2016 Lakes Monitoring Report

MARCH 2017

Prepared By: CAPITOL REGION WATERSHED DISTRICT

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Dear Stakeholders and Interested Parties:

I am pleased to provide to you a copy of our *2016 Lakes Monitoring Report*. Capitol Region Watershed District's (CRWD) 2016 monitoring program was enhanced by the contributions of numerous agencies and individuals, most notably: Ramsey County Environmental Services Staff, John Manske; and Ramsey Conservation District, Andrea Prichard.

Prior to 2013, CRWD reported District lake water quality data within the larger monitoring report that included stormwater data. For the fourth time in 2016, the District produced a stand-alone Lakes Monitoring Report. The report comprehensively reports chemical, physical, and biological data for each District lake, which provides a complete picture of factors influencing lake water quality and overall lake health. Data contained in this report will support ongoing future lake and watershed management decisions.

I would also like to recognize staff who assisted with the preparation of this report. Britta Suppes, Sarah Wein, Maddie Vargo, Joe Sellner, and Mike Sousa had a major role in analyzing and reporting the data.

The *2016 Lakes Monitoring Report* is available at the District's website: www.capitolregionwd.org/press/crwd-reports. If you have any questions pertaining to this report, contact District Monitoring Coordinator, Britta Suppes at (651) 644-8888 or britta@capitolregionwd.org.

Sincerely,

Bob Fossum
Water Resource Program Manager

enc: Capitol Region Watershed District's *2016 Lakes Monitoring Report*

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ACRONYMS AND ABBREVIATIONS

ac	Acre
BMP	Best Management Practice
Chl-a	Chlorophyll-a
Cl	Chloride
CRWD	Capitol Region Watershed District
CS	Chronic Standard
DNR	Department of Natural Resources
DO	Dissolved Oxygen
E. coli	*Escherichia coliform*
EPA	Environmental Protection Agency
ft	Foot/Feet
GPS	Global Positioning System
ha	Hectare
IBI	Index of Biological Integrity
in	Inch
kg	Kilogram
L	Liter
lb	Pound
m	Meter
MCES	Metropolitan Council Environmental Services
MCWG	Minnesota Climatological Working Group
mg	Milligram
mL	Milliliter
MnDOT	Minnesota Department of Transportation
MPCA	Minnesota Pollution Control Agency
MPN	Most probable number
MS4	Municipal Separate Storm Sewer System
MSP	Minneapolis-St. Paul International Airport
NA	Not Available
NCHF	North Central Hardwood Forest
NH_3	Ammonia
NO_2	Nitrite
NO_3	Nitrate
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
OHWL	Ordinary High Water Level
Ortho-P	Ortho-phosphate
RCD	Ramsey Conservation District
RCLML	Ramsey County Lake Management Laboratory

RCPW	Ramsey County Public Works
sec	Second
SRP	Soluble Reactive Phosphorus
TB	Trout Brook
TBI	Trout Brook Storm Sewer Interceptor
TKN	Total Kjeldahl Nitrogen
TN	Total Nitrogen
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
TSS	Total Suspended Solids
µg/L	Micrograms per liter
UMN	University of Minnesota-St. Paul Campus
WD	Watershed District
WMO	Watershed Management Organization

DEFINITIONS

Bathymetric – the measurement of water depth in a body of water.

Benthic – the ecological region at the bottom of a body of water.

Biomanipulation – the deliberate alteration of an ecosystem by adding or removing species.

Bioturbation – the disturbance of sedimentary deposits (as in a lake bottom) by moving organisms, such as fish.

Class 2 Waters – waters of the State that are designated for aquatic life and recreational use.

Chlorophyll-a – a type of chlorophyll pigment found in plants used in oxygenic photosynthesis; used as a measure of phytoplankton production in lakes and streams.

Conductivity – the measure of the ability of water to pass an electrical current; affected by the presence of inorganic dissolved solids and temperature.

Designated Use – the water quality standards regulation requires that States and authorized Indian Tribes specify appropriate water uses to be achieved and protected.

Epilimnion – the top layer of water in a lake, characterized in the summer by warm, circulating water. MPCA lake standards are based on water sampled from this layer.

Eutrophic – a water body with high nutrient concentrations and primary biological productivity. These waters are murky and an extensive macrophyte population. Algal blooms are common.

Fingerling – fish harvested from rearing ponds after one summer of growth.

Fry – newly hatched fish ready to be stocked.

Hypereutrophic – a water body with excessive nutrient concentrations and primary biological productivity. These waters are characterized by very murky water, frequent algal blooms and fish kills, foul odor, and rough (or less desirable) fish.

Hypolimnion – the part of a lake below the thermocline made up of water that is stagnant and of essentially uniform temperature except during the period of overturn.

Impaired Waters – waters that are not meeting their designated uses because of excess pollutants violating water quality standards.

Littoral Area/Zone – the area of a lake less than 15 feet in depth where the majority of plants are found.

Mesotrophic – a water body that has intermediate nutrient concentrations and primary biological productivity. These waters are moderately clear and are characterized by late-summer algal blooms, moderate macrophyte populations, and occasional fish kills.

Morphometric – describing parameters relating to external form.

Oligotrophic – a water body that has low nutrient concentrations and primary biological productivity, and is characterized by clear water, few macrophytes, and salmonid fish.

Ordinary High Water Level – highest water level that has been maintained for a sufficient period of time to leave evidence upon the landscape, commonly the point where the natural vegetation changes from predominantly aquatic to predominantly terrestrial.

Phytoplankton – autotrophic plant members of the plankton (drifting organisms) community.

Secchi depth – a measure of the transparency of lake water using a Secchi disk.

Senescence – the condition or process of cellular deterioration, such as plant decomposition.

Stormwater – water that becomes runoff on a landscape during a precipitation event.

Stormwater Best Management Practices – activities, practices, and structures designed to reduce stormwater pollution and runoff volume and increase groundwater recharge.

Subwatershed – a delineated area of land within a larger watershed where surface waters and runoff drain to a single point before ultimately discharging from the encompassing watershed.

Thermal stratification – refers to the changes in temperature at different depths in a lake as a result of the different densities of water at different temperatures.

Thermocline – the region in a thermally stratified body of water which separates warmer surface water from cold deep water and in which temperature decreases rapidly with depth.

Total Maximum Daily Load – the maximum amount of a substance that can be received by a water body while still meeting water quality standards. This may also refer to the allocation of acceptable portions of this load to different sources.

Turbidity – a measure of the relative clarity of a liquid. Turbidity measurements can provide a simple indicator of potential pollution in a sample. Turbid water will appear cloudy or hazy.

Watershed – a delineated area of land where surface waters and runoff drain to a single point at a lower elevation.

Zooplankton – the heterotrophic animal members of the plankton (drifting organisms) community.

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1 EXECUTIVE SUMMARY

1.1 CAPITOL REGION WATERSHED DISTRICT

Capitol Region Watershed District (CRWD) in Ramsey County, Minnesota is a special purpose unit of government that manages, protects, and improves water resources within its watershed boundaries. CRWD is a 41 square mile subwatershed nested in the Upper Mississippi River basin that contains portions of five cities, including: Falcon Heights, Lauderdale, Maplewood, Roseville, and Saint Paul. CRWD is highly urbanized with a population of 245,000 and 42% impervious surface coverage. All runoff from CRWD eventually discharges to the Mississippi River from 42 outfall locations within the District.

One goal of CRWD is to understand and address the presence of pollutants and their impacts on water quality within the District in order to better protect, restore, and manage local water resources. To address this goal, CRWD established a monitoring program in 2004 to begin assessing water quality and quantity of various District subwatersheds and the performance of stormwater best management practices (BMPs) over time. CRWD collects water quality and quantity data from major subwatersheds, lakes, ponds, and stormwater BMPs.

1.2 PURPOSE OF REPORT

This annual report focuses on the water quality of the five lakes (Como, Crosby, Little Crosby, Loeb, and McCarrons) in Capitol Region Watershed District during the 2016 monitoring season (April through October). Specific water quality data (total phosphorus, chlorophyll-a, and Secchi disk depth) for each lake from 2016 were compared to historical data collected in previous monitoring years. Additional biological and physical parameter results (i.e. phytoplankton, zooplankton, macrophytes, fisheries, lake morphometry, and water levels) are also included in this report.

The purpose of this report is to characterize overall lake water quality and health in 2016 and to examine trends over time, which in turn will inform lake management decisions for continued protection and improvement of District lakes. Previous annual monitoring reports (2005-2015) are available on the CRWD website at www.capitolregionwd.org.

1.3 LAKE MONITORING METHODS

Within CRWD, the five lakes are located in four of the sixteen major subwatersheds (Como, Crosby, McCarrons, and Trout Brook). CRWD organized the collection of water quality data for all of these lakes including information on chemical parameters (nutrients, pH, and conductivity), physical parameters (water clarity, dissolved oxygen, and temperature), and biological parameters (chlorophyll-a, aquatic vegetation type and abundance, phytoplankton, zooplankton, and fisheries populations).

CRWD partners with Ramsey County Public Works, Ramsey Conservation District, and the Minnesota Department of Natural Resources to collect lake data. Also, rainfall data was collected by CRWD from six precipitation gauges across the watershed.

1.4 2016 MONITORING RESULTS

The 2016 calendar year was the wettest year on record for the Twin Cities. The total amount of precipitation for the 2016 calendar year was 40.66 inches, which was 10.05 inches greater than the 30-year normal of 30.61 inches. August was the wettest month of 2016, with a total of 9.45 inches and capturing the two largest storms recorded for the year on August 10 (2.13 inches) and August 16 (1.82 inches). Along with a wet August, July and September were also particularly wet with both months being well-above the monthly normal. Overall, only three months of the year (January, May, and June) exhibited lower-than-normal precipitation. All other months were wetter-than-normal, attributing to the large total departure from normal annual precipitation.

In 2016, the water quality of the five District lakes (Como, Crosby, Little Crosby, Loeb, and McCarrons) varied by water body and by time of year. Based on the MPCA eutrophication numeric water quality standards, Little Crosby Lake, Loeb Lake, and Lake McCarrons met the MPCA eutrophication water quality standards (for shallow/deep lakes) for all parameters during the 2016 growing season (May to September) (Table 1-1). Crosby met both the chlorophyll-a (Chl-a) concentration and Secchi disk depth standards, but failed to meet the standard for total phosphorus (TP) (Table 1-1). Como Lake did not meet the MPCA shallow lake standards for any of the eutrophication standards in 2016 (Table 1-1). Como Lake was the only District lake designated as impaired on the MPCA's 2014 303(d) proposed impaired waters list, and has been listed on the MPCA 303(d) list since 2002.

Table 1-1: CRWD 2016 average, historical average, and lake standards for TP/Chl-a/Secchi depth

Lake	2016 Averages			Historical Averages			State Lake Standards		
	TP (µg/L)	Chl-a (µg/L)	Secchi (m)	TP (µg/L)	Chl-a (µg/L)	Secchi (m)	TP (µg/L)	Chl-a (µg/L)	Secchi (m)
Como	139	32.7	0.8	176	34.1	1.5	<60	<20	>1.0
Crosby	93	16.2	1.6	82	11.3	2.3	<60	<20	>1.0
Little Crosby	51	5.9	2.6	89	10.7	2.4	<60	<20	>1.0
Loeb	18	2.3	3.4	29	6.1	3.2	<60	<20	>1.0
McCarrons	14	3.3	4.5	33	9.6	2.9	<40	<14	>1.4

(shaded) Value does not meet the state standard
(unshaded) Value meets the state standard

Lake grades were calculated for each lake based on the 2016 water chemistry data to provide a more understandable depiction of lake health and to better track lake water quality changes over time. The seasonal means of TP, Chl-a, and Secchi depth were examined for 2016 and previous years and grades were based on scoring ranges for each parameter (Table 1-2). Based on the lake grading system, Loeb Lake and Lake McCarrons both received excellent lake grades with grades of 'A', which is at or above the historical average lake grade for each lake. Little Crosby Lake received a 'B' grade, an improvement in lake grade from the historical average, and Crosby Lake received a 'C' grade, just under the historical average grade for this lake of 'C+'. Como Lake received the lowest grade ('D+') of any CRWD lake, which was the same as its historical average.

Table 1-2: CRWD 2016 lake grades and historical lake grades for TP/Chl-a/Secchi depth.

Lake	2016 Lake Grade			2016 Average	Historical Lake Grade			Historical Average
	TP	Chl-a	Secchi		TP	Chl-a	Secchi	
Como	D	C	D	**D+**	F	C	C	**D+**
Crosby	D	B	C	**C**	D	B	B	**C+**
Little Crosby	C	A	B	**B**	D	B	B	**C+**
Loeb	A	A	A	**A**	B	A	A	**A**
McCarrons	A	A	A	**A**	C	A	B	**B**

1.5 2017 RECOMMENDATIONS

Based on the results and findings of the *2016 Lakes Monitoring Report*, CRWD has several goals and recommendations for 2017 to continue improving the monitoring program and the water quantity and quality dataset. Specifically, CRWD aims to complete the following in 2017:

1. **Report all lakes data in CRWD's online Data Analysis and Reporting Tool (DART):** In 2017, CRWD is developing an online, user-driven, interactive, map-based Data Analysis and Reporting Tool (DART) that interfaces with the monitoring database technology, the WISKI database. DART will serve as a dynamic data reporting tool that provides: data visualization and user interaction; expanded statistical and spatial analysis capabilities; instant, customizable reporting and data downloading/exporting; real-time data viewing; and a tool that assists in meeting annual reporting requirements.

2. **Analyze additional chemical and physical parameters:** CRWD intends to expand the analysis of chemical and physical data previously collected but not fully analyzed in prior reports. Analysis of other water chemistry and physical attributes will allow a better understanding of overall lake health, such as total nitrogen, chloride, soluble reactive phosphorus (SRP), and temperature profiles.

3. **Continue to conduct fish surveys:** In 2017, CRWD plans to survey fish populations at Como Lake only to continue to understand fish community dynamics.

4. **Install a multi-parameter water quality sensor in Como Lake to monitor continuous DO, temperature, conductivity, pH, and turbidity at varying lake depths:** In 2016, staff determined that continuous data on multiple water quality parameters at various lake depths is needed in Como Lake. Currently, DO and temperature values are measured at multiple depths, but only collected every two weeks during the growing season. Installing a multi-parameter water quality sensor (e.g. YSI Sonde) that is continuously measuring and logging water quality data at various depths will capture changes occurring between bi-weekly sampling events. This data will be used to better understand when lake turnover is occurring in Como Lake. In addition, this data will assist in identifying periods of anoxia, which will help better quantify internal phosphorus loading within the lake.

5. **Complete an internal loading assessment of Lake McCarrons:** In 2017, CRWD will investigate the changes to internal loading in Lake McCarrons that have occurred since the 2004 alum treatment using sediment cores from the bottom sediments that were extracted in February 2016 and February 2017. The results of these sediment cores will be used to complete a phosphorus budget that will evaluate all internal and external sources to the lake, which will assist in determining future management strategies for Lake McCarrons.

6. **Complete an in-lake management analysis of Como Lake:** CRWD began working with LimnoTech in 2016 to conduct an in-lake analysis of all historically collected Como Lake data with the goal of determining the drivers of water quality in the lake. In 2017, LimnoTech will complete the "*Como Lake Water Quality Drivers Analysis Study*" in order to better understand the complex relationships between the chemical, physical, and biological parameters of the lake. The report will also make recommendations for the District's future management efforts for the lake.

2 INTRODUCTION

2.1 CRWD BACKGROUND

The Capitol Region Watershed District (CRWD) represents a small urban watershed nested in the Upper Mississippi River basin, located entirely in Ramsey County, Minnesota. All runoff from the watershed eventually discharges to the Mississippi River along a 13-mile reach in St. Paul, Minnesota through 42 storm tunnel outfall pipes. All surface water and stormwater runoff in the watershed is managed by CRWD, a special purpose unit of government founded in 1998 with the goal of managing, protecting, and improving all water resources within the watershed. CRWD contains portions of five cities, including: Falcon Heights, Lauderdale, Maplewood, Roseville, and Saint Paul (Figure 2-1). CRWD is highly developed and urbanized with a population of 245,000 and 42%+ impervious surfaces. Land use in CRWD is primarily residential and commercial with areas of industrial use and parkland.

2.2 CRWD WATER QUALITY ISSUES

Urban development in the watershed over time has significantly impacted the health and sustainability of the Mississippi River as well as CRWD lakes, wetlands, and streams. Impervious surfaces generate polluted stormwater runoff which causes poor water quality, increased peak storm flows, decreased groundwater recharge, increased flooding, and loss of biological habitat. Subsequently, stormwater runoff is one of the most significant sources of pollution to CRWD water resources. It delivers fertilizers, pesticides, pet and wildlife waste, nutrients, sediment, heavy metals, and other anthropogenic pollutants to lakes, ponds, and wetlands located in the District. As stormwater runs off the urban landscape, it is collected and conveyed through an extensive network of underground storm sewer pipes that eventually drain to the Mississippi River.

Both historical and current water quality data of CRWD lakes, ponds, and the Mississippi River indicate that these water bodies are impaired for various pollutants (including nutrients, bacteria, and turbidity) and are not meeting their designated uses for fishing, aquatic habitat, and recreation. The Mississippi River and Como Lake were listed on the Minnesota Pollution Control Agency (MPCA) 2014 303(d) proposed impaired waters list (MPCA, 2017). Impaired waters require a total maximum daily load (TMDL) study for pollutants of concern including nutrients, turbidity, metals, bacteria, and chloride.

The nutrient of primary concern in CRWD lakes is phosphorus. Phosphorus is a biological nutrient which limits the growth of algae in most lakes and streams and is often found in high concentrations in stormwater. Phosphorus occurs naturally in the environment, but in excess can cause the overgrowth of algae and aquatic plants in lakes and rivers which reduces dissolved oxygen levels and increases turbidity of the water column. Common sources of phosphorous include fertilizers from lawns and gardens, leaves and grass clippings, pet and wildlife waste, and automobile emissions.

Chlorophyll-a (Chl-a) is a pigment present in algae. Measuring Chl-a concentration is a proxy for measuring algal population. Algal blooms can make recreation unpleasant and prevent it entirely, and certain species of algae are toxic to humans and other animals. In addition, as algae die and decompose, oxygen is consumed from the water column and made unavailable for fish and other aquatic animals. Chronic low dissolved oxygen concentrations (<5 mg/L) may result in fish kills and low diversity of aquatic species (Kalff, 2002).

Water transparency, or water clarity, (determined using a Secchi disk) is another concern in area lakes. Lakes with high water clarity are generally considered healthier, and are characterized by more submerged aquatic plant growth, as clear water allows light to permeate to lower depth levels (Kalff, 2002). Increased plant growth also provides better habitat for aquatic organisms, including fish. Poor water clarity is a result of increased turbidity caused by suspended sediments, organic matter, and/or phytoplankton (algae).

Chloride in water bodies is a contaminant of concern for CRWD. High concentrations of chloride can harm fish and plant life by creating a saline environment. Also, once in dissolved form, chloride cannot be removed from a water body. Chloride is primarily sourced from road salt application for de-icing in the winter months.

2.3 CRWD MONITORING PROGRAM GOALS

CRWD was formed to understand and address water quality impacts and to better protect and manage local water resources. In 2004, CRWD established a monitoring program to assess water quality and quantity of District stormwater, lakes, wetlands, and stormwater best management practices (BMPs). The overall objectives of the program are to identify water quality problem areas, quantify subwatershed runoff pollutant loadings, evaluate the effectiveness of BMPs, provide data for the calibration of hydrologic, hydraulic, and water quality models, and promote understanding of District water resources and water quality. Prior to the CRWD monitoring program, there was no consistent District-wide monitoring of any of the above resources. While there was limited data on stormwater quantity and quality, wetland quality, and BMP performance, a few of the lakes had been previously monitored, some with extensive datasets. Ramsey County has monitored Como Lake since 1984, Lake McCarrons since 1988, and Crosby Lake since 1999.

The *CRWD 2016 Lakes Monitoring Report* presents information on annual CRWD lake water quality monitoring, including data collection methods and results for water chemistry, physical parameters, and biological parameters. A climatological summary is also included to summarize the precipitation, snowpack, and notable climatic events from 2016. Previous annual monitoring reports (2005-2015), including stormwater monitoring, stormwater BMPs, and wetlands, are available on the CRWD website at www.capitolregionwd.org.

2.4 OVERVIEW OF CRWD LAKES

There are five lakes within the boundaries of CRWD: Como Lake, Crosby Lake, Little Crosby Lake, and Loeb Lake in St. Paul, and Lake McCarrons in Roseville (Figure 2-1). The lakes are monitored by Ramsey County Public Works (RCPW), Ramsey Conservation District (RCD), the Minnesota Department of Natural Resource (DNR), and CRWD to assess overall lake health and to determine if each lake supports their designated uses for swimming, fishing, and/or aesthetics. All of the lakes receive stormwater runoff (directly and/or indirectly) and are nested within the Mississippi River Basin.

Como Lake, Crosby Lake, Little Crosby Lake, and Loeb Lake are classified as shallow lakes and Lake McCarrons is classified as a deep lake. Shallow lakes have a maximum depth less than 15 ft, or more than 80% of the lake within the littoral zone (MPCA, 2016). The littoral zone is the near-shore area of the lake in which plants grow (Kalff, 2002). Deep lakes have a maximum depth greater than 15 ft, or less than 80% of the lake within the littoral zone (MPCA, 2016).

2.4.1 COMO LAKE

Como Lake (Chapter 6) is a 70.5 acre lake with a maximum depth of 15.5 ft and is located in the City of Saint Paul. The 1,856 acre Como Lake watershed land uses are primarily residential and parkland. Como Lake is classified as a shallow lake because nearly 100% of the lake is considered the littoral zone. The lake has been monitored since 1984, and although water quality has improved slightly over time, there has been an observed cyclical variation in historical water quality (Noonan, 1998). In an effort to improve water quality in the lake, the Como Lake Strategic Management Plan (CRWD, 2002) was developed in 2002 and can be found on the District website (www.capitolregionwd.org). Como Lake was listed on the MPCA’s 2014 303(d) proposed impaired waters list for chloride impairment (MPCA, 2017). Como lake was also listed as impaired by the MPCA for nutrients (2002) and mercury (1998).

2.4.2 CROSBY LAKE & LITTLE CROSBY LAKE

Crosby Lake (45 acres) (Chapter 7) and Little Crosby Lake (8 acres) (Chapter 8) are shallow lakes situated in the Mississippi River floodplain in Saint Paul and part of the Crosby Farm Regional Park and the Mississippi River National River and Recreation Area. The lakes are located within the 1,522 acres of Crosby Lake subwatershed; 197 acres of the subwatershed drain to Crosby Lake while 37 acres drain to Little Crosby Lake. The lakes are divided into two separate water bodies by a marsh/bog area 825 ft long. Crosby Lake is classified as a shallow lake because it has a maximum depth of 17 ft and the littoral zone covers 100% of the lake area. Little Crosby Lake is also considered a shallow lake even though it has a maximum depth of 34 ft, because it has a littoral area of 90% (<15 ft in depth). The watershed land uses for both water bodies are primarily parkland, single family residential, and industrial. A management plan for Crosby Lake (which included information regarding Little Crosby Lake) was created in 2012 (CRWD, 2012a), and can be found on the District website (www.capitolregionwd.org). Crosby Lake has been monitored since 2005; Little

Crosby Lake has been monitored since 2011. Water quality of both lakes can be greatly affected by the Minnesota and Mississippi Rivers, since it is located in the floodplain of their confluence. Both lakes are not currently on the MPCA 303(d) list.

2.4.3 LOEB LAKE

Loeb Lake (Chapter 9) is a 9.7 acre shallow lake with a maximum depth of 28 ft and has a littoral area of 81%. Located in Marydale Park in the City of Saint Paul, the predominant land uses in the surrounding drainage area (44 acres) are mixed residential and parkland. The lake has a small drainage area, with no outlets. Loeb Lake has been monitored since 2003. A management plan for the lake was created in 2009 (CRWD, 2009), and can be found on the District website (www.capitolregionwd.org). Loeb Lake is an unimpaired water body and is not currently on the MPCA 303(d) list.

2.4.4 LAKE MCCARRONS

Located in the City of Roseville, Lake McCarrons (Chapter 10) is a 74.7 acre lake with a maximum depth of 57 ft. It is considered a deep lake with less than a 34% littoral zone. Lake McCarrons has a watershed area of 1,070 acres, with land use of mainly mixed residential and open space, including the entire Villa Park wetland system, which outlets to the lake. Lake McCarrons has been monitored since 1988, and is the only District lake that allows swimming and has development (residential) directly on its shoreline. Lake McCarrons received an alum treatment in 2004 and water quality of the lake has shown improvement since this occurred. A management plan for the lake was created in 2003 (CRWD, 2003), and can be found on the District website (www.capitolregionwd.org). The lake is considered unimpaired and is not currently listed on the MPCA 303(d) list of impaired waters.

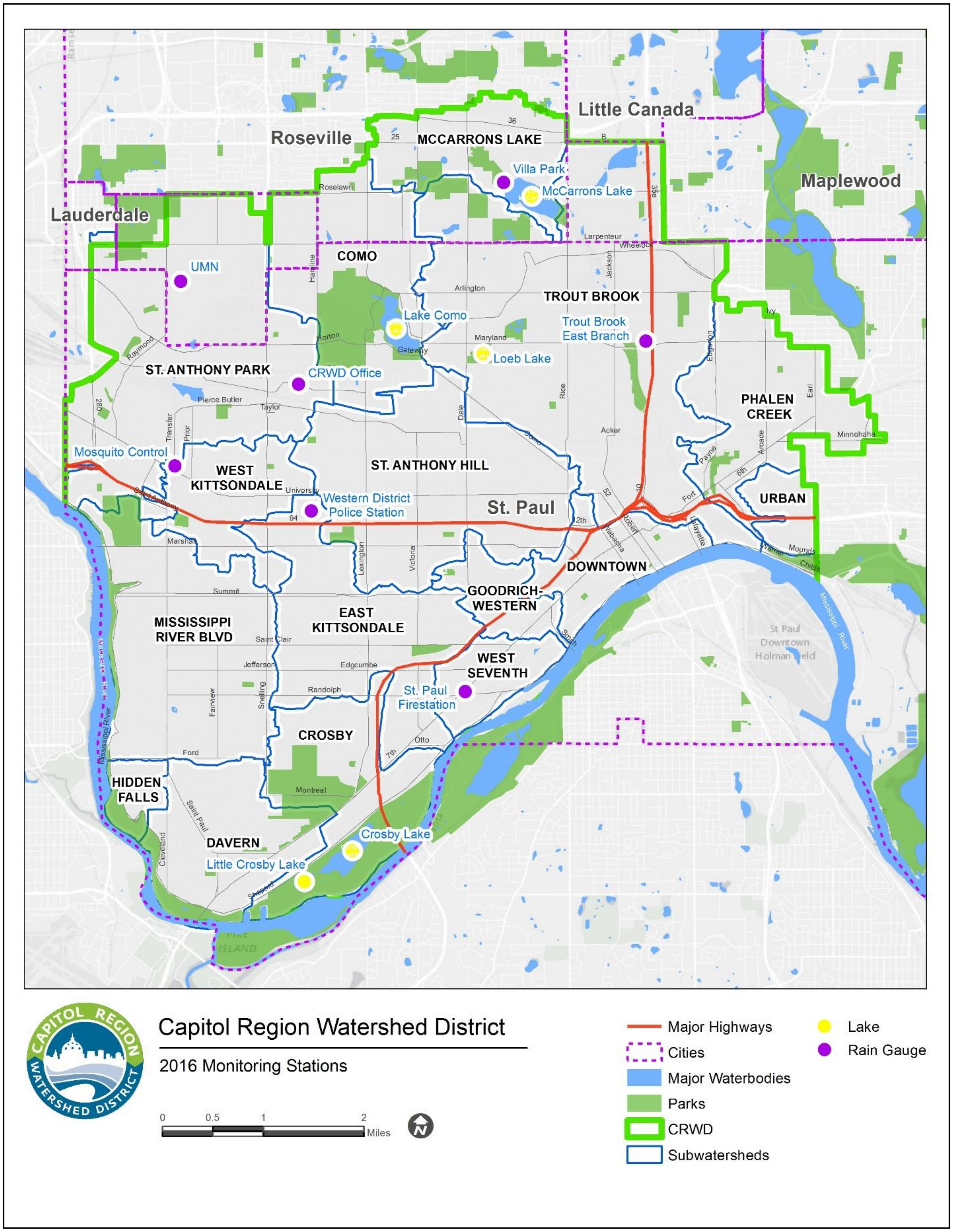

Figure 2-1: CRWD 2016 lake and rain gauge monitoring locations in Ramsey County, Minnesota.

3 METHODS

3.1 MONITORING METHODS

3.1.1 LAKE LEVEL

Historical lake elevation data published by the Minnesota DNR can be accessed for a particular lake in the DNR's LakeFinder database (DNR, 2016b). While lake elevation monitoring organized by the DNR through the Lake Level Minnesota program (DNR, 2015i) is completed on many lakes throughout the state, including Como, Loeb, and McCarrons, this only occurs twice per month, and is completed by a singular manual reading of the level on a staff gauge during a lake visit. In order to obtain continuous level data for CRWD lakes, CRWD staff installed level loggers on four of the five lakes in the District in 2016. CRWD collected lake level data from early spring to late fall in 2016 on Como Lake (March – November), Crosby Lake (April – November), Loeb Lake (June – November), and Lake McCarrons (April – November). Lake level in Little Crosby Lake is directly influenced by the level in Crosby Lake, as the two are hydrologically connected, so a level logger was not necessary in this lake and a lake level graph was not completed. Historical lake elevation graphs therefore are represented by both DNR lake level data, as well as CRWD collected level logger data.

The ordinary high water level (OHWL) is one other parameter that is shown on the historical lake level graphs (where applicable). The OHWL is defined as the "highest water level that has been maintained for a sufficient period of time to leave evidence upon the landscape, commonly the point where the natural vegetation changes from predominantly aquatic to predominantly terrestrial" (Scherek, 1993). The OHWL is used to determine regulatory controls, with the Minnesota DNR regulating activity below the OHWL and local units of government regulating activity above the OHWL. By including this as a part of the lake elevation graph, observations can be made as to how current and past years compare to the "normal" lake level. This does not always mean that the lake level ever reaches or surpasses the OHWL, as this level is based on landscape evidence indicating the historical water level and is not an average of past monitored water levels.

3.1.2 CHEMICAL AND PHYSICAL DATA COLLECTION

Historically, lake water quality data has been collected by RCPW throughout the growing season (May through October), resulting in an average of eight samples for each year (RCPW, 2009). In 2016, lakes were monitored beginning in early April and ending in late October to capture a greater range of lake water quality, resulting in a total of ten samples for all lakes. At each lake, RCPW staff anchored a watercraft over the deepest part of the lake, and sampled for various water quality parameters along a depth profile. The physical and chemical parameters of depth, temperature, dissolved oxygen, conductivity, and pH were measured at one-meter sampling intervals for the full depth profile of the lake using a multi-probe. From these recordings, the depths of the epilimnion, thermocline (if applicable), and hypolimnion were recorded. Water transparency, or water clarity, was determined on the lake with the use of a Secchi disk. A Secchi disk is a black and white patterned disk that is connected to a line or pole. To take a measurement, the Secchi disk is lowered slowly into the water column until the pattern is no longer visible. The depth at which the disk is no longer visible is then recorded.

Additionally, at the lake sampling location, water chemistry samples were collected at multiple depths along the profile of the lake. At all lakes, two samples were obtained within the epilimnion, or mixed water layer. If RCPW staff was able to identify thermal stratification (where depths for the divisions between the epilimnion, thermocline, and hypolimnion can be identified), additional water samples from other depths were collected. One additional water sample was collected from within the thermocline and two were collected from within the hypolimnion. Any water samples collected were then stored and transported back to the RCPW lab and analyzed for the following parameters: turbidity, Chl-a, TP, soluble reactive phosphorous (SRP) (i.e. ortho-phosphorus(ortho-P)), total Kjeldahl nitrogen (TKN), nitrate (NO_3), ammonia (NH_3), and chloride ion concentrations (Cl).

3.1.3 PHYTOPLANKTON AND ZOOPLANKTON COLLECTION

Phytoplankton and zooplankton data collection occurred at the same time as water quality data collection by RCPW for 2016 and previous monitoring years. For phytoplankton analysis, a composite sample was collected using a plastic tube that was inserted vertically 2 m into the upper layer of the water column. This sample was emptied into a bucket, thoroughly mixed, and a sub-sample was collected and preserved. This water sample was placed in an enclosed cooler and taken back to the lab for analysis (RCPW, 2012).

To collect a zooplankton sample, a net tow was lowered down to the observed thermocline in order to collect samples from the oxygenated layer of the lake. The net tow was allowed to settle and then pulled back up to the water surface at a rate of 1 m/sec. The net and capture bucket were drained by swirling the capture bucket which allowed the water to drain out of the net and screen. Once the volume was reduced to 100 mL, the contents of the capture bucket were poured into another container and preserved in a 5% formaldehyde solution, then taken back to the RCPW lab for analysis (RCPW, 2012).

3.1.4 AQUATIC VEGETATION SURVEYS

Point-Intercept Survey Method

In 2016, all lakes were surveyed by the Ramsey Conservation District (RCD) for aquatic vegetation presence and abundance using the point-intercept method. This method consisted of using a GPS to pre-select specific monitoring points throughout the full area of the lake. At each evenly spaced (70 m distance) point, a double-tined metal rake was thrown out 1 m from the boat, dragged a distance of 1 m and brought back into the boat. Plant species were identified and given an abundance ranking based on the amount collected on the rake (Table 3-1). Any plants floating on the water surface were also identified. RCD surveyed all CRWD lakes three times throughout the course of the year: spring, summer, and early fall.

Table 3-1: Average abundance rating and description for aquatic vegetation (RCPW, 2009).

Percent Cover of Tines	Abundance Ranking
81-100	5
61-80	4
41-60	3
21-40	2
1-20	1

Biovolume Survey Method

To collect data on submerged aquatic vegetation as well as data about the lake bottom, RCD used a Lowrance HDS-5 GPS enabled depth finder to assess evenly spaced transects at a minimum distance of 40 meters. The sonar log data that was collected was then analyzed by CI BioBase software to determine the depth of the lake and the amount of aquatic vegetation (biomass) along each transect. These surveys also produced information estimating lake area, bathymetry, and lake water volume.

3.1.5 FISH STOCKING AND SURVEYS

Fish stocking occurs annually through the Minnesota DNR in an effort to improve fishing conditions on selected Minnesota lakes. Roughly 25% of Minnesota's 5,400 fishing lakes have a set stocking schedule (DNR, 2015f). Fish are stocked at different life stages depending on the desired effect in the lake. Table 3-2 describes the different types of fish used for stocking.

Table 3-2: Minnesota DNR fish stocking size definitions (DNR, 2015f).

Fry	Fish stocked in lakes shortly after hatching from eggs.
Fingerling	Fish harvested from rearing ponds after one summer of growth.
Yearling	Fish that are a year old at the time of stocking.
Adult	Fish more than 1 year old, usually transferred from other waters.

Fish surveys are conducted every 5-10 years by the DNR on the majority of Minnesota lakes. Surveys occur more frequently, however, on lakes of higher fishing importance. Through fish surveys, the DNR gains information on the species of fish in a lake in order to make management decisions and understand changes in lake water quality. Fish are collected using various field techniques based on the type and size of fish to be collected. These survey techniques include: gill netting (to capture larger, predator fish), trap netting (to capture smaller panfish), trawl and shoreline seines (to capture young fish), and electrofishing (to survey for bass, crappies and young walleyes). Once captured, information is recorded on the species, count, weight, and length, as well as how these measures compare to the normal expected range for the species (DNR, 2015f). In 2016, the DNR surveyed Como Lake. CRWD contracted Wenck Associates, Inc. to conduct surveys on Crosby Lake, Little Crosby Lake, Loeb Lake, and Lake McCarrons in 2016. These additional surveys by CRWD were conducted in 2016 to supplement DNR sampling efforts in order to obtain more information about annual fish populations on all CRWD lakes. Wenck Associates staff followed DNR procedures for sampling of fish in these lakes.

3.2 DATA ANALYSIS METHODS

3.2.1 MORPHOMETRIC DATA

Morphometric data was compiled for each lake. This included information regarding lake surface area, mean and maximum depth, littoral area percentage, lake water volume, watershed area, and watershed-to-lake area ratio. The watershed-to-lake area ratio represents how large the watershed is compared to the size of the lake. A high ratio indicates a large portion of land for potential runoff to the lake, while a low ratio indicates a smaller area conducting runoff. In general, having a lower ratio in urban areas decreases external nutrient loading to lakes, which in turn can result in improved water quality.

3.2.2 WATER QUALITY STANDARDS COMPARISON

A lake is considered eutrophic if it has high nutrient levels, low dissolved oxygen concentrations, and frequent algal blooms. Although some lakes are naturally eutrophic, many have become eutrophic as a result of anthropogenic activities. In order to identify eutrophic water bodies in Minnesota, the MPCA establishes eutrophication numeric water quality standards in lakes for TP, Chl-a, and Secchi depth (Table 3-3) (MPCA, 2016). In the NCHF ecoregion, a different standard exists for shallow and deep lakes. Summer mean values are determined for each of these parameters based on all June – September data. A lake is considered impaired under MPCA standards if it exceeds the standard for TP concentration and either the Secchi disk depth or Chl-a concentration. Lakes that do not meet the standards may be placed on the MPCA 303(d) list of impaired waters. To account for differences in natural trophic state, the standards vary by ecoregion and lake type.

Table 3-3: Deep and shallow lake state water quality standards (MPCA, 2016).

Parameter	Deep Lake Standard[a,b]	Shallow Lake Standard[a,c]	Units	Source
TP	<40	<60	µg/L	Minn. Stat. § 7050.0222
Chlorophyll-*a*	<14	<20	µg/L	Minn. Stat. § 7050.0222
Secchi depth	>1.4	>1.0	m	Minn. Stat. § 7050.0222

[a] Standards apply to Class 2B waters in the North Central Hardwood Forest ecoregion. Class 2B waters are designated for aquatic life and recreational use. All standard concentrations apply to chronic exposure.
[b] A deep lake is defined as a lake with a maximum depth > 15 feet or one in which < 80% of the lake is in the littoral zone .

[c] A shallow lake is defined as a lake with a maximum depth < 15 feet or one in which > 80% of the lake is in the littoral zone.

Several steps are taken to calculate summer TP and Chl-a averages for comparison to state standards. As described in the chemical monitoring methods in Section 3.1.2, water quality samples are collected at discrete depths in the water column. In accordance with the MPCA's Guidance Manual that outlines how summer lake eutrophication parameters are calculated, if two samples were collected within the epilimnion, the average of these values was used to find the daily average TP and Chl-a values (MPCA, 2016). The daily average TP and Chl-a values were then used to calculate the seasonal (May – September) average. While the MPCA Guidance Manual restricts the data range from June – September to calculate the average, the more applicable range in CRWD is May – September, as this more accurately represents the growing season in our area. This calculated May – September average was compared against the state standards outlined in Table 3-3.

Additionally, annual average hypolimnetic TP values were calculated for historical data for all lakes, and compared against the epilimnetic TP averages. Daily hypolimnetic values were determined by selecting the TP value from the deepest point in the hypolimnion during each sampling event, and taking the May – September average from all of these points to calculate a summer average.

3.2.3 LAKE GRADING SYSTEM

CRWD uses a lake grading system in order to give a qualitative measure to the water quality data and compare between years monitored (Table 3-4). This is based on the Metropolitan Council's lake grading system that is used to compare lakes across the metro region and to offer a non-technical value of lake water quality that is more understandable to a wide variety of audiences (Osgood, 1989). The seasonal means of TP, Chl-a, and Secchi depth were examined for 2016 and previous years and grades were based on ranges for each parameter. The range is weighted such that a certain percentage of Minnesota lakes fall into each grade. Each grade corresponds not only to ranges in the three lake eutrophication parameters (TP, Chl-a, and Secchi depth), but also to a recreational value for the lake that provides a description of user quality (MC, 2015). CRWD assigned each letter grade a numerical value (A = 5, B = 4, C = 3, D = 2, F = 1), and the average of these three values provided an overall lake grade (Table 3-5). The ranges in Table 3-5 are based off methods used by the Minnehaha Creek Watershed District in their monitoring reports (MCWD, 2015).

Table 3-4: Water quality parameter lake grade ranges, percentile ranges, and description of lake grade user quality (MC, 2015; Osgood, 1989).

Grade	Percentile	TP (µg/l)	Chl-*a* (µg/l)	Secchi (m)	Description of User Quality
A	<10	<23	<10	>3.0	Full recreational use capability
B	10-30	23-32	10-20	2.2-3.0	Very good water quality but some recreational use impairment
C	30-70	32-68	20-48	1.2-2.2	Average water quality but are recreationally impaired
D	70-90	68-152	48-77	0.7-1.2	Severly impaired recreational use
F	>90	>152	>77	<0.7	Extremely poor water quality; little to no recreational use

Table 3-5: CRWD overall lake grade ranges (MCWD, 2015).

Grade	Range
A	4.67 - 5.00
A-	4.34 - 4.66
B+	4.01 - 4.33
B	3.67 - 4.00
B-	3.34 - 3.66
C+	3.01 - 3.33
C	2.67 - 3.00
C-	2.34 - 2.66
D+	2.01 - 2.33
D	1.67 - 2.00
D-	1.34 - 1.66
F	< 1.33

3.2.4 PHYTOPLANKTON AND ZOOPLANKTON LAB ANALYSIS

All methods for lab analysis of phytoplankton and zooplankton were obtained from Ramsey County Lake Management Laboratory (RCLML), a part of RCPW (RCPW, 2012). In the lab, the preserved phytoplankton sample was analyzed and identity/counts were recorded. The classes/phylums that were identified are listed and described in Table 3-6 (Kalff, 2002; UCMP, 2015).

Table 3-6: Phytoplankton types, taxonomic classification, description, and water quality significance (Kalff, 2002; UCMP, 2015).

Phytoplankton	Classification	Description	Water Quality Significance
Bacillariophyta	Class	Diatoms	Large populations suggest higher levels of dissolved silica needed to build external skeletons
Chlorophyta	Phylum	Green algae	Greatly contribute to freshwater lake species richness; contribute most significantly to biomass of eutrophic systems
Chrysophyta	Class	Golden-brown algae	Not overly abundant in eutrophic lakes; more plentiful in oligotrophic, clear-water lakes
Cryptophyta	Phylum	Cryptomonads	Most prevelant in oligotrophic and mesotrophic lakes; division does not contain an abundance of species types
Cyanophyta	Phylum	Blue-green algae	Indicative of highly nutrient-rich (eutrophic and hypereutrophic) lakes; large blooms are aesthetically displeasing and some can be toxic
Euglenophyta	Phylum	Euglenoids	Generally small contribution to overall biomass except in small, highly eutrophic bodies of water
Pyrrophyta	Phylum	Dinoflagellates	Typically contribute small portion of total biomass or species richness in temperate lakes

To analyze zooplankton, the preserved sample from the field was measured and a subvolume was analyzed for identity/counts. The zooplankton that were identified in this process are shown and described in Table 3-7 (Kalff, 2002). The Cladocerans identified during analysis consisted of Daphnia, Bosminae, Chydorus, Ceridaphnia, Diaphnosoma, and Leptodora. These genus-level organisms were combined and grouped under the heading 'Cladocera' for analysis.

Table 3-7: Zooplankton types, taxonomic classification, description, and water quality significance (Kalff, 2002).

Zooplankton	Classification	Description	Water Quality Significance
Cyclopoida	Order	Carniverous copepods	Primarily carniverous crustaceans; feed on other zooplankton and fish larvae but also eat algae, bacteria, and detritus
Calanoida	Order	Omnivorous copepods	Crustaceans that feed on ciliates as well as algae; change diet based on multiple variables including season and food availability
Nauplii	Genus	Juvenile copepods	Classified as *nauplii* during the first 5 or 6 molts (motling occurs 11 times before adulthood) during the life span of a copepod
Rotifera	Phylum	Soft-bodied, multicellular invertebrates	Name originates from rotating wheel of cilia by mouth; important among invertebrates as many species can produce multi-generations per year
Cladocera	Suborder	Type of crustacean	Mainly important filter-feeders covered by a hard cover; specific species *Daphnia* are main food source for planktivorous fish

Techniques for creation of phytoplankton and zooplankton figures in the following individual lake results sections were based off methods used in the Minneapolis Park and Recreation Board 2012 Water Resources Report (MPRB, 2015). There are two figures for both phytoplankton and zooplankton. The first figure for phytoplankton compares total phytoplankton concentration and TP concentration from April – October . The first figure for zooplankton compares total zooplankton density and Chl-a concentration from April – October. The second figures depict the relative abundance of each type of phytoplankton and zooplankton in order to examine changes in their populations throughout the months monitored.

3.2.5 AQUATIC VEGETATION ANALYSIS

Biovolume Analysis

Sonar data was entered into CI BioBase software that generates aquatic vegetation and bathymetric maps (CIBB, 2015). The biovolume heat maps were coded by different color zones to highlight differences in cover of aquatic vegetation. Red indicates that 100% of the water column is being taken up by biovolume, or vegetation is growing to the water surface, and blue indicates 0%, or bare lake bottom. Statistics calculated along with the maps included plant biovolume (the percentage of the water column that is vegetation) and percent area covered (the amount of the lake area where vegetation exists) (CIBB, 2015).

Point-Intercept Analysis

Aquatic vegetation has been monitored infrequently in past years on CRWD lakes. Establishing a baseline of vegetation data for all lakes will be a key factor in making future monitoring decisions. Aquatic vegetation within a lake is dependent on many different factors, including: water clarity, water chemistry, and physical lake parameters (including depth, sediment substrate type, lake size/shape, and shoreline vegetation). Not only does aquatic vegetation stabilize bottom sediment, plants also provide habitat for aquatic animals and are usually the main primary producers in shallow lakes (Kalff, 2002). Collecting data on aquatic vegetation provides baseline information on what vegetation is in the lake, where it exists on the lake, and how much is present. Measuring annual changes in these factors can help identify trends in aquatic vegetation and water quality.

Collecting data on aquatic vegetation using the point-intercept method allowed for two primary analyses to occur: computation of percent occurrence and average abundance. Percent occurrence represents the number of times a plant species was observed divided by the number of total sample sites where vegetation was observed. This information gives a good picture of the most common species of aquatic vegetation found on the lake. Average abundance is calculated as the average of the abundance rankings (measured at each location found) for a species. This shows how much vegetation of each species is occurring at the locations where vegetation is noted. A high average abundance ranking indicates thick cover of a species where it is observed. Conversely, a low average abundance ranking indicates minimal growth of a species.

4 CLIMATOLOGICAL SUMMARY

4.1 PRECIPITATION DATA COLLECTION METHODS

CRWD utilizes climatological data collected by the Minnesota Climatology Working Group (MCWG) at the University of Minnesota-St. Paul and National Weather Service (NWS) at the Minneapolis-St. Paul International Airport (MSP) to assist in calculating annual precipitation, runoff, and loading.

MCWG records precipitation every fifteen minutes from an automatic rain gauge located approximately two miles west of the CRWD office. The MCWG rain gauge was used as CRWD's primary precipitation monitoring station for rainfall because of the gauge's close proximity to the District. Rainfall totals (15-minute and daily) were recorded by CRWD from the MCWG public website (MCWG, 2016). Snow and ice totals were not accurately reported by MCWG due to equipment limitations.

The NWS weather station at MSP, located approximately ten miles south of the CRWD office, records many climate variables for each day, including: maximum, minimum, and average temperature; rainfall; snowfall and snow water equivalent; and depth of snowpack. These variables were recorded by CRWD from the NWS public website (NWS, 2016). If a snow or ice event occurred, the NWS daily precipitation totals were utilized by CRWD since their measurement equipment more accurately measures snow-water and ice-water equivalents than the MCWG gauge.

4.2 2016 PRECIPITATION RESULTS

Annual precipitation data from 2005-2016 was compared to the 30-year normal for the Minneapolis-St. Paul region in Table 4-1 and Figure 4-1. The total amount of precipitation recorded in CRWD in 2016 was 40.66 inches, which was 10.05 inches above the 30-year normal (Table 4-1 and 4-1). The 30-year normal is recalculated every 10 years. In 2010, the annual 30-year normal was recalculated for 1981-2010 to be 30.61 inches (formerly 29.41 inches (1971-2000)) (NOAA, 2016a).

Table 4-2 lists 2016 daily precipitation totals, 2016 monthly precipitation totals, the 30-year monthly normal (1981-2010) (NOAA, 2016a), and the 2016 departure from historical monthly normals. In 2016, NWS data was used for the months of January, February, March, November and December, as the events during this time period primarily exhibited frozen precipitation (Table 4-2). MCWG data was used for the remaining period (April through October), as rainfall events occurred during this time. Figure 4-2 compares CRWD monthly precipitation totals to the 30-year monthly normal (NOAA, 2016a).

Table 4-1: CRWD annual precipitation totals and departure from the 30-year normal.

Year	Precipitation (inches)[a]	Departure from 30-Year Normal
2005	35.98	(+) 5.37"
2006	31.69	(+) 1.08"
2007	29.72	(-) 0.89"
2008	21.67	(-) 8.94"
2009	23.34	(-) 7.27"
2010	36.32	(+) 5.71"
2011	33.62	(+) 3.01"
2012	30.26	(-) 0.35"
2013	36.36	(+) 5.75"
2014	35.66	(+) 5.05"
2015	35.21	(+) 4.60"
2016	40.66	(+) 10.05"
30-Year Normal	30.61	--

[a] Annual precipitation reported by the Minnesota Climatology Working Group (MCWG) and National Weather Service (NWS)

Figure 4-3 is a cumulative precipitation plot for 2016 which shows the total accumulated amount of precipitation throughout the entire year as well as fluctuations in precipitation trends and significant precipitation events. Precipitation gradually accumulated throughout the spring, staying slightly above the historic record. A relatively average early summer yielded to 9.45" of rain in the month of August, over twice as much as the 30-year monthly normal (NOAA, 2016a). The 2016 fall and winter months recorded precipitation totals all above the historical normal values.

August 2016 was the wettest month (9.45") of 2016, and the wettest August on record since 1891 in St. Paul (MCWG, 2017). Four large storm events measuring over 1" of precipitation occurred during the month of August, the largest of which measured 3.32" on August 10-11 (Table 4-2 and 4-4; Figure 4-3). Both July and September also recorded precipitation amounts over the monthly normal, yet not to the degree of August (Figure 4-2). No precipitation was recorded for the first half of November until three relatively large precipitation events were recorded later in the month (Table 4-2). The total precipitation in November (2.98 inches) recorded about one inch more precipitation than the monthly normal (Figure 4-2).

In total, 37.70 inches of snow fell during the 2016 calendar year, which was 16.7 inches less than the 30-year normal (Table 4-5; Figure 4-4). This resulted in a less robust snowpack which did not significantly contribute to spring groundwater recharge or surface runoff in comparison to previous winters.

Table 4-2: Daily and monthly precipitation totals for 2016 compared to the 30-year normal.

