CRWD 2024 Lakes Data Summary

February 11, 2025

CRWD 2024 Lakes Data Summary

Saint Paul, Minnesota

Cover image: Como Lake, [CRWD Staff]

Contents

1 Background

1.1 Report Purpose

The *CRWD 2024 Lakes Data Summary* presents a subset of the 2024 Capitol Region Watershed District (CRWD or District) lakes monitoring data and includes data collection methods, overall results and lake-specific results from the 2024 monitoring season, and a comparison to previous monitoring years. Additionally, a large part of lake health is influenced by annual variation in climatic factors, including total precipitation, air temperature, total winter snowfall and snowpack, and ice-in/ice-out dates. Information on these factors can be found in the *CRWD 2024 Climatological Summary*.

1.2 CRWD Lakes Overview

CRWD was formed to better protect and manage local water resources, including District 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 1).

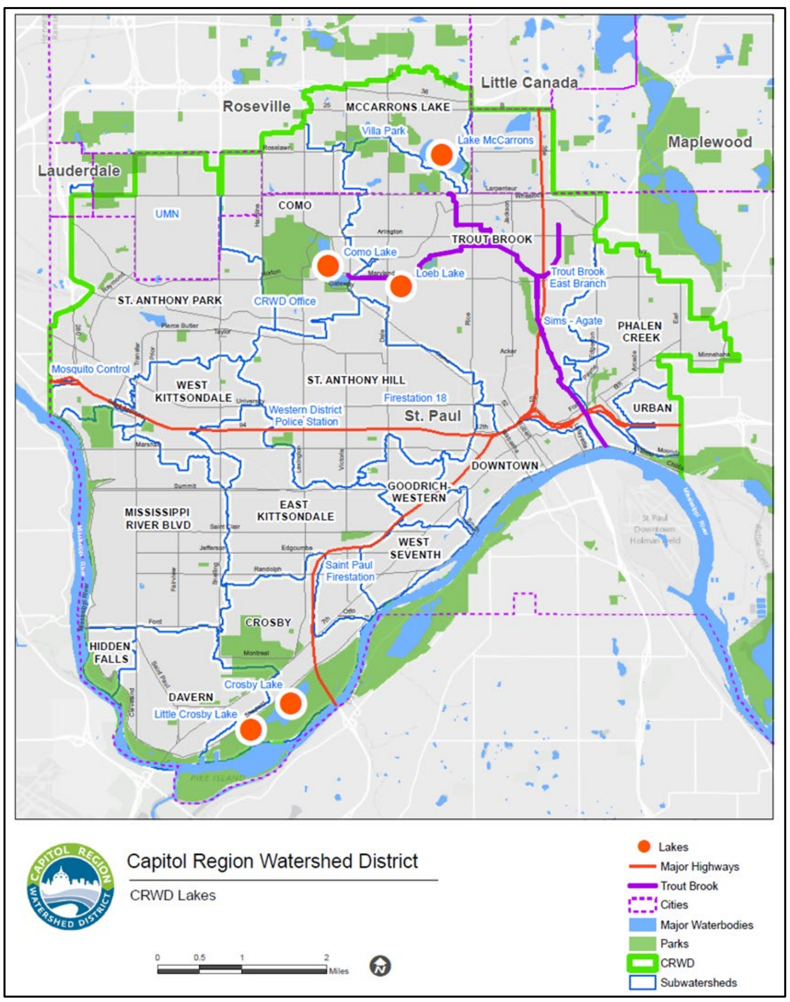

Figure 1: Map of CRWD Lakes

1.2.1 Como Lake

Como Lake is a shallow lake with primarily parkland and residential land uses (Table 1). 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, with an observed cyclical variation in water quality over time (Noonan, 1998). Since then, Como Lake declined significantly in water quality and usability. In an effort to improve water quality in the lake, the 2019 Como Lake Management Plan was developed to provide adaptive management strategies. Como Lake is currently listed on the MPCA's 303(d) impaired waters list for mercury in fish tissue (1998), nutrients (2002), and chloride (2014) impairments.

1.2.2 Crosby and Little Crosby Lakes

Crosby and Little Crosby Lakes (Table 1) are shallow lakes situated in the Mississippi River floodplain in Saint Paul. Additionally, the lakes are 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 that is 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 waterbodies are primarily parkland, single family residential, and industrial. The water quality of both lakes is greatly affected by flooding periods of the Minnesota and Mississippi Rivers, since it is located in the floodplain of their confluence. Both lakes are considered unimpaired and are not currently on the MPCA 303(d) list.

1.2.3 Loeb Lake

Loeb Lake is a shallow lake located in Marydale Park, and the predominant land uses in the surrounding drainage area are mixed residential and parkland (Table 1). The lake has a small drainage area with no outlets and has therefore exhibited relatively stable water quality since monitoring began in 2003. Loeb Lake is an unimpaired water body and is not currently on the MPCA 303(d) list.

1.2.4 Lake McCarrons

Lake McCarrons is considered a deep lake, with a drainage area consisting of mainly mixed residential and open space, and includes the entire Villa Park wetland system, which discharges directly to the lake (Table 1). Lake McCarrons has been monitored since 1988, is the only District lake that allows swimming, and is the only lake with residential shoreline development. Lake McCarrons received an alum treatment in 2004, and the water quality of the lake has shown improvement since this occurred. A management plan for the lake was created in 2020 to maintain a healthy lake and support recreational uses. Lake McCarrons is currently listed on the MPCA's 303(d) impaired waters list for mercury in fish tissue (2010) and perfluorooctane sulfonate (PFOS) in fish tissue (2022), which primarily impact fish consumption.

Table 1: Morphometric data for District lakes

Lake	Surface Area (acres)	Maximum Depth (ft)	Littoral Area	Volume (acre-ft)	Watershed Area (acres)	Watershed: Lake Area (ratio)
Como	70.5	15.5	97%	469	1,711	24.3
Crosby	45.0	17.0	100%	130	197	4.4
Little Crosby	8.0	34.0	88%	59	37	4.6
Loeb	9.7	28.0	81%	84	44	4.5
McCarrons	74.7	57.0	34%	1,892	1,070	14.3

1.3 Monitoring goals and methods

All five District lakes are monitored from early spring until late fall on an annual basis to characterize overall health, evaluate trends over time, determine if each lake supports their designated uses for swimming, fishing, and/or aesthetics, and inform lake management decisions for continued protection and improvement.

Lake data is collected by CRWD, Ramsey County Public Works, Ramsey Conservation Division of Ramsey County, and the Minnesota Department of Natural Resources (MN DNR). CRWD organizes and coordinates the monitoring and analysis of this data including chemical parameters (nutrients, pH, chloride, and conductivity), physical parameters (water clarity, dissolved oxygen, and temperature), and biological parameters (chlorophyll-a, aquatic vegetation type and abundance, and phytoplankton, zooplankton, and fisheries populations). For more information on the detailed methods for monitoring and analysis of these parameters, see Appendix A.

2 Overall results of 2024 lake water quality data

District lakes showed a general decrease in water quality in 2024 compared to 2023; however, it was a distinctly different year climatologically. One of the primary factors affecting lake water quality results this year was the substantial increase in precipitation from 2023. June of 2024 was the fourth wettest June on record, and total growing season precipitation (May through September) increased substantially from 2023, both in frequency and volume. 2024 growing season precipitation totaled 22.64 inches, a significant increase from the 16.47 inches received in 2023's growing season. This increase led to higher nutrient loading to lakes, particularly affecting Como Lake, which receives significant stormwater runoff compared to other District lakes. For further climatological details, see the *2024 Climatological Summary*.

Tables 2 & 3 in the section below use lake grades as a measure of water quality for a given year, whereas Table 4 directly compares the 2024 data to the MPCA state water quality standards for the three eutrophication parameters (total phosphorus (TP), chlorophyll-a (chl-a), and Secchi disk depth). See Appendix A for further information on how lake grades and state standards are developed and calculated.

2.1 Comparison between 2023 and 2024 monitoring years

When comparing 2024 lake grades to 2023 lake grades in Table 2, Little Crosby Lake showed an increase (green arrow), Crosby Lake stayed the same (yellow arrow), and Como Lake, Loeb Lake, and Lake McCarrons all decreased in grade level (red arrow).

Table 2: 2023 and 2024 lake grade comparison for all District lakes

Lake	2023 Lake Grade	2024 Lake Grade
Como Lake	C →	D+
Crosby Lake	C →	C
Little Crosby Lake	C →	B
Loeb Lake	B+ →	B
Lake McCarrons	A →	B

2.2 Comparison between 2024 and historical monitoring

When comparing 2024 lake grades to historical lake grades (which is calculated using the range of annual lake grades from 2023 to when monitoring began for each lake), Table 3 shows that Como Lake aligned with its historical average, Little Crosby had a slightly higher grade, and Crosby Lake, Loeb Lake, and Lake McCarrons had lower grades this year. Lake water quality varies year-to-year due to many different factors, so it is important to compare any given year to the historical dataset to view how one year compares to "typical" for that individual lake.

Table 3: Lake grade comparison between historical grade and 2024 grade for all District lakes

Lake	Historical Lake Grade	2024 Lake Grade
Como Lake	D+	D+
Crosby Lake	C+	C
Little Crosby	C+	B
Loeb Lake	A	B
Lake McCarrons	A	B

2.3 Comparison of 2024 water quality data to the MPCA state standards

Table 4 shows whether the annual average of each of the eutrophication parameters met the state standard by lake, where a green checkmark indicates that the lake met the standard and a red "x" indicates that it did not meet the standard. Based on these results for 2024, Como, Crosby, and Little Crosby Lakes would be considered impaired, while Loeb Lake and Lake McCarrons would not be considered impaired. It is important to note that to list or delist a lake, an extensive process must be completed in collaboration with the MPCA that evaluates current and historical data as well as the lake's potential to maintain current conditions.

Table 4: Comparison of eutrophication parameters to the MPCA state standards for all lakes

Lake	Total Phosphorus Standard	Chlorophyll-a Standard	Secchi Depth Standard
Como Lake	✖	✖	✔
Crosby Lake	✖	✔	✔
Little Crosby Lake	✖	✔	✔
Loeb Lake	✔	✔	✔
Lake McCarrons	✔	✔	✔

3 Individual lake results for 2024

3.1 Como Lake

3.1.1 Water quality data

In 2024 Como Lake experienced an overall decline in water quality compared to 2023, but in the context of a much rainier season, there were water quality successes. To put into perspective the additional stressors put on Como Lake by the intensity of growing season precipitation in 2024, one can look at data from the Como 3 monitoring station, which measures the flow and water quality from the Como D subwatershed (which lies southwest of the lake and includes McMurray Field) just before it enters the lake. In 2023 from April through September, this subwatershed brought 49 pounds of TP to the lake. In 2024 the volume of water during those same months increased by 91%, bringing 81 pounds of TP. This is only one subwatershed, but it represents an overall trend in stormwater input in 2024 compared to 2023.

Despite these extra pressures, Como Lake met the standard for Secchi depth, doing particularly well in the spring (Figure 2), and although TP did not meet the state standard in 2024, at an average of 89 µg/L, it was significantly below the historical average of 163.3 µg/L (Figure 3). This shows an overall increase in resiliency as a result of several strategic management efforts that have been implemented on Como Lake and its watershed since the adoption of the 2019 Como Lake Management Plan, including an alum treatment in 2020, invasive species management for curly-leaf pondweed and common carp, watershed projects such as the Como Zoo BMP, and increasing the native aquatic plant population through transplanting efforts. These projects have shown great success in reducing phosphorus in the lake over time, increasing the lake's capacity to handle higher TP loads during years with more stormwater input.

