Item 6C.
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BARR

2014 Lake Water Quality Study

Sweeney Lake and Twin Lake

Prepared for
Bassett Creek Watershed Management Commission

January 2015

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Executive Summary

Since 1970, when the Bassett Creek Flood Control Commission—now known as the Bassett Creek Watershed Management Commission (BCWMC)—was formed, the BCWMC has periodically monitored water quality conditions in the watershed's 10 major lakes and six ponds. The objective of the lake/pond monitoring program, as specified in the draft 2015-2025 BCWMC Plan, is to detect changes or trends in lake or pond water quality over time. These observations help identify the effects of changing land-use patterns within the watershed. They also help assess the effectiveness of efforts by BCWMC and cities within the watershed to maintain and improve water quality. This report summarizes the results of water quality monitoring during 2014 in Sweeney Lake and Twin Lake. The conclusions from this study are outlined below.

Sweeney Lake

Conclusions drawn from the 2014 study of Sweeney Lake include the following:

- Average summer total phosphorus and chlorophyll *a* concentrations and Secchi disc transparency failed to meet the BCWMC/MPCA standard in 2014.
- Trend analyses indicate that during the period of record (1972 to present), changes in total phosphorus and chlorophyll *a* concentrations were not significant; however, a significant decline in average summer Secchi disc transparency depths has occurred. The long-term trend line shows that transparency depths have declined at a rate of 0.01 meters (0.4 inches) per year.
- High total phosphorus and chlorophyll *a* concentrations have been observed in the lake for more than 40 years. Since 1972, the summer averages for total phosphorus and chlorophyll concentrations have met the BCWMC/MPCA standard only 29 percent of the time. Summer averages for Secchi disc transparency have met the standard 62 percent of the time.
- The 2014 average summer chlorophyll *a* concentration was the highest on record, consistent with the observation that Sweeney Lake experienced the worst summer algal blooms to date.
- Severe algal blooms began in June and continued into September. During this period, massive quantities of floating algal mats were consistently observed throughout the lake and clumps or balls of algae were observed throughout the water column. While the algal bloom persisted from June into September, the species causing the bloom continually changed: blue-green algae predominated, but the early August bloom was caused by green algae. Blue-green algae can produce harmful algal toxins, while green algae do not.
- Algal toxin testing in early July found that Microcystin, an algal toxin produced by the blue-green algae species *Microcystis,* was present. *Mycrocystis* dominated the mid-July algal bloom.
- The 2014 Sweeney Lake zooplankton community was both healthy and diverse and relatively similar to previous years.

- The number of plant species in Sweeney Lake has increased over time, going from nine species in 1992 to 20 species in 2014, the highest number to date.
- The Sweeney Lake plant community has generally been of average quality since 2000, but was slightly below average during 2014. The slight degradation was likely due to the severe algal blooms that affected growing conditions (i.e., poorer light quality).
- Curly-leaf pondweed has been observed in Sweeney Lake since 1992, but was a minor component of the 2014 plant community. Hence, management does not appear to be needed at this time. However, plant survey data collected in the future should be reviewed to identify any changes.
- Purple loosestrife has been observed in Sweeney Lake in 1992, 2008, and 2014. In 2014, the plant was found at one location in June and expanded to three additional locations in August. Because it is expanding, Barr recommends that the BCWMC explore the feasibility of managing purple loosestrife with purple-loosestrife-eating beetles.
- In 2014, reed canary grass was observed at one location at the northwest corner of the lake. Because it was only found at one location, management does not appear warranted at this time. However, plant survey data collected in the future should be reviewed to identify any changes.

Recommendations include:

Implementation of the Sweeney Lake TMDL

In accordance with the Sweeney Lake TMDL implementation strategy, the BCWMC, working closely with the member cities, should continue to take a lead role in implementation efforts for the categorical wasteload allocations and the internal load reductions for the lake. The following external load reduction actions should be implemented:

- Schaper Pond improvements project (expected construction in 2015)
- Maximize phosphorus load reduction through redevelopment
- Continue ongoing watershed management practices, including education, street sweeping, shoreline buffers, and monitoring of existing best management practices.

As noted in the Sweeney Lake TMDL, a significant reduction in internal phosphorus loading is also necessary to meet the State water quality standards for Sweeney Lake. This would likely require an in-lake alum treatment. However, before implementing an in-lake alum treatment, the BCWMC should consider performing a study regarding the impact of the current aeration system on Sweeney Lake water quality (see following paragraphs). If, after completion of the study, the BCWMC decides to implement an in-lake alum treatment, then a feasibility study would be prepared, which would include completion of a sediment study to determine the appropriate alum dose.

Study Impact of Current Aeration System on Sweeney Lake Water Quality

After completion of the Schaper Pond improvements project and prior to implementing an in-lake alum treatment, it is recommended that the aerators in Sweeney Lake be turned off for 1 or 2 years. While the aerators are off, the BCWMC would have an excellent opportunity to monitor the lake water quality and estimate the impact of the aerators on water quality through the use of three-dimensional water quality models.

The monitoring program should expand the typical BCWMC monitoring to include collection of samples at additional depths, analysis of additional types of phosphorus, and addition of a May sample collection. Ideally, the monitoring program would also include monitoring the outflows from Schaper Pond.

The monitoring data should then be used to develop and calibrate models to evaluate the lake's water quality for different scenarios. It is recommended that a three-dimensional hydrodynamic model (ELCOM), coupled with an aquatic ecological model (CAEDYM), be used to model in-lake water quality for the year (or years) when the aerators were off and a year when the aerators were on. The existing P8 model would need to be run for each modeled year to estimate watershed loading to Sweeney Lake. The model results would provide an estimation of the impact of the aerators on lake water quality, including transport of phosphorus between the bottom (from internal phosphorus release) and surface waters of the lake. The model could also be used to assess the effect of aerator operation on Sweeney Lake water quality (phosphorus, dissolved oxygen, and temperature) and whether aerator operation would have any adverse effects on the successful attainment of the TMDL goals.

Purple loosestrife control

Barr recommends that BCWMC or cities within the watershed introduce purple-loosestrife-eating beetles to the infested areas surrounding Sweeney Lake. Some beetles were observed on purple loosestrife plants at the southeast corner of the lake and could possibly be introduced to the other infested areas. Introduction of the beetles is expected to control purple loosestrife and protect the native vegetation.

Twin Lake

Conclusions of the 2014 study of Twin Lake include:

- In 2014, average summer total phosphorus and chlorophyll *a* concentrations and Secchi disc transparency met the BCWMC/MPCA standard.
- Trend analyses indicate that during the period of record (1972 to present), changes in total phosphorus, chlorophyll *a*, and Secchi disc transparency in Twin Lake are not significant.
- During the period of record, Twin Lake has met the BCWMC/MPCA total phosphorus standard 70 percent of the time and the chlorophyll *a* and Secchi disc transparency standard 90 percent of the time.
- Twin Lake water quality in 2014 was similar to water quality observed prior to 2008 and an improvement over 2008 and 2009 water quality. The long cold winter and late spring in 2014

resulted in lower water temperatures (compared with 2008 and 2009). These lower temperatures correlate with a more stable thermocline. This protected surface waters from the internal phosphorus load in the lake's hypolimnion—resulting in increased water quality.

- Reduced numbers of phytoplankton and blue-green algae in 2014 confirmed improvement in the lake's water quality.
- The 2014 Twin Lake zooplankton community is both healthy and diverse and was relatively similar to previous years.
- The number of plant species in Twin Lake has consistently increased over time, doubling from 12 species in 1992 to 24 species in 2014.
- The Twin Lake plant community has generally been average in quality, but has steadily improved since 1982. The quality of the 2014 plant community was above average and the highest quality to date.
- Curly-leaf pondweed was observed at one location in the lake in June and August. It is not a current problem, but future data should be reviewed to detect changes.
- In 2014, purple loosestrife was found at three locations in June, expanding to a total of seven locations by August. Because it is expanding, Barr recommends that the BCWMC explore the feasibility of managing purple loosestrife with purple-loosestrife-eating beetles.
- In 2014, reed canary grass plants were scattered in disturbed areas, primarily along the southeastern shoreline. Because it was a minor component of the shoreline plant community, management does not appear warranted at this time. However, plant survey data collected in the future should be reviewed to identify any changes.

Recommendations include:

<u>Alum treatment</u>

Barr recommends that BCWMC proceed with the alum treatment slated for completion in 2015. The alum treatment will reduce the pool of phosphorus in the hypolimnion and protect the lake's water quality from degradation.

<u>Purple loosestrife control</u>

Barr recommends that BCWMC or cities within the watershed introduce purple-loosestrife-eating beetles to the infested areas surrounding Twin Lake. Some beetles were observed on purple loosestrife plants at the southeast corner of Sweeney Lake and could possibly be introduced to the infested areas of Twin Lake. Introduction of the beetles is expected to control purple loosestrife and protect the native vegetation.

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Sweeney Lake and Twin Lake

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1.0 Introduction

Since 1970, when the Bassett Creek Flood Control Commission—now known as the Bassett Creek Watershed Management Commission (BCWMC)—was formed, the BCWMC has periodically monitored the water quality conditions in the watershed's 10 major lakes and six ponds. The objective of the lake/pond monitoring program, as specified in the draft 2015–2025 BCWMC Watershed Management Plan, is to detect changes or trends in lake or pond water quality over time. These observations help identify the effects of changing land-use patterns within the watershed. They also help assess the effectiveness of efforts by BCWMC and cities within the watershed to maintain and improve water quality. This report summarizes the results of water quality monitoring during 2014 in Sweeney Lake and Twin Lake.

In 1991, the BCWMC established an annual lake/pond water quality monitoring program that generally followed the recommendations of the Metropolitan Council (Osgood 1989a) for a "Level 1 Survey and Surveillance" data-collection effort. The lake/pond sampling program generally involved monitoring the lakes/ponds on a 4-year rotating basis (three or four lakes/ponds per year). However, the BCWMC has dropped some of the water bodies from the program, including Lost Lake, Sunset Hill (Cavanaugh) Lake, North Rice Pond, and South Rice Pond. Major lakes/ponds monitored by the BCWMC are listed in Table 1-1, with prior monitoring years noted parenthetically.

Table 1-1 Lakes Monitored by the Bassett Creek Watershed Management Commission (years with sampling data are in parenthesis)

· **Crane** (1977, 1982, 1993, 1994, 1997, 2001, 2007[1], 2011)	· **Sunset Hill (Cavanaugh)** (1977, 1982, 1994, 1998)
· **Lost** (1977, 1982, 1993, 1997)	· **Sweeney**[2] (1977, 1982, 1985, 1992, 1996, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014)
· **Medicine** (1977, 1982, 1983, 1984, 1988, 1994[1], 1999[1], 2006[1], 2010[1])	· **Twin** (1977, 1982, 1992, 1996, 2000, 2005, 2008, 2009, 2014)
· **Northwood**[2] (1972, 1977, 1982, 1992, 1996, 2001, 2002, 2003, 2004, 2005,2006, 2007, 2008, 2009[1], 2010, 2011, 2012, 2013	· **Westwood**[2] **(**1977, 1982, 1993, 1997, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011)
· **North Rice Pond** (1994, 1998, 2009, 2013)	· **South Rice Pond**[2] (1994, 1998, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2013)

Although located within the BCWMC watershed, Wirth Lake is monitored annually by the Minneapolis Park and Recreation Board. Medicine Lake is monitored annually by the Three Rivers Park District (TRPD);

[1] Monitoring performed jointly with Three Rivers Park District (formerly Suburban Hennepin Regional Park District).

[2] Includes monitoring by citizens as a part of the Metropolitan Council's Citizen Assisted Monitoring Program (CAMP)

however, the BCWMC periodically assists TRPD in monitoring a second Medicine Lake site. Westwood Lake, Sweeney Lake, Northwood Lake, and Parkers Lake have been monitored annually since 2000 by citizen volunteers participating in the Metropolitan Council's Citizen Assisted Monitoring Program (CAMP). Crane Lake was monitored almost annually by Ridgedale Center from 1975 through 1988.

The BCWMC lake sampling program has occasionally included limited monitoring of other water bodies. These are listed below, with the year sampled noted in parenthesis.

- Cortlawn, East Ring, and West Ring Ponds (1993)
- Grimes Pond (1996)

This report presents the results of the 2014 BCWMC water quality monitoring of Sweeney Lake and Twin Lake (locations shown on Figure 1). The lakes were monitored for water quality and biota, specifically phytoplankton, zooplankton, and macrophytes (aquatic plants). Results are summarized in the following pages.

The discussion of water quality conditions focuses on the three principal nutrient-related water quality indicators: total phosphorus concentrations, chlorophyll *a* concentrations, and Secchi disc transparency. Phosphorus is a nutrient that usually limits the growth of algae. Chlorophyll *a* is the primary photosynthetic pigment in lake algae; therefore, the concentration of chlorophyll *a* in a lake sample indicates the amount of algae present. Secchi disc transparency is a measure of water clarity and is inversely related to algal abundance.

The water quality conditions were classified as to trophic state, based on the total phosphorus concentration, chlorophyll *a* concentration, and Secchi disc transparency (Table 1-2).

Table 1-2 Trophic State Classifications for Total Phosphorus, Chlorophyll *a*, and Secchi Disc Transparency

Trophic State	Total Phosphorus (micrograms/liter)	Chlorophyll *a* (micrograms/liter)	Secchi Disc Transparency (feet and meters)
Oligotrophic (nutrient-poor)	Less than 10 µg/L	Less than 2 µg/L	Greater than 15 ft (4.6 m)
Mesotrophic (moderate nutrient levels)	10 µg/L–24 µg/L	2 µg/L–7.5 µg/L	15 ft–6.6 ft (4.6 m–2.0 m)
Eutrophic (nutrient-rich)	24 µg/L–57 µg/L	7.5 µg/L–26 µg/L	6.6 ft–2.8 ft (2.0 m–0.85 m)
Hypereutrophic (extremely nutrient rich)	Greater than 57 µg/L	Greater than 26 µg/L	Less than 2.8 ft (0.85 m)

In addition to chemically based water quality parameters, biological data were collected and evaluated. Phytoplankton, zooplankton, and macrophyte data can help determine the health of aquatic systems and can also indicate changes in nutrient status over time. Biological communities in lakes interact with each other and influence both short- and long-term variations in observed water quality.

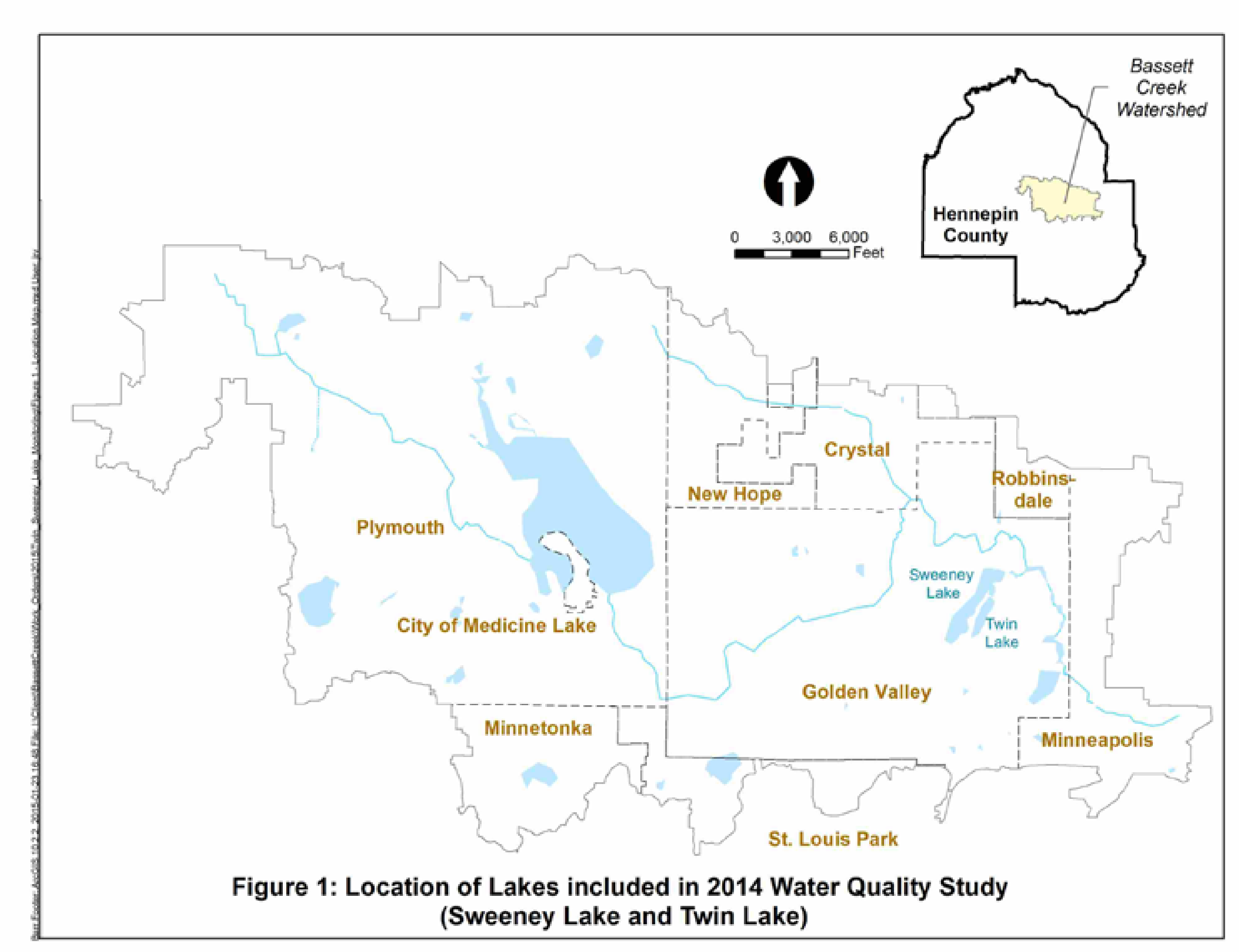


Figure 1 Location of Lakes Included in 2014 Water Quality Study (Sweeney Lake and Twin Lake)

Phytoplankton (algae) forms the base of the food web in lakes and directly influences fish production and recreational use. Chlorophyll *a*, the main pigment found in algae, is a general indicator of algal biomass in lake water. The identification of species and their abundance provides additional information about the health of a lake and can indicate changes in lake status, as algal populations change over time. The presence of some types of algae is indicative of the quality of food available for small animals living in the lake. Larger algal species that are difficult to consume or those of low food quality are less desirable for zooplankton (microscopic crustaceans) and can limit overall productivity in a lake.

Zooplankton (microscopic crustaceans) is vital to the health of a lake's ecosystem because they feed on phytoplankton and provide food for many fish species. They are also important to a lake's water quality. Proper water quality management practices protect the lake's zooplankton community and, subsequently, the lake's fishery. The zooplankton community is comprised of three groups: Cladocera, Copepoda, and Rotifera. Large, abundant Cladocera can decrease the number of algae and improve water transparency.

Macrophytes (large aquatic plants) grow in the shallow (littoral) area of a lake. They are a natural part of lake communities and provide many benefits to fish, wildlife, and people. Macrophytes are primary producers in the aquatic food web, providing food for other life forms in and around the lake.

Phytoplankton, such as the *Rhizoclonium hieroglyphicum*, pictured above, form the base of the food web in lakes and directly influence fish production and recreational use.

Zooplankton, such as the *Cyclops,* pictured above, is vital to the health of a lake ecosystem because they feed on the phytoplankton and provide food for fish.

2.0 Methods

2.1 Water Quality Sampling

As part of the Bassett Creek Watershed Management Commission (BCWMC) water quality monitoring program, water samples were collected from Sweeney Lake and Twin Lake. These samples were taken at the deepest location(s) in each lake basin on six occasions. Samples were collected from one location in Twin Lake and two locations in Sweeney Lake from April through September as follows:

- One sample was collected within two weeks of ice out (late-April)
- One sample was collected in mid-June
- One sample was collected in mid-July
- Two samples were collected in August (bi-weekly, during the first and third weeks)
- One sample was collected during the first week of September

Table 2-1 lists the water quality parameters and specifies the depths at which samples or measurements were collected during each sample event. Dissolved oxygen, temperature, specific conductance, pH, oxidation reduction potential (ORP), and Secchi disc transparency (Secchi depth) were measured in the field. Water samples were analyzed in the laboratory for total phosphorus, soluble reactive phosphorus, total nitrogen, and chlorophyll *a*.

Table 2-1 Lake/Pond Water Quality Parameters

Parameters	Depth (meters)
Dissolved oxygen	Surface-to-bottom profile at 1-meter intervals
Temperature	Surface-to-bottom profile at 1-meter intervals
Specific conductance	Surface-to-bottom profile at 1-meter intervals
pH	Surface-to-bottom profile at 1-meter intervals
Oxidation reduction potential (ORP)	Surface-to-bottom profile at 1-meter intervals
Secchi disc	Measured from surface
Total phosphorus	· 0–2 meter composite sample · Above thermocline sample · Below thermocline sample · 0.5 meters above bottom
Soluble reactive phosphorus	0–2 meter composite
Total nitrogen	0–2 meter composite
Chlorophyll *a*	0–2 meter composite
Turbidity	0–2 meter composite

2.2 Ecosystem Data

Ecosystem data were collected from April to September 2014.

Phytoplankton (algae)—A 0–2 meter water sample for phytoplankton was collected at each Sweeney and Twin Lake water sampling location from April through September (see Section 2.1 for schedule). Sample analysis included identification and enumeration of phytoplankton species. Additional algal samples were collected from Sweeney Lake in July and August to assess the algal species causing the lake's massive and prolonged algal bloom. An algal toxin sample was collected on July 2, 2014, and sent to a specialty laboratory for analysis of Anatoxin-a, a toxin produced by some species of blue-green algae. The laboratory also scanned the sample for other toxins produced by blue-green algae.

Zooplankton (microscopic crustaceans)—A zooplankton sample (bottom to surface tow) was collected from each Sweeney and Twin Lake water sampling location from April through September (see Section 2.1 for schedule). Sample analysis included identification and enumeration of species.

Macrophytes (aquatic plants)—Macrophyte surveys were completed in June and August using the point-intercept method. The plant surveyor located equally spaced, preset points with GPS and took measurements at each point, including the following:

1. Individual species present
2. Overall density of plants, as measured by rake method
3. Density of individual species, as measured by rake method
4. Water depth
5. Dominant sediment type

The following statistics from the macrophyte survey were compiled:

- **Number of species**—the number of plant species that were either collected on the rake or observed in the lake (e.g., water lilies or cattail beds not collected on the rake but observed). This number includes both invasive and native species.
- **Number of native species**—the number of native plant species that were either collected on the rake or observed in the lake.
- **Number of native species collected on rake—**native plants (only) collected on the rake.
- **Number of invasive species—**the number of invasive plant species that were either collected on the rake or observed in the lake.
- **Maximum depth of plant growth**—the maximum depth at which plants was found in the lake.
- **Frequency of occurrence—**the frequencies with which plants were found in water shallower than the maximum depth of plant growth.
- **Average rake fullness—**the density of plant growth, as measured by rake fullness on a scale of 1 to 4, where:

  1 = less than 1/3 of the rake head full of plants.

  2 = from 1/3 to 2/3 of the rake head full of plants.

  3 = more than 2/3 of the rake head full of plants.

  4 = rake head is full, with plants overtopping.

A rake was used to collect plants for the surveys. The fullness of the rake above (at a Sweeney Lake sampling location) was measured at 4: the rake head is full, with plants overtopping the rake head.

- **Simpson diversity index value**—index used to measure plant diversity, which assesses the overall health of the lake's plant communities. This index, with scores ranging from 0 to 1, considers both the number of species and the evenness of species distribution. The scores represent the probability that two randomly selected plants will belong to different species. A high score indicates a more diverse plant community—a higher probability that two randomly selected plants will represent different species.

- **C value—**scale of values used to measure the average tolerance of the plant community to degraded conditions. Plant species are assigned C values on a scale of 0 to 10; increasing values indicate plants are less tolerant of degraded conditions and, hence, of higher quality. An average of the C values for individual species within a lake's plant community indicates the average tolerance of the community to degraded conditions.

- **Floristic quality index (FQI) value—**FQI was used to assess the quality of the plant communities in Sweeney and Twin Lake. FQI considers both the quality of the individual native species found in the lake (C value) and the number of native species collected on the rake. Although Minnesota has not kept a record of FQI values, recorded Wisconsin FQI values range from 3 (degraded plant communities) to 49 (diverse native plant communities). The median FQI for Wisconsin is 22.

3.0 Sweeney Lake

3.1 Site Description

Sweeney Lake (Minnesota Department of Natural Resources (MDNR) public water #27-003501) is a 67-acre lake located in the City of Golden Valley in the eastern portion of the BCWMC. It is frequently used by residents for swimming, fishing, boating, and aesthetic viewing. A public access at the southern end of the lake provides carry-in boat access.

Sweeney Lake, pictured above, is currently on the 303(d) impaired waters list for excess nutrients (phosphorus). The lake is not always suitable for swimming or wading because of low clarity and excessive algae growth.

Sweeney Lake has an estimated mean depth of 12 feet, a maximum depth of 25 feet, and a littoral area of approximately 34 acres. Shallow areas near the shoreline of the lake allow for both emergent and submerged vegetation growth. The normal water elevation is approximately 827.5 feet and the 100-year elevation is approximately 831.5 feet.

Portions of St. Louis Park and Golden Valley drain into Sweeney Lake, which has a contributing drainage area of approximately 2,396 acres. Sweeney Lake receives outflows from the Ring Ponds, Cortlawn Pond, Schaper Pond, and Twin Lake. It drains northeast into the Sweeney Lake branch of Bassett Creek, connecting to the Bassett Creek main stem shortly downstream. A steel sheet pile and concrete cap serve as the lake's outlet structure at an elevation of 827.5 feet.

The Sweeney Lake watershed (including the watersheds of the contributing ponds) is almost fully developed. The major land use (44.5%) is for low-density residential property, followed by highway (12%) and industry (7%). Other land-use classifications include: medium-density residential, natural space, park and open space, commercial, developed parks, golf course, institutional, open water, and office.

Sweeney Lake is a BCWMC "priority 1" deep lake. Classification as "deep" is based on the MPCA's shallow/deep classification. The lake is currently on the 303(d) impaired waters list for excess nutrients (phosphorus) and a TMDL study has been conducted. Low clarity and excessive algae growth due to the excessive phosphorus sometimes make the lake unsuitable for swimming or wading.

3.2 BCWMC/MPCA Water Quality Standards

For priority water waterbodies, such as Sweeney Lake, the BCWMC has adopted water quality standards that are consistent with Minnesota Pollution Control Agency (MPCA) water quality standards, as published in Minnesota Rules 7050 for lakes within the North Central Hardwood Forest Ecoregion. These rules apply to water bodies within the BCWMC, regardless of their BCWMC classification. The BCWMC/MPCA water quality standards for Sweeney Lake are as follows:

1. Average summer total phosphorus concentration not to exceed 40 µg/L
2. Average summer chlorophyll *a* concentration not to exceed 14 µg/L
3. Average summer Secchi disc transparency of at least 1.4 meters or 4.6 feet (Minn. R. Ch. 7050.0222 Subp. 4)

As shown in Figure 2 through Figure 7, the average summer total phosphorus, chlorophyll *a*, and Secchi disc transparency in Sweeney Lake failed to meet the BCWMC/MPCA water quality standards in 2014.

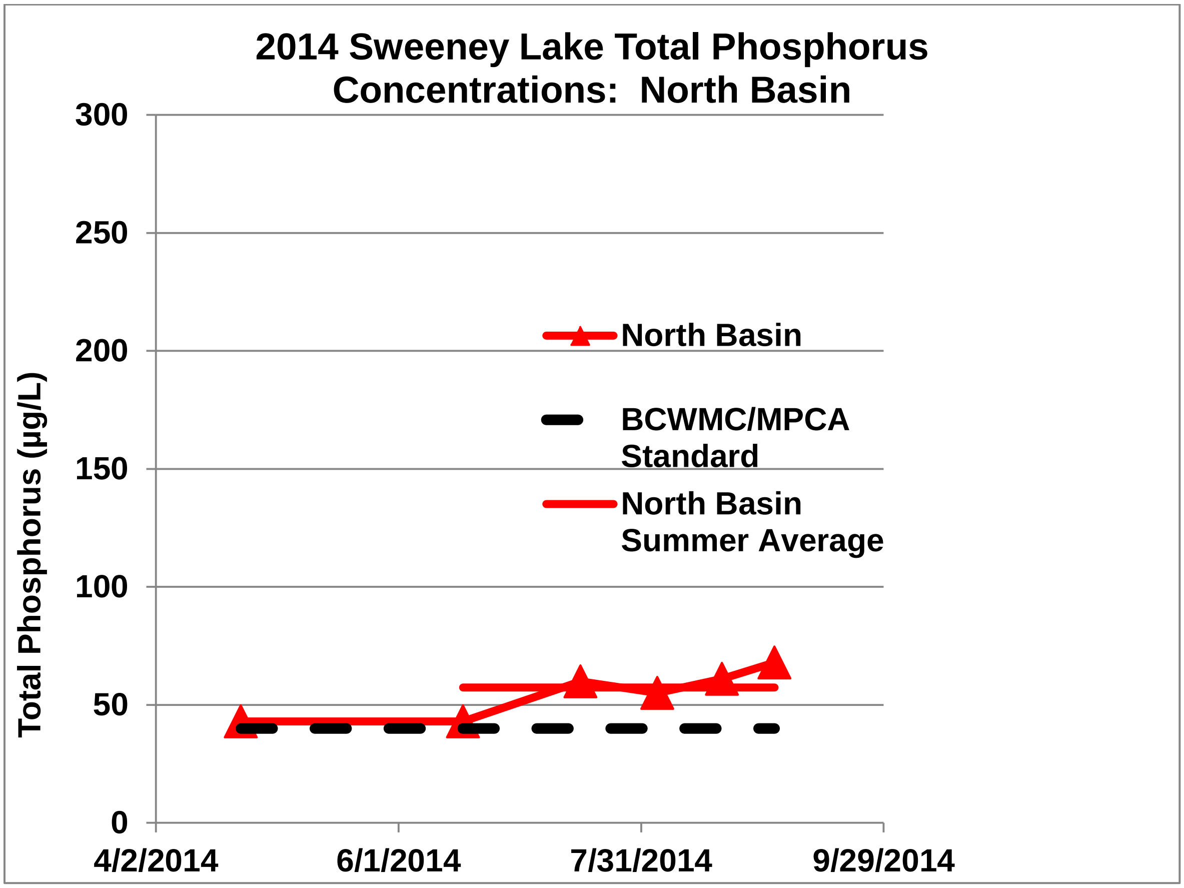


Figure 2 **2014 Sweeney Lake North Basin Total Phosphorus Concentrations Compared to BCWMC/MPCA Total Phosphorus Standard**

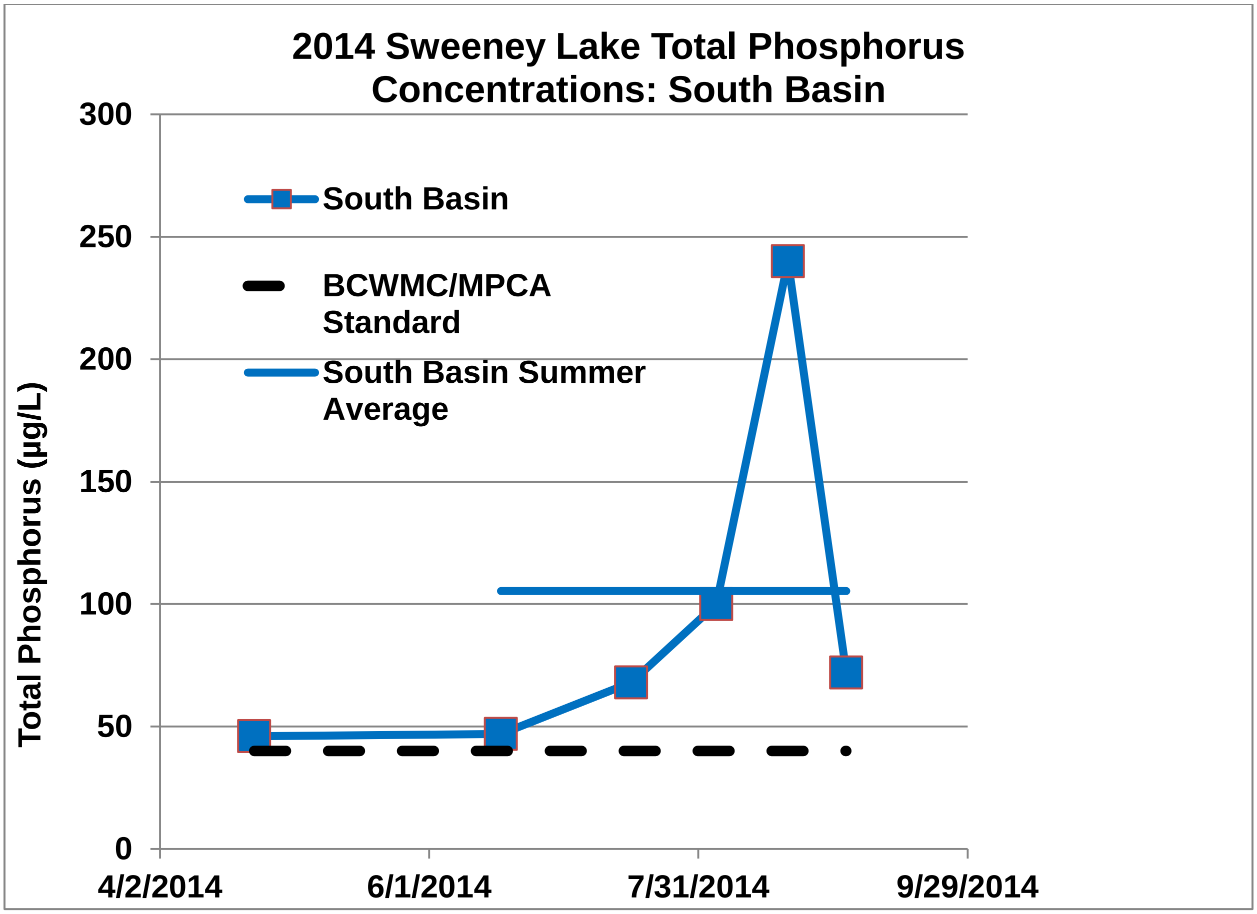


Figure 3 **2014 Sweeney Lake South Basin Total Phosphorus Concentrations Compared to BCWMC/MPCA Total Phosphorus Standard**