Day	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	0	0	0	0.04	0	0	0	0	0	0	0.00	0.00	
2	0	0.51	0	0	0	0	0	0	0	0	0.00	0.00	
3	0	0.04	0	0	0	0.14	0	0	0	0	0.00	0.00	
4	0	0.03	0.05	0	0	0.05	0	1.55	0.01	0.09	0.00	0.13	
5	0	0	0	0.08	0	0	1.8	0	0.55	0.54	0.00	0.00	
6	0.05	0	0	0	0	0.03	0	0	1.28	0.986	0.00	0.00	
7	0.04	0.02	0	0.01	0	0	0.03	0	0.01	0.04	0.00	0.00	
8	0.08	0	0	0.11	0	0.04	0	0	0	0	0.00	0.00	
9	0	0	0	0	0.31	0.71	0	0	0.11	0	0.00	0.00	
10	0	0	0	0	0.38	0	0.24	2.13	0	0	0.00	0.16	
11	0.02	0.01	0	0	0.09	0	0	1.19	0	0	0.00	0.33	
12	0	0	0	0	0.01	0.39	0.07	0.2	0	0.02	0.00	0.00	
13	0.01	0	0.05	0	0.17	0.51	0	0	0	0	0.00	0.00	
14	0	0.04	0.01	0	0	1.56	0.1	0	0	0	0.00	0.00	
15	0	0	0.85	0	0	0	0.03	0	0.79	0	0.00	0.03	
16	0	0	0.05	0	0	0	0.17	1.82	0	0	0.00	0.35	
17	0	0	0.01	0	0	0	0.07	0	0	0.49	0.00	0.07	
18	0	0	0	0.09	0	0	0	0	0	0.03	0.80	0.00	
19	0	0.37	0.07	0.12	0	0.03	0.01	0.61	0.02	0	0.00	0.00	
20	0.02	0	0	0.25	0	0	0.01	0.33	0	0	0.00	0.00	
21	0	0	0	0.19	0	0	0.12	0	1.35	0	0.00	0.00	
22	0	0	0	0	0	0.01	0	0	0.28	0	0.74	0.00	
23	0	0.4	0.31	0	0	0	1.08	1.08	0.27	0	0.06	0.10	
24	0.01	0	0	1.14	0	0	0	0.12	0	0	0.04	0.00	
25	0.05	0	0	0.47	0.32	0	0	0	0.17	0.33	0.00	0.97	
26	0.01	0	0.12	0	0.26	0	0	0	0	0.44	0.00	0.00	
27	0	0	0.07	0.31	0.27	0	1.26	0.03	0.06	0	0.31	0.00	
28	0	0.03	0	0.69	0.16	0	0	0	0	0	0.97	0.00	
29	0.01	0	0.19	0	0	0	0	0.08	0	0.1	0.01	0.00	
30	0.01		0.4	0	0	0.09	0	0.31	0	0	0.05	0.00	
31	0		0.13		0.02		0	0		0.01		0.00	Total
Monthly Total	0.31	1.45	2.31	3.50	1.99	3.56	4.99	9.45	4.90	3.08	2.98	2.14	40.66
Monthly Normal	0.9	0.77	1.89	2.66	3.36	4.25	4.04	4.3	3.08	2.43	1.77	1.16	30.61
Departure from Normal	-0.59	0.68	0.42	0.84	-1.37	-0.69	0.95	5.15	1.82	0.65	1.21	0.98	10.05

(blue)	Data supplied by NWS-MSP
(white)	Data supplied by UMN Climatological Observatory
(grey)	No Date

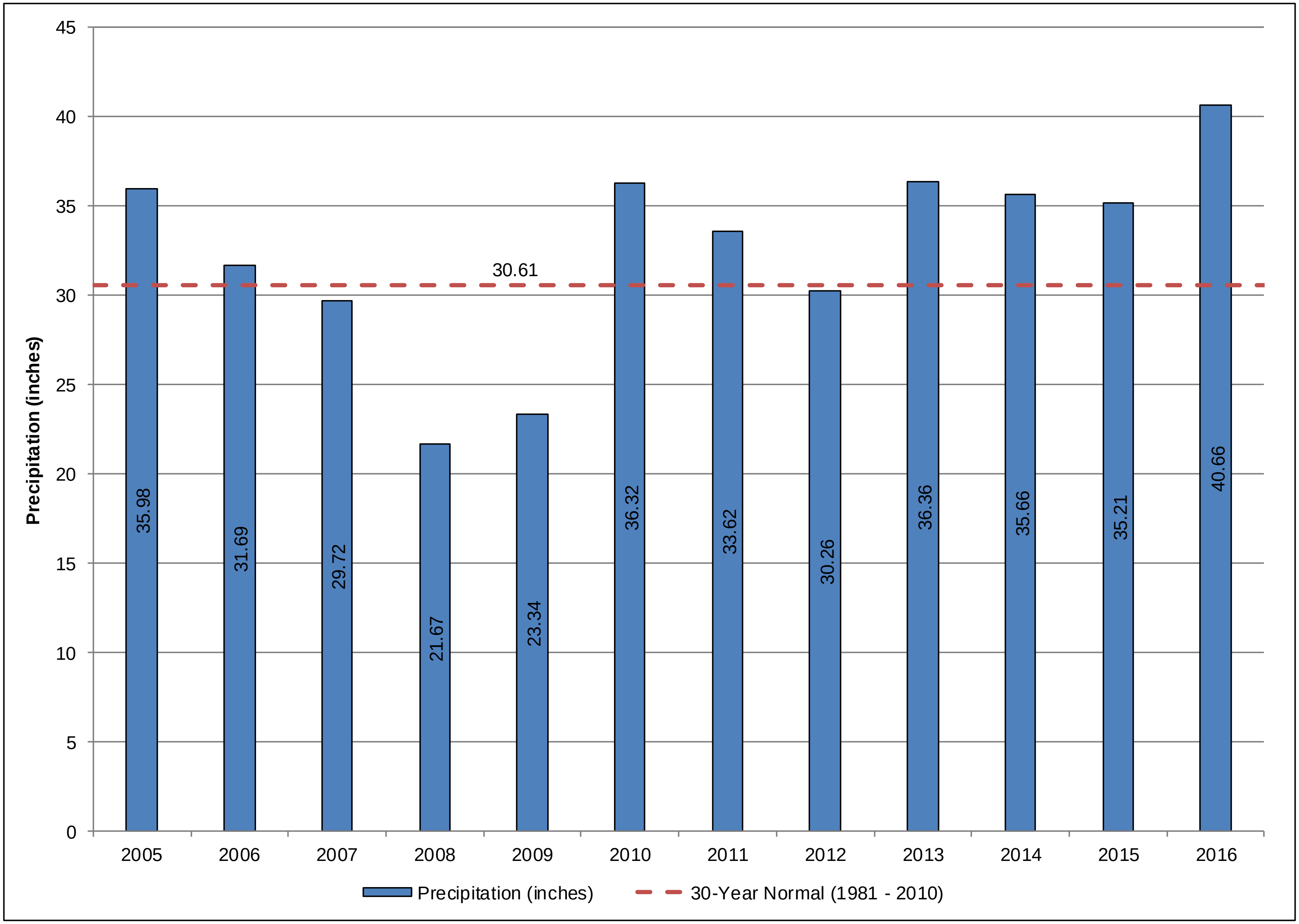

Figure 4-1: Annual precipitation totals (2005-2016) observed by CRWD compared to the 30-yr normal.

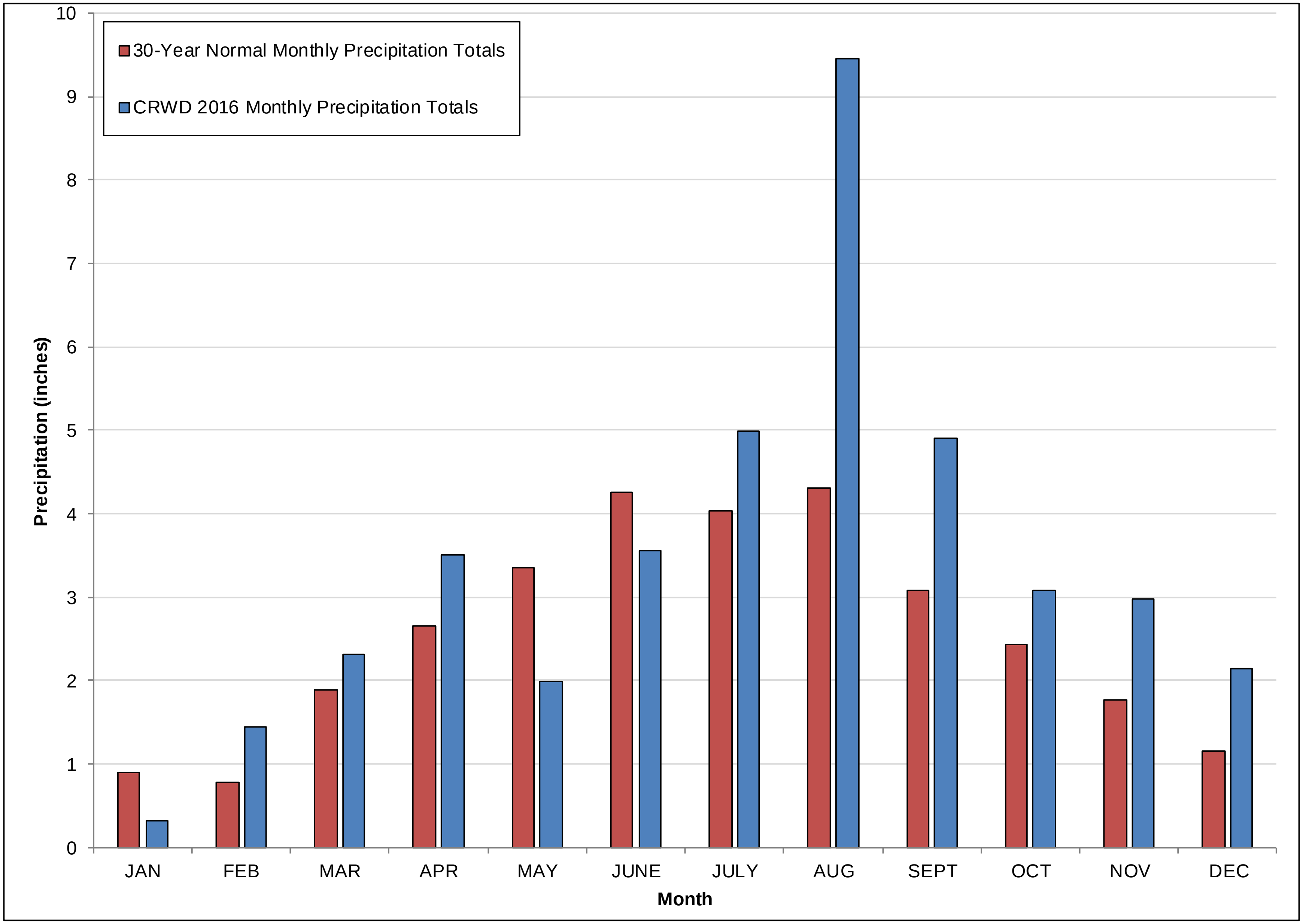

Figure 4-2: 30-year normal and 2016 monthly precipitation totals for CRWD.

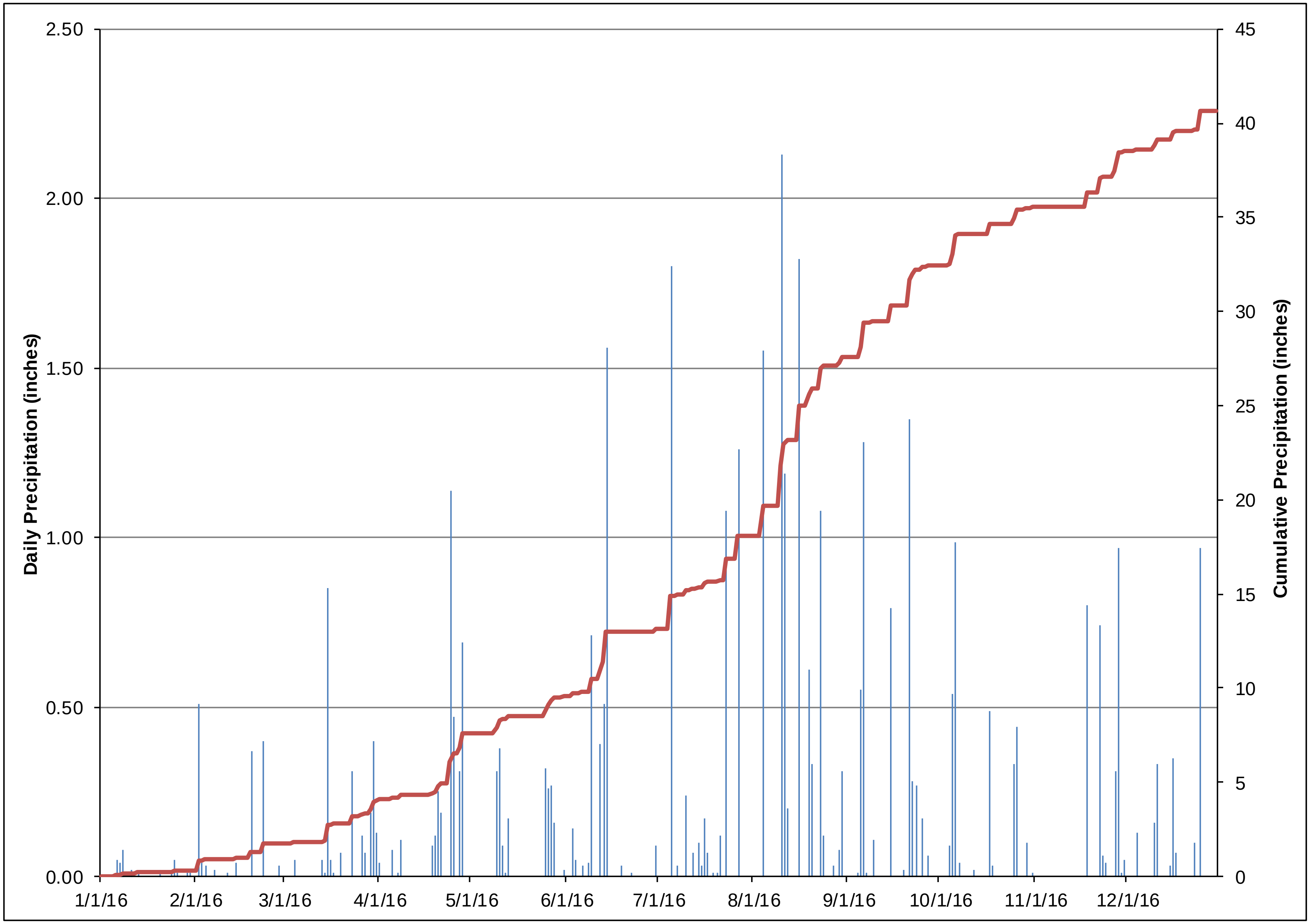

Figure 4-3: Daily precipitation totals and cumulative precipitation for January to December 2016.

4.3 2016 NOTABLE CLIMATOLOGICAL EVENTS

The 2016 calendar year was the wettest year on record for the Twin Cities (NWS, 2017). Also, all months in 2016 were warmer than the average monthly temperatures (Table 4-3) (DNR, 2017).

Table 4-3: 2016 Monthly departure from 30-year normal average temperature in the Twin Cities (DNR, 2017).

Month	Avg Temp (F)	Dept. from 1981-2010 Normal
January	17.6	+ 2.0
February	24.9	+ 4.0
March	41.3	+ 8.5
April	48.1	+ 0.6
May	61.3	+ 2.2
June	71.3	+ 2.4
July	75.2	+ 1.4
August	73.4	+ 2.2
September	66.1	+ 4.1
October	52.9	+ 4.0
November	44.1	+ 10.4
December	20.9	+ 1.2

Table 4-4 shows the most intense rain events in 15-minute, 1-, 6-, and 24-hour intervals during 2016 as well as the corresponding Atlas 14 precipitation frequency ratings (NOAA, 2016b). Three events produced the most intense 15-minute, 1-, 6-, and 24-hour intervals for the entire year (Table 4-4). The 8/10-8/11 event produced two year events for the 15-minute, 1-hour, and 6-hour categories. When observed on a 24-hour interval, the storm produced 3.32” of precipitation and was categorized as a 5-year storm.

Table 4-4: Rainfall intensity statistics for 2016 from MCWG rain gauge data.

Rainfall Intensity			Atlas 14 Rating
Time Period	**Date & Event End Time**	**Amount (in)**	**Frequency (yr)**
15-minute	8/16/16 16:30	0.72	2
	7/5/16 17:15	0.66	1
	8/10/16 19:30	0.66	1
1-hour	8/10/16 20:15	1.66	2
	8/16/16 16:45	1.61	2
	7/5/16 17:45	1.35	2
6-Hour	8/11/16 1:15	2.38	2
	8/16/16 18:30	1.82	1
	7/5/16 20:30	1.8	1
24-Hour	8/11/16 6:30	3.32	5
	8/16/16 18:30	1.82	1
	7/5/16 20:30	1.8	1

Snowpack in CRWD was a not as prominent a climatic variable in 2016 than in previous years. The 2016 snowfall total of 37.70 inches measured at MSP was 16.7 inches lower than the 30-year normal of 54.5 inches (Table 4-5). Snowpack levels remained at seasonally low levels as a result of seasonally low precipitation in early winter months and record high spring temperatures, including multiple near 70 degree days in March (Table 4-3 and Figure 4-4).

Daily snowpack depths recorded at MSP were plotted against daily high temperature for the 2015-2016 winter in Figure 4-4 (DNR, 2016d). The 2016 calendar year began with a 4-inch snowpack from snowfall events occurring in late December 2015. One significant snowfall event occurred on February 3 (10.3 inches). The last date with a 1-inch snowfall measured at MSP was February 23 (DNR, 2016d), 36 days earlier than the normal date of March 31 (DNR, 2015j). A few small snow events occurred after February 23, but nothing contributed to a measureable snowpack.

Table 4-5: Summary of 2016 climatological events in CRWD.

2016 Climate Summary			
Variable	**2016**	**Average**	**Notes**
Total Precipitation (inches)	40.66	30.61	10.05" higher than 30-yr normal
Total Snow (inches)	37.70	54.4	16.7" lower than 30-yr normal
Last Significant Snowfall	2/3 (10.3")	N/A	49 days earlier than 2016
Last Spring date with greater than 1" snowpack	2/23	3/31	36 days earlier than normal
Spring Ice Out	3/15	4/5	9 days earlier than normal
Fall Leaf Off	11/2	N/A	Later than normal

With a mild winter and above average March temperatures, ice out on CRWD-area lakes occurred generally three weeks earlier than normal in 2016. Historical median ice out dates have not been established for any of the five CRWD lakes, nor were any observations made by CRWD on the lakes in spring 2016 (DNR, 2016a; DNR, 2016c). However, the DNR has collected annual and historical median ice out dates for lakes nearby CRWD, including the five observed in Table 4-6 (DNR, 2016a; DNR, 2016c).

Table 4-6: Summary of ice out dates for Twin Cities lakes nearby CRWD (DNR, 2016a; DNR 2016c).

Lake Name	2016 Ice Out Date	Historical Median Ice Out Date
Lake Nokomis	March 15	April 4
Powderhorn Lake	N/A	April 4
Lake Josephine	N/A	April 7
Lake Owasso	March 14	April 6
Lake Phalen	March 16	April 3

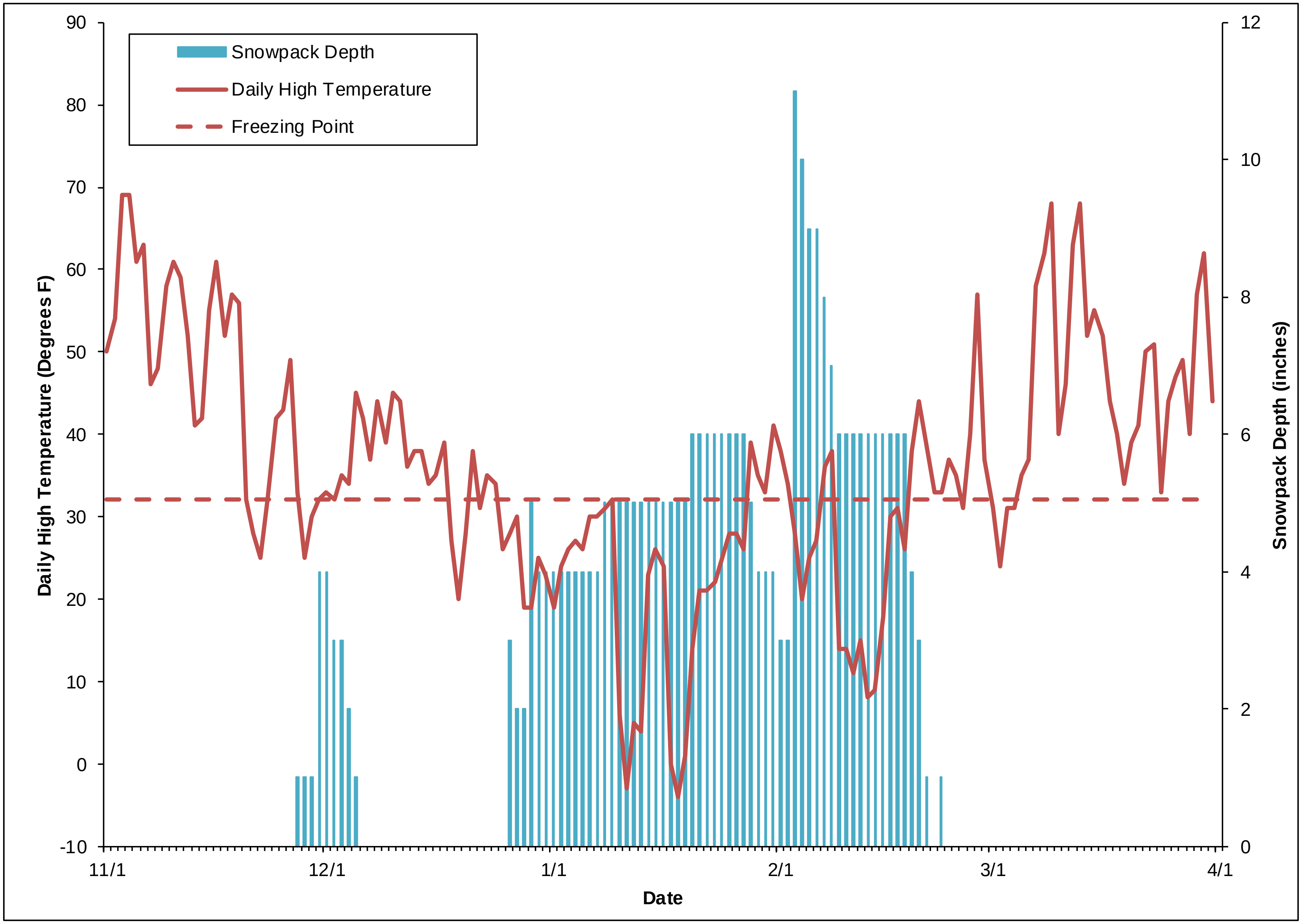

Figure 4-1: Daily temperature highs and snowpack depths from November 2015 to April 2016 as observed at MSP (DNR, 2016d).

5 CRWD LAKES RESULTS SUMMARY

5.1 OVERALL DISTRICT LAKES RESULTS

Table 5-1 shows the 2016 averages, historical averages, and lake standards for TP and Chl-a concentrations and Secchi depth for each lake. The data is shown graphically in Figures 5-1, 5-2, and 5-3. In accordance with MPCA eutrophication standards for Class 2B waters, a lake is considered impaired if it does not meet the MPCA standard for TP and either Chl-a or Secchi disk depth (MPCA, 2016). In 2016, Como Lake and Crosby Lake did not meet MPCA standards for TP. Como Lake also did not meet the standard for Chl-a nor Secchi depth, so it was considered impaired in 2016. All other lakes met the standards for Chl-a and Secchi depth. In general, all CRWD lakes exhibited an increase in water quality compared to 2015.

Table 5-1: CRWD 2016 average, historical average, and lake standards for TP/Chl-a/Secchi depth.

Lake	2016 Averages			Historical Averages			State Lake Standards		
	TP (µg/L)	Chl-a (µg/L)	Secchi (m)	TP (µg/L)	Chl-a (µg/L)	Secchi (m)	TP (µg/L)	Chl-a (µg/L)	Secchi (m)
Como	139	32.7	0.8	176	34.1	1.5	<60	<20	>1.0
Crosby	93	16.2	1.6	82	11.3	2.3	<60	<20	>1.0
Little Crosby	51	5.9	2.6	89	10.7	2.4	<60	<20	>1.0
Loeb	18	2.3	3.4	29	6.1	3.2	<60	<20	>1.0
McCarrons	14	3.3	4.5	33	9.6	2.9	<40	<14	>1.4

Value does not meet the state standard (shaded: Como TP, Chl-a, Secchi 2016 and historical TP, Chl-a; Crosby TP 2016 and historical; Little Crosby historical TP)

Value meets the state standard

In 2016, CRWD determined lake grades for each of its lakes based on the lake grade system created by the Metropolitan Council (Table 5-2) (Osgood, 1989). Similar to previous years, Loeb Lake and Lake McCarrons were the only two lakes that received good grades of 'A' in 2016. An average water quality grade of 'C' was given to Crosby Lake, and Little Crosby Lake improved to a 'B' grade after receiving a 'C' in 2015. This grade increase was due to improvements in all three eutrophication parameters. Como Lake received the lowest grade of 'D+', similar to the more recent years of monitoring. All five of the lakes exhibited 2016 lake grades that were similar to their average historical grades (Table 5-2).

Table 5-2: CRWD 2016 and historical lake grades and averages for TP/Chl-a/Secchi depth.

Lake	2016 Lake Grade			2016	Historical Lake Grade			Historical
	TP	Chl-a	Secchi	Average	TP	Chl-a	Secchi	Average
Como	D	C	D	**D+**	F	C	C	**D+**
Crosby	D	B	C	**C**	D	B	B	**C+**
Little Crosby	C	A	B	**B**	D	B	B	**C+**
Loeb	A	A	A	**A**	B	A	A	**A**
McCarrons	A	A	A	**A**	C	A	B	**B**

5.2 SUMMARY OF INDIVIDUAL LAKES RESULTS

5.2.1 COMO LAKE

Como Lake has been monitored since 1984, so historical averages represent 32 years of data. Como Lake improved in water quality for TP and Chl-a in 2016 in comparison to the previous year (TP decreased from 215 µg/L in 2015 to 139 µg/L in 2016, and Chl-a decreased from 42.8 µg/L in 2015 to 32.7 µg/L in 2016), and both parameters fell below the calculated historical averages (176 µg/L and 34.1 µg/L, respectively) in 2016 (Figures 5-1, 5-2, and 5-3). Como Lake degraded with respect to Secchi depth, reducing in clarity from 1.2 m in 2015 to 0.8 m in 2016 and falling below the historical average of 1.5 m (Figures 5-1, 5-2, and 5-3). Como Lake has historically not met shallow lake state standards for TP and Chl-a concentrations. This was the case in 2016 as well. Como Lake has historically met shallow lake state water quality standards for Secchi depth, but did not meet the standard in 2016.

5.2.2 CROSBY LAKE

Crosby Lake has been monitored since 1999, so historical averages represent 17 years of data. Crosby Lake degraded in all eutrophication parameters in 2016 when compared to the historical average (Figures 5-1, 5-2, and 5-3). Even though the 2016 TP average (93 µg/L) was still above the historical average (82 µg/L), however, it improved significantly over the previous year, decreasing 35% from 144 µg/L in 2015. Crosby Lake has historically been impaired for TP concentration, which was also the case in 2016. In concurrence with past trends, Crosby Lake met water quality standards for both Chl-a concentration and Secchi depth.

5.2.3 LITTLE CROSBY LAKE

Little Crosby Lake has been monitored since 2011, so historical averages represent only five years of data. In 2016, Little Crosby Lake improved in water quality when compared to the historical averages for all parameters (Figures 5-1and 5-3). With only 5 historical data points, comparisons to other historical averages are not as robust as they are for other lakes with a greater degree of longitudinal monitoring. Little Crosby Lake has previously not met the shallow lake standards for TP during its short monitoring history, but met the standards for TP for the first time in 2016. Little Crosby Lake has consistently met the standards for Chl-a and Secchi depth.

5.2.4 LOEB LAKE

Loeb Lake has been monitored annually since 2003, so historical averages represent 13 years of data. In 2016, Loeb Lake improved in water quality when compared to the historical averages of all three parameters (Figures 5-1, 5-2, and 5-3). Loeb Lake has met all of the shallow lakes standards throughout its sampling period to date. Loeb displayed improved water quality from the previous year, and maintained its position as exhibiting the best water quality of any of the District lakes.

5.2.5 LAKE MCCARRONS

Lake McCarrons has been monitored annually since 1988, so historical averages represent 28 years of data. When compared to the historical average, Lake McCarrons showed improved water quality as indicated by an improvement in all three parameters from the historical average (Figures 5-1, 5-2, and 5-3). Both TP and Secchi depth also showed an improvement from 2015 monitoring values, with Chl-a exhibiting only a slightly higher value in 2016 than in 2015. It should be noted that the historical averages are skewed towards worse water quality, as the monitoring period includes data in the average that was collected prior to the 2004 alum treatment. In 2016, Lake McCarrons still met all of the deep lake standards; the historical averages met all of the deep lake standards as well.

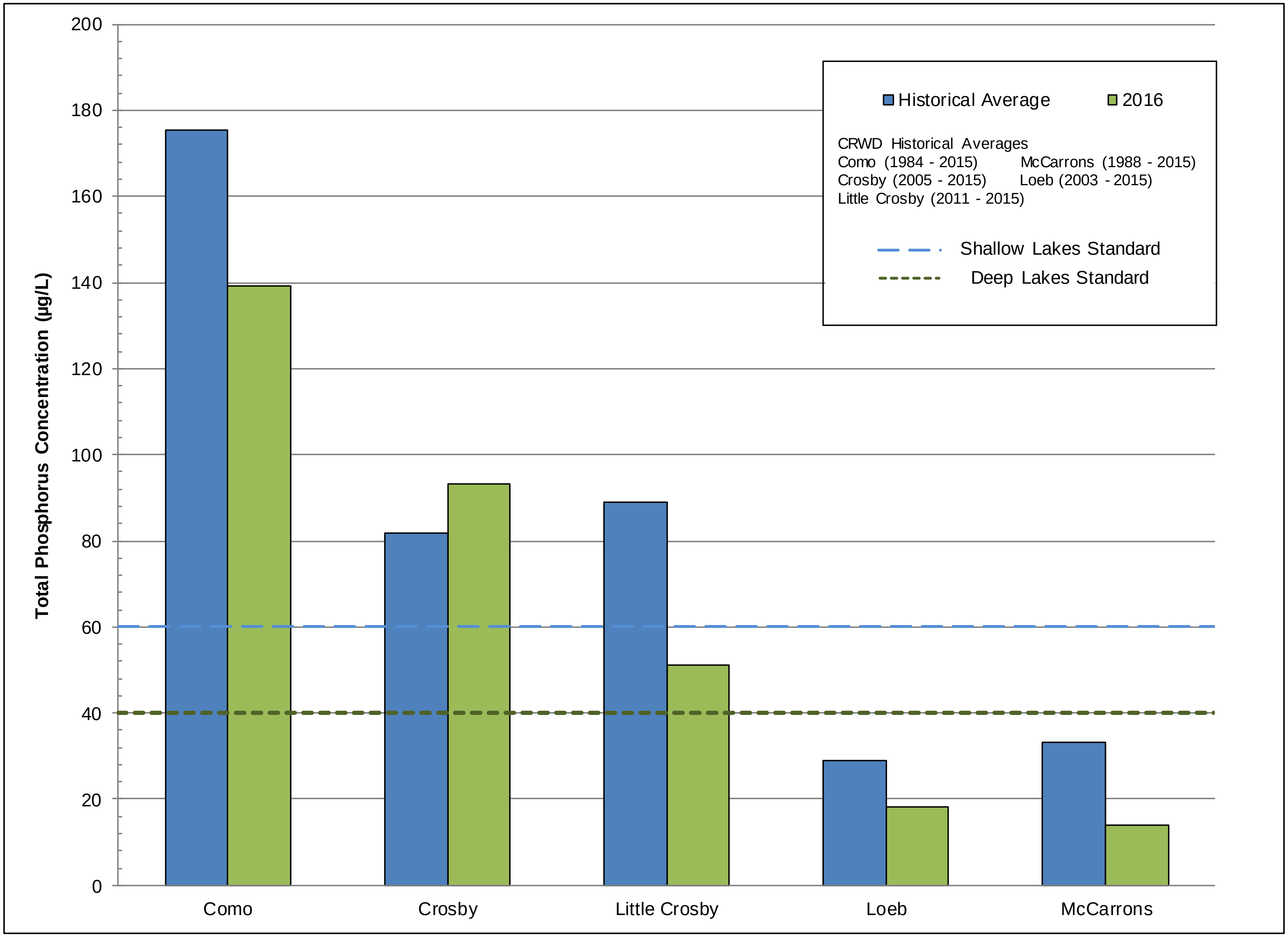

Figure 5-1: CRWD 2016 vs. historical average TP concentrations and lake standard comparisons.

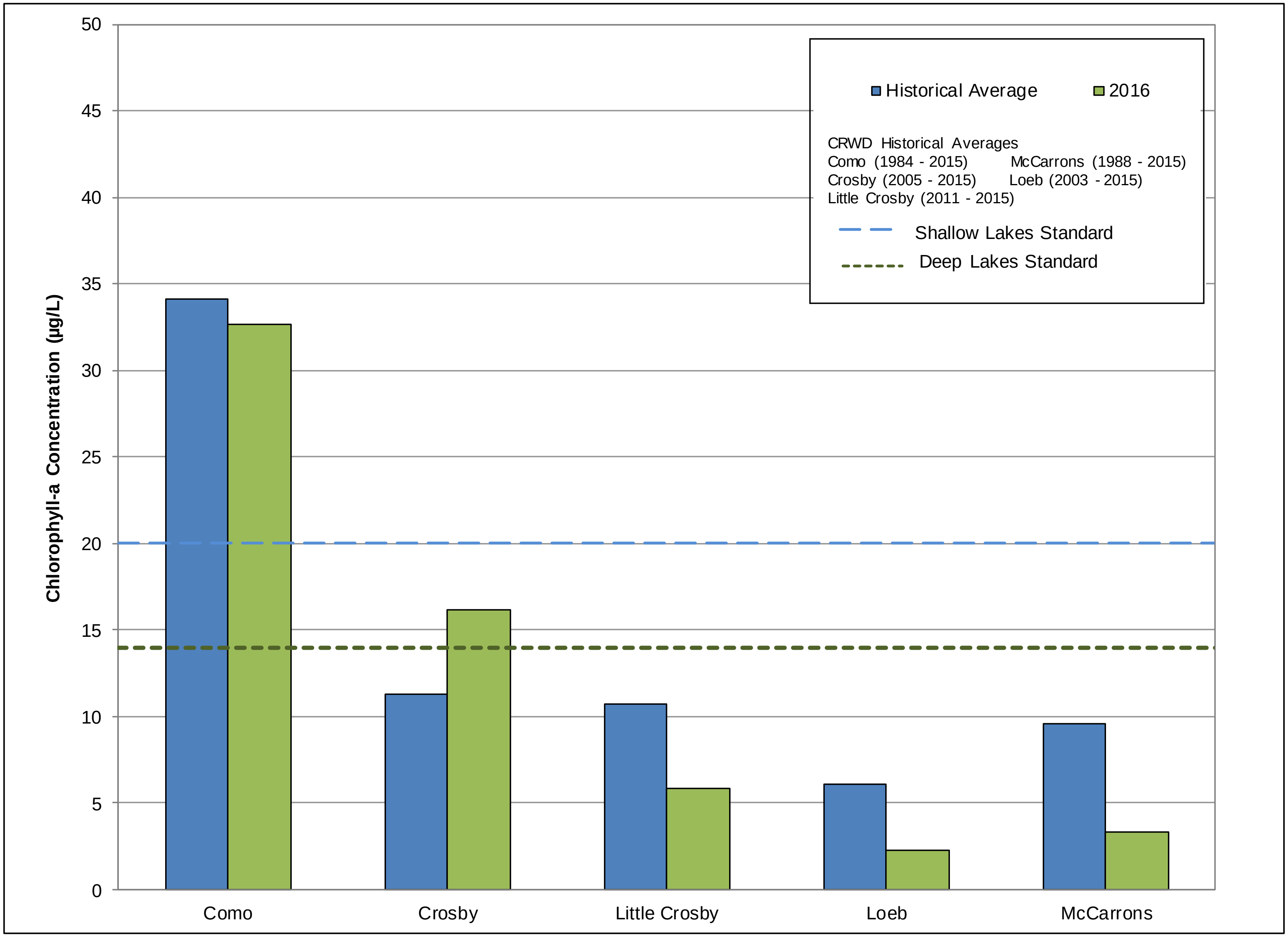

Figure 5-2: CRWD 2016 vs. historical average Chl-a concentrations and lake standard comparisons.

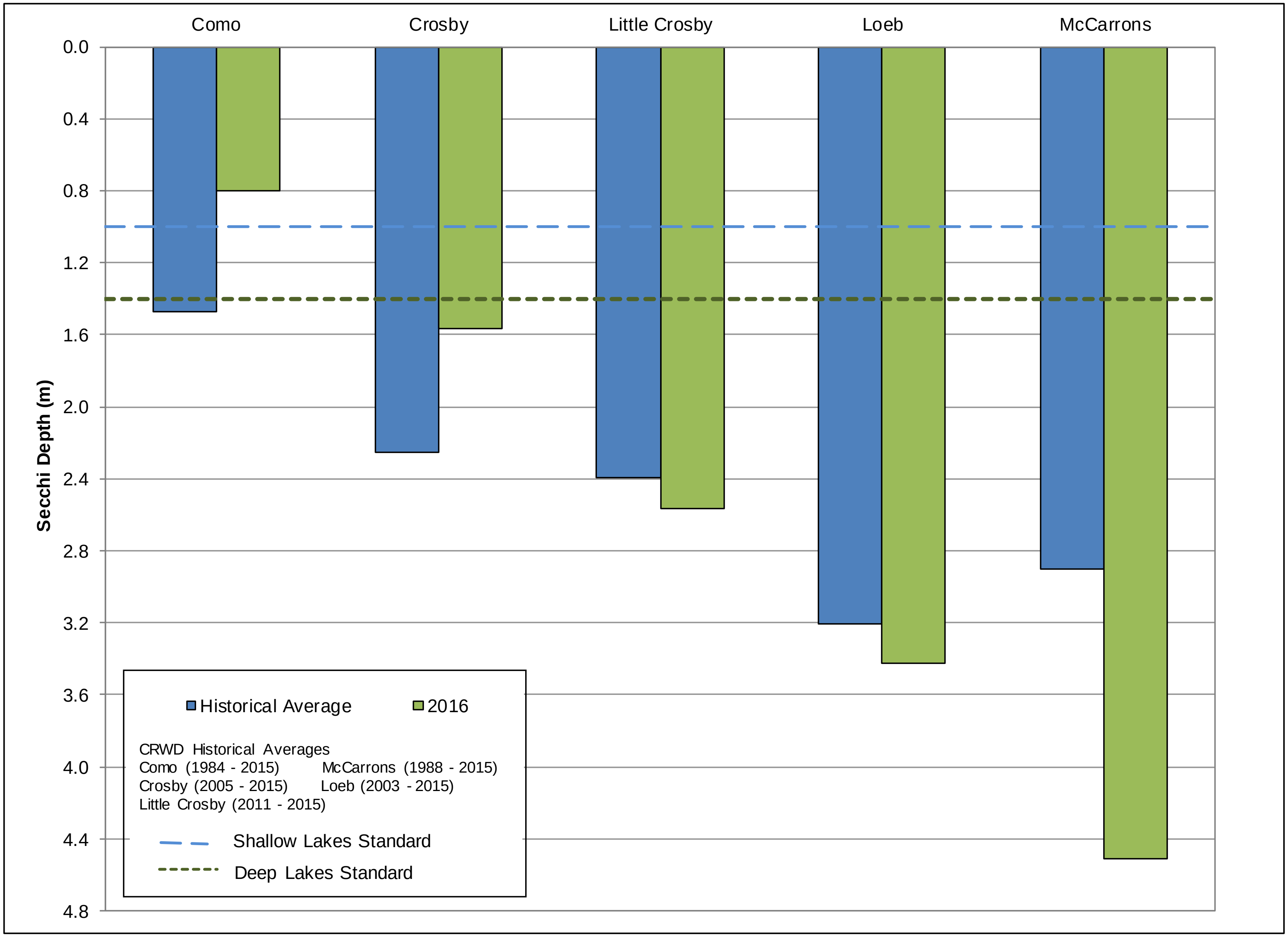

Figure 5-3: CRWD 2016 vs. historical average Secchi depths and lake standard comparisons.

6 COMO LAKE RESULTS

6.1 COMO LAKE BACKGROUND

Como Lake, a 70.5 acre shallow lake located in St. Paul's 348 acre Como Regional Park, is one of the most popular lakes in CRWD (Figure 6-1). In 2015, Como Regional Park was the second most frequently visited park in the Twin Cities Regional Parks System, with more than 4.3 million visits over the course of the year (MC, 2017). The lake is frequented by residents and visitors who come for various forms of outdoor recreation, including running/walking, fishing, and boating. The lake does not offer swimming opportunities and does not have a public boat launch. Only non-motorized, car top carried boats and electric trolling motors are allowed on the lake for fishing/recreation purposes.

Figure 6-1: View of the northwest shoreline of Como Lake.

Como Lake is a shallow urban lake with a volume of 468.8 acre-ft, a littoral area that covers 100% of the lake, and a maximum depth at 15.5 ft, (Table 6-1; Figure 6-2). Como Lake receives water from the surrounding watershed (1,856 acres), which consists of runoff from primarily residential areas, as well as from Como Regional Park and Golf Course (Figure 6-3). Runoff from the residential areas is directed to the lake through a system of stormwater pipes located under the streets. Located upstream of Como Lake, Gottfried's Pit receives drainage from Roseville, Falcon Heights, Ramsey County right-of-ways, and the City of St. Paul before being pumped into Como Lake. Water occasionally outflows from the lake at the southeast corner, discharging into the Trout Brook storm sewer system which is routed to the Mississippi River (CRWD, 2002). The shallow depth of the lake, coupled with the large nutrient inputs from upland runoff sources, has had significant negative impacts to the lake's overall health.

Table 6-1: Como Lake morphometric data.

Surface Area (acres)	Maximum Depth (ft)	Littoral Area	Volume (acre-ft)	Watershed Area (acres)	Watershed: Lake Area (ratio)
70.5	15.5	100%	469	1,856	26.3

Figure 6-2: Como Lake bathymetric map.

One major water quality problem Como Lake has historically faced is the excessive amount of sediment entering the lake from construction, roads, and general erosion. In the past, this led to the formation of sediment deltas near stormwater inlets to the lake, which reduced overall lake volume, increased water turbidity, and decreased habitat value for the lake's fish populations. Sediment can also provide a means by which other pollutants, including metals and hydrocarbons, can be transported to lakes. To address this problem, in 2001-2002, the lake was dredged to reduce the sediment deltas seen on the southwest side of the lake. This dredging reduced the amount of sediment that had accumulated in the lake and increased lake volume, giving the lake a higher capacity to absorb nutrient inflows.

In September 1985, after numerous years of problems with algal standing crops on Como Lake, biomanipulation management occurred in order to improve overall water quality. This biomanipulation consisted of a rotenone treatment which effectively removed all current fish populations in the lake. This treatment was followed by a complete restocking of the fish populations. By changing the fish populations, zooplankton populations rebounded and fed off of the algal growth in the lake. In this way, algal growth was reduced through a "top-down" management approach (control of the top members of the food chain, i.e. fish). This management occurred with the goal of decreasing extreme algal biomass growth on the lake and improve lake aesthetic and recreation for users.

In addition, low oxygen levels during winter months caused partial fish kills dating back to 1945, leading Ramsey County to install an aerator in 1985 (CRWD, 2002). After the complete restocking of the fish populations occurred in 1985, the aerator was installed to prevent any further fish kills. The original aerator was replaced in the winter of 2014-2015 by two floating aerators that improved the efficiency and breadth of aeration on the lake. Fish kills are now rare, but could potentially occur if there was aerator equipment failure or if an especially cold winter with deep snowpack occurred.

Como Lake's greatest water quality problem is excessive phosphorus. External and internal inputs of phosphorus have caused annual algal blooms and overgrowth, further reducing the integrity of the lake. Subsequently, Como Lake has historically not met the shallow lake state water quality standards for TP and Chl-a concentrations (< 60 µg/L and < 20 µg/L, respectively), but has met the standards for Secchi disk depth (> 1.0 m). The Como Lake Strategic Management Plan (CRWD, 2002) was published in 2002 to identify management issues surrounding Como Lake and develop goals to improve the lake's health. From this plan, a water quality goal of less than 59 µg/L for annual average TP was developed, in order to reduce the number and severity of algal blooms and improve overall water quality (CRWD, 2002).

In an effort to meet state nutrient standards and the goals defined in the management plan, various shoreline improvement projects have been completed on the lake since 2003 by the City of St. Paul and Ramsey Conservation District, with help from CRWD and other organizations. These projects have stabilized the shoreline, reduced erosion, increased habitat for wildlife, replaced non-native invasive plants with native species and improved the aesthetics of the shoreline for visitors. Harvesting of aquatic plants at specific locations on the lake (e.g. near the dock and pavilion areas) has occurred at various times since the 1980s in order to enhance recreational opportunities for visitors.

Numerous BMPs have been installed by CRWD, the City of St. Paul, and others in the Como Lake subwatersheds to reduce external pollutant loading to the lake and to meet the state standards and management goals. In 2007, the Arlington-Pascal Stormwater Improvement Project was constructed upland of Como Lake in the Como 7 subwatershed, which consisted of a series of BMPs including raingardens, infiltration trenches, an underground facility, and stormwater ponds. More information about these BMPs may be found in the CRWD *Stormwater BMP Performance Assessment and Cost-Benefit Analysis* (CRWD, 2012b).

Finally, Como Lake was listed on the MPCA's 2012 303(d) list for nutrient impairment because of hypereutrophic conditions (MPCA, 2012). Also, Como Lake is currently listed on the MPCA's 2014 303(d) proposed impaired waters list for chloride impairment (MPCA, 2016). Como Lake was first listed in 1998 for mercury in fish tissue (TMDL plan approved in 2008) and in 2002 for nutrient/eutrophication biological indicators (TMDL plan approved in 2010) (MPCA, 2012). Odor problems due to end-of-summer algal blooms also continue to be a problem and have been recorded since 1945.

It is hypothesized that the water quality (referring to the TP, Chl-a, and Secchi disk depth) in Como Lake historically displayed a cyclical pattern, fluctuating every five to six years between fair and poor water quality (Figure 6-7) (Noonan, 1998). This pattern, however, has not been observed in recent years of monitoring. This suggests that the interactions among the biological, chemical, and physical parameters of the lake need to be better understood in order to make informed management decisions to improve the lake's future health. In 2016, CRWD started working on an in-lake management plan to better understand the complex interactions occurring among the various chemical, biological, and physical parameters in Como Lake.

Figure 6-3: Como Lake and subwatershed boundary.

6.2 LAKE LEVEL

The level of Como Lake has fluctuated around the OHWL (881.4 ft) since monitoring of the lake level began in 1978 with a range of 4.3 ft, varying between 879.2 ft to 883.5 ft. The lowest of the range extremes occurred in June 1987, and the highest occurred in October of 2007 (Figure 6-4).

The 2016 lake level reported in Figure 6-5 consists solely of the 15 min level logger data collected from May to November by CRWD. The average level for 2016 was 881.09 ft. The level followed normal fluctuation patterns in 2016 (Figure 6-5). From early- to mid-summer, the level oscillated between spikes following rain events. The level reached its lowest point at 880.63 on July 21 after two weeks without more than 0.25" of rain from a single event. The largest spikes were observed in June, August, and October, when the water level exceeded the OHWL.

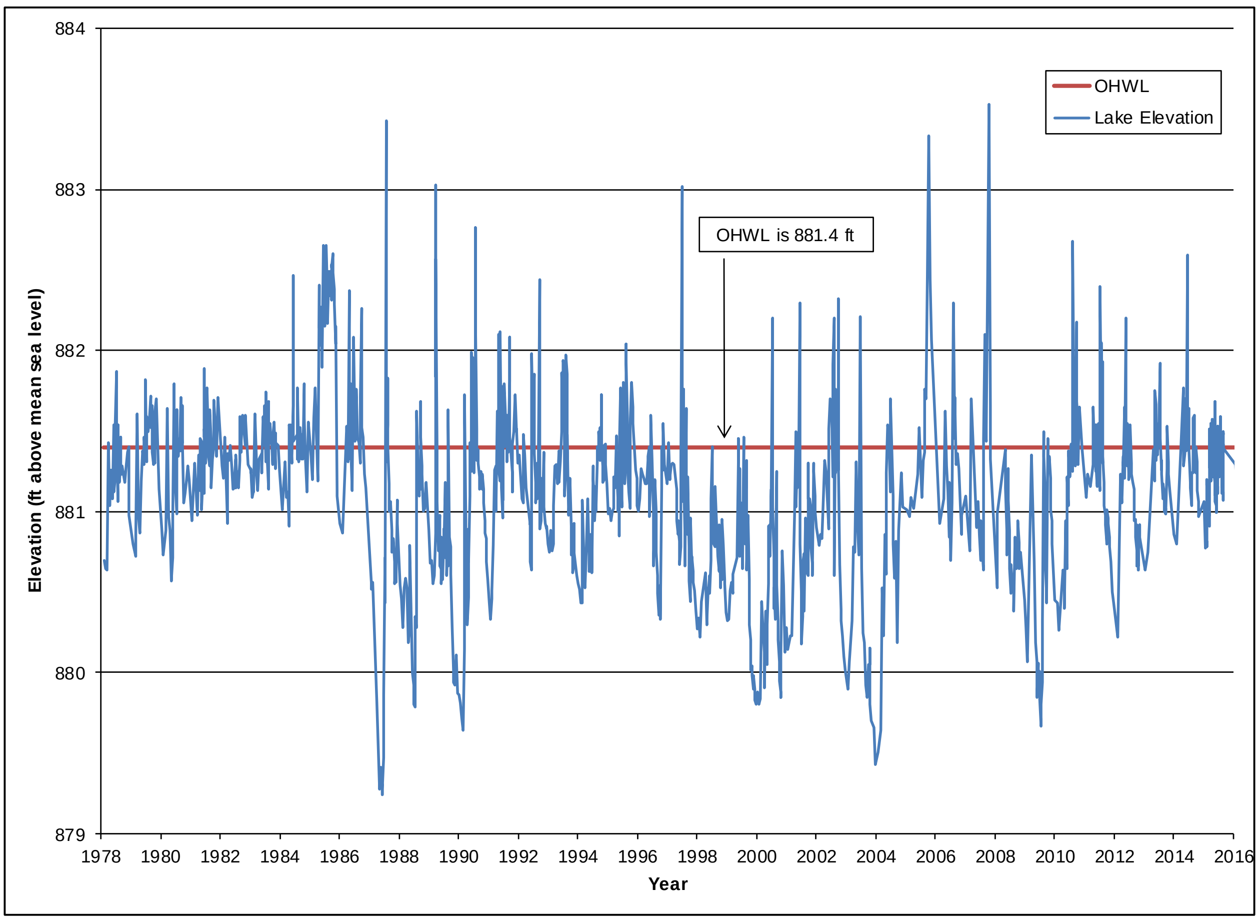

Figure 6-4: Como Lake historical lake elevations and the OHWL (DNR, 2016b).

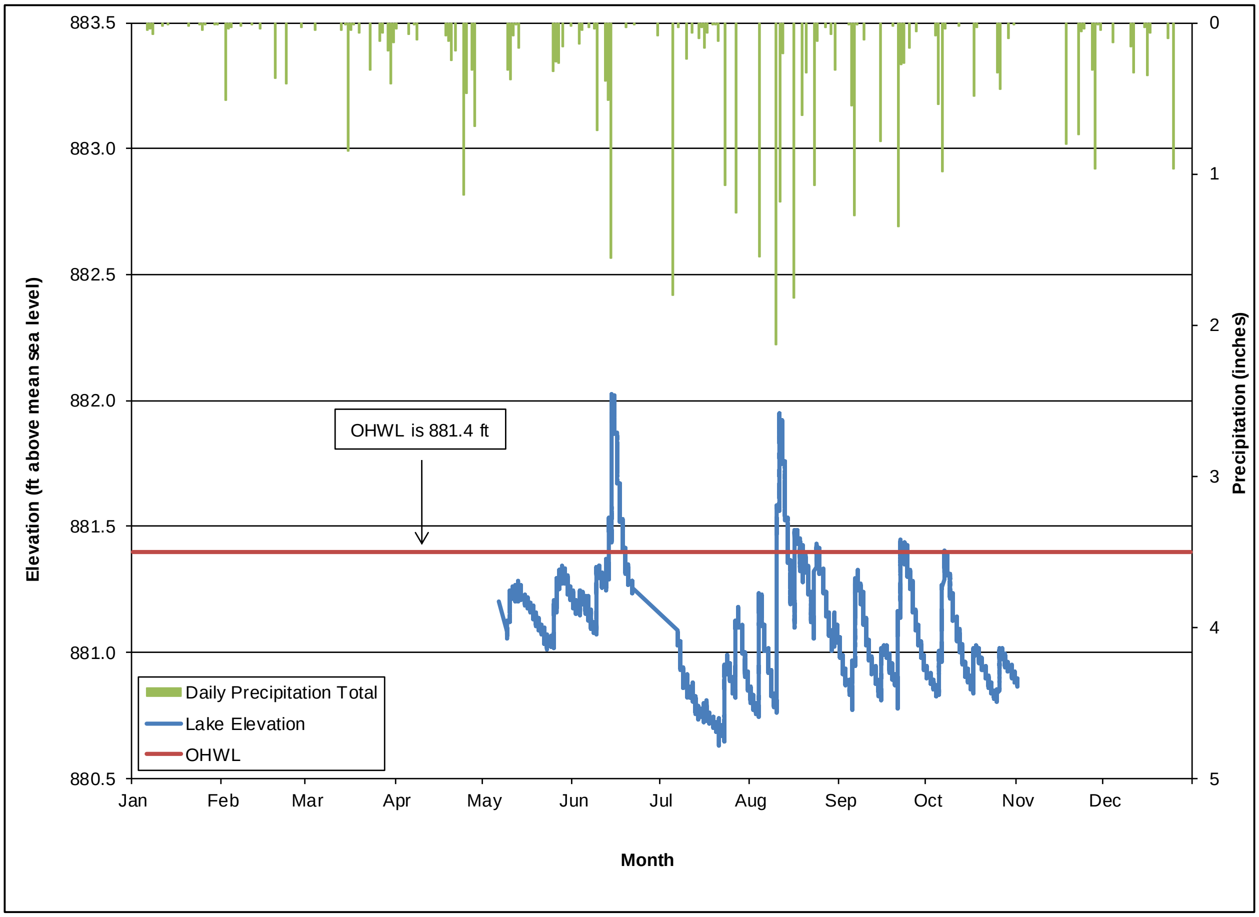

Figure 6-5: Como Lake 2016 lake elevations, OHWL, and daily precipitation events (DNR, 2016b; MCWG, 2016).

6.3 WATER QUALITY RESULTS

During 2016, Como Lake was sampled ten times from April 6 to October 21 (Figure 6-6). Similar to previous years, Como Lake was generally characterized by high TP and Chl-a concentrations, and low Secchi depths (Figure 6-7).

Sampling shows that TP and Chl-a concentrations were generally lower early spring (April through May) than at the end of the season (July through October) (Figure 6-6). While Chl-a fluctuated throughout the monitoring season, TP rose steadily into the summer, peaking in late August. Secchi disk readings only met the state standard through the first June sampling. In previous years, higher TP concentrations were generally correlated with both higher Chl-a concentrations and lower Secchi depths. TP and Chl-a, however, were not strongly correlated during 2016, indicating that TP was not the only driver of lake productivity. Secchi depth was more closely correlated to increases and decreases in Chl-a, suggesting that Chl-a was a more prominent driver for water clarity in Como Lake during 2016.

Seasonally, Como Lake exhibits the best and least variable water quality during the month of May for TP and Chl-a (Figure 6-7). Secchi disk depth varies the least during the month of August. Water quality worsens as the summer months continue into fall. The month of August has the highest medians for TP and Chl-a, and the lowest median for Secchi disk depth, which cumulatively indicates that the month of August generally exhibits the worst water quality.

In 2016, TP and Chl-a decreased from 2015 values. TP decreased from 215 µg/L in 2015 to 139 µg/L in 2016, and Chl-a decreased from 42.8 µg/L in 2015 to 32.7 µg/L in 2016. Both parameters fell below the calculated historical averages (176 µg/L and 34.1 µg/L, respectively), indicating an improvement in water quality in these parameters (Tables 6-2 and 5-1). Average Secchi depth in 2016, however, decreased from 2015 (from 1.2 m in 2015 to 0.8 m in 2016), indicating declining water clarity. With decreases in TP and Chl-a in 2016, it would have been expected that water clarity (as represented by Secchi depth) would have simultaneously increased. Since these are not in concert, this indicates that another process within the lake other than algal growth is influencing water clarity. Examination of all three parameters in 2016 as a whole does not lead to a definitive conclusion of the current trend in water quality in Como Lake, as compared to previous years of monitoring (Figure 6-8). It also appears that the cyclical pattern (see Section 6.1, page 38) observed historically in these water quality parameters may no longer be an active process for Como Lake based on the most recent data collected.