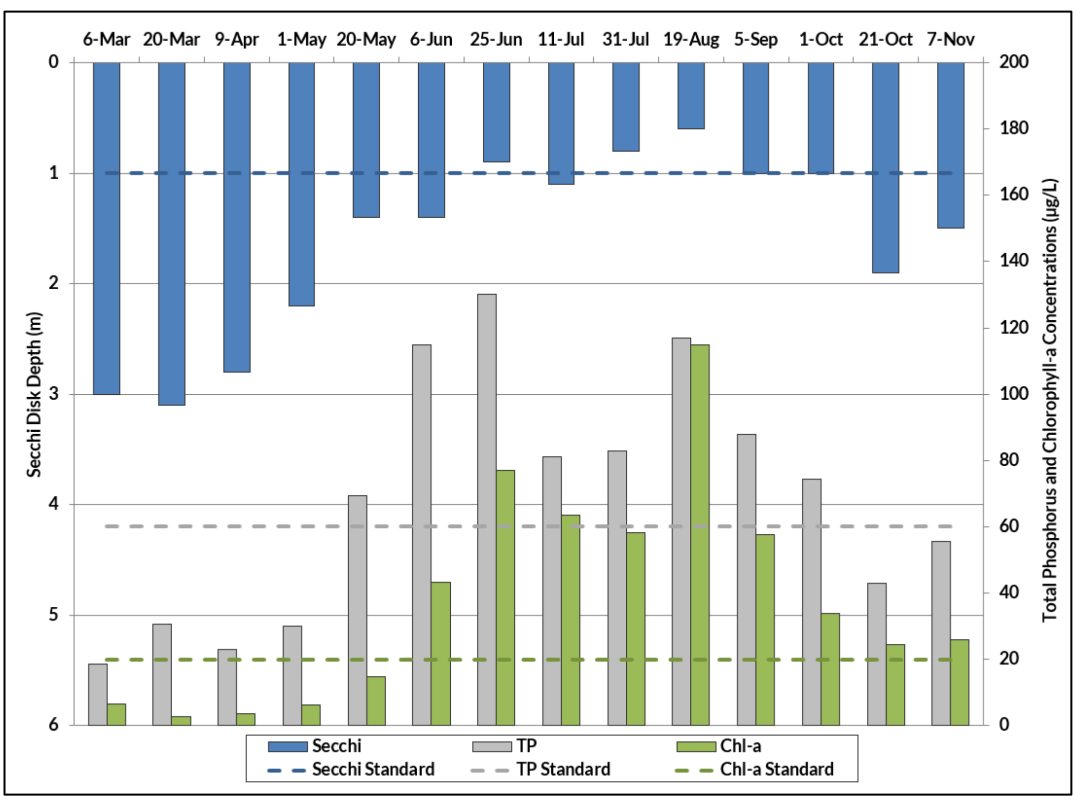

Figure 2: Como Lake 2024 daily epilimnetic total phosphorus, chlorophyll-a, and Secchi disk depth

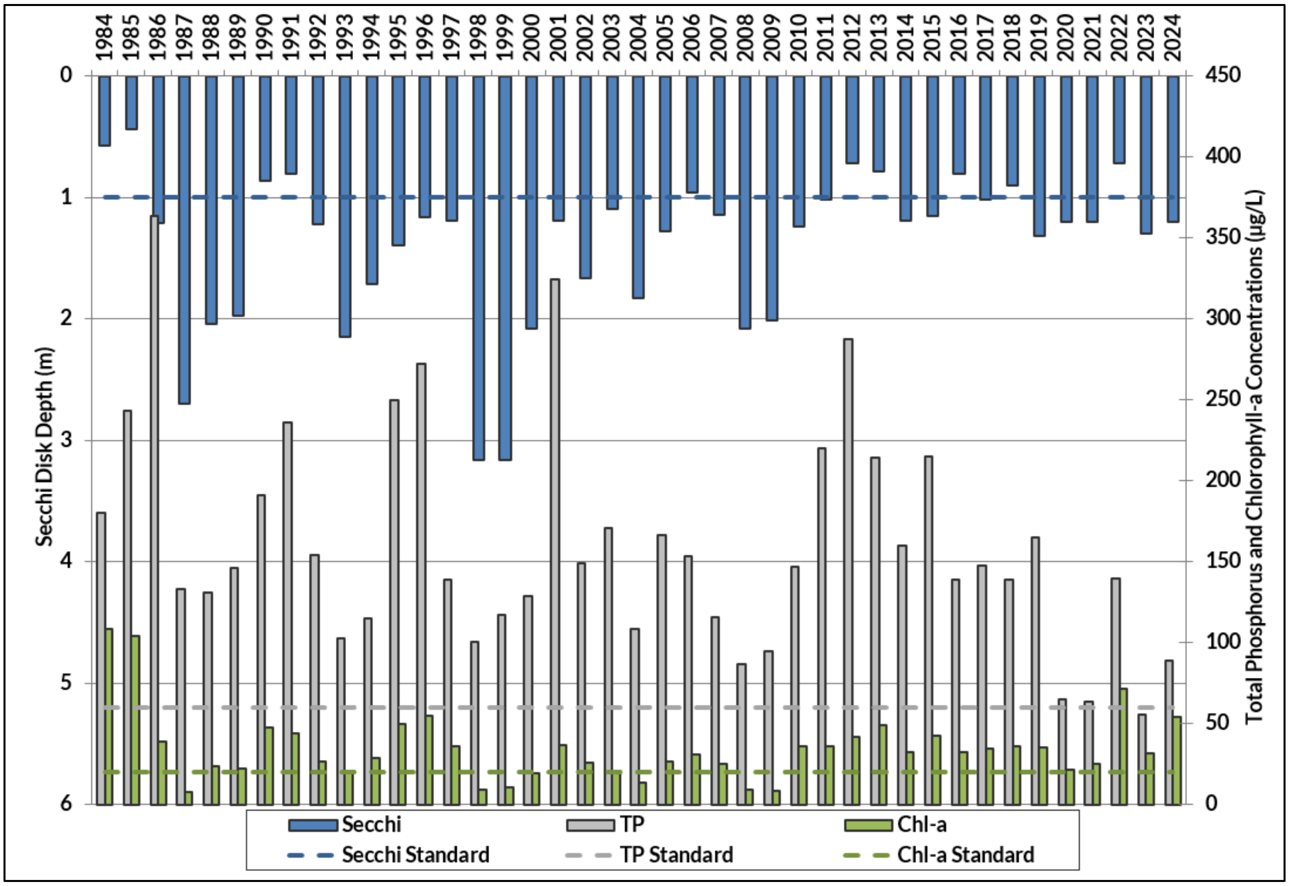

Figure 3: Como Lake historical average annual epilimnetic total phosphorus, chlorophyll-a, and Secchi disk depth

3.1.2 2024 Highlight: Aquatic Plants

Plants play an important role in lake health by storing phosphorus within their biomass, providing good habitat for other lake organisms, stabilizing the lake bottom, and increasing dissolved oxygen. Since the 2019 Como Lake Management Plan, actions have been taken to balance the native aquatic plant population of the lake, including treatments to reduce the presence of invasive curly-leaf pondweed (CLP) and several rounds of native aquatic plant transplanting. These efforts have resulted in a major shift in the plant community of Como Lake, which was once heavily dominated by CLP with little to no native vegetation. Compared to pre-project conditions in 2020, the lake had a more robust native plant population and significantly less CLP in 2024.

However, in 2024 the native plant population faced a unique set of circumstances. Over the 2023-2024 winter, Como Lake had one of the shortest ice-on periods on record, and in addition to being short, it was non-continuous, with the lake opening back up mid-winter. In total there were only 88 days of ice cover for the lake, which averages 117. There was also very little snow cover on the ice, meaning sunlight was able to reach submerged vegetation, potentially allowing aquatic plants to begin their growing season earlier than usual. While this may have contributed to higher levels of dissolved oxygen, it may also have presented a challenge by allowing CLP to grow significantly. Paired with the high density of CLP turions found in the lake during the 2023 fall turion survey, this led to an increase in CLP compared to 2023, creating a more difficult environment for the native plant population.

CLP management continued in 2024, addressing the increase in CLP from 2023 with an early-spring herbicide treatment. The timing of the application was planned carefully to have as minimal an impact on native vegetation as possible. Preliminarily, this strategy appears to have worked, given that there was an overall reduction in the Frequency of Occurrence (FO) for CLP in summer months (Figure 4), though it is important to note that FO does not take density into account. There was also a decrease in turion density from 459.1 turions/m^2 in 2023 to 201.5 turions/m^2 in 2024. Simultaneously, the number of native species observed during the three point-intercept surveys increased from seven to eight, with coontail being the dominant native plant, and the biovolume mapping results in 2024 were quite similar to 2023 (Figure 5).

In the process of routine vegetation monitoring, staff found watermilfoil in Como Lake in 2023. Staff preliminarily identified it as Eurasian watermilfoil (EWM) or hybridized watermilfoil, which is a hybrid of the invasive EWM and native Northern watermilfoil (NWM). In 2024 it was confirmed by the MN DNR to be hybridized watermilfoil. There are not separate listings on the infested waters list for hybridized and Eurasian watermilfoil, so the DNR is in the process of adding Como Lake to the infested waters list for Eurasian watermilfoil. The District will continue to monitor EWM abundance moving forward in order to make informed management decisions, as it does with CLP.

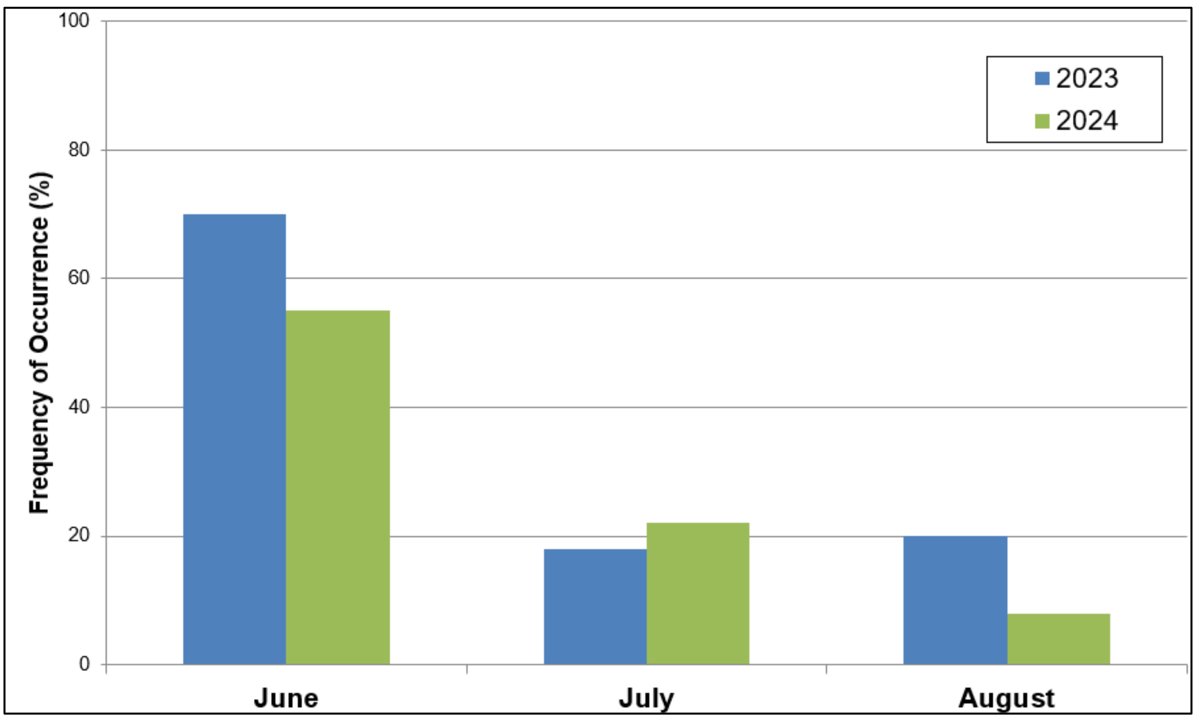

Figure 4: Como Lake Curly-Leaf Pondweed Frequency of Occurrence (%) 2023 and 2024