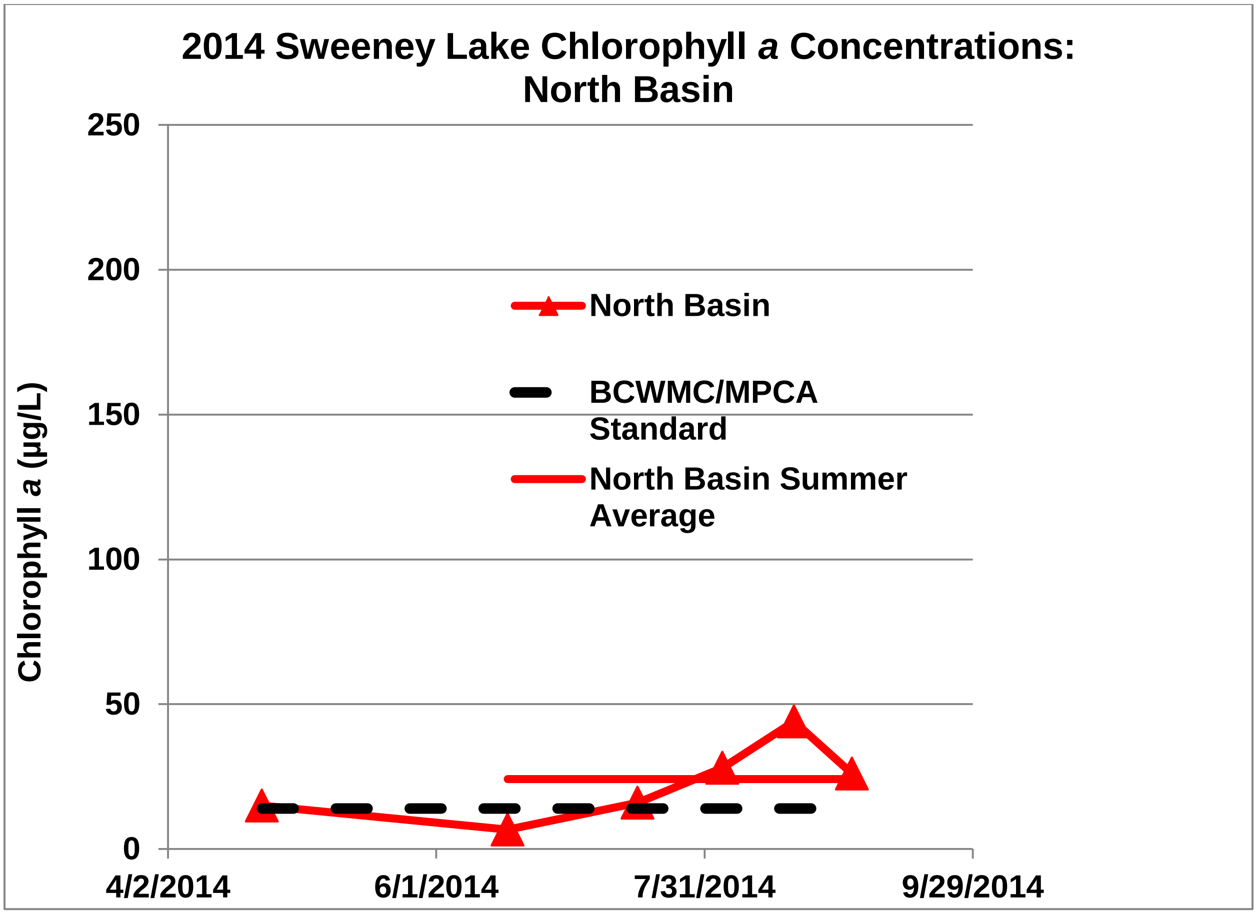


Figure 4 **Sweeney Lake North Basin Chlorophyll *a* Concentrations Compared to BCWMC/MPCA Chlorophyll *a* Standard**

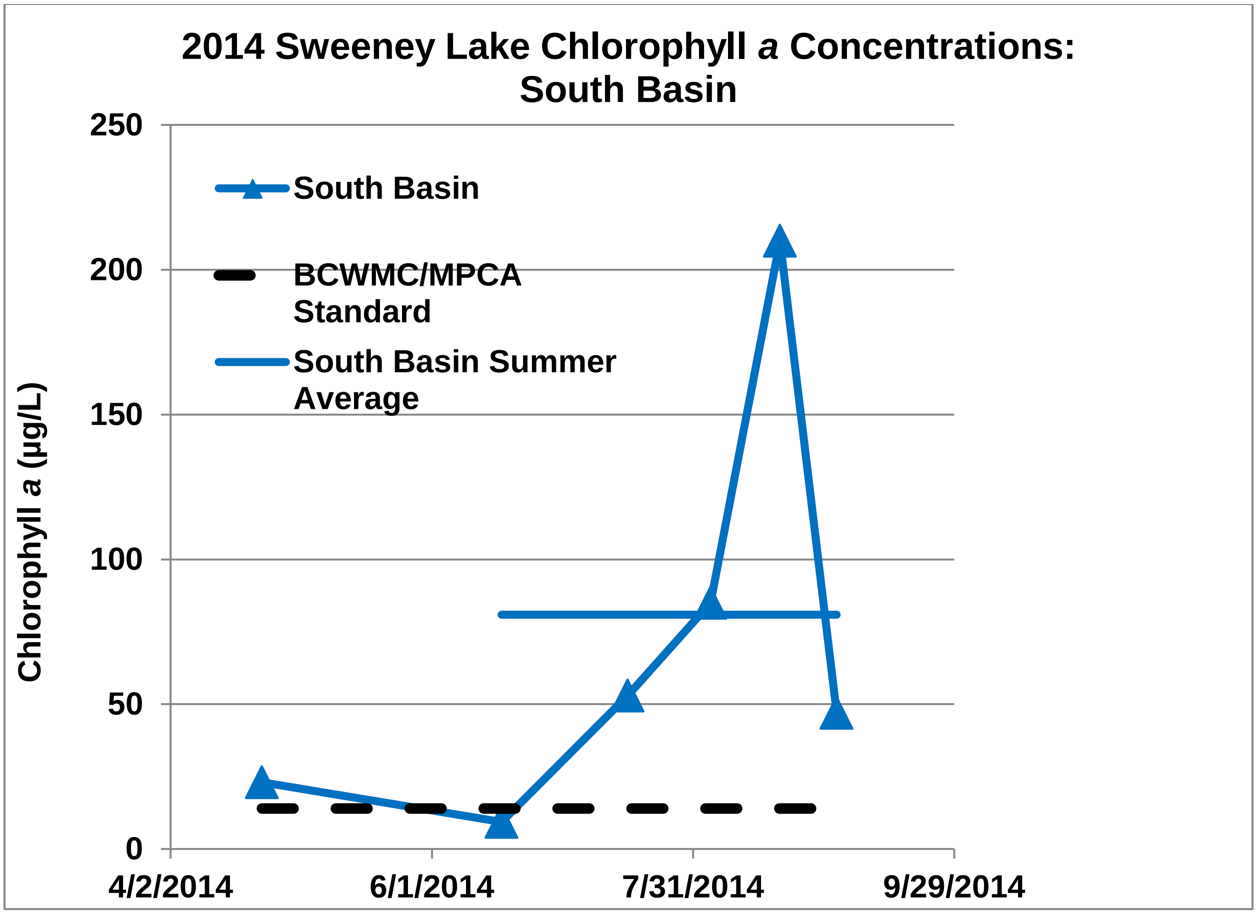


Figure 5 **Sweeney Lake South Basin Chlorophyll *a* Concentrations Compared to BCWMC/MPCA Chlorophyll *a* Standard**

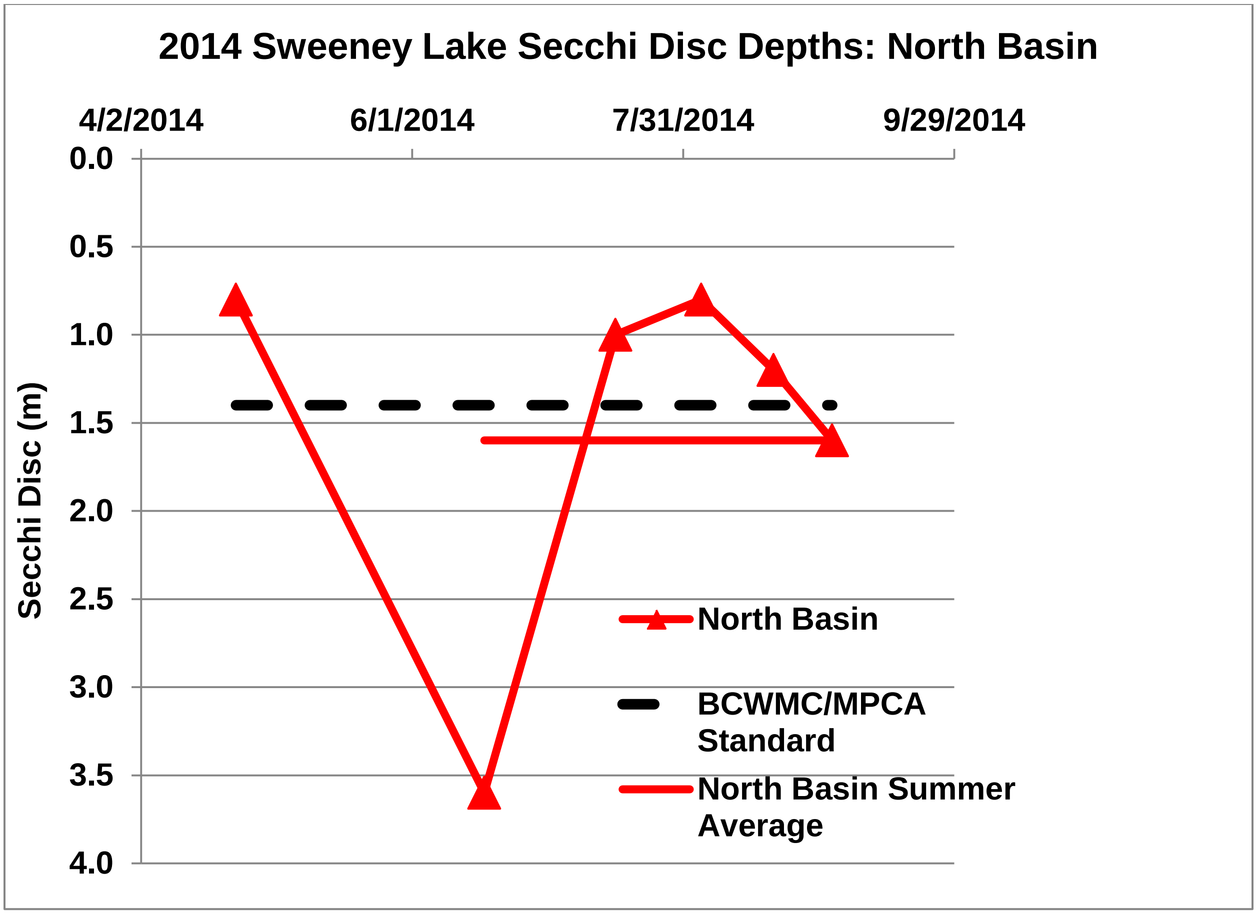


Figure 6 **Sweeney Lake North Basin Secchi Disc Depths Compared to BCWMC/MPCA Secchi Disc Standard**

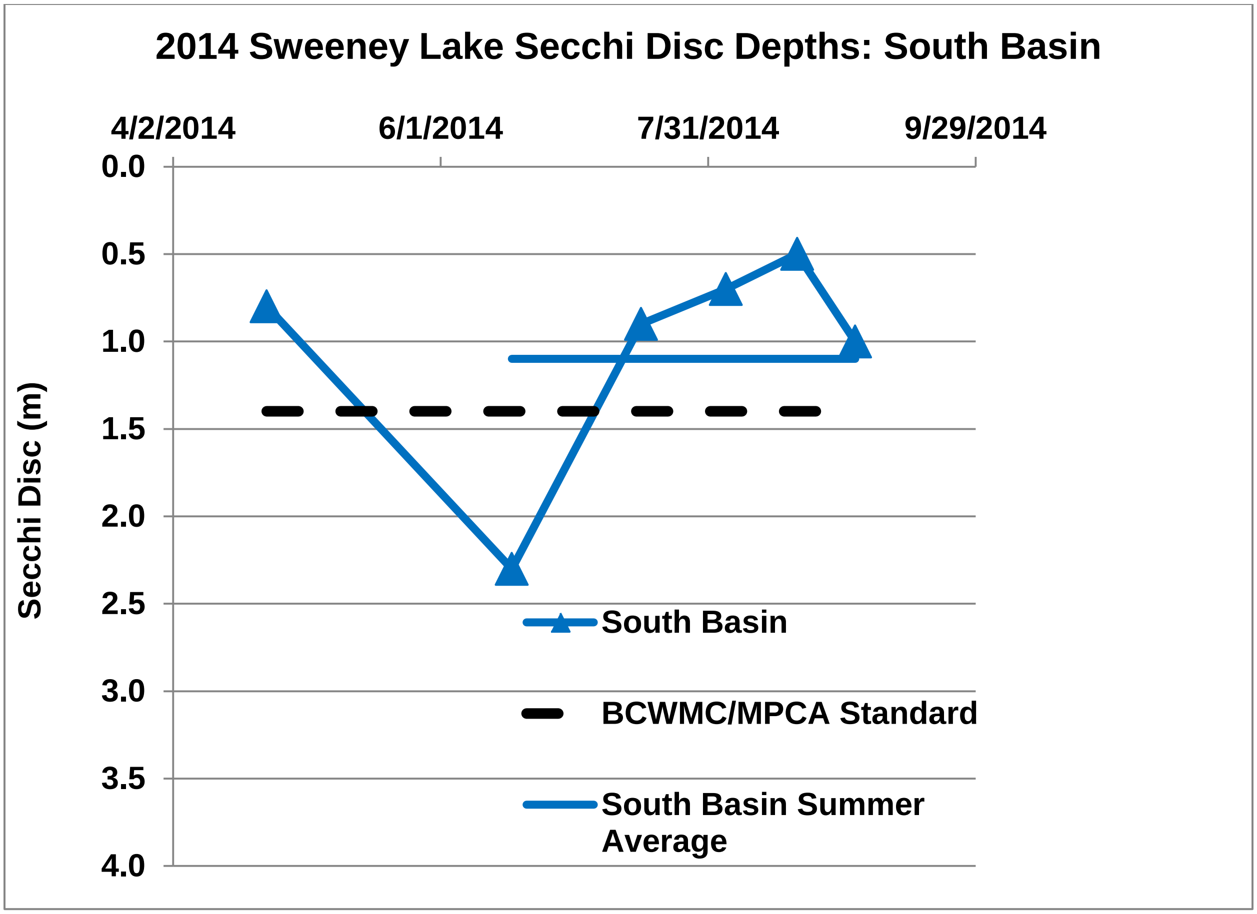


Figure 7 **Sweeney Lake South Basin Secchi Disc Depths Compared to BCWMC/MPCA Secchi Disc Standard**

3.3 Water Quality Monitoring Results

Water quality monitoring results for temperature, dissolved oxygen, specific conductance, total phosphorus, chlorophyll *a*, and Secchi disc transparency are summarized below.

3.3.1 Temperature

Vertical profiles of temperature collected during 2014 (Figure 8 and Figure 9) show the lake was generally mixed throughout the monitoring period. The vertical lines in Figure 8 and Figure 9 show that temperature was the same from lake surface to bottom, except for a brief time in August when the temperature of the lake surface was a couple of degrees warmer. Change in temperature in Figure 8 and Figure 9 is represented by changes in color. The change in color from dark green at the far left (i.e., spring) to light yellow at the far right (i.e., late summer) shows that the lake warmed throughout the growing season, increasing from 6º C in the spring to 24º C in the summer.

The continuous mixing of the lake throughout the growing season was accomplished by the lake's aerators, which were on throughout the monitoring period. The aerators add oxygen to the water and continuously mix the water column.

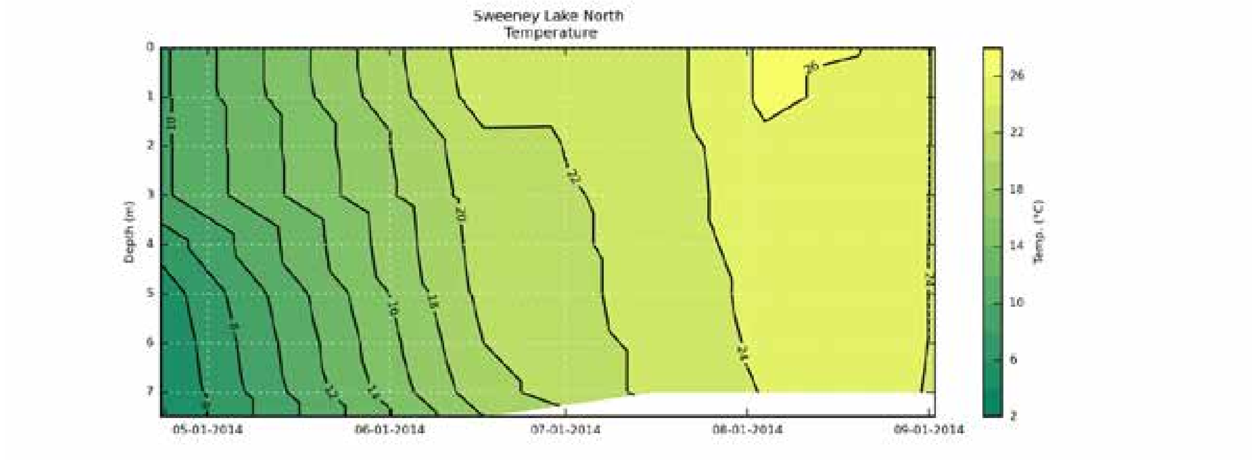


Figure 8 2014 Sweeney Lake North Basin Temperature Isopleths

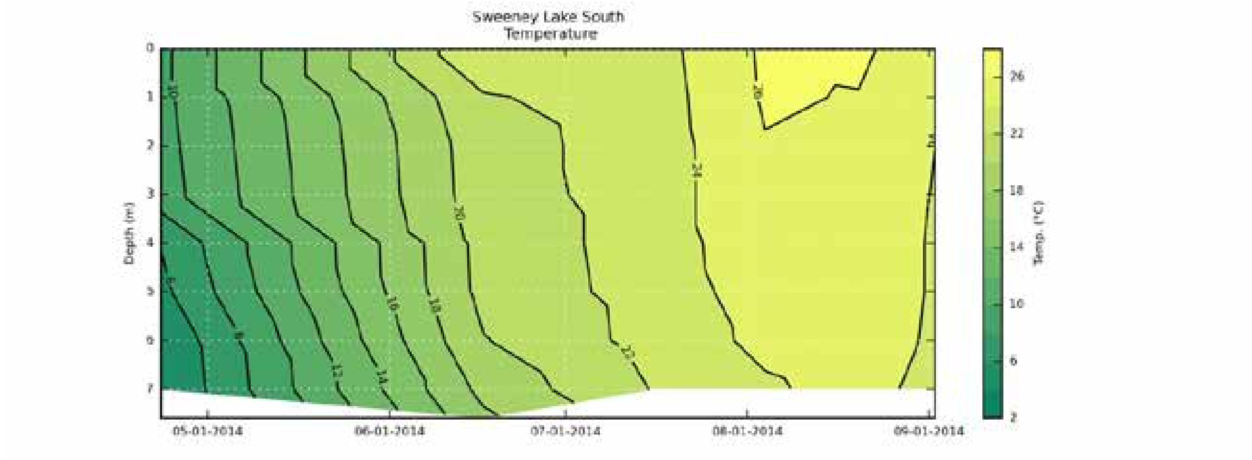


Figure 9 2014 Sweeney Lake South Basin Temperature Isopleths

3.3.2 Dissolved Oxygen

The amount of oxygen dissolved in water depends on water temperature, the amount of wind mixing that brings water into contact with the atmosphere, the biological activity that consumes or produces oxygen within a lake, and the composition of groundwater and surface water entering the lake (2004 Shaw et al.).

As shown in Figure 10 and Figure 11, Sweeney Lake experienced oxygen depletion throughout the monitoring period, except for a brief period in mid-July. The oxygen differences between the bottom and top of Sweeney Lake are shown as color differences in Figure 10 and Figure 11. The gray color shows the oxygen-depleted bottom waters, while the purple colors show the well oxygenated surface waters. Oxygen concentrations were less than 2 mg/L at depths ranging from 4 to 7 meters. Oxygen depletion in the bottom waters was due to microbial decomposition of dead biota. This condition is typical of a highly productive system. Oxygen depletion increased in late summer when severe algal blooms increased the quantity of dead algal cells available for microbial decomposition. Though the aerators operated throughout the growing season, they were unable to overcome the high oxygen demand from microbial decomposition of dead biota.

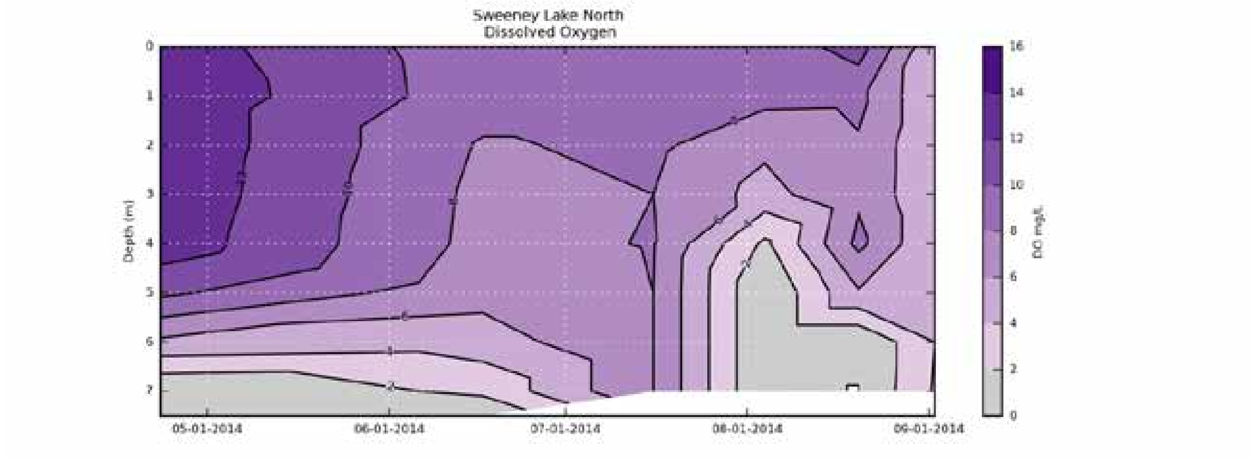


Figure 10 **2014 Sweeney Lake North Basin Dissolved Oxygen Isopleths**

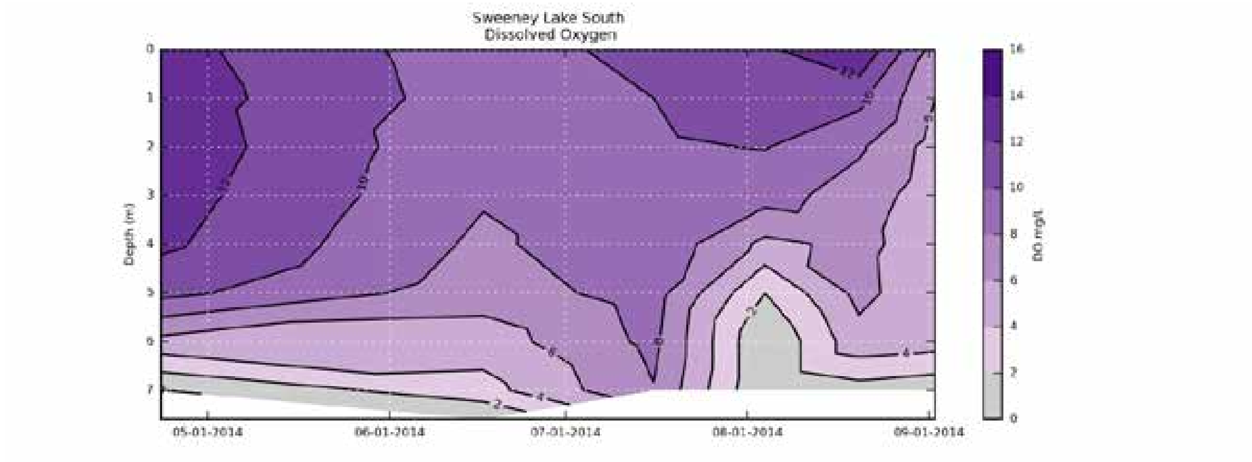


Figure 11 **2014 Sweeney Lake South Basin Dissolved Oxygen Isopleths**

3.3.3 Specific Conductance

Conductivity is the measure of a material's ability to conduct an electrical current. In the case of water, it also serves as an indicator of total dissolved inorganic compounds. Since conductivity is temperature related, reported values are normalized at 25 degrees Celsius and termed "specific conductance." Specific conductance increases as the concentration of dissolved compounds in a lake increases (Shaw et al. 2004). Chlorides, a dissolved compound added to lakes during snowmelt runoff from roads and parking lots, increases specific conductance levels.

High specific conductance values were observed in Sweeney Lake from April through June of 2014. Average specific conductance values in April ranged from 1,907 µmhos/cm @ 25 C in the South Basin to 1,914 µmhos/cm @ 25º C in the North Basin. Average specific conductance values in June ranged from 1,048 µmhos/cm @ 25º C in the South Basin to 1,089 µmhos/cm @ 25º C in the North Basin. The high values were most likely related to deicing chemicals applied to streets and parking lots in the lake's watershed the previous winter. Specific conductance values declined steadily from spring to summer (Figure 12 and Figure 13). The change from red and purple at the far left of Figure 12 and Figure 13 to light purple and gray at the far right shows that specific conductance declined throughout the growing season.

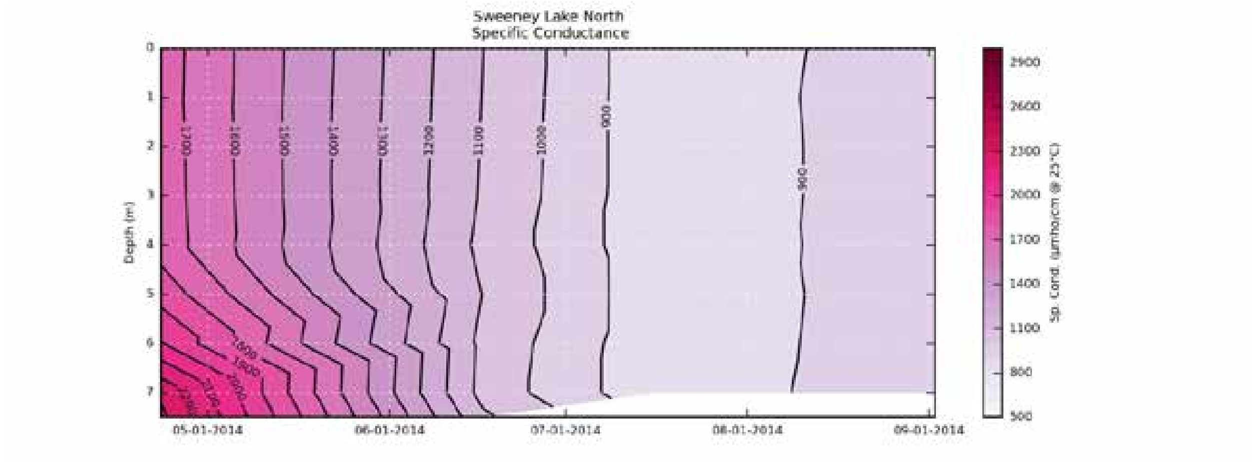


Figure 12 2014 Sweeney Lake North Basin Specific Conductance Isopleths

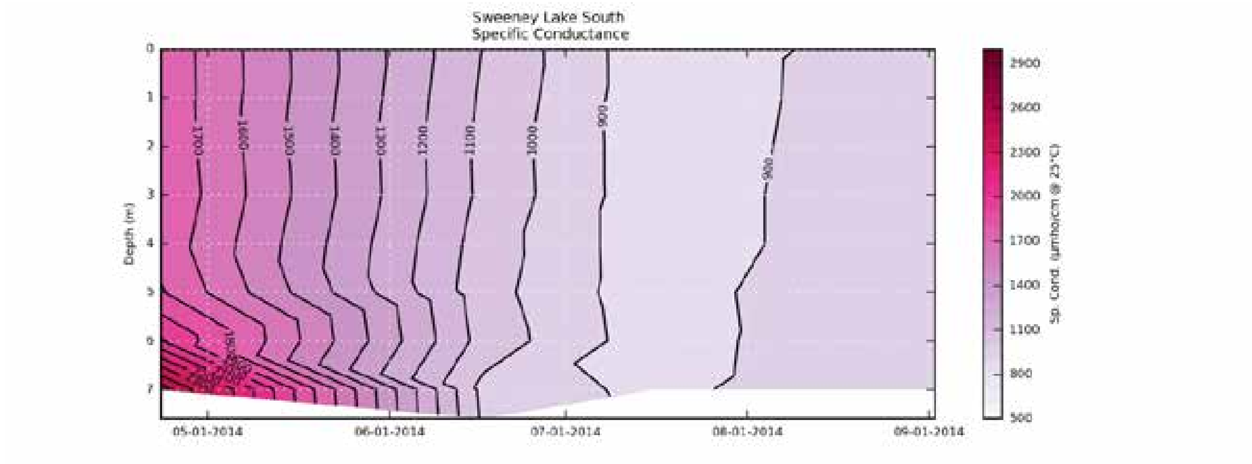


Figure 13 2014 Sweeney Lake South Basin Specific Conductance Isopleths

3.3.4 Total Phosphorus

Phosphorus is necessary for plant and algae growth in lakes. It occurs naturally in soils, rocks, and the atmosphere and can make its way into lakes through groundwater and runoff from the lake's watershed. While phosphorus is necessary for plant and animal growth, excessive amounts lead to an overabundance of growth. This can decrease water clarity and lead to water quality impairment (Shaw et al. 2004). The BCWMC/MPCA standard for phosphorus in Sweeney Lake is an average summer total phosphorus concentration not to exceed 40 µg/L (Minn. R. Ch. 7050.0222 Subp. 4). This standard was selected to prevent nuisance algal blooms in Minnesota lakes.

Total phosphorus concentrations for Sweeney Lake, measured by the 0–2 meter composite (surface or epilimnetic) sample, are summarized in Figure 14 and Figure 15. These concentrations increased throughout the growing season, but were consistently higher in the South Basin of the lake, as shown in the Table 3-1.

Table 3-1 Total Phosphorous Concentrations for the North and South Basins of Sweeney Lake: Low, High, and Summer Average

Total Phosphorous Concentration (0–2 meters)	North Basin	South Basin
Low	43 µg/L (April and June)	46 µg/L (April)
High	68 µg/L (September)	240 µg/L (late August)
Summer Average	57 µg/L	105 µg/L

Total phosphorus concentrations in the spring were within the eutrophic category (poor water quality). Summer concentrations were generally within the hypereutrophic category (very poor water quality). Neither basin met the BCWMC/MPCA average summer total phosphorus standard (40 µg/L).