TP concentrations in the hypolimnion displayed even more drastic fluctuations than in the epilimnion, despite maintaining a similar 5-6 year cyclical pattern for the first 20 years on record (Figure 6-9). In eutrophic lakes, the hypolimnion is generally richer in phosphorus than the epilimnion because bed sediments readily release phosphorus into the anoxic (or oxygen depleted) bottom layer, usually peaking in fall just prior to lake turnover (Kalff, 2002). Within the last 10 years, Como Lake hypolimnetic TP concentrations have not followed the peaks in epilimnetic TP during the same period. The most recent peak in hypolimnetic TP concentration in 2014 was the highest on record, but were followed by a decline in both 2015 and 2016. Data collected during future monitoring seasons will help determine if this phenomenon is an abnormality from the hypolimnetic TP cycling pattern and what could be causing this to occur.

Yearly average historical TP concentrations, Chl-a concentrations, Secchi depths, and their comparisons to lake standards are shown in Table 6-2. Como Lake TP yearly average concentrations have exceeded the MPCA standards for all years of monitoring, including 2016. Chl-a concentrations have also exceeded the standard for 2016 and the majority of years monitored. Conversely, approximately 75% of the historical Secchi depth yearly averages met the standards. Similar to 2015, CRWD issued a ‘D+’ grade for Como Lake based on the annual average eutrophication parameters in 2016 (Table 6-3). The historical average grade for Como Lake is ‘D+’. The highest grade the lake has ever received was ‘B’, which occurred in 1998 and 1999.

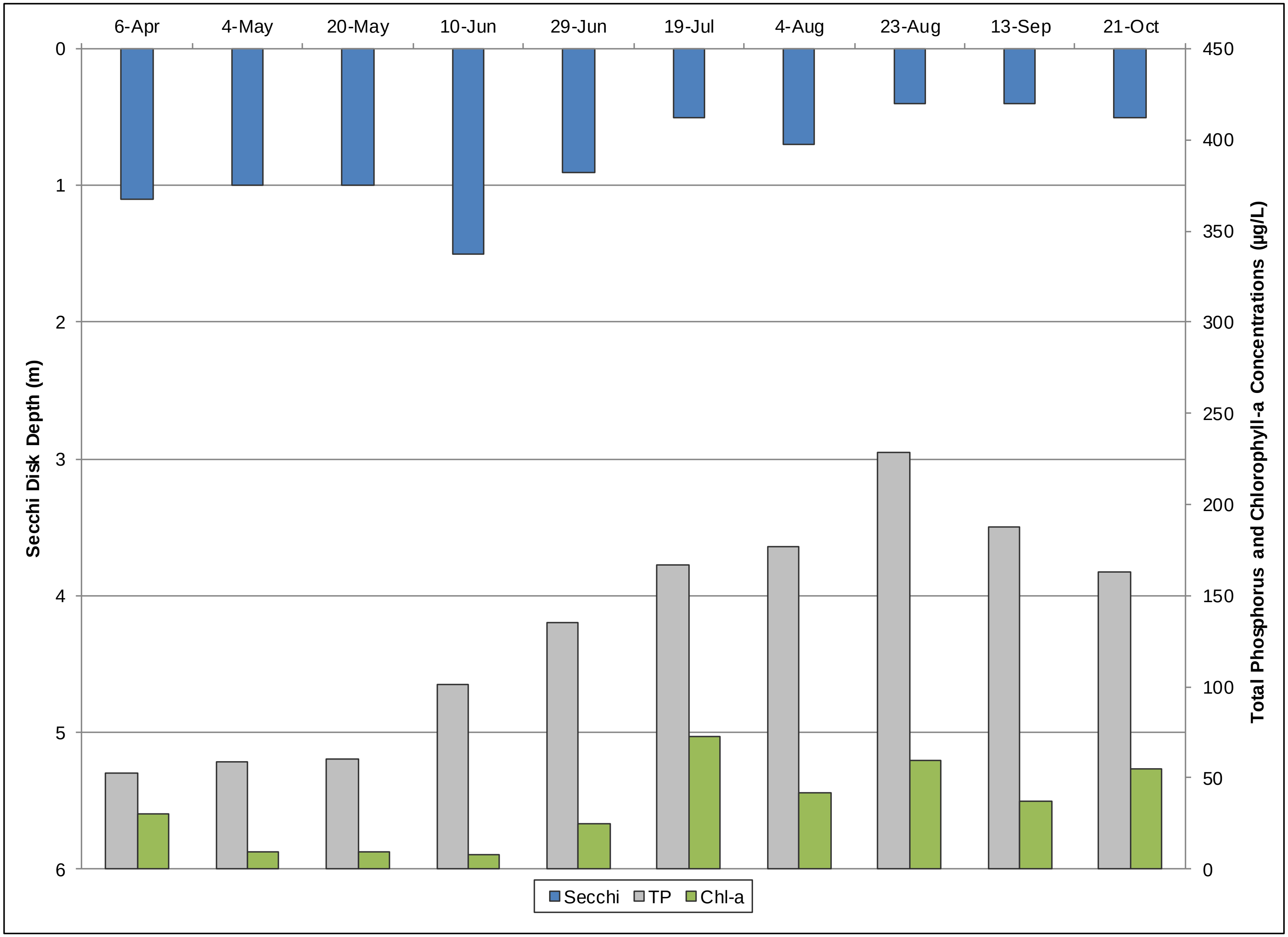

Figure 6-6: Como Lake 2016 Secchi/TP/Chl-a comparison.

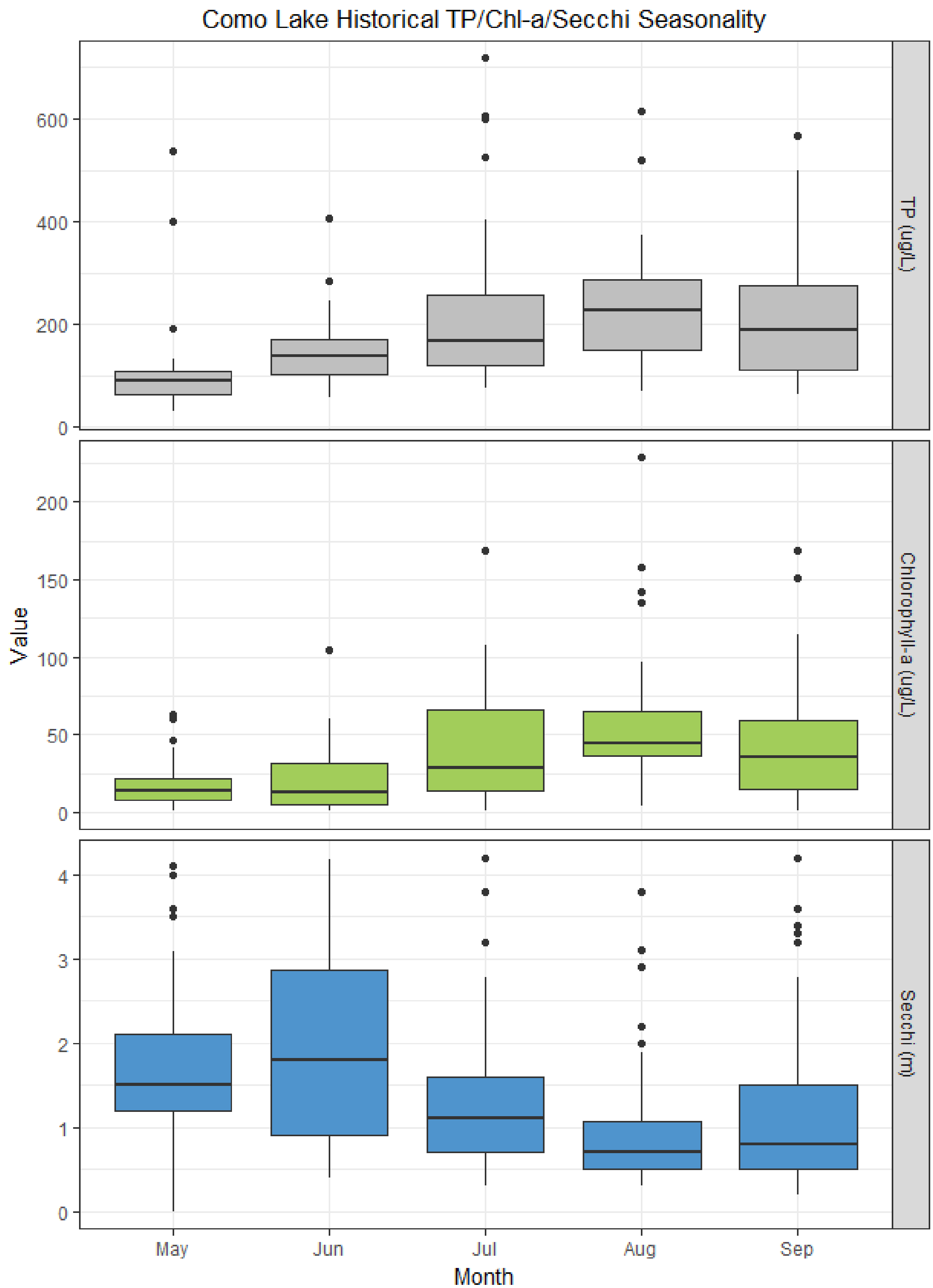

Figure 6-7: Como Lake seasonality boxplots of historical Secchi/TP/Chl-a samples.

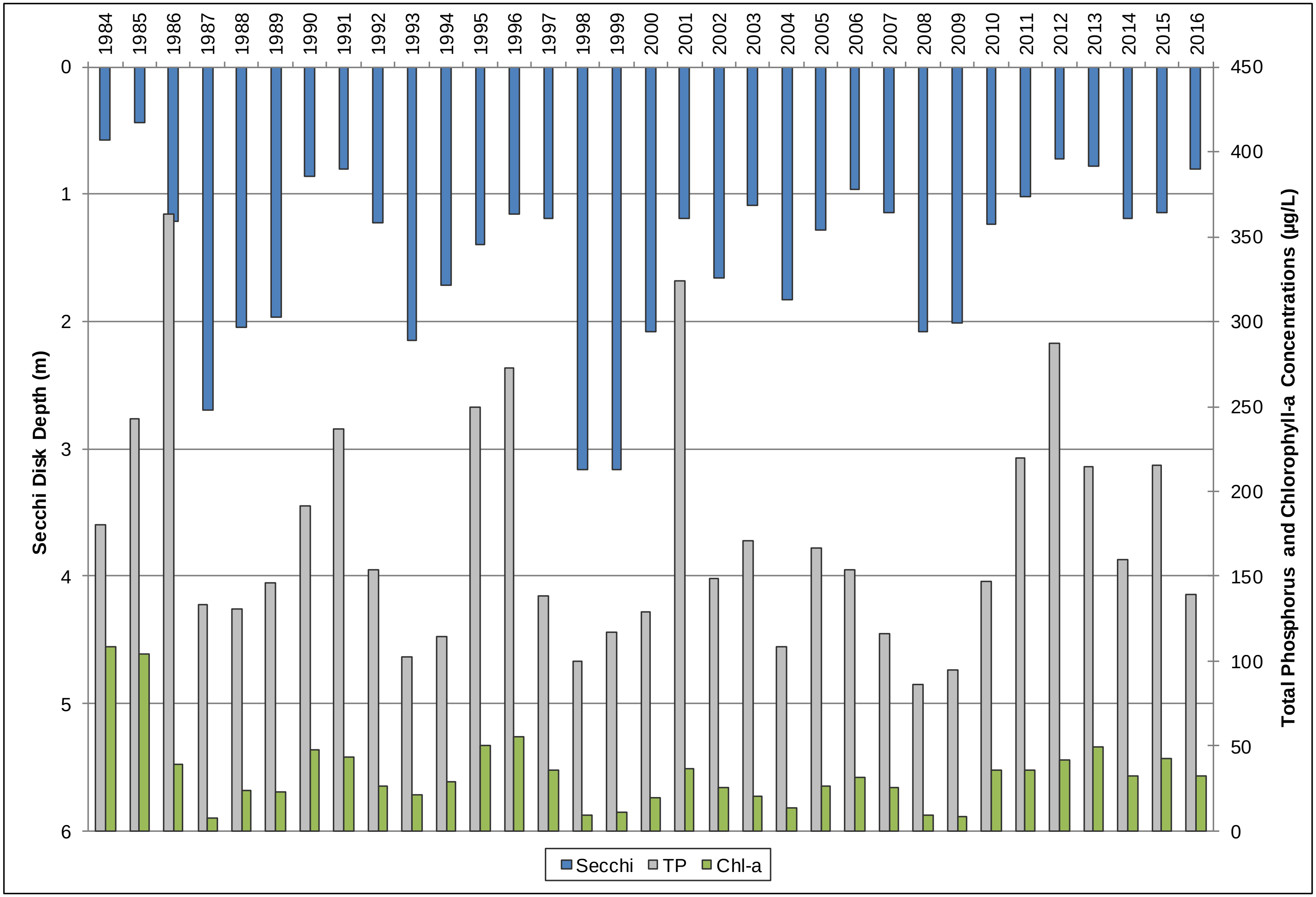

Figure 6-8: Como Lake historical annual average Secchi/TP/Chl-a comparison.

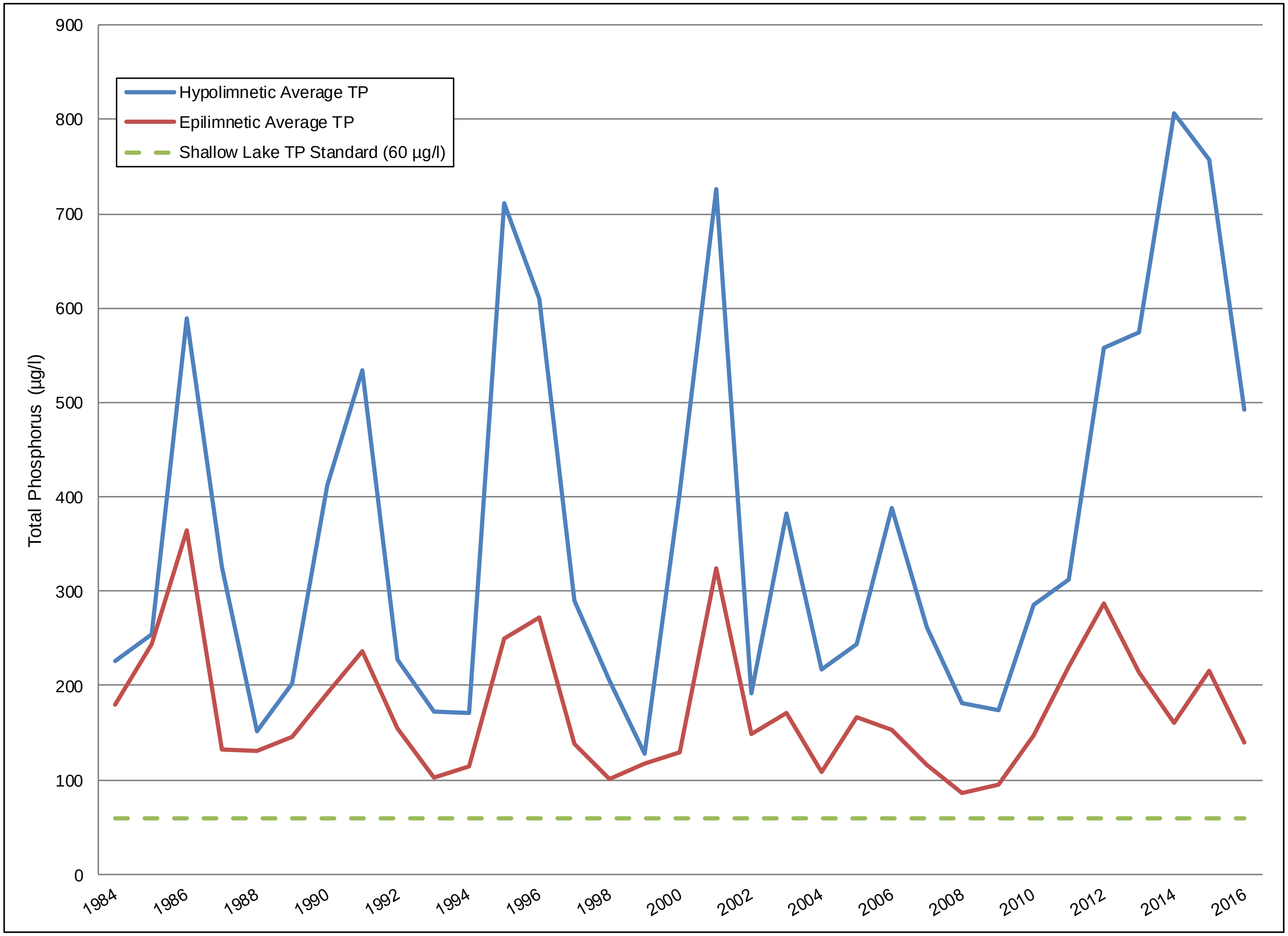

Figure 6-9: Como Lake historical annual average hypolimnetic and epilimnetic total phosphorus.

Table 6-2: Como Lake historical yearly TP/Chl-a/Secchi depth averages compared to shallow lake state standards.

Year	TP (µg/L)	Chl-a (µg/L)	Secchi (m)
1984	180	108.7	0.6
1985	243	104.4	0.4
1986	364	39.0	1.2
1987	133	7.8	2.7
1988	131	23.5	2.0
1989	146	22.7	2.0
1990	191	47.9	0.9
1991	236	43.9	0.8
1992	154	26.8	1.2
1993	103	21.2	2.2
1994	115	29.0	1.7
1995	250	50.0	1.4
1996	273	55.1	1.2
1997	139	35.9	1.2
1998	100	9.2	3.2
1999	117	11.0	3.2
2000	129	19.6	2.1
2001	324	36.5	1.2
2002	149	25.8	1.7
2003	171	20.8	1.1
2004	109	13.4	1.8
2005	167	26.7	1.3
2006	154	31.3	1.0
2007	116	25.4	1.1
2008	87	9.4	2.1
2009	95	8.8	2.0
2010	147	36.1	1.2
2011	220	36.2	1.0
2012	288	42.2	0.7
2013	215	49.4	0.8
2014	160	32.3	1.2
2015	215	42.8	1.2
2016	139	32.7	0.8

(shaded)	Value does not meet state standard*
(unshaded)	Value meets state standard

*MPCA shallow lake standards must be less than 60 µg/L for TP and 20.0 µg/L for Chl-a, with a Secchi disk depth of greater than 1.0 m.

Table 6-3: Como Lake historical lake grades.

Year	TP Grade	Chl-a Grade	Secchi Grade	Overall Grade
1984	F	F	F	**F**
1985	F	F	F	**F**
1986	F	C	C	**D+**
1987	D	A	B	**C+**
1988	D	C	C	**C**
1989	D	C	C	**C**
1990	F	C	D	**D**
1991	F	C	D	**D**
1992	F	C	C	**D+**
1993	D	C	C	**C**
1994	D	C	C	**C**
1995	F	D	C	**D**
1996	F	D	D	**D**
1997	D	C	D	**D+**
1998	D	A	A	**B**
1999	D	B	A	**B**
2000	D	B	C	**C**
2001	F	C	D	**D**
2002	D	C	C	**C**
2003	F	C	D	**D**
2004	D	B	C	**C**
2005	F	C	C	**D+**
2006	F	C	D	**D**
2007	D	C	D	**D+**
2008	D	A	C	**C+**
2009	D	A	C	**C+**
2010	D	C	C	**C**
2011	F	C	D	**D**
2012	F	C	D	**D**
2013	F	D	D	**D**
2014	F	C	C	**D+**
2015	F	C	C	**D+**
2016	D	C	D	**D+**

6.4 PHYTOPLANKTON AND ZOOPLANKTON

During 2016, Como Lake was sampled for phytoplankton and zooplankton ten times from April 6 to October 16. Total phytoplankton concentration was moderate at the beginning of the year, peaking at the late June sampling date, then decreasing throughout the month of July until generally plateauing through the end of the year (Figure 6-10). Throughout the entire monitoring season, the phytoplankton community was dominated by Chlorophyta and Cyanophyta (Figure 6-12). Chlorophyta blooms occurred during April and early May, June, and late September into October. The large increase in total concentration corresponds to the Chlorophyta increase observed in June. Cyanophyta blooms occurred during mid-May, and from mid-July through mid-September. The large peak in Cyanophyta during the mid-August sampling event occurs at the same time as TP peaks for the year (Figures 6-10 and 6-12). There was a minor presence of Cryptophyta from the beginning of April through mid-July, and then again during the final sampling events of the year. Chrysophyta was observed during July.

Zooplankton communities in Como Lake were mainly dominated by Rotifers and Cladocerans during the month of April (Figure 6-13). Rotifer presence decreased by the early May sample, but spiked again in the sample collected in mid-May. Cladocerans dominated the zooplankton community for the majority of the field season, contributing greatly to the overall density, especially during the peak in total density in early June (Figure 6-11). Cladocerans, including the genus *Daphnia*, are important filter feeders and vital components of lower trophic levels in lake environments. Populations of nauplii and cyclopoida were observed in moderate numbers throughout the year, and densities for both were greatest during late June/early July. After peaking in early June, overall zooplankton density decreased and remained stable through the last sampling event in mid-October (Figure 6-11). Zooplankton density did not strongly correlate with Chl-a concentrations in 2016.

Total phytoplankton and zooplankton trends do not appear to correlate, as zooplankton peaks in early June, while phytoplankton does not peak until late June (Figures 6-10 and 6-11). In general, we might expect to see the opposite relationship occur, in which zooplankton populations peak after phytoplankton populations surge, as phytoplankton are a food source for zooplankton (Kalff, 2002).

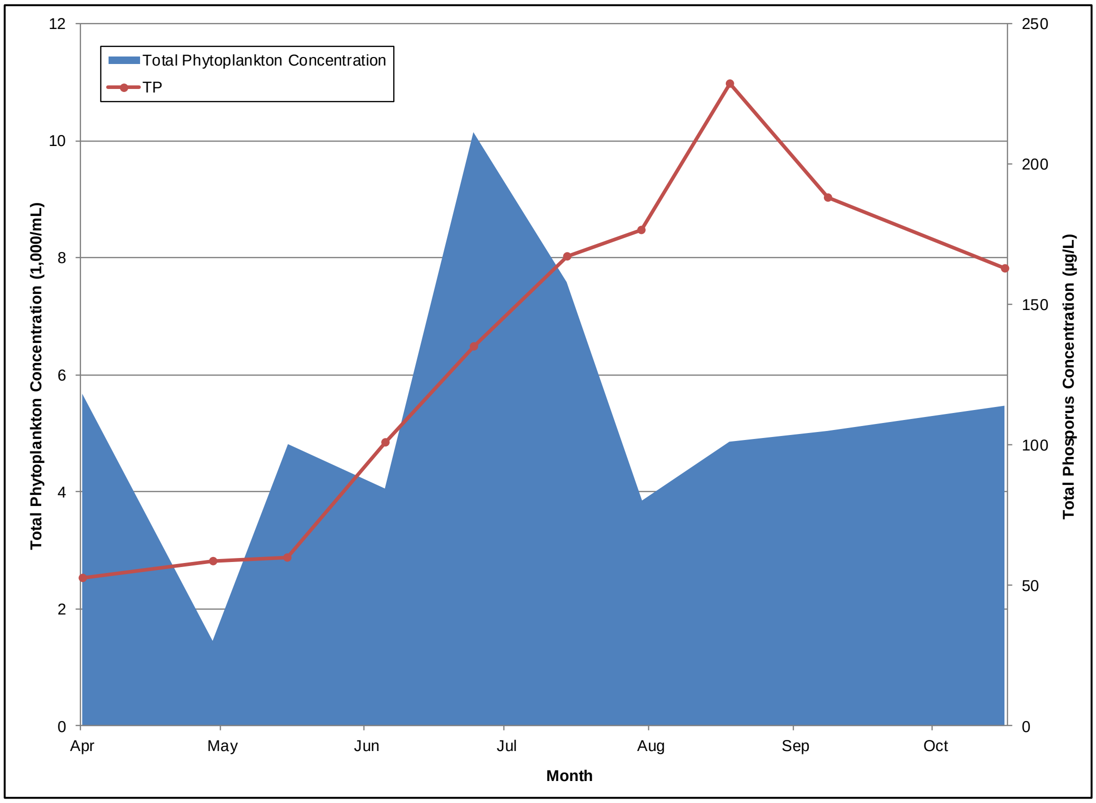

Figure 6-10: Como Lake 2016 total phytoplankton concentration and TP concentration.

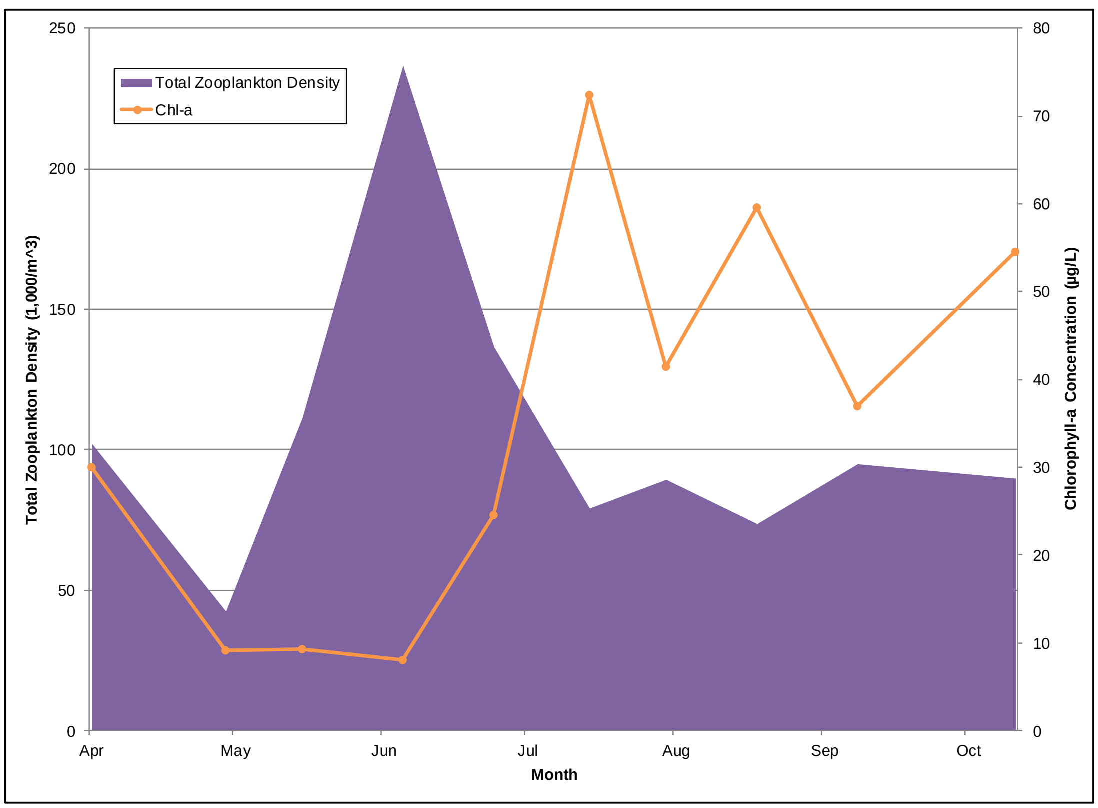

Figure 6-11: Como Lake 2016 total zooplankton density and Chl-a concentration.

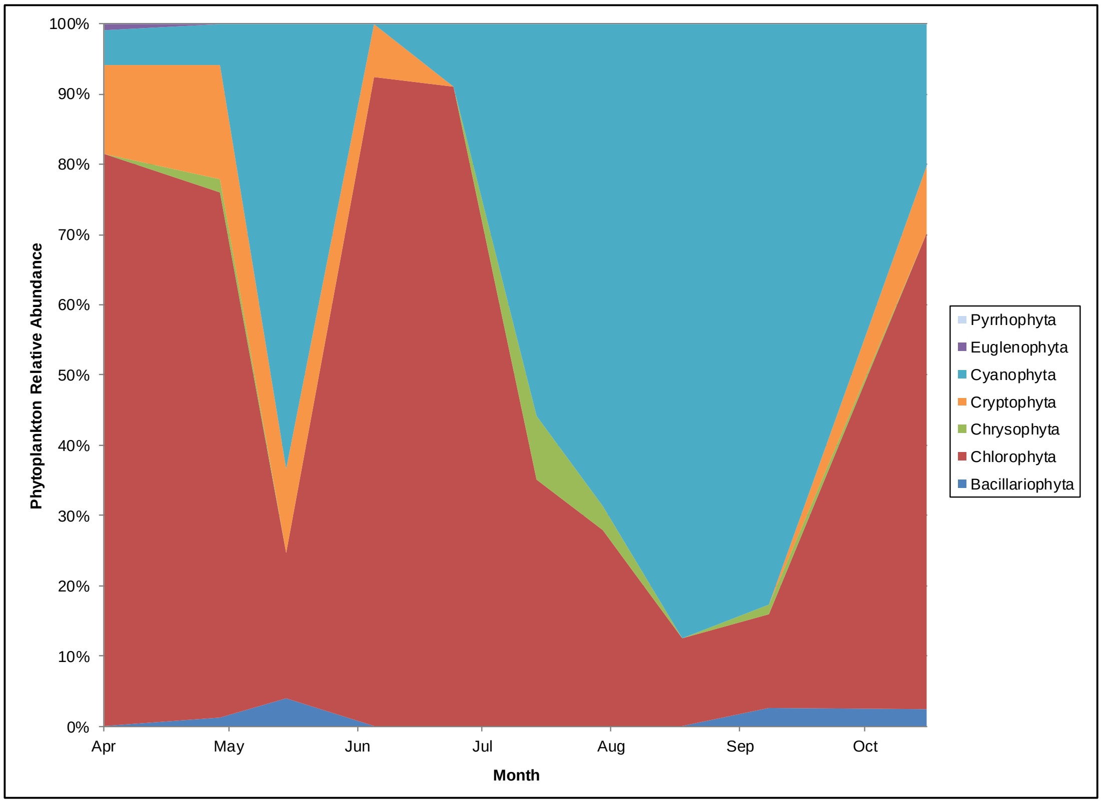

Figure 6-12: Como Lake 2016 phytoplankton relative abundance.

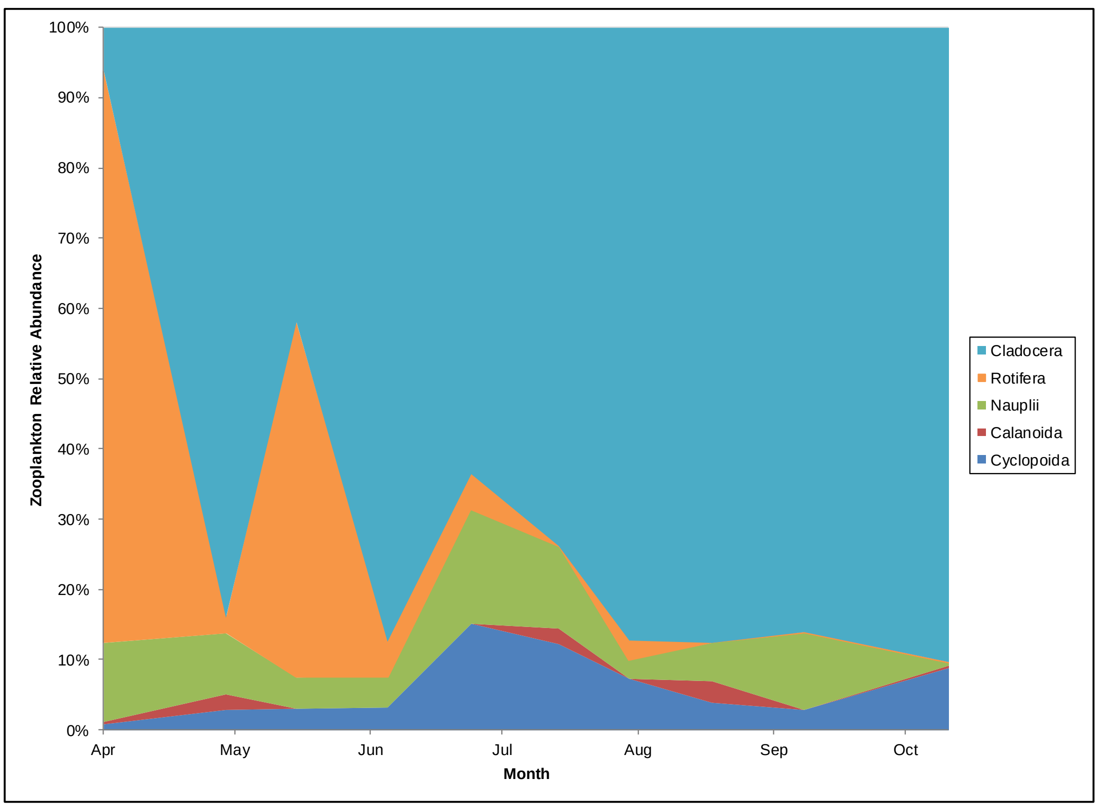

Figure 6-13: Como Lake 2016 zooplankton relative abundance.

6.5 AQUATIC VEGETATION

6.5.1 BIOVOLUME ANALYSIS

Aquatic plants stabilize bottom sediment which prevents re-suspension of sediment that decreases water clarity (DNR, 2015h). Aquatic plants also intake nutrients for growth, making those nutrients unavailable for use by algae, which reduces algal overabundance and improves water quality. As shown by the biovolume heat maps of seasonal vegetation changes in Como Lake, the majority of the lake vegetation in 2016 was observed along the shoreline in the littoral zone (Figure 6-14). Overall, Como Lake exhibited heavy aquatic vegetation growth in June, primarily along the southeastern shore. In July, plant coverage remained heavy in shallow and gently sloping areas, but decreased throughout the littoral zone lying between 1-2 meters in depth. Plant biomass decreased slightly in August, with a few zones of heavy biovolume remaining in the corners of bays around the lakeshore.

6.5.2 POINT-INTERCEPT SURVEYS

In June of 2016, plant species most widely observed in Como Lake were curly-leaf pondweed, slender leaf naiad, and filamentous algae. (Figure 6-15). From the June to the July survey, curly-leaf pond weed fell from being present at nearly 100% of locations surveyed to just over 60% of the locations surveyed. During the July survey, Canada waterweed was the most ubiquitous in the July survey, present at 81% of the locations surveyed. Leafy pondweed, greater duckweed, and slender leaf naiad were also present. By the end of August, Canada waterweed remained dominant and increased slightly in occurrence to 88% of survey locations. Curly-leaf pondweed was also observed at just over 20% of survey locations, despite its normal die-back by mid-summer.

Aside from a moderately-high average abundance ranking (3.6) observed in early June for curly-leaf pondweed, all species throughout the summer received below average abundance rankings, indicating that where species were observed, none were overly abundant (Figure 6-16). Curly-leaf pondweed is a non-native invasive species that is prevalent in many lakes across the region. While it is very common in area lakes, it is a challenging plant to control, as it can contribute to poor water quality due to high growth early in the year, displacing other native plants and contributing to in-lake phosphorus levels in late summer when the plants die-off (DNR, 2005). Eurasian watermilfoil, another disruptive invasive aquatic plant, has not yet been observed in Como Lake. In general, observing Canada waterweed throughout the course of the growing season at higher percent occurrences is good overall for the health of the lake, as it is a native plant, a good producer of oxygen, and has a good structure for providing habitat to small aquatic organisms (DNR, 2015b).

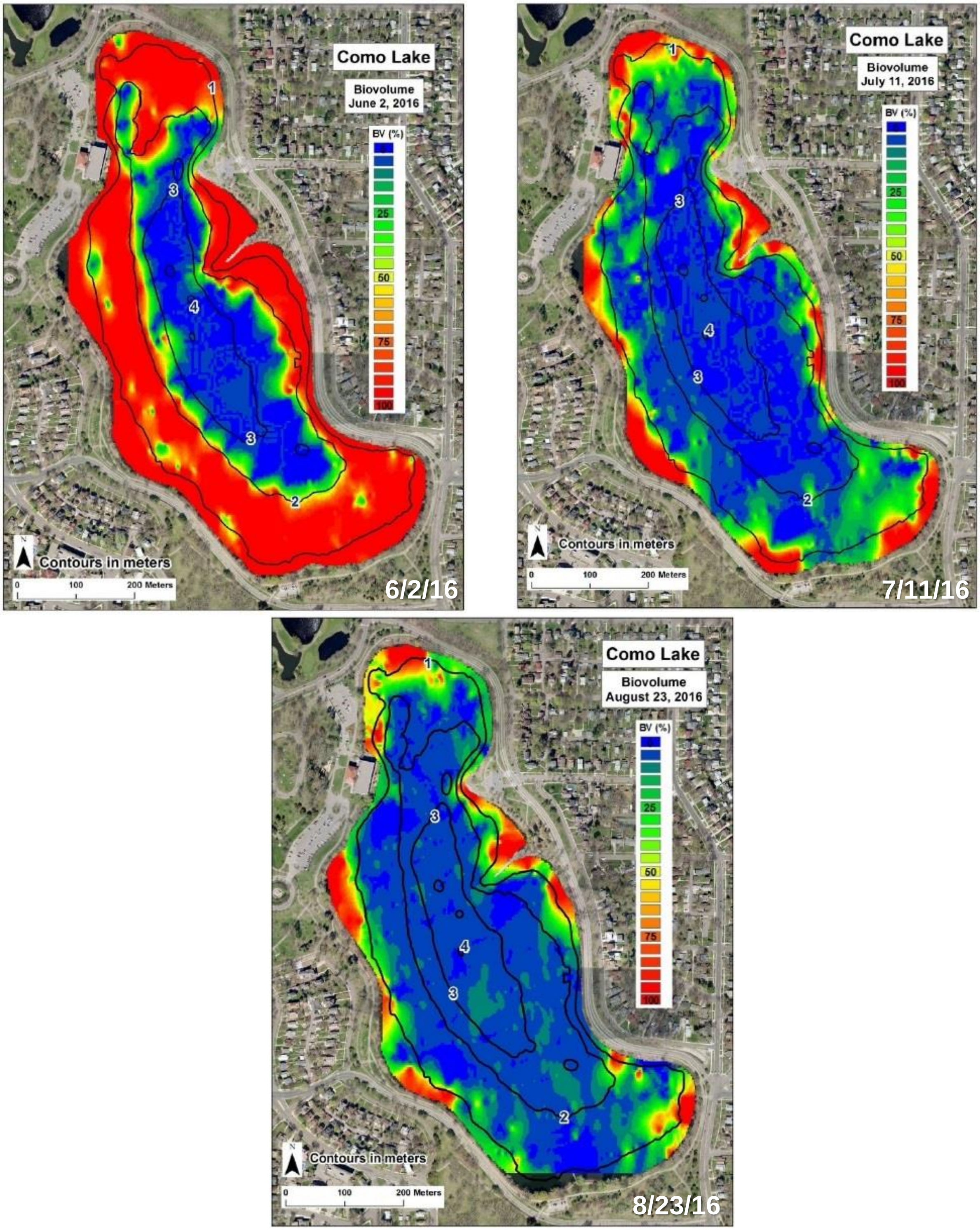

Figure 6-14: Como Lake 2016 seasonal vegetation changes (6/2/16, 7/11/16, 8/23/16).

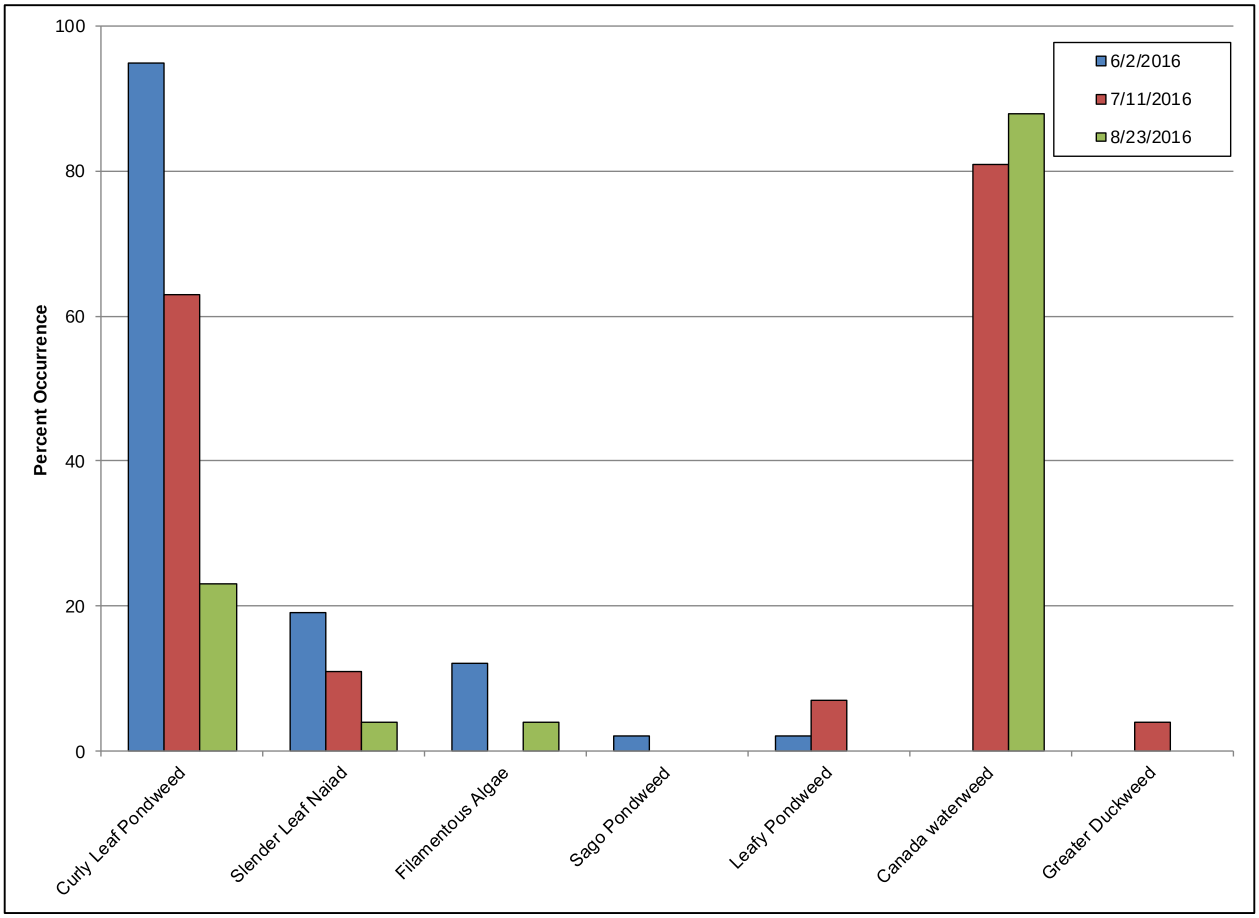

Figure 6-15: Como Lake 2016 percent occurrence of vegetation present.

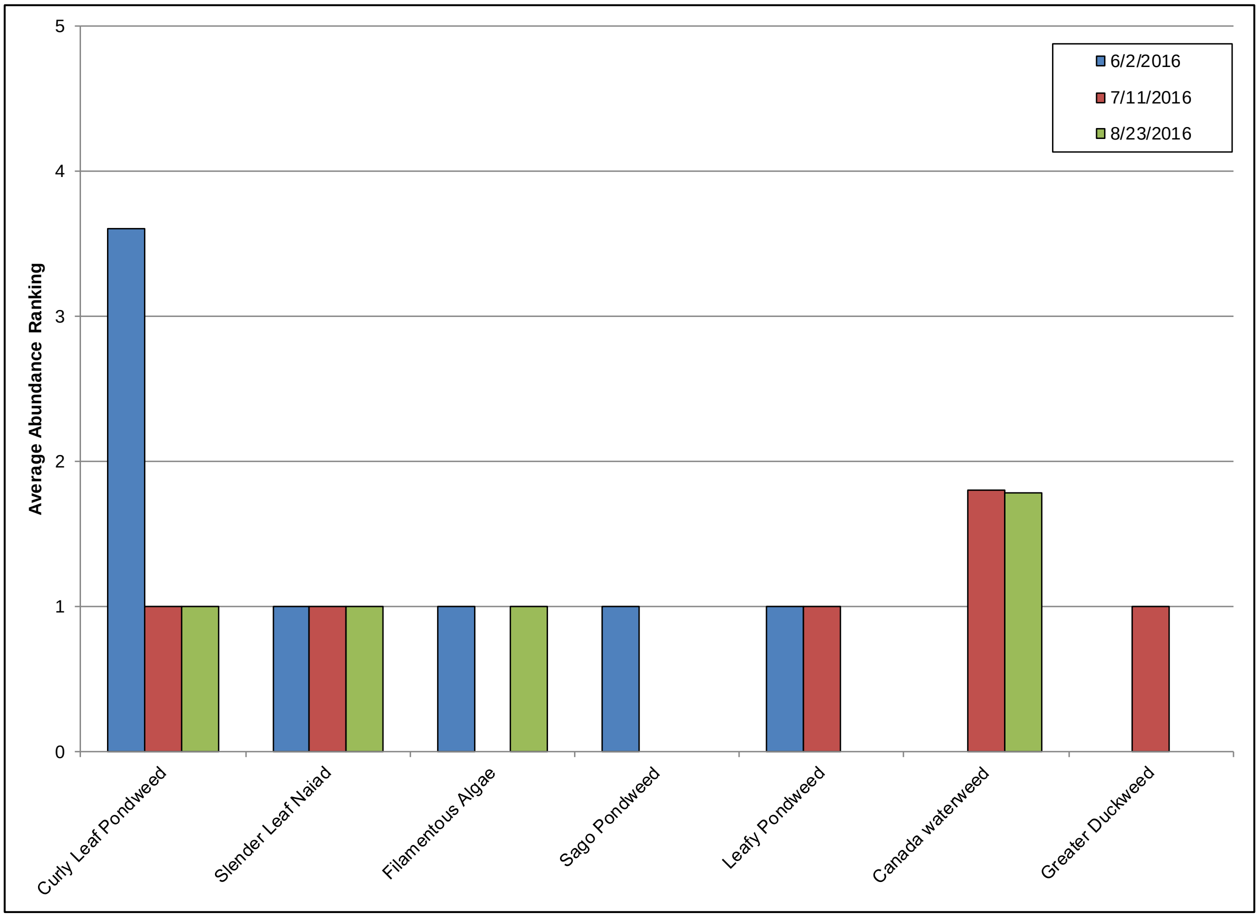

Figure 6-16: Como Lake 2016 average abundance ranking of vegetation present.

6.6 FISH STOCKING AND SURVEYS

While fish stocking in Como Lake has historically focused on bluegill and channel catfish because they are primary management species for the lake, walleye was the sole species stocked in 2016 (Table 6-4). Como Lake is part of the Minnesota DNR's "Fishing in the Neighborhood" program, which increases angling opportunities for residents in urban environments, encourages environmental stewardship, and improves knowledge of natural resources (DNR, 2015g). Therefore, these lakes are generally stocked with fish that are better for general angling activities.

The DNR conducted a fish survey of Como Lake in August of 2016. The most prevalent fish found were black crappie, which was similar to years previous (Table 6-5). Varieties of panfish accounted for 69% of the fish observed during the survey. The northern pike surveyed in both years were relatively large given the size and type of the lake. The number of walleye in the 2016 survey (2) was not as high the number observed in 2015 (19). Four species observed in 2015 (brown bullhead, common carp, white sucker, and yellow bullhead) were not observed in the 2016 survey. While three species of bullhead previously observed were not present in 2016, the large number of black bullhead found during the survey is concerning (28% of total observed fish), as these species can contribute to poor water quality (DNR, 2015a). Common carp were observed during the 2015 survey, and were not found in the 2016 survey. Even though only one carp was observed in the 2015 survey, the noted presence of common carp in a lake can be of high concern, as they can be the cause of significant declines in water quality (DNR, 2015c) and are difficult to manage and remove. CRWD plans to survey fish populations on Como Lake in 2017.

Table 6-4: Como Lake historical record of fish stocking.

Year	Bluegill	Channel catfish		Largemouth bass		Walleye			Yellow perch	
	Adult	Adult	Yearling	Adult	Yearling	Fry	Yearling	Fingerling	Adult	Yearling
2016							903			
2015		181					2,840			
2014			130	8		71,000		4,108	1211	
2013								486		
2011		124	3900					3593		
2010	24	91	3900				4			
2009			3457						816	1200
2008		155	4502							
2007	284	150	3864	179	414					
2006	1384									
2005										
2004	959									

Table 6-5: Como Lake 2016 fish populations (DNR, 2016b).

Species	Number of fish caught in each category (inches)								Total
	0-5	6-8	9-11	12-14	15-19	20-24	25-29	30+	
Black bullhead	1	113	39	1					154
Black crappie	64	193							257
Bluegill	62	44							106
Channel catfish					1	2			3
Golden shiner	1	3							4
Hybrid Sunfish	4	7							11
Northern pike					1	3	1	1	6
Pumpkinseed	3								3
Walleye		1			1				2
Yellow Perch		3							3

6.7 OVERALL LAKE EVALUATION

Como Lake has historically experienced a cyclic pattern in water quality and biological response, fluctuating between poor and fair water quality generally every five to six years (Noonan, 1998). In recent years, however, this pattern has not been observed, and measured water quality parameters have remained relatively poor in comparison to historical fluctuations. The period of record indicates that while TP has consistently been a primary driver for Chl-a concentrations and water clarity, recent years demonstrate that other factors could be driving concentrations of Chl-a and measurements of water clarity. While Como has historically received lower lake grades, fluctuating between grades of ‘F’ in the earliest years of monitoring, to grades of ‘B’ in the late 1990’s, it has only received grades of ‘D’ and ‘D+’ in the most recent six years of monitoring. This is another demonstration of the deviation from cyclical patterns between poor and fair water quality in the lake. None of the eutrophication parameters (TP, Chl-a, and Secchi) met the MPCA state eutrophication standards in 2016, indicating water quality impairment in the lake.

Como lake generally supports a fair variety of fish, with 10 different species observed in 2016. However, fish populations in 2016 contained a large percentage of black bullhead (28% of the total fish surveyed), which are known to contribute to poor water quality in lakes and can be a concern for management. While the lake also contains a variety of aquatic vegetation, the majority of the vegetation observed in the spring consists of curly-leaf pondweed, an invasive species that can contribute to poor water quality due to die-back in late summer. Conversely, increases in Canada waterweed were observed later in the growing season, which can contribute to better lake health because it is a native plant that provides good structure for other aquatic life.

7 CROSBY LAKE RESULTS

7.1 CROSBY LAKE BACKGROUND

Crosby Lake is situated within Crosby Farm Regional Park in Saint Paul and is also a part of the National Park Service's Mississippi National River and Recreation Area. The park itself is 736 acres and consists of floodplain and bluff areas. It offers various outdoor activities for fishing, canoeing, walking, hiking and winter cross-country skiing. The park has diverse wetland and forest habitats that support a large variety of plants, trees, and wildlife (Figure 7-1). Crosby Lake is 45 acres and has a maximum depth of 17 ft with a 100% littoral area (Table 7-1; Figure 7-2). It is located in the floodplain area of the park between a large bluff and the main channel of the Mississippi River.

Figure 7-1: View of the northeast shoreline of Crosby Lake.

Crosby Lake has a relatively small watershed area of only 197 acres (Table 7-1; Figure 7-3). Water flows into the lake during high water periods from wetlands on the east and north sides via culverts. Seepage from the base of the bluff (consisting of sandstone and limestone) is also an input to Crosby Lake. The major groundwater input to the lake comes from the St. Peter aquifer to the west.

Table 7-1: Crosby Lake morphometric data.

Surface Area (acres)	Maximum Depth (ft)	Littoral Area	Volume (acre-ft)	Watershed Area (acres)	Watershed: Lake Area (ratio)
45.0	17.0	100%	130	197	4.4

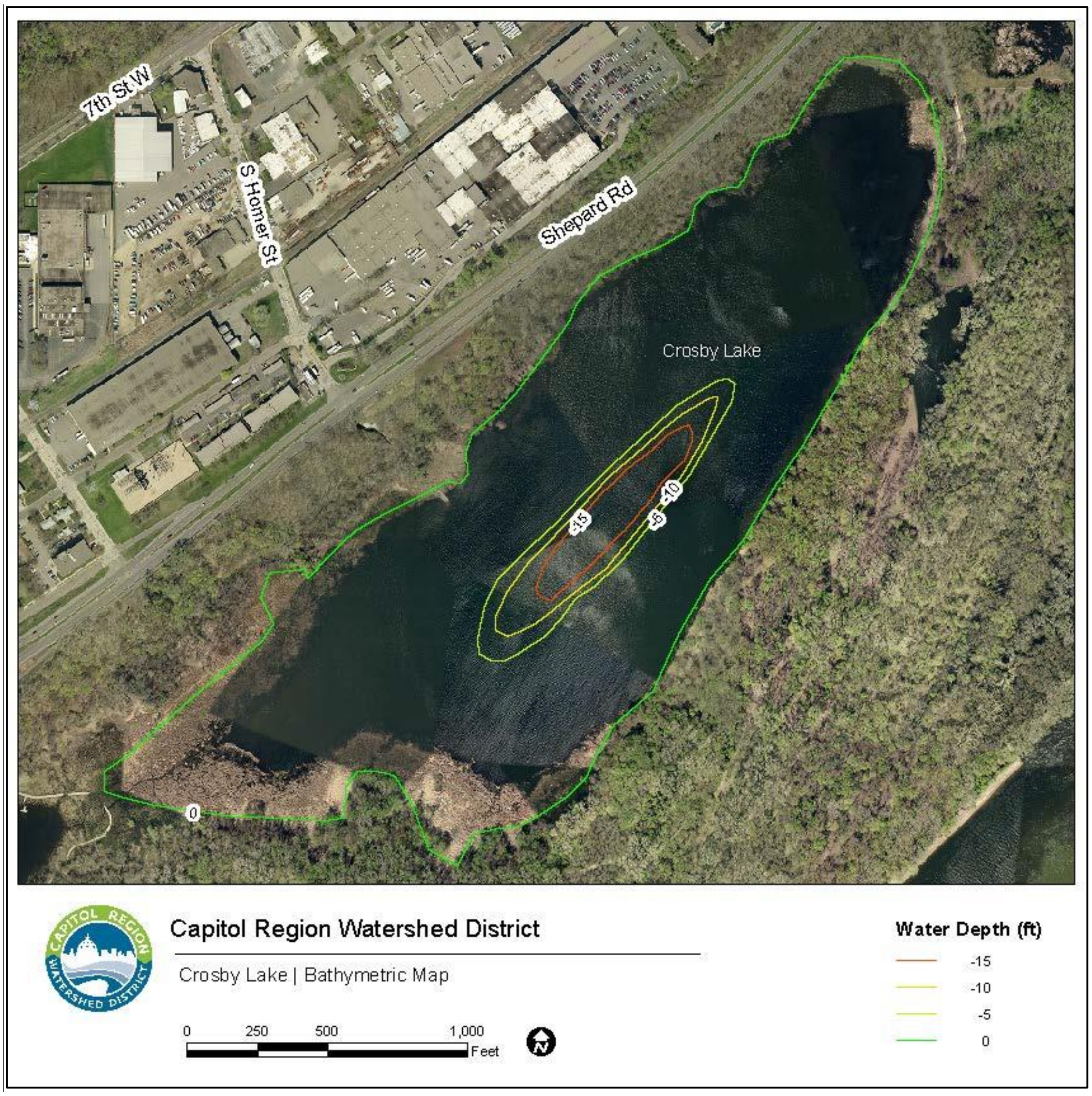

Figure 7-2: Crosby Lake bathymetric map.

