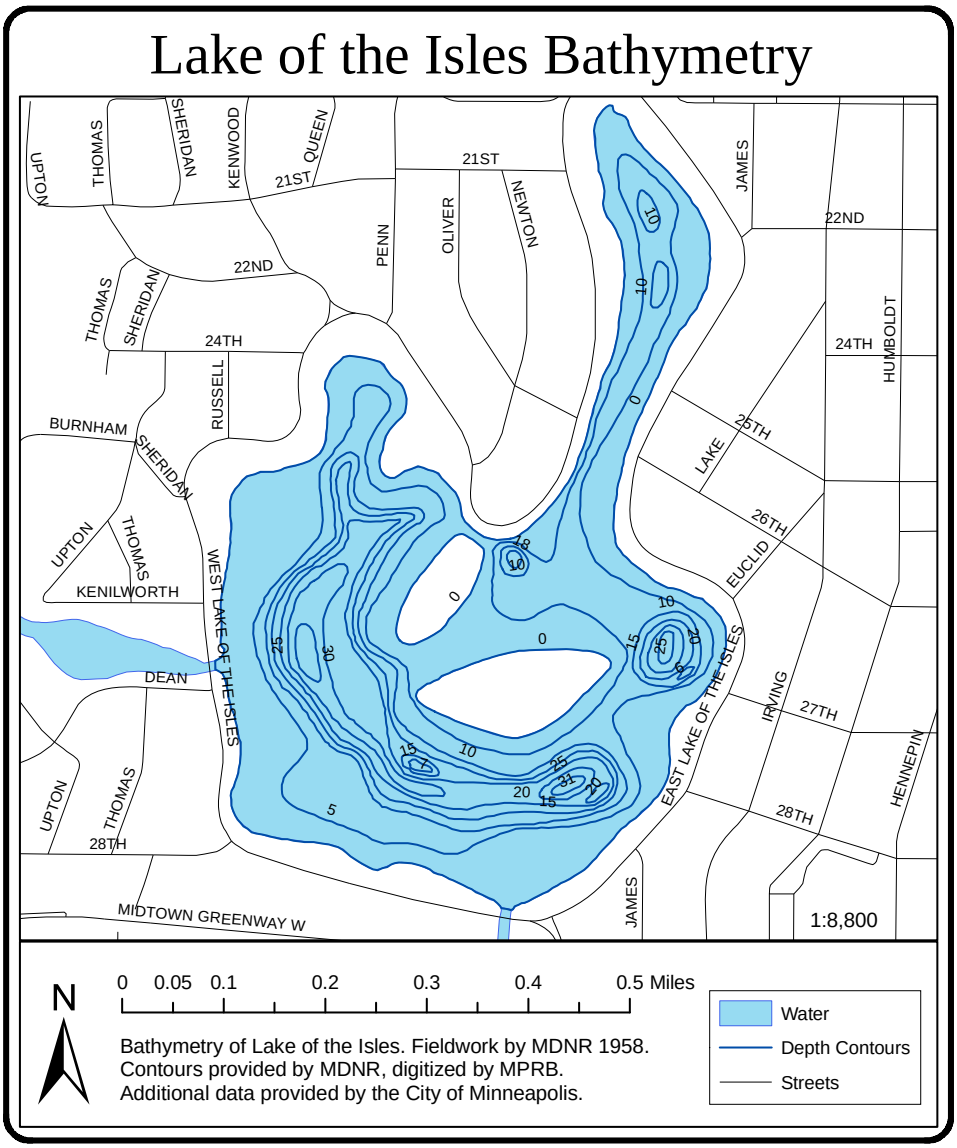


Figure 10-2. Bathymetric map of Lake of the Isles.

LAKE LEVEL

The ordinary high water level (OHW) designated by the MDNR for Lake of the Isles is 853 ft msl. The designated OHW is an estimate of the highest regularly sustained water level that has made a physical imprint on the land. This mark may be a transition in vegetation or a physical characteristic. For additional lake level information see Lake Calhoun in **Section 4**.

WATER QUALITY TRENDS – TROPHIC STATE INDEX (TSI)

Figure 10-3 shows the Lake of the Isles linear regression of TSI scores from 1991 to the present. The Lake of the Isles 2014 TSI score is 55, average for this ecoregion (based on calculations from the Minnesota Pollution Control Agency using the Minnesota Lake Water Quality Data Base Summary, 2004). There has been no significant trend in TSI score since 1991 ($p > 0.05$). The alum treatment in 1997 coincided with the lowest/best TSI score for Lake of the Isles, but did not result in a long term decrease in TSI scores. A detailed explanation of TSI can be found in **Section 1**.

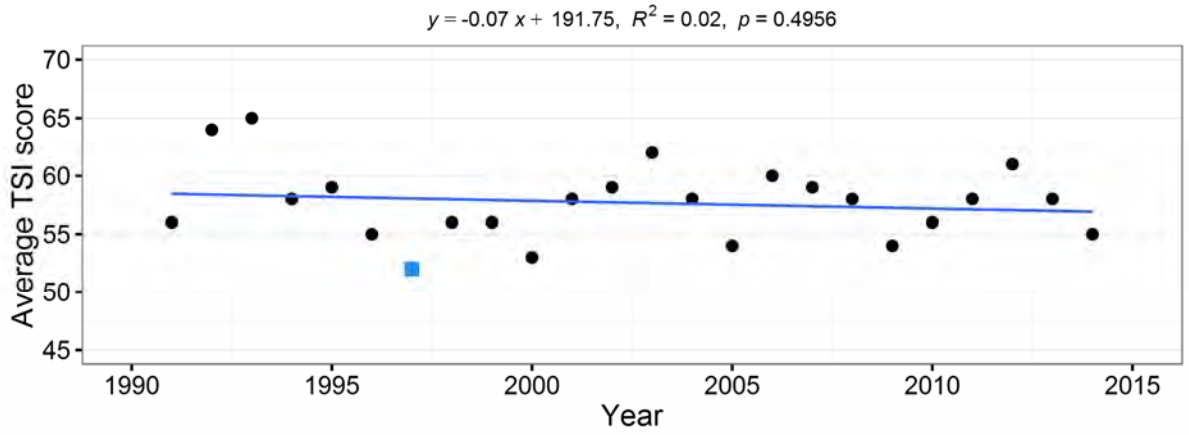


Figure 10-3. Lake of the Isles TSI scores and regression analysis. The blue square highlights the 1997 alum treatment.

BOX AND WHISKER PLOTS

The box and whisker plots in **Figure 10-4** show the data distribution for the Secchi, chlorophyll-*a*, and total phosphorus for the past ten years. MPCA standards are indicated by a horizontal line on the plots. A detailed explanation of box and whisker plots can be found in **Section 1**, and all available data in box and whisker format can be found in **Appendix A.**

All data shown in **Figure 10-4** were measured after Clean Water Partnership project improvements installed between 1994 and 1997. Water transparency in 2014 was clearer than 2013 and more similar to previous years. Similarly, median chlorophyll-*a* levels were lower than the previous two years, but was comparable to concentrations in the late 2000s. Total phosphorus levels appear to vary year to year and 2014 was on the low end compared to the past 10 years.

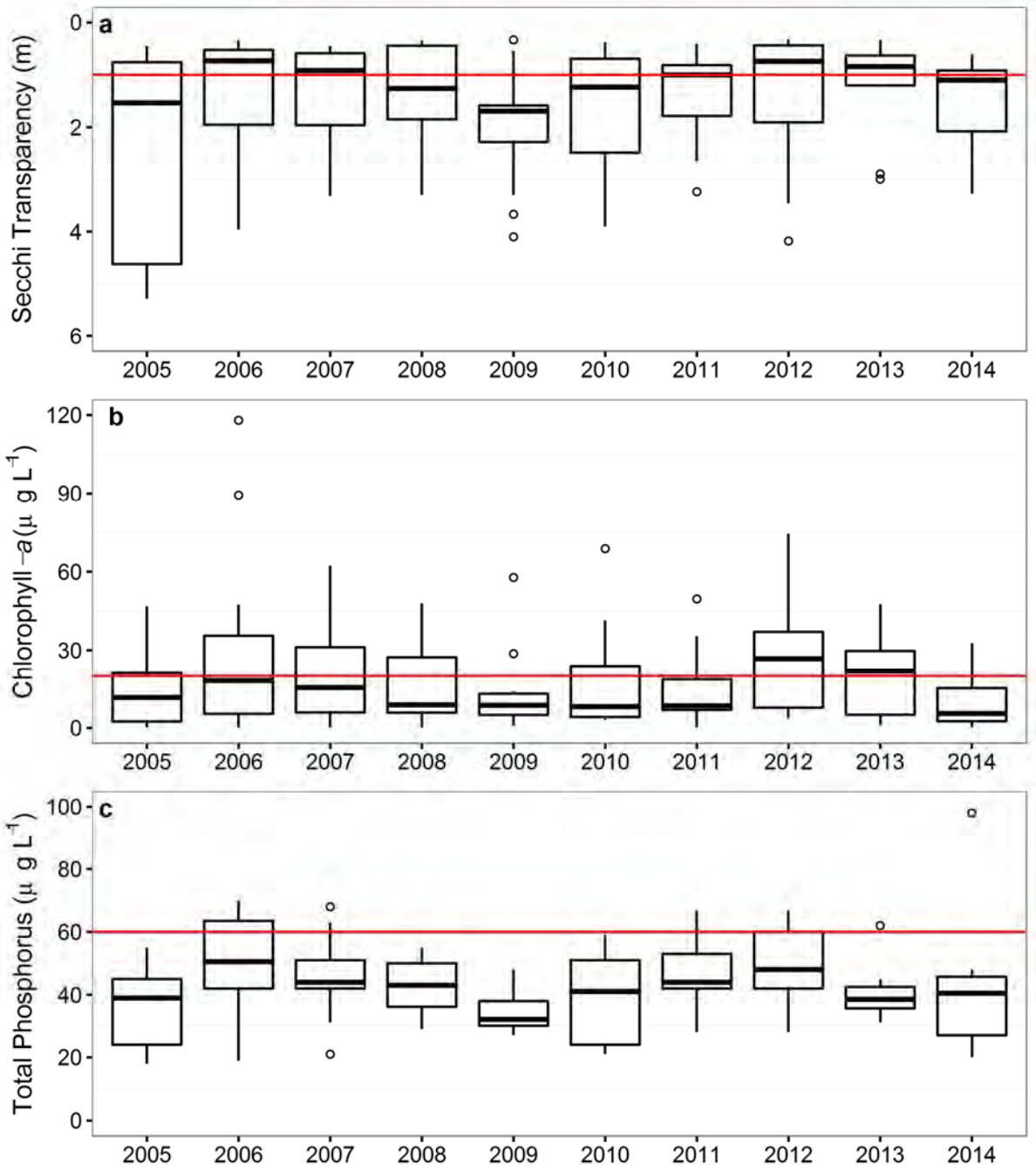


Figure 10-4. Lake of the Isles box and whisker plots of TSI data from 2005-2014. Horizontal lines represent MPCA eutrophication standard for shallow lakes. See Appendix A for the entire period of record.

LAKE AESTHETIC AND USER RECREATION INDEX (LAURI)

The LAURI for Lake of the Isles is shown in **Figure 10-5**. In 2014, Lake of the Isles scored "excellent" in aesthetics, habitat quality, and recreational access. The lake scored in the "good" category for water clarity. 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 **Section 1**.

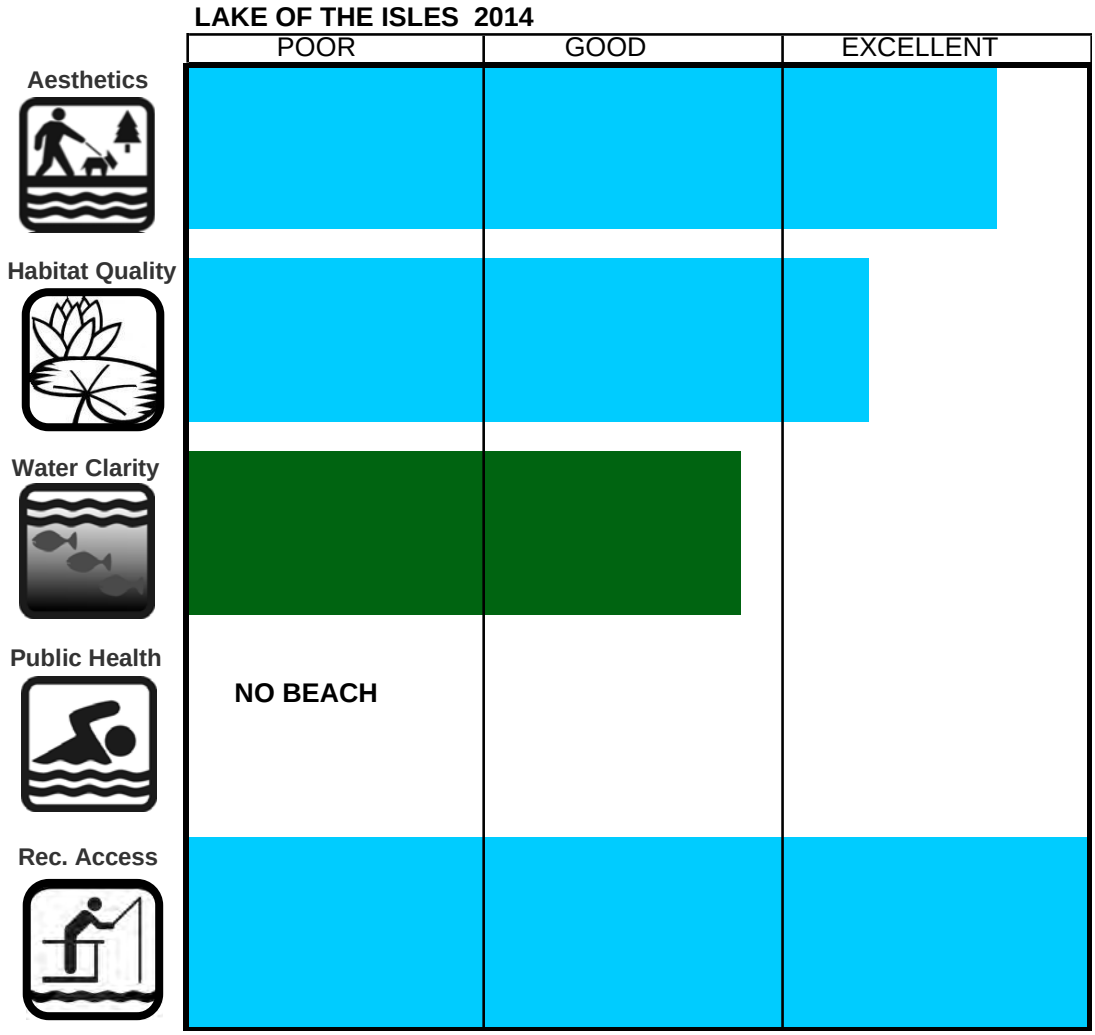


Figure 10-5. The LAURI for Lake of the Isles in 2014.

WINTER ICE COVER

Ice came off Lake of the Isles on April 19, 2014, 14 days later than average. Ice fully covered the lake on November 17, 2014, which was 13 days earlier than average for Lake of the Isles. See **Section 1** for details on winter ice cover records and **Section 18** for a comparison with other lakes.

EXOTIC AQUATIC PLANT MANAGEMENT

The MDNR requires a permit to remove or control Eurasian water milfoil. In order to protect fish habitat, the MDNR permits limit the area from which milfoil 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 milfoil harvesting in Lake of the Isles in 2014 was 38 acres which is just over 40% of the littoral zone (area shallower than 15 feet). See **Section 1** and **Section 20** for details on aquatic plants.

PHYTOPLANKTON AND ZOOPLANKTON

Phytoplankton and zooplankton are the microscopic plant and animal life that form the foundation of the food web in lakes. **Figure 10-6** shows the Secchi transparency, chlorophyll-*a* concentrations, and relative abundance of phytoplankton division during the 2014 sampling season. **Figure 10-7** shows the abundance of zooplankton groups in 2014. The winter sample was dominated by cryptomonads and a small amount of blue green algae (Cyanophyta); however, algal biomass was very low with chlorophyll-*a* concentration below detection. Secchi depth was around 1 m in the May samples, but chlorophyll-*a* levels remained low (< 6 µg L^{-1}) comprised mainly of diatoms (Bacillariophyta), Chrysophytes, and small haptophytes in late May. The best water transparency occurred in June when the phytoplankton community was comprised mainly of Cryptomonads. Water transparency decreased the rest of the summer as chlorophyll-*a* levels increased led by the emergence of green algae (Chlorophyta) and later blue green algae (Cyanophyta). Secchi depth increased and cholorophyll-*a* concentrations returned to low levels in the fall.

The distribution of zooplankton for Lake of the Isles is shown in **Figure 10-7**. Nauplii and juvenile zooplankton were present in high numbers until the end of the season. The rotifer community were also in high numbers all season, but were the lowest in July. Cladocerans, large zooplankton that graze on algae were present in most samples and were abundant in October. Similar to other lakes, the carnivorous cyclpoids were present in low levels in most samples.

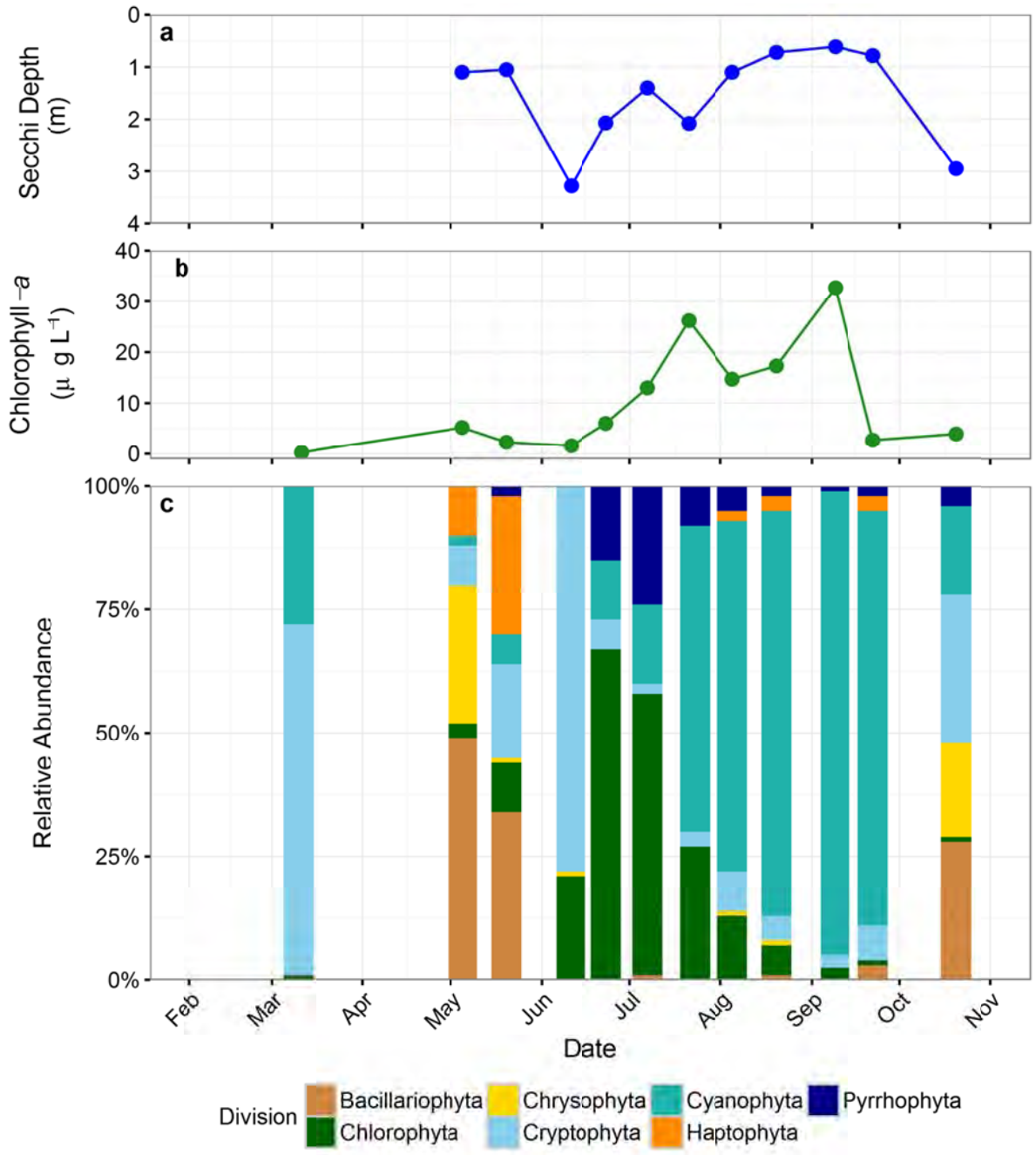


Figure 10-6. Secchi transparency (a), chlorophyll-*a* concentration (b), and relative abundance of phytoplankton (c) during the 2014 Lake of the Isles sampling season. Note that the Secchi depth axis is reversed.

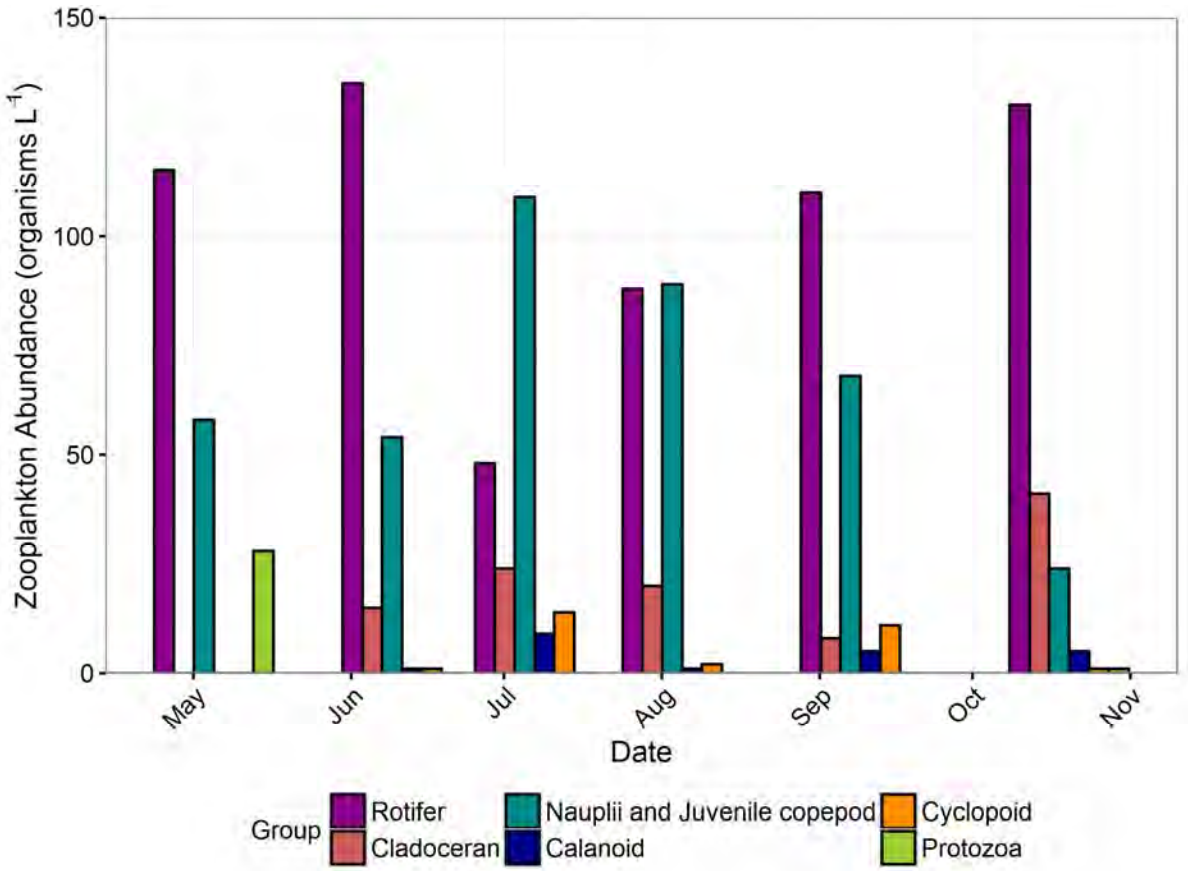


Figure 10-7. Lake of the Isles 2014 zooplankton distribution.

FISH STOCKING

Additional information and a definition of fry, fingerling, yearling, and adult fish can be found in **Section 1**.

Lake of the Isles was stocked by MDNR in:

2000 with 300 fingerling Tiger Muskellunge.

2004 with 300 fingerling Tiger Muskellunge.

2007 with 180 fingerling Tiger Muskellunge.

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. The smaller north basin 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 basin that would hold open water. Stormwater diversion has reduced the watershed of Loring Pond to the surrounding 24.1 acres of parkland and has left the lake with a negative water balance; therefore a groundwater augmentation well is used to maintain water levels.

Figure 11-1 is a photograph of Loring Pond, and **Figure 11-2** is a map of the pond showing estimated bathymetry. **Table 11-1** shows the morphometric data for Loring Pond.

Figure 11-1. Photograph of Loring Pond, Fall 2013.

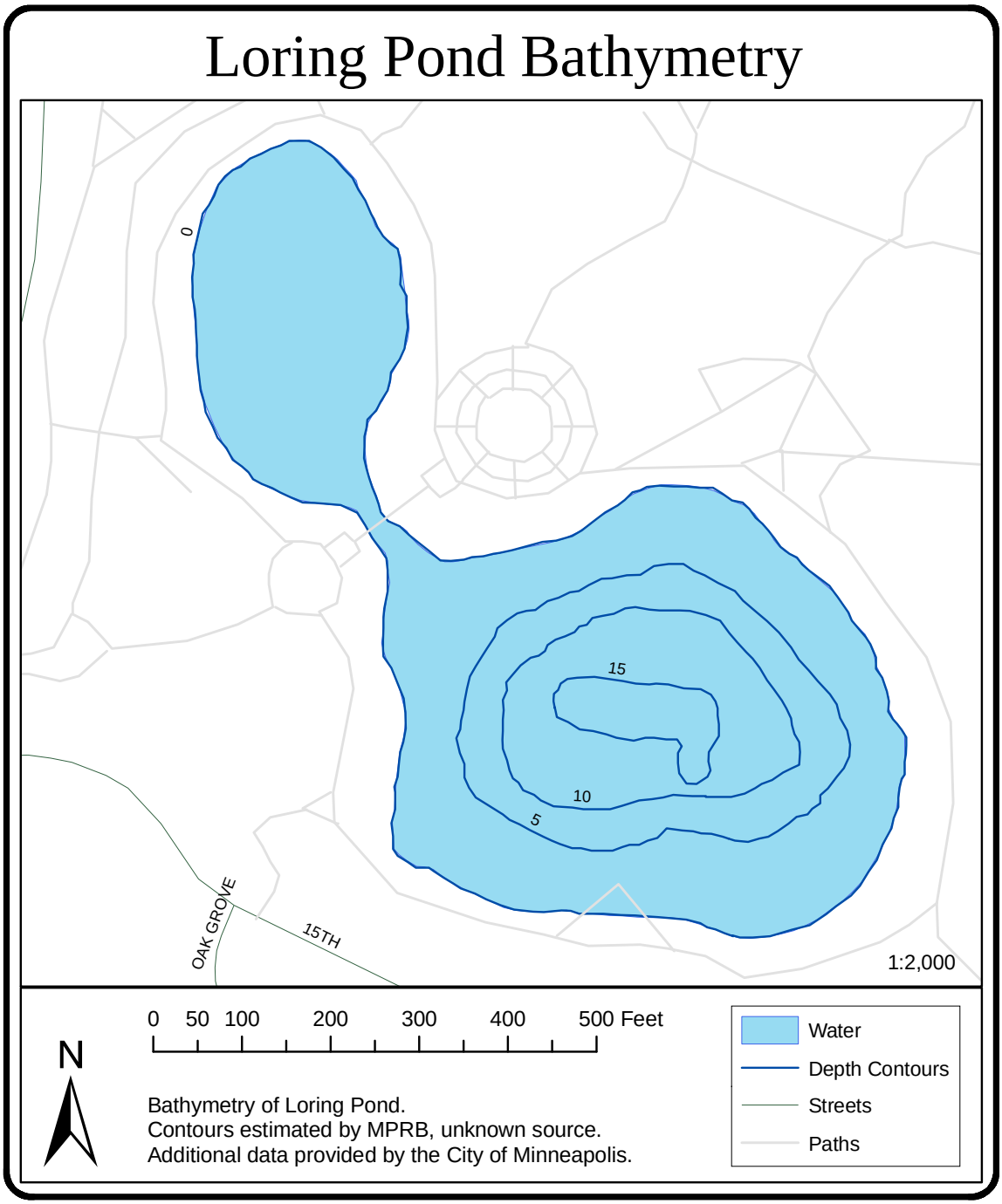


Figure 11-2. Map of Loring Pond showing bathymetry contours.

Table 11-1. Loring Pond morphometric data.

Surface Area (acres)	Mean Depth (m)	Maximum Depth (m)	Volume (m^3)	Watershed Area (acres)	Watershed: Lake Area (ratio)
8	1.5	5.3	4.88×10^4	24.1	3.0

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 hypolimnetic water from the lake. The tube never functioned properly and was abandoned. Dredging of the north arm from 1976 to1977 also did not improve the water quality of the lake. Augmentation of the lake level with groundwater appears to have had a positive effect on water quality and continues today.

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. A fishing pier, bike and pedestrian trails, and horseshoe courts were also installed to increase park recreational opportunities. In 1999, the shoreline was planted with native vegetation in cooperation with the Minnesota Department of Natural Resources (MDNR) 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 basin was dredged to remove accumulated sediment and restore original depths in the channel between the northern and southern basins. In order to accomplish this, the northern basin was dewatered and the water level in the southern basin was lowered. The project had the unintended consequence of stimulating cattail growth that led to a multi-year cattail removal project that MPRB began in 2013.

LAKE LEVEL

Lake levels for Loring Pond are recorded weekly during ice free conditions and are shown in **Figure 11-3** for 1994-2014. Loring Pond lake levels are influenced by an augmentation well that is used to pump groundwater into the lake periodically throughout the year to maintain a consistent level. As the water level was often below the bottom of the lake gauge on the outlet structure, a new auxiliary gauge was installed in 2013.

Dewatering for the north bay dredging project lowered water levels in Loring significantly in 2007. Stormsewer backflow entered Loring several times in 2010 and 2011 during high-intensity rain events, and the largest of these events can be seen as peaks in the level graph. 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. Staff were able to raise the level of the lake using groundwater, but pumping could not overcome the amount of water lost in the late summer drought. High water levels in 2012 were due to a malfunction in the groundwater pump. Water levels were manipulated and drawn down throughout the summer and then raised to the top of the outlet wall as part of a cattail removal in 2014. See Water Quality Projects for more details.

The ordinary high water level (OHW) designated by the MDNR for Loring Pond is 818.0 ft msl. The designated OHW is an estimate of the highest regularly sustained water level that has made a physical imprint on the land. See **Section 18** for a comparison between other MPRB lake levels.

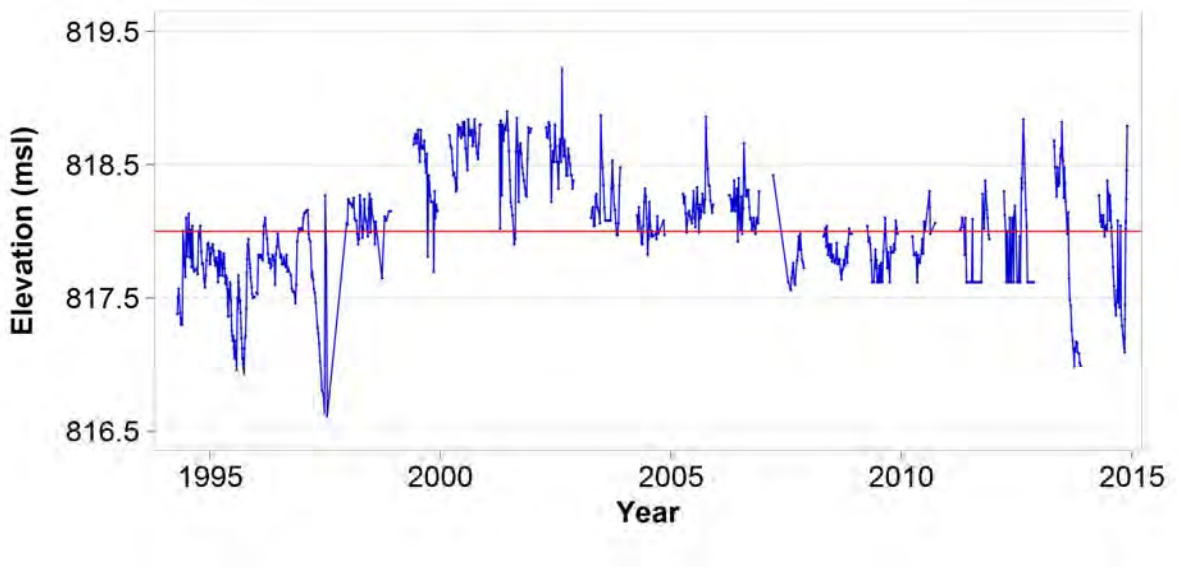


Figure 11-3. Lake levels for Loring Pond from 1994 – 2014. Water levels frequently dropped below the gage in the 2000s and water levels couldn't be accurately measured during that time. Auxiliary gage installed in 2013 is able to read lower lake levels. Horizontal line represents Loring Pond OHW (818.0 ft msl).

AUGMENTATION WELLS

An augmentation well is used to maintain the water levels at Loring Pond. The Minnesota Department of Natural Resources (MDNR) issues the permits and determines pumping limits for augmentation wells. The MPRB staff records groundwater usage monthly. **Table 11-2** shows annual usage for the past five years. No data is available for 2010 due to a broken meter. In 2014, 6.9 million gallons of groundwater was pumped into Loring Pond.

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

2010 Total (gal)	2011 Total (gal)	2012 Total (gal)	2013 Total (gal)	2014 Total (gal)
Meter broken	8,475,000	11,572,500	1,378,500	6,871,020

WATER QUALITY TRENDS – TROPHIC STATE INDEX (TSI)

The 2014 TSI score for Loring Pond was 62. Loring Pond has a TSI score that falls near the bottom 25th percentile category for lakes in the Northern Central Hardwood Forest ecoregion (MPCA, 2004). **Figure 11-4** shows the TSI data for Loring Pond along with a linear regression. A detailed explanation of TSI can be found in **Section 1**.

There is no significant trend in TSI from 1992-2014 in Loring Pond ($p < 0.05$). Caution should be used when viewing the Loring Pond data in total since dredging projects that disturbed all or a large portion of the lake occurred in 1997-1998 and during the summer of 2007. Additionally, water levels have been manipulated in both 2013 and 2014.

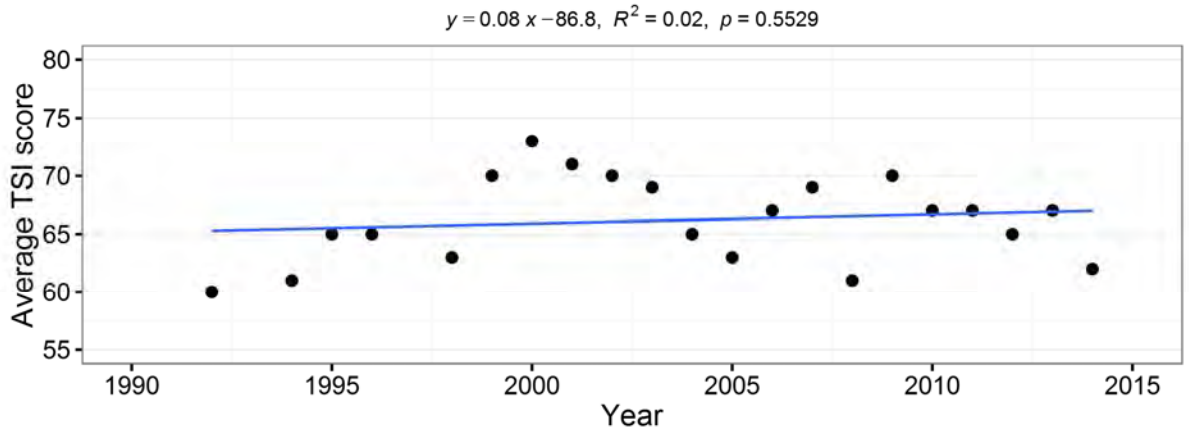


Figure 11-4. Loring Pond TSI data and regression analysis from 1990 to 2014. The lake was significantly manipulated during 1997-1998 and the summer of 2007. Due to these disturbances, data should be viewed with caution.

BOX AND WHISKER PLOTS

The box and whisker plots in **Figure 11-5** show the distribution of data for the Secchi, chlorophyll-*a*, and total phosphorus measurements for the past ten years. MPCA shallow lake standards are shown as a horizontal line across the box plots. A detailed explanation of box and whisker plots can be found in **Section 1**. Data presented in box and whisker plot format for the entire period of record can be found **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 (8 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 determine lake water quality. Median Secchi transparency was slightly deeper than most years and similar to 2012; however, there was a large range in clarity in 2014 with some Secchi readings greater than 3 meters. Chlorophyll-*a* levels were significantly lower than previous years and the some of the lowest levels observed in Loring. However, total phosphorus concentrations in 2014 were some of the highest observed.

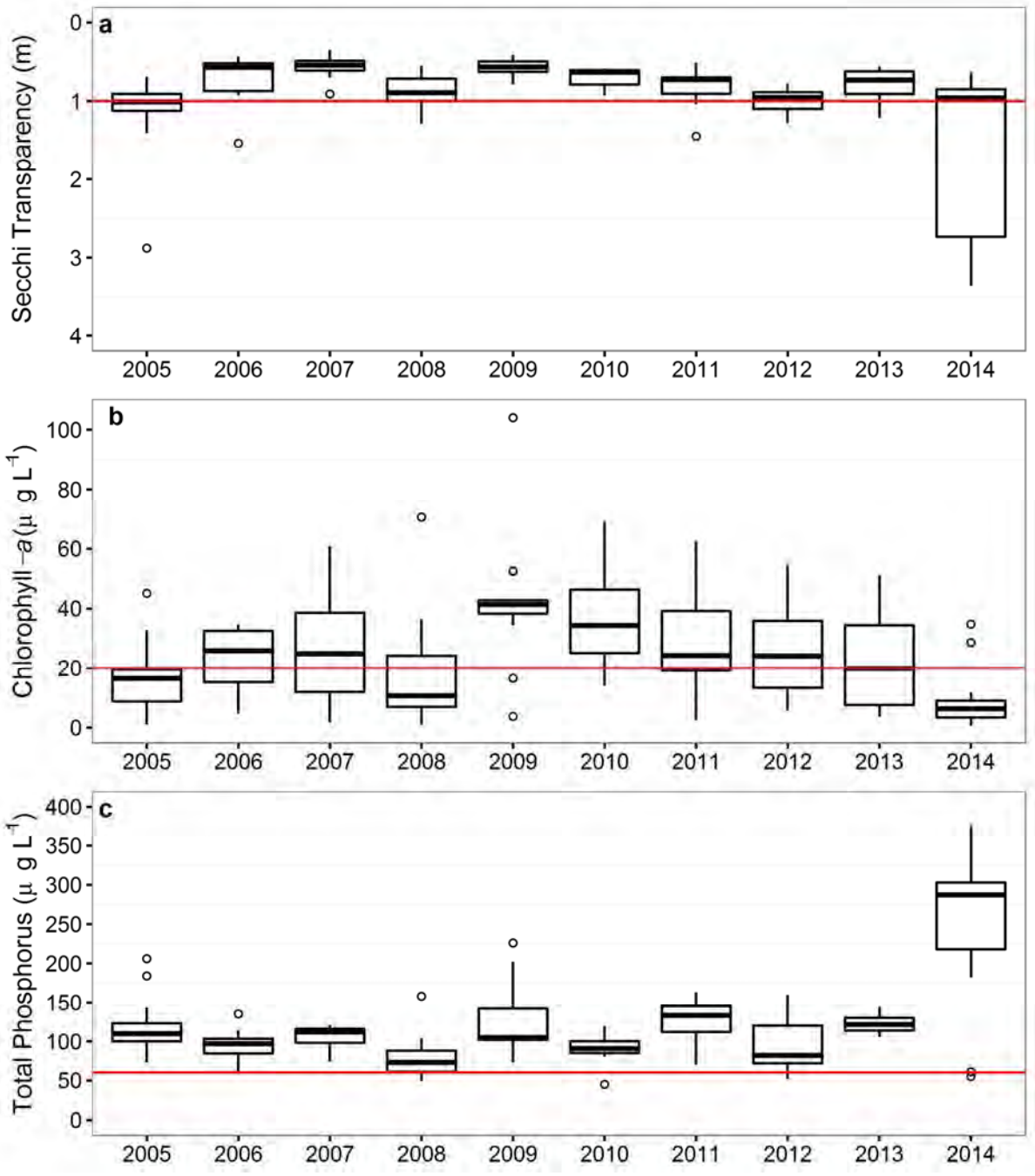


Figure 11-5. Box and whisker plots of Loring Pond TSI data for the most recent 10 years. Horizontal lines represent MPCA eutrophication standard for shallow lakes. See Appendix A for the entire period of record.

LAKE AESTHETIC AND USER RECREATION INDEX (LAURI)

The LAURI for Loring Pond is shown in **Figure 11-6**. In 2014, Loring Pond scored "excellent" in aesthetics and water clarity. Loring scored "good" in habitat quality. Loring Pond does not have a swimming beach and was therefore not scored for public health. Loring does not have boat or canoe access and therefore scored a "poor" in recreational access. Details on the LAURI index can be found in **Section 1**.

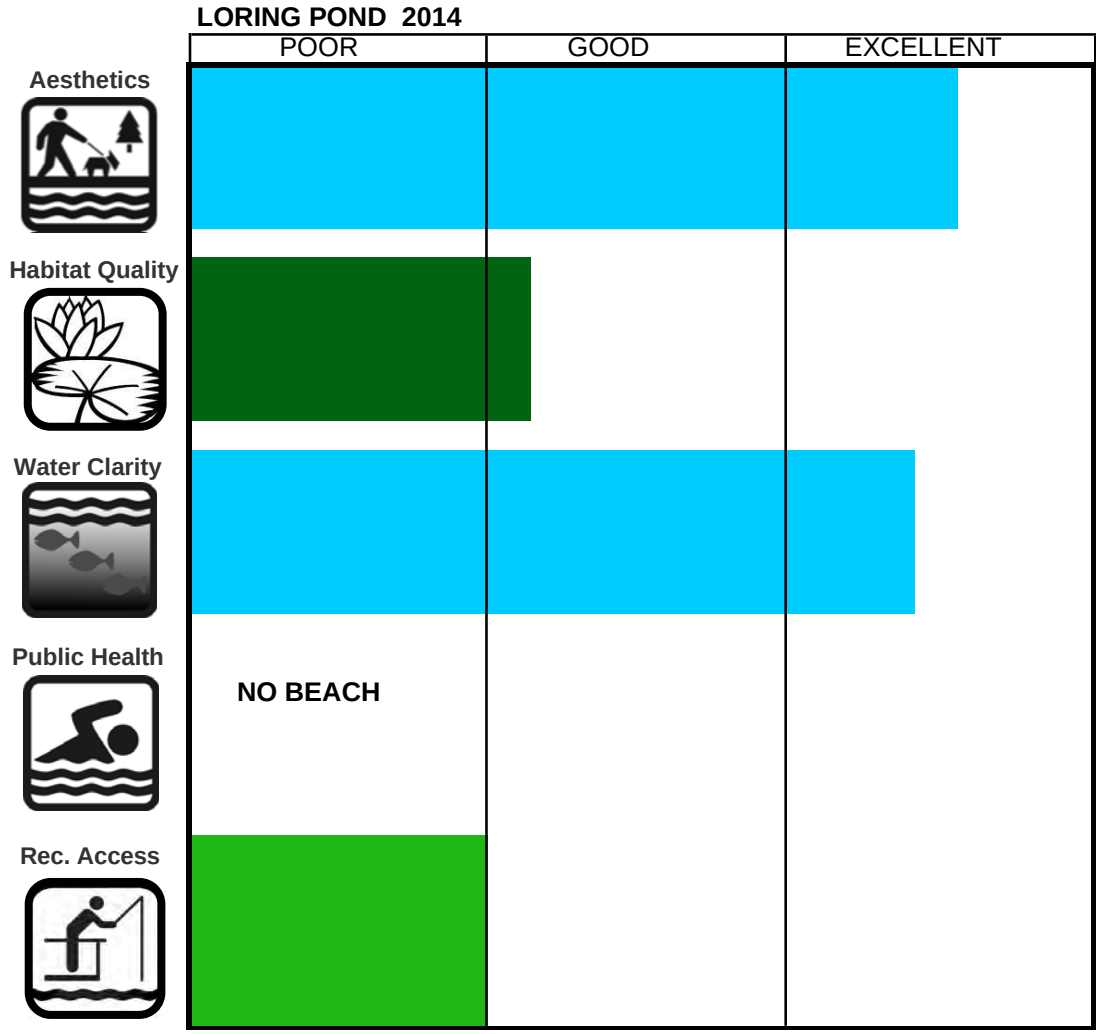


Figure 11-6. The 2014 LAURI for Loring Pond.

WINTER ICE COVER

Ice came off Loring Pond on April 10, 2014, eight days later than average ice-off date. Ice came on to the pond on November 14, 2014, 16 days before the average ice-on date for Loring Pond. Loring Pond is a popular spot for geese, ducks and gulls, and some years waterfowl keep an open hole of water from freezing past normal ice-on. See **Section 1** for details on winter ice cover records and **Section 18** for a comparison with other lakes.

PHYTOPLANKTON AND ZOOPLANKTON

Phytoplankton and zooplankton are the microscopic plant and animal life that form the foundation of the food web in lakes. Zooplankton preferentially graze on phytoplankton and play a part in water clarity. **Figure 11-7** shows the Secchi transparency, chlorophyll-*a* concentrations, and relative abundance of phytoplankton division and **Figure 11-8** shows the zooplankton abundance in 2014.

The winter sample contained little algal biomass (< 8µg L^{-1}) and was comprised of green algae (Chlorophyta), cryptophytes (Cryptophyta), euglenoids (Euglenophyta), and dinoflaggelates (Pyrrhophyta). Water transparency started low (< 1m) in May but slowly improved through July to a depth of greater than three meters. Chlorophyll-*a* concentrations remained stable through this time (< 6µg L^{-1}), but there was a shift in phytoplankton community from a mix of diatoms (Bacillariophyta) and green algae to cryptophytes and green algae in June. From August to October, Secchi depth decreased to less than one meter as chlorophyll-*a* levels rose to 35µg L^{-1} by the end of the season.

Zooplankton density at Loring Pond in 2014 is shown in **Figure 11-8**. Nauplii and juvenile zooplankton were abundant in the May sample and then at moderate densities the remainder of the season. Cladocerans, primary grazers of algae, were in high abundance in 2014, especially in the September sample. Rotifers were only abundant in June and were only present in low numbers the remainder of the season. Cyclopoids were only present at very low levels periodically throughout the year.

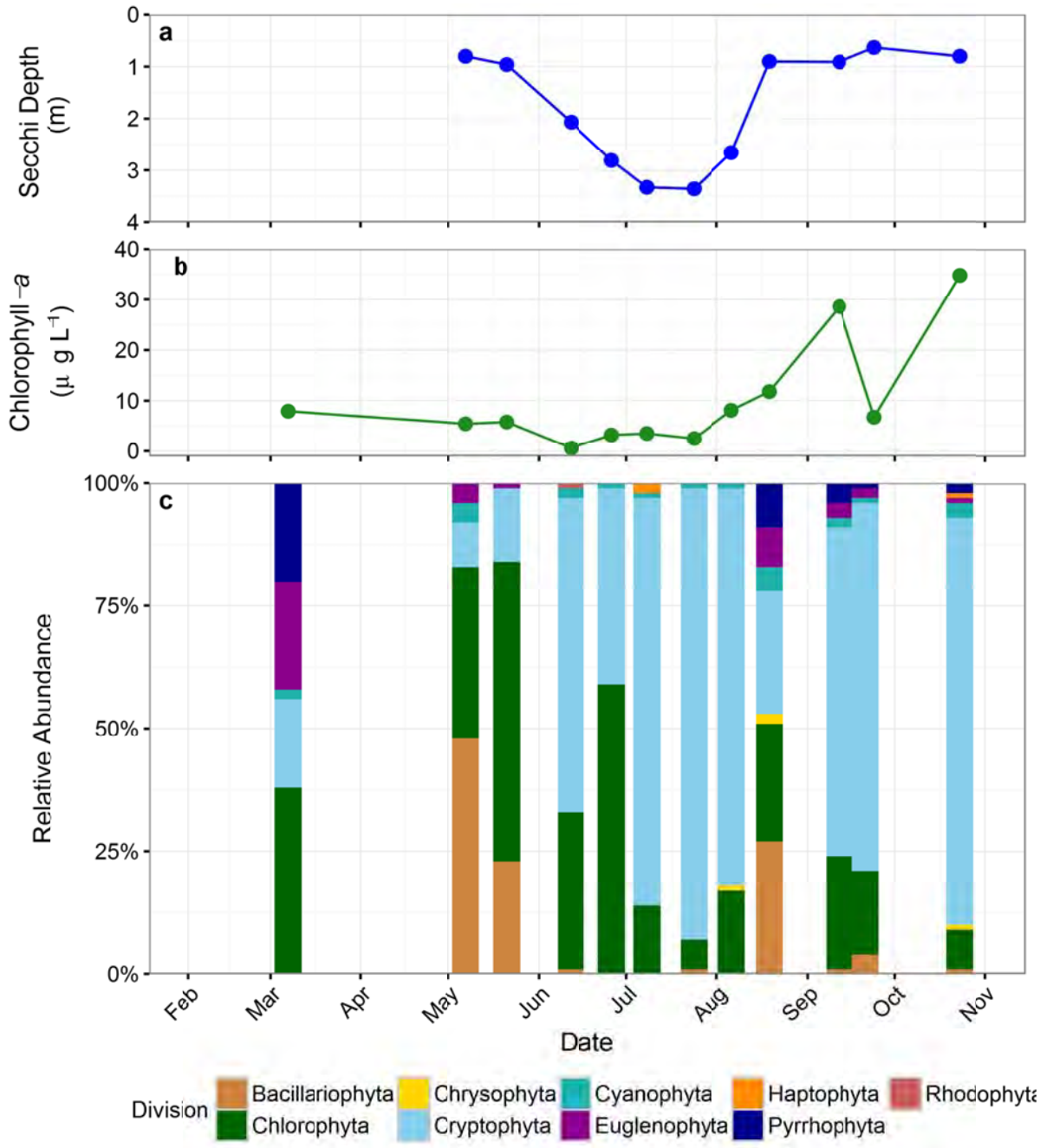


Figure 11-7. Secchi transparency (a), chlorophyll-*a* concentration (b), and relative abundance of phytoplankton (c) during the 2014 Loring Pond sampling season. Note that the Secchi depth axis is reversed.

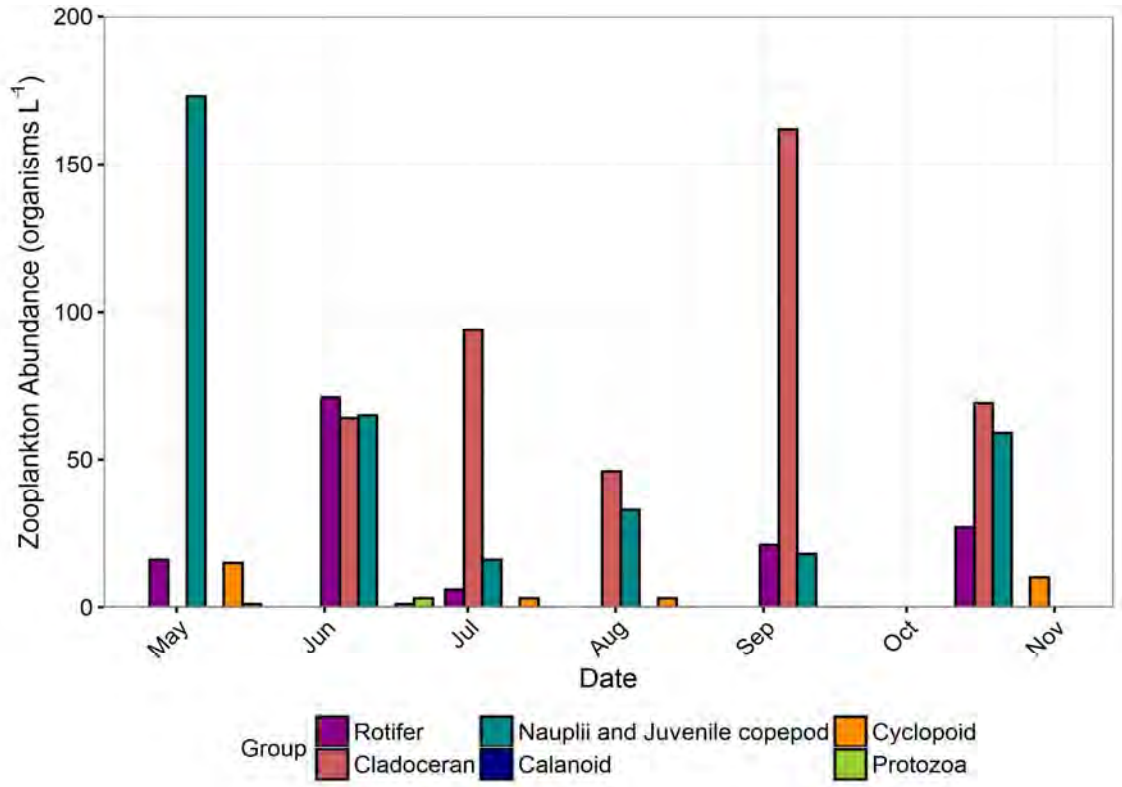


Figure 11-8. Zooplankton distribution at Loring Pond during the 2014 sampling season.

FISH STOCKING

Additional information and a definition of fry, fingerling, yearling, and adult fish sizes can be found in **Section 1**.

Loring Pond was stocked by MDNR in:

2001 with 417 adult Black Crappie, 465 adult Bluegill Sunfish.
2002 with 268 adult Black Crappie, 423 adult Bluegill Sunfish.
2003 with 107 adult Black Crappie, 417 adult Bluegill Sunfish.
2004 with 102 adult Black Crappie, 485 adult Bluegill Sunfish.
2005 with 100 adult Black Crappie, 402 adult Bluegill Sunfish, 50 adult Channel Catfish.
2006 with 102 adult Black Crappie, 400 adult Bluegill Sunfish, 50 adult Channel Catfish.
2007 with 158 adult Black Crappie, 200 adult Bluegill Sunfish.
2008 with 200 adult Black Crappie, 400 adult Bluegill Sunfish, 50 adult Channel Catfish.
2009 with 102 adult Black Crappie, 403 adult Bluegill Sunfish.
2010 with 108 adult Black Crappie, 402 adult Bluegill Sunfish, 50 adult Channel Catfish.
2011 with 79 adult Black Crappie, 329 adult Bluegill Sunfish, 28 adult Channel Catfish.
2014 with 92 adult Black Crappie, 35 adult Blugill Sunfish, 75 adult Channel Catfish

WATER QUALITY PROJECTS

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 South 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 was to have cattails removed and the area planted with native aquatic emergent vegetation. Maintenance of the 100 foot restoration zone plantings and removal of cattails near the dock and outlet structure has been continuous.

In the fall of 2014, the AES contract was expanded to include cutting as many cattails as possible beneath the water surface. AES cut as many cattails as possible below the water in an effort to suffocate cattails and prepare the site for future vegetation management. It was anticipated that cutting cattails during this timeframe would either kill or reduce cattail populations the following growing season (2015).

During the fall 2014 cattail cutting project, AES found that the North Bay was predominantly a floating mat of cattails and there were also additional floating mats in the South Bay. It is not possible to cut floating mats of cattails below the surface of the water. When floating mats of cattails are cut, the mats float higher in the water. Additionally, it was found during this process that there were many cattails growing in shallow water and in upland conditions none of which could be cut beneath the surface of the water.

Through Minnesota State Legislative action passed in 2014, the MPRB was "authorized 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).

12. LAKE NOKOMIS

HISTORY

In 1907, the Minneapolis Park and Recreation Board (MRPB) purchased 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. Dredging began in 1914, moving nearly 2.5 million cubic yards of material to increase the park by 100 acres, create beaches, solid shoreline, and parkways around the lake. Wirth predicted that the new parkland would settle, which was corrected by a 1934 Works Progress Administration project.

Numerous restoration projects have been implemented to improve water quality in the lake. Carp were seined from the lake during the winter of 2001-02 in order to limit internal phosphorus loading caused by the fish foraging in the sediment. Increased street sweeping, grit chambers and wetland detention ponds were also implemented in 2001. An inflatable weir was installed in 2002 to prevent nutrients from Minnehaha Creek from entering the lake and was operational in 2003. In 2012, Minnehaha Creek Watershed District (MCWD) replaced it with a more durable fixed weir which allows the lake to overflow during periods of high water, yet still prevent the creek from flowing into the lake. A photograph of the Lake Nokomis weir during record high water levels in June, 2014 is presented below in **Figure 12-1. Figure 12-2** is a bathymetric map of Lake Nokomis and **Table 12-1** contains morphometric data.

Figure 12-1. The Nokomis weir during record high water levels in June, 2014. Two boards placed flat across the weir with sandbags stacked on top of them and wrapped in a tarp were needed to keep Minnehaha Creek from flowing into the lake.

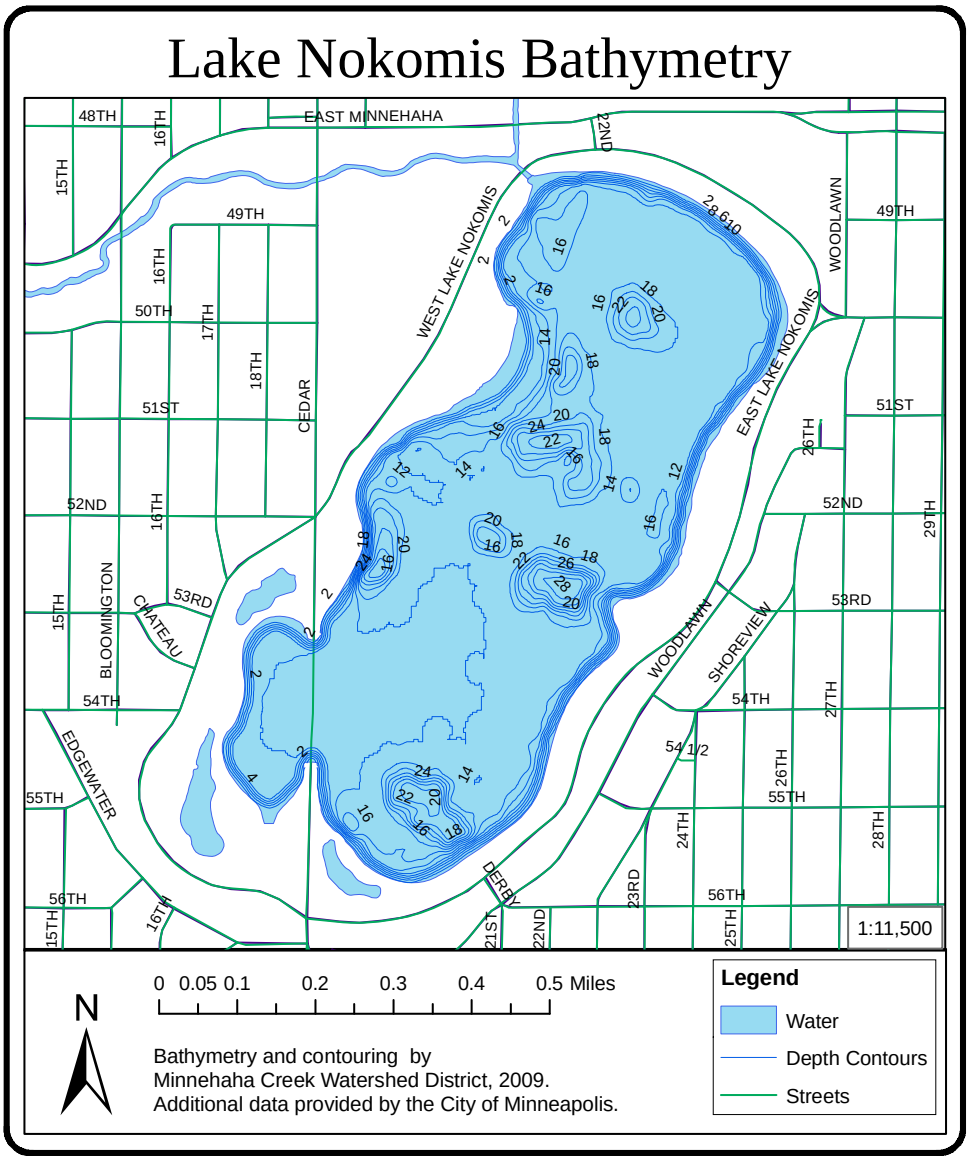


Figure 12-2. Bathymetric map of Lake Nokomis based on data collected by the Minnehaha Creek Watershed District.

Table 12-1. Nokomis Lake morphometric data.

Surface Area (acres)	Mean Depth (m)	Max Depth (m)	Littoral Area*	Volume (m^3)	Watershed Area (acres)	Watershed: Lake Area (ratio)	Residence Time (years)
204	4.3	10.1	51%	$3.54x10^6$	869	4.3	4.0

* Littoral area defined as less than 15 feet deep.

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. This has 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.

LAKE LEVEL

Weekly lake levels at Lake Nokomis for 1999 through 2014 are shown in **Figure 12-3**. In 2003, a new staff gage was surveyed in at the Lake Nokomis outlet. The ordinary high water level (OHW) designated by the MDNR for Lake Nokomis is 815.4 ft msl. The designated OHW is an estimate of the highest regularly sustained water level that has made a physical imprint on the land. See **Section 18** for a comparison between other MPRB lake levels. Nokomis lake levels were very low for several years (2003-2011) due to a combination of factors including: several consecutive drought years, less discharge from the Mother Lake watershed, and the separation from Minnehaha Creek. Higher levels were recorded in 2011-2013 after large snowmelt and spring rains. Heavy rains between April and June resulted in the highest water levels ever recorded in Lake Nokomis and flooding issues around the lake lasted until late 2014.

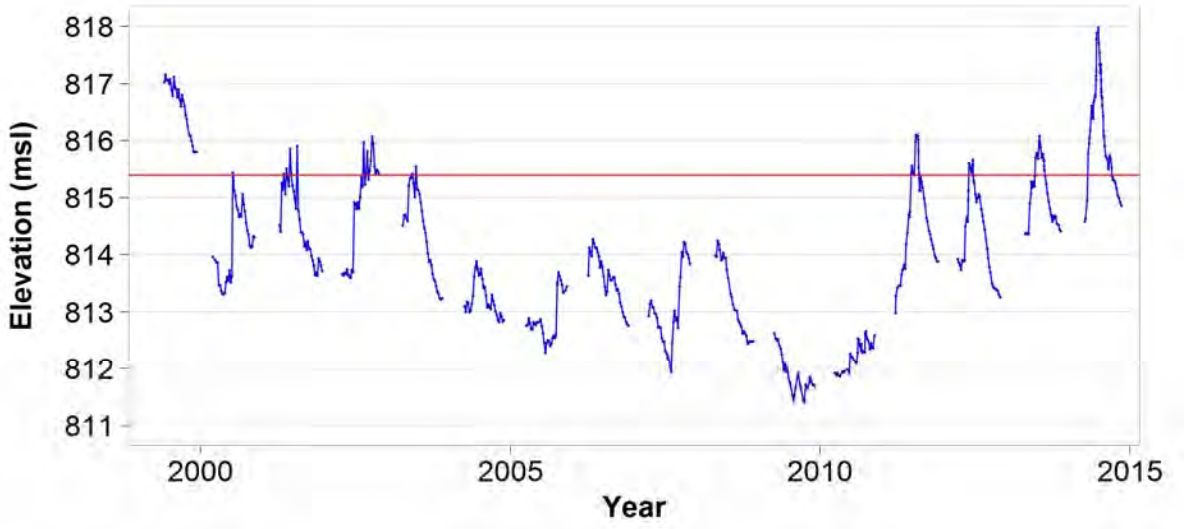


Figure 12-3. Lake levels recorded at Lake Nokomis, 1999-2014. Horizontal line represents Lake Nokomis OHW elevation (815.4 ft msl).

WATER QUALITY TRENDS – TROPHIC STATE INDEX (TSI)

The Lake Nokomis TSI scores over time are shown in **Figure 12-4**. There has been no significant change in TSI scores from 1992-2014 ($p > 0.05$). Lake Nokomis's 2014 TSI score is 53 and the lowest observed since 1992. This value puts Nokomis between the 50th and top 25th percentile compared to other lakes in our ecoregion (based on calculations from the Minnesota Pollution Control Agency, using the Minnesota Lake Water Quality Data Base Summary, 2004). A detailed explanation of TSI can be found in **Section 1**.

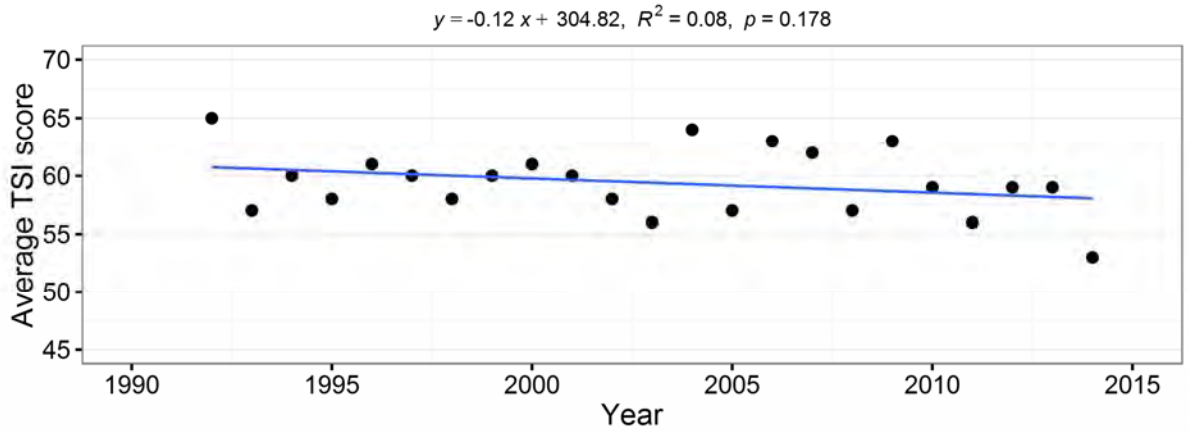


Figure 12-4. Lake Nokomis TSI scores and regression analysis.

BOX AND WHISKER PLOTS

Figure 12-5 shows box and whisker plots of Secchi transparency, chlorophyll-a, and total phosphorus data for Lake Nokomis for the most recent 10 years of data. Lake Nokomis site specific standards are indicated by a horizontal line on the box plot graphs. The EPA approved a new 50 µg L^{-1} TP standard for Lake Nokomis in 2013. A detailed explanation of box and whisker plots can be found in **Section 1**. Data in box and whisker format from the entire period of record can be found in **Appendix A**.

The relatively wide range in the Lake Nokomis data may be due to the polymictic nature of the lake. Years with more mixing events and less stable stratification may result in greater phosphorus return from the sediments and more algal productivity near the surface. The ten years since the weir separated the lake from Minnehaha Creek may represent a new normal for Lake Nokomis.

In 2014, Secchi transparency was lower than most years and similar to 2011 and 2005. Chlorophyll-*a* and total phosphorus were some of the lowest concentrations observed in recent years and met the MPCA standard for both measurements (**Figure 12-5**). A biomanipulation study began in 2010 at Lake Nokomis, which aims to reduce sediment disturbance by burrowing fish. While there appears to be a change in the fish community away from burrowing species, the project may now be having a positive effect on clarity as there is a lower level of sediment phosphorus release. Future monitoring will continue to show how effective this approach is on water quality in Lake Nokomis.

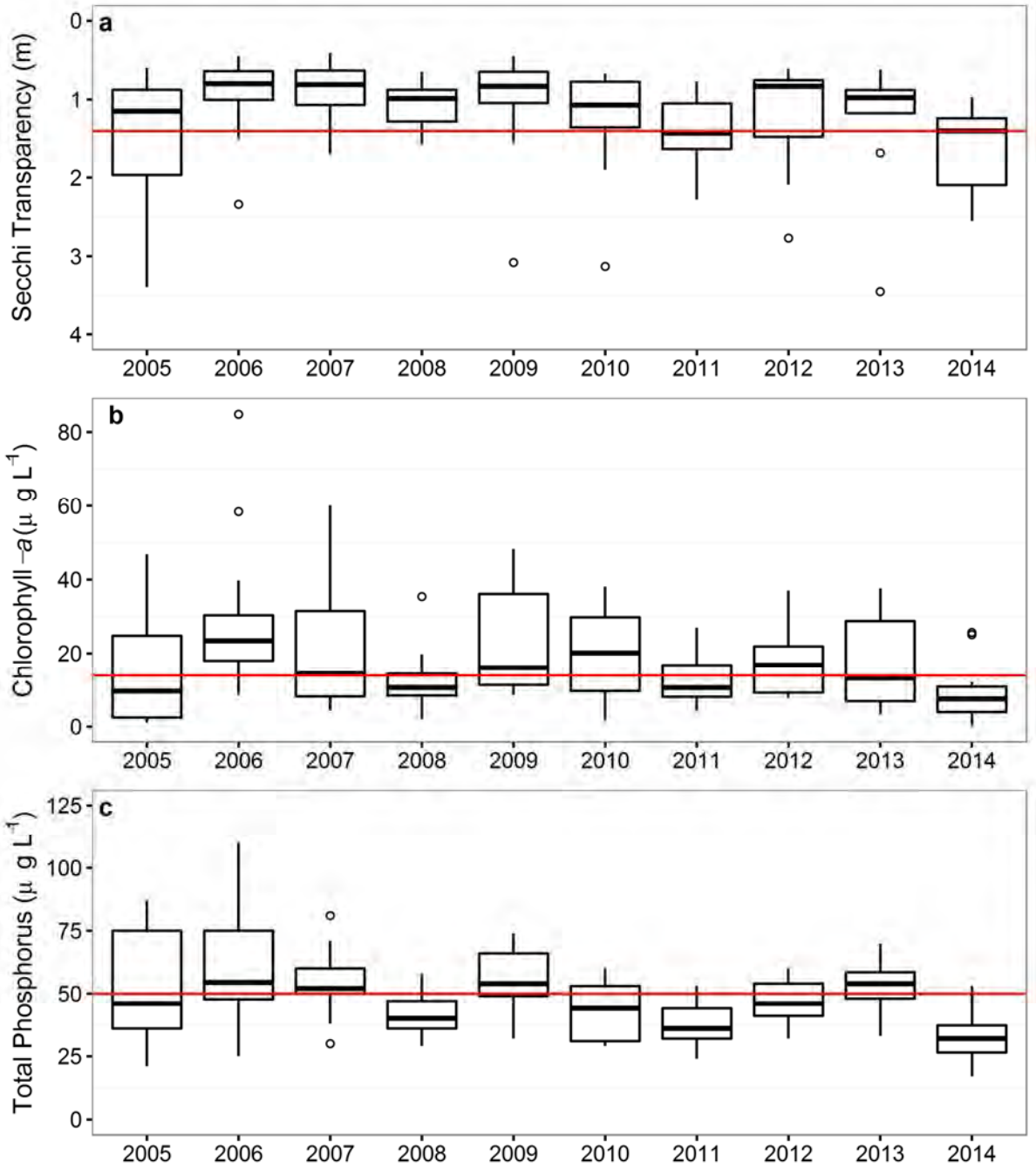


Figure 12-5. Box and whisker plots of Lake Nokomis TSI data from the last ten years. Horizontal lines represent Lake Nokomis site specific eutrophication standards. See Appendix A for the entire period of record

BEACH MONITORING

Bacteria levels were monitored at Nokomis Main Beach and Nokomis 50th Street Beach during 2014. As shown in **Table 12-2**, the season long geometric mean for *Escherichia coli* (*E. coli*) was low for both beaches. The beaches on Lake Nokomis remained open for the entire 2014 beach season. Further details on MPRB beach monitoring can be found in **Section 19**.

Table 12-2. Summary of 2014 *E. coli* results (MPN colonies per 100 mL) on Lake Nokomis beaches.

Statistical Calculations	Nokomis 50th	Nokomis Main
Number of Samples	13	13
Minimum	2	4
Maximum	102	239
Median	18	33
Mean	27	61
Geometric Mean	15	35
Max 30-Day Geo Mean	30	61
Standard Deviation	33	69

Figure 12-6 shows the box and whisker plots for *E. coli* sampling results (per 100 mL) for data collected over the past ten years. The light red line represents the *E. coli* standard for the 30-day geometric mean (126 MPN/100mL), while the dark red line represents the single-sample maximum standard (1260 MPN/100mL). The box and whisker plots show the data distribution for the sampling between years.

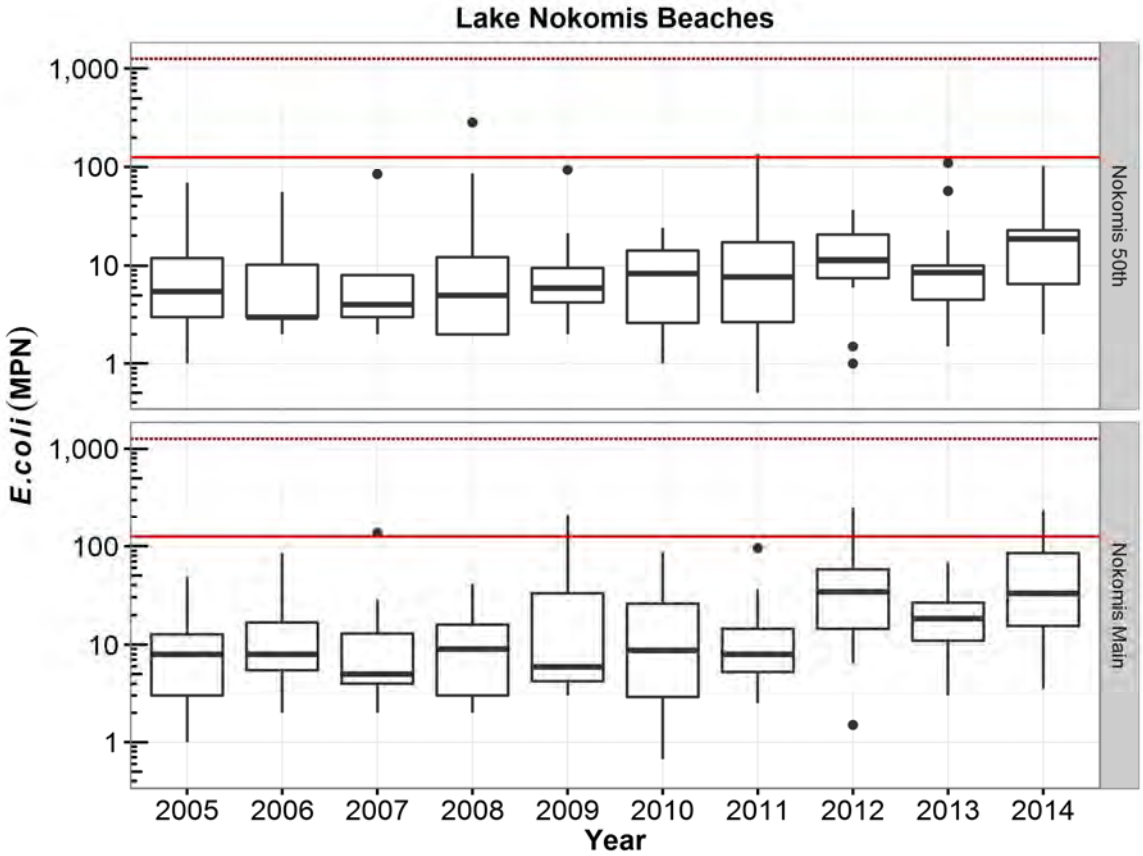


Figure 12-6. Box plots of Nokomis beach *E. coli* results (MPN per 100 mL), 2005–2014. The horizontal lines represent the *E. coli* standard for the 30-day geometric mean (126 MPN/100mL) and the single-sample maximum standard (1260 MPN/100mL). Note the log scale on the Y-axis. From 2004-2009 E. coli concentrations were determined as colony forming units (CFU/100ml).