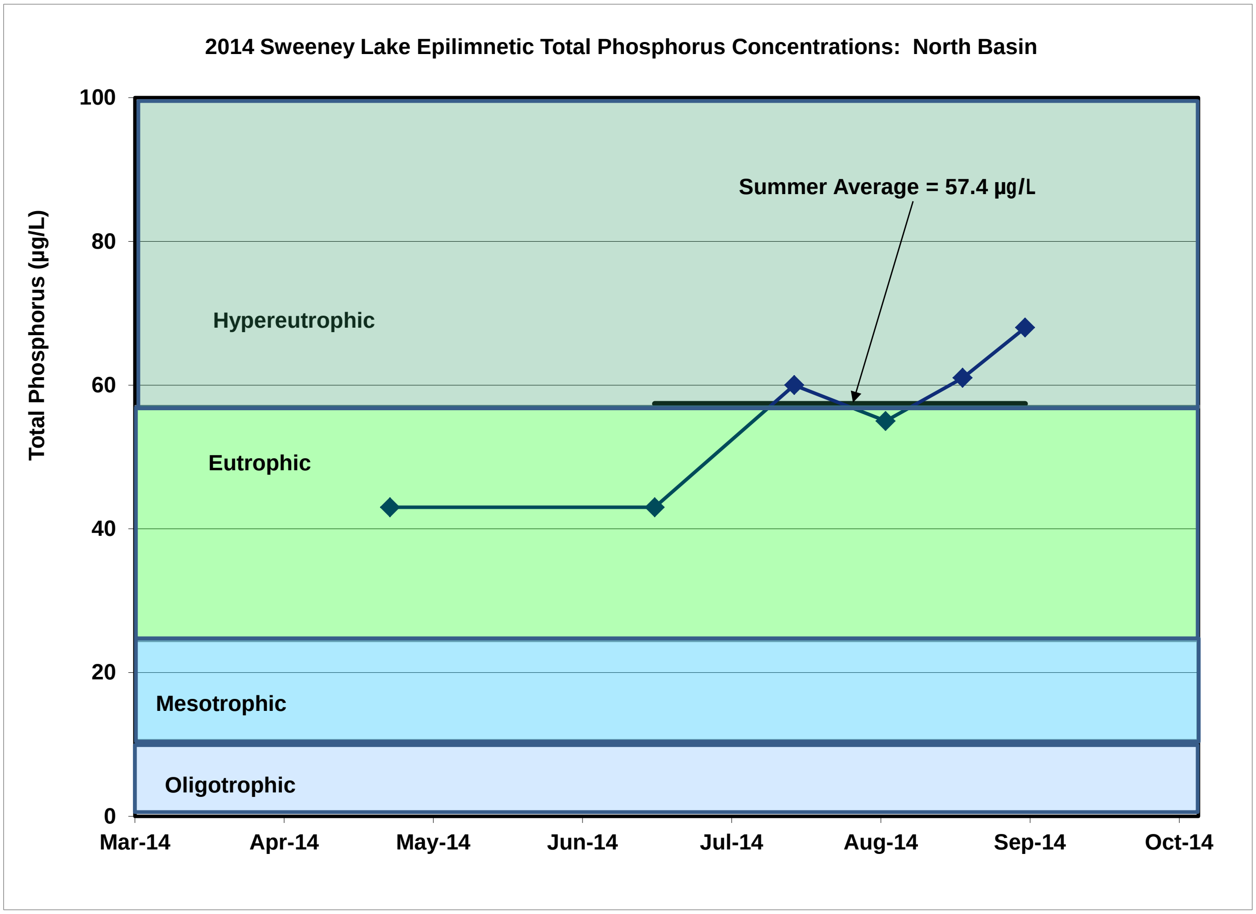


Figure 14 2014 Sweeney Lake North Basin Total Phosphorus Data

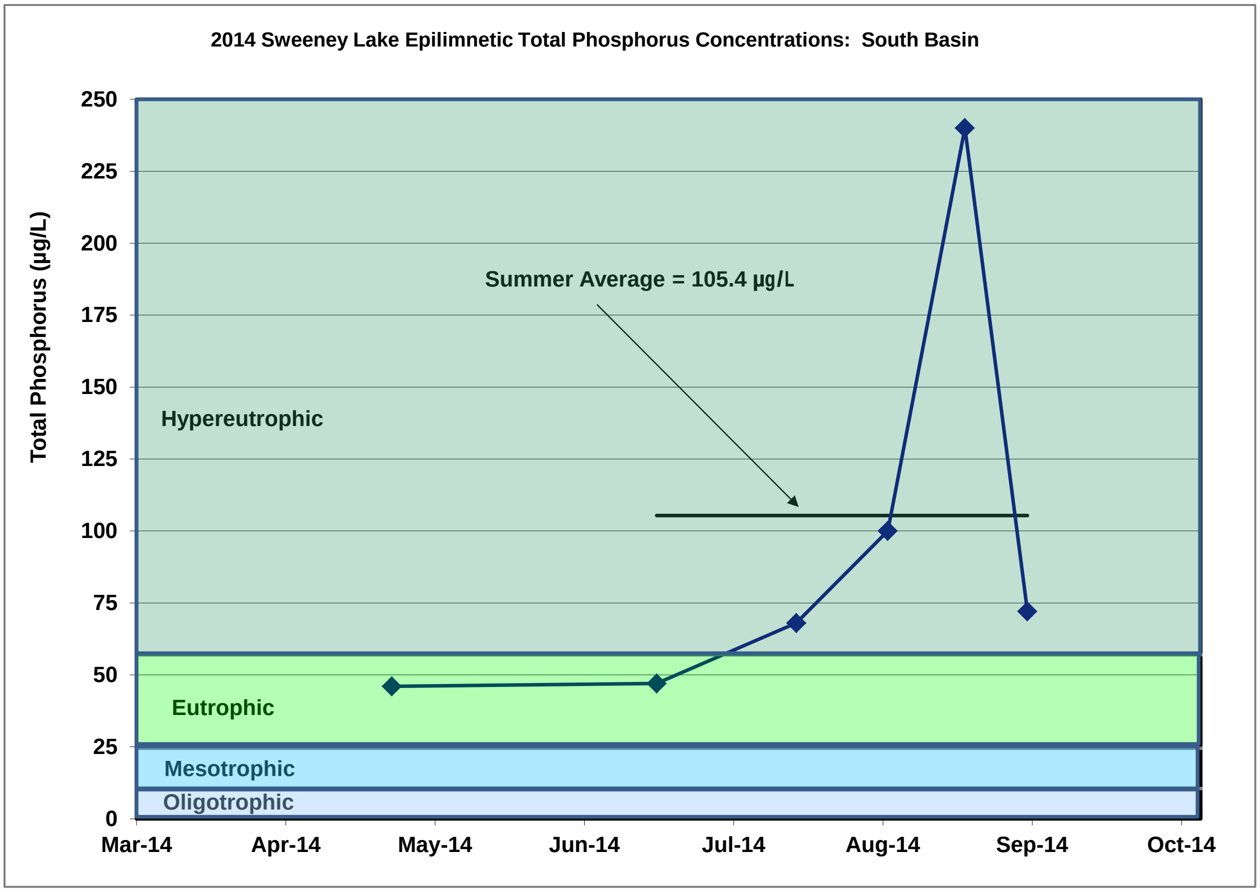


Figure 15 2014 Sweeney Lake South Basin Total Phosphorus Data

Total phosphorus concentrations measured by samples collected throughout the water column are graphically summarized in Figure 16 and Figure 17. Each line on the graph represents a different concentration of phosphorus. The units for the phosphorus concentrations in Figures 16 and 17 are milligrams per liter. One milligram per liter equals 1,000 micrograms per liter. The depth at which the line is drawn shows the depth at which this concentration was measured. Internal loading of phosphorus from lake sediment occurred throughout the growing season. However, greater internal loading occurred in the North Basin from late April through mid-July; internal loading in the South Basin was greater from mid-July through September.

Internal loading from sediment occurs when oxygen concentrations are low. As discussed in Section 3.3.2, low oxygen concentrations were recorded in the bottom waters throughout the growing season despite the operation of aerators. Phosphorus released from the sediment through internal loading is considered immediately available because it is in a dissolved form that algae and plants can directly use. Figure 16 and Figure 17 show that the internal load was mixed throughout the water column in mid-July. After this mixing, little internal loading occurred in the North Basin; however, substantial internal loading continued in the South Basin.

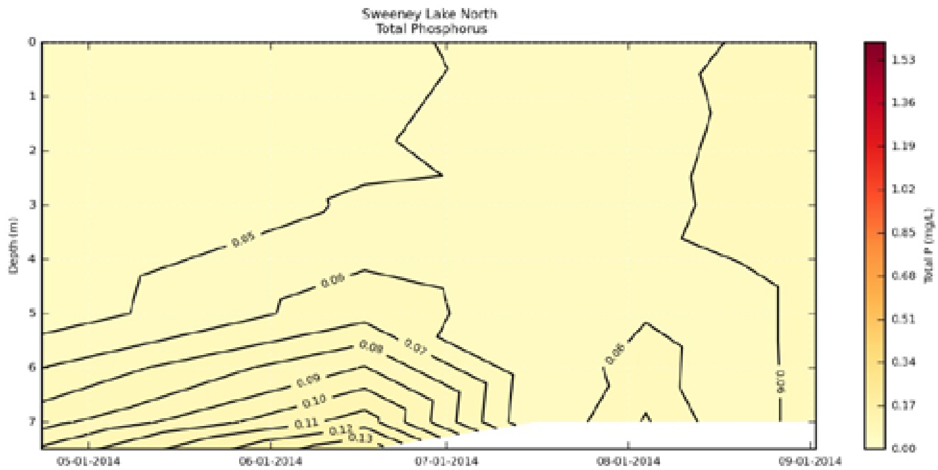


Figure 16 2014 Sweeney Lake North Basin Total Phosphorus Isopleths

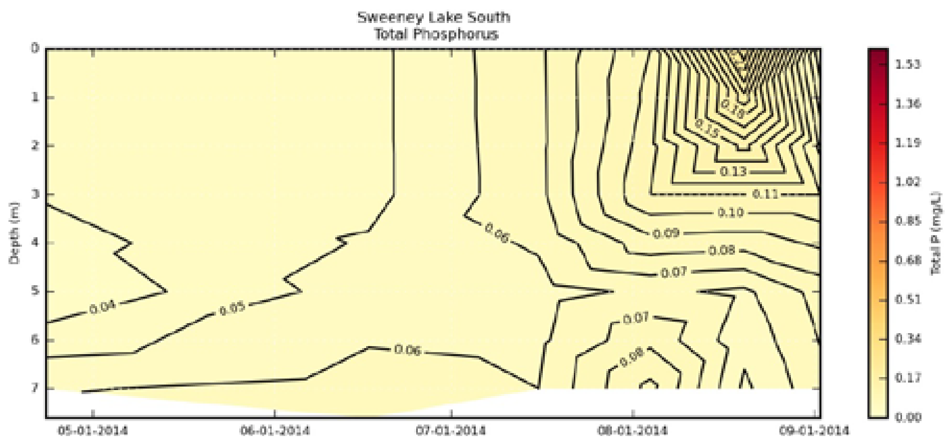


Figure 17 2014 Sweeney Lake South Basin Total Phosphorus Isopleths

3.3.5 Chlorophyll *a*

Chlorophyll *a* is a pigment in plants and algae necessary for photosynthesis; it is an indicator of water quality in a lake. Chlorophyll *a* generally reflects the amount of algae growth in a lake, with greater chlorophyll *a* values indicating greater amounts of algae. Lakes which appear clear generally have chlorophyll *a* levels less than 15 µg/L (Shaw et al. 2004). The chlorophyll *a* limit for Sweeney Lake is 14 µg/L (Minn. R. Ch. 7050.0222 Subp. 4). This criteria has been selected to limit algal growth and prevent nuisance algal blooms.

Chlorophyll *a* concentrations, measured by 0–2 meter composite samples from the lake's deep-basin sample locations, are summarized in Figure 18 and Figure 19. These concentrations declined from spring through June and then increased through August. Concentrations remained high in September, despite a decline. Concentrations were consistently higher in the South Basin of Sweeney Lake, as shown in Table 3-2.

Table 3-2 Chlorophyll *a* Concentrations for the North and South Basins of Sweeney Lake: Low, High, and Summer Average

Chlorophyll *a* Concentration (0–2 meters)	North Basin	South Basin
Low	6.7 µg/L (June)	9.3 µg/L (June)
High	44 µg/L (late August)	210 µg/L (late August)
Summer Average	24 µg/L	81 µg/L

Chlorophyll *a* concentrations in spring to early summer were within the mesotrophic category (good water quality) or eutrophic category (poor water quality); mid-summer concentrations were within the eutrophic category (poor water quality) or hypereutrophic category (very poor water quality); late summer concentrations were consistently in the hypereutrophic category (very poor water quality). The average summer chlorophyll *a* concentrations (81 µg/L in the South Basin and 24 µg/L in the North Basin) did not meet the BCWMC/MPCA standard (14 µg/L).

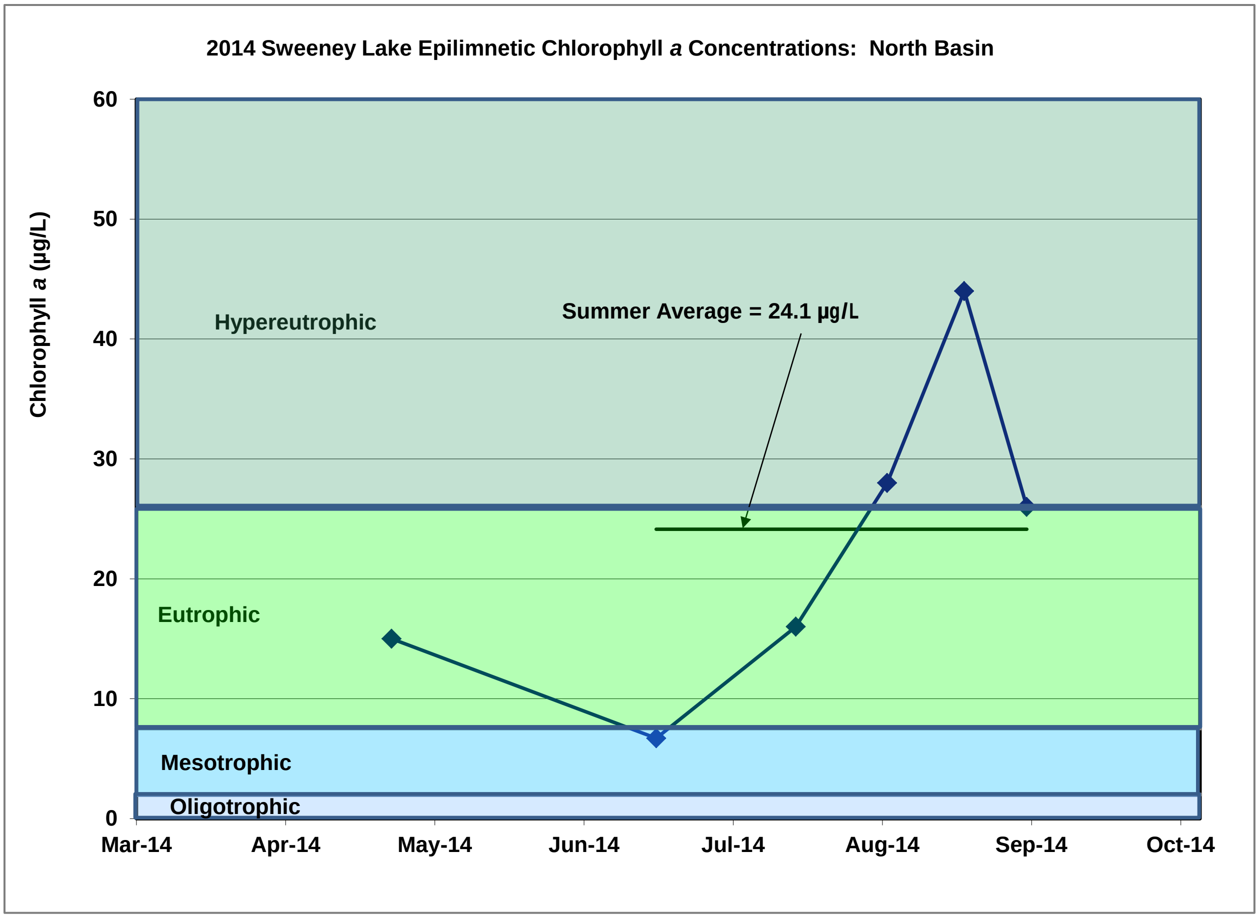


Figure 18 **2014 Sweeney Lake North Basin Chlorophyll *a* Data**

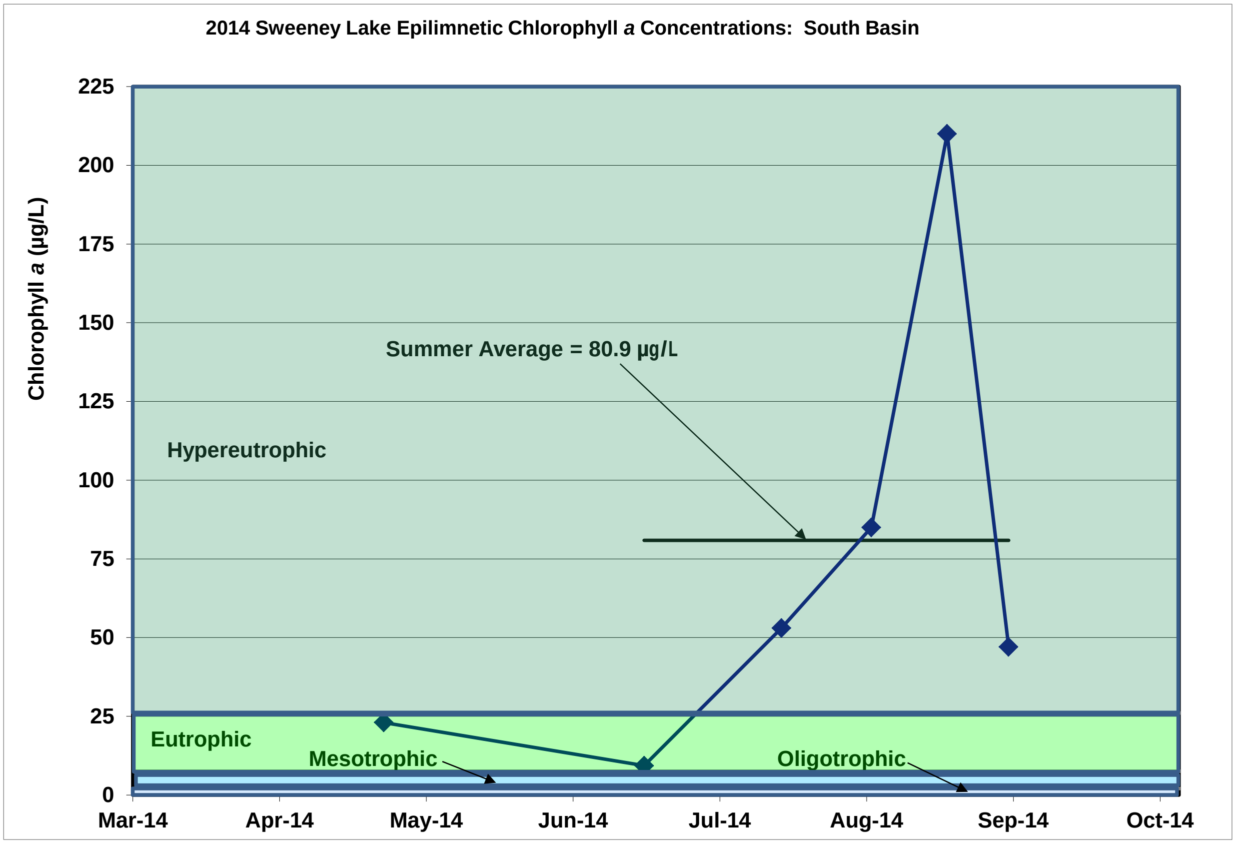


Figure 19 2014 Sweeney Lake South Basin Chlorophyll *a* Data

While the quantity of blue-green algae in the 0-2 meter sample used for the chlorophyll analyses was low (Figure 18 and Figure 19), clumps of blue-green algae were observed in the water column during the June 17 sample event. A zooplankton tow collected on that day also contained clumps of blue-green algae, verifying the start of a blue-green algae bloom.

A zooplankton tow on June 17 contained clumps of blue-green algae (top photo), verifying the start of a massive blue-green algae bloom in Sweeney Lake. The main species causing this bloom was, *Aphanizomenon flos-aquae*, pictured above.

On June 25, the City of Golden Valley received a number of communications from residents about the rapid increase in blue-green algae. During a plant survey of Sweeney Lake on June 26, the plant surveyor made the following statement: "A toxic blue-green algae bloom was occurring in the north bay. Hands were itchy after putting them in the water and the smell was nauseating." The algal bloom that began in June continued through September and caused an increase in chlorophyll *a* concentrations from June through September.

3.3.6 Secchi Disc

The depth to which light can penetrate water is affected by suspended particles, dissolved pigments, and absorbance. Often, the ability of light to penetrate the water column is determined by the abundance of algae or other photosynthetic organisms in a lake. One method of measuring light penetration is with a Secchi disc—a black-and-white disc mounted on a pole or a line. The depth at which the pattern on the disc is no longer visible after being lowered into the water is considered a measure of the water's transparency (i.e., Secchi disc transparency depth). A greater Secchi disc transparency depth indicates greater water clarity (Shaw et al. 2004). Minnesota's Secchi disc transparency criteria for shallow lakes, designed to protect water clarity, is at least 1.4 meters (Minn. R. Ch. 7050.0222 Subp. 4).

Secchi disc data are summarized in Figure 20 and Figure 21. Secchi disc transparencies increased from spring through June and then declined throughout the remainder of the summer. Transparencies were generally lower in the South Basin of Sweeney Lake, as shown in Table 3-3.

Table 3-3 Secchi Disc Transparency for the North and South Basins of Sweeney Lake: Low, High, and Summer Average

Secchi Disc Transparency	North Basin	South Basin
Low	0.8 meters (early August)	0.5 meters (late August)
High	3.6 meters (June)	2.3 meters (June)
Summer Average	1.6 meters	1.1 meters

Secchi disc transparencies were in the mesotrophic (good category) in June. Spring and summer transparencies were within the eutrophic category (poor water quality) or hypereutrophic category (very poor water quality). The average summer Secchi disc transparency in the North Basin (1.6 meters) did meet the BCWMC/MPCA standard of 1.4 meters, but transparency in the South Basin (1.1 meters) did not.

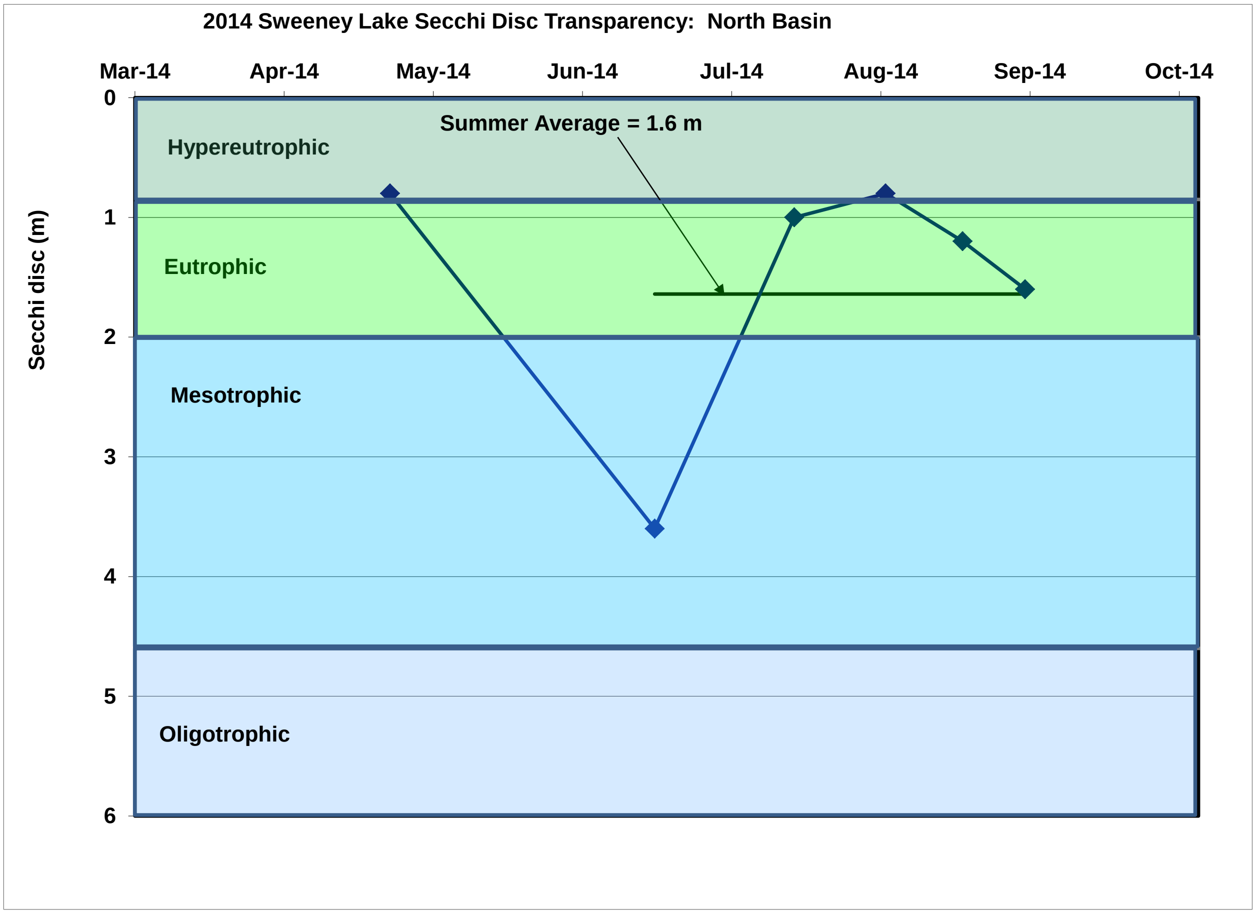


Figure 20 **2014 Sweeney Lake North Basin Secchi Disc Transparency Data**

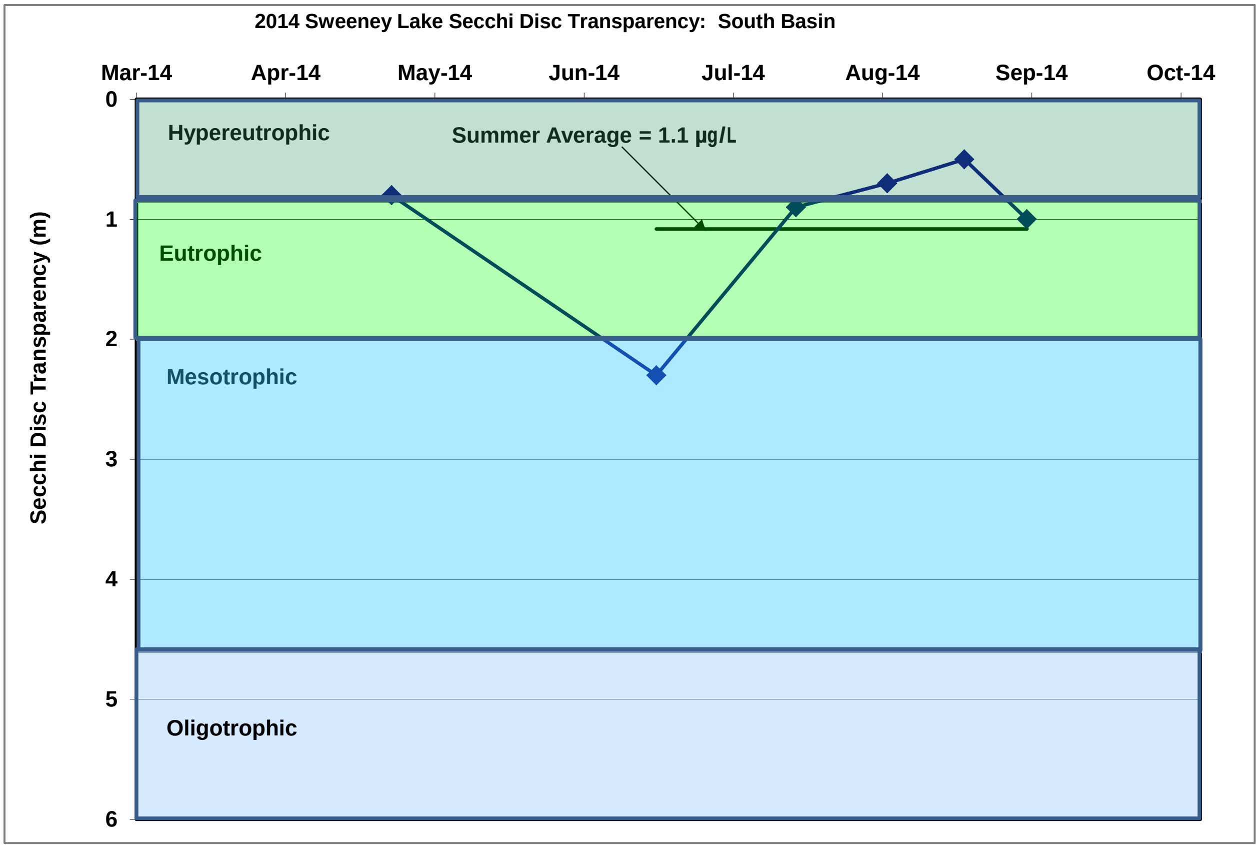


Figure 21 **2014 Sweeney Lake South Basin Secchi Disc Transparency Data**

3.4 Historical Trends

Historical water quality trends are shown on Figure 22, Figure 23, and Figure 24. The black diamonds on the figures show the average summer values during the period of record (i.e., average summer total phosphorus and chlorophyll *a* concentrations and Secchi disc transparency depths). The summer averages include CAMP data and BCWMC data. Data from the North and South Basins were averaged. The line on each figure shows the long-term trend; the slope of the line shows the rate of change over time.

The changes in total phosphorus and chlorophyll *a* concentrations since 1972 are not significant because there is more than a 5-percent probability that the changes are due to chance (Figure 22 and Figure 23). Although fluctuations in total phosphorus concentrations have occurred, the long-term trend line has a slope of 0, indicating no change over time. The long-term trend line for chlorophyll *a* indicates concentrations have declined at a rate of 0.185 µg/L per year. However, this decline is not considered significant because there is more than a 5-percent probability that the decline is due to chance.

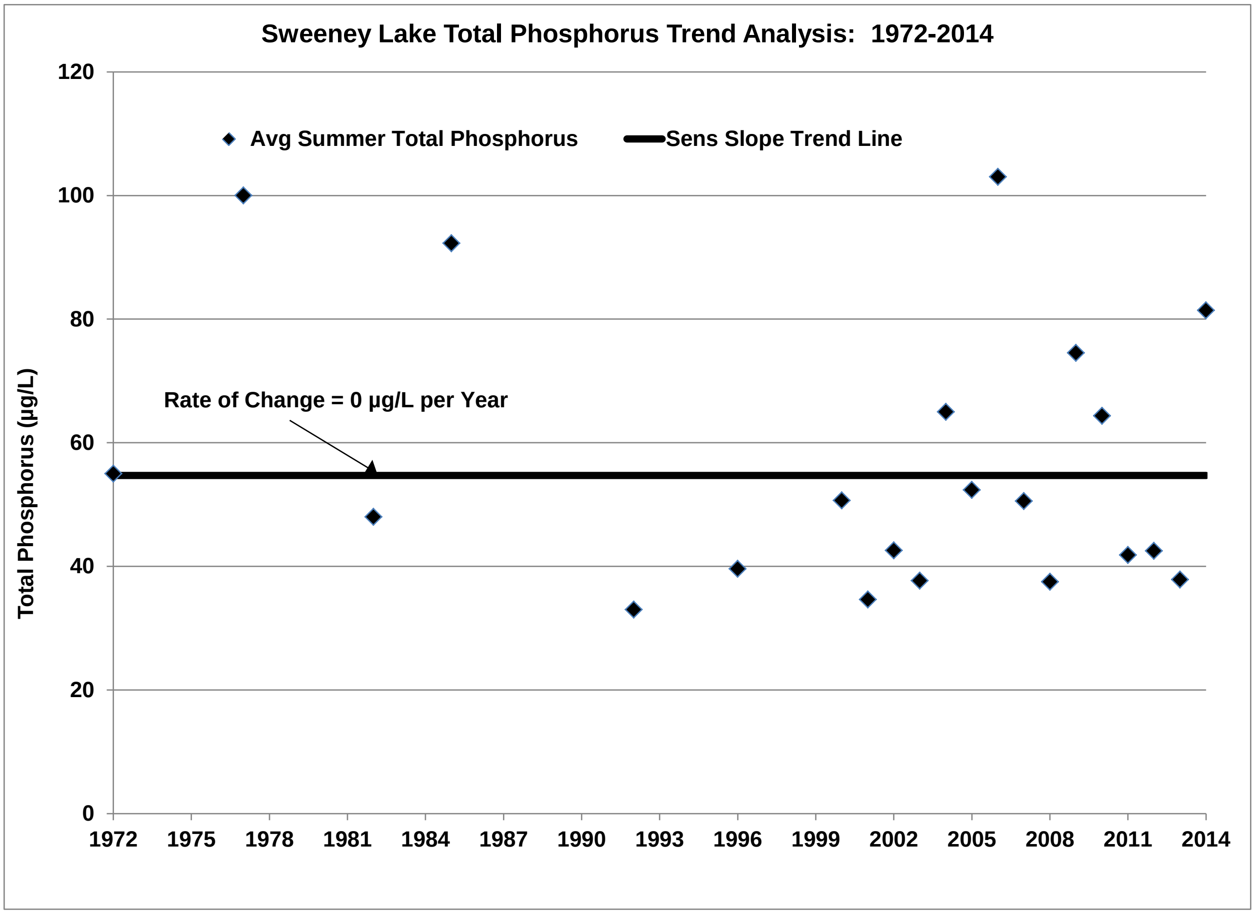


Figure 22 Sweeney Lake Total Phosphorus Trend Analysis: 1972–2014

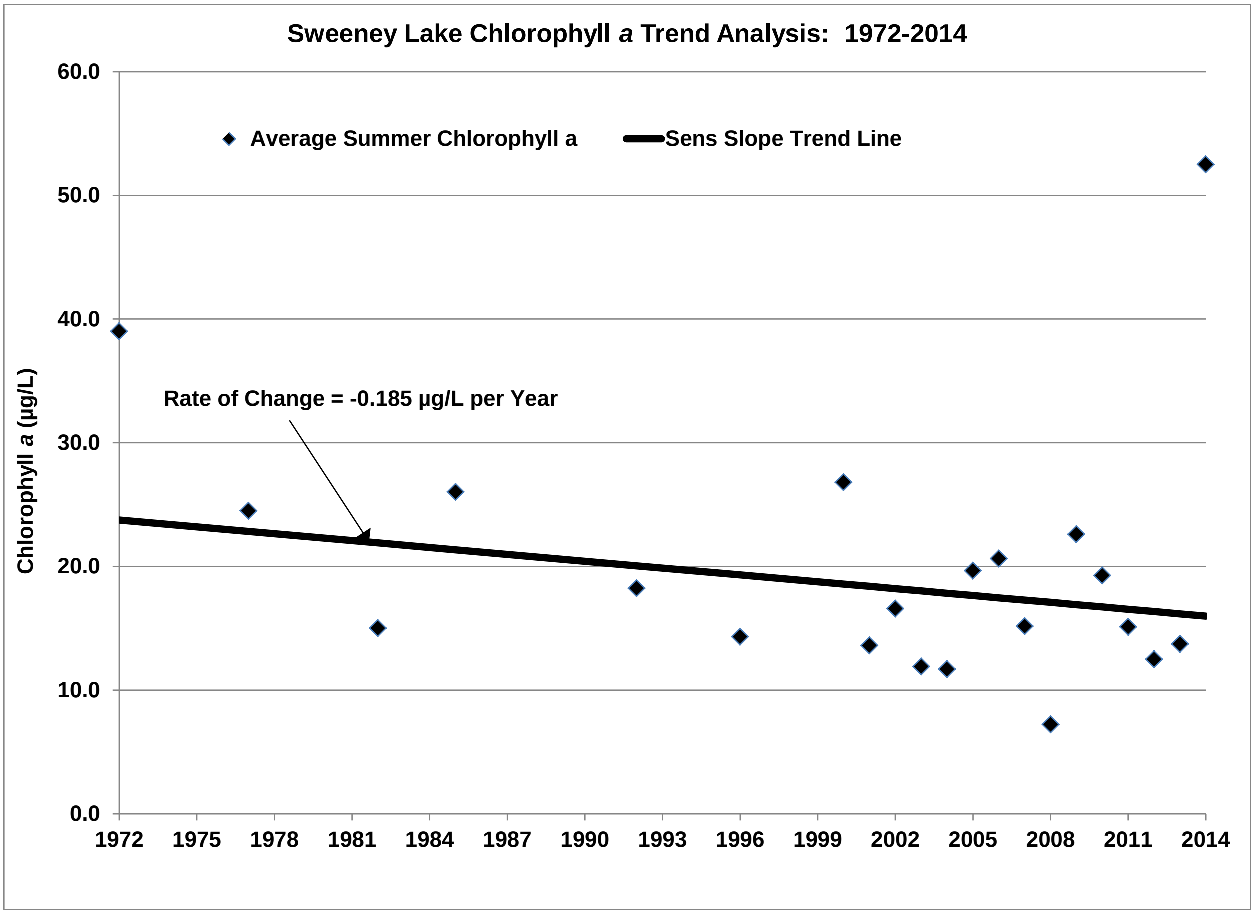


Figure 23 Sweeney Lake Chlorophyll *a* Trend Analysis: 1972–2014

A significant decline in average summer Secchi disc transparency depths has occurred since 1972. The long-term trend line indicates transparency depths have declined at a rate of 0.01 meters (0.4 inches) per year. The reduction in Secchi disc transparency depths is significant because there is less than a 5-percent probability that the transparency changes are due to chance (Figure 24).