CRWD developed a lake management plan for Crosby Lake that assessed the current condition of the Lake and characteristics of its watershed, identified the issues of greatest concern, and established management goals and an implementation plan for addressing identified issues (CRWD, 2012a). A key piece of understanding that came out of the plan was the interaction between Crosby Lake and the Mississippi River. As Crosby Lake sits within the floodplain of the Mississippi River, it is intermittently flooded during periods of high water. The normal water level (or ordinary water level) of the lake is 694 ft, and the normal pool elevation of the river is 687 ft (CRWD, 2012a). Therefore, under normal, non-flood conditions, groundwater flows from the lake to the river. The lake does not normally directly output to the river. Under high water conditions, however, the river will overflow to the lake near the northeast corner.

CRWD determined that a 49,000 cfs flow (equivalent of a stage of 697 ft) would cause an exchange between the river and the lake to occur, equating to a 3-year storm event, meaning that this has a 33% chance of occurring each year (CRWD, 2012a). Looking at the historical record since 1982, only 2.5% of recorded river flows have been high enough for an exchange to occur (based on river flow and lake elevation). Table 7-2 shows the number of days the Mississippi River interacted with Crosby Lake during the historical monitoring period for the lake. During these exchanges, the water bodies interchange not only water, but nutrients, other pollutants, and biological organisms contained within.

Table 7-2: Historical record of Mississippi River interaction with Crosby Lake.

Year	Number of Days Mississippi River Interacts with Crosby Lake
1999	14
2000	0
2001	63
2002	0
2003	0
2004	0
2005	0
2006	19
2007	0
2008	0
2009	15
2010	36
2011	103
2012	10
2013	13
2014	50
2015	0
2016	1

Crosby Lake has historically only met the shallow lake state water quality standards for TP concentration (< 60 µg/L) for half of the years monitored, but has consistently met the standards for Chl-a concentration (< 20 µg/L) and Secchi disk depth (≥ 1.0 m) since monitoring began in 1999. The Crosby Lake management plan sets a similar goal of meeting the state standard for TP of 60 µg/L (CRWD, 2012a).

Since the development of the Crosby Lake Management Plan, a number of water quality improvement projects have been implemented by CRWD, the City of Saint Paul and others to reduce stormwater runoff to Crosby Lake. In 2010, the City of Saint Paul installed filtration swales as part of the reconstruction of the Samuel Morgan pedestrian and bikeway trails along Shepard Road. CRWD provided the City of Saint Paul a grant in 2012 for the installation of a rain garden and swale during the reconstruction of the east end parking lot in Crosby Farm Regional Park. In addition, CRWD supports the Friends of the Mississippi River's efforts to restore the native prairie areas in Crosby Farm Regional Park. Lastly, as part of the reconstruction of the Madison-Benson Streets area near Crosby Lake in 2013, the City of Saint Paul constructed boulevard tree trench systems and rain gardens to treat street and sidewalk runoff.

Management efforts need to take into account the dynamic relationship between the lake and the river. Although past water quality has been good with TP concentrations below the state standards, recent years have shown increasing TP concentrations that have surpassed the standard (Figure 7-8; Table 7-3). The source of these high nutrient concentrations could be from high flow periods of the Mississippi River where large sediment loads enter the lake. For example, the lake was inundated by the river for 103 days in 2011, and for 50 days in 2014 (CRWD, 2012a). Water quality data observed in the years following these inundation periods showed average TP concentrations well above the normal historical values (Figure 7-8; Table 7-3). In 2015, however, there were no documented days of river flooding, followed by only a single day of inundation in 2016. Water quality showed drastic improvements in TP and Chl-a during these years (Figure 7-8). From a management perspective, this relationship could make it hard to control and improve Crosby Lake water quality in the long-term.

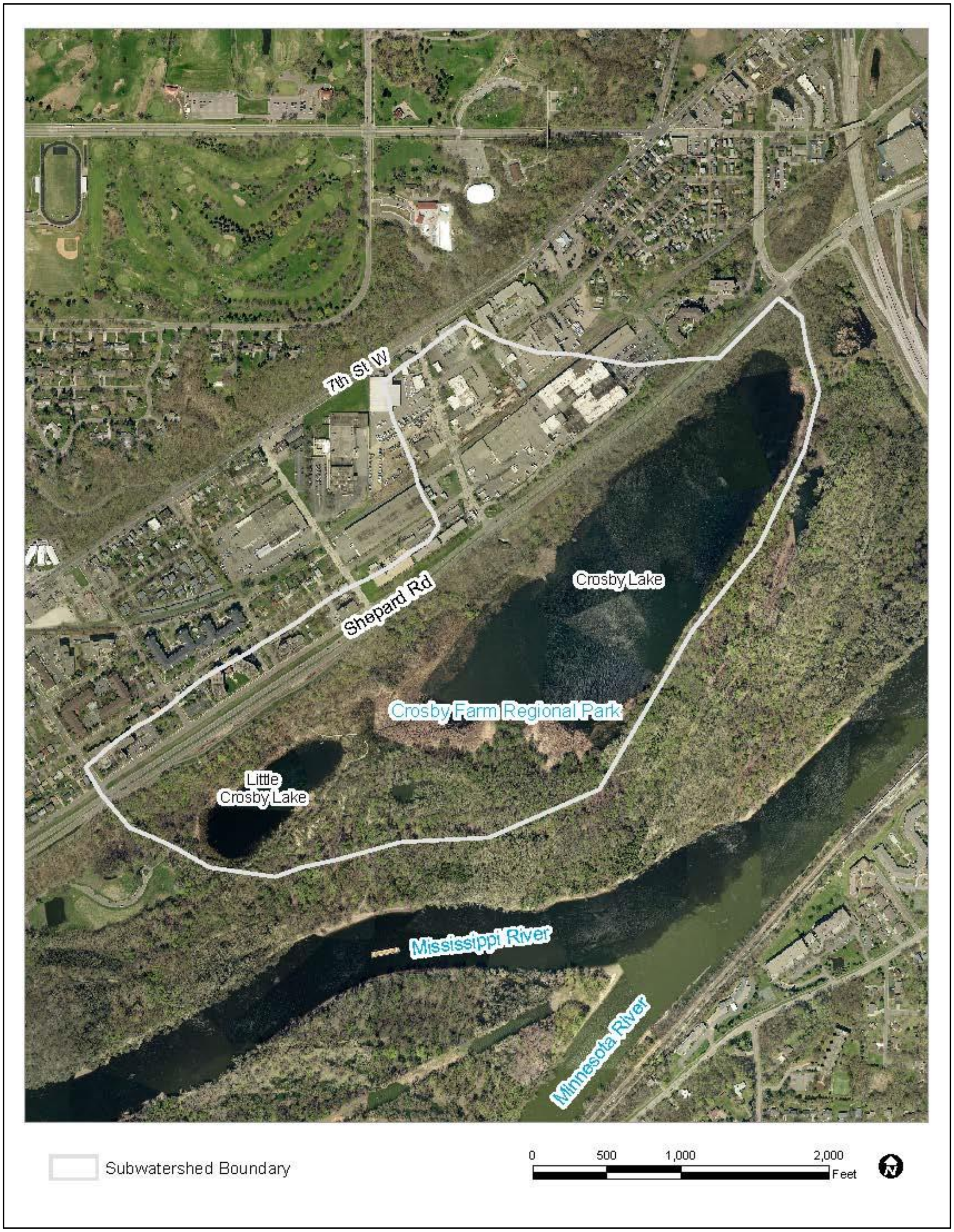

Figure 7-3: Crosby and Little Crosby Lakes and subwatershed boundary.

7.2 LAKE LEVEL

The Minnesota DNR does not record or report historical lake level data for Crosby Lake, so CRWD began monitoring Crosby Lake level in June 2014. Figure 7-4 shows the fluctuation in Crosby Lake level from 2014-2016. During 2014, the lake level was greatly influenced by flooding from the Mississippi River. In 2015 there were no days in which flooding from the river occurred, and there was only a single day in 2016 where river flow indicated inundation occurred (Table 7-2).

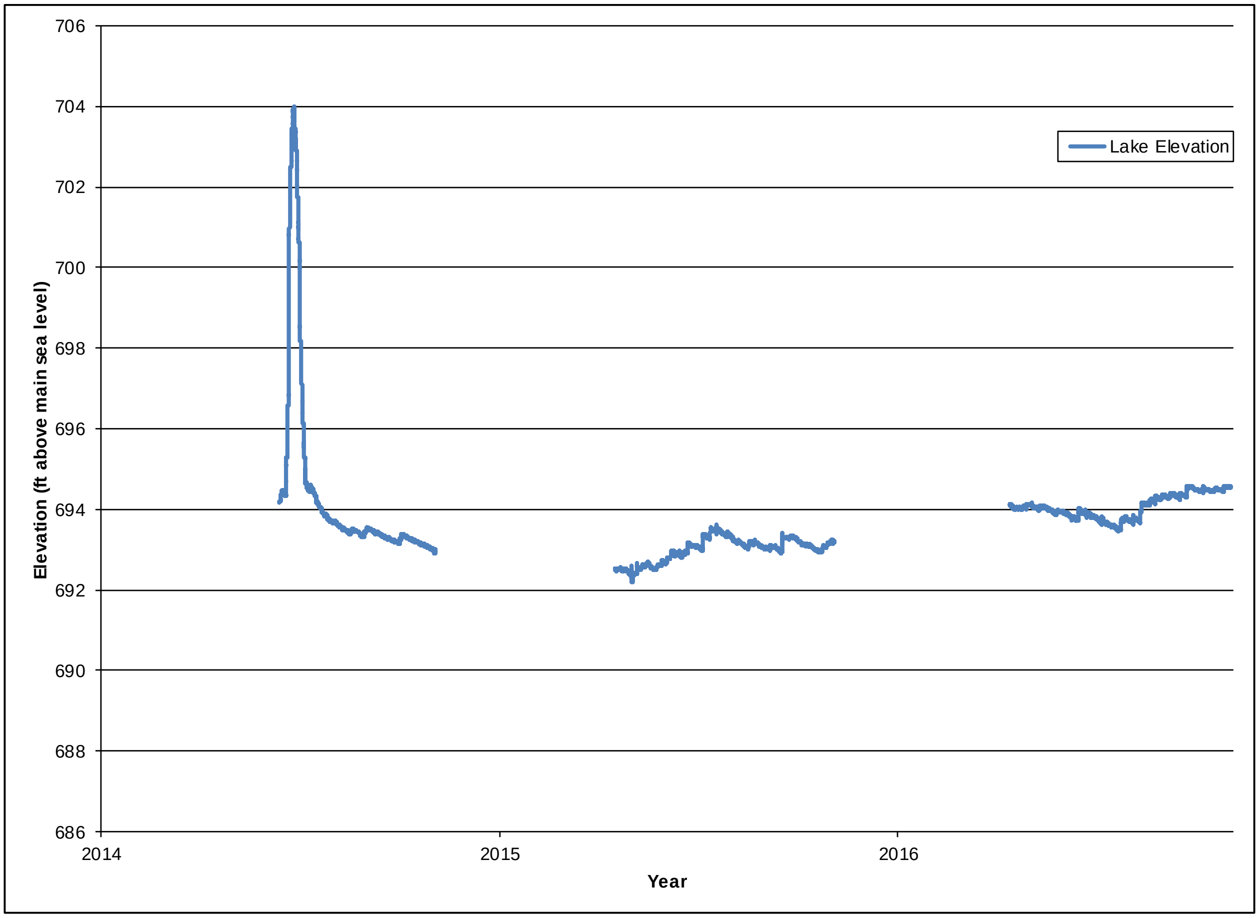

Figure 7-4: Crosby Lake historical lake elevations.

Figure 7-5 shows the continuous lake levels for Crosby Lake in 2016. Lake level did not fluctuate very drastically during the course of the year. Level decreased from April until late July, with a few significant increases after two large rainfall events in early June and early July. Lake level then increased from late July through the end of the monitoring season, with significant increases after storms in late July and mid-August. Lake level peaked for the year in late September, after a very rainy August and early fall. After this peak, level generally stayed consistent until the level logger was removed in early November.

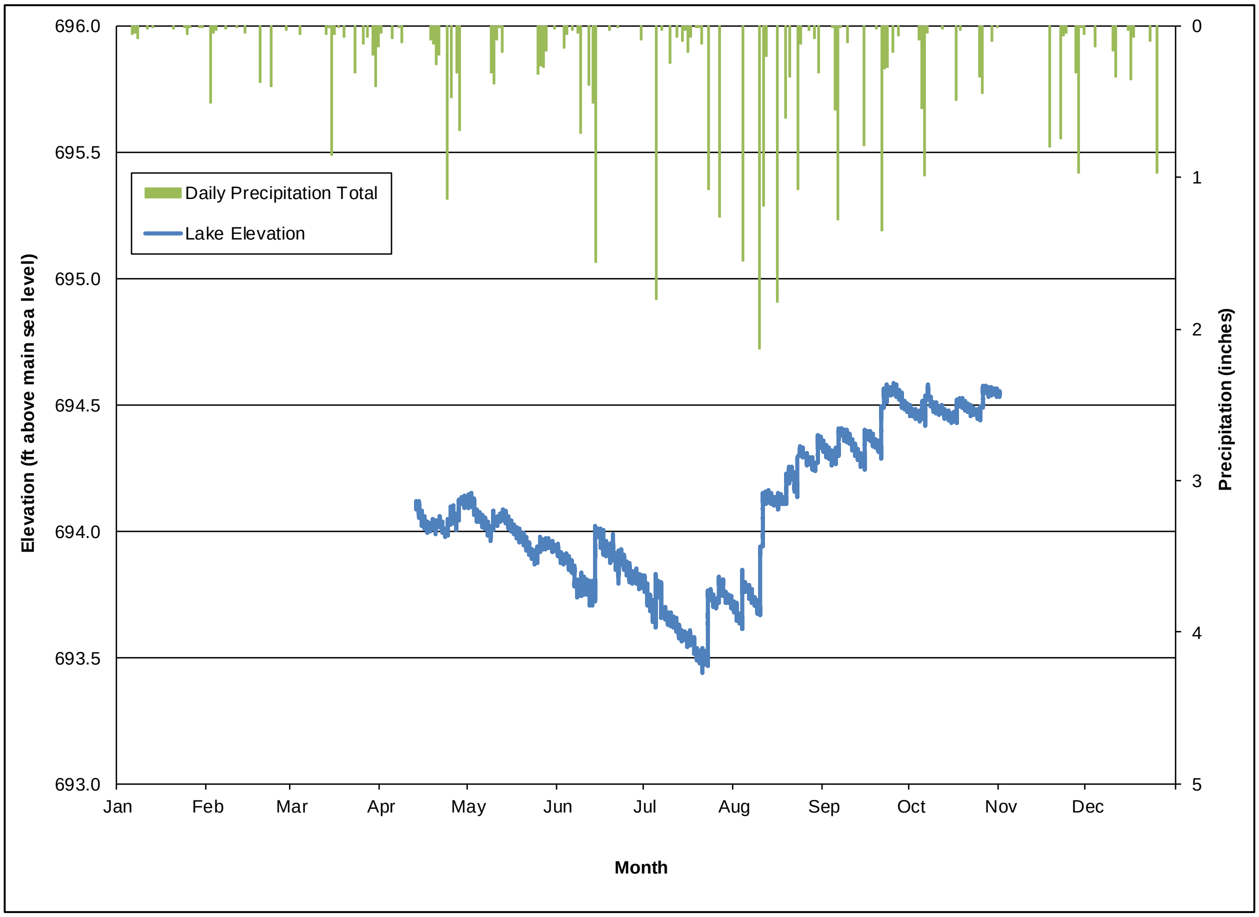

Figure 7-5: Crosby Lake 2016 lake elevations and daily precipitation events (MCWG, 2016).

7.3 WATER QUALITY RESULTS

Crosby Lake was sampled ten times during 2016, from April 1 to October 24 (Figure 7-6). As in recent years, Crosby Lake was characterized by high TP concentrations, but moderate Chl-a concentrations and Secchi depths (Figure 7-6).

Samples show epilimnetic TP concentrations in the lake exceeded state standards throughout the monitoring season and did not exhibit a pattern of increasing or decreasing TP concentration throughout the year, with peaks during the early June sample, as well as the beginning of September.

Epilimnetic Chl-a concentrations varied throughout the year, peaking in late August/early September (Figure 7-6). Only two 2016 samples exceeded the state standard for Chl-a during this summer/fall peak. During 2016, fluctuations in Chl-a concentration were generally associated with fluctuations in TP concentration, indicating that TP was the main driver of algae growth in the lake during the year.

Water transparency was highest during the first sampling events on April 1 and May 17 (2.6m and 2.9m, respectively), remained below 2m throughout the summer, and peaked again during the final sampling event on October 24 (2.4m). During 2016, fluctuations in Secchi depth were generally associated with fluctuations in TP and Chl-a concentration (Figure 7-6).

Seasonally, Crosby Lake exhibits the best and least variable TP and Chl-a values during the month of May (Figure 7-7). TP values do not exhibit substantial monthly variation from June through September. August shows the greatest variation as well as the highest median of Chl-a values. The month of May shows the deepest Secchi disk depth median of all months (Figure 7-7).

Figure 7-8 shows yearly average historical TP concentrations, Chl-a concentrations, and Secchi disk depths graphically. Crosby Lake has been characterized by high epilimnetic TP concentrations over the last seven years. The average TP concentration from 1999-2009 was 53.2 µg/L, while the average TP concentration from 2010-2015 was 139.0 µg/L, a 165% increase from the previous time period. 2016, however, exhibited the lowest annual average TP since 2009, with a value of 93 µg/L. Hypolimnetic TP annual averages followed a similar trend as epilimnetic TP, but with larger fluctuations and greater concentrations (Figure 7-9). The annual average hypolimnetic TP value for 2016 is also the lowest observed since 2010.

Chlorophyll-a concentrations have exhibited elevated concentrations since 2007 (Figure 7-8). Figure 7-8 shows that water clarity is principally affected by Chl-a concentration over the period of record. In the first year Crosby Lake was monitored (1999) the Secchi depth average was the deepest on record at 3.8 m. Since then, Secchi depths have fluctuated annually but have generally decreased as Chl-a concentrations increased and vice versa. Chl-a and Secchi values in 2016 were similar to recent annual averages.

Yearly average historical TP concentrations, Chl-a concentrations, Secchi depths, and their comparisons to lake standards are shown in Table 7-3. Historically, Crosby Lake has met the standards for Chl-a and Secchi depth, with only two years exceeding TP standards, from 1999-2009 (Table 7-3). Since 2010, however, it has consistently exceeded the standards for TP, which was also the case in 2016. However, there has been improvement in the last two years in the TP annual average since it peaked at 211 µg/L (the highest value on record), dropping to 93 µg/L in 2016. In 2016, Crosby Lake received a grade of ‘C’, consistent with the average since 2010 (Table 7-4). In general, all eutrophication parameters improved in 2016.

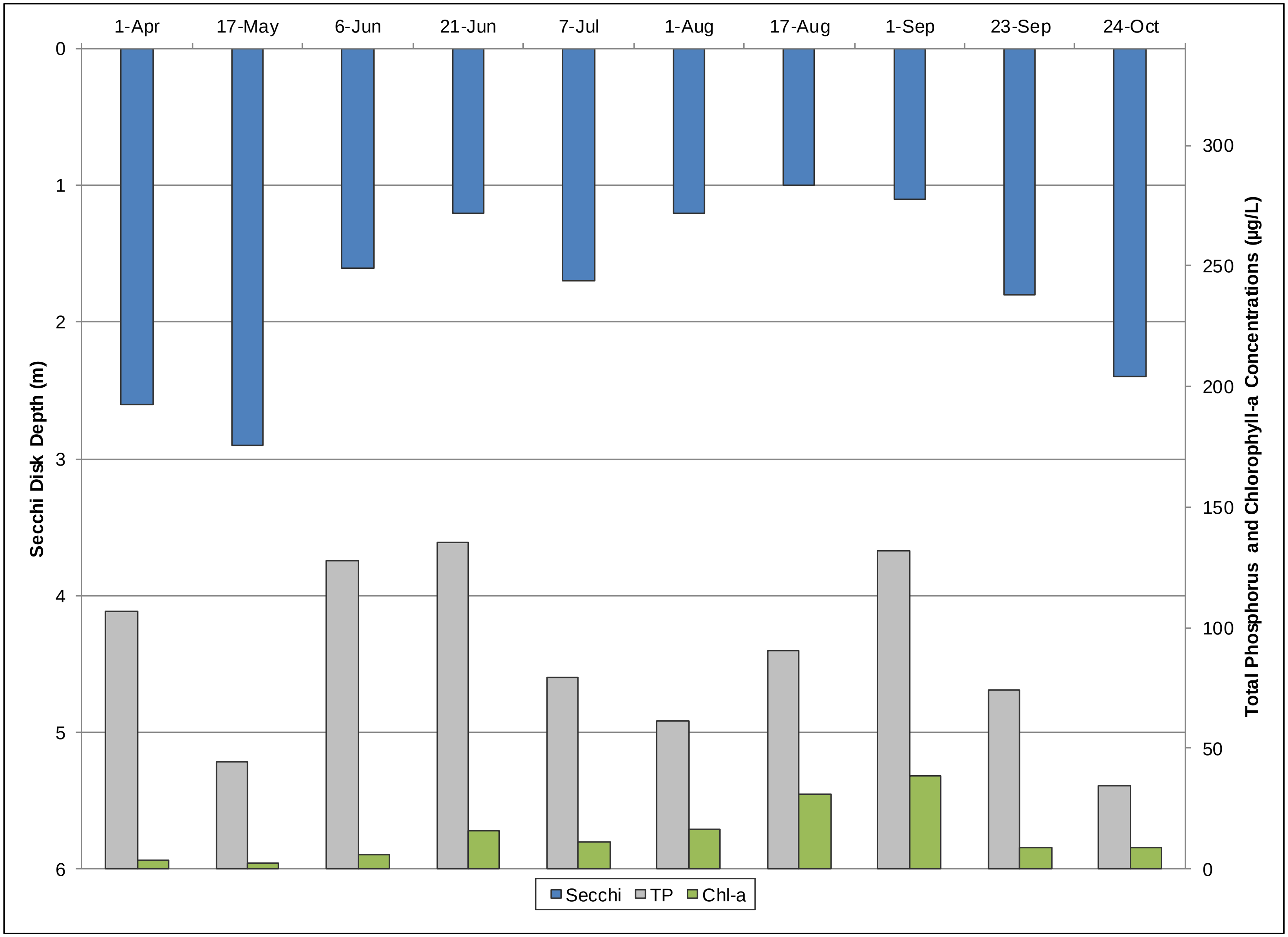

Figure 7-6: Crosby Lake 2016 Secchi/TP/Chl-a comparison.

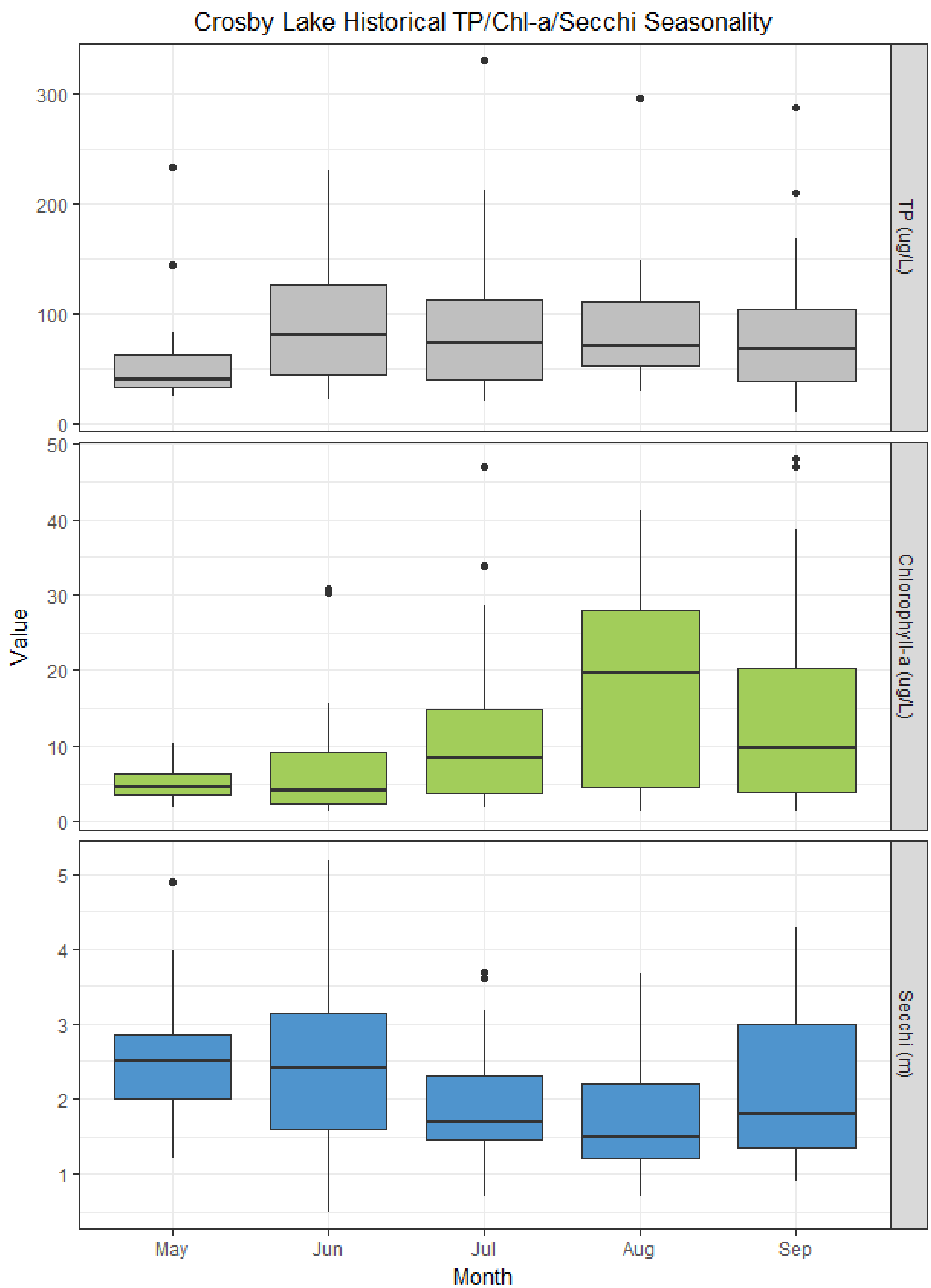

Figure 7-7: Crosby Lake seasonality boxplots of historical Secchi/TP/Chl-a samples.

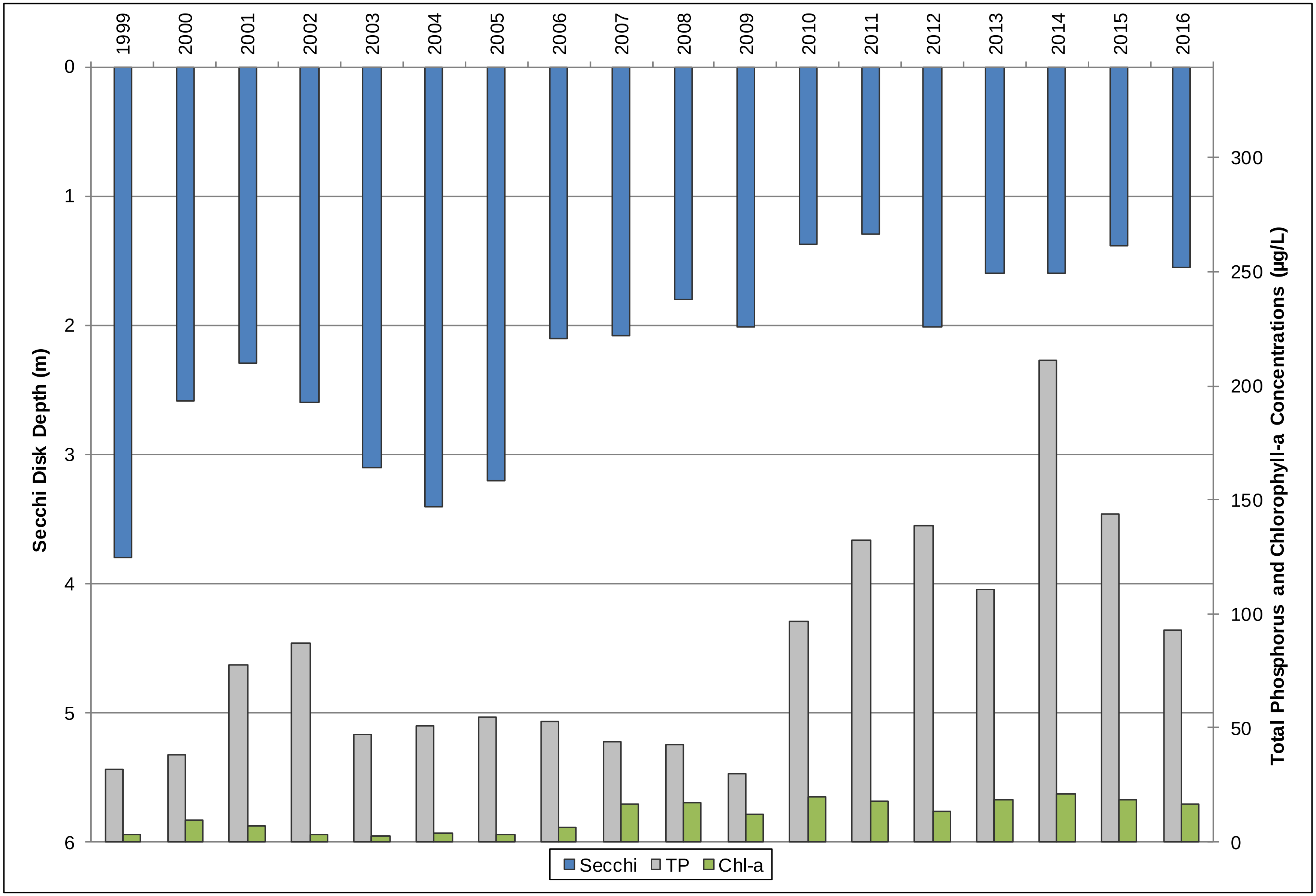

Figure 7-8: Crosby Lake historical annual average Secchi/TP/Chl-a comparison.

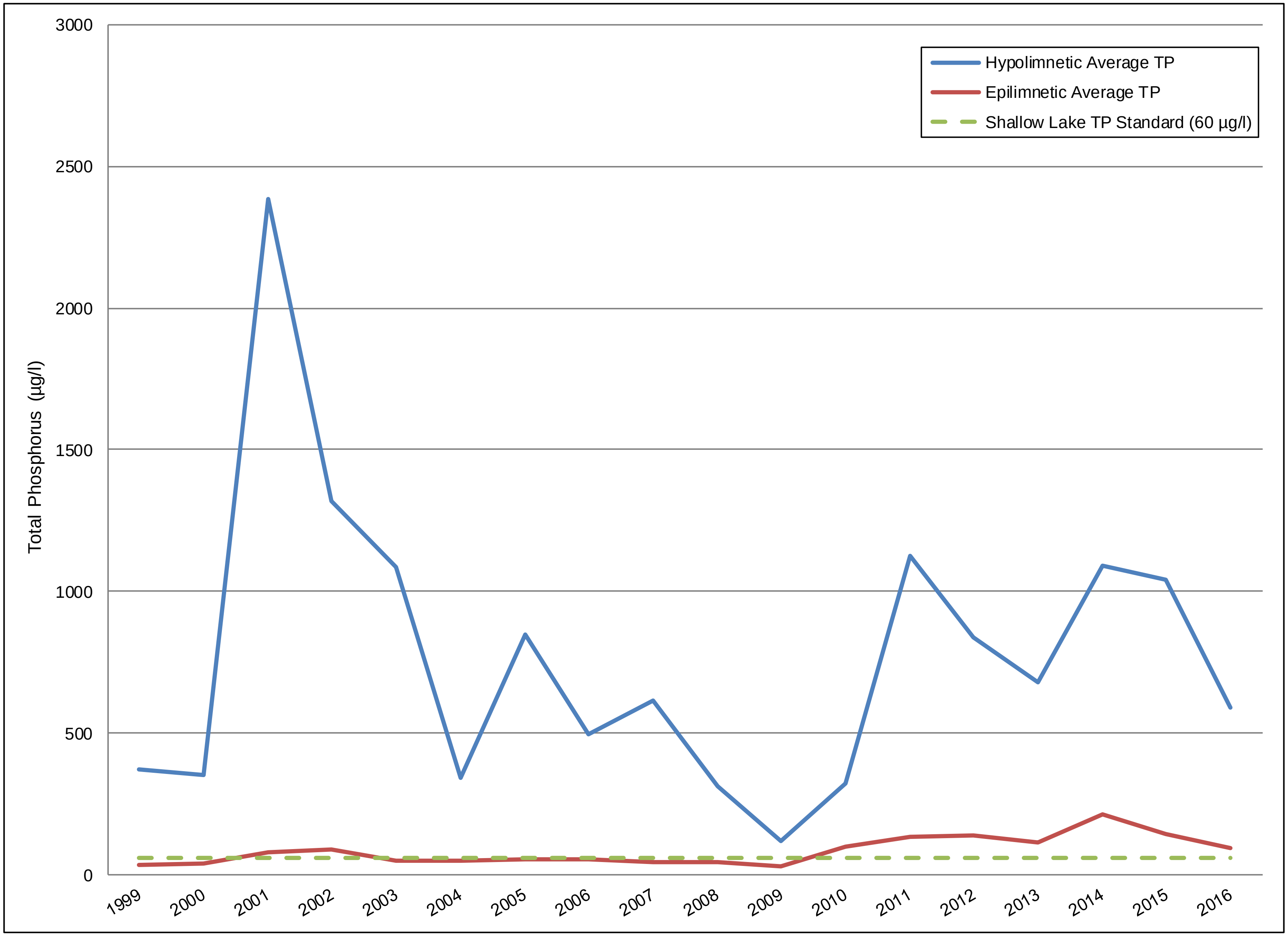

Figure 7-9: Crosby Lake historical annual average hypolimnetic and epilimnetic total phosphorus.

Table 7-3: Crosby Lake historical yearly TP/Chl-a/Secchi depth averages compared to shallow lake state standards.

Year	TP (µg/L)	Chl-a (µg/L)	Secchi (m)
1999	32	3.0	3.8
2000	38	9.6	2.6
2001	78	7.0	2.3
2002	87	2.9	2.6
2003	47	2.2	3.1
2004	51	3.7	3.4
2005	54	3.2	3.2
2006	53	6.6	2.1
2007	44	16.3	2.1
2008	43	17.0	1.8
2009	30	12.0	2.0
2010	97	19.7	1.4
2011	132	17.8	1.3
2012	139	13.5	2.0
2013	111	18.4	1.6
2014	211	21.0	1.6
2015	144	18.5	1.4
2016	93	16.2	1.6

(shaded)	Value does not meet state standard*
(unshaded)	Value meets state standard

*MPCA shallow lake standards must be less than 60 µg/L for TP and 20.0 µg/L for Chl-a, with a Secchi disk depth of greater than 1.0 m.

Table 7-4: Crosby Lake historical lake grades.

Year	TP Grade	Chl-a Grade	Secchi Grade	Overall Grade
1999	B	A	A	**A**
2000	C	A	B	**B**
2001	D	A	B	**B**
2002	D	A	B	**B**
2003	C	A	A	**B+**
2004	C	A	A	**B+**
2005	C	A	A	**B+**
2006	C	A	C	**B**
2007	C	B	C	**C+**
2008	C	B	C	**C+**
2009	B	B	C	**B**
2010	D	B	C	**C**
2011	D	B	C	**C**
2012	D	B	C	**C**
2013	D	B	C	**C**
2014	F	C	C	**D+**
2015	D	B	C	**C**
2016	D	B	C	**C**

7.4 PHYTOPLANKTON AND ZOOPLANKTON

Crosby Lake was sampled for phytoplankton and zooplankton ten times during 2016 from April 1 to October 24. Total 2016 phytoplankton concentrations are observed in Figure 7-10. In general, total phytoplankton concentration remains very low from April through late July, before drastically increasing to a peak level in early August, before declining during the fall to an amount roughly triple the level observed in spring and early summer. Total phytoplankton concentration does not appear to follow any patterns in TP observed throughout the year.

Overall, there was a diverse phytoplankton community observed throughout the year (Figure 7-12). From April through late July (when overall concentrations of phytoplankton were low), the population consisted of a variety of all observed phytoplankton types, with a large part of the population being cyanobacteria. From late July through the end of the year, however, when phytoplankton concentration drastically increased, the population was dominated by Chlorophyta, as well as two blooms of Cryptophyta in early August and late October.

Total zooplankton density can be seen in Figure 7-11. The Crosby Lake zooplankton community was predominately comprised of Nauplii (juvenile crustaceans) and Cyclopoids in 2016 (Figure 7-13). Cladoceran (important lake filter-feeders including the order *Daphnia*) populations spiked during the late July sampling event, but stayed relatively low throughout the year. Aside from a growth in the populations of Calanoids in late June/early July and Rotifers in mid-August, the zooplankton communities were dominated mainly by Nauplii and Cyclopoida throughout the entire year. Zooplankton density generally followed the Chl-a concentration pattern during 2016, with the total zooplankton density significantly peaking in late July/early August, and Chl-a peaking shortly after during the early September sampling event. It's worth noting that the only two times during the year when Chl-a did not meet the state water quality standard of 20 µg/L were during the August 18 and September 1 sampling events, occurring directly after the two highest zooplankton densities for the year were measured on August 1 and 17 (Figure 7-11). These high Chl-a values can be considered a reflection of the high productivity of zooplankton in the lake.

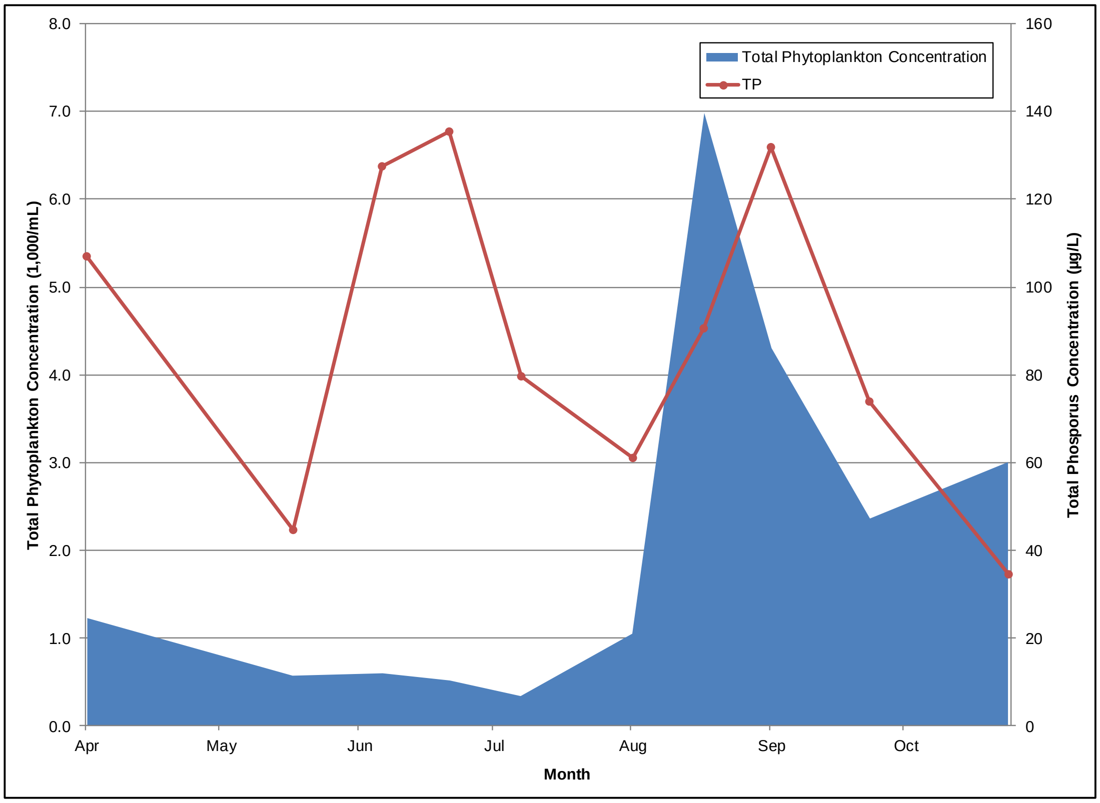

Figure 7-10: Crosby Lake 2016 total phytoplankton concentration and TP concentration.

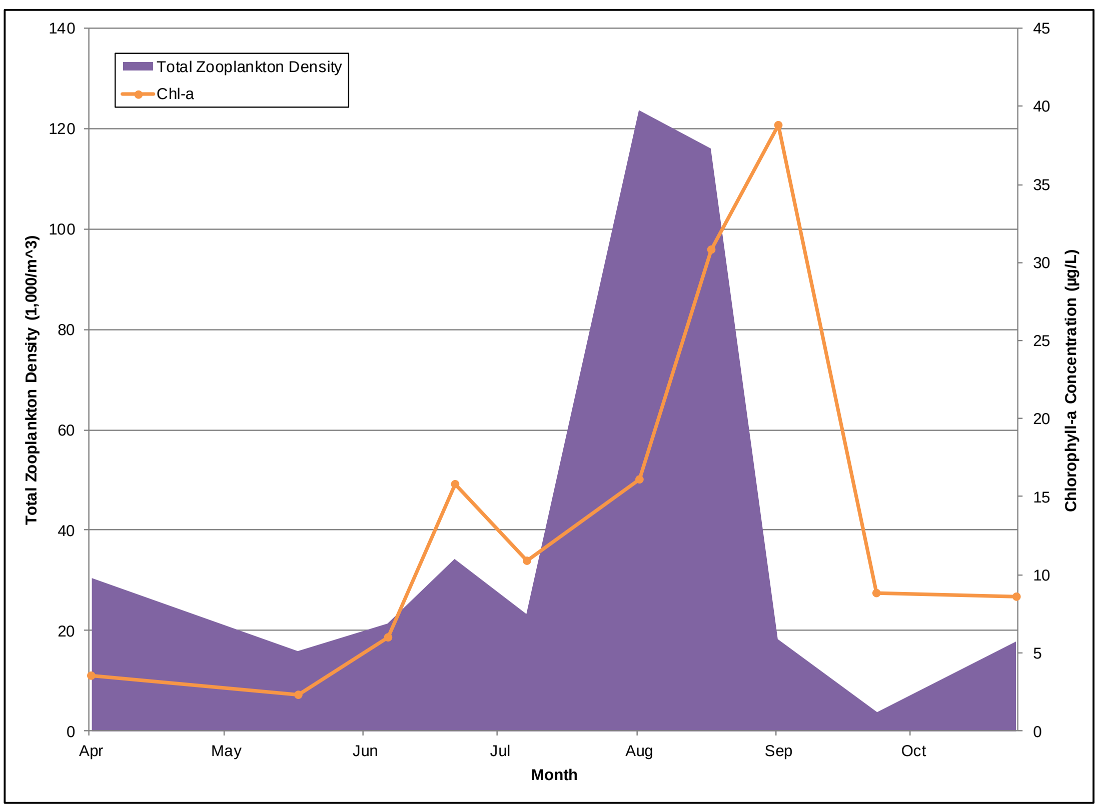

Figure 7-11: Crosby Lake 2016 total zooplankton density and Chl-a concentration.

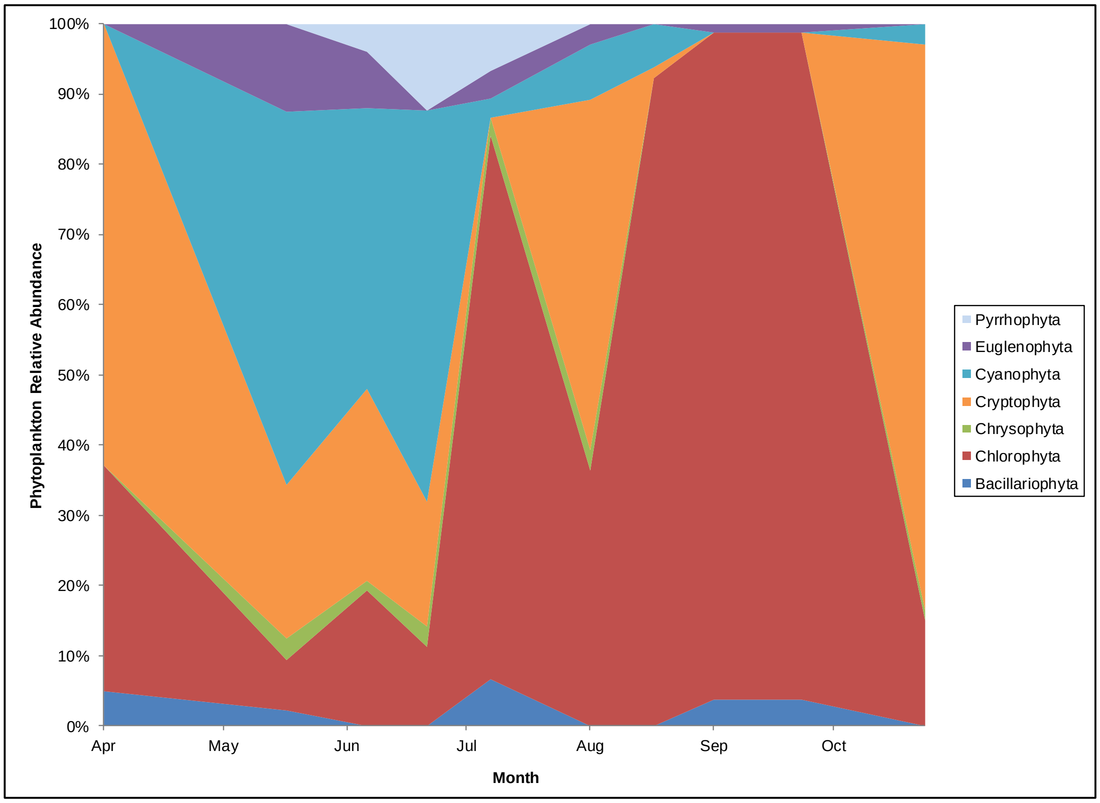

Figure 7-12: Crosby Lake 2016 phytoplankton relative abundance.

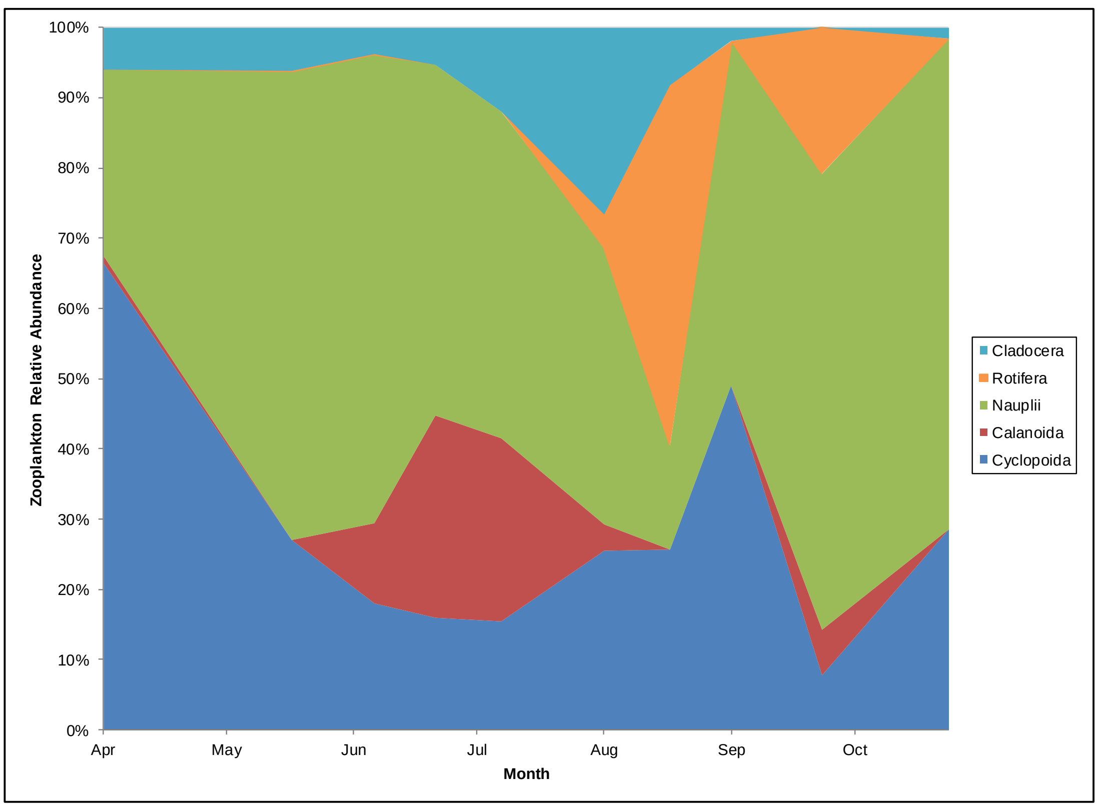

Figure 7-13: Crosby Lake 2016 zooplankton relative abundance.

7.5 AQUATIC VEGETATION

7.5.1 BIOVOLUME ANALYSIS

The 2016 biovolume heat maps of submerged aquatic vegetation for Crosby Lake are shown in Figure 7-14. Since 100% of the lake area lies within the littoral zone, submerged biomass was observable at nearly all points in the lake in the June survey, the large majority of the lake in the July survey, and over 50% of the lake in the August survey. While the macrophyte occurrence rate was comparable to that of 2015, 2016 surveys showed a decrease in the abundance of vegetation for all three surveys, especially at depths greater than 10 ft. There is a general decrease in aquatic biomass present from the initial survey in June to the final survey in August; only the bays on the northern and southern tips of the lake maintained heavy biomass throughout the growing season.

7.5.2 POINT-INTERCEPT SURVEYS

A diverse aquatic plant community was observed in Crosby Lake in 2016, with 16 distinct species observed throughout the season (Figure 7-15). The following plants were observed at mid-to-high percent occurrence during all three survey events: star duckweed, white water lily, and coontail (Figures 7-15 and 7-16). Sago pondweed was observed at a lower abundance and occurrence rate than in 2015. Water celery, while present in all three comparable 2015 surveys, was not present in 2016. Seven floating aquatic plant species were observed at varying levels of occurrences in Crosby Lake: three species of duckweed, white water lily, American lotus, watermeal and common bladderwort. Curly-leaf pondweed was present during the first two surveys, and had lower abundance and occurrence in 2016 than in the comparable 2015 surveys. Curly-leaf pondweed is an aquatic invasive species and was only first found in the lake in the 2013 survey.

Eurasian water milfoil was not observed in Crosby Lake in 2016; the first and only recorded observance of it was during the August 2015 survey. Unlike native northern watermilfoil, Eurasian watermilfoil forms dense mats at the surface of the water, impeding recreational accessibility and decreasing light available to other aquatic plants beneath its canopy (DNR 2015d). Eurasian watermilfoil does not easily become established in lakes with previously well-established and diverse populations of native plants. Further surveying efforts will confirm whether or not Eurasian water milfoil has become established in Crosby Lake.