LAKE AESTHETIC AND USER RECREATION INDEX (LAURI)

Figure 12-7 shows the LAURI scores for Lake Nokomis. In 2014, the lake scored "excellent" in aesthetics, public health, water clarity, and recreation access. Habitat quality was scored as "good." Large amounts of algae typically limit water clarity which prevents light from penetrating into the water column and limits the amount of plant growth in the lake. See **Section 1** for details on the LAURI index.

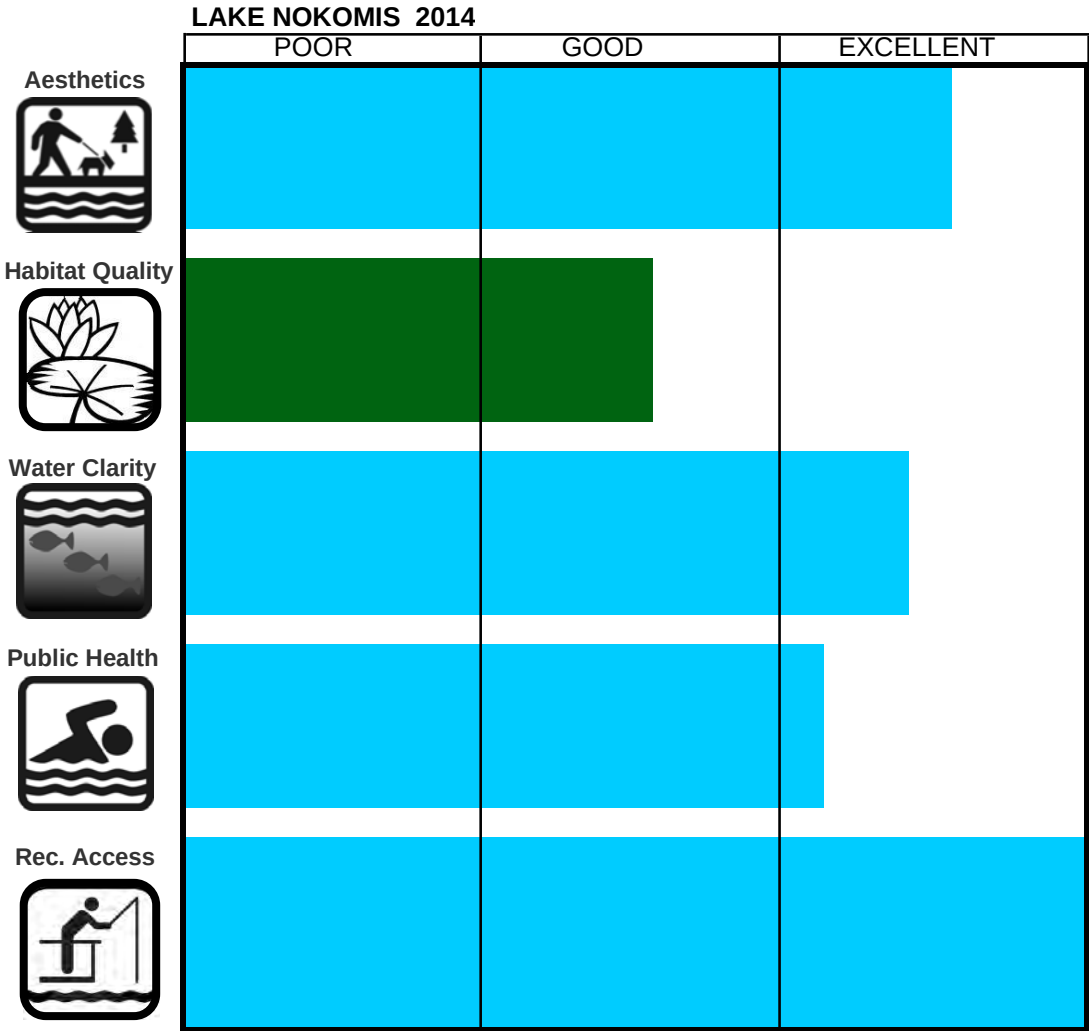


Figure 12-7. The 2014 LAURI Index scores for Lake Nokomis.

WINTER ICE COVER

Ice came off Lake Nokomis on April 17, 2014, 12 days later than average and the latest ice-off date recorded for the lake. Ice came back on to the lake for the winter on November 17, 2014, which was 14 days earlier than average for the lake. See **Section 1** for detailed winter ice records and **Section 18** for comparison with other lakes.

EXOTIC AQUATIC PLANT MANAGEMENT

The MDNR requires a permit to remove or control Eurasian watermilfoil. Permits limit the area from which milfoil 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 was 15 acres, which is just under 15% of the littoral zone (area shallower than 15 feet). In 2014, 1truckload of aquatic plants was removed from the beach areas at Lake Nokomis using SCUBA divers. See **Section 1** and **Section 20** for details on aquatic plants.

PHYTOPLANKTON AND ZOOPLANKTON

Phytoplankton and zooplankton are the microscopic plant and animal life that form the foundation of the food web in lakes. **Figure 12-8** shows the Secchi transparency, chlorophyll-*a* concentrations, and relative abundance of phytoplankton divisions and **Figure 12-9** shows the zooplankton abundance during the 2014 sampling season. The winter sample in 2014 was comprised predominantly of cryptomonads (Cryptophyta) and some green algae; however, algal abundance was low with chlorophyll-*a* concentrations below detection. Algal abundance remained low through most of the year with chlorophyll-*a* levels less than 13 µg L^{-1}, with the exception of September and October when levels reached 25 µg L^{-1}. Diatoms (Bacillariophyta) were abundant in the spring and again in October and blue green algae (Cyanophyta) was abundant the majority of the summer and fall, at times making up more than 90% of the community. The emergence of chrysophytes at the end of May and then again in the beginning of July is interesting as this group is typical of cool, deep waters.

The 2014 zooplankton distribution in Lake Nokomis is shown in **Figure 12-9**. Nauplii and juveniles were present in high numbers in the spring and slowly tapered off to low levels in the fall. Rotifers were present the entire year but were in the highest density in June, August, and September. Cladocerans, the primary grazers, were also present throughout the year and were abundant in June. Calanoid, cyclopoids, and protozoa were present in small numbers during the year as well. Overall density was low in July and November.

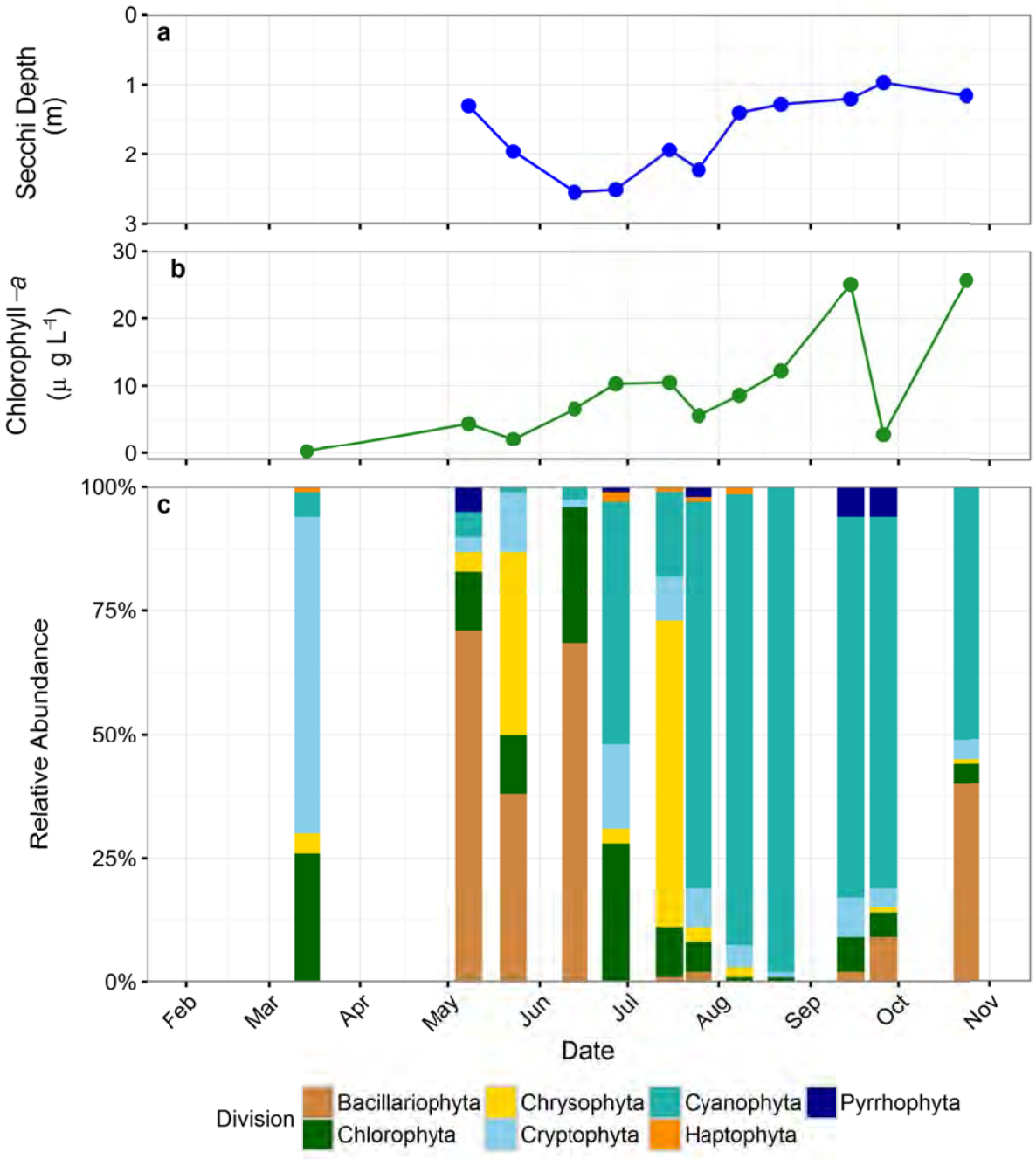


Figure 12-8. Secchi transparency (a), chlorophyll-*a* concentration (b), and relative abundance of phytoplankton (c) during the 2014 Lake Nokomis sampling season. Note that the Secchi depth axis is reversed.

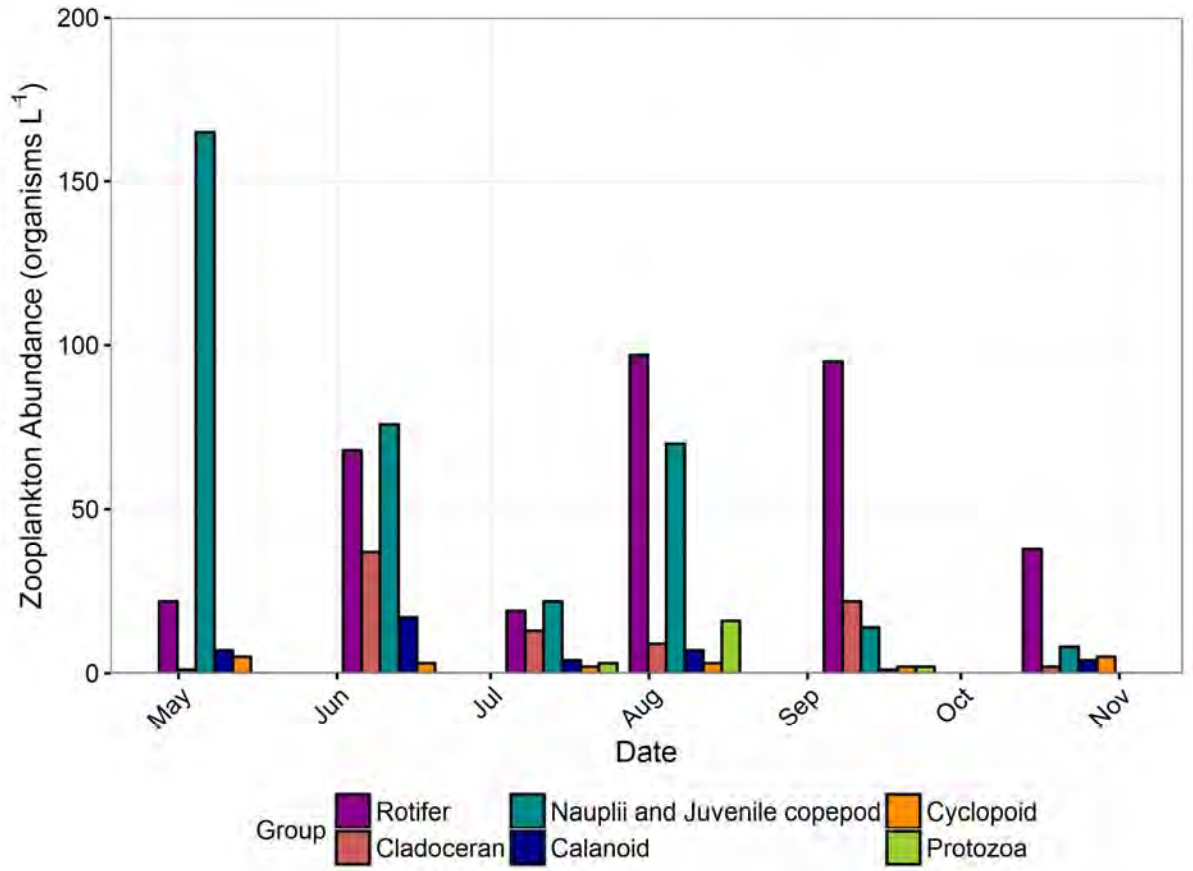


Figure 12-9. Zooplankton distribution in 2014 in Lake Nokomis.

FISH STOCKING

Additional information and a definition of fry, fingerling, yearling and adult fish can be found in **Section 1**.

Lake Nokomis was stocked by the MDNR in:

1998 with 400 fingerling Tiger Muskellunge.

1999 with 82,144 fry Tiger Muskellunge, 773 fingerling Walleye, 46 yearling Walleye.

2000 with 300 fingerling Tiger Muskellunge.

2001 with 8,065 fingerling Walleye.

2002 with 300 fingerling Tiger Muskellunge.

2003 with 7,873 fingerling Walleye.

2005 with 4,266 fingerling Walleye.

2006 with 300 fingerling Tiger Muskellunge.

2007 with 740 yearling Walleye, 63 fingerling Walleye, 156 adult Walleye.

2009 with 458 fingerling Tiger Muskellunge and 7,718 fingerling Walleye.

2010 with 200 fingerling Tiger Muskellunge.

2011 with 9,376 fingerling Walleye.

2012 with 200 Tiger Muskellunge and 2,000 yearling Walleye.

2013 with 8,476 fingerling Walleye.

2014 with 200 fingerling Tiger Muskellunge.

EVENTS REPORT

On July 28, 2010, zebra mussels (*Dreissena polymorpha*) were confirmed to be present in Lake Minnetonka and at the headwaters of Minnehaha Creek by MDNR ecologists. The MDNR declared both Lake Minnetonka and Minnehaha Creek to be infested with zebra mussels. All public waters with Minnehaha Creek connections were also declared infested with zebra mussels including: Meadowbrook Lake, Lake Nokomis, and Lake Hiawatha. MRPB and affiliate group Friends of Lake Nokomis monitor zebra mussel sampling plates in Lake Nokomis monthly. Additionally, the fixed weir installed in 2012 will protect Lake Nokomis from zebra mussel veligers floating down Minnehaha Creek, a proactive approach to protect the lake from invading forces. As of the fall of 2014, no zebra mussels have been found in Lake Nokomis.

MPRB's Zebra Mussel Action Plan can be found on the MPRB website keywords Zebra Mussel Action Plan.

MCWD wrapped up a three year biomanipulation study in the fall of 2013 to reduce excessive algal growth by manipulating the fish community. Black bullheads were seined from the lake and walleyes were stocked in order to reduce sediment disturbance by fish foraging. Early results show a decline in black bullhead and stunted bluegill populations and an above normal walleye population. However, the macrophyte community is not responding quickly, as much of the littoral zone remains free of aquatic plants. It may take years to see potential benefits to biomanipulation and MPRB will continue to monitor any long term effects. More information can be found at http://www.minnehahacreek.org/project/lake-nokomis-biomanipulation-project.

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 gun's powderhorn. Dipper dredge operations were conducted shortly thereafter from 1894 to 1904. 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. Powderhorn Lake has always been a very popular neighborhood lake. It has been stocked by the MDNR as a Kid's Fishing Pond since 1980. Powderhorn Park hosts several large community events including the May Day Festival and the Powderhorn Art Festival.

Figure 13-1. Powderhorn Lake.

Powderhorn is a shallow lake with an island and one deep hole at its southeastern end (**Figures 13-1 and 13-2, Table 13-1**). Computer modeling indicates the lake was historically eutrophic (MPRB, 1999). Restoration activities were implemented as early as 1975 when a temporary summer aerator was installed to increase oxygen content in deeper water and to prevent fish kills. In 1995, a winter aeration system was installed with the MDNR to provide a refuge for fish and prevent winter fish kills. Lake water levels are occasionally augmented with groundwater.

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 plants were planted to improve aesthetics and habitat, and to filter overland flow from the park. Restoration also included repairing the Works Progress Administration (WPA) stone wall, removing concrete sluiceways, and installing a permanent summer aerator. An alum treatment was conducted in May 2003 to limit phosphorus availability. The combined effects of these restoration projects have improved water quality in Powderhorn Lake; however, the large amount of stormwater entering the lake from its watershed inhibits further improvement.

The MPRB has installed barley straw treatments at Powderhorn every spring since 2004 to control algal growth. While it is difficult to ascertain which restoration activities have benefited the lake the most, the barley straw treatments seem to have been an important tipping point for improving water clarity. Macrophyte beds were first noted in 2006 and led to improved clarity and lower nutrient levels in the lake. In 2010, extensive duckweed (*Lemna spp.*) beds covered the lake and shaded out macrophyte growth. Since 2011, filamentous algae dominated large portions of the lake bed and water surface. The decomposition of thick plant and filamentous algae growth combined with a hot dry summer has led to low oxygen levels in the lake.

Restoration efforts shifted in 2007 when the invasive species *Egeria densa* (Brazilian waterweed) was discovered growing in several small but dense stands in the lake. During the fall of 2007, the MDNR treated the invasive plant with herbicide Diquat to target and eradicate the unwanted species. At the request of the MDNR, 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 based off 5 years of surveys indicating no presence of *Egeria densa*.

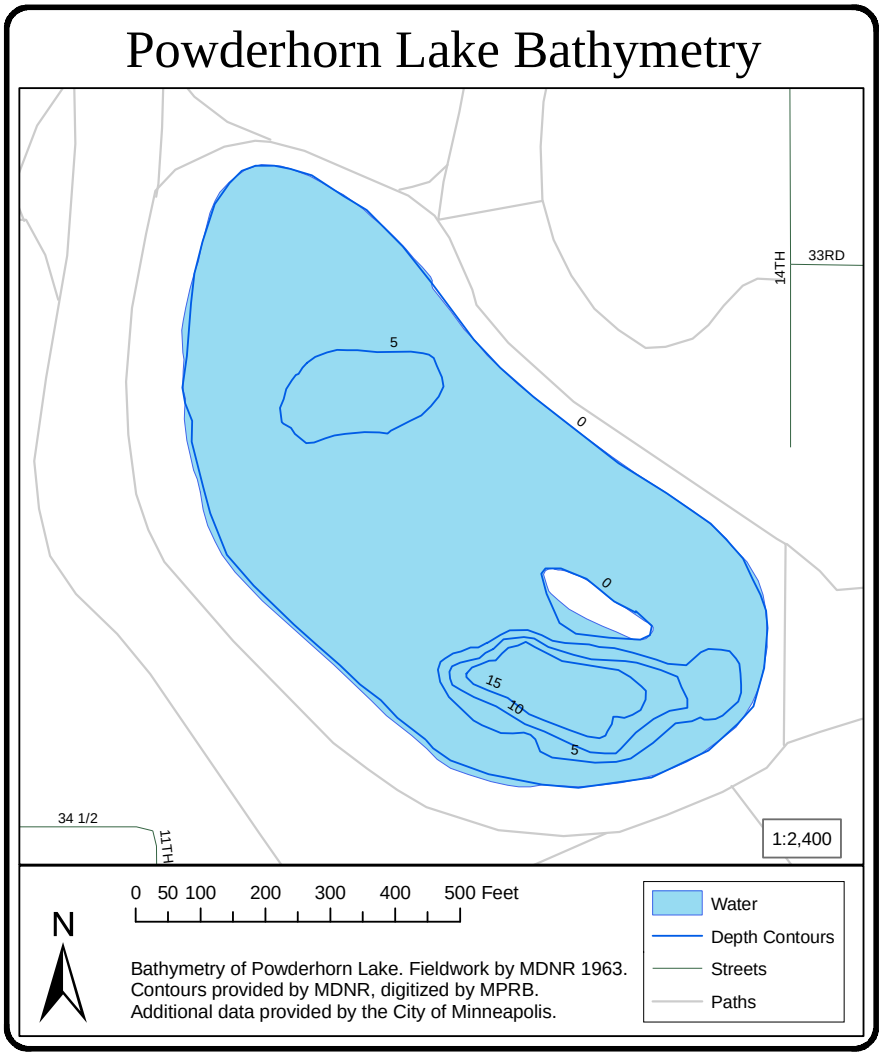


Figure 13-2. Bathymetric map of Powderhorn Lake.

MPCA removed Powderhorn Lake from the EPA 303(d) list of impaired waters in 2012 due to a strong trend towards improved water quality. MPCA and MPRB will continue to evaluate the lake for potential improvement options. Improving oxygen levels, reducing trash accumulation, and reducing filamentous algae growth are all areas where improvements could continue at the lake.

Table 13-1. Powderhorn Lake morphometric data.

Surface Area (acres)	Mean Depth (m)	Maximum Depth (m)	Littoral Area*	Volume (m^3)	Watershed Area (acres)	Watershed: Lake Area (ratio)	Residence Time (years)
11	1.2	6.1	99%	$5.43x10^4$	286	26.0	0.2

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

LAKE LEVEL

Powderhorn Lake levels are recorded weekly during ice free season and are shown in **Figure 13-3** for 1999 through 2014. Water levels were high in 2014 due to heavy rains from April-June. Powderhorn Lake levels are occasionally augmented with a groundwater well. There is no MDNR designated ordinary high water level (OHW) for Powderhorn Lake. See **Section 18** for comparison with other MPRB lake levels.

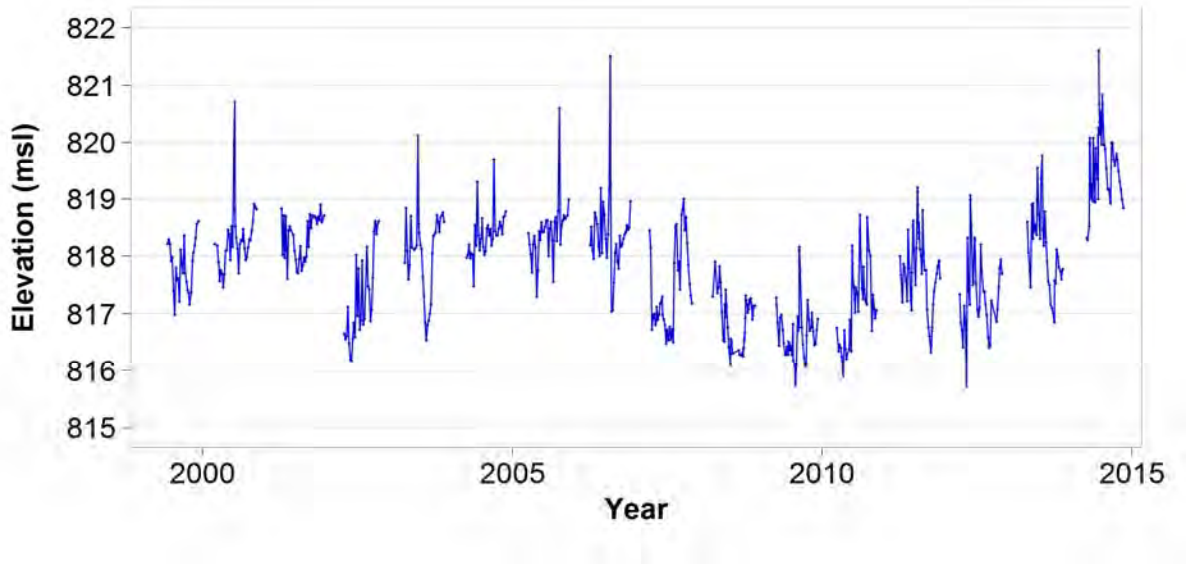


Figure 13-3. Powderhorn Lake levels from 1999 – 2014.

AUGMENTATION WELL

A groundwater well is used to maintain the water level at Powderhorn. The MDNR issues permits and determines pumping limits for augmentation wells. In 2006, the permitted pumping volume decreased from 26 million gallons per year to 10 million gallons per year. MPRB staff records groundwater usage monthly. **Table 13-2** shows the annual water usage since 2007. The groundwater well was not used in 2010 or 2014. See **Section 1** for detailed information on MPRB augmentation wells.

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

2007 Total (gal)	2008 Total (gal)	2009 Total (gal)	2010 Total (gal)	2011 Total (gal)	2012 Total (gal)	2013 Total (gal)	2014 Total (gal)
11,184,600	8,785,200	5,824,800	0	10,371,600	8,014,500	3,261,600	0

WATER QUALITY TRENDS – TROPHIC STATE INDEX (TSI)

Powderhorn Lake has historically been eutrophic due to high nutrient levels. **Figure 13-4** shows TSI scores and a regression line for Powderhorn Lake. Powderhorn Lake has a TSI score of 70 in 2014 and is below average for the Northern Central Hardwood Forest ecoregion falling in the 75^{h} percentile for this ecoregion based on calculations from the Minnesota Pollution Control Agency, using the Minnesota Lake Water Quality Data Base Summary, 2004. There is no linear trend in TSI scores with water quality fluctuating over the past 20 years with improved TSI scores during restoration efforts from 2001-2009. CDS units decreased phosphorus, solids, and sediment inputs, annual barley straw treatments increased water clarity, and an alum treatment briefly decreased phosphorus and increased water clarity. However, after the majority of the restoration plan projects had been completed in 2009, the trend is changing towards higher TSI scores and lower water quality. A detailed explanation of TSI can be found in **Section 1**.

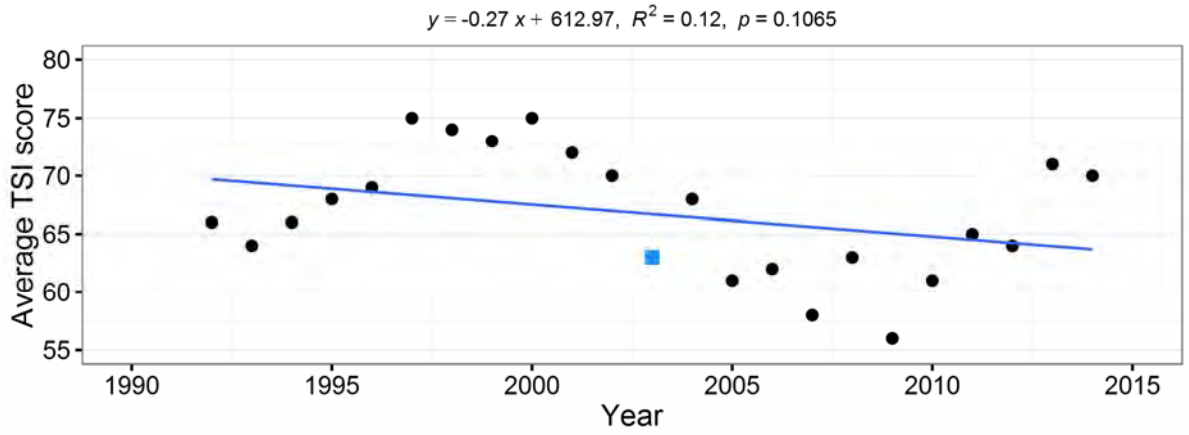


Figure 13-4. Powderhorn Lake TSI scores and regression analysis. The blue square highlights the 2003 alum treatment.

BOX AND WHISKER PLOTS

Figure 13-5 shows box and whisker plots for the Powderhorn Lake data for the past ten years. MPCA shallow lake standards are shown as a horizontal line across the graph. A further detailed explanation of box and whisker plots can be found in **Section 1**. Box and whisker plots from the entire period of record from Powderhorn Lake can be found in **Appendix A.**

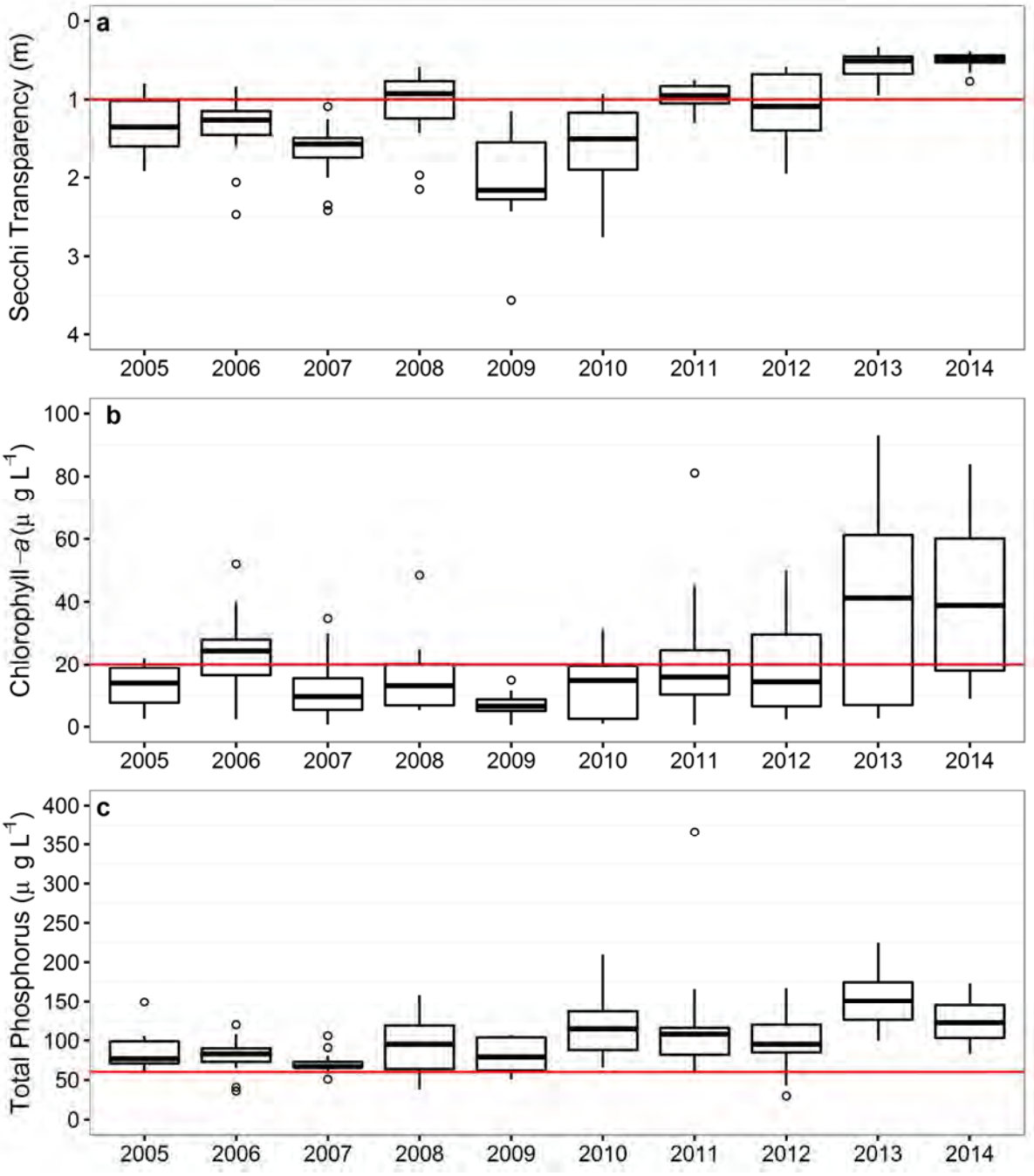


Figure 13-5. Box and whisker plots of data from Powderhorn Lake: 2005-2014. Horizontal lines represent MPCA eutrophication standard for shallow lakes. See Appendix A for the entire period of record.

Marked improvements in the TSI parameters have been seen in Powderhorn Lake during the restoration projects, but have increased to pre-restoration levels in recent years. The Secchi transparency, chlorophyll-*a* and total phosphorus concentrations in 2014 were similar to 2013where none of them met MPCA eutrophication standards. As shown in **Appendix A**, 2014 resemble data from the late 1990s more than the mid-2000s.

Nitrogen levels remain lower than pre-2001 levels, as shown in **Figure 13-6.** It is unknown why nitrogen levels have decreased so drastically. CDS units and grit chambers were installed in the watershed at this time, but the mechanism by which these BMPs would influence nitrogen is not known.

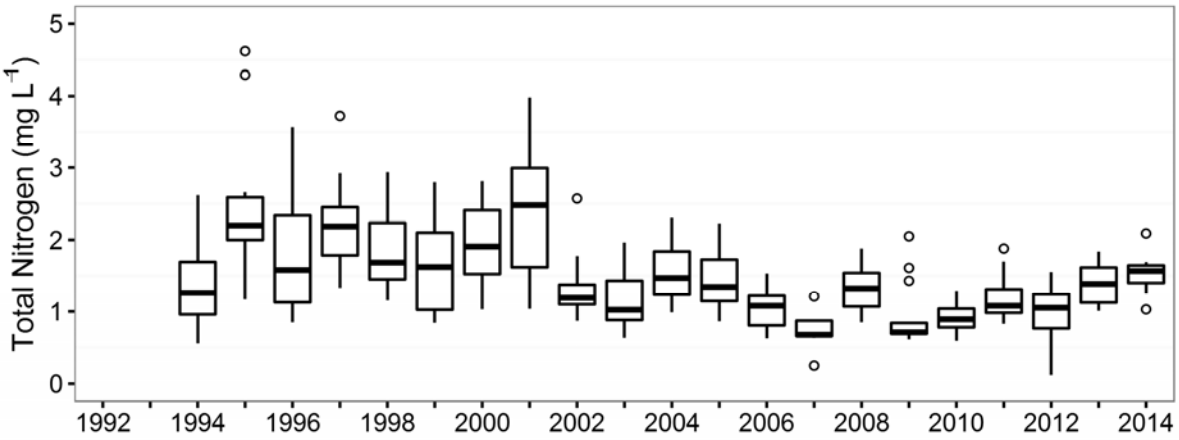


Figure 13-6. Total nitrogen data from Powderhorn Lake: 1994- 2014.

LAKE AESTHETIC AND USER RECREATION INDEX (LAURI)

The LAURI for Powderhorn Lake is shown in **Figure 13-7**. In 2014, Powderhorn Lake scored "excellent" in aesthetics and "good" in habitat quality. Powderhorn received a score of "poor" in recreational access and water clarity. Powderhorn Lake does not have a swimming beach and was not scored for public health. See **Section 1** for details on the LAURI.

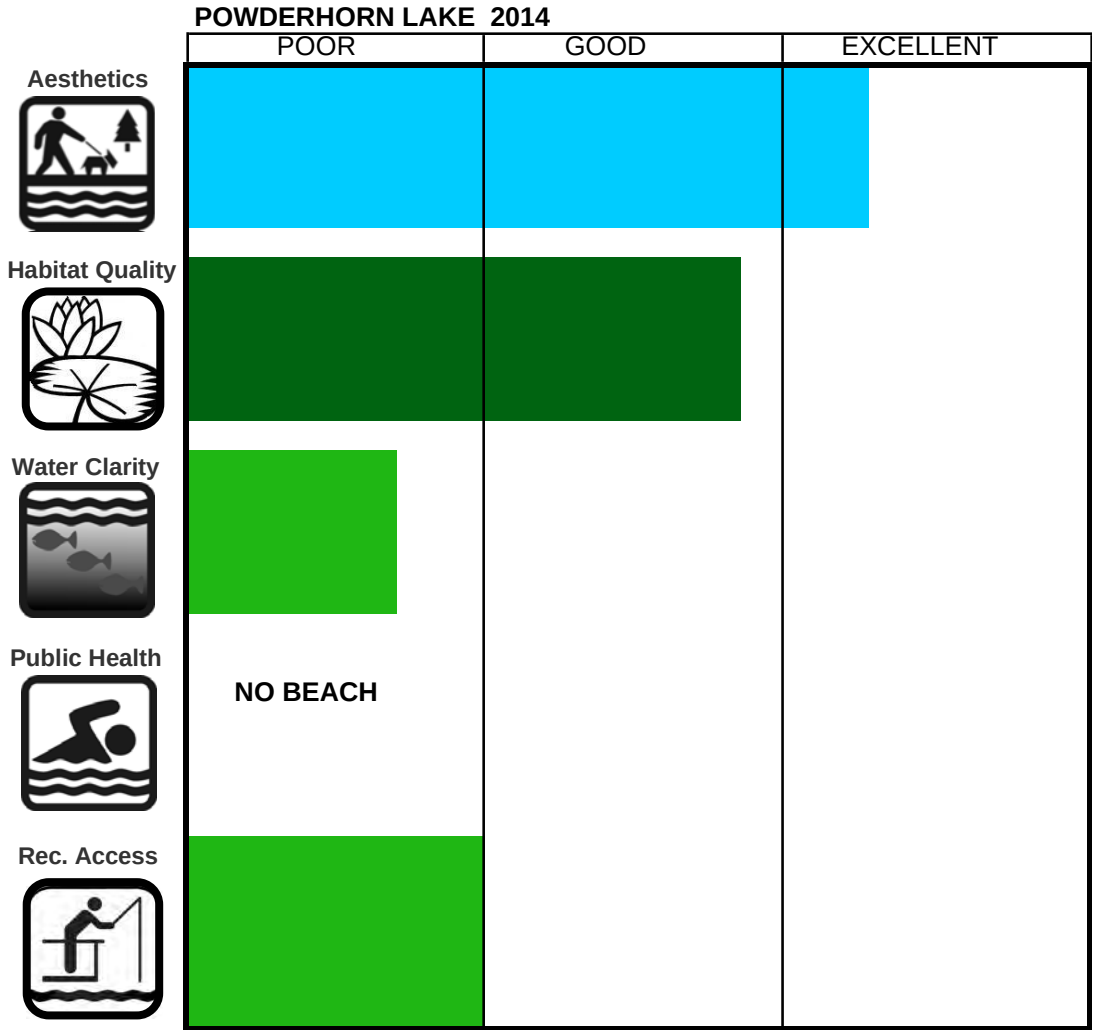


Figure 13-7. The 2014 LAURI scores for Powderhorn Lake.

WINTER ICE COVER

Ice came off of Powderhorn Lake on April 14, 2014, ten days later than average. Ice came back onto the lake on November 17, 2014, which was 11 days earlier than the average ice-on date for the lake. Waterfowl keep Powderhorn Lake open later in some years. See **Section 1** for details on winter ice cover records and **Section 18** for a comparison with other lakes.

PHYTOPLANKTON AND ZOOPLANKTON

Phytoplankton and zooplankton are the microscopic plant and animal life that form the foundation of the food web in lakes. **Figure 13-8** shows the Secchi transparency, chlorophyll-*a* concentrations, and relative abundance of phytoplankton divisions and **Figure 13-9** shows the zooplankton abundance during the 2014 sampling season.

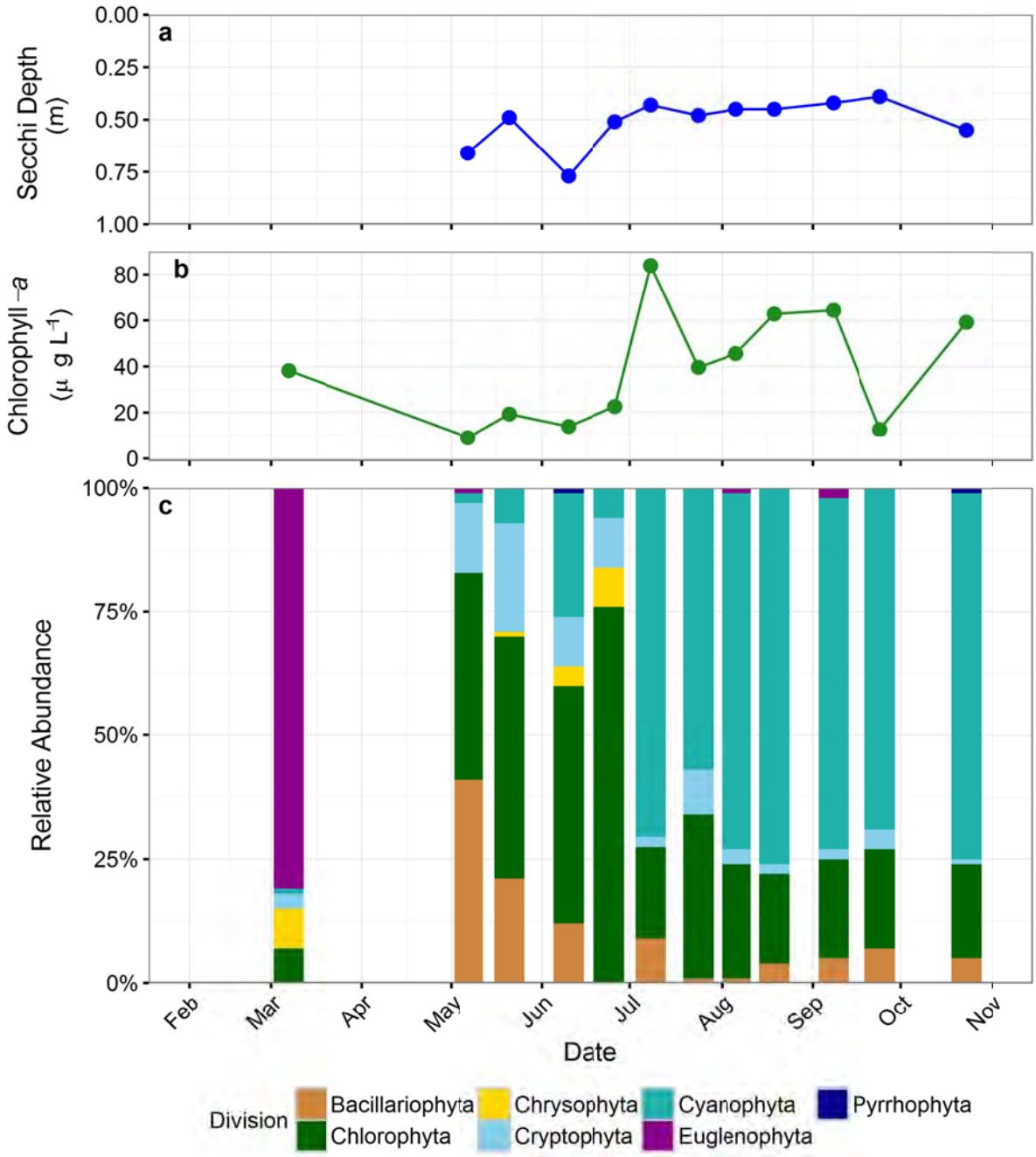


Figure 13-8. Secchi transparency (a), chlorophyll-*a* concentration (b), and relative abundance of phytoplankton (c) during the 2014 Powderhorn Lake sampling season. Note that the Secchi depth axis is reversed.

The phytoplankton community in the winter was greater than 75% euglenoids (Euglenophyta), a group that is characteristic of waters with high nutrients and organic matter. Water clarity was poor (< 1 m) for the entire year with chlorophyll-*a* concentrations ranging from 9-84 µg L^{-1} and often exceeding 40 µg L^{-1} from July through October. The open water season was characterized by a phytoplankton community comprised of a mix of diatoms (Bacillariophyta), green algae (Chlorophyta), and blue green algae (Cyanophyta). Diatoms and green algae being more abundant in the spring before blue greens made up over 70% from July through October, when chlorophyll-*a* levels were at their highest.

Rotifers were at high levels in May, June, and then again in August. Interestingly, rotifers comprised the entire zooplankton sample in May. Cladocerans were present at low numbers in the rest of the samples and reached the highest density in July. Nauplii and juveniles were present in the rest of the samples as well with the highest abundance in August. Cyclopoids were present in Powderhorn, but only at low numbers (**Figure 13-9**).

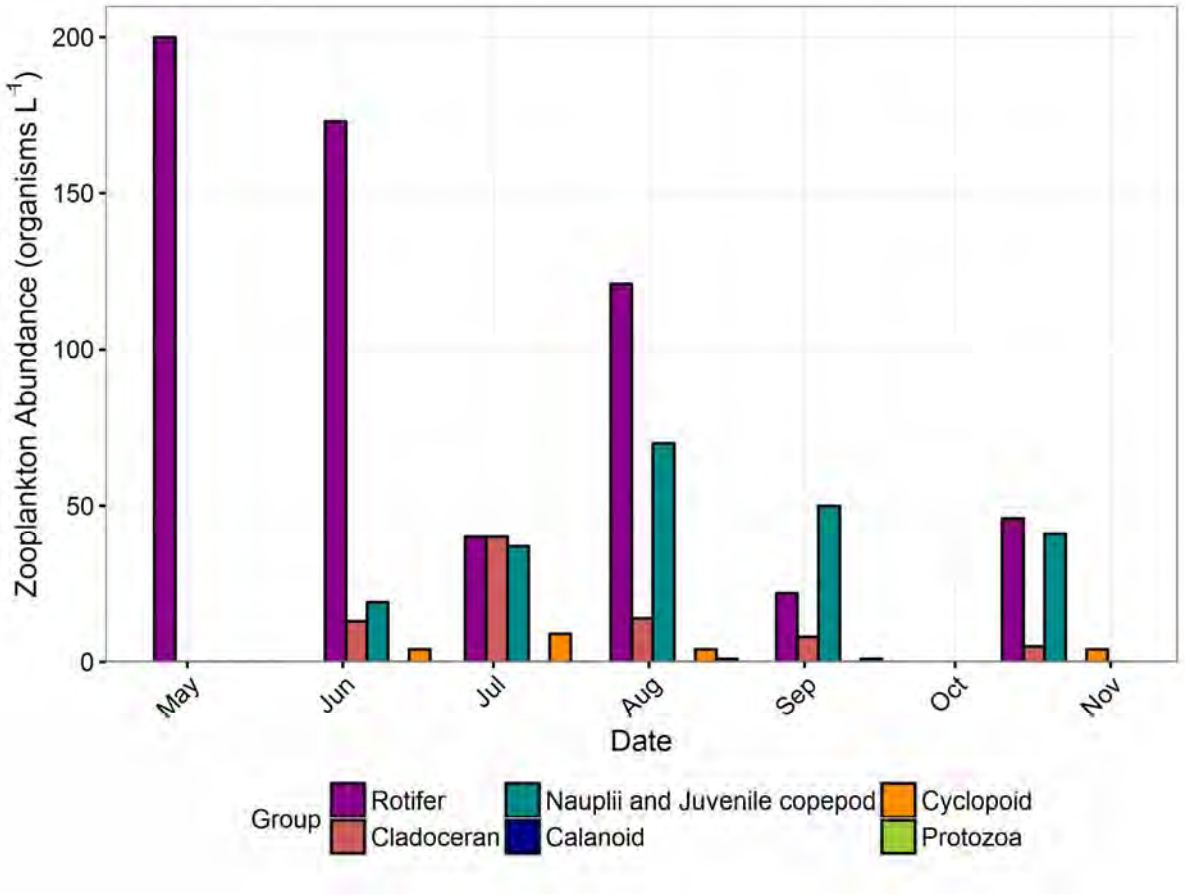


Figure 13-9. Zooplankton distribution in Powderhorn Lake during 2014.

FISH STOCKING

Additional fish stocking information can be found in **Section 1**.

Powderhorn Lake was stocked by the MDNR in:

1998 with 585 adult Bluegill Sunfish.
1999 with 501 adult Black Crappie, 1,008 adult Bluegill Sunfish, 9 adult Largemouth Bass.
2000 with 380 adult Black Crappie, 1,728 adult Bluegill Sunfish.
2001 with 510 adult Black Crappie, 1,002 adult Bluegill Sunfish.
2002 with 510 adult Bluegill Sunfish.
2003 with 422 adult Black Crappie, 1,614 adult Bluegill Sunfish.

2004 with 270 adult Black Crappie, 516 adult Bluegill Sunfish, 99 adult Channel Catfish.

2005 with 500 adult Bluegill Sunfish, 120 adult Channel Catfish.

2006 with 500 adult Bluegill Sunfish, 100 adult Channel Catfish.

2007 with 500 adult Bluegill Sunfish, 85 adult Channel Catfish.

2008 with 500 adult Bluegill Sunfish, 117 adult Channel Catfish, and 1 adult Largemouth Bass.

2009 with 499 adult Bluegill Sunfish, 75 adult Channel Catfish, 20 adult Largemouth Bass.

2010 with 623 adult Bluegill Sunfish, and 137 adult Channel Catfish.

2011 with 277 adult Bluegill Sunfish, 116 adult Channel Catfish, and 13 adult Largemouth Bass.

2012 with 711 adult Bluegill Sunfish, and 35 adult Channel Catfish.

2014 with 3 adult Black Crappie, 346 adult Bluegill Sunfish, 173 adult Channel Catfish, 4 adult Hybrid Sunfish, and 4 adult Pumpkinseed.

WATER QUALITY PROJECTS

Water quality improvement projects have been implemented to improve the health of Powderhorn Lake and are detailed in the History section of this chapter. Barley straw was first used at Powderhorn Lake in 2004 when 250 pounds/acre were added. Barley straw is applied by staking loose bales below the surface of the water where it slowly decomposes. The first treatment appeared to have little effect. Application rates were increased to 364 lbs/ac or 4000 pounds for the lake, and appear to have been more successful. 2014 was the 11th application of barley straw to Powderhorn Lake.

14. RYAN LAKE

HISTORY

Ryan Lake is a small body of water that borders the cities of Robbinsdale, Brooklyn Center, and Minneapolis and is shown below in **Figure 14-1**. The Canadian Pacific Railway owns a rail line corridor in the Humboldt Industrial Park that runs along the northern shore of the lake. The City of Minneapolis owns land on the east side of the lake which is maintained by the Minneapolis Park and Recreation Board (MPRB). Private residents own the west and the south shores of Ryan Lake. The 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. **Figure 14-2** shows a bathymetric map of Ryan Lake and **Table 14-1** shows the morphometric data on Ryan Lake.

Figure 14-1. View at Ryan Lake, 2012.

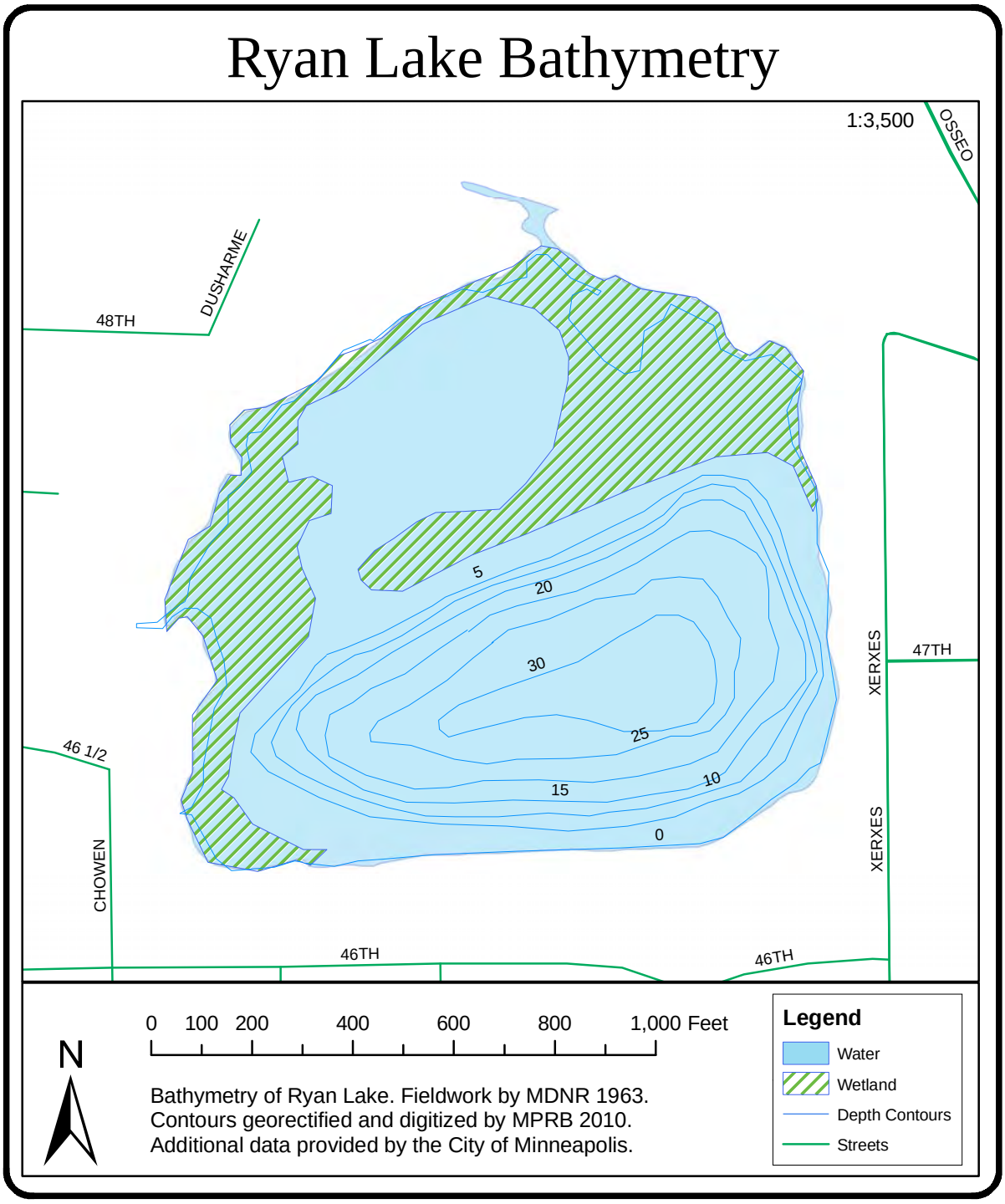


Figure 14-2. Bathymetric map of Ryan Lake.

Table 14-1. Ryan Lake morphometric data. OHW= designated ordinary high water level.

Surface Area (acres)	Max Depth (m)	Littoral Area*	Watershed Area (acres)	Watershed:Lake Area (ratio)	OHW (ft msl)
19	10.7	50%	5,510	306	849.6

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

Ryan Lake has been monitored periodically through the Metropolitan Council's Citizen Assisted Monitoring Program (CAMP) since 1994, but was not monitored in 2014. Over the years, the Ryan Lake CAMP score has fluctuated between a "B" and "D", with a most recent score of a "B". Additional information on the CAMP monitoring at Ryan Lake can be found through the Metropolitan Council on their Wastewater and Water Publications and Resources webpage.

WINTER ICE COVER

Ice was off of Ryan Lake on April 14, 2014, eight days later than average. Ice came back to Ryan Lake on November 17, 2014, 19 days earlier than the average ice-on date. See **Section 1** for details on winter ice cover records and **Section 18** for a comparison with other lakes.

FISH STOCKING

Additional information on fish stocking can be found in **Section 1**. Ryan Lake was stocked by MDNR in:

2004 with 20 adult Black Crappie, 30 adult Bluegill Sunfish, and 5 adult Largemouth Bass

2007 with 20 adult Black Crappie, 24 adult Bluegill Sunfish, 10 adult Largemouth Bass, and 8 adult Northern Pike.

2008 with 31 adult Bluegill Sunfish, and 100 Yellow Perch.

2009 with 20 adult Bluegill Sunfish, and 21 adult Yellow Perch.

2010 with 20 adult Black Crappie, 20 adult Bluegill Sunfish, and 20 adult Yellow Perch.

2011 with 20 adult Bluegill Sunfish, 20 Black Crappie, and 6 Largemouth Bass

2013 with 130 yearling Yellow Perch.

2014 with 9 adult Black Crappie, 14 adult Bluegill Sunfish, 3 adult Largemouth Bass, 9 adult Northern Pike, 15 adult Pumpkinseed, and 5 adult White Crappie.

15. SPRING LAKE

HISTORY

Spring Lake is located to the west of Loring Pond adjacent to Kenwood Parkway and the Parade Stadium grounds in central Minneapolis. Spring Lake was acquired by the MPRB in 1893 through a special assessment requested by citizens. 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, a 2-acre area including the lake and surrounding land was designated as a bird sanctuary and kept in a natural state. Historic photos and documents show that the north side of the lake was once a lumberyard.

Despite being surrounded by parkland on three sides, Spring Lake is a definite urban lake, **Figure 15-1**. Highway 394 borders the northwest portion of the riparian zone and contributes stormwater runoff to the lake. Spring Lake receives water from a 195-acre subwatershed of the Bassett Creek watershed. These urban stormwater inputs contribute to meromixis in Spring 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.

The typical sampling schedule requires Spring Lake to be monitored every other year; however, the lake has been sampled each year since 2011 in order to assess the water quality effects of artificial islands (see Water Quality Projects section below). **Table 15-1** shows morphometric data for the lake and **Figure 15-2** shows a map of Spring Lake.

Figure 15-1. Spring Lake in October, 2011. Two of the artificial islands are visible.

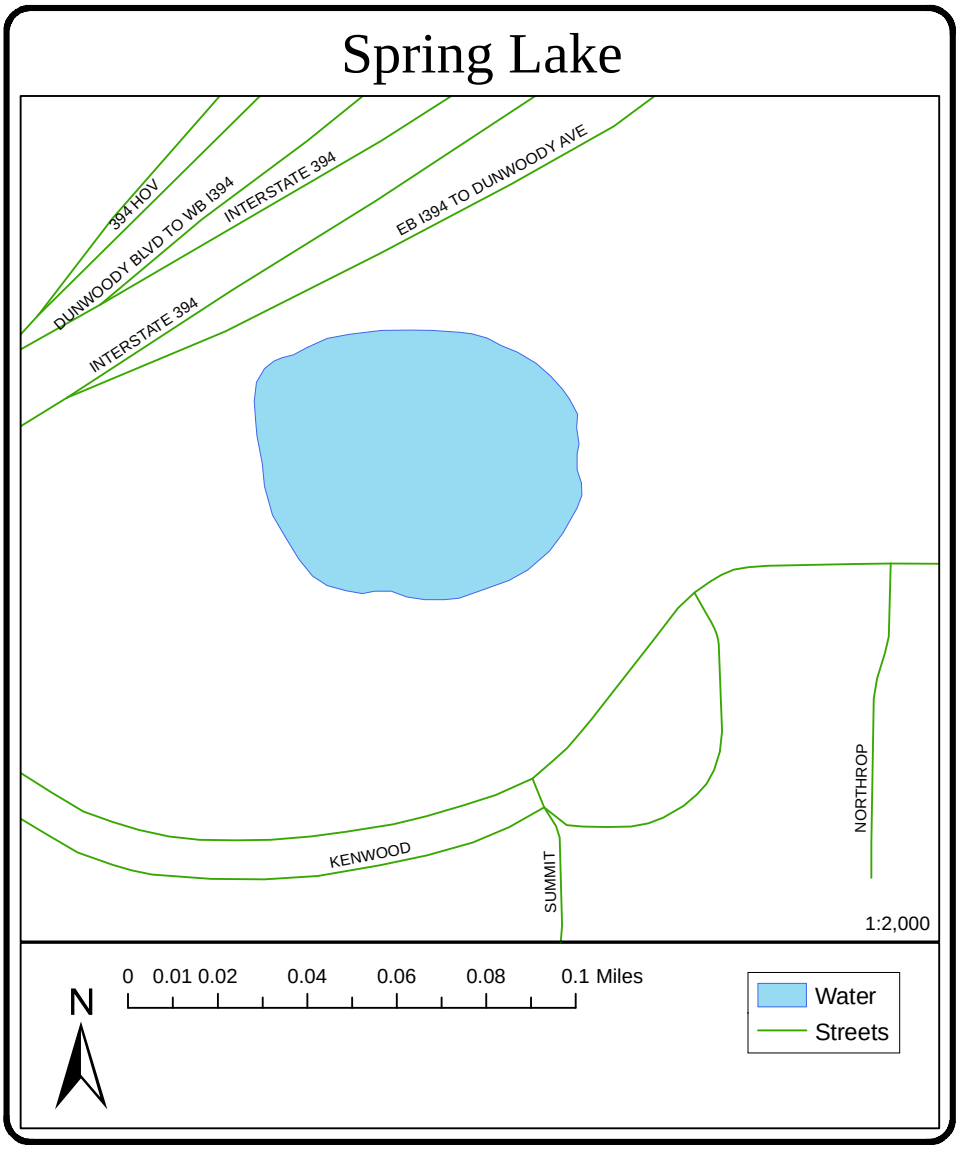


Figure 15-2. Spring Lake map.

Table 15-1. Spring Lake morphometric data. OHW=ordinary high water level.

Surface Area (acres)	Mean Depth (m)	Maximum Depth (m)	Volume (m^3)	Watershed Area (acres)	Watershed: Lake Area (ratio)	OHW (ft msl)
3	3.0	8.5	3.65×10^4	45	15.0	820.46

WATER QUALITY TRENDS – TROPHIC STATE INDEX (TSI)

Figure 15-3 shows the Spring Lake TSI scores and linear regression since 1995. In 2014, Spring Lake had a TSI score of 73, or hypereutrophic. There is no significant trend in TSI from 1995-2014 ($p > 0.05$). Spring Lake's TSI scores and trend line must be viewed with caution as both are based on a limited number of samples and the number of samples collected in a season has changed over time. 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. During 2002, 2003, and subsequent odd-numbered years Spring Lake was sampled monthly in order to calculate a TSI score. A detailed explanation of TSI can be found in **Section 1**.

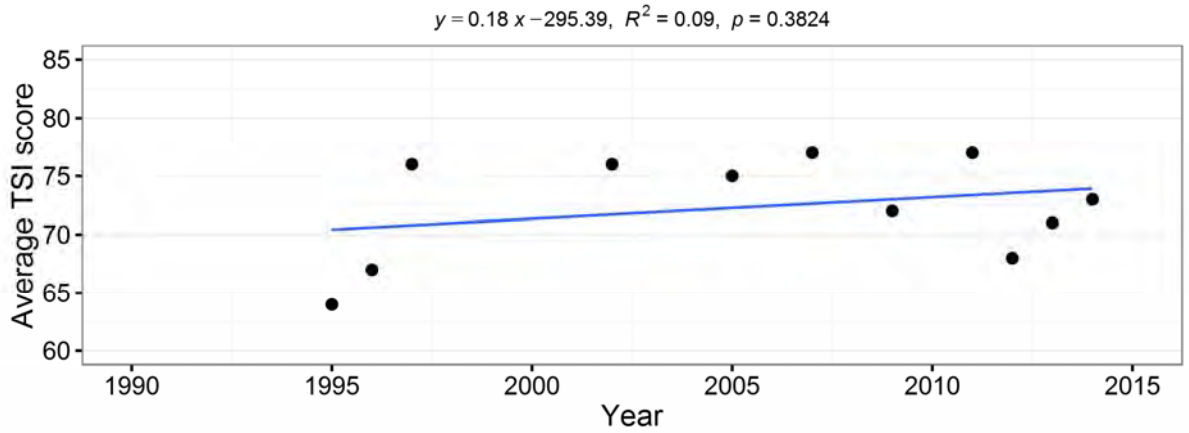


Figure 15-3. Spring Lake TSI scores and regression analysis.

BOX AND WHISKER PLOTS

The box and whisker plots in **Figure 15-4** show the data distribution for the Secchi, chlorophyll-*a*, total phosphorus, and total nitrogen for Spring Lake over the last ten years. Horizontal lines indicate the MPCA nutrient criteria. 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 **Section 1**. Data in similar format for the entire period of record can be found in **Appendix A**.

Spring Lake is eutrophic with considerable amounts of algae at times. High nutrient concentrations in the lake generally contribute to high algal growth and shallow Secchi depths. Although total phosphorus concentrations were lower than the previous few years, levels remained high in 2014. Chlorophyll-*a* concentrations were similar to the previous three years and significantly better than pre-2011 values; however, the lake had one extremely high sample value in September. Since 2011, duckweed (*Lemna spp.*) has covered the lake for much of the summer. The thick layer of duckweed can shade photosynthetic algae, leading to lower chlorophyll-*a* concentrations, and creating low dissolved oxygen levels. The fresh oxygenated layer that typically forms on the surface of Spring Lake was very thin to non-existent in 2014.

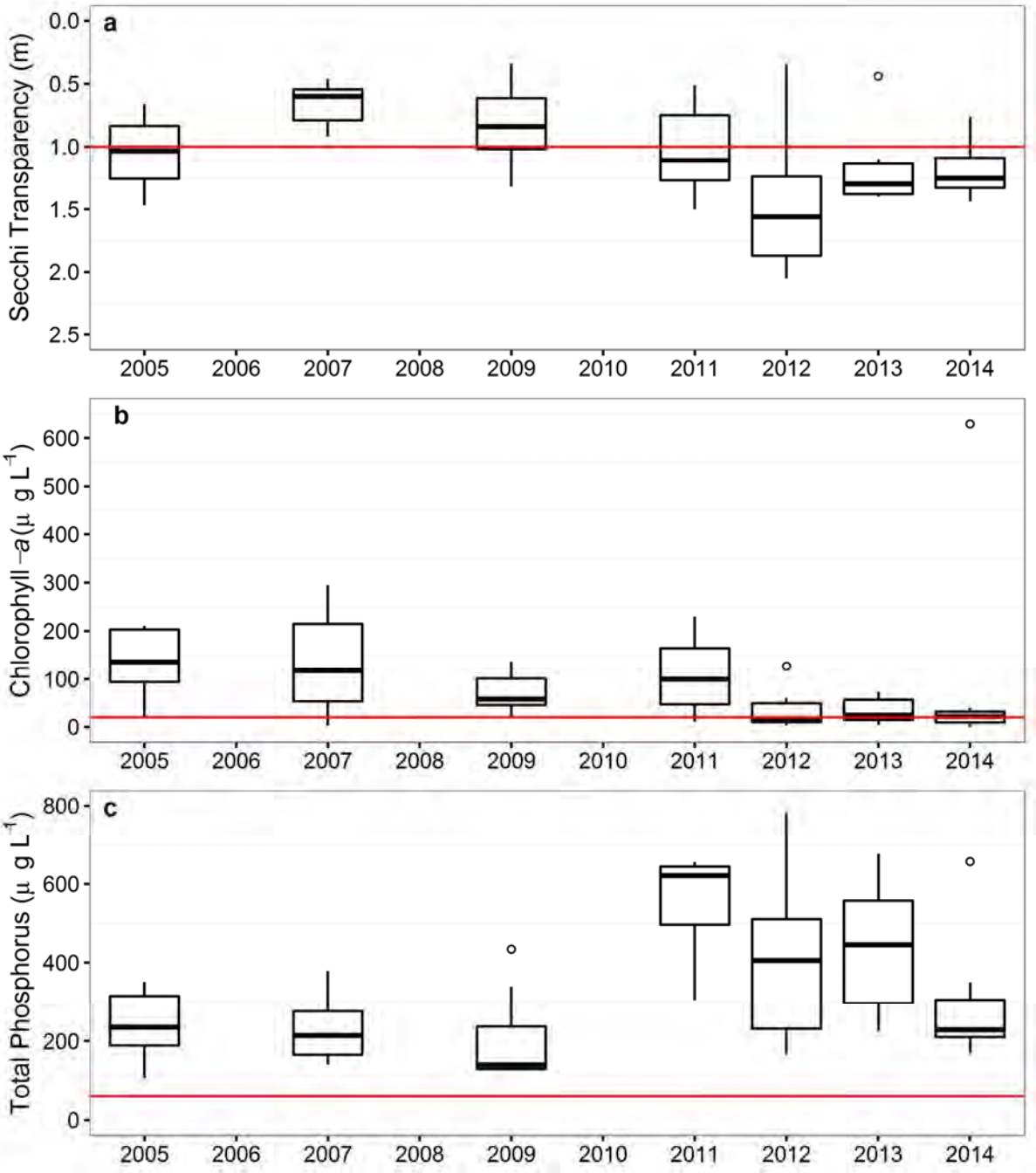


Figure 15-4. Box and whisker plots of Spring Lake TSI data: 2005-2014. Horizontal lines represent MPCA eutrophication standard for shallow lakes. See Appendix A for the entire period of record.

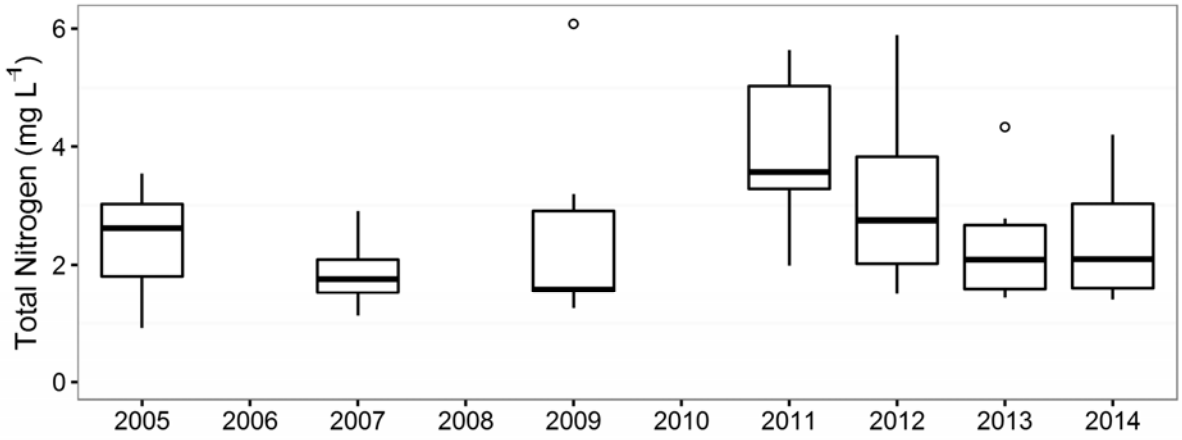


Figure 15-4 continued. Box and whisker plots of Spring Lake TSI data: 2005-2014. Horizontal lines represent MPCA eutrophication standard for shallow lakes. See Appendix A for the entire period of record.

WINTER ICE COVER

The ice came off Spring Lake on April 10, 2014, nine days later than average. Ice covered Spring Lake on November 14, 2014, 14 days earlier than the average ice-on date for the lake. See **Section 1** for details on winter ice cover records and **Section 18** for a comparison with other lakes.

PHYTOPLANKTON AND ZOOPLANKTON

Phytoplankton are the 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 Secchi transparency, chlorophyll-*a* concentrations, and relative abundance of phytoplankton divisions for Spring Lake in 2014. 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.

Water transparency remained fairly stable between 1-1.5 m for much of the open water season until chlorophyll-*a* concentrations went from below 40 µg L^{-1} to greater than 600 µg L^{-1} in September. It is unknown why chlorophyll-*a* levels were that high. Green algae (Chlorophyta) made up the majority of the phytoplankton community (>75%) in May, but cryptomonads (Cyrptophyta) made up over 80% of the samples the remainder of the year. In past sampled years, Spring Lake has had a diverse phytoplankton community; however since 2012, Spring Lake has exhibited a strongly homogenous phytoplankton population dominated by cryptomonads (Cyrptophyta). It is possible that less-frequent sampling makes the community appear less complex, but *Lemna* cover in recent years may also be affecting the phytoplankton community composition.

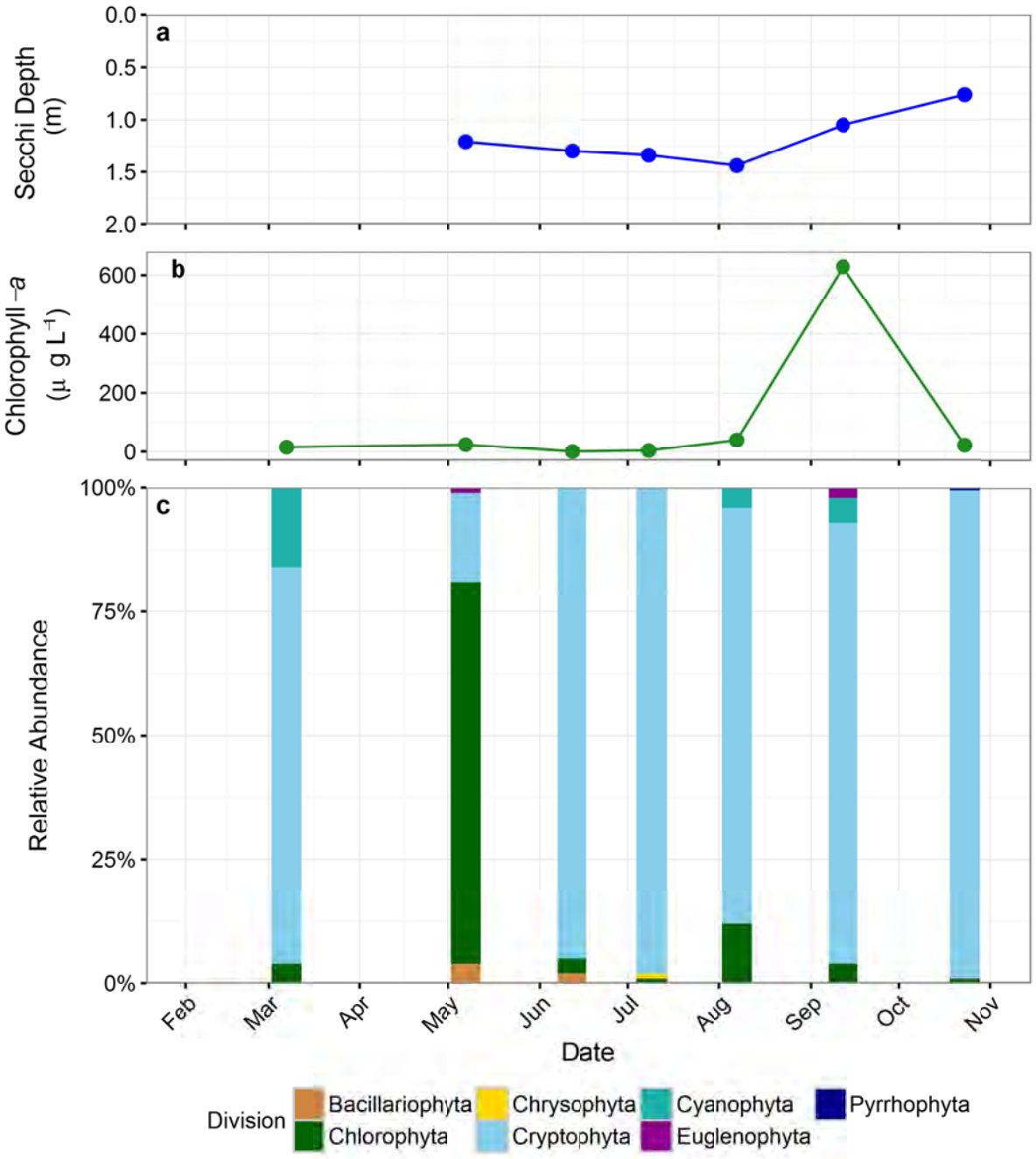


Figure 15-5. Secchi transparency (a), chlorophyll-*a* concentration (b), and relative abundance of phytoplankton (c) during the 2014 Powderhorn Lake sampling season. Note that the Secchi depth axis is reversed.