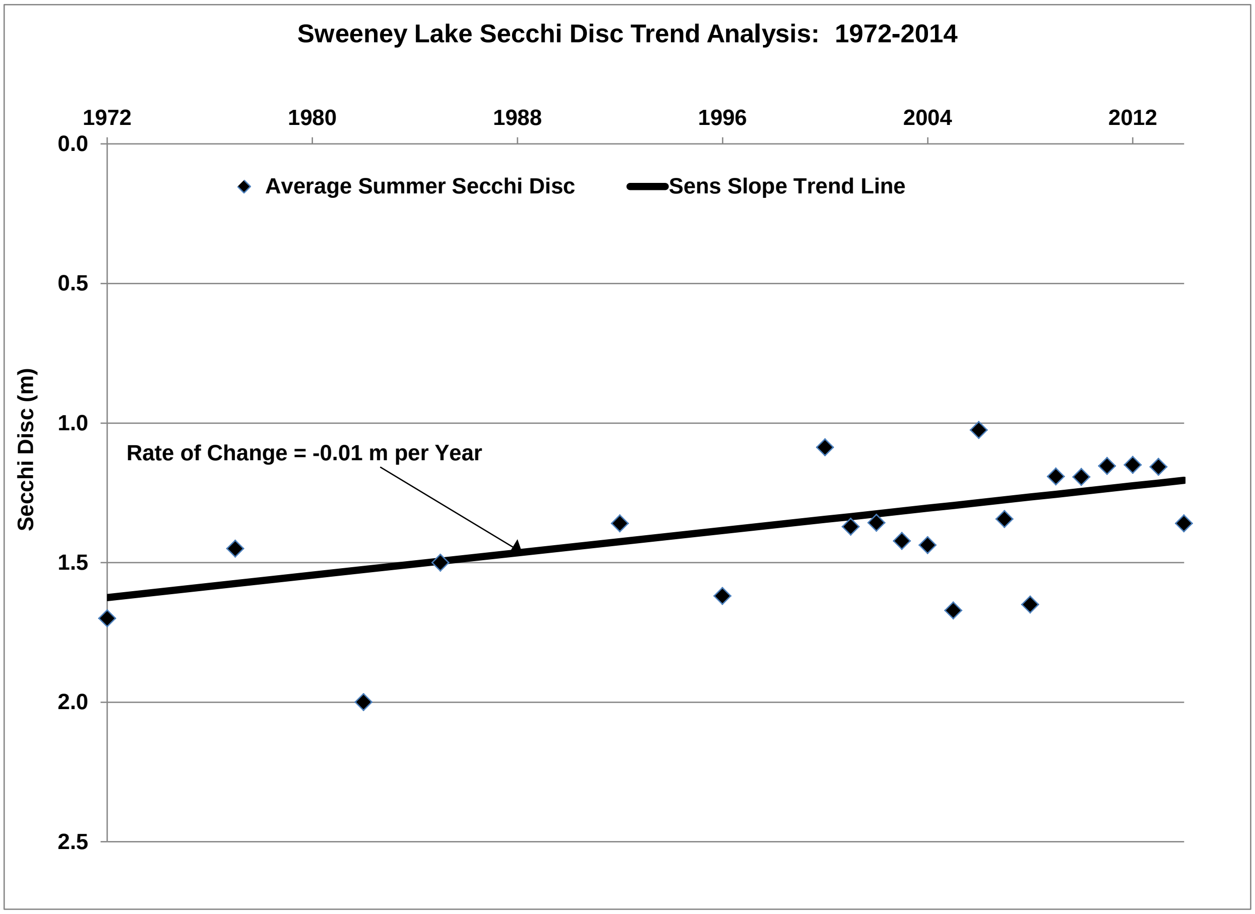


Figure 24 **Sweeney Lake Secchi Disc Trend Analysis: 1972–2014**

3.5 Historical Attainment of BCWMC/MPCA Standards

Figure 25, Figure 26, and Figure 27 compare historical water quality data from Sweeney Lake for the period 1972 through 2014 with BCWMC/MPCA standards. The data include CAMP data and BCWMC data. Data collected from the North and South basins were averaged. High total phosphorus and chlorophyll concentrations have been observed in the lake for more than 40 years. During the period of record, only 29 percent of the summer averages for total phosphorus and chlorophyll concentrations met the BCWMC/MPCA standard (Figure 25 and Figure 26). Although Secchi disc transparencies have generally been low, they have more frequently met the BCWMC/MPCA standard. During the period of record, 62 percent of the Secchi disc summer averages have met the BCWMC/MPCA standard (Figure 27).

Although the 2014 average summer total phosphorus concentration and Secchi disc transparency were within the range of values observed during the period of record, the 2014 average summer chlorophyll *a* concentration was the highest to date. The record-setting high chlorophyll *a* value is consistent with the observation that Sweeney Lake experienced its worst summer algal blooms.

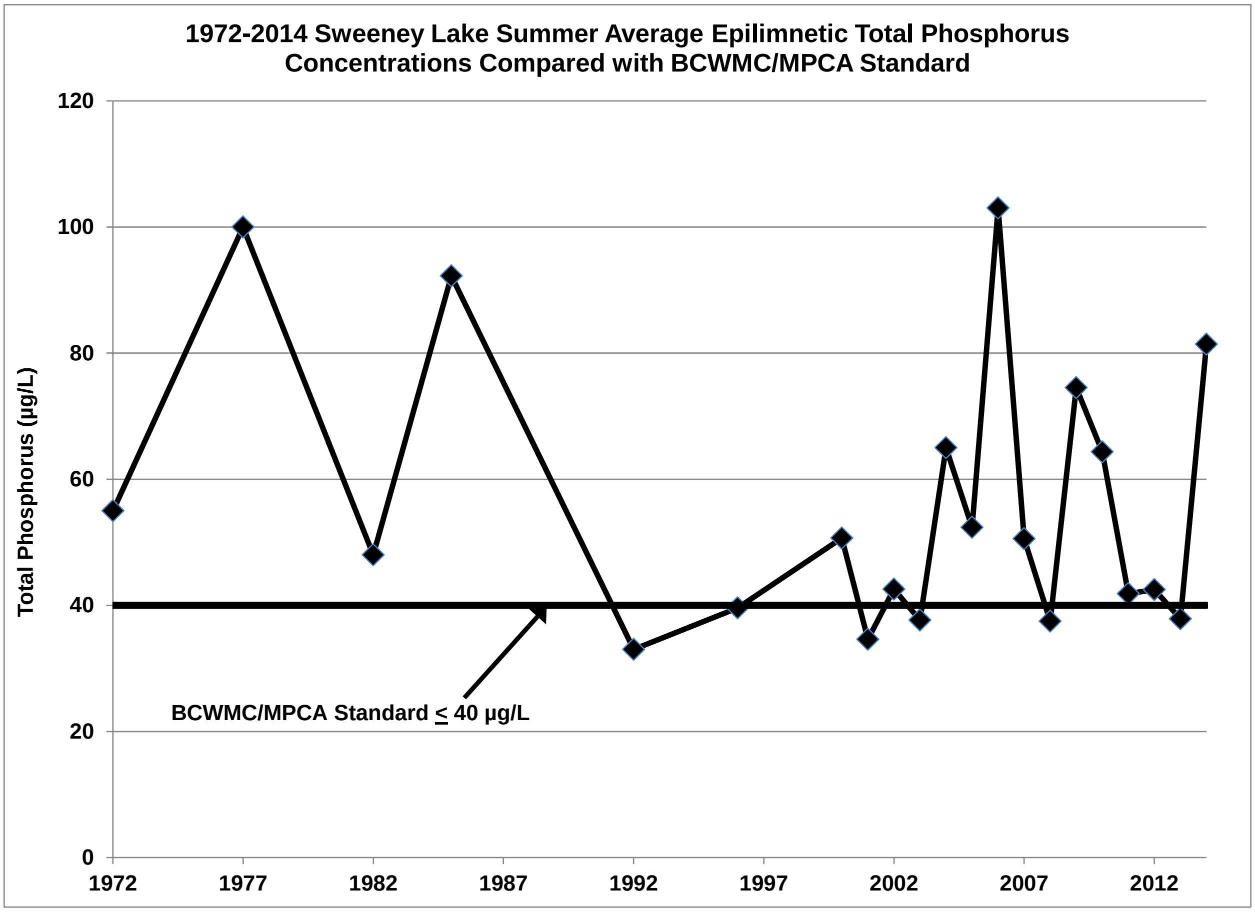


Figure 25 **Sweeney Lake Historical Total Phosphorus Concentrations Compared with BCWMC/MPCA Total Phosphorus Standard**

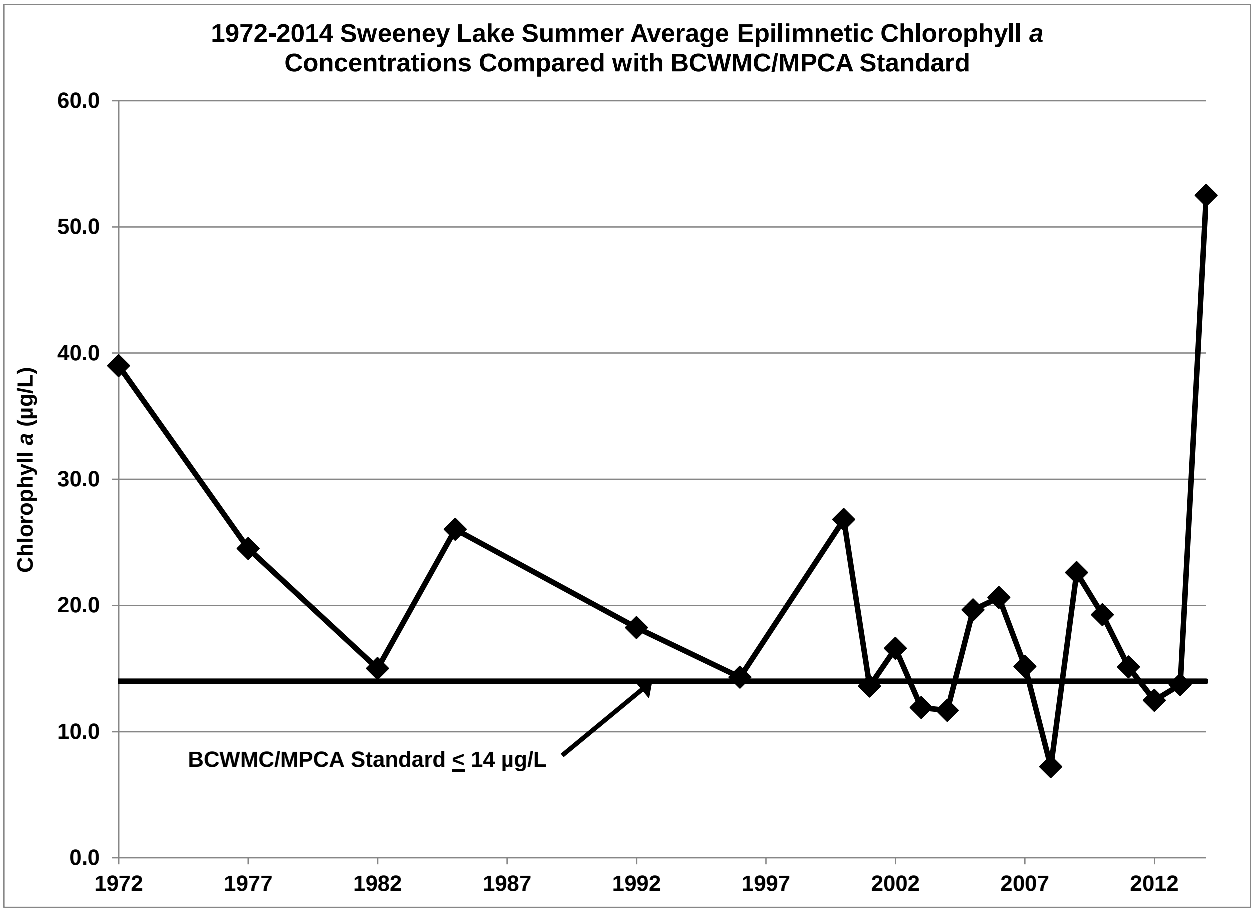


Figure 26 **Sweeney Lake Historical Chlorophyll *a* Concentrations Compared with BCWMC/MPCA Chlorophyll *a* Standard**

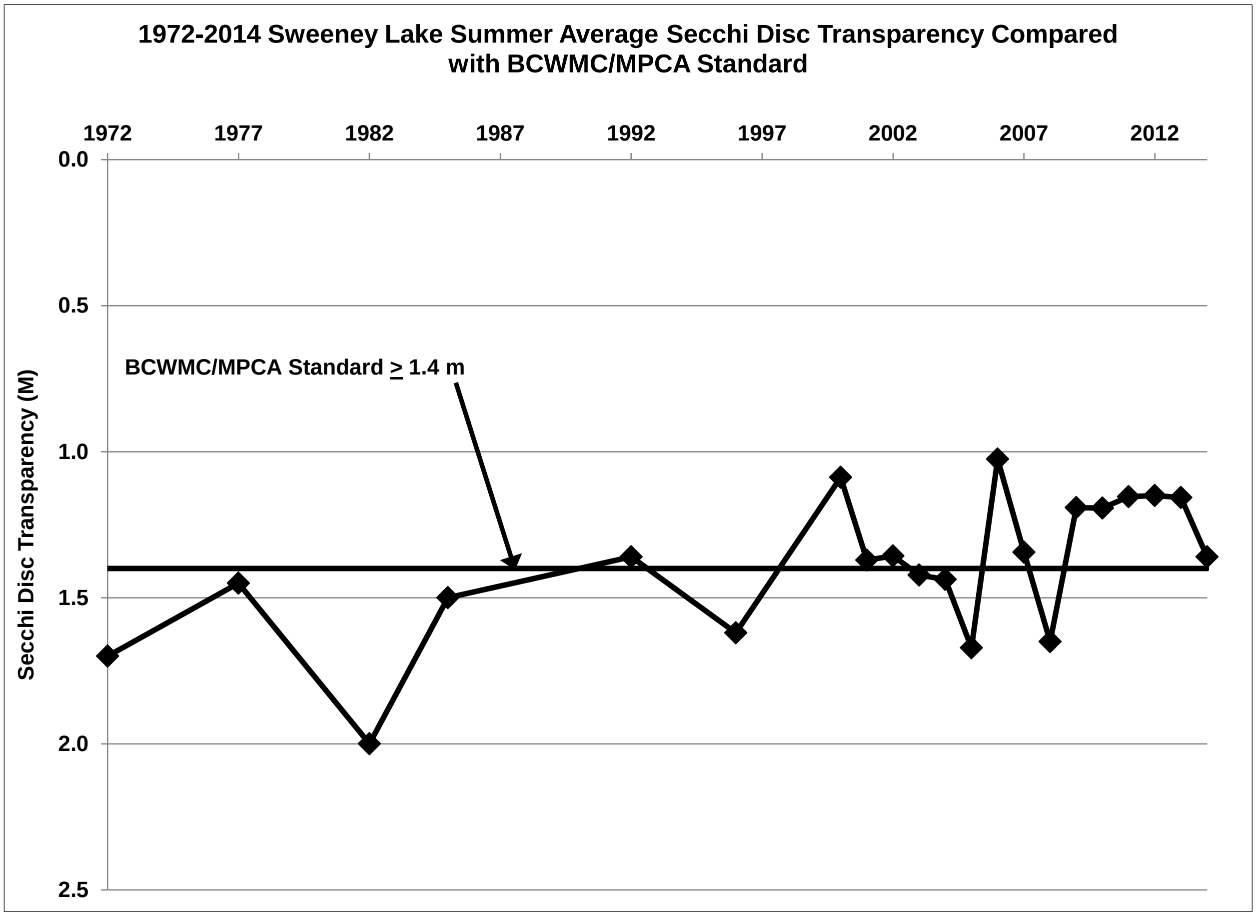


Figure 27 **Sweeney Lake Historical Secchi Disc Depths Compared with BCWMC/MPCA Secchi Disc Standard**

3.6 Biota

Three components of lake biota are presented: macrophytes, phytoplankton, and zooplankton. Fisheries status is managed by the Minnesota Department of Natural Resources (MDNR) and is not covered in this report.

3.6.1 Macrophytes

Macrophytes are aquatic plants that are large enough to be visible to the naked eye. They are divided into three groups:

- Submerged—grow beneath the water surface
- Floating leaf—leaves float on the water surface
- Emergent—stem and leaves are above the water surface

Plants from all three groups were present in Sweeney Lake during 2014. Plant survey statistics are presented in Table 3-4. A comparison of plant survey statistics from 1996 through 2014 is presented in Table 3-5. The 2014 frequency of occurrence of individual species is presented in Figure 28.

Table 3-4 2014 Sweeney Lake Aquatic Plant Survey Statistics

Parameters	6/26/2014	8/11/2014
Total Number of Sites Visited	124	124
Total Number of Sites with Vegetation	49	43
Total Number of Sites Shallower than Maximum Depth of Plants	52	50
Frequency of Occurrence of Plants at Sites Shallower than Maximum Depth of Plants	94	86
Simpson Diversity Index (0-1, higher number, higher diversity)	0.84	0.82
Maximum Depth of Plants (ft)	10	7
Average Number of all Species Per Site (Shallower than Maximum Depth of Plants)	2.12	2.16
Average Number of All Species Per Site (Vegetated Sites Only)	2.24	2.51
Average Number of Native Species Per Site (Shallower than Maximum Depth of Plants)	1.92	2.16
Average Number of Native Species Per Site (Vegetated Sites Only)	2.08	2.30
Number of Species	15	15
Species Richness (Including Visuals)	15	18
Species Richness (Including Visuals and Boat Survey)	17	20
Average Rake Fullness (1-4)	2.45	2.30
Mean C (0-10, increasing values, decreased tolerance to disturbance, higher quality)	5.5	5.3
FQI (3-49 observed in Wisconsin, median value in Wisconsin is 22, higher number, more diverse, higher quality)	20.6	20.7

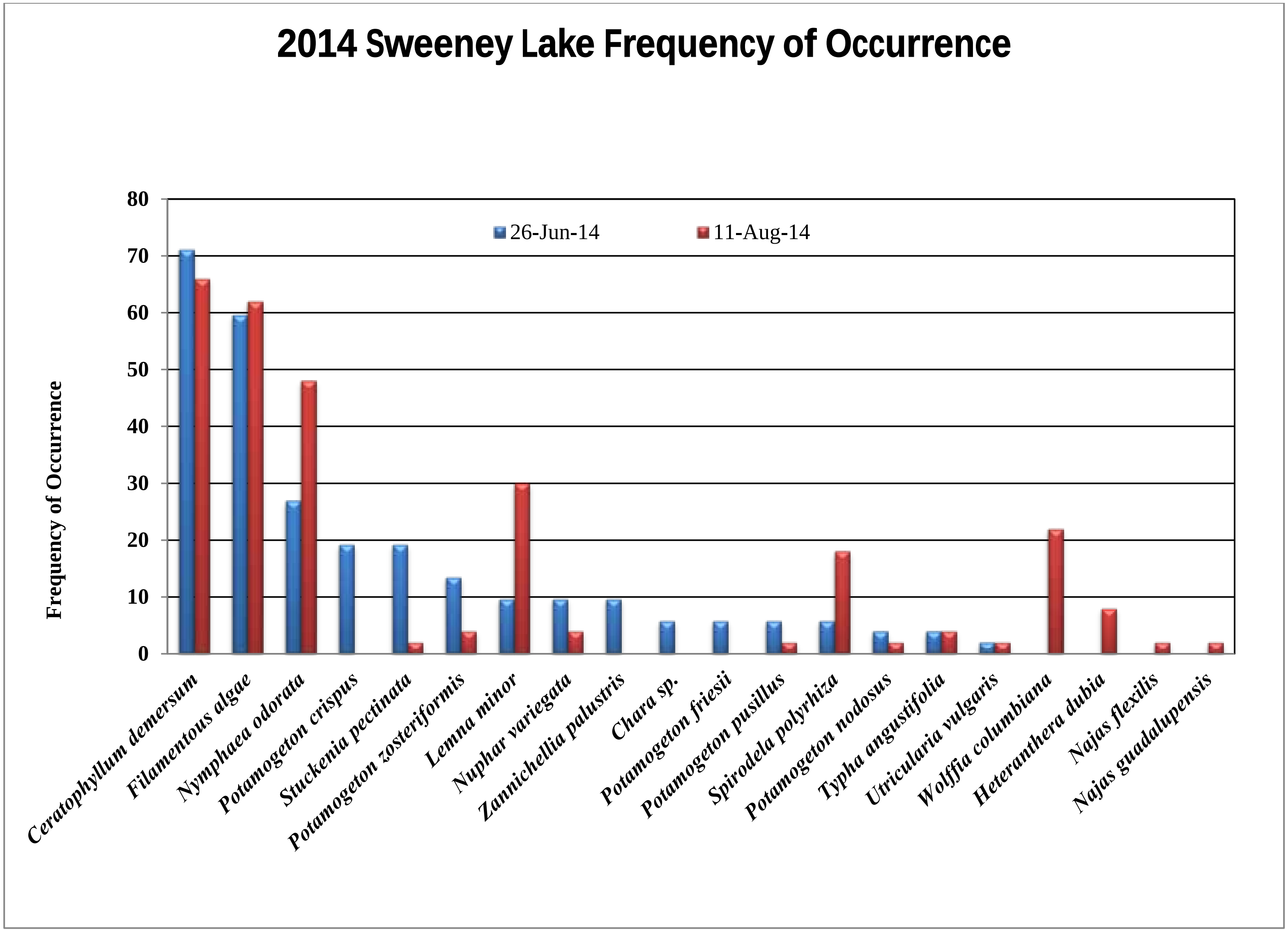


Figure 28 **2014 Sweeney Lake Frequency of Occurrence of Plant Species: June and August**

Table 3-5 1996–2014 Sweeney Lake Aquatic Plant Survey Statistics: Number of Species, Average C, and FQI

Year	# of Species: June	# of Species: August	June Average C*	August Average C *	June FQI**	August FQI**
1992	12	9	5.4	5.1	17.8	14.5
1996	12	17	5.6	5.8	18.7	23.3
2000	17	16	5.6	5.6	22.5	22.5
2005	17	18	5.6	5.6	22.5	23.3
2008	17	17	5.6	5.6	22.3	22.3
2014	17	20	5.5	5.3	20.6	20.7

*C indicates the average tolerance to disturbance by the plant community. Values are on a scale of 1 to 10 with increasing values indicating decreasing tolerance to disturbance.

**FQI or floristic quality index indicates the quality of the plant community; increasing values indicate increasing quality. Although Minnesota has not kept a record of FQI values, the median value in Wisconsin is 22.

From 1992 to 2014, a ring of vegetation, with a maximum depth of 6 to 10 feet, was found in Sweeney Lake. In June 2014, plants grew up to to the 10-foot depth; in August they were observed at a depth of 7 feet.

The number of species observed in Sweeney Lake increased between 1992 and 1996 and then remained relatively stable through 2008. From nine to 12 species were found in 1992 compared with 12 to 17 in 1996. From 16 to 18 species were observed from 2000 through 2008. In 2014 17 species were observed in June and 20 species were observed in August (Table 3-5).

From 1992 through 2014, the tolerance of plant species in Sweeney Lake to degraded conditions has been evaluated using “C” values. Plant species were assigned C values on a scale of 0 to 10, with increasing values indicating plants are less tolerant to degraded conditions. A value of 5 indicates average tolerance to degraded conditions. An average of the C values for individual species in the lake indicates the average tolerance of the community to degraded conditions. From 1992 through 2014, C values in Sweeney Lake have ranged from 5.1 to 5.8; values in 2014 ranged from 5.3 to 5.5.

In June of 2014, plants were canopied (reached the surface) to the 6 foot depth. As pictured above, the plant community was dominated by coontail, filamentous algae, and white water lily.

The quality of the Sweeney Lake plant community was assessed using the floristic quality index (FQI). FQI considers both the quality of the individual native species in the lake (C value) and the number of native species. Although Minnesota has not kept a record of FQI values, recorded Wisconsin FQI values range from 3 (degraded, poor-quality plant communities) to 49 (diverse, good-quality plant communities). The median FQI for Wisconsin is 22. Sweeney Lake FQI values from 1992 through 2014 have ranged from 14.5 to 23.3 (Table 3-5). Since 2000, values have generally been very close to the Wisconsin median, indicating the Sweeney Lake plant community has generally been of average quality. 2014 FQI values were 20.6 in June and 20.7 in August, slightly lower than values observed since 2000 and slightly lower than the Wisconsin median. The decreased quality of the 2014 Sweeney Lake plant community was likely caused by the severe algal blooms; these degraded conditions (e.g., poorer light), adversely impacted the plant community.

Purple loosestrife-eating *Galerucella* beetles control purple loosestrife by inflicting damage on purple loosestrife plants, shown in the picture above.

Three invasive species were observed in 2014: curly-leaf pondweed, purple-loosestrife, and reed canary grass.

Curly-leaf pondweed has been present in Sweeney Lake since BCWMC's first plant survey in 1992, but does not seem to be "invading" the lake. Although in June it was found at 19 percent of the survey locations shallower than the maximum depth of plant growth, curly-leaf pondweed was a minor component of the overall plant community (Figure 29). Because it is not a problem, management of curly-leaf pondweed does not seem necessary at this time. However, plant survey data collected in the future should be reviewed to identify any changes in spatial extent or density so that management needs can be identified.

Purple loosestrife has been observed near the lake's outlet, pictured above, since 2005.

Purple loosestrife has been observed in Sweeney Lake in 1992, 2008, and 2014. In 2014, the plant was found at one location in June and expanded to three additional locations in August. Because it is expanding, Barr recommends that the BCWMC explore the feasibility of managing purple loosestrife with purple-loosestrife-eating beetles.

In 2014, reed canary grass was observed at one location at the northwest corner of the lake (Figure 31). Although it is not a problem at this time, plant survey data collected in the future should be reviewed to identify any changes in spatial extent or density so that so that management needs may be identified.