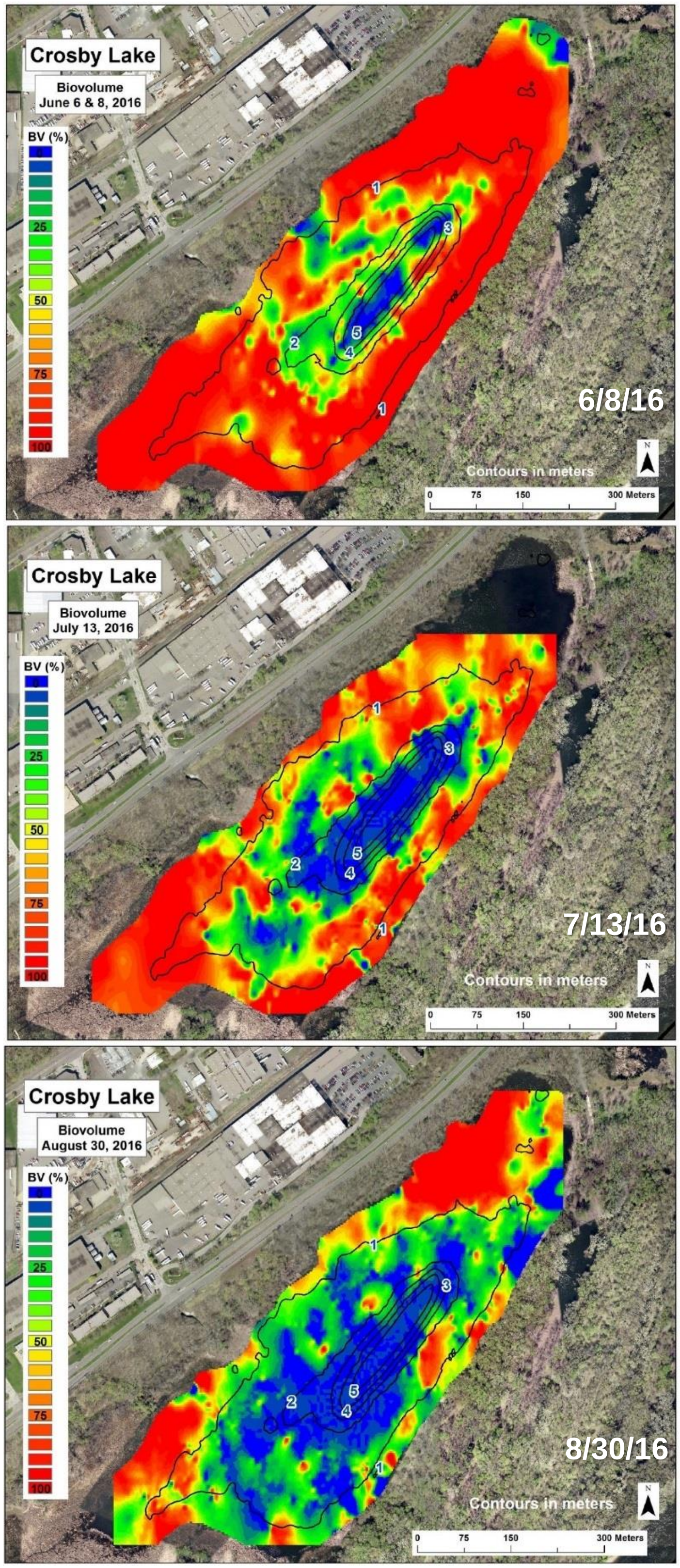

Figure 7-14: Crosby Lake 2016 seasonal vegetation changes (6/8/16, 7/13/16, 8/30/16)

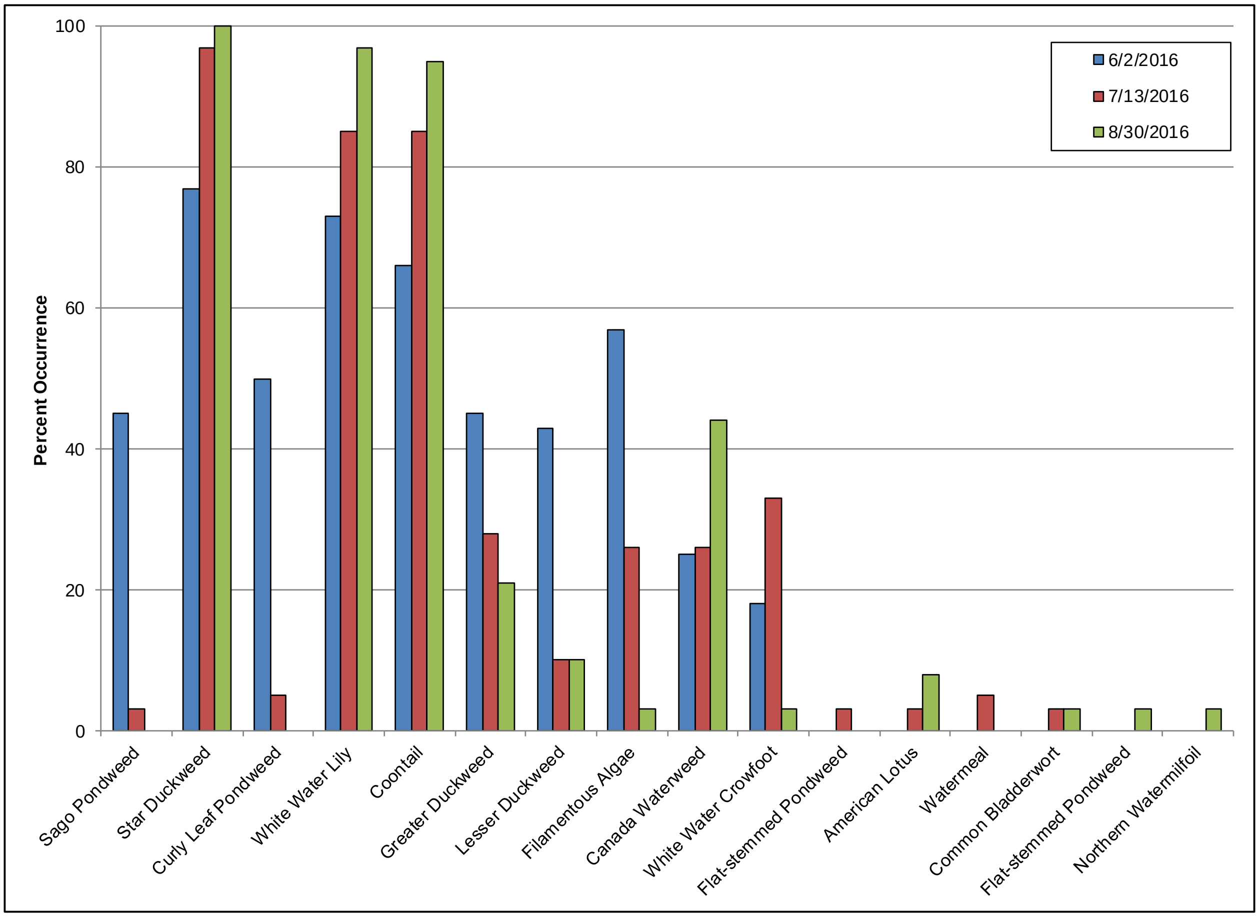

Figure 7-15: Crosby Lake 2016 percent occurrence of vegetation present.

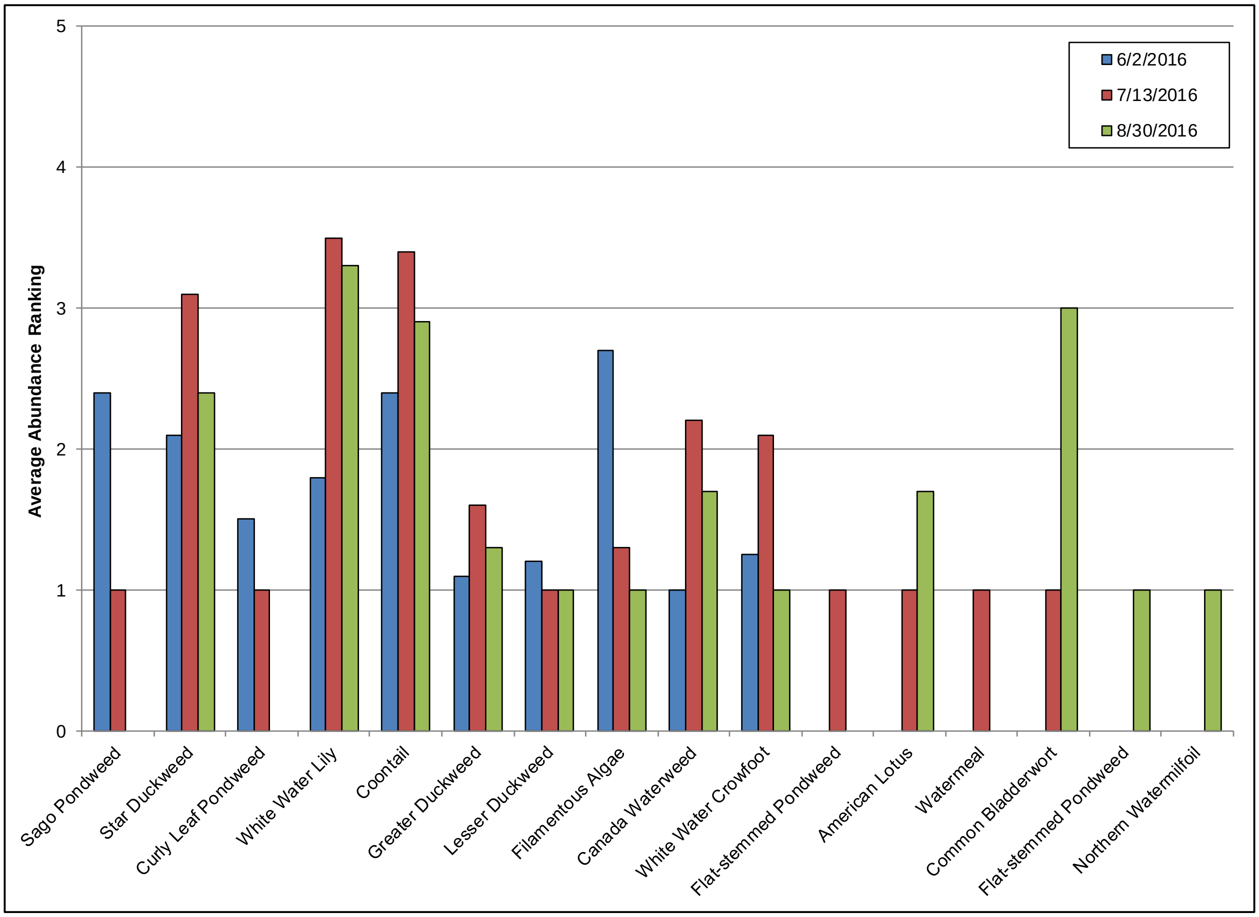

Figure 7-16: Crosby Lake 2016 average abundance ranking of vegetation present.

7.6 FISH STOCKING AND SURVEYS

CRWD conducted a fish survey of Crosby Lake in 2016 (Table 7-5). The DNR does not stock this lake, so populations observed are naturally present in the lake and can be influenced by overflow from the Mississippi River during high water levels. Northern pike were observed, but not in high abundance. Panfish accounted for 13% of the total fish surveyed. Seventy-eight percent of the total fish observed in 2016 were black and yellow bullheads. This ratio of rough fish (fish that are undesirable for fishing and are often bottom-feeders) to more desirable fish categories is far larger than the 2015 survey (14%), and the 2014 survey (38%).

Table 7-5: Crosby Lake 2016 fish populations.

Species	Number of fish caught in each category (inches)								Total
	0-5	6-8	9-11	12-14	15-19	20-24	25-29	30+	
Black bullhead	38	17	12	2					69
Black crappie		3	1						4
Bluegill	2	3							5
Bowfin (Dogfish)							1		1
Hybrid Sunfish	1								1
Largemouth bass			1						1
Northern pike					2				2
Pumpkinseed sunfish	5								5
Yellow bullhead	6	5	10	1					22
Yellow perch	2	3	1						6

7.7 OVERALL LAKE EVALUATION

In 2016, the annual average TP (93 µg/L) decreased to a value more in-line with the historical average (82 µg/L) after exhibiting a dramatic peak in 2014 (211 µg/L). In addition, Crosby Lake exhibited similar Chl-a concentration and Secchi Disk depth to previous years, and also showed improvement over 2015 values. The lake grade in 2016 was a ‘C’, just below the historical grade of ‘C+’. Crosby Lake has historically received average lake grades, indicating that it generally has average water quality. More recent years of monitoring (2011-present), however, have exhibited poorer water quality for all three eutrophication parameters when compared to the earliest years of monitoring on the lake. This could be a potential consequence of the large period of flooding that occurred in 2011, and other periods of flooding in subsequent years.

The lake contained a large and diverse variety of vegetation during the 2016 vegetation surveys, with extensive vegetation covering the majority of the lake from early June through mid-July, and decreasing to just over half of the lake by the late August survey. The majority of the fish found in Crosby Lake in 2016 were black and yellow bullhead. Bullhead are bottom feeders and can contribute to poor water quality, so observing them in such large percentages in the 2016 survey poses a concern for the effect of these populations on overall lake health.

8 LITTLE CROSBY LAKE RESULTS

8.1 LITTLE CROSBY LAKE BACKGROUND

Little Crosby Lake is 8 acres with an average depth of 7 ft and a maximum depth of 34 ft (Figure 8-1; Table 8-1). Little Crosby Lake is a shallow lake with a littoral area of 88% and has a small watershed area of only 37 acres (Table 8-1). Little Crosby Lake is hydrologically connected to Crosby Lake through a small marsh area 825 ft long, and thus shares the same subwatershed (Figure 8-2). For information on Little Crosby Lake Background, see Crosby Lake Background (page 59).

Figure 8-1: View facing northwest from the southern shoreline of Little Crosby Lake.

Table 8-1: Little Crosby Lake morphometric data.

Surface Area (acres)	Maximum Depth (ft)	Littoral Area	Volume (acre-ft)	Watershed Area (acres)	Watershed: Lake Area (ratio)
8.0	34.0	88%	59	37	4.6

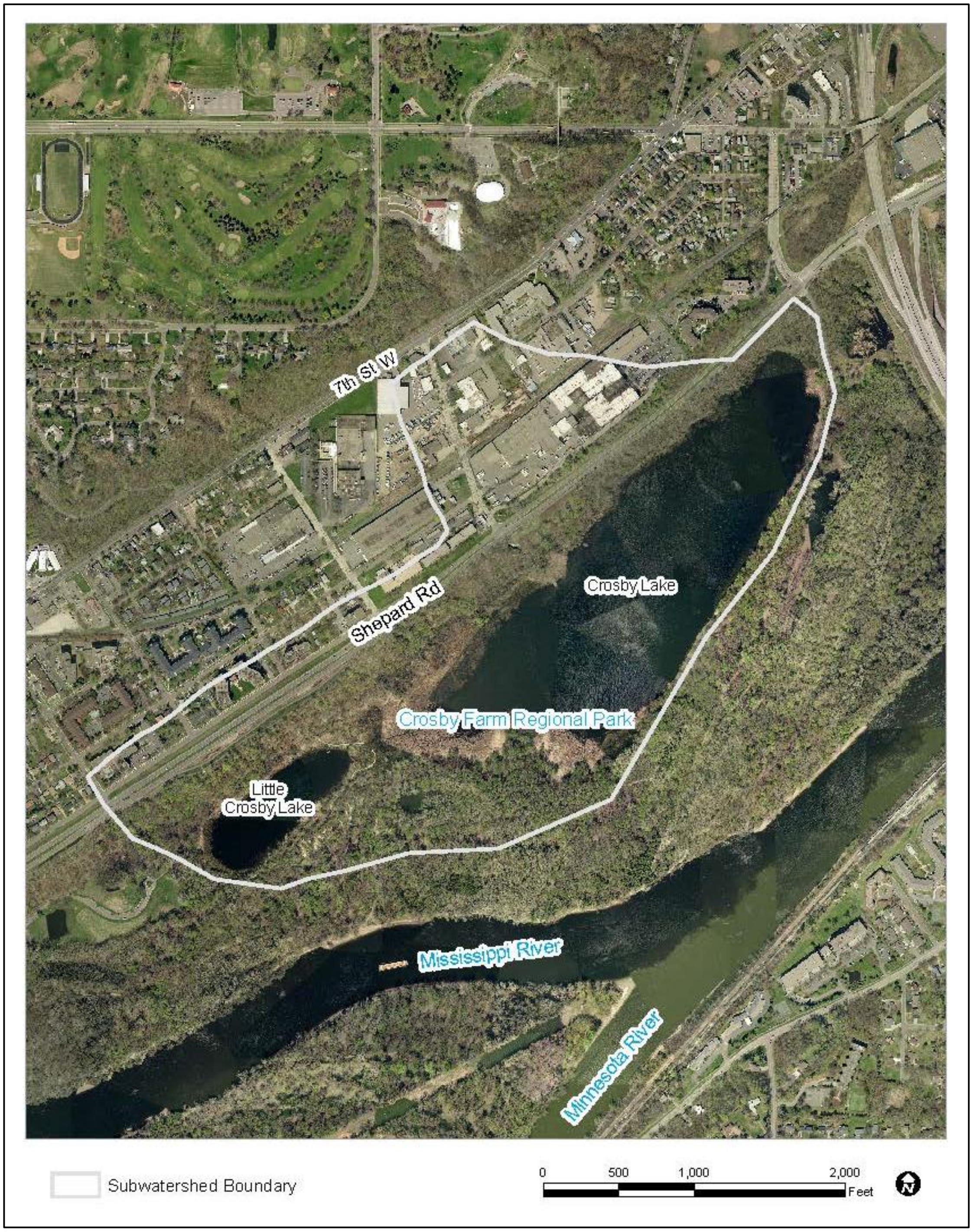

Figure 8-2: Crosby and Little Crosby Lakes and subwatershed boundary.

8.2 LAKE LEVEL

There is no historical lake level data for Little Crosby Lake from the Minnesota DNR. CRWD began monitoring Crosby Lake level in 2014. General trends in lake level can be seen by looking at Crosby Lake level (Figure 7-4), as these two bodies of water are hydrologically connected and reside at the same elevation on the Mississippi River floodplain.

8.3 WATER QUALITY RESULTS

Little Crosby Lake was sampled ten times in 2016, from April 1 to October 24 (Figure 8-3). Samples indicated that all parameters exhibited the poorest state of water quality in early June, with a gradual trend towards improved water quality later in the season (Figure 8-3). TP values exceeded the state standard during the two June sampling events, as well as the final sampling event in October. This is an improvement from 2015, when all TP sample values exceeded the state standard throughout the entire monitoring season. The Chl-a and Secchi disk readings also showed improvement over 2015 values.

Historically, Little Crosby Lake exhibits the lowest level of water quality during July, which exhibits the highest medians of TP and Chl-a and the lowest Secchi disk readings than any other month (Figure 8-4). This could be related to typically drier weather and higher temperatures, which contributes to more stagnant water and more primary productivity.

Figure 8-5 shows yearly average historical TP concentrations, Chl-a concentrations, and Secchi disk depths graphically. Since monitoring on Little Crosby Lake began in 2011, only six years of records exist for comparison. Little Crosby Lake exhibited the poorest water quality in 2011 and 2014, both years in which it was inundated by river flooding (Table 7-2). In the years following both of these flooding events, water quality shows improvement. Throughout the last five years, high water transparency has been associated with lower TP and Chl-a concentrations.

While 2012 and 2013 exhibited the lowest epilimnetic TP concentrations and overall highest water quality in the historical record (Figure 8-5), these years produced the highest hypolimnetic TP concentrations yet recorded (Figure 8-6). Without additional sample data, it can be difficult to determine the cause of this, but, as discussed above, the lake is affected by seasonal flooding from the Mississippi River, which can influence mixing in the lake. These high hypolimnetic TP values occurred in the two years following a record number of days of flooding with the river (103 days). Conversely, hypolimnetic and epilimnetic TP values in 2016 were the lowest on record for Little Crosby Lake.

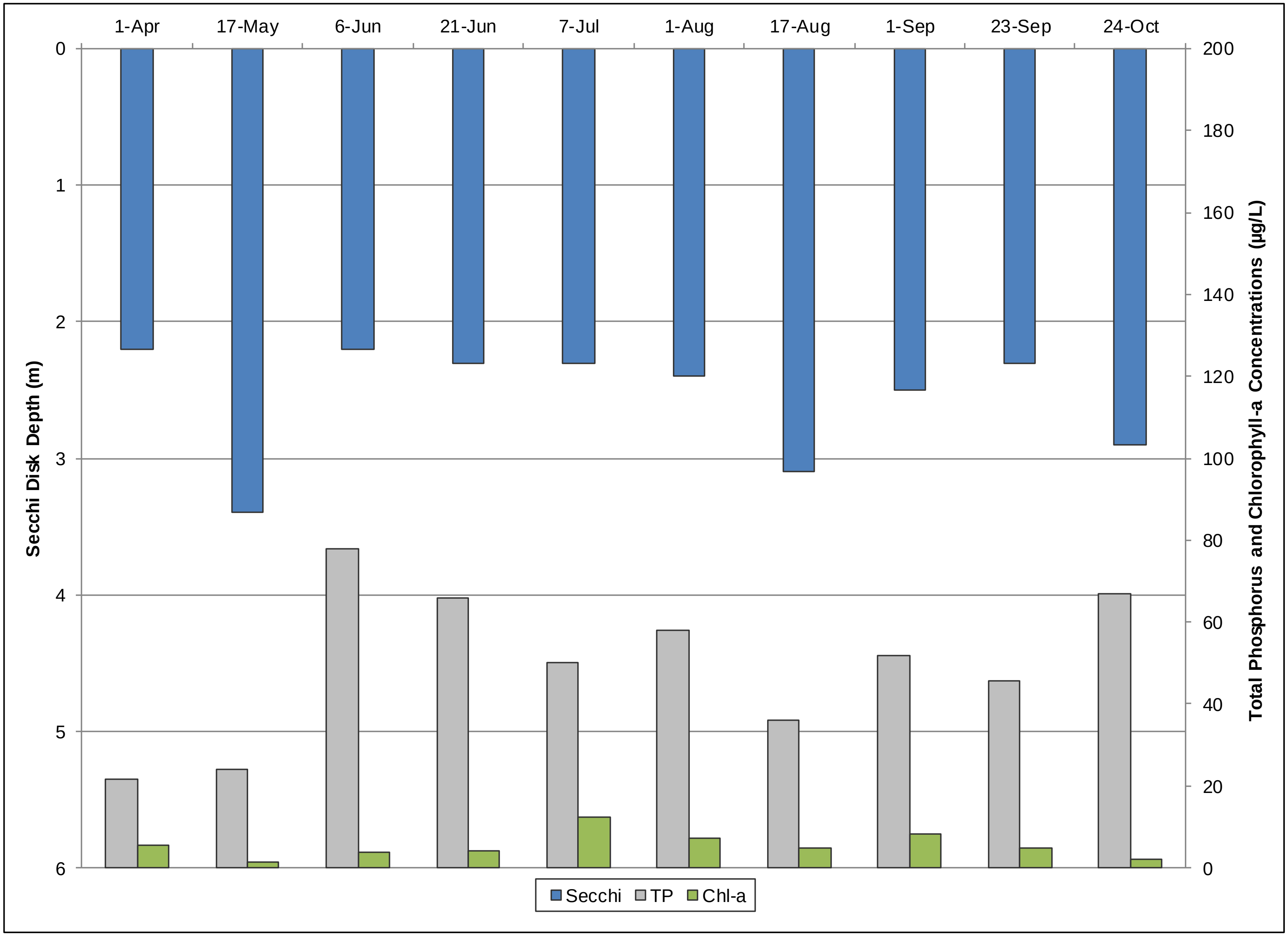

Figure 8-3: Little Crosby Lake 2016 Secchi/TP/Chl-a comparison.

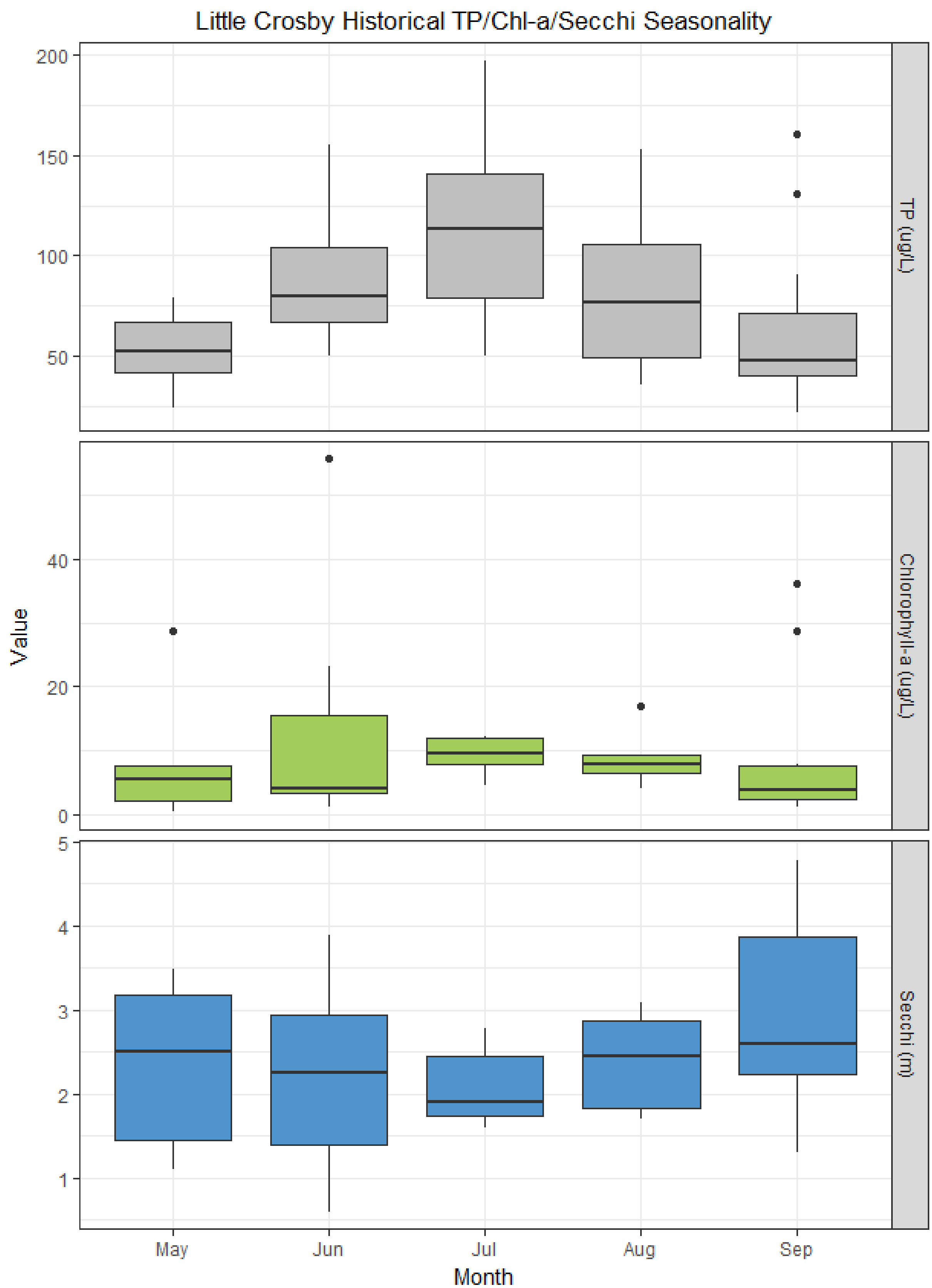

Figure 8-4: Little Crosby Lake seasonality boxplots of historical Secchi/TP/Chl-a samples.

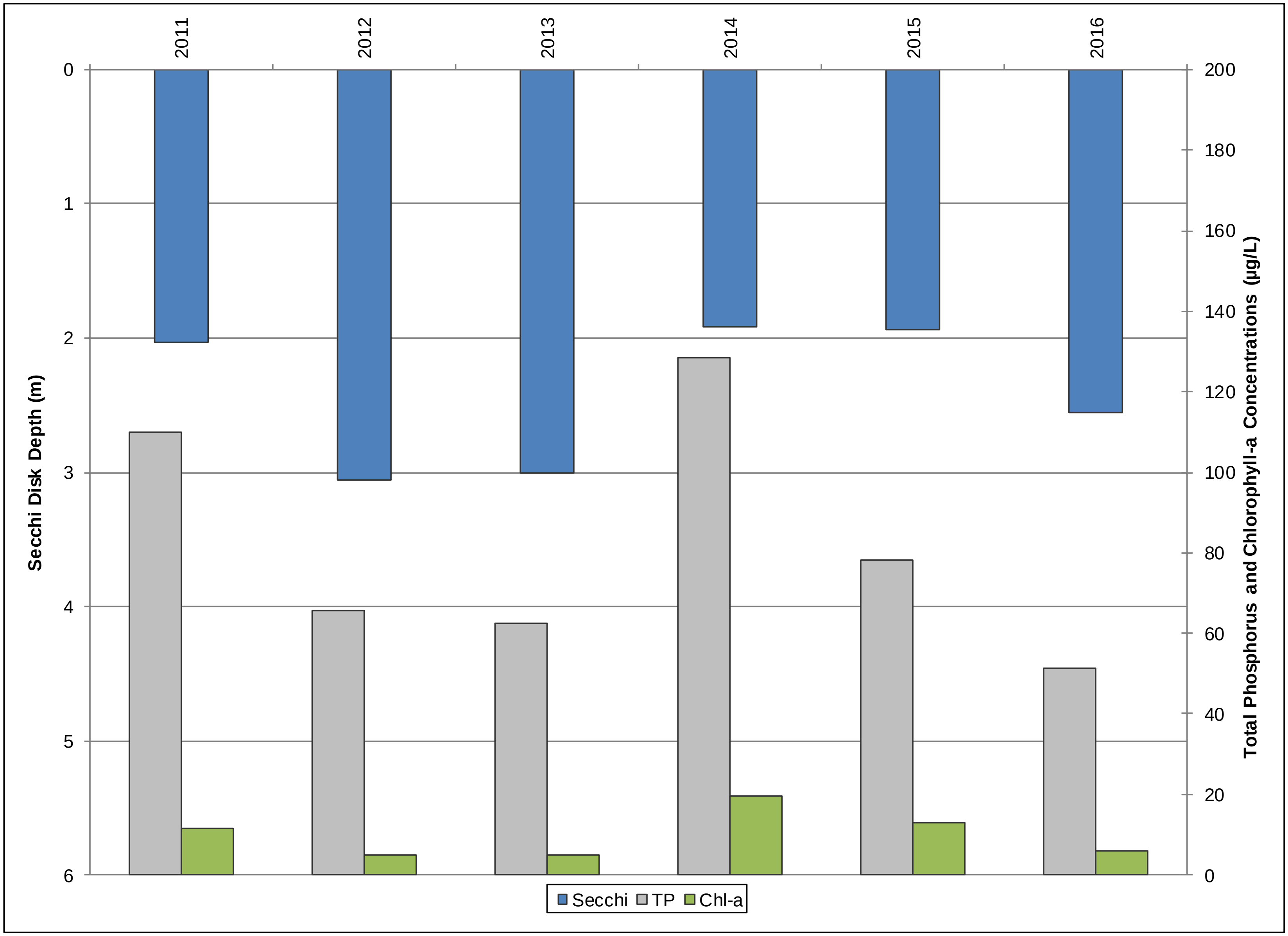

Figure 8-5: Little Crosby Lake historical annual average Secchi/TP/Chl-a comparison.

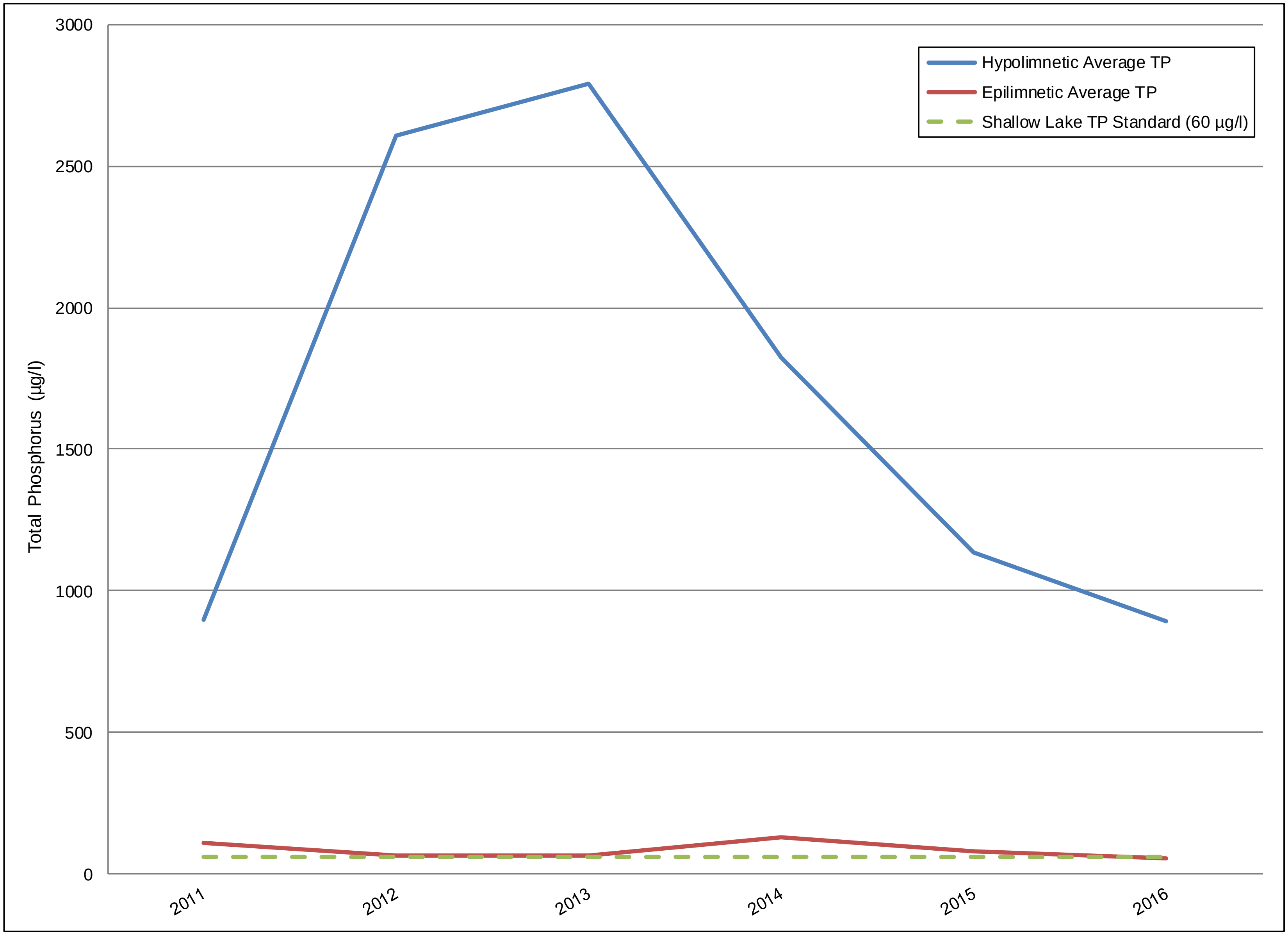

Figure 8-6: Little Crosby Lake historical annual average hypolimnetic and epilimnetic total phosphorus.

Yearly average historical TP concentrations, Chl-a concentrations, Secchi depths, and their comparisons to lake standards are shown in Table 8-2. Little Crosby Lake TP concentrations exceeded the MPCA standards from 2011-2015, but met the standards in 2016 for the first time since monitoring began. Chl-a and Secchi depth have both met the lake standards for all years of monitoring. Historical lake grades for TP/Chl-a/Secchi depth are shown in Table 8-3. In 2016, Little Crosby Lake was evaluated with an overall grade of 'B', an improvement over the 2014-2015 monitoring years. Overall, Little Crosby Lake exhibited moderate water quality for the years monitored. In the future, a larger data set with more monitoring seasons will provide better information to interpret trends in water quality, as well as better understand the effect of river flooding on lake water quality.

Table 8-2: Little Crosby Lake historical yearly TP/Chl-a/Secchi depth averages compared to shallow lake state standards.

Year	TP (µg/L)	Chl-a (µg/L)	Secchi (m)
2011	110	11.4	2.0
2012	66	5.0	3.1
2013	63	4.9	3.0
2014	129	19.4	1.9
2015	78	12.9	1.9
2016	51	5.9	2.6

(shaded)	Value does not meet state standard*
(unshaded)	Value meets state standard

*MPCA shallow lake standards must be less than 60 µg/L for TP and 20.0 µg/L for Chl-a, with a Secchi disk depth of greater than 1.0 m.

Table 8-3: Little Crosby Lake historical lake grades.

Year	TP Grade	Chl-a Grade	Secchi Grade	Overall Grade
2011	D	B	C	**C**
2012	C	A	A	**B+**
2013	C	A	A	**B+**
2014	D	B	C	**C**
2015	D	B	C	**C**
2016	C	A	B	**B**

8.4 PHYTOPLANKTON AND ZOOPLANKTON

Little Crosby Lake was sampled for phytoplankton and zooplankton ten times in 2016, from April 1 to October 24. Phytoplankton concentrations were low throughout the year, with the exception of two spikes during the year which occurred during the late June sampling event and the mid-September sampling event (Figure 8-7). While the first increase in total concentration followed the peak in TP for the year, the second, and larger, increase in total concentration was not preceded by a significant increase in TP. The phytoplankton population was relatively diverse through mid-May, followed by a surge in the Pyrrhophyta population in early June (Figure 8-9). The increase in total population observed in late June was the result of a dramatic increase in the Cyanophyta population, which then remained one of the dominant taxa observed through the rest of the monitoring season. Additionally, Chlorophyta represented a significant proportion of the population from July through October. The second major increase in total population in mid-September consisted almost entirely of Cyanophyta and Chlorophyta. Euglenophyta was observed at the very beginning and very end of the monitoring season.

Zooplankton densities remained low from early April through late June, before increasing significantly to a peak in early July (Figure 8-8). During this time the population was comprised of varying ratios of Cladocerans, Nauplii, and Cyclopoids, with a small population of Calanoids increasing in significance (Figure 8-10). The Cladocerans dominated the zooplankton community for the remainder of the year from early July through late October. During this time there was a small presence of Rotifers observed. From early July and through the rest of the season, total density closely mirrored Chl-a concentration, with both measures peaking at the early July and early September sampling events (Figure 8-8). Total phytoplankton concentration and total zooplankton density do not appear to affect one another in a consistent pattern (Figures 8-7 and 8-8).

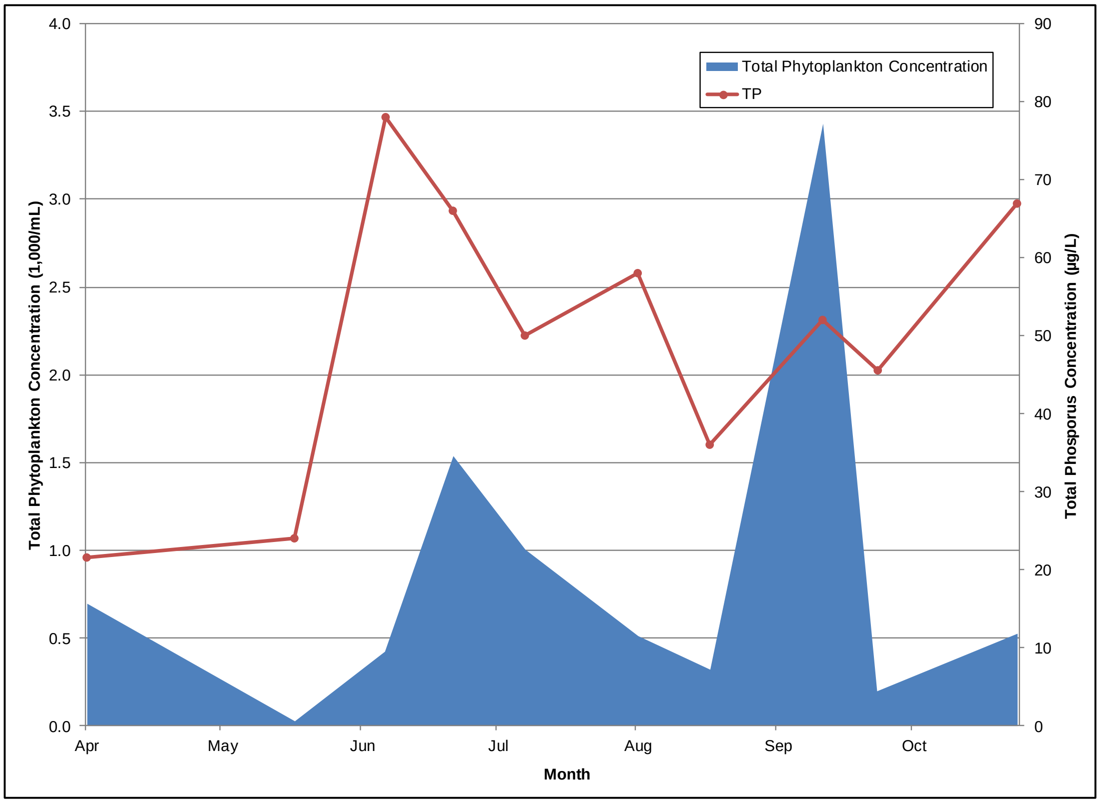

Figure 8-7: Little Crosby Lake 2016 total phytoplankton concentration and TP concentration.

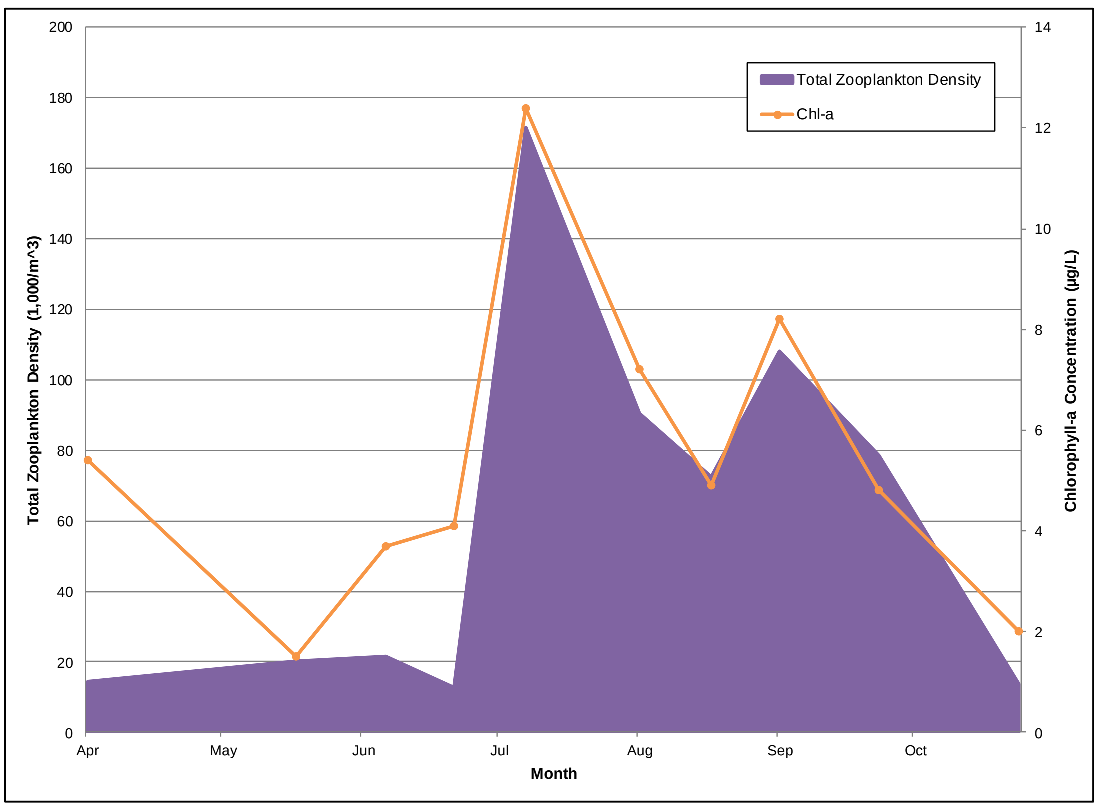

Figure 8-8: Little Crosby Lake 2016 total zooplankton density and Chl-a concentration.

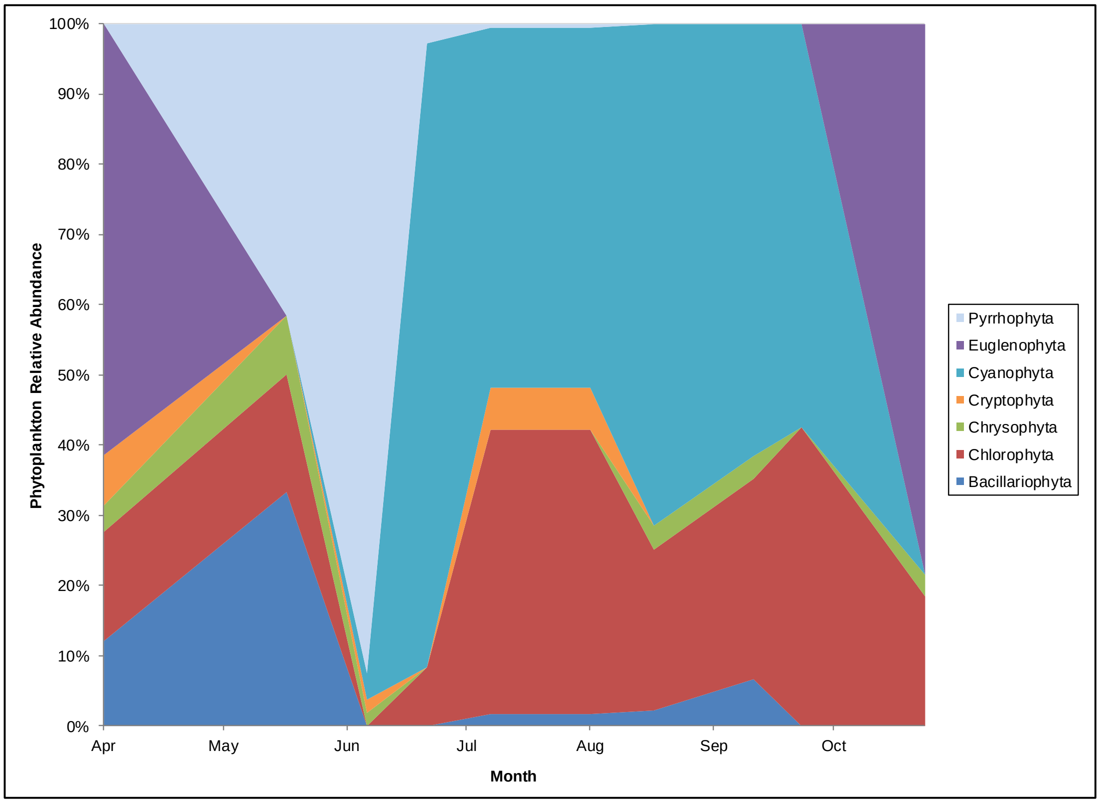

Figure 8-9: Little Crosby Lake 2016 phytoplankton relative abundance.

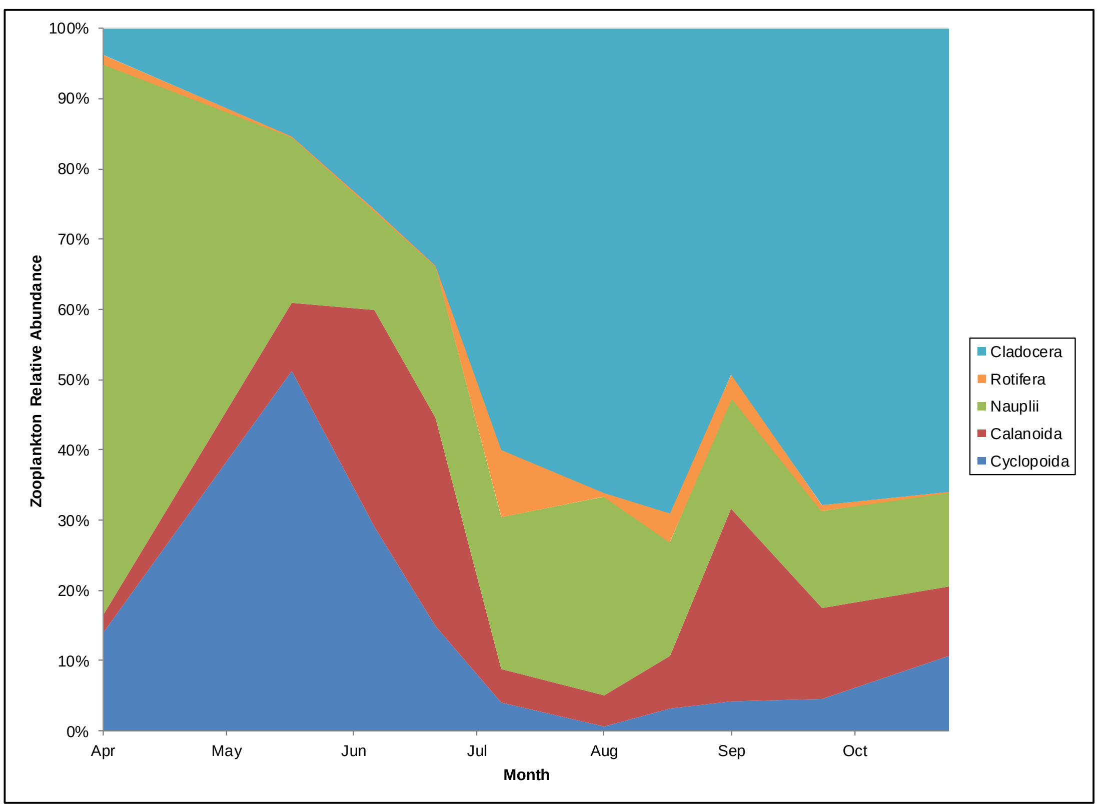

Figure 8-10: Little Crosby Lake 2016 zooplankton relative abundance.

8.5 AQUATIC VEGETATION

8.5.1 BIOVOLUME ANALYSIS

Figure 8-11 shows the results of the June, July, and August 2016 biovolume analyses of Little Crosby Lake. Vegetation growth was generally limited to the 15 ft littoral zone. Aquatic plant biovolume remained consistent between the three surveys. Spatial biovolume growth patterns generally matched the results from previous years' surveys.

8.5.2 POINT-INTERCEPT SURVEYS

Thirteen distinct species were observed in Little Crosby Lake during 2016. All but one species found in Little Crosby Lake were also found to be present in Crosby Lake. Flat-stemmed pondweed and northern water milfoil were found at higher occurrence and abundance rates in Little Crosby Lake than in Crosby Lake. The following plants were observed at mid- to high-level occurrences throughout all three survey sessions: filamentous algae, star duckweed, coontail, flat stemmed pondweed, and greater duckweed (Figures 8-12 and 8-13).

Curly-leaf pondweed was observed in Little Crosby Lake during the initial June survey at 55% occurrence and low density. It was not observed during the July and September surveys. Curly-leaf pondweed is an invasive plant that has a biological advantage of beginning its growth cycle early while ice still covers the lake. Thus, it causes problems by displacing other native plants during early open-water season and forming thick mats on the surface of a lake that disrupt boating and recreation. Additionally, when the plants die back in mid-summer, the resulting decomposing plant material increases phosphorus levels, which can lead to disruptive algal blooms (DNR, 2005).

The presence of Eurasian watermilfoil has not yet been observed in Little Crosby Lake; however, the first and only observance of Eurasian watermilfoil happened in Crosby Lake in September 2015. As the lakes are hydrologically connected through a marsh area and seasonally flooding via the Mississippi River, it is possible that Eurasian watermilfoil will be observed in Little Crosby Lake in future years. Eurasian watermilfoil can propagate from stem and rhizome fragments on the inch scale (DNR, 2015d).

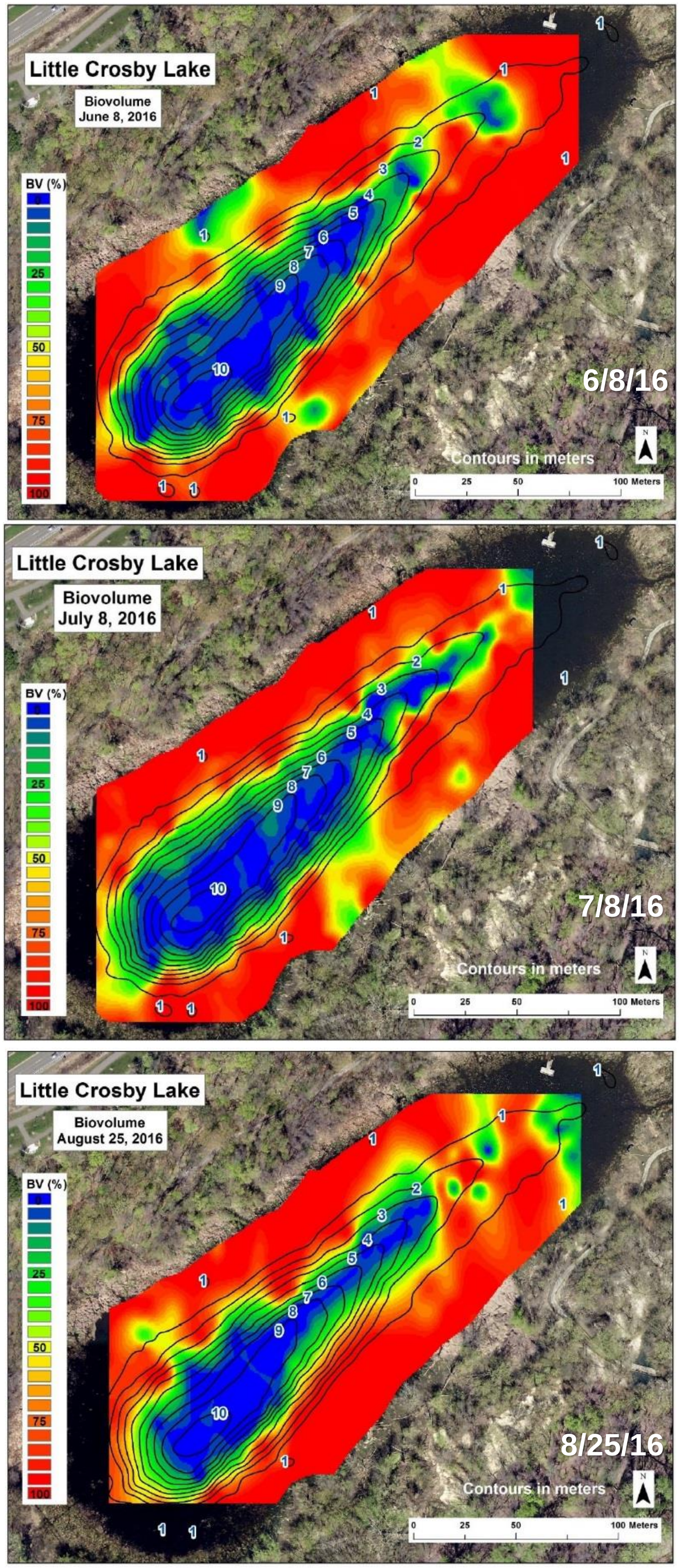

Figure 8-11: Little Crosby Lake 2016 seasonal vegetation changes (6/8/16, 7/8/16, 8/25/16).