WATER QUALITY PROJECTS

In August of 2011, the Minnesota Chapter of the American Society of Landscape Architects (ASLA), the Lowry Hill Neighborhood Association, and Blake School partnered with the MPRB to install seven floating artificial biohavens in Spring Lake (**Figure 15-6)**. Funds for the project were donated by the Lowry Hill Neighborhood and Midwest Floating Islands. Volunteers planted the biohavens

with a combination of native vegetation chosen as aggressive, pioneer species, cover plants, or plants with food value for birds. Each biohaven was planted with a unique combination of plant species.

The biohavens were intended to add aesthetic value, bird habitat, and potential water quality benefits to Spring Lake. The biohavens are composed of a high surface area recycled plastic matrix, which will grow a biofilm together with root systems established by the plantings. As the biofilm and the plants on the biohaven grow, it is theorized that nutrients will be removed from the water and will be recycled back to the lake as the plants and biofilm senesce. Birds may be sources and sinks of nutrients for Spring Lake as they may eat seeds and fruits produced on the biohavens but may contribute nutrients from outside of the system as well.

Plant growth and biohaven performance were qualitatively monitored monthly during the growing season by MPRB. Regular monitoring of TSI parameters in Spring Lake will allow comparison between pre- and post-island years. Biohaven performance will be evaluated for use in other MPRB projects such as stormwater ponds and shoreline restoration.

Figure 15-6. Locations of biohavens in Spring Lake.

2014 Observations

2014 marked the third full year of growth for the biohavens. Monthly monitoring trips showed the islands are in need of general maintenance. The purple loosestrife infestation is increasing, with all 7 islands having at least 20% coverage of the invasive plant and making up greater than 90% of the vegetation at times. Contrary to what was observed in 2013, volunteer cattails have receded from the islands. The lower numbered islands are suffering from the greatest purple loosestrife invasion while the higher numbered islands are exhibiting more species diversity and a greater vegetative cover. Plants that are doing well so far in 2014 include sweet flag, blue joint grass, Joe Pye weed, marsh milkweed, boneset, and hardstem bullrush. While these plantings were original plantings on some islands, very few islands exhibit any of the plants on the original planting list **(Figure 15-7**).

Flourishing sweet flag and Joe Pye weed on Island #7	Purple loosestrife accounts for 90% of the vegetation on Island #4	Diversity on Island #6

Figure 15-7. Examples of vegetation on the islands in June of 2014.

Further, there was damage to all the islands ranging from bent fences to exposing substrate. The fences on the majority of islands are it bad shape and in need of repair. The substrate on Islands #1, 2, and 5 are exposed and are in need of more coir wrapping. No holes or burrows in the substrate have been recorded. Islands #5, 6 and 7 detached by the end of 2013 have clustered together on the northwest side of the lake in the cattails. More data is needed before any conclusions can be made on the capability of the floating islands to improve water quality. The MPRB will continue to monitor Spring Lake water quality either on a monthly or bimonthly basis in years to come **(Figure 15-8**).

Examples of bent fences on Islands #1, 2 and 3. All seven fences are in need of maintenance

Figure 15-8. Examples of damage to the islands in June of 2014.

16. WEBBER POND

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 a 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 the configuration of Webber Pond that existed until 2013.

Figure 16-1. Webber Natural Swimming Pool under construction

On August 14, 2013, Webber Park was redeveloped to make way for the Webber Natural Swimming Pool (**Figure 16-1**). In February 2012, the MPRB Board of Commissioners approved a $6.1 million Master Plan to renovate Webber Park. The plan consists of a natural swimming pool, regeneration area, stormwater pond, and pool house (**Figure 16-2**). MPRB contracted BioNova Natural Pool and Landform companies for the project. The Webber natural swimming pool will rely on a biological filtration system rather than chemicals to maintain a safe swimming environment. Water will flow from the swimming area through filters to remove particulate matter and a 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 them unavailable to nuisance algae. Webber Park will be the site of the first public natural filtration swimming pool in the United States.

Figure 16-2. The new Webber Natural Swimming Pool from the Webber Park Master Plan

AUGMENTATION WELL

An augmentation well was used to maintain the water level at Webber Pond and was occasionally used for winter ice rinks. The well was sealed in 2014.

17. WIRTH LAKE

HISTORY

Wirth Lake was acquired by the Minneapolis Park and Recreation Board (MPRB) in 1909, enlarging the adjacent park from its previous size of 64 acres that was purchased in 1889. 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. A plant nursery was established on the west side of the lake in 1910 that provided the system with plantings through 1980.

As with most other lakes in the MPRB system 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 17-1**.

Figure 17-1. Wirth Lake in October, 2012.

Wirth Lake is generally dimictic but can mix during extreme events if Bassett Creek backflows to the lake (Wirth Lake TMDL Report, 2010). Historically, the lake was considered oligotrophic to mesotrophic. Early restoration projects included Rotenone in 1977 to remove rough fish and subsequent stocking of channel catfish, largemouth bass, walleye, and bluegills. A summer aerator was installed and operated from the early 1980s until 1991. A portable winter aerator was used for a few years before a permanent aeration system was put in place in 2002. **Figure 17-2** shows a bathymetric map of Wirth Lake and **Table 17-1** shows the Wirth Lake morphometric data.

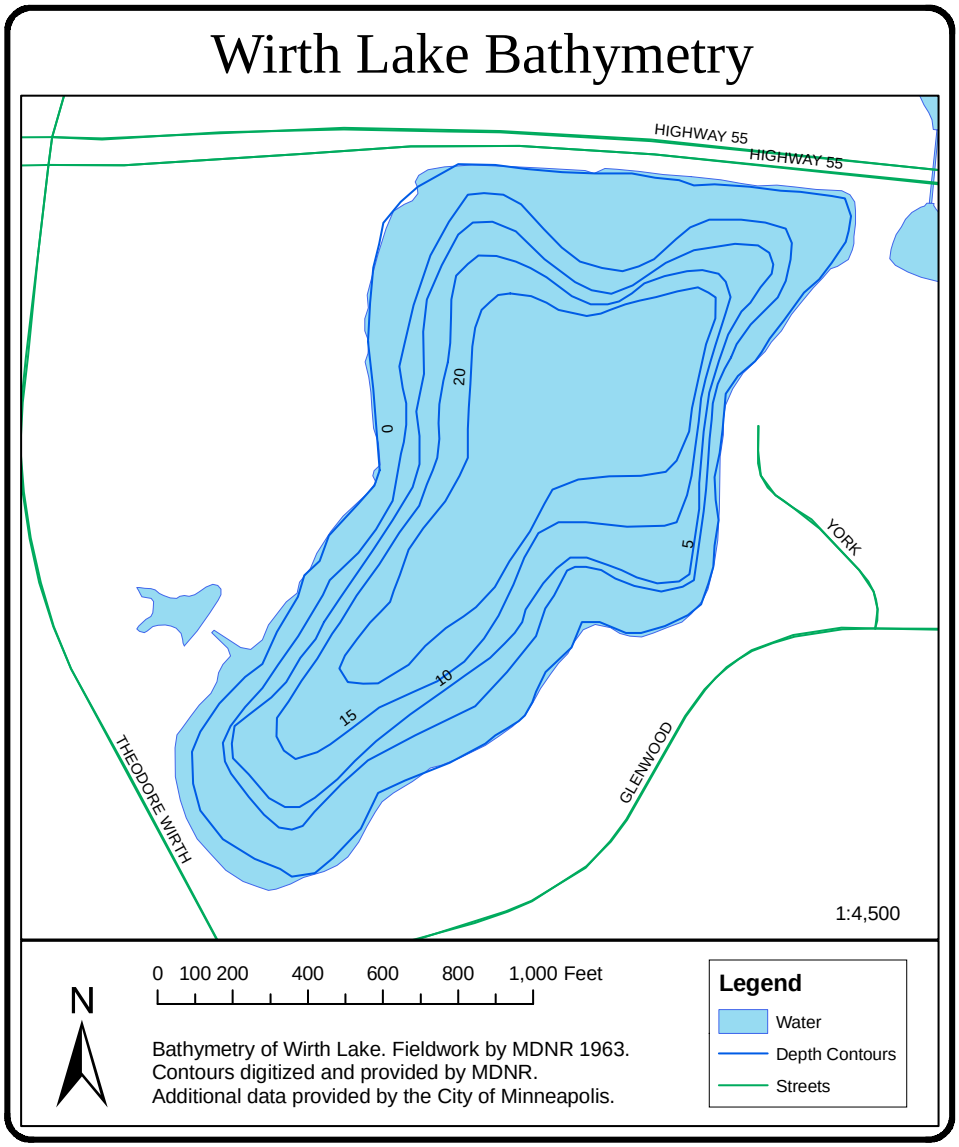


Figure 17-2. Bathymetric map of Wirth Lake.

Table 17-1. Wirth Lake morphometric data.

Surface Area (acres)	Mean Depth (m)	Maximum Depth (m)	Littoral Area*	Volume (m^3)	Watershed Area (acres)	Watershed: Lake Area (ratio)
39	4.3	7.9	59%	6.70×10^5	348	9.4

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

LAKE LEVEL

Wirth Lake levels are recorded weekly during ice free conditions. The lake levels for Wirth Lake are shown in **Figure 17-3** from 1971 through 2014. The effects of new outlets installed in 1978 and in 1996 can be seen in the graph. 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 Outlet was renovated and a new staff gauge was installed in August 2013. High rainfall in April through June led to sustained high water levels in 2014. The MDNR has not designated an ordinary high water level (OHW) for Wirth Lake. See **Section 18** for a comparison between other MPRB lake levels.

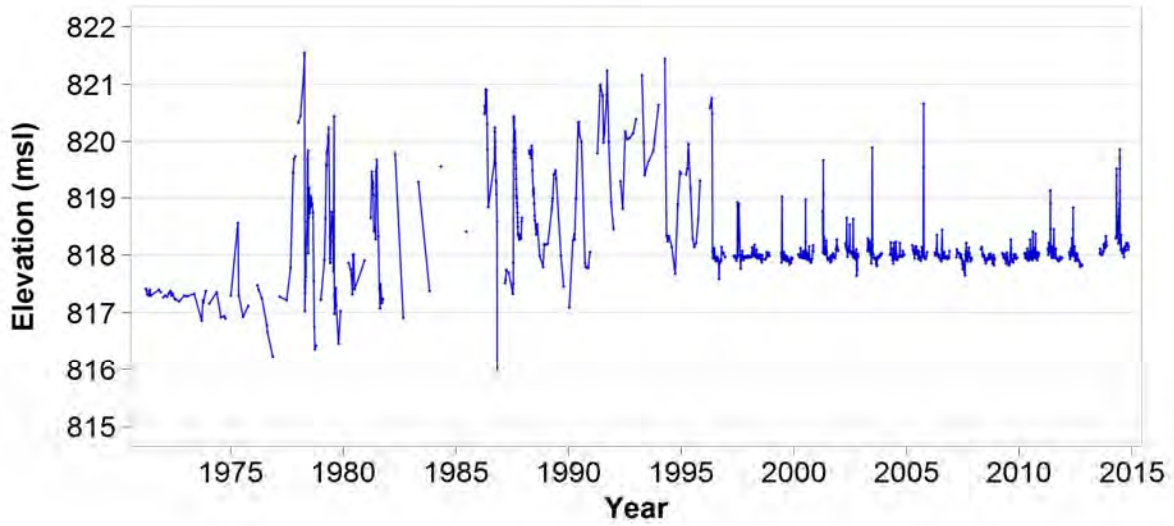


Figure 17-3. Lake levels for Wirth Lake from 1971–2014.

WATER QUALITY TRENDS – TROPHIC STATE INDEX (TSI)

Figure 17-4 shows the Wirth Lake TSI scores over time. The 2014 TSI score for Wirth Lake was 49. Overall, there has been a significant decrease in TSI score from 1992-2014 ($p < 0.05$) with TSI scores being on average 15 TSI units lower in the past few years than when monitoring began. Wirth Lake now has a TSI score that falls within the 25th percentile category for lakes in this ecoregion (based on calculations from the Minnesota Pollution Control Agency, using the Minnesota Lake Water Quality Data Base Summary, 2004). A detailed explanation of TSI can be found in **Section 1**.

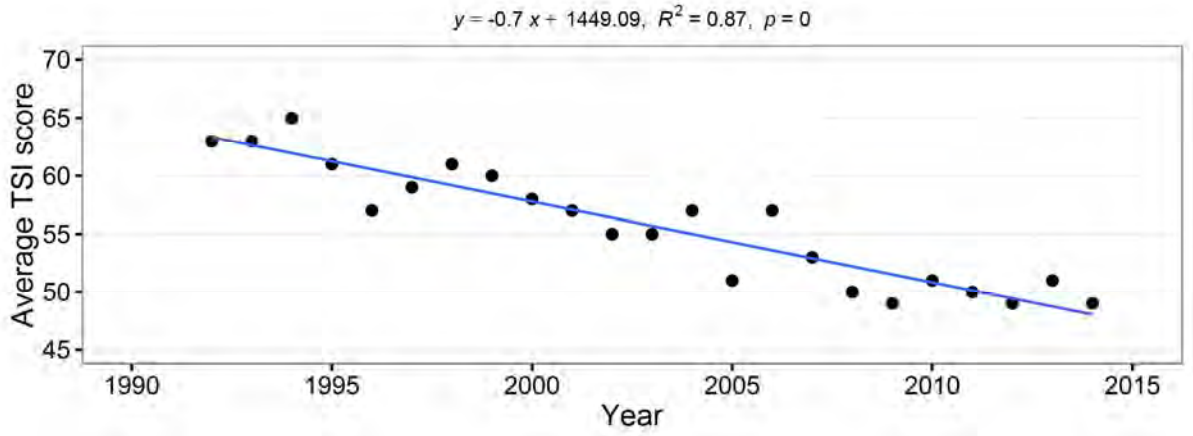


Figure 17-4. Wirth Lake TSI scores and regression line.

BOX AND WHISKER PLOTS

The box and whisker plots in **Figure 17-5** show the distribution of data for the Secchi, chlorophyll-*a*, and total phosphorus for Wirth Lake over the past ten years. The red horizontal lines indicate MPCA deep lake nutrient criteria. A detailed explanation of box and whisker plots can be found in **Section 1**. Data from the entire period of record in box and whisker format can be found in **Appendix A**.

The separation of Bassett Creek from Wirth Lake and upstream water quality improvements in the watershed may be responsible for continued improvement in Wirth Lake. Secchi transparency is increasing with deeper average readings, with 2014 being similar to the previous six years. Both phosphorus and chlorophyll-*a* levels are similar to recent years. All parameters met the MPCA nutrient criteria in 2014.

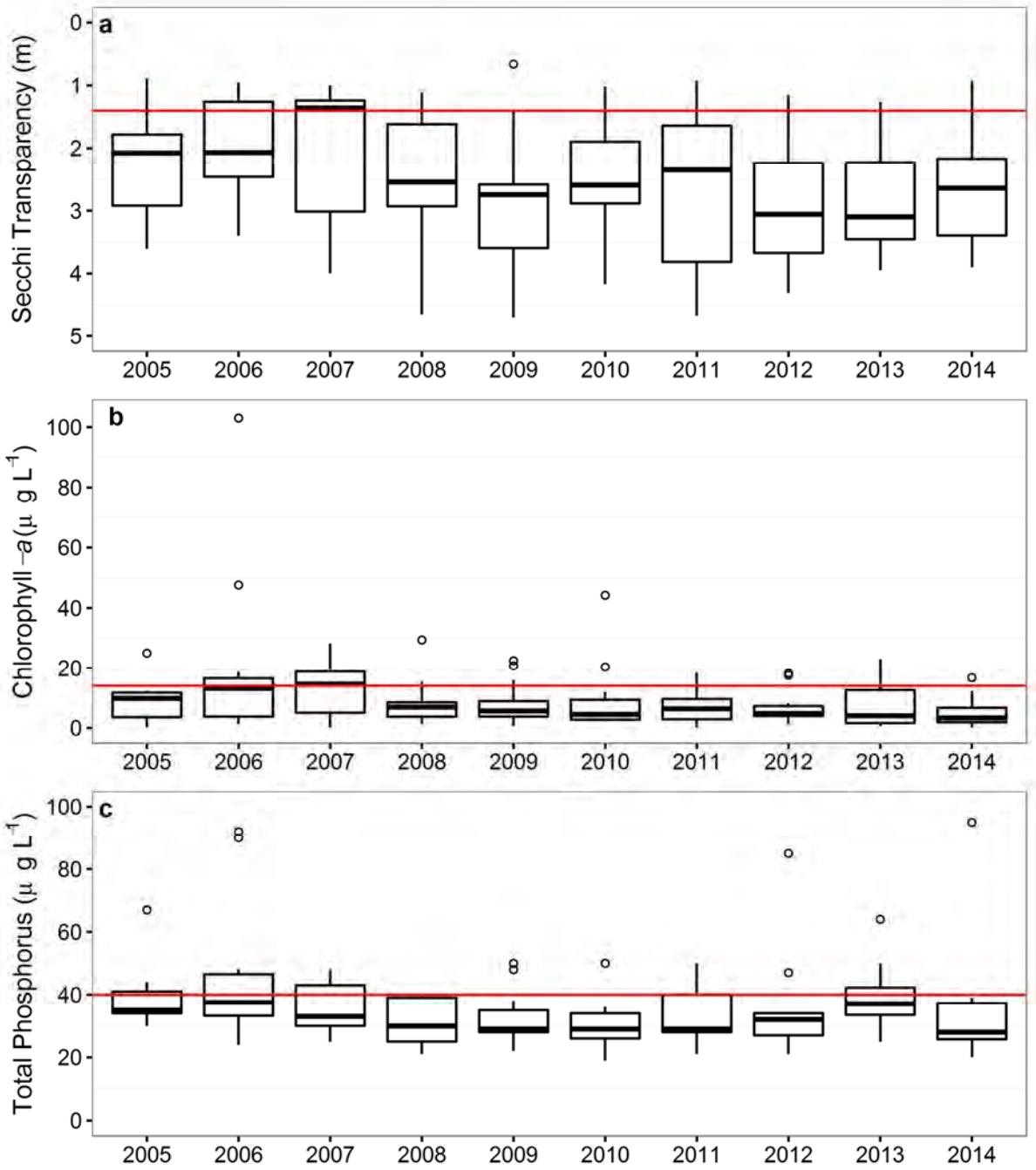


Figure 17-5. Box and whisker plots of Wirth Lake data from over the past ten years. Horizontal lines represent MPCA eutrophication standard for shallow lakes. See Appendix A for the entire period of record.

BEACH MONITORING

Bacteria levels were monitored weekly from June through August at Wirth Beach in 2014 (**Table 17-2)**. **Figure 17-6** illustrates the box and whisker plots of *E. coli* sampling results (per 100 mL) for all data collected between 2005 and 2014. Bacteria levels at Wirth Beach in 2014 were similar to values recorded in previous years. Bacteria levels remained low for much of the season with a maximum sample of 193 MPN per 100 mL and a season long geometric mean of 6 MPN per 100 mL.

Table 17-2. Summary of *E. coli* results (MPN per 100 mL) for Wirth Beach in 2014.

Statistical Calculations	Wirth
Number of Samples	13
Minimum	1
Maximum	193
Median	6
Mean	23
Geometric Mean	6
Max 30-Day Geo Mean	23
Standard Deviation	53

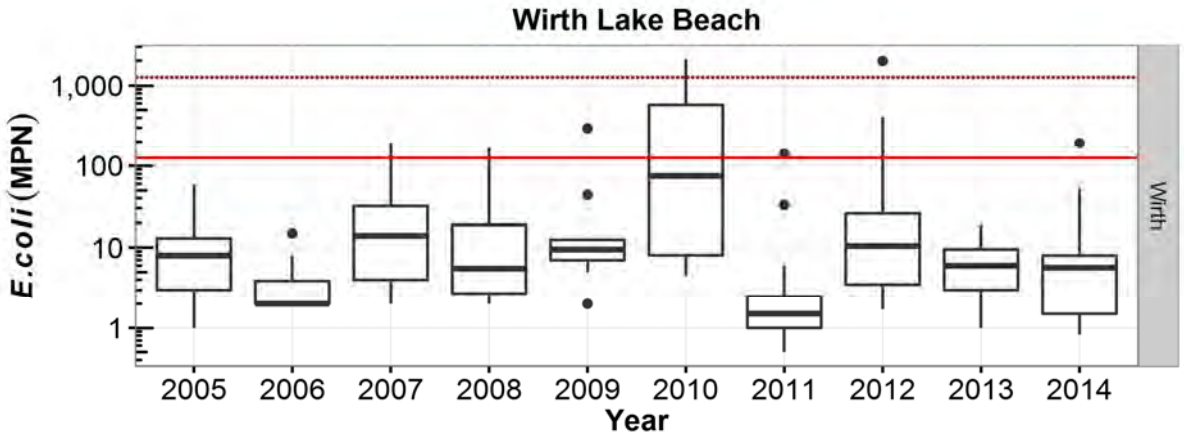


Figure 17-6. Box and whisker plot of Wirth Beach *E. coli* results (colonies per 100 mL), for 2005–2014. The horizontal lines represent the *E. coli* standard for the 30-day geometric mean (126 MPN/100mL) and the single-sample maximum standard (1260 MPN/100mL). Note the log scale on the Y-axis. From 2004-2009 E. coli concentrations were determined as colony forming units (CFU/100ml).

LAKE AESTHETIC AND USER RECREATION INDEX (LAURI)

The 2014 LAURI for Wirth Lake is shown in **Figure 17-7**. Wirth Lake scored "excellent" for aesthetics, habitat quality, public health, and recreational access opportunities and "good" for water clarity. Details on the updated LAURI can be found in **Section 1**.

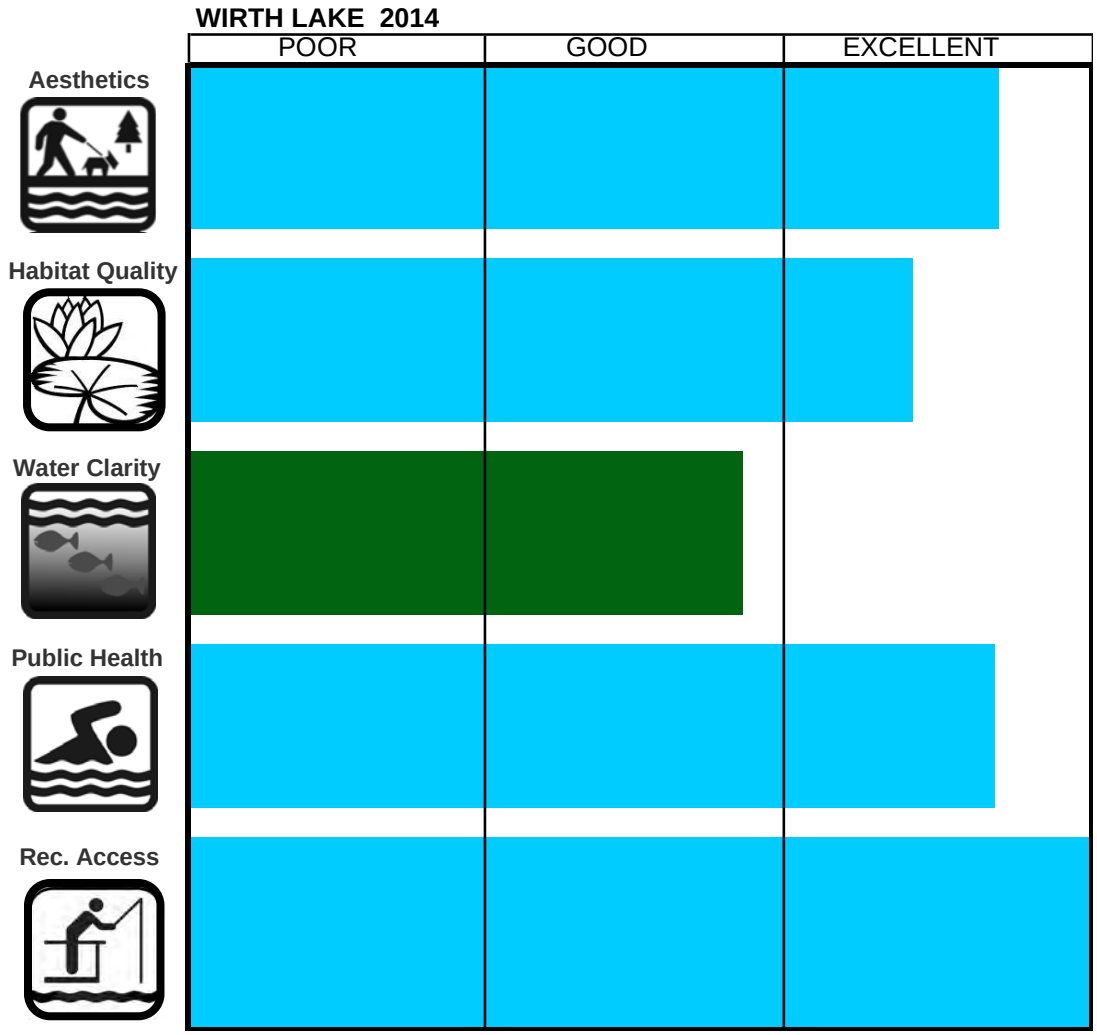


Figure 17-7. Wirth Lake LAURI for 2014.

WINTER ICE COVER

Ice came off Wirth Lake on April 14, 2014, 12 days later than the average date. Ice came on to the lake for the winter on November 18, 2014, which was 11 days earlier than average. Details on winter ice cover records can be found in **Section 1** and a comparison with other lakes can be found in **Section 18**.

EXOTIC AQUATIC PLANT MANAGEMENT

The MDNR requires a permit to remove or control Eurasian water milfoil. Aquatic plant control permits limit the area from which milfoil can be harvested to protect fish habitat. The permits issued to the MPRB allow for harvesting at the beach and the boat launch. The permitted area on Wirth Lake was 5 acres which is 20% of the littoral zone of the lake (area shallower than 15 feet). MPRB contracted SCUBA divers to remove vegetation from areas around the swimming beach, boardwalk, and boat launch. The mechanical harvester could not be used inside of the beach boardwalk. A total of 5.25 trailer loads of aquatic plants were removed from Wirth Lake in 2014. See **Section 1** and **Section 20** for details on aquatic plants.

PHYTOPLANKTON AND ZOOPLANKTON

Phytoplankton and zooplankton are the microscopic plant and animal life that form the foundation of the food web in lakes. **Figure 17-8** displays the Secchi transparency, chlorophyll-*a* concentrations, and relative abundance of phytoplankton division and **Figure 17-9** shows the distribution of zooplankton sampled in 2014.

The winter phytoplankton community was fairly diverse with a mix of green algae (Chlorophyta), cryptomonads (Cryptophyta), dinoflaggelates (Pyrrhophyta), blue green algae (Cyanophyta), a small amount of haptophytes, and some miscellaneous microflagellates. However, there was low algal abundance with chlorophyll-*a* levels below detection. Water clarity initially started out poor in the May samples with a Secchi depth around 1 meter. This corresponded with a phytoplankton community dominated by haptophytes and chlorophyll-*a* concentrations below 6 µg L^{-1}. Algal density remained low until August and levels gradually rose to the highest level in September at 17 µg L^{-1} and Secchi depth varied between 2 and 4 meters. The phytoplankton community had a lot of turnover during this time. Dinoflaggelates comprised over 50% of the sample in June and green algae and blue green algae comprised a majority in early and late July. Dinoflaggelates and blue green algae both comprised around 40% of the community throughout August and dinoflaggelates comprised 85% of the community at peak algal density. The remainder of the fall algal biomass remained low with a continued diverse phytoplankton population.

Zooplankton populations varied over the 2014 sampling season in Wirth Lake, as shown in **Figure 17-9**. Nauplii and juvenile zooplankton were at their highest levels throughout the early season and leveled off in late summer through fall. Cladocerans, primary grazers of phytoplankton, were in high numbers in the June sample and were present in lower numbers throughout the rest of the year. Rotifers were in low abundance in the spring and summer months but became more abundant in the fall. Cyclopoids and calanoids were only present in low concentrations in 2014.

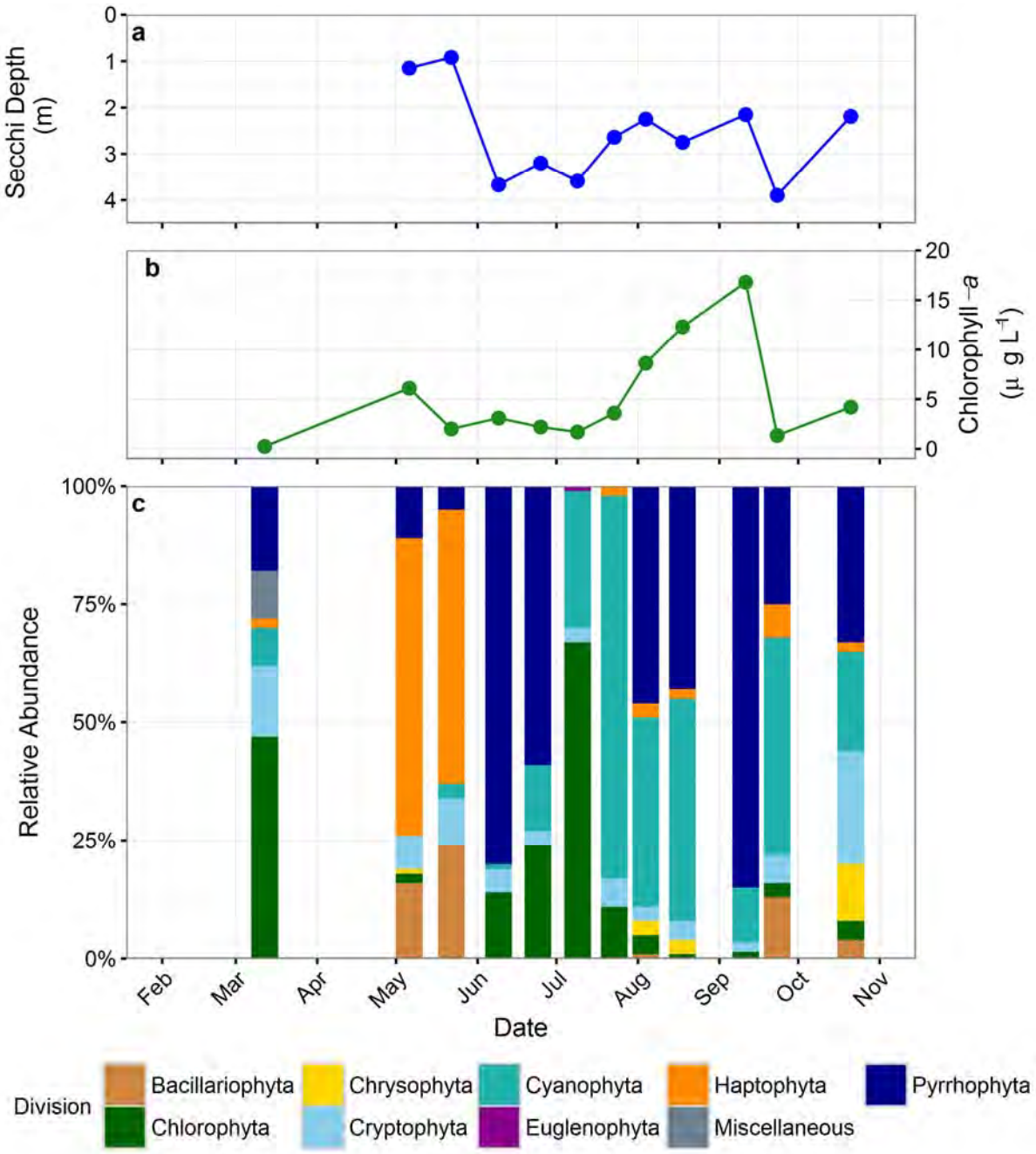


Figure 17-8. Secchi transparency (a), chlorophyll-*a* concentration (b), and relative abundance of phytoplankton (c) during the 2014 Wirth Lake sampling season. Note that the Secchi depth axis is reversed.

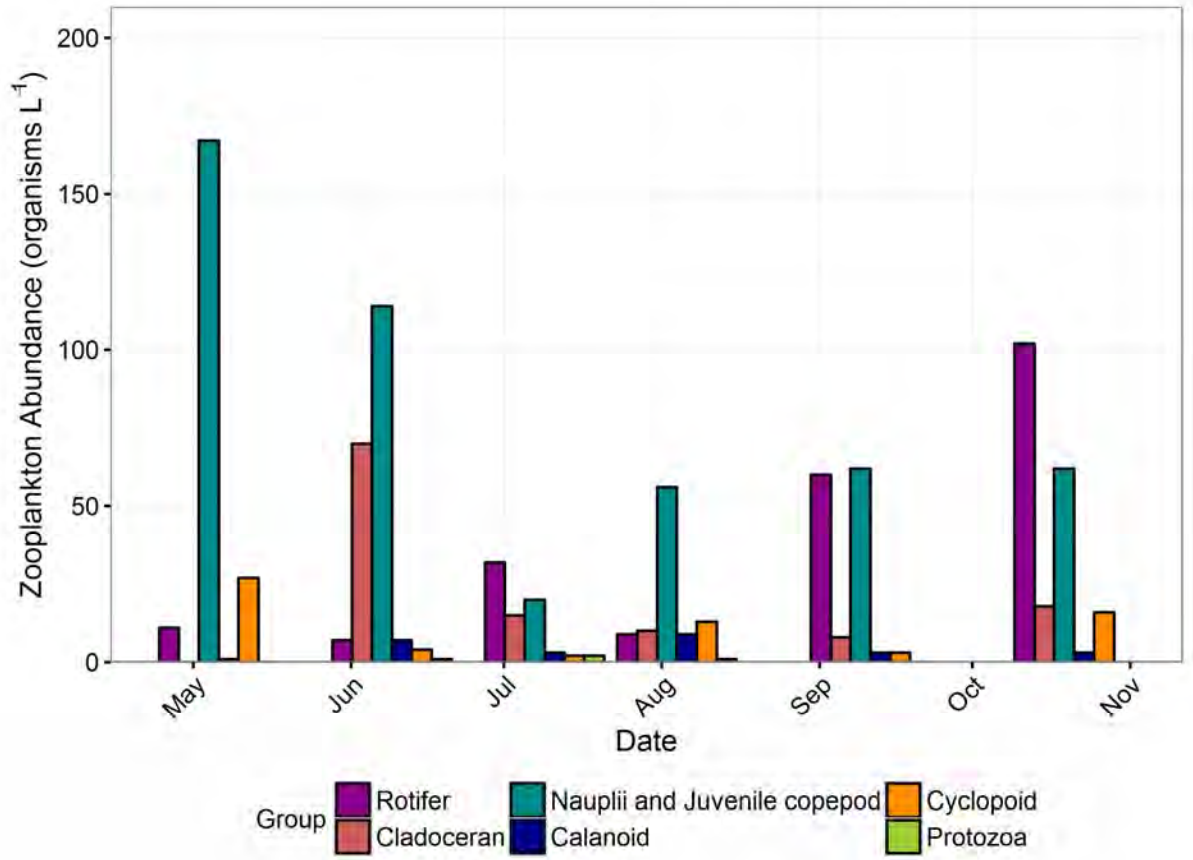


Figure 17-9. Wirth Lake 2014 zooplankton distribution.

FISH STOCKING

Additional information and a definition of fry, fingerling, yearling, and adult fish sizes can be found in **Section 1**.

Wirth Lake was stocked by MDNR in:

1998 with 290 adult Black Crappie 258 adult Bluegill Sunfish.

1999 with 1,900 fingerling Channel Catfish.

2000 with 1,900 fingerling Channel Catfish.

2001 with 2,304 yearling Channel Catfish.

2003 with 600 adult Walleye.

2007 with 23,000 fry Walleye.

2008 with 40 adult Walleye and 57 fingerling Walleye.

2011 with 2,772 fingerling Walleye.

2012 with 23,000 fry Walleye.

18. 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 18-1** presents the physical characteristics of the Minneapolis lakes.

Table 18-1. Minneapolis lakes physical characteristics.

Lake	Surface Area (acres)	Mean Depth (m)	Max Depth (m)	Littoral Area*	Volume (m^3)	Watershed Area (acres)	Watershed: Lake Area (ratio)	Residence Time (years)
Birch	5.8	ND	ND	ND	ND	ND	ND	ND
Brownie	18	6.8	15.2	67%	$4.98x10^5$	369	20.5	2.0
Calhoun	421	10.6	27.4	31%	$1.80x10^7$	2,992	7.1	4.2
Cedar	170	6.1	15.5	37%	$4.26x10^6$	1,956	11.5	2.7
Diamond	41	0.9	2.1†	100%	$7.15x10^4$	669‡	16.3	ND
Grass	27	0.6	1.5	NA	NA	386‡	14.3	ND
Harriet	353	8.7	25.0	25%	$1.25x10^7$	1,139	3.2	3.4
Hiawatha	54	4.1	7.0	26%	$8.95x10^5$	115,840	2,145	0.03
Isles	103	2.7	9.4	89%	$1.11x10^6$	735	7.1	0.6
Loring	8	1.5	5.3	NA	$4.88x10^4$	24	3.0	ND
Nokomis	204	4.3	10.1	51%	$3.54x10^6$	869	4.3	4.0‡
Powderhorn	11	1.2	6.1	99%	$5.43x10^4$	286	26.0	0.2‡
Ryan	18	NA	10.7	50%	ND	5,510	306	ND
Spring	3	3.0	8.5	ND	$3.65x10^4$	45	15.0	ND
Wirth	39	4.3	7.9	61%	$6.70x10^5$	348	9.4	ND

* Littoral area defined as less than 15 feet deep. ND= No Data Available. NA= Not Applicable
† Based on long-term data. ‡ Recent projects within the watersheds have altered these statistics.

Summary statistics of interest include:

- Largest Lake: Lake Calhoun at 421 acres.
- Smallest Lake: Spring Lake at 3 acres.
- Deepest Lake: Lake Calhoun at 89 feet 11 inches.
- Largest Watershed: Lake Hiawatha at 115,340 acres.
- Smallest Watershed: Loring Pond at 24 acres.
- Longest Residence Time: Lake Calhoun at 4.3 years.
- Shortest Residence Time: Lake Hiawatha at 11 days.

WATER QUALITY TRENDS – TROPHIC STATE INDEX (TSI)

The Minneapolis Park and Recreation Board (MPRB) calculates a trophic state index score (TSI) for each lake using chlorophyll-*a*, Secchi depth, 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 **Section 1**.

In 2014, MPRB water resources scientists monitored 13 of the city's most heavily used lakes in order to calculate TSI scores. **Figure 18-1** shows the 2014 TSI data plotted on the trophic state continuum. All of the Minneapolis lakes fell into the mesotrophic or eutrophic categories, which is the typical distribution for lakes in the North Central Hardwood Forest ecoregion (MPCA, 2004). With some exceptions, the deeper lakes had lower TSI scores than the shallow lakes. Scores for Diamond Lake should be viewed with caution since these lakes are too shallow to calculate the Secchi portion of the TSI index.

Changes in lake water quality can be tracked by looking for trends in TSI scores over time. Historical trends in TSI scores are used by lake managers to assess the effectiveness of restoration and management activities on the trophic state of the lakes. Comparing TSI trends in single lakes to trends seen in all of the lakes can help to identify whether changes in lake water quality may be due to climate cycles or to changes specific to a watershed.

Trends were identified by using a linear regression of the TSI scores through time. **Table 18-2** shows the historical trends in TSI scores since 1991, the year sampling began for most lakes. Because 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 18-3** shows the TSI trends since 2005. Graphs of TSI scores over the entire period of record for each lake are shown in **Figures 18-2**. For more detailed information on a particular lake's trend in TSI scores and nutrient related water quality parameters, see the individual lake sections. Details on TSI scores and linear regression analysis can be found in **Section 1**.

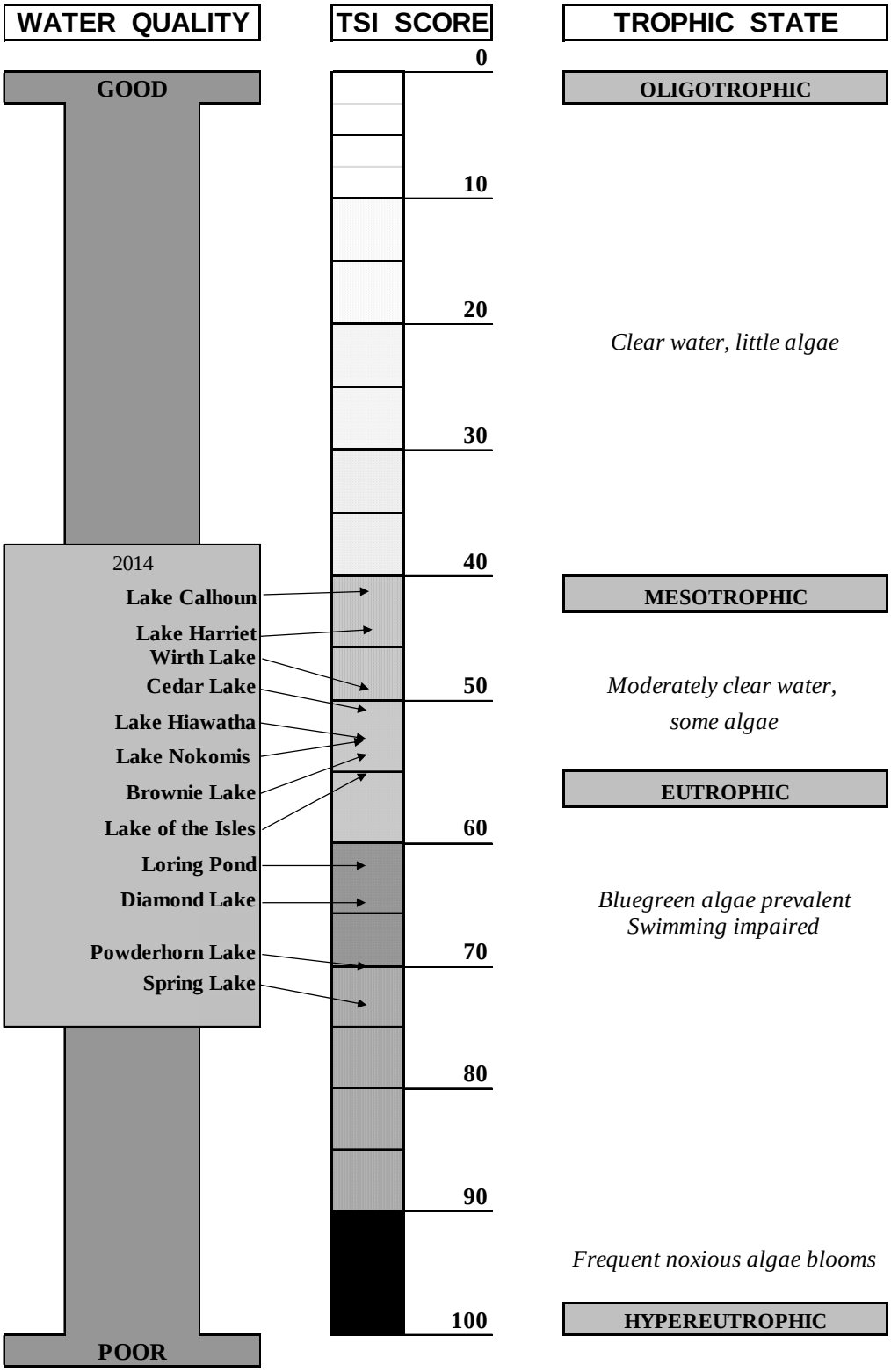


Figure 18-1. 2014 lake trophic state comparison. In general, the deeper lakes have lower TSI scores.

Table 18-2. Water quality trends in Minneapolis lakes from 1991-2014.

Lakes with increasing water quality indicators	Lakes with stable trend	Lakes with decreasing water quality indicators
Lake Calhoun Powderhorn Lake Wirth Lake	Brownie Lake Cedar Lake Lake Harriet Lake Hiawatha Lake of the Isles Loring Pond Lake Nokomis Spring Lake	Diamond Lake

Table 18-3. Water quality trends in Minneapolis lakes from 2005-2014.

Lakes with increasing water quality indicators	Lakes with stable trend	Lakes with decreasing water quality indicators
Diamond Lake Wirth Lake	Brownie Lake Lake Calhoun Cedar Lake Lake Harriet Lake Hiawatha Lake of the Isles Loring Pond Lake Nokomis Spring Lake	Powderhorn Lake

Diamond Lake is a very shallow lake that can change quickly between a green colored, algae dominated state and a clear water, aquatic plant dominated state. Over the last decade, Diamond has been trending towards lower TSI scores; however, when all years of record are considered, the trend is less clear. Recent drought conditions in summer may be causing a lower nutrient load to this shallow waterbody.

Lake Nokomis might be at the beginning of a trend towards improved water quality. A biomanipulation project has been taking place in this lake for the past five years and may be starting to affect TSI scores.

Wirth Lake has had both ponding and two different lake outlet configurations implemented in its watershed, and is showing a very strong trend towards better water quality. It is expected that Wirth Lake will be taken off of the impaired waters list.

Brownie Lake, Cedar Lake, and Lake of the Isles were part of the Chain of Lakes Clean Water Partnership Project that occurred in the 1990s. Trends in Brownie Lake are difficult to evaluate because the sampling regime has changed over time. Recent improvements in this lake's watershed outside of Minneapolis have decreased the amount of phosphorus coming to the lake, so the lake may start to respond in several years. Cedar Lake responded positively to an alum treatment in 1996, which was assumed to last until approximately 2003. Recent higher TSI scores at Cedar may be showing a new normal that does not include the residual effects from the alum treatment. Lake of the Isles also had an alum treatment in 1997, and similar to Cedar Lake, the treatment may not be currently affecting its TSI score.

Lake Hiawatha is strongly influenced by flow in Minnehaha Creek, and the lake does not seem to exhibit a temporal trend at this time.

Although the long term water quality trend for Powderhorn lakes show increased water quality since the early 1990s, the 10-year regression for these lakes show a trend towards lower water quality. This could partly be because the 10-year timeline begins with years that these lakes exhibited the best water quality in all of the years of record. Trends in TSI scores at Powderhorn are not linear, but rather have three distinct periods (1992-2000, 2001-2009, and 2010-2014).

Lake Calhoun has a long term water quality trend towards improved TSI scores, but the 10-year regression shows a more stable trend. However, the scores are considerably better (lower) than prior to restoration in the early 1990s (**Figure 18-2**). Both Lake Harriet and Lake Calhoun have outstanding water quality for urban lakes and have better water quality than a decade ago, when restoration efforts began.

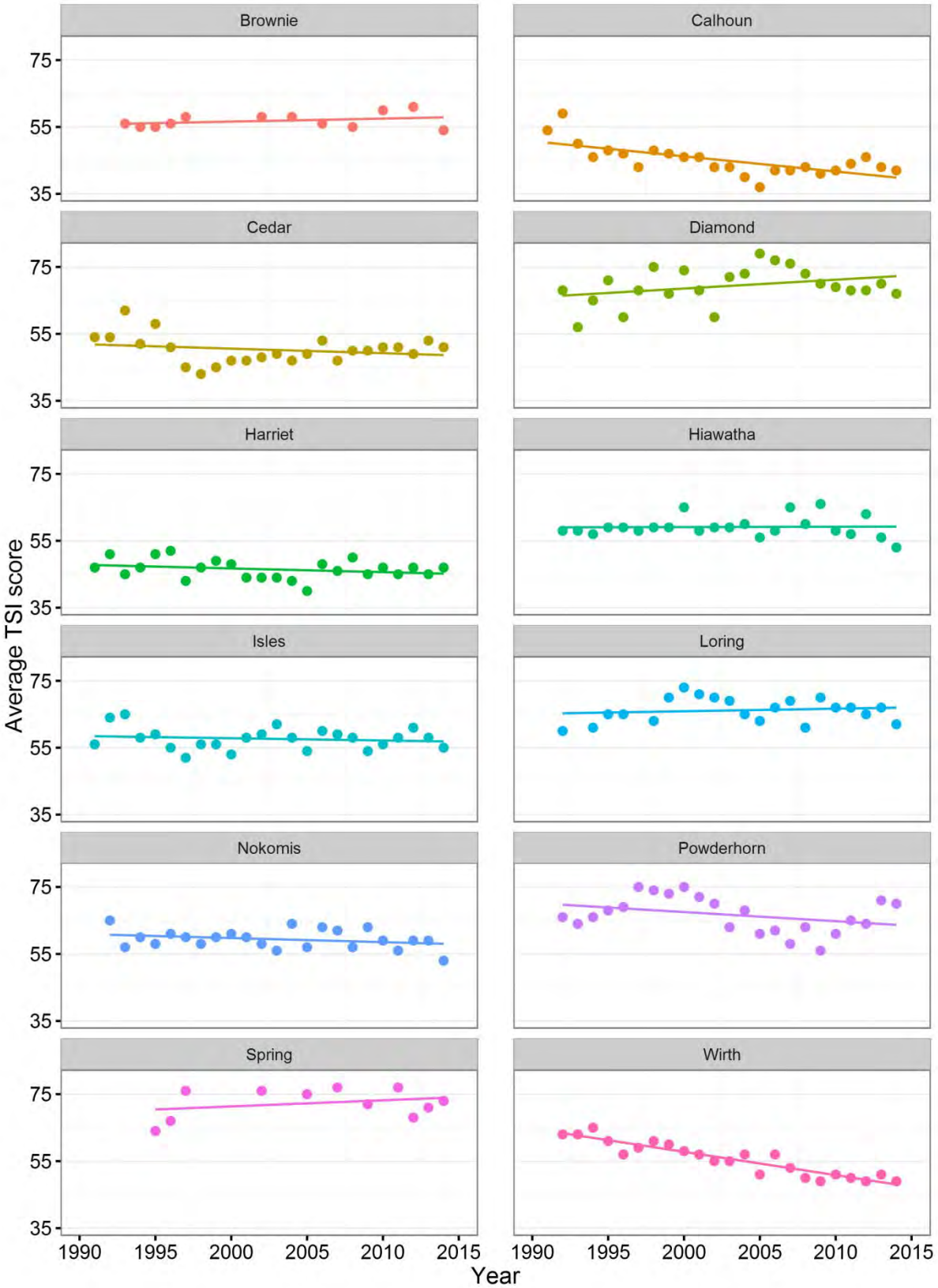


Figure 18-2. TSI scores for selected Minneapolis lakes 1991–2014.

LAKE LEVELS

Lake levels are recorded weekly for Harriet, Hiawatha, Nokomis, Loring, Powderhorn, Wirth, and the Upper Chain of Lakes (Brownie, Calhoun, Cedar and Isles) at Lake Calhoun from ice-out to ice-on. Channels connect the Upper Chain of Lakes which makes the level at Calhoun representative of all four lakes. Fixed staff gauges are used at all locations that are shown in **Figure 18-3.** Average annual lake levels and selected statistics for each lake with a staff gauge are shown in **Tables 18-4** and **18-5**. Water levels for Minneapolis lakes are illustrated in **Figure 18-4**.

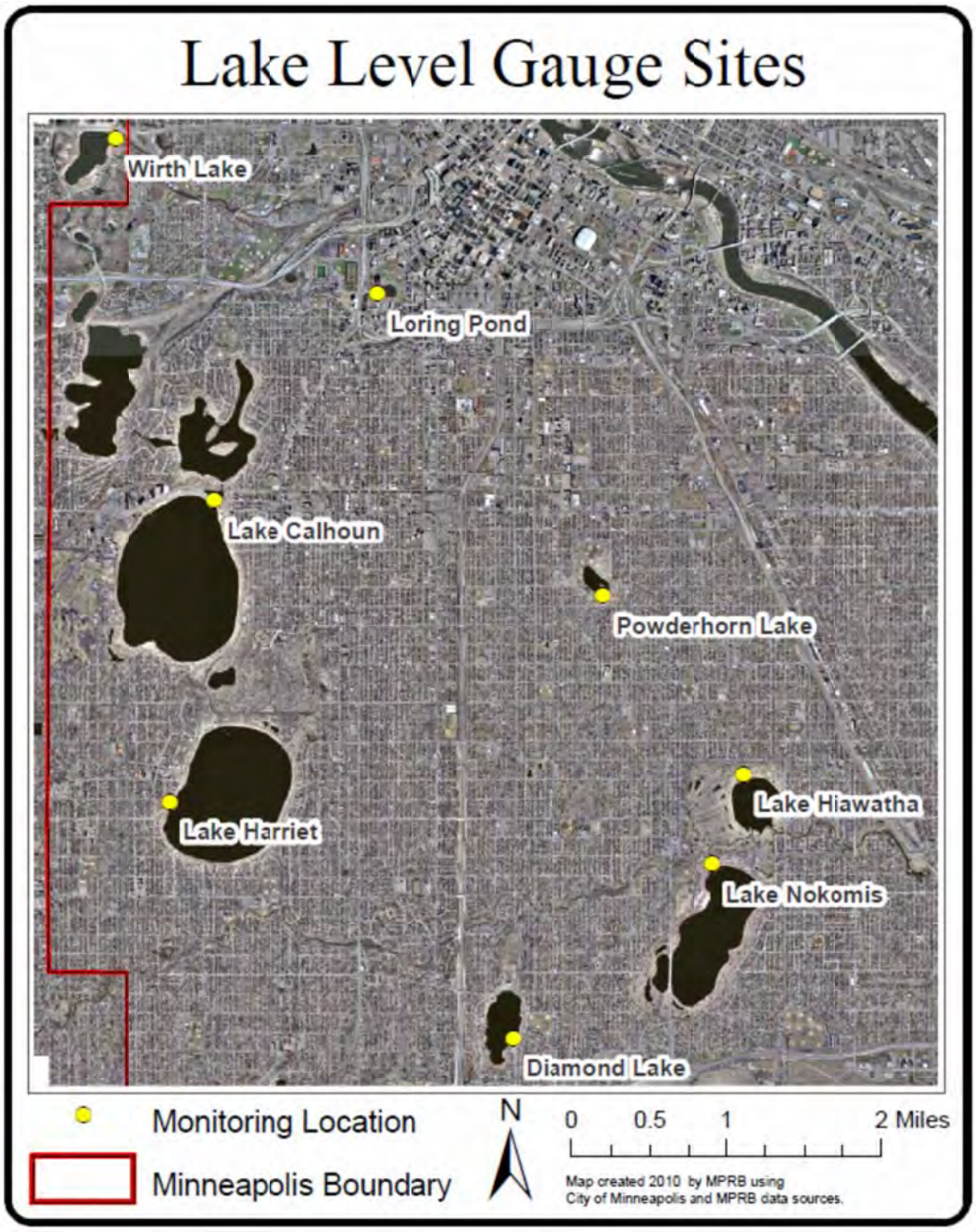


Figure 18-3. Minneapolis lake level monitoring locations.

Lake levels vary annually based on precipitation, stream flow, and stormwater inflow. The spring of 2014 saw significant rain with the precipitation between April and June totaling 22.18 inches. June 2014 was the wettest June on record with 11.36 inches of rain. The heavy rain caused many lakes in the region to see record-high water levels, and the Minneapolis Lakes and Minnehaha Creek rose to levels where significant flooding in the parks occurred. Water levels then slowly fell over the remainder of 2014. Over the 2014 season, all lakes were above their 10-year averages as can be seen in **Tables 18-4** and **18-5.** Groundwater augmentation occurred at Loring Pond in the fall. Historical lake levels can be found in the individual lake **Sections 2-17**.

Lake levels rose during spring storms in all the lakes, except Loring, and then fell through the remainder of the year, as shown in **Figure 18-4.** All lakes, with the exception of Loring, were above their 10-year averages elevation as shown in **Table 18-5**. Lake Nokomis experienced the worst flooding in 2014 with lake levels 2.38 feet above the 10 year average elevation.

Loring's water level was allowed to fall below the outlet in order allow the cattails to be cut at the manipulated water surface. Water levels were then augmented with groundwater in November, flooding the cut shoots and preventing oxygen from reaching the rhizomes and thus killing the plant. Large storms have caused stormsewers 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, the augmentation well was not used in 2014. The lake is strongly influenced by stormwater. Peaks in Powderhorn's level in 2013 followed large storms. The lake was 1.89 feet above its 10-year average in 2014 (**Table 18-5**).

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 Grey's Bay opened in April 2014 and was open up to 300 cfs from May through July with a maximum flow in Minnehaha creek of over 500 cfs. The dam remained open in some capacity until the end of October. The 2014 average lake level was 1.45 feet above the 10-year average for the lake.

Groundwater recharge to Wirth Lake is likely responsible for its stable levels. The 2014 lake level is comparable to the 10-year average.

Table 18-4. Average annual lake levels in feet above msl for the past 10 years.

Lake	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Chain[§]	852.90	852.85	852.53	852.14	851.75	852.50	852.94	852.05	852.66	853.80
Harriet	847.31	847.11	847.37	847.13	846.89	847.28	847.63	847.14	847.48	847.84
Hiawatha	812.92	812.61	812.31	812.14	811.64	812.79	813.36	811.83	813.05	814.14
Loring*	818.23	816.68	817.63	817.85	817.80	817.77	817.84	817.95	817.85	814.87
Nokomis	812.89	812.96	813.00	813.22	811.89	812.24	814.71	814.46	815.13	816.37
Powderhorn*	818.35	818.40	817.43	816.89	816.70	817.18	817.76	817.39	818.15	819.67
Wirth	818.13	817.81	817.95	817.96	817.95	818.03	818.07	818.00	818.10	818.47

[§] The Chain of lakes includes: Calhoun, Cedar, Isles, & Brownie.
* In dry years the level can be below recordable stage.

Table 18-5. Selected statistics for lakes with level data based on the past 10 years of data.

Lake	10-year avg (ft msl)	2014 avg (ft msl)	2014 comparison to 10yr average (ft)	Standard deviation around 10-year avg (ft)
Chain	852.71	853.80	1.09	0.85
Harriet	847.37	847.84	0.47	0.44
Hiawatha	812.69	814.14	1.45	1.16
Loring	817.95	817.87	-0.08	0.34
Nokomis	813.99	816.37	2.38	1.56
Powderhorn	817.78	819.67	1.89	1.10
Wirth	818.08	818.47	0.39	0.32

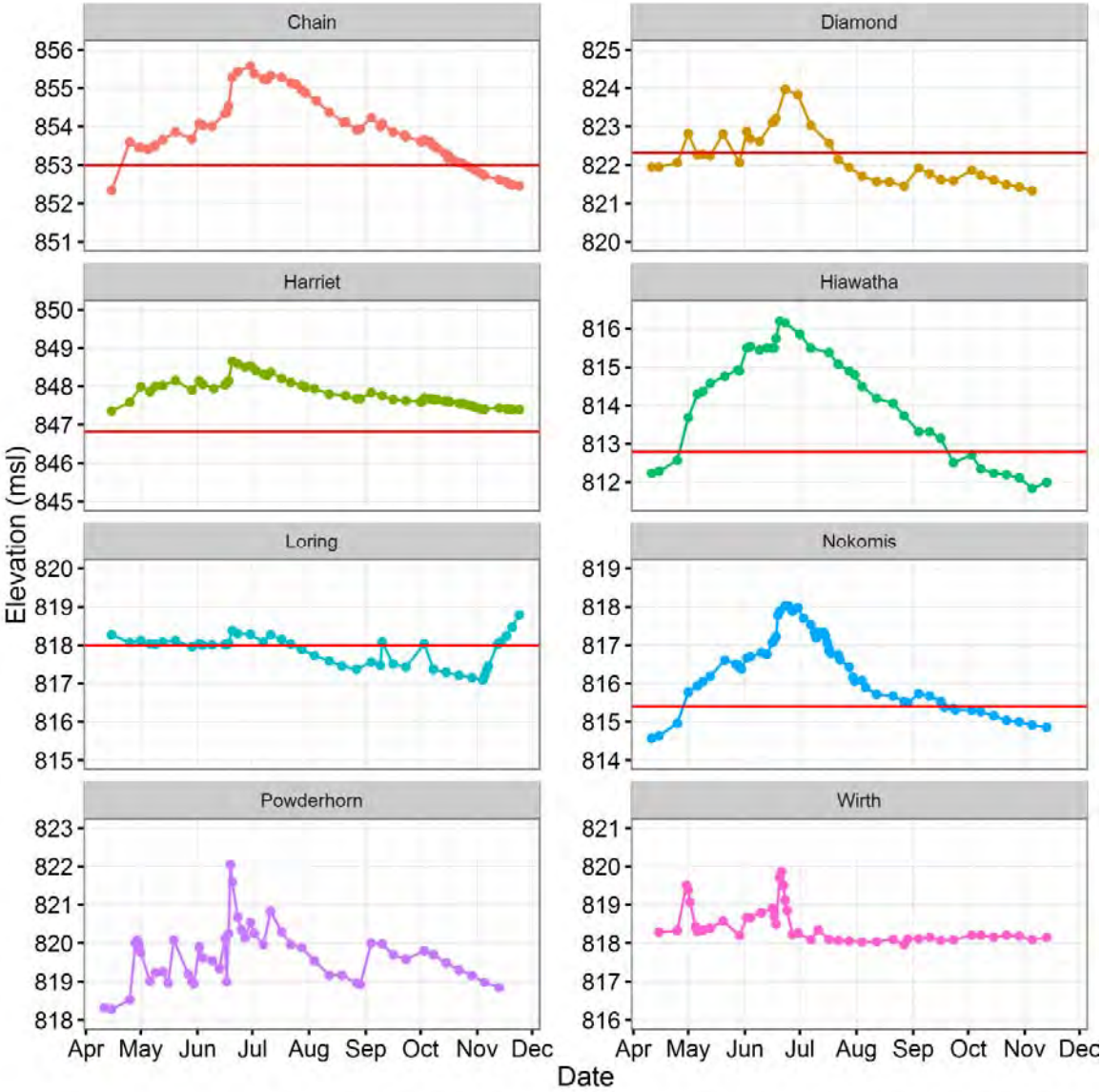


Figure 18-4. Lake levels for the Minneapolis Lakes in 2014. Horizontal lines represent ordinary high water elevation (OHW). Note the MDNR has not designated an OHW for Powderhorn or Wirth Lakes.

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 **Section 1**. The LAURI index was updated in 2009 to include measures of habitat quality and recreational access, and has been used by Minneapolis and the Minneapolis Greenprint as a Citywide Metric.

All scores in the LAURI are between 1 and 10 with 10 as the best possible score. **Table 18-6** shows the LAURI scores of each lake for 2014. If the LAURI parameters were looked at for all of the lakes together, it would look like the LAURI presented in **Figure 18-5.**

Table 18-6. 2014 sub-scores and classifications for each LAURI category.

Lake	Aesthetics	Habitat Quality	Water Clarity	Public Health	Rec. Access
Calhoun	9.3	9	9	4	10
Cedar	9	8	4	8	10
Harriet	8.7	8.5	8	8	10
Hiawatha*	7	6.3	8	1	4
Isles*	9.1	7.5	6	NB	10
Loring*	8.5	3.5	8	NB	3
Nokomis*	8.8	4.8	8	7	10
Powderhorn*	7.4	6	2	NB	3
Wirth	9.2	8	6	9	10

LEGEND

Excellent	Good	Poor

* Denotes shallow lake.
NB = 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.

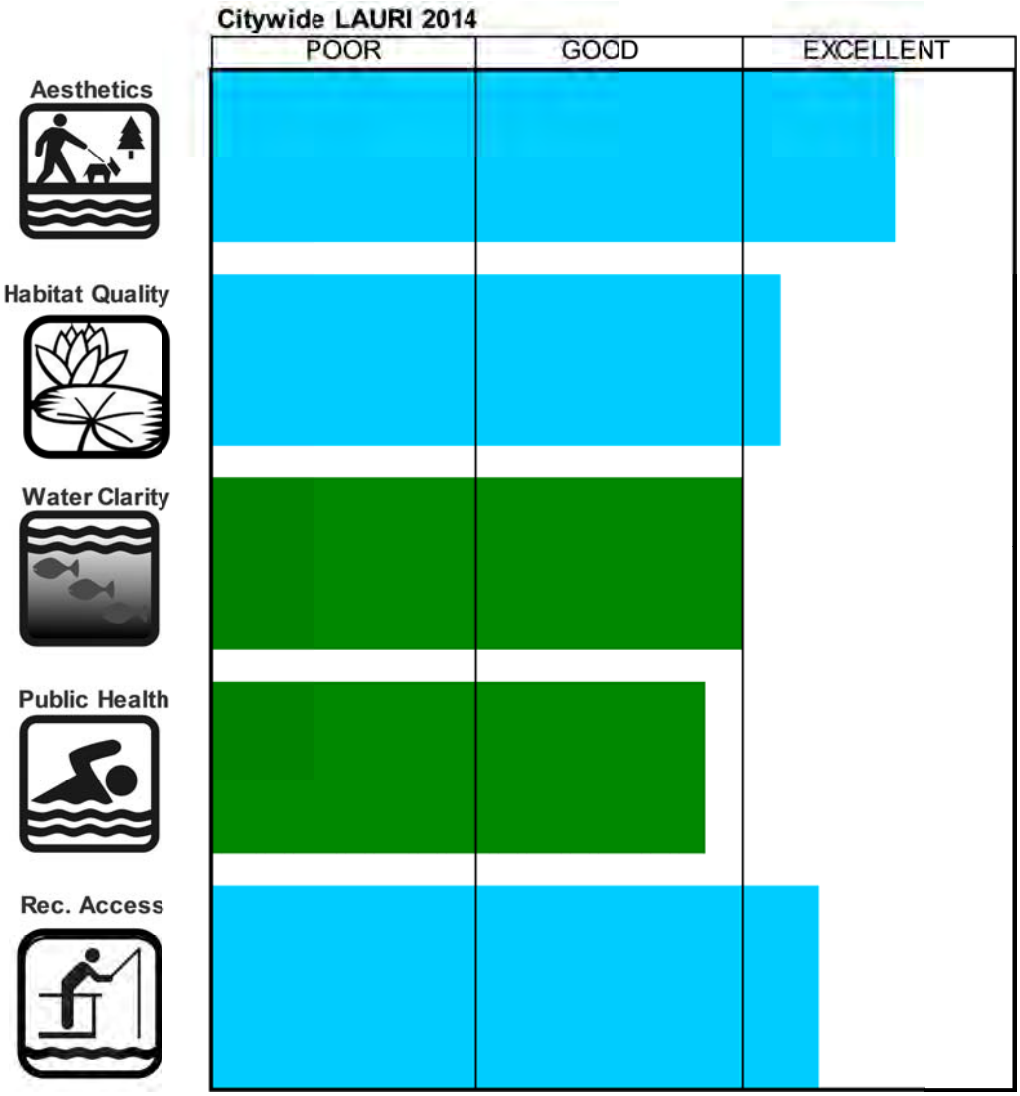


Figure 18-5. 2014 Average LAURI for Minneapolis. Includes: Calhoun, Cedar, Harriet, Hiawatha, Isles, Loring, Nokomis, Powderhorn, and Wirth Lakes.

WINTER ICE COVER

The Minneapolis lakes had a shorter than average ice-free period in 2014. Ice came off the lakes around 10 days after the average ice-off date and varied based on lake size, as shown in **Table 18-7.** Most lakes were completely frozen between a week and two weeks earlier than the average recorded ice-on date, as can be seen from **Table 18-8.** Similar to ice-on, 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. For further information on winter ice cover records see **Section 1** and individual lake sections.

Table 18-7. Statistics related to ice-off dates.

Lake	2014	Earliest Ice Off	Year Occurred	Latest Ice Off	Year Occurred	Mean	Median	Years of Record
Birch	4/19	3/8	2000	4/28	2013	4/4	4/5	29
Brownie	4/14	3/9	2000	4/28	2013	4/4	4/3	33
Calhoun	4/20	3/9	2000	4/28	1965, 2013	4/9	4/10	65
Cedar	4/19	3/9	2000	4/28	2013	4/7	4/6	41
Diamond	4/10	3/6	2000	4/24	2013	4/2	4/4	22
Harriet	4/19	3/9	2000	4/28	1965, 2013	4/7	4/7	47
Hiawatha	4/14	3/8	2000	4/26	2013	4/4	4/4	40
Isles	4/19	3/8	2000	4/28	2013	4/5	4/5	45
Loring	4/10	3/6	2000	4/25	2013	4/2	4/3	34
Nokomis	4/17	3/8	2000	4/27	2013	4/5	4/4	43
Powderhorn	4/14	3/8	2000	4/27	1965, 2013	4/4	4/3	35
Spring	4/10	3/6	2000	4/24	2013	4/1	4/2	24
Wirth	4/14	3/7	2000	4/27	2013	4/2	4/3	38

Table 18-8. Statistics related to ice-on dates.

Lake	2014	Earliest Ice On	Year Occurred	Latest Ice On	Year Occurred	Mean	Median	Years of Record
Birch	11/13	11/1	1991	12/16	1998	11/25	11/26	29
Brownie	11/18	11/5	1991	12/20	2001	11/28	11/30	33
Calhoun	12/2	11/25	1996	1/16	2006-07	12/12	12/11	45
Cedar	11/21	11/18	1989	12/21	1998, 1999, 2001	12/3	12/4	33
Diamond	11/13	11/13	2008, 2014	12/20	2001	11/30	12/1	20
Harriet	12/2	11/25	1996	1/16	2006-7	12/12	12/11	42
Hiawatha	11/25	11/1	1991	1/31	2006-7	12/2	12/2	34
Isles	11/17	11/5	1991	1/2	2006-7	11/30	12/2	40
Loring	11/14	11/1	1991	12/21	1999, 2001	11/30	12/2	30
Nokomis	11/17	11/1	1991	1/17	2011-12	11/30	11/30	35
Powderhorn	11/17	11/1	1991	12/20	2001	11/28	11/30	30
Spring	11/14	11/10	1995	12/20	2001	11/28	11/26	24
Wirth	11/18	11/5	1991	12/21	2001	11/29	12/2	34

INVASIVE SPECIES MONITORING

MPRB has been actively monitoring invasive species since the late-1980s to early 1990s when Eurasian watermilfoil (*Myriophyllum spicatum*) was first discovered in the Chain of Lakes. By 1992, MPRB and the Hennepin County Conservation District began managing milfoil in the Chain of Lakes with financial support from the MDNR. In the early 1990s MPRB staff tracked areas of invasive Eurasian watermilfoil (EWM) versus native northern watermilfoil (*Myriophyllum exalbescens*). Later, MPRB partnered with Dr. Ray Newman of the University of Minnesota. Dr. Newman conducted some early studies in the Minneapolis lakes and the potential use of a native beetle, *Euhrychiopsis lecontei*, that prefers to feed on EWM and can be grow to high enough densities to diminish the growth of EWM in lakes in certain situations.

MPRB first began managing aquatic invasive species when Eurasian water milfoil was discovered; however, the EWM was not the first invasive aquatic species to be introduced to the MPRB lakes. In 1910, curly-leaf pondweed (*Potamogeton crispus*) was first documented 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. During spring, after mild winters, curly-leaf pondweed often produces thick mats of vegetation that are a nuisance for boating; however, this plant can be held to low levels of growth by harsh Minnesota winters. Macrophyte surveys by Shapiro (1974) documented curly-leaf pondweed in Lakes Calhoun, Harriet, Isles, and 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.

The 1974 Shapiro surveys found that aquatic plants grew to only about 15 feet of depth in Lakes Calhoun and Harriet. 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 invasion by exotics. Therefore, the lack of plant growth throughout the littoral zones of the Minneapolis lakes may have left them vulnerable to invasion by EWM two decades later.

Most other exotic aquatic species only occur in a few lakes in the MPRB system as can be seen from **Figure 18-6** and **Table 18-9**. Brazilian water weed (*Egeria densa*) was found in Powderhorn Lake in 2007 during a routine MPRB plant survey. The MDNR mapped areas where the invasive plant was growing and chemically treated those areas with diquat, an herbicide approved for aquatic use. Brazilian water weed has not been identified in the lake since treatment. This plant can grow to extremely high densities limiting growth for native plants. It is a common aquarium plant and likely found its way to Powderhorn Lake via an aquarium release. Powderhorn was delisted for Brazilian water weed in 2014 after five years of surveys not finding the plant.

Chinese Mystery Snails (*Bellamya chinensis*) have been identified by MDNR and MPRB in Loring Pond, Powderhorn Lake, and Grass Lake as shown in **Figure 18-6** and **Table 18-9.** The Chinese mystery snail, which is native to Asia, was introduced to California in 1892, and was found on the East Coast by 1915 (MDNR, AIS website). The species is a popular aquarium snail, and new populations are often a result of an aquarium release. This species has the capability of growing to high densities and tends to have boom and bust cycles. When the population reaches the "bust" portion of the cycle, large concentrations of dead snails can ring the shoreline and create odor and aesthetic issues as they decompose.

Lakes Nokomis and Hiawatha have been declared infested with zebra mussels (*Dreissena polymorpha*) because of their connection with Minnehaha Creek and Lake Minnetonka. However, as of fall 2014, zebra mussels have not been confirmed to be present in Lake Nokomis. The Minnehaha Creek Watershed District (MCWD) and MPRB have performed rapid assessments on MPRB lakes each fall since zebra mussels were confirmed in Lake Minnetonka in 2010. MPRB also deploys monthly samplers in Calhoun, Harriet, and Hiawatha as an early detection method. Additionally, Friends of Lake Nokomis monitors two monthly samplers in Lake Nokomis. In August 2013, zebra mussels were confirmed as present in Lake Hiawatha. Zebra mussels were found on the sampling plate in Hiawatha again in the fall of 2014. No zebra mussels were found in the other Minneapolis lakes via MPRB and MCWD's rapid assessments or zebra mussel sampling program in 2014.