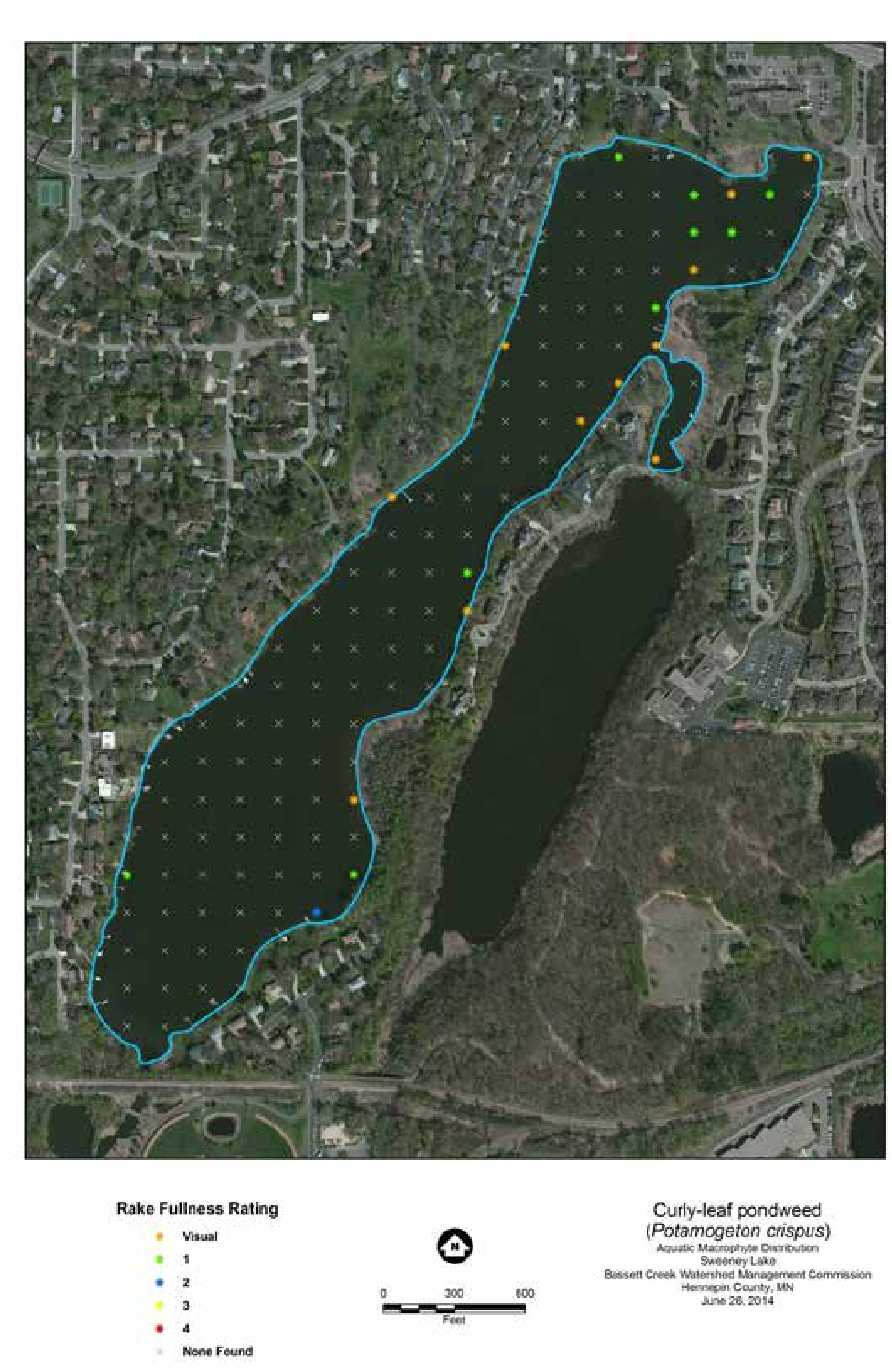


Figure 29 2014 Sweeney Curly-Leaf Pondweed Locations: June

Figure 30 **2014 Sweeney Lake Purple Loosestrife Locations: August**

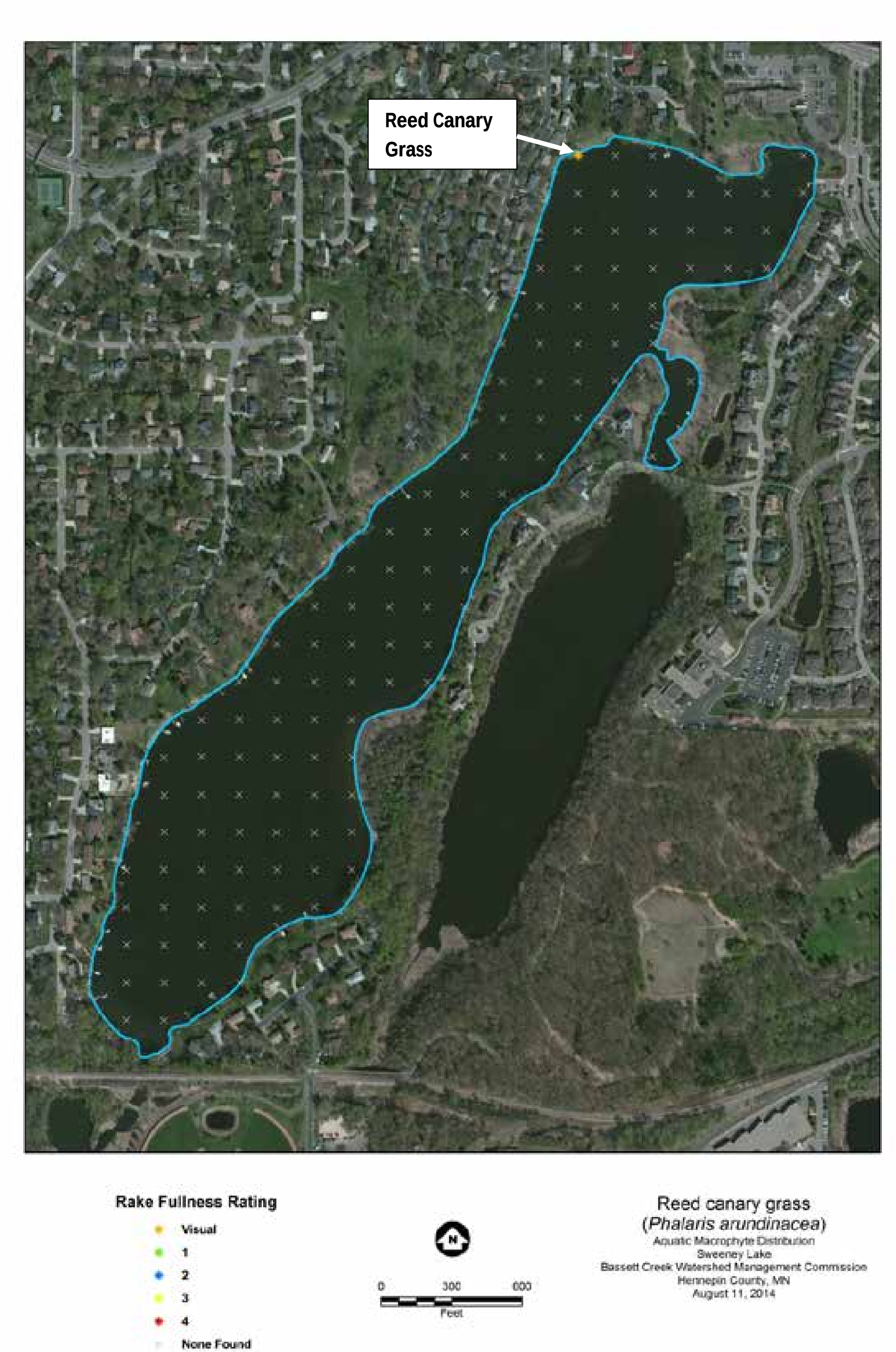


Figure 31 2014 Sweeney Lake Reed Canary Grass Location: August

3.6.2 Phytoplankton

Algae are microscopic plants that convert sunlight and nutrients into biomass. They can live on the bottom sediments and substrates (filamentous algae), on plants and leaves (periphyton), or in the water column (phytoplankton).

Phytoplankton samples have been collected periodically from Sweeney Lake since 1982 to evaluate the lake's water quality and determine the quality of food available to the lake's small animals (zooplankton). Algae have short life cycles. As a result, changes in water quality are often reflected by changes in the algal community within a few days or weeks. The types of algae in a lake will change over the course of a year. Typically, there are fewer algae in winter and spring because of ice cover and cold temperatures. As a lake warms up and sunlight increases, algae communities begin to increase. Their short life span quickly cycles the nutrients in a lake and affects nutrient dynamics.

There are seven divisions of algae found in typical lakes of Minnesota (Table 3-6); all seven have been observed in Sweeney Lake during the period of record (Figures 32 and 33).

Table 3-6 Characteristics of Algae Observed in Sweeney Lake from 1982 through 2013 (Shaw et al. 2004, Brown 2002, Guedes et al. 2012)

Algal Division	Common Name	Characteristics
Chlorophyta	Green algae	Provide high nutritional value to consumers. Can be single-celled, colonial, or filamentous. Filamentous often intermingle with macrophytes.
Bacillariophyta	Diatoms	Provide high nutritional value to consumers. Sensitive to chloride, pH, color, and total phosphorus in water. As total phosphorus increases, diatoms decrease. Generally larger in size. Tend to be abundant in spring and late spring.
Cryptophyta	Cryptomonads	Provide high nutritional value to consumers. Bloom-forming and used to feed small zooplankton.
Cyanophyta	Blue-green algae	Provide low nutritional value to consumers. Prevail in nutrient-rich standing waters. Blooms can be toxic to zooplankton, fish, livestock, pets, and humans. Can be unicellular, colonial, planktonic, or filamentous. Can live on almost any substrate. More prevalent in late- to mid-summer. Colonies and filaments are often too large to be ingested by zooplankton.
Pyrrophyta	Dinoflagellates	Have starch reserves and serve as food for grazers.
Chrysophyta	Golden-brown algae	A genus of single-celled algae with ovoid cells and a distinctive golden color.
Euglenophyta	Euglenoids	Commonly found in freshwater that is rich in organic materials. Most are unicellular.

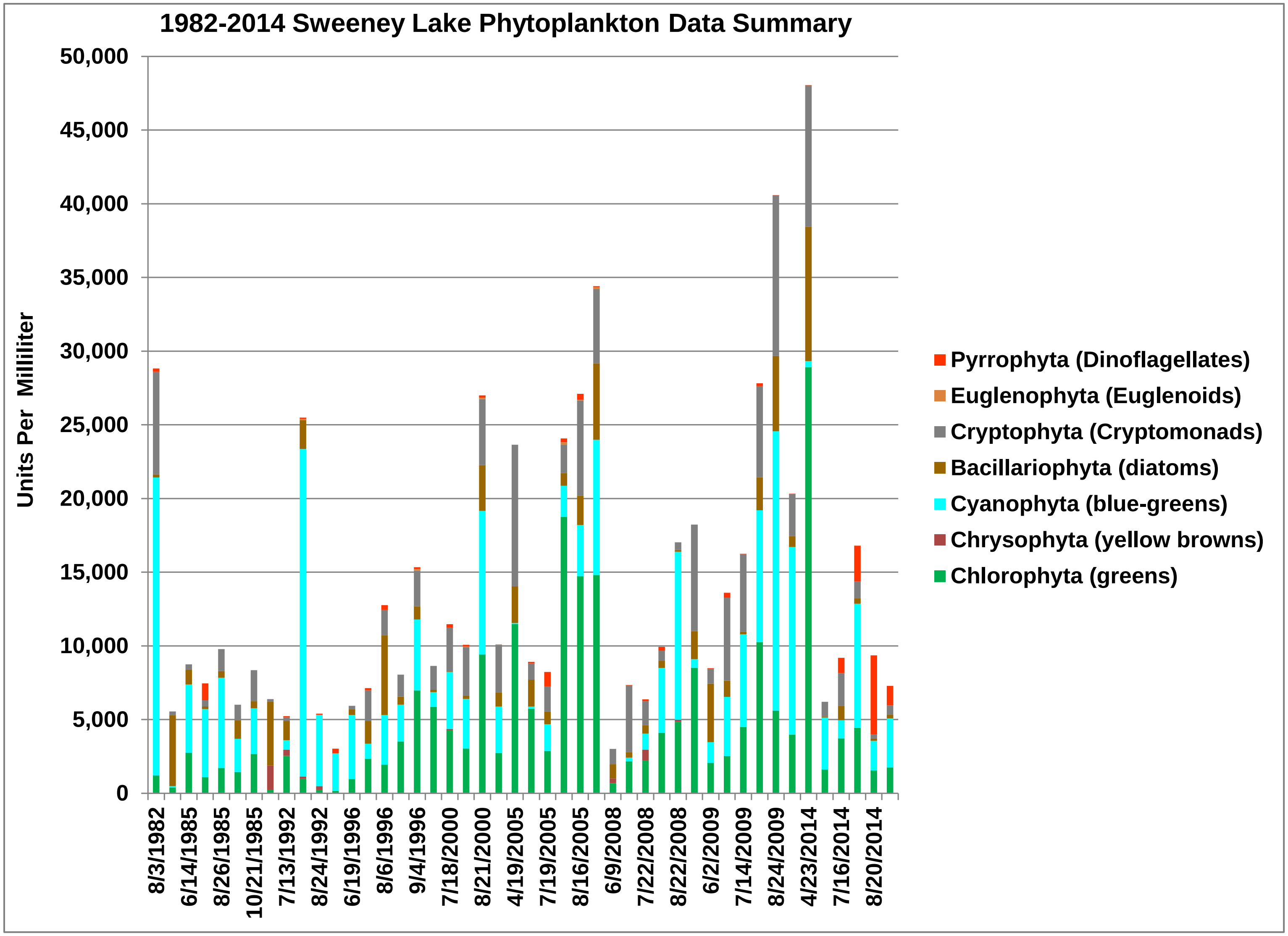


Figure 32 **1982-2014 Sweeney Lake Phytoplankton Data Summary**

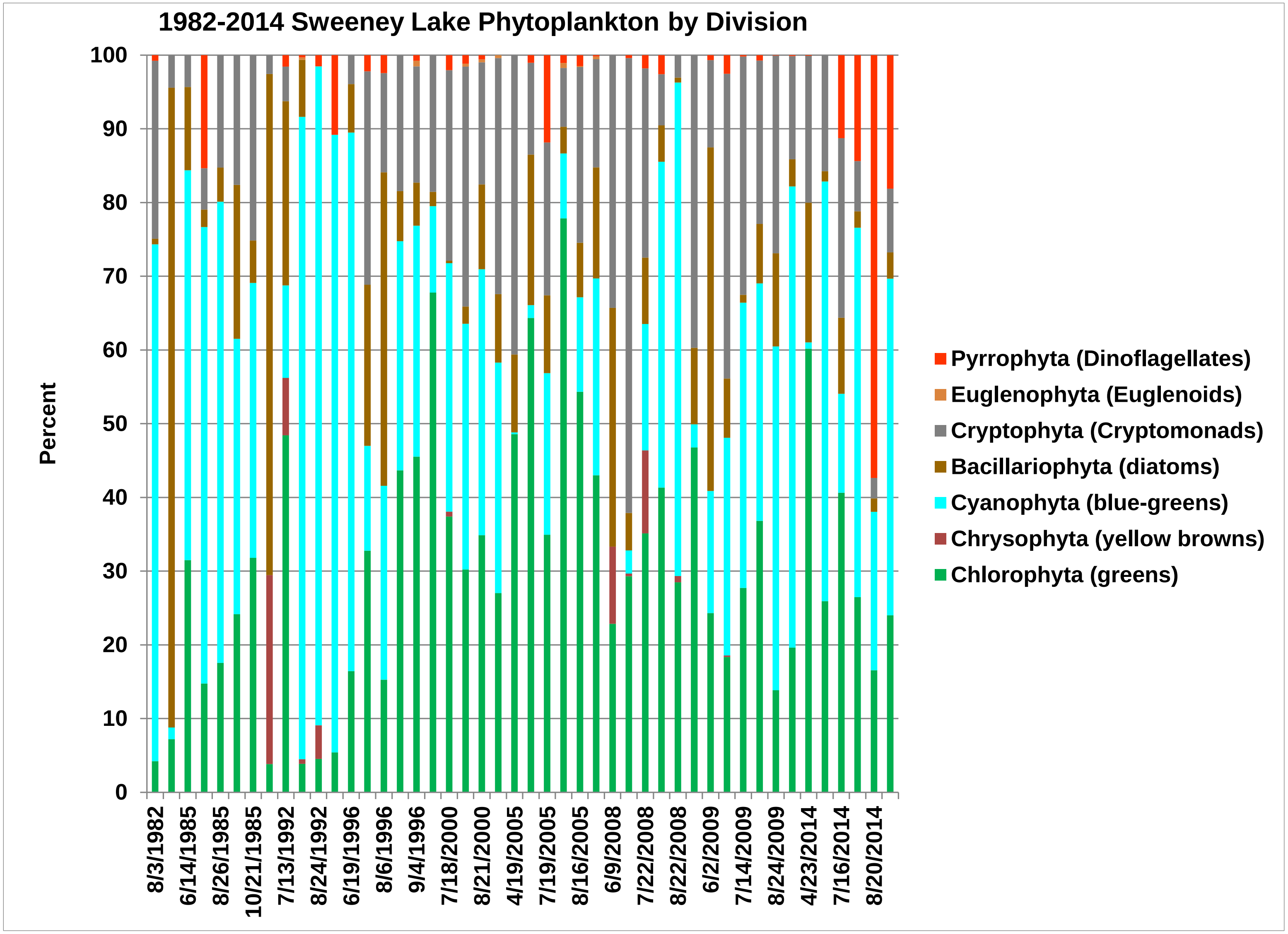


Figure 33 1982-2014 Sweeney Lake Phytoplankton Composition by Division

For the first time during a monitoring year, the lake experienced very severe algal blooms beginning in June 2014 and continuing through September. During this period, massive quantities of floating algal mats and clumps or balls of algae throughout the water column were observed. Algae samples were collected by the BCWMC engineer on the following dates to determine the types of algae causing the problematic blooms with the following results:

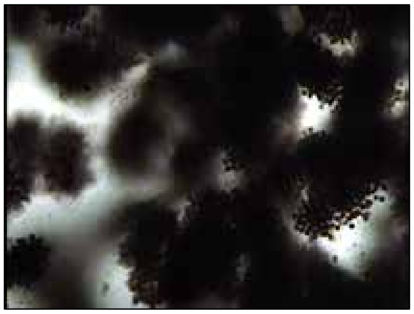
- **June 17:** Significant blue-green algae, dominated by *Aphanizomenon flos-aquae,* found. *Aphanizomenon flos-aquae* produces the dangerous toxin Anatoxin-a.
- **July 2:** *Aphanizomenon flos-aquae*, again dominated the lake. Due to the potential health risk, the City of Golden Valley issued a health alert, advising citizens to stay out of Sweeney Lake. This was distributed to area residents and posted on the City's website. An algae sample was sent to a specialty lab for analysis and, while Anatoxin-a was not detected, the toxin Microcystin was identified. This toxin is produced by *Microcystis aeruginosa*, a blue-green algae present in the sample, but not dominant.
- **July 16:** *Microcystis aeruginosa* was the dominant form of algae.
- **August 4:** Green filamentous algal mats proliferated in the near-shore areas of the lake's perimeter. The species of algae found in the algal mats was *Rhizoclonium hieroglyphicum,* a green algae. While unsightly, this algae does not produce toxins and posed no threat to public health.
- **September 2:** *Aphanizomenon flos-aquae*, which had dominated the lake in June and July returned, forming large clumps throughout the lake and was present in a dense blue-green algal scum near the boat launch. A sample collected from the scum near the boat launch area was found to contain six species of blue-green algae—all of them are capable of producing toxins: *Microcystis aeruginosa*, *Aphanizomenon flos-aquae*, *Anabaena affinis*, *Anabaena flos-aquae*, *Anabaena spiroides var. crassa*, and *Lyngbya sp.* (see photo on the following page).

Severe blue-green algae blooms, pictured above, were observed during June and July.

The species comprising the lake's algae bloom changed to a green algae in August, pictured above.

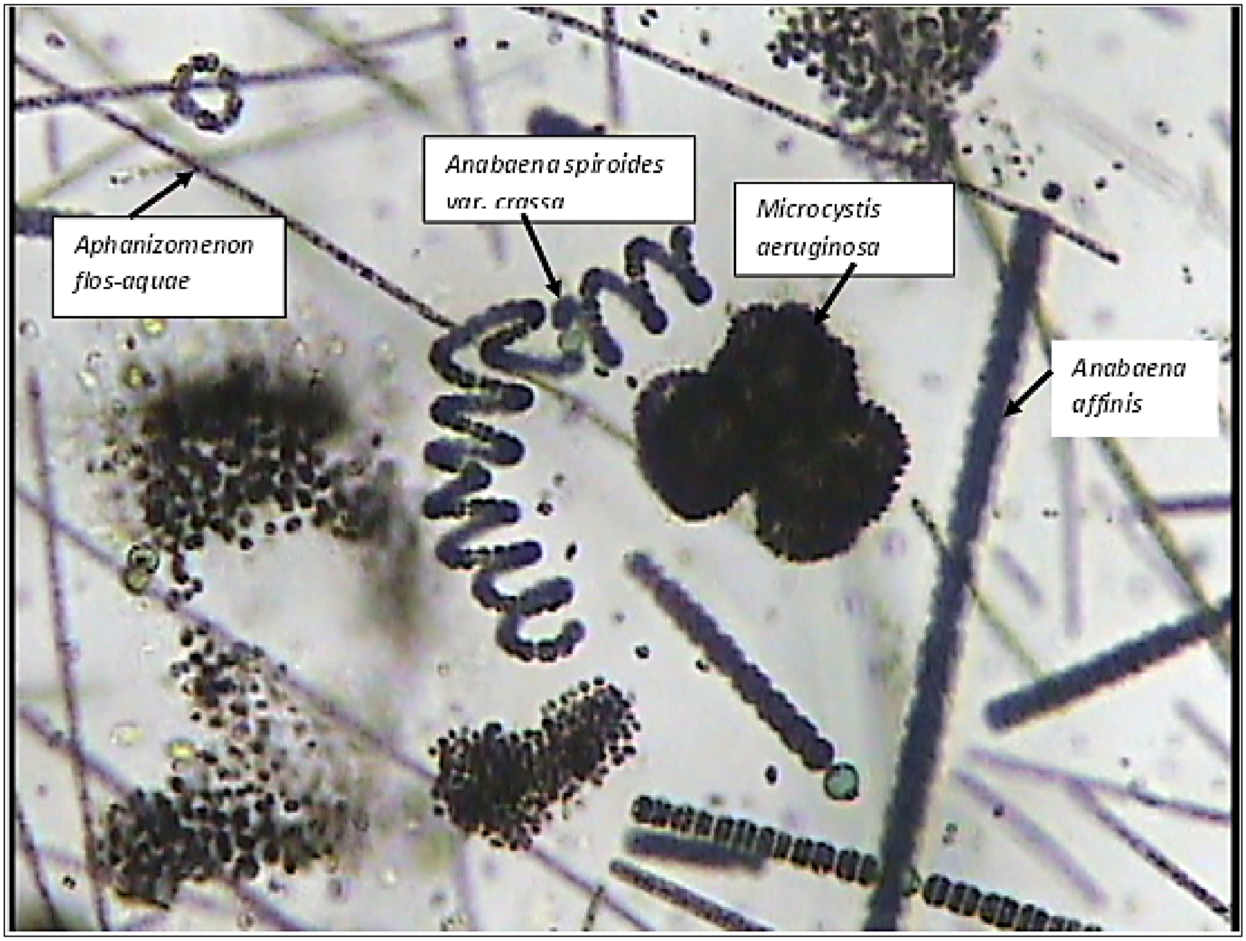
Blue-green algae returned in September. The algal scum near the boat launch, pictured above, contained six species of blue-green algae

Aphanizomenon flos-aquae, a blue-green algae pictured above, dominated the algae bloom on June 17, and July 2.



Microcystis aeruginosa, a blue-green algae pictured above, was present in the July 2 algae bloom and dominated the algae bloom on July 16.

Rhizoclonium hieroglyphicum, a green algae pictured above, dominated the algae bloom on August 4.



The sample collected from the scum near the boat landing on September 2 contained several species of blue-green algae, pictured above.

3.6.3 Zooplankton

Zooplankton is small aquatic animals that feed on algae and are eaten by fish. They are divided into three main groups: rotifers, copepods, and cladocerans.

- **Rotifers** eat algae, other zooplankton, and sometimes each other. Due to their small size, rotifers are not capable of significantly reducing algal biomass, although they are able to shift the algae community to favor larger species (Shaw et al. 2004).
- **Copepods** feed on algae and other plankton. They are eaten by larger plankton and are preyed heavily upon by panfish, minnows, and the fry of larger fish (Shaw et al. 2004).
- **Cladocerans** are filter feeders that play an important part in the food web. Species of cladocerans (particularly Daphnia) are well known for their ability to reduce algal biomass and help maintain clear water in lake ecosystems (Shaw et al. 2004).

Aquatic plants help zooplankton avoid predation by taking refuge within the plant community (Shaw et al. 2004). Hence, the Sweeney Lake plant community provides a refuge for the lake's zooplankton.

During the period of record, all three groups of zooplankton were represented in Sweeney Lake**.** However, small rotifers and copepods have generally dominated the community (Figures 34 and 35). The rotifers graze primarily on extremely small particles of plant matter and do not significantly affect the lake's water quality. The copepods are less effective predators than Cladocerans and also do not significantly affect the lake's water quality. The presence of larger numbers of rotifers and copepods is an indication of fish predation. Cladocerans are more easily seen and more desirable as food than small-bodied zooplankters. In addition, they are slow swimmers and easily preyed upon by fish. Fish "sight feed," selecting and depleting the number of large-bodied zooplanters in the water body.

The numbers of zooplankton observed in Sweeney Lake in 2014 was within the range of previous years (Figure 34). In addition, the community composition in 2014 was similar to previous years (Figure 35).

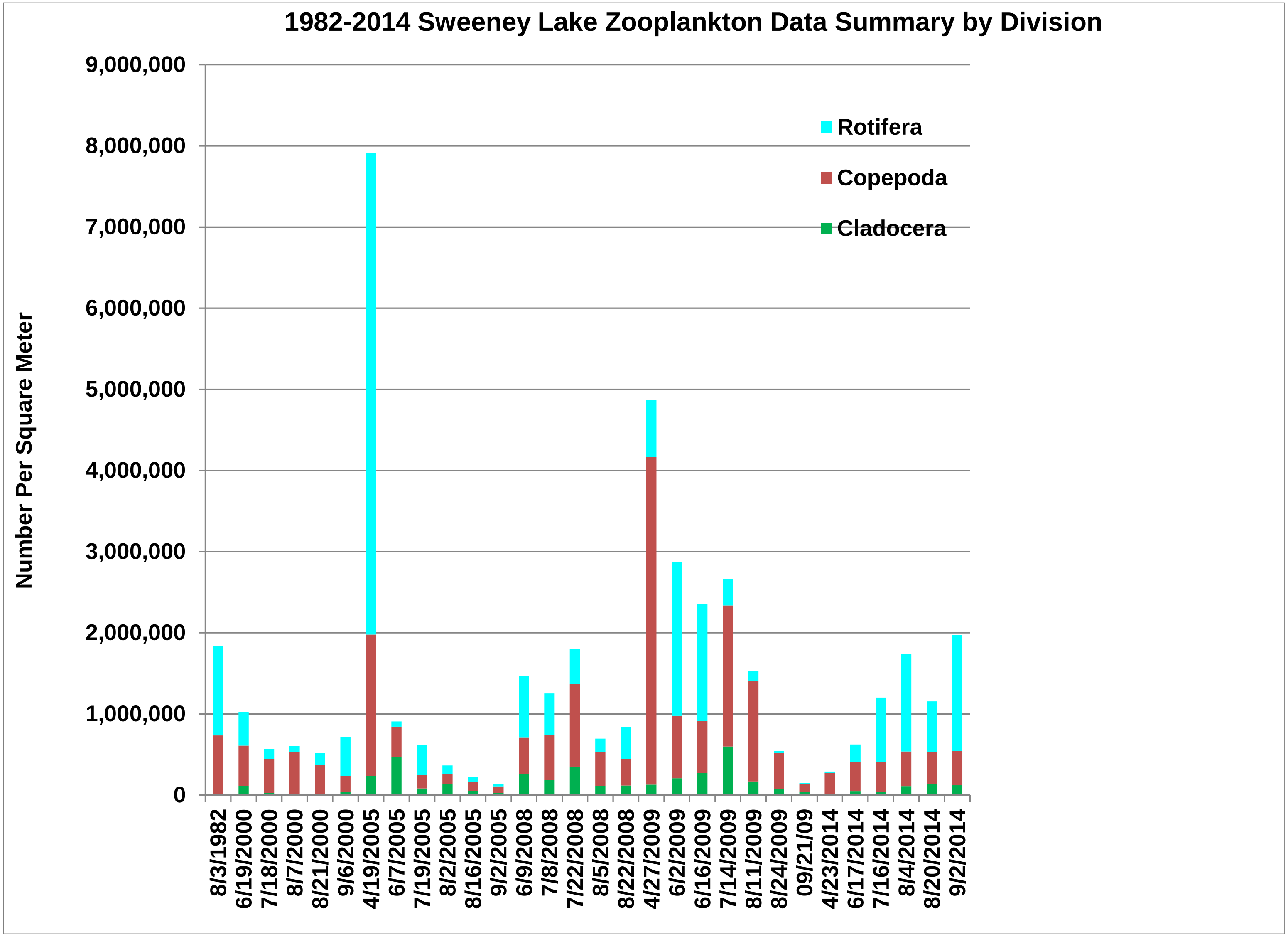


Figure 34 **1982–2014 Sweeney Lake Zooplankton Data Summary by Division**

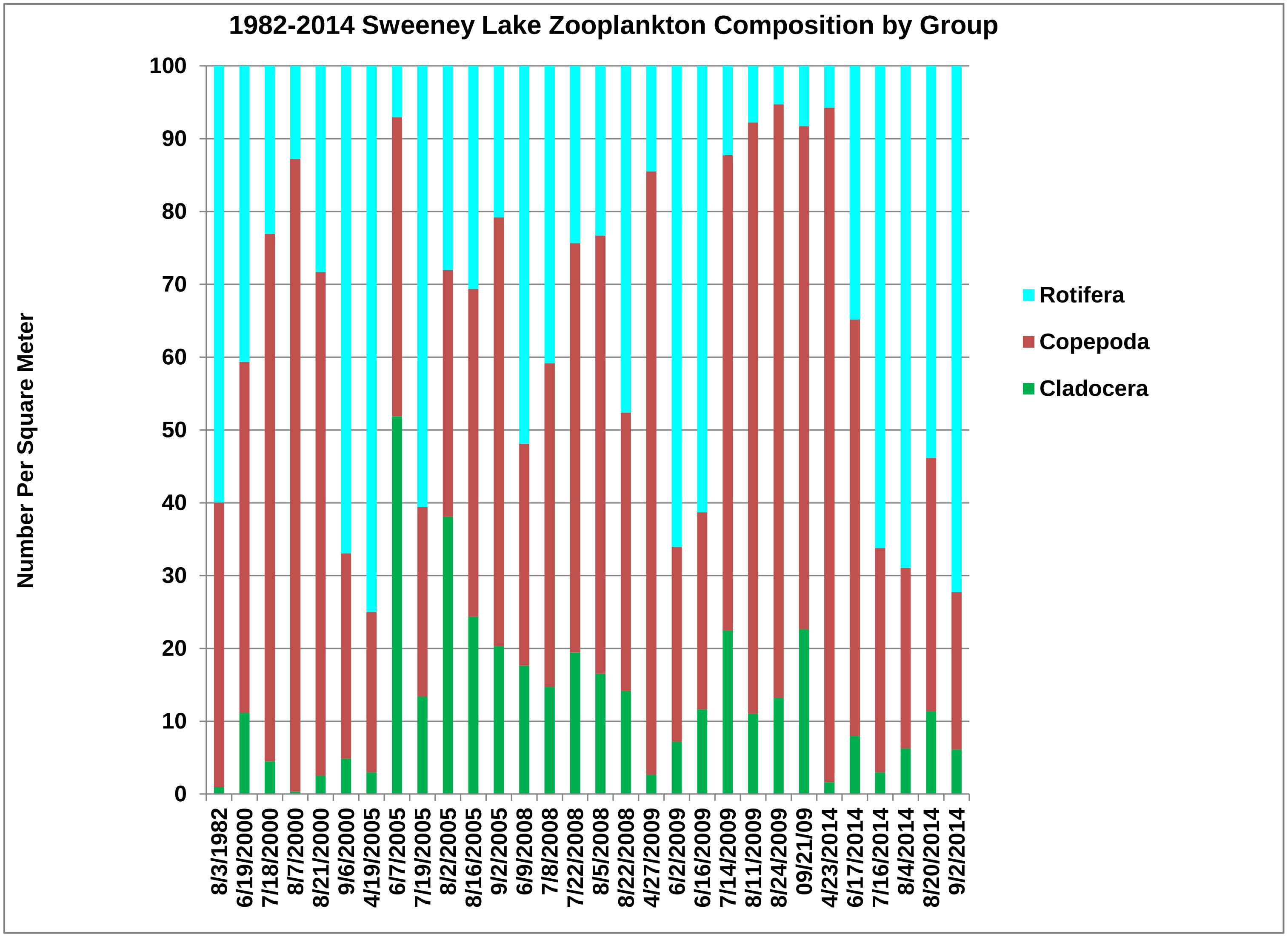


Figure 35 **2000–2014 Sweeney Lake Zooplankton Composition by Group**

3.7 Conclusions and Recommendation

3.7.1 Conclusions

Conclusions of the 2014 study of Sweeney Lake include:

- In 2014, average summer total phosphorus and chlorophyll *a* concentrations and Secchi disc transparency failed to meet the BCWMC/MPCA standard.

- Trend analyses indicate that during the period of record, changes in total phosphorus and chlorophyll *a* concentrations were not significant. There has been a significant decline in average summer Secchi disc transparency depths since 1972. The long-term trend line indicates that depths have declined at a rate of 0.01 meters (0.4 inches) per year.

- High total phosphorus and chlorophyll *a* concentrations have been observed in the lake for more than 40 years. Since 1972, the summer averages for total phosphorus and chlorophyll concentrations have met the BCWMC/MPCA standard only 29 percent of the time. Summer averages for Secchi disc transparency have met the standard 62 percent of the time.

- The 2014 average summer chlorophyll *a* concentration was the highest on record, consistent with the observation that Sweeney Lake experienced the worst summer algal blooms to date.

- Severe algal blooms began in June and continued into September. During this period, massive quantities of floating algal mats were consistently observed throughout the lake and clumps or balls of algae were observed throughout the water column. While the algal bloom persisted from June into September, the species causing the bloom continually changed: blue-green algae predominated, but the early August bloom was caused by green algae. Blue-green algae can produce harmful algal toxins, while green algae do not.

- Algal toxin testing in early July found that Microcystin, produced by *Microcystis,* a blue-green algae species, was present in the lake. *Microcystis* was found in the early July algal bloom and dominated the mid-July algal bloom.

- The 2014 Sweeney Lake zooplankton community is both healthy and diverse and was relatively similar to previous years.

- The number of plant species in Sweeney Lake has increased over time, more than doubling from 9 species in 1992 to 20 species in 2014, the highest number of species to date.

- The Sweeney Lake plant community has generally been of average quality since 2000, but was slightly below average during 2014. The degradation in plant community quality was likely due to the severe algal blooms that caused degraded growing conditions (i.e., poorer light quality).

- Curly-leaf pondweed has been observed in Sweeney Lake since 1992, but was a minor component of the 2014 plant community. Hence, management does not appear to be needed at this time. However, plant survey data collected in the future should be reviewed to identify any changes.

- Purple loosestrife has been observed in Sweeney Lake in 1992, 2008, and 2014. In 2014, the plant was found at one location in June and expanded to three additional locations in August. Because it is expanding, Barr recommends that the BCWMC explore the feasibility of managing purple loosestrife with purple-loosestrife-eating beetles.

- In 2014, reed canary grass was observed at one location at the northwest corner of the lake. Because it was only found at one location, management does not appear warranted at this time. However, plant survey data collected in the future should be reviewed to identify any changes.

3.7.2 Recommendation

Recommendations include:

Implementation of the Sweeney Lake TMDL

In accordance with the Sweeney Lake TMDL implementation strategy, the BCWMC, working closely with the member cities, should continue to take a lead role in implementation efforts for the categorical wasteload allocations and the internal load reductions for the lake. The following external load reduction actions should be implemented:

- Schaper Pond improvements project (expected construction in 2015)

- Maximize phosphorus load reduction through redevelopment

- Continue ongoing watershed management practices, including education, street sweeping, shoreline buffers, and monitoring of existing best management practices.