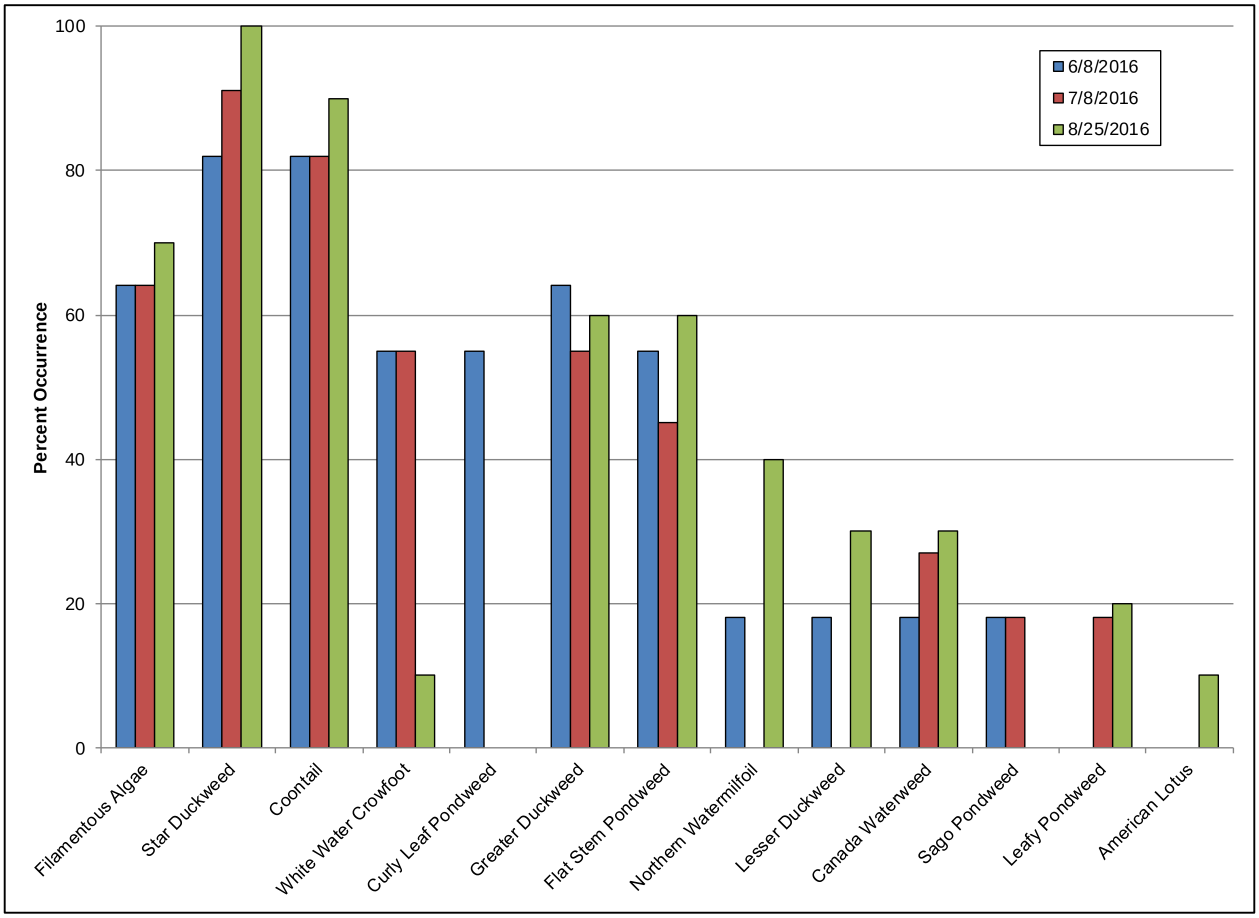

Figure 8-12: Little Crosby Lake 2016 percent occurrence of vegetation present.

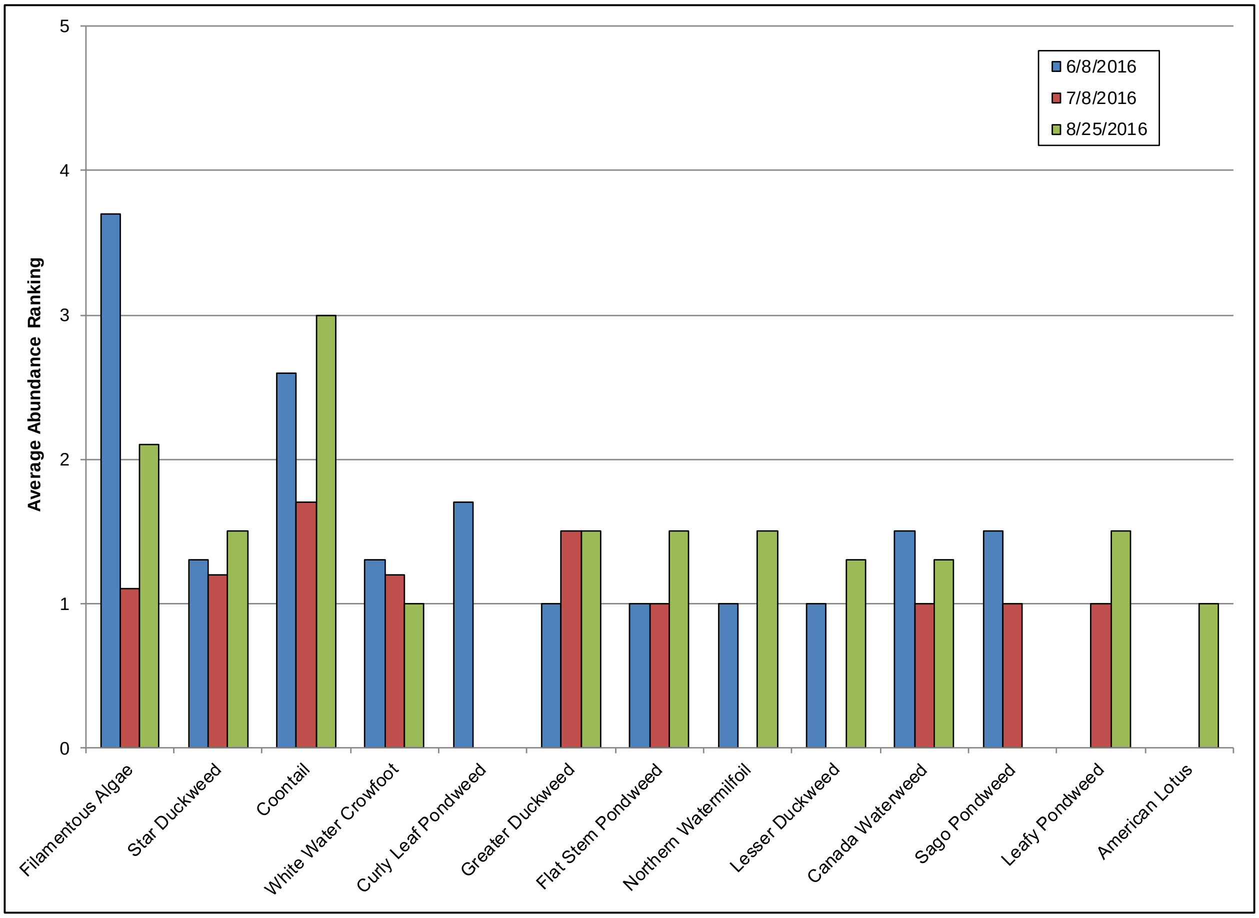

Figure 8-13: Little Crosby Lake 2016 average abundance ranking of vegetation present.

8.6 FISH STOCKING AND SURVEYS

There is no history of fish stocking for Little Crosby Lake by the Minnesota DNR. CRWD conducted fish surveys on Little Crosby Lake in 2014, 2015, and 2016.

In 2016, 7 species of fish were observed during the August fish survey, with a total catch of 23 fish (Table 8-4). The initial 2014 fish survey produced the largest population of observable fish (62), the majority of which were black bullheads. The 2015 and 2016 surveys were more comparable to each other, with 24 fish caught in 2015. The lake exhibits low species diversity, with only 6 species observed in 2014, 5 species observed in 2015, and 7 species observed in 2016. Pumpkinseed and bluegill made up the majority (78%) of fish observed in 2016 (Table 8-4). All but one species observed in Little Crosby Lake was also observed in the 2016 Crosby Lake fish survey (Table 7-5), which is expected given that they are hydrologically connected. A green sunfish was observed in 2016, an unexpected find for Little Crosby Lake.

Table 8-4: Little Crosby Lake 2016 fish populations.

Species	Number of fish caught in each category (inches)								Total
	0-5	6-8	9-11	12-14	15-19	20-24	25-29	30+	
Black bullhead		1							1
Yellow bullhead	1								1
Bluegill	5								5
Northern pike							1		1
Pumpkinseed sunfish	11	2							13
Green Sunfish	1								1
Yellow perch	1								1

8.7 OVERALL LAKE EVALUATION

Little Crosby Lake has a relatively short monitoring record when compared to the other District lakes. During years in which flooding from the river occurred (2011 and 2014), poorer water quality was observed for all eutrophication parameters. In comparison, all eutrophication parameters showed improvement in the two years following the flood inundation events. Improvement in all three eutrophication parameters was observed in 2016, including the lowest annual average TP value (51 µg/L) observed since monitoring began in 2011. Therefore, 2016 was the first year in which Little Crosby met the state standards for all three eutrophication parameters.

Much of the lake area was covered by vegetation throughout 2016. The lake contained a moderate diversity of plant species by early fall. Fish populations exhibited low diversity and low abundance in 2016, the majority of which were panfish.

9 LOEB LAKE RESULTS

9.1 LOEB LAKE BACKGROUND

Loeb Lake (Figure 9-1), located in Marydale Park in the northwestern portion of the City of St. Paul, is a 9.7-acre lake with a maximum depth of 28 feet and an 81% littoral area (Table 9-1). The area has a walking path, children's play area, picnic areas, a fishing pier, and a boat launch. The surrounding area is primarily residential land use.

Figure 9-1: View of the northwest shoreline from the dock of Loeb Lake.

Table 9-1: Loeb Lake morphometric data.

Surface Area (acres)	Maximum Depth (ft)	Littoral Area	Volume (acre-ft)	Watershed Area (acres)	Watershed: Lake Area (ratio)
9.7	28.0	81%	84	44	4.5

The watershed area contributing inflow to the lake is 44 acres (Table 9-1; Figure 9-2). Water enters the lake from the north half of the watershed through sheet flow traveling through Marydale Park, as well as a storm sewer that collects runoff from Mackubin Street between Maryland and Jessamine Avenues (CRWD, 2009). Runoff from the south half of the watershed enters Loeb Lake through two different storm sewers. The storm sewers drain streets on the south and east sides of the lake, discharging to a stormwater pond on the southeast corner. A pipe directly connects this pond to Loeb Lake. There are no direct outlets from Loeb Lake.

Loeb Lake has been monitored since 2003 and has had relatively stable TP, Chl-a, and Secchi disk depth values that have consistently met the state standards. Therefore, lake conditions have appeared to remain stable since monitoring began. Because of the lake's stable and high quality conditions, the Loeb Lake management plan recommends a phosphorus goal for non-degradation, or maintaining water quality at current levels.

Previous winter kills of fish have been observed in Loeb Lake, but have not occurred since 2000, when an aerator was installed in the lake (CRWD, 2009). Future management efforts on Loeb Lake should focus on reduced loading in the surrounding watershed and naturalizing the shoreline (CRWD, 2009). Both of these actions would reduce the subsequent influx of nutrients into the lake. While water quality is currently stable, good management efforts around the lake to prevent further increases in nutrient inputs will be key in preventing lake degradation.

Figure 9-2: Loeb Lake and subwatershed boundary.

9.2 LAKE LEVEL

Loeb Lake level has been monitored since 2003, with the exception of May 2004 through February 2006 when level data was not available (Figure 9-3). Loeb Lake does not have an OHWL to compare the current year to historical "normal" lake levels. The lowest recorded water level of the lake occurred in May 2009 at a level of 848.6 ft. In July 2014, the lake reached the highest level on record at 852.32 ft following a record-setting storm event. The previous record high was in August of 2011 at a height of 851.63 ft. Historical data for 2016 consisted of both level logger data from CRWD, as well as staff gauge data from the Minnesota DNR. The spike in lake level observed in late 2016 (a level of 852.1 ft) was a value recorded by the DNR (which is why this value is not shown in Figure 9-4, as this figure only represents level data from CRWD).

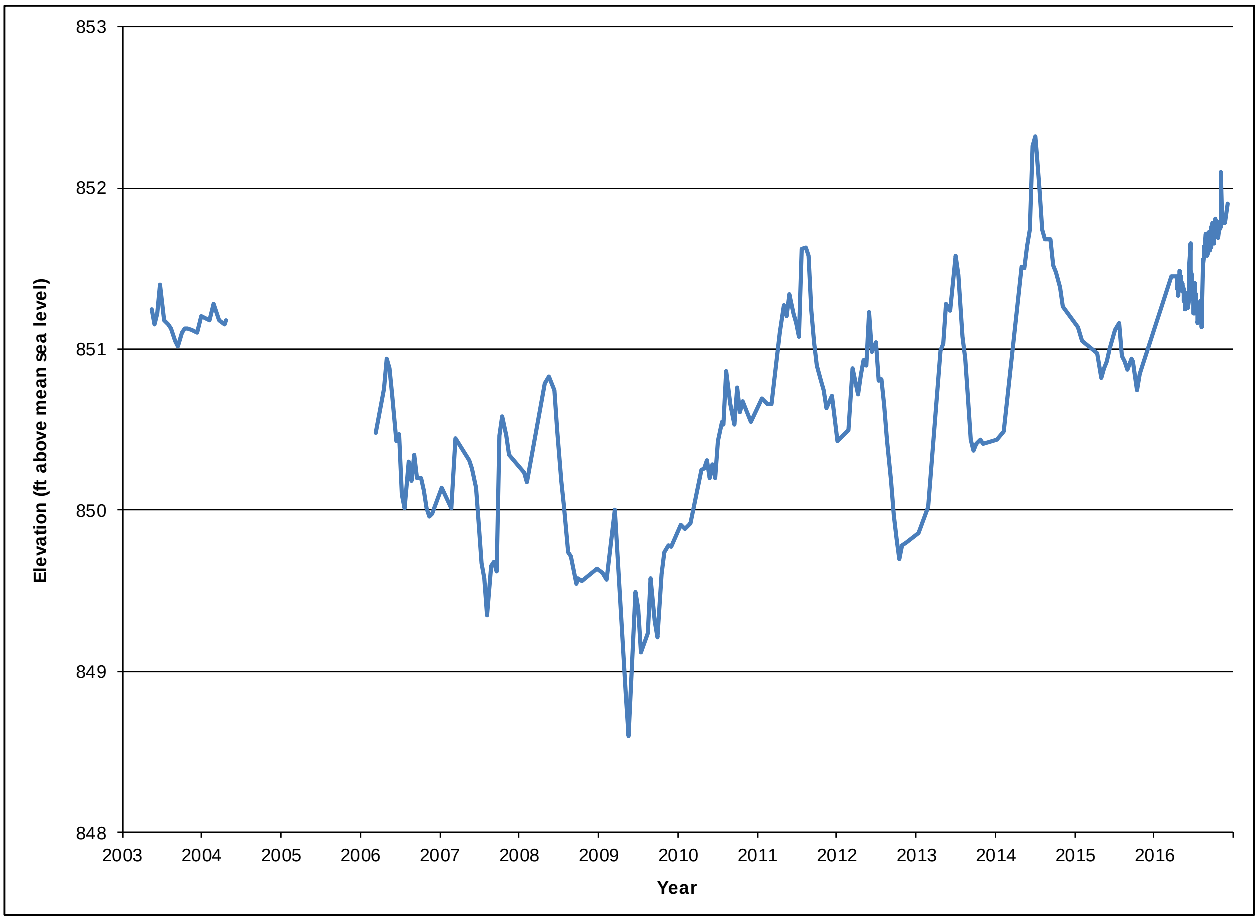

Figure 9-3: Loeb Lake historical lake elevations (DNR, 2016b).

In 2016, lake level generally decreased from early April through mid-August, with two large increases during that time coming from two large precipitation events in early June and early July (Figure 9-4). In mid-August, lake level rose steeply as a result of the largest precipitation event observed during 2016 on August 10th, spiked again as a result of another large precipitation event on August 16th, and stayed high throughout the rest of the CRWD monitoring season as a result of a very wet late summer and fall (Figure 9-4). The level response to precipitation events in Loeb Lake is generally minimal (lake level only fluctuates within a 1 ft range) compared to other lakes with more stormwater inputs and therefore greater variability in level.

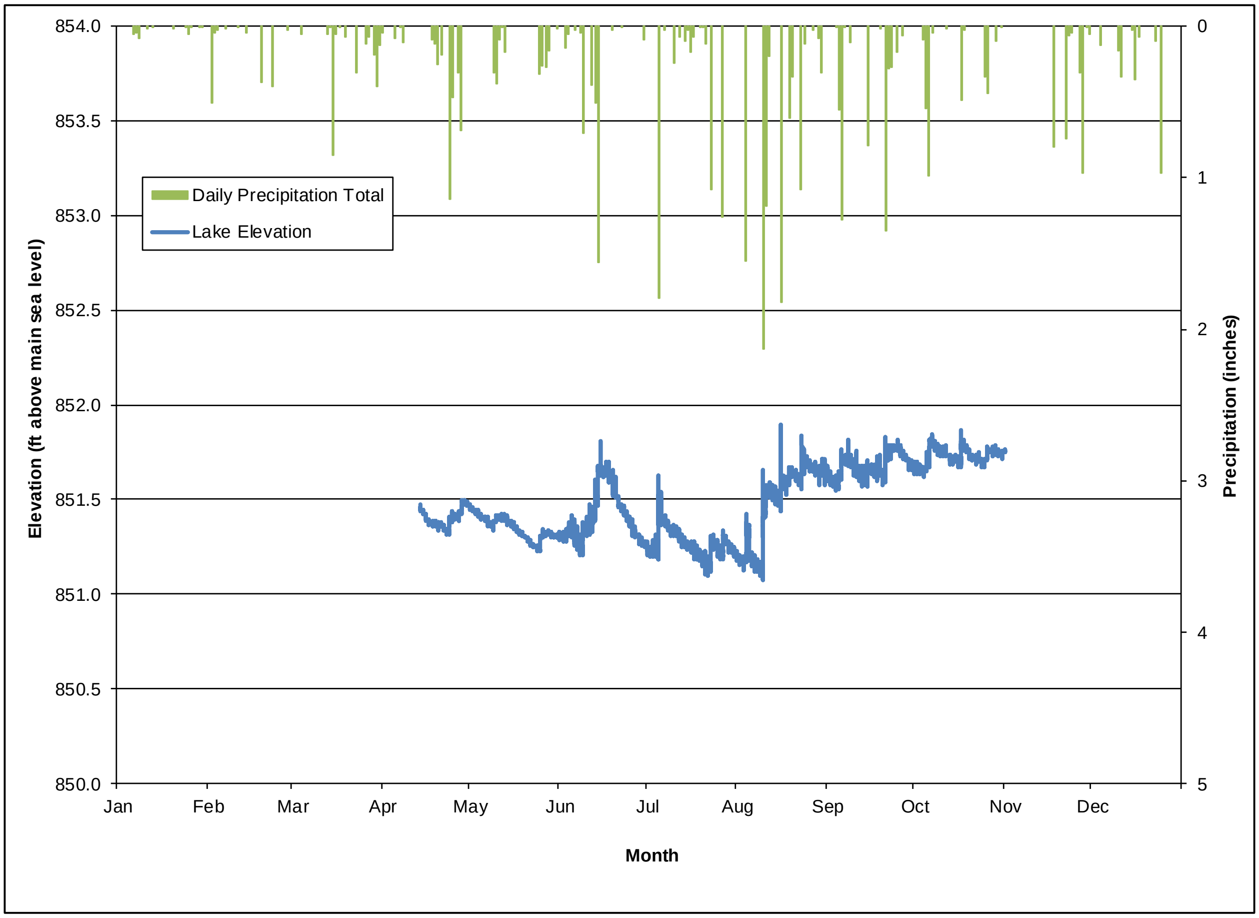

Figure 9-4: Loeb Lake 2016 lake elevations and daily precipitation events (MCWG, 2016).

9.3 WATER QUALITY RESULTS

Loeb Lake was sampled ten times during 2016 from April 6 to October 21 (Figure 9-5). As in previous years, Loeb Lake was characterized by low TP and Chl-a concentrations, and deep Secchi depths. TP levels were highest during the early April sampling event, and during the two sampling events in August. However, all TP values remained well below the cutoff for the shallow lake state standard.

Chlorophyll-a concentrations also began with a season high value of 6.1 µg/L on April 6 and followed a similar pattern as TP concentrations. Secchi depths were generally deepest during May-July and September-October when TP and Chl-a values were lower. The data suggests that during 2016, and for the monitoring record, higher water clarity was associated with lower TP and Chl-a concentrations.

Loeb Lake does not exhibit much seasonal variation throughout the historical record for TP, Chl-a or Secchi disk depth (Figure 9-6). All three parameters are typically indicative of the highest level of water quality during June, closely followed by May. Water quality generally decreases slightly throughout July, August, and September, but the lake still consistently meets the shallow lake standards for each parameter.

Figure 9-7 shows yearly average historical TP concentrations, Chl-a concentrations, and Secchi disk depths graphically. Based on the historical data since 2003, Loeb Lake has demonstrated a high degree of consistency. TP concentrations decreased from 2003-2009 and while TP increased during 2010-2013, concentrations have improved from 2014 to the present. Overall TP concentrations, however, are the lowest of any District Lake, and also low compared with other area lakes (Table 5-1) (DNR, 2016b).

Chl-a concentrations have been low and varied only slightly throughout the period of record. Concentrations for Chl-a were lowest from 2005-2012 and 2014-2016, whereas 2003, 2004, and 2013 were characterized by slightly higher Chl-a concentrations (Figure 9-7). Secchi depths were shallowest in 2003 (2.7m), deepest in 2005 and 2006 (3.8 m and 3.7 m) and have been generally getting shallower since. Secchi Depth values in 2015 and 2016, however, appear to be improving over more recent years.

Despite exhibiting low epilimnetic TP concentrations, Loeb Lake produced very high annual average hypolimnetic TP concentrations early in its sampling record (Figure 9-8). In 2005, Loeb Lake exhibited the lowest epilimnetic TP and Chl-a and highest Secchi disk readings in its record (Figure 9-7). The highest hypolimnetic TP reading, however, was also recorded during this year (1,036 µg/L) (Figure 9-8). In eutrophic lakes, the hypolimnion is generally richer in phosphorus than the epilimnion, as bed sediments readily release phosphorus into the anoxic bottom layer, peaking in fall just prior to lake turnover (Kalff, 2002). In the years since 2005, however, hypolimnetic TP has drastically decreased and despite an increase in 2014, has remained low.

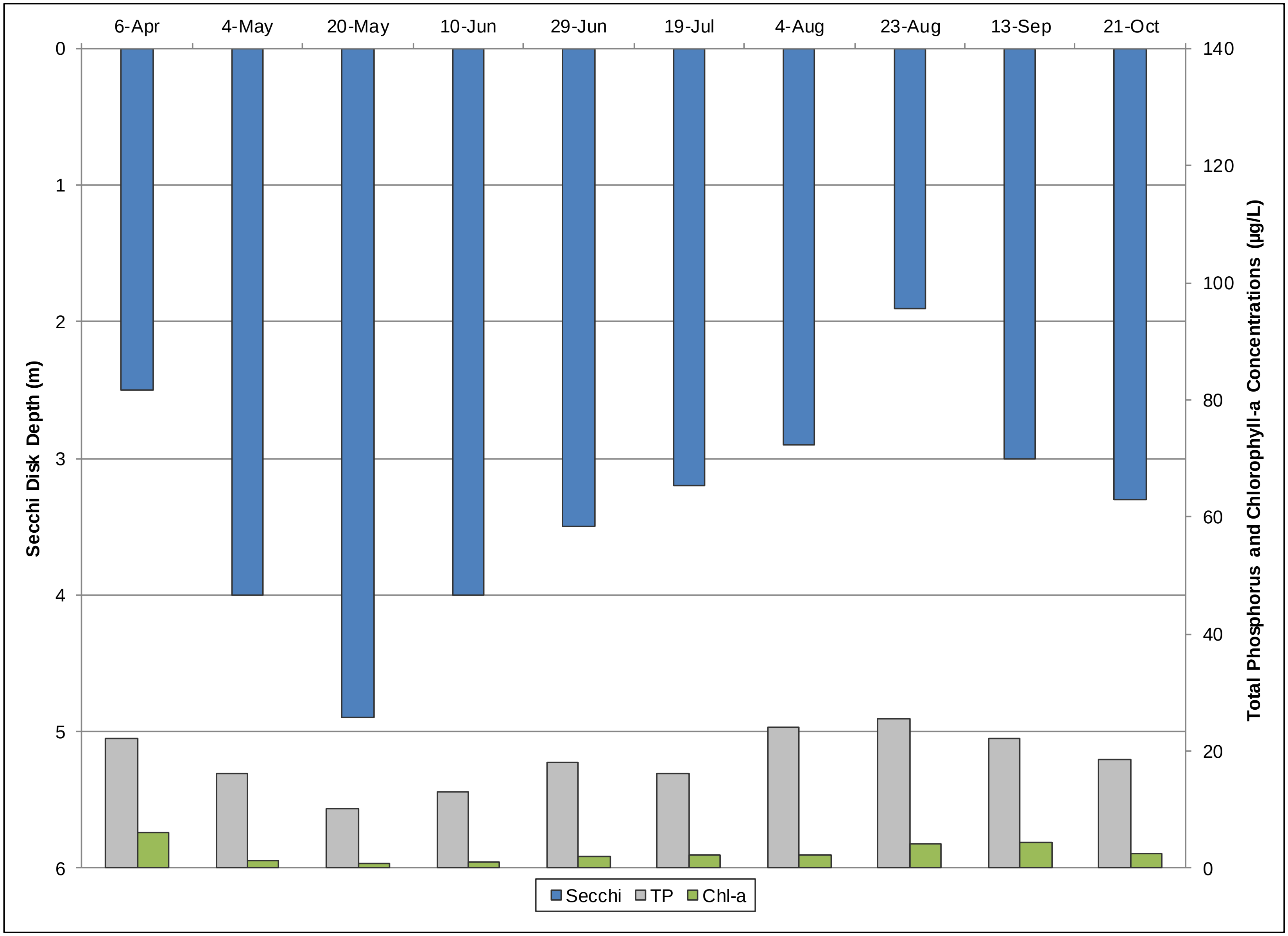

Figure 9-5: Loeb Lake 2016 Secchi/TP/Chl-a comparison.

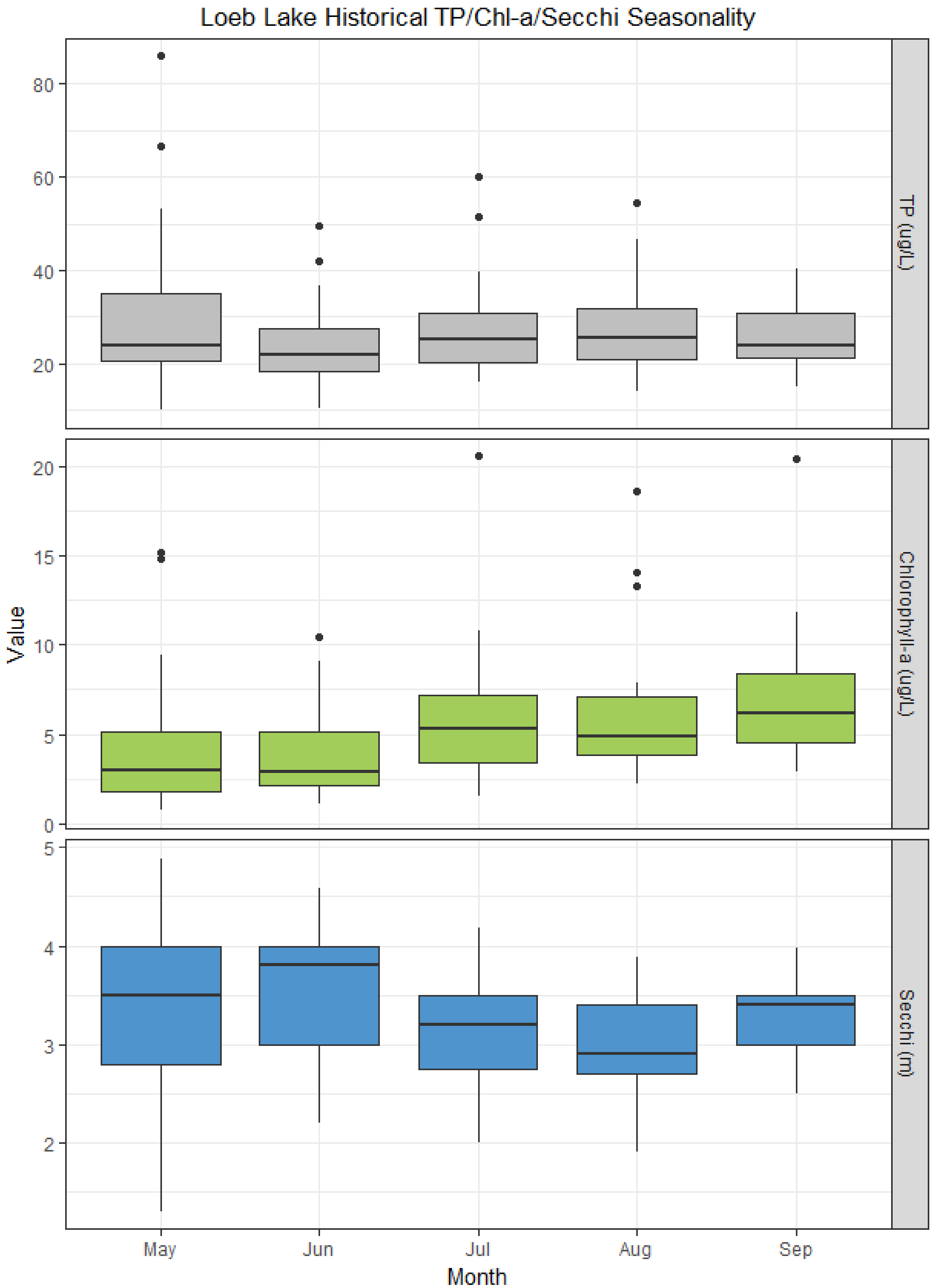

Figure 9-6: Loeb Lake seasonality boxplots of historical Secchi/TP/Chl-a samples.

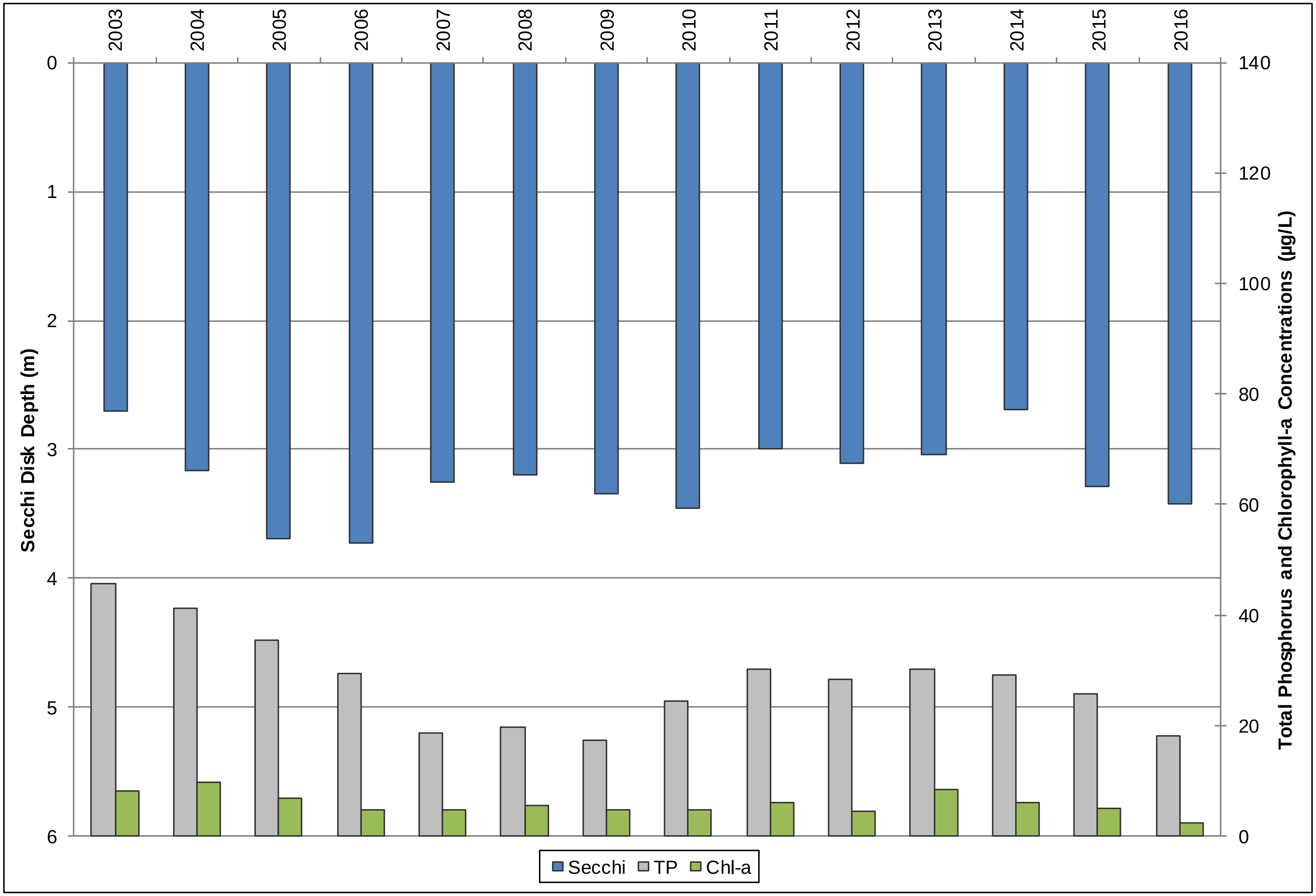

Figure 9-7: Loeb Lake historical annual average Secchi/TP/Chl-a comparison.

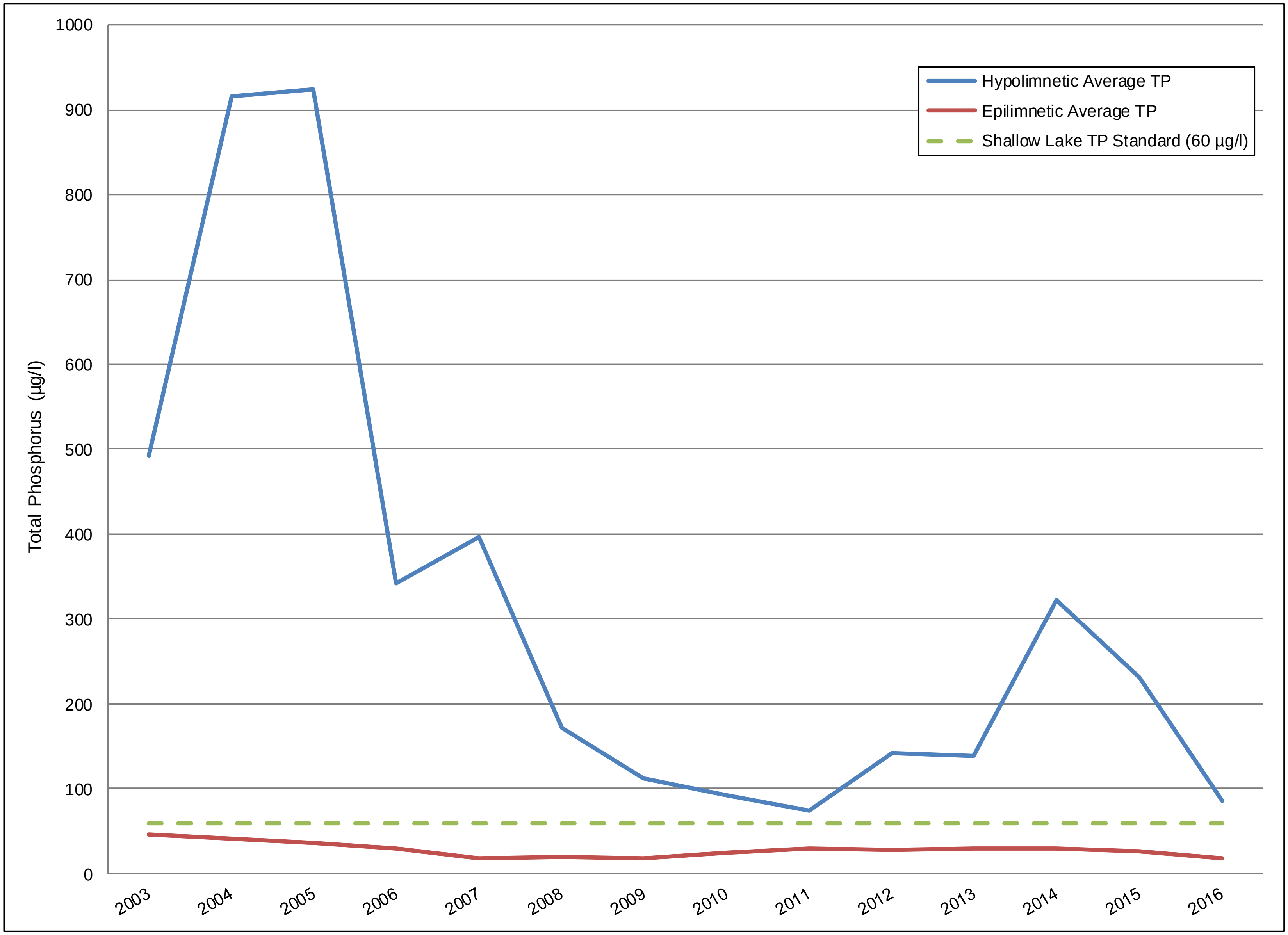

Figure 9-8: Loeb Lake historical annual average hypolimnetic and epilimnetic total phosphorus.

Yearly average historical TP concentrations, Chl-a concentrations, Secchi depths, and their comparisons to lake standards are shown in Table 9-2. Loeb Lake has had a stable and consistent water quality history. It has not exceeded the average summer TP, Chl-a or Secchi disk depth water quality standards in its monitoring history.

The overall lake grade has historically been an 'A', with only one 'B' grade occurring in 2003 and three 'B+' grades in 2004, 2005, and 2014 (Table 9-3). The drop from an 'A' grade in 2013 to a 'B+' grade in 2014 was the result of the slight decrease in Secchi disk depth observed between the two years. The high water quality lake grades associated with Loeb Lake indicate that it continues to be one of the highest water quality lakes in the District.

Table 9-2: Loeb Lake historical yearly TP/Chl-a/Secchi depth averages compared to shallow lake state standards.

Year	TP (µg/L)	Chl-a (µg/L)	Secchi (m)
2003	46	8.1	2.7
2004	41	9.6	3.2
2005	35	6.8	3.7
2006	29	4.8	3.7
2007	19	4.6	3.3
2008	20	5.5	3.2
2009	17	4.7	3.4
2010	24	4.7	3.5
2011	30	6.1	3.0
2012	29	4.4	3.1
2013	30	8.3	3.0
2014	29	6.0	2.7
2015	26	5.1	3.3
2016	18	2.3	3.4

(shaded)	Value does not meet state standard*
	Value meets state standard

*MPCA shallow lake standards must be less than 60 µg/L for TP and 20.0 µg/L for Chl-a, with a Secchi disk depth of greater than 1.0 m.

Table 9-3: Loeb Lake historical lake grades.

Year	TP Grade	Chl-a Grade	Secchi Grade	Overall Grade
2003	C	A	B	**B**
2004	C	A	A	**B+**
2005	C	A	A	**B+**
2006	B	A	A	**A**
2007	A	A	A	**A**
2008	A	A	A	**A**
2009	A	A	A	**A**
2010	B	A	A	**A**
2011	B	A	A	**A**
2012	B	A	A	**A**
2013	B	A	A	**A**
2014	B	A	B	**B+**
2015	B	A	A	**A**
2016	A	A	A	**A**

9.4 PHYTOPLANKTON AND ZOOPLANKTON

During 2016, Loeb Lake was sampled for phytoplankton and zooplankton ten times from April 6 to October 21. There were two peaks in total phytoplankton concentration in early May and again in mid-July (Figure 9-9). Aside from these two peaks, total overall concentration remained relatively low during the rest of the season. The second peak in concentration occurred after an increase in TP concentration, but no additional increases were observed for the rest of the year in phytoplankton concentration despite an increase in TP. While four different taxa (Cryptophyta, Chrysophyta, Chlorophyta, and Bacillariophyta) were observed in the early and late parts of the monitoring season, overall the population of phytoplankton was dominated by Cyanophyta, especially from mid-May through October (Figure 9-11). There was a small population of Euglenophyta observed during August. The peak in total concentration observed in mid-July almost entirely consisted of Cyanobacteria.

While all five groupings of zooplankton were observed throughout the year at Loeb Lake, Cyclopoids dominated the zooplankton community during the first two months of sampling in 2016, and Cladocerans dominated the population for the remainder of the year (Figure 9-12). Nauplii had a small presence during the first month and then was observed in moderate proportions from July through October. Calanoids and Rotifers were also present in consistent proportions from July through October. Overall zooplankton density roughly was not aligned with changes in Chl-a in 2016, with the highest Chl-a value observed on April 6, and zooplankton density exhibiting a peak on July 19 (Figure 9-10). Total phytoplankton and total zooplankton concentrations generally mirror each other in when the two populations are rising and falling in total amount (Figures 9-9 and 9-10).

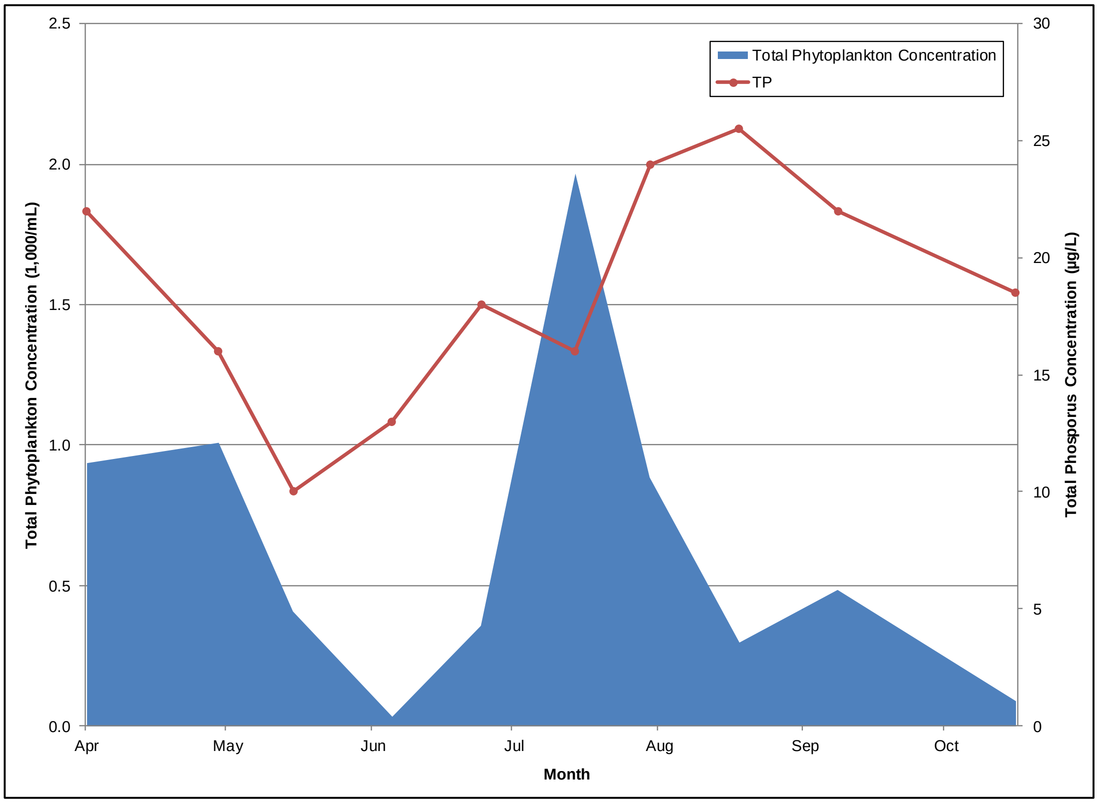

Figure 9-9: Loeb Lake 2016 total phytoplankton concentration and TP concentration.

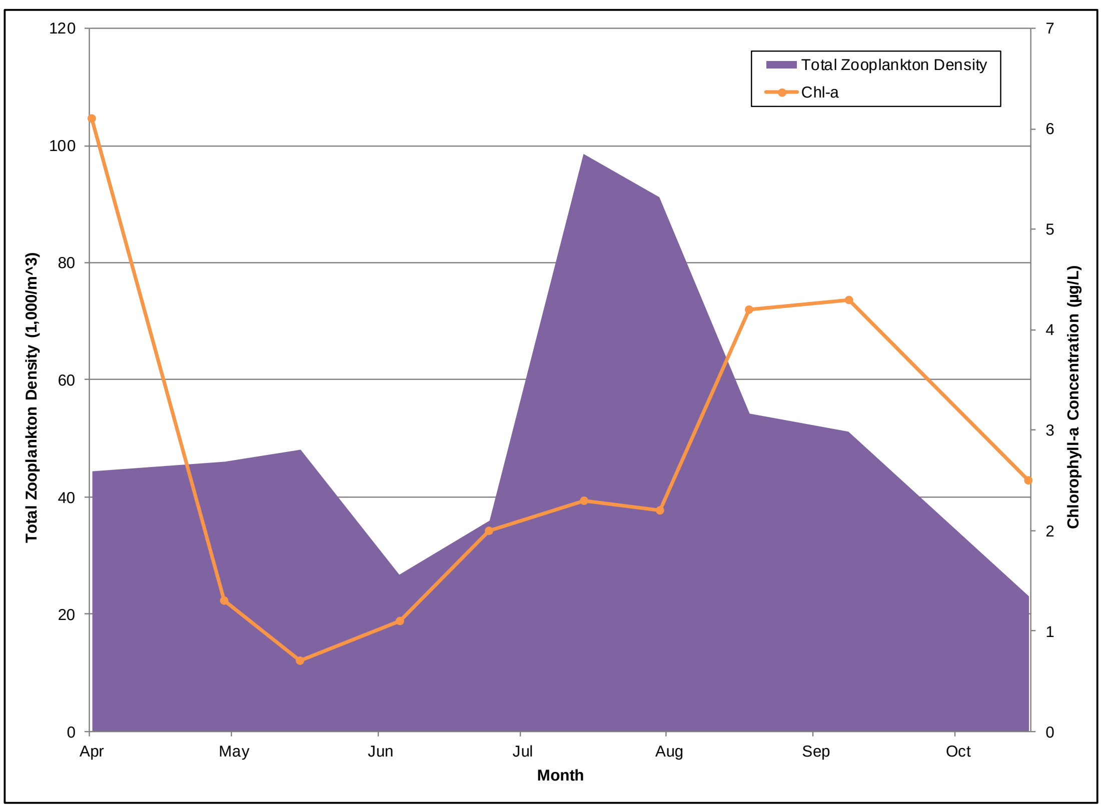

Figure 9-10: Loeb Lake 2016 total zooplankton density and Chl-a concentration.

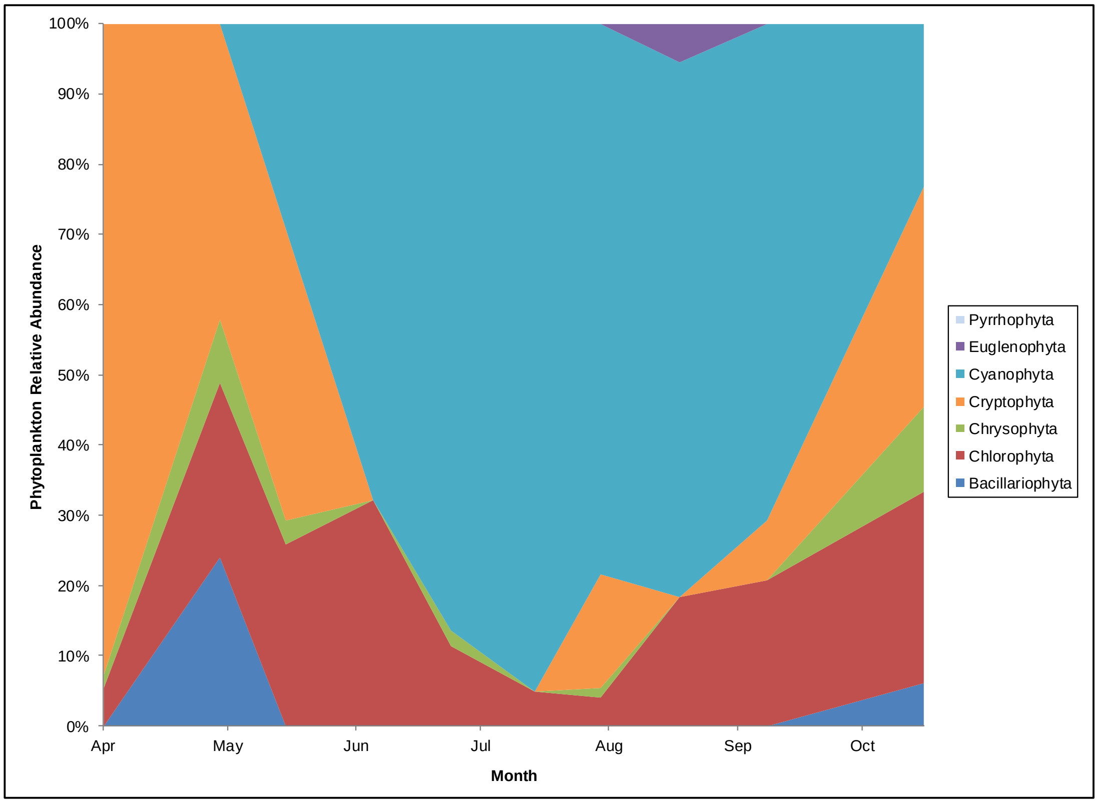

Figure 9-11: Loeb Lake 2016 phytoplankton relative abundance.

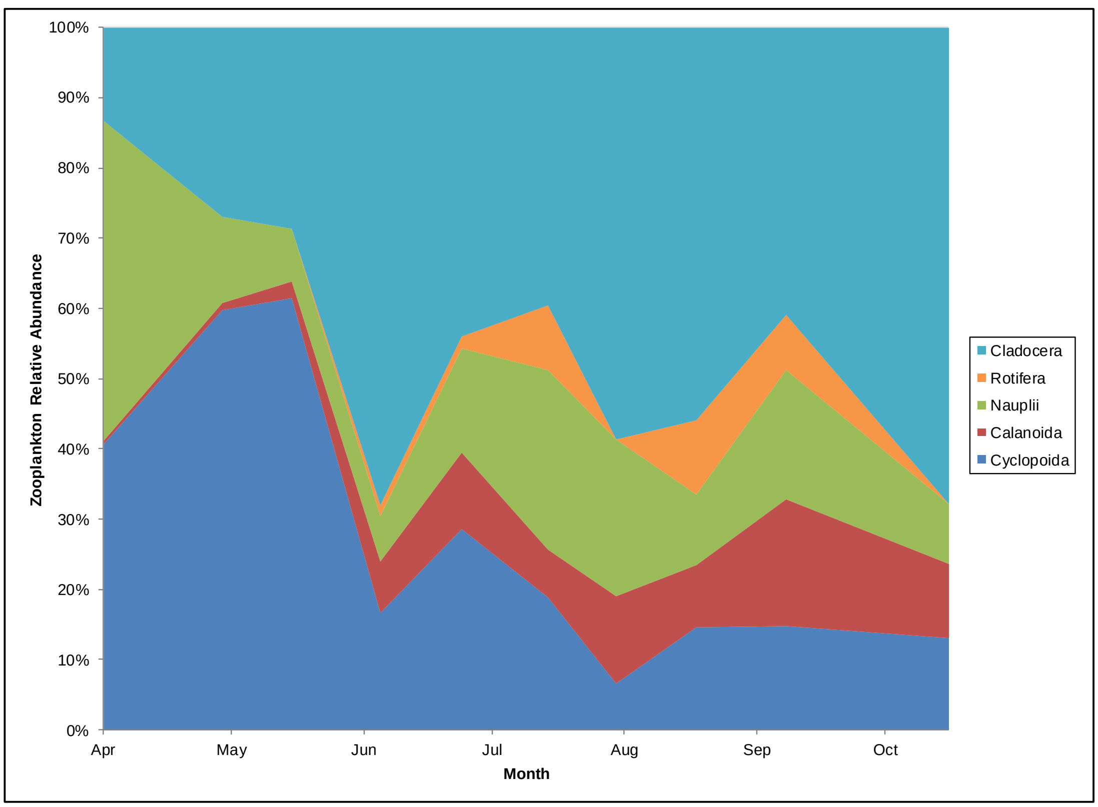

Figure 9-12: Loeb Lake 2016 zooplankton relative abundance.

9.5 AQUATIC VEGETATION

9.5.1 BIOVOLUME ANALYSIS

Figure 9-13 shows the 2016 aquatic plant biovolume survey results of Loeb Lake. Heavy biovolume was consistently observed throughout all three surveys, with the June survey showing the least amount of plant growth. During the July and August surveys, nearly 100% of the littoral zone had heavy biovolume throughout, with a small patch of low macrophyte density on the eastern portion of the lake.

9.5.2 POINT-INTERCEPT SURVEYS

Twelve unique species of aquatic plants were observed in Loeb Lake in 2016. The lake is widely dominated by the native coontail community (Figures 9-14 and 9-15). Leafy pondweed was found at lower occurrence and abundance levels in 2016 than in 2015. Eurasian watermilfoil was present throughout all three surveys, and curly-leaf pondweed was present in the first two surveys, both at low abundance rankings. Filamentous algae was observed at a majority (75%) of locations on the lake where vegetation was present during the early June survey, but was not observed at all in the July survey, and only observed at 27% of the locations by the late August survey.

The presence of both curly-leaf pondweed and Eurasian watermilfoil in Loeb Lake presents potential problems for future management decisions. Curly-leaf pondweed and Eurasian watermilfoil are both non-native invasive species, causing problems by displacing other native plants, and forming thick mats on the surface of a lake that disrupt boating and recreation (DNR, 2005; DNR, 2015d). In addition, when curly-leaf pondweed plants die back in mid-summer, the resulting increase in phosphorus from the decomposing plant material can cause disruptive algal blooms (DNR, 2005). The spreading of Eurasian watermilfoil makes it an especially difficult plant to manage, as a new plant can grow from just a tiny piece of an original plant. This makes it easy to float and grow quickly in other areas of a lake, as well as be transported between lakes on boat trailers and fishing gear (WSDE, 2015). Both Eurasian watermilfoil and curly-leaf pondweed have been observed in Loeb Lake since 2005.

