CRWD 2023 Lakes Data Summary

February 22, 2024

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Saint Paul, Minnesota

Cover image: Como Lake, [CRWD Staff]

Contents

1 Background

1.1 Report Purpose

The *CRWD 2023 Lakes Data Summary* presents a subset of the 2023 Capitol Region Watershed District (CRWD or District) lakes monitoring data and includes data collection methods, overall results and lake-specific results from the 2023 monitoring season (April through October), 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 2023 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).

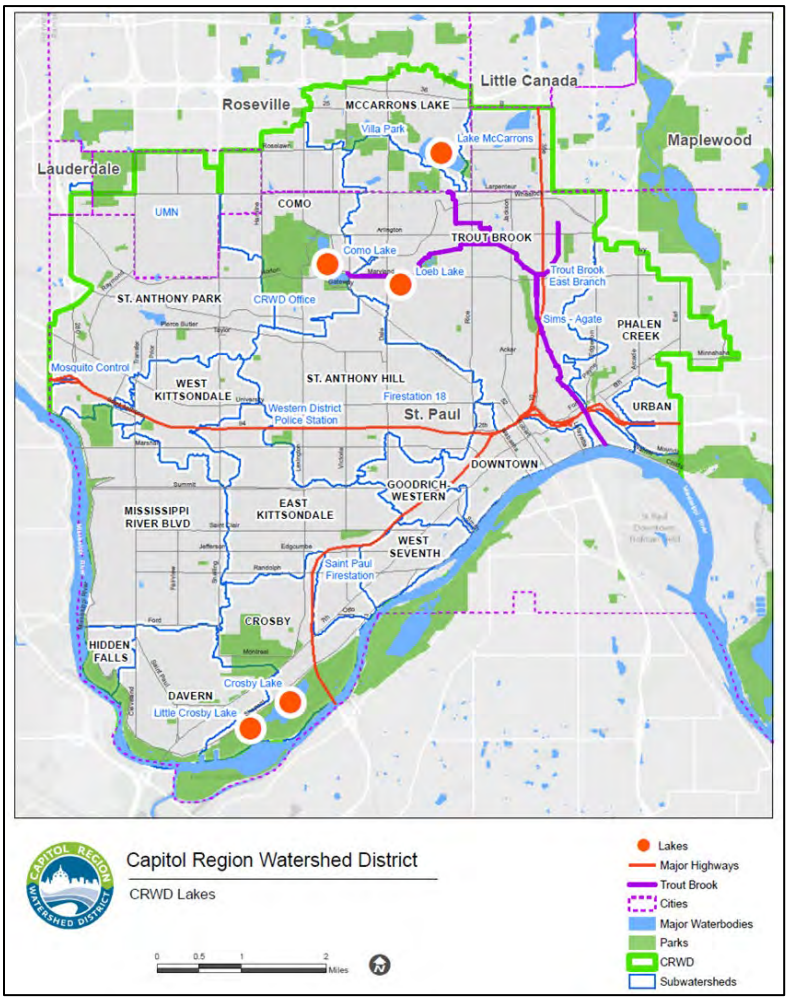

Figure 1: Map of CRWD Lakes

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 (1998), nutrients (2002), and chloride impairments (2014).

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 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. The lake is considered unimpaired and is not currently listed on the MPCA 303(d) list of impaired waters.

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 2023 lake water quality data

2023 was generally a good year for District lakes in comparison to the 2022 monitoring year, the historical record for each lake, and the state standards. 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 2023 data to the MPCA state water quality standards for the three eutrophication parameters (total phosphorus, chlorophyll-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 2022 monitoring years

When comparing 2023 lake grades to 2022 lake grades in Table 2, Crosby Lake showed a slight decrease (red arrow), Loeb Lake stayed the same (yellow arrow), and Como Lake, Crosby Lake, and Lake McCarrons all increased in grade level (green arrow). Two factors that played important roles in lake health in 2023 were the large snowpack in the winter of 2022-2023 and the above average precipitation in 2023. These two factors combined to bring lake elevation back to more normal levels for District lakes.

Table 2: 2022 and 2023 lake grade comparison for all District lakes

Lake	2022 Lake Grade		2023 Lake Grade
Como Lake	D	→	C
Crosby Lake	C+	→	C
Little Crosby Lake	D+	→	C
Loeb Lake	B+	→	B+
Lake McCarrons	B+	→	A

2.2 Comparison between 2023 and historical monitoring

When comparing 2023 lake grades to historical lake grades (which is calculated using the range of annual lake grades from 2022 to when monitoring began for each lake), Table 3 shows that Crosby, Little Crosby, and Loeb Lakes decreased, Lake McCarrons stayed the same, and Como Lake increased in grade level. 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 2023 grade for all District lakes

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

2.3 Comparison of 2023 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 yellow smile indicates that the lake met the standard and a red "x" indicates that it did not meet the standard. Based on these results for 2023, Crosby and Little Crosby Lakes would be considered impaired, while Como Lake, Loeb Lake, and Lake McCarrons would not be considered impaired. Note: Como Lake, which is currently identified as impaired on the State's 303(d) list if impaired waters, was not "delisted" in 2023. To "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 2023

3.1 Como Lake

3.1.1 Water quality data

In 2023 Como Lake exhibited some of the best overall water quality in comparison to the last 20 years of monitoring. The annual average epilimnetic total phosphorus value was the lowest it has been since monitoring began in 1984 (Figure 3) and met the State eutrophication standards for the first time on record (Table 4). It also had very deep Secchi disk readings observed in both the spring and fall, indicating that water clarity was very good in 2023 as well (Figure 2). As a shallow lake, external climatic factors can greatly influence the water quality in any given year. However, many science-based, data-driven strategic management strategies have had a large impact on Como lake's quality, especially since the development of the 2019 Como Lake Management Plan. These projects have shown great success in reducing phosphorus in the lake over time, resulting in such high water quality in 2023.

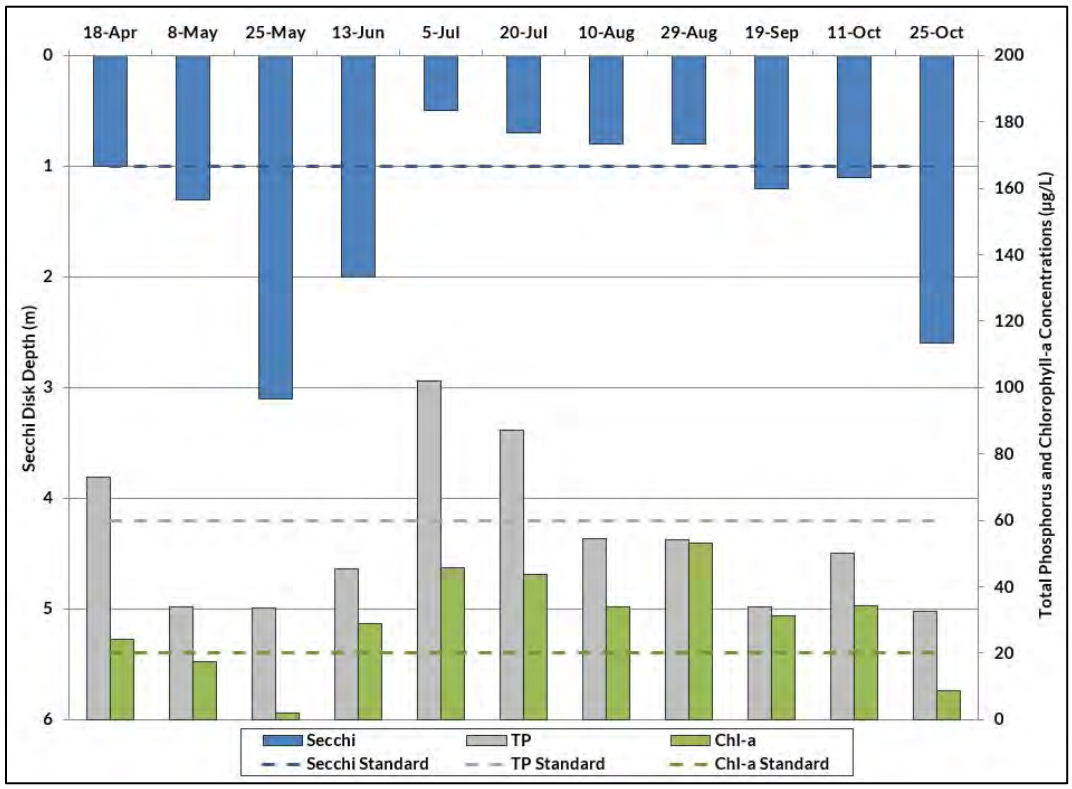

Figure 2: Como Lake 2023 daily epilimnetic total phosphorus, chlorophyll-a, and Secchi disk depth