Lakes containing European carp (*Cyprinus carpio*) and goldfish (*Carassius auratus*) are identified in **Figure 18-6.** The data shown were taken from MDNR Lake Finder and is based on MDNR fish surveys. Other Minneapolis lakes may have carp or goldfish but these species have not been identified specifically in fish surveys. Each of these species can reproduce to very high densities. At high densities, these bottom-feeding fish are capable of disturbing lake beds to the extent that water quality can be diminished. Lakes with an overgrowth of European carp typically have high phosphorus concentrations, low water clarity, and little to no aquatic plant growth. Carp eat vegetation and can alter or destroy the aquatic plant community in a lake. In 1977, MDNR chemically treated Wirth Lake with Rotenone to remove rough fish and stocked the lake with largemouth bass, walleye, and channel catfish. In 2002, the MCWD sponsored a carp removal at Lake Nokomis.

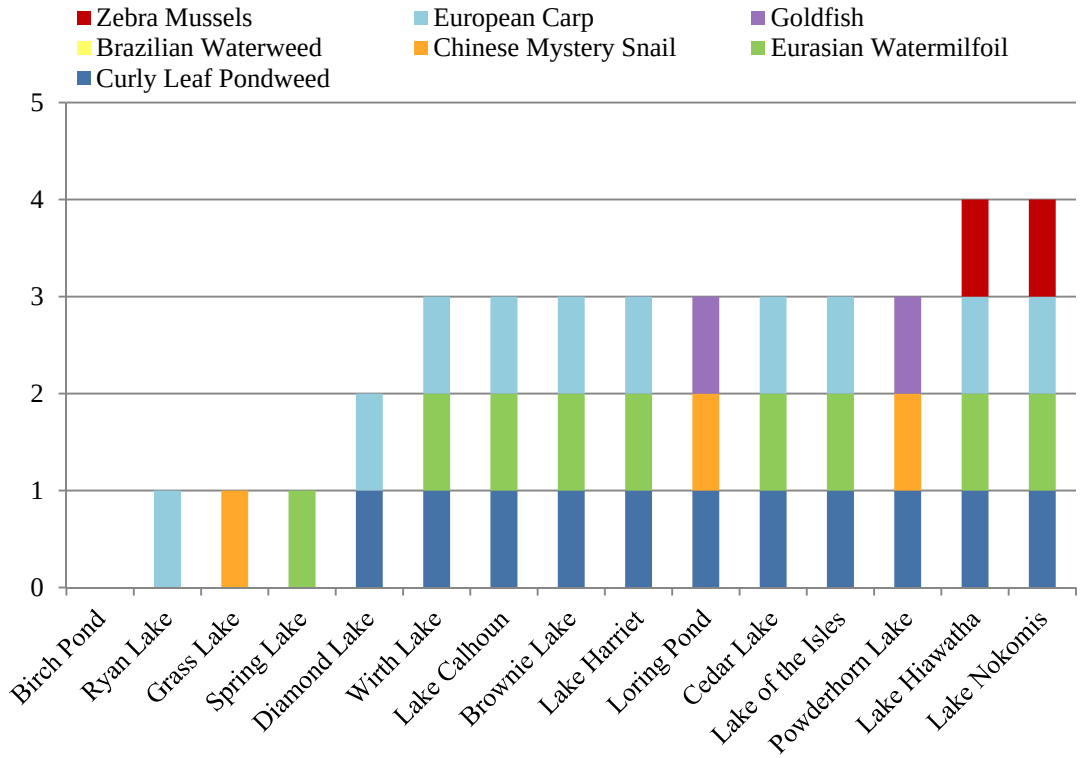


Figure 18-6. Invasive and exotic aquatic species found in MPRB Lakes. Birch Pond, Ryan, and Grass Lakes have not been fully surveyed for invasive species. Zebra mussels have not been confirmed present in Lake Nokomis. Brazilian water weed in Powderhorn was successfully treated with chemicals in 2007.

Table 18-9. Exotic species established in MPRB lakes, the number of lakes where the species are found and the data source used.

Common Name	Scientific Name	# of Lakes	Data Source
Curly leaf pondweed	*Potamogeton crispus*	11	MPRB
Eurasian watermilfoil	*Myriophyllum spicatum*	10	MDNR infested waters list
European carp	*Cyprinus carpio*	8	MDNR fish survey
Chinese mystery snail	*Bellamya chinensis*	3	MDNR
Zebra mussel§	*Dreissena polymorpha*	2	MDNR infested waters list
Goldfish	*Carassius auratus*	2	MDNR fish survey
Brazilian water weed*	*Egeria densa*	0	MDNR infested waters list

§Lakes Nokomis is considered infested with zebra mussels due to its connection with Minnehaha Creek and Lake Minnetonka. The species has not been confirmed present in Lake Nokomis as of fall 2014.
* Treated successfully in 2007 by MDNR and delisted in 2014.

19. PUBLIC BEACH MONITORING

BACKGROUND

The Minneapolis Park and Recreation Board (MPRB) has twelve official beaches located on six lakes (**Figure 19-1**). Prior to 2003 the City of Minneapolis Environmental Health Department monitored the beaches for fecal coliform bacteria. The 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 Operations staff monitored the beaches for *E. coli* alone as recommended by the US Environmental Protection Agency (USEPA). USEPA 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 to develop an inland lakes standard which MPRB has followed since 2006. The inland lakes standard has a single-sample limit of 1,260 organisms per 100 mL and was accepted into rule during 2008 and has been used by MPRB since that time.

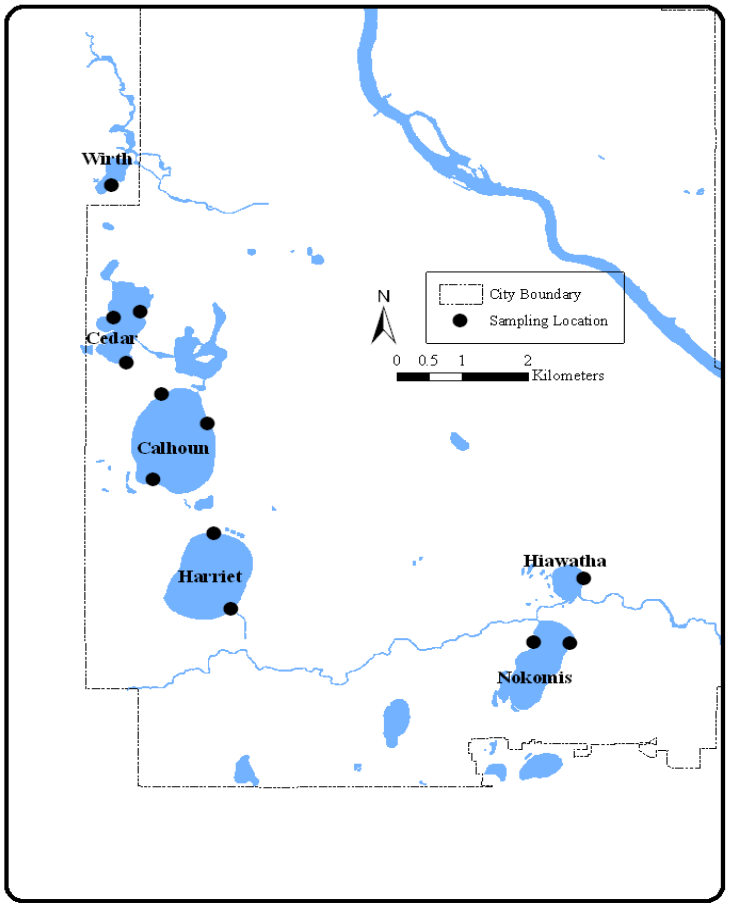


Figure 19-1. Map MPRB public beaches monitored in 2014.

A great diversity of pathogenic microorganisms exist, 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 (USEPA, 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
- wild and domestic animal waste (such as geese, gulls, raccoons, dogs, etc.).

Research originally used to develop *E. coli* as an indicator organism held that it does not survive well outside of the digestive systems of warm-blooded animals. Half-lives of approximately 1 day in water, 1.5 days in sediment, and 3 days in soil were once thought to be typical survival rates of *E. coli* outside of its host environment (Winfield and Groisman, 2003).

More recent findings indicate that *E. coli* is able to survive and grow outside of its host environment. New 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. *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, 2008).

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 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 (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.

METHODS

Samples were collected from twelve MPRB beaches every Monday during the beach season (6/09/14 through 8/25/14). Beaches monitored in the 2014 MPRB program were:

- Calhoun 32nd Street
- Calhoun Main (North)
- Calhoun Thomas (South)
- Cedar Main (South)
- Cedar Point
- East Cedar (Hidden)
- Harriet Main
- Harriet Southeast
- Hiawatha
- Nokomis 50th Street (East)
- Nokomis Main
- Wirth Main.

Two 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 temperature 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 temperature
- current weather
- LAURI parameters of beach (For additional information on the LAURI see **Section 1**)
- number of adults, children, and children in diapers not in the water broken
- 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)
- water temperature
- 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.

RESULTS & DISCUSSION

Specific lake and beach results are discussed in each of the lake sections.

Table 19-1 shows the basic descriptive statistics of *E. coli* (mpn organisms per 100 mL of water) in the beach water sampled during the 2014 beach season. Most beaches had low season-long geometric means, but there were several beach closures during the 2014 beach season. Three times during the 2014 season beaches were closed due to high geometric means. The first instance occurred at Lake Calhoun's Thomas Beach, which was closed on 7/23. The geometric mean returned to acceptable levels with the following week's Monday samples, and the beach was reopened on 7/29. The other two instances occurred on 8/5 at Lake Hiawatha's beach and Lake Calhoun's Thomas Beach. Both beaches remained closed through the end of the beach sampling season due to geometric means remaining above the standard. Only once during the sampling season was a beach closed due to the single sample limit of 1,260 *E. coli* per 100 mL of water being exceeded. This occurred at Lake Calhoun's 32nd Beach. The beach was closed on 8/5, and reopened on 8/7 once samples showed *E. coli* had returned to acceptable levels. The presence of significant amounts of waterfowl waste was observed at the beach during the closure, and may have contributed to the observance of high *E. coli*.

Table 19-1. 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 2014.

Statistical Calculations	Calhoun 32nd	Calhoun Main	Calhoun Thomas	Cedar Hidden	Cedar Main	Cedar Point	Harriet Main	Harriet SE	Hiawatha	Nokomis 50th	Nokomis Main	Wirth
Number of Samples	15	13	15	13	13	13	13	14	15	13	13	13
Minimum	12	3	19	4	0.5	2	3	6	28	2	4	1
Maximum	1643	215	1252	143	84	237	86	2420	1210	102	239	193
Median	62	14	76	25	20	9	13	11	125	18	33	6
Mean	240	33	326	41	28	29	23	206	288	27	61	23
Geometric Mean	75	16	133	24	13	11	14	21	157	15	35	6
Max 30-Day Geo Mean	112	30	218	77	20	30	18	47	322	30	61	23
Standard Deviation	455	56	410	43	29	63	26	642	346	33	69	53

In general, rain is likely the single most influential cause of elevated *E. coli* levels in Minneapolis lakes. Rain washes the bacteria off of hard surfaces and sends it through the storm sewer system to the lakes. **Table 19-2** 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 gauge.

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 19-2. Number of storms, largest storm (inches), average storm (inches), and total rain (inches), for the 2008–2014 beach seasons.

	2008	2009	2010	2011	2012	2013	2014
Number of storms	11	11	20	15	16	12	15
Max rain single event	0.85	2.27	2.52	3.71	0.85	3.0	3.0
Avg rain per event	0.38	0.64	0.62	0.91	0.42	0.8	0.66
Total Rain	4.21	7.02	12.49	13.81	6.7	9.66	10.15

It is difficult to assess the quality of water the same day of sample collection since testing requires 24 hours. The lag time between sample collection and receipt of test results can result in unnecessary beach closures and/or exposure to poor water quality. A study by Ha Kim and Grant (2004) found that the public is misnotified about current water quality status and beaches are misposted up to 40% of the time. An example of this at MPRB occurred in 2013 when a sample was taken at Calhoun 32nd Beach on July 22nd. The beach was closed around noon on the 23rd when the results were found to exceed the single sample limit and the beach was re-sampled. The results from that sample came back on July 24th and were below the limit. The beach was open on July 22nd when it should have been closed and closed unnecessarily on July 23rd when it should have been open. The 24-hour delay caused posting errors on 2 days.

Beach management decisions are made using the best available methods and data. MPRB Environmental Stewardship 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 USEPA Environmental Health Perspective (2005), the number of illnesses attributable to recreational water exposures was reported to be increasing. In Minnesota, there were 11reported outbreaks which were traced to recreational contact at lakes since 2005. The outbreaks were associated with 6 different pathogens (Minnesota Department of Health, 2015). It should be noted that none of the waterborne illness outbreaks were at Minneapolis beaches.

Communicating the results of beach monitoring with the public is a very important aspect of the process and also offers an opportunity for water and public health education. A phone and email tree is utilized to quickly notify staff and elected officials of beach closures and re-openings. A Beach Information Telephone Line (612.313.7713) is updated daily on beach closures due to bacteria testing. Results from testing are also put on the MPRB website the day results are received (https://www.minneapolisparks.org/park_care__improvements/water_resources/beach_water_resources/). The communication efforts were very successful in 2014 and offered the public many opportunities to obtain information regarding beach water quality and closures.

20. AQUATIC PLANT MANAGEMENT

EURASIAN WATER MILFOIL (*MYRIOPHYLLUM SPICATUM*)

Eurasian watermilfoil (*Myriophyllum spicatum*) has been an ongoing concern in several Minneapolis lakes. 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.

The Minneapolis Park and Recreation Board (MPRB) primarily uses harvesting to maintain recreational access to city lakes. Only the top two meters of the milfoil plants are removed and this temporarily allows for problem-free boating and swimming. The MDNR permits limit the area of milfoil harvest. Harvesting was completed on Calhoun, Cedar, Harriet, Isles, Wirth, and Nokomis in 2014. MPRB Staff removed 114 flatbed truck loads of milfoil in 2014 which is comparable to 630 cubic yards of aquatic plant material. For harvested acreage see each individual lake section. MPRB contracted out harvesting work on Wirth and Nokomis to Waterfront Restoration, LLC, who removed milfoil from high traffic recreational areas by hand via SCUBA.

In the early 2000s, the MPRB and the University of Minnesota released aquatic weevils that eat Eurasian water milfoil into Cedar Lake, Lake of the Isles, Lake Harriet, and Lake Hiawatha. The weevils were not successful controlling milfoil. The most likely explanation is that the high density of sunfish in the lakes fed on the weevils and limited their population.

BRAZILIAN WATERWEED *(EGERIA DENSA)*

In August of 2007, a new aquatic invasive species, *Egeria densa* (*E. densa*), was identified in Powderhorn Lake. The new invasive is native to South America and used extensively in aquariums and water gardens. It is likely that *Egeria* was introduced to Powderhorn Lake though an aquarium release. In September of 2007, the MDNR spot-treated stands of *E. densa* with diquat, an herbicide approved for aquatic use. The lake was removed from the list of waterbodies infested with this plant in 2014 following five years of MDNR and MPRB surveys not finding *E. densa* in Powderhorn.

PURPLE LOOSESTRIFE (*LYTHRUM SALICARIA*)

Since 1999, the MPRB has collaborated with the MDNR to introduce leaf-feeding beetles (*Galerucella spp*.) as a biocontrol for purple loosestrife (*Lythrum salicaria*). Both biocontrol methods and chemical herbicides are used to manage purple loosestrife throughout the park system. Beetles were found feeding at major purple loosestrife sites on MPRB properties in 2013. The MPRB and MDNR staff continues to monitor beetle release sites. Additionally, MPRB led a volunteer effort to cut purple loosestrife inflorescence around Lake of the Isles in order to limit seed dispersal. 2014 was the third year of volunteer management efforts around Lake of the Isles. MPRB has tracked the spread of purple loosestrife around Lake of the Isles to monitor its spread and efforts to limit seed dispersal.

21. Wetland Health Evaluation Project (WHEP)

BACKGROUND

The Wetland Health Evaluation Project (WHEP) began in 1997 in Dakota County with Environmental Protection Agency (USEPA) 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 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 the partner organizations and to the public.

MPRB has sponsored citizen volunteer teams who monitor wetlands within the park system each year since 2002. Every summer between two and four wetlands are monitored within Minneapolis depending on the needs of the MPRB. During 2014 the wetlands monitored were: a portion of the wetland edge of Diamond Lake, Heritage Park North Wetland, Wirth Golf Course wetland, and Wirth Beach Restored Wetland. The Roberts Bird Sanctuary wetland is also monitored annually as a reference wetland site for the City of Minneapolis.

For more information see the Minnesota WHEP website at www.mnwhep.org.

METHODS

Volunteers for the project are trained in three sessions by 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 two samples from a dip-net within the emergent vegetation zone, near the shoreline, and in six overnight bottle trap samples.

The information is then used to evaluate the wetland's biological health based on metrics developed by the Minnesota Pollution Control Agency. 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 21-1**. 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.

Table 21-1. 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**
6-14	Poor	7-15	Poor
15-22	Moderate	16-25	Moderate
23-30	Excellent	26-35	Excellent

RESULTS AND DISCUSSION

During the summer of 2014, WHEP-trained volunteers monitored five wetlands within the MPRB system. Roberts Bird Sanctuary was monitored for its twelfth 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. Results and discussion for each wetland are presented individually within this section.

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 is estimated to be ten acres in size, within a 1000+ acres watershed. The WHEP team accesses the monitoring location near a tamarack stand from the boardwalk. 2014 was the twelfth year that WHEP monitored the site. **Table 21-2** shows the results for Roberts Bird Sanctuary. In 2014, the wetland scored 26/excellent for invertebrates and 15/poor for vegetation.

Table 21-2. 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

Diamond Lake Wetland Fringe

Diamond Lake has been monitored ten times in the WHEP Program. The wetland fringe at Diamond Lake has typically scored poor in both the invertebrate and vegetation IBI (**Table 21-3**). In 2014, the Diamond Lake Wetland Fringe scored 12/poor for vegetation quality and 19/moderate for invertebrates. This site is located in an urban setting with a large urban watershed and provides valuable bird habitat.

Table 21-3. 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

Heritage Park North Wetland

Heritage Park North Wetland is located in Sumner Field Park. The wetland was developed in 2006-2007. It catches stormwater runoff from multiple inlets and outlets at corner of 8th and Aldrich N where water then flows to Bassett Creek Tunnel, under downtown and to Mississippi River. The site was planted with wetland vegetation and infiltration trenches have been re-worked several times which has disturbed vegetation in the immediate area. The site has many best management practices (BMPs) in design, such as grit chambers and level spreaders, with additional rain gardens upstream. 2014 was the third year Heritage Park was included in WHEP monitoring, as presented below in

Table 21-4. In 2014, Heritage Park received an invertebrate score of 10/poor and a vegetation quality score of 15/poor.

Table 21-4. WHEP scores at Heritage Park North Wetland

Year	Invertebrate Score	Invertebrate Quality Rating	Vegetation Score	Vegetation Quality Rating
2012	12	Poor	23	Moderate
2013	20	Moderate	23	Moderate
2014	10	Poor	15	Poor

Wirth Golf Course Wetland

Wirth Golf Course Wetland is located on the par 3 golf course at Theodore Wirth Park. This site is fed by groundwater springs year-round, receives runoff from the adjoining development, and it outlets under Glenwood Avenue to Wirth Lake.

2014 was the seventh year of monitoring at the Wirth Golf Course Wetland, as presented below in **Table 21-5**. Wirth Golf Course Wetland received a score of 21/moderate for the vegetative IBI metric and a score of 10/poor for invertebrates. The site is difficult to monitor due to the steep drop-off on the wetland's sides.

Table 21-5. WHEP scores at Wirth Golf Course Wetland

Year	Invertebrate Score	Invertebrate Quality Rating	Vegetation Score	Vegetation Quality Rating
2002	10	Poor	15	Poor
2003	18	Moderate	13	Poor
2004	22	Moderate	19	Moderate
2008	30	Excellent	19	Moderate
2009	24	Excellent	19	Moderate
2013	18	Moderate	19	Moderate
2014	10	Poor	21	Moderate

Wirth Beach Restored Wetland

Wirth Beach Restored Wetland is located near the southern tip of Wirth Lake just southeast of the swimming beach. The site has inlets from the Upper/Lower Wirth wetland complex and parkland and from the basins adjacent to the parking lot to the east of the wetland. The outlet is to Wirth Lake. Additionally, there are multiple groundwater springs at the north end of the wetland. The wetland was historically filled with debris from the old Wirth Beachhouse. Debris was removed and the wetland was replanted. 2014 is the 3rd season post-planting. Previous condition was a cattail/purple loosestrife monoculture.

2014 was the first year of monitoring at the Wirth Beach Restored Wetland, as in **Table 21-6**. Wirth Beach Restored Wetland received a score of 25/moderate for the vegetative IBI metric and a score of 18/ for invertebrates.

Table 21-6. WHEP scores at Wirth Beach Restored Wetland

Year	Invertebrate Score	Invertebrate Quality Rating	Vegetation Score	Vegetation Quality Rating
2014	18	Moderate	25	Moderate

22. NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM (NPDES) MONITORING

BACKGROUND

The Minneapolis Park and Recreation Board (MPRB) and the City of Minneapolis are co-signatories on the National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) Permit. The MPRB has performed the NPDES MS4 stormwater monitoring since 2000. The purpose of the stormwater monitoring is to characterize the quantity and pollutant load of runoff from small areas representing various types of land use under a "no BMP" scenario. In reality, the results do not represent actual conditions for either runoff quantity or quality because there are numerous BMPs – Best Management Practices and other structural controls and management practices that reduce pollutants in stormwater runoff and/or temper stormwater runoff quantity in the watershed.

At the beginning of the first NPDES MS4 permit (2001-2004), the MPRB and City of Minneapolis partnered with the City of St. Paul to fulfill the NPDES monitoring requirements. Five sites in Minneapolis and St. Paul were jointly monitored between 2001–2004. In 2005, the MPRB stopped monitoring stormwater in St. Paul, and four new sites in Minneapolis were selected for monitoring. In 2006, new sites were chosen in Minneapolis to comply with the NPDES permit and to assist with modeling and load allocation efforts.

In 2014, the same four sites, representing the major land uses in Minneapolis -- residential, commercial/industrial, mixed use, and parkland -- were monitored for stormwater runoff quantity and quality. Representative sampling is mathematically extrapolated to calculate potential contaminant loading on a citywide scale, under the "no BMP" scenario. While the results do not represent actual impacts of stormwater discharge to receiving waters because they do not reflect the effects of structural controls and management practices, they nevertheless are useful to compare land uses and to posit baseline conditions for water quality modeling exercises.

METHODS

The summary below includes descriptions of equipment installation at each site, parameters monitored, field quality assurance sampling, computer models used, data handling, validation, and reporting.

Site Installation

The ISCO equipment installed at each site included a 2150 datalogger with low profile area/velocity pressure transducer probe, 2105 interface module, 2105ci or 2103ci cell phone modem, and a 3700 sampler. The sampler collected stormwater with 3/8" ID vinyl intake tubing complete with strainer. The dataloggers flow-paced the samplers to collect flow-weighted stormwater samples over the entire storm hydrograph. Each site automatically uploaded data, via cell phone modem, to the network server database Monday through Friday. Each site could also be communicated with remotely by Flowlink Pro software in order to adjust pacing, enable or disable samplers, and see if a site had triggered.

Equipment installation began when freezing spring temperatures were no longer a concern in order to prevent area velocity transducer damage. See **Figure 22-1** for a map of site locations. Site 6

(22nd/Aldrich) was installed on 5/6/14. Site 7 (14th/Park), was installed on 5/2/14. Site 8a (Pershing Park) and Site 9 (61st/Lyndale) were installed on 4/25/14. See **Table 22-1** for site characteristics.

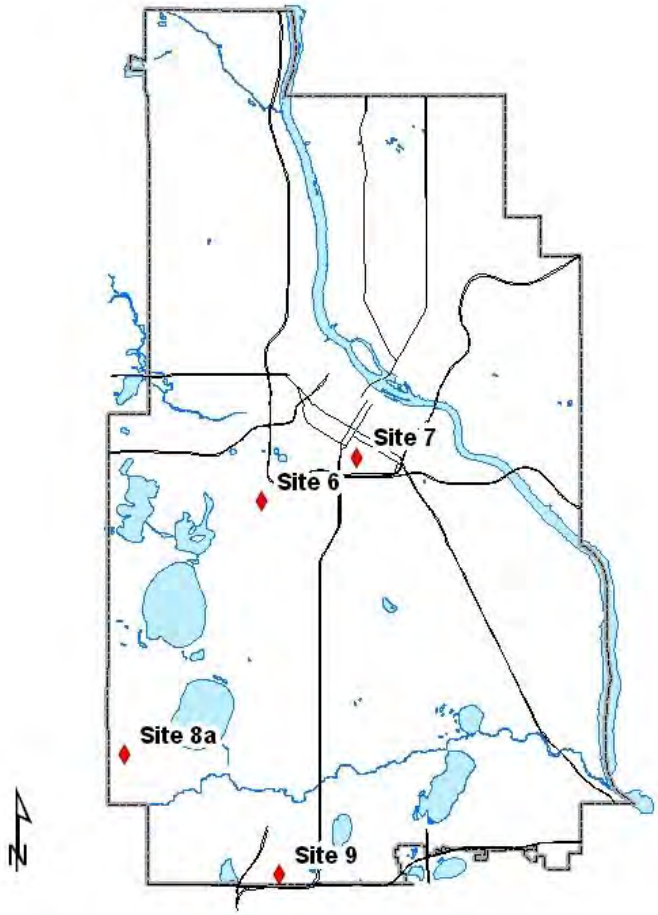


Figure 22-1. Map of the 2014 NPDES sites located in Minneapolis.

Table 22-1. 2014 NPDES stormwater monitoring sites for Minneapolis.

Site ID	Site 6	Site 7	Site 8a	Site 9
Location	22nd St & Aldrich Ave S	E 14th St & Park Ave S	Pershing Field east of 49th St & Chowen Ave	335 ft. east of 61st St & Harriet Ave S
Land Use	Multi–Family Residential	Commercial/Industrial/ High Rise Residential	Recreational/Parkland	Commercial/Industrial
Area (acres)	8.9	13.1	2.5	34.9
Pipe Diameter (inches)	18	42	12	36
Outfall ID#	10 – 430J	10 – 430D	57 – 100A/B	71 – 070

Sample Collection and Monitored Parameters

The MS4 permit target frequency for storm event sample collection is 15 samples per site, per year. If a sample was missed during one month due to lack of precipitation events, then two or more were taken the next month. In 2014, flow-paced storm event samples were collected from May through early November.

The total volume sampled for each site and total recorded volumes in 2014 are given in **Table 22-2** along with the seasonal aggregate percentage sampled. Detailed information on sampling events is shown in **Table 22-3**.

Table 22-2. NPDES site volume totals for the sampling period 5/8/14 – 11/6/14.

	Site 6	Site 7	Site 8a	Site 9
Total volume recorded (with Flowlink) for 2014 (cf)	282,613	767,212	69,580	1,685,780
Total volume of sampled events (cf)	168,594	482,412	54,410	1,087,615
% sampled ANNUAL	60%	63%	78%	65%
% sampled SPRING (May- June)	71%	76%	93%	88%
% sampled SUMMER (July- September)	29%	19%	6%	5%
% sampled FALL (October- November)	0%	5%	2%	7%

Table 22-3. 2014 precipitation event data and samples collected for NDPES sites. A precipitation event is defined as being greater than 0.10 inches and separated by 8 hours. The rain gage is located at 3800 Bryant Ave. S., Minneapolis, MN.

Event	Start Date/Time		End Date/Time		Precip (inches)	Duration (hours)	Intensity (in/hr)	Time since last Precip. (hours)	Sample Type	2014 NPDES Events Collected			
										Site 6 22nd/Aldrich	Site 7 14th/Park	Site 8a Pershing	Site 9 61st/Lyndale
+1	2/19/2014	14:15	n/a	n/a	n/a	n/a	n/a	n/a	grab		X(w/Ecoli)		X(w/Ecoli)
+2	3/10/2014	14:30	n/a	n/a	n/a	n/a	n/a	n/a	grab	X(w/Ecoli)	X(w/Ecoli)		X(w/Ecoli)
+3	3/14/2014	15:05	n/a	n/a	n/a	n/a	n/a	n/a	grab	X			
+4	3/21/2014	14:00	n/a	n/a	n/a	n/a	n/a	n/a	grab			X(w/Ecoli)	
+5	3/26/2014	13:55	n/a	n/a	n/a	n/a	n/a	n/a	grab	X(w/Ecoli)	X(w/Ecoli)		
+6	3/27/2014	13:55	n/a	n/a	n/a	n/a	n/a	n/a	grab			X(w/Ecoli)	
+7	4/27/2014	11:58	n/a	n/a	n/a	n/a	n/a	n/a	grab			X	X
8	5/8/2014	0:30	5/8/2014	20:00	1.02	19.5	0.05	180.0	composite	X	X	X(lmtd)	X
9	5/11/2014	21:30	5/12/2014	21:30	0.82	24.0	0.03	46.5	composite	X	X	X	X
10	5/19/2014	10:30	5/19/2014	22:30	1.80	12.0	0.15	169.0	comp/grab	X(w/Ecoli)	X(w/Ecoli)	X	X(w/Ecoli)
11	5/31/2014	16:30	6/1/2014	21:00	1.97	28.5	0.07	310.5	composite	X	X(lmtd)	X(lmtd)	X(lmtd)
12	6/11/2014	23:30	6/12/2014	12:00	0.11	0.5	0.22	118.5	composite	X(lmtd)	X		X
13	6/14/2014	10:00	6/15/2014	9:30	1.90	23.5	0.08	69.5	composite		X(lmtd)	X(lmtd)	X(lmtd)
14	6/16/2014	17:00	6/16/2014	21:00	0.45	4.0	0.11	35.5	composite	X	X		
15	6/18/2014	2:30	6/18/2014	4:30	0.43	2.0	0.22	31.5	composite	X	X	X	X
16	6/19/2014	3:30	6/19/2014	20:30	3.00	17.0	0.18	40.0	comp/grab	X(w/Ecoli)	X(w/Ecoli)	X	X
17	6/28/2014	15:30	6/29/2014	1:30	1.00	10.0	0.10	221.0	composite				X(lmtd)
18	7/7/2014	18:00	7/7/2014	22:30	0.33	4.5	0.07	38.5	composite	X	X	X(lmtd)	X(lmtd)
19	7/11/2014	6:00	7/11/2014	10:00	1.11	4.0	0.28	83.5	composite	X		X	
20	7/25/2014	5:00	7/25/2014	7:00	0.42	2.0	0.21	250.5	composite	X	X	X(lmtd)	X
21	8/17/2014	14:00	8/18/2014	0:30	0.32	10.5	0.03	365.5	composite	X			X
22	8/29/2014	1:15	8/30/2014	11:15	1.02	34.0	0.03	214.0	composite	X			
23	9/3/2014	8:30	9/3/2014	21:00	0.16	12.5	0.01	65.0	comp/grab	X(Ecoli only)	X(w/Ecoli)		X(Ecoli only)
24	9/9/2014	21:15	9/10/2014	9:00	0.41	11.8	0.03	156.0	composite		X	X	X
25	9/20/2014	17:30	9/20/2014	18:30	0.21	1.0	0.21	249.5	composite		X(lmtd)		
26	9/28/2014*	15:00	9/29/2014	1:00	0.51*	11.0*	0.21*	96.2*	composite		X(lmtd)		
27	10/1/2014	7:30	10/2/2014	22:45	1.04	39.2	0.03	292.2	composite		X(lmtd)	X	X(lmtd)
			Totals		**17.52**					**17**	**19**	**15**	**18**

+ snowmelt event

n/a = not applicable

X = event sampled with full parameters

X(lmtd) = event sampled with limited parameters generally due to holding times e.g.BOD, Ortho P, and TDP

X(w/Ecoli) = event sampled with *E. coli*

X(Ecoli only) = only *E. coli* sampled

*NWS data collected at MSP airport

Table 22-4 shows the parameters tested as part of the MS4 permit for each sample collected. **Table 22-5** gives the approved methods used for analysis, reporting limit, and holding time for each parameter as reported by the contract laboratory Instrumental Research, Inc. (IRI). Legend Technical Services Laboratory analyzed all metals samples.

Limited parameter sample designation is when the sample is collected after some of the parameters (e.g. BOD, TDP) holding times have expired and those parameters are not analyzed. In 2014, limited parameters were collected nineteen times. These samples were recovered after more than 24 hours and parameters with short holding times were not analyzed (e.g. cBOD, TDP) or there was limited composite volume.

As required by the MS4 permit, *Escherichia Coliform* (*E. coli*) grab and pH samples were collected by quarterly sampling. *E.coli* was collected annually at all sites except at Site 8a (Pershing). Site 8a was inaccessible for grab sampling after snowmelt and equipment installation. When flow and time were sufficient, *E. coli* grab samples were collected. A total of eighteen *E. coli* grabs were collected in 2014. Site 6 (22nd/Aldrich) was collected five times. Site 7 (14th/Park) was collected six times. Site 8a (Pershing) was collected twice. Site 9 (61st/Lyndale) was collected five times. The pH was measured in the field using an Oakton Waterproof pHTestr 2™ or at the laboratory IRI. If the Oakton field meter was used, the pH meter was calibrated with 2-point calibration prior to each sampling trip.

With the exception of Site 8 (Pershing) all required *E. coli* grab and pH samples sampling were successfully accomplished in 2014.

Table 22-4. The list of monitored chemical parameters for the NPDES permit. BOD is biochemical oxygen demand.

Parameter	Abbreviation	Units	Sample Type
BOD –carbonaceous, 5 Day	cBOD	mg/L	Composite
Chloride, Total	Cl	mg/L	Composite
Specific Conductivity	Sp. Cond	µmhos/cm	Composite
E. coli (*Escherichia Coliform*)	*E. coli*	MPN/100mL	Grab (4X year)
Hardness	Hard	mg/L	Composite
Copper, Total	Cu	µg/L	Composite
Lead, Total	Pb	µg/L	Composite
Zinc, Total	Zn	µg/L	Composite
Nitrite+Nitrate, Total as N	NO_3NO_2	mg/L	Composite
Ammonia, Un-ionized as N	NH_3	mg/L	Composite
Kjeldahl Nitrogen, Total	TKN	mg/L	Composite
pH	pH	standard unit	Grab (4X year)
Phosphorus, Ortho-P	Ortho-P	mg/L	Composite
Phosphorus, Total Dissolved	TDP	mg/L	Composite
Phosphorus, Total	TP	mg/L	Composite
Solids, Total Dissolved	TDS	mg/L	Composite
Solids, Total Suspended	TSS	mg/L	Composite
Solids, Volatile Suspended	VSS	mg/L	Composite
Sulfate	SO_4	mg/L	Composite

Table 22-5. Analysis method, reporting limit, and holding times for parameters used by Instrumental Research, Inc.

Parameter	Method	Reporting Limit	Holding Times
cBOD, carbonaceous, 5 Day (20°C)	SM 5210 B	1.0 mg/L	24 hours
Chloride, Total	SM 4500-Cl^- B	2.0 mg/L	28 days
Specific Conductivity	SM 2510 B	10 µmhos/cm	28 days
E. coli (*Escherichia Coliform*)	SM 9223B	1 MPN per 100mL	< 24hrs
Hardness	SM 2340 C	2.0 mg/L	6 months
Copper, Total	EPA 200.9	1.4 µg/L	6 months
Lead, Total	SM 3500-Pb B	3 µg/L	6 months
Zinc, Total	SM 3500-Zn B	2 µg/L	6 months
Nitrite+Nitrate, Total as N	SM 4500-NO_3 E	0.030 mg/L	28 days
Ammonia, Un-ionized as N	SM 4500-NH_3 F	0.500 mg/L	7 days
Kjeldahl Nitrogen, Total	SM 4500-Norg B	0.500 mg/L	7 days
pH	SM 4500 H^+ B	0.01 units	15 minutes
Phosphorus, Ortho-P	SM 4500-P A, B, G	0.010 mg/L	48 hours
Phosphorus, Total Dissolved	SM 4500-P A, B, G	0.010 mg/L	48 hours
Phosphorus, Total	SM 4500-P A, B, E	0.010 mg/L	48 hours
Solids, Total Dissolved	SM 2540 C	10.0 mg/L	7 days
Solids, Total Suspended	SM 2540 D	1.0 mg/L	7 days
Solids, Volatile Suspended	SM 2540 E	2.0 mg/L	7 days
Sulfate*	ASTM D516-90	15 mg/L	28 days

Sulfate* samples were spiked (10 mg/L) and then spike later subtracted to lower the 2014 detection limit to 5 mg/L.

FIELD QUALITY ASSURANCE SAMPLES

Ten percent of samples were laboratory quality assurance samples (e.g. duplicates, spikes). Field blanks consisted of deionized water which accompanied samples from the field sites to the analytical laboratory. A field blank was generated for each sampling trip and was analyzed for all NPDES parameters. All field blank parameters were below the minimum detection limits in 2014. As part of the overall QA/QC program, blind monthly performance samples were made for all monitored parameters and delivered to IRI.

If the Oakton field meter was used, the pH meter was calibrated with 2-point calibration prior to each sampling trip.

An equipment blank (~ 2 L sample) was collected at Site 8a (Pershing) 11/07/14. This site has a standard NPDES stormwater monitoring set up. To collect the equipment blank, a large bottle of deionized water was placed at the strainer end of the sampler tubing. The intake line was filled and flushed with deionized water simulating the presample flush. After the flush was pumped to waste, a sample of deionized water was collected. The sample taken was of sufficient volume to allow analysis of all parameters. All analytes came back from the laboratory below the minimum detection limits.

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 **Section 28**, Quality Assurance Assessment Report for details.

Field measurements were recorded on a Field Measurement Form in the 2014 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 Storm Water 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.

A Chain of Custody form accompanied each set of sample bottles delivered to the lab. Each sampler tray or container was iced and labeled indicating the date and time of collection, the site location, and the field personnel initials. The ultimate collection date and time assigned to the sample was the time when the last sample of the composite was collected. The time that each composite sample was collected was recorded from the ISCO sampler onto field sheets. A complete description of methods can be found in the Storm Water Monitoring Program Manual (MPRB, 2001). All statistics were calculated using Microsoft Excel.

Computer Models used (P-8 and Flux)

The computer model P8 (v3.4) was calibrated and verified for each site. P8 was used to estimate daily cfs snowmelt runoff from January through May. Daily temperature and hourly precipitation files used as P8 inputs were obtained from the National Oceanic and Atmospheric Administration (NOAA) National Data Center (NDC). Data from a heated rain gauge (for snowmelt water equivalent) was used and is located at the Minneapolis/St. Paul International Airport.

A description of P8 as described in the software's introduction:

> P8 is a model for predicting the generation and transport of stormwater runoff pollutants in small urban catchments. Simulations are driven by hourly rainfall and daily air-temperature time series.

The P8 estimated daily average cfs snowmelt data, with the ISCO Flowlink measured daily average cfs runoff data, the grab and composite water chemistry data were put into FLUX32 (v3.10) and used to calculate flow-weighted mean concentrations.

In Flux32, all the data were run unstratified, and also if possible stratified by flow and month. A minimum of three data points are required to cut the data in any stratification. FLUX32 methods 2 and 6 were recorded for each parameter run. The mean concentration value with the lowest coefficient of variation was chosen and used for load calculations.

A description of FLUX32 as described in the help menu (US Army Corps, 2009):

> Flux32 is interactive software designed for use in estimating the transport (load) of nutrients or other water quality constituents past a tributary sampling station over a given period of time. The basic approach of Flux32 is to use several calculation techniques to map the flow/concentration relationship developed (modeled) from the sample record onto the entire flow record. This provides an estimate of total mass transport for the whole period of study with associated error statistics. Note that this approach does NOT focus on estimating changes in loads over time (i.e. time series).

An important option within Flux32 is the ability to stratify the data into groups based upon flow, date, and/or season. This is a key feature of the FLUX approach and one of its greatest strengths. In many (most) cases, stratifying the data increases the accuracy and precision of loading estimates.

RESULTS & DISCUSSION

Seasonal statistics (snowmelt, spring, summer, and fall) of the data for the combination of all sites were calculated and are listed in **Table 22-6**. Seasonal patterns are evident.

Snowmelt had the highest geometric mean concentrations for most of the parameters: TP, TDP, TKN, NH_3, Cl, hardness, TDS, cBOD, sulfate, pH, Cu, and Zn. Snowmelt had the lowest geometric mean concentration for *E coli*, which is temperature dependent.

Spring stormwater had the highest geometric mean concentrations for Ortho-P, TSS, VSS, and Pb. Spring had the lowest geometric mean concentration for sulfate.

Summer had the highest geometric mean concentrations of NO_3NO_2, and *E. coli.* Summer had the lowest geometric mean concentrations for NH_3, hardness, VSS, TDS, cBOD, pH, and Zn.

Fall had none of the highest geometric mean concentrations. Fall had lowest geometric mean concentration for the majority of parameters: TP, TDP, Ortho-P, TKN, NO_3NO_2, Cl, TSS, CU, and Pb.

Table 22-6. 2014 statistical summary of concentrations by season from all sites (6 –9).

2014 Season	Statistical Function	TP mg/L	TDP mg/L	Ortho-P mg/L	TKN mg/L	NH_3 mg/L	NO_3NO_2 mg/L	Cl mg/L	Hardness mg/L	TSS mg/L	VSS mg/L	TDS mg/L	cBOD mg/L	Sulfate mg/L	pH std units	*E. coli* MPN/100mL	Cu ug/L	Pb ug/L	Zn ug/L
SNOWMELT (February-March)	**MEAN (geometric)**	0.575	0.183	0.127	3.39	1.53	0.512	507	65	109	36	592	17	17	7.5	63	33	12	119
	MEAN (arithmetic)	0.675	0.238	0.136	3.83	1.75	0.653	1402	91	180	51	2244	20	23	7.6	90	36	15	145
	MAX	1.25	0.515	0.185	6.80	3.20	1.54	5895	308	610	161	9699	57	63	10.8	166	78	30	270
	MIN	0.158	0.043	0.087	0.90	0.536	0.146	10	24	24	10	45	8	5	6.6	10	22	3	27
	MEDIAN	0.596	0.228	0.136	4.08	1.71	0.608	382	56	115	37	558	14	14	7.0	102	32	13	140
	STDEV	0.352	0.160	0.069	1.65	0.825	0.429	1978	85	187	44	3340	15	20	1.32	62	18	8	77
	NUMBER	12	12	2	12	11	12	12	12	12	12	12	10	10	12	8	9	10	9
	COV	0.521	0.67	0.510	0.431	0.472	0.656	1.41	0.937	1.04	0.867	1.49	0.726	0.882	0.175	0.685	0.492	0.557	0.531
SPRING (April-May)	**MEAN (geometric)**	0.200	0.104	0.142	3.19	1.20	1.57	9	38	172	50	54	8	5	7.1	786	32	14	71
	MEAN (arithmetic)	0.266	0.120	0.185	3.59	1.25	1.80	35	43	239	65	63	8	6	7.2	1736	37	21	95
	MAX	1.10	0.274	0.686	8.16	2.14	4.68	438	96	913	170	147	13	15	9.2	4352	95	87	280
	MIN	0.064	0.037	0.061	1.34	0.858	0.578	2	16	51	17	23	3	3	6.3	160	20	3	20
	MEDIAN	0.150	0.105	0.142	2.90	1.11	1.35	8	40	169	47	52	8	5	6.9	697	28	15	69
	STDEV	0.244	0.070	0.168	1.93	0.368	1.05	101	21	213	48	35	3	4	0.9	2281	23	21	76
	NUMBER	19	15	14	17	13	18	18	18	19	19	15	14	8	17	3	10	18	18
	COV	0.919	0.579	0.909	0.538	0.295	0.581	2.90	0.493	0.889	0.749	0.565	0.316	0.670	0.123	1.31	0.629	1.01	0.800
SUMMER (June-August)	**MEAN (geometric)**	0.237	0.070	0.101	1.73	0.775	0.629	7	28	53	20	47	6	7	6.8	8418	24	13	61
	MEAN (arithmetic)	0.276	0.108	0.126	2.12	0.886	0.838	16	33	74	26	64	7	7	6.8	12975	24	26	75
	MAX	0.678	0.490	0.438	6.47	2.25	3.07	70	136	230	91	188	15	15	8.4	19863	30	150	280
	MIN	0.071	0.017	0.038	0.710	0.295	0.167	1	12	3	2	15	3	3	5.0	1733	21	3	22
	MEDIAN	0.239	0.054	0.109	1.58	0.641	0.589	5	24	68	21	44	5	6	6.7	17329	24	9	58
	STDEV	0.153	0.111	0.093	1.51	0.514	0.717	23	23	55	20	56	5	4	0.7	9818	3	34	57
	NUMBER	37	27	25	35	16	37	20	36	37	37	27	22	12	26	3	6	26	25
	COV	0.553	1.03	0.739	0.712	0.580	0.856	1.37	0.717	0.746	0.770	0.869	0.637	0.505	0.102	0.757	0.134	1.32	0.761
FALL (Sept-Nov)	**MEAN (geometric)**	0.186	0.043	0.061	1.24	0.989	0.446	5	33	51	22	59	8	9	6.9	3270	23	5	82
	MEAN (arithmetic)	0.195	0.051	0.068	1.47	1.09	0.503	10	36	70	26	83	9	10	6.9	3347	23	6	86
	MAX	0.271	0.113	0.132	3.51	1.76	1.03	42	70	219	50	233	12	13	7.6	4352	27	10	140
	MIN	0.098	0.022	0.037	0.531	0.638	0.170	1	18	14	8	23	5	6	6.3	2613	20	3	53
	MEDIAN	0.211	0.033	0.063	1.18	0.862	0.452	3	28	43	20	44	9	10	6.8	3076	23	5	77
	STDEV	0.058	0.037	0.038	0.974	0.594	0.259	14	17	64	14	86	3	5	0.4	901	3	3	28
	NUMBER	10	5	5	10	3	9	9	10	9	9	5	4	2	10	3	5	7	9
	COV	0.299	0.73	0.560	0.663	0.546	0.515	1.32	0.476	0.918	0.550	1.04	0.320	0.500	0.054	0.269	0.111	0.468	0.329
	-highest concentration																		
	-lowest concentration																		

STDEV= standard deviation, COV= coefficient of variation, “Blue” highlighted cells have the highest seasonal geometric mean, “Orange” has the lowest seasonal geometric mean.

Table 22-7 shows the 2014 sampled storm event raw data concentrations. These data generally show peaks during snowmelt and early spring for many parameters, but at some sites there are additional peaks that occurred in late fall. Stormwater concentrations can be extremely variable because the concentrations can be due to precipitation, the intensity of precipitation, BMP activity and maintenance, etc.

Table 22-7. 2014 NDPES sampled event data by site.

Date Sampled	Time	Site Location	Sample Type	TP mg/L	TDP mg/L	OPO4 mg/L	TKN mg/L	NH3 mg/L	NO3NO2 mg/L	Cl mg/L	Hardness mg/L	TSS mg/L	VSS mg/L	TDS mg/L	cBOD mg/L	Sulfate mg/L	Sp.Cond. uhmos	pH std units	E. Coli MPN	Cu ug/L	Pb ug/L	Zn ug/L
3/10/2014	14:45	Site 6, 22nd & Aldrich	Grab	1.20	0.475		6.80	3.20	0.517	1719	108	143	51	2829	24	21	5310	6.8	166	32	19	210
3/14/2014	15:05	Site 6, 22nd & Aldrich	Grab	1.246	0.515		5.15	2.31	0.321	382	56	120	30	755	8	12	1461	7.1		22	24	140
3/26/2014	14:15	Site 6, 22nd & Aldrich	Grab	0.619	0.225		4.02	1.82	0.224	238	36	80	24	317	11	5	614	7.0	21	25	30	140
5/8/2014	9:09	Site 6, 22nd & Aldrich	Composite	0.346			7.68		2.636	8	52	360	122				130	6.3		42	16	26
5/8/2014	20:20	Site 6, 22nd & Aldrich	Composite	0.229	0.105	0.154	4.91	2.14	2.35	2	16	326	102	48	6	<5.0	7101	7.0		21	87	130
5/12/2014	2:20	Site 6, 22nd & Aldrich	Composite	0.150	0.111	0.083		0.924	0.990	2	16	77	27	26	10	<5.0	52	6.5		<5.00	29	51
5/12/2014	22:17	Site 6, 22nd & Aldrich	Composite	0.393	0.149	0.088	3.19	1.57	1.45	9	48	76	29	80	7	8	143	7.0		21	27	58
5/19/2014	10:25	Site 6, 22nd & Aldrich	Grab																4352			
5/19/2014	13:05	Site 6, 22nd & Aldrich	Composite	0.147	0.128	0.090	3.28	1.50	1.15	3	32	169	53	23	11	3	45	6.4		20	57	98
6/1/2014	2:39	Site 6, 22nd & Aldrich	Composite	0.197			2.51		0.251	3	32	74	28				63			<5.00	20	<20.0
6/12/2014	0:44	Site 6, 22nd & Aldrich	Composite	0.678			5.78		1.95	<2.0	36	104	44				97			<5.00	150	280
6/13/2014	20:43	Site 6, 22nd & Aldrich	Composite	0.152			2.38		0.324	<2.0	20	83	33				49			<5.00	46	81
6/16/2014	21:19	Site 6, 22nd & Aldrich	Composite	0.191	0.08	0.074	1.39	<0.500	0.653	<2.0	16	12	7	20	4	<5.0	43	6.5		<5.00	15	29
6/18/2014	3:34	Site 6, 22nd & Aldrich	Composite	0.198	0.046	0.083	1.97	0.576	0.469	<2.0	20	77	28	19	3	<5.0	39	6.8		<5.00	50	58
6/19/2014	14:10	Site 6, 22nd & Aldrich	Composite	0.136	0.041	0.068	1.03	0.530	0.367	<2.0	24	39	13	24	3	<5.0	29	6.5		<5.00	11	22
6/19/2014	20:49	Site 6, 22nd & Aldrich	Composite	0.307	0.041	0.055	0.891	<0.500	0.421	1	28	20	8	31	3	3	41	6.4	19863	<5.00	7	<20.0
7/7/2014	18:22	Site 6, 22nd & Aldrich	Composite	0.347	0.097	0.115	6.47	1.40	0.799	<2.0	22	230	91	44	<1.00	<5.0	61	6.3		30	90	160
7/11/2014	9:09	Site 6, 22nd & Aldrich	Composite	0.184	0.048	0.121	1.06	0.576	0.248	<2.0	12	82	26	20	6	<5.0	26	6.5		<5.00	47	58
7/25/2014	6:17	Site 6, 22nd & Aldrich	Composite	0.496	0.200	0.238	2.50	0.652	1.32	<2.0	24	82	35	49	15	<5.0	67	6.9		21	31	74
8/18/2014	15:45	Site 6, 22nd & Aldrich	Composite	0.498	0.280	0.151	4.28	1.12	1.44	<2.0	26	174	72	44	7	<5.0	78	7.5		23	30	70
8/29/2014	10:11	Site 6, 22nd & Aldrich	Composite	0.277	0.122	0.116	2.89	0.768	1.02	1	24	105	41	16	13	<5.0	58	6.7		<5.00	58	90
9/3/2014	10:20	Site 6, 22nd & Aldrich	Grab																3076			
2/19/2014	14:15	Site 7, 14th & Park	Grab	0.720	0.097		4.64	2.55	0.690	5020	192	161	66	8409	35	54	15950	7.3	109	46	13	27
3/10/2014	14:30	Site 7, 14th & Park	Grab	0.429	0.342		3.56	1.71	0.526	1003	76	110	44	1710	14	16	3230	7.0	94	22	7	160
3/26/2014	13:55	Site 7, 14th & Park	Grab	0.547	0.181		1.81	0.536	0.146	286	28	76	27	361	13	13	702	6.7	32	24	8	130
5/8/2014	8:36	Site 7, 14th & Park	Composite	0.146			5.22		2.10	17	40	328	97				167	6.5		47	35	280
5/8/2014	20:20	Site 7, 14th & Park	Composite	0.064	0.037	0.193	2.90	1.32	1.89	3	36	229	64	52	6	<5.0	76	7.7		<5.00	14	87
5/12/2014	1:06	Site 7, 14th & Park	Composite	0.105	0.075	0.067	2.26	0.858	1.30	4	16	117	34	30	6	<5.0	66	6.8		<5.00	11	79
5/19/2014	10:40	Site 7, 14th & Park	Grab																697			
5/19/2014	13:12	Site 7, 14th & Park	Composite	0.073	0.066	0.061	2.05	1.00	1.18	3	24	109	29	31	11	4	52	6.8		<5.00	15	86
5/30/2014	7:45	Site 7, 14th & Park	Composite	1.10			3.76		0.578	26	72	441	112							95	8	<20.0
6/1/2014	2:45	Site 7, 14th & Park	Composite	0.131			2.34		0.666	4	36	90	26				78			<5.00	41	<20.0
6/12/2014	1:01	Site 7, 14th & Park	Composite	0.301	0.044	0.104	5.12	1.49	1.97	5	36	162	66	67	14	11	97	6.3		<5.00	5	51
6/14/2014	22:04	Site 7, 14th & Park	Composite	0.141			0.910		0.435	<2.0	16	42	16				44			<5.00	10	55
6/16/2014	21:02	Site 7, 14th & Park	Composite	0.090	0.025	0.038	<0.500	<0.500	0.362	4	20	10	6	29	4	12	48	6.3		<5.00	3	32
6/18/2014	4:10	Site 7, 14th & Park	Composite	0.123	0.017	0.047	1.04	<0.500	0.407	3	16	31	9	15	3	<5.0	42	7.1		<5.00	5	32
6/19/2014	5:13	Site 7, 14th & Park	Composite	0.087	0.019	0.046	0.888	<0.500	0.222	5	20	21	6	28	4	<5.0	28	6.1		<5.00	<3.00	<20.0
6/19/2014	20:30	Site 7, 14th & Park	Composite	0.071	0.019	0.041	0.732	<0.500	0.513	6	36	17	8	48	3	4	62	6.6	1733	<5.00	<3.00	22
7/7/2014	18:55	Site 7, 14th & Park	Composite	0.125	0.050	0.038	1.07	<0.500	0.167	<2.0	12	38	13	20	<1.00	<5.0	36	6.4		<5.00	4	33
7/25/2014	6:41	Site 7, 14th & Park	Composite	0.214	0.074	0.151	1.89	0.295	1.14	3	18	43	21	43	13	<5.0	58	7.7		<5.00	6	77
9/3/2014	11:10	Site 7, 14th & Park	Composite	0.147	0.059	0.042	1.55	<0.500	1.03	2	24	34	16	44		<5.0	64	7.3	2613	<5.00	3	53
9/9/2014	23:27	Site 7, 14th & Park	Composite	0.124	0.029	0.037	1.14	0.638	0.717	1	18	43	19	23	5	<5.0	47	6.9		<5.00	4	63
9/20/2014	18:34	Site 7, 14th & Park	Composite	0.219			0.531		0.286	1	28	58	26				58	7.6		<5.00	10	94
9/24/2014	13:01	Site 7, 14th & Park	Composite	0.173			0.694		0.318	2	28	37	20				74	7.0		23	6	86
9/29/2014	10:48	Site 7, 14th & Park	Composite	0.213			0.903		0.505	3	28	24	14				70	6.8		<5.00	<3.00	69
10/1/2014	7:37	Site 7, 14th & Park	Composite	0.231			1.57			8	40						118	6.5		20	<3.00	70

Table 22-7. 2014 NDPES sampled event data by site. (Continued)

Date Sampled	Time	Site Location	Sample Type	TP mg/L	TDP mg/L	OPO4 mg/L	TKN mg/L	NH3 mg/L	NO3NO2 mg/L	Cl mg/L	Hardness mg/L	TSS mg/L	VSS mg/L	TDS mg/L	cBOD mg/L	Sulfate mg/L	Sp.Cond. uhmos	pH std units	E. Coli MPN	Cu ug/L	Pb ug/L	Zn ug/L
3/21/2014	14:00	Site 8, Pershing	Grab	0.555	0.234		3.70	1.57	0.150	10	44	24	14	79	14	9	129	6.8	147	<5.00	3	<20.0
3/27/2014	13:55	Site 8, Pershing	Grab	0.573	0.375		4.14	2.39	0.789	382	28	24	12	67	11	7	106	6.8	144	<5.00	<3.00	<20.0
4/27/2014	13:48	Site 8, Pershing	Grab	0.158	0.073	0.087	0.895	<0.500	0.986	227	24	29	10	45	<1.00	<5.0	63	6.6		<5.00	<3.00	<20.0
5/8/2014	1:04	Site 8, Pershing	Composite	0.122	0.095							400	157	86		5		6.9		27	14	180
5/8/2014	17:10	Site 8, Pershing	Composite	0.322	0.129	0.225	2.64	0.902	1.40	438	40	177	47	58	10	<5.0	98	7.0		<5.00	10	46
5/12/2014	2:07	Site 8, Pershing	Composite	0.301	0.252	0.225	2.33	1.11	1.03	3	44	51	23	64	7	<5.0	106	6.5		<5.00	<3.00	35
5/19/2014	13:27	Site 8, Pershing	Composite	0.187	0.183	0.148	1.86	0.935	1.00	3	32	57	20	37	13	3	57	6.5		<5.00	3	23
6/1/2014	2:57	Site 8, Pershing	Composite	0.267			1.58		0.566	3	36	68	21				59			<5.00	<3.00	<20.0
6/14/2014	23:19	Site 8, Pershing	Composite	0.473			0.973		0.437	<2.0	20	16	7				51			<5.00	<3.00	<20.0
6/18/2014	9:02	Site 8, Pershing	Composite	0.589	0.490	0.438	2.75	1.42	0.669	<2.0	48	17	9	100	10	5	121	7.3		<5.00	<3.00	<20.0
6/19/2014	4:26	Site 8, Pershing	Composite	0.330	0.175	0.164	1.50	0.518	0.265	<2.0	24	45	18	32	4	<5.0	42	6.6		<5.00	<3.00	<20.0
6/19/2014	20:09	Site 8, Pershing	Composite	0.237	0.187		0.955	<0.500	0.645		136	3	2	188		10	268	6.7		<5.00	<3.00	<20.0
7/7/2014	18:52	Site 8, Pershing	Composite	0.413					0.571	7	24	127	50				90					
7/11/2014	9:41	Site 8, Pershing	Composite	0.335	0.241	0.274	1.13	0.565	0.365	<2.0	32	39	14	29	5	<5.0	42	6.6		<5.00	4	<20.0
7/25/2014	6:24	Site 8, Pershing	Composite	0.516	0.284		2.53		1.84			28	17	83		6	105					
9/9/2014	21:41	Site 8, Pershing	Composite	0.271	0.022	0.065	3.51	0.862	0.419	10	40	86	43	80	8	6	110	6.3		23	3	77
10/2/2014	22:53	Site 8, Pershing	Composite	0.209	0.113	0.132	0.736	<0.500	0.452	<2.0	24	14	8	37	10	<5.0	58	6.7		<5.00	<3.00	<20.0
2/19/2014	13:30	Site 9, 61st & Lyndale	Grab	1.05	0.066		4.31	1.39	1.14	5895	308	610	161	9699	57	63	18710	10.8	<10	78	17	39
3/10/2014	13:55	Site 9, 61st & Lyndale	Grab	0.807	0.230		5.12	1.16	0.807	1480	136	461	96	2567	17	28	4890	9.4	10	42	11	270
4/27/2014	11:58	Site 9, 61st & Lyndale	Grab	0.198	0.043	0.185	1.83	0.582	1.54	180	56	316	75	89	<1.00	<5.0	209	8.6		37	13	190
5/9/2014	4:24	Site 9, 61st & Lyndale	Composite	0.137	0.092	0.686	4.16	1.41	3.13	17	52	913	170	109	3	6	190	9.2		46	21	250
5/12/2014	6:00	Site 9, 61st & Lyndale	Composite	0.132	0.048	0.063	1.34	<0.500	1.10	10	36	123	28	52	9	<5.0	120	8.2		<5.00	4	59
5/13/2014	4:43	Site 9, 61st & Lyndale	Grab	0.423	0.274	0.377	2.76	1.46	3.20	27	72	56	17	147	6	15	263	8.0		<5.00	4	53
5/19/2014	11:05	Site 9, 61st & Lyndale	Composite																160			
5/19/2014	12:40	Site 9, 61st & Lyndale	Composite	0.105	0.063	0.135	2.53	1.07	1.28	12	52	433	72	99	8	5	114	8.8		29	15	140
5/31/2014	23:54	Site 9, 61st & Lyndale	Composite	0.569			8.16		4.68	41	96	107	21				295			20	6	20
6/12/2014	0:32	Site 9, 61st & Lyndale	Composite	0.471	0.054	0.145	4.90	2.25	3.07	29	84	62	50	184	15	5	249	5.0		<5.00	4	71
6/15/2014	20:58	Site 9, 61st & Lyndale	Composite	0.148			0.823		0.589	11	24	98	19				100			<5.00	4	56
6/18/2014	5:59	Site 9, 61st & Lyndale	Composite	0.201	0.024	0.104	1.53	0.611	0.695	9	32	114	25	56	5	<5.0	96	7.7		<5.00	7	90
6/19/2014	23:36	Site 9, 61st & Lyndale	Composite	0.131	0.020	0.051	0.710	<0.500	0.225	9	20	47	11	76	3	4	82	6.7	17329	<5.00	<3.00	24
6/28/2014	19:20	Site 9, 61st & Lyndale	Composite	0.239			0.944		0.681	59	48	139	30				530			22	7	83
7/7/2014	19:14	Site 9, 61st & Lyndale	Composite	0.277	0.103	0.109	1.59		0.638	70	32	71	20	124		6	236	6.8		<5.00	3	50
7/25/2014	7:10	Site 9, 61st & Lyndale	Composite	0.298	0.048	0.254	2.34	0.630	1.80	67	50	162	43	164	14	8	297	8.4		26	9	170
8/18/2014	9:13	Site 9, 61st & Lyndale	Composite	0.331	0.086	0.114	2.81	0.780	2.80	32	72	166	46	182	7	15	313	8.0		24	<3.00	110
9/3/2014	9:40	Site 9, 61st & Lyndale	Grab																4352			
9/10/2014	8:15	Site 9, 61st & Lyndale	Composite	0.267	0.033	0.063	2.84	1.76	0.17	42	62	116	35	233	12	13	287	7.2		22	5	120
10/1/2014	11:34	Site 9, 61st & Lyndale	Composite	0.098			1.23		0.638	23	70	219	50				187	6.8		27	9	140

Median Comparison

Table 22-8 shows a comparison of MPRB and Nationwide Urban Runoff Program (NURP) median residential, mixed use, and composite land use stormwater values. The MPRB data are split into 2014 and 2001-2013 data for comparison.

In 2014, all three MPRB land use categories saw a significant decrease in the median value concentrations of all parameters when compared to the NURP data, with the exception of TKN. It is unknown why all MPRB TKN data are higher than the NURP TKN data. A possible explanation is there is more vegetative material in the Minneapolis watersheds decaying than in the NURP watersheds, studied from 1979 to 1983.

When the NURP study data were collected lead (Pb) was widely used in gasoline (from the 1920's to 1990's) and banned after 1996. The lead reduction in the environment is clearly seen in the MPRB data sets.

It is important to note that the MPRB sites monitored in 2001-2004 are located in different watersheds and have similar but not identical land uses to those monitored in 2005-2014.

Table 22-8. Typical Median stormwater sampled concentrations.

Land Use	Residential			Mixed			Composite of all categories		
Location	MPRB[1]	MPRB[2]	NURP	MPRB[3]	MPRB[4]	NURP	MPRB[5]	MPRB[6]	NURP
Year(s)	2014	2001–2013		2014	2001–2013		2014	2001–2013	
TP (mg/L)	0.292	0.436	0.383	0.146	0.251	0.263	0.234	0.364	0.33
TKN (mg/L)	3.19	2.39	1.9	1.57	1.59	1.29	2.33	2.04	1.5
NO_3NO_2 (mg/L)	0.726	0.338	0.736	0.552	0.416	0.558	0.675	0.406	0.68
cBOD (mg/L)	7	12	10	6	8	8	8	10	9
TSS (mg/L)	83	85	101	51	62	67	82	84	100
Cu (µg/L)	11	18	33	3	19	27	3	18	30
Pb (µg/L)	30	31	144	6	13	114	8	14	140
Zn (µg/L)	72	79	135	63	85	154	58	84	160

[1] Site 6 data.
[2] Sites 1 and 2 data, (Site 6, 2005-2013).
[3] Site 7 data.
[4] Sites 5 and 5a data, (Site 7, 2005-2013).
[5] Sites 6 – 9 data.
[6] Sites 1 – 5a data, (Site 6 – 9, 2005-2013).
NURP = median event mean concentrations as reported by the Nationwide Urban Runoff Program (USEPA, 1996).
MPRB = median values calculated by the MPRB for the identified year(s).

Geometric Mean Comparison

Table 22-9 lists the statistical calculations for all measured parameters for each site. Most of the geometric mean maximums occurred at Site 9 (61st and Lyndale) the industrial site. The lowest geometric mean values generally occur at Site 8 (Pershing) and Site 7 (14th & Park). This is as expected since Site 8 (Pershing) is parkland and Site 7 (14th & Park) is a mixed use watershed with little vegetation.

Table 22-9. 2014 event concentration statistics.

Site ID	Statistical Function	TP mg/L	TDP mg/L	Ortho-P mg/L	TKN mg/L	NH_3 mg/L	NO_3NO_2 mg/L	Cl mg/L	Hardness mg/L	TSS mg/L	VSS mg/L	TDS mg/L	cBOD mg/L	Sulfate mg/L	pH std units	E. coli MPN/100mL	Cu ug/L	Pb ug/L	Zn ug/L
6, 22nd Aldrich	MEAN (geometric)	0.314	0.122	0.102	2.98	0.711	0.962	4	28	93	34	57	6	4	6.7	985	8	32	64
6, 22nd Aldrich	MEAN (arithmetic)	0.400	0.166	0.110	3.59	0.945	1.22	119	32	122	43	272	8	5	6.7	5496	14	42	90
6, 22nd Aldrich	MAX	1.25	0.52	0.238	7.68	2.64	3.20	1719	108	360	122	2829	24	21	7.5	19863	42	150	280
6, 22nd Aldrich	MIN	0.136	0.041	0.055	0.89	0.224	0.250	1	12	12	7	16	1	3	6.3	21	3	7	10
6, 22nd Aldrich	MEDIAN	0.292	0.117	0.090	3.19	0.726	1.02	1	25	83	32	38	7	3	6.7	3076	11	30	72
6, 22nd Aldrich	STDEV	0.323	0.15	0.049	2.07	0.722	0.830	389	22	92	31	708	6	5	0.3	8246	13	34	70
6, 22nd Aldrich	NUMBER	20	16	13	19	20	16	20	20	20	20	16	16	16	17	5	20	20	20
6, 22nd Aldrich	COV	0.809	0.874	0.442	0.577	0.765	0.678	3.27	0.666	0.754	0.721	2.61	0.710	1.07	0.051	1.50	0.911	0.811	0.778
7, 14th Park	MEAN (geometric)	0.176	0.051	0.061	1.56	0.596	0.563	7	29	64	24	73	6	5	6.8	318	6	6	51
7, 14th Park	MEAN (arithmetic)	0.242	0.076	0.072	2.04	0.779	0.793	279	37	101	34	727	9	9	6.9	880	14	9	70
7, 14th Park	MAX	1.10	0.342	0.193	5.22	2.10	2.55	5020	192	441	112	8409	35	54	7.7	2613	95	41	280
7, 14th Park	MIN	0.064	0.017	0.037	0.250	0.146	0.250	1	12	10	6	15	1	3	6.1	32	3	2	10
7, 14th Park	MEDIAN	0.146	0.050	0.047	1.57	0.552	0.536	4	28	51	23	43	6	3	6.8	403	3	6	63
7, 14th Park	STDEV	0.247	0.085	0.051	1.49	0.588	0.700	1055	37	109	29	2169	9	13	0.5	1067	22	10	59
7, 14th Park	NUMBER	23	15	12	23	22	15	23	23	22	22	15	14	15	20	6	23	23	23
7, 14th Park	COV	1.02	1.12	0.709	0.731	0.755	0.882	3.79	1.00	1.08	0.877	2.98	0.915	1.503	0.068	1.21	1.63	1.07	0.844
8, Pershing	MEAN (geometric)	0.313	0.164	0.169	1.80	0.608	0.721	7	35	40	17	62	7	4	6.7	145	3	2	18
8, Pershing	MEAN (arithmetic)	0.345	0.204	0.195	2.08	0.724	0.919	78	40	71	28	70	9	5	6.7	146	6	3	31
8, Pershing	MAX	0.589	0.490	0.438	4.14	1.84	2.39	438	136	400	157	188	14	10	7.3	147	27	14	180
8, Pershing	MIN	0.122	0.022	0.065	0.736	0.150	0.250	1	20	3	2	29	1	3	6.3	144	3	2	10
8, Pershing	MEDIAN	0.322	0.185	0.164	1.86	0.608	0.882	3	32	39	17	65	10	4	6.7	146	3	2	10
8, Pershing	STDEV	0.150	0.124	0.113	1.11	0.442	0.640	153	28	96	36	41	4	3	0.3	2	8	4	46
8, Pershing	NUMBER	17	14	9	15	16	12	14	15	17	17	14	11	14	13	2	15	15	15
8, Pershing	COV	0.435	0.608	0.580	0.532	0.610	0.697	1.97	0.706	1.35	1.30	0.580	0.473	0.542	0.038	0.01	1.45	1.08	1.48
9, 61st Lyndale	MEAN (geometric)	0.257	0.064	0.141	2.23	1.11	0.866	46	58	162	40	196	7	8	7.9	227	12	6	85
9, 61st Lyndale	MEAN (arithmetic)	0.327	0.085	0.191	2.77	1.57	1.05	445	72	234	54	984	12	13	8.0	4371	22	8	108
9, 61st Lyndale	MAX	1.05	0.274	0.686	8.16	4.68	2.25	5895	308	913	170	9699	57	63	10.8	17329	78	21	270
9, 61st Lyndale	MIN	0.098	0.020	0.051	0.710	0.170	0.250	9	20	47	11	52	1	3	5.0	5	3	2	20
9, 61st Lyndale	MEDIAN	0.253	0.059	0.125	2.44	1.12	1.07	30	54	131	39	136	8	6	8.0	160	22	7	87
9, 61st Lyndale	STDEV	0.258	0.075	0.181	1.93	1.28	0.60	1402	65	232	47	2592	14	16	1.4	7479	20	6	74
9, 61st Lyndale	NUMBER	18	14	12	18	18	13	18	18	18	18	14	13	14	15	5	18	18	18
9, 61st Lyndale	COV	0.790	0.893	0.952	0.696	0.815	0.573	3.15	0.901	0.993	0.864	2.63	1.19	1.29	0.172	1.71	0.942	0.699	0.686
All	MEAN (geometric)	0.253	0.090	0.107	2.06	0.726	0.765	10	35	79	28	83	7	5	7.0	363	7	8	50
All	MEAN (arithmetic)	0.324	0.133	0.138	2.62	0.998	1.00	238	45	131	40	509	10	8	7.0	3050	14	16	76
All	MAX	1.25	0.515	0.686	8.16	4.68	3.20	5895	308	913	170	9699	57	63	10.8	19863	95	150	280
All	MIN	0.064	0.017	0.037	0.250	0.146	0.250	1	12	3	2	15	1	3	5.0	5	3	2	10
All	MEDIAN	0.234	0.092	0.107	2.33	0.675	0.860	5	32	82	27	56	8	3	6.8	163	3	8	58
All	STDEV	0.257	0.122	0.120	1.79	0.863	0.708	919	43	152	37	1703	9	11	0.9	5867	18	24	68
All	NUMBER	78	59	46	75	76	56	75	76	77	77	59	54	59	65	18	76	76	76
All	COV	0.793	0.918	0.869	0.684	0.866	0.707	3.86	0.968	1.16	0.924	3.35	0.937	1.43	0.125	1.92	1.28	1.46	0.887
	-Highest value																		
	-Lowest value																		

All = all 4 sites, STDEV = standard deviation, COV = coefficient of variation.

Site 6 (22nd & Aldrich), a residential watershed, had the highest geometric means for TP, TKN, NO_2NO_3, *E. coli* , and Pb. The cause of the higher TP, TKN, and NO_2NO_3 values may be the dense leaf canopy in the watershed adding to the organic load. Higher *E. coli* levels may be shed from urban wildlife or the pets owned by the higher population density at this site. The geometric mean concentration of Pb has been persistently high at this site, and is possibly a remnant of lead based paints shedding from the older houses and soils.

Site 7 (14th & Park) had none of highest geometric mean concentrations for any of the parameters. Site 7 also had the lowest geometric mean for all phosphorus, nitrogen, and chloride values. This is likely the result of the hard surface landscape in this mixed use watershed.

Site 8 (Pershing) had the highest geometric mean TDP and Ortho-P values likely due to decaying organic material in the parkland watershed or turf maintenance. Site 8 also had the lowest geometric mean TSS, VSS, *E. coli*, and all metals this is also likely due to the parks vegetated watershed.

Site 9 (61st and Lyndale) had the highest geometric mean for NH_3, Cl, hardness, TSS, VSS, TDS, cBOD, sulfate, Cu, and Zn. Site 9 had none of the lowest geometric mean values. This watershed is a light industrial site (cement factory, natural gas facility, etc.) and it is expected that many of the parameters would be higher than other watersheds due to industrial activities.

Mean Comparison

Mean data were comparable to typical urban stormwater data from the Nationwide Urban Runoff Program (NURP), Center for Watershed Protection (CWP), and Bannerman *et al.* (1993) (**Table 22-10)**.

Data from MPRB Sites 1–5a (2001–2004) and 6–9 (2005–2014) were generally similar to Sites 6–9 in 2014. All measured and compared parameters were roughly equal to or lower in 2014, with the exception of NO_3NO_2 and TSS. The 2014 mean increase in NO_3NO_2 and TSS are likely the result of organic material in the watersheds interacting with the wet spring and dry summer/fall.

Table 22-10. Typical Mean urban stormwater concentrations. " -- " = not reported.