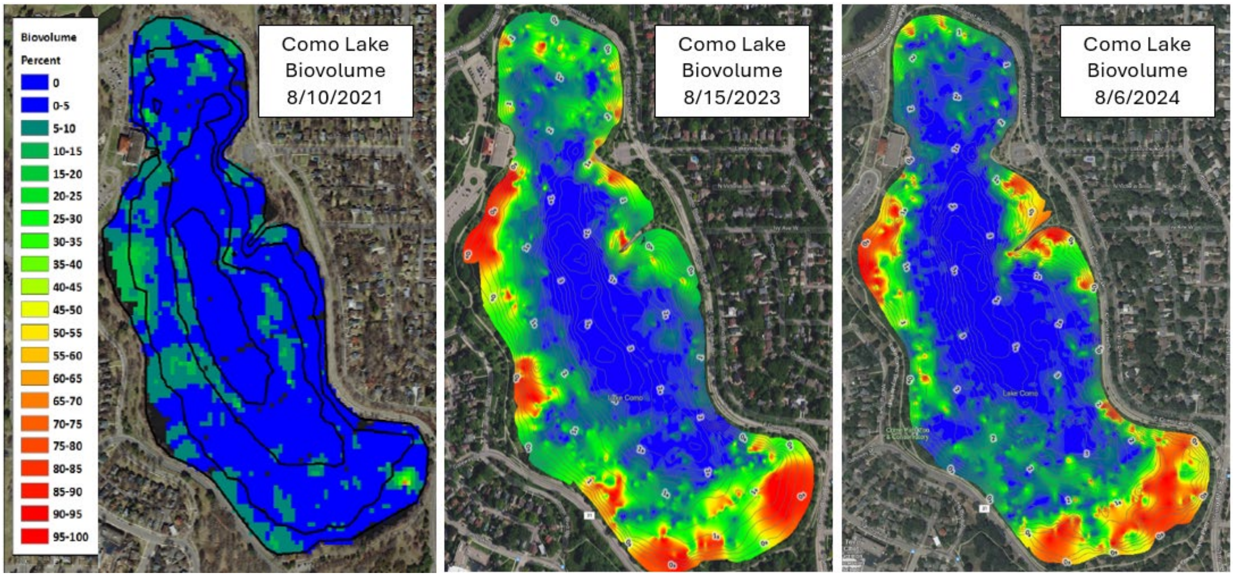

Figure 5: Aquatic plant biovolume in August 2021 (pre-project), August 2023 (After 3 rounds of transplanting), and August 2024 (after no additional transplanting and a CLP herbicide treatment)

3.2 Crosby Lake

3.2.1 Water quality data

Crosby Lake had average water quality in 2024 when examining all three of the eutrophication parameters. The overall lake grade stayed the same as 2023 and was slightly below the historical average lake grade (Tables 2 & 3). Mid to late summer exhibited relatively high total phosphorus levels, whereas the first half of the monitoring season (March through early June) showed more consistent water quality (Figure 6). Historically, Crosby Lake has had periods of better water quality, but in the last 15 years has had higher annual average TP and chl-a values and less deep Secchi disk depth measurements (Figure 7).

It is important to note that Crosby Lake (and Little Crosby Lake) sits in the floodplain of the Mississippi River. During periods of river flooding, water inundates the lakes, bringing in nutrients and aquatic organisms (macroinvertebrates, fish, etc.) that can have a large impact on lake health. In 2024 the June 26th monitoring date occurred during the flooding period, so this is indicative of how much of an impact river flooding can have not only at the time of flooding, but for the remainder of the year as well (Figure 6).

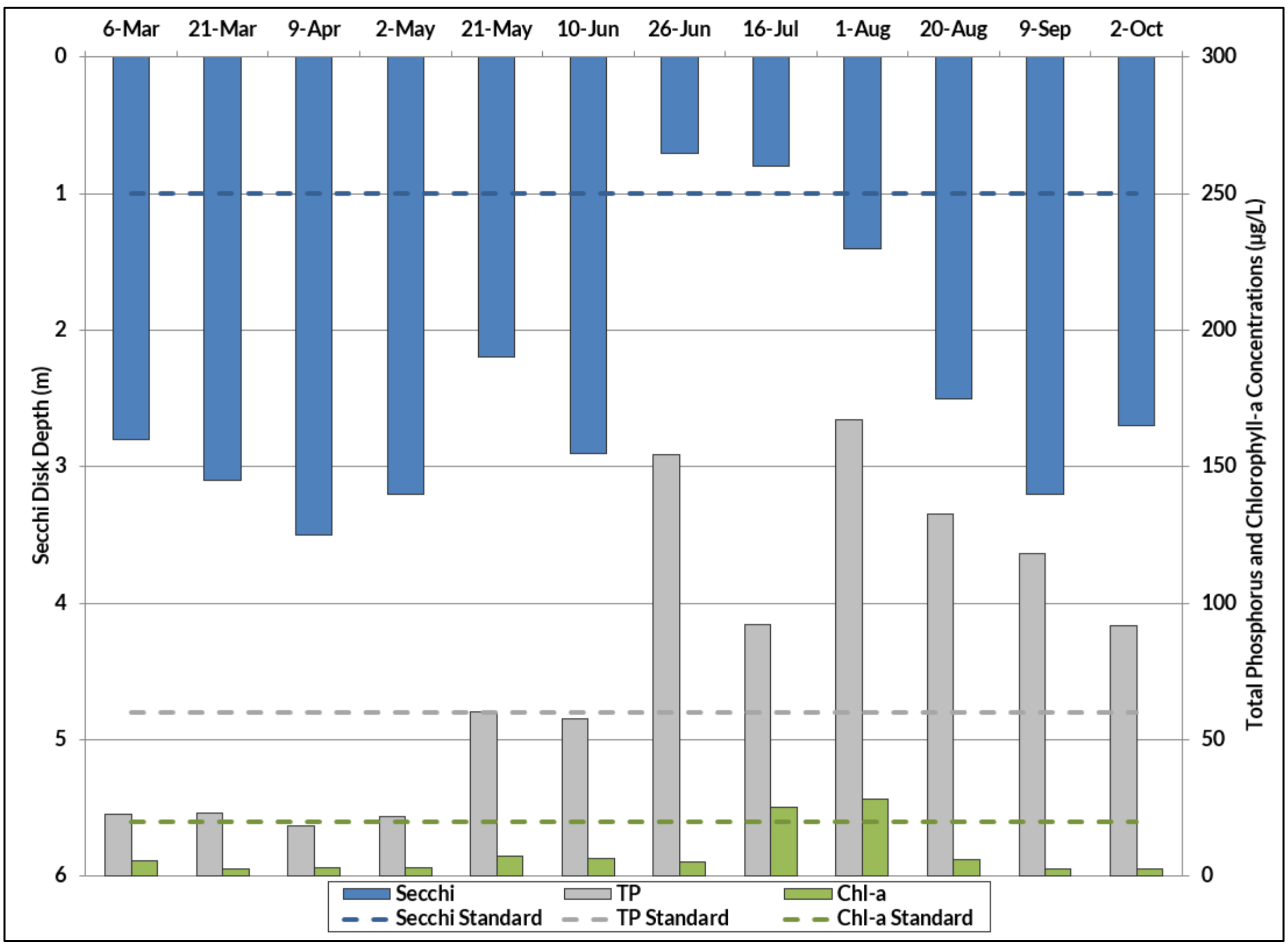

Figure 6: Crosby Lake 2024 daily epilimnetic total phosphorus, chlorophyll-a, and Secchi disk depth

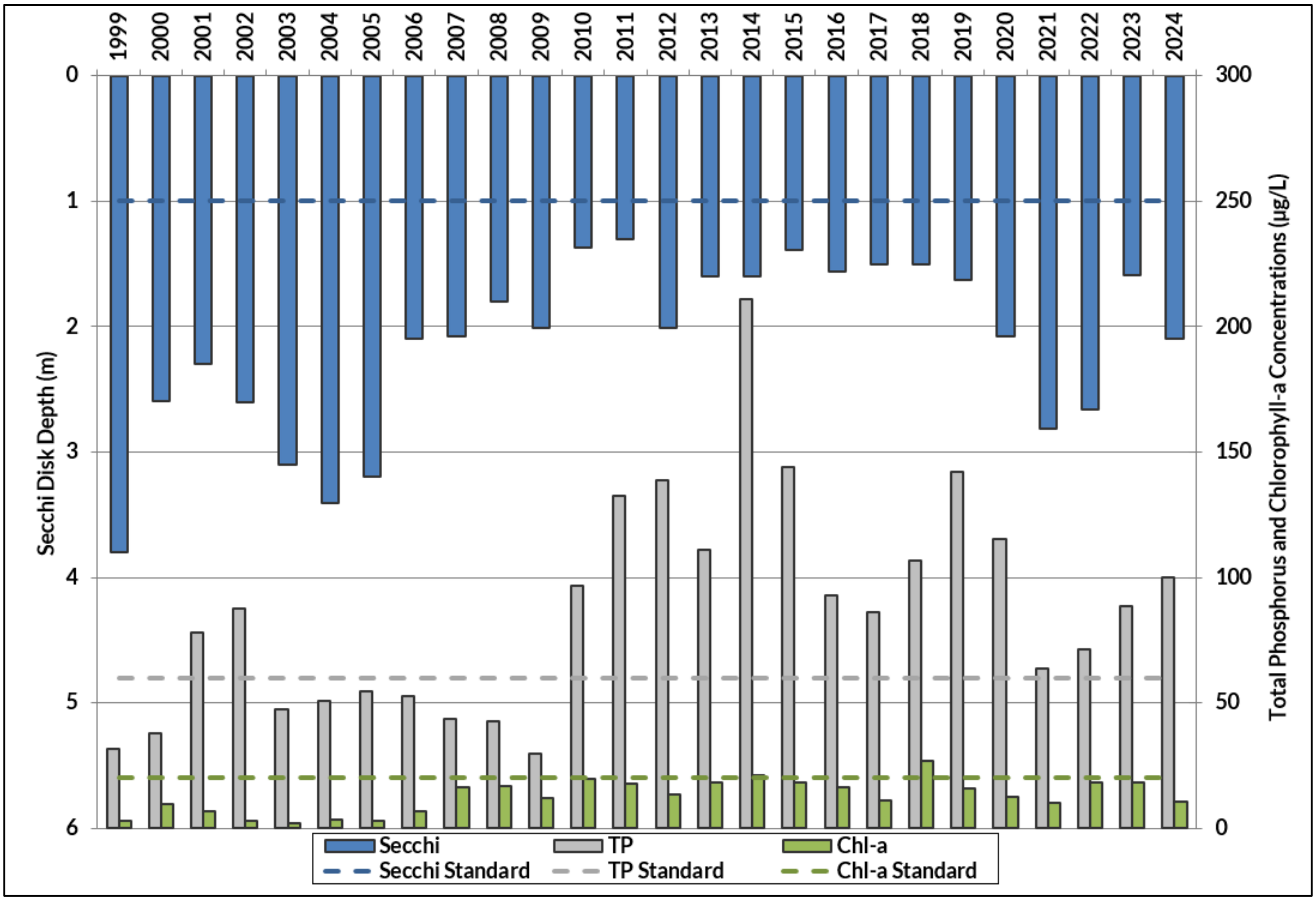

Figure 7: Crosby Lake historical average annual epilimnetic total phosphorus, chlorophyll-a, and Secchi disk depth

3.2.2 2024 Highlight: Lake Elevation

It is not uncommon for Crosby Lake to experience flooding from the Mississippi River, as it did in 2023. Typically, in years where flooding occurs, it happens in the springtime due to snowmelt. In 2024 there was not sufficient upstream snowpack for spring flooding; however, the river did flood in July due to above normal spring precipitation in the upstream watershed, creating an atypical mid-summer rise of nearly 10 feet for Crosby Lake, beginning its rise on 6/22 and returning to typical levels around 7/10 (Figure 8). The effects of this flooding and the influx of nutrients can be seen in Figure 6. TP, Chl-a, and Secchi depth all had some of their poorest quality results of the year during that flooding, and the effects continued on for the remainder of the year, illustrating just how much the river directly impacts the lake.