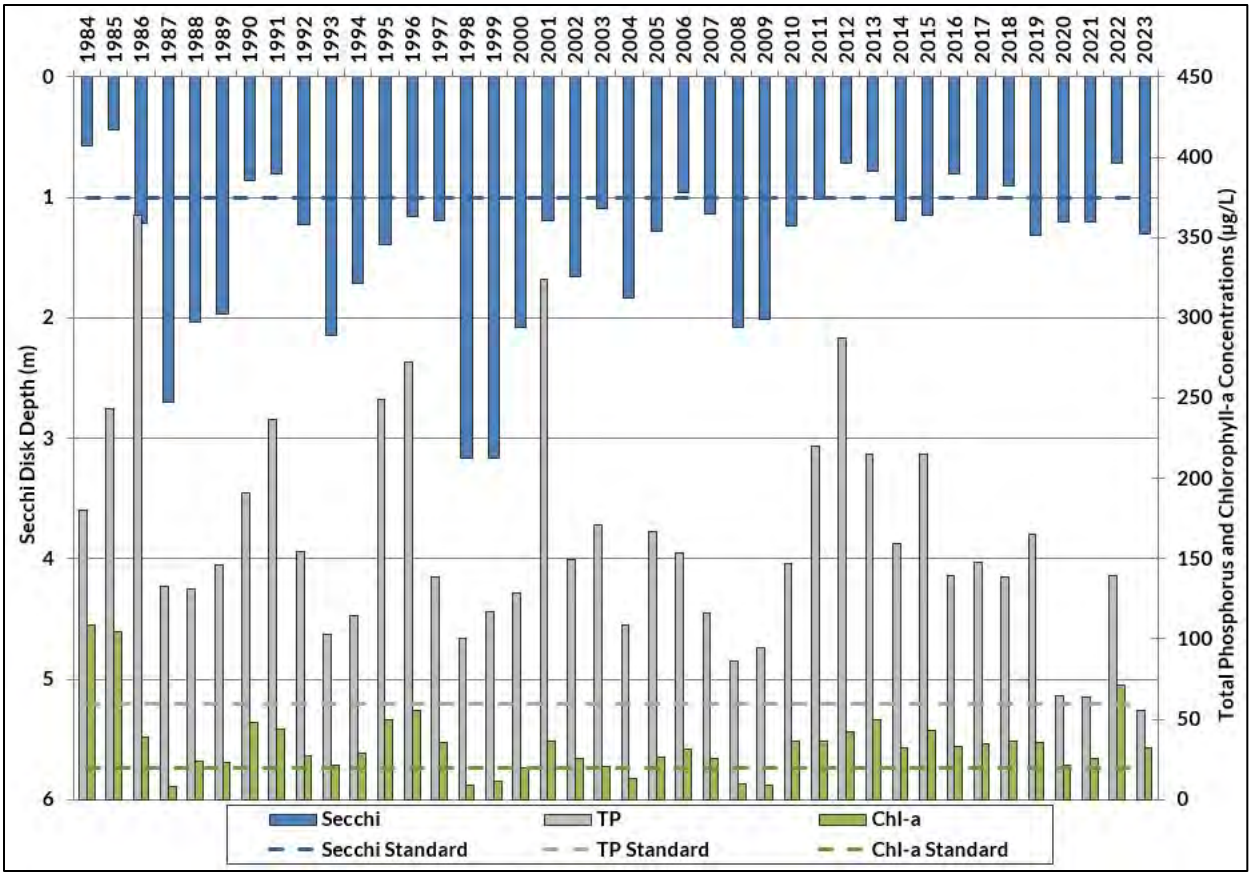

Figure 3: Como Lake historical average annual epilimnetic total phosphorus, chlorophyll-a, and Secchi disk depth

3.1.2 2023 highlight: Aquatic plants

There have been many projects affecting aquatic plants in Como since the 2019 Como Lake Management Plan laid out strategic actions for management. These actions aimed to reduce the density of curly-leaf pondweed (CLP) and increase the number and abundance of native plants in the lake. An invasive, non-native plant, CLP can take over the plant community in a lake and dies off in summer, providing a large input of nutrients to the system when the lake is already primed for algae blooms. Herbicide treatments in 2020 and 2021 greatly reduced the amount of CLP but also resulted in a lack of native aquatic plants growing in the lake. This was likely due to a combination of seedbank degradation in the lake over time, long-term CLP impacts on the native plant community, and some interaction of the herbicide with the native plants.

With the goal of restoring the native aquatic plant community in Como Lake to achieve many of the benefits provided by them, CRWD implemented a vegetation reestablishment project in 2021-2023. CRWD worked with partners to transplant live native aquatic plants from a donor lake to Como Lake into four fenced enclosures. Live plant cuttings were also dispersed to many areas of the lake. This not only increased the total number of native plants observed (Table 5) but also the overall plant biomass in the lake (Figure 4). Native plants play an important role in lake health by storing phosphorus within their biomass the entire summer, providing good habitat for other lake organisms, stabilizing the lake bottom, and increasing dissolved oxygen. Therefore, a robust native plant population in Como Lake will continue to be a key part of the measure of overall health of the lake.

Table 5: Como Lake 2022 and 2023 vegetation enclosure monitoring results

2022 & 2023 Totals (Enclosures 1-4)	2022 Stem Count Totals (Enclosures 1-4)	2023 Stem Count Totals (Enclosures 1-4)
Total # Native Species Observed	8 →	12*
Total # Plants Observed	304 →	958

**3 species observed that were not transplanted into enclosures*

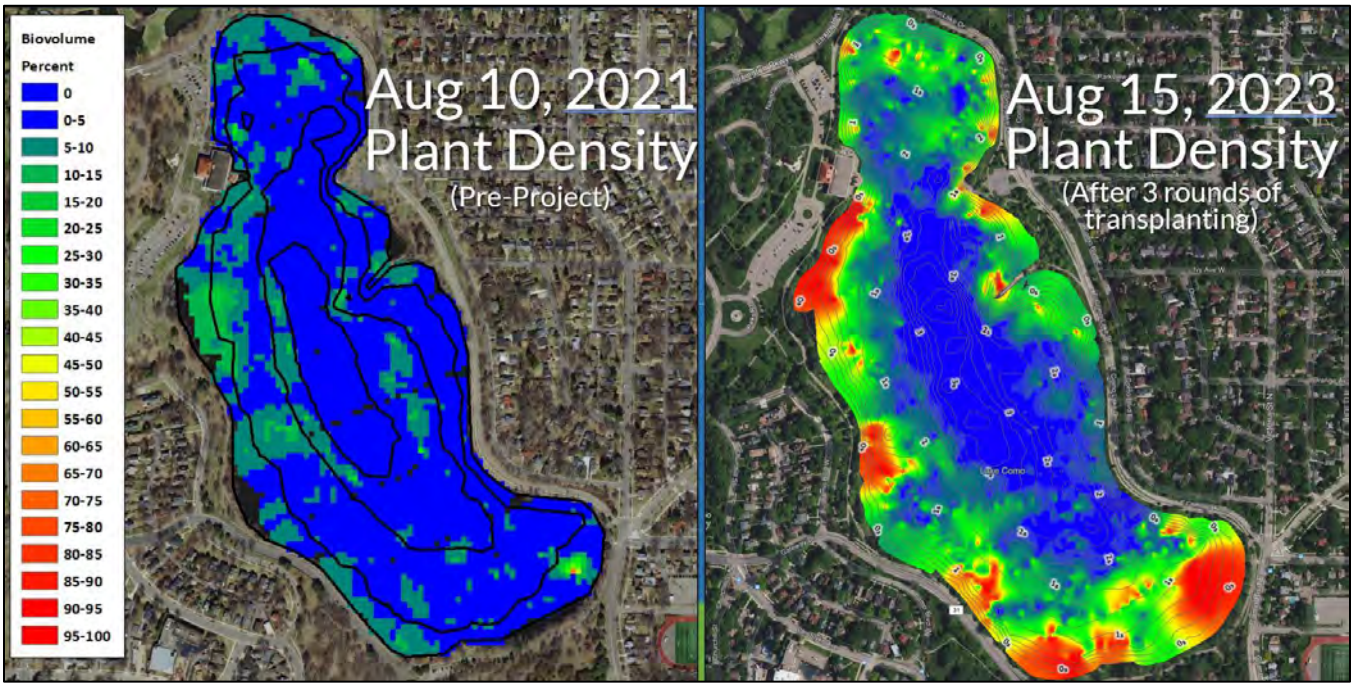

Figure 4: Aquatic plant biovolume comparison between August 10, 2021 (Pre-Project) and August 2023 (After 3 rounds of transplanting)

3.2 Crosby Lake

3.2.1 Water quality data

Crosby Lake had average water quality in 2023 when examining all three of the eutrophication parameters. The overall lake grade slightly decreased between 2022 and 2023 and was slightly below the historical average lake grade (Tables 2 & 3). Late spring/early summer of 2023 exhibited relatively high total phosphorus levels, whereas the remainder of the year (late July through October) showed more consistent water quality (Figure 5). Historically, Crosby Lake has had periods of better water quality, but in the last 14 years has had much higher annual average total phosphorus and chlorophyll-a values and less deep Secchi disk depth measurements (Figure 6).