Parameter	NURP[1]	CWP[2]	Bannerman *et al.*[3]	Mpls PW[4]	St. Paul[5]	MWMO 2014[6]	MPRB[7] 2001–2013	MPRB[8] 2014
TP (mg/L)	0.5	0.3	0.66	0.417	0.484	0.490	0.476	0.324
TDP (mg/L)	--	--	0.27	0.251	--	0.173	0.147	0.133
TKN (mg/L)	2.3	--	--	--	2.46	2.69	2.80	2.62
NO_3NO_2 (mg/L)	0.86	--	--	--	0.362	0.562	0.516	0.998
NH_3 (mg/L)	--	--	--	0.234	--	0.350	1.02	1.00
Cl (mg/L)	--	230 (winter)	--	--	--	334	284	238
BOD (mg/L)	12	--	--	14.9	25	14	16	10
TDS (mg/L)	--	--	--	73.3	78	656	556	509
TSS (mg/L)	239	80	262	77.6	129	202	123	131
Cu (µg/L)	50	10	16	26.7	30	25.0	26.0	14.1
Pb (µg/L)	240	18	32	75.5	233	26.0	25.3	16.5
Zn (µg/L)	350	140	204	148	194	154	124	76

[1] USEPA (1996)
[2] Center for Watershed Protection (2000)
[3] Monroe study area of Bannerman *et al*. (1993)
[4] City of Minneapolis Public Works Department (1992) – average from a combination of land uses
[5] City of St. Paul 1994 stormwater data – average from a combination of land uses
[6] Mississippi Watershed Management Organization 2014 data, average of snowmelt and storms from all sites
[7] MPRB arithmetic mean data calculated from NPDES Sites 1 – 5a (2001 – 2004), 6 – 9 (2005 – 2013)
[8] MPRB arithmetic mean data calculated from NPDES Sites 6 – 9 (2014)

Flow-weighted Mean Comparison

The flow-weighted mean concentrations presented in **Table 22-11** were calculated using FLUX32. Sample chemistry concentrations and associated daily average flows were used as input for these calculations. The data were run unstratified and often stratified by flow or season to achieve the most accurate and precise results. The method (2 or 6) and event mean concentration with the lowest coefficient of variation was chosen as the final concentration value.

Table 22-11. Flow–weighted mean concentrations and related statistics for NPDES parameters in 2014.

Site	TP (mg/L)	TDP (mg/L)	Ortho-P (mg/L)	TKN (mg/L)	NO_3NO_2 (mg/L)	NH_3 (mg/L)	Cl* (mg/L)	Hardness (mg/L)	TSS (mg/L)	VSS (mg/L)	TDS* (mg/L)	cBOD (mg/L)	Sulfate (mg/L)	Cu (µg/L)	Pb (µg/L)	Zn (µg/L)
6, 22nd Aldrich	0.378	0.161	0.108	3.11	0.786	1.30	165	35.2	118	40	393	9	7.8	14	42	94
7, 14th Park	0.274	0.073	0.066	1.93	0.716	0.866	242	33.1	85	30	422	9	6.5	13	11	58
8a, Pershing	0.315	0.186	0.176	1.65	0.724	0.931	139	30.0	51	18	50	9	3.2	3	3	18
9, 61st Lyndale	0.284	0.066	0.167	2.92	1.52	0.919	274	65.1	238	49	572	12	9.9	20	8	100
MEAN	**0.313**	**0.121**	**0.129**	**2.40**	**0.937**	**1.00**	**205**	**40.9**	**123**	**34**	**359**	**10**	**6.8**	**13**	**16**	**68**
MEDIAN	**0.300**	**0.117**	**0.138**	**2.43**	**0.755**	**0.925**	**204**	**34.2**	**102**	**35**	**408**	**9**	**7.1**	**14**	**10**	**76**
STANDEV	**0.047**	**0.061**	**0.052**	**0.721**	**0.390**	**0.199**	**63**	**16.3**	**81**	**13**	**221**	**2**	**2.8**	**7**	**18**	**38**
	-Highest value															
	-Lowest value															

* Flow–weighted mean concentrations for Cl and TDS were difficult to estimate using FLUX32 due to large outliers from the two snowmelt samples; these estimates should be used with caution. STANDEV= standard deviation.

Site 6 (22nd & Aldrich) is a multi-family residential watershed. Site 6 had the highest modeled concentrations of TP, TKN, NH_3, and Pb. It is believed this may be due to its location between two heavily traveled thoroughfares (Hennepin and Lyndale) where a mature leaf canopy may collect airborne material and deposit it following precipitation. Site 6 had none of the lowest modeled parameters.

Site 7 (14th & Park) is a densely developed mixed-use watershed. Site 7 did not have any of the highest modeled parameters. Site 7 had the lowest modeled TP, Ortho-P, NO_3NO_2, and cBOD.

Site 8a (Pershing) is a parkland watershed. Site 8a had the highest modeled event mean concentrations of TDP and Ortho-P. The reason is unknown, but it may be due to turf maintenance. Site 8a had the lowest modeled TKN, Cl, hardness, TSS, VSS, TDS, sulfate, Cu, Pb, and Zn.

Site 9 (61st and Lyndale) is a commercial/industrial watershed. Site 9 had the highest modeled concentration of NO_3NO_2, Cl, hardness, TSS, VSS, TDS, cBOD, sulfate, Cu, and Zn. Site 9 had the lowest modeled NH_3. Industrial activities in this watershed likely explain the higher pollutant loads. Site 9 is located adjacent to a large cement aggregate mixing facility which may explain the higher TSS values. This site sometimes had a very small baseflow. In 2008, the baseflow was significantly diminished when the cement aggregate mixing facility improved its on-site runoff and ponding.

Table 22-12 includes flow-weighted mean pollutant concentrations of data collected in the 1980s and reported by the U.S. Geological Survey (USGS) for various sites within the Twin Cities (as cited in MPCA, 2000). The Yates watershed was a stabilized residential area, the Iverson site was a residential watershed under development, and the Sandberg watershed was predominantly a light industrial land-use area, as reported by the USGS. Site 6 (22nd & Aldrich) is more closely related to the Yates residential watershed land-use characteristics. Site 7 (14th & Park) and Site 9 (61st and Lyndale) are more comparable to the Sandberg light industrial watershed land-use characteristics.

When comparing the USGS flow-weighted mean concentrations to the MPRB sites in **Table 22-12** Site 6 had lower or similar concentrations with Yates for all parameters. The Iverson data are shown for comparison purposes of a developing residential neighborhood only.

Compared to Sandberg, Sites 7 and 9 have lower flow-weighted mean concentrations for almost all parameters and are well within the ranges shown in **Table 22-12**. Site 7 had significantly lower values than Sandberg for all parameters. Site 9 had roughly half of the Sandberg values with the notable exception of TKN. The Site 9 TKN was slightly higher than Sandberg's TKN but was comparable.

The overall mean comparison of **Table 22-12** to MPRB water quality values at sites 6, 7, 8a, and 9 shows Minneapolis sites were the same or roughly half of the values for the compared parameters. The Minneapolis mean lead values are much lower than the Yates and Sandburg studies.

Table 22-12. Flow-weighted mean stormwater pollutant concentrations (mg/L) and ranges as reported by the USGS (as cited in MPCA, 2000).

Pollutant	Monitoring Site					
	Yates area (stabilized residential)	**Site 6 (22nd Aldrich)**	**Iverson area (developing residential)**	**Sandburg area (light industrial)**	**Site 7 (14th Park)**	**Site 9 (61st Lyndale)**
TSS (Mean Range)	133 (2 – 758)	118 (12 – 360)	740 (17- 26,610)	337 (7 – 4,388)	85 (10 – 441)	238 (47 – 913)
Pb (Mean Range)	0.23 (0.015 –1.8)	0.042 (0.007 -0.150)	0.02 (0.008-0.31)	0.19 (0.003 –1.5)	0.011 (0.002 – 0.041)	0.008 (0.002 – 0.021)
Zn (Mean Range)	0.198 (0.02 – 2.2)	0.094 (0.010 -0.280)	0.235 (0.028-0.53)	0.185 (0.02 –0.81)	0.058 (0.010 – 0.280)	0.100 (0.020 – 0.270)
TKN (Mean Range)	3.6 (0.6 – 28.6)	3.11 (0.89 – 7.68)	1.2 (1.0 – 29.2)	2.5 (0.4 – 16.0)	1.93 (0.250 – 5.22)	2.92 (0.710 – 8.16)
TP (Mean Range)	0.63 (0.10 –3.85)	0.378 (0.136 – 1.25)	0.62 (0.2 – 13.1)	0.63 (0.07 – 4.3)	0.274 (0.064 – 1.10)	0.284 (0.098 – 1.05)

Table 22-13 shows the flow-weighted mean concentrations in 2014 compared to previous years. Flow-weighted mean concentrations for Cl and TDS were difficult to estimate using FLUX32 due to large outliers from the snowmelt samples. These estimates should be used with caution. When samples were below the RL (reporting limit), half of the RL was used for calculations.

Table 22-13. MPRB Flow–weighted mean concentration compared to previous years. Each year is the average flow–weighted mean concentration of all sites monitored that year.

	Flow-weighted mean concentrations													
	Sites 1-5a				Site 6-9									
Parameter	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
TP (mg/L)	0.470	0.337	0.474	0.332	0.354	0.548	0.472	0.486	0.583	0.341	0.355	0.368	0.369	0.313
TDP (mg/L)	0.112	0.095	0.114	0.121	0.123	0.135	0.108	0.139	0.249	0.063	0.126	0.123	0.157	0.121
Ortho-P (mg/L)	nc	nc	nc	nc	nc	nc	nc	nc	nc	nc	0.179	0.097	0.194	0.129
TKN (mg/L)	2.21	1.60	2.10	1.94	3.48	3.54	4.43	3.22	3.61	1.53	1.74	2.00	2.34	2.40
NO_3NO_2 (mg/L)	0.398	0.423	0.496	0.382	0.448	0.638	0.496	0.582	0.755	0.414	0.498	0.397	0.402	0.937
NH_3(mg/L)	0.494	0.722	0.346	0.918	1.74	1.64	0.970	0.966	1.64	0.666	0.922	0.719	0.747	1.00
Cl (mg/L)	37	11	587	40	18	91	412	139	803	60	213	14	72	205
Hardness (mg/L)	nc	na	nc	nc	na	nc	nc	nc	nc	na	48.0	37	41	41
TSS (mg/L)	116	83	116	70	108	156	180	148	121	107	104	101	95	123
VSS (mg/L)	nc	nc	nc	nc	nc	nc	nc	nc	nc	nc	30.2	31	29	34
TDS (mg/L)	306	85	725	130	252	183	737	507	3323	124	693	97	301	359
cBOD (mg/L)	12	8	16	20	9	9	17	25	53	7	11	13	13	10
Sulfate (mg/L)	nc	nc	nc	nc	nc	nc	nc	nc	nc	nc	15.4	18.4	8.1	6.8
Cd (µg/L)	0.532	0.518	2.11	2.80	2.50	nc	nc	nc	nc	nc	nc	nc	nc	nc
Cu (µg/L)	15	31	23	15	19	29	36	16	40	23	25	16	19	13
Pb (µg/L)	23	17	22	14	41	31	34	28	23	24	18	15	22	16
Zn (µg/L)	180	76	107	76	86	94	133	132	204	100	103	90	79	68

nc = data not collected.
na= data not analyzed for.
Note: Cadmium (Cd) was discontinued from monitoring in 2006 because Cd concentrations had typically been below detection for the Minneapolis/St. Paul area and it was not useful information. It should also be noted the detection limit for Cd has changed over time. In 2002 it was <0.500 µg/L; in 2003 it was <2.00 µg/L and in 2004 it was <5.00 µg/L. In 2011, ortho-P (or TDP), hardness (for metals toxicity calculations), and sulfate were added.

Chemical concentrations in stormwater are highly variable. Climatological factors such as precipitation amount and intensity, street sweeping type and frequency, BMP maintenance schedule frequency, etc. can cause fluctuations in chemical concentrations. **Table 22-13** illustrates the variability of stormwater from year to year.

The variability from year to year is due to three likely causes. First, the watersheds monitored have occasionally changed. Second, the timing between street sweeping frequency, BMP maintenance frequency, and sampling probably affect variability within the monitoring year and between years. Third, precipitation frequency, intensity, and duration affect results.

Surcharge Events

Surcharge events happen during high precipitation totals or high intensity storm events that exceed the drainage capacity of the pipes. Surcharges occur when water backs up in pipes and creates a hydrostatic pressure head, beyond the diameter of the pipe, which can result in inaccurate daily flow calculations and must be considered when evaluating flow-weighted mean concentrations. If surcharge water inundates the auto-sampler tray the samples are considered contaminated and dumped.

Table 22-14 show the 2014 NPDES surcharge dates. With the exception of Site 8a, most of the surcharging events were storms greater than 1 inch.

Table 22-14. Surcharge events in 2014 at associated NPDES sites.

Site	Surcharge Dates
Site 6 (22nd and Aldrich)	6/7, 6/15, 6/19, 6/28, 7/11, 7/25, 9/20.
Site 7 (Park and 14th)	7/11.
Site 8a (Pershing)	4/27, 5/8, 5/19, 6/1, 6/7, 6/14, 6/19, 6/28, 7/7, 7/11, 8/29, 8/31.
Site 9 (61st and Lyndale)	5/13, 6/19.

Site 8a (Pershing) is of special concern as it had twelve surcharges in 2014. At this site, storms as small as 0.33 inches or as large as 3.00 inches caused surcharging. At this site, two pipes and overland flow enter the manhole basin and exit the outlet, a 12 inch PVC pipe. The Site 8 watershed/area of Minneapolis is lower in elevation than the surrounding areas causing a regular back up of many stormsewers in the system. Minneapolis Public Works is aware of this problem. The surcharges at this site do not appear to have caused any flooding problems. Site 8a samples appear to not be significantly affected by surcharging because the sampler is secured in an above ground enclosure.

23. NOKOMIS 56TH & 21ST BMP MONITORING

BACKGROUND

Best management practices (BMPs) include procedures and structures designed to help reduce water pollution through good housekeeping practices like street sweeping. Monitoring of BMPs in Minneapolis is done as a part of the Federal NPDES MS4 stormwater permit activities (permit #MN0061018).

Minneapolis Public Works is attempting to quantify the measurable stormwater effects of street sweeping. The project will use both grab (snowmelt) and flow paced (event) sampling to collect runoff and measure stormwater solids (TSS, TVS) and phosphorus (TP, TDP) in a watershed targeted to monitor the effects of streetsweeping and its effects on stormwater.

Target watersheds chosen for study were on the southeast side of Lake Nokomis. A paired watershed design was initially attempted. After initial reconnaissance the paired watershed design was deemed unworkable due to site conditions. Three sites were investigated. 1) Woodlawn & 50th was too shallow to hang a sampler and had four 10 inch leaders making laminar flow and accurate measurement impossible. 2) Woodlawn & 53rd had 12+ inches of standing water in the pipe which would negatively affect results due to settling and re-suspension. 3) The watershed outlet of 56th & 21st was acceptable. It had approximately 3 inches of standing water but did not have major issues with standing water, and it had room for equipment. It was chosen and monitored in 2012 - 2014 for baseline conditions (see **Figure 23-1)** prior to commencement of the project.

The drainage area to the 56th and 21st site is approximately 50 acres, as measured from the Minneapolis pipeshed GIS layer, and the majority land use is single family homes. The outfall ID associated with the site is 72-060.

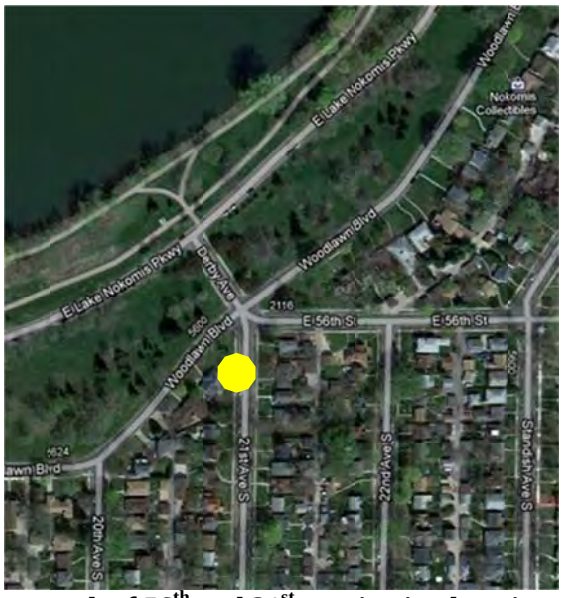


Figure 23-1. Aerial photograph of 56th and 21st monitoring location on the S.E. side of Lake Nokomis in Minneapolis.

METHODS

The summary below includes descriptions of equipment installation at each site, parameters monitored, field quality assurance sampling, data handling, validation, and reporting.

Site Installation
The 56th & 21st outlet is a 30" reinforced concrete pipe, as shown in **Figure 23-2**. The ISCO equipment installed at each site included a 2150 datalogger with low profile area/velocity pressure transducer probe, 2105 interface module, 2103ci cell phone modem, and a 3700 sampler. The sampler collected stormwater with 3/8" ID vinyl intake tubing complete with strainer. The dataloggers flow-paced the samplers to collect flow-weighted stormwater samples over the entire storm hydrograph. Each site automatically uploaded data, via cell phone modem, to the network server database Monday through Friday. Each site could also be communicated with remotely by Flowlink Pro software in order to adjust pacing, enable or disable samplers, or view events.

Equipment installation began when freezing temperatures were no longer a concern in order to prevent area velocity transducer damage. Installation occurred on 5/5/14.

Figure 23-2. View into the manhole access at the 56th and 21st, 30" pipe.

Monitoring

The MS4 permit target frequency for storm event sample collection is 15 samples per site per year. If a sample was missed during one month due to lack of precipitation events, then two or more were taken the next month. Snowmelt grab samples were collected on 2/18, 2/19, and 3/10 in 2014. The auto monitoring sampling period was from 5/5/14 – 11/7/14. With the exception of snowmelt grabs, all stormwater samples in 2014 were collected by flow weighted auto monitoring. **Figure 23-3** shows the sample intake strainer and A/V probe being placed in the invert of the pipe for monitoring.

Figure 23-3. The AV probe and intake strainer being anchored to the invert.

Normally the 56th & 21st site has approximately 3" of standing water that was present for most of the season. In 2014, significant spring/summer flooding occurred. Flooding resulted in large amounts of tailwater from Lake Nokomis inundating the site, which made monitoring impossible.

The 2014 sampled events collected are shown in **Table 23-1.** The precipitation data were collected from a weather station at 38th and Bryant Ave S. Minneapolis, the MPRB Southside Service Center.

Table 23-1. The 56th and 21st 2014 events and illicit discharge events. A precipitation event was defined as greater than 0.10 inches separated by 8 hours.

Event	Start Date/Time		End Date/Time		Precip (inches)	Duration (hours)	Intensity (in/hr)	Time since last Precip. (hours)	Sample Type	2014, 56th & 21st Events Collected
+1	2/18/2014	14:00	n/a	n/a	n/a	n/a	n/a	n/a	grab	X
+2	2/19/2014	14:15	n/a	n/a	n/a	n/a	n/a	n/a	grab	X
+3	3/10/2014	14:30	n/a	n/a	n/a	n/a	n/a	n/a	grab	X
4	5/8/2014	0:30	5/8/2014	20:00	1.02	19.5	0.05	180.0	composite	X
5	5/11/2014	21:30	5/12/2014	21:30	0.82	24.0	0.03	46.5	composite	X
6	5/19/2014	10:30	5/19/2014	22:30	1.80	12.0	0.15	169.0	comp/grab	X
7	6/14/2014	10:00	6/15/2014	9:30	1.90	23.5	0.08	69.5	composite	X
8	6/18/2014	2:30	6/18/2014	4:30	0.43	2.0	0.22	31.5	composite	X
9	9/9/2014	21:15	9/10/2014	9:00	0.41	11.8	0.03	156.0	composite	X
10	10/1/2014	7:30	10/2/2014	22:45	1.04	39.2	0.03	292.2	composite	X
			Totals		**7.42**					**10**

+ snowmelt event

n/a = not applicable

X = event sampled with full parameters

Monitored Parameters

The parameters chosen for this site were solids (TSS, VSS) and phosphorus (TP, TDP), listed below in **Table 23-2**. These were chosen as the best parameters to evaluate the effectiveness of street sweeping.

Table 23-2 Parameters monitored at 56th and 21st.

Parameter	Abbreviation	Units	Sample Type
Phosphorus, Total Dissolved	TDP	mg/L	Composite
Phosphorus, Total	TP	mg/L	Composite
Solids, Total Suspended	TSS	mg/L	Composite
Solids, Volatile Suspended	VSS	mg/L	Composite

Holding times and detection limits for all parameters are listed in **Section 22, Table 22-5**.

FIELD QUALITY ASSURANCE SAMPLES

Ten percent of samples were laboratory quality assurance samples (e.g. duplicates, spikes). Field blanks consisted of deionized water which accompanied samples from the field sites to the analytical laboratory. A field blank was generated for each sampling trip and was analyzed for all NPDES parameters. All field blank parameters were below the minimum detection limits in 2014. As part of the overall QA/QC program, blind monthly performance samples were made for all monitored parameters and delivered to IRI.

An equipment blank (~ 2 L sample) was collected at 8a (Pershing) 11/07/14. This site has a standard NPDES stormwater monitoring set up. To collect the equipment blank, a large bottle of deionized water was placed at the strainer end of the sampler tubing. The intake line was filled and flushed with deionized water simulating the pre-sample flush. After the flush was pumped to waste, a sample of

deionized water was collected. The sample taken was of sufficient volume to allow analysis of all parameters. All analytes came back from the laboratory below the minimum detection limits.

Data Handling
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 **Section 28**, Quality Assurance Assessment Report for details.

Field measurements were recorded on a Field Measurement Form in the 2014 Field Log Book and then entered into a computer database. Electronic data from the laboratory were forwarded to the MPRB in pre-formatted 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 Storm Water Monitoring Program Manual (MPRB, 2001).

A Chain of Custody form accompanied each set of sample bottles delivered to the lab. Each sampler tray or container was iced and labeled indicating the date and time of collection, the site location, and the field personnel initials. The ultimate collection date and time assigned to the sample was when the last sample of the composite was collected. The time that each composite sample was collected was recorded from the ISCO sampler onto field sheets. A complete description of methods can be found in the Storm Water Monitoring Program Manual (MPRB, 2001).

RESULTS & DISCUSSION

In 2014, monitoring became extremely difficult due to flooding and back water from Lake Nokomis. **Figure 23-4** shows the 2014 level and discharge at the 56th and 21st monitoring site.
Surcharge events are normally very infrequent at this site. But in 2014 there were eight surcharge events, 5/19, 6/1, 6/14, 6/18, 6/19, 6/28, 7/11, and 8/29. The 6/19 event reached 64" in the 30" pipe.

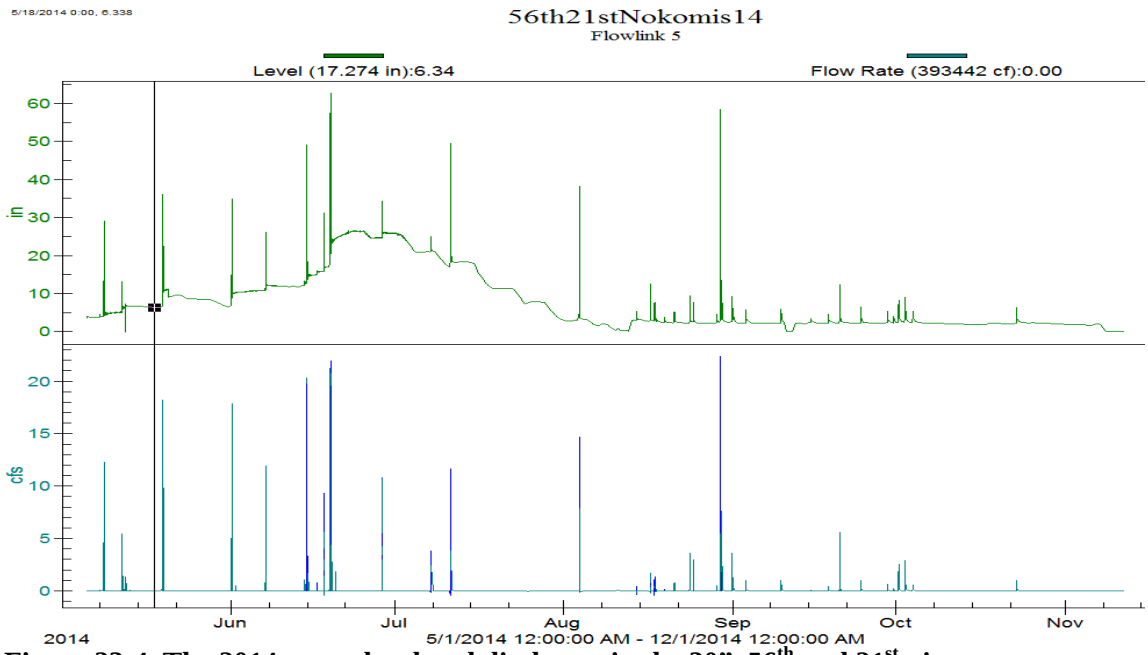


Figure 23-4 The 2014 water level and discharge in the 30", 56th and 21st pipe.

Table 23-3 shows the volumes collected for each event, the total annual volume, and the annual percentage of runoff collected. Using flow paced sampling approximately 48% of the annual storm runoff was measured and collected. No illicit discharges were detected. The flooding required the sampling to be shut down for much of the summer (mid-June through early September) but data collection continued.

Table 23-3. The 56th and 21st, 2014 sampled event discharges, annual flow measured, and percent captured.

Event	Start Date/Time		End Date/Time		Precip (inches)	Duration (hours)	Intensity (in/hr)	Time since last Precip. (hours)	Sample Type	2014, 56th & 21st Event Volumes (cf)
+1	2/18/2014	14:00	n/a	n/a	n/a	n/a	n/a	n/a	grab	X
+2	2/19/2014	14:15	n/a	n/a	n/a	n/a	n/a	n/a	grab	X
+3	3/10/2014	14:30	n/a	n/a	n/a	n/a	n/a	n/a	grab	X
4	5/8/2014	0:30	5/8/2014	20:00	1.02	19.5	0.05	180.0	composite	15,637
5	5/11/2014	21:30	5/12/2014	21:30	0.82	24.0	0.03	46.5	composite	19,498
6	5/19/2014	10:30	5/19/2014	22:30	1.80	12.0	0.15	169.0	comp/grab	73,242
7	6/14/2014	10:00	6/15/2014	9:30	1.90	23.5	0.08	69.5	composite	25,837
8	6/18/2014	2:30	6/18/2014	4:30	0.43	2.0	0.22	31.5	composite	7,026
9	9/9/2014	21:15	9/10/2014	9:00	0.41	11.8	0.03	156.0	composite	5,239
10	10/1/2014	7:30	10/2/2014	22:45	1.04	39.2	0.03	292.2	composite	43,143
			Totals		**7.42**	Number of Events				**10**

+ snowmelt event

n/a = not applicable

X = event sampled with full parameters

Total volume of sampled events (cf)	**189,622**
Total volume of recorded (with Flowlink) for 2014 (cf)	**393,442**
Percent Annual Volume Sampled	**48%**

Flow-weighted composite data and associated statistics are shown in **Table 23-4**. It is interesting to note that the geometric mean percentage of TDP is 34% of the TP, and VSS is 43% of the TSS. This means in 2014 one third of the phosphorus (TP) are dissolved (TDP) and over 40% of the solids (TSS) are organic solids (VSS). The data show most of the TSS (57%) as inert, and most likely sand.

It would be expected that street sweeping would address the TP, TSS, and VSS but have a very small effect on TDP, which makes up approximately a third of the load. This watershed may be a candidate for an enhanced iron sand filter, which targets dissolved phosphorus.

Table 23-4. The 56th & 21st 2014 Sampled event data with associated statistics.

Date Sampled	Time	Site Location	Type	TP mg/L	TDP mg/L	% TDP	TSS mg/L	VSS mg/L	% VSS
2/18/2014	14:00	56th & 21st	Grab	1.75	0.110	6%	334	108	32%
2/19/2014	13:45	56th & 21st	Grab	1.21	0.578	48%	290	113	39%
3/10/2014	14:05	56th & 21st	Grab	0.957	0.407	43%	159	55	35%
5/8/2014	3:14	56th & 21st	Composite	0.447	0.138	31%	59	24	41%
5/8/2014	3:14	56th & 21st	Composite	0.447	0.138	31%	59	24	41%
5/12/2014	22:14	56th & 21st	Composite	0.164	0.099	60%	12	6	55%
5/19/2014	13:17	56th & 21st	Composite	0.298	0.087	29%	159	45	28%
6/1/2014	7:43	56th & 21st	Composite	0.222	0.075	34%	75	24	32%
6/14/2014	20:31	56th & 21st	Composite	0.396	0.133	34%	130	57	43%
6/18/2014	1:44	56th & 21st	Composite	1.05	0.256	24%	45	35	78%
9/10/2014	0:58	56th & 21st	Composite	0.603	0.354	59%	20	16	80%
10/1/2014	13:37	56th & 21st	Composite	0.425	0.244	57%	40	15	38%
			Mean	0.664	0.218	33%	115	43	38%
			Geo Mean	0.528	0.177	**34%**	75	32	**43%**
			Median	0.447	0.138	31%	67	29	44%
			Std Dev	0.478	0.157		105	35	
			Max	1.75	0.578	60%	334	113	80%
			Min	0.164	0.075	6%	12	6	28%
			Number	12	12		12	12	

Baseline data have been collected and future monitoring will be done to assess the efficacy of street sweeping and any impacts on TP, TDP, TSS, and VSS.

24. MINNEHAHA CREEK AT XERXES AVENUE MONITORING STATION

BACKGROUND

The headwaters of Minnehaha Creek originates at Gray's Bay on Lake Minnetonka and discharges into the Mississippi River below Minnehaha Falls, as seen in **Figure 24-1**. The creek carries significant amounts of stormwater from seven upstream suburban communities located between Lake Minnetonka and Minneapolis. Approximately one third of the downstream length of Minnehaha Creek is located within Minneapolis.

In 2009, the City of Minneapolis and MPRB added a monitoring station where Xerxes Avenue South crosses Minnehaha Creek at the Minneapolis border. Monitoring at the Xerxes station is used to determine what is coming into the City from upstream areas and helps to determine the impact of Minneapolis stormwater on Minnehaha Creek.

The water in Minnehaha Creek at Xerxes has four main sources:

- runoff from the immediately surrounding watershed.
- runoff from the watershed between Lake Minnetonka and Xerxes.
- discharge from Lake Minnetonka at Gray's Bay dam, which is intermittent because the outlet from Lake Minnetonka (into Minnehaha creek) is adjustable so discharge rates vary and the dam closes when Lake Minnetonka reaches 928.6 msl.
- groundwater, which can flow into (discharge to) and out of (recharge from) Minnehaha Creek.

Figure 24-1. Map of Minnehaha Creek showing Gray's Bay Dam, the outlet from Lake Minnetonka, the Xerxes station, and the USGS station.

METHODS

Site Installation

To monitor the creek in 2014, an ISCO 2150 datalogger, 2105 interface module, and 2013ci cell phone modem were installed with a low-profile A/V (area velocity) level probe. Power was provided to all equipment by a 12 V deep cycle battery. The datalogger used the cell phone modem to remotely upload data to the server Monday through Friday. The datalogger could also be remotely called up and programmed to change the pacing or triggers.

The sampler was a flow-paced ISCO 3700 equipped with 24 one liter bottles, 3/8" ID (inner diameter) vinyl tubing, and an intake strainer. The sampler was programmed to multiplex and take four flow-paced samples per bottle allowing 96 flow-paced samples per storm. Both the level probe cable and intake strainer tubing were armored in flexible metal conduit and anchored to the northwest upstream Xerxes bridge abutment (**Figure 24-2)**.

Figure 24-2. Top: Xerxes monitoring station location at Minnehaha Creek looking downstream. The staff gauge is a vertical white line in the middle right. Left: Knaack box installation with sampler and datalogger. Right: Close up of intake strainer and level probe anchored to the northwest bridge abutment.

Rating Curve

Standard protocols and methodology were used to build a stage discharge rating curve and look up table, **Figure 24-3**. A USGS wading rod (or 15 pound lead fish), and a Marsh McBirney Flowmate™ velocity meter were used to gather stage discharge data points in the field, at one foot cross sectional increments. The MPRB continues to refine and check the stage/discharge rating curve.

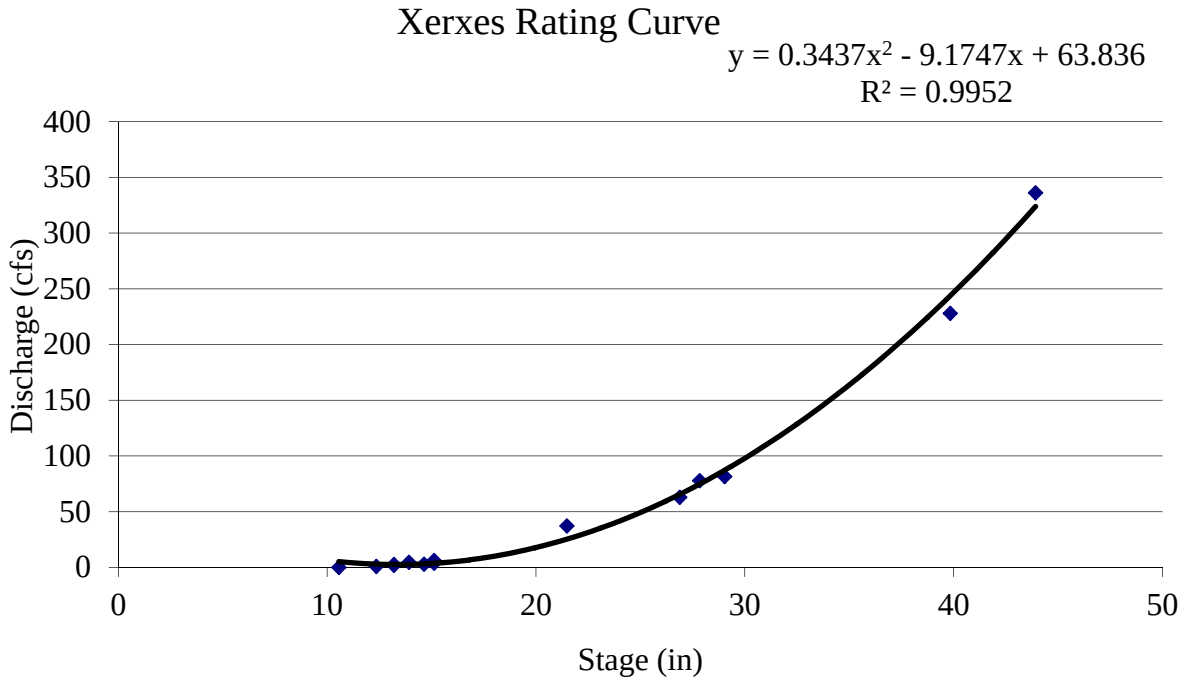


Figure 24-3. Xerxes rating curve at Minnehaha Creek.

Stage readings were checked against tape-downs and adjusted accordingly. Tape downs are a measured distance from a fixed point located at the middle of the upstream side of the Xerxes bridges to the top of the water. From the tape down point on the bridge to the stream bed is 18.00 ft. (Eighteen feet minus the distance from the bridge to the water surface is the water depth or stage). The bridge tape down point elevation is 863.01 msl. There is also a staff gauge affixed to the southwest bridge abutment. The staff gauge reading minus 4.00 equals the stream depth (stage) in feet.

The level feature of the ISCO A/V probe was used to obtain stage. The stage discharge rating curve was used by the datlogger for accurate flow weighted sampler pacing.

Sample Collection

Storm events were collected with flow-paced multiplexed ISCO auto samplers. Snowmelt and baseflow samples were both collected as grab samples. Snowmelt stage readings were rough estimations of the depth of flow on top of the ice. Baseflow sampling was year round if moving water was available. Tape-down stage readings were always collected during baseflow sampling, except during winter ice conditions.

RESULTS & DISCUSSION

2014 was the sixth year of monitoring at the Xerxes-Minnehaha Creek station. Freezing temperatures can damage the level feature of the A/V probe. In 2014, installation was on 4/25/14 when freezing conditions had subsided.

Stage and Discharge Hydrograph

Stream stage (level) and discharge (cubic feet per second -cfs) fluctuated widely over the sampling season, (see **Figure 24-4)**. The average 2014 stage was approximately 35 inches. In 2014, peak stage was 70 inches on June 19th, and the lowest stage was ~15 inches November 5th.

In reviewing **Figure 24-4**, most of the storms collected were characterized by a sharp peak from the immediate watershed, followed by a sustained pulse of water from the larger watershed and Lake Minnetonka which can last two to four days. The spring of 2014 was very wet and was followed by a significant late-summer drought.

In **Figure 24-4** both the large rainfall volumes and sustained rainstorms of April through June and the July through September drought can be seen in the hydrograph. The Gray's Bay dam was opened April 28th remained open until October 27th when it was closed for the remainder of the year.

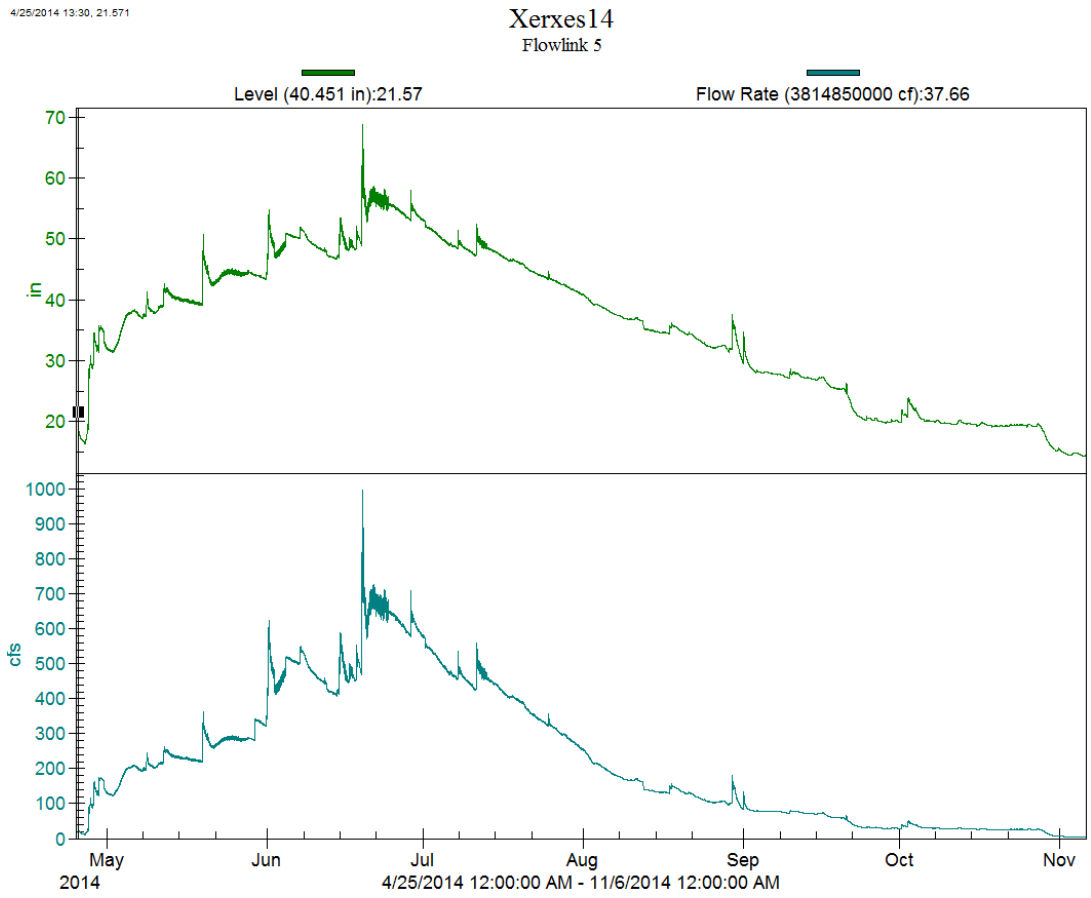


Figure 24-4. 2014 stage discharge graph of the Minnehaha Creek Xerxes monitoring station from late April to November. The (top) line represents stage data (inches) and the (bottom) line depicts discharge (cubic feet per second).

Sample Collection

In 2014, three snowmelt, eleven baseflow, and sixteen storm samples were captured, and are shown in **Table 24-1**. Both the event-pacing and stage trigger were adjusted for each storm to attempt collection of the entire hydrograph.

Table 24-1. The 2014 snowmelt, precipitation, and baseflow events captured at the Xerxes Minnehaha Creek station. A precipitation event was defined as a storm greater than 0.10 inches, separated by eight hours or more from other precipitation. If the sample exceeded holding time, some parameters (e.g. TDP, cBOD) were dropped from analysis.

Event	Start Date/Time		End Date/Time		Precip (inches)	Duration (hours)	Intensity (in/hr)	Time since last Precip. (hours)	Sample Type	2014 Xerxes Events Collected
+1	3/10/2014	14:30	n/a	n/a	n/a	n/a	n/a	n/a	grab	X(w/Ecoli)
+2	3/14/2014	14:40	n/a	n/a	n/a	n/a	n/a	n/a	grab	X
+3	3/27/2014	13:55	n/a	n/a	n/a	n/a	n/a	n/a	grab	X(w/Ecoli)
4	4/29/2014	3:00	5/1/2014	8:00	0.67	53.0	0.01	62.0	composite	X
5	5/8/2014	0:30	5/8/2014	20:00	1.02	19.5	0.05	180.0	composite	X
6	5/10/2014	20:00	5/10/2014	23:00	0.11	3.0	0.04	51.0	composite	X
7	5/11/2014	21:30	5/12/2014	21:30	0.82	24.0	0.03	46.5	composite	X(lmtd)
8	5/19/2014	10:30	5/19/2014	22:30	1.80	12.0	0.15	169.0	comp/grab	X
9	5/31/2014	16:30	6/1/2014	21:00	1.97	28.5	0.07	310.5	composite	X(lmtd)
10	6/14/2014	10:00	6/15/2014	9:30	1.9	23.5	0.08	69.5	composite	X
11	6/18/2014	2:30	6/18/2014	4:30	0.43	2.0	0.22	31.5	composite	X
12	6/19/2014	3:30	6/19/2014	20:30	3.00	17.0	0.18	40.0	comp/grab	X
13	7/6/2014	5:30	7/6/2014	8:00	0.13	2.5	0.05	174.5	composite	X
14	7/25/2014	5:00	7/25/2014	7:00	0.42	2.0	0.21	250.5	composite	X
15	9/9/2014	21:15	9/10/2014	9:00	0.41	11.8	0.03	156.0	composite	X
16	10/1/2014	7:30	10/2/2014	22:45	1.04	39.2	0.03	292.2	composite	X(lmtd)
			Totals		**13.72**					**16**

Baseflow Event	Date	Time	Sample Type	Collected
1	1/10/2014	13:30	Grab	X
2	2/7/2014	11:45	Grab	X
3	4/14/2014	9:25	Grab	X(w/Ecoli)
4	5/19/2014	9:55	Grab	X(w/Ecoli)
5	6/13/2014	13:30	Grab	X
6	7/9/2014	10:00	Grab	X(w/Ecoli)
7	8/20/2014	9:05	Grab	X(w/Ecoli)
8	9/2/2014	9:30	Grab	X(w/Ecoli)
9	10/6/2014	0.5625	Grab	X(w/Ecoli)
10	11/4/2014	0.572917	Grab	X(w/Ecoli)
11	12/5/2014	0.364583	Grab	X

+ snowmelt event

n/a = not applicable

X = event sampled with full parameters

X(lmtd) = event sampled with limited parameters generally due to holding times e.g.BOD, TDP, etc.

X(w/Ecoli) = event sampled with fecal coliform

Event and Baseflow Raw Data

Table 24-2 shows the 2014 raw baseflow and event data collected at the Xerxes station. The duplicates have been averaged and the less than values are shown. These event runoff data show a general tendency of both very dirty snowmelt and early spring runoff as seen in the TP and TSS data.

The baseflow data show Cl and TDS being higher in January, April, and December. The January and December chloride levels are just below the 230 mg/L chronic level MPCA standards. The April chloride level is above the standard. The baseflow data show a relativity consistent concentration of most parameters in summer and fall.

Table 24-2. Minnehaha Creek at Xerxes 2014 water chemistry of snowmelt, event, and baseflow data. Cells with "less than" values indicate that the concentration of that parameter was below detection limit. NA = data not available due to expired holding time or low volume, SM = snowmelt, BF=baseflow.

Date Sampled	Time	Site Location	Sample Type	TP mg/L	TDP mg/L	OPO4 mg/L	TKN mg/L	NH3 mg/L	NO3NO2 mg/L	Cl mg/L	Hardness mg/L	TSS mg/L	VSS mg/L	TDS mg/L	cBOD mg/L	Sulfate mg/L	Sp.Cond. uhmos	pH std units	E. Coli MPN	Cu ug/L	Pb ug/L	Zn ug/L
3/10/2014	13:40	Xerxes SM	Grab	0.692	0.407	NA	5.30	1.67	0.514	1385	132	313	100	2361	17.9	24	4460	7.7	19863	45	14	250
3/14/2014	14:40	Xerxes SM	Grab	0.417	0.274	NA	3.26	1.86	0.302	668	316	27	8	1256	4	17	2310	7.6		<5.00	<3.00	26
3/27/2014	14:05	Xerxes SM	Grab	0.230	0.116	NA	2.24	1.48	1.07	382	232	16	7	836	4	18	1477	7.5	411	<5.00	<3.00	26
4/29/2014	10:12	Xerxes	Composite	0.146	0.041	0.067	1.03	<0.500	0.684	275	156	47	16	1820	<1.00	9	753	7.6		<5.00	<3.00	26
5/2/2014	7:51	Xerxes	Composite	0.071	0.063	0.024	0.689	<0.500	0.723	180	148	9	5	385	<1.00	11	655	7.4		<5.00	<3.00	<20.0
5/9/2014	5:22	Xerxes	Composite	0.044	0.028	0.032	1.04	<0.500	1.84	68	148	44	12	263	<1.00	5	491	7.6		<5.00	3.3	<20.0
5/11/2014	10:12	Xerxes	Composite	0.038	0.015	0.003	0.640	<0.500	0.600	88	160	9	3	275	<1.00	5	509	7.8		<5.00	<3.00	<20.0
5/13/2014	18:03	Xerxes	Composite	0.036	NA	NA	<0.500	NA	0.091	83	144	7	<2.0	NA	NA	NA	493	NA		<5.00	<3.00	<20.0
5/20/2014	9:05	Xerxes	Composite	0.041	0.028	0.019	0.616	<0.500	0.260	79	136	29	7	245	3	5	432	6.7		<5.00	<3.00	<20.0
5/30/2014	19:53	Xerxes	Composite	0.046	NA	NA	0.957	NA	0.061	63	164	5	<2.0	NA	NA	NA	415	NA		<5.00	<3.00	<20.0
5/31/2014	17:35	Xerxes	Composite	0.026	NA	NA	0.697	NA	<0.030	58	164	5	<2.0	NA	NA	NA	398	NA		<5.00	<3.00	<20.0
6/3/2014	6:47	Xerxes	Composite	0.035	0.035	NA	0.610	NA	0.041	72	192	5	3	NA	NA	NA	381	NA		<5.00	3.1	<20.0
6/15/2014	21:17	Xerxes	Composite	0.049	0.033	0.031	<0.500	<0.500	0.103	56	136	9	2	234	<1.00	<5.0	356	7.5		<5.00	<3.00	<20.0
6/18/2014	10:03	Xerxes	Composite	0.058	0.027	0.030	0.779	<0.500	0.057	71	144	8	2	251	<1.00	5	386	7.6		<5.00	<3.00	<20.0
6/20/2014	8:04	Xerxes	Composite	0.088	0.038	0.060	0.700	<0.500	0.147	61	116	22	5	250	<1.00	5	317	7.0		<5.00	<3.00	<20.0
7/7/2014	22:25	Xerxes	Composite	0.060	0.036	0.030	0.526	<0.500	0.107	70	144	9	<2.0	267	<1.00	<5.0	389	7.8		<5.00	<3.00	<20.0
7/25/2014	7:52	Xerxes	Composite	0.069	0.045	0.040	0.840	<0.500	0.071	67	148	12	5	213	<1.00	<5.0	408	6.7		<5.00	<3.00	<20.0
9/10/2014	8:10	Xerxes	Composite	0.052	0.025	0.029	0.837	<0.500	0.385	67	168	11	5	298	<1.00	<5.0	447	7.9		<5.00	<3.00	<20.0
10/1/2014	14:27	Xerxes	Composite	0.063	NA	NA	0.725	NA	0.152	67	168	6	4	NA	NA	NA		NA		<5.00	<3.00	30
1/10/2014	13:30	Xerxes BF	Grab	0.032	0.010	0.012	1.44	<0.500	0.811	215	490	4	1	801	<1.00	10	1462	7.1		<5.00	<3.00	<20.0
2/7/2014	11:45	Xerxes BF	Grab	0.029	0.006	0.024	<0.500	<0.500	0.426	NA	448	5	3	685	<1.00	41	1306	7.5		<5.00	<3.00	<20.0
4/14/2014	9:25	Xerxes BF	Grab	0.091	0.043	0.022	0.879	<0.500	0.522	240	224	10	4	681	3	14	1234	7.7	15	<5.00	<3.00	<20.0
5/19/2014	9:55	Xerxes BF	Grab	0.017	0.011	0.006	<0.500	<0.500	0.128	73	160	5	<2.0	278	<1.00	<5.0	491	7.7	35	<5.00	<3.00	<20.0
6/13/2014	13:30	Xerxes BF	Grab	0.032	0.024	0.020	0.576	<0.500	0.060	66	160	5	2	268	<1.00	<5.0	389	7.1		<5.00	<3.00	<20.0
7/9/2014	10:00	Xerxes BF	Grab	0.061	0.038	0.027	0.559	<0.500	0.067	75	156	5	<2.0	250	<1.00	6	394	7.6	96	<5.00	<3.00	<20.0
8/20/2014	9:05	Xerxes BF	Grab	0.048	0.031	0.040	1.07	<0.500	0.441	62	156	8	2	254	<1.00	6	425	7.7	74	<5.00	<3.00	<20.0
9/2/2014	9:30	Xerxes BF	Grab	0.038	0.034	0.026	0.574	<0.500	0.190	62	160	7	4	276	<1.00	<5.0	444	7.8	109	<5.00	<3.00	<20.0
10/6/2014	13:30	Xerxes BF	Grab	0.026	0.019	0.014	0.725	<0.500	0.284	86	200	<1.00	<2.00	344	<1.00	<5.0	559	8.0	34	<5.00	<3.00	<20.0
11/4/2014	13:45	Xerxes BF	Grab	0.043	0.017	0.009	<0.500	<0.500	0.132	95	224	8	3	382	<1.00	<5.0	610	8.0	32	<5.00	<3.00	30
12/5/2014	8:45	Xerxes BF	Grab	0.022	0.013	0.010	0.719	<0.500	0.459	200	352	<1.00	<2.00	680	<1.00	14	1220	7.9		<5.00	<3.00	<20.0

Baseflow Data and Statistics

Table 24-3 show the Xerxes station baseflow data and associated statistics. Statistics were only calculated for a chemical parameter if there were two or more measured values. When statistical analysis was performed on the data sets and less than values were present, half of the reporting limit less than value was used in the calculations.

Throughout the 2014 sampling season, a total of eleven baseflow samples were taken to determine background conditions in the stream. In April no baseflow sample was collected because the stream was frozen to the bed. Seven *E. coli* grab samples were collected during baseflow conditions.

Winter baseflow had high concentrations for Cl, hardness, TDS, and specific conductivity. The levels of these dissolved parameters indicate that there was a problem with winter chlorides as well as a background amount of chloride being shed the rest of the year.

Baseflow samples generally had lower concentrations of nutrients and metals than storm events (**Table 24-4**). All metals and *E. coli* levels were relatively low and not of concern.

Table 24-3. Minnehaha Creek at Xerxes 2014 baseflow data showing both water chemistry data and statistics. All "less than data" were transformed into half the reporting limit for statistical calculations (e.g. Pb <3 becomes 1.5). NA = data not available due to expired holding time or low volume, BF = baseflow.

Date Sampled	Time	Site Location	Sample Type	TP mg/L	TDP mg/L	OPO4 mg/L	TKN mg/L	NH3 mg/L	NO3NO2 mg/L	Cl mg/L	Hardness mg/L	TSS mg/L	VSS mg/L	TDS mg/L	cBOD mg/L	Sulfate mg/L	Sp.Cond. uhmos	pH std units	E. Coli MPN	Cu ug/L	Pb ug/L	Zn ug/L
1/10/2014	13:30	Xerxes BF	Grab	0.032	0.010	0.012	1.444	0.250	0.811	215	490	4	1	801	1	10	1462	7.1		2.5	1.5	10
2/7/2014	11:45	Xerxes BF	Grab	0.029	0.006	0.024	0.250	0.250	0.426		448	5	3	685	1	41	1306	7.5		2.5	1.5	10
4/14/2014	9:25	Xerxes BF	Grab	0.091	0.043	0.022	0.879	0.250	0.522	240	224	10	4	681	3	14	1234	7.7	15	2.5	1.5	10
5/19/2014	9:55	Xerxes BF	Grab	0.017	0.011	0.006	0.250	0.250	0.128	73	160	5	1	278	1	3	491	7.7	35	2.5	1.5	10
6/13/2014	13:30	Xerxes BF	Grab	0.032	0.024	0.020	0.576	0.250	0.060	66	160	5	2	268	1	3	389	7.1		2.5	1.5	10
7/9/2014	10:00	Xerxes BF	Grab	0.061	0.038	0.027	0.559	0.250	0.067	75	156	5	1	250	1	6	394	7.6	96	2.5	1.5	10
8/20/2014	9:05	Xerxes BF	Grab	0.048	0.031	0.040	1.07	0.250	0.441	62	156	8	2	254	1	6	425	7.7	74	2.5	1.5	10
9/2/2014	9:30	Xerxes BF	Grab	0.038	0.034	0.026	0.574	0.250	0.190	62	160	7	4	276	1	3	444	7.8	109	2.5	1.5	10
10/6/2014	13:30	Xerxes BF	Grab	0.026	0.019	0.014	0.725	0.250	0.284	86	200	1	10	344	1	3	559	8.0	34	2.5	1.5	10
11/4/2014	13:45	Xerxes BF	Grab	0.043	0.017	0.009	0.250	0.250	0.132	95	224	8	3	382	1	3	610	8.0	32	2.5	1.5	30
12/5/2014	8:45	Xerxes BF	Grab	0.022	0.013	0.010	0.719	0.250	0.459	200	352	1	10	680	1	14	1220	7.9		2.5	1.5	10
			Mean	0.040	0.022	0.019	0.663	0.250	0.320	117	248	5	4	445	1	9	776	7.6	56	2.5	1.5	12
			Geo Mean	0.036	0.019	0.017	0.570	0.250	0.237	102	226	4	3	401	1	6	678	7.6	46	2.5	1.5	11
			Median	0.032	0.019	0.020	0.576	0.250	0.284	81	200	5	3	344	1	6	559	7.7	35	2.5	1.5	10
			Std Dev	0.021	0.012	0.010	0.370	0.000	0.234	71	124	3	3	217	1	11	429	0.3	36	0	0	6
			Max	0.091	0.043	0.040	1.44	0.250	0.811	240	490	10	10	801	3	41	1462	8.0	109	2.5	1.5	30
			Min	0.017	0.006	0.006	0.250	0.250	0.060	62	156	1	1	250	1	3	389	7.1	15	2.5	1.5	10
			Number	11	11	11	11	11	11	10	11	11	11	11	11	11	11	11	7	11	11	11

Storm Event Data and Statistics

Table 24-4 shows the Xerxes station event data and associated statistics. Statistics were only calculated for a chemical parameter if there were two or more measured values. When statistical analysis was performed on the data sets and less than values were present, half of the reporting limit value was used in the calculations.

Table 24-4 shows snowmelt as having the highest values for all measured parameters. Two of the snowmelt grab sample parameters of concern are phosphorus and chloride since they are quite high at 0.692 mg/L and 1385 mg/L respectively. The non-snowmelt chloride values were between 56 mg/L and 275 mg/L. The MPCA chronic stream chloride standard is 230 mg/L for four days and an acute standard of 860 mg/L for one hour. Chloride was generally below the MPCA acute and chronic standards.

The source of low level chronic chloride in Minnehaha Creek is likely caused by winter road salt (NaCl) continuously leaching from the upstream soils. The MPCA TCMA Chloride Management Plan states the natural background chloride level is considered to be 8% or 18.7 mg/L for the chronic criteria.

Table 24-4. Minnehaha Creek at Xerxes 2014 precipitation event water chemistry data showing concentrations during or after a precipitation event (defined as more than 0.10 inches) or snowmelt. All "less than data" were transformed into half the reporting limit for statistical calculations (e.g. Pb <3 becomes 1.5). SM = snowmelt, NA = data not available.

Date Sampled	Time	Site Location	Sample Type	TP mg/L	TDP mg/L	OPO4 mg/L	TKN mg/L	NH3 mg/L	NO3NO2 mg/L	Cl mg/L	Hardness mg/L	TSS mg/L	VSS mg/L	TDS mg/L	cBOD mg/L	Sulfate mg/L	Sp.Cond. uhmos	pH std units	E. Coli MPN	Cu ug/L	Pb ug/L	Zn ug/L
3/10/2014	13:40	Xerxes SM	Grab	0.692	0.407	NA	5.30	1.67	0.514	1385	132	313	100	2361	18	24	4460	7.7	19863	45	14	250
3/14/2014	14:40	Xerxes SM	Grab	0.417	0.274	NA	3.26	1.86	0.302	668	316	27	8	1256	4	17	2310	7.6		2.5	1.5	26
3/27/2014	14:05	Xerxes SM	Grab	0.230	0.116	NA	2.24	1.48	1.07	382	232	16	7	836	4	18	1477	7.5	411	2.5	1.5	26
4/29/2014	10:12	Xerxes	Composite	0.146	0.041	0.067	1.03	0.250	0.684	275	156	47	16	1820	1	9	753	7.6		2.5	1.5	26
5/2/2014	7:51	Xerxes	Composite	0.071	0.063	0.024	0.689	0.250	0.723	180	148	9	5	385	1	11	655	7.4		2.5	1.5	10
5/9/2014	5:22	Xerxes	Composite	0.044	0.028	0.032	1.04	0.250	1.84	68	148	44	12	263	1	5	491	7.6		2.5	3.3	10
5/11/2014	10:12	Xerxes	Composite	0.038	0.015	0.003	0.640	0.250	0.600	88	160	9	3	275	1	5	509	7.8		2.5	1.5	10
5/13/2014	18:03	Xerxes	Composite	0.036	NA	NA	0.250	NA	0.091	83	144	7	1	NA	NA	NA	493	NA		2.5	1.5	10
5/20/2014	9:05	Xerxes	Composite	0.041	0.028	0.019	0.616	0.250	0.260	79	136	29	7	245	3	5	432	6.7		2.5	1.5	10
5/30/2014	19:53	Xerxes	Composite	0.046	NA	NA	0.957	NA	0.061	63	164	5	1	NA	NA	NA	415	NA		2.5	1.5	10
5/31/2014	17:35	Xerxes	Composite	0.026	NA	NA	0.697	NA	0.015	58	164	5	1	NA	NA	NA	398	NA		2.5	1.5	10
6/3/2014	6:47	Xerxes	Composite	0.035	0.035	NA	0.610	NA	0.041	72	192	5	3	NA	NA	NA	381	NA		2.5	3.1	10
6/15/2014	21:17	Xerxes	Composite	0.049	0.033	0.031	0.250	0.250	0.103	56	136	9	2	234	1	3	356	7.5		2.5	1.5	10
6/18/2014	10:03	Xerxes	Composite	0.058	0.027	0.030	0.779	0.250	0.057	71	144	8	2	251	1	5	386	7.6		2.5	1.5	10
6/20/2014	8:04	Xerxes	Composite	0.088	0.038	0.060	0.700	0.250	0.147	61	116	22	5	250	1	5	317	7.0		2.5	1.5	10
7/7/2014	22:25	Xerxes	Composite	0.060	0.036	0.030	0.526	0.250	0.107	70	144	9	1	267	1	3	389	7.8		2.5	1.5	10
7/25/2014	7:52	Xerxes	Composite	0.069	0.045	0.040	0.840	0.250	0.071	67	148	12	5	213	1	3	408	6.7		2.5	1.5	10
9/10/2014	8:10	Xerxes	Composite	0.052	0.025	0.029	0.837	0.250	0.385	67	168	11	5	298	1	3	447	7.9		2.5	1.5	10
10/1/2014	14:27	Xerxes	Composite	0.063	NA	NA	0.725	NA	0.152	67	168	6	4	NA	NA	NA		NA		2.5	1.5	30
			Mean	0.119	0.081	0.033	1.16	0.555	0.380	203	164	31	10	640	2	8	838	7.5	10137	4.7	2.3	26
			Geo Mean	0.073	0.048	0.027	0.846	0.375	0.194	112	160	14	4	431	1	6	591	7.4	2857	2.9	1.8	15
			Median	0.058	0.036	0.030	0.725	0.250	0.152	71	148	9	5	271	1	5	440	7.6	10137	2.5	1.5	10
			Std Dev	0.167	0.111	0.018	1.22	0.610	0.459	325	44	69	22	689	5	7	1031	0.4	13755	9.8	2.9	55
			Max	0.692	0.407	0.067	5.30	1.86	1.84	1385	316	313	100	2361	18	24	4460	7.9	19863	45	14	250
			Min	0.026	0.015	0.003	0.250	0.250	0.015	56	116	5	1	213	1	3	317	6.7	411	2.5	1.5	10
			Number	19	15	11	19	14	19	19	19	19	19	14	14	14	18	14	2	19	19	19

In comparing **Table 24-3** (baseflow) with **Table 24-4** (runoff events) geometric means and medians, the runoff events have a higher concentration of every parameter measured except hardness and conductivity. Baseflow appears to be dominated by both groundwater and overflow from Lake Minnetonka. The runoff events show precipitation picking up significant amounts of surface and erosion debris and carrying it downstream. The watershed map shows that Minnehaha Creek appears to be an urban stream used as a stormwater conduit for many communities draining to it. The MPRB data has been used with Minnehaha Creek Watershed District to create TMDL's for *E. Coli* and phosphorus in Minnehaha Creek with chlorides being of recent concern.

Due to the annual and seasonal variability, long term water quality is important to understand both background and year to year variations in stream chemistry.

25. GOLF COURSE WETLAND MONITORING

BACKGROUND

Environmental Stewardship assists the MPRB golf courses in water and vegetation monitoring. The Theodore Wirth and Meadowbrook Golf Courses have requested annual monitoring since 2001. In 2009, Columbia, Hiawatha, and Gross Golf Courses added environmental monitoring to their programs.

Golf Course Foremen assisted Water Resources Staff in choosing representative waterbodies on each course. Physical parameters (temperature, conductivity, pH, DO and % DO) were measured at each study site with a Hydrolab Minisonde 5 Multiprobe. Chemical parameters: total phosphorus, nitrate/nitrite, and ammonia (TP, NO_3NO_2 and NH_3) were collected and taken to Instrumental Research, Inc. (IRI) laboratory for analysis. Standard MPRB sampling and QA/QC procedures were followed. A visual survey of aquatic and wetland vegetation was conducted at each sample site and at sites of interest.

COLUMBIA GOLF COURSE

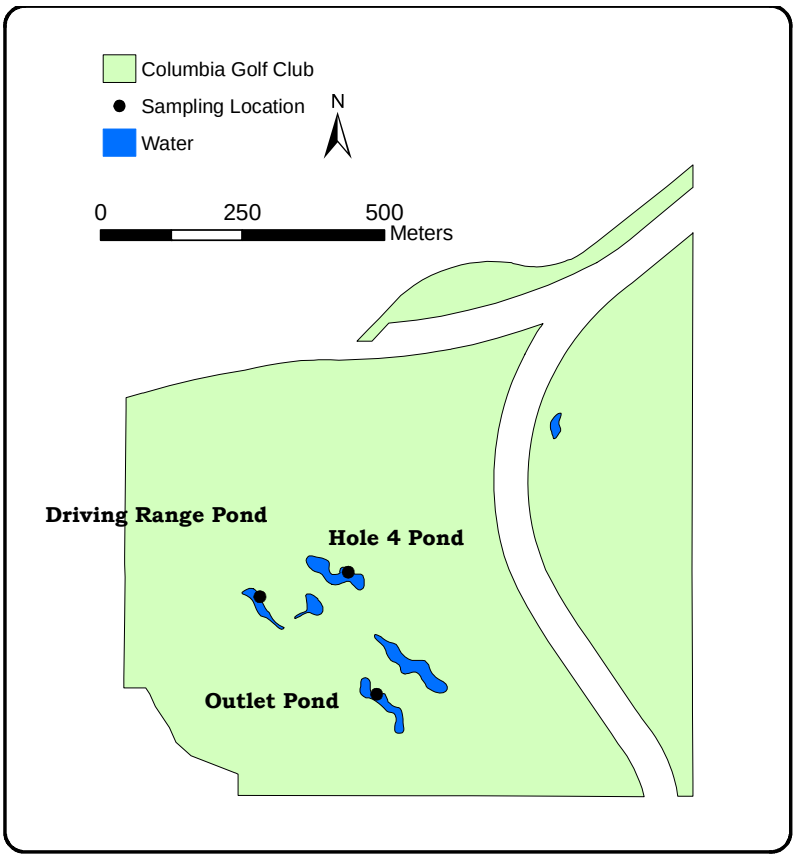


Figure 25-1. Sample sites on the Columbia Golf Club course.

Three ponds on the Columbia Golf Course were chosen for monitoring and are shown above in **Figure 25-1**. The headwaters pond is just off of Pond 1(Hole 4). Pond 1 receives water from a groundwater well used to irrigate the golf course and has clear water all year. Pond 2 (the Driving Range Pond) receives surface drainage from the driving range and drains to an unsampled pond downstream of Pond 1. Pond 3 (Outlet Pond) is the last pond in the series and outlets to a low area before entering a storm sewer that drains to the Mississippi River.

2014 was the sixth year of sampling at Columbia Golf Course. Aquatic, terrestrial, and wetland plants in the ponds and surrounding buffers were surveyed at the end of July. A few new plant species were discovered around each pond. Dominant species identified from the Columbia Golf Course ponds and buffer zones are presented in **Table 25-1**. Data presented are from the last five years of sampling only. Older data can be found in previous reports.

Table 25-1. Dominant plants within and surrounding the Columbia Golf Course Ponds.

Columbia Golf Course		Pond 1, Hole 4					Pond 2, Driving Range Pond					Pond 3, Outlet Pond				
Scientific Name	**Common Name**	Sep-10	Jun-11	Jul-12	Aug-13	Jul-14	Sep-10	Jun-11	Jul-12	Aug-13	Jul-14	Sep-10	Jun-11	Jul-12	Aug-13	Jul-14
Terrestrial and Wetland Species																
Agrostis gigantea	Redtop													X		X
Alisma subcordatum	Water Plantain														X	X
Ambrosia artemisiifolia	Ragweed											X				
Arctium minus	Burdock					X										
Asclepias incarnata	Marsh Milkweed					X										
Asclepias syriaca	Common Milkweed					X										
Aster spp	Aster 1				X	X										X
Aster spp	Aster 2															
Bidens cernua	Beggarstick	X											X			
Brassica spp	Mustard			X										X		
Bromus inermis	Smooth Brome						X							X		
Carex spp	Sedge											X	X		X	
Cerastium vulgatum	Mouse-eared Chickweed					X										
Cirsium spp	Thistle	X	X	X	X	X	X	X	X	X	X	X	X	X		
Cyperus esculentus	Yellow Nut Sedge														X	
Eliocharis obtusa	Spike Rush		X					X						X	X	X
Fraxinus Pennsylvanica	Green Ash										X					
Helenium autumnale	Common Sneezeweed													X		
Helianthus spp	Sunflower													X		
Nepta cataria	Catnip		X			X								X		
Parthenocissus quinquefolia	Virginia Creeper				X	X										
Polygonum pensylvanicum	Smartweed	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Pontedaria cordata	Pickerelweed		X						X							
Poa pratensis	Kentucky Bluegrass		X		X			X					X	X	X	X
Potentilla millegrana	Diffuse Cinquefoil					X					X					
Potentilla norvegica	Rough Cinquefoil		X				X	X	X				X	X	X	X
Rorippa palustris	Common Yellowcress										X					X
Rumex crispus	Curled Dock	X	X	X	X	X	X			X	X	X	X	X	X	X
Salix spp	Sandbar Willow		X		X											
Schoenoplectus acutus	Hardstem Bulrush														X	
Scirpus fluviatilis	River Bulrush											X	X	X		
Scirpus validus	Soft stem Bulrush													X		
Setaria veridis	Foxtail	X							X							
Sinapis spp	Mustard				X	X										
Solanum dulcamara	Bittersweet Nightshade				X	X	X	X		X	X	X				
Solidago spp	Goldenrod	X	X	X	X	X	X	X								
Typha spp	Cattail	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Ulmaceaespp	Elm				X											
Urtica dioica	Stinging Nettle	X	X	X	X	X	X	X	X	X	X	X	X	X		X
Verbena hastata	Blue Vervain				X	X	X				X	X	X	X	X	
Vitus riparia	Riverbank Grape	X	X	X	X	X						X	X			
Aquatic Species		Pond 1, Hole 4					Pond 2, Driving Range Pond					Pond 3, Outlet Pond				
Filamentous algae	Filamentous algae			X		X			X							
Ceratophyllum demersum	Coontail	X														
Chara spp	Muskgrass	X														
Lemna minor	Lesser Duckweed					X	X	X	X	X	X	X	X	X		
Potamogeton spp	Narrow Leaf Pondweed	X	X	X									X	X		
Potamogeton zosteriformis	Flat Stem Pondweed														X	
Vallisneria americana	Water Celery	X													X	
Wolfia colombiana	Wolfia	X					X						X	X		
Zosterella dubia	Water Stargrass	X														

Water quality monitoring results for Columbia Golf Course are shown in **Table 25-2**. Temperature, dissolved oxygen, dissolved oxygen percent, pH, and specific conductivity measurements were made in each pond with a Hydrolab 5 sonde. The chemical parameters, total phosphorus, ammonia, and nitrate/nitrite were analyzed by IRI, Inc.

In surface waters, nitrate/nitrite and ammonia levels are typically below 1 mg/L. In 2014, nitrate/nitrite levels were high in Ponds 2 and 3. This is likely from oxidizing nitrogen released from decomposing material or oxidizing nitrogen fertilizer applied to the golf course.

The amount of NH_3 in all ponds has fluctuated considerably over the past few years with Pond 3 surpassing suitable levels for surface water and groundwater. The increase in NH_3 may also be indicative of increased fertilizer inputs or increased organic decay.

The low dissolved oxygen measurements taken in Ponds 2 and 3 are of some concern and should be remedied. Groundwater is likely responsible for a lower than expected water temperature in Pond 1.

Table 25-2. Water quality monitoring results for Columbia Golf Course. NS = not sampled.

Colombia	Date	Time	Temp	DO%	DO	pH	SpCond	TP	NH3	NO3/NO2
			øC	Sat	mg/l	Units	µS/cm	mg/L	mg/L	mg/L
Pond 1 - Hole 4	9/3/2010	10:30	14.0	89.4	8.93	8.0	112	0.019	<0.500	0.304
Pond 1 - Hole 4	6/29/2011	10:20	21.3	109.6	9.48	7.3	1300	0.018	<0.500	0.042
Pond 1 - Hole 4	7/17/2012	10:35	16.7	84.2	7.90	7.6	1482	0.029	0.416	0.090
Pond 1 - Hole 4	8/15/2013	10:00	14.9	83.3	8.23	8.1	1615	0.058	0.871	<0.030
Pond 1 - Hole 4	7/30/2014	10:30	16.3	82.4	7.87	7.5	1633	0.057	0.684	0.064
Pond 2 - Driving Range	9/3/2010	10:30	23.2	37.3	3.12	7.1	834	0.983	2.40	0.090
Pond 2 - Driving Range	6/29/2011	10:35	15.7	7.6	0.73	7.6	754	1.27	3.36	<0.030
Pond 2 - Driving Range	7/17/2012	NS	NS	NS	NS	NS	NS	NS	NS	NS
Pond 2 - Driving Range	8/15/2013	10:15	19.6	8.7	0.78	7.7	1357	2.24	6.23	<0.030
Pond 2 - Driving Range	7/30/2014	10:50	19.6	0.0	0.00	7.2	926	0.67	1.53	1.28
Pond 3 - Outlet	9/3/2010	10:46	16.6	15.2	1.44	8.0	NS	0.460	1.15	0.093
Pond 3 - Outlet	6/29/2011	10:45	23.5	80.9	6.73	7.4	837	0.389	2.61	0.033
Pond 3 - Outlet	7/17/2012	NS	NS	NS	NS	NS	NS	NS	NS	NS
Pond 3 - Outlet	8/15/2013	10:25	19.2	111.3	10.04	7.2	1591	0.058	3.37	0.063
Pond 3 - Outlet	7/30/2014	11:00	20.7	13.7	1.19	7.2	1372	0.847	3.33	2.58

GROSS NATIONAL GOLF COURSE

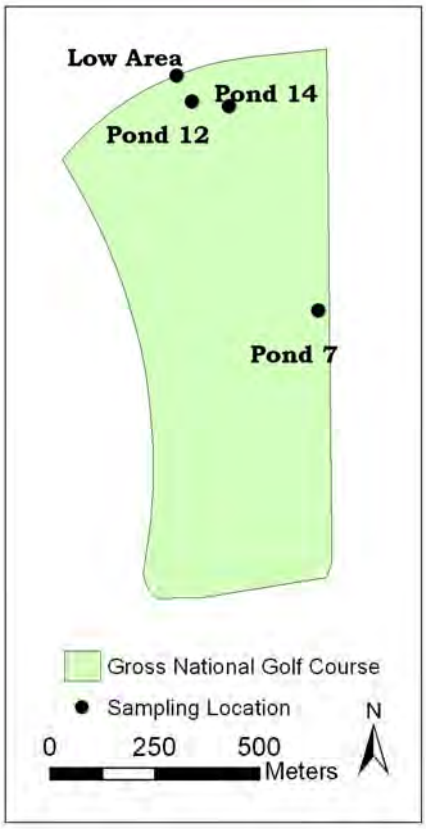


Figure 25-2. Sample sites on the Gross National Golf Course.

Three ponds and one additional vegetation monitoring site were chosen on Gross National Golf Course presented above in **Figure 25-2**. Pond 7 is one of the oldest water bodies on the golf course and may be a remnant of a natural wetland. The pond is hydrologically isolated, with no drain tile outlets and no connection to the golf course irrigation system. Ponds 14 and 12 were constructed in the mid-1990's 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 drains to Pond 12 and Pond 12 can be pumped to the site marked Low Area in **Figure 25-2**. The "low area" was chosen as an additional vegetation survey site since water is pumped to it and it had different vegetation than most of the golf course.

2014 was the sixth year of sampling at Gross National Golf Course. Aquatic, terrestrial, and wetland plants in the ponds and surrounding buffers were surveyed at the end of July. MPRB staff observed 8 new species in Pond 14 with a few more at the other sampling sites. Dominant species identified from the Gross National Golf Course ponds and buffer zones are presented in **Table 25-3**. Data presented are from the last five years of sampling only. Older data can be found in previous reports.

Table 25-3. Dominant plants at the Gross National Golf Course sample sites.