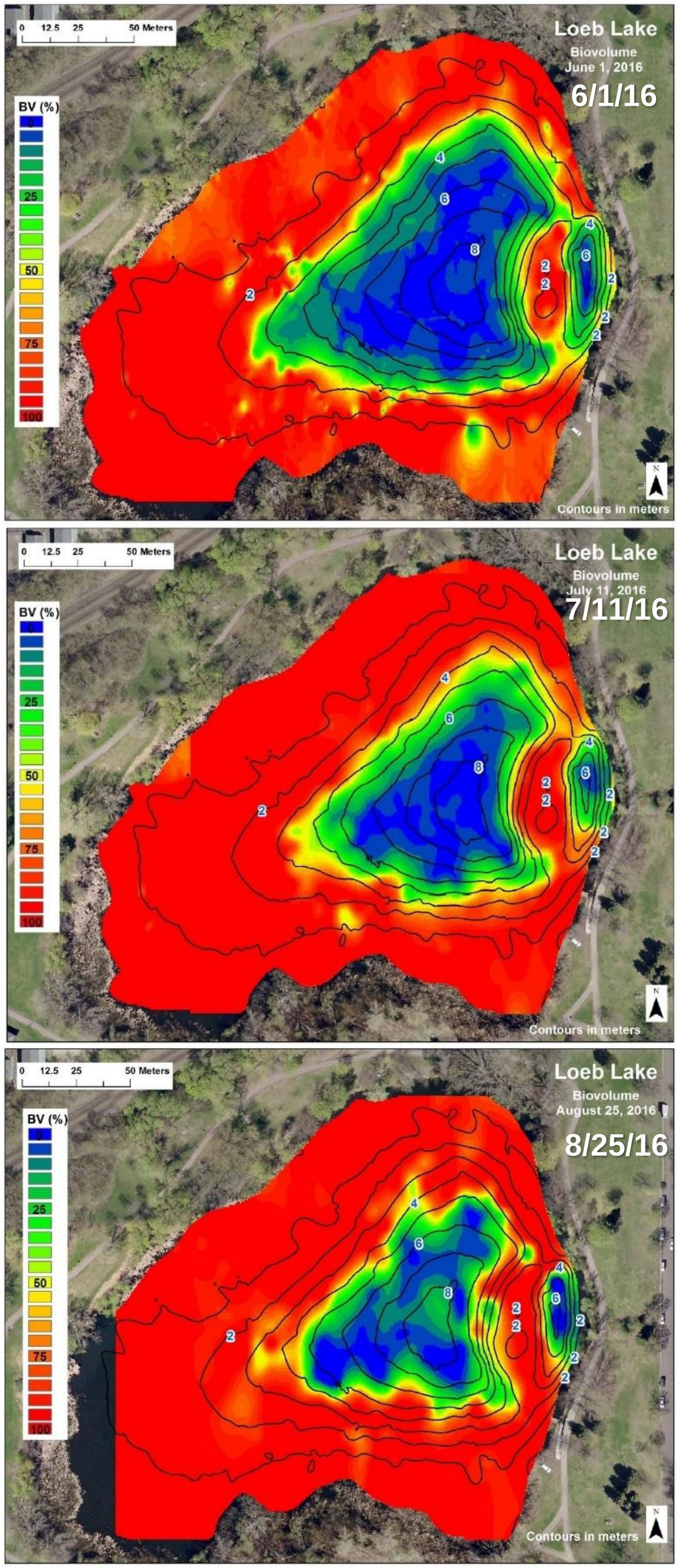

Figure 9-13: Loeb Lake 2016 seasonal vegetation changes (6/1/16, 7/11/16, 8/25/16).

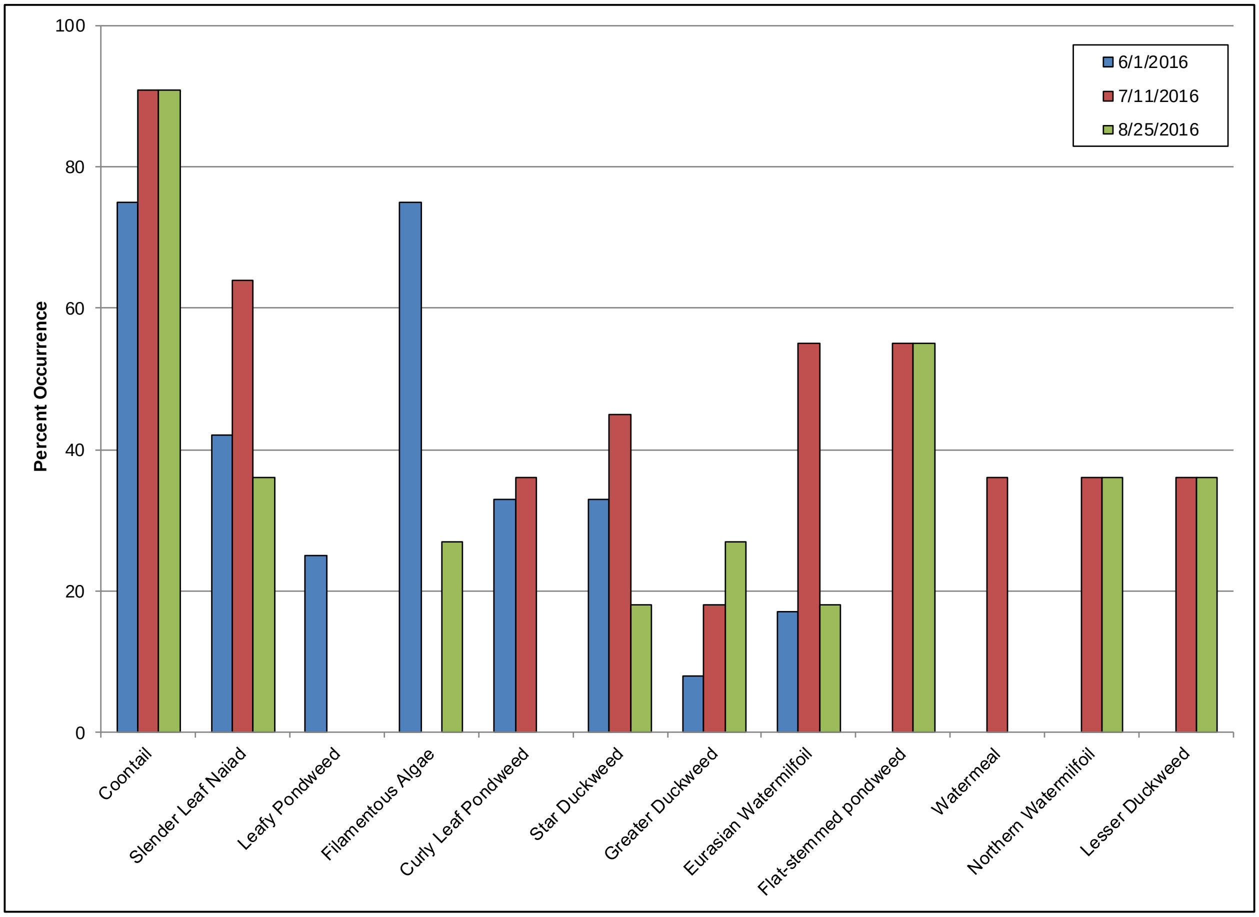

Figure 9-14: Loeb Lake 2016 percent occurrence of vegetation present.

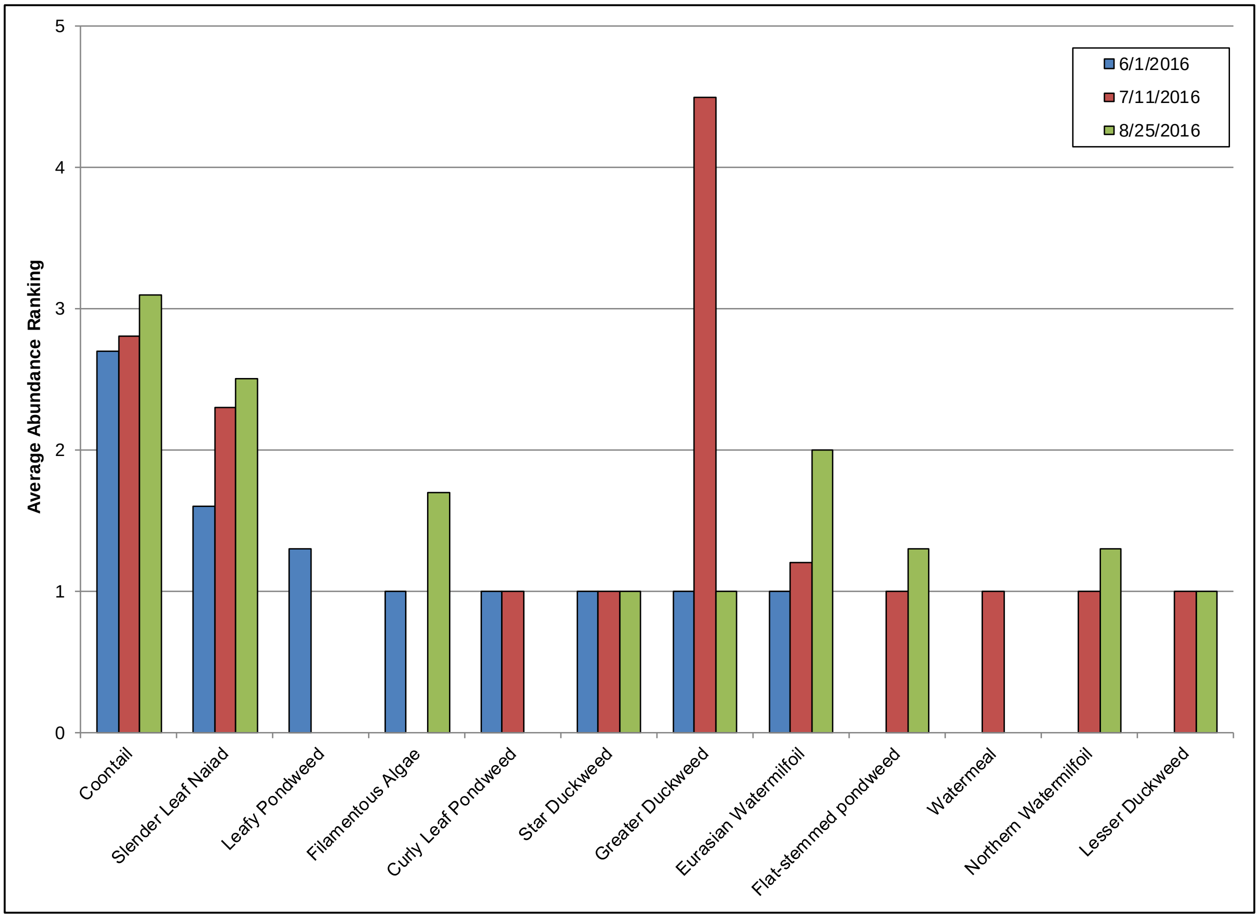

Figure 9-15: Loeb Lake 2016 average abundance ranking of vegetation present.

9.6 FISH STOCKING AND SURVEYS

Loeb Lake is part of the Minnesota DNR's "Fishing in the Neighborhood" program which provides angling opportunities for children and families in urban environments, encourages environmental stewardship, and improves knowledge of natural resources (DNR, 2015g). Therefore, these lakes are stocked with fish that are better for general angling activities. Loeb Lake was stocked with adult walleye in 2016 (Table 9-4).

The 2016 fish survey resulted in 23 fish caught (Table 9-5). The previous survey at Loeb in 2014 indicated 51 individuals observed. Similar to 2014, bluegill was the most observed species in the 2016 survey. Distribution among the remaining species was low, especially considering the large number of walleye that have been stocked in the lake in recent year. Ninety-one percent of fish caught were categorized as panfish. In general, the fish populations on the lake are historically stable and are affected mainly by stocking and angling activity.

Table 9-4: Loeb Lake historical record of fish stocking.

Year	Black crappie	Bluegill		Channel catfish		Largemouth bass		Walleye			
	Adult	Adult	Yearling	Adult	Yearling	Adult	Yearling	Adult	Yearling	Fingerling	Fry
2016								290			
2015		176							960		
2014		289								380	
2013		185								610	
2012		152									
2011	26	144			689					709	
2010		74		50	1211						
2009	207	106		47	622						
2008	244	380		55	1290						
2007	69	1018		38	1040	138	630				13,000
2006		524								34	10,000
2005	9	242	627							19	10,000
2004		444							3	149	10,000

Table 9-5: Loeb Lake 2016 fish populations.

Species	Number of fish caught in each category (inches)								Total
	0-5	6-8	9-11	12-14	15-19	20-24	25-29	30+	
Black bullhead			1						1
Black crappie	3	1							4
Bluegill	14	1							15
Hybrid sunfish	1								1
Pumpkinseed sunfish	1								1
Walleye			1						1

9.7 OVERALL LAKE EVALUATION

Loeb Lake exhibits the best water quality of any District lake. Historically, Loeb Lake has received an ‘A’ lake grade, indicating high water quality and user quality. In 2016, the lake received an ‘A’ lake grade, which is in line with the historical average grade. All historical years of monitoring have met the MPCA state standards for TP, Chl-a, and Secchi disk depth. Hypolimnetic TP was highest in 2005, but has remained relatively low since 2008.

Loeb Lake had a variety of aquatic vegetation in 2016, but most species monitored (aside from coontail and greater duckweed in the July survey) only showed low to moderate abundance throughout the lake and throughout the year. The fish populations on the lake are historically stable and are affected mainly by stocking and angling activity. In 2016, 91% of fish caught were categorized as panfish.

10 LAKE MCCARRONS RESULTS

10.1 LAKE MCCARRONS BACKGROUND

Lake McCarrons is a 74.7 acre, deep lake located in the City of Roseville (Figure 10-1). With a maximum depth of 57 ft and a 36% lake littoral area, it supports a variety of activities including swimming, boating, and fishing (Table 10-1; Figure 10-2). Lake McCarrons County Park, located on the east shore of the lake, supports visitors to the lake with a beach building, picnic shelter, and boat access with car/trailer parking.

Figure 10-1: View of the public beach on the southeast shoreline of Lake McCarrons.

Table 10-1: Lake McCarrons morphometric data.

Surface Area (acres)	Maximum Depth (ft)	Littoral Area	Volume (acre-ft)	Watershed Area (acres)	Watershed: Lake Area (ratio)
74.7	57.0	34%	1,892	1,070	14.3

Figure 10-2: Lake McCarrons bathymetric map.

The 1,070 acre watershed of Lake McCarrons consists of residential properties, commercial and public areas, highway, wetland/grassland/woodland areas, and a park bordering it on the east side (Figure 10-3). The primary source of water inflowing to Lake McCarrons is stormwater from surrounding subwatersheds. The outlet of the Villa Park Wetland Treatment System located on the western edge of the lake is the primary inlet to Lake McCarrons. A secondary inlet enters on the north side of the lake via William Street Pond. The main outlet on the east end of the lake is the headwaters of the Trout Brook-West Branch Subwatershed, where water enters the Trout Brook Storm Sewer Interceptor (CRWD, 2003).

One of the primary water quality concerns in Lake McCarrons is phosphorus. Currently, Lake McCarrons is considered unimpaired and is not listed on the MPCA 303(d) list of impaired waters. The Lake McCarrons Management Plan (CRWD, 2003) was developed in 2003 and set a TP goal of 33 µg/L to minimize summer algal blooms (CRWD, 2003). While this management goal is less than the deep lake state standard (40 µg/L), it is still attainable and presents the best achievable goal to continue to improve lake water quality.

In order to achieve the phosphorus goals outlined in the Lake McCarrons Management Plan, several projects have been implemented to improve lake water quality. Most notably, CRWD completed an alum treatment on Lake McCarrons in October 2004 in order to reduce the amount of total phosphorus in the lake. In this type of treatment, aluminum sulfate is applied below the lake surface and binds to free phosphorus particles causing them to drop out of the water column and settle on the bottom of the lake (Kennedy and Cook, 1982). This removes phosphorus from the water column, as well as prevents additional phosphorus release from the bottom sediments (CRWD, 2003). Water quality in Lake McCarrons after the alum treatment showed improvements when compared to pre-alum treatment water quality (Figure 10-8, Table 10-3).

In addition, the Villa Park subwatershed has been a high-priority focus area for management efforts in the Lake McCarrons subwatershed because it has the largest drainage area to the lake (753 acres, or 70% of the watershed area of the lake) (CRWD, 2010). At the outlet of the Villa Park subwatershed, the Villa Park Wetland Treatment System was constructed in 1987 to receive and treat runoff at the subwatershed outlet before flowing into Lake McCarrons. The wetland system consists of a series of wetland cells that channel stormwater to decrease flow velocity and allow sediments and bound nutrients to settle before entering the lake. This system reduced the amount of TP and dissolved phosphorus entering the lake (CRWD, 2003). In 2004, improvements (i.e. timber weirs) were made to the system to enhance nutrient retention. In 2013, CRWD dredged a total of more than 17,000 cubic yards of sediment from the system to improve stormwater treatment and residence time before water flows into Lake McCarrons.

While Lake McCarrons currently exhibits good water quality overall and is still considered unimpaired, the lake is dynamic and should be evaluated annually to monitor changes in integrity and effectiveness of the aforementioned improvements. For example, Lake McCarrons exhibited higher than normal early-May TP and Chl-a values in 2014, as well as in April of 2015, which prompted an evaluation of potential drivers of these high observed values. Subsequently, it was recommended in the *2014 Lakes Monitoring Report* and *2015 Lakes Monitoring Report* to complete an internal loading assessment of the lake. In February 2016 and February 2017, CRWD completed sediment coring in order to better understand alum efficacy in the lake from the 2004 alum treatment. Results and conclusions from the sediment coring are still in progress.

Another ongoing management issue is the presence of invasive species in the lake including carp, Eurasian watermilfoil, and curly-leaf pondweed, all of which have been observed in recent years. Excessive aquatic vegetation growth on the west end of the lake has become a management concern, and CRWD coordinated plant removal on this area of the lake twice in 2014 and again in June and August of 2015. There was no plant removal completed in 2016, and future plant removal will be evaluated as needed.

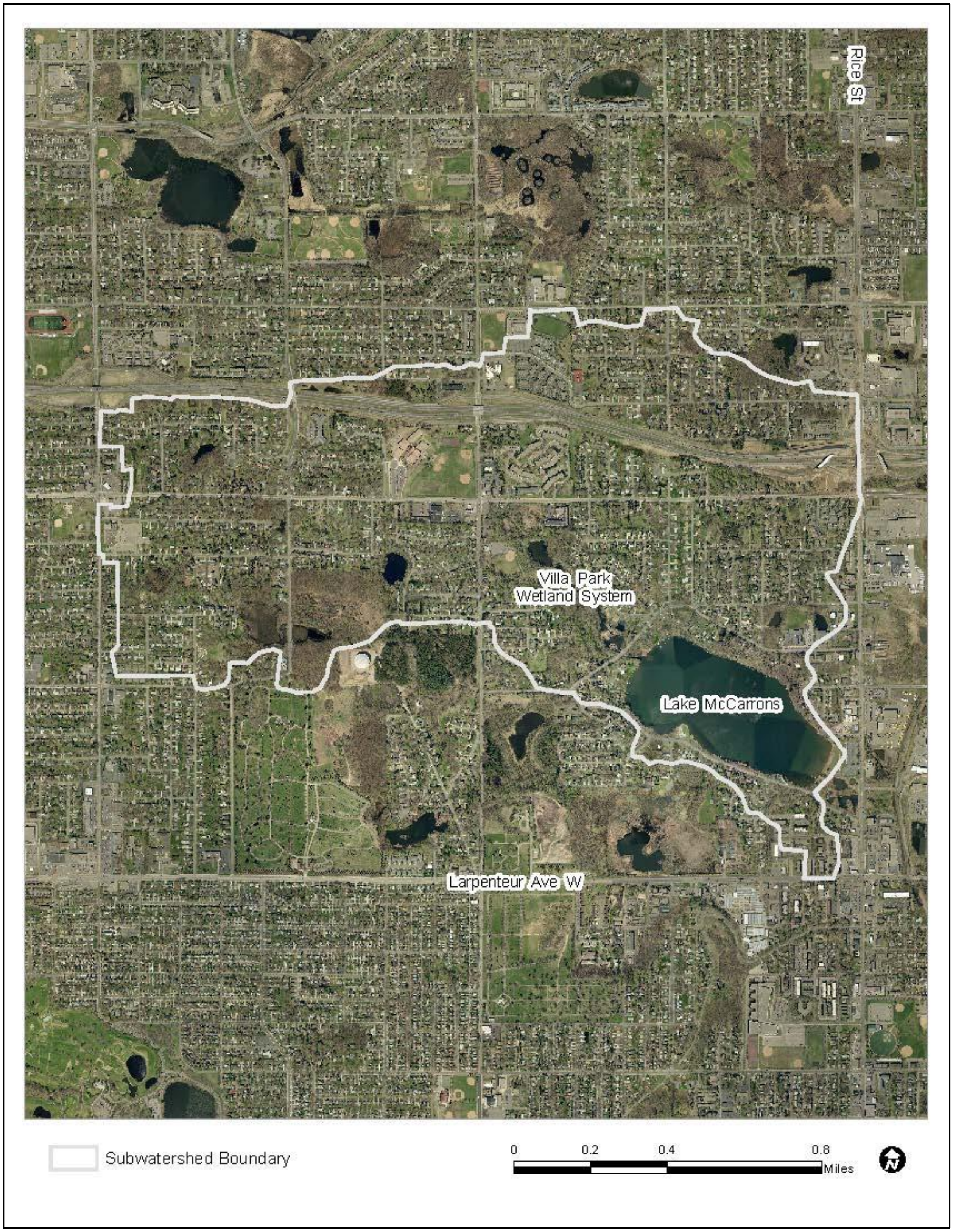

Figure 10-3: Lake McCarrons and subwatershed boundary.

10.2 LAKE LEVEL

Lake McCarrons level has been consistently below the OHWL of 842.2 ft throughout the historical lake level record (Figure 10-4). The water level came close to the OHWL in 1984 and 1997. A significantly low water level period occurred from 1932-1939. The water level has consistently stayed within 840-842 ft for the past 35 years.

The 2016 lake level reported in Figure 10-5 consisted of 10 min level logger data collected from April to November by CRWD. In 2016, lake level steadily increased during open-water season, responding to larger rain events throughout, particularly from early July through early October (Figure 10-5).

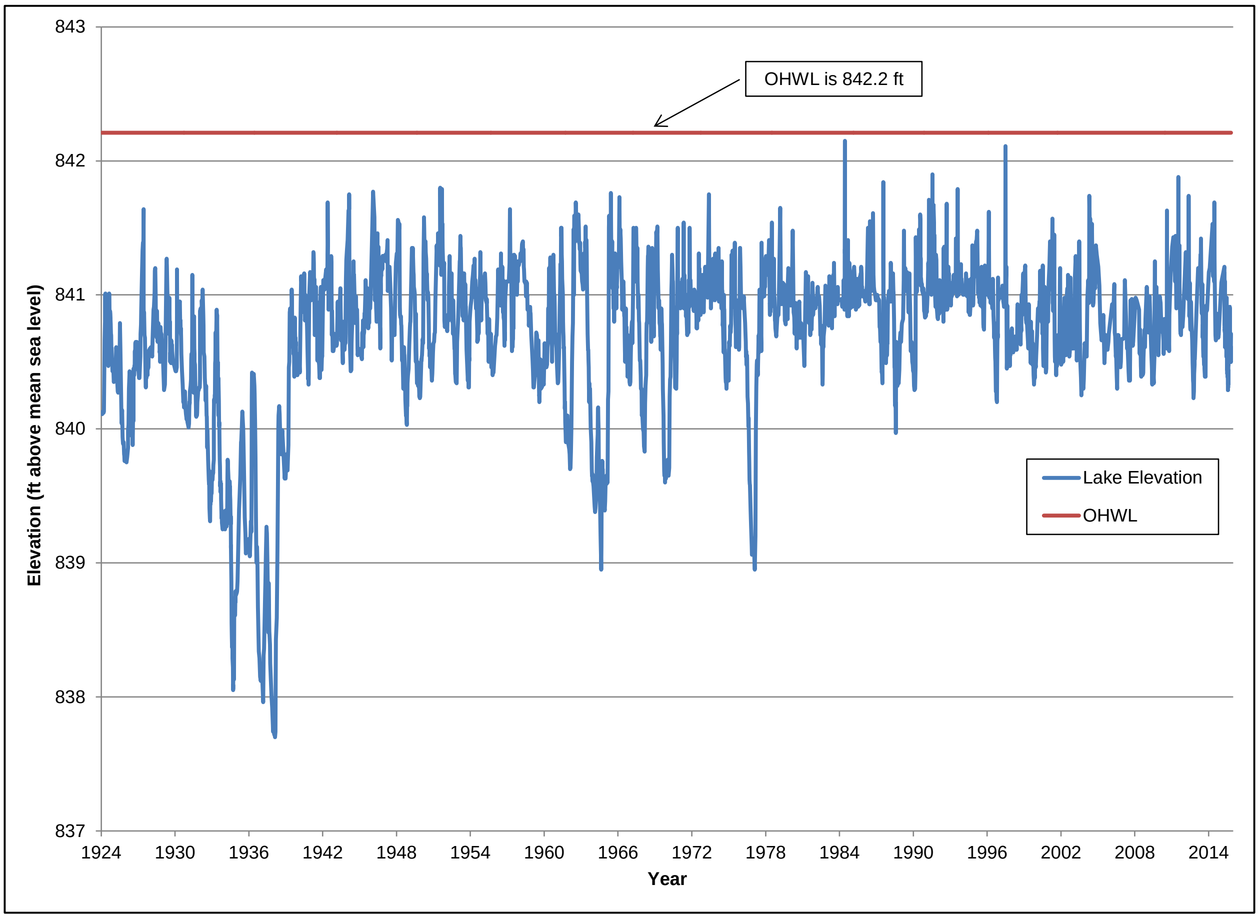

Figure 10-4: Lake McCarrons historical lake elevations and the OHWL (DNR, 2016b).

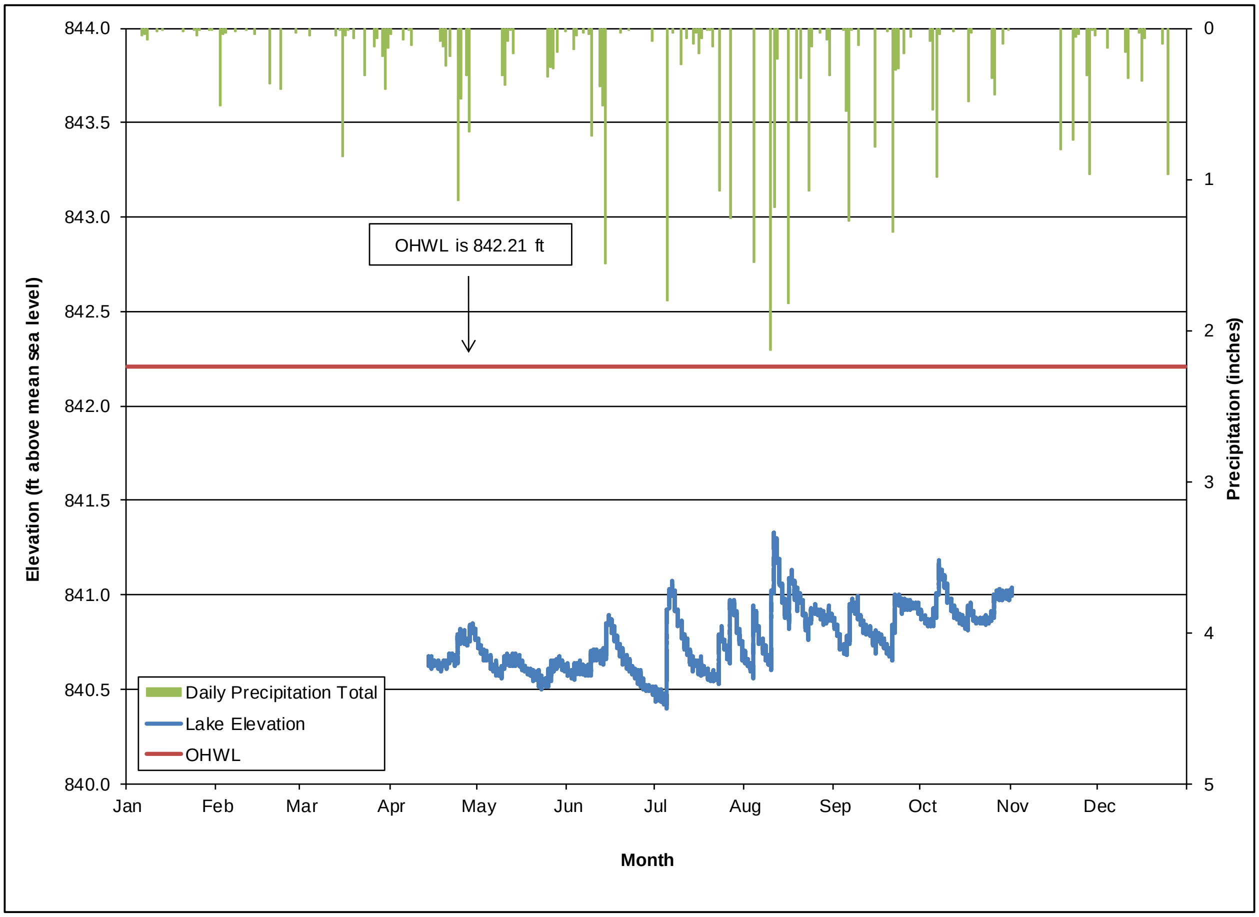

Figure 10-5: Lake McCarrons 2016 lake elevations, OHWL, and daily precipitation events (MCWG, 2016).

10.3 WATER QUALITY RESULTS

Lake McCarrons was sampled ten times in 2016 from April 6 to October 21 (Figure 10-6). Sampling in 2016, similar to the previous two years, showed the highest epilimnetic TP concentration (26 µg/L) during the first sampling event on April 6, which then dropped significantly to 11 µg/L one month later at the May 5 sample date. TP concentrations were lowest during May-July, and increased slightly during the final months of sampling from August-October. It is important to note that even though a high spring TP value was observed, all sampled values in 2016 remained below not only the state deep lake standard (40 µg/L), but also below the standard set in the Lake McCarrons Management Plan (33 µg/L) (CRWD, 2003).

Chl-a concentrations followed the same trend as TP by beginning the season with a high concentration of 19.9 µg/L (a value that does not meet the state deep lake standard for Chl-a). Chl-a values then declined and stayed low through July, then increased into the fall sampling period. Water transparency was highest in May with an average of 7.8 m (Figure 10-6), which occurred a month after the lowest observed value of the year during the April 6 sample date. The two Secchi depths observed during the May sample dates (8.0 m and 7.5 m) were among the highest observed on record for the lake. Water transparency then decreased throughout the rest of the season with a July-October average of 3.0 m. High water transparency is generally associated with low TP and Chl-a concentrations throughout the season. Secchi depth values generally followed the same trend as TP in 2016. Based on other years in the historical record, TP is generally a major driver of water transparency in Lake McCarrons.

Figure 10-7 displays the seasonal variation in Lake McCarrons for TP, Chl-a, and Secchi disk readings throughout the historical record using box-and-whisker plots. Chl-a and Secchi disk readings are not closely correlated with TP, likely due to the 2004 alum treatment which stratified the historical TP data into two categories, thus affecting seasonal generalizations that could be gathered. Chl-a and Secchi depth medians indicate the highest level of water quality is observed in May and the lowest observed in August. TP medians suggest the lowest level of water quality in May, increasing in health as the season progresses.

Figure 10-8 shows yearly average historical TP concentrations, Chl-a concentrations, and Secchi disk depths graphically. Throughout the period of record, high Chl-a concentrations have generally been associated with high TP concentrations (Figure 10-8). Low Secchi depths have generally been associated with high Chl-a and TP concentrations, indicating that they are primary drivers for water clarity in Lake McCarrons. Since the 2004 alum treatment, the lake has experienced a significant improvement in water quality. Table 10-2 illustrates the differences between the average TP/Chl-a/Secchi values for the years 1988-2004 and 2005-2016, and the percent change from the former to latter.

Table 10-2: Differences between the 1988-2004 average, 2005-2016 average, and the percent change for TP/Chl-a/Secchi in Lake McCarrons.

Parameter	1988-2004 Average	2005-2016 Average	Percent Change
TP (µg/L)	42.9	18.3	-57%
Chl-a (µg/L)	12.9	4.3	-67%
Secci (m)	2.4	3.7	57%

Overall, the alum treatment is still effective in maintaining water quality in the lake in 2016. However, 2014 was the first year following the alum treatment that a decline in water quality was observed as evidenced by higher TP and Chl-a concentrations as well as shallower Secchi disk readings than other years since the alum treatment. 2015 and 2016 exhibited this same trend, albeit to a lesser extent than in 2014. The efficacy of an alum treatment can vary between 8-20 years, and CRWD will continue to monitor the water quality variables that could signify a decline in the treatment on Lake McCarrons into the future.

Figure 10-9 displays the annual average hypolimnetic and epilimnetic TP in Lake McCarrons thought the period of record. In addition to the epilimnion, the hypolimnion experienced a drastic drop in TP after the 2004 alum treatment. In eutrophic lakes, the hypolimnion is generally richer in phosphorus than the epilimnion, as bed sediments readily release phosphorus into the anoxic bottom layer, peaking in fall just prior to lake turnover (Kalff, 2002). Since 2004, the annual hypolimnetic TP concentrations have gradually increased, but still remain below pre-treatment concentrations. Also, the annual epilimnetic average has gradually increased since 2004, but is still meeting the deep lake standard for phosphorus (40 µg/L) as well as the goal set in the Lake McCarrons Management Plan (33 µg/L) (CRWD, 2003). This increasing trend in recent years in hypolimnetic TP, alongside epilimnetic TP, is a concern for lake management and will require further investigation, as discussed in the prior sections.

Table 10-3 shows yearly average historical concentrations for TP, Chl-a, Secchi depths, and their comparisons to MPCA lake standards. Lake McCarrons has exceeded the state standards for TP for one-third of the years monitored and for roughly one-quarter of the years monitored for Chl-a, all prior to the alum treatment in 2004. It only exceeded the deep lake standard for Secchi disk depth during the first year of monitoring in 1988. With the exception of 2014 when the lake received a 'B' due to the high May samples for TP and Chl-a, the lake has received an 'A' lake grade since the 2004 alum treatment (Table 10-4). All eutrophication parameters in 2016 showed improvement over 2015 values.

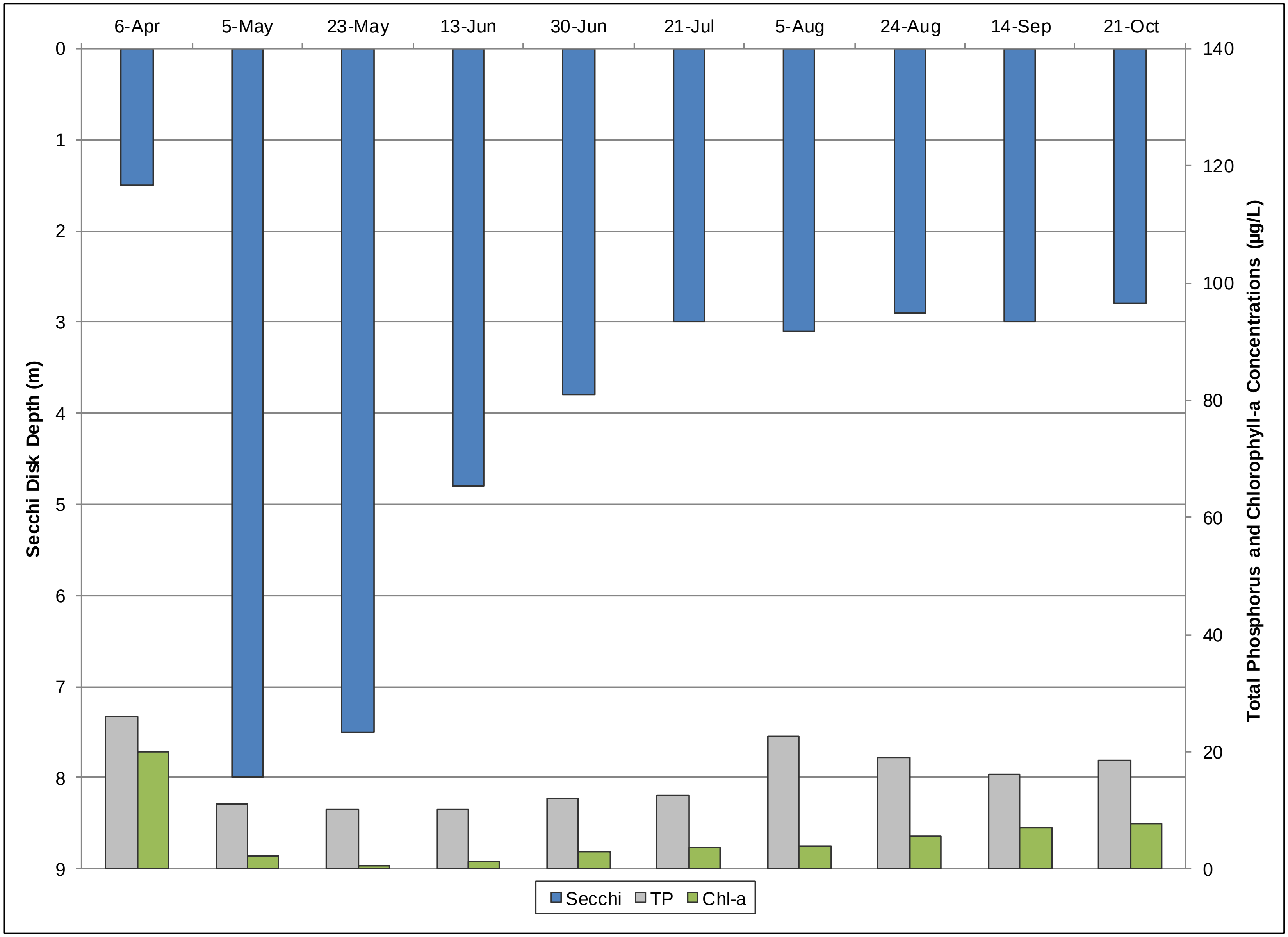

Figure 10-6: Lake McCarrons 2016 Secchi/TP/Chl-a comparison.

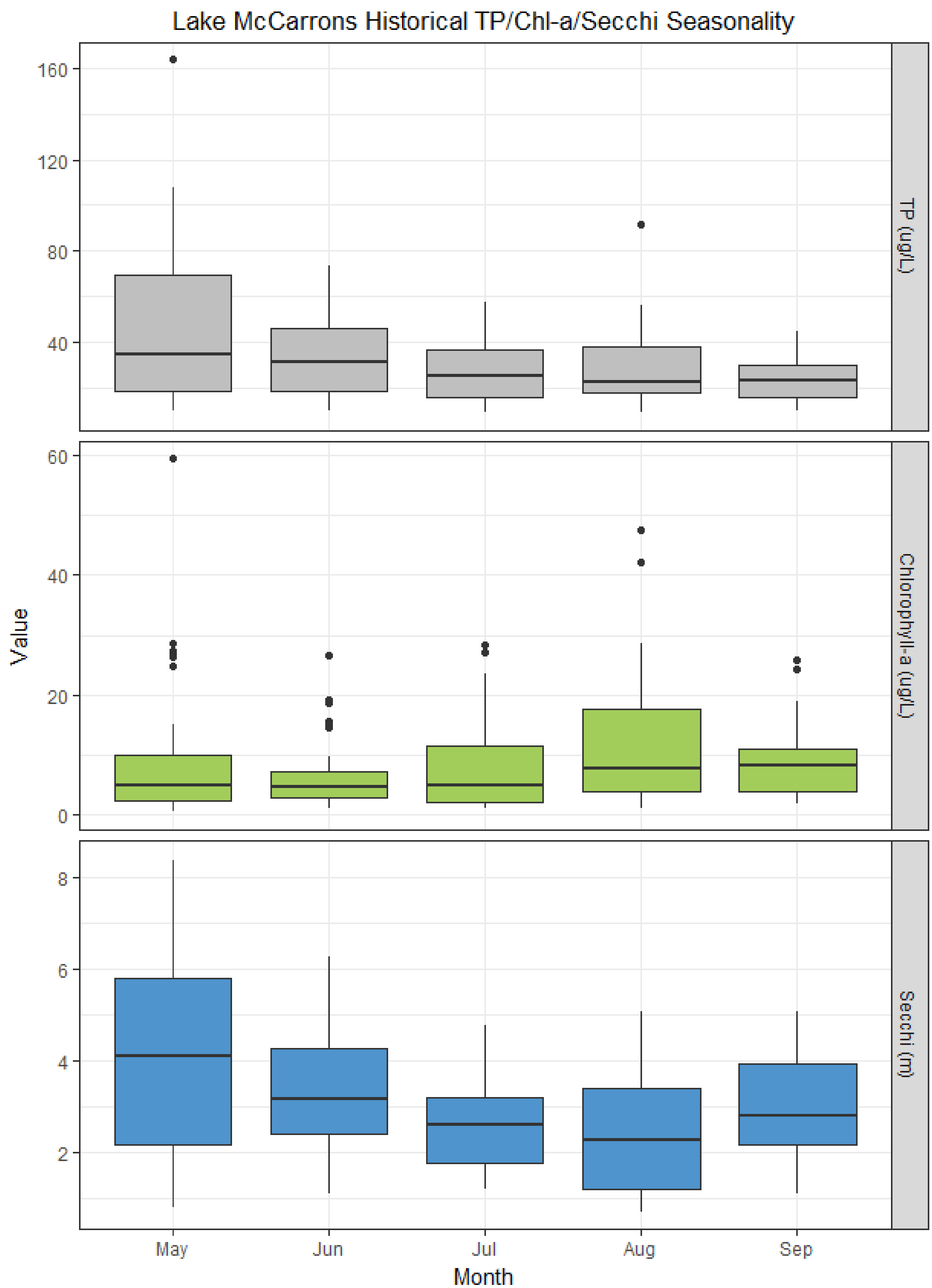

Figure 10-7: Lake McCarrons seasonality boxplots of historical Secchi/TP/Chl-a samples.

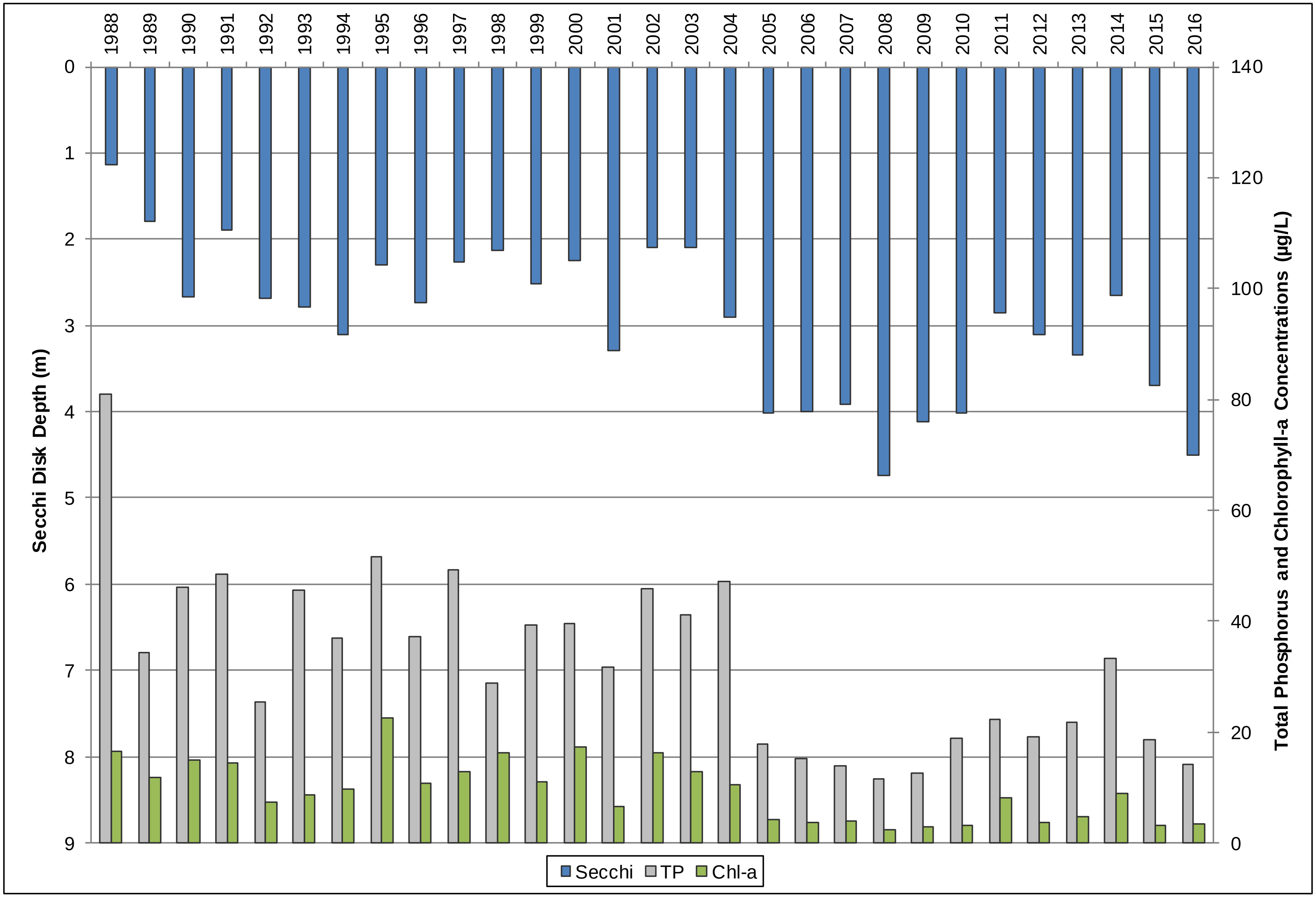

Figure 10-8: Lake McCarrons historical annual average Secchi/TP/Chl-a comparison.

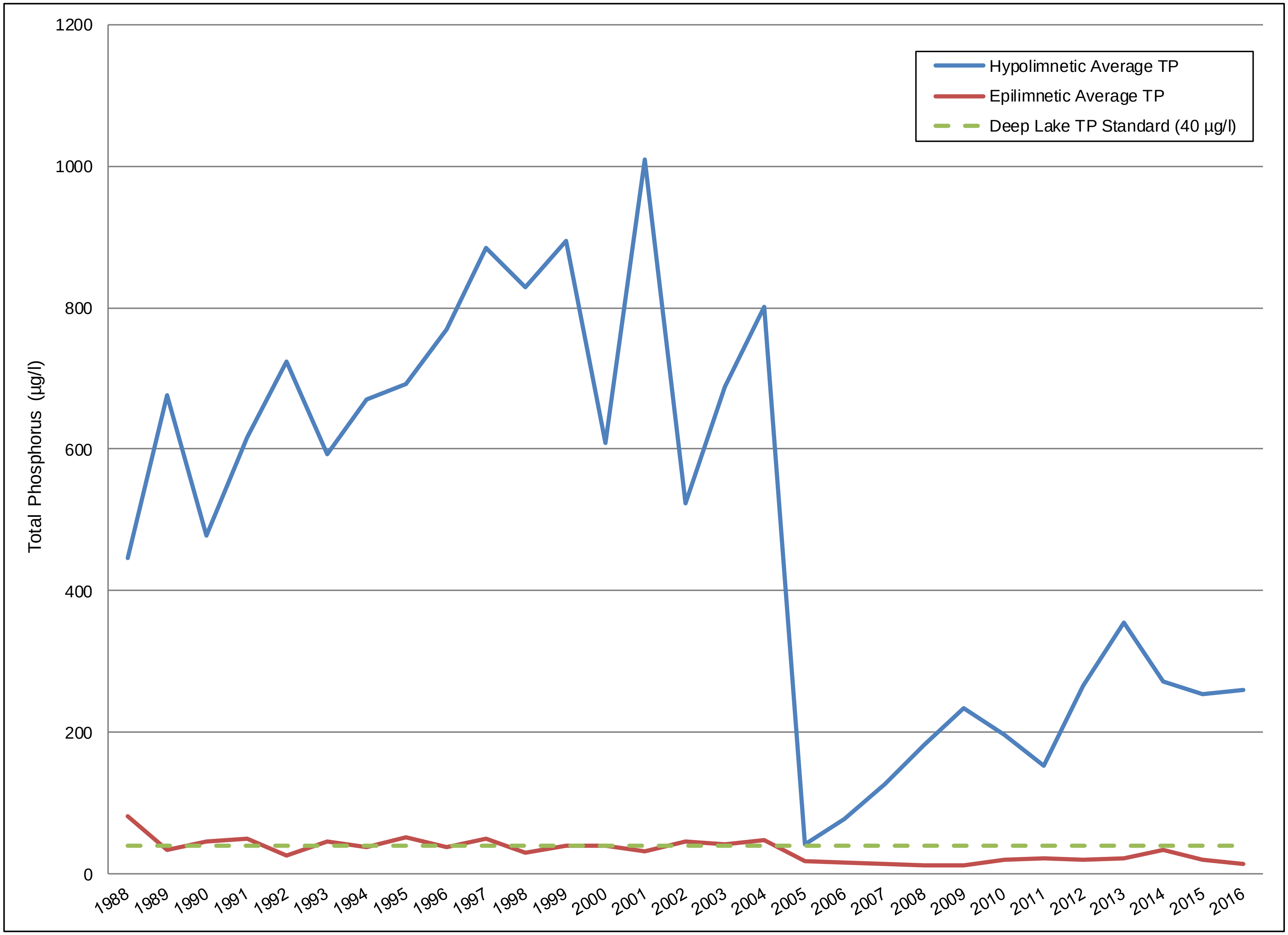

Figure 10-9: Lake McCarrons historical annual average hypolimnetic and epilimnetic total phosphorus.

Table 10-3: Lake McCarrons historical yearly TP/Chl-a/Secchi depth averages compared to deep lake state standards.

Year	TP (µg/L)	Chl-a (µg/L)	Secchi (m)
1988	81	16.4	1.1
1989	34	11.7	1.8
1990	46	14.8	2.7
1991	48	14.5	1.9
1992	25	7.2	2.7
1993	46	8.7	2.8
1994	37	9.7	3.1
1995	52	22.6	2.3
1996	37	10.6	2.7
1997	49	12.8	2.3
1998	29	16.3	2.1
1999	39	11.0	2.5
2000	40	17.3	2.2
2001	32	6.6	3.3
2002	46	16.3	2.1
2003	41	12.7	2.1
2004	47	10.4	2.9
2005	18	4.1	4.0
2006	15	3.6	4.0
2007	14	3.9	3.9
2008	12	2.3	4.7
2009	12	2.9	4.1
2010	19	3.0	4.0
2011	22	8.1	2.9
2012	19	3.7	3.1
2013	22	4.6	3.3
2014	33	8.9	2.7
2015	19	3.2	3.7
2016	14	3.3	4.5

(shaded)	Value does not meet state standard*
(unshaded)	Value meets state standard

*MPCA deep lake standards must be less than 40 µg/L for TP and 14.0 µg/L for Chl-a, with a Secchi disk depth of greater than 1.4 m.

Table 10-4: Lake McCarrons historical lake grades.

Year	TP Grade	Chl-a Grade	Secchi Grade	Overall Grade
1988	D	B	D	**C**
1989	C	B	C	**C+**
1990	C	B	B	**B**
1991	C	B	C	**C+**
1992	B	A	B	**B+**
1993	C	A	B	**B**
1994	C	A	A	**B+**
1995	C	C	B	**C+**
1996	C	B	B	**B**
1997	C	B	B	**B**
1998	B	B	C	**B**
1999	C	A	B	**B**
2000	C	B	B	**B**
2001	B	A	A	**A**
2002	C	B	C	**C+**
2003	C	B	C	**C+**
2004	C	B	B	**B**
2005	A	A	A	**A**
2006	A	A	A	**A**
2007	A	A	A	**A**
2008	A	A	A	**A**
2009	A	A	A	**A**
2010	A	A	A	**A**
2011	A	A	B	**A**
2012	A	A	A	**A**
2013	A	A	A	**A**
2014	C	A	B	**B**
2015	A	A	A	**A**
2016	A	A	A	**A**

10.4 PHYTOPLANKTON AND ZOOPLANKTON

Lake McCarrons was sampled ten times for phytoplankton and zooplankton in 2016 from April 6 to October 21. Total phytoplankton concentration peaked for the year during the first sampling event on April 6 (Figure 10-10). This early spring bloom of phytoplankton was likely a result of high nutrient availability (as seen by a peak in TP concentration) and increased light availability (Figure 10-10) (Kalff, 2002; UWE, 2004). Total concentration remains low throughout the rest of the year, with a small peak in early August, as well as a small peak during the final sampling date on October 21. Generally, peaks in total phytoplankton concentration are observed at the same time as peaks in TP concentration, which indicates that algal blooms were driven by phosphorus in the system (Figure 10-10). In the spring, phytoplankton population varied among Bacillariophyta, Chlorophyta, Chrysophyta, Cryptophyta, and Cyanophyta (Figure 10-12). The majority of the April 6 spike in population was comprised of Cryptophyta. In June, an increase in Chrysophyta was observed, but the population quickly changed to mainly Cyanophyta for the remained of the year. There was a small population of Pyrrhophyta observed from mid-May through early September.

The 2016 zooplankton population of Lake McCarrons was divided among populations of Cyclopoids, Calanoids, Nauplii, and Cladocerans for the entire monitoring season (Figure 10-13). A small amount of Rotifers was observed at various points during the year, but at insignificant amounts. The overall zooplankton population peaked in early May at a time when Chl-a values neared zero (Figure 10-11). It peaked again in mid-September at a time when the population consisted mainly, and in almost equal proportions, of Cyclopoids, Calanoids, and Nauplii. Total zooplankton concentration did not follow the Chl-a concentration fluctuations observed in 2016 (Figure 10-11). Finally, while a peak in total zooplankton concentration closely follows the early spring peak observed in total phytoplankton concentration, this pattern does not necessarily hold true for the rest of the monitoring season in Lake McCarrons in 2016 (Figures 10-10 and 10-11).