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 2023 the April monitoring date occurred during the flooding period, so this is indicative of how much of an impact river flooding can have (Figure 5).

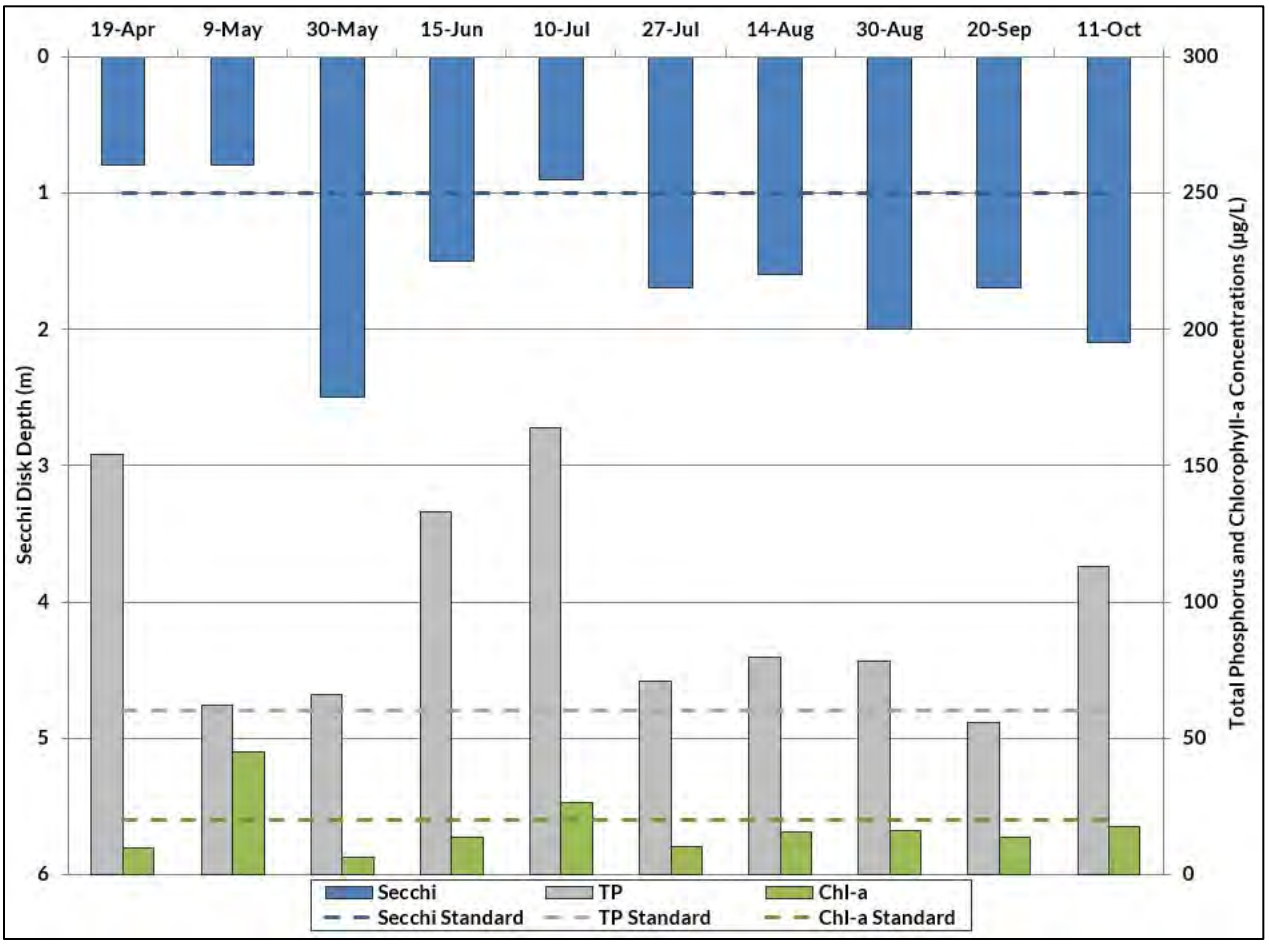

Figure 5: Crosby Lake 2023 daily epilimnetic total phosphorus, chlorophyll-a, and Secchi disk depth

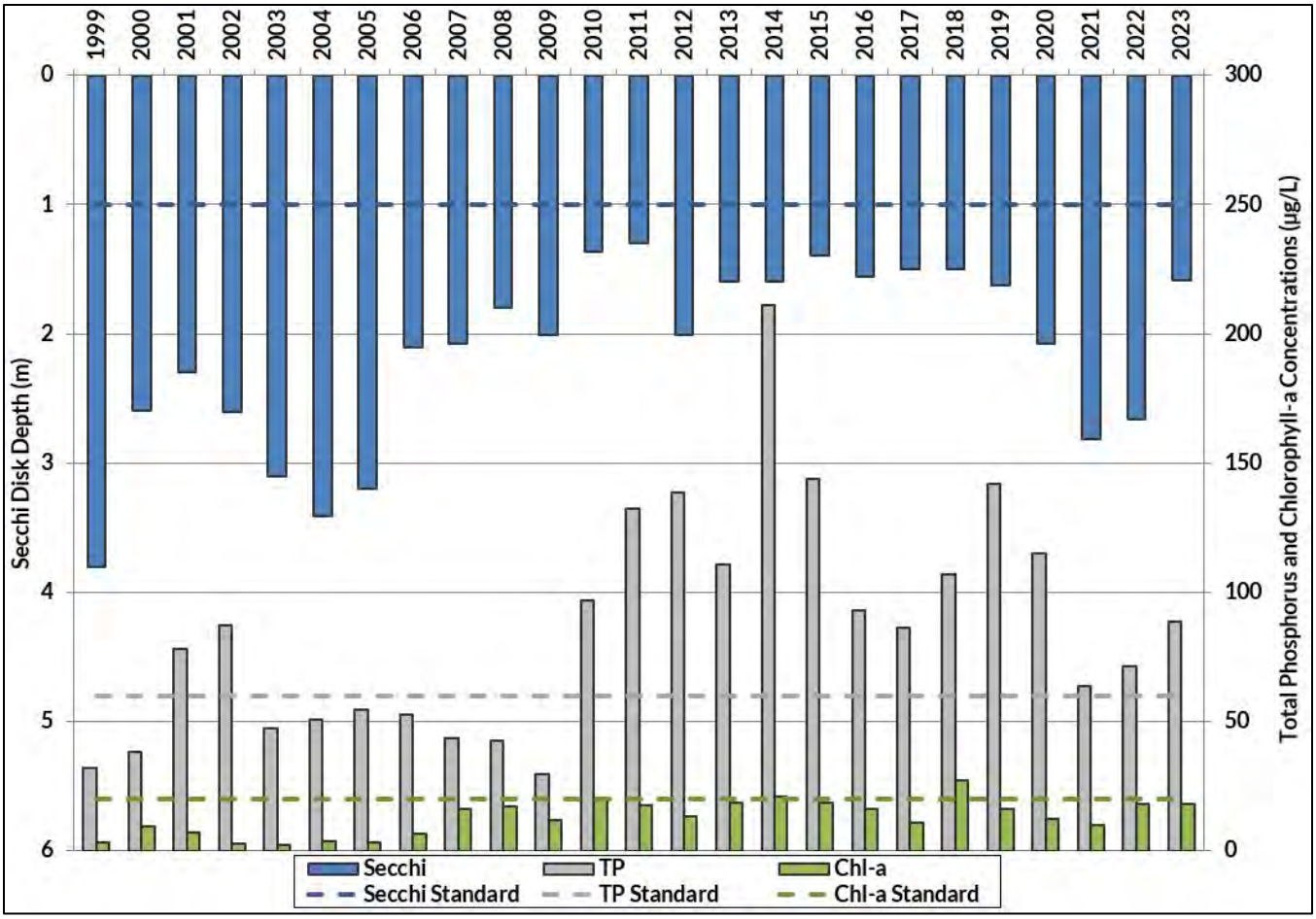

Figure 6: Crosby Lake historical average annual epilimnetic total phosphorus, chlorophyll-a, and Secchi disk depth

3.2.2 2023 highlight: Lake elevation

In 2023 Crosby Lake was affected by flooding from the Mississippi River. Figure 7 shows the lake elevation change from mid-April, when monitoring staff installed level monitoring equipment in the lake, to early November, when this equipment was removed. Because staff were able to capitalize on the short window between when ice went out on the lake in early April and when flooding began to occur in mid-April, we were able to view the extreme elevation change this lake has during periods of flooding. The lake rose almost 7.5 ft over 10 days during this flooding period, and this impacts the lake for the rest of the year and into the future.