As noted in the Sweeney Lake TMDL, a significant reduction in internal phosphorus loading is also necessary to meet the State water quality standards for Sweeney Lake. This would likely require an in-lake alum treatment. However, before implementing an in-lake alum treatment, the BCWMC should consider performing a study regarding the impact of the current aeration system on Sweeney Lake water quality (see following paragraphs). If, after completion of the study, the BCWMC decides to implement an in-lake alum treatment, then a feasibility study would be prepared, which would include completion of a sediment study to determine the appropriate alum dose.

Study Impact of Current Aeration System on Sweeney Lake Water Quality

After completion of the Schaper Pond improvements project and prior to implementing an in-lake alum treatment, it is recommended that the aerators in Sweeney Lake be turned off for 1 or 2 years. While the aerators are off, the BCWMC would have an excellent opportunity to monitor the lake water quality and estimate the impact of the aerators on water quality through the use of three-dimensional water quality models.

The monitoring program should expand the typical BCWMC monitoring to include collection of samples at additional depths, analysis of additional types of phosphorus, and addition of a May sample collection. Ideally, the monitoring program would also include monitoring the outflows from Schaper Pond.

The monitoring data should then be used to develop and calibrate models to evaluate the lake's water quality for different scenarios. It is recommended that a three-dimensional hydrodynamic model (ELCOM), coupled with an aquatic ecological model (CAEDYM), be used to model in-lake water quality for the year (or years) when the aerators were off and a year when the aerators were on. The existing P8 model would need to be run for each modeled year to estimate watershed loading to Sweeney Lake. The model results would provide an estimation of the impact of the aerators on lake water quality, including transport of phosphorus between the bottom (from internal phosphorus release) and surface waters of the lake. The model could also be used to assess the effect of aerator operation on Sweeney Lake water quality (phosphorus, dissolved oxygen, and temperature) and whether aerator operation would have any adverse effects on the successful attainment of the TMDL goals.

Purple loosestrife control

Barr recommends that BCWMC or cities within the watershed introduce purple-loosestrife-eating beetles to the infested areas surrounding Sweeney Lake. Some beetles were observed on purple loosestrife plants at the southeast corner of the lake and could possibly be introduced to the other infested areas. Introduction of the beetles is expected to control purple loosestrife and protect the native vegetation.

4.0 Twin Lake

4.1 Site Description

Twin Lake (Minnesota Department of Natural Resources (MDNR) public water # 27033900) is a 21-acre lake in the eastern portion of the Bassett Creek Watershed. The lake is located in the City of Golden Valley, with the southern half in Theodore Wirth Park. Connected to Sweeney Lake through a navigable channel, it is used for swimming, non-motorized boating, fishing, and aesthetic viewing.

Twin Lake has a maximum depth of 56 feet, an average depth of 25.7 feet, and a littoral area of approximately 8 acres. Shallow areas near the shoreline allow for both emergent and submerged vegetation growth. Floating-leaf vegetation is primarily seen in the northern portion of the lake. The lake's normal water elevation is estimated at 827.5 feet, with a 100-year elevation of 831.5 feet. Twin Lake's watershed area is 131 acres. A portion of the City of Golden Valley drains to Twin Lake through an open channel at the south side of the lake. An outlet channel discharges beneath a bridge at the north side of the lake into a wetland that is hydraulically connected to Sweeney Lake.

The Twin Lake watershed is fully developed. The area surrounding the lake has three major land uses: park, recreational, or preserve (60%); institutional (20%); and low-density residential (20%).

Twin Lake is a BCWMC "priority 1" deep lake water body. Classification as "deep" is based on the Minnesota Pollution Control Agency's (MPCA's) shallow/deep classification. The lake is not listed as impaired by the MPCA. The relatively high ratio of lake surface to drainage area and absence of highly impervious land nearby have prevented Twin Lake from experiencing many of the negative effects of urbanization (i.e., increased stormwater runoff and pollutant loading).

4.2 BCWMC/MPCA Standards

For priority water bodies, such as Twin Lake, the BCWMC has adopted water quality standards that are consistent with MPCA water quality standards, as published in Minnesota Rules 7050 for lakes within the North Central Hardwood Forest Ecoregion. These rules apply to water bodies within the BCWMC, regardless of their BCWMC classification. The BCWMC/MPCA water quality standards for Twin Lake are as follows:

1. Average summer total phosphorus concentration not to exceed 40 µg/L
2. Average summer chlorophyll *a* concentration not to exceed 14 µg/L
3. Average summer Secchi disc transparency of at least 1.4 meters or 4.6 feet (Minn. R. Ch. 7050.0222 Subp. 4)

As shown in Figures 36 through 38, the average summer total phosphorus, chlorophyll *a*, and Secchi disc transparency in Twin Lake met the BCWMC/MPCA water quality standards in 2014.

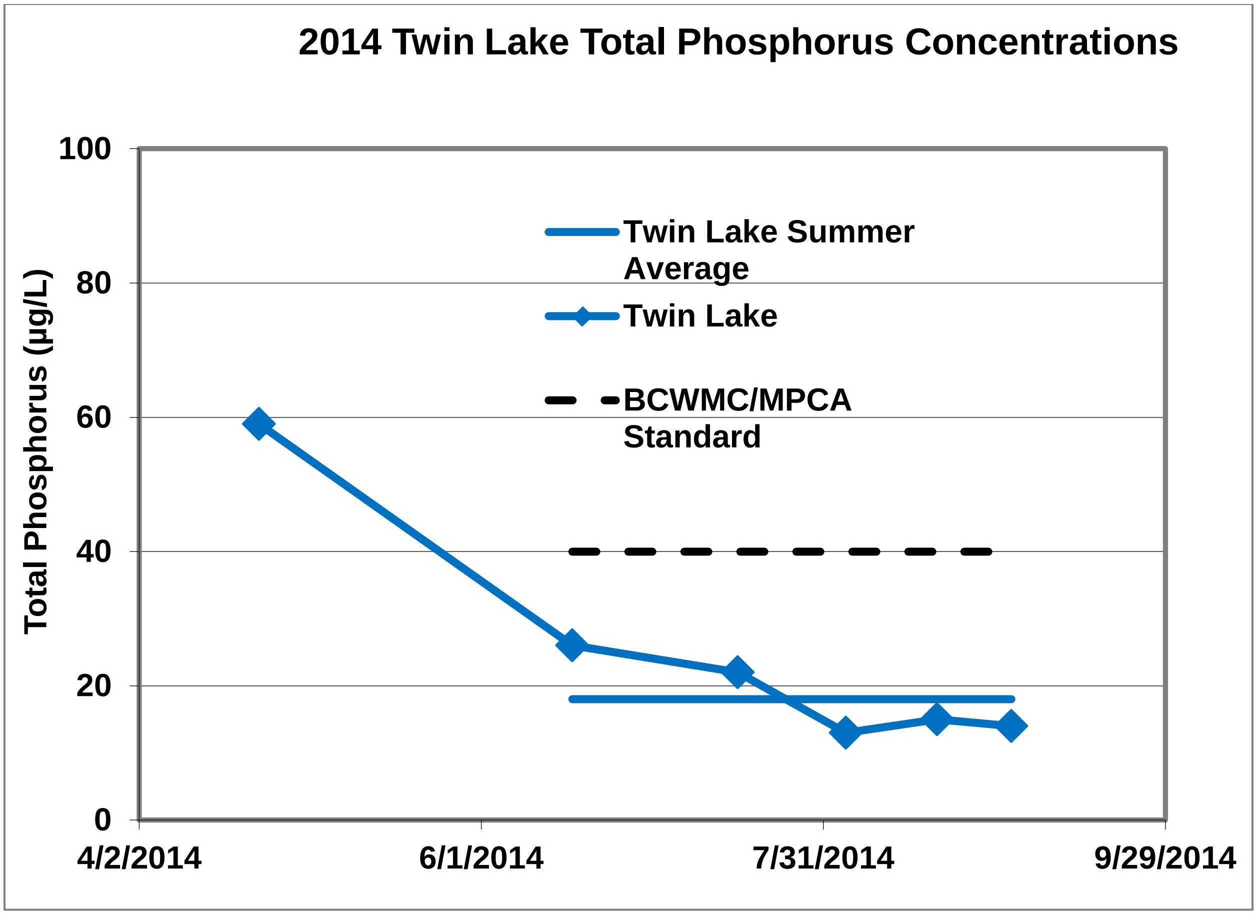


Figure 36 **2014 Twin Lake Total Phosphorus Concentrations Compared with BCWMC/MPCA Total Phosphorus Standard**

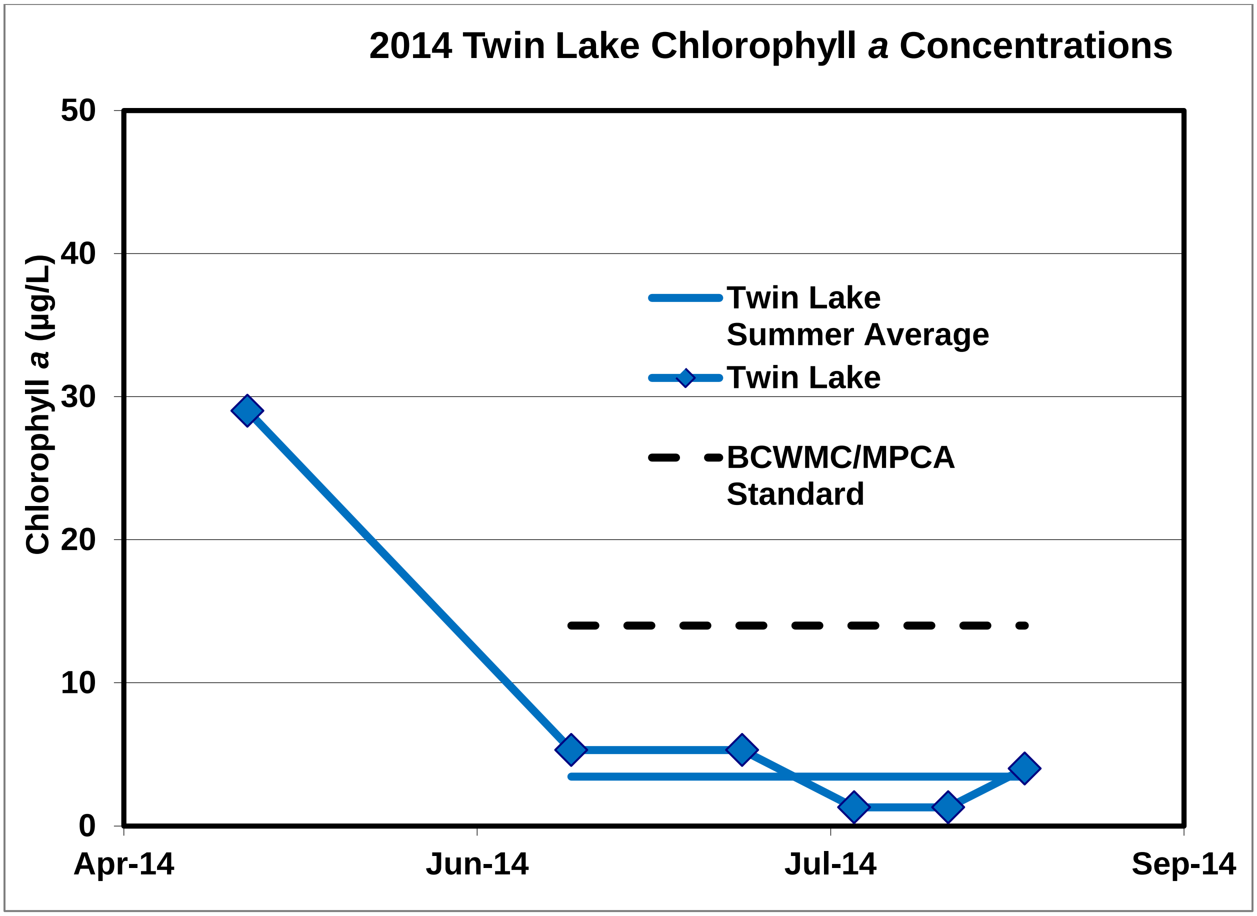


Figure 37 **2014 Twin Lake Chlorophyll *a* Concentrations Compared with BCWMC/MPCA Chlorophyll *a* Standard**

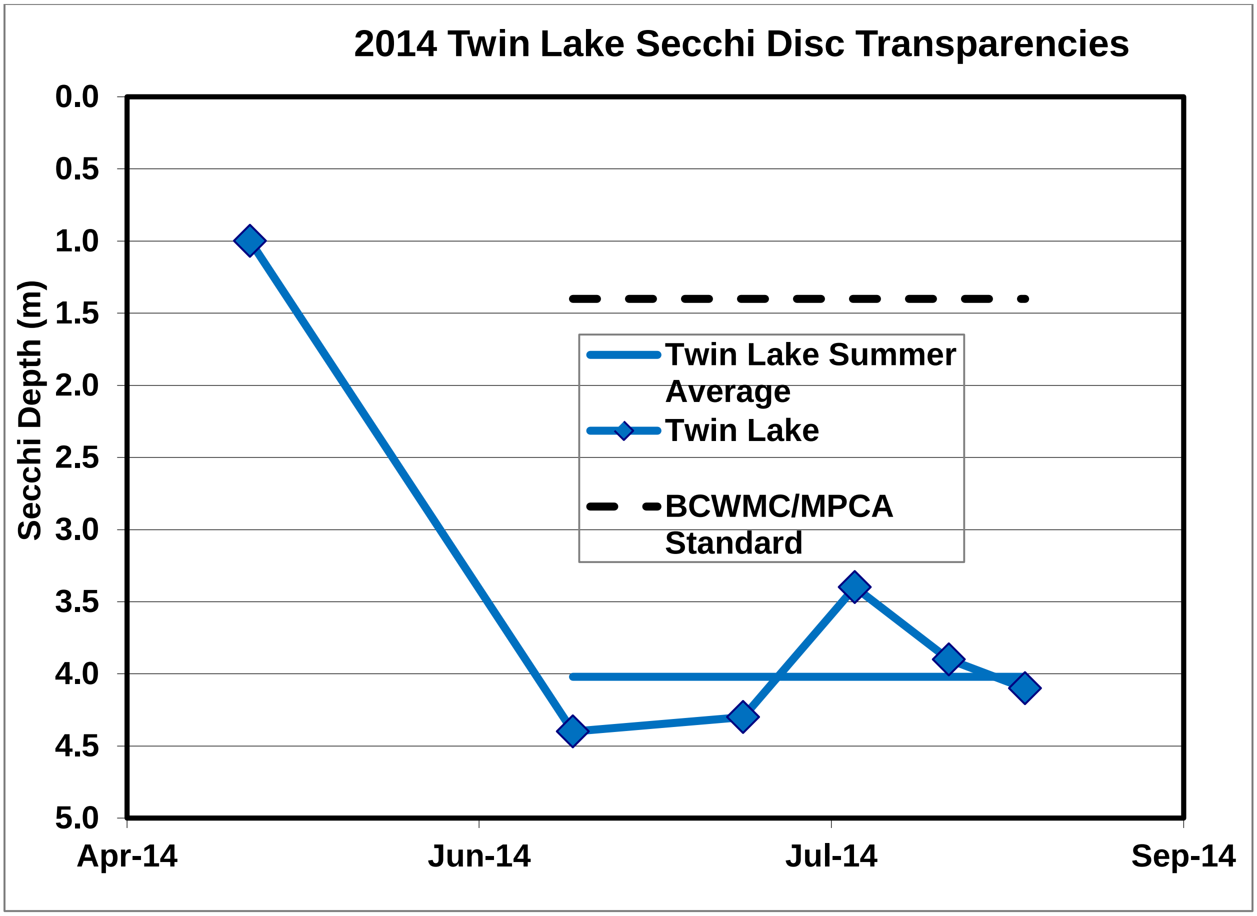


Figure 38 **2014 Twin Lake Secchi Disc Depths Compared with BCWMC/MPCA Secchi Disc Standard**

4.3 Water Quality Monitoring Results

Water quality monitoring results for temperature, dissolved oxygen, specific conductance, total phosphorus, chlorophyll *a*, and Secchi disc transparency are summarized below.

4.3.1 Temperature and Dissolved Oxygen

Vertical profiles of temperature during 2014 (Figure 39) show the lake was stratified during the summer. The surface waters were warmed by the sun throughout the summer, but the bottom waters remained cool. Warmer water is lighter and cooler water is heavier due to its higher density. The dense, cool bottom water formed a barrier to wind-mixing of the lake water column. This barrier is termed the thermocline. Change in temperature in Figure 39 is shown by color changes. The change in color from the lighter green and yellow colors at the surface to the dark green at the bottom shows the cooling of the lake from surface to bottom. The dark green color shows the cold bottom waters, while the lighter green and yellow colors show the warm surface waters.

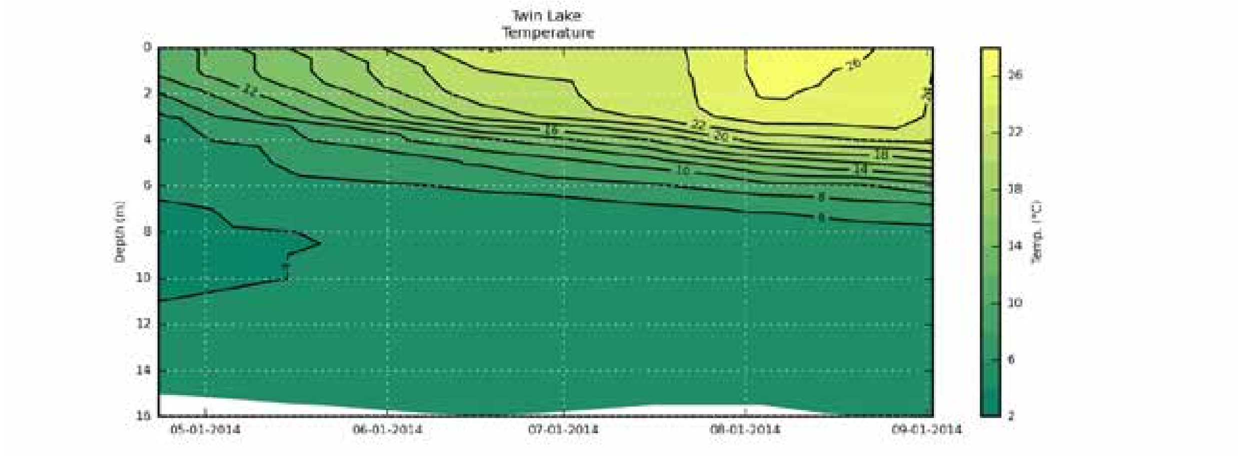


Figure 39 2014 Twin Lake Temperature Isopleths

2014 oxygen isopleths shown on Figure 40 indicate that oxygen from about 6 meters to the bottom was depleted by the decomposition of organic matter. Because the temperature difference between the surface waters and the area of oxygen depletion prevented mixing of the water column, the oxygen depleted water had no opportunity for replenishment. Wind mixing of surface water, however, consistently added fresh oxygen throughout the growing season. The oxygen differences between the surface waters and oxygen depleted area of Twin Lake are represented by color differences in Figure 40. The gray color shows the oxygen-depleted waters; the purple colors show the well-oxygenated surface waters.

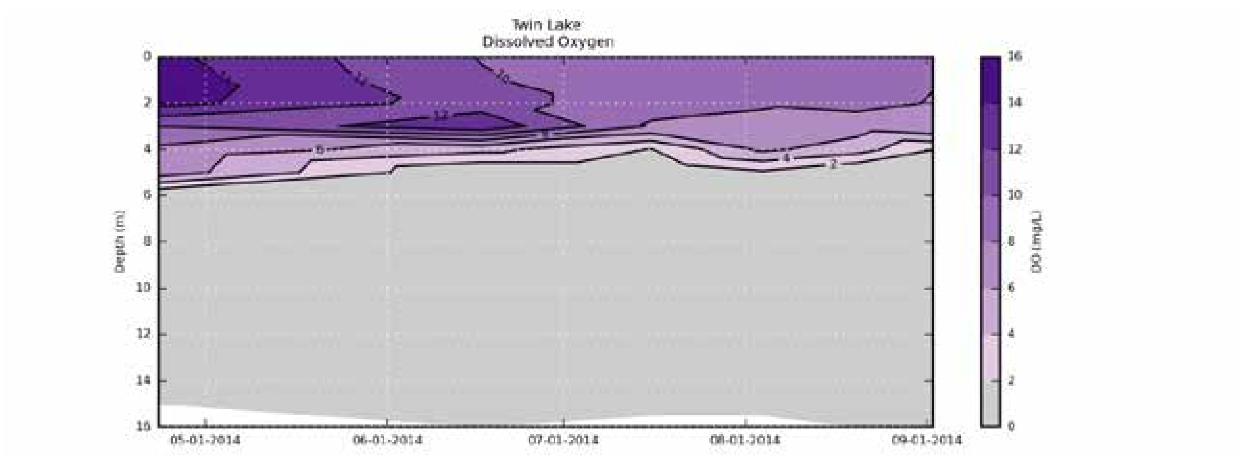


Figure 40 2014 Twin Lake Dissolved Oxygen Isopleths

4.3.2 Specific Conductance

Specific conductance is a measure of water's ability to conduct electricity and is linked to the total dissolved inorganic compounds in the water. Specific conductance increases as the concentration of dissolved compounds in a lake increases (Shaw et al. 2004). Specific conductance also increases as phosphorus concentrations increase.

Vertical specific conductance profiles collected during 2014 (Figure 41) verify the internal loading of phosphorus from the lake's sediment. Phosphorus was released from sediment due to oxygen depletion in the lake's bottom waters. The increase in specific conductance from surface to bottom is shown by color changes in Figure 41. The change from light pink at the top to dark pink at the bottom shows that specific conductance increased from 750 to 850 µhmos/cm @ 25º C near the surface to 1,000 µhmos/cm @ 25º C near the bottom due to internal loading.

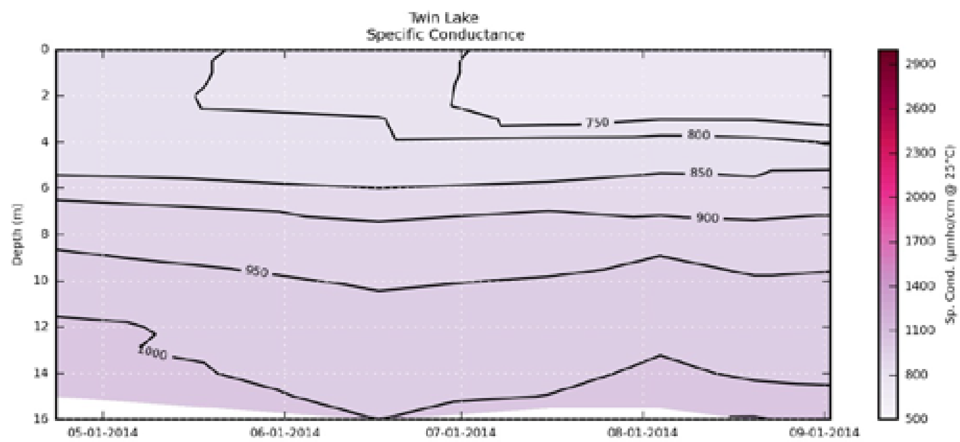


Figure 41 2014 Twin Lake Specific Conductance Isopleth

4.3.3 Total Phosphorus

Total phosphorus concentrations for Twin Lake, measured by the 0-2 meter composite (surface or epilimnetic) sample, are summarized in Figure 42. These concentrations declined from spring to summer and good water quality was observed during the summer. The total phosphorus concentration in April was within the hypereutrophic category (very poor water quality). The June concentration was in the eutrophic category (poor water quality). Both the July through September and summer average concentrations were in the mesotrophic category (good water quality).

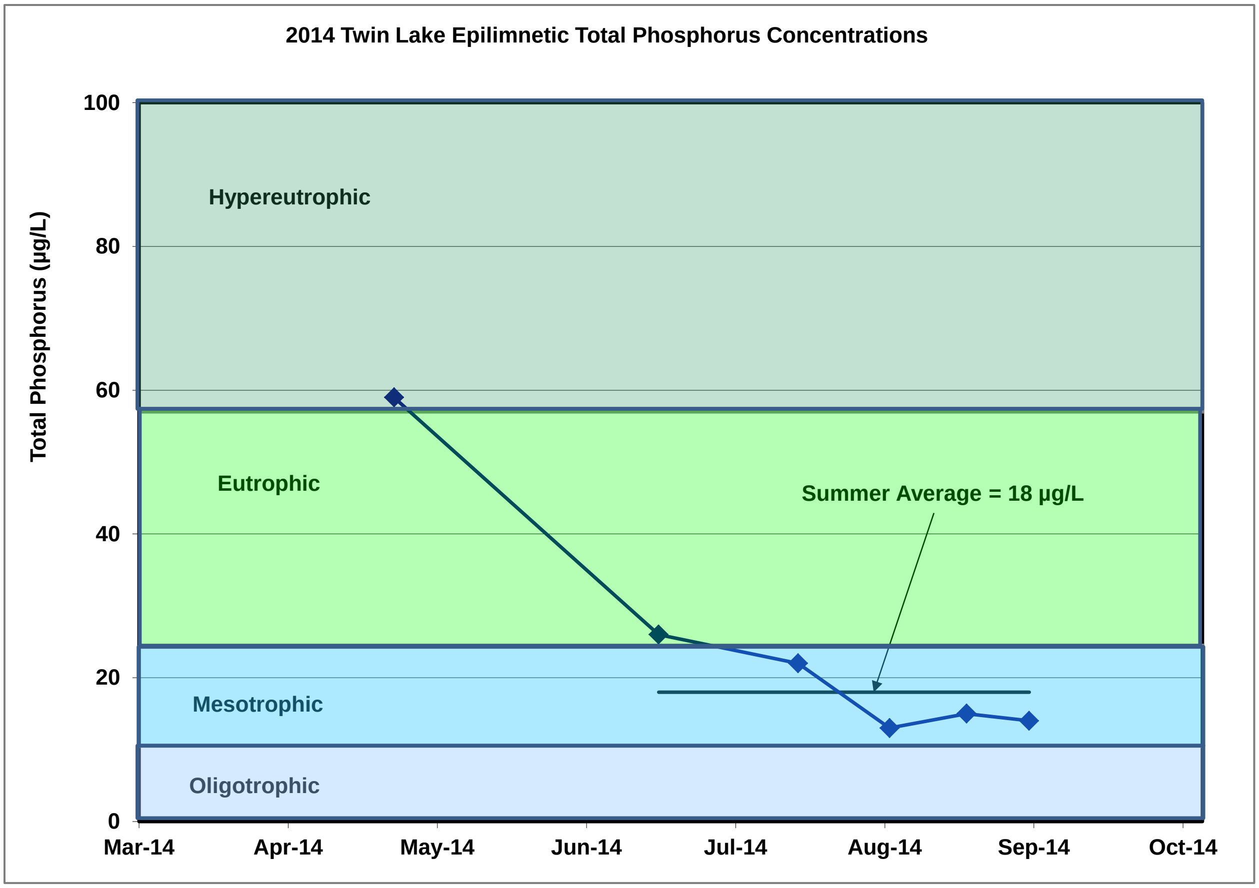


Figure 42 2014 Twin Lake Total Phosphorus Data

Total phosphorus concentrations measured by samples collected throughout the water column are summarized in Figure 43. The units for the phosphorus concentrations in Figure 43 are milligrams per liter. One milligram per liter equals 1,000 micrograms per liter. The change in phosphorus concentrations from the surface to bottom of the lake is represented by color changes. The change in color from yellow at the surface to red at the bottom shows that total phosphorus increased from the surface to the bottom.

As discussed in Section 4.3.1, the lake's bottom waters had low oxygen levels throughout the growing season. This provided ideal conditions for the release of phosphorus from the sediment. This release, termed internal loading, produced high phosphorus concentrations in the lake's bottom waters. The lake's surface waters, however, had low phosphorous concentrations in the summer. This is because the temperature difference between the surface and the bottom waters prevented the high phosphorus bottom waters from mixing with the surface waters. This protected the surface waters from the internal load in the lake's hypolimnion.

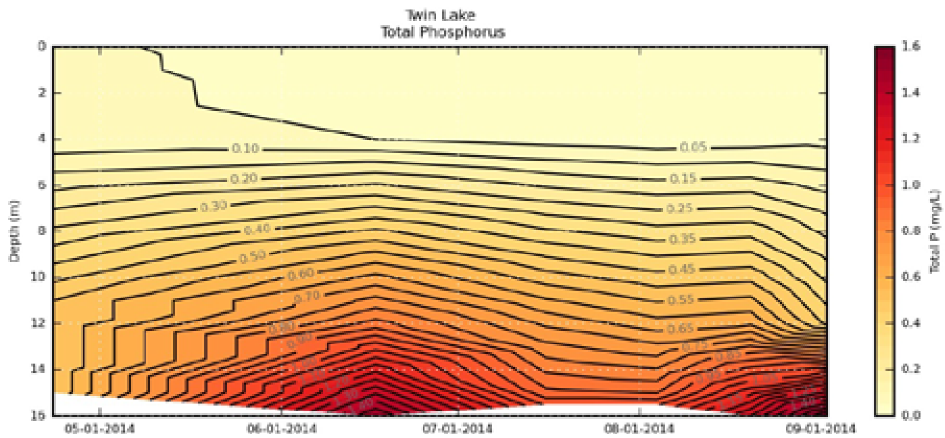


Figure 43 2014 Twin Lake Total Phosphorus Isopleths

4.3.4 Chlorophyll *a*

Chlorophyll *a* concentrations for Twin Lake, measured by the 0–2 meter composite (surface or epilimnetic) sample, are summarized in Figure 44. A high total chlorophyll *a* concentration was measured in the spring after ice-out. This was likely caused by an algae bloom fueled by phosphorus that had been added to the lake from internal loading throughout the winter. The spring mixing of this internal load fueled the growth of algae and caused a high chlorophyll *a* concentration. Chlorophyll *a* concentrations then declined from April through early August and remained low through August. While concentrations increased in September, they were still relatively low. The April chlorophyll *a* concentration was in the hypereutrophic category (very poor water quality); the June, July, and September concentrations were in the mesotrophic category (good water quality); and the August concentrations were in the oligotrophic category (excellent water quality). The summer average was in the mesotrophic category (good water quality).

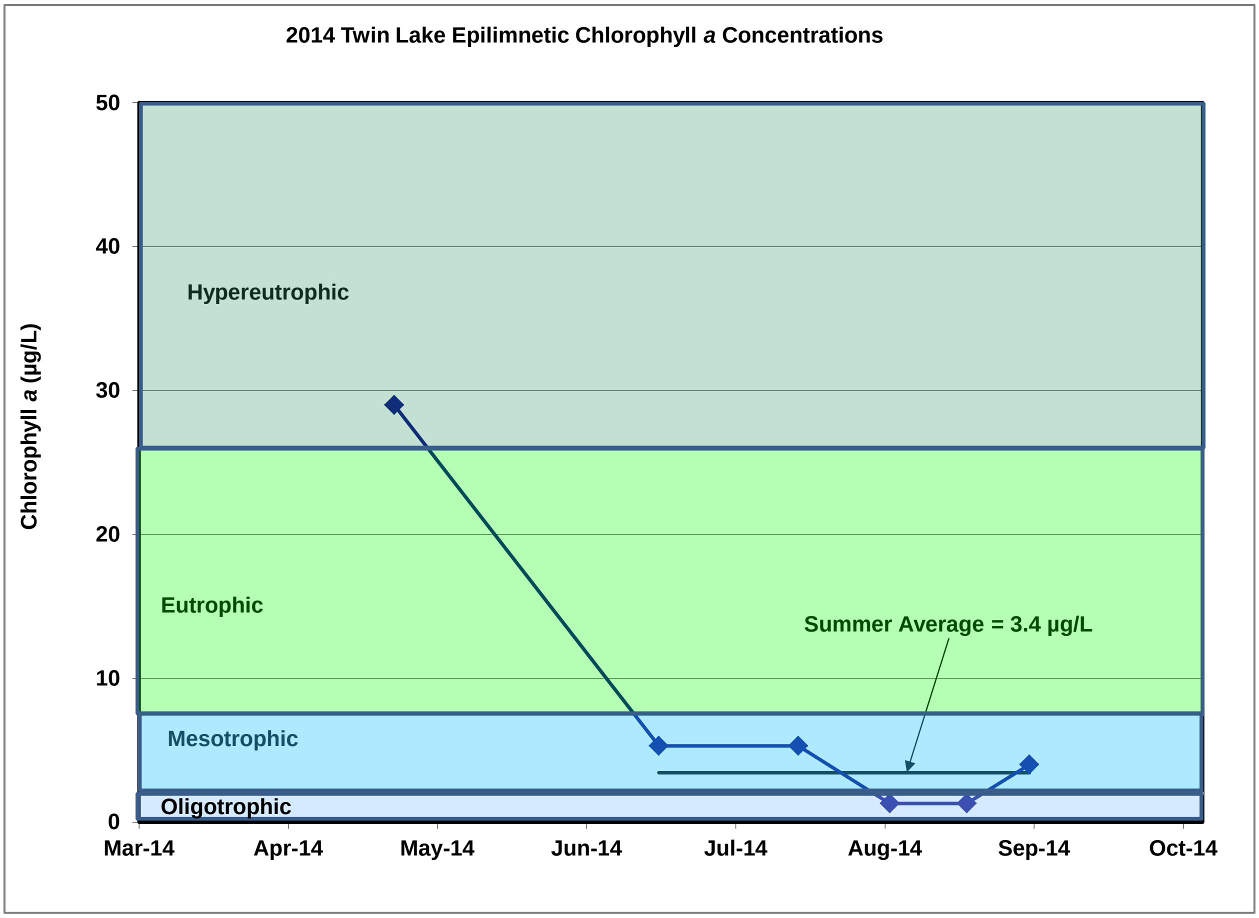


Figure 44 2014 Twin Lake Chlorophyll *a* Data

4.3.5 Secchi Disc

Secchi disc transparency data for Twin Lake is summarized in Figure 45. Low water transparency was observed in the spring after ice-out, with high spring phosphorous concentrations causing increased numbers of algae (high chlorophyll *a* concentrations). Secchi disc transparency increased from a low of 1.0 meters in April to a high of 4.4 meters in June and remained high throughout the summer. The average summer Secchi disc transparency was 4.0 meters. The April Secchi disc transparency was in the eutrophic category (poor water quality); both the June through September and summer average transparencies were in the mesotrophic category (good water quality).