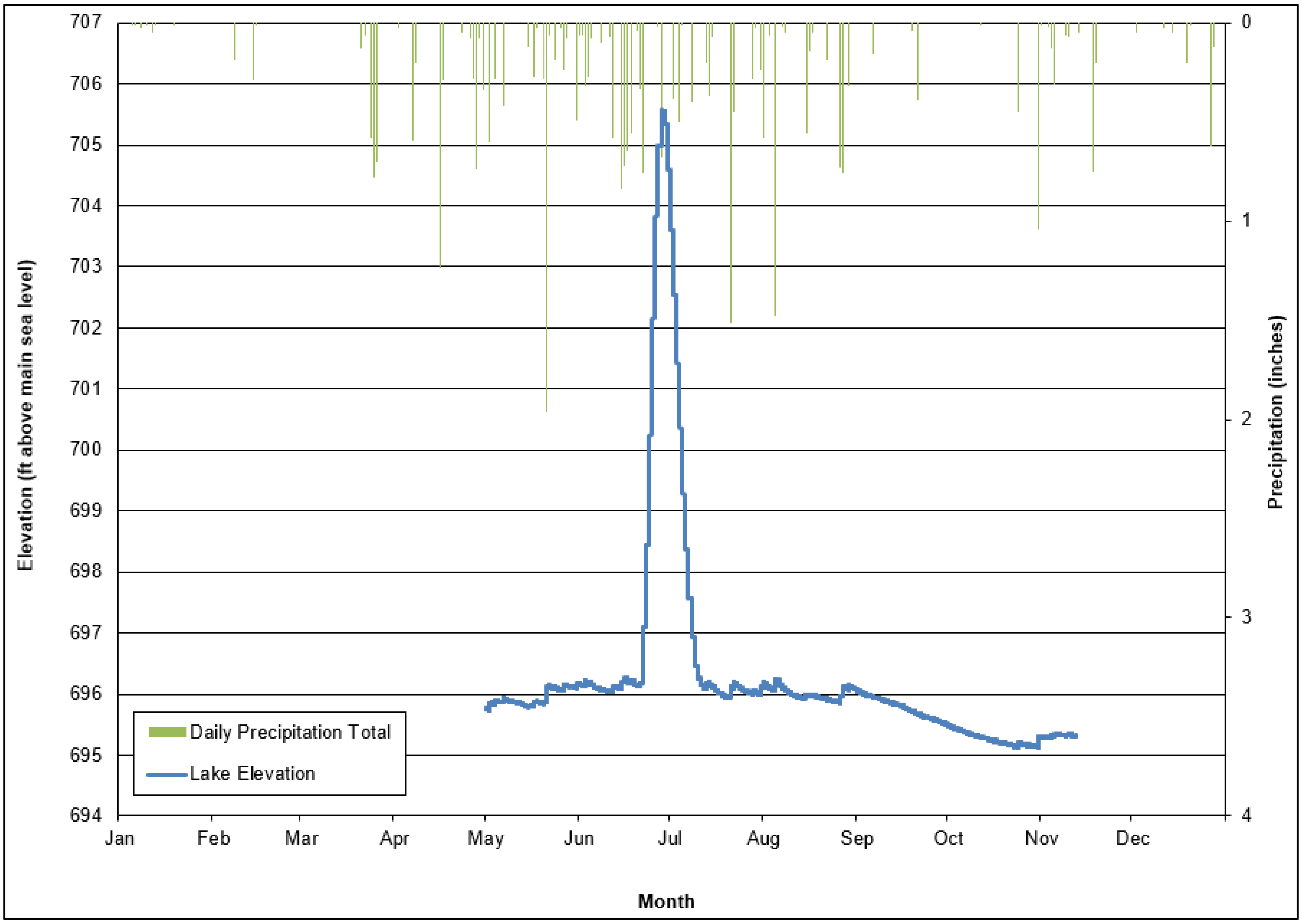

Figure 8: Crosby Lake 2024 elevation

3.3 Little Crosby Lake

3.3.1 Water quality data

Little Crosby Lake had relatively average water quality in 2024 when examining all three of the eutrophication parameters in the long-term, but it fared better than other lakes in some ways. It was the only District lake whose lake grade increased from 2023 to 2024 and the only one whose lake grade was higher than the historical average (Tables 2 & 3). It did not meet the standard for total phosphorus, but did meet the standards for chlorophyll-a and Secchi depth, and it was the only District lake to have improved values for all three eutrophication parameters compared to 2023. Like Crosby Lake, its water quality results correlated strongly with the late June flooding (Figure 9). TP was below state standards from the beginning of the monitoring season until June, which contrasts with 2023, when all TP measurements exceeded the standard. Chl-a also did quite well in 2024, only exceeding the state standard once in July. Overall, the water quality results were fair, doing better than the historical average in terms of Secchi depth and chl-a and slightly worse for TP (Figure 10).

Like Crosby Lake, Little Crosby Lake sits in the floodplain of the Mississippi River, and it experiences the same effects during periods of river flooding (an influx of nutrients, sediment, and aquatic organisms). In 2024 the June 26th monitoring date occurred during the flooding period, and its effects can be seen on that date as well as the rest of the monitoring season.

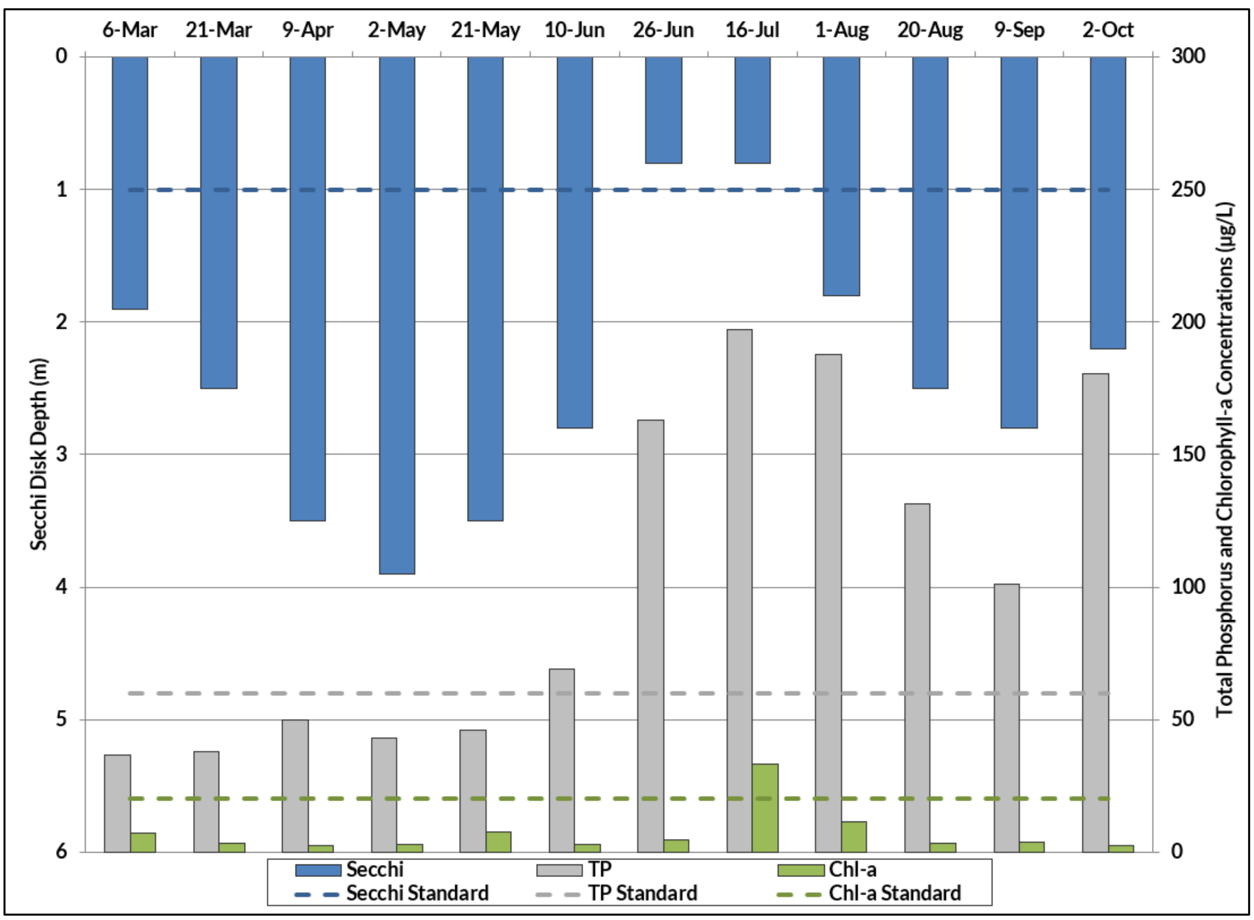

Figure 9: Little Crosby Lake 2024 daily epilimnetic total phosphorus, chlorophyll-a, and Secchi disk depth

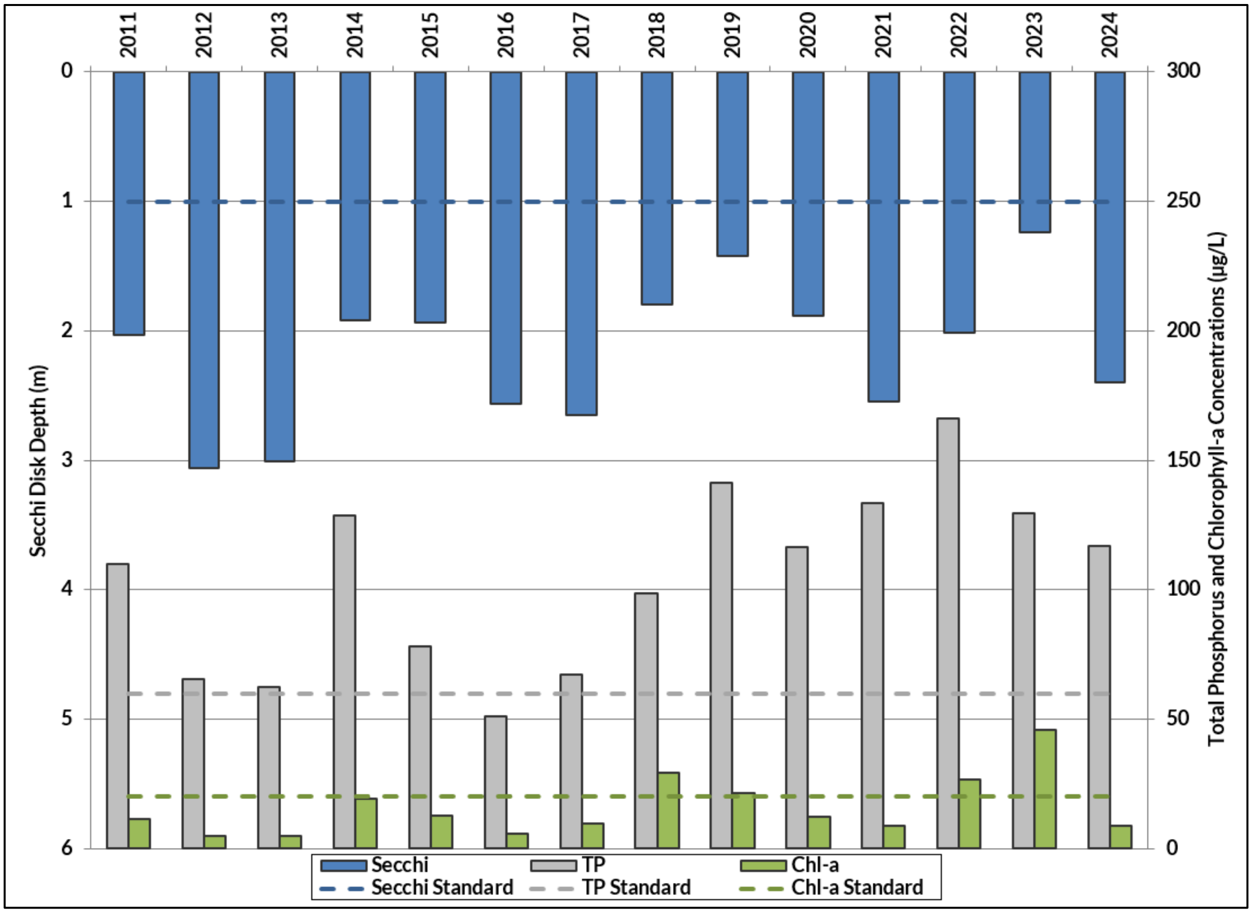

Figure 10: Little Crosby Lake historical average annual epilimnetic total phosphorus, chlorophyll-a, and Secchi disk depth