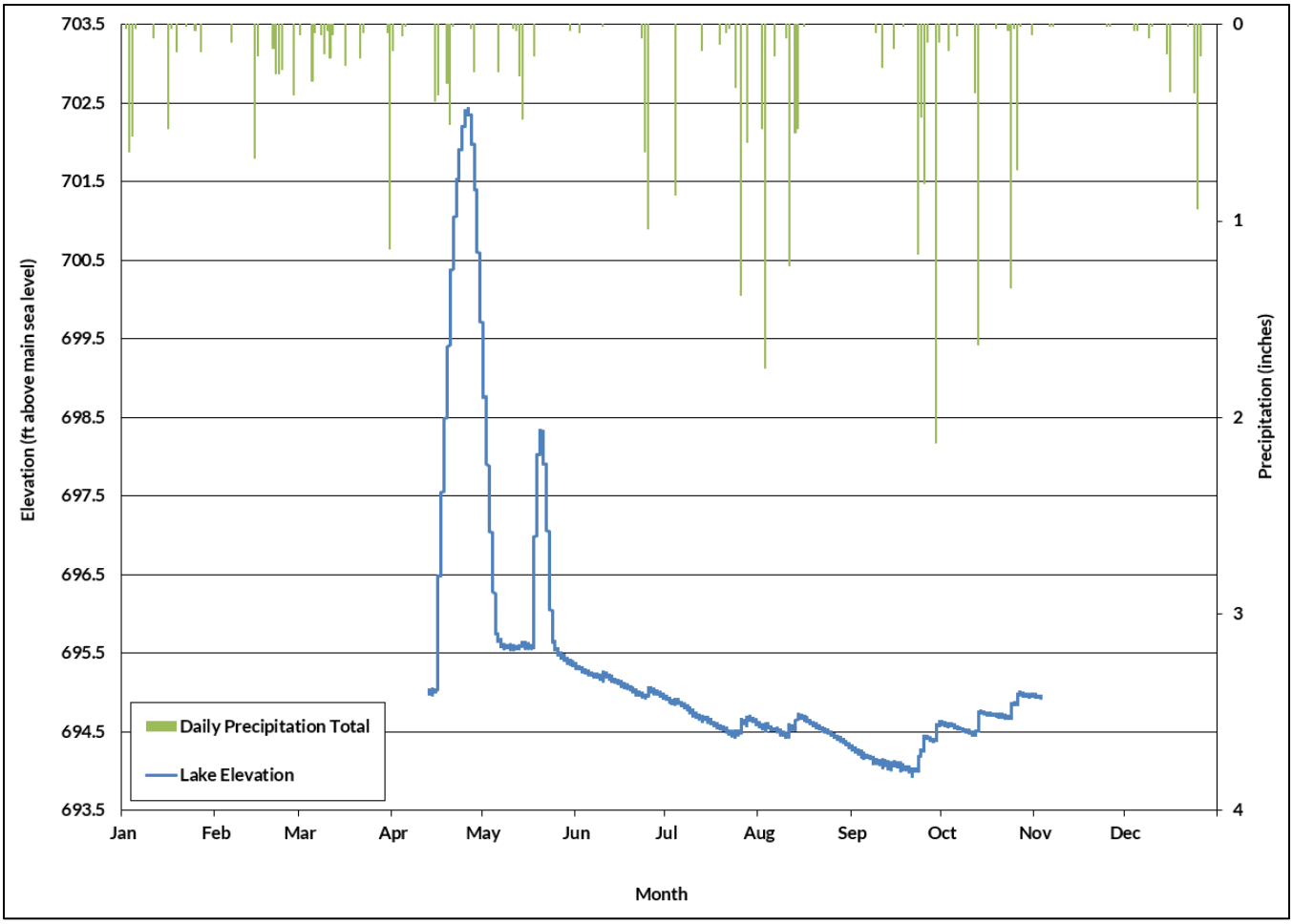

Figure 7: Crosby Lake 2023 elevation

3.3 Little Crosby Lake

3.3.1 Water quality data

Little Crosby Lake had average water quality in 2023 when examining all three of the eutrophication parameters. The overall lake grade increased between 2022 and 2023 but was slightly below the historical average lake grade (Tables 2 & 3). It did not meet the standard for total phosphorus or for chlorophyll-a and was therefore considered impaired for the 2023 monitoring year. Total phosphorus was higher in the first half of the year than the second, but all values were above the state standard of 60 µg/L (Figure 8). Routine monitoring has occurred since 2011 on Little Crosby Lake and consistently high epilimnetic phosphorus values are relatively normal to observe (Figure 9).

Like Crosby Lake, 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 2023 the April monitoring date occurred during the flooding period, so this is indicative of how much of an impact river flooding can have on water quality.

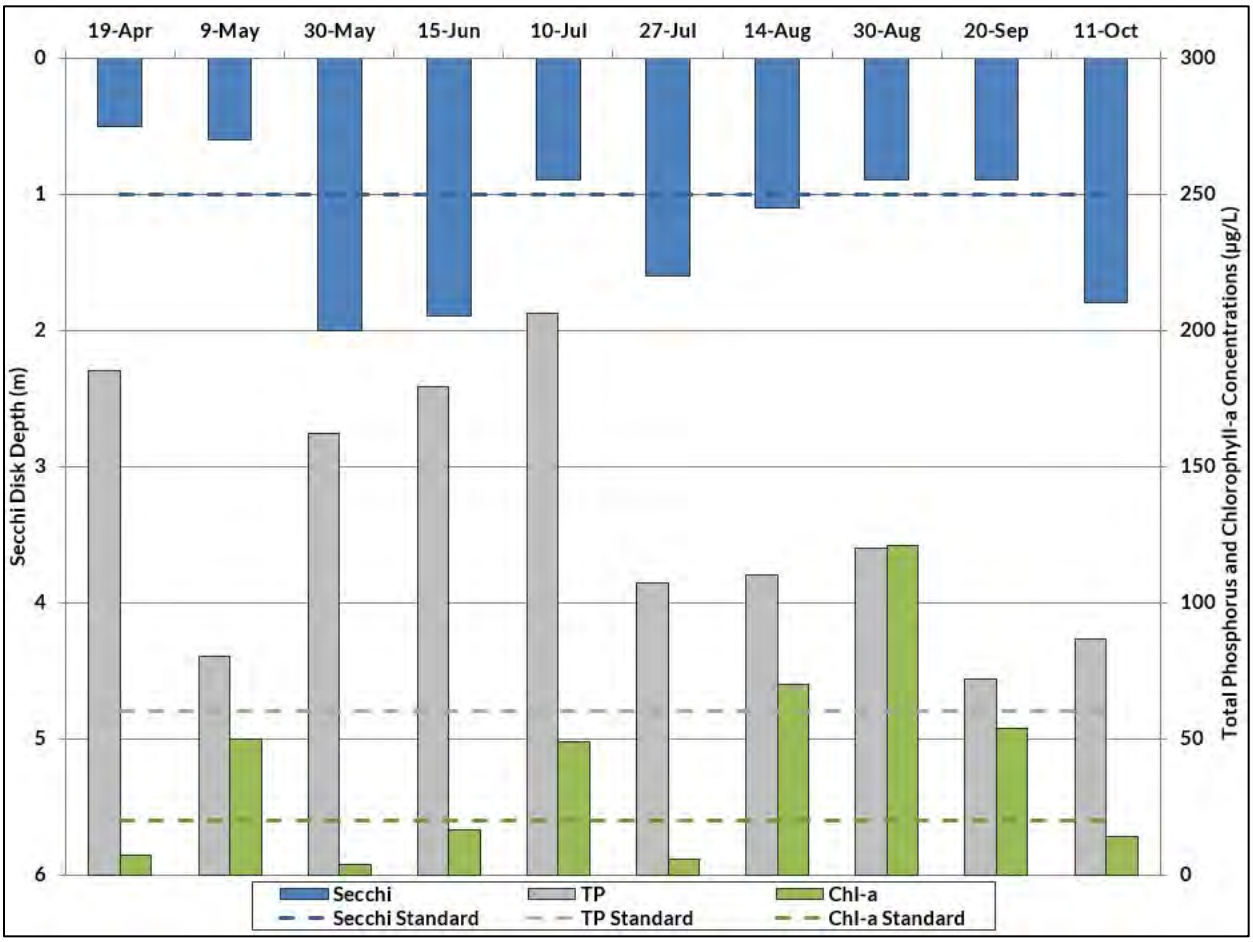

Figure 8: Little Crosby Lake 2023 daily epilimnetic total phosphorus, chlorophyll-a, and Secchi disk depth