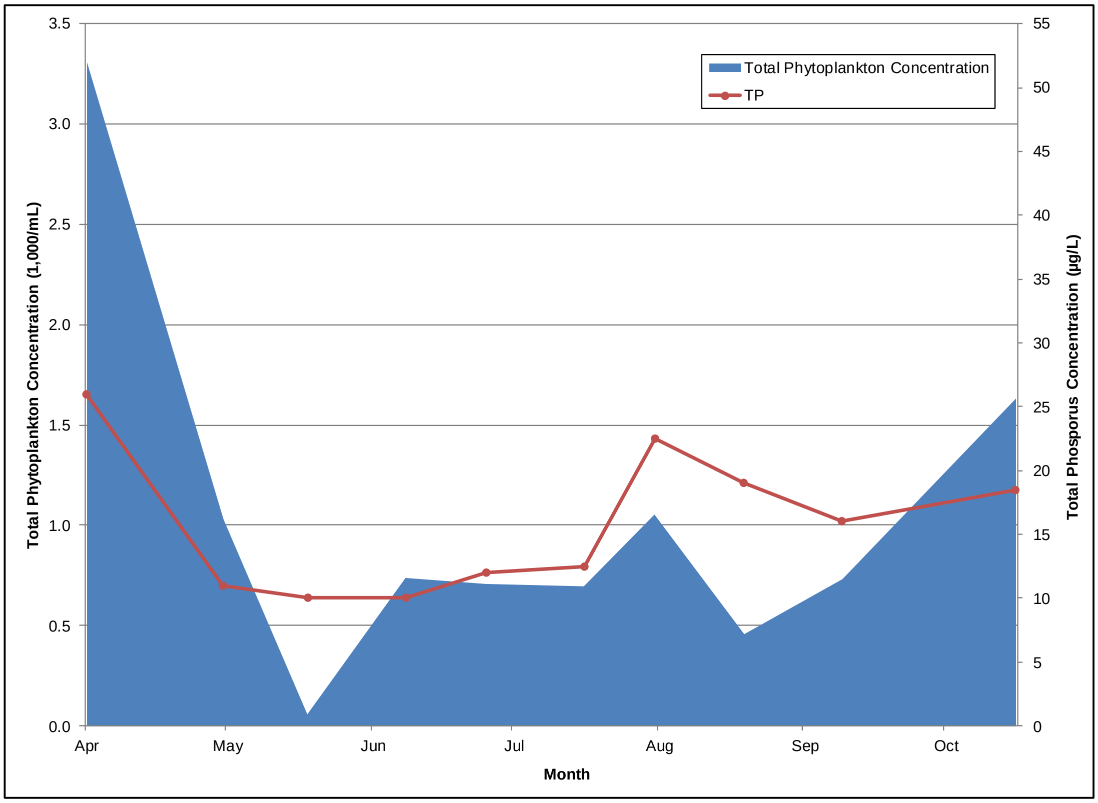

Figure 10-10: Lake McCarrons 2016 total phytoplankton concentration and TP concentration.

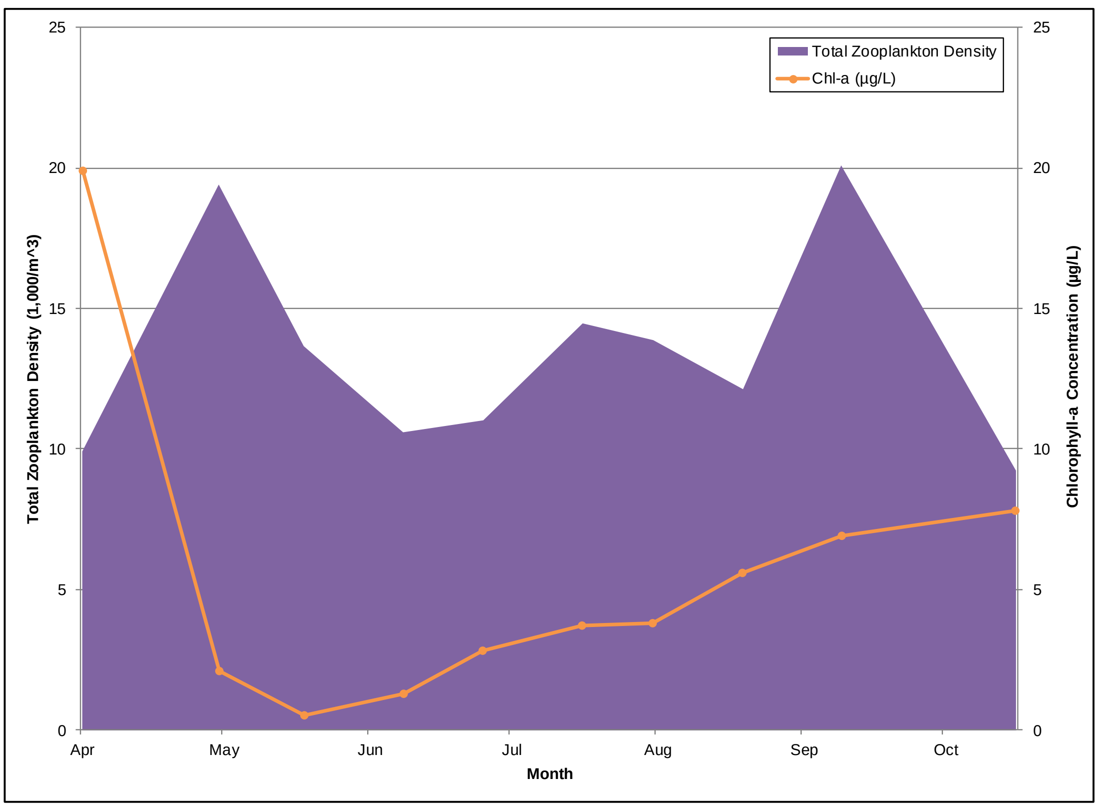

Figure 10-11: Lake McCarrons 2016 total zooplankton density and Chl-a concentration.

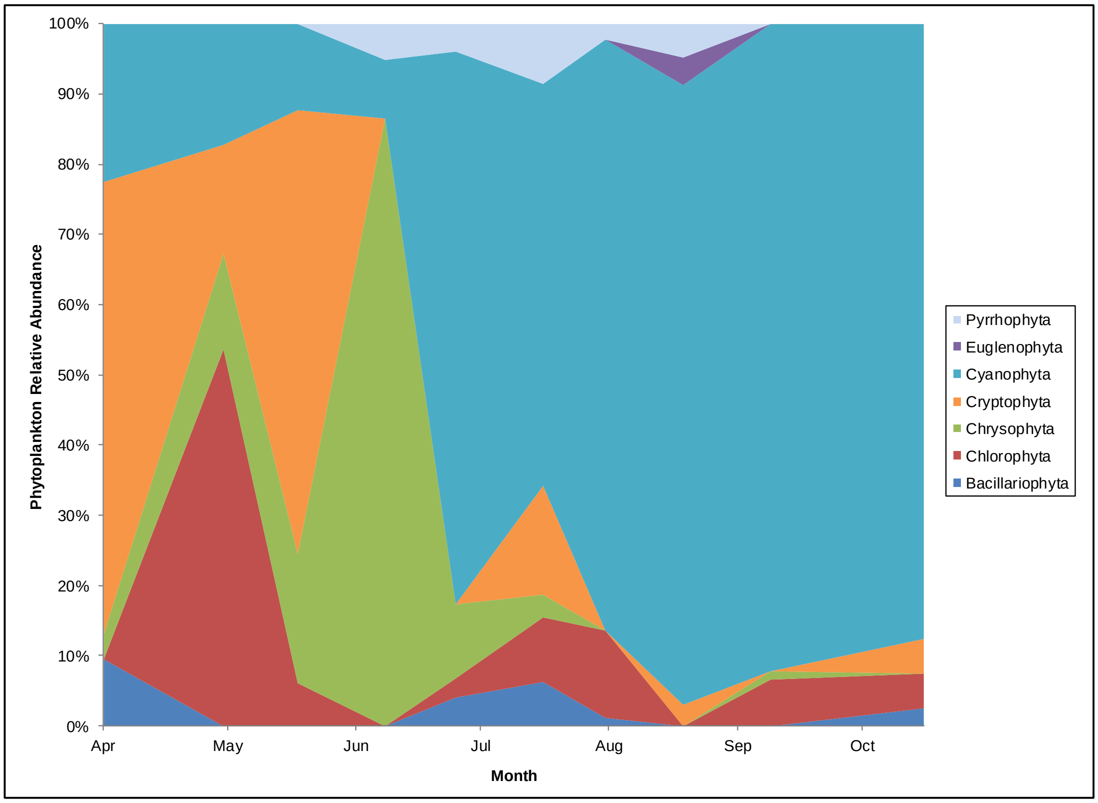

Figure 10-12: Lake McCarrons 2016 phytoplankton relative abundance.

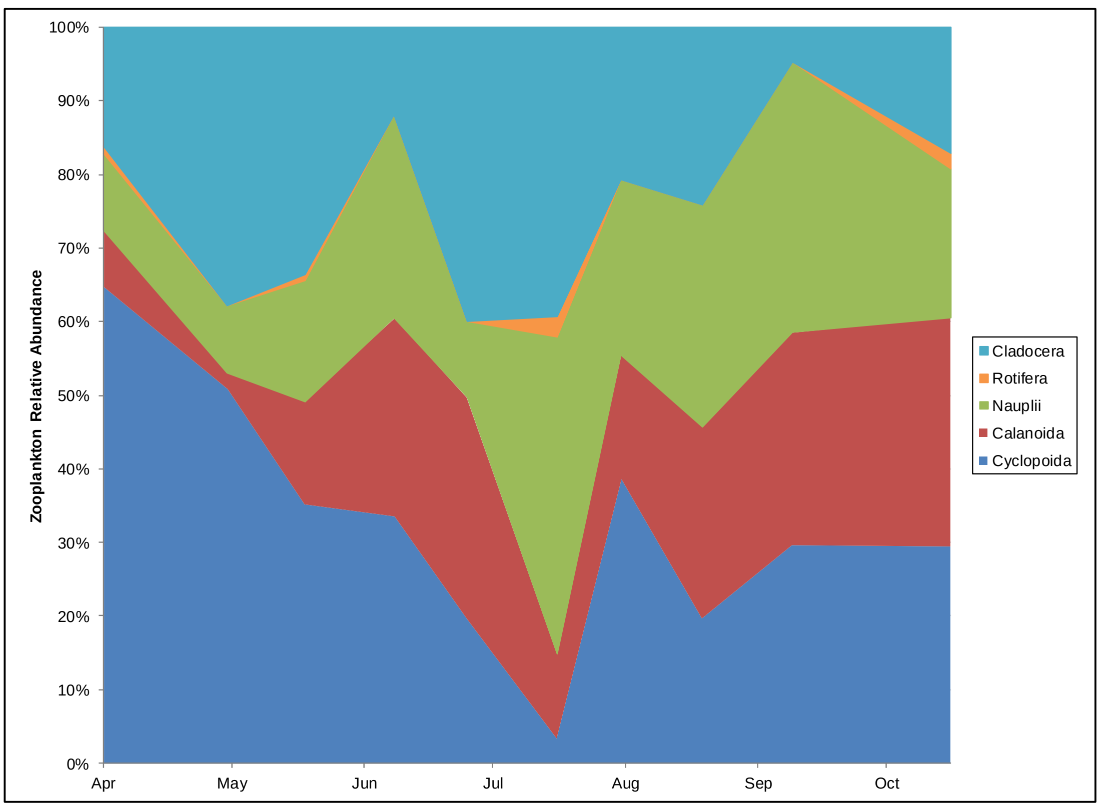

Figure 10-13: Lake McCarrons 2016 zooplankton relative abundance.

10.5 AQUATIC VEGETATION

10.5.1 BIOVOLUME ANALYSIS

The biovolume heat maps of Lake McCarrons show that the majority of the aquatic vegetation in the lake in 2016 occurred in the littoral areas (less than 15 ft) near the shoreline (Figure 10-14). Aquatic plants were most abundant along the eastern and western bays of the lake, where the red color indicates that 100% of the water column contained aquatic vegetation. Overall plant abundance decreased slightly from the June to August survey.

10.5.2 POINT-INTERCEPT SURVEYS

Coontail was the most frequently occurring plant in Lake McCarrons in 2016 with respect to the number of locations in which it was observed, increasing in frequency from previous years' surveys (Figure 10-15). Eurasian water milfoil decreased in presence and abundance in 2016 as compared to the 2015 survey. Seven native plants had an abundance value greater than or equal to 2 for at least one of the three surveys; neither Eurasian water milfoil or curly leaf pondweed were as abundant. (Figure 10-16). However, besides coontail, none of the seven occurred at high occurrences where vegetation was present throughout the lake. The July survey had the greatest number (13) of unique species observed.

While filamentous algae decreased in occurrence throughout the year, it was the most abundant species observed during the August survey. This means that where it was found in the lake, it was found in high abundance. Filamentous algae can become a nuisance species when in high abundance as it forms thick, green mats on the water surface that can impede lake activities. It is also indicative of the presence of excessive nutrients (especially phosphorus) in a lake, which is common in urban lakes like Lake McCarrons (DNR, 2015e).

Eurasian watermilfoil and curly leaf pondweed have been observed in surveys since 2005. Curly leaf pondweed and Eurasian watermilfoil are both non-native invasive species, causing problems by displacing other native plants and forming thick mats on the surface of a lake that disrupt boating and recreation (DNR, 2005; DNR, 2015d). Curly leaf pondweed begins its lifecycle earlier than other plants underneath the ice and subsequently dies back earlier than others in mid-summer. This results in an increase in phosphorus from the decomposing plant material which can contribute to disruptive algal blooms (DNR, 2005). Eurasian watermilfoil spreads easily, as a small fragment of the stem or rhizome can propagate a new plant. It can easily float and grow quickly in other areas of a lake, as well as be transported between lakes on boat trailers and fishing gear (WSDE, 2015).

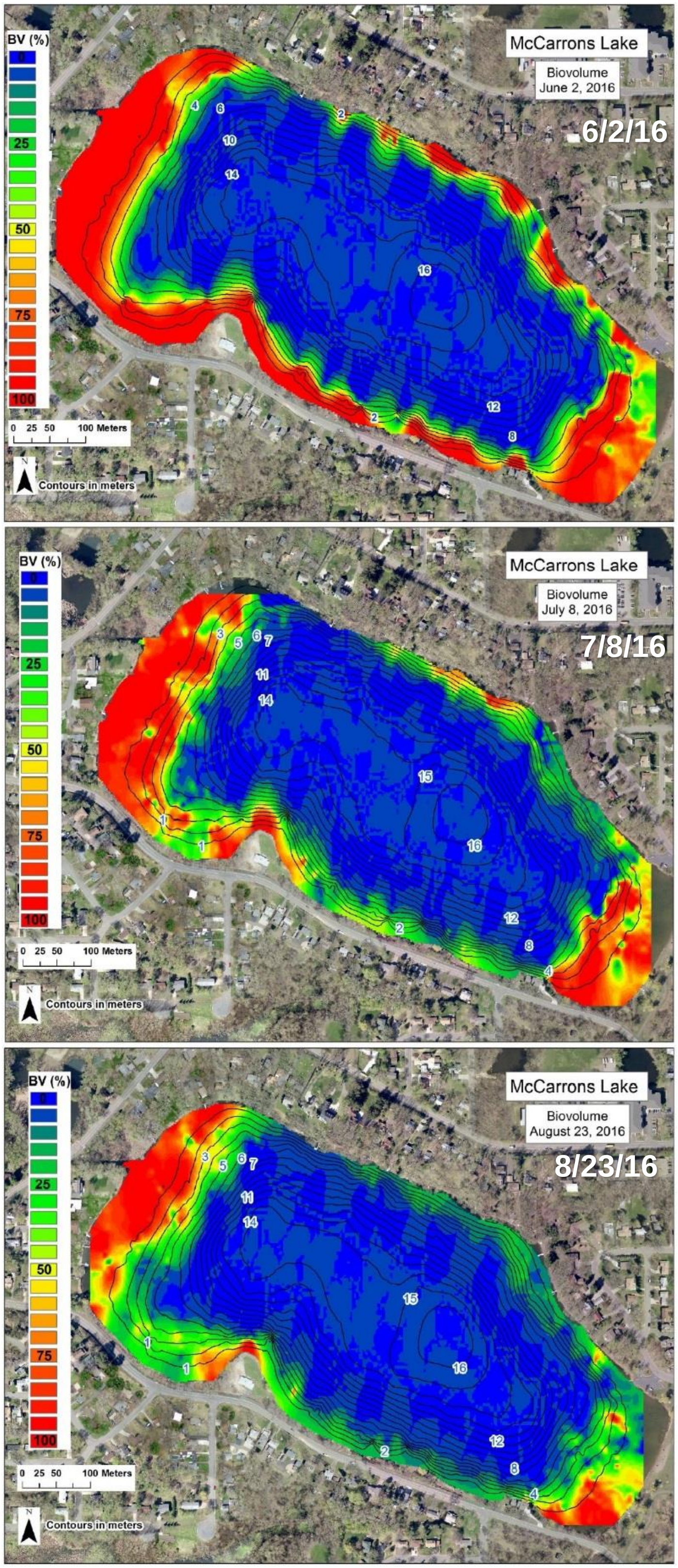

Figure 10-14: Lake McCarrons 2016 seasonal vegetation changes (6/2/16, 7/8/16, 8/23/16).

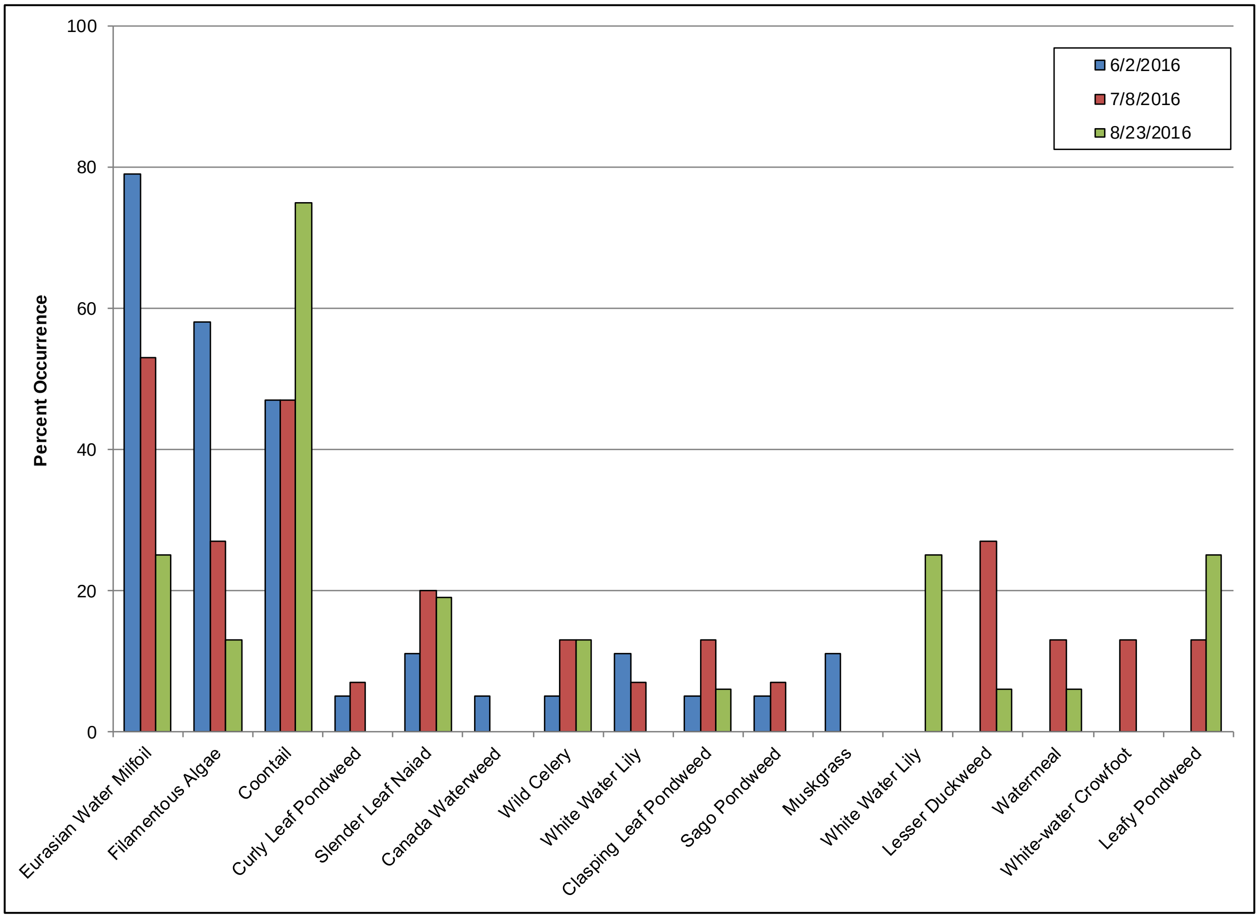

Figure 10-15: Lake McCarrons 2016 percent occurrence of vegetation present.

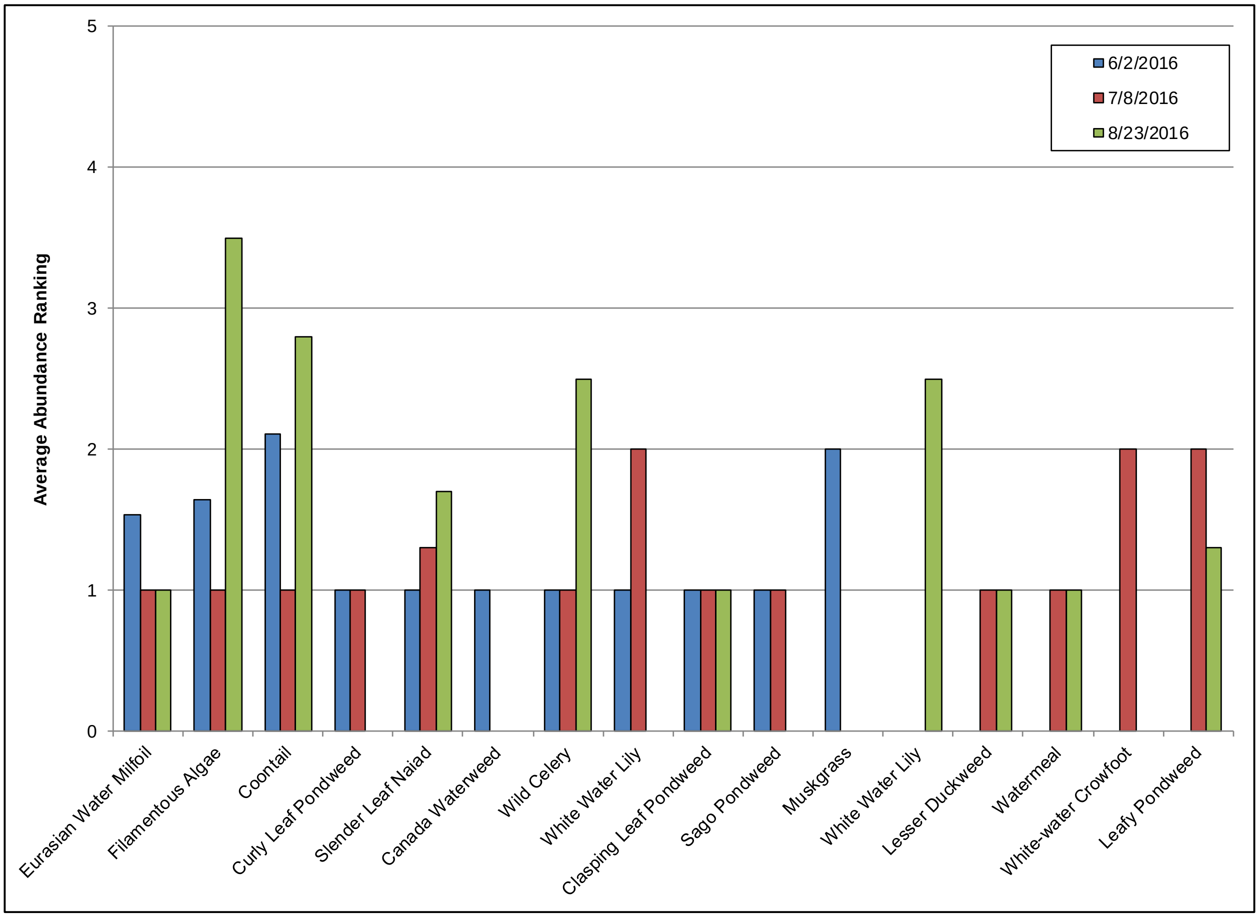

Figure 10-16: Lake McCarrons 2016 average abundance ranking of vegetation present.

10.6 FISH STOCKING AND SURVEYS

Previous stocking in Lake McCarrons has included black crappie, northern pike, and walleye, which occurred intermittently from 2004 – 2009 (Table 10-5). No fish have been stocked in the lake since 2009.

The 2016 fish survey on Lake McCarrons resulted in 212 fish caught (as opposed to 431 in 2015 and 334 in 2014) (Table 10-6). Eleven individual species were observed, 71% of which were panfish. There were 55 northern pike caught in the 2016 survey, all of which measured greater than 15 inches, indicating the potential for a high level of predatory behavior in this population. Because of low stocking activity, fish populations on the lake are dependent upon the interactions of the various fish species observed during the year, as well as potential winterkills of panfish populations during harsh winters. For example, Lake McCarrons typically exhibits a large bluegill population (bluegills were 90% of the 2008 survey, and 77% of the 2014 survey). In 2016, however, bluegills consisted of only 30% of the population of fish present in the lake, and the 2016 survey indicated that the northern pike population was much larger than in past year’s surveys.

Table 10-5: Lake McCarrons historical record of fish stocking.

Year	Black crappie	Northern pike		Walleye
	Adult	Adult	Yearling	Fry
2009		80		
2007	630			
2005			124	
2004				75,000

Table 10-6: Lake McCarrons 2016 fish populations.

Species	Number of fish caught in each category (inches)								Total
	0-5	6-8	9-11	12-14	15-19	20-24	25-29	30+	
Black crappie	8	60	3						71
Bluegill	9	54							63
Channel catfish					1				1
Green sunfish	2								2
Hybrid sunfish	2								2
Largemouth bass	1								1
Northern pike					15	27	12	1	55
Pumpkinseed sunfish	10	2							12
Smallmouth bass				1	1	1			3
Yellow bullhead					1				1
Yellow perch		1							1

10.7 OVERALL LAKE EVALUATION

Lake McCarrons has had significant water quality improvements since the 2004 alum treatment, which aimed to reduce TP in the lake. While 2014 exhibited decreased TP, Chl-a, and Secchi quality, 2015 and 2016 values were closer in line with previous years. This is reflected in the 'A' lake grade that the lake received in 2015, similar to the 'A' grades the lake was given in the years since the alum treatment (from 2005-2013). Hypolimnetic TP values also decreased in 2015 and 2016 from 2014 levels. The observation of higher TP values in early spring monitoring in recent years, however, still highlights the need to understand what is contributing to TP increases, how TP increases affects the lake's overall water quality, and the efficacy of the alum treatment.

Lake McCarrons supports a variety of vegetation at different points in the growing season, but the primary vegetation species in the lake throughout the year are Eurasian watermilfoil and coontail. The number of fish surveyed in 2016 was lower than in 2014, and also consisted of fewer bluegill (a panfish species) and more northern pike (a predator species) than in 2014.

11 CONCLUSIONS & RECOMMENDATIONS

11.1 CONCLUSIONS

In 2016, the water quality of the five District lakes (Como, Crosby, Little Crosby, Loeb, and McCarrons) varied by water body and by time of year. In comparing 2016 water quality results to 2015 results, all lakes improved by varying degrees. This was similar to 2015, when all lakes, with the exception of Como Lake, improved in water quality from 2014.

Based on the MPCA eutrophication numeric water quality standards, Little Crosby Lake, Loeb Lake and Lake McCarrons met the MPCA standards for all parameters (TP, Chl-a, Secchi) during the 2016 growing season. Crosby Lake met the MPCA shallow lake standards for Chl-a concentration and Secchi disk depth, but failed for TP concentration in 2016. Como Lake did not meet the MPCA shallow lake standards for any of the eutrophication parameters during the 2016 growing season.

Total phosphorus was an important driver for water quality in all five District lakes in 2016. High phosphorus in lakes can cause overgrowth of algae (measured by Chl-a concentrations) and aquatic plants, which reduces water clarity (as measured by Secchi depth). Phosphorus will continue to be a contaminant of concern in CRWD as inputs of fertilizers, leaves, grass clippings, and pet/wildlife waste in this urban watershed are very prevalent and difficult to control. Water quality improvement projects upstream of lakes that reduce the amount of phosphorus runoff will continue to be a priority in the District.

Invasive species are a management challenge to District lakes. In 2016, curly leaf pondweed was observed in all lakes. Eurasian watermilfoil was observed in Crosby Lake for the first time in 2015, but it was not found in 2016 during the three surveys on the lake. Eurasian watermilfoil has been observed, however, in Loeb Lake and Lake McCarrons since aquatic macrophyte surveys began in 2005. Invasive species can cause harm to lakes through displacement of native species and disruption of the food chain, both of which can affect overall lake health.

Como Lake has historically exhibited a cyclical pattern in water quality for the monitored eutrophication parameters, though such trends are not as apparent in recent years. Loeb Lake and Lake McCarrons have had historically good water quality, but will continue to be monitored in the future to identify annual changes and trends. Crosby and Little Crosby Lakes will also continue being monitored in order to better understand the dynamic interaction between the lakes and the Mississippi River and how that influences lake water quality.

Since 2014, CRWD has collected a more robust dataset of biological parameters that had not been consistently collected from year to year. As more data is collected and analyzed, future reports will contain more analysis of this collected data and the interaction of biological data with the chemical and physical data collected. CRWD lakes are an important District resource, offering both economic and environmental benefits, and better understanding overall lake health will be beneficial for the District and region. Having a deeper annual dataset for more years of monitoring will give a better starting point from which to evaluate trends and analyze all drivers of lake water quality to holistically manage lake water quality.

11.2 RECOMMENDATIONS

11.2.1 ACCOMPLISHMENTS IN 2016

Many improvements have been made to the lake monitoring program in recent years in order to better understand the water quality in individual lakes as well as how the watershed as a whole could be affecting lake water quality. Data collection and analysis through the monitoring program helps to further CRWD's mission "to protect, manage and improve the water resources of the Capitol Region Watershed District."

In 2016, CRWD made progress towards the goals stated in the *2015 Lakes Monitoring Report* (found online at www.capitolregionwd.org) for monitoring and reporting. The following goals were accomplished in 2016:

1. **Conducted fish surveys:**

   In 2016, CRWD surveyed fish populations at Crosby Lake, Little Crosby Lake, Loeb Lake, and Lake McCarrons. The DNR surveyed Como Lake in 2016. This data was collected as part of the goals of the *2014 CRWD Enhanced Lake Biological Monitoring Workplan* to collect a more complete dataset of biological data on all CRWD lakes.

2. **Completed sediment coring on Lake McCarrons:**

   In February 2016, CRWD completed sediment coring on Lake McCarrons with the goal of using the collected data to evaluate the effectiveness of the 2004 alum treatment. Sediment cores were extracted from the lake bottom at incremental depths and analyzed for sediment physical properties (organic matter, bulk density), total metal concentrations (iron, aluminum, manganese), and total phosphorus release rates to inform the internal phosphorus budget and the effectiveness of an alum treatment. Wenck Associates completed a report called "*Sediment Characterization for Lake McCarrons and Como Lake*". Based on the results from this report, it was determined that additional coring was needed in 2017 for validation. CRWD organized an additional round of sediment coring on the lake in February 2017 by the University of Minnesota LacCore Lab (see 11.2.2 Recommendations, 5).

3. **Initiated an in-lake management study of Como Lake:**

   Como Lake has a long history of nutrient impairment due to excess phosphorus. The District has implemented several projects to address external phosphorus loading into the lake, including the Arlington-Pascal Stormwater Improvement Project. Despite efforts to control external sources, measurable water quality improvements have not been realized. In 2016, CRWD contracted LimnoTech to conduct a complete analysis of all historical lake data in order to make conclusions about the major drivers of water quality in Como Lake. The "*Como Lake Water Quality Drivers Analysis Study*" will be finalized in 2017 and will guide the District's future management efforts for the lake.

11.2.2 RECOMMENDATIONS FOR 2017

For 2017, CRWD has several goals and recommendations that are aimed at improving the lake monitoring program. Goals for 2017 include:

1. **Report all lakes data in CRWD's online Data Analysis and Reporting Tool (DART)**

   In 2017, CRWD is developing an online, user-driven, interactive, map-based Data Analysis and Reporting Tool (DART) that interfaces with the monitoring database technology, the WISKI database. DART will serve as a dynamic data reporting tool that provides: data visualization and user interaction; expanded statistical and spatial analysis capabilities; instant, customizable reporting and data downloading/exporting; real-time data viewing; and a tool that assists in meeting annual reporting requirements.

   - To complete this, all lakes data (chemical, biological, physical) will be imported into the WISKI database.

2. **Analyze additional chemical and physical parameters:**

   CRWD intends to expand the analysis of chemical and physical data previously collected but not fully analyzed in prior reports. This can now be completed more efficiently and effectively through the use of a new database. Analysis of other water chemistry and physical attributes will allow a better understanding of overall lake health, such as:

   - *Chloride:* It is a contaminant of concern in metro area lakes. Como Lake is listed on the draft 2014 303(d) Impaired Waters List for chloride (MPCA, 2016), so this contaminant is becoming more of a management concern in CRWD lakes.

   - *SRP*: Soluble Reactive Phosphorus, or Ortho-Phosphate. Evaluate separately from Total Phosphorus to better understand the role of this parameter in determining lake water quality.

   - *Temperature profile*: Temperatures at different depths within the water column are currently measured by RCPW during their summer lake visits. Graphically creating temperature profiles of the lake throughout the monitoring season may also be helpful in explaining water quality trends.

- *Total Nitrogen*: This includes Ammonia-Nitrogen (NH_3-N), nitrate as nitrogen (NO_3-N), and Total Kjehldahl Nitrogen (TKN). While the limiting factor for algal growth in CRWD lakes is most often phosphorus, other nutrients such as nitrogen could also be playing a role in temporal blooms.

3. Continue to conduct fish surveys:

In 2017, CRWD plans to survey fish populations at Como Lake only to continue to understand fish community dynamics. CRWD and the DNR will not be conducting fish surveys on McCarrons, Loeb, Crosby, or Little Crosby Lakes in 2017. Crosby and Little Crosby Lake have received surveys for three years in a row and have not exhibited any major changes in populations, so will not be monitored in 2017. Also, CRWD only surveys Lake McCarrons and Loeb Lake bi-annually (except for years the DNR is scheduled to survey) since these lakes exhibit stable fish populations.

4. Install a multi-parameter water quality sensor in Como Lake to monitor continuous DO, temperature, conductivity, pH, and turbidity at varying lake depths:

During the initial phase of the Como in-lake water quality drivers analysis (see 11.2.1 Accomplishments, 3), staff determined that continuous data on multiple water quality parameters at various lake depths is needed. Como Lake is a shallow lake (defined as having a maximum depth of less than 15 feet or at least 80% of the lake in the littoral zone), so the lake can turn over or mix multiple times in a growing season. While current monitoring of water quality parameters such as DO and temperature occurs at multiple depths from the surface to the lake bottom, these values are only collected every two weeks during the growing season (April-October). Subsequently, changes within the lake that may have occurred between those two weeks are not observed. Installing a multi-parameter water quality sensor (e.g. YSI Sonde) that is continuously measuring and logging water quality data at various depths will capture changes occurring between bi-weekly sampling events. This data will be used to better understand when lake turnover is occurring in Como Lake. In addition, this data will assist in identifying periods of anoxia, which will help better quantify internal phosphorus loading within the lake.

5. Complete an internal loading assessment of Lake McCarrons:

Internal loading (the release of phosphorus from lake sediments into the water column) can have a large effect on the amount of available phosphorus in a lake. Lake McCarrons received an alum treatment in 2004 in order to reduce internal phosphorus loading and improve lake water quality. Since the alum treatment, lake water quality has drastically improved in comparison to pre-alum treatment conditions. However, slow degradation of epilimnetic and hypolimnetic water quality has been observed in Lake McCarrons in recent years. The expected efficacy of an alum treatment is 8-20 years. It has been 11 years since the alum treatment, so deterioration in its effectiveness is expected.

Sediment coring was completed on Lake McCarrons in February 2016, and additionally in February 2017, with the goal of using the sample results to evaluate the effectiveness of the 2004 alum treatment. The 2016 and 2017 sediment cores will be used to investigate the changes to internal loading that have occurred since the 2004 alum treatment. The results of these sediment cores will be used to complete an internal loading assessment, which includes a phosphorus budget for Lake McCarrons that evaluates all internal and external sources to the lake. The results of this assessment will assist in determining future management strategies for Lake McCarrons.

6. **Complete an in-lake management analysis of Como Lake:**

   CRWD began working with LimnoTech in 2016 to conduct an in-lake analysis of all historically collected Como Lake data with the goal of determining the drivers of water quality in the lake. In 2017, LimnoTech will complete the "*Como Lake Water Quality Drivers Analysis Study*" in order to better understand the complex relationships between the chemical, physical, and biological parameters of the lake. The report will also make recommendations for the District's future management efforts for the lake.

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APPENDIX A:
TECHNICAL MEMO — SUMMARY OF 2016 LAKE FISH SURVEYS

Technical Memo

Responsive partner.
Exceptional outcomes.

To: Britta Suppes, Monitoring Coordinator
Capital Region Watershed District

From: Tom Langer, Wenck Associates, Inc.
Jeff Madejczyk, Wenck Associates, Inc.

Date: August 29, 2016

Subject: Summary of 2016 Lake Fish Surveys

Introduction

The Capitol Region Watershed District (CRWD or District) is located in Ramsey County, Minnesota. The District covers over 40 square miles in portions of five cities. CRWD conducts a variety of monitoring, implementation and educational efforts and projects aimed at improving the water and recreation resources within the watershed. CRWD has partnered with Wenck Associates, Inc. (Wenck) since 2014 to conduct fish community surveys in lakes within the District to supplement routine fish monitoring efforts conducted by the Minnesota Department of Natural Resources (MnDNR). Wenck conducted fish community surveys in four of five monitoring lakes in 2016, including Crosby Lake, Little Crosby Lake, Loeb Lake and McCarrons Lake. Fish community surveys in Crosby Lake and Little Crosby Lake were completed the week of August 1-4, 2016. Loeb and McCarrons Lake surveys were completed the week of August 8-11, 2016. Crosby Lake, Little Crosby Lake and Como Lake were sampled by Wenck in 2015 and Little Crosby Lake and Como Lake were sampled by Wenck in 2014. The party responsible for the surveys within the five CRWD lakes for the last three years is presented in Table 1.

All fish surveys were conducted following MnDNR standard trap and gill nets survey methods. Depending on lake size Wenck (or the MnDNR) would deploy a combination of 4 trap nets and 1 gill net or 8 trap nets and 2 gill nets per annual assessment for a given lake. In all lakes except Little Crosby the MnDNR had established survey locations which were also used by Wenck during surveys. Little Crosby Lake had no established MnDNR sampling points therefore Wenck established monitoring locations in 2014 and used these points in each annual assessment.

Table 1: Sampling summary of CRWD lakes form 2014 – 2016.

Lake	2016	2015	2014
Little Crosby	Wenck/CRWD	Wenck/CRWD	Wenck/CRWD
Crosby	Wenck/CRWD	Wenck/CRWD	MnDNR
Loeb	Wenck/CRWD	**	MnDNR
McCarrons	Wenck/CRWD	**	MnDNR
Como	MnDNR	Wenck/CRWD	Wenck/CRWD

** Unknown if MnDNR sampled.

All fish collected from all sampling gears were identified, counted, weighed and measured. Live fish were released back into the lake. Dead fish were disposed of within the lake. Special attention was given to minimize the spread of aquatic plants and AIS species. Lakes were strategically sampled and nets were cleaned as needed between lakes. The proper infested water tags were placed on nets after they had been deployed in infested waters as required under the terms of the MnDNR survey permit.

Results

Crosby Lake

There were 10 species and 131 total individual fish collected from Crosby Lake in 2016 (Table 2). The most numerous fish in 2016 were black bullheads (72), yellow bullheads (22) and northern pike (13). Over the past three years of fish assessments on Crosby Lake a total of 13 species and 357 individual fish have been collected.

Black bullhead and bluegill are among the most abundant species observed with black bullhead catch rates highly variable across years and bluegill decreasing every year. There was a much lower catch per unit effort (CPUE) of black bullheads in 2015 with only 2 total black bullheads observed among both gill net sets, compared to the 47 (2016, two gill net sets) and 45 (2014, one gill net set) black bullhead observation in gill net sets during the other two surveys. In 2016 gill net placement varied from deeper waters in the center of the basin to shallower areas just along the weed line. Gill nets produced no fish when the net was set in deeper waters (Gill Net #1 – 2016), possibly due to anoxic conditions or limited habitat in deeper waters, while gill net places at the edge of the weed line produced 77 total fish (Gill Net #2 - 2016). Future sampling efforts should likely target weed line gill net sets on Crosby Lake to increase fish catch rates. However, if changes are made to sampling depth this should be noted when comparing annual results as a potential reason for catch rate differences.

The decline of bluegill in the total catch in Crosby Lake could be due to variety of potential factors including: 1) winterkill followed by minimal spring flooding events; 2) increased predation; or 3) random chance and net placement. Bluegills can be prone to winterkill and the Crosby Lake fish community is likely reliant on occasional spring flooding events to revive the fish community. The potential for winterkill coupled with the increased presence of observed northern pike (a bluegill predator) in 2016 may have led to a decrease in the observed catch rate. Both processes are natural phenomena for floodplain lakes and therefore considered part of the natural cycles of a healthy fish community. It should also be noted that there were some bluegills observed along the shoreline within the submerged vegetation in greater numbers than were collected within the trap nets so it is possible that the 2016 sampling under represented the bluegill community within the lake (as suggested by item #3 above).

Table 2: Summary comparison of Crosby Lake fish community surveys.

Species	2016	% catch	2015	% catch	2014	% catch
Black Bullhead	72	55.0%	8	10.7%	57	37.7%
Black Crappie	4	3.1%	4	5.3%	0	0.0%
Bluegill	5	3.8%	32	42.7%	57	37.7%
Bowfin	1	0.8%	4	5.3%	1	0.7%
Common Carp	0	0.0%	0	0.0%	1	0.7%
Golden Shiner	0	0.0%	0	0.0%	4	2.6%
Hybrid Sunfish	1	0.8%	0	0.0%	11	7.3%
Largemouth Bass	1	0.8%	1	1.3%	1	0.7%

Species	2016	% catch	2015	% catch	2014	% catch
Northern Pike	13	9.9%	3	4.0%	6	4.0%
Pumpkinseed Sunfish	6	4.6%	16	21.3%	0	0.0%
White Crappie	0	0.0%	0	0.0%	11	7.3%
Yellow Bullhead	22	16.8%	2	2.7%	1	0.7%
Yellow Perch	6	4.6%	5	6.7%	1	0.7%
Total	**131**	**100.0%**	**75**	**100.00%**	**151**	**100.00%**

Little Crosby Lake

There were seven species collected from Little Crosby Lake in 2016 and the total catch was relatively low, at 24 total fish (Table 3). The most numerous fish collected in 2016 were pumpkinseed sunfish. Northern pike appear to be the only top predator species in Little Crosby Lake. Over the past three years black bullheads appear to be the most abundant species collected, however, this is largely skewed due to 53 individuals collected during the 2014 gill net set. Bullhead species were observed swimming in the lake during net deployment, however, large catch rates were not observed in 2015 or 2016. Overall Little Crosby may be supporting a relatively stable fish community that experiences little fluctuation outside of winterkill and spring flooding events. The small lake does have a relatively deep hole which is difficult to survey and it is not known to what extent fish may be using deeper areas of the lake. The overall biomass is relatively low compared to other lakes in the District; however; this is not surprising due to the small size of the lake.

Table 3: Summary comparison of Little Crosby Lake fish community surveys.

Species	2016	% catch	2015	% catch	2014	% catch
Black Bullhead	1	4.2%	1	2.9%	57	80.3%
Bluegill	5	20.8%	9	26.5%	2	2.8%
Golden Shiner	0	0.0%	0	0.0%	1	1.4%
Green Sunfish	1	4.2%	1	2.9%	0	0.0%
Hybrid Sunfish	0	0.0%	0	0.0%	1	1.4%
Northern Pike	2	8.3%	5	14.7%	2	2.8%
Pumpkinseed Sunfish	13	54.2%	14	41.2%	2	2.8%
Yellow Bullhead	1	4.2%	1	2.9%	0	0.0%
Yellow Perch	1	4.2%	3	8.8%	6	8.5%
Total	**24**	**100.0%**	**34**	**100.0%**	**71**	**100.0%**

Loeb Lake

There were six species observed on Loeb Lake in 2016 with a low total catch (Table 4). The most numerous fish collected in 2016 were bluegill. The presence of walleye in the lake suggest previous stocking efforts as there is no evidence that suggests that walleye are native to the lake and viable spawning habitat for walleyes appears to be limited to non-existent within the lake. In total eight species have been observed in the lake between the 2016 and 2014 surveys. The total catch in 2016 was down compared to the survey results from the MnDNR in 2014. However, the variability observed between the 2014 and 2016 surveys is similar to what has been observed at other lakes within CRWD. Similar to Little Crosby Lake, Loeb Lake appears to support a lower biomass of fish likely due to its size. Fishing pressure is unknown on the lakes, however, Loeb is located in a residential area and does appear to have at least moderate shoreline fishing opportunities, suggesting that fishing pressure could be an influencing factors on the fish community within the lake.

Table 4: Summary comparison of Loeb Lake fish community surveys.

Species	2016	% catch	2014	% catch
Black Bullhead	1	4.3%	1	1.9%
Black Crappie	4	17.4%	2	3.8%
Bluegill	15	65.2%	22	42.3%
Green Sunfish	0	0.0%	4	7.7%
Hybrid Sunfish	1	4.3%	14	26.9%
Largemouth Bass	0	0.0%	2	3.8%
Pumpkinseed Sunfish	1	4.3%	5	9.6%
Walleye	1	4.3%	2	3.8%
Total	**23**	**100.0%**	**52**	**100.0%**

McCarrons Lake

There were 11 species collected from McCarrons Lake in 2016 with 212 individual fish collected (Table 5). The most numerous fish collected in 2016 were black crappie (71), bluegill (63) and northern pike (55). The 2016 fish community appears to be balanced with the presence of a large top predator community to provide "top-down" influence on the overall fish community, little to no evidence of a stunted panfish population, and limited benthic species (i.e. bullheads). The presence of large top predator species can be very important in fisheries management as trophic dynamics can contribute to water quality. McCarrons is a relatively small deep lake that has various habitats that assist in supporting a variety of species. There were more species collected in 2016 as compared to the 2014 survey. There was also a notable decrease in bluegill individuals and increase in northern pike in 2016 as compared to 2014 (see Table 5). A similar trend was observed on Crosby Lake (decreased catch of bluegills and an increased catch of northern pike) and may support the idea that the northern pike population is assisting in controlling the bluegill population within the lake.

Table 5: Summary comparison of McCarrons Lake fish community surveys.

Species	2016	% catch	2014	% catch
Black Crappie	71	33.5%	36	10.7%
Bluegill	63	29.7%	259	77.3%
Channel Catfish	1	0.5%	0	0.0%
Green Sunfish	2	0.9%	0	0.0%
Hybrid Sunfish	2	0.9%	4	1.2%
Largemouth Bass	1	0.5%	0	0.0%
Northern Pike	55	25.9%	13	3.9%
Pumpkinseed Sunfish	12	5.7%	9	2.7%
Smallmouth Bass	3	1.4%	0	0.0%
Yellow Bullhead	1	0.5%	0	0.0%
Yellow Perch	1	0.5%	14	4.2%
Total	**212**	**100.0%**	**335**	**100.0%**

Como Lake

Fisheries information collected by the MnDNR in 2016 is currently unavailable and therefore not included in this assessment. Rather information drafted in the 2015 memo is restated here to supply a more complete sampling report of the fishery since work with Wenck began.

A total of 14 different species have been observed in Como Lake in 2014 and 2015. The most dominant species observed in these two surveys were black crappie (384 individuals) and black bullhead (204); (see Table 6). The total catch in 2015 was more than double the catch in 2014. The large total catch of black bullheads in 2015 compared to 2014 coincided with a change in lake water quality state in Como Lake. In 2014 Como Lake was reported to be in a relatively clear water state and in 2015 the Como Lake persisted in the turbid water state. The large number of planktivore and benthivore species within the lake likely have a strong trophic cascade influence on the water quality of the lake. The fish biomass given the lake volume appears to significantly greater in Como Lake than in other District lakes suggesting not only a potential species influence but a biomass issue on Como Lake. Special attention should be given to the fish community and fisheries management within Como Lake to aide in improving water quality and the health of the lake ecosystem.

Table 6: Summary Comparison of Como Lake Fish Community Surveys

Species	**2015**	**% catch**	**2014**	**% catch**
Black Bullhead	190	37.4%	14	6.0%
Black Crappie	239	47.0%	145	62.5%
Bluegill	2	0.4%	7	3.0%
Brown Bullhead	1	0.2%	0	0.0%
Channel Catfish	10	2.0%	3	1.3%
Common Carp	1	0.2%	0	0.0%
Golden Shiner	7	1.4%	19	8.2%
Hybrid Sunfish	2	0.4%	0	0.0%
Northern Pike	21	4.1%	16	6.9%
Pumpkinseed Sunfish	0	0.0%	7	3.0%
Walleye	19	3.7%	6	2.6%
White Sucker	3	0.6%	0	0.0%
Yellow Bullhead	12	2.4%	1	0.4%
Yellow Perch	1	0.2%	14	6.0%
Total	**508**	**100.0%**	**232**	**100.0%**

Additional Information

Wenck will supply summarized field datasheet from each lake assessed in 2016.

Conclusions

In summary, of the four lakes assessed in 2016 McCarrons Lake appears to be present the best recreational fishing opportunity of the District lakes and currently supports a healthy fishery. McCarrons Lake is a larger and deeper lake compared to the other assessed lakes in

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the District and has good water quality and clarity as well as a variety of native aquatic vegetation species providing habitat for the fish community. McCarrons Lake has numerous shoreline residents with boats and piers along the lake as well as a public access that shows evidence of at least moderate public use for recreation and fishing, accentuating the importance of this resource within CRWD. The presence of a variety of fish species and as well as sizes classes within the species suggests a relatively balanced fishery. Efforts to maintain a balanced fishery may be the best management strategy to protect the current fish community. Fish harvesting and fishing pressure assessments would allow for greater insight to whether the current fish community is at risk from fisherman. Efforts to protect large top predators may be a favorable strategy in managing McCarrons Lake.

Natural characteristics appear to limit the scope of fisheries management for the other three assessed waterbodies. Little Crosby Lake and Crosby Lake are relatively small lakes within the Mississippi River floodplain and the fish community is likely influenced by recolonization during spring flooding events. As a result these lakes are subject to more natural factors influencing the fish community and any direct management activity (i.e. stocking) may be trumped by these natural factors. Protection of these lakes is recommended as they appear to support many amphibians, birds and wildlife. Drastic changes to the fish community could have cascading impacts to these other biotic communities, however landscape/watershed alterations likely pose the greatest threat to the lake ecosystem.

Loeb Lake is a relatively small lake that is located within the city and appears to have ample fishing opportunities (i.e. shoreline, fishing pier). The small lake size suggests natural limitations to sustain many large fish that anglers target for harvest when fishing. If fishing pressure is high on the lake establishing a stable fishery may be difficult to manage. Rather the lake may be best managed as a put and take fishery with some natural reproduction for littoral species (i.e. bluegill). Loeb Lake is part of the FIN (Fishing in the Neighborhood) program suggesting that it is being managed to promote fishing opportunities and as a put and take fishery.

Loeb, Crosby, and Little Crosby Lakes currently appear to have good water quality with clear waters and as a result it is unlikely that the fish community is creating concerns related to water quality degradation.

Como Lake is a shallow lake similar to Crosby Lake but has a much greater fish biomass which may be contributing to degraded water quality within the lake. Current efforts to address internal nutrient loading issues within Como Lake should consider assessing and addressing the fishery of the lake. The findings of these fisheries assessments, in addition to literature on shallow lake ecology, suggest that Como Lake water quality may be strongly correlated to the fish community.

2016 Notable Findings

- Curly leaf pondweed is observed in the Crosby lakes. It is recommended to continue monitoring this known aquatic invasive species (AIS) as its presence does not appear to be causing detrimental influences on the vegetation community at this time. However, if either a significant loss in native species presence and/or abundance is noted, or an increase in AIS presence and/or biomass is observed within the lake, an immediate response could be favorable to AIS control. Actions to control AIS such as hand harvesting or spot treatments could be warranted to control/ eradicate the AIS

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to avoid nuisance levels of vegetation or potential water quality impairments often associated with curly leaf pondweed.

- Softshell turtles were observed during fish sampling on McCarrons Lake. This tends to be a rarer species in the Twin Cities metro area compared to more common turtle species such as the Western Painted Belly and the Common Snapping turtles.

- Substantial trash (i.e. worm containers, plastic bags, fishing line) were noted on Loeb Lake. Efforts to address this concern may be warranted.

Future Recommendations

- Consideration to include assessing the nearshore fish community via beach siene and backpack electrofishing assessments. Though none of the Capital Region WD lakes meet the size requirements to be assessed using the MnDNR fish Index of Biotic Integrity (IBI) tool, this information can still provide important information that is sometimes missed during standard trap and gill net assessments.
  - Examples:
    - Largemouth bass often avoid trap and gill nets but are often captured with nearshore survey methods.
    - Smaller fish species (i.e. Fathead Minnow, Johnny Darter, Central Mudminnow) are not effectively sampled with standard trap and gill net assessments and therefore limited conclusions can be made about these species. These species also tend to make up the low tiers of the aquatic food web which can be important for understanding the health of a larger game fish (targeted by anglers) community.

- Collect more fisheries information on Loeb and McCarrons lakes. Seeing variations in Little Crosby and Crosby lake fish communities on an annual basis can be important to understand a general baseline of information. It is possible the MnDNR has recent fisheries assessment information that would suffice for additional year assessments.

- Continued vegetation monitoring efforts and development of a rapid response plan in the event that AIS species become more prevalent in lakes within the CRWD including Little Crosby and Crosby Lakes. The current water quality and vegetation community appear to be healthy in the Crosby Lakes making these lakes great habitat for many amphibians, waterfowl, invertebrates. AIS can pose a serious threat to these habitats required by a balanced aquatic community. There appears to be a good opportunity to monitor and intercept AIS within CRWD before they reach nuisance levels and begin to degrade an ecosystem to the point where impairment occurs.