3.3.2 2024 Highlight: Hypolimnetic Total Phosphorus

Little Crosby Lake has been monitored since 2011 and consistently exhibits high hypolimnetic (i.e. lake bottom) TP (Figure 11). This can be due to many factors, including river flooding. As mentioned in the above section, when the lake experiences flooding from the Mississippi River, nutrients that otherwise would not enter this system can flow in and contribute to excess phosphorus that can negatively affect lake water quality. In 2019 the Mississippi River experienced one of the biggest flooding events in recent years, and there was a large response in hypolimnetic TP in the years following this flooding. Epilimnetic TP has also remained high since this event. Perhaps due to the unusual timing of the 2024 flooding, it did not have a similarly dramatic effect, despite its magnitude. Data in 2025 and beyond will show the impact of this flooding event on lake water quality.

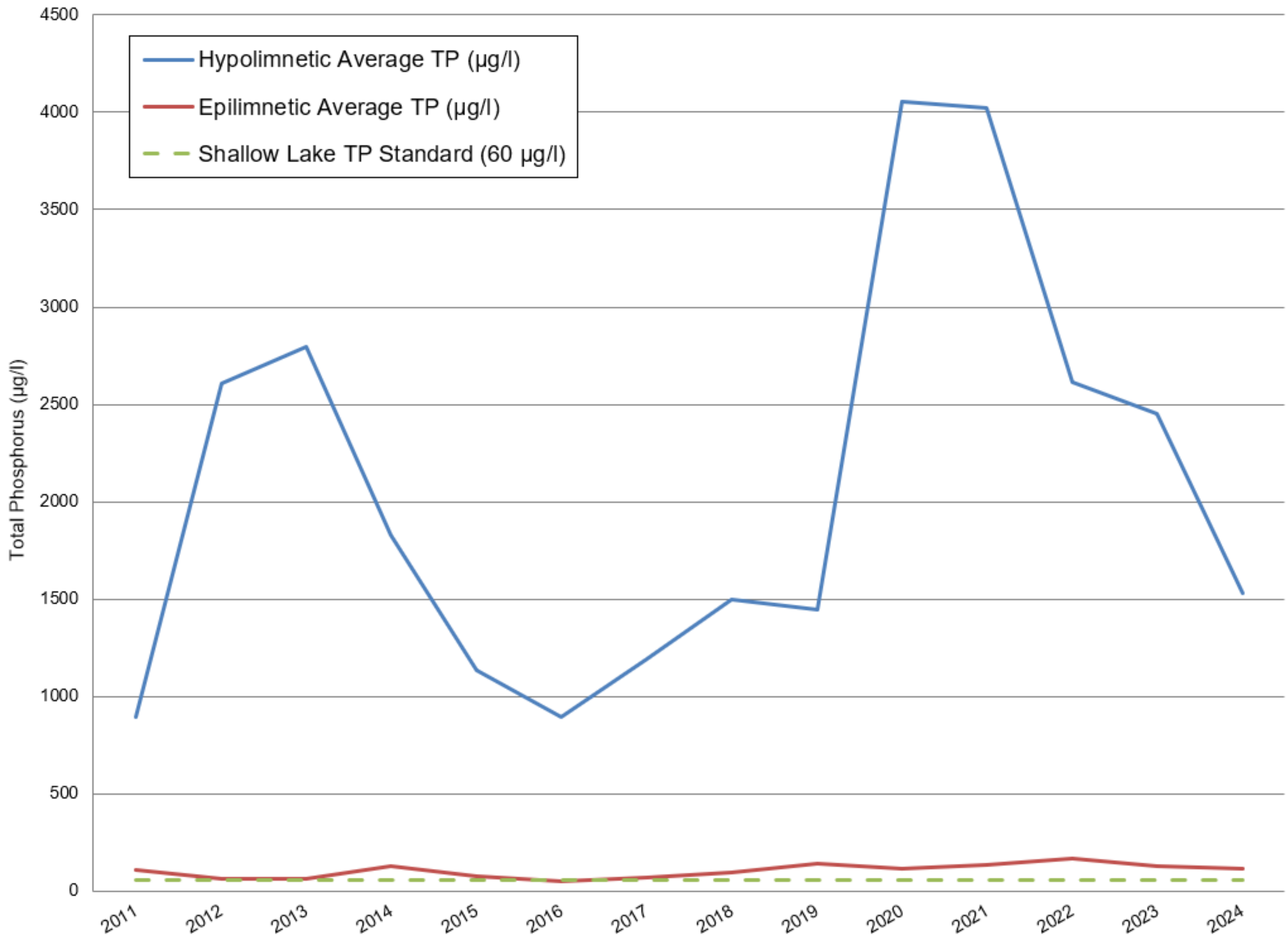

Figure 11: Little Crosby Lake historical average annual hypolimnetic total phosphorus, epilimnetic total phosphorus, and comparison to the deep lake state standard

3.4 Loeb Lake

3.4.1 Water quality data

In 2024 Loeb Lake's grade was lower than the historical average (Table 3), but it still met all state standards and exhibited average water quality. Loeb Lake has much lower stormwater input when compared to Como Lake and Lake McCarrons (both located nearby and in a similar urban setting). Therefore, Loeb Lake tends to have higher water quality (it has met the standards for all eutrophication parameters since monitoring began in 2011), as it is not as impacted by external nutrient runoff (Figure 13). There were only two monitored dates in 2024 where chlorophyll-a was above the state standard (Figure 12) and none where Secchi Disk depth or total phosphorus failed to meet the standard.

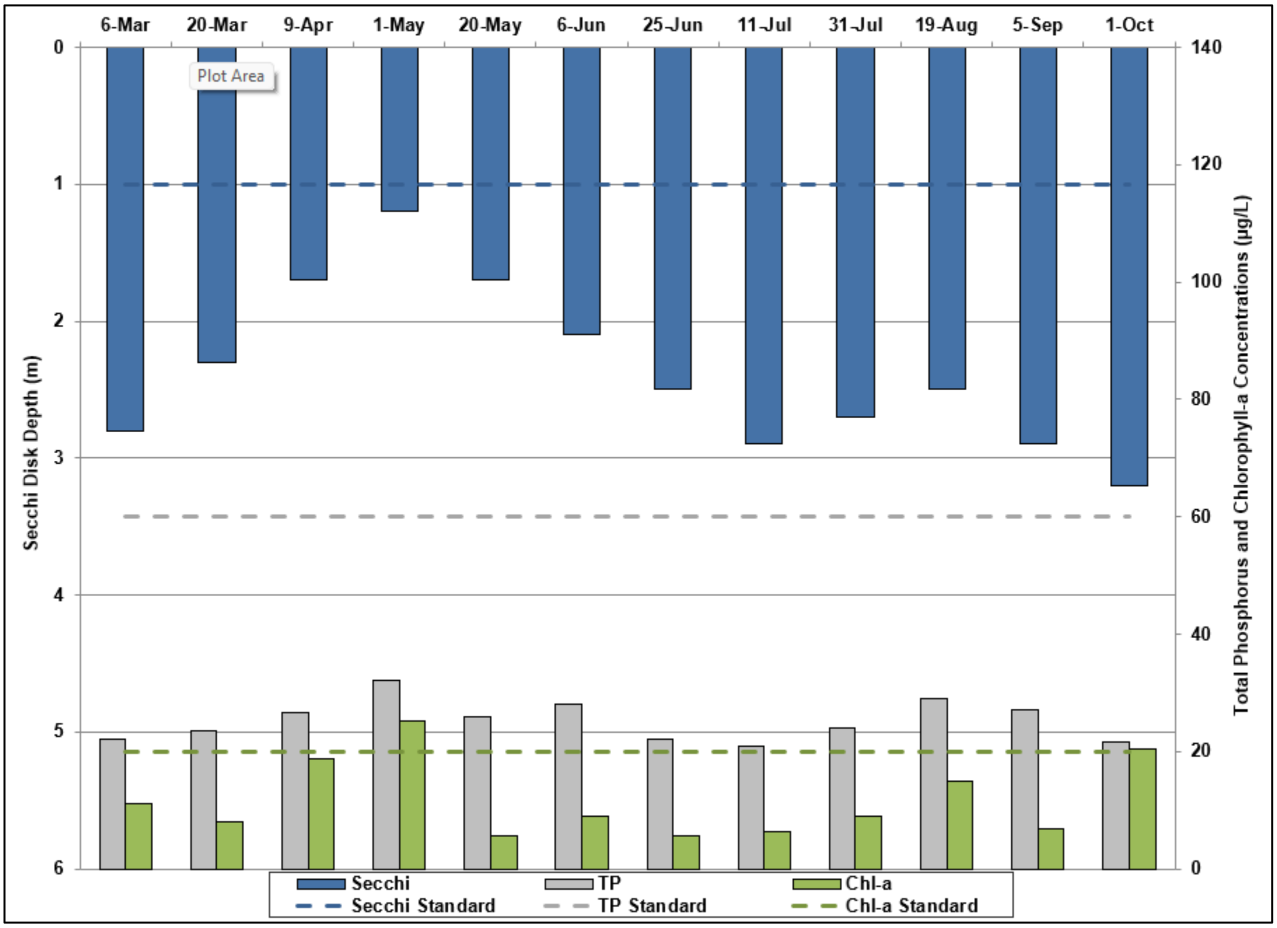

Figure 12: Loeb Lake 2024 daily epilimnetic total phosphorus, chlorophyll-a, and Secchi disk depth