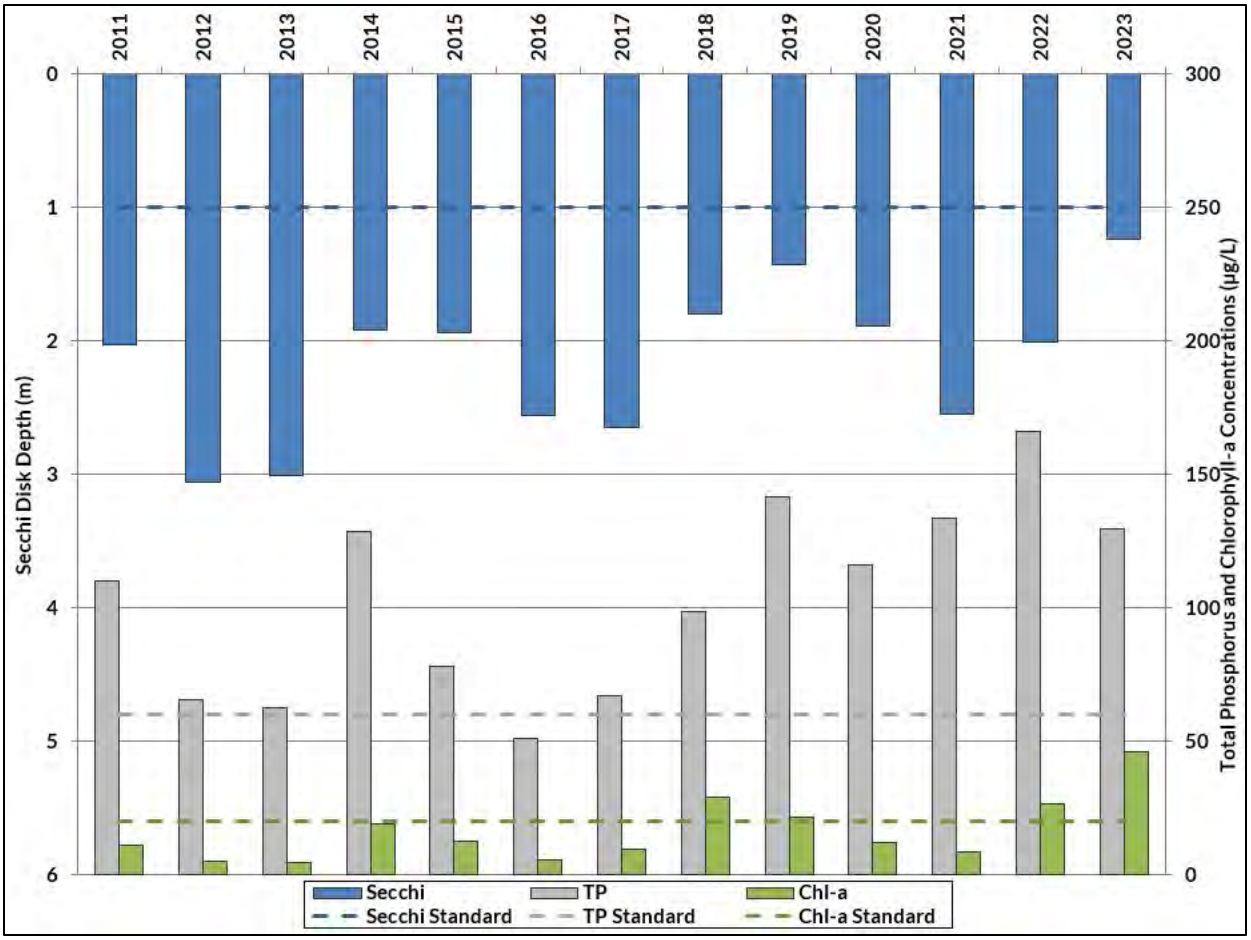

Figure 9: Little Crosby Lake historical average annual epilimnetic total phosphorus, chlorophyll-a, and Secchi disk depth

3.3.2 2023 highlight: Hypolimnetic total phosphorus

Little Crosby Lake has been monitored since 2011 and consistently exhibits high hypolimnetic (i.e. lake bottom) total phosphorus (Figure 10). 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 total phosphorus in the years following this flooding. Epilimnetic total phosphorus has also remained high since this event. In 2023 after a winter that had a deeper-than-average snowpack, the river flooded into Crosby and Little Crosby Lakes. Future data will show the impact of this flooding event on lake water quality.

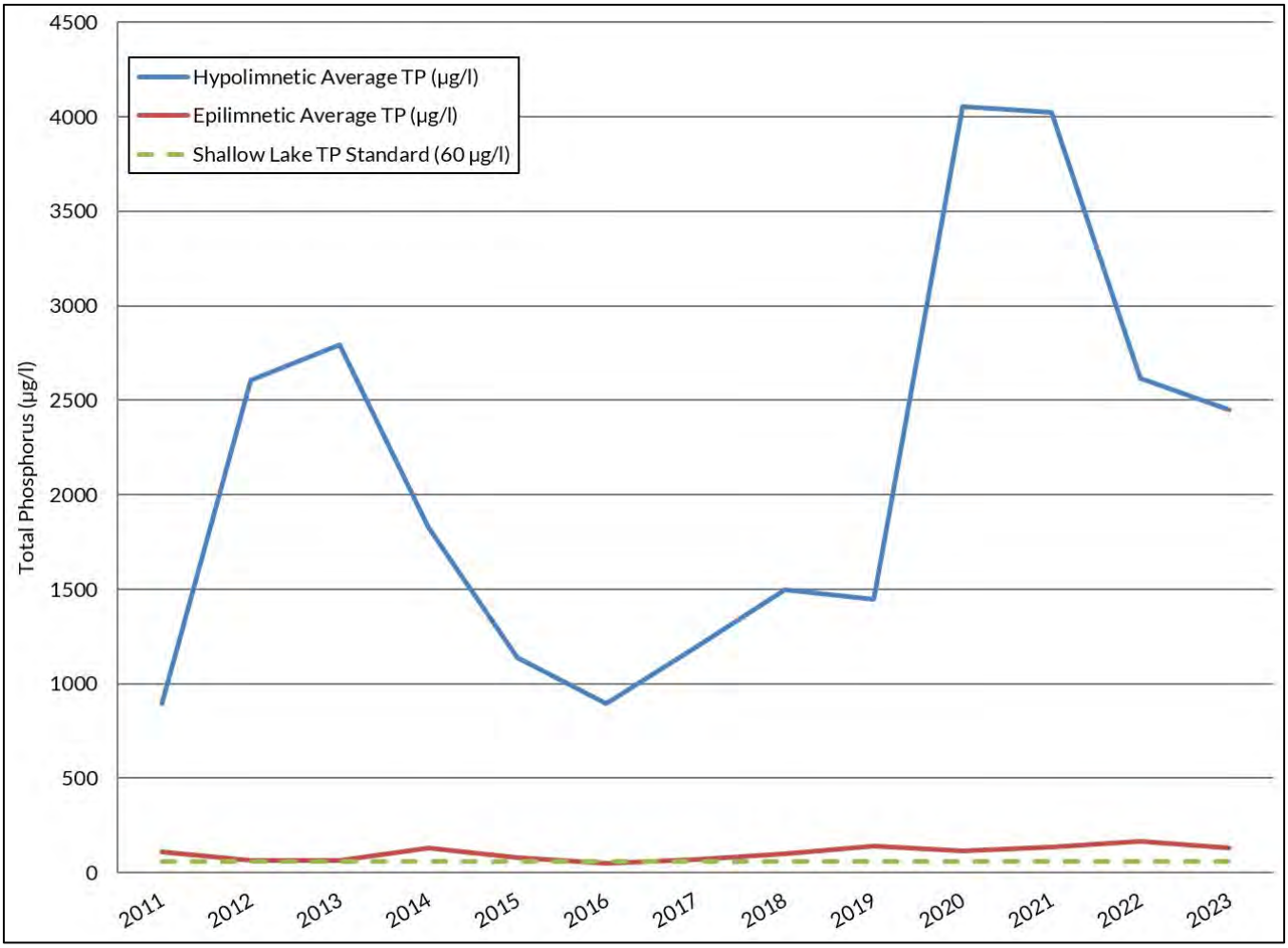

Figure 10: Little Crosby Lake historical average annual hypolimnetic total phosphorus, epilimnetic total phosphorus, and comparison to the deep lake state standard

3.4 Loeb Lake

3.4.1 Water quality data

Loeb lake had average water quality in 2023. Loeb lake has much lower stormwater runoff 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 12). There was only one monitored date in 2023 where chlorophyll-a was above the state standard (Figure 11).