Gross Golf Course		Pond 7					Pond 12					Pond 14					Low Area				
Scientific Name	Common Name	Sep-10	Jun-11	Jul-12	Aug-13	Jul-14	Sep-10	Jun-11	Jul-12	Aug-13	Jul-14	Sep-10	Jun-11	Jul-12	Aug-13	Jul-14	Sep-10	Jun-11	Jul-12	Aug-13	Jul-14
Terrestrial and Wetland Species																					
Acer saccharinum	Silver Maple	X	X		X	X															
Achillea millefolium	Yarrow				X	X															
Ajuga reptans	Bugleweed					X															
Alnus incana	Speckled Alder																X	X	X	X	X
Ambrosia spp	Ragweed				X	X															
Arctium ssp	Burdock					X															
Asclepcias incarnata	Marsh Milkweed			X	X																
Asclepcias syriaca	Common Milkweed					X										X					
Aster lanceolatus	Marsh Aster													X							
Aster spp	Aster				X							X	X		X						
Brassica rapa	Field Mustard					X															
Bromus inermis	Smooth Brome																X				
Carex spp	Sedge	X		X	X		X	X				X	X	X							
Carex spp	Sedge 2						X						X								
Carex spp	Upland sedge																				
Circaea spp	Enchanter's Nightshade													X	X						
Cirsium spp	Thistle				X	X			X	X	X	X	X	X	X	X	X				
Cirsium avense	Canadian Thistle					X			X		X					X					
Cyperus esculentus	Yellow Nutsedge				X	X															
Cyperus odoratus	Flat sedge								X												
Daucus carota	Queen Anne's Lace			X		X															
Erigeron annuus	Daisy fleabane															X					
Echinochloa crusgalli	Barnyard Grass				X		X			X		X									
Eloecharis obtusa	Blunt Spikerush							X	X	X		X	X	X	X						
Eupatorium perfoliatum	Boneset			X	X	X															
Fraxinus pennsylvanica	Green Ash															X					
Helenium autumnale	Sneezeweed											X	X								
Juncus tenuis	Slender Rush													X							
Leonurus cariaca	Motherwort			X																	
Lycopus americanus	American bugleweed			X																	
Lythrum salicaria	Purple Loosestrife			X	X	X															
Mimulus ringens	Square-stemed Monkeyflower										X					X					
Parthenocissus quinquefolia	Virginia Creeper					X															
Phalaris arundinacea	Reed Canary Grass		X	X	X	X	X	X						X				X	X	X	X
Poa pratensis	Kentucky Bluegrass	X	X		X	X	X	X		X	X	X	X				X	X		X	X
Polygonum pensylvanicum	Smartweed	X			X	X	X					X	X		X		X		X		
Populus deltoides	Eastern Cottonwood						X														X
Populus tremuloides	Aspen	X	X		X	X						X					X	X	X	X	
Potentilla norvegica	Rough Cinquefoil												X			X					
Rhamnus cathartica	Common Buckthorn																			X	X
Rudbeckia hirta	Black eyed susan				X										X	X					
Rumex crispus	Curled Dock		X	X	X	X	X	X	X	X	X	X	X	X	X	X				X	X
Sagittaria latifolia	Broad-leaved Arrowhead			X	X	X	X	X	X	X	X	X	X	X	X						
Salix spp	Weeping Willow	X	X	X	X	X															
Salix spp	Sandbar Willow (?)						X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Salix nigra	Black Willow																				X
Schoenoplectus acutus	Hardstem Bulrush				X										X						
Scripus atrovirens	Green Bulrush														X						
Scirpus cyperinus	Woolgrass			X					X												
Scirpus fluviatilis	River Bulrush						X	X	X	X	X	X	X	X	X	X					X
Scirpus validus	Soft stem Bulrush								X												
Scutellaria galericulata	Marsh Skullcap													X	X						
Solanum dolcamara	Bittersweet Nightshade					X										X					
Sonchus ssp	Sow Thistle															X					
Setaria veridis	Foxtail		X		X	X						X			X						
Sinapis spp	Mustard				X	X															
Solidago canadensis	Canada goldenrod													X	X	X		X		X	X
Sonchus oleraceus	Common Sow-thistle								X						X						
Typha spp	Cattail	X					X	X	X	X	X	X	X	X	X	X					
Urtica dioica	Stinging Nettle			X	X																
Verbena hastata	Blue Vervain			X	X							X		X	X	X					
Verbena urticifolia	White Vervain					X															
Vitus riparia	Riverbank Grape														X					X	
Aquatic Species		**Pond 7**					**Pond 12**					**Pond 14**					**Low Area**				
Ceratophyllum demersum	Coontail															X					
Filamentous algae	Filamentous algae								X												
Lemna minor	Lesser Duckweed	X	X		X				X	X		X	X			X					
Potamogeton spp	Pondweed 1	X	X																		
Potamogeton spp	Pondweed 2																				
Potamogeton pectinatus	Sago Pondweed												X								
Riccia fluitans	Slender Riccia												X								
Spirodela polyrhiza	Big Duckweed									X		X	X								
Wolfia colombiana	Wolfia						X	X				X									

Water quality monitoring results for Gross National Golf Course are shown in **Table 25-4**. Temperature, dissolved oxygen, dissolved oxygen percent, pH, and specific conductivity measurements were made in each pond with a Hydrolab 5 sonde. Chemical parameters such as total phosphorus, ammonia, and nitrate/nitrite were analyzed by IRI, Inc.

Table 25-4. Water quality monitoring results for Gross National Golf Course.

Gross	Date	Time	Temp	DO%	DO	pH	SpCond	TP	NH3	NO3/NO2
			øC	Sat	mg/l	Units	µS/cm	mg/L	mg/L	mg/L
Pond 7	9/3/2010	9:10	17.0	85.0	7.99	8.3	416	0.727	<0.500	<0.030
Pond 7	6/29/2011	9:15	20.8	104.4	9.16	8.5	352	0.583	<0.500	0.036
Pond 7	7/17/2012	9:25	26.6	69.8	5.42	7.5	441	1.08	0.982	<0.030
Pond 7	8/15/2013	8:50	18.9	5.1	0.47	6.8	412	1.60	1.02	<0.030
Pond 7	7/30/2014	9:00	21.0	1.8	0.15	7.3	360	0.81	<0.500	0.485
Pond 12	9/3/2010	9:29	18.9	64.9	5.87	8.3	296	0.051	<0.500	<0.030
Pond 12	6/29/2011	9:40	21.1	66.6	5.81	7.2	367	0.071	<0.500	0.033
Pond 12	7/17/2012	9:45	26.1	77.3	6.06	7.8	427	0.138	0.081	<0.030
Pond 12	8/15/2013	9:15	19.1	12.7	1.15	6.7	346	0.320	1.01	<0.030
Pond 12	7/30/2014	9:40	20.5	21.1	1.86	7.4	289	0.119	<0.500	<0.030
Pond 14	9/3/2010	9:20	18.9	60.4	5.46	8.3	344	0.053	<0.500	<0.030
Pond 14	6/29/2011	9:30	21.3	91.7	7.97	7.7	454	0.083	<0.500	<0.030
Pond 14	7/17/2012	9:35	25.8	53.5	4.21	7.6	443	0.198	0.107	<0.030
Pond 14	8/15/2013	9:10	18.1	95.9	8.90	7.6	385	0.075	0.637	<0.030
Pond 14	7/30/2014	9:30	20.1	85.9	7.62	7.9	391	0.244	<0.500	<0.030

Ponds 7 and 12 show decreasing dissolved oxygen levels which should be addressed. The dissolved oxygen level in Pond 14 continues to fluctuate from year to year. A fountain operating in Pond 14 may have caused high dissolved oxygen levels. Ponds 7 and 12 showed an increasing trend of TP. Pond 7 showed a marked increase in measured NO_3/NO_2 which is likely caused by decaying organic material releasing nitrogen.

HIAWATHA GOLF COURSE

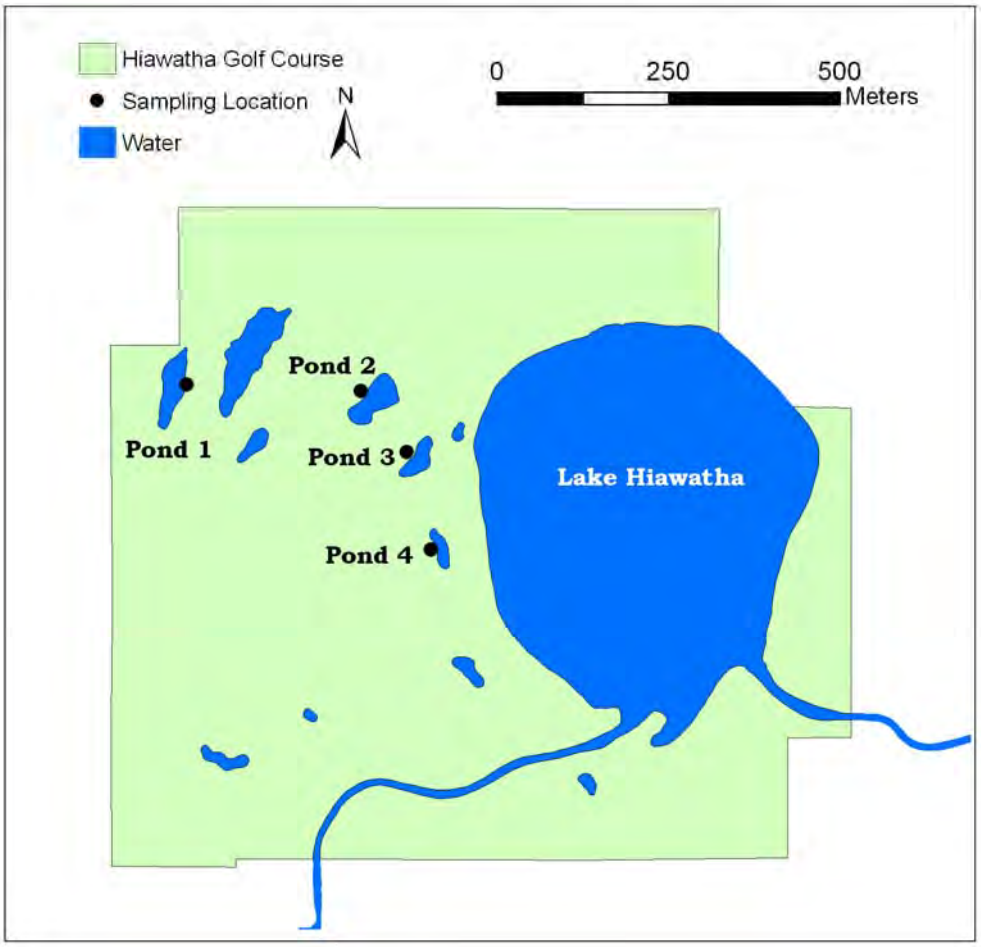


Figure 25-3. Sample sites on the Hiawatha Golf Course.

Four sample sites were chosen at the Hiawatha Golf Course. Ponds 1, 2, and 3 are part of an interconnected chain of ponds pumped to Lake Hiawatha. Several sources contribute water to the pond chain. Groundwater and drain tile are the two local sources of water to these ponds. During storm events water from neighborhood streets overflow to the Hiawatha pond chain. To alleviate flooding, the area covering the course's parking lot is drained to Pond 1. Over the next several years, an additional upstream neighborhood may be piped to Pond 1 as well. The golf has the ability to pump water from Lake Hiawatha to Pond 4, using a MDNR permit for water appropriation, but this ability has rarely if ever been used.

2014 was the fifth year of sampling at Hiawatha Golf Course. 2014 also saw significant spring flooding on the Hiawatha Golf Course. The 2014 flooding affected the results. Aquatic, terrestrial, and wetland plants in the ponds and surrounding buffers were surveyed in late July. Dominant plants from the Hiawatha Golf Course ponds and buffer zones are presented in **Table 25-5.** Data presented are from the last four years of sampling only. Hiawatha was not monitored in 2012. Older data can be found in previous reports.

Table 25-5. Dominant plants within and surrounding the Hiawatha Golf Course sample sites.

Hiawatha Golf Course		Pond 1				Pond 2				Pond 3				Pond 4			
Scientific Name	**Common Name**	Sep-10	Jul-11	Aug-13	Jul-14	Sep-10	Jul-11	Aug-13	Jul-14	Sep-10	Jul-11	Aug-13	Jul-14	Sep-10	Jul-11	Aug-13	Jul-14
Terrestrial and Wetland Species																	
Acer spp	Maple (saplings)		X		X	X	X	X	X						X	X	
Alnus incana	Speckled Alder													X	X		
Ambrosia artemisiifolia	Ragweed	X		X					X	X		X	X			X	
Ambrosia trifida	Giant Ragweed								X				X				
Asclepias spp	Milkweed	X	X											X	X	X	
Asclepias incarnata	Marsh Milkweed		X														
Asclepias syriaca	Common Milkweed																X
Aster spp	Aster			X				X									
Bromus spp	Smooth Brome	X															
Carex comosa	Bottlebrush Sedge		X														
Carex spp	Sedge	X	X	X	X	X								X	X		
Cirsium spp	Thistle					X	X	X		X	X	X		X			
Cirsium spp 2	Thistle 2																
Cornus stolonifera	Red Osier Dogwood																
Eloecharis obtusa	Blunt Spikerush	X	X		X												
Eupatorium perfoliatum	Common Boneset		X														
Fraxinus pennsylvanica	Green Ash												X				
Gleditsia triacanthos	Honey Locust								X								
Impatiens pallida	Pale Jewel Weed									X				X	X	X	
Larix laricina	Tamarack									X	X	X	X	X			
Lythrum salicaria	Purple Loosestrife															X	
Menispermum canadence	Moonseed																X
Phalaris arundinacea	Reed Canary Grass					X	X	X	X	X	X	X	X	X	X	X	X
Poa pratensis	Kentucky Bluegrass	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Polyganum perfoliatum	Tearthumb			X	X				X			X	X	X			
Rubus spp	Raspberry (?)														X		
Rumex crispus	Curled Dock							X		X	X	X	X	X	X	X	
Sagiteria latifolia	Broad-leaf Arrowhead	X	X	X	X												
Salix spp	Sandbar Willow (?)			X	X					X				X		X	X
Scirpus atrovirens	Green Bulrush		X												X		
Scirpus fluviatiis	River Bulrush	X		X	X												X
Scirpus validus	Softstem Bulrush	X	X			X	X			X							
Solidago spp	Goldenrod	X	X	X	X	X	X										
Sonchus oleraceous	Common Sow Thistle							X	X			X	X				
Sparganium eucarpum	Giant Burr Reed					X								X			
Typha spp	Cattail	X	X	X	X	X	X	X	X					X	X	X	
Unknown	Annual Weeds	X				X					X	X	X	X			
Urtica diotica	Stinging Nettle					X					X			X	X	X	
Aquatic Species		Pond 1				Pond 2				Pond 3				Pond 4			
Ceratophyllum demersum	Coontail		X	X							X	X		X			
Chara spp	Muskgrass	X	X			X											
Elodea canadensis	Canadian Waterweed	X	X	X		X					X			X			
Lemna minor	Lesser Duckweed										X			X	X	X	
Najas flexalis	Bushy Pondweed		X														
Nymphaea odorata	White Water Lily											X		X			
Potamogeton foliosus	Narrow Leaf Pondweed	X	X	X	X			X			X	X					
Potamogeton natans	Floating Leaf Pondweed	X	X														
Potamogeton pectinatus	Sago Pondweed										X				X		
Potamogeton zosterformis	Flatstem Pondweed													X			

Water quality monitoring results for Hiawatha Golf Course are shown in **Table 25-6**. Temperature, dissolved oxygen, dissolved oxygen percent, pH, and specific conductivity measurements were made in each pond with a Hydrolab 5 Sonde. Chemical parameters, total phosphorus, ammonia, and nitrate/nitrite were analyzed by IRI, Inc.

Table 25-6. Water quality monitoring results for Hiawatha Golf Course. NS = no sample.

Hiawatha	Date	Time	Temp	DO%	DO	pH	SpCond	TP	NH3	NO3/NO2
			øC	Sat	mg/l	Units	µS/cm	mg/L	mg/L	mg/L
Pond 1	8/31/2010	13:48	29.5	154.1	11.42	8.0	580	0.033	<0.500	<0.030
Pond 1	7/1/2011	9:06	27.1	118.0	9.09	7.4	636	0.036	<0.500	0.034
Pond 1	2012	NS	NS	NS	NS	NS	NS	NS	NS	NS
Pond 1	8/16/2013	9:30	21.4	129.2	11.21	7.9	598	0.046	<0.500	<0.030
Pond 1	7/31/2014	9:50	23.1	93.6	7.82	7.8	668	0.179	<0.500	0.081
Pond 2	8/31/2010	13:58	24.0	150.9	12.33	7.4	900	0.028	<0.500	0.097
Pond 2	7/1/2011	9:20	22.6	74.3	6.21	7.1	975	0.032	0.743	2.02
Pond 2	2012	NS	NS	NS	NS	NS	NS	NS	NS	NS
Pond 2	8/16/2013	9:20	16.9	65.1	6.18	7.2	986	0.039	0.660	0.622
Pond 2	7/31/2014	10:10	18.6	149.5	13.63	7.5	1004	0.150	<0.500	2.31
Pond 3	8/31/2010	14:08	28.1	166.7	12.64	7.4	853	0.090	0.897	0.065
Pond 3	7/1/2011	9:30	26.4	139.8	10.90	7.5	862	0.045	1.33	0.616
Pond 3	2012	NS	NS	NS	NS	NS	NS	NS	NS	NS
Pond 3	8/16/2013	9:10	18.9	70.9	6.45	7.4	936	0.073	0.590	0.54
Pond 3	7/31/2014	10:20	21.0	94.2	8.17	7.5	952	0.193	0.760	0.390
Pond 4	8/31/2010	14:17	28.5	128.2	9.65	7.2	842	0.265	1.62	<0.030
Pond 4	7/1/2011	9:35	24.5	24.6	1.99	6.8	987	0.055	3.44	0.532
Pond 4	2012	NS	NS	NS	NS	NS	NS	NS	NS	NS
Pond 4	8/16/2013	8:55	18.3	20.9	1.93	7.1	937	0.118	1.27	0.771
Pond 4	7/31/2014	10:30	18.1	21.1	1.94	7.1	996	0.240	2.81	2.66

In 2014, all of the ponds show a marked increase in TP concentrations. This may be due to the extremely wet 2014 spring flushing organic material through the ponds. When compared to previous years, all of the ponds showed a general decrease in temperature. This may also be an artifact of the cool wet spring. Pond 2 was super-saturated with oxygen, likely due to large amounts of algae in the pond.

Although the chain of ponds is interconnected, each pond retains its own character. Their differences can be seen both visually and chemically. Pond 4 exhibited distinctly higher phosphorus and ammonia levels than other ponds.

MEADOWBROOK GOLF COURSE

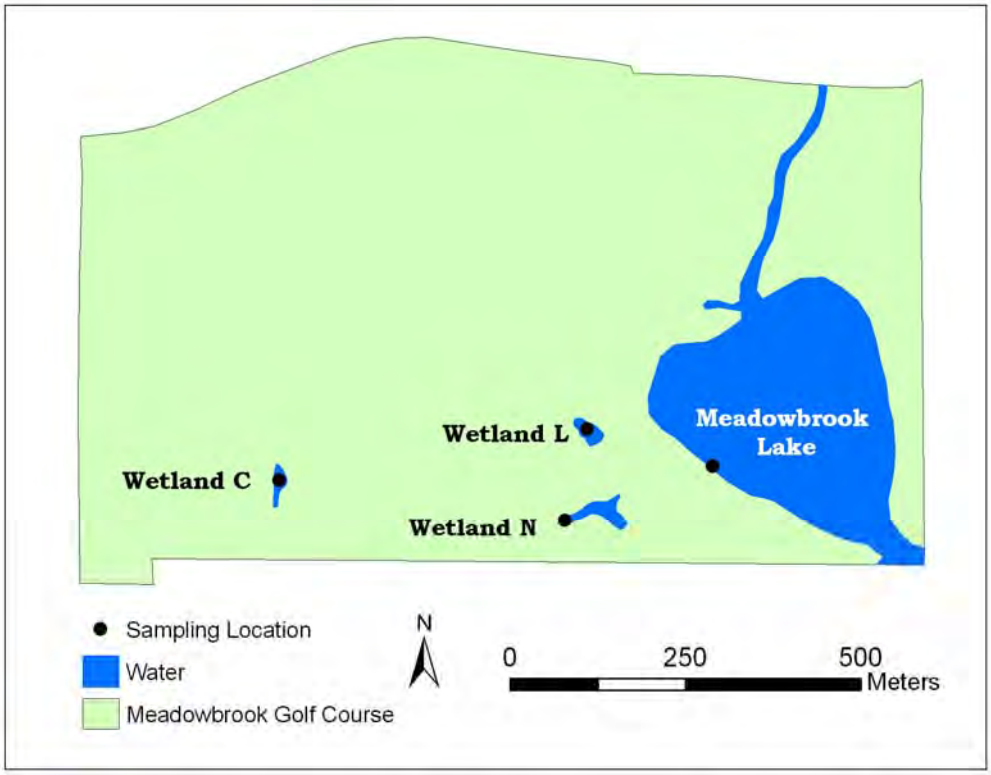


Figure 25-4. Meadowbrook Golf Course water quality and vegetation monitoring locations.

Four water bodies are monitored at Meadowbrook Golf Course: Meadowbrook Lake, Wetland C, Wetland L, and Wetland N (**Figure 25-4)**. The wetland's alphabetic labels are derived from nomenclature used by Meadowbrook Golf Course.

Each of the sampled waterbodies on the Meadowbrook Golf Course has unique hydrologic characteristics. Wetland C is the furthest upstream sample site and only receives runoff from the surrounding course. Wetland N is near the course edge and receives stormwater from the neighborhood in order to reduce the risk of flooding in homes. Wetland L is a deep pond and receives water that is pumped from all the other wetlands prior to discharge into Meadowbrook Lake. Minnehaha Creek flows through Meadowbrook Lake.

2014 was the fifteenth year of water monitoring on the Meadowbrook Golf Course. Aquatic, terrestrial, and wetland plants within the ponds and in surrounding buffers were surveyed in late July. Meadowbrook Lake was not monitored in 2014 due to inaccessibility due to flooding. The 2014 flooding damage at Meadowbrook Golf course was significant and severe and likely affected the Audubon survey results.

Dominant buffer zone plants found in the Meadowbrook ponds for the years 2010 through 2014 are presented in **Table 25-7A** and dominant aquatic plants are presented in **25-7B.** Data presented are from the last five years of sampling only. Older data can be found in previous reports.

Table 25-7A. Dominant buffer zone plants surrounding the Meadowbrook Golf Course sample sites. (Meadowbrook Lake was not monitored in 2014 due to flooding.) NS=not sampled.

Meadowbrook Golf Course		Wetland C					Wetland N					Wetland L					Medowbrook Lake				
Scientific Name	**Common Name**	Sep-10	Jun-11	Jul-12	Aug-13	Jul-14	Sep-10	Jun-11	Jul-12	Aug-13	Jul-14	Sep-10	Jun-11	Jul-12	Aug-13	Jul-14	Sep-10	Jun-11	Jul-12	Aug-13	NS
Wetland and Upland Species																					
Acer ginnala	Amur maple				X	X															
Ajuga spp	Bugleweed				X																
Ambrosia trifida	Giant Ragweed	X																			
Andropogon gerardii	Big Bluestem	X		X					X									X			
Arctium minus	Burdock				X					X											
Asclepias incarnata	Marsh Milkweed	X			X					X											
Asclepias syriaca	Common Milkweed	X		X	X					X							X				
Aster lanceolatus	Marsh Aster		X						X				X								
Asteraceae sonchus	Sow Thistle														X						
Bromus spp	Brome Grass			X													X				
Carex spp	Sedge spp			X				X	X	X									X		
Carex meadii	Mead's Sedge				X																
Cirsium avense	Canadian Thistle	X	X	X	X				X			X		X	X						
Echinochloa crusgalli	Barnyardgrass	X	X				X	X													
Echinocystis lobata	Wild Cucumber														X				X		
Eleocharis acicularis	Needle spike-rush			X																	
Eupatorium perfoliatum	Boneset							X													
Eupatorium purpureum	Joe Pye weed								X												
Fraxinus pennsylvanica	Green Ash				X	X											X	X		X	
Harkelia virginiana	Beggars lice																				
Helenium autumnale	Common Sneezeweed	X		X	X																
Helianthus grosseserratus	Sawtooth Sunflower			X																	
Impatiens capensis	Orange Jewelweed											X	X	X	X			X			
Iris versicolor L.	Blue Flag Iris																X				
Leersia oryzoides	Rice cutgrass								X												
Leonurus cariaca	Motherwort														X				X		
Lycopus americanus	American Bugleweed			X	X				X												
Lycopus spp.	Bugleweed									X											
Lythrum salicaria	Purple Loosestrife				X	X															
Melilotus albus medikus	Sweet White Clover				X								X								
Monarda	Bee Balm				X																
Parthenocissus quinquefolia	Virginia Creeper				X															X	
Phalaris arundinacea	Reed Canary Grass	X	X	X	X	X	X	X	X	X		X	X	X	X		X	X	X	X	
Poa pratensis	Kentucky Bluegrass	X	X	X	X		X	X	X	X		X	X	X	X						
Polygonum amphibium	Water Smartweed	X							X					X							
Polygonum hydropier	Common Smartweed				X		X		X			X									
Polygonum persicaria	Ladies Thumb							X													
Populus deltoides	Eastern Cottonwood	X										X	X	X	X		X		X	X	
Populus ssp	Aspen															X					
Potentilla norvegica	Rough Cinquefoil							X	X								X				
Rhamnus cathartica	Buckthorn																	X	X		
Rubus strigosus	Raspberry				X																
Rudbeckia hirta	Black eyed susan			X	X								X								
Rumex crispus	Curled dock	X	X	X	X	X	X	X									X				
Salix exigua	Sandbar Willow		X	X		X						X		X	X	X	X		X		
Salix nigra	Black Willow				X	X						X	X	X	X	X			X		
Schoenoplectus acutus	Hardstem Bulrush									X											
Scirpus atrovirens	Green Bulrush			X	X				X	X			X								
Scirpus fluviatilis	River Bulrush																	X			
Scirpus validus	Soft stem Bulrush								X												
Scutellaria galericulata	Marsh Skullcap								X	X											
Sedge spp.	Sedge spp				X																
Seteria viridis	Foxtail	X																			
Solanum dulcamara	Bittersweet Nightshade			X	X								X	X	X						
Solidago canadensis	Canada Goldenrod	X		X	X							X									
Sonchus oleraceus	Common Sow-thistle			X	X									X							
Sparganium eurycarpum	Common Bur-reed	X	X	X	X		X	X	X	X											
Spartina pectinata	Prairie cordgrass			X	X								X								
Typha angustifolia	Narrow leaved cattail	X					X			X							X	X		X	
Typha latifolia	Broad-leaved cattail	X		X	X	X	X		X	X							X	X		X	
Typha X glauca	Hybrid Cattail	X	X	X	X	X	X			X	X						X	X		X	
Ulmus pumilla	Siberian Elm																X	X	X	X	
Ulmus americana	American Elm					X															
Urtica dioica	Stinging Nettle	X		X	X				X	X		X	X		X		X				
Verbena hastata	Blue vervain			X																	
Vicia cracca	Cow Vetch	X		X	X							X	X	X	X						
Vitus riparia	Riverbank Grape			X	X							X	X	X	X		X	X	X	X	
Zizea aurea	Golden Alexanders									X											

Table 25-7B. Dominant aquatic plants within the Meadowbrook Golf Course sample sites. (Meadowbrook Lake was not monitored in 2014 due to flooding.) NS=not sampled.

Meadowbrook Golf Course		Wetland C					Wetland N					Wetland L					Medowbrook Lake				
Scientific Name	**Common Name**	Sep-10	Jun-11	Jul-12	Aug-13	Jul-14	Sep-10	Jun-11	Jul-12	Aug-13	Jul-14	Sep-10	Jun-11	Jul-12	Aug-13	Jul-14	Sep-10	Jun-11	Jul-12	Aug-13	NS
Floating Species																					
Lemna minor	Lesser Duckweed	X	X	X	X	X	X	X		X	X					X	X	X	X	X	
Spirodela polyrhiza	Big duckweed		X	X	X	X		X			X					X		X		X	
Wolffia columbiana	Watermeal	X		X			X			X											
Submerged Species																					
Ceratophyllum demersum	Coontail		X														X	X	X	X	
Elodea canadensis	Common Waterweed			X													X	X			
Myriophyllum spicatum	Eurasian Watermilfoil																X			X	
Potamogeton berchtoldii	Narrow leaved pondweed																		X		
Potamogeton crispus	Curly-leaf pondweed																	X		X	
Potamogeton pectinatus	Sago Pondweed																		X		
Potamogeton zosteriformis	Flat-stem pondweed																		X	X	
Vallisneria americana	Water celery																			X	
Zosterella dubia	Water Stargrass																X				

Water quality monitoring results for Meadowbrook Golf Course are shown in **Table 25-8**. Temperature, dissolved oxygen, dissolved oxygen percent, pH, and specific conductivity measurements were made in each pond with a Hydrolab 5 sonde. Chemical parameters, total phosphorus, ammonia, and nitrate/nitrite were analyzed by IRI, Inc.

Table 25-8. Water quality monitoring results for Meadowbrook Golf Course. (Meadowbrook Lake was not monitored in 2014 due to flooding.) NS=not sampled.

Meadowbrook	Date	Time	Temp	DO%	DO	pH	SpCond	TP	NH3	NO3/NO2
			øC	Sat	mg/l	Units	µS/cm	mg/L	mg/L	mg/L
Meadowbrook Lake	9/1/2010	9:10	24.3	49.7	4.07	7.4	412	0.059	<0.500	0.049
Meadowbrook Lake	6/30/2011	10:50	25.2	112.3	8.98	7.6	414	NS	NS	NS
Meadowbrook Lake	7/19/2012	9:45	26.1	63.7	5.04	7.4	493	0.104	0.313	0.093
Meadowbrook Lake	8/13/2013	9:25	22.9	60.9	5.13	7.6	445	0.030	0.714	<0.030
Meadowbrook Lake	7/29/2014	NS	NS	NS	NS	NS	NS	NS	NS	NS
Wetland C	9/1/2010	9:24	20.1	53.0	4.71	7.3	176	0.288	<0.500	<0.030
Wetland C	6/30/2011	10:30	22.6	14.6	1.23	6.8	286	0.133	<0.500	0.031
Wetland C	7/19/2012	8:55	22.8	3.9	0.33	6.7	347	0.235	1.34	<0.030
Wetland C	8/13/2013	9:00	18.7	2.3	0.21	6.8	218	0.130	0.794	<0.030
Wetland C	7/29/2014	9:45	20.8	4.6	0.41	7.0	544	0.767	1.13	0.078
Wetland L	9/1/2010	9:46	23.8	81.0	6.69	7.6	415	0.206	2.09	<0.030
Wetland L	6/30/2011	11:00	19.5	11.9	1.06	6.8	707	0.341	1.27	0.087
Wetland L	7/19/2012	9:45	19.8	6.8	0.61	7.2	823	0.353	2.59	<0.030
Wetland L	8/13/2013	9:35	16.1	3.5	0.34	7.0	875	0.206	2.29	0.131
Wetland L	7/29/2014	10:25	23.5	14.8	1.23	7.4	516	0.290	<0.500	0.052
Wetland N	9/1/2010	9:33	20.7	60.2	5.28	7.6	254	0.662	0.792	0.034
Wetland N	6/30/2011	10:45	23.0	3.7	0.31	6.8	371	0.185	<0.500	<0.030
Wetland N	7/19/2012	9:15	23.2	4.0	0.33	7.0	335	0.811	1.48	<0.030
Wetland N	8/13/2013	9:15	19.3	5.0	0.45	7.0	373	0.201	0.771	<0.030
Wetland N	7/29/2014	10:15	22.4	18.2	1.55	7.4	417	0.325	<0.500	<0.030

The Meadowbrook Golf Course wetlands typically have low levels of dissolved oxygen. Oxygen levels in 2014 were low at all monitored locations. It is not unusual for wetlands to have anoxic environments due to the abundance of organic material decaying.

In 2014, conductivity levels increased in both Wetlands C and N. This is indicative of more dissolved material in the water. This is likely an artifact from floodwaters from the golf course or neighborhood draining to these wetlands or higher than typical groundwater levels. Levels of NH_3 were lower in both Wetland L and N. This is likely caused by the rapid oxidation and denitrification in the flood waters.

THEODORE WIRTH GOLF COURSE

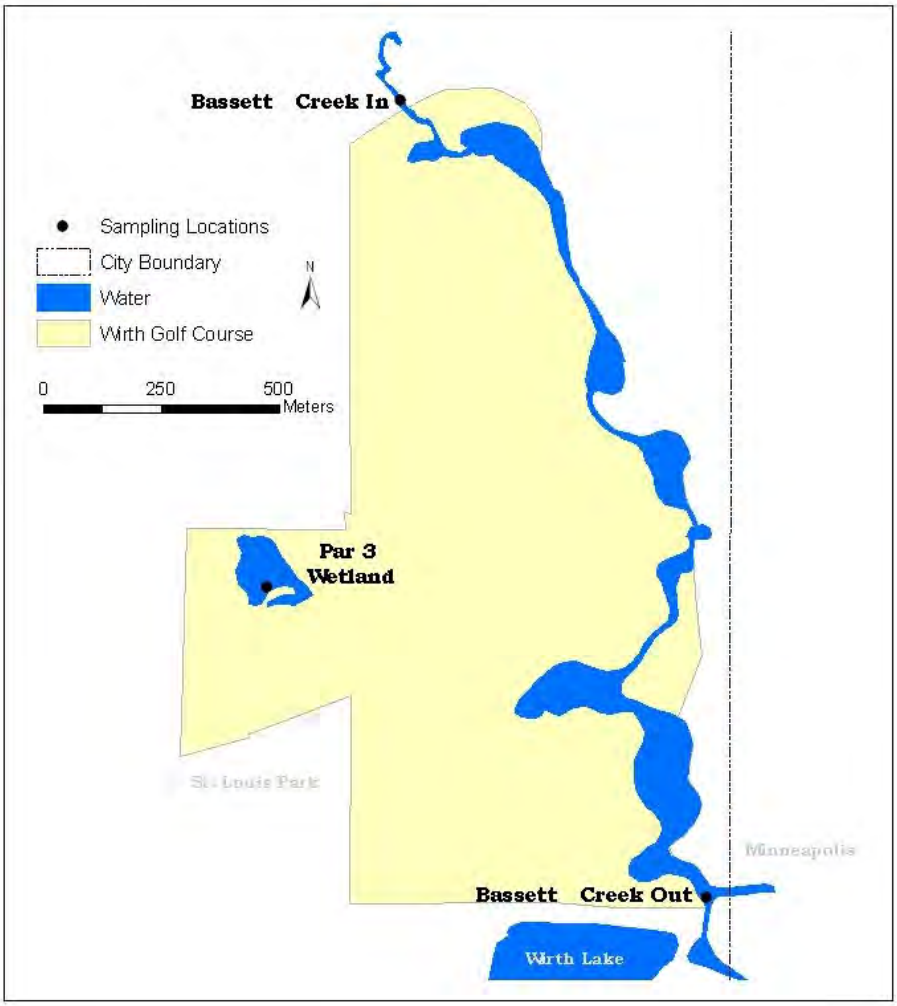


Figure 25-5. Wirth Golf Course water quality and vegetation monitoring locations.

The sampling sites at Wirth Golf Course include an inlet and an outlet of Bassett creek as it enters and leaves the golf course, as well as an unconnected Par 3 wetland. The two sampling sites on Bassett Creek were chosen to assess the effect the golf course has on the creek. The Par 3 wetland was chosen because it was not connected to Bassett Creek. The Par 3 wetland is located between the golf course and a recently developed housing complex. The wetland accepts stormwater from the adjacent development and has had a significant increase in the volume of stormwater it accepts since 2000. **Figure 25-5** shows the location of the monitoring sites on the golf course.

2014 was the seventeenth year of sampling on the Wirth Golf Course. Aquatic, terrestrial, and wetland plants in the ponds and surrounding buffers were surveyed in mid-August.

Dominant plants identified at the Wirth Golf Course ponds and buffer zones are presented in **Table 25-9**. Data presented are from the last five years of sampling only. Older data can be found in previous reports.

Table 25-9. Aquatic vegetation monitoring results for the Wirth Golf Course.

Wirth Golf Course		Bassett IN					Bassett Out					Par 3 Wetland				
Scientific Name	**Common Name**	Sep-10	Jun-11	Jul-12	Aug-13	Jul-14	Sep-10	Jun-11	Jul-12	Aug-13	Jul-14	Sep-10	Jun-11	Jul-12	Aug-13	Jul-14
Wetland and Upland Vegetation																
Acer negundo	Box Elder				X											
Achillea millefolia	Yarrow		X	X	X	X										
Ambrosia artemisiifolia	Ragweed			X	X	X				X	X			X		
Asclepias syriaca L.	Common Milkweed			X	X	X										
Bidens spp	Beggars Tick															X
Bromus spp	Smooth Brome		X		X	X	X		X							
Carex hystericina Muhl.	Porcupine Sedge			X												
Cirsium avense	Canadian Thistle	X	X	X	X	X										
Cyperus bipartitus	Umbrella Sedge						X									
Echinochloa crusgalli	Barnyardgrass	X														
Eleocharis obtusa	Blunt Spikerush						X									X
Elymus repens	Quack Grass	X														
Impatiens pallida	Pale Jewelweed	X			X											
Leonurus cardiaca	Motherwort				X											
Linaria vulgaris	Butter and eggs				X	X										
Lythrum salicaria	Purple Loosestrife				X						X					
Melilotus officinalis	Sweet Clover					X										
Mimulus ringens	Square-stemmed Monkeyflower										X					
Oxalis ssp	Wood Sorrel					X										
Parthenocissus quinquefolia	Virginia Creeper				X	X										
Phalaris arundinacea	Reed canary grass	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Phleum pratense	Timothy Grass					X										
Plantago major	Common Plantain					X										
Poa pratensis	Kentucky Bluegrass	X	X	X	X	X							X		X	X
Polygonum amphibium	Water smartweed						X		X	X	X					
Polygonum persicaria	Lady's thumb				X	X			X	X	X					
Populus deltoides	Eastern cottonwood											X	X	X	X	
Rhamnus cathartica	Buckthorn	X		X	X	X										
Ribes spp	Currant									X						
Rudbeckia ssp	Cone Flower					X										
Salix babalonica	Weeping willow						X	X	X	X	X					
Salix exigua	Sandbar willow	X	X	X	X	X	X	X	X	X	X		X		X	X
Salix nigra	Black willow	X	X	X	X	X										
Scirpus validus	Soft stem bulrush						X									
Seteria gracilis	Foxtail bristlegrass						X					X				
Solidago candidensis	Canada Goldenrod				X	X	X	X		X		X	X			
Solidago spp.	Goldenrod				X	X	X		X							
Sonchus arvensis	Sow Thistle					X			X							
Typha angustifolia	Narrow leaved cattail	X														
Typha latifolia	Broad leaved cattail											X	X	X	X	X
Typha X glauca	Hybrid cattail											X	X	X	X	X
Urtica dioica	Stinging nettle			X	X	X										
Viola ssp	Violet															
Vitus riparia	Riverbank Grape			X	X	X					X					
Aquatic Species		**Bassett IN**					**Bassett OUT**					**Par 3 Wetland**				
Lemna minor	Lesser duckweed	X					X			X	X	X	X	X	X	
Lemna trisulca	Star duckweed												X	X	X	
Nymphaea odorata	White water lily									X	X					
Riccia fluitans	Floating slender liverwort											X	X	X	X	
Spirodela polyrhiza	Big duckweed									X		X			X	
Wolffia columbiana	Watermeal											X		X	X	
Ceratophyllum demersum	Coontail						X	X		X	X					
Elodea canadensis	Common Waterweed	X					X			X						
Potamogeton nodusus	Long leaved pondweed							X		X	X					
Potamogeton pectinatus	Sago pondweed									X	X					
Zosterella dubia	Water stargrass							X	X	X						

Water quality monitoring results for Wirth Golf Course are shown in **Table 25-10**. Dissolved oxygen, dissolved oxygen percent, pH, and specific conductivity measurements were made in each pond with a Hydrolab 5 sonde. Chemical parameters, total phosphorus, ammonia, and nitrate/nitrite were analyzed by IRI, Inc.

Table 25-10. Water quality monitoring results for Wirth Golf Course.

Wirth	Date	Time	Temp	DO%	DO	pH	SpCond	TP	NH3	NO3/NO2
			øC	Sat	mg/l	Units	µS/cm	mg/L	mg/L	mg/L
Bassett In	9/1/2010	11:33	21.4	83.1	7.17	7.4	667	0.130	<0.500	0.291
Bassett In	6/30/2011	9:06	22.8	82.0	6.86	7.2	742	0.097	<0.500	0.214
Bassett In	7/19/2012	11:00	23.7	76.5	6.32	7.7	502	0.188	0.879	0.221
Bassett In	8/13/2013	10:35	19.2	80.2	7.25	7.8	880	0.072	0.760	0.196
Bassett In	7/29/2014	11:45	20.5	94.9	8.37	7.8	821	0.074	<0.500	<0.030
Bassett Out	9/1/2010	11:59	23.4	55.1	4.58	7.4	621	0.138	<0.500	0.122
Bassett Out	6/30/2011	9:30	23.4	60.3	4.99	7.2	770	0.067	<0.500	0.097
Bassett Out	7/19/2012	11:25	24.8	42.0	3.40	7.7	471	0.153	0.274	0.158
Bassett Out	8/13/2013	11:15	22.0	39.3	3.36	7.5	867	0.085	0.840	0.110
Bassett Out	7/29/2014	12:25	21.2	0.0	0.00	7.6	810	0.099	<0.500	0.289
Par 3 Wetland	9/1/2010	12:22	21.2	16.4	1.42	6.9	347	0.263	<0.500	0.122
Par 3 Wetland	6/30/2011	8:55	22.6	11.9	1.00	6.8	396	0.101	<0.500	0.037
Par 3 Wetland	7/19/2012	10:40	23.0	10.3	0.86	7.5	438	0.350	1.01	<0.030
Par 3 Wetland	8/13/2013	11:00	20.6	1.2	0.11	7.0	422	0.422	1.15	<0.030
Par 3 Wetland	7/29/2014	11:15	22.3	11.5	0.98	7.3	334	0.231	<0.500	<0.030

Overall, the results at Wirth Golf Course were typical for urban streams and wetlands. The Bassett IN and Bassett OUT samples had similar conductivity, and amounts of phosphorus and ammonia, similar to past sampling years. The two sites differed slightly in nitrate/nitrite levels, the OUT sample being higher than the IN sample suggesting that the water picks up nutrients as it travels though the golf course. The low dissolved oxygen levels at Bassett OUT are of concern. The Par-3 wetland had lower nitrate/nitrite, ammonia, and phosphorus than previous years. These results may be an artifact of the wet spring.

26. 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 26-1** shows total monthly precipitation and monthly average temperature for the year 2014 as recorded by the National Weather Service (NWS).

2014 was generally wet and cold for the first half of the year, and dry and warm the second half. The annual recorded precipitation total for 2014 was 35.40 inches, 0.40 inches above normal. The annual mean temperature was 43.3° F, 2.88° F below normal.

2014 had a very wet spring from January-June (with the exception of March), and drought from July-December. The wettest month of the year was June, and the driest month of the year was December.

Table 26-1. Minneapolis precipitation, mean temperature and deviation from normal as recorded by the National Weather Service.

Year 2014	Total Precip. (inches)	"Normal" Comparison:	Mean Temp. (F)	"Normal" Comparison:
January	1.42	0.52" above normal	8.0	7.6 F below normal
February	1.41	0.64" above normal	8.6	12.2 F below normal
March	0.82	1.07" below normal	25.5	7.3 F below normal
April	6.27	3.61" above normal	42.7	4.8 F below normal
May	4.55	1.19" above normal	58.6	0.5 F below normal
June	11.36	7.11" above normal	69.5	0.7 F above normal
July	2.27	1.77" below normal	71.5	2.3 F below normal
August	2.90	1.40" below normal	73.3	2.1 F above normal
September	0.92	2.16" below normal	62.7	0.7 F above normal
October	1.75	0.68" below normal	49.2	0.3 F above normal
November	0.87	0.90" below normal	25.4	8.3 F below normal
December	0.86	0.30"below normal	24.3	4.6 F above normal
Annual Data	**35.40**	**0.40" above normal**	**43.3**	**2.88 F below normal**

The 2014 annual 0.40 inch departure from normal represents a near normal year, but individual months were above or below normal by up to 7 inches, with June being one of the wettest Junes on record.

The 2014 NWS monthly data are plotted in **Figure 26-1**. In general the 2014 average monthly temperatures were below normal from January through May, and the months of July and November. Temperatures were above normal in June, and August through October, and then December. The average annual temperature for 2014 was 43.3° F which was 2.88° F below normal.

In 2014 **Figure 26-1** shows a very wet first half of the year, followed by a very dry second half of the year.

All NWS data was obtained from http://www.ncdc.noaa.gov/IPS/lcd/lcd.html?_page=1&state=MN&stationID=14922&_target2=Next+%3E and the National Oceanic and Atmospheric Administration (NOAA) monthly publications.

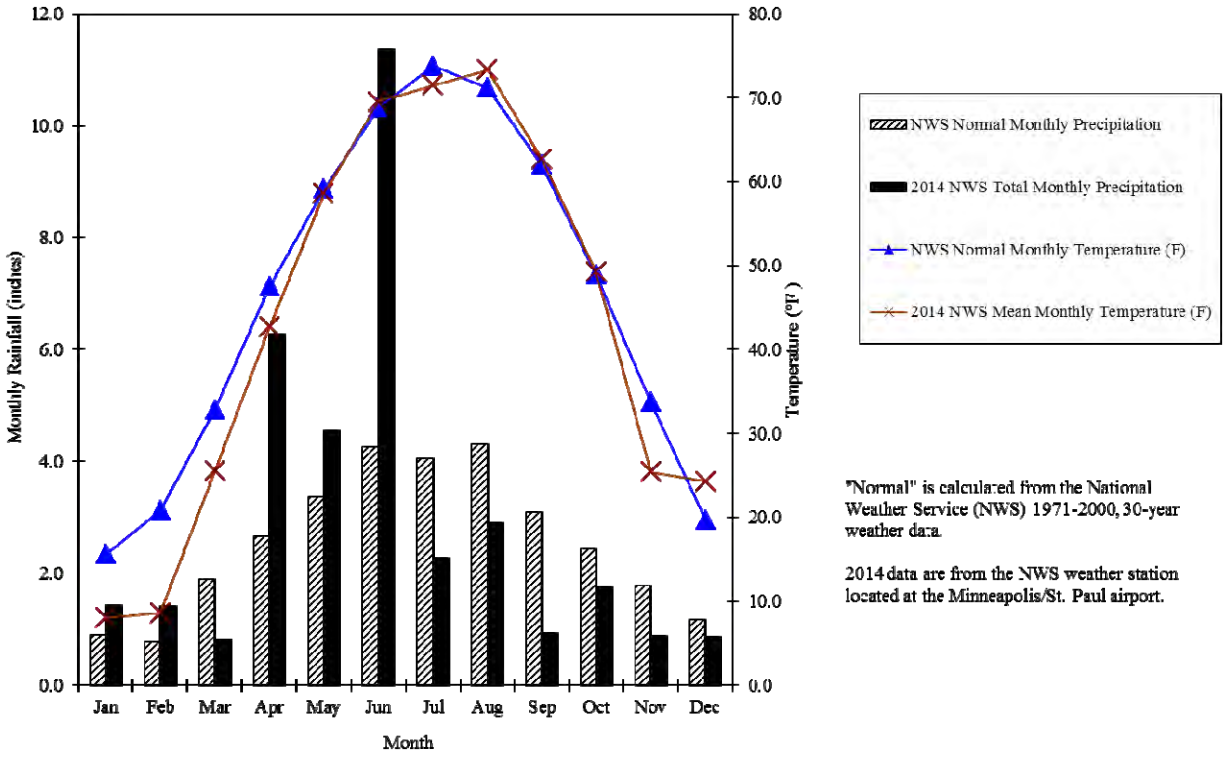


Figure 26-1. Comparison showing the NWS 30-year "normal" with 2014 temperature and precipitation data.

TWIN CITIES RAIN GAUGE COMPARISON

In order to understand the local spatial pattern of precipitation, monthly NWS rainfall data were compared to the MPRB weather station.

The MPRB operates a tipping bucket rain gauge in southwest Minneapolis at its Southside Operations Center at 3800 Bryant Ave. South. The NWS rain gauge is located at the Twin Cities airport. The MPRB rain gauge is not heated and cannot measure snowmelt. Only totals for May through October were calculated with these instruments. The monthly precipitation differences between the MPRB and NWS and the standard deviations can be seen in **Table 26-2**.

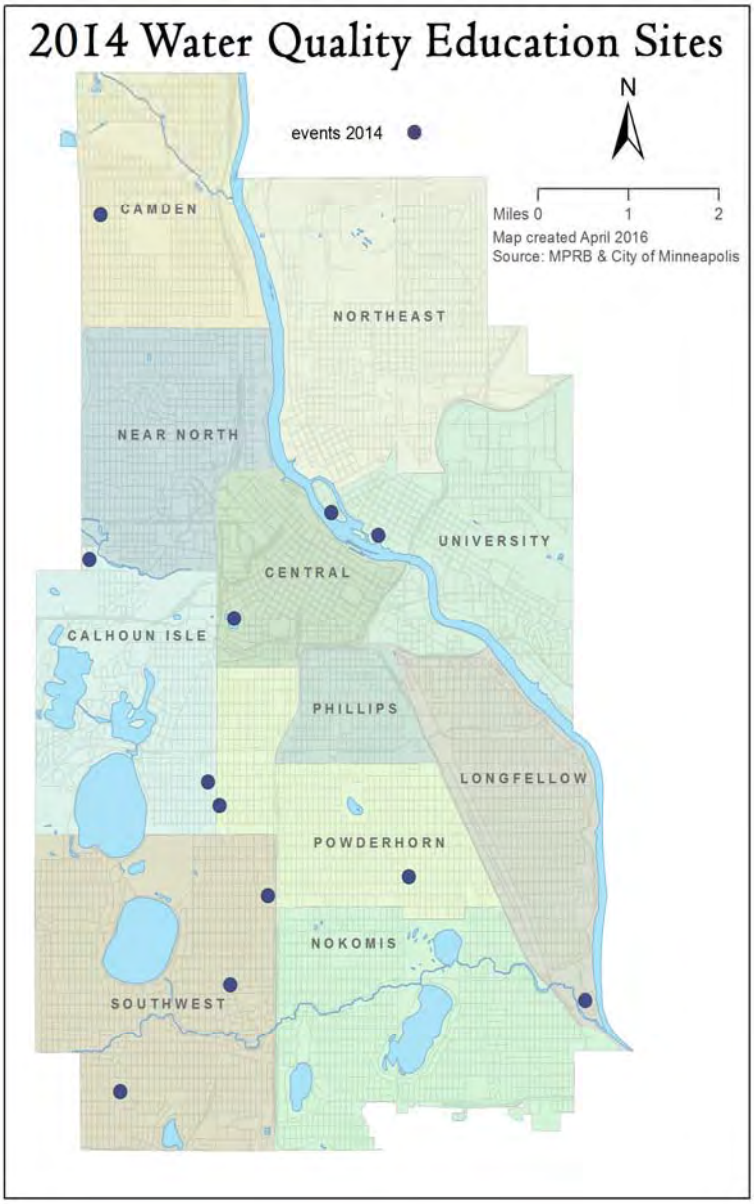
Table 26-2. Monthly totals for the 2014 growing season (May-October) recorded at the NWS, and MPRB rain gages.

Month	NWS (inches)	MPRB (inches)	Difference
May	4.55	4.33	0.22
June	11.36	9.19	2.17
July	2.27	2.24	0.03
August	2.90	2.68	0.22
September	0.92	1.19	0.27
October	1.75	2.40	0.65
Totals	**23.75**	**22.03**	**1.72**

27. WATER QUALITY EDUCATION

ACTIVITIES

In 2014, Minneapolis Park & Recreation Board (MPRB) staff provided water quality education programs throughout the City. Environmental Operations naturalist staff participated in 53 Minneapolis community festivals and neighborhood events (**List 27-1**), including concerts at Bryant Square, Lake Harriet, Theodore Wirth Park, Father Hennepin Bluffs Park, Minnehaha Park, Nicollet Island, and along Victory Memorial Drive. Hands-on water quality educational displays focused on neighborhood watersheds and how human activities impact local water bodies.



List 27-1:
Neighborhood water quality education event sites. Some sites had multiple events.

- Armatage
- Bryant Square
- Father Hennepin Bluffs
- Fuller
- Loring
- Minnehaha Falls
- Martin Luther King
- Nicollet Island Amphitheatre
- Open Streets Minneapolis
- Painter
- Sibley Park
- Victory Memorial Parkway
- Wirth Park

CANINES FOR CLEAN WATER

More than 100,000 dogs reside in the City of Minneapolis. They generate an estimated 41,000 pounds of solid waste each day. A water quality education program targeting dog owners was initiated in 2009 called Canines for Clean Water, and we continue to build on this work.

In 2014 the Canines for Clean Water campaign continued to focus on Public Service Announcements (PSAs) shown at the Riverview Theatre, located near the Mississippi River and Lakes Nokomis and Hiawatha. The PSAs focus on two main actions: getting pet owners to pick up after the dogs and encouraging all property owners to stop or reduce their use of salt or chlorides. The PSAs had a simple message with images of the Mississippi River, Lake Nokomis, and Minnehaha Creek. The summer and fall message was to Protect the River, Protect the Lake, Protect the Creek: Grab a Bag and Scoop the Poop. For winter, the images featured winter scenes of the Mississippi River, Lake Nokomis, and dogs frolicking in the snow. The message here was to Protect the River, Protect the Lakes, Protect the Paws: Shovel, Don't Salt. The word chloride was not used in the PSA because more people understood ice melt as salt. However, detailed information about chlorides, their impacts, best practices for distribution was found on the Minneapolis Park & Recreation Board website www.minneapolisparks.org/dogs. The same was true for information about the impact of dog poop on water quality.

THE MISSISSIPPI RIVER GREEN TEAM

The Mississippi River Green Team (Green Team) is a conservation-based teen crew engaged in daily hands-on environmental work throughout the summer. There are two crews of ten youth each that work mostly in the natural areas of the Minneapolis park system, and also within the watershed of the Mississippi River. Typical work days include invasive species removal, weed wrenching, planting, watering, mulching, and citizen science work. Weekly education days included learning from National Park Service Rangers, Minneapolis Park & Recreation Board Gardeners, Conservation Corps Minnesota, as well as touring the City of Minneapolis Water Works and exploring the University of Minnesota's Monarch Lab. An overview of their summer work and education activities can be seen here: https://www.youtube.com/watch?v=2IPzAJkuhjQ

In 2014 the Green Team continued to serves as citizen scientists for the Minnesota Dragonfly Society (formerly known as the Minnesota Odonata Survey Project). Each week the teens helped catch and identify dragonflies at North Mississippi Regional Park. The crew also surveyed Heritage Park. Dragonflies are an indicator species for assessing habitat and water quality in wetlands, riparian forests, and lakeshore habitats. You can read more about the survey work here: http://www.mndragonfly.org

Other summer work sites included Lake Nokomis, Mill Ruins Park, B.F. Nelson Park, Heritage Park/Sumner Field, Audubon Park, JD Rivers' Children's Garden, and Powderhorn Park. The Green Team also worked at stormwater holding ponds owned by the City of Minneapolis including Heritage Park, Camden Central Pond, Central Avenue Pond at Columbia Golf Course, Columbus Ave S. pond, and the Park Avenue ponds. The teens removed invasive species and volunteer trees, picked up trash, and mulched trees and shrub beds. The crews also planted native species in prairie areas to enhance wildlife habitat and improve diversity of the BMPs.

The Mississippi River Green Team is made possible through a partnership between the Minneapolis Park & Recreation Board and the Mississippi Watershed Management Organization, with additional funding through the City of Minneapolis STEP-UP Youth Employment Program.

RUINATION: CITY OF DUST

Ruination: City of Dust is an interactive, site-specific, multi-player mystery game played on bicycles, using the landscape of Lake Nokomis and Minnehaha Creek as a game board. Contemporary environmental science informs the sci-fi narrative, while elements of art intertwine with physical and mental challenges. Almost 400 people time traveled to the year 2314 to explore the ruins of Minneapolis, a city abandoned and covered in dust. Teams of explorers braved the harsh conditions (in reality, it was gorgeous fall weather) to excavate the ruins, searching for answers about which of six 'Deadly Problems' brought the city to its final ruination.

With the help of costumed guides, explorers learned how water quality is impacted by chemicals, trash, poop, and invasive species, and actions they could take to improve water quality. Explorers

sampled smoked Asian carp, paddled to a plastic bag island, and battled giant dung beetles to keep *E.coli* out of the lake.

The game took take place on October 18 and 19 and was produced by Northern Lights.mn in collaboration with the Minnehaha Creek Watershed District and WriterGuy Ken Eklund, and in partnership with the Minneapolis Park & Recreation Board.

Photographs courtesy of northenlights.mn Additional images of the game can be seen here: https://www.flickr.com/photos/northernlightsmn/sets/72157648495135188/with/15408138129/

EARTH DAY CLEAN UP EVENT

The Earth Day Clean-Up in 2014 took place on April 26th and was a huge success with over 8,000 pounds of trash was collected total (6700 litter, 1100 Recycling and 250 pounds of metal) The clean-up had an outstanding volunteer turnout with over 1700 volunteers contributing to the clean-up efforts.

Cleanup was initiated in 1995 to draw attention to the water quality improvement needs of Minneapolis' lakes and the effects that individual actions have on urban water quality.
The goal of Earth Day Cleanup is to provide a volunteer experience and environmental education to Minneapolis residents and park users. This annual event involves cleaning Minneapolis parks, neighborhoods, watersheds and water bodies including the Chain of Lakes, Lake Nokomis, Lake Hiawatha, Powderhorn Lake, Diamond Lake, Shingle Creek, Minnehaha Creek, Bassett's Creek and the Mississippi River. Since the inception of the Earth Day cleanup we have removed more than 140,000 pounds of garbage from Minneapolis parks.

28. QUALITY ASSURANCE ASSESSMENT REPORT

BACKGROUND

Environmental monitoring and management requires 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 2014 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, **Section 1**. Stormwater monitoring procedures are explained in the Stormwater Monitoring Program Manual (MPRB, 2001).

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 28-1**. The QA/QC plan follows the recommendations of *Standard Methods for the Examination of Water and Wastewater* (2005).

Table 28-1. 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 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 different laboratories for analysis	Determining comparability	2 different lakes, 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. Metals analysis was performed by Legend Technical Services located in St. Paul, 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 more or less 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. In order 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 QA/QC activities:

- Every sampling batch included analysis blanks, standards, and duplicates for each set of samples analyzed.
- Ten percent of all samples were run in duplicate.
- The fall sampling trip had equipment blanks associated with them.
- A bottle field blank was associated with every sampling trip.
- One laboratory reagent blank was analyzed for every ten samples run.
- Filter blanks were analyzed where appropriate.
- A matrix spike was analyzed 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:

- Blanks for water and reagents (one for each) were analyzed for every 10 samples run.
- A standard of known concentration was analyzed for each analytical run.
- One spike (recovery of known additions) was analyzed for every 10 samples run.
- 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:

- 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 28-2**.
- Experienced individuals trained technicians before they were allowed to conduct analyses by themselves and their supervisors routinely reviewed their performance.

Table 28-2. 2014 IRI analytical laboratory and Legend Technical Services reporting limits, the performance evaluation (PE) percent recovery acceptance limits, and relative percent difference (RPD) allowed with duplicates. *NA = Not Applicable.*

Parameter	Abbreviation	RL	PE % Rec Limits	Duplicate RPD Limits
Alkalinity, Total	Alk	2.0 mg/L	80-120	±10%
Ammonia, Un-ionized as N	NH_3	0.500 mg/L	80-120	±10%
Biochemical Oxygen Demand, 5 Day carbonaceous	$_C$BOD	1.0 mg/L	80-120	±10%
Calcium, Total	Ca	1.0 mg/L	NA	±10%
Chloride, Total	Cl	2.0 mg/L	80-120	±10%
Chlorophyll-*a*	Chl-*a*	5 µg/L	NA	±25%
Conductivity	Cond	10µohms	80-120	±25%
Copper, Total	Cu	1.4 µg/L	80-120	±25%
Escherichia coli	*E. coli*	1 mpn/100	80-120	NA
Hardness	Hardness	1.0 mg/L	80-120	±10%
Kjeldahl Nitrogen, Total	TKN	0.500 mg/L	80-120	±10%
Lead, Total	Pb	3 µg/L	80-120	±25%
Nitrite+Nitrate, Total as N	NO_X	0.030 mg/L	80-120	±10%
Nitrogen, Total (persulfate)	TN	0.500 mg/L	80-120	±10%
pH	pH	1.00 Std Units	80-120	±10%
Phosphorus, Soluble Reactive	SRP	0.003 mg/L	80-120	±25%
Phosphorus, Total	TP	0.010 mg/L	70-130	±10%
Phosphorus, Total Dissolved	TDP	0.010 mg/L	80-120	±10%
Silica, Reactive	Si	0.500 mg/L	NA	±10%
Solids, Total Dissolved	TDS	2.0 mg/L	80-120	±10%
Solids, Total Suspended	TSS	1.0 mg/L	80-120	±10%
Solids, Volatile Suspended	VSS	2.0 mg/L	NA	±10%
Sulfate	SO_4	15 mg/L	80-120	±10%
Zinc, Total	Zn	2 µg/L	80-120	±25%

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 of 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 relative percent difference of less than 20% and if reported values were consistent with past results. If the relative percent difference between labs for a given parameter was more than 20% but the majority of data reported were within 20% the data set for that parameter was deemed to be moderately comparable. Coefficient of variation (CV) was used as another measure of how close the laboratories were to each other.

$$\textbf{Coefficient of Variation (CV)} = \frac{\text{standard deviation}}{\text{mean}}$$

Precision: Data sets were deemed precise if two criteria were met (*Standard Methods*, 2005):

1. The relative percent difference of results for each pair of duplicate analyses was within acceptance limits for each given parameter.
2. The percent recovery of known standard additions met the established acceptance limits for each parameter.

$$\textbf{Percent Recovery (\% Rec)} = \frac{\text{Observed Value}}{\text{Expected Value}} \times 100\%$$

Precision was further quantified by calculating the average range and standard deviation of results for duplicates.

$$\textbf{Relative Percent Difference (RPD)} = \frac{|X_1 - X_2|}{(X_1 + X_2)/2} \times 100\%$$

Where: X_1 and X_2 are duplicate pair values; sum for all duplicates

$$\textbf{Average Range (R)} = \frac{\Sigma\,|X_1 - X_2|}{n}$$

Where: X_1 and X_2 are duplicate pair values; sum for all duplicates, and n = number of duplicate pairs

Standard Deviation (estimated)

$$s = \sqrt{\frac{\sum(x - \bar{x})^2}{n - 1}}$$

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 30-2). 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 translates to high accuracy.

The standard solutions used for performance evaluation samples were manufactured by Environmental Resource Associates (ERA) located in Arvada, 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, 1980, 1985). 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 of 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 28-2** 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%) and the error was greater than two times the reporting limit, the entire month's data were flagged by underlining it. There were a total of four data points in May and August that were flagged in 2014. These include the May –BOD5C and Pb and the August –*E. coli* and TP02. Of the two monthly TP standards, TP02 is the higher TP standard made for the month.

Completeness

The data collected in 2014 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 2014 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 meter 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 2014 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 2012 - 2013 monitoring seasons. The 2014 monitoring season was roughly comparable to the 2013 monitoring season. Stormwater data for 2014 appeared to be very comparable to other stormwater data, however, it should be noted that stormwater concentrations are highly variable.

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 RMB Environmental Laboratories, Detroit Lakes, MN as their laboratory and TRPD uses their own in-house laboratory. The 2014 lake split data set were deemed to be generally comparable to data analyzed by TRPD and MCWD as seen in **Table 28-3**. The MPRB shared "round-robin" format split samples with the participating laboratories from one sampling event on August 18th, 2014. The results from all agency split samples are summarized in **Table 28-3** and in **Figures 28-1** through **28-5**.

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 a majority 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. In **Table 28-3** the SRP values reported below reporting limits did not have CV's calculated if more than two laboratories were below reporting limits.

Table 28-3. Summary of 2014 split sample results reported by IRI, MCWD, and TRPD.

Sample ID	Parameter	Units	Depth	Lake	MPRB	MCWD	TRPD	CV
1	Chla	mg/M3	0-2	MED	73	99	140	32%
2	Chla	mg/M3	0-2	WIR	14	19	24	26%
3	Chla	mg/M3	0	LKZ	11	13	18	27%
4	TP	mg/l	0-2	MED	0.132	0.119	0.120	6%
5	TP	mg/l	12	MED	1.09	1.05	1.02	3%
6	TP	mg/l	0-2	WIR	0.027	0.025	0.025	4%
7	TP	mg/l	7	WIR	0.150	0.476	0.600	57%
8	TP	mg/l	0	LKZ	0.037	0.034	0.032	7%
9	TP	mg/l	Syn	MED BAY	0.227	0.243	0.250	5%
10	SRP	mg/l	0-2	MED	0.022	0.034	0.013	46%
11	SRP	mg/l	12	MED	0.763	0.680	0.630	10%
12	SRP	mg/l	0-2	WIR	0.004	0.003	0.006	nc
13	SRP	mg/l	7	WIR	0.080	0.095	0.064	19%
14	SRP	mg/l	0	LKZ	0.004	0.003	0.012	nc
15	SRP	mg/l	Syn	MED BAY	0.148	0.164	0.170	7%
16	TN	mg/l	0-2	MED	1.09	1.60	1.40	19%
17	TN	mg/l	0-2	WIR	0.517	0.624	0.610	10%
18	TN	mg/l	0	LKZ	0.696	0.857	0.880	12%
19	TN	mg/L	Syn	MED BAY	2.96	0.300	3.10	74%
20	Cl	mg/l	0-2	MED	134	139	140	2%
21	Cl	mg/l	12	MED	149	154	150	2%
22	Cl	mg/l	0-2	WIR	154	152	150	1%
23	Cl	mg/l	7	WIR	380	NS	430	9%
24	Cl	mg/l	0	LKZ	21	28	26	13%

Notes: CV = Coefficient of Variation. Underlined data are less than values. nc = not calculated. NS = no sample.

The comparability of the inter-laboratory split sample within each of the parameters differed considerably. **Table 28-4** details the variability within parameters and lists the determined level of comparability for each. The comparability between years was determined by comparing 2014 values to previous year's data. The 2014 data set were somewhat comparable to previous years. The final CV calculated for SRP should not be used if many are below or near detection limit values.

Table 28-4. 2014 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.

	Coefficient of Variation		Comparability	
Parameter	**2014 Range**	**2014 Mean %**	**Between labs**	**Between years**
Chl-*a*	26%-32%	28%	Moderate	Moderate
TP	3%-57%	14%	Moderate	Moderate
SRP	7%-46%	21%	Low	Moderate
TN	10%-74%	29%	Moderate	Moderate
Cl	1%-13%	5%	Moderate	High

The split samples for chlorophyll-*a* were moderately comparable as seen in **Figure 28-1**. All laboratories used a spectrophotometer. In 2014 one chlorophyll-*a* lake data points had suspect samples. The outlier was sample ID number 1. Further investigation will need to take place to understand the reasons why. Since there is no chlorophyll-*a* standard, the MRPB should seriously consider using HPLC to determine the "true" chlorophyll-*a* concentration of each sample. 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 28%.

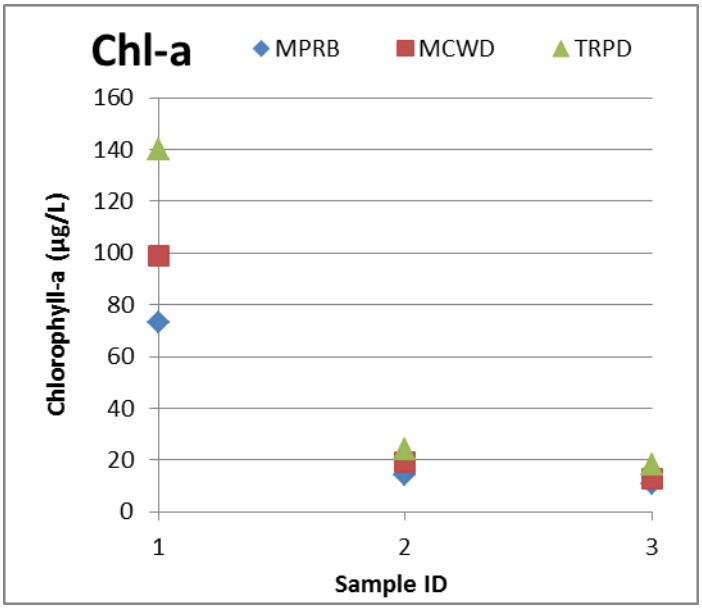


Figure 28-1. Plot of chlorophyll-*a* split sample results reported for 2014. See Table 28-3 to reference ID numbers with sample descriptions and results.

Total phosphorus splits were highly comparable as seen in **Figure 28-2**. Most of the samples were moderate to lower level concentrations but none were at detection limit. The low outlier was sample ID number 7, analyzed by the MPRB. Phosphorus is an important and limiting aquatic nutrient and accuracy for this element is critical. The average CV for TP was 14%.

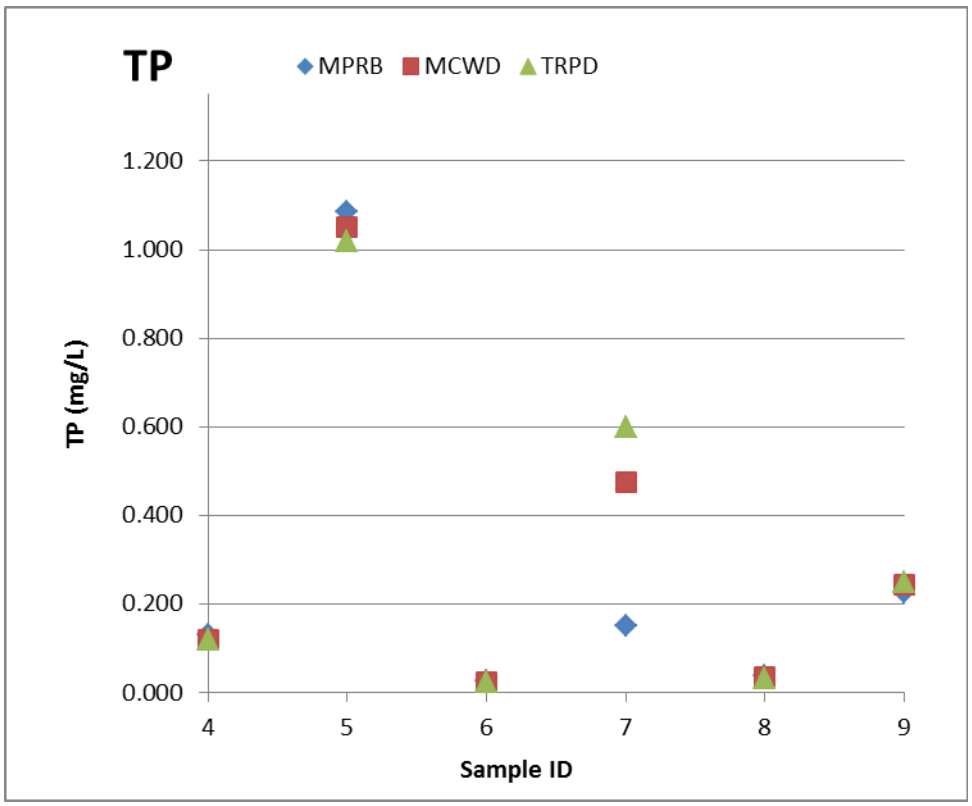


Figure 28-2. Scatter plot of total TP split sample results reported for 2014. See Table 28-3 to reference ID numbers with descriptions and results.

Many concentrations of the submitted SRP split samples were near lab reporting limits and a few analyses were reported at or near detection levels as seen in **Figure 28-3**. There were three outlier samples; ID numbers 10, 13, and 14. The outliers of samples 10 and 13 could not be determined, but they show the same pattern of MCWD high and TRPD low. Sample number 14 shows TRPD as the high outlier. IRI and MCWD (RMB laboratory) had a reporting limit of 0.003 mg/L, while TRPD has a reporting limit of 0.006 mg/L. The 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 21%.

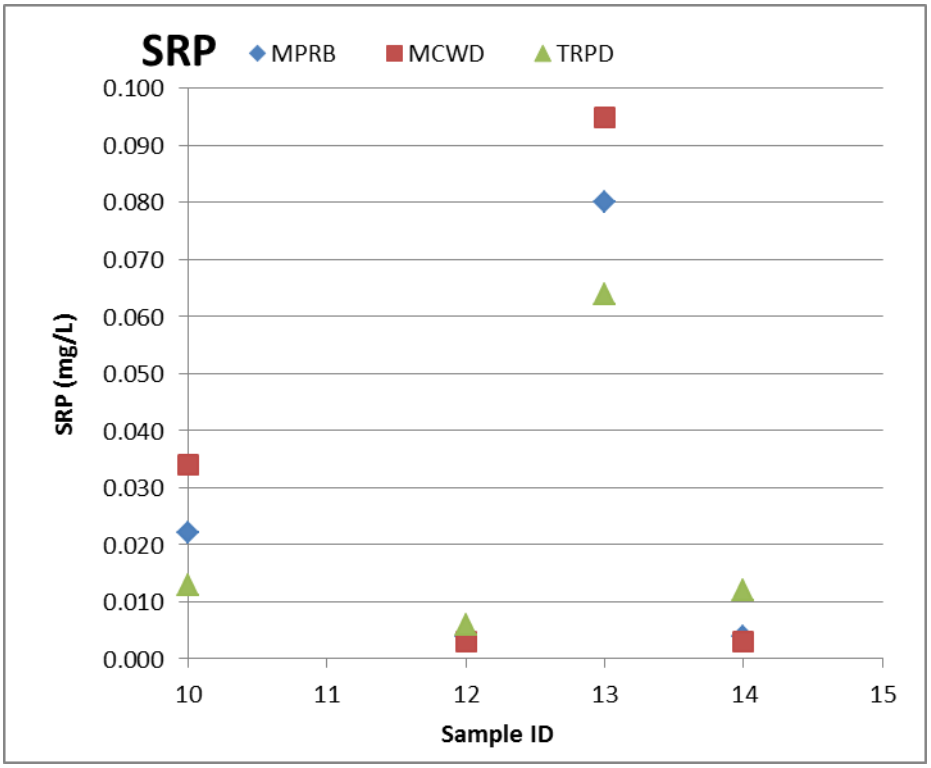


Figure 28-3. Scatter plot of SRP split sample results reported for 2014. See Table 28-3 to reference sample ID numbers with descriptions and results.

Total nitrogen splits were completed by IRI, TRPD and MCWD as seen in **Figure 28-4**. The significant outliers for TN were sample ID numbers 16 and 19. Sample number 16 had an equal spread among the labs and the error could not be determined. TRPD and IRI perform a persulfate digestion and MCWD (RMB laboratory) performs a sum of the nitrogen species TKN and NO_3NO_2. The average CV for TN was 29%.