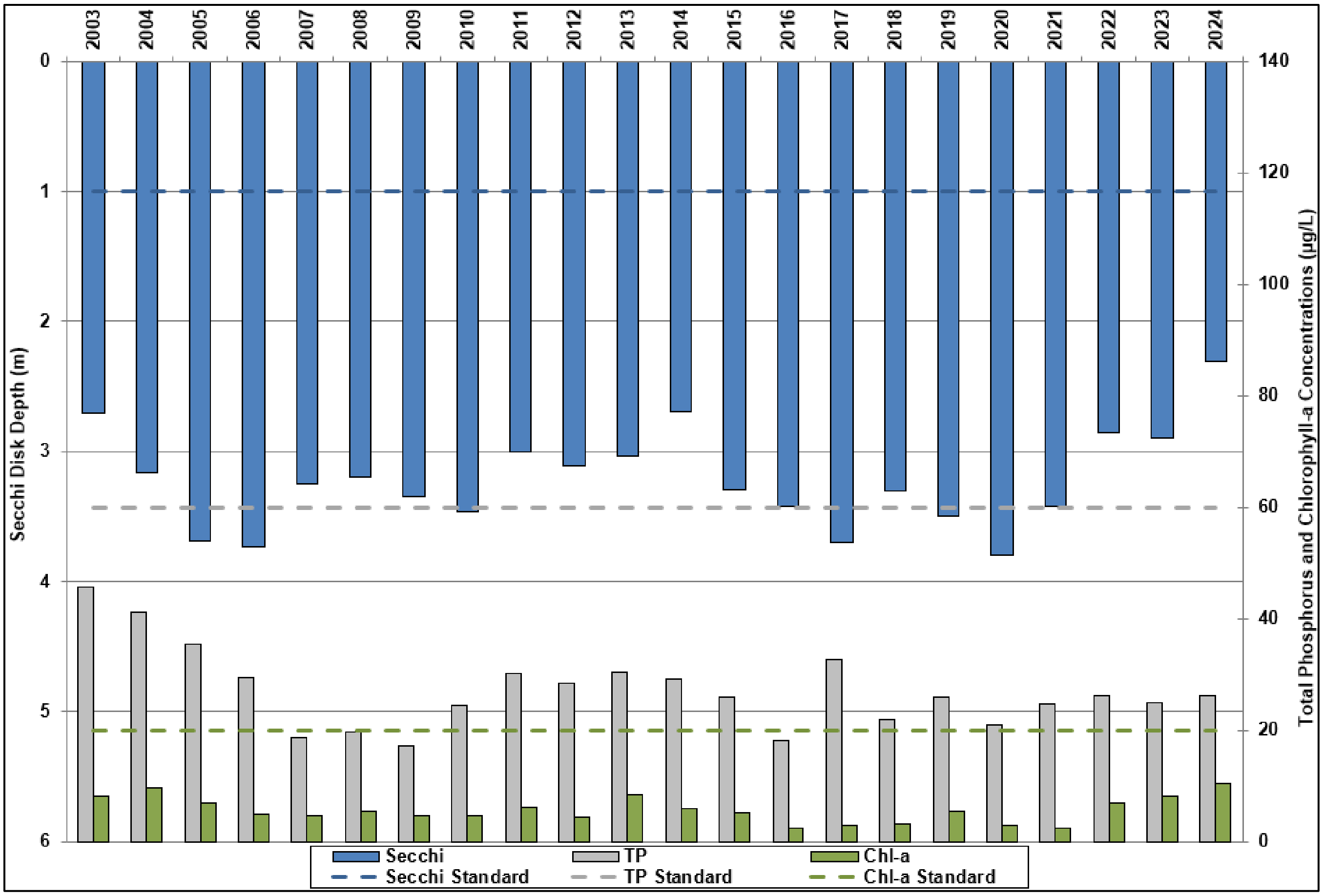

Figure 13: Loeb Lake historical average annual epilimnetic total phosphorus, chlorophyll-a, and Secchi disk depth

3.4.2 2024 Highlight: Aquatic Plants and Prickly Water Lily

During a routine field visit to Loeb Lake in September, District staff noted the presence of an unusual aquatic species along the southern portion of the lake. The plant, which can be seen in Figure 14, was identified by staff and confirmed by the DNR as Prickly Water Lily (*Euryale ferox*). This was the first confirmed occurrence of Prickly Water Lily in Minnesota waters and was classified by the DNR as an unlisted non-native species. Because it is a non-native species and its potential long-term effects on the ecosystem and water quality of Loeb Lake are unknown, the decision was made to remove as much biomass as possible. Because of strong partnerships, a team was able to mobilize quickly, and a removal event was conducted with staff from CRWD, MNDNR, Ramsey County, and the City of Saint Paul on 9/30/2024, only six days after the plant was first spotted.

All accessible biomass was removed, but continued monitoring and removal may be necessary. There were likely some smaller lilies hidden in the cattails that were not removed, and the extent of seeds in the lake is unknown. However, all organizations that conduct monitoring and survey work on the lake are now aware of the species, and smaller removal efforts can be scheduled as needed.

Figure 14: Prickly Water Lily in Loeb Lake (left) and a close-up of the purple, spiked underside (right)

As for the rest of its aquatic plant population, Loeb Lake continued to exhibit a healthy plant community, with eleven different species found during the aquatic plant surveys that occur in June, July, and August (Figure 15). This balanced native plant population continues to do well despite the presence of curly-leaf pondweed (CLP), which has been found in these surveys since 2013 but has not become the dominant plant within the aquatic plant community. This can be due to the bathymetry of the lake as well as consistently low levels of phosphorus and chl-a in the lake, resulting in fewer algae blooms, higher water clarity, and better overall conditions for native plants to thrive throughout the entire year, which is a success story for this lake.

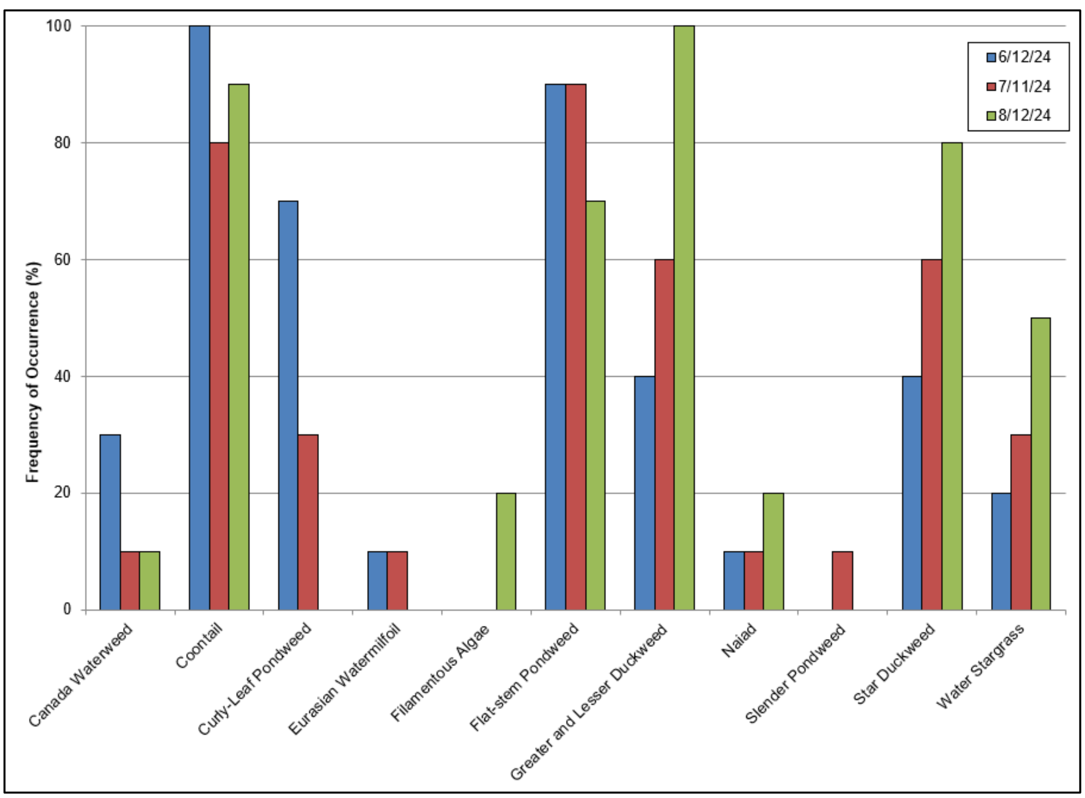

Figure 15: Loeb Lake 2024 aquatic plant frequency of occurrence (%)

3.5 Lake McCarrons

3.5.1 Water quality data

Lake McCarrons had mixed water quality results in 2024. Like Como Lake, it also receives a lot of stormwater input and is affected year-to-year by the climate. In comparison to 2023, total phosphorus and chlorophyll-a increased while Secchi depth decreased, causing the lake grade to decrease as well (Table 2). However, this is all relative, as Lake McCarrons has some of the best water quality of any District lake. A relatively "poor" water quality year for this lake can still show some very good results. As can be seen in Figure 16, TP met state standards for all samples after April, even with heavy summer rain. It also met the standard for Secchi depth for all but one date. In the context of nearly 40 years of historical data and a particularly wet summer season, the lake had decent water quality, even if it was poor relative to other post-alum treatment years (Figure 17).

This lake dataset will continue to be important for making management decisions outlined in the 2020 Lake McCarrons management plan, including evaluating the effectiveness of the 2004 alum treatment over time.

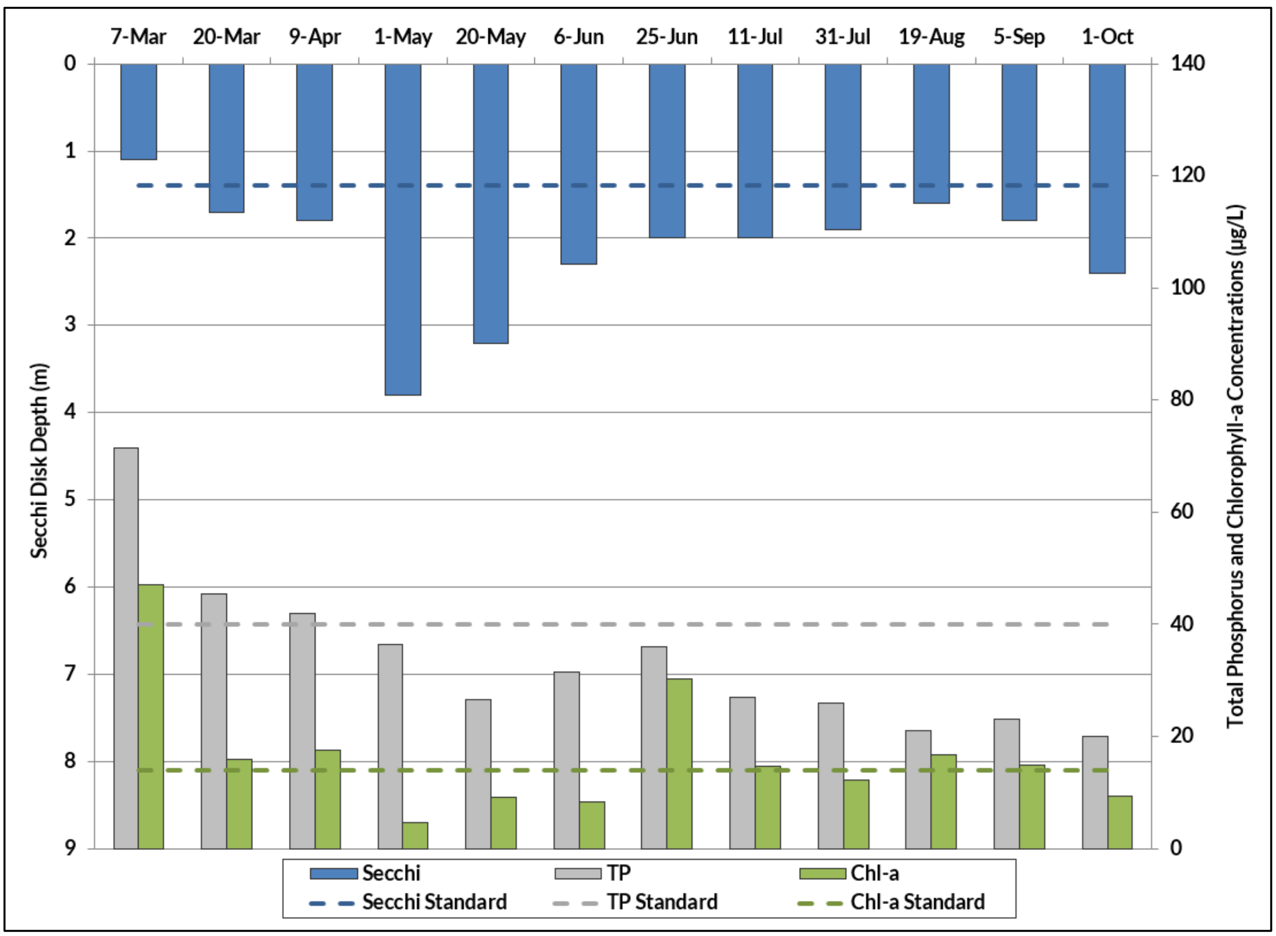

Figure 16: Lake McCarrons 2024 daily epilimnetic total phosphorus, chlorophyll-a, and Secchi disk depth