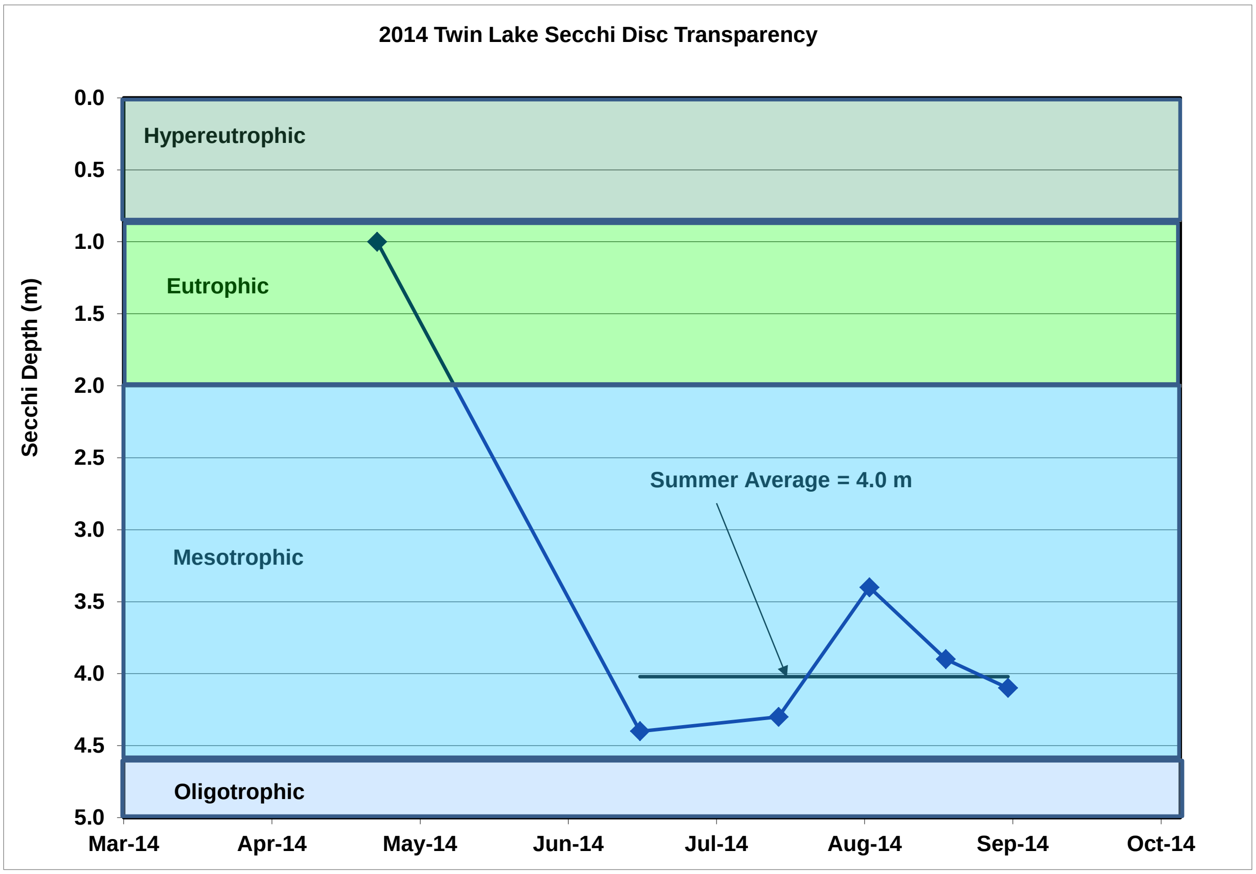


Figure 45 2014 Twin Lake Secchi Disc Transparency Data

4.4 Historical Trends

Historical water quality trends for Twin Lake are shown in Figure 46, Figure 47, and Figure 48. The black diamonds on the figures show the average summer values during the period of record (i.e., average summer total phosphorus and chlorophyll *a* concentrations and Secchi disc transparency depths). The line on each figure shows the long-term trend; the slope of the line shows the rate of change over time. Long-term trends are as follows:

- Total phosphorus concentrations have increased at a rate of 0.125 µg/L per year.
- Chlorophyll *a* concentrations have increased at a rate of 0.05 µg/L per year.
- Secchi disc transparencies have declined at a rate of 0.032 meters per year.

These changes, however, are not considered significant because there is more than a 5-percent probability that they are due to chance (Figure 46, Figure 47, and Figure 48).

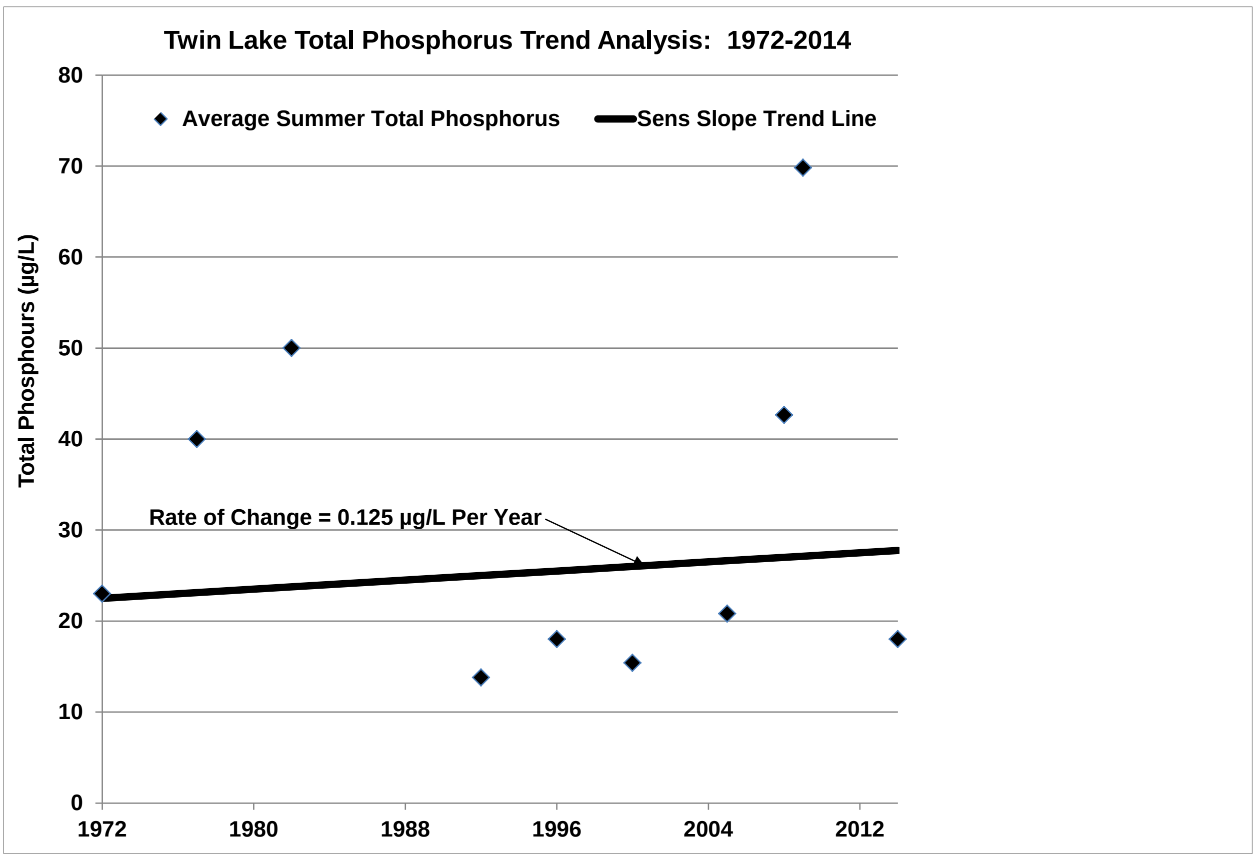


Figure 46 Twin Lake Total Phosphorus Trend Analysis: 1972–2014

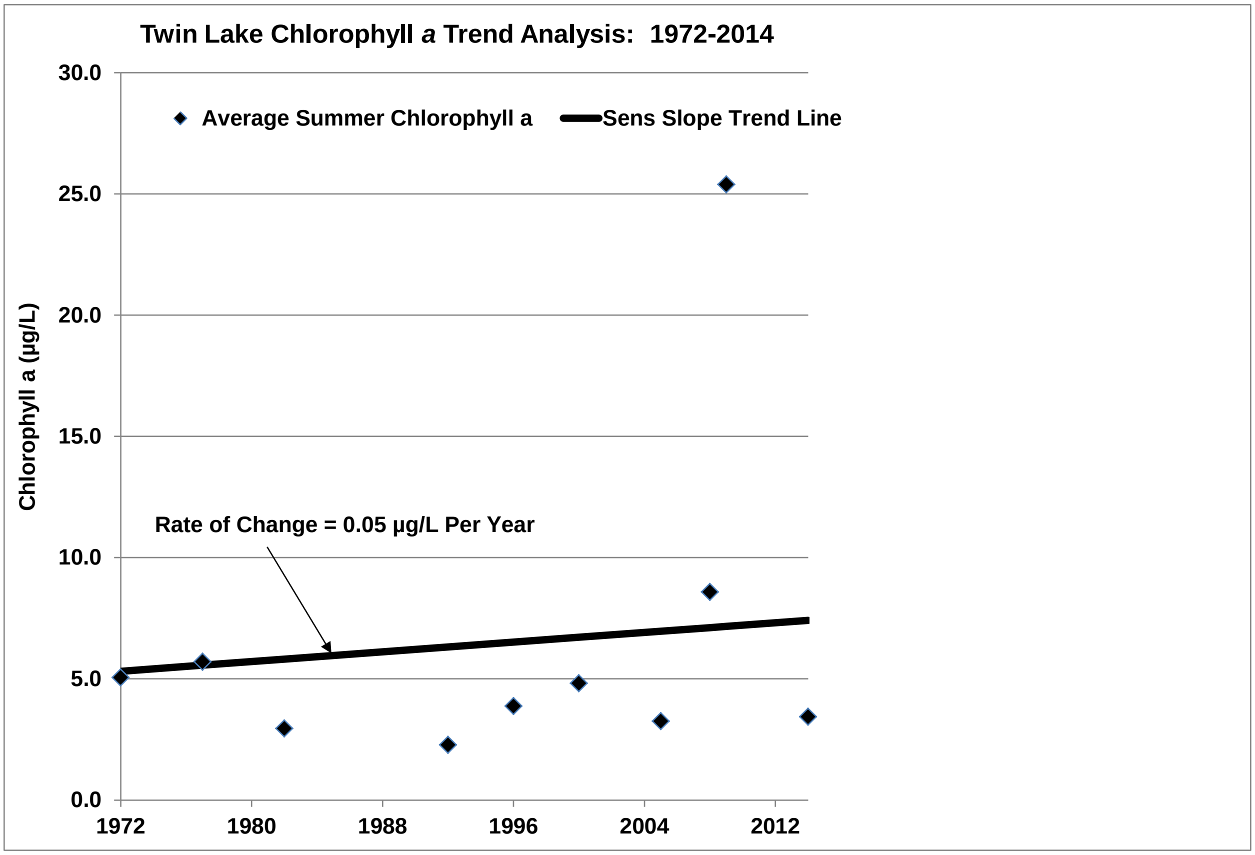


Figure 47 Twin Lake Chlorophyll *a* Trend Analysis: 1972–2014

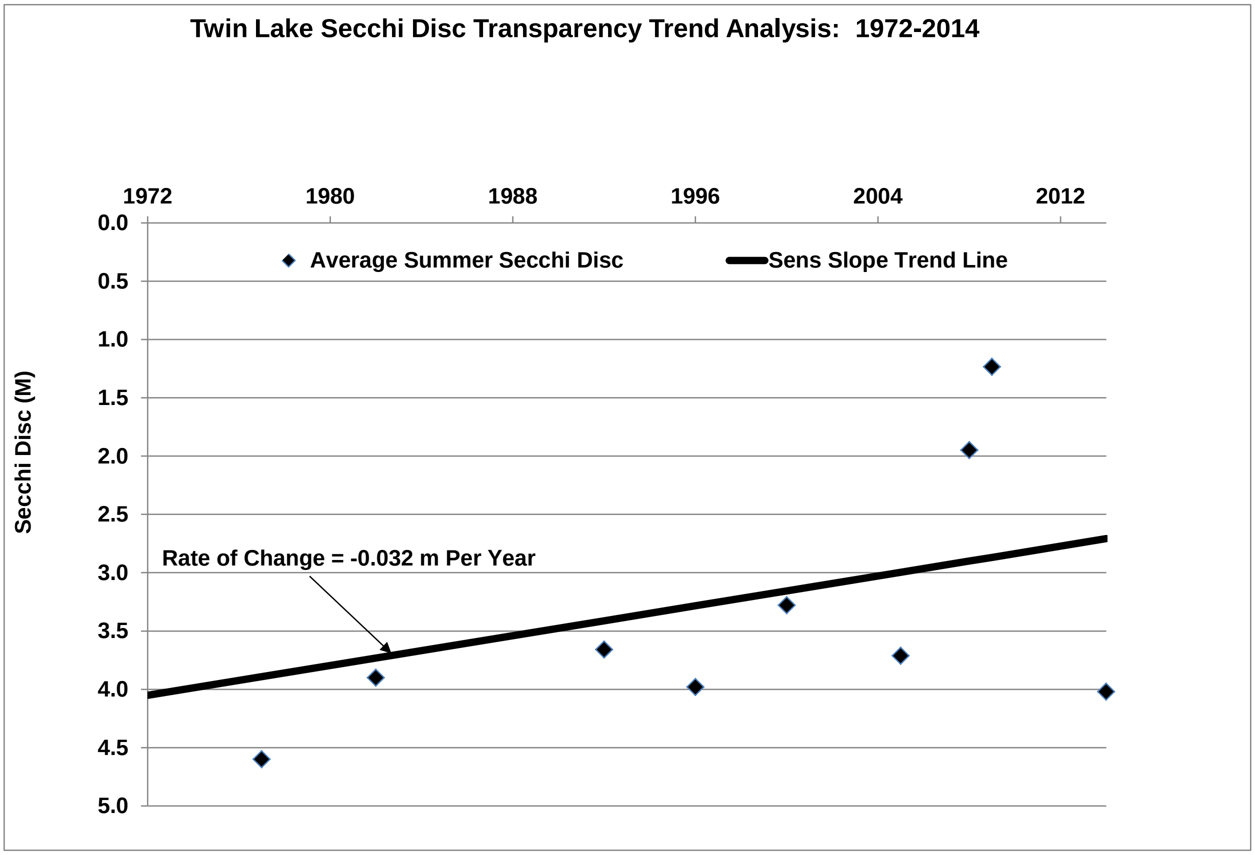


Figure 48 **Twin Lake Secchi Disc Transparency Trend Analysis: 1972–2014**

4.5 Historical Attainment of BCWMC/MPCA Standards

Figure 49, Figure 50, and Figure 51 show historical water quality data from Twin Lake (1972–2014), as compared to BCWMC's water quality goals. Total phosphorus and chlorophyll *a* concentrations and Secchi disc transparency depths have generally met the BCWMC/MPCA standard during the period of record. Since 1972, 70 percent of the summer averages for total phosphorus, 90 percent of the summer averages for chlorophyll *a*, and 90 percent of the summer averages for Secchi disc transparency depth have met the BCWMC/MPCA standard (Figure 49, Figure 50, and Figure 51).

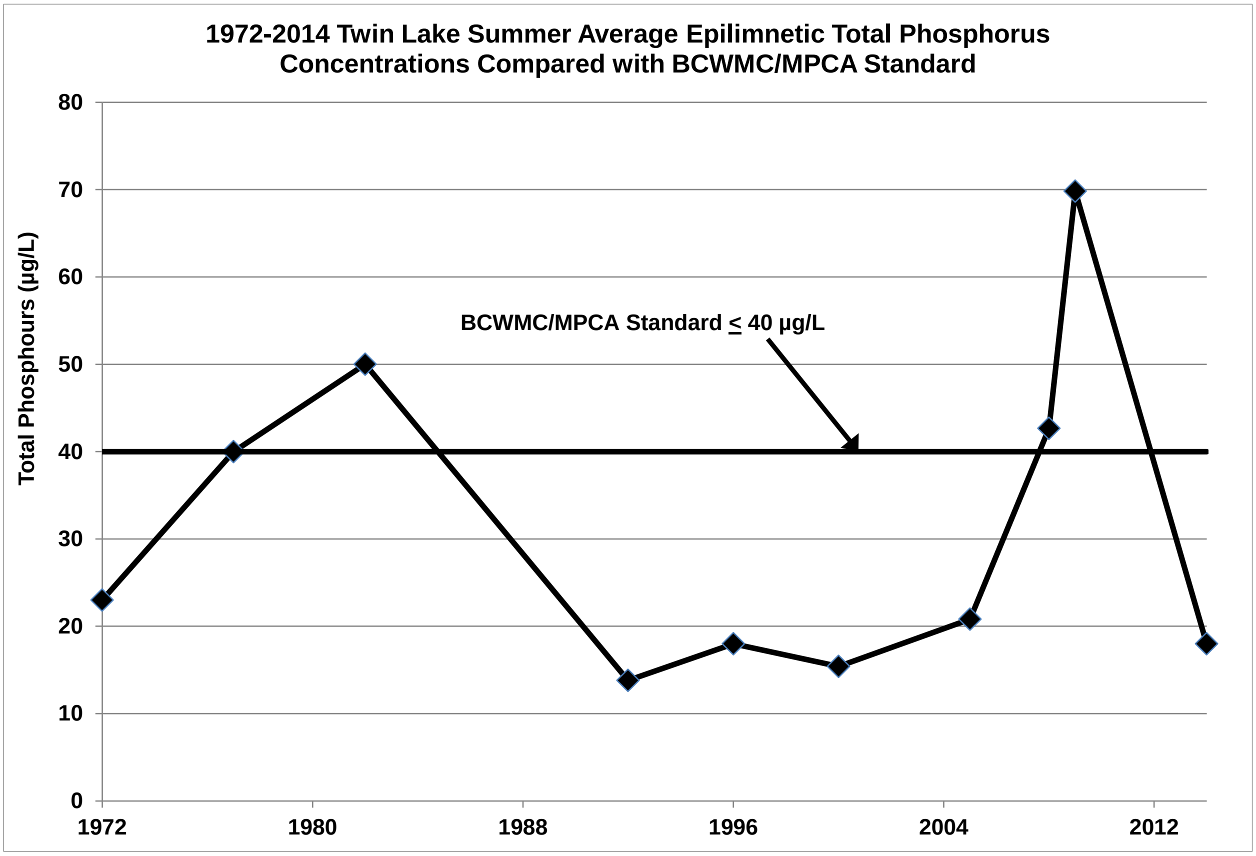


Figure 49 **1972–2014 Twin Lake Total Phosphorus Concentrations Compared with BCWMC/MPCA Total Phosphorus Standard**

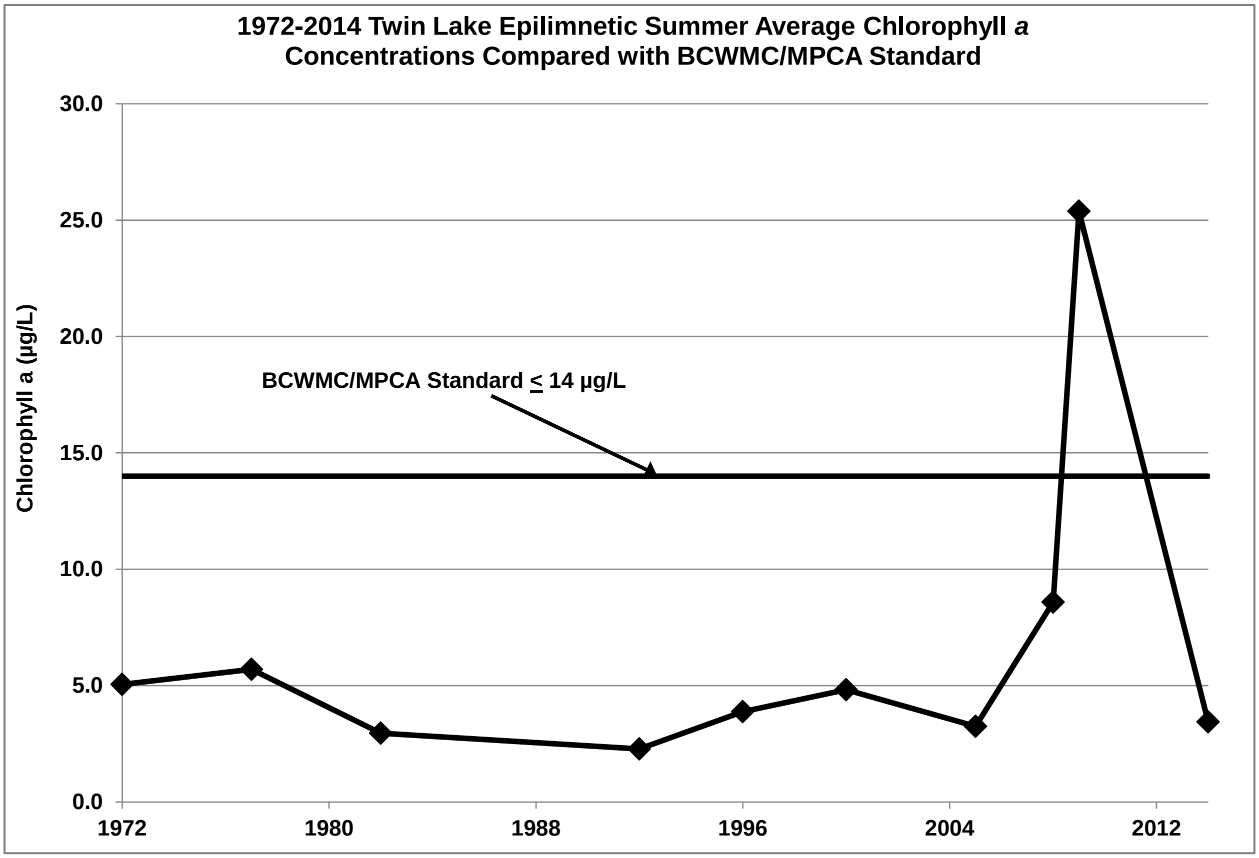


Figure 50 1972–2014 Twin Lake chlorophyll *a* Concentrations Compared with BCWMC/MPCA Chlorophyll *a* Standard

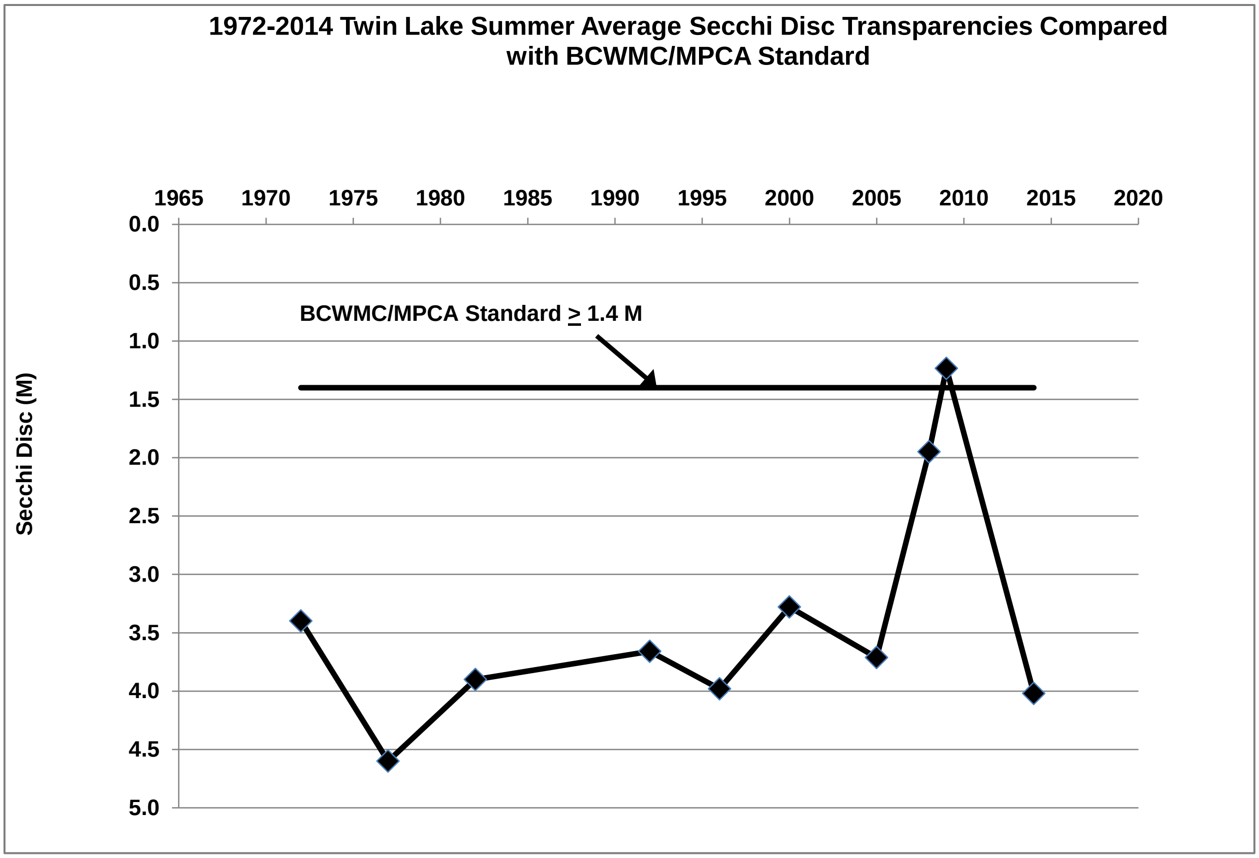


Figure 51 **1972–2014 Twin Lake Secchi Disc Transparency Depths Compared with BCWMC/MPCA Secchi Disc Transparency Standard**

Although Twin Lake's water quality declined in 2008 and 2009, in 2014 it improved to a pre-2008 level. This fluctuation appears to be correlated to changes in bottom water temperatures—where increasing temperature in the hypolimnion corresponds to greater total phosphorus at the lake's surface and decreasing temperature in the hypolimnion corresponds to lower total phosphorus at the surface (Figure 52).

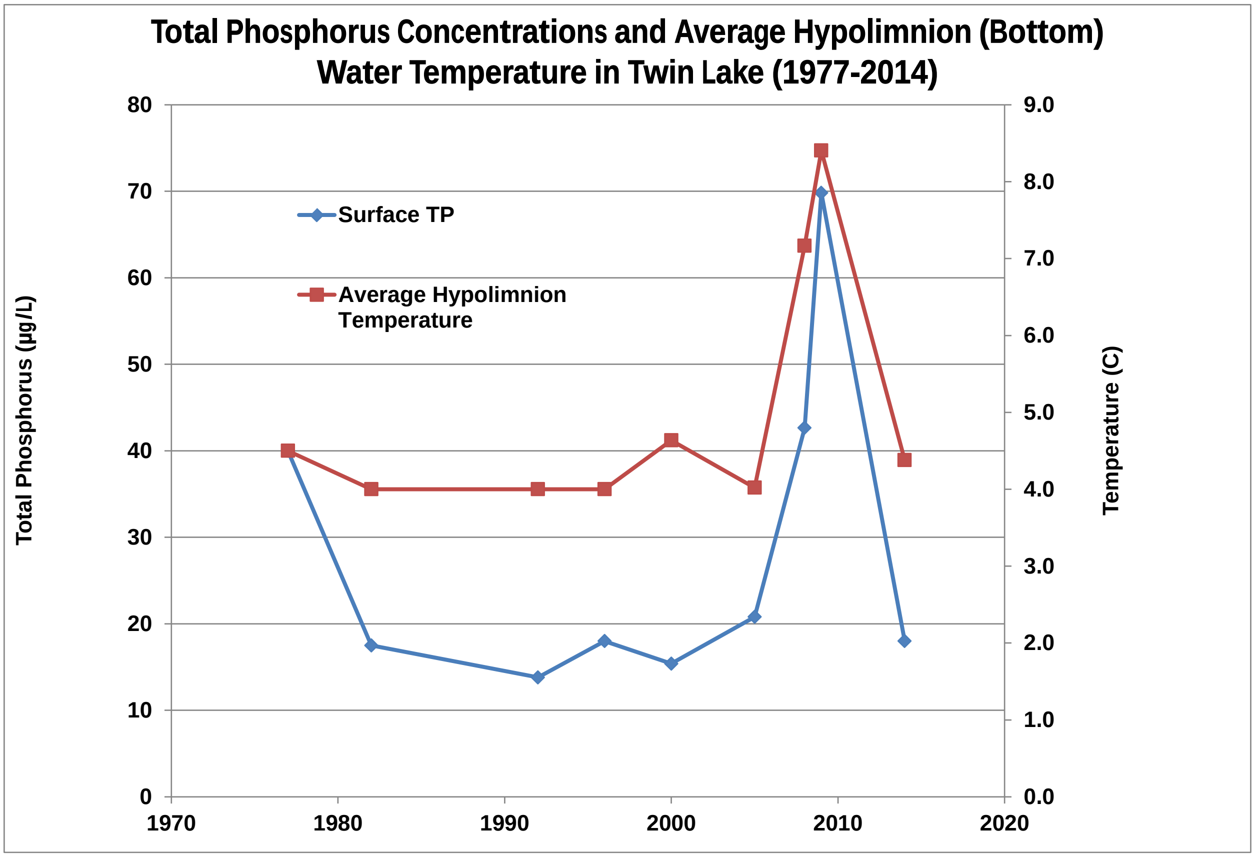


Figure 52 **Total Phosphorus (TP) Concentrations and Average Bottom Water Temperatures in Twin Lake (1992–2014)**

Average temperature in the hypolimnion was generally stable through 2005 but increased sharply in 2008 and was more than double in 2009, compared to data from 1977 through 2005. It is difficult to determine if the increase in temperature in the hypolimnion was due to increased mixing of the lake or increased temperatures in the lake as a whole; but, it is safe to say that overall water temperatures in Twin Lake during 2008 and 2009 were substantially higher than in previous years. Hypolimnion temperature declined in 2014 and was similar to temperatures from 1977 through 2005.

Dissolved oxygen concentrations in Twin Lake changed during the period from 1992–2009. Figure 53 compares surface water total phosphorus to the water column depth of oxygen depletion (i.e., the depth at which dissolved oxygen concentration is less than 2 mg/L) in Twin Lake.