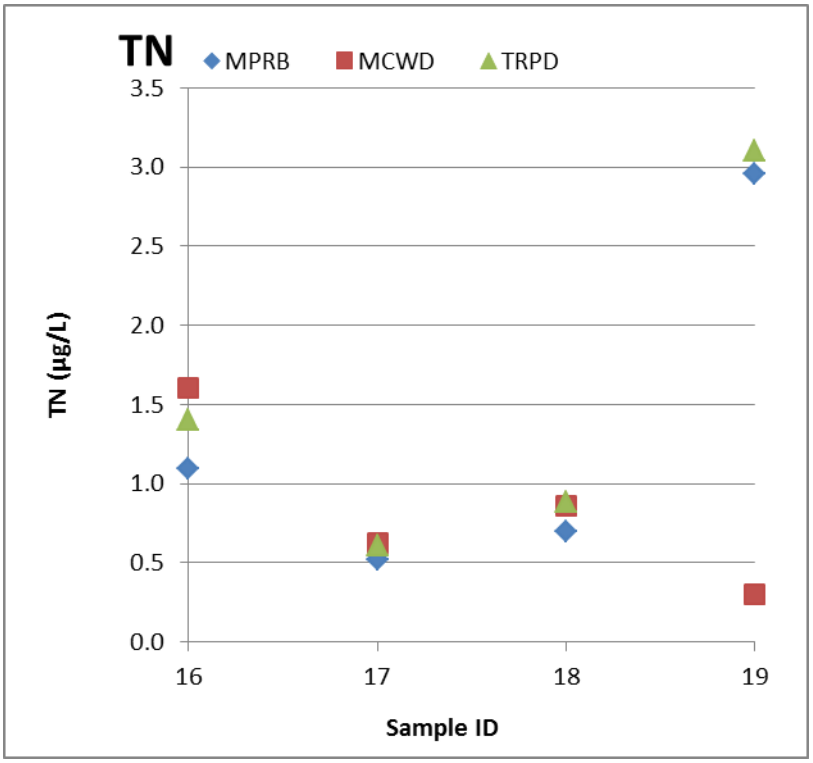


Figure 28-4. Scatter plot of TN split sample results reported for 2014. See Table 28-3 to reference ID numbers with descriptions and results.

Chloride splits were completed by IRI, TRPD and MCWD as seen in **Figure 28-5**. Sample ID number 23 had an outlier. The outlier was analyzed by MCWD. Chloride is an extremely stable test and there was generally little variability between laboratories. The average CV for chloride was 5%.

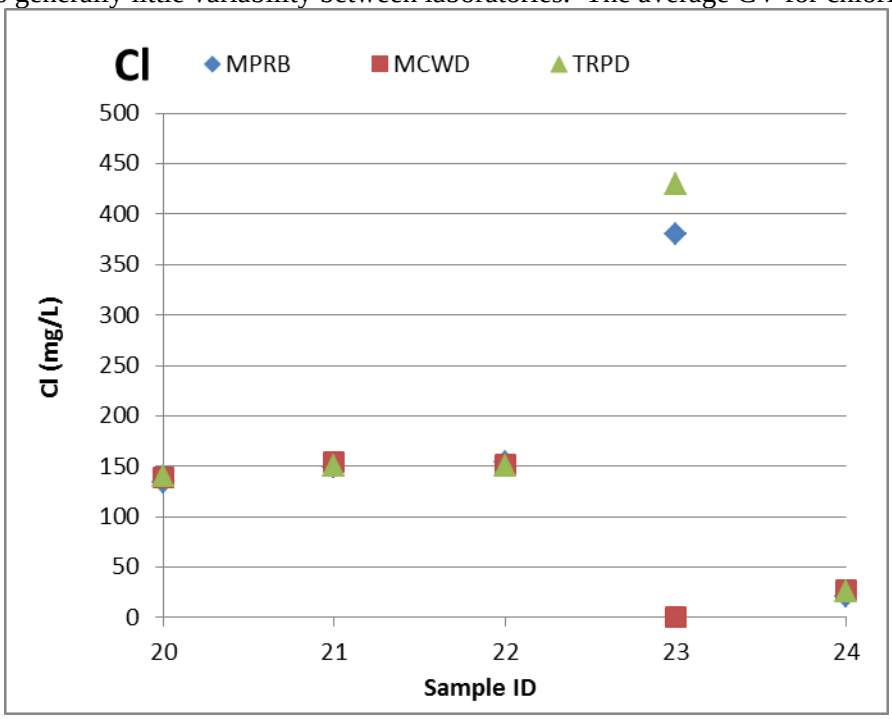


Figure 28-5. Scatter plot of Cl split sample results reported for 2014. See Table 28-3 to reference ID numbers with descriptions and results.

The split data show no laboratory as a consistent and significant outlier in the split samples. With the exception of SRP's, the data sets appear moderately comparable since all parameters had some outliers. Depending on the parameter, 2014 saw both more and less scatter among the splits than in 2013.

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 also lake uniformity. **Table 28-5** summarizes the results from field duplicate samples in 2014. Significant differences between duplicates was defined as having a RPD greater than 20%. The goal is to have the average RPD for parameters to be 10% or less. When values are near the reporting limit the RPD calculations are skewed but most times the data are considered acceptable. There was one sampling trip field duplicate failure of significance.

• Grass (Grab, 7/8/14) had Silica (mg/L) values of 1.31 and 1.04 resulting in a RPD of 23%.

The difference in some samples may also be the result of lake or pond sediment being disturbed by a boat anchor, water sampling device such as the Kemmerer sampler, or particles in the epilimnion. Further investigation should look into the cause(s). Finally, the Cedar 8/5/14 SRP values of 0.003

and 0.004 with a RPD of 29% should not be considered a true duplicate failure but rather a statistical anomaly.

Table 28-5. 2014 summary of field duplicate sample results and acceptability for IRI Laboratory.

Parameter	Units	Average Relative % Difference	Average Range	Std. Dev. (estimated)	Acceptable
Chl-a	µg/L	9.14	1.28	1.13	Yes
Silica	mg/L	5.52	0.144	0.128	Yes
TP	mg/L	5.68	0.007	0.006	Yes
SRP	mg/L	5.08	0.002	0.001	Yes
TKN	mg/L	3.88	0.061	0.054	Yes
TN	mg/L	7.00	0.094	0.083	Yes
NO_2NO_3	mg/L	3.83	0.012	0.011	Yes
Alk	mg/L	0.279	0.250	0.222	Yes
Hard	mg/L	5.00	4.00	3.55	Yes
Cl	mg/L	1.18	2.33	2.07	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 quality staff used prepared standards mixed to "real world" concentrations for submission to the contract laboratory. The "rule of sensibility" was used to evaluate the data and whether to flag it or not. **Table 28-6** and **Figures 28-6** through **28-11** summarize the performance evaluation sample results for each parameter. Of the performance parameters tested only four fell outside the recovery limits. Four data points (parameters) were flagged in 2014, the May BOD5c and Pb as well as the August *E. coli* and TP02. All other performance evaluation samples fell within acceptance limits.

Table 28-6. Summary of performance evaluation samples analyzed by IRI in 2014. Results in red are outside acceptance limits.

Sample ID	Parameter	Date	Calc. Value	IRI Value	% Recovery
1	Alk	2/27/2014	60	55	92%
2	Alk	3/29/2014	60	55	92%
3	Alk	4/22/2014	38	35	93%
4	Alk	5/21/2014	84	80	95%
5	Alk	6/13/2014	84	80	95%
6	Alk	7/9/2014	84	80	95%
7	Alk	8/5/2014	95	92	96%
8	Alk	9/11/2014	96	94	98%
9	Alk	10/8/2014	81	82	101%
10	Alk	11/20/2014	78	77	98%
11	BOD5C	2/27/2014	6	6	98%
12	BOD5C	3/29/2014	6	5	86%
13	BOD5C	4/22/2014	6	6	97%
14	BOD5C	5/21/2014	17	13	77%
15	BOD5C	6/13/2014	17	15	89%
16	BOD5C	7/9/2014	17	16	95%
17	BOD5C	8/5/2014	17	16	97%
18	BOD5C	9/11/2014	17	17	99%
19	BOD5C	10/8/2014	8	9	106%
20	BOD5C	11/20/2014	8	10	118%
21	Cl	2/27/2014	105	100	95%
22	Cl	3/29/2014	105	99	95%
23	Cl	4/22/2014	116	116	100%
24	Cl	5/21/2014	76	79	104%
25	Cl	6/13/2014	76	79	104%
26	Cl	7/9/2014	76	75	99%
27	Cl	8/5/2014	71	68	96%
28	Cl	9/11/2014	75	73	98%
29	Cl	10/8/2014	47	46	99%
30	Cl	11/20/2014	42	46	109%
31	Cond	2/27/2014	554	556	100%
32	Cond	3/29/2014	554	554	100%
33	Cond	4/22/2014	515	533	103%
34	Cond	5/21/2014	506	518	102%
35	Cond	6/13/2014	506	446	88%
36	Cond	7/9/2014	506	482	95%
37	Cond	8/5/2014	474	463	98%
38	Cond	9/11/2014	518	510	98%
39	Cond	10/8/2014	357	357	100%
40	Cond	11/20/2014	380	383	101%
41	Cu	2/27/2014	314	300	95%
42	Cu	3/29/2014	314	290	92%
43	Cu	4/22/2014	314	330	105%
44	Cu	5/21/2014	624	610	98%
45	Cu	6/13/2014	624	600	96%
46	Cu	7/9/2014	624	630	101%
47	Cu	8/5/2014	624	610	98%
48	Cu	9/11/2014	624	610	98%
49	Cu	10/8/2014	330	310	94%
50	Cu	11/20/2014	330	340	103%

Table 28-6. (continued) Summary of performance evaluation samples analyzed by IRI in 2014. Results in red are outside acceptance limits.

Sample ID	Parameter	Date	Calc. Value	IRI Value	% Recovery
51	E coli	2/27/2014	105 (52-213)	111	100%
52	E coli	2/27/2014	<1	<1	100%
53	E coli	8/5/2014	922 (463-1830)	411	44%
54	E coli	8/5/2014	<1	<1	100%
55	E coli	10/8/2014	468 (150-1420)	548	100%
56	E coli	10/8/2014	<1	<1	100%
57	NH3	2/27/2014	1.04	1.04	100%
58	NH3	3/29/2014	1.04	1.03	99%
59	NH3	4/22/2014	1.04	1.14	110%
60	NH3	5/21/2014	2.70	2.65	98%
61	NH3	6/13/2014	2.70	2.88	107%
62	NH3	7/9/2014	2.70	2.70	100%
63	NH3	8/5/2014	2.70	2.46	91%
64	NH3	9/11/2014	2.70	2.83	105%
65	NH3	10/8/2014	0.484	0.387	80%
66	NH3	11/20/2014	0.484	<0.5	100%
67	Nox	2/27/2014	7.24	7.47	103%
68	Nox	3/29/2014	7.24	7.65	106%
69	Nox	4/22/2014	7.24	7.68	106%
70	Nox	5/21/2014	1.40	1.53	109%
71	Nox	6/13/2014	1.40	1.33	95%
72	Nox	7/9/2014	1.40	1.51	108%
73	Nox	8/5/2014	1.40	1.49	106%
74	Nox	9/11/2014	1.40	1.57	112%
75	Nox	10/8/2014	0.970	0.884	91%
76	Nox	11/20/2014	0.970	0.864	89%
77	Ortho-P	2/27/2014	0.026	0.028	108%
78	Ortho-P	3/29/2014	0.026	0.027	103%
79	Ortho-P	4/22/2014	0.026	0.029	111%
80	Ortho-P	5/21/2014	0.014	0.013	94%
81	Ortho-P	6/13/2014	0.014	0.013	93%
82	Ortho-P	7/9/2014	0.139	0.143	103%
83	Ortho-P	8/5/2014	0.014	0.015	108%
84	Ortho-P	9/11/2014	0.139	0.163	117%
85	Ortho-P	10/8/2014	0.042	0.044	104%
86	Ortho-P	11/20/2014	0.042	0.045	104%
87	Pb	2/27/2014	35	35	99%
88	Pb	3/29/2014	35	38	107%
89	Pb	4/22/2014	35	36	102%
90	Pb	5/21/2014	34	26	77%
91	Pb	6/13/2014	34	31	92%
92	Pb	7/9/2014	34	32	95%
93	Pb	8/5/2014	34	28	83%
94	Pb	9/11/2014	34	32	95%
95	Pb	10/8/2014	7	7	96%
96	Pb	11/20/2014	7	6	92%

Table 28-6. (continued) Summary of performance evaluation samples analyzed by IRI in 2014. Results in red are outside acceptance limits.

Sample ID	Parameter	Date	Calc. Value	IRI Value	% Recovery
97	SO4	2/27/2014	33.0	35.2	107%
98	SO4	3/29/2014	33.0	35.8	108%
99	SO4	4/22/2014	22.2	18.1	82%
100	SO4	5/21/2014	35.8	33.5	94%
101	SO4	6/13/2014	35.8	34.5	96%
102	SO4	7/9/2014	35.8	35.2	98%
103	SO4	8/5/2014	26.7	24.4	91%
104	SO4	9/11/2014	39.1	41.3	106%
105	SO4	10/8/2014	23.4	24.1	103%
106	SO4	11/20/2014	37.4	35.1	94%
107	SRP	2/27/2014	0.026	0.028	107%
108	SRP	3/29/2014	0.026	0.028	107%
109	SRP	4/22/2014	0.026	0.028	107%
110	SRP	5/21/2014	0.014	0.013	94%
111	SRP	6/13/2014	0.014	0.013	94%
112	SRP	7/9/2014	0.139	0.141	101%
113	SRP	8/5/2014	0.014	0.015	108%
114	SRP	9/11/2014	0.139	0.163	117%
115	SRP	10/8/2014	0.042	0.044	104%
116	SRP	11/20/2014	0.042	0.044	104%
117	TDP	2/27/2014	0.026	0.028	108%
118	TDP	3/29/2014	0.026	0.029	110%
119	TDP	4/22/2014	0.026	0.026	99%
120	TDP	5/21/2014	0.014	0.011	79%
121	TDP	6/13/2014	0.014	0.012	86%
122	TDP	7/9/2014	0.139	0.139	100%
123	TDP	8/5/2014	0.014	0.017	122%
124	TDP	9/11/2014	0.139	0.149	107%
125	TDP	10/8/2014	0.042	0.045	106%
126	TDP	11/20/2014	0.042	0.045	106%
127	TDS	2/27/2014	353	347	98%
128	TDS	3/29/2014	353	353	100%
129	TDS	4/22/2014	301	303	101%
130	TDS	5/21/2014	367	376	102%
131	TDS	6/13/2014	367	366	100%
132	TDS	7/9/2014	367	337	92%
133	TDS	8/5/2014	364	364	100%
134	TDS	9/11/2014	421	395	94%
135	TDS	10/8/2014	314	295	94%
136	TDS	11/20/2014	322	303	94%
137	TKN	2/27/2014	5.06	4.79	95%
138	TKN	3/29/2014	5.06	5.28	104%
139	TKN	4/22/2014	5.06	5.24	104%
140	TKN	5/21/2014	1.72	1.7	99%
141	TKN	6/13/2014	1.72	1.74	101%
142	TKN	7/9/2014	1.72	1.61	94%
143	TKN	8/5/2014	1.72	1.7	99%
144	TKN	9/11/2014	1.72	1.79	104%
145	TKN	10/8/2014	1.24	1.14	92%
146	TKN	11/20/2014	1.24	1.14	92%

Table 28-6. (continued) Summary of performance evaluation samples analyzed by IRI in 2014. Results in red are outside acceptance limits.

Sample ID	Parameter	Date	Calc. Value	IRI Value	% Recovery
147	TN	2/27/2014	5.06	5.0	98%
148	TN	3/29/2014	5.06	5.05	100%
149	TN	4/22/2014	5.06	4.87	96%
150	TN	5/21/2014	1.72	1.73	101%
151	TN	6/13/2014	1.72	1.77	103%
152	TN	7/9/2014	1.720	1.8	105%
153	TN	8/5/2014	1.720	1.88	109%
154	TN	9/11/2014	1.72	1.8	105%
155	TN	10/8/2014	1.24	1.16	94%
156	TN	11/20/2014	1.24	1.23	99%
157	Total Hardness	2/27/2014	298	272	91%
158	Total Hardness	3/29/2014	387	364	94%
159	Total Hardness	4/22/2014	293	272	93%
160	Total Hardness	5/21/2014	305	284	93%
161	Total Hardness	6/13/2014	305	284	93%
162	Total Hardness	7/9/2014	305	280	92%
163	Total Hardness	8/5/2014	281	260	93%
164	Total Hardness	9/11/2014	185	164	89%
165	Total Hardness	10/8/2014	275	268	97%
166	Total Hardness	11/20/2014	202	208	103%
167	TP01	2/27/2014	0.172	0.171	99%
168	TP01	3/29/2014	0.172	0.166	97%
169	TP01	4/22/2014	0.172	0.177	103%
170	TP01	5/21/2014	0.134	0.130	97%
171	TP01	6/13/2014	0.134	0.130	97%
172	TP01	7/9/2014	0.134	0.127	95%
173	TP01	8/5/2014	0.134	0.130	97%
174	TP01	9/11/2014	0.134	0.131	98%
175	TP01	10/8/2014	0.316	0.325	103%
176	TP01	11/20/2014	0.316	0.303	96%
177	TP02	2/27/2014	0.688	0.733	107%
178	TP02	3/29/2014	0.688	0.690	100%
179	TP02	4/22/2014	0.688	0.718	104%
180	TP02	5/21/2014	0.534	0.544	102%
181	TP02	6/13/2014	0.534	0.551	103%
182	TP02	7/9/2014	0.534	0.532	100%
183	TP02	8/5/2014	0.534	2.59	**484%**
184	TP02	9/11/2014	0.534	0.543	102%
185	TP02	10/8/2014	1.26	1.33	105%
186	TP02	11/20/2014	1.26	1.27	100%
187	TSS	2/27/2014	43	35	81%
188	TSS	3/29/2014	47	42	90%
189	TSS	4/22/2014	87	78	90%
190	TSS	5/21/2014	36	40	111%
191	TSS	6/13/2014	36	31	86%
192	TSS	7/9/2014	36	32	89%
193	TSS	8/5/2014	51	42	82%
194	TSS	9/11/2014	41	37	92%
195	TSS	10/8/2014	56	50	89%
196	TSS	11/20/2014	72	67	93%

Table 28-6. (continued) Summary of performance evaluation samples analyzed by IRI in 2014. Results in red are outside acceptance limits.

Sample ID	Parameter	Date	Calc. Value	IRI Value	% Recovery
197	Zn	2/27/2014	676	690	102%
198	Zn	3/29/2014	676	710	105%
199	Zn	4/22/2014	676	710	105%
200	Zn	5/21/2014	660	760	115%
201	Zn	6/13/2014	660	680	103%
202	Zn	7/9/2014	660	680	103%
203	Zn	8/5/2014	660	680	103%
204	Zn	9/11/2014	660	680	103%
205	Zn	10/8/2014	292	290	99%
206	Zn	11/20/2014	292	320	110%

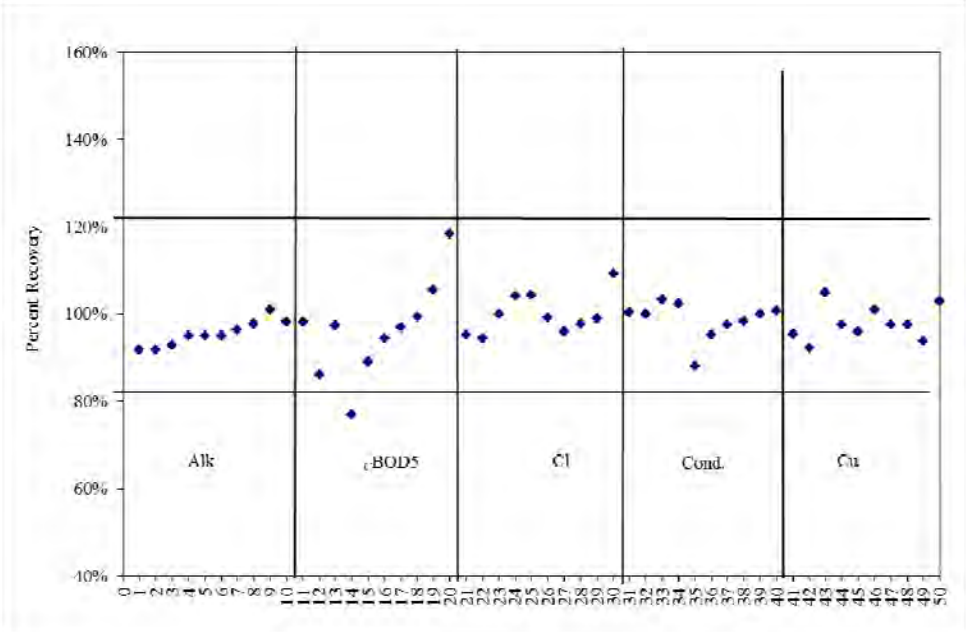


Figure 28-6. Scatter plot of reported percent recoveries for performance evaluation samples in 2014. See Table 28-6 to reference ID numbers with descriptions and results.

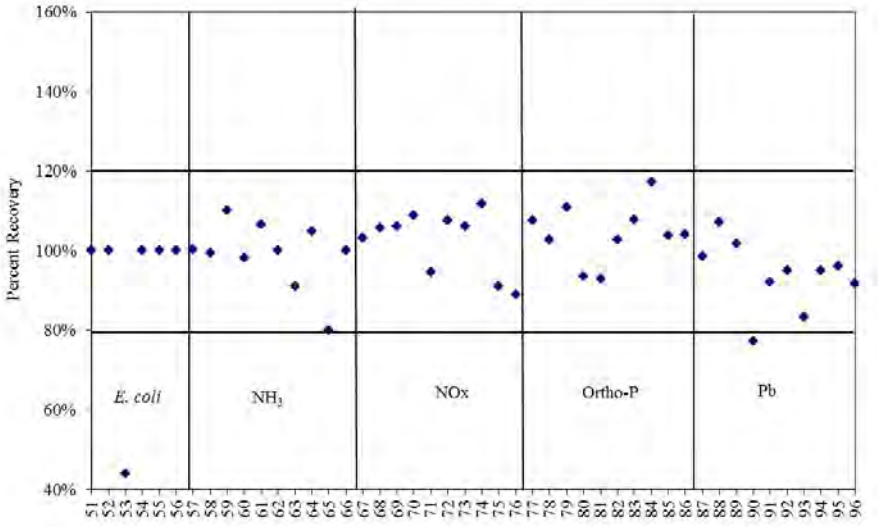


Figure 28-7. Scatter plot of reported percent recoveries for performance evaluation samples in 2014. See Table 28-6 to reference ID numbers with descriptions and results.

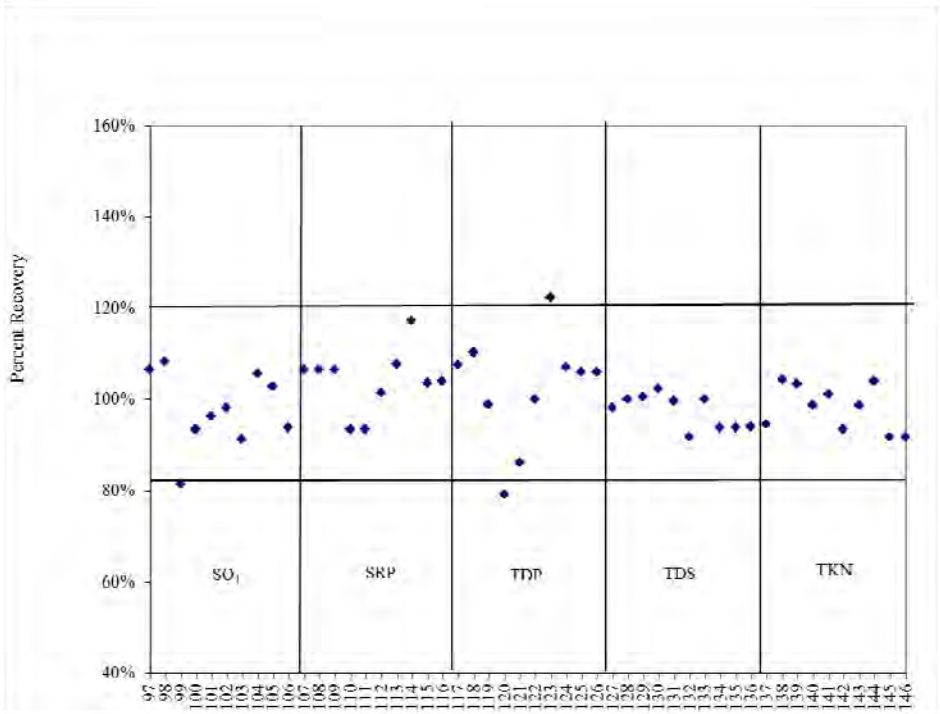


Figure 28-8. Scatter plot of reported percent recoveries for performance evaluation samples in 2014. See Table 28-6 to reference ID numbers with descriptions and results.

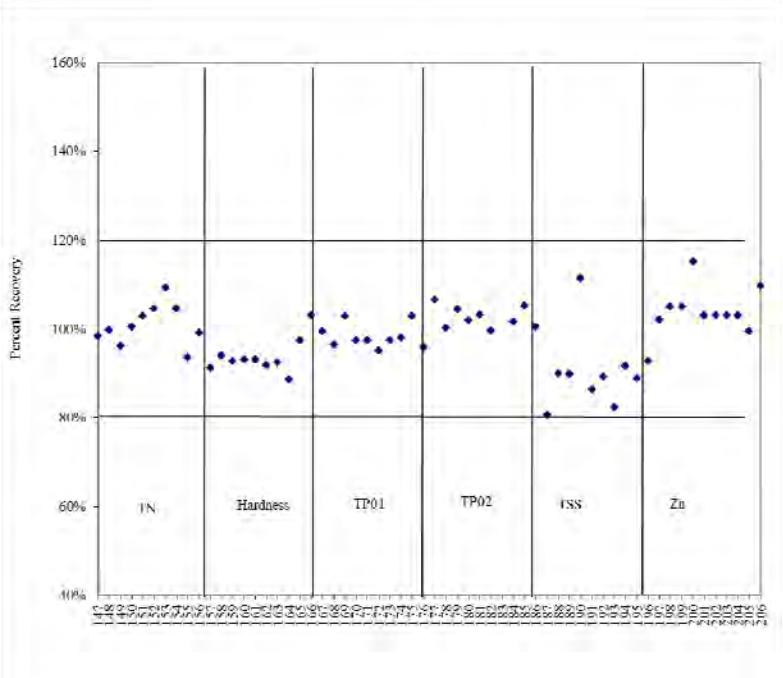


Figure 28-9. Scatter plot of reported percent recoveries for performance evaluation samples in 2014. See Table 28-6 to reference ID numbers with descriptions and results.

Most of the performance evaluation standards were acceptable for all months. Alkalinity, chloride, hardness, pH, 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.

Except for the month of August the *E. coli* standards were acceptable. The performance acceptance limits for *E coli* supplied by ERA are much wider than for the other parameters, (+/- 50%). The coliform standards are shipped directly to the (MPRB laboratory) IRI from ERA.

SRP and TDP performance evaluation samples were mixed to low concentrations approximately 10-20 times the minimum detection limit. *Standard Methods* (2005) recommends that performance evaluation samples be mixed to a minimum concentration of 5 times the minimum detection limit. Because of the low concentrations the acceptance limit for SRP and TDP were widened from the recommended 80-120% range to 70-130% recovery. All SRP samples were acceptable in both the 70-130% and 80-120% range.

The May BOD5c and Pb as well as the August *E. coli* and TP02 samples were flagged as failing.

Analysis of Equipment Blanks and Field Blanks
Equipment blanks were run for both lake water and stormwater sampling equipment. Results from lake and stormwater equipment blanks for 2014 yielded non-detects for all parameters. The 2014 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 of the recovery values for spike samples (known additions) reported by IRI were within acceptance limits. All of the reported recoveries for internally supplied standards of known concentration were within acceptance limits.

FINAL ASSESSMENT OF DATA USABILITY

Table 28-7 lists the overall completeness, representativeness, comparability, and precision determined for the 2014 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 2014 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 parameters listed on **Table 28-7** as questionably usable are only so for the months that they failed monthly performance standards or for split comparability. No parameters in 2014 failed performance standards. When reviewing the monthly performance samples the “rule of sensibility” must be applied and percent recovery must be viewed in relation to the values (low or high), stability of the test and multiple of the reporting limit (2X) used to qualify the data.

Table 28-7. Summary of 2014 data usability by parameter. '+' denotes that acceptance criteria were met, 'O' denotes that some of the data were of questionable usability, '+' denotes that data were not within acceptable range.

Parameter	Completeness (<5% missing data)	Representativeness (representative of natural samples)	Comparability (splits, 2014 data)	Precision (lab field dups, performance)
Alkalinity	+	+	+	+
Ammonia	+	+	+	+
BOD 5 day	+	+	+	O
Conductivity	+	+	+	+
Chloride	+	+	+	O
Chlorophyll-*a*	+	+	+	+
Copper	+	+	+	+
E. coli	+	+	+	O
Hardness	+	+	+	+
Lead	+	+	+	O
Nitrate+Nitrite	+	+	+	+
Ortho-P	+	+	+	+
pH	+	+	+	+
Silica	+	+	+	+
Soluble Reactive Phosphorus	+	+	O	+
Sulfate	+	+	+	+
Total Dissolved Phosphorus	+	+	+	+
Total Dissolved Solids	+	+	+	+
Total Kjeldahl Nitrogen	+	+	+	+
Total Nitrogen	+	+	O	O
Total Phosphorus	+	+	+	O
Total Suspended Solids	+	+	+	+
Zinc	+	+	+	+

29. 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/

Results Minneapolis
Lake water quality
http://www.ci.minneapolis.mn.us/results/env/waterquality

Watershed Management Organizations

Bassett Creek Watershed Management Commission
http://www.bassettcreekwmo.org/

Minnehaha Creek Watershed District
http://www.minnehahacreek.org/
952.471.0590

Mississippi Watershed Management Organization
http://www.mwmo.org/
651-287-0948

Shingle Creek Watershed Management Commission
http://www.shinglecreek.org/
763-553-1144

Hennepin County or Metro Resources

Hennepin County Environmental Services
http://www.hennepin.us/residents#environment
612.348.3777

Minnesota Wetland Health Evaluation Project (WHEP)
http://www.mnwhep.org/

Metropolitan Council – Environmental Services
http://www.metrocouncil.org/environment/environment.htm
651.602.1000

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/
651.296.6157

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.
http://www.pca.state.mn.us/water/index.html
651.296.6300

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 & Land
http://www.mda.state.mn.us/protecting.aspx
651.297.2200

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
http://www.mvp-wc.usace.army.mil/

US Geological Survey – Minnesota
Stream data and links to the national website
http://mn.water.usgs.gov/
763.783.3100

US Geological Survey – Nonindigenous Aquatic Species
Information and maps of invasive aquatic plants and animals
http://nas.er.usgs.gov/default.aspx

Other Resources

Minnesota Climatology Working Group
http://climate.umn.edu/

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/

30. REFERENCES

Aplikowski, S., Hafner, J., & Wilson, B. (2005). Minneapolis chain of lakes: A decade of watershed rehabilitation. *LakeLine*. 25(1), 37-43.

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

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.

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.

Corsi, S. R., Graczyk, D. J., Geis, S. W., Booth, N. L., & Richards, K, D. (2010). A fresh look at road salt: aquatic toxicity and water-quality impacts on local, regional, and national scales. *Environmental Science and Technology, 44*, 7376-7382.

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.

Edmondson, W. T. (Ed.). (1959). *Ward and Whipple's freshwater biology.* New York: John Wiley and Sons, Inc.

Environment Canada, Minister of Public Works and Government Services, Health Canada. (2001). Priority substances list assessment report - road salts (201). Ottowa, ON, Canada.

Fairless, B.J., & D.I. Bates. (1989). Estimating the quality of environmental data. *Pollution Engineering.* March, 108-111.

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.

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.

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.

Horne, A. J., & C. R. Goldman. (1994). *Limnology* (2nd ed.). New York: McGraw-Hill.

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.

Jensen, K.M. (1997). *Chemical limnology and historical water quality in the Minneapolis Chain of Lakes.* (Unpublished master's thesis) University of Minnesota, Minneapolis.

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. (1997). Phytoplankton-zooplankton communities in the Minneapolis Chain of Lakes. Minneapolis Lakes and Parks - Special Session Proceedings. Sixteenth Annual North American Lakes Management Society International Symposium. Minneapolis, MN.

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.

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. (2014). *ANNUAL USE ESTIMATE OF THE METROPOLITAN REGIONAL PARKS SYSTEM FOR 2013*. St. Paul, MN. http://www.metrocouncil.org/METC/files/c7/c7d33d34-b6de-4bd2-bac7-05d6e2feb822.pdf

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.

Minnesota Department of Health (MDH). (2005) 2005 Gastrointestinal Disease Outbreak Summary. St Paul, MN: Author.

Minnesota Department of Health (MDH). (2015) Waterborne Illness Outbreak Statistics: 2005-2014. St Paul, MN: Author.

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 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, (2009). *Phase I chloride feasibility study for the Twin Cities Metropolitan Area* Retrieved from, http://www.pca.state.mn.us/index.php/view-document.html?gid=13300

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 Session Laws 2014, Chapter 290, Sec. 60

Minnesota Stormwater Steering Committee (MSSC). (2005). State of Minnesota stormwater manual, Version 1.0. http://www.pca.state.mn.us/water/stormwater/stormwater-manual.html#manual

Novothy, E. V., Sander, A. R., Mohseni, O., & Stefan, H. G. (2009). Chloride ion transport and mass balance in a metropolitan area using road salt. *Water Resources. Research*, 45(W12410)

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.

Prescott, G.W. (1951). *Algae of the western Great Lakes area*. Dubuque, IA: William C. Brown Company Publishers.

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.

Rangel, J.M., Crowe, C., Griffin, P.M., Sparling, P.H., & Swerdlow, D.L. (2005). Epidemiology of *Escherichia coli* O157:H7 outbreaks, United States, 1982-2002. *Emerging Infectious Diseases,* 11(4), 603-609.

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.

Shapiro, J. (1997). Physiological and biological factors affecting the phytoplankton. In: Minneapolis Lakes and Parks - Special Session Proceedings. Sixteenth Annual North American Lakes Management Society International Symposium. Minneapolis, MN.

Solo-Gabriele, H.M., Desmarais, T.R., Palmer, C.J., & Wolfert, M.A. (2000). Sources of *Escherichia coli* in a coastal subtropical environment. *Applied and Environmental Microbiology*, 66(1), 230-237.

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.

Swain, E.B. (1984). *The paucity of blue-green algae in meromictic Brownie Lake: iron limitation or heavy-metal toxicity?* Unpublished doctoral dissertation, University of Minnesota, Minneapolis.

Trembley, N. G. (2012). *The Changing Face of Cedar Lake: 1900–1918.* (Unpublished master's thesis). University of Minnesota, Minneapolis, 131 p.

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.

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/

Walker, W.W. (1996). *Simplified procedures for eutrophication assessment and prediction: User manual* (Instruction Report W-96-2). Vicksburg, MS: U.S. Army Engineer Waterways Experiment Station.

Weber, C.I. (1971). *A guide to the common diatoms at water pollution surveillance system stations.* Cincinnati, OH: US EPA. (ERIC Document Reproduction Service No. ED157796)

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.

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.

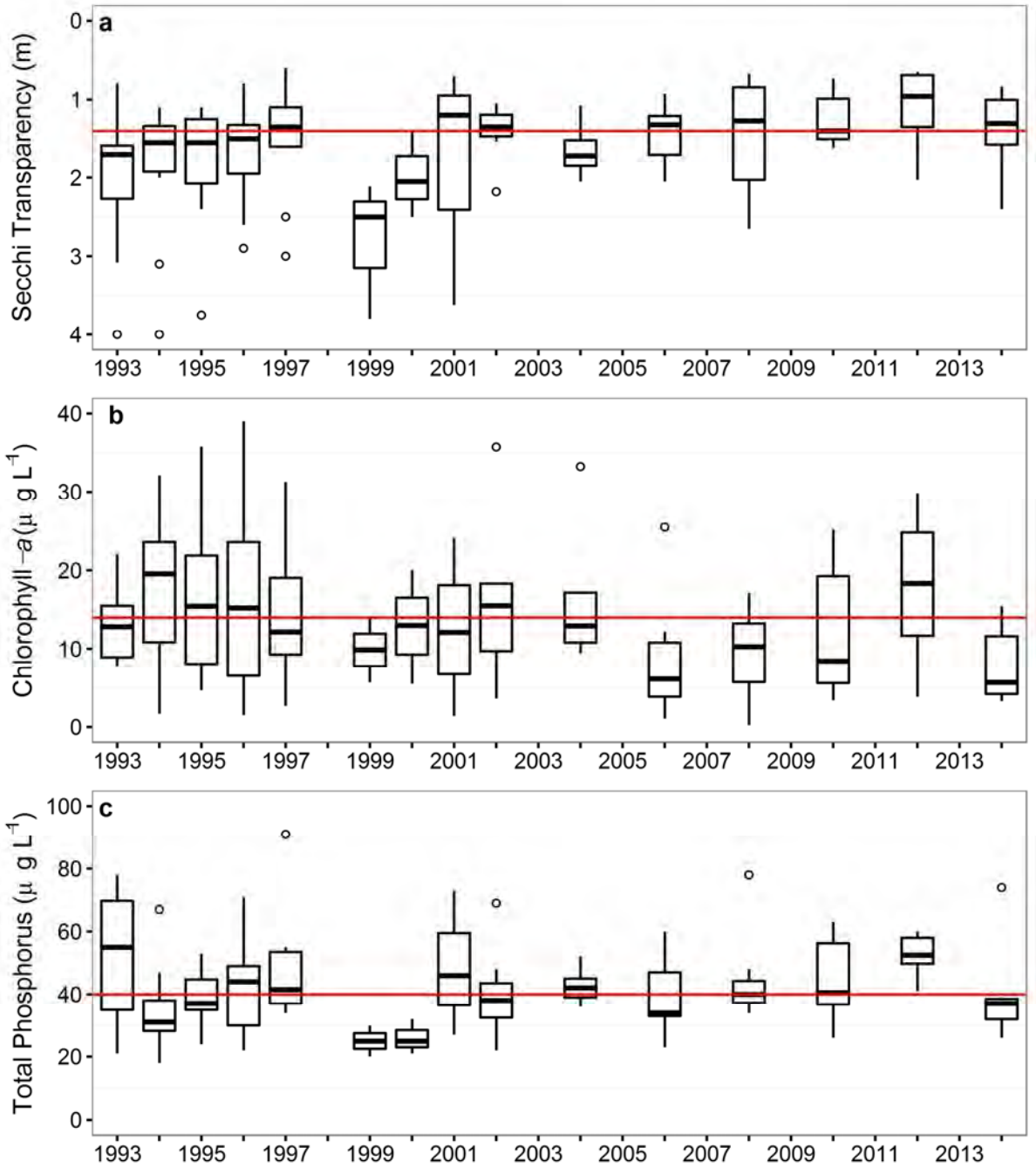
Wirth, Theodore. (1945). *Minneapolis Park System, 1883-1944.* Minneapolis: Board of Park Commissioners.

Zumberge, J.H. (1952). *The lakes of Minnesota: Their origin and classification*. St. Paul, MN: The University of Minnesota Press.

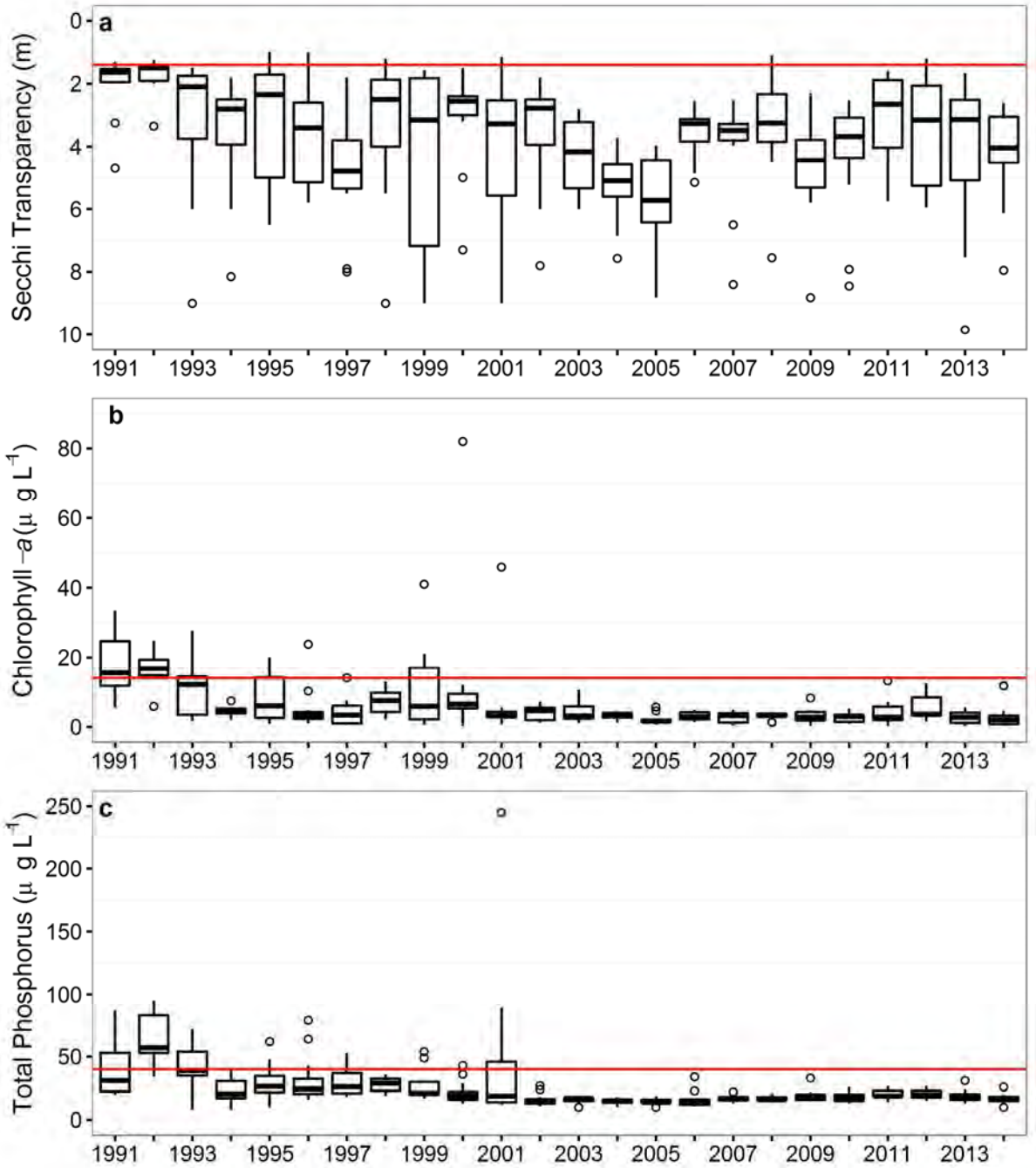
APPENDIX A

This section contains box-and-whisker plots 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 **Section 1**.

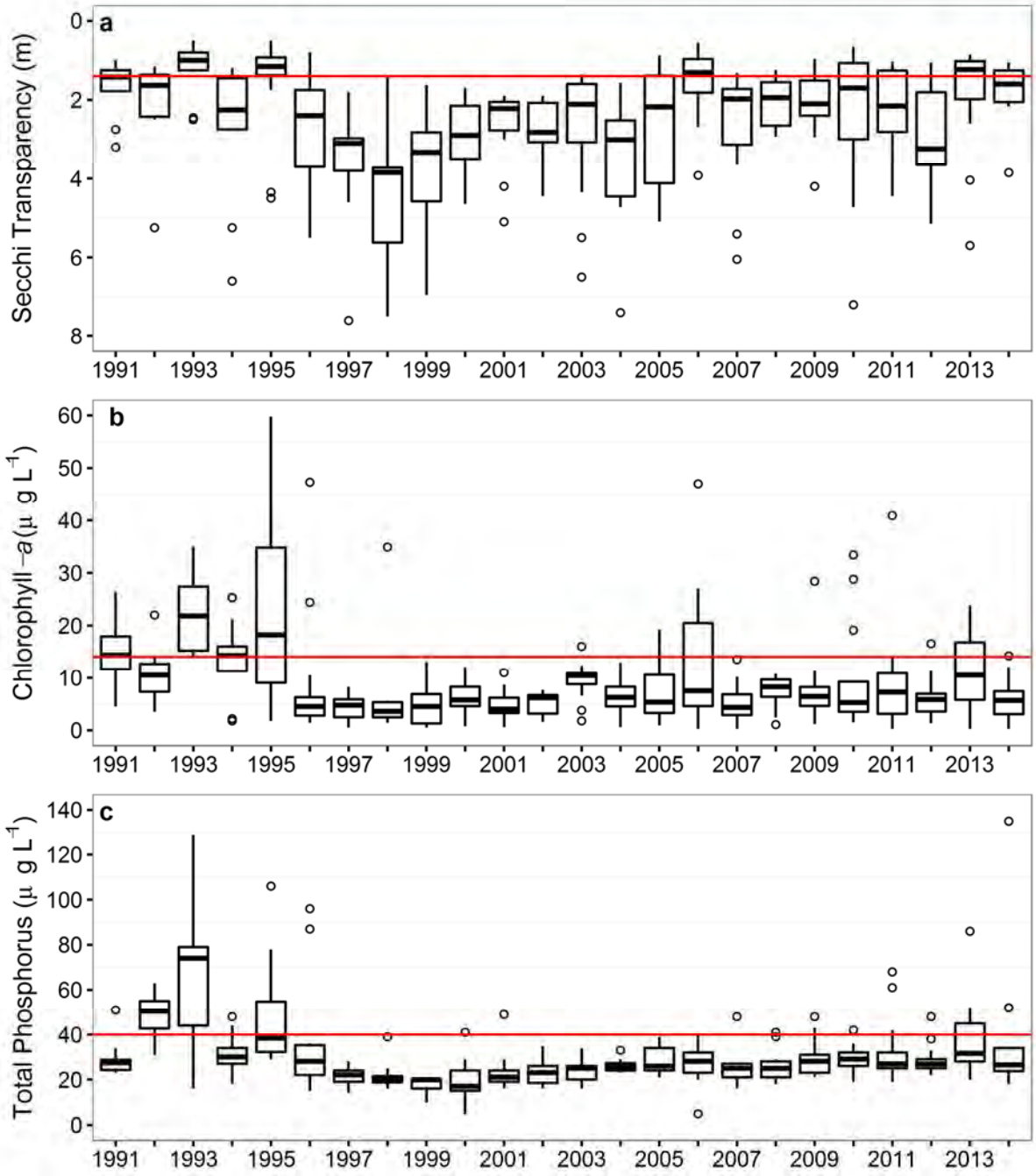
Brownie Lake 1991-2014



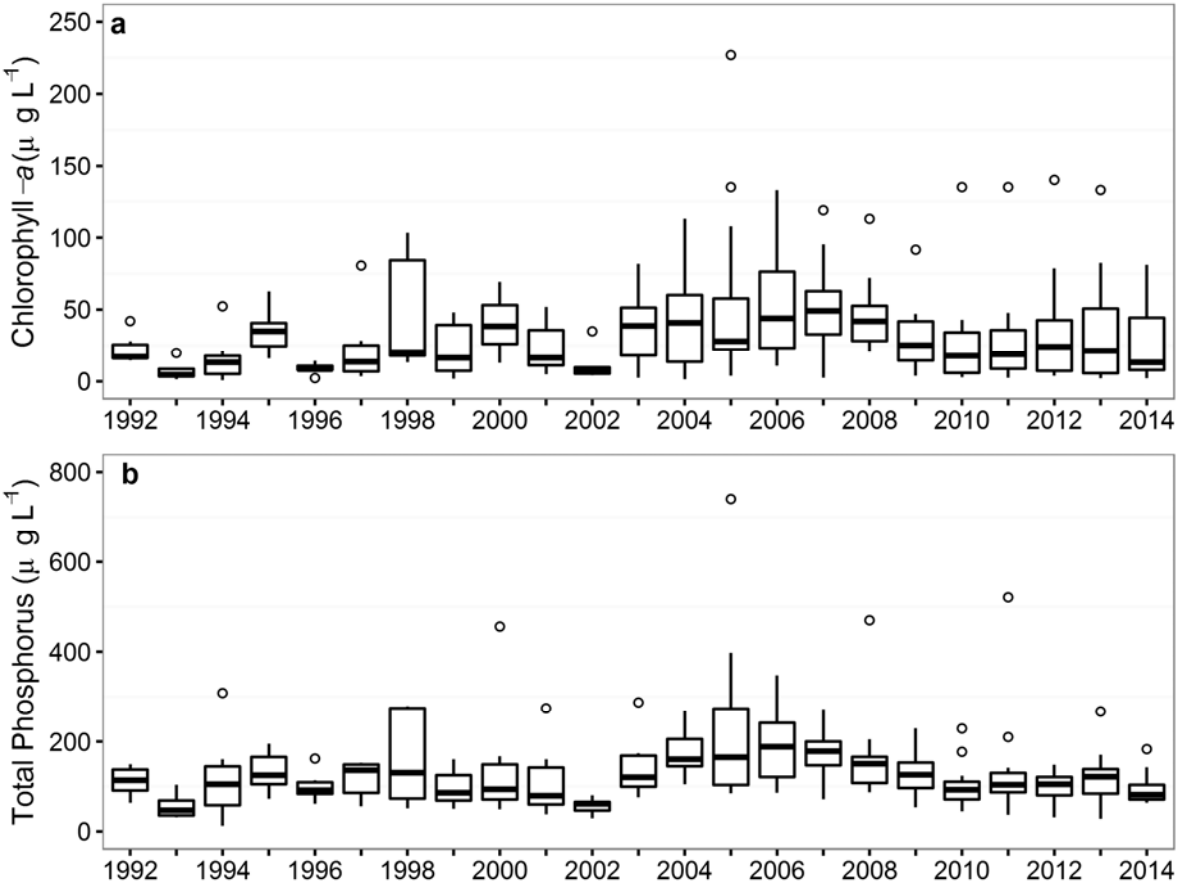
Lake Calhoun 1991-2014



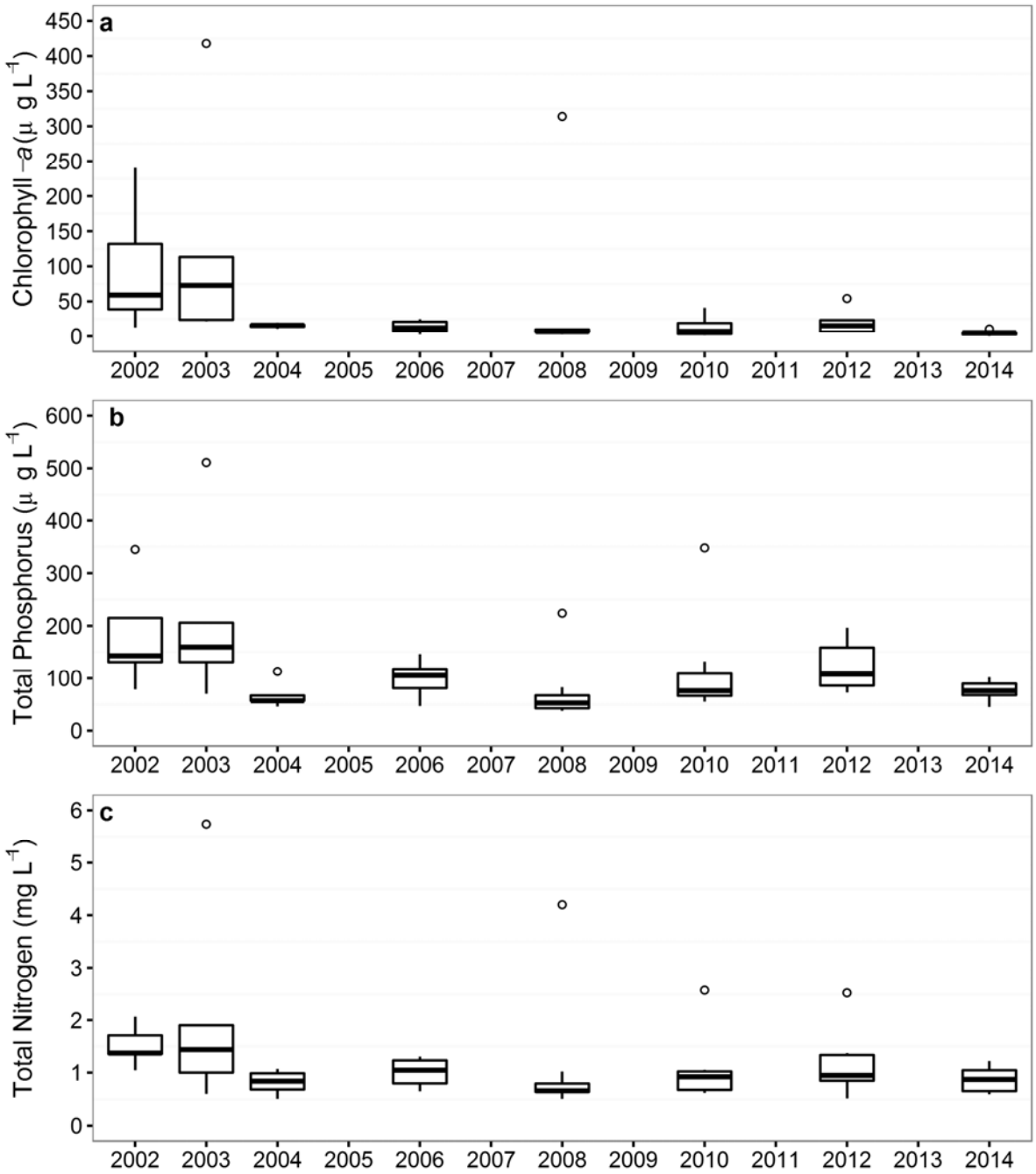
Cedar Lake 1992-2014



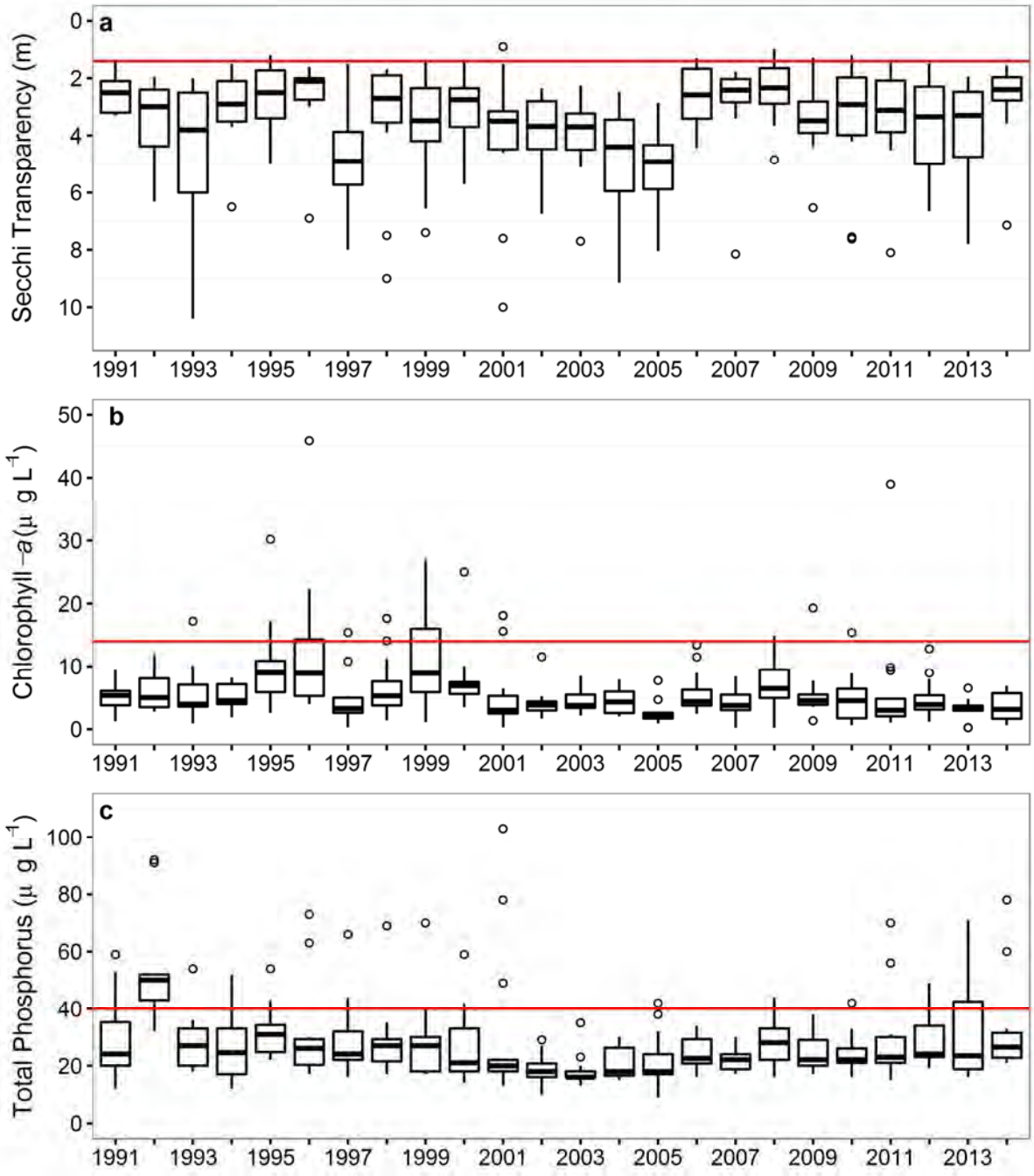
Diamond Lake 1992-2014



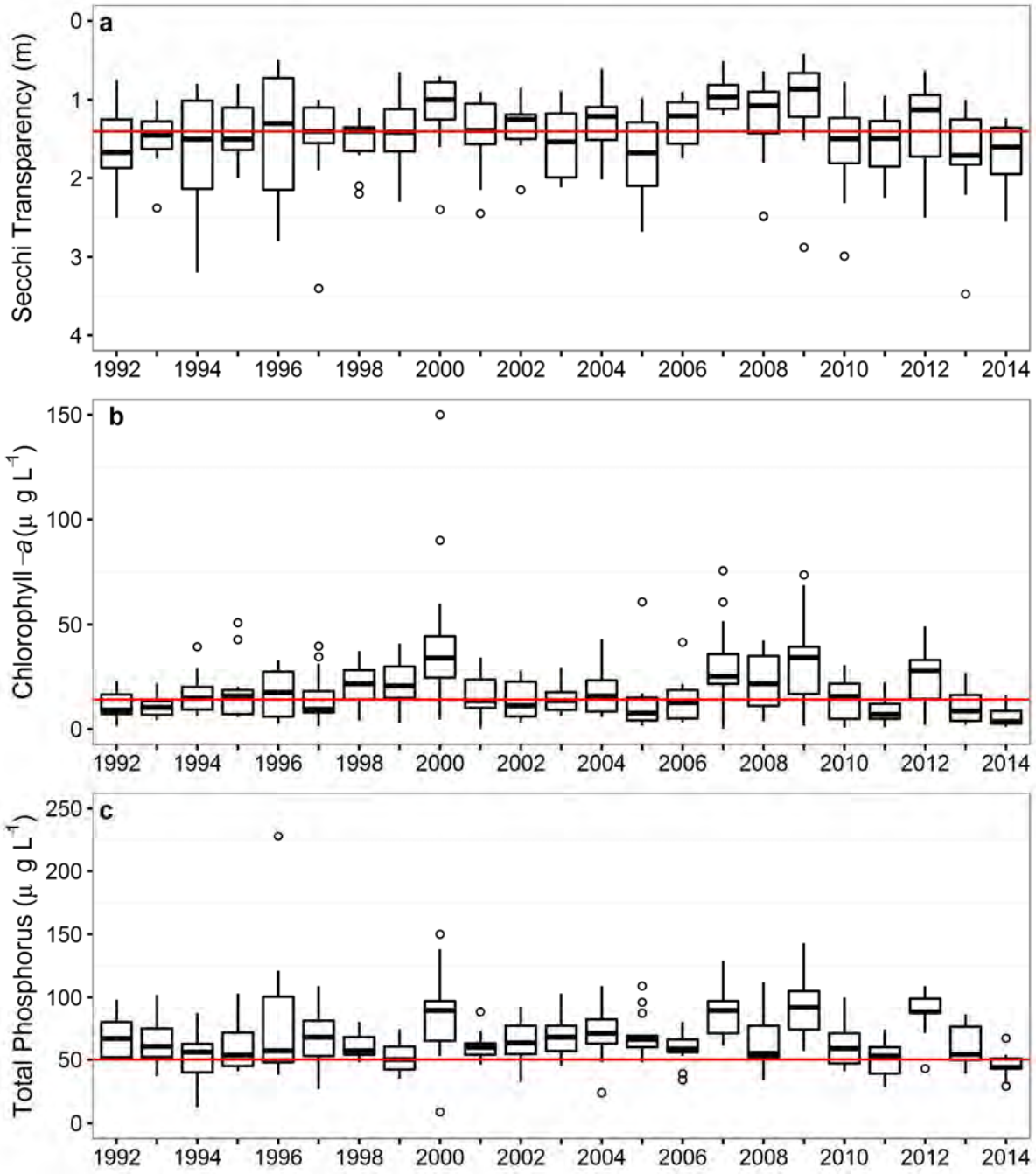
Grass Lake 2002-2014



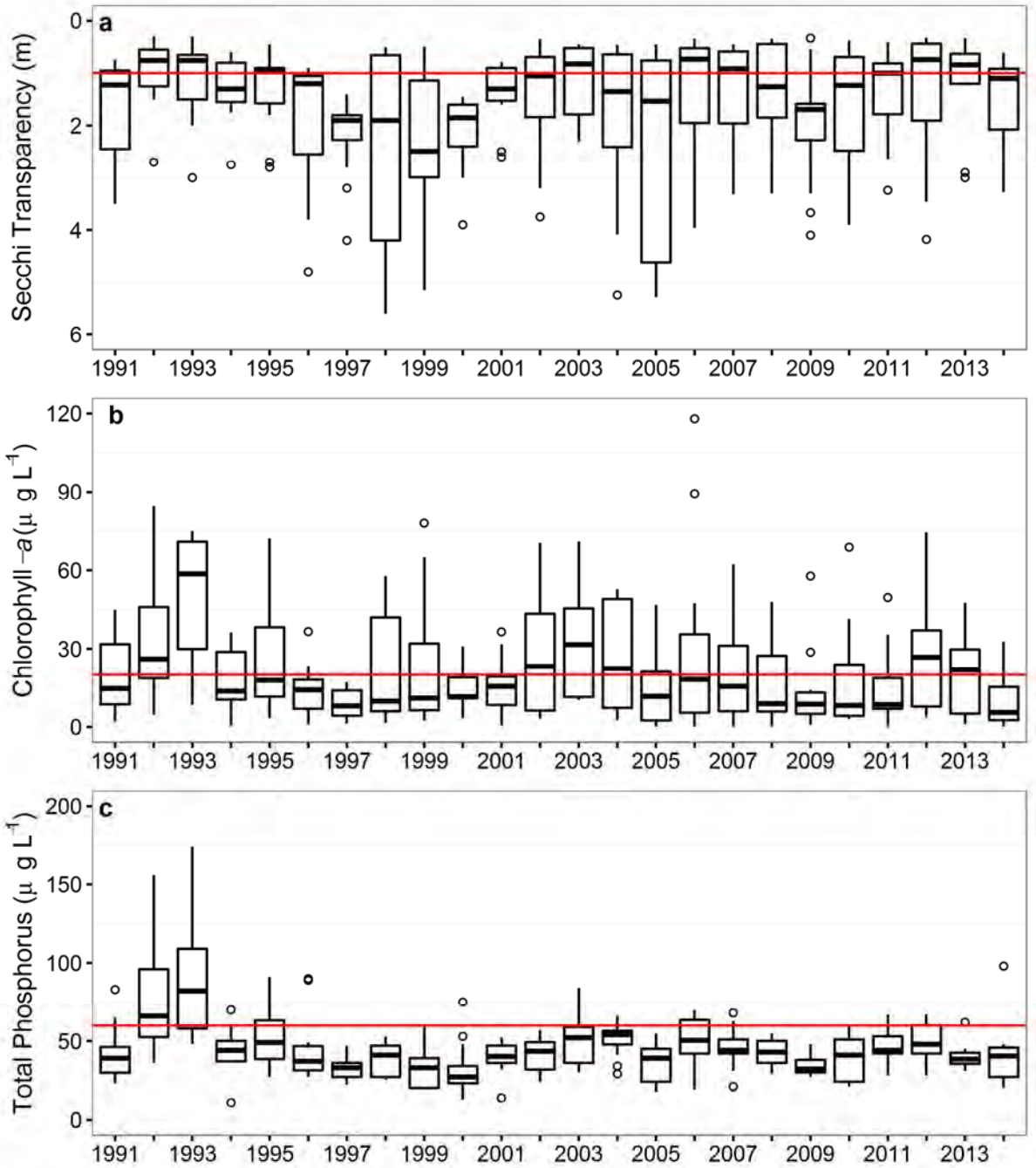
Lake Harriet 1991-2014



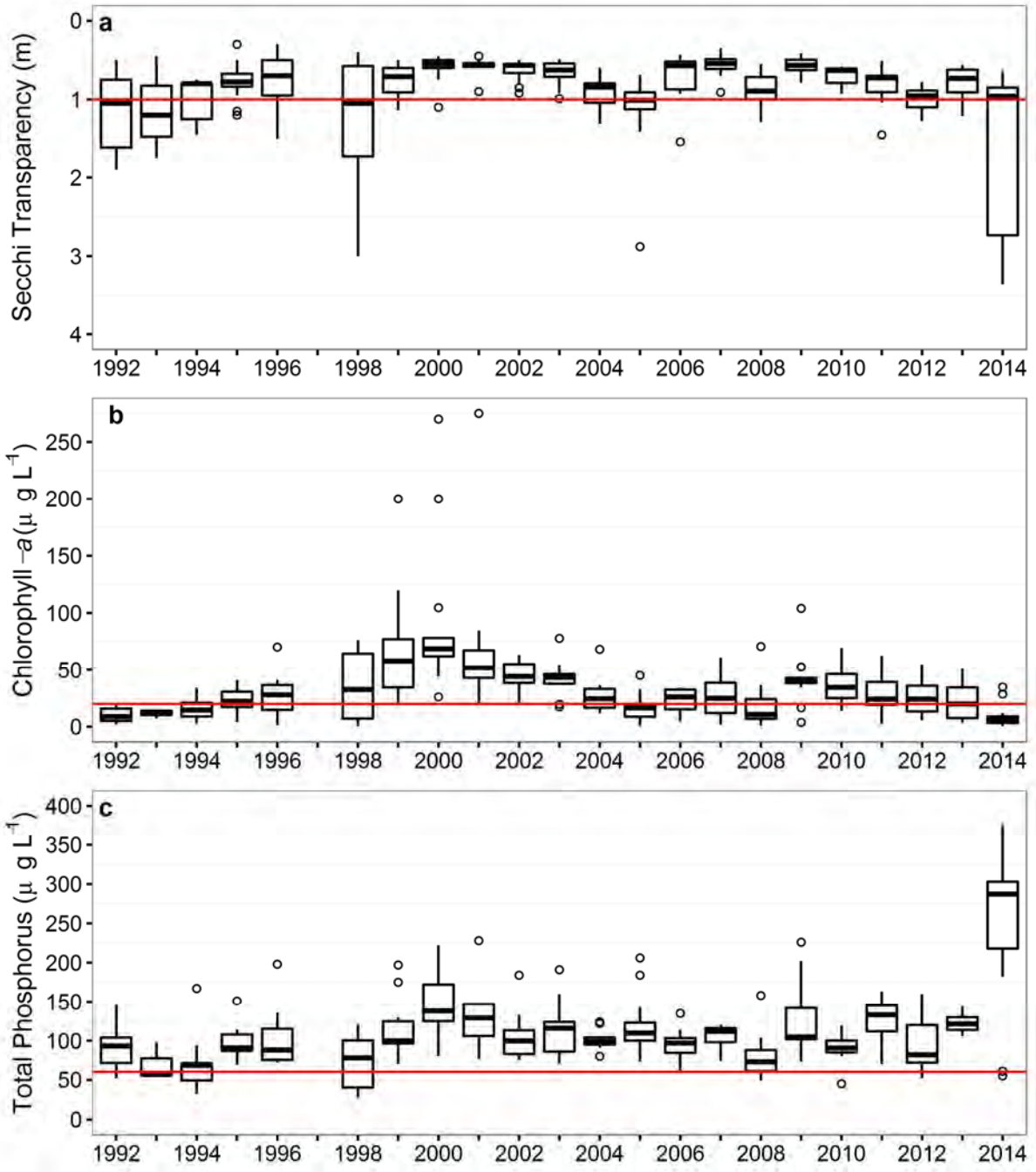
Lake Hiawatha 1992-2014



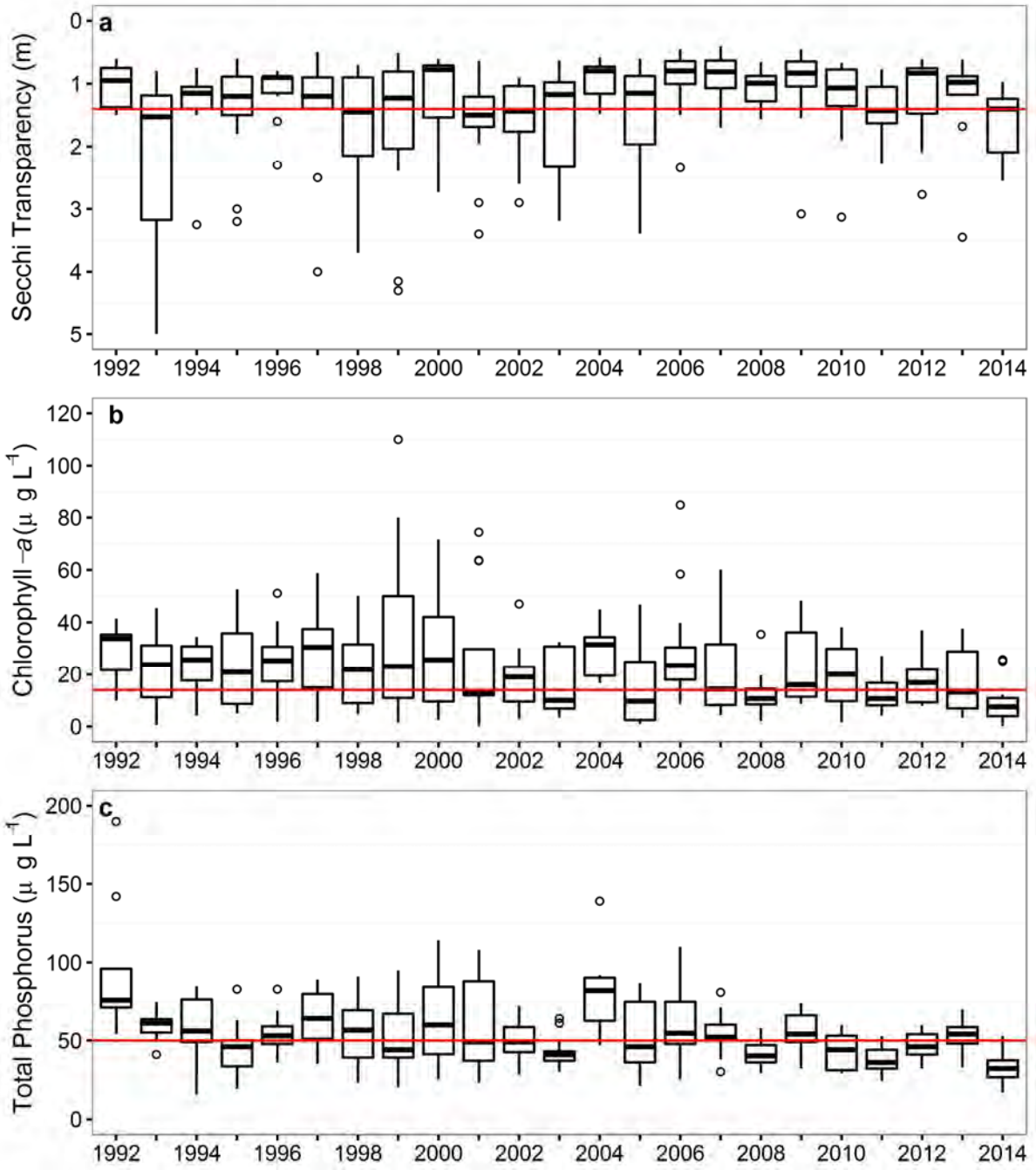
Lake of the Isles 1991-2014



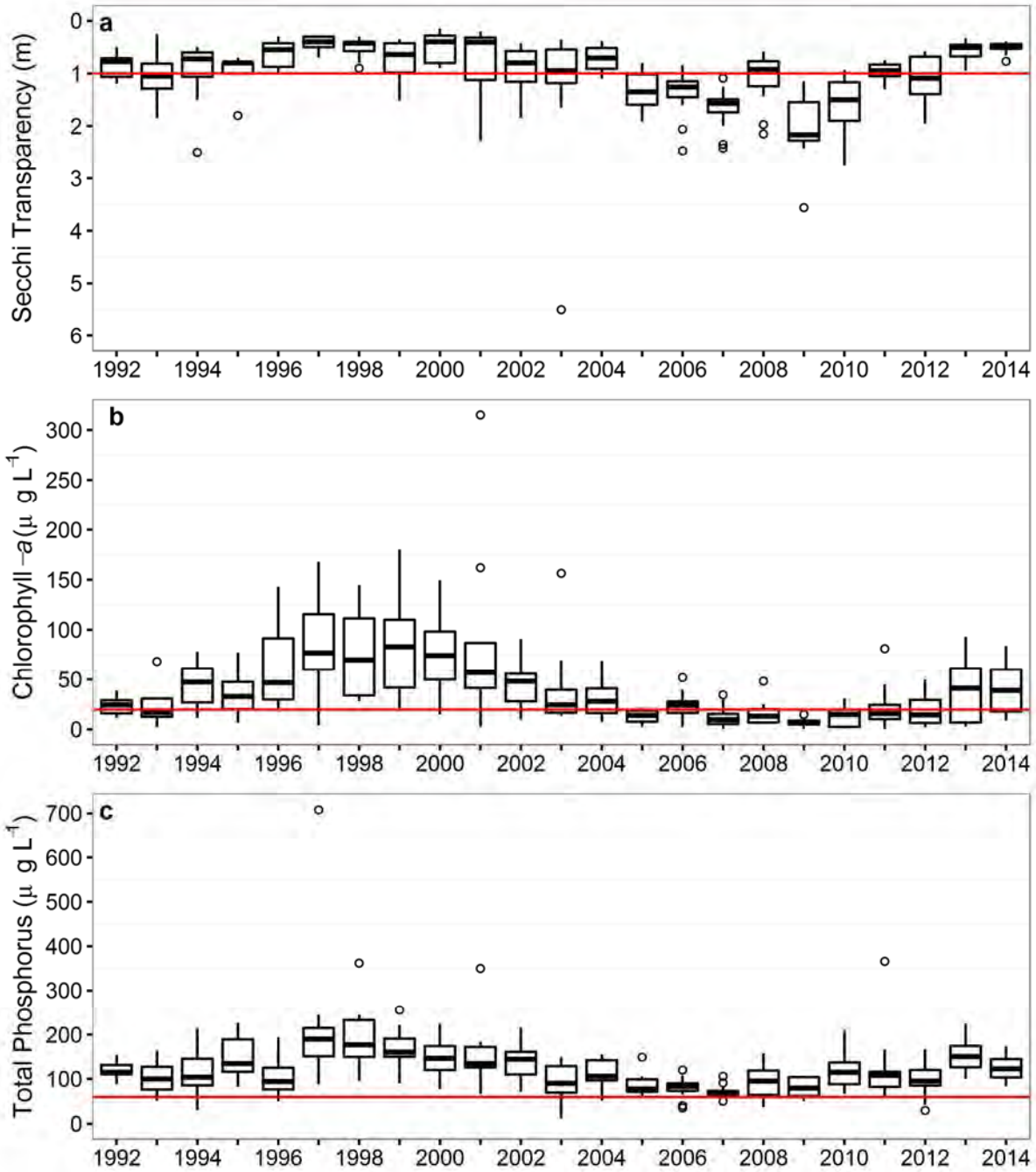
Loring Pond 1992-2014, Note: Loring was not sampled in 1997.