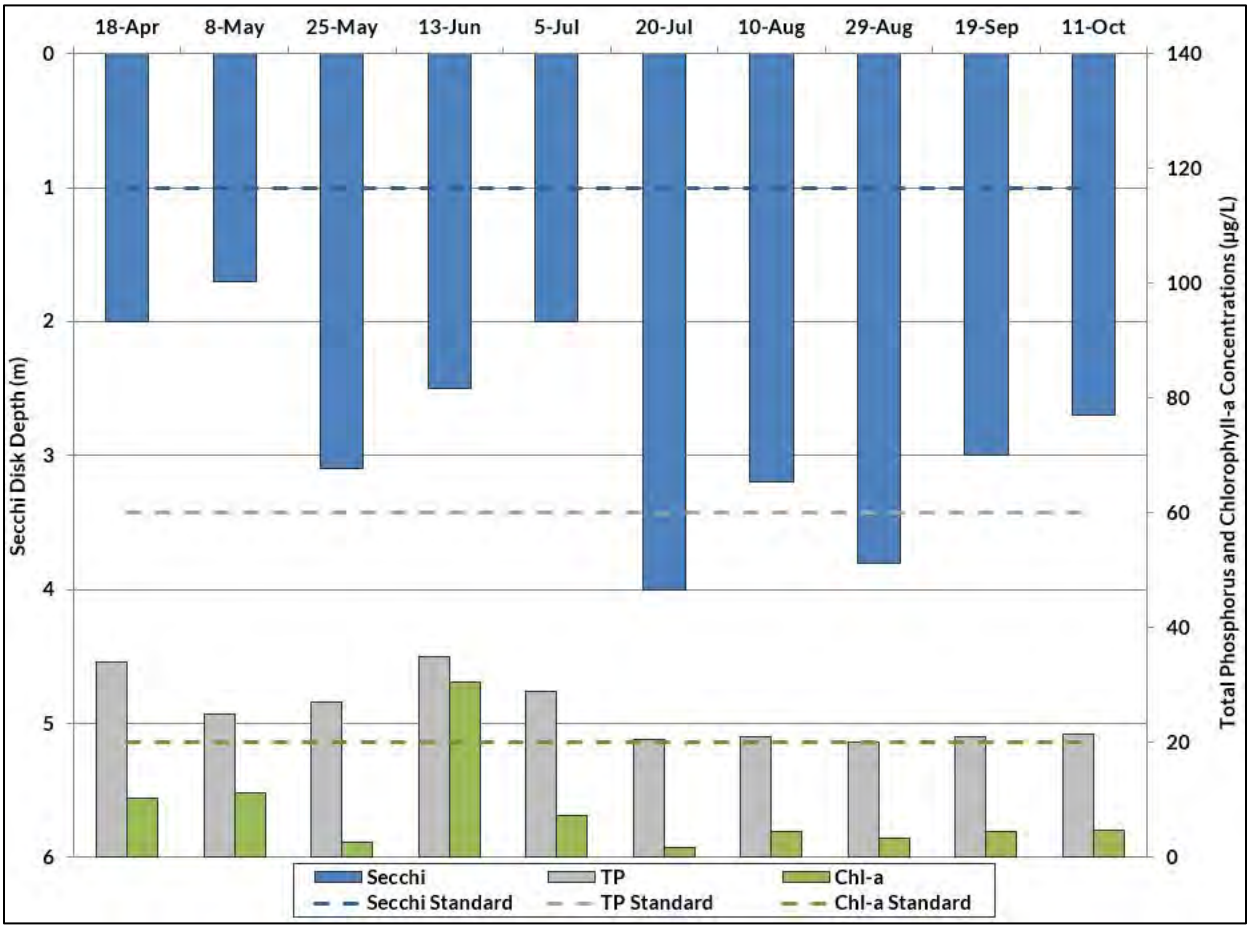

Figure 11: Loeb Lake 2023 daily epilimnetic total phosphorus, chlorophyll-a, and Secchi disk depth

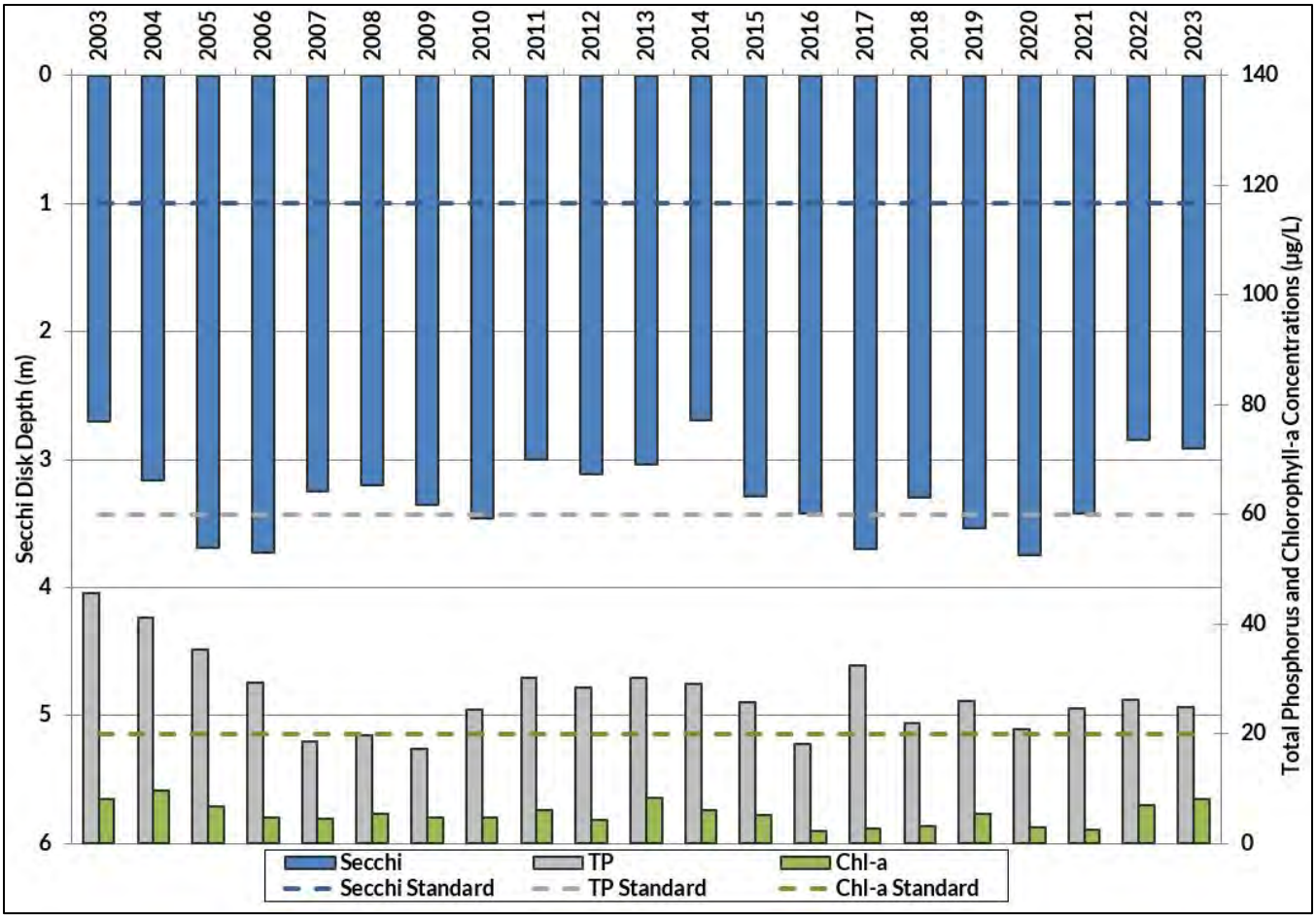

Figure 12: Loeb Lake historical average annual epilimnetic total phosphorus, chlorophyll-a, and Secchi disk depth

3.4.2 2023 highlight: Aquatic plants

In 2023, Loeb Lake continued to exhibit a robust plant population, with ten different species found during the aquatic plant surveys that occur in June, July, and August (Figure 13). This balanced native plant population continues to do well despite the presence of curly leaf pondweed (CLP). CLP 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 consistently low levels of phosphorus and chlorophyll-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.