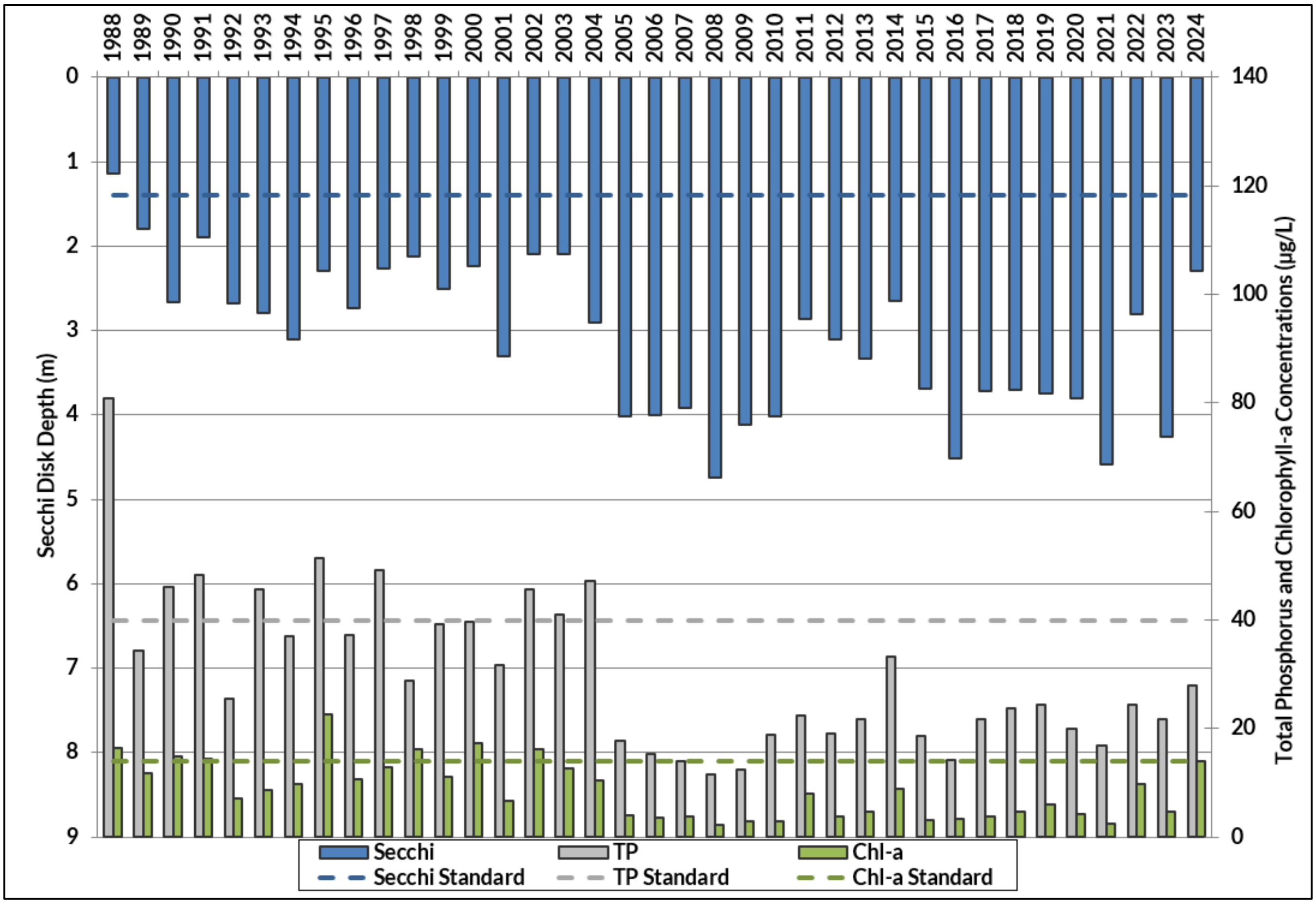

Figure 17: Lake McCarrons historical average annual epilimnetic total phosphorus, chlorophyll-a, and Secchi disk depth

3.5.2 2024 Highlight: Chloride Trends

Chloride, which comes primarily from road salt and makes its way to lakes through snowmelt and stormwater, is an important pollutant to monitor in any lake. In 2024 the seasonal average (April – October) for chloride using both epilimnetic and hypolimnetic data in Lake McCarrons was 133 mg/L, which is well below the chronic state standard of 230 mg/L. This is good news for the lake, as chloride is considered a permanent pollutant, making prevention key.

One important component of pollution prevention is routine monitoring and the analysis of long-term trends. Figure 18 shows the seasonal averages and maximums for each year from 1988 to 2024, which shows that while average chloride has never exceeded the standard, there have been years when maximum values have reached or exceeded that standard of 230 mg/L. Generally, there is a trend upward: all seasonal averages from 2005 to 2024 have been above 100 mg/L, whereas between 1988 and 2004, only one year reached above 100 mg/L. Continued chloride monitoring will be key, alongside education and other prevention strategies, to keep Lake McCarrons from becoming impaired in the future.

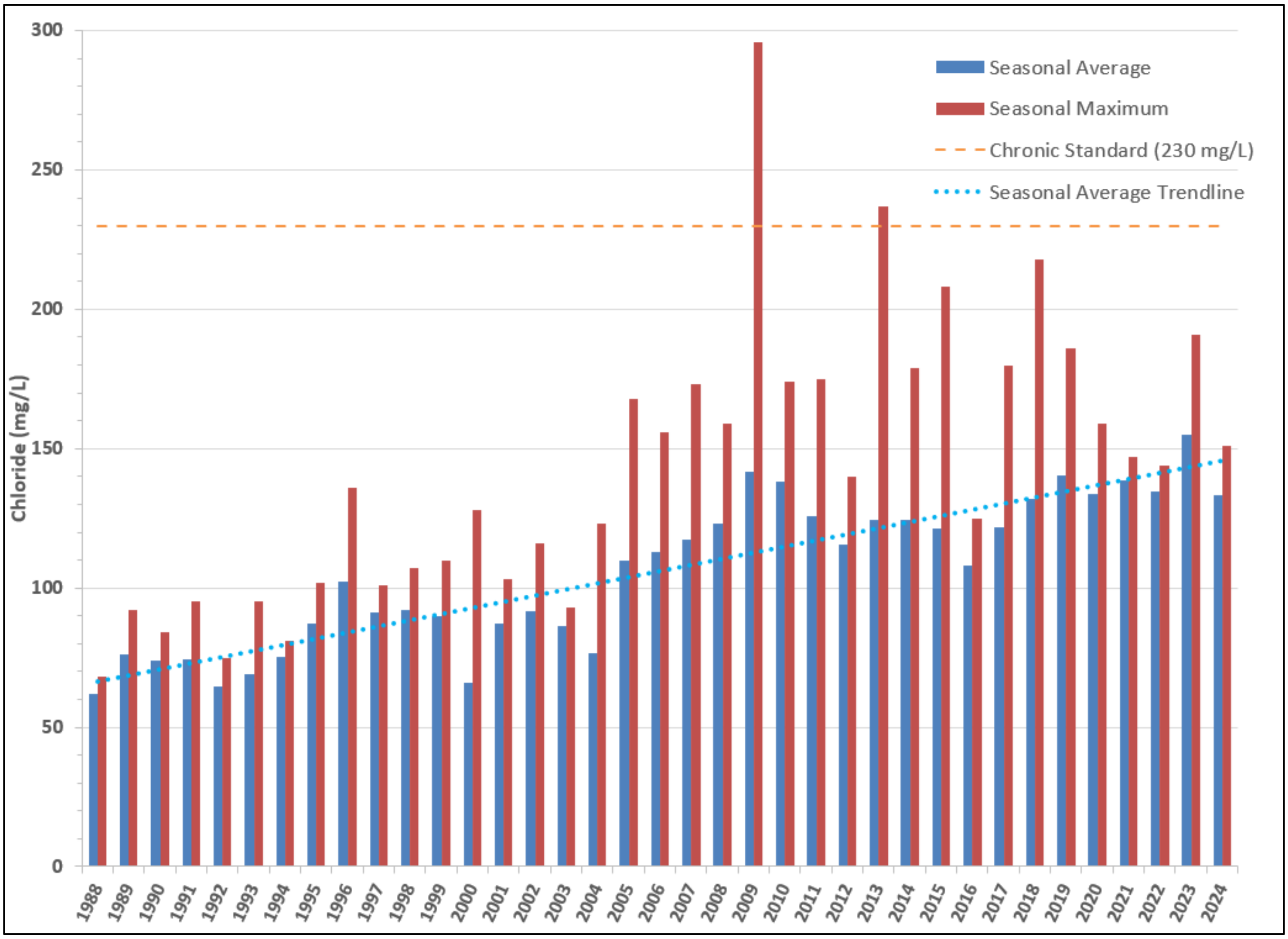

Figure 18: Lake McCarrons historical average and maximum chloride (mg/L) using epilimnetic and hypolimnetic samples for each annual monitoring season (April through October); the state chronic standard is the dashed orange line (230 mg/L) and a trendline for the annual seasonal average is the dotted light blue line

4 Summary

2024 was a climatologically challenging year for District lakes. After several years of drought, the summer of 2024 produced frequent precipitation events of varying intensities, bringing larger loads of nutrients, sediments, and pollutants to the lakes, and raising lakes to higher levels than usual. This led to an overall decline in water quality compared to 2023, but relative to the amount of precipitation received, all District lakes had some successes. In more heavily managed lakes like Como Lake, there is ample evidence that District projects such as the alum treatment, watershed BMPs, and aquatic plant management, helped buffer the effects of a large uptick in stormwater input in 2024.

As climate change continues to create varying extremes, such as warmer winters and earlier springs, drought, and high-intensity precipitation events, District lakes will experience fewer typical or average years. This only further emphasizes the importance of climate resiliency in lake management planning and projects.

In summary, lake monitoring and lake management will continue to be a priority for the District. In 2025 and future years, we will:

- Continue to monitor all five lakes to add to our robust dataset that forms the basis of all future management strategies
- Evaluate actions guided by the 2020 Lake McCarrons Management Plan, including:
    - Carp management
    - Alum treatment effectiveness monitoring
- Continue to implement 2019 Como Lake Management Plan actions, namely:
    - Herbicide treatment to address CLP regrowth
    - Aquatic plant transplanting and monitoring
    - Lakeshore vegetation management and erosion control
    - Watershed BMP construction – McMurray Field

The above goals will continue to make our lakes as resilient as possible in the face of the external impacts impacting all facets of lake health.

Appendix A: CRWD Lake Monitoring and Analysis Methods

1 Monitoring Methods

1.1 Lake level

Lake elevation monitoring is organized by the Minnesota Department of Natural Resources (DNR) Lake Level Minnesota Program (DNR, 2024c). This program coordinates the monitoring by organizations and volunteers to gather weekly data of elevations on lakes throughout the state. Lake levels are measured using staff gages that are placed near the lakeshore in a stable and accessible location. Data on lake levels is collected by Ramsey County staff and provided to the DNR for inclusion in the LakeFinder database that can be accessed online to view historical lake levels for a particular lake (DNR, 2024b). Lake elevation monitoring by the DNR within CRWD occurs on Como Lake, Loeb Lake, and Lake McCarrons (via staff at Ramsey County Public Works (RCPW)).