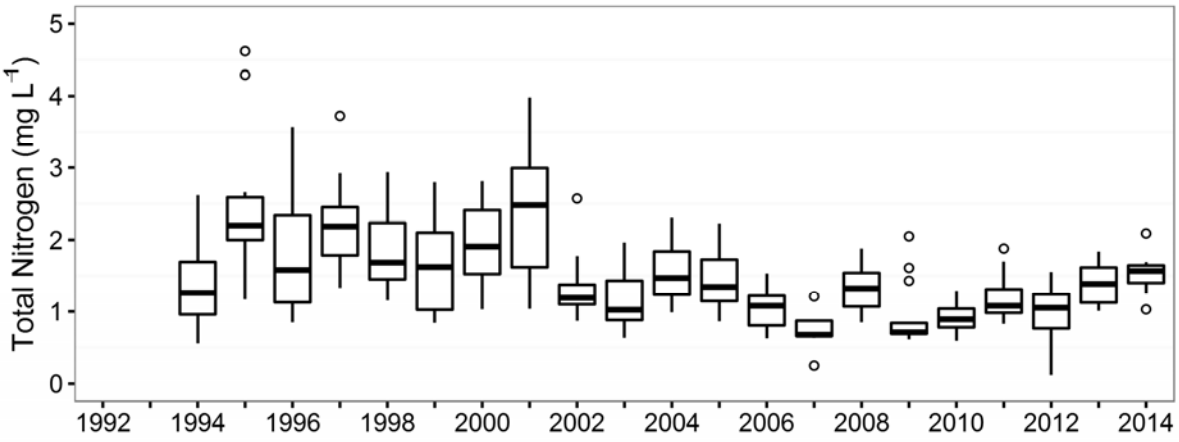
Lake Nokomis 1992-2014



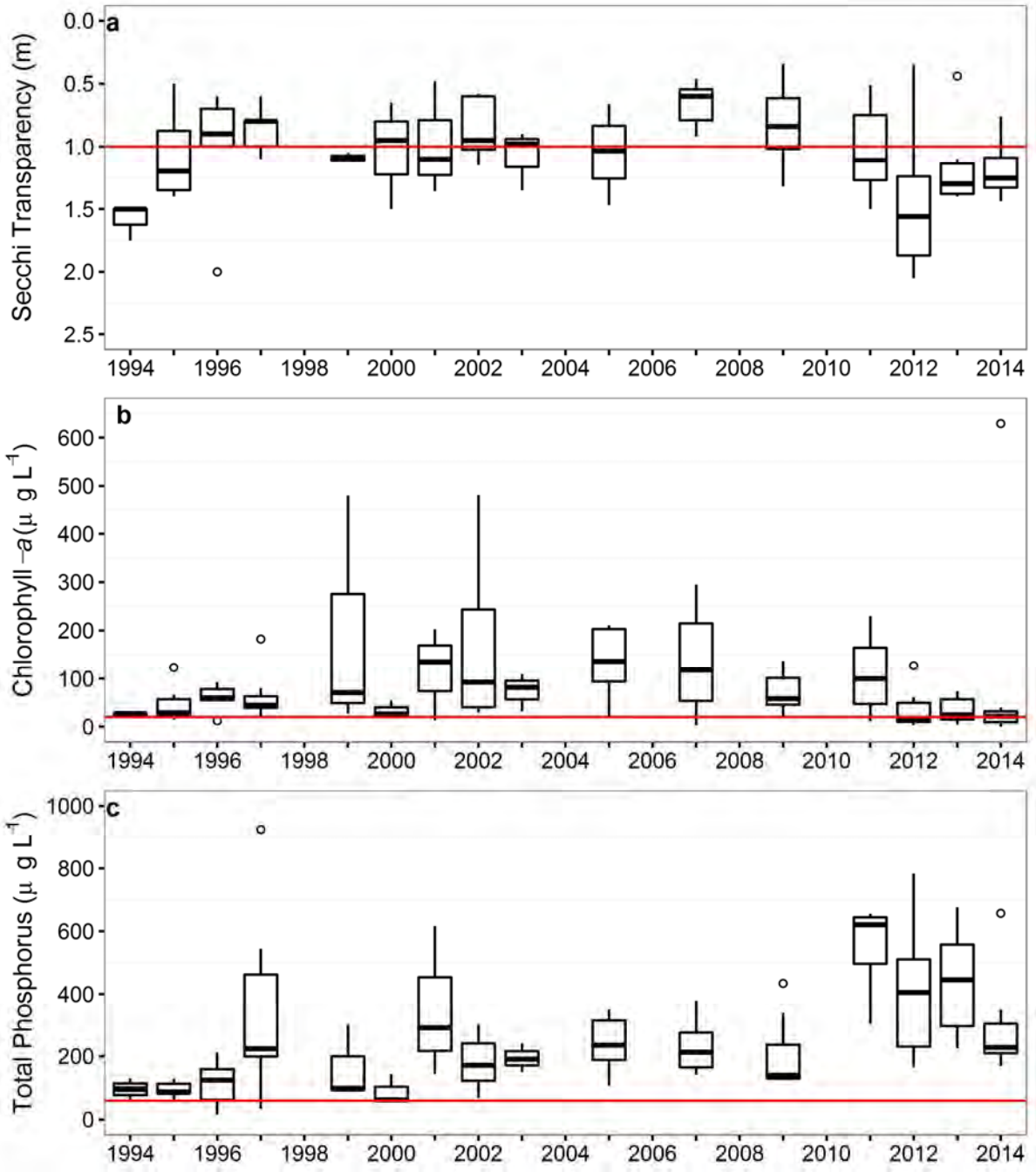
Powderhorn Lake 1992-2014



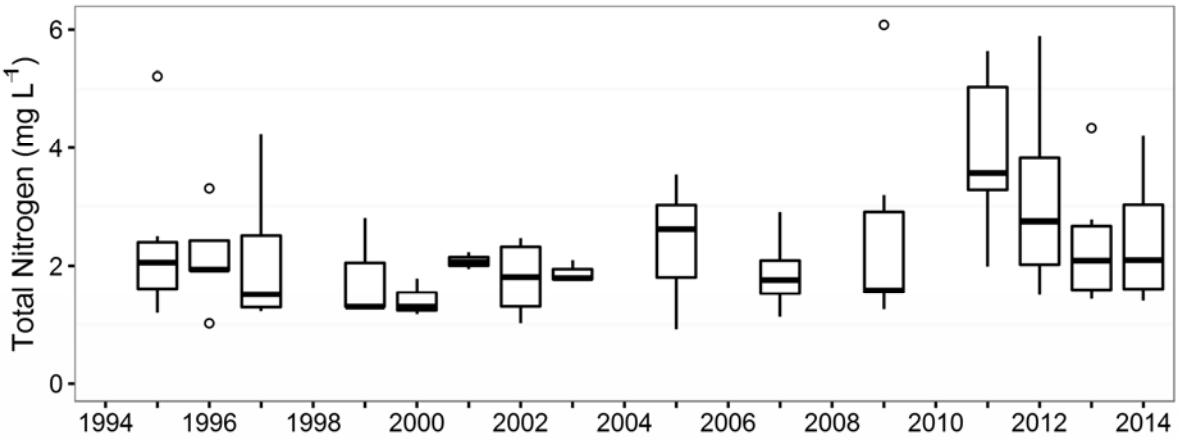
Powderhorn Lake Nitrogen 1994-2014



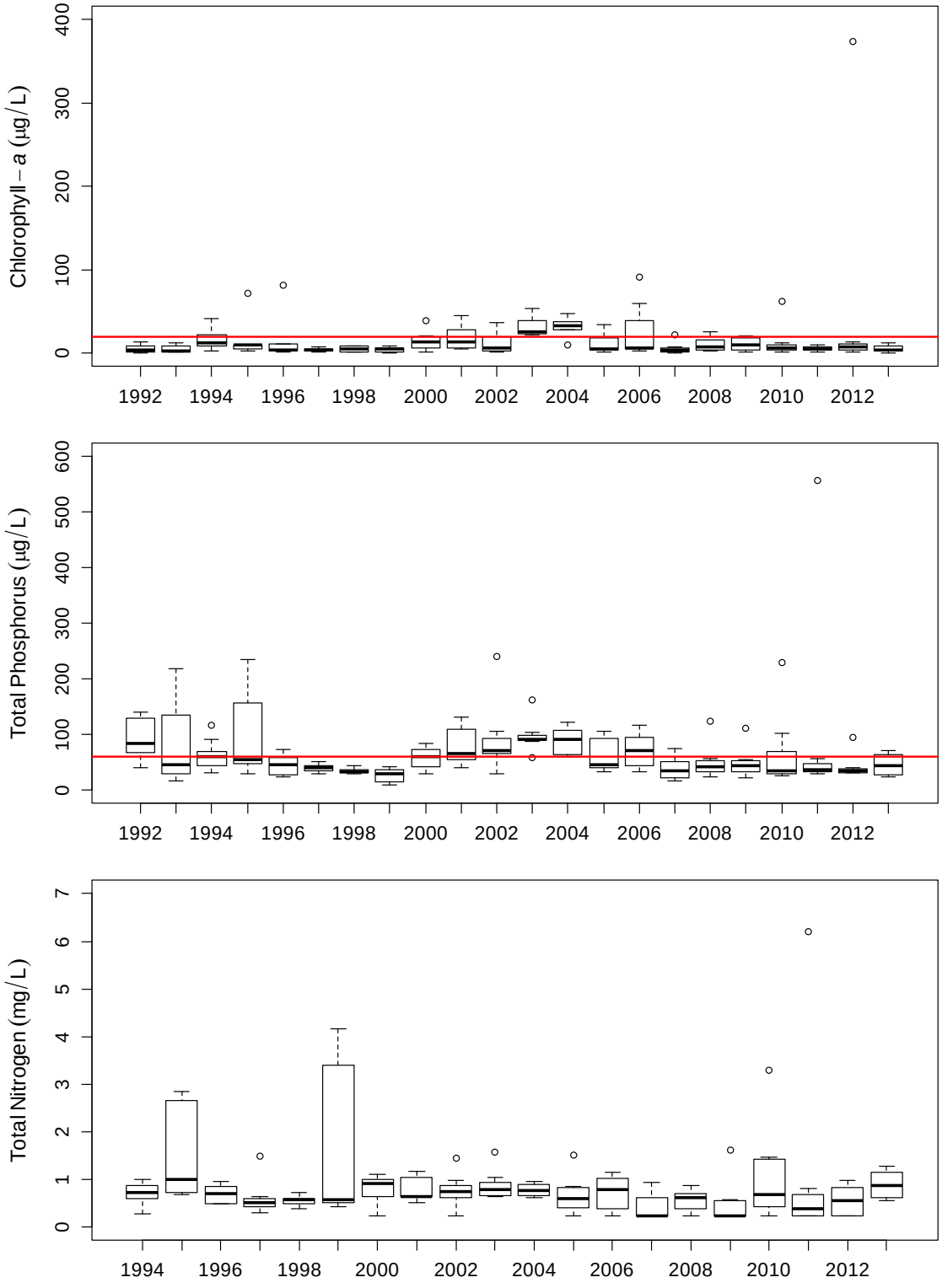
Spring Lake 1994-2014



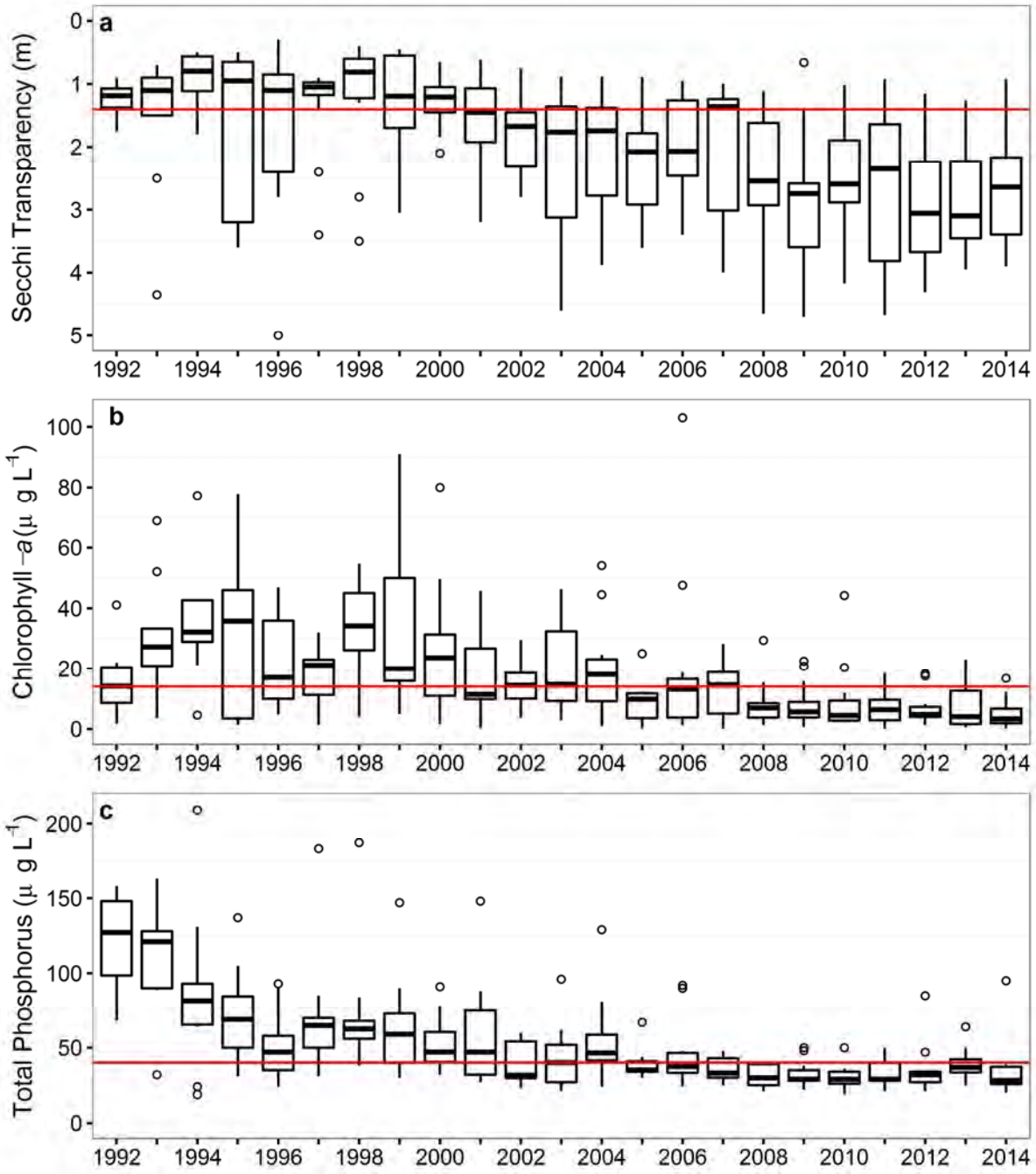
Spring Lake 1994- 2013 Nitrogen



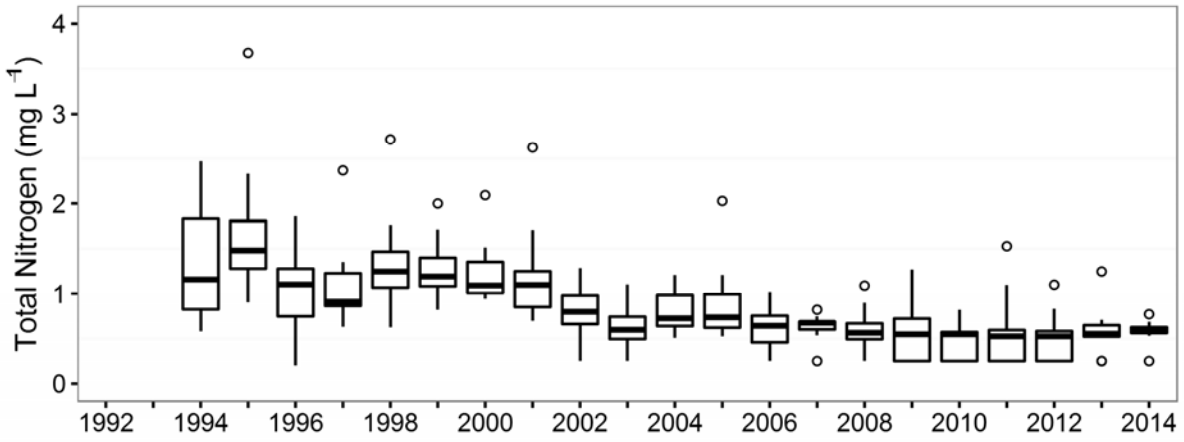
Webber Pond 1992-2013



Wirth Lake 1992-2014



Wirth Lake 1994-2014 Nitrogen



Appendix B

This section contains lake monitoring data for 2014.

Underlined data indicates monthly performance standard failure.

Lake ID	Lake Name	MM/DD/YYY	HH:MM:SS	meters	meters	Temp °C	DO mg/L	%DO	pH units	µS/cm	NTU	mg/M3	mg/M3	Silica mg/L	TP mg/L	SRP mg/L	TKN mg/L	TN mg/L	mg/L	Alk mg/L	Hard mg/L	Cl mg/L	SO4 mg/L	mpn/100m	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/	cfu/10
27-0038	Brownie	3/20/2014	10:29:34		0	0.46	2.07	14.7	7.22	1150	5.2	3.72	5.24	9.35	0.074	0.007	1.61	1.730	<0.030	159	244	344												
27-0038	Brownie	3/20/2014	10:28:38		1	2.78	1.37	10.4	7.09	1684	671																							
27-0038	Brownie	3/20/2014	10:27:32		2	3.14	1.25	9.60	7.00	2184	12																							
27-0038	Brownie	3/20/2014	10:26:48		3	3.20	1.58	12.2	6.92	2570	15																							
27-0038	Brownie	3/20/2014	10:26:17		4	3.40	1.14	8.80	6.85	2808	24																							
27-0038	Brownie	3/20/2014	10:25:47		5	3.66	1.42	11.1	6.79	2953	27																							
27-0038	Brownie	3/20/2014	10:25:22		6	4.23	2.06	16.4	6.68	3078	20				0.298	0.017																	
27-0038	Brownie	3/20/2014	10:24:03		7	4.67	1.62	13.1	6.59	3193	15																							
27-0038	Brownie	3/20/2014	10:23:31		8	4.89	0	0	6.55	3261	15																							
27-0038	Brownie	3/20/2014	10:22:56		9	5.30	0	0	6.47	3352	13																							
27-0038	Brownie	3/20/2014	10:22:26		10	5.98	0	0	6.37	3401	12																							
27-0038	Brownie	3/20/2014	10:21:49		11	6.14	0	0	6.36	3424	12																							
27-0038	Brownie	3/20/2014	10:21:05		12	6.44	0	0	6.32	3454	12				5.199	0.144						859											
27-0038	Brownie	3/20/2014	10:19:54		13	6.81	0	0	6.26	3517	16																							
27-0038	Brownie	5/5/2014	11:25:53	0.84	0	10.27	14.2	130	8.37	0	5.6	4.71	2.10	2.86	0.026	<0.003	0.75	0.865	0.112	72	104	221	7.8											
27-0038	Brownie	5/5/2014	11:24:23		1	11.20	13.2	123	7.99	849	7.5																							
27-0038	Brownie	5/5/2014	11:22:34		2	7.64	9.81	84.4	7.44	869	9.9																							
27-0038	Brownie	5/5/2014	11:20:38		3	5.19	0	0	7.02	2198	19																							
27-0038	Brownie	5/5/2014	11:19:55		4	3.89	0	0	6.88	2690	10																							
27-0038	Brownie	5/5/2014	11:19:24		5	4.21	0	0	6.77	2842	9.4																							
27-0038	Brownie	5/5/2014	11:18:58		6	4.75	0	0	6.68	3008	9.5				0.536	0.018																	
27-0038	Brownie	5/5/2014	11:18:25		7	5.23	0	0	6.61	3144	8.9																							
27-0038	Brownie	5/5/2014	11:18:02		8	5.56	0	0	6.54	3212	9.6																							
27-0038	Brownie	5/5/2014	11:17:36		9	5.79	0	0	6.50	3289	11																							
27-0038	Brownie	5/5/2014	11:17:11		10	6.11	0	0	6.43	3360	12																							
27-0038	Brownie	5/5/2014	11:16:48		11	6.34	0	0	6.40	3394	12																							
27-0038	Brownie	5/5/2014	11:16:09		12	6.52	0	0	6.37	3421	12				5.314	0.011						929	<5.00											
27-0038	Brownie	5/5/2014	11:15:48		13	6.62	0	0	6.37	3434	13																							
27-0038	Brownie	5/5/2014	11:15:19		14	6.69	0	0	6.36	3435	22																							
27-0038	Brownie	6/11/2014	12:24:59	2.40	0	23.04	9.88	119	7.88	722	0.0	3.30	2.15	3.24	0.037	<0.003		0.738				192												
27-0038	Brownie	6/11/2014	12:23:51		1	21.15	7.83	91.0	7.50	740	5.7																							
27-0038	Brownie	6/11/2014	12:22:53		2	17.37	5.72	61.7	7.15	1416	7.2																							
27-0038	Brownie	6/11/2014	12:21:48		3	13.40	1.65	16.4	7.01	1528	7.8																							
27-0038	Brownie	6/11/2014	12:19:43		4	6.53	0.00	0	6.79	2367	21																							
27-0038	Brownie	6/11/2014	12:18:42		5	4.62	0.00	0	6.65	2827	13																							
27-0038	Brownie	6/11/2014	12:17:58		6	4.51	0.00	0	6.54	3002	8.7				0.347	0.074																	
27-0038	Brownie	6/11/2014	12:17:16		7	4.89	0.00	0	6.46	3163	8.7																							
27-0038	Brownie	6/11/2014	12:16:26		8	5.30	0.00	0	6.39	3270	10																							
27-0038	Brownie	6/11/2014	12:15:10		9	5.89	0.00	0	6.33	3345	13																							
27-0038	Brownie	6/11/2014	12:13:13		10	6.11	0.00	0	6.28	3414	3000																							
27-0038	Brownie	6/11/2014	12:12:37		11	6.31	0.00	0	6.26	3447	3000																							
27-0038	Brownie	6/11/2014	12:13:52		12	6.43	0.00	0	6.27	3460	21				5.629	0.034						961											
27-0038	Brownie	7/7/2014	11:44:06	1.17	0	25.26	12.0	152	8.61	963	4.0	14.90	3.00	3.38	0.039	<0.003	0.66	0.733	0.034	121	216	242											
27-0038	Brownie	7/7/2014	11:43:38		1	23.27	14.9	181	8.40	1106	5.2																							
27-0038	Brownie	7/7/2014	11:42:34		2	18.02	11.2	123	7.50	1712	7.3																							
27-0038	Brownie	7/7/2014	11:41:17		3	16.64	6.90	73.6	7.26	1944	8.2																							
27-0038	Brownie	7/7/2014	11:40:24		4	13.89	0.49	4.90	7.06	1871	7.5																							
27-0038	Brownie	7/7/2014	11:39:26		5	8.82	0	0	6.91	2411	29																							
27-0038	Brownie	7/7/2014	11:38:11		6	5.20	0	0	6.68	2950	17				0.093	0.019																	
27-0038	Brownie	7/7/2014	11:37:26		7	5.03	0	0	6.56	3113	12																							
27-0038	Brownie	7/7/2014	11:36:48		8	5.33	0	0	6.49	3207	10																							
27-0038	Brownie	7/7/2014	11:35:41		9	5.69	0	0	6.44	3285	10																							
27-0038	Brownie	7/7/2014	11:35:07		10	5.97	0	0	6.40	3350	12																							
27-0038	Brownie	7/7/2014	11:34:31		11	6.18	0	0	6.37	3403	16																							
27-0038	Brownie	7/7/2014	11:33:13		12	6.39	0	0	6.37	3425	14				4.830	0.022						946											
27-0038	Brownie	7/7/2014	11:32:26		13	6.64	0	0	6.38	3437	15																							
27-0038	Brownie	7/7/2014	11:31:56		14	6.69	0	0	6.39	3448	14																							
27-0038	Brownie	8/5/2014	11:05:37	1.44	0	25.02	11.3	139	8.44	1214	1.7	5.70	1.40	9.20	0.029	0.004		<0.500				398											
27-0038	Brownie	8/5/2014	11:04:47		1	24.74	10.8	134	8.36	1204	1.5																							
27-0038	Brownie	8/5/2014	11:03:26		2	18.75	9.45	104	7.68	1931	12																							
27-0038	Brownie	8/5/2014	11:02:14		3	16.23	0.23	2.4	7.44	1983	6.4																							
27-0038	Brownie	8/5/2014	11:00:43		4	13.72	0	0	7.32	1975	5.7																							
27-0038	Brownie	8/5/2014	10:59:46		5	9.74	0	0	7.21	2377	15																							
27-0038	Brownie	8/5/2014	10:58:51		6	6.27	0	0	7.05	2923	13				0.057	0.004																	
27-0038	Brownie	8/5/2014	10:57:09		7	5.21	0	0	6.89	3109	9.5																							
27-0038	Brownie	8/5/2014	10:56:29		8	5.28	0	0	6.79	3227	7.7																							
27-0038	Brownie	8/5/2014	10:55:20		9	5.67	0	0	6.69	3335	8.5																							
27-0038	Brownie	8/5/2014	10:54:11		10	5.97	0	0	6.63	3397	10																							
27-0038	Brownie	8/5/2014	10:53:34		11	6.31	0	0	6.59	3411	11																							
27-0038	Brownie	8/5/2014	10:52:59		12	6.35	0	0	6.58	3445	11				5.492	0.030						901											
27-0038	Brownie	8/5/2014	10:52:05		13	6.69	0	0	6.55	3463	47																							
27-0038	Brownie	9/9/2014	11:32:43	0.95	0	20.73	10.09	116.3	8.29	1187	10.9	15.41	2.55	9.34	0.035	0.004		0.587				313											
27-0038	Brownie	9/9/2014	11:32:01		1	20.63	10.22	117.6	8.27	1223	10.3																							
27-0038	Brownie	9/9/2014	11:30:54		2	19.97	7.7	87.5	7.74	1499	12.3																							
27-0038	Brownie	9/9/2014	11:29:14		3	18.27	2.78	30.6	7.46	1732	12.6																							
27-0038	Brownie	9/9/2014	11:28:08		4	14.83	0	0	7.28	1942	19.2																							
27-0038	Brownie	9/9/2014	11:27:27		5	10.72	0	0	7.15	2346	17.2																							
27-0038	Brownie	9/9/2014	11:26:12		6	7.13	0	0	6.84	2936	23.2				0.038	0.004																	
27-0038	Brownie	9/9/2014	11:25:41		7	5.78	0	0	6.69	3133	19.3																							
27-0038	Brownie	9/9/2014	11:25:04		8	5.63	0	0	6.62	3228	18.5																							

Underlined data indicates monthly performance standard failure.

Lake ID	Lake Name	MM/DD/YYY	HH:MM:SS	meters	meters	Temp °C	DO mg/L	%DO	pH units	µS/cm	NTU	mg/M3	mg/M3	Silica mg/L	TP mg/L	SRP mg/L	TKN mg/L	TN mg/L	mg/L	Alk mg/L	Hard mg/L	Cl mg/L	SO4 mg/L	mpn/100m	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/	cfu/10
27-0038	Brownie	9/9/2014	11:24:14		9	5.81	0	0	6.55	3300	20.1																							
27-0038	Brownie	9/9/2014	11:23:18		10	6.14	0	0	6.51	3382	19.9																							
27-0038	Brownie	9/9/2014	11:22:25		11	6.31	0	0	6.49	3400	20.4																							
27-0038	Brownie	9/9/2014	11:21:31		12	6.63	0	0	6.48	3443	20.4				5.974	0.019						881											
27-0038	Brownie	9/9/2014	11:20:24		13	6.68	0	0	6.48	3471	23.7																							
27-0038	Brownie	9/9/2014	11:19:23		14	6.78	0	0	6.49	3497	25.2																							
27-0038	Brownie	10/20/2014	14:19:43	1.62	0	12.77	9.24	89.8	7.79	1517	1.6	8.30	3.93	13.54	0.038	<0.003	0.52	0.598	0.075	205	336	338	36.4											
27-0038	Brownie	10/20/2014	14:19:12		1	12.55	9.2	89	7.75	1515	1.8																							
27-0038	Brownie	10/20/2014	14:18:25		2	11.92	8.94	85.2	7.65	1513	1.6																							
27-0038	Brownie	10/20/2014	14:17:37		3	11.83	7.13	67.8	7.53	1541	1.4																							
27-0038	Brownie	10/20/2014	14:16:28		4	12.1	2.62	25.1	7.27	1897	5.6																							
27-0038	Brownie	10/20/2014	14:15:47		5	10.05	0	0	7.04	2654	16.6																							
27-0038	Brownie	10/20/2014	14:15:02		6	7.3	0	0	6.91	3048	11.6				0.048	<0.003																	
27-0038	Brownie	10/20/2014	14:14:24		7	6.04	0	0	6.83	3208	10																							
27-0038	Brownie	10/20/2014	14:13:33		8	5.77	0	0	6.78	3300	10.4																							
27-0038	Brownie	10/20/2014	14:12:56		9	5.87	0	0	6.75	3376	9.6																							
27-0038	Brownie	10/20/2014	14:12:21		10	6.07	0	0	6.74	3436	9.6																							
27-0038	Brownie	10/20/2014	14:11:47		11	6.49	0	0	6.75	3471	10.6																							
27-0038	Brownie	10/20/2014	14:11:05		12	6.54	0	0	6.79	3515	13.6				6.015	0.019						832	<5.00											
27-0038	Brownie	10/20/2014	14:10:30		13	6.66	0.01	0.1	6.84	3543	17.8																							
27-0038	Brownie	10/20/2014	14:09:48		14	6.74	0	0	6.95	3552	19.6																							
27-0031	Calhoun	2/18/2014	12:21:33		0	0.44	13.5	97.3	8.33	735	171	<0.500	<0.500	<0.500	0.015	0.006	0.91	0.661	0.305	123	148	137											
27-0031	Calhoun	2/18/2014	12:21:16		1	1.56	13.2	97.9	8.30	731	34																							
27-0031	Calhoun	2/18/2014	12:20:52		2	2.06	13.2	98.9	8.27	725	59																							
27-0031	Calhoun	2/18/2014	12:20:33		3	2.25	13.1	99.1	8.24	748	23																							
27-0031	Calhoun	2/18/2014	12:19:49		4	2.35	12.5	94.9	8.19	722	21																							
27-0031	Calhoun	2/18/2014	12:19:24		5	2.43	12.1	92.1	8.13	721	2.9																							
27-0031	Calhoun	2/18/2014	12:18:54		6	2.51	11.8	89.7	8.04	720	3.2				0.016	0.007																	
27-0031	Calhoun	2/18/2014	12:18:26		7	2.59	11.2	85.8	7.97	721	3.0																							
27-0031	Calhoun	2/18/2014	12:17:59		8	2.68	10.9	83.5	7.90	722	3.7																							
27-0031	Calhoun	2/18/2014	12:17:15		9	2.75	9.64	73.9	7.80	725	3.7																							
27-0031	Calhoun	2/18/2014	12:16:32		10	2.78	8.86	68.0	7.76	729	3.9																							
27-0031	Calhoun	2/18/2014	12:15:53		11	2.80	8.84	67.8	7.73	732	3.6																							
27-0031	Calhoun	2/18/2014	12:15:21		12	2.83	8.63	66.3	7.69	735	4.4				0.018	0.013																	
27-0031	Calhoun	2/18/2014	12:14:44		13	2.87	7.75	59.6	7.61	738	4.2																							
27-0031	Calhoun	2/18/2014	12:14:03		14	3.01	4.45	34.3	7.49	739	3.5																							
27-0031	Calhoun	2/18/2014	12:13:13		15	3.00	3.10	23.9	7.42	747	3.0																							
27-0031	Calhoun	2/18/2014	12:12:47		16	3.01	3.83	29.6	7.40	755	3.0																							
27-0031	Calhoun	2/18/2014	12:12:17		17	3.01	3.80	29.3	7.33	766	3.0																							
27-0031	Calhoun	2/18/2014	12:11:48		18	3.01	3.55	27.4	7.32	770	3.2				0.022	0.014																	
27-0031	Calhoun	2/18/2014	12:11:10		19	3.10	2.10	16.2	7.23	795	2.9																							
27-0031	Calhoun	2/18/2014	12:10:20		20	3.16	0.11	0.90	7.15	796	3.2																							
27-0031	Calhoun	2/18/2014	12:10:00		21	3.27	0	0	7.12	802	3.1																							
27-0031	Calhoun	2/18/2014	12:09:37		22	3.36	0	0	7.09	808	3.3				0.042	0.021						132											
27-0031	Calhoun	2/18/2014	12:09:17		23	3.43	0	0	7.07	821	3.4																							
27-0031	Calhoun	5/5/2014	9:50:57	2.92	0	7.61	11.0	94.5	7.99	713	7.4	2.60	0.54	<0.500	0.026	<0.003	0.72	0.746	0.087	117	116	152	7.8											
27-0031	Calhoun	5/5/2014	9:50:15		1	7.59	11.0	94.4	8.00	713	2.6																							
27-0031	Calhoun	5/5/2014	9:49:42		2	7.54	11.0	94.1	7.98	713	2.7																							
27-0031	Calhoun	5/5/2014	9:49:04		3	7.51	11.0	94.1	7.99	713	3.2																							
27-0031	Calhoun	5/5/2014	9:48:16		4	7.41	10.9	92.8	7.96	713	4.0																							
27-0031	Calhoun	5/5/2014	9:47:32		5	6.81	10.8	90.6	7.93	712	6.4																							
27-0031	Calhoun	5/5/2014	9:46:32		6	6.55	10.6	88.9	7.90	712	5.0				0.021	<0.003																	
27-0031	Calhoun	5/5/2014	9:45:51		7	6.46	10.5	88.0	7.88	712	5.7																							
27-0031	Calhoun	5/5/2014	9:44:51		8	6.35	10.4	86.9	7.88	713	3.0																							
27-0031	Calhoun	5/5/2014	9:44:18		9	6.31	10.4	86.7	7.86	713	4.1																							
27-0031	Calhoun	5/5/2014	9:43:16		10	6.27	10.5	87.2	7.84	712	3.8																							
27-0031	Calhoun	5/5/2014	9:42:18		11	6.21	10.4	86.0	7.83	712	4.1																							
27-0031	Calhoun	5/5/2014	9:41:48		12	6.16	10.4	85.9	7.82	712	3.5				0.022	0.003																	
27-0031	Calhoun	5/5/2014	9:41:02		13	6.09	10.3	84.8	7.80	712	3.5																							
27-0031	Calhoun	5/5/2014	9:40:36		14	6.04	10.2	84.3	7.79	713	3.2																							
27-0031	Calhoun	5/5/2014	9:40:06		15	6.03	10.2	84.0	7.78	713	3.0																							
27-0031	Calhoun	5/5/2014	9:39:35		16	6.03	10.2	84.0	7.76	713	3.4																							
27-0031	Calhoun	5/5/2014	9:39:14		17	6.03	10.2	84.0	7.75	713	3.3																							
27-0031	Calhoun	5/5/2014	9:38:33		18	6.02	10.2	83.7	7.73	714	2.8				0.023	<0.003																	
27-0031	Calhoun	5/5/2014	9:38:00		19	6.01	10.1	83.3	7.71	713	2.7																							
27-0031	Calhoun	5/5/2014	9:37:30		20	6.01	10.0	82.7	7.69	714	2.5																							
27-0031	Calhoun	5/5/2014	9:37:02		21	6.00	10.1	82.9	7.67	714	2.5																							
27-0031	Calhoun	5/5/2014	9:36:12		22	6.02	10.0	82.5	7.63	714	2.5				0.017	<0.003						152	<5.00											
27-0031	Calhoun	5/5/2014	9:35:25		23	6.02	10.1	83.2	7.59	714	2.3																							
27-0031	Calhoun	5/5/2014	9:34:52		24	6.03	10.1	83.3	7.54	714	2.0																							
27-0031	Calhoun	5/20/2014	10:45:40	7.95	0	13.26	10.3	102	8.13	702	498	0.70	<0.500		0.019	<0.003		0.774				143											
27-0031	Calhoun	5/20/2014	10:45:01		1	11.26	10.5	99.3	8.11	709	517																							
27-0031	Calhoun	5/20/2014	10:44:11		2	11.03	10.6	98.9	8.09	712	0.0																							
27-0031	Calhoun	5/20/2014	10:43:02		3	11.00	10.6	98.8	8.08	712	0.0																							
27-0031	Calhoun	5/20/2014	10:42:26		4	10.98	10.5	98.4	8.06	711	0.0																							
27-0031	Calhoun	5/20/2014	10:41:42		5	10.95	10.5	98.1	8.05	709	0.0																							
27-0031	Calhoun	5/20/2014	10:41:09		6	10.87	10.5	98.0	8.01	711	0.0				0.020	0.003																	
27-0031	Calhoun	5/20/2014	10:40:23		7	10.64	10.5	97.0	7.97	712	0.0																							
27-0031	Calhoun	5/20/2014	10:39:42		8	10.16	10.3	94.2	7.92	712	0.0																							
27-0031	Calhoun	5/20/2014	10:38:39		9	9.43	10.4	93.8	7.85	720	4.4																							

Underlined data indicates monthly performance standard failure.

Lake ID	Lake Name	MM/DD/YYY	HH:MM:SS	meters	meters	Temp °C	DO mg/L	%DO	pH units	µS/cm	NTU	mg/M3	mg/M3	Silica mg/L	TP mg/L	SRP mg/L	TKN mg/L	TN mg/L	mg/L	Alk mg/L	Hard mg/L	Cl mg/L	SO4 mg/L	mpn/100m	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/	cfu/10
27-0031	Calhoun	5/20/2014	10:37:27		10	7.43	9.14	78.6	7.76	718	0.0																							
27-0031	Calhoun	5/20/2014	10:36:25		11	6.74	9.02	76.2	7.75	719	0.0																							
27-0031	Calhoun	5/20/2014	10:34:51		12	6.66	8.93	75.3	7.74	719	0.0				0.020	0.004																	
27-0031	Calhoun	5/20/2014	10:33:15		13	6.54	8.83	74.3	7.73	721	0.0																							
27-0031	Calhoun	5/20/2014	10:32:30		14	6.50	8.94	75.1	7.72	721	0.0																							
27-0031	Calhoun	5/20/2014	10:31:24		15	6.42	8.49	71.2	7.72	722	0.0																							
27-0031	Calhoun	5/20/2014	10:30:13		16	6.36	8.32	69.6	7.71	722	0.0																							
27-0031	Calhoun	5/20/2014	10:29:36		17	6.38	8.30	69.5	7.71	722	0.0																							
27-0031	Calhoun	5/20/2014	10:28:15		18	6.34	8.33	69.7	7.71	723	0.0				0.018	0.007																	
27-0031	Calhoun	5/20/2014	10:27:08		19	6.34	8.25	69.0	7.71	722	0.0																							
27-0031	Calhoun	5/20/2014	10:26:13		20	6.34	8.24	68.9	7.71	723	0.0																							
27-0031	Calhoun	5/20/2014	10:25:21		21	6.36	8.10	67.8	7.71	722	0.0																							
27-0031	Calhoun	5/20/2014	10:24:22		22	6.36	7.94	66.4	7.72	723	0.0				0.031	0.006						153											
27-0031	Calhoun	5/20/2014	10:23:15		23	6.47	7.73	64.9	7.73	722	0.0																							
27-0031	Calhoun	5/20/2014	10:22:10		24	6.40	7.53	63.1	7.76	724	0.0																							
27-0031	Calhoun	6/11/2014	10:11:17	6.13	0	21.44	9.66	113	8.42	704	0.0	0.77	<0.500	<0.500	0.010	<0.003		0.818				152											
27-0031	Calhoun	6/11/2014	10:10:52		1	21.15	9.74	113	8.43	705	1.1																							
27-0031	Calhoun	6/11/2014	10:10:25		2	21.09	9.63	112	8.44	705	0.0																							
27-0031	Calhoun	6/11/2014	10:09:42		3	20.80	9.60	111	8.41	704	365																							
27-0031	Calhoun	6/11/2014	10:08:57		4	17.80	9.53	104	8.09	726	127																							
27-0031	Calhoun	6/11/2014	10:08:08		5	14.15	10.4	105	8.06	713	155																							
27-0031	Calhoun	6/11/2014	10:07:20		6	12.67	10.3	99.7	8.01	715	23				0.012	<0.003																	
27-0031	Calhoun	6/11/2014	10:05:18		7	11.43	9.44	89.3	7.86	718	9.0																							
27-0031	Calhoun	6/11/2014	10:04:31		8	10.15	8.82	81.0	7.77	720	22																							
27-0031	Calhoun	6/11/2014	10:03:58		9	9.26	7.45	66.9	7.67	723	0.0																							
27-0031	Calhoun	6/11/2014	10:03:12		10	8.18	6.97	61.0	7.62	728	0.0																							
27-0031	Calhoun	6/11/2014	10:02:28		11	7.64	6.65	57.5	7.59	727	0.0																							
27-0031	Calhoun	6/11/2014	10:01:56		12	7.29	6.96	59.6	7.58	726	0.0				0.024	0.012																	
27-0031	Calhoun	6/11/2014	10:01:29		13	6.98	6.72	57.2	7.55	726	0.0																							
27-0031	Calhoun	6/11/2014	10:00:59		14	6.79	6.30	53.3	7.54	728	0.0																							
27-0031	Calhoun	6/11/2014	9:57:37		15	6.76	5.82	49.2	7.50	727	0.0																							
27-0031	Calhoun	6/11/2014	9:57:14		16	6.71	5.57	47.0	7.49	728	0.0																							
27-0031	Calhoun	6/11/2014	9:56:44		17	6.67	5.14	43.4	7.47	729	0.0																							
27-0031	Calhoun	6/11/2014	9:56:04		18	6.61	4.74	39.9	7.45	729	0.0				0.030	0.016																	
27-0031	Calhoun	6/11/2014	9:55:26		19	6.57	4.59	38.7	7.44	731	0.0																							
27-0031	Calhoun	6/11/2014	9:54:48		20	6.52	4.11	34.6	7.43	732	0.0																							
27-0031	Calhoun	6/11/2014	9:54:18		21	6.59	3.89	32.7	7.43	731	0.0																							
27-0031	Calhoun	6/11/2014	9:53:49		22	6.57	3.63	30.5	7.42	732	0.0				0.035	0.025						157											
27-0031	Calhoun	6/11/2014	9:53:05		23	6.78	3.29	27.8	7.42	734	77																							
27-0031	Calhoun	6/25/2014	11:53:14	4.74	0	23.92	9.77	119	8.58	660	0.1	1.60	<0.500		0.013	<0.003		0.701				133											
27-0031	Calhoun	6/25/2014	11:51:37		1	23.90	9.80	119	8.59	660	0.3																							
27-0031	Calhoun	6/25/2014	11:50:14		2	23.67	9.91	120	8.59	658	1.2																							
27-0031	Calhoun	6/25/2014	11:49:01		3	23.25	9.89	119	8.55	658	1.8																							
27-0031	Calhoun	6/25/2014	11:48:10		4	20.69	9.69	111	8.39	682	1.4																							
27-0031	Calhoun	6/25/2014	11:46:58		5	18.67	8.11	89.0	7.82	723	2.4																							
27-0031	Calhoun	6/25/2014	11:45:51		6	17.23	8.97	95.5	8.00	708	1.0				0.022	<0.003																	
27-0031	Calhoun	6/25/2014	11:45:07		7	13.34	8.65	84.8	7.81	726	1.3																							
27-0031	Calhoun	6/25/2014	11:43:59		8	10.84	7.43	68.8	7.69	726	2.8																							
27-0031	Calhoun	6/25/2014	11:42:34		9	10.24	6.87	62.7	7.64	727	2.1																							
27-0031	Calhoun	6/25/2014	11:41:20		10	9.30	5.92	52.8	7.58	728	1.9																							
27-0031	Calhoun	6/25/2014	11:39:35		11	8.53	5.52	48.3	7.53	731	2.5																							
27-0031	Calhoun	6/25/2014	11:38:14		12	7.80	5.27	45.4	7.51	731	3.3				0.021	0.005																	
27-0031	Calhoun	6/25/2014	11:36:48		13	7.46	4.93	42.1	7.49	730	3.4																							
27-0031	Calhoun	6/25/2014	11:35:44		14	7.34	4.82	41.0	7.47	729	3.4																							
27-0031	Calhoun	6/25/2014	11:34:16		15	7.12	4.48	37.9	7.45	731	3.5																							
27-0031	Calhoun	6/25/2014	11:32:48		16	7.07	4.21	35.6	7.45	732	4.4																							
27-0031	Calhoun	6/25/2014	11:31:42		17	7.07	4.08	34.5	7.43	732	3.4																							
27-0031	Calhoun	6/25/2014	11:30:25		18	7.02	3.84	32.5	7.45	733	2.2				0.039	0.025																	
27-0031	Calhoun	6/25/2014	11:29:22		19	6.96	3.75	31.6	7.46	731	1.9																							
27-0031	Calhoun	6/25/2014	11:28:37		20	6.94	3.72	31.4	7.47	730	1.9																							
27-0031	Calhoun	6/25/2014	11:27:47		21	6.98	3.65	30.8	7.47	731	1.5																							
27-0031	Calhoun	6/25/2014	11:26:37		22	7.24	3.47	29.5	7.50	732	0.2				0.077	0.033						143											
27-0031	Calhoun	6/25/2014	11:25:32		23	7.00	3.24	27.3	7.53	731	0.0																							
27-0031	Calhoun	7/7/2014	10:00:31	4.27	0	23.37	9.34	114	8.67	670	8.4	3.60	0.80	1.26	0.015	<0.003	<0.500	0.623	0.229	110	136	129											
27-0031	Calhoun	7/7/2014	9:59:30		1	23.34	9.34	114	8.67	670	29																							
27-0031	Calhoun	7/7/2014	9:58:41		2	23.31	9.36	114	8.67	670	224																							
27-0031	Calhoun	7/7/2014	9:57:59		3	23.27	9.39	114	8.67	670	78																							
27-0031	Calhoun	7/7/2014	9:56:54		4	23.18	9.34	113	8.65	670	162																							
27-0031	Calhoun	7/7/2014	9:56:07		5	21.86	8.72	103	8.37	684	190																							
27-0031	Calhoun	7/7/2014	9:55:12		6	18.10	8.58	94.1	7.86	737	5.8				0.014	<0.003																	
27-0031	Calhoun	7/7/2014	9:53:39		7	14.21	8.48	85.7	7.82	717	28																							
27-0031	Calhoun	7/7/2014	9:52:50		8	11.16	6.86	64.7	7.68	722	9.0																							
27-0031	Calhoun	7/7/2014	9:51:19		9	10.05	5.64	51.8	7.59	726	19																							
27-0031	Calhoun	7/7/2014	9:50:23		10	9.36	5.10	46.0	7.55	728	2.6																							
27-0031	Calhoun	7/7/2014	9:48:38		11	9.02	4.22	37.8	7.52	728	5.1																							
27-0031	Calhoun	7/7/2014	9:47:44		12	8.43	4.21	37.2	7.50	730	3.8				0.013	<0.003																	
27-0031	Calhoun	7/7/2014	9:46:55		13	8.00	4.22	36.9	7.48	726	4.1																							
27-0031	Calhoun	7/7/2014	9:45:44		14	7.54	3.97	34.3	7.46	726	4.7																							
27-0031	Calhoun	7/7/2014	9:44:33		15	7.37	3.78	32.5	7.45	728	4.6																							
27-0031	Calhoun	7/7/2014	9:43:21		16	7.25	3.21	27.6	7.43	729	4.5																							

Underlined data indicates monthly performance standard failure.

Lake ID	Lake Name	MM/DD/YYY	HH:MM:SS	meters	meters	Temp °C	DO mg/L	%DO	pH units	µS/cm	NTU	mg/M3	mg/M3	Silica mg/L	TP mg/L	SRP mg/L	TKN mg/L	TN mg/L	mg/L	Alk mg/L	Hard mg/L	Cl mg/L	SO4 mg/L	mpn/100m	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/	cfu/10
27-0031	Calhoun	7/7/2014	9:42:01		17	7.19	2.99	25.6	7.42	730	4.2																							
27-0031	Calhoun	7/7/2014	9:41:00		18	7.18	2.77	23.7	7.42	728	4.9				0.034	0.019																		
27-0031	Calhoun	7/7/2014	9:40:04		19	7.10	2.36	20.2	7.41	730	5.0																							
27-0031	Calhoun	7/7/2014	9:39:26		20	7.11	2.35	20.1	7.41	730	3.5																							
27-0031	Calhoun	7/7/2014	9:38:28		21	7.04	2.16	18.4	7.38	730	4.4																							
27-0031	Calhoun	7/7/2014	9:37:58		22	7.07	2.13	18.2	7.37	729	3.6				0.064	0.047						158												
27-0031	Calhoun	7/7/2014	9:36:58		23	7.00	1.97	16.8	7.26	731	6.6																							
27-0031	Calhoun	7/21/2014	10:20:51	3.00	0	23.48	9.51	115	8.79	672	0.0	4.60	1.41		0.016	<0.003		<0.500				136												
27-0031	Calhoun	7/21/2014	10:19:55		1	23.16	9.64	116	8.80	672	2.4																							
27-0031	Calhoun	7/21/2014	10:18:50		2	22.94	9.64	116	8.79	673	2.5																							
27-0031	Calhoun	7/21/2014	10:17:45		3	22.88	9.58	115	8.78	674	2.9																							
27-0031	Calhoun	7/21/2014	10:16:27		4	22.78	9.51	114	8.76	673	2.7																							
27-0031	Calhoun	7/21/2014	10:15:35		5	21.85	9.06	106	8.60	684	2.9																							
27-0031	Calhoun	7/21/2014	10:14:32		6	21.44	8.24	96.1	8.34	696	4.9				0.018	<0.003																		
27-0031	Calhoun	7/21/2014	10:13:22		7	15.71	6.53	67.7	7.76	726	5.3																							
27-0031	Calhoun	7/21/2014	10:12:28		8	12.32	4.69	45.2	7.70	728	6.5																							
27-0031	Calhoun	7/21/2014	10:09:40		9	10.58	4.14	38.3	7.65	730	0.0																							
27-0031	Calhoun	7/21/2014	10:08:22		10	9.50	2.65	23.9	7.61	733	0.0																							
27-0031	Calhoun	7/21/2014	10:07:46		11	8.97	1.61	14.3	7.59	734	0.0																							
27-0031	Calhoun	7/21/2014	10:07:10		12	8.30	2.08	18.2	7.60	733	0.0				0.017	<0.003																		
27-0031	Calhoun	7/21/2014	10:06:17		13	8.02	2.20	19.1	7.60	732	0.0																							
27-0031	Calhoun	7/21/2014	10:05:00		14	7.70	1.90	16.4	7.60	733	0.0																							
27-0031	Calhoun	7/21/2014	10:04:01		15	7.40	1.64	14.0	7.60	732	0.0																							
27-0031	Calhoun	7/21/2014	10:02:48		16	7.28	1.39	11.9	7.60	731	0.0																							
27-0031	Calhoun	7/21/2014	10:01:43		17	7.18	0.53	4.5	7.60	733	0.0																							
27-0031	Calhoun	7/21/2014	10:00:39		18	7.01	0	0	7.60	734	0.0				0.019	0.003																	
27-0031	Calhoun	7/21/2014	10:00:23		19	6.98	0	0	7.60	736	0.0																							
27-0031	Calhoun	7/21/2014	9:59:45		20	6.98	0	0	7.59	735	0.0																							
27-0031	Calhoun	7/21/2014	9:59:17		21	6.99	0	0	7.58	735	0.0																							
27-0031	Calhoun	7/21/2014	9:58:08		22	6.96	0	0	7.56	737	0.0				0.076	0.057						156												
27-0031	Calhoun	7/21/2014	9:57:50		23	6.92	0	0	7.54	736	0.0																							
27-0031	Calhoun	7/21/2014	9:57:22		24	6.93	0	0	7.53	738	0.0																							
27-0031	Calhoun	8/5/2014	9:47:24	3.35	0	25.02	9.62	119	8.87	666	1.9	1.68	0.56	1.70	0.018	0.005		<0.500				140												
27-0031	Calhoun	8/5/2014	9:45:41		1	25.01	9.65	119	8.86	665	1.4																							
27-0031	Calhoun	8/5/2014	9:45:13		2	24.94	9.69	120	8.85	665	1.6																							
27-0031	Calhoun	8/5/2014	9:44:49		3	24.91	9.72	120	8.83	664	1.5																							
27-0031	Calhoun	8/5/2014	9:43:59		4	23.90	8.81	107	8.59	673	2.6																							
27-0031	Calhoun	8/5/2014	9:42:55		5	23.07	7.84	93.4	8.15	693	1.8																							
27-0031	Calhoun	8/5/2014	9:41:46		6	19.89	5.17	57.9	7.80	750	2.4				0.025	0.004																		
27-0031	Calhoun	8/5/2014	9:40:51		7	15.55	2.33	23.9	7.74	739	0.0																							
27-0031	Calhoun	8/5/2014	9:40:07		8	12.65	1.23	11.8	7.72	729	0.0																							
27-0031	Calhoun	8/5/2014	9:39:16		9	10.48	0.90	8.20	7.70	735	0.0																							
27-0031	Calhoun	8/5/2014	9:38:23		10	9.61	0	0	7.67	736	0.0																							
27-0031	Calhoun	8/5/2014	9:38:01		11	8.92	0	0	7.66	735	0.0																							
27-0031	Calhoun	8/5/2014	9:37:10		12	8.49	1.19	10.4	7.69	732	0.0				0.022	0.004																		
27-0031	Calhoun	8/5/2014	9:35:59		13	8.15	0.03	0.30	7.66	732	0.0																							
27-0031	Calhoun	8/5/2014	9:35:17		14	7.81	0	0	7.64	732	0.0																							
27-0031	Calhoun	8/5/2014	9:34:53		15	7.48	0	0	7.63	732	0.0																							
27-0031	Calhoun	8/5/2014	9:34:32		16	7.36	0	0	7.63	732	0.0																							
27-0031	Calhoun	8/5/2014	9:34:15		17	7.29	0	0	7.62	732	0.0																							
27-0031	Calhoun	8/5/2014	9:33:55		18	7.28	0	0	7.62	733	0.0				0.023	0.007																		
27-0031	Calhoun	8/5/2014	9:33:33		19	7.22	0	0	7.62	733	0.0																							
27-0031	Calhoun	8/5/2014	9:33:01		20	7.05	0	0	7.60	735	0.0																							
27-0031	Calhoun	8/5/2014	9:32:28		21	7.00	0	0	7.59	736	0.6																							
27-0031	Calhoun	8/5/2014	9:31:55		22	7.04	0	0	7.59	736	0.0				0.097	0.072						151												
27-0031	Calhoun	8/5/2014	9:31:08		23	7.00	0	0	7.58	737	11																							
27-0031	Calhoun	8/20/2014	11:09:07	3.10	0	24.99	9.09	114	8.82	671	2.6	2.30	1.78		0.015	0.003		0.397				139		4										
27-0031	Calhoun	8/20/2014	11:08:33		1	24.84	9.28	116	8.84	672	1.9																							
27-0031	Calhoun	8/20/2014	11:07:46		2	24.70	9.25	115	8.85	671	1.7																							
27-0031	Calhoun	8/20/2014	11:06:58		3	24.55	9.20	114	8.82	672	1.7																							
27-0031	Calhoun	8/20/2014	11:06:14		4	23.66	8.65	106	8.60	690	0.7																							
27-0031	Calhoun	8/20/2014	11:05:17		5	22.97	7.29	87.7	8.30	709	1.0																							
27-0031	Calhoun	8/20/2014	11:04:16		6	20.10	3.50	39.9	7.86	749	1.0				0.024	0.003																		
27-0031	Calhoun	8/20/2014	11:02:55		7	16.08	0.12	1.30	7.78	748	0.0																							
27-0031	Calhoun	8/20/2014	11:02:03		8	12.90	0	0	7.77	745	0.0																							
27-0031	Calhoun	8/20/2014	11:01:01		9	9.99	0	0	7.71	739	0.0																							
27-0031	Calhoun	8/20/2014	11:00:23		10	9.40	0	0	7.70	739	0.0																							
27-0031	Calhoun	8/20/2014	10:59:42		11	8.92	0	0	7.69	736	0.0																							
27-0031	Calhoun	8/20/2014	10:58:54		12	8.51	0	0	7.69	736	0.0				0.014	0.003																		
27-0031	Calhoun	8/20/2014	10:58:00		13	7.92	0	0	7.68	733	0.0																							
27-0031	Calhoun	8/20/2014	10:56:53		14	7.63	0	0	7.67	731	0.0																							
27-0031	Calhoun	8/20/2014	10:55:44		15	7.34	0	0	7.66	732	0.0																							
27-0031	Calhoun	8/20/2014	10:54:56		16	7.18	0	0	7.65	734	0.0																							
27-0031	Calhoun	8/20/2014	10:54:13		17	7.09	0	0	7.65	736	0.0																							
27-0031	Calhoun	8/20/2014	10:53:33		18	7.11	0	0	7.64	735	0.0				0.068	0.040																		
27-0031	Calhoun	8/20/2014	10:52:54		19	7.04	0	0	7.64	737	0.0																							
27-0031	Calhoun	8/20/2014	10:52:10		20	7.00	0	0	7.64	737	0.0																							
27-0031	Calhoun	8/20/2014	10:50:54		21	7.14	0	0	7.67	736	1.3																							
27-0031	Calhoun	8/20/2014	10:49:38		22	7.24	0	0	7.71	737	9.4				0.101	0.081						149												
27-0031	Calhoun	9/9/2014	10:07:20	2.60	0	21.42	8.36	97.5	8.61	679.3	4.1	11.80	<0.500	2.20	0.017	0.006		<0.500				140												

Underlined data indicates monthly performance standard failure.

Lake ID	Lake Name	MM/DD/YYY	HH:MM:SS	meters	meters	Temp °C	DO mg/L	%DO	pH units	µS/cm	NTU	mg/M3	mg/M3	Silica mg/L	TP mg/L	SRP mg/L	TKN mg/L	TN mg/L	mg/L	Alk mg/L	Hard mg/L	Cl mg/L	SO4 mg/L	mpn/100m	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/	cfu/10
27-0031	Calhoun	9/9/2014	10:06:39		1	21.43	8.3	96.9	8.61	679.4	7.1																							
27-0031	Calhoun	9/9/2014	10:06:15		2	21.44	8.29	96.7	8.6	679.5	7.3																							
27-0031	Calhoun	9/9/2014	10:05:30		3	21.42	8.34	97.2	8.59	679.8	7.2																							
27-0031	Calhoun	9/9/2014	10:04:49		4	21.41	8.19	95.6	8.58	680.5	8.6																							
27-0031	Calhoun	9/9/2014	10:04:02		5	21.41	7.98	93.1	8.55	681.5	11.6																							
27-0031	Calhoun	9/9/2014	10:02:39		6	21.26	7.33	85.3	8.42	686.1	2.3				0.024	0.003																	
27-0031	Calhoun	9/9/2014	10:01:27		7	18.99	0.68	7.5	7.67	743.3	6.3																							
27-0031	Calhoun	9/9/2014	10:00:40		8	13.29	0	0	7.62	745.1	4.6																							
27-0031	Calhoun	9/9/2014	10:00:14		9	10.88	0	0	7.56	744	6.4																							
27-0031	Calhoun	9/9/2014	9:59:38		10	9.82	0	0	7.5	740.8	8.5																							
27-0031	Calhoun	9/9/2014	9:59:14		11	9.16	0	0	7.48	740.3	8.1																							
27-0031	Calhoun	9/9/2014	9:58:37		12	8.53	0	0	7.47	736.2	5.7				0.018	0.004																	
27-0031	Calhoun	9/9/2014	9:58:14		13	7.93	0	0	7.46	734.4	8.4																							
27-0031	Calhoun	9/9/2014	9:57:53		14	7.62	0	0	7.45	733.1	6.7																							
27-0031	Calhoun	9/9/2014	9:57:26		15	7.44	0	0	7.44	734.3	7.9																							
27-0031	Calhoun	9/9/2014	9:57:04		16	7.29	0	0	7.42	735.5	7.9																							
27-0031	Calhoun	9/9/2014	9:56:44		17	7.16	0	0	7.4	737.3	7.1																							
27-0031	Calhoun	9/9/2014	9:56:22		18	7.14	0	0	7.4	738.3	6.7				0.125	0.090																	
27-0031	Calhoun	9/9/2014	9:56:00		19	7.12	0	0	7.4	738.2	6.5																							
27-0031	Calhoun	9/9/2014	9:55:37		20	7.13	0	0	7.41	737.9	8.2																							
27-0031	Calhoun	9/9/2014	9:55:02		21	7.1	0	0	7.42	738.1	7.2																							
27-0031	Calhoun	9/9/2014	9:54:34		22	7.29	0	0	7.42	735	401				0.149	0.114						150											
27-0031	Calhoun	9/22/2014	10:21:48	4.30	0	17.94	9.13	98	8.71	682.7	371.5	0.82	0.60		0.017	0.015		<0.500				144											
27-0031	Calhoun	9/22/2014	10:21:23		1	17.93	9.14	98.1	8.71	682.1	359.8																							
27-0031	Calhoun	9/22/2014	10:20:50		2	17.89	9.14	98	8.7	681.6	361.6																							
27-0031	Calhoun	9/22/2014	10:20:11		3	17.85	9.18	98.3	8.7	681.7	54.9																							
27-0031	Calhoun	9/22/2014	10:19:27		4	17.83	9.11	97.5	8.71	682	58.3																							
27-0031	Calhoun	9/22/2014	10:18:47		5	17.8	9.13	97.7	8.7	681.6	91.2																							
27-0031	Calhoun	9/22/2014	10:17:58		6	17.79	9.1	97.4	8.7	681.5	10				0.015	0.005																	
27-0031	Calhoun	9/22/2014	10:16:12		7	17.75	9.03	96.6	8.69	681.8	11.5																							
27-0031	Calhoun	9/22/2014	10:13:41		8	15.35	2.33	23.6	7.84	717.4	8.5																							
27-0031	Calhoun	9/22/2014	10:12:31		9	11.61	0.09	0.9	7.66	739.1	11.1																							
27-0031	Calhoun	9/22/2014	10:10:22		10	9.85	0	0	7.62	734.6	23.4																							
27-0031	Calhoun	9/22/2014	10:08:41		11	9.18	0	0	7.58	736.1	42.8																							
27-0031	Calhoun	9/22/2014	10:06:57		12	8.77	0	0	7.58	734.7	18.4				0.022	0.005																	
27-0031	Calhoun	9/22/2014	10:06:02		13	8.3	0	0	7.58	731.2	6.4																							
27-0031	Calhoun	9/22/2014	10:05:08		14	7.77	0	0	7.56	729.3	7.1																							
27-0031	Calhoun	9/22/2014	10:04:23		15	7.51	0	0	7.53	730.3	6.3																							
27-0031	Calhoun	9/22/2014	10:03:49		16	7.36	0	0	7.51	731.5	6.7																							
27-0031	Calhoun	9/22/2014	10:03:00		17	7.25	0	0	7.49	732.1	6.7																							
27-0031	Calhoun	9/22/2014	10:02:16		18	7.18	0	0	7.48	733.8	7.4				0.107	0.080																	
27-0031	Calhoun	9/22/2014	10:01:33		19	7.14	0	0	7.48	734	7.3																							
27-0031	Calhoun	9/22/2014	9:59:33		20	7.15	0	0	7.48	734.1	8.2																							
27-0031	Calhoun	9/22/2014	9:59:04		21	7.14	0	0	7.47	733.9	7.2																							
27-0031	Calhoun	9/22/2014	9:58:22		22	7.09	0	0	7.47	734.9	6.7				0.141	0.114						149											
27-0031	Calhoun	9/22/2014	9:57:30		23	7.16	0	0	7.49	733.8	7																							
27-0031	Calhoun	10/20/2014	11:58:32	4.05	0	12.53	9.67	93.2	8.52	716.9	5.5	3.10	2.05	1.30	0.020	<0.003	<0.500	0.659	0.155	120	144	142	8.0											
27-0031	Calhoun	10/20/2014	11:58:06		1	12.48	9.66	93	8.52	717.1	117.7																							
27-0031	Calhoun	10/20/2014	11:57:24		2	12.46	9.68	93.2	8.52	717.3	2.8																							
27-0031	Calhoun	10/20/2014	11:56:49		3	12.46	9.68	93.1	8.53	717.3	3.2																							
27-0031	Calhoun	10/20/2014	11:56:16		4	12.41	9.69	93.1	8.52	716.6	2.4																							
27-0031	Calhoun	10/20/2014	11:55:32		5	12.35	9.51	91.3	8.49	717.3	2.4																							
27-0031	Calhoun	10/20/2014	11:54:57		6	12.34	9.55	91.6	8.48	716.7	5.2				0.022	<0.003																	
27-0031	Calhoun	10/20/2014	11:54:13		7	12.33	9.51	91.2	8.48	716.9	4.8																							
27-0031	Calhoun	10/20/2014	11:53:37		8	12.32	9.53	91.5	8.47	717.6	2.6																							
27-0031	Calhoun	10/20/2014	11:52:59		9	12.32	9.49	91	8.46	717.6	4																							
27-0031	Calhoun	10/20/2014	11:52:06		10	12.32	9.36	89.8	8.41	717.5	4.5																							
27-0031	Calhoun	10/20/2014	11:51:26		11	12.25	8.96	85.8	8.3	718.2	4.7																							
27-0031	Calhoun	10/20/2014	11:50:29		12	10.49	0	0	7.69	747.5	6.3				0.021	<0.003																	
27-0031	Calhoun	10/20/2014	11:49:43		13	8.65	0	0	7.65	753.6	6.1																							
27-0031	Calhoun	10/20/2014	11:48:47		14	7.93	0	0	7.61	753.9	5.7																							
27-0031	Calhoun	10/20/2014	11:47:59		15	7.59	0	0	7.57	754.7	6.2																							
27-0031	Calhoun	10/20/2014	11:47:16		16	7.42	0	0	7.55	755.2	6.5																							
27-0031	Calhoun	10/20/2014	11:46:36		17	7.28	0	0	7.52	757	6.3																							
27-0031	Calhoun	10/20/2014	11:45:55		18	7.23	0	0	7.51	758.2	6.5				0.114	0.094																	
27-0031	Calhoun	10/20/2014	11:45:18		19	7.2	0	0	7.5	757.9	6.2																							
27-0031	Calhoun	10/20/2014	11:44:39		20	7.17	0	0	7.48	758.5	6.1																							
27-0031	Calhoun	10/20/2014	11:44:03		21	7.16	0	0	7.47	759	5.4																							
27-0031	Calhoun	10/20/2014	11:43:20		22	7.18	0	0	7.45	758.9	5.5				0.167	0.139						147	5.7										
27-0031	Calhoun	10/20/2014	11:42:38		23	7.15	0	0	7.44	759.3	5.3																							
27-0031	Calhoun	10/20/2014	11:41:49		24	7.16	0	0	7.43	759.8	4.1																							
27-0039	Cedar	3/12/2014	11:43:18		0	0.30	6.18	43.5	7.39	717	3.0	<0.500	<0.500	1.28	0.135	0.023	1.37	0.792	0.577	134	164	129											
27-0039	Cedar	3/12/2014	11:42:50		1	1.67	5.82	42.6	7.36	743	2.3																							
27-0039	Cedar	3/12/2014	11:42:01		2	2.72	5.17	39.0	7.34	741	2.0																							
27-0039	Cedar	3/12/2014	11:41:19		3	2.87	4.74	35.9	7.32	739	2.4																							
27-0039	Cedar	3/12/2014	11:40:37		4	3.00	4.24	32.1	7.29	739	1.9																							
27-0039	Cedar	3/12/2014	11:39:26		5	3.07	3.36	25.5	7.26	740	1.9				0.174	0.027																	
27-0039	Cedar	3/12/2014	11:38:38		6	3.14	2.69	20.5	7.22	747	1.6																							
27-0039	Cedar	3/12/2014	11:38:07		7	3.26	1.01	7.70	7.20	748	2.6																							
27-0039	Cedar	3/12/2014	11:37:31		8	3.33	0.02	0.20	7.18	751	3.1																							

Underlined data indicates monthly performance standard failure.

Lake ID	**Lake Name**	MM/DD/YYY	HH:MM:SS	meters	meters	**Temp** °C	**DO** mg/L	**%DO**	**pH** units	µS/cm	NTU	mg/M3	mg/M3	**Silica** mg/L	**TP** mg/L	**SRP** mg/L	**TKN** mg/L	**TN** mg/L	mg/L	**Alk** mg/L	**Hard** mg/L	**Cl** mg/L	**SO4** mg/L	mpn/100m	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/	cfu/10
27-0039	Cedar	3/12/2014	11:37:07		9	3.39	0	0	7.17	752	4.0																								
27-0039	Cedar	3/12/2014	11:36:37		10	3.42	0	0	7.12	755	4.5				0.182	0.045																			
27-0039	Cedar	3/12/2014	11:36:05		11	3.47	0	0	7.13	759	5.2																								
27-0039	Cedar	3/12/2014	11:34:57		12	3.57	0	0	7.07	765	6.4																								
27-0039	Cedar	3/12/2014	11:34:23		13	3.51	0	0	7.04	776	5.0																								
27-0039	Cedar	3/12/2014	11:33:45		14	3.38	0	0	7.01	792	42				0.192	0.059						138												
27-0039	Cedar	5/5/2014	10:58:58	1.41	0	8.99	12.6	111	8.64	0	3.5	5.47	5.10	<0.500	0.052	0.003	1.00	1.180	0.144	122	152	162	9.2											
27-0039	Cedar	5/5/2014	10:58:27		1	9.17	12.4	111	8.29	701	3.5																								
27-0039	Cedar	5/5/2014	10:57:29		2	8.66	12.2	108	8.24	699	3.9																								
27-0039	Cedar	5/5/2014	10:55:51		3	7.83	11.6	99.9	8.09	699	2.8																								
27-0039	Cedar	5/5/2014	10:54:29		4	7.56	10.8	92.3	7.97	698	3.3																								
27-0039	Cedar	5/5/2014	10:53:39		5	7.43	10.4	88.7	7.93	698	3.6				0.033	0.005																			
27-0039	Cedar	5/5/2014	10:52:39		6	7.24	10.3	87.4	7.88	702	3.1																								
27-0039	Cedar	5/5/2014	10:51:40		7	7.08	9.59	81.3	7.83	702	3.6																								
27-0039	Cedar	5/5/2014	10:50:41		8	6.91	9.34	78.8	7.78	703	3.5																								
27-0039	Cedar	5/5/2014	10:49:47		9	6.77	8.85	74.4	7.74	704	4.4																								
27-0039	Cedar	5/5/2014	10:48:45		10	6.35	7.56	62.9	7.68	710	3.9				0.030	0.005																			
27-0039	Cedar	5/5/2014	10:47:38		11	6.26	7.40	61.5	7.65	711	3.1																								
27-0039	Cedar	5/5/2014	10:46:03		12	4.99	2.25	18.1	7.49	745	4.6																								
27-0039	Cedar	5/5/2014	10:43:55		13	4.10	0	0	7.52	797	14																								
27-0039	Cedar	5/5/2014	10:43:24		14	3.96	0	0	7.52	821	16																								
27-0039	Cedar	5/5/2014	10:43:02		15	3.95	0	0	7.54	833	18				0.114	0.025						162	8.4												
27-0039	Cedar	5/5/2014	10:42:44		16	3.99	0	0	7.57	840	19																								
27-0039	Cedar	5/20/2014	12:28:04	1.10	0	13.94	13.4	134	9.03	680	0.0	3.30	1.23		0.052	<0.003		0.964				133													
27-0039	Cedar	5/20/2014	12:27:23		1	13.41	13.1	130	8.99	680	0.6																								
27-0039	Cedar	5/20/2014	12:26:19		2	13.32	12.5	123	8.93	680	0.0																								
27-0039	Cedar	5/20/2014	12:25:29		3	12.75	12.4	121	8.79	671	0.0																								
27-0039	Cedar	5/20/2014	12:24:27		4	11.96	10.8	103	8.39	682	0.0																								
27-0039	Cedar	5/20/2014	12:23:23		5	9.56	8.35	75.6	7.81	704	0.0				0.044	<0.003																			
27-0039	Cedar	5/20/2014	12:21:54		6	7.74	7.01	60.7	7.65	706	0.0																								
27-0039	Cedar	5/20/2014	12:20:01		7	7.12	6.94	59.2	7.64	706	0.0																								
27-0039	Cedar	5/20/2014	12:18:38		8	6.83	6.09	51.6	7.64	709	0.0																								
27-0039	Cedar	5/20/2014	12:17:32		9	6.57	5.50	46.3	7.65	711	0.0																								
27-0039	Cedar	5/20/2014	12:15:41		10	6.27	3.89	32.5	7.75	718	0.0				0.025	<0.003																			
27-0039	Cedar	5/20/2014	12:13:19		11	6.12	3.07	25.6	7.49	722	0.0																								
27-0039	Cedar	5/20/2014	12:11:12		12	5.73	1.22	10.1	7.49	734	0.0																								
27-0039	Cedar	5/20/2014	12:09:28		13	5.48	0	0	7.51	747	3.0																								
27-0039	Cedar	5/20/2014	12:08:34		14	5.35	0	0	7.54	764	13																								
27-0039	Cedar	5/20/2014	12:07:06		15	4.97	0	0	7.59	778	16				0.096	0.012						148												
27-0039	Cedar	6/11/2014	11:28:52	3.85	0	22.63	9.68	116	8.11	651	0.0	2.40	0.50	<0.500	0.020	<0.003		0.855				131												
27-0039	Cedar	6/11/2014	11:28:20		1	22.54	9.71	116	8.13	650	0.0																								
27-0039	Cedar	6/11/2014	11:27:26		2	22.00	9.47	112	8.10	650	0.0																								