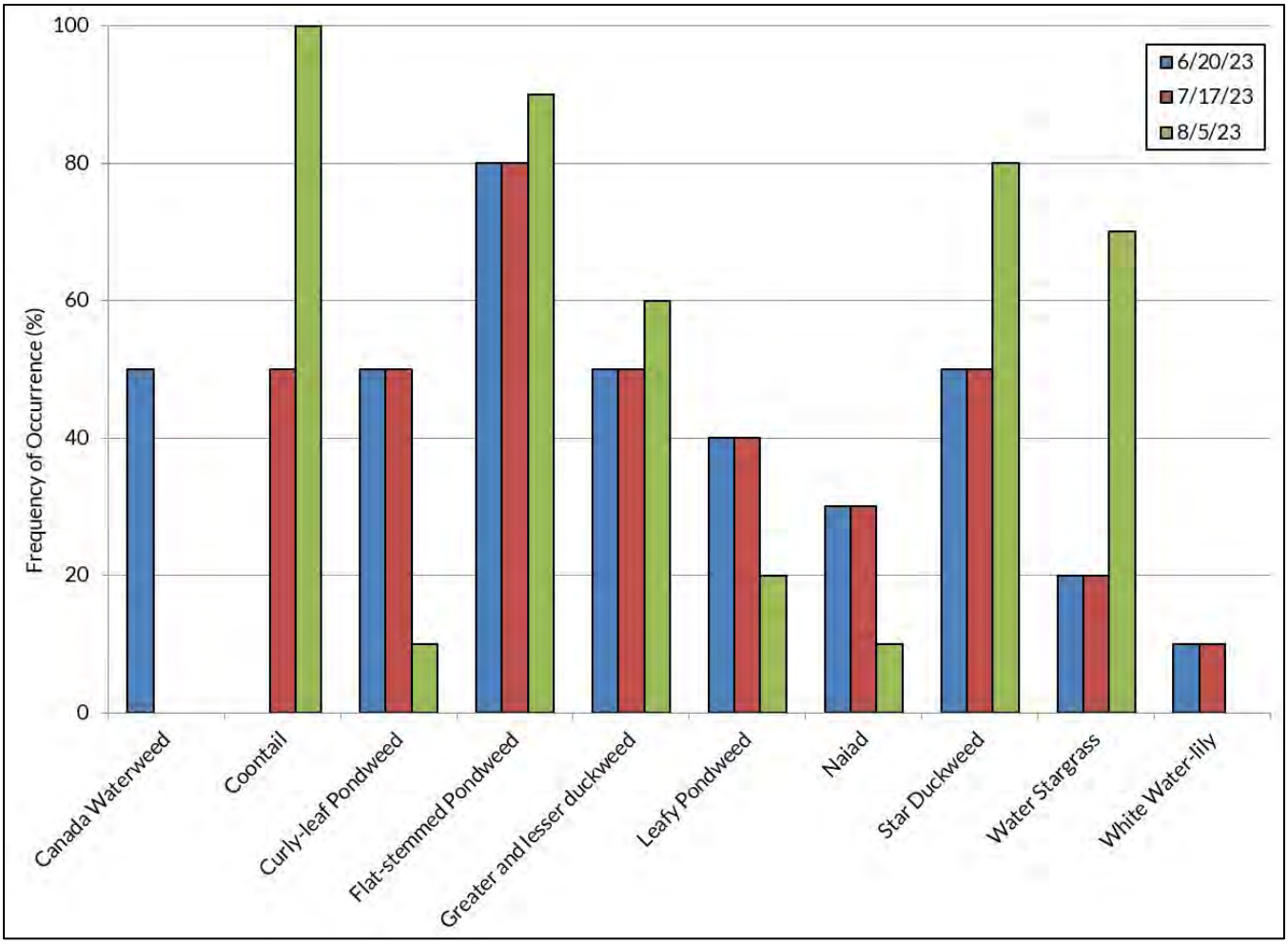

Figure 13: Loeb Lake 2023 aquatic plant frequency of occurrence (%)

3.5 Lake McCarrons

3.5.1 Water quality data

Lake McCarrons had good water quality in 2023 and had the fourth deepest average annual Secchi disk depth measurement on record (Figure 15). Water quality improved compared to 2022, largely due to lake levels rebounding after back-to-back years of drought lowered lake levels in 2021 and 2022. Both total phosphorus and chlorophyll-a also improved in 2023 from 2022. Lake McCarrons had high Secchi disk depth measurements and low total phosphorus/chlorophyll-a values for the entire summer in 2023 (Figure 14). 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.

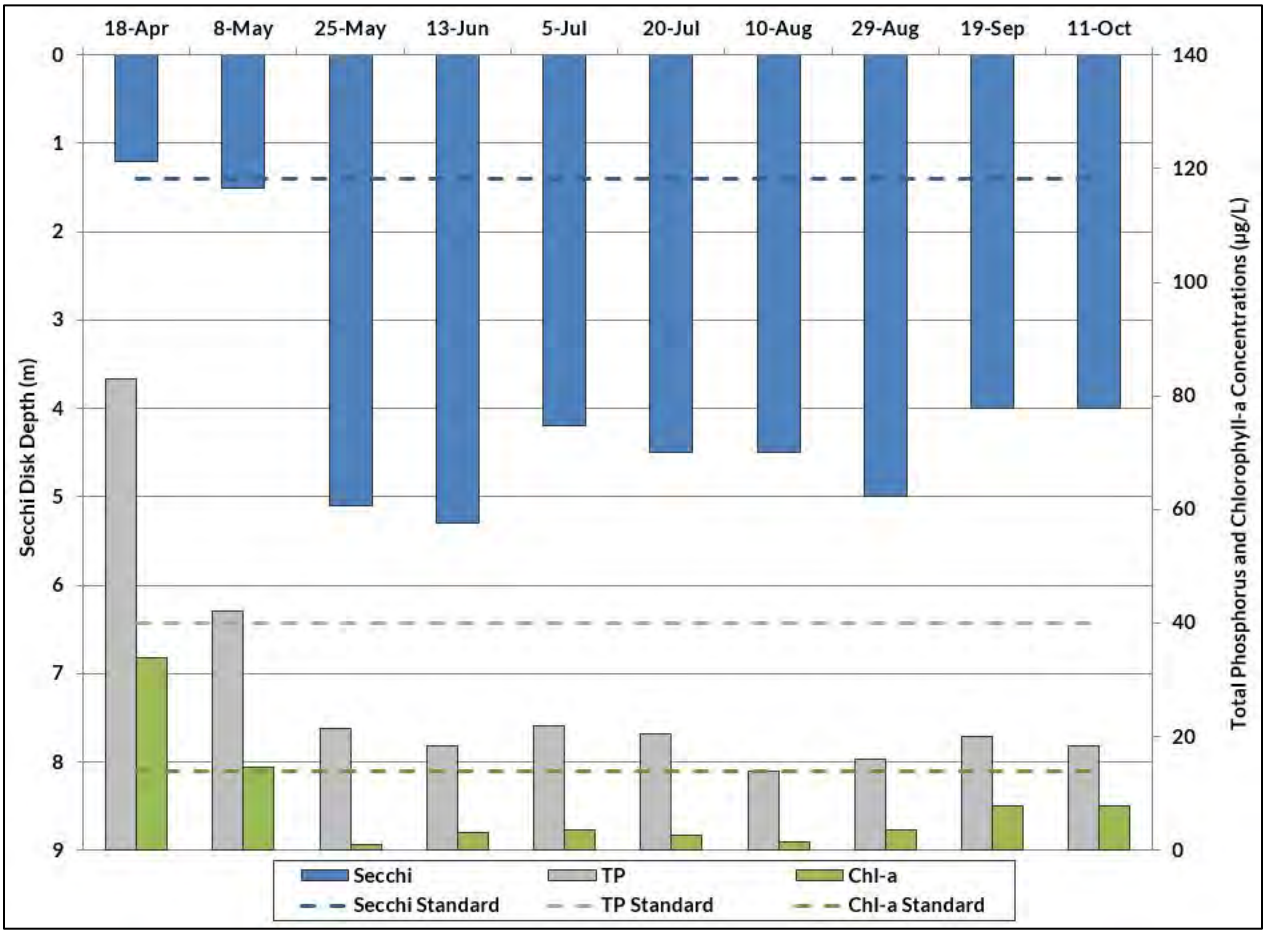

Figure 14: Lake McCarrons 2023 daily epilimnetic total phosphorus, chlorophyll-a, and Secchi disk depth