CRWD has been collecting continuous lake level data since 2014 from early spring to late fall on Como Lake, Crosby Lake, Loeb Lake, and Lake McCarrons. Little Crosby Lake is hydrologically connected to Crosby Lake, and Crosby Lake data can therefore serve as a proxy for Little Crosby Lake. Continuous lake level is measured using Onset HOBO pressure sensors.

As this data continues to be compiled, a lake elevation graph is updated annually to view historical fluctuations in lake levels. The ordinary high water level (OHWL) is one other parameter that is shown on these 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.

1.2 Chemical and physical data collection

Lake water quality data is collected by RCPW throughout the growing season (~April through October), resulting in ~8-10 samples for each year (RCPW, 2009). The initial monitoring day is dependent upon ice out on any given year. At each lake, RCPW staff anchor a watercraft over the deepest part of the lake and monitor for various water quality parameters. The physical and chemical parameters of depth, temperature, dissolved oxygen, conductivity, and pH are 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 (i.e. top, warmer layer), thermocline (i.e. middle/temperature mixing layer), and hypolimnion (i.e. colder, bottom layer) are recorded.

Additionally, at the lake sampling location, water chemistry samples are collected at multiple depths along the profile of the lake. At all lakes, two samples arere obtained within the epilimnion, or mixed water layer at the surface. RCPW staff also identify if thermal stratification (where depths for the divisions between the epilimnion, thermocline, and hypolimnion) can be identified on the day of sample collection. Additional water samples within the thermocline (if present), and within the hypolimnion are also collected, and a bottom sample is collected on every visit. Any water samples collected are then stored and transported back to the lab and analyzed for the following parameters: chlorophyll-a, total phosphorus (TP), soluble reactive phosphorous (SRP) (i.e. ortho phosphorus), total Kjeldahl nitrogen (TKN), nitrate (NO_3), ammonia (NH_3), and chloride ion concentrations (Cl). Historically, these samples were processed by RCPW at the RC lab. Beginning in 2022, RCPW staff contracted with RMB labs to complete sample analysis. Methods between each lab were determined to be similar.

Water transparency, or water clarity, data is determined 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.

1.3 Phytoplankton and zooplankton collection

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

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

1.4 Aquatic vegetation surveys

1.4.1 Point-intercept survey method

All lakes are surveyed by the Soil and Water Conservation Division of Ramsey County (RC) (previously called Ramsey Conservation District) for aquatic vegetation presence and abundance using the point-intercept method. This method consists 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 is thrown out 1 m from the boat, dragged a distance of 1 m and brought back into the boat. Plant species are identified and given an abundance ranking based on the amount collected on the rake. Any plants floating on the water surface are also identified. RC staff survey all CRWD lakes three times throughout the course of the year: spring, summer, and early fall.

Data collected from 2014 – 2018 used an abundance ranking with a 1 – 5 ranking scale (Table 1). Beginning in 2019, Ramsey County staff switched to a 1 – 3 scale for the abundance ranking to make it easier to interpret in the field, resulting in a more accurate representation of abundance (Table 2).

Table 1: Average abundance rating and description for aquatic vegetation (2014 – 2018)

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

Table 2: Average abundance rating and description for aquatic vegetation (2019 – Current)

Percent Cover of Tines	Abundance Ranking
41-100	3
21-40	2
1-20	1

Prior to 2014, aquatic vegetation sampling was conducted by both CRWD and Ramsey Conservation District staff, but not at regular intervals for any of the 5 lakes.

1.4.2 Biovolume survey method

To collect data on submerged aquatic vegetation as well as data about the lake bottom, RC uses 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 is collected is 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 produce information estimating lake area, bathymetry, and lake water volume.

1.5 Fish stocking and surveys

Fish stocking occurs annually through the Minnesota DNR in an effort to improve fishing conditions on select Minnesota lakes. Roughly 25% of Minnesota's 5,400 fishing lakes have a set stocking schedule (DNR, 2024a). Fish are stocked at different life stages depending on the desired effect in the lake. Table 3 describes the different types of fish used for stocking.

Table 3: Minnesota DNR fish stocking size definitions (DNR, 2024a)

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 to aid in fisheries management decisions. Surveys occur more frequently, however, on lakes of higher fishing importance. 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, 2024a). If CRWD requires fish surveys in a year when the DNR is not conducting surveys on the desired lake, CRWD staff hires a consultant to complete this work.

2 Data analysis methods

2.1 Morphometric data

Morphometric data is compiled for each lake. This includes 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.

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 surface water quality standards in lakes for TP, Chl-a, and Secchi depth, which were updated in 2014 (Table 4) (MPCA, 2014). To account for differences in natural trophic state, the standards vary by ecoregion and lake type. In the NCHF ecoregion, a different standard exists for shallow and deep lakes. Annual seasonal means are determined for each of these parameters based on the monitoring events that occur between June and September each year. A lake is considered impaired under MPCA standards if the annual seasonal mean 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.

Table 4: Deep and shallow lake state water quality standards (MPCA, 2014)

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.
*MPCA standard for TP is listed in mg/L, but has been converted to µg/L.

In order to calculate an annual seasonal mean for both TP and Chlorophyll-a (there is only a single value inherently collected for Secchi depth), there needs to be a daily surface value found for each parameter for each monitoring event. In CRWD lakes, there are generally two samples collected within the surface (upper 2 m) of the lake. Where two samples are collected in the upper 2 m of the water column and both of these samples are considered to be in the epilimnion (i.e. the stratification depth on the day the samples were collected was deeper than 2 m), then the average of these values was calculated. If the lake stratified above 2 m, then only samples collected shallower than the stratification depth are used for the daily average. If there was a single sample collected to represent the surface, then this single value is used for the daily value.

To determine the seasonal mean for each parameter, the average of the daily means from May – September was calculated. The MPCA considers the growing season for the state of Minnesota as a whole to be June – September, but the CRWD growing season is generally from May – September. Comparisons to the MPCA state standards need to be made using June – September averages.

2.3 Lake grading system

CRWD uses a lake grading system to give a qualitative measure to the water quality data and compare between years monitored (Table 5). This is based on the lake grading system developed by the Metropolitan Council 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 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 (Johnson, 2014).

CRWD assigns each letter grade a numerical value (A = 5, B = 4, C = 3, D = 2, F = 1), and the average of these three values provide an overall annual lake grade (Table 3-5). The ranges in Table 6 are based off methods used by the Minnehaha Creek Watershed District in their monitoring reports (MCWD, 2015).

Table 5: Water quality parameter lake grade ranges, percentile ranges, and description of lake grade user quality (Johnson, 2014; 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 6: 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

2.4 Phytoplankton and zooplankton lab analysis

All methods for lab analysis of phytoplankton and zooplankton are obtained from Ramsey County Lake Management Laboratory (RCLML), a part of RCPW (RCPW, 2012). In the lab, the preserved phytoplankton sample is analyzed and identity/counts are recorded. The classes/phylums identified are listed and described in Table 7 (Kalff, 2002; UCMP, 2015).

Table 7: Phytoplankton types, taxonomic classification, description, and water quality significance

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 is measured and a subvolume is analyzed for identity/counts. The zooplankton that are identified in this process are shown and described in Table 8 (Kalff, 2002). The Cladocerans identified during analysis consisted of Daphnia, Bosminae, Chydorus, Ceridaphnia, Diaphnosoma, and Leptodora. These genus-level organisms are combined and grouped under the heading 'Cladocera' for analysis.

Table 8: Zooplankton types, taxonomic classification, description, and water quality significance

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

There are two figures for both phytoplankton and zooplankton. The first figure for phytoplankton compares total phytoplankton concentration (divided by type) and TP concentration for all individual visits between April and October. The first figure for zooplankton compares total zooplankton density (divided by type), and Chl-a concentration for all individual visits between April and October. The second figures depict the relative abundance of each type of phytoplankton and zooplankton to examine changes in their populations between individual visits between April and October.

2.5 Aquatic vegetation analysis

2.5.1 Biovolume analysis

Sonar data is entered into CI BioBase software that generates aquatic vegetation and bathymetric maps (CIBB, 2015). The biovolume heat maps are 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 include 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).

2.5.2 Point-intercept analysis

Aquatic vegetation has been monitored infrequently in past years on CRWD lakes. Establishing a baseline of vegetation data for all lakes is a key factor in making management 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 allows for two primary analyses to occur: computation of frequency of occurrence and average abundance. Previously, Ramsey County staff used “Percent occurrence” to describe plant cover in a lake. Percent occurrence represents the number of times a plant species was observed divided by the number of total sample sites where vegetation was observed. In 2022, Ramsey County staff switched to using the method “Frequency of occurrence” to be more consistent with DNR standards. Frequency of occurrence is the number of times a plant species was observed within the littoral zone divided by the total number of sample points within the littoral zone. Therefore, while most plants in CRWD lakes are found within the littoral zone, caution should be used when comparing data before and after this switch in 2022, since pre-2022 data calculations use all sample points in the lake to calculate the occurrence, where 2022 and future data calculations use only the littoral zone sample points.

Average abundance is calculated as the average of the abundance rankings (measured at each location found) for a species on each sample date. 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.

3 References

CI BioBase, (CIBB), 2015. Frequently Asked Questions. Contour Innovations. Accessed online from http://cibiobase.com/Home/FAQ

Kalff, Jacob. 2002. Limnology. Upper Saddle River, NJ: Prentice Hall.

Johnson, B., 2014. 2012 Study of Water Quality of 168 Metropolitan Area Lakes. Metropolitan Council. Saint Paul, MN.

Minneapolis Parks and Recreation Board (MPRB), 2015. 2012 Water Resources Report. Minneapolis, MN. Accessed online from https://www.minneapolisparks.org/_asset/30kcfb/water_resources_report_2012.pdf

Minnehaha Creek Watershed District (MCWD), 2015. Water Quality Technical Report - 2014. Minnetonka, MN.

Minnesota Department of Natural Resources (DNR), 2024a. Fisheries Lake Surveys. Saint Paul, MN. Accessed online from http://www.dnr.state.mn.us/lakefind/surveys.html

Minnesota Department of Natural Resources (DNR), 2024b. Lake Finder. Saint Paul, MN. Accessed online from http://www.dnr.state.mn.us/lakefind/index.html

Minnesota Department of Natural Resources (DNR), 2024c. Lake Level Minnesota. Saint Paul, MN. Accessed online from http://www.dnr.state.mn.us/climate/waterlevels/lakes/index.html

Minnesota Pollution Control Agency (MPCA), 2014. Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 305(b) Report and 303(d) List. Saint Paul, MN. Accessed online from https://www.pca.state.mn.us/sites/default/files/wq-iw1-04l.pdf

Osgood, R.A., 1989. An Evaluation of Lake and Stream Monitoring Programs in the Twin Cities Metropolitan Area. Metropolitan Council Publ. 590-89-128.

Ramsey County Public Works (RCPW), 2012. Quality Assurance and Procedures Manual for the Ramsey County Lake Management Laboratory. Arden Hills, MN.

Ramsey County Public Works (RCPW), 2009. Ramsey County Lake Management Program 2009 Lake Sampling Protocol. Arden Hills, MN.

Scherek, J. and G. Yakal. (1993). Guidelines for Ordinary High Water Level (OHWL) Determinations. Saint Paul, MN. (Technical Paper 11, Minnesota Department of Natural Resources, Waters).

University of California Museum of Paleontology (UCMP), 2015. Taxon Lift. Berkeley, CA. Accessed online from: http://www.ucmp.berkeley.edu/help/taxaform.html