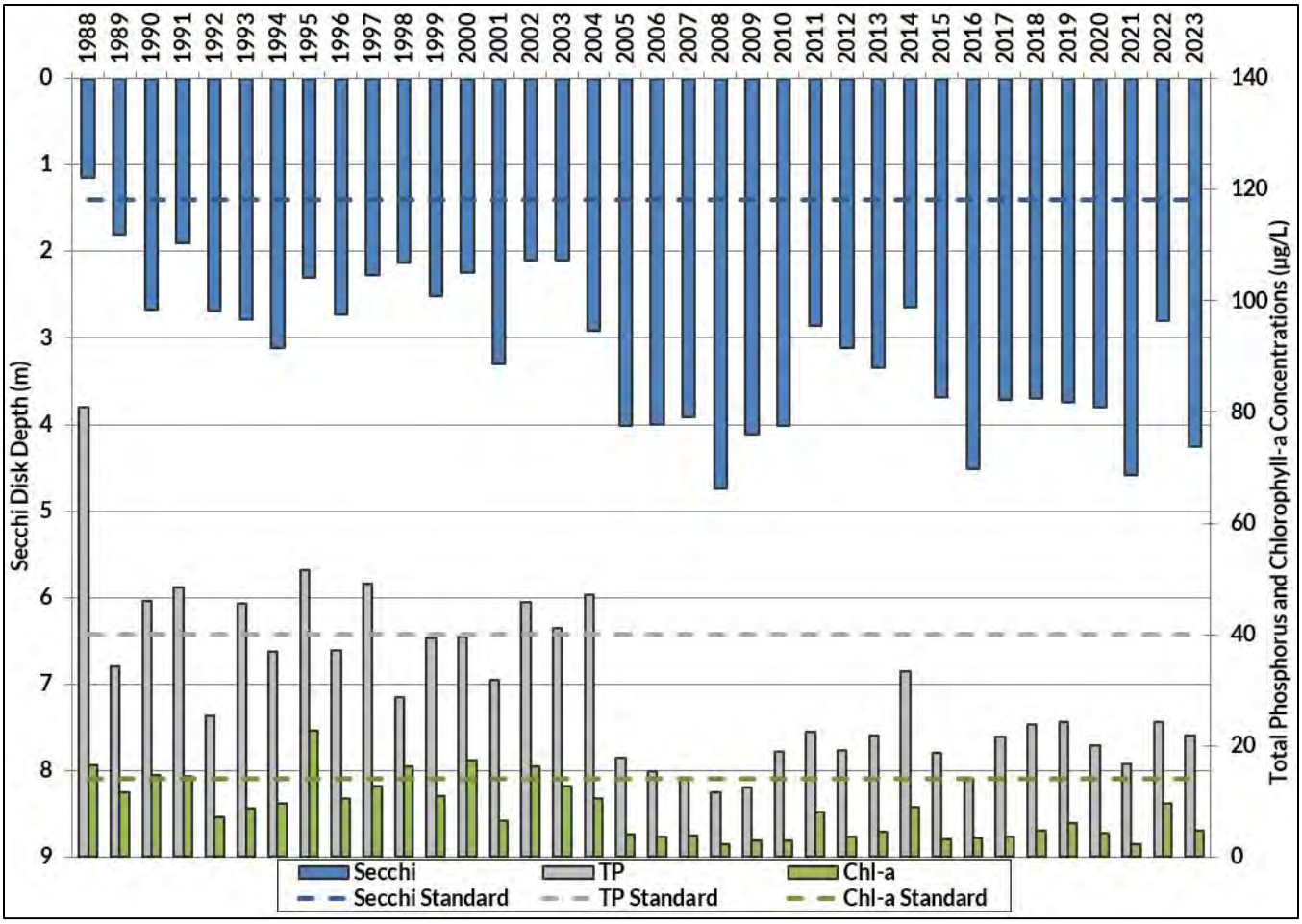

Figure 15: Lake McCarrons historical average annual epilimnetic total phosphorus, chlorophyll-a, and Secchi disk depth

3.5.2 2023 highlight: Alum treatment effectiveness

In 2023, hypolimnetic total phosphorus decreased in comparison to 2022 and epilimnetic total phosphorus stayed below the state standard (Figure 16). In 2004 an alum treatment was successful in reducing phosphorus levels in the lake and bringing the epilimnetic total phosphorus measurement back down below the state standard. While an overall increasing trend in hypolimnetic total phosphorus has been observed in the lake since the alum treatment, which is not unexpected, epilimnetic total phosphorus has continued to remain below the state standard. These data demonstrate that the alum treatment continues to be effective for keeping Lake McCarrons total phosphorus values below the standard and also show the importance of monitoring these parameters. By continuing to track changes over time, we can determine when an additional alum treatment may be needed to maintain the high level of water quality Lake McCarrons currently exhibits.

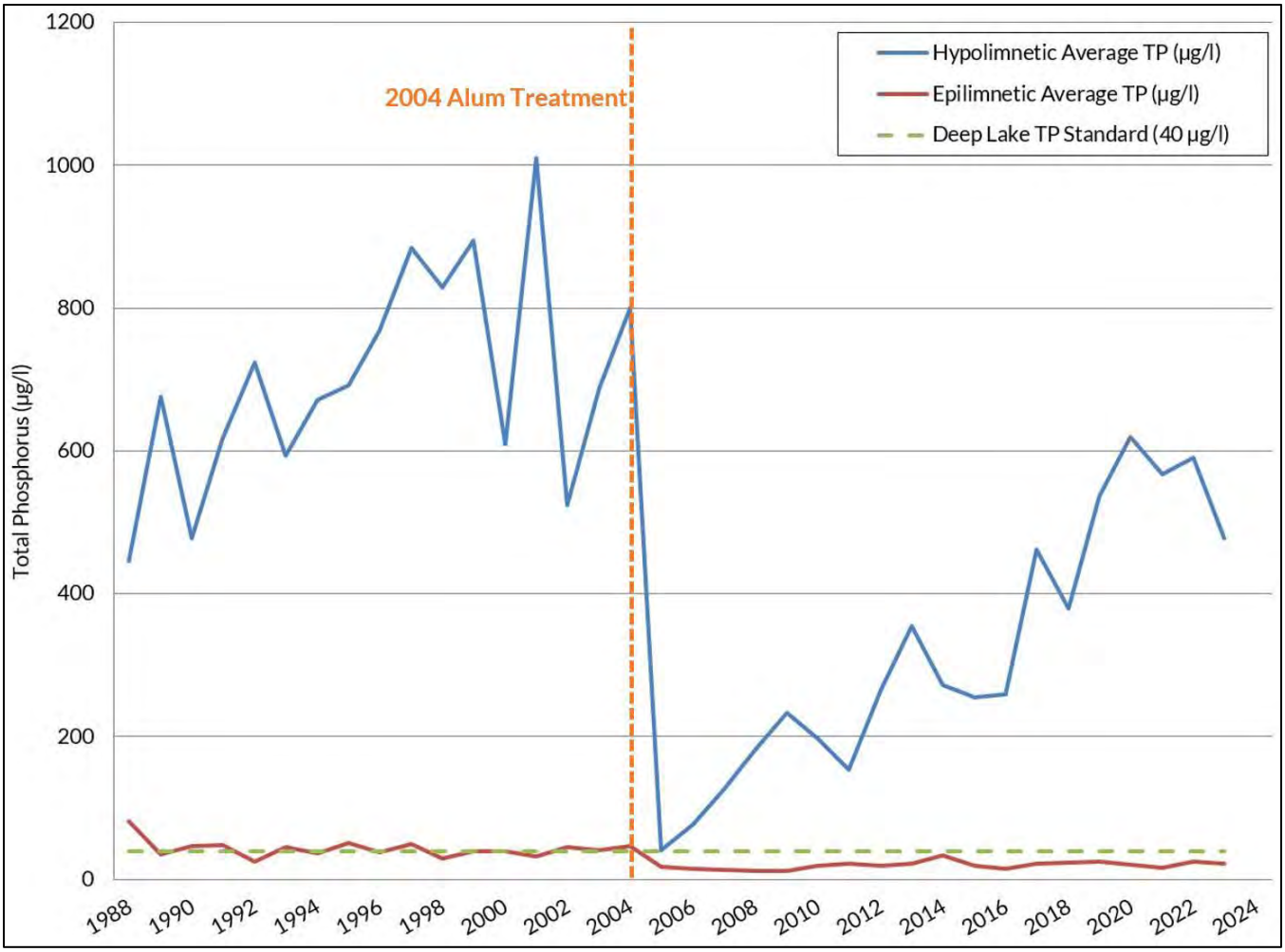

Figure 16: Lake McCarrons historical average annual hypolimnetic total phosphorus, epilimnetic total phosphorus, and comparison to the deep lake state standard

4 Summary

2023 was generally a good year for District lakes and was again impacted by changes in climate as it has been in the past number of years. Not only does our climate have an immense impact on our lake health (affecting lake levels through precipitation and snowmelt, transport of external sources of nutrients through increased rainfall and runoff intensity, increasing water temperature with increasing air temperatures, etc.), but it is also a factor completely outside of our control. Lake health, however, is complicated and multi-faceted, and CRWD will continue to work on implementing management strategies we do have control over.

Como Lake has been a huge success story in this regard, as our science-based, data-driven management actions over time have made a big impact on many facets of lake health. The guidance from the 2002 Como Lake Strategic Management Plan directed many actions for external watershed management that are continuing to make a difference in phosphorus reduction. The updated 2019 Como Lake Management Plan provided continued guidance on external controls, and also focused on internal management strategies, namely: curly-leaf pondweed removal, native plant transplanting, carp removal, and an alum treatment. These combined actions over the last 20+ years have proven immensely effective in reducing phosphorus and improving lake health.

In summary, lake monitoring and lake management will continue to be a priority for the District. In 2024 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
- Bring other lake management plans up to date as needed
- Evaluate actions guided by the 2020 Lake McCarrons Management Plan
- Continue to implement 2019 Como Lake Management Plan actions, namely:
    - Herbicide treatments to address CLP regrowth
    - Aquatic plant transplanting and monitoring
    - Carp management
    - Lakeshore vegetation management

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.

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