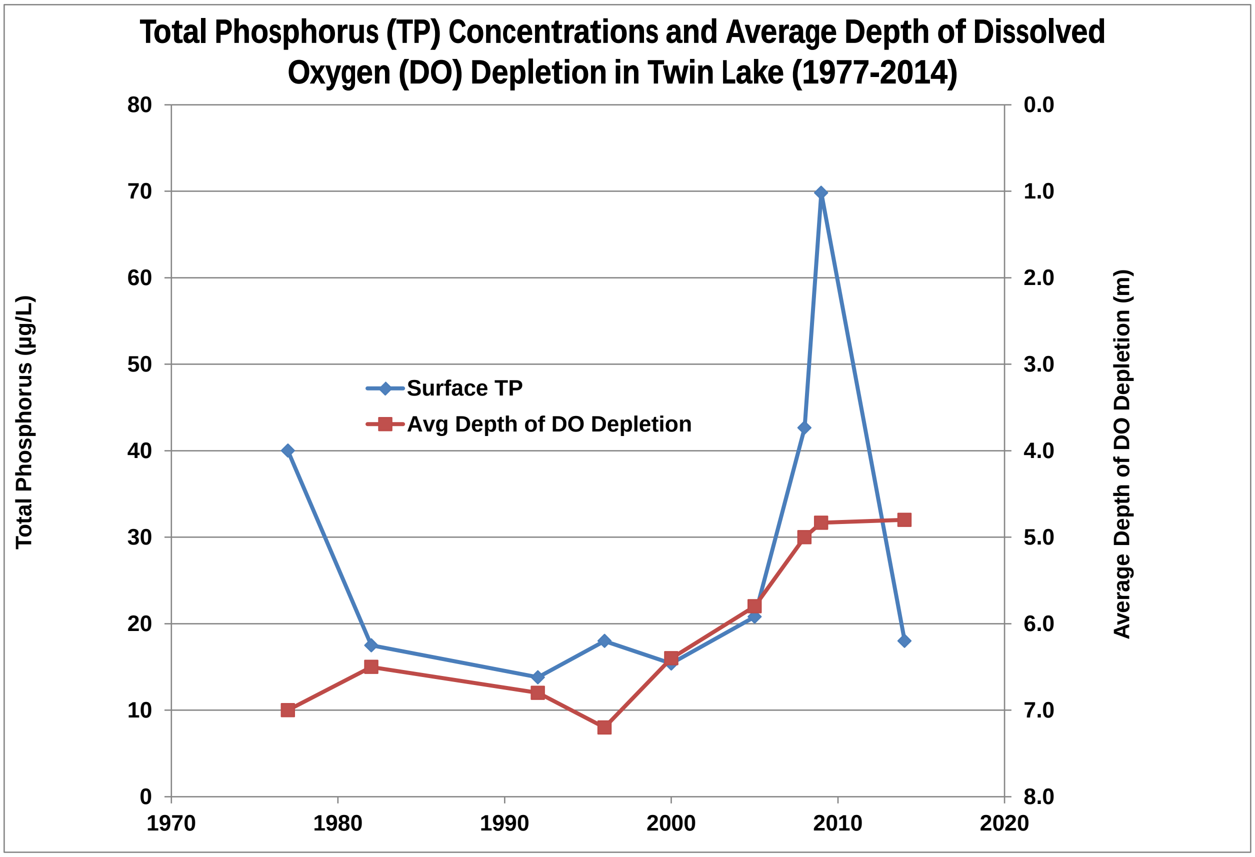


Figure 53 **Total Phosphorus (TP) Concentrations and Average Depth of Oxygen Depletion (DO) in Twin Lake (1977–2014)**

The total water column depth of oxygen depletion increased slightly in 2000. It continued to increase through 2008 and then stabilized in 2009. What this means is that the zone of water with low dissolved oxygen has been increasing in size—from an average upper water depth of 7 meters (1996) to approximately 5 meters (2008). This means the area of lake sediment exposed to low oxygen levels has increased, from approximately 10.4 to 13.4 acres, an increase of nearly 30% between 1996 and 2008. The depth of oxygen depletion in 2014 was the same as in 2009 (i.e., 4.8 meters); but, the surface total phosphorus concentration in 2014 was much lower than the 2009 concentration. In 2014 the surface total phosphorus concentration level was similar to levels from 1982 through 2005.

Changes in temperature and dissolved oxygen correlate well to changes in hypolimnetic phosphorus concentrations. As Figure 54 shows, average summer total phosphorus in the hypolimnion nearly doubled, increasing from approximately 550–650 µg/L between 1992 and 2000 to over 1000 µg/L between 2009 and 2014. Surface water total phosphorous increased similarly in 2009, but declined in 2014, despite an additional increase in hypolimnetic phosphorus concentration.

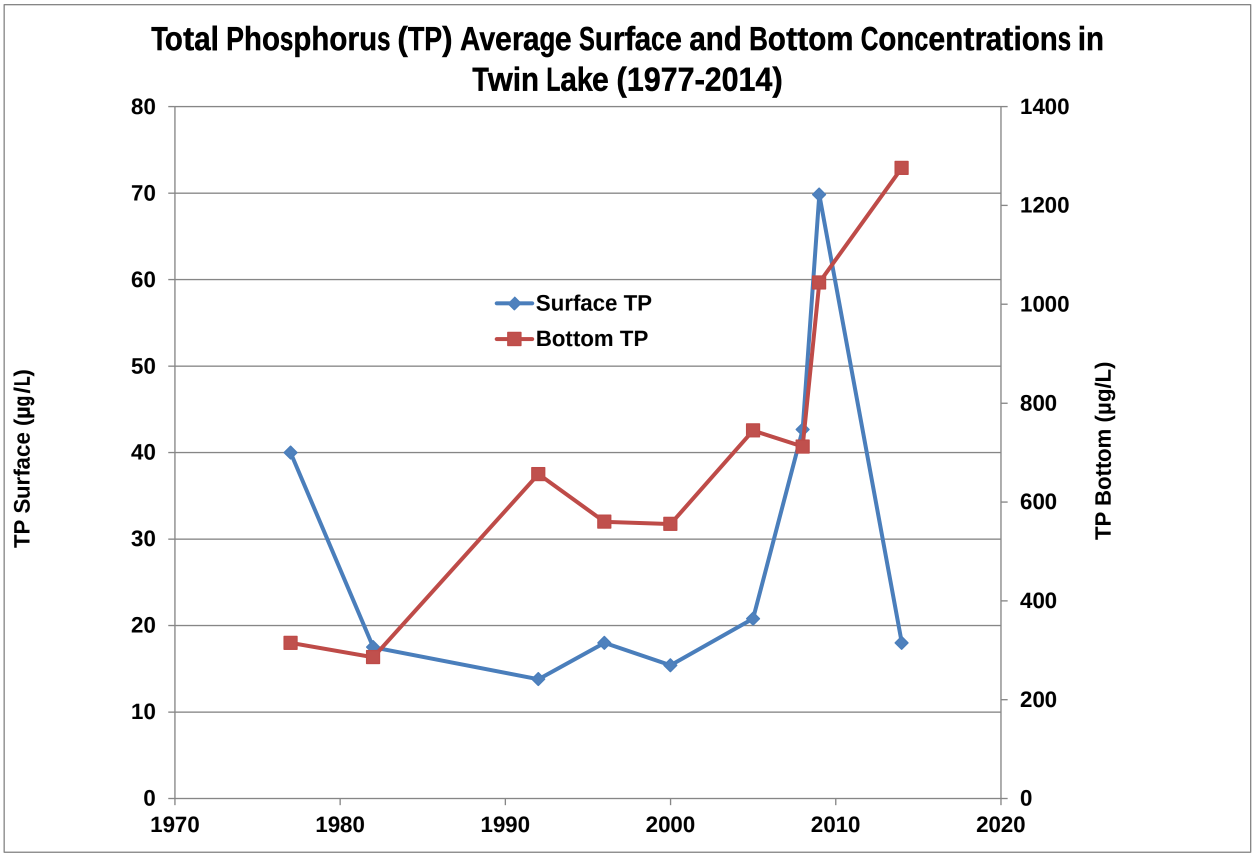


Figure 54 **Total Phosphorus Average Surface and Bottom Concentrations in Twin Lake (1977–2014)**

The graphs above show that temperature increased and dissolved oxygen decreased in recent years, leading to both an increase in the amount of sediment exposed to low oxygen conditions and an increase in total phosphorus concentration in the hypolimnion of the lake. These changes, along with the increased mixing potential due to elevated lake water temperature, are the likely reasons for increased internal loading effects and degraded water quality in Twin Lake during 2008 and 2009.

The long cold winter and late spring in 2014 resulted in lower water temperatures, compared with 2008 and 2009. This correlates with reduced mixing potential and a more stable thermocline. Hence, despite higher phosphorus concentrations in the lake's hypolimnion, the surface total phosphorus concentration declined to levels relatively similar to those observed between 1982 and 2005 (Figure 54). The lake's stable thermocline in 2014 protected the lake's surface waters from the internal load; this, in turn, improved water quality.

4.6 Biota

Three components of lake biota are presented: macrophytes, phytoplankton, and zooplankton. Fisheries status is managed by the MDNR and is not covered in this report.

4.6.1 Macrophytes

Macrophytes are aquatic plants that are large enough to be visible to the naked eye. They are divided into three groups:

- Submerged—grow beneath the water surface
- Floating leaf—leaves float on the water surface
- Emergent—stem and leaves are above the water surface

Plants from all three groups were present in Twin Lake during 2014. Plant survey statistics are presented in Table 4-1 and a comparison of plant survey statistics from 1992 through 2014 is presented in Table 4-1. The 2014 frequency of occurrence of individual species is presented in Figure 55.

Table 4-1 2014 Twin Lake Aquatic Plant Survey Statistics

Parameters	6/26/2014	8/11/2014
Total Number of Sites Visited	146	146
Total Number of Sites with Vegetation	62	65
Total Number of Sites Shallower than Maximum Depth of Plants	71	69
Frequency of Occurrence of Plants at Sites Shallower than Maximum Depth of Plants	87.3	94.2
Simpson Diversity Index (0-1, higher number, higher diversity)	0.87	0.90
Maximum Depth of Plants (ft)	21.0	19.0
Average Number of all Species Per Site (Shallower than Maximum Depth of Plants)	1.94	3.14
Average Number of All Species Per Site (Vegetated Sites Only)	2.23	3.34
Average Number of Native Species Per Site (Shallower than Maximum Depth of Plants)	1.93	3.12
Average Number of Native Species Per Site (Vegetated Sites Only)	2.21	3.31
Number of Species	18	22
Species Richness (Including Visuals)	20	23
Species Richness (Including Visuals and Boat Survey)	21	24
Average Rake Fullness (1-4)	2.66	2.98
Mean C (0-10, increasing values, decreased tolerance to disturbance, higher quality)	5.5	5.5
FQI (3-49 observed in Wisconsin, median value in Wisconsin is 22, higher number, more diverse, higher quality)	22.6	25.3

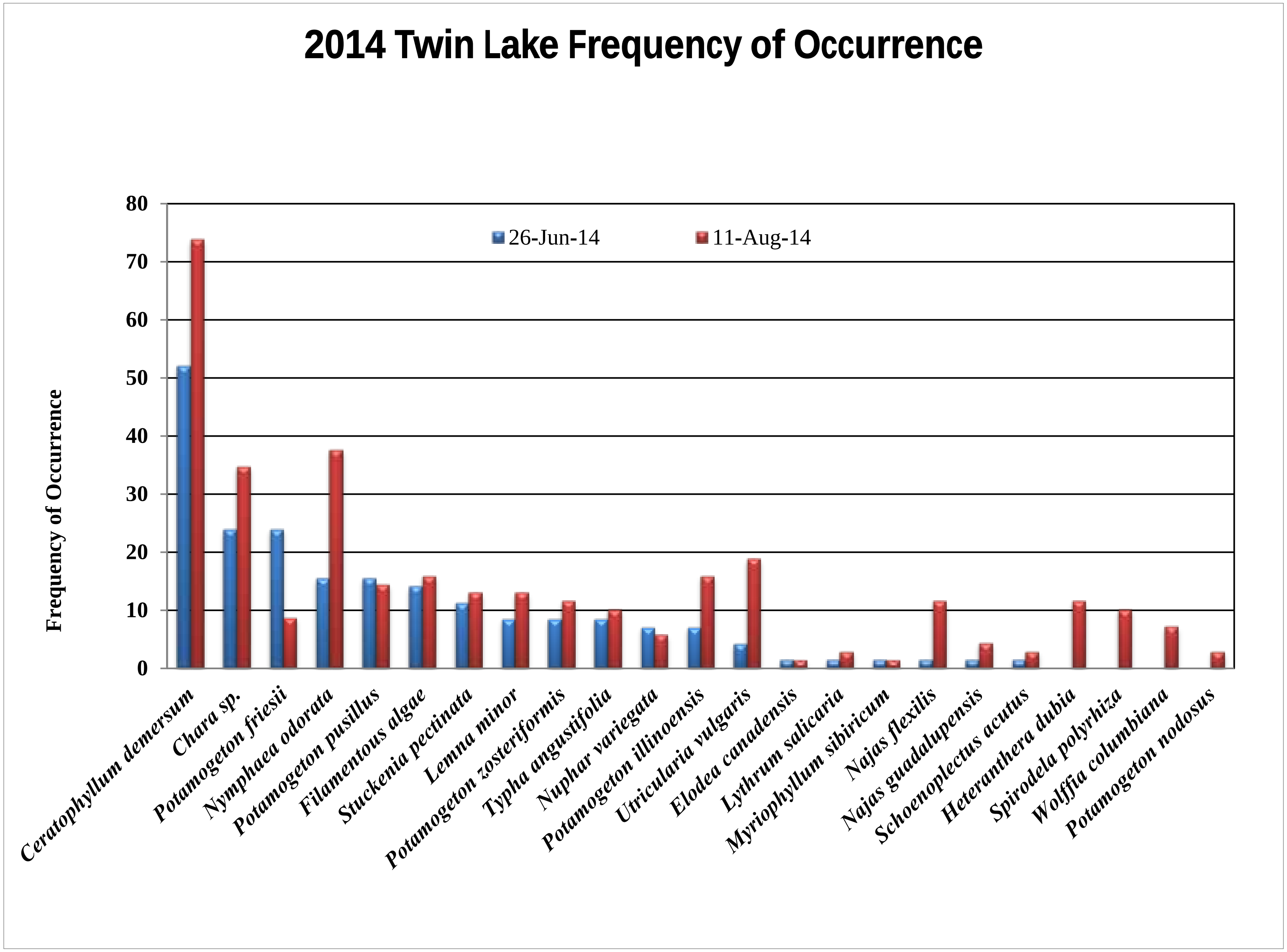


Figure 55 **2014 Twin Lake Frequency of Occurrence of Plant Species: June and August**

Table 4-2 1992–2014 Twin Lake Aquatic Plant Survey Statistics: Number of Species, Average C, and FQI

Year	# of Species: June	# of Species: August	June Average C*	August Average C *	June FQI**	August FQI**
1992	12	13	5.3	5.3	18.2	18.2
1996	16	18	5.0	5.1	20.0	21.7
2000	18	16	5.4	5.3	22.1	20.4
2005	19	19	5.4	5.4	23.1	23.1
2008	20	21	5.7	5.5	22.2	24.1
2014	21	24	5.5	5.5	22.6	25.3

*C indicates the average tolerance to disturbance by the plant community. Values are on a scale of 1 to 10 with increasing values indicating decreasing tolerance to disturbance.

** FQI or Floristic Quality Index indicates the quality of the plant community with increasing values indicating increasing value. Although MN has not kept a record of FQI values, the median value in WI is 22.

During 2014, a ring of vegetation, with a maximum depth of 19 to 21 feet, was found in Twin Lake. In previous years the maximum depth of vegetation has ranged from 8 to 16 feet.

The number of plant species observed in Twin Lake, pictured above, has increased over time, doubling from 12 species in 1992 to 24 species in 2014.

The number of plant species observed in Twin Lake has consistently increased over time, doubling from 12 species in 1992 to 24 species in 2014 (Table 4-2).

From 1992 through 2014, the tolerance of plant species in Twin Lake to degraded conditions has been evaluated using “C” values. Plant species were assigned C values on a scale of 0 to 10, with increasing values indicating plants that are less tolerant to degraded conditions. A value of 5 indicates average tolerance to degraded conditions. An average of the C values for individual species in the lake indicates the average tolerance of the community to degraded conditions. From 1992 through 2014, C values in Twin Lake ranged from 5.0 to 5.7 (5.5 in 2014). All values indicate Twin Lake plants are average in tolerance to degraded conditions.

The quality of the Twin Lake plant community was assessed using the floristic quality index (FQI). FQI values from 1992 through 2014 have ranged from 18.2 to 25.3 (Table 4-2), with the highest value to date observed in August of 2014 (25.3). Since 1996, values have generally been very close to the Wisconsin median of 22, indicating average quality. Both 2014 values were greater than the Wisconsin median value, indicating the quality of the plant community was above average (Table 4-2).

Coontail (*Ceratophyllum demersum*) was the most prevalent species in Twin Lake during 2014, occurring at a frequency of 52 percent in June and 74 percent in August (see photo below). Coontail density ranged from light to heavy, with dense coontail growing among white waterlilies. The second most prevalent species, *Chara*, was found at a frequency of 24 percent in June and 35 percent in August (see photo below). A dense ring of *Chara* was near canopy (reaching the surface) along the western shoreline to a depth of about 5 feet.

Three invasive species were observed in 2014: curly-leaf pondweed, purple-loosestrife, and reed canary grass.

Curly-leaf pondweed has been present in Twin Lake since 2000, but does not seem to be "invading" the lake. It was not collected on the rake at any of the sample locations in 2014, but was observed at one location in both June and August (Figure 56). It was a rare member of the overall plant community and not invasive. Because it is not a problem, management of curly-leaf pondweed does not seem necessary. However, plant survey data collected in the future should be reviewed to identify any changes in spatial extent or density so that management needs can be identified.

Purple loosestrife has been observed in Twin Lake since 1992. In 2014 it was growing among the cattails at three locations along the western shoreline in June (Figure 57) and expanded to an additional four areas by August (Figure 58). Because it is expanding, Barr recommends that the BCWMC explore the feasibility of managing the purple loosestrife by obtaining purple-loosestrife-eating beetles and introducing them to infested areas along the shoreline of Twin Lake. Follow-up monitoring of the beetles would be necessary to assess their numbers and effectiveness in reducing the purple loosestrife infestation.

Pictured above, coontail was the most prevalent species in Twin Lake in 2014.

Pictured above, *Chara* was the second most prevalent species in Twin Lake in 2014. A dense ring of *Chara* grew along the western shoreline in 2014.

Pictured above, purple loosestrife growing among the cattails along the western shoreline.

Figure 56 2014 Twin Lake Curly-Leaf Pondweed Location: June

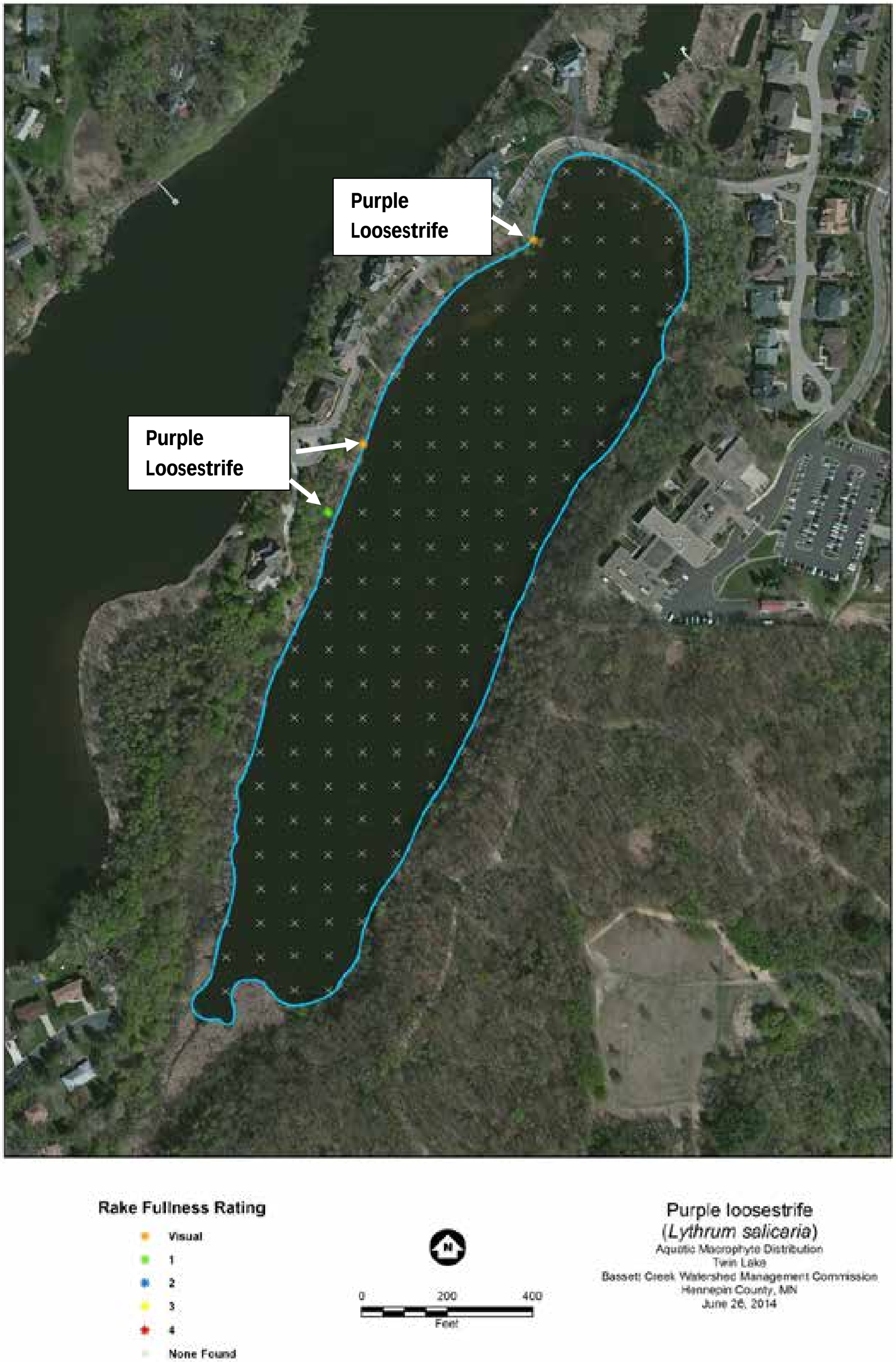


Figure 57 2014 Twin Lake Purple Loosestrife locations: June

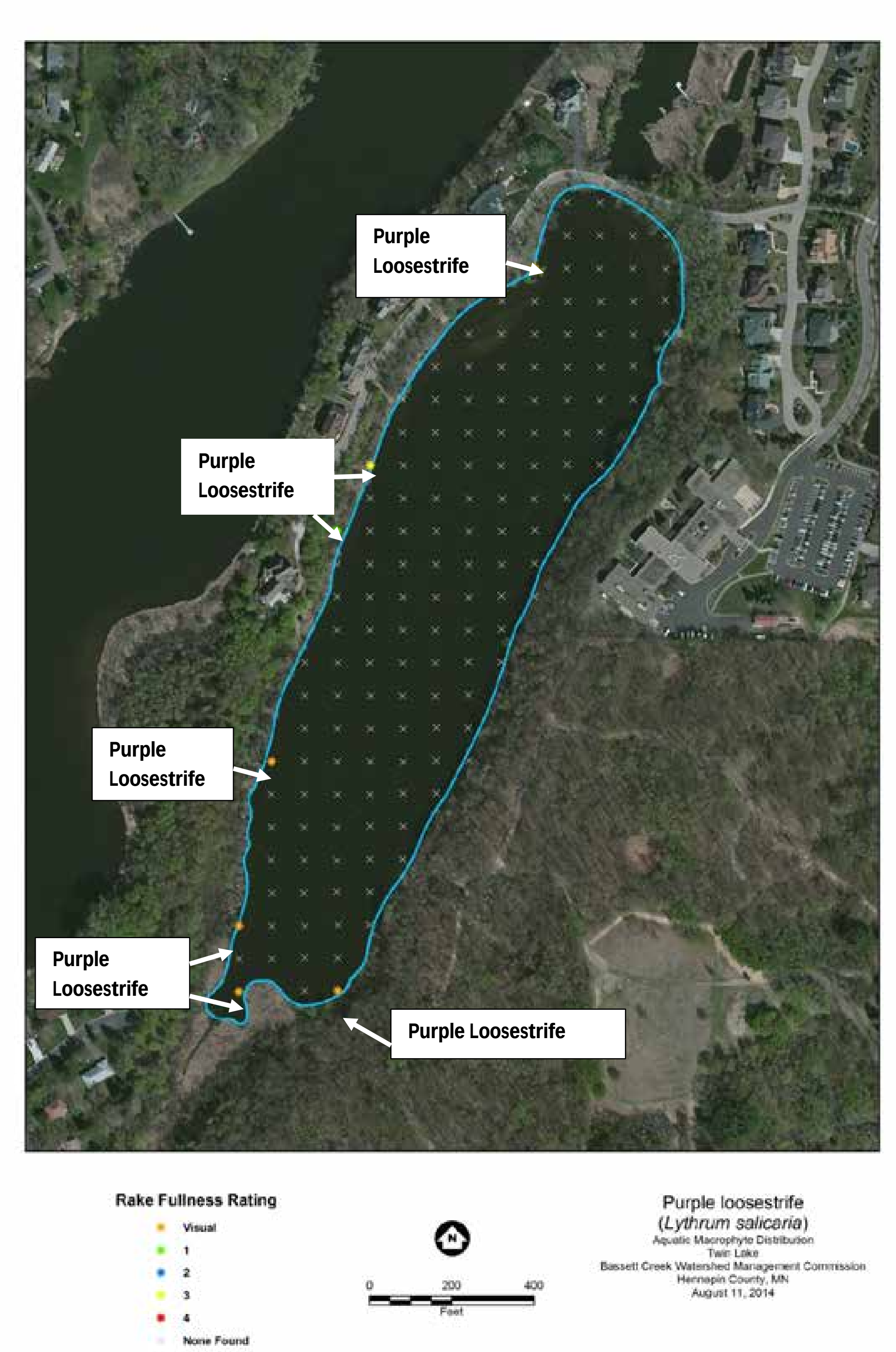


Figure 58 **2014 Twin Lake Purple Loosestrife Locations: August**

In 2014, reed canary grass plants were scattered in disturbed areas, primarily along the southeastern shoreline. Although not currently a problem, plant survey data collected in the future should be reviewed to identify any changes in spatial extent or density so that management needs can be identified.

4.6.2 Phytoplankton

Phytoplankton (algae) is single-celled aquatic plants naturally present in lakes. Excess phytoplankton reduce the lake's water clarity

Reduced numbers of phytoplankton in 2014 verified the lake's improved water quality. The lake's good water transparency in 2014 correlated with relatively low numbers of phytoplankton while poor water transparency in 2009 correlated with high numbers of phytoplankton. Peak phytoplankton numbers during the summer of 2014 were 11,085 per milliliter compared with 67,831 in 2009 (Figure 59).

Under poor water conditions, blue-green algae comprise a greater portion of the lake's phytoplankton community. Hence, a reduced presence of blue-green algae in 2014 further confirmed the lake's improved water quality. Blue-greens comprised up to 86 percent of the phytoplankton community in 2009, compared with up to 56 percent in 2014 (Figure 60).

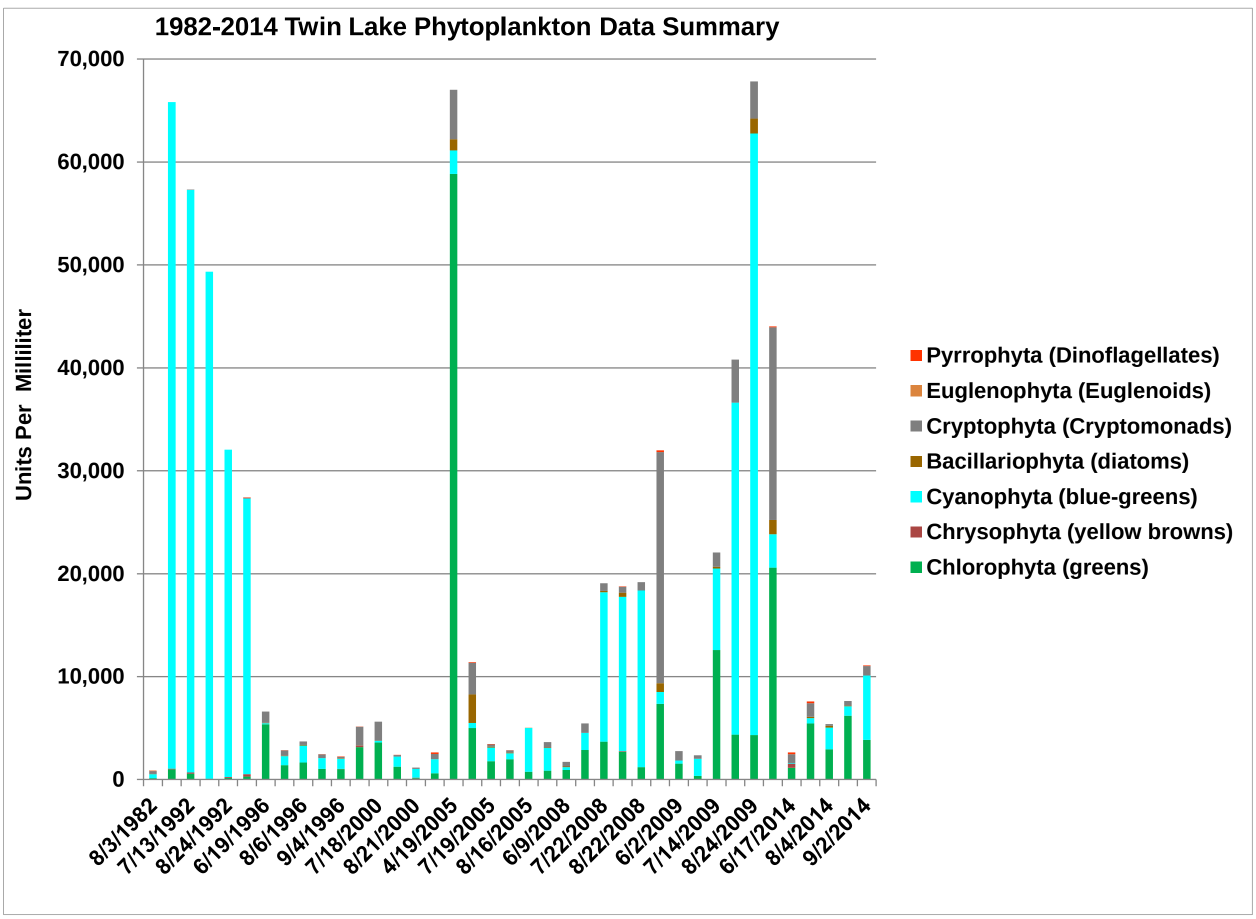


Figure 59 1982–2014 Twin Lake Phytoplankton Data Summary

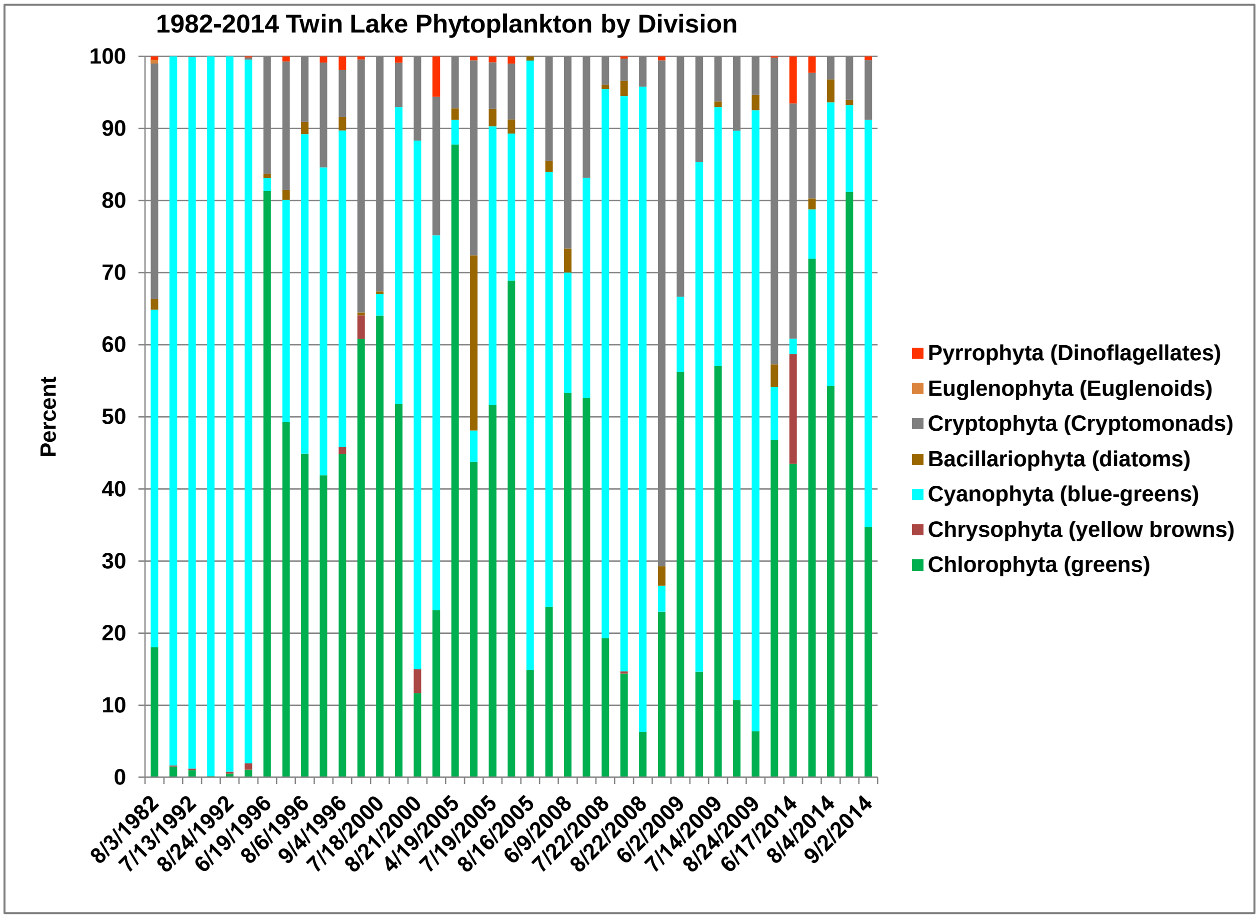


Figure 60 1982-2014 Twin Lake Phytoplankton Composition by Division

4.6.3 Zooplankton

The zooplankton community in 2014 was relatively similar to previous years, except for the timing of peak numbers. In 2005 and 2009, peak numbers occurred in April; in 2014 peak numbers occurred in mid-July (Figure 61). The Twin Lake zooplankton community is both healthy and diverse, consisting of all three groups: rotifers, copepods, and cladocerans (Figure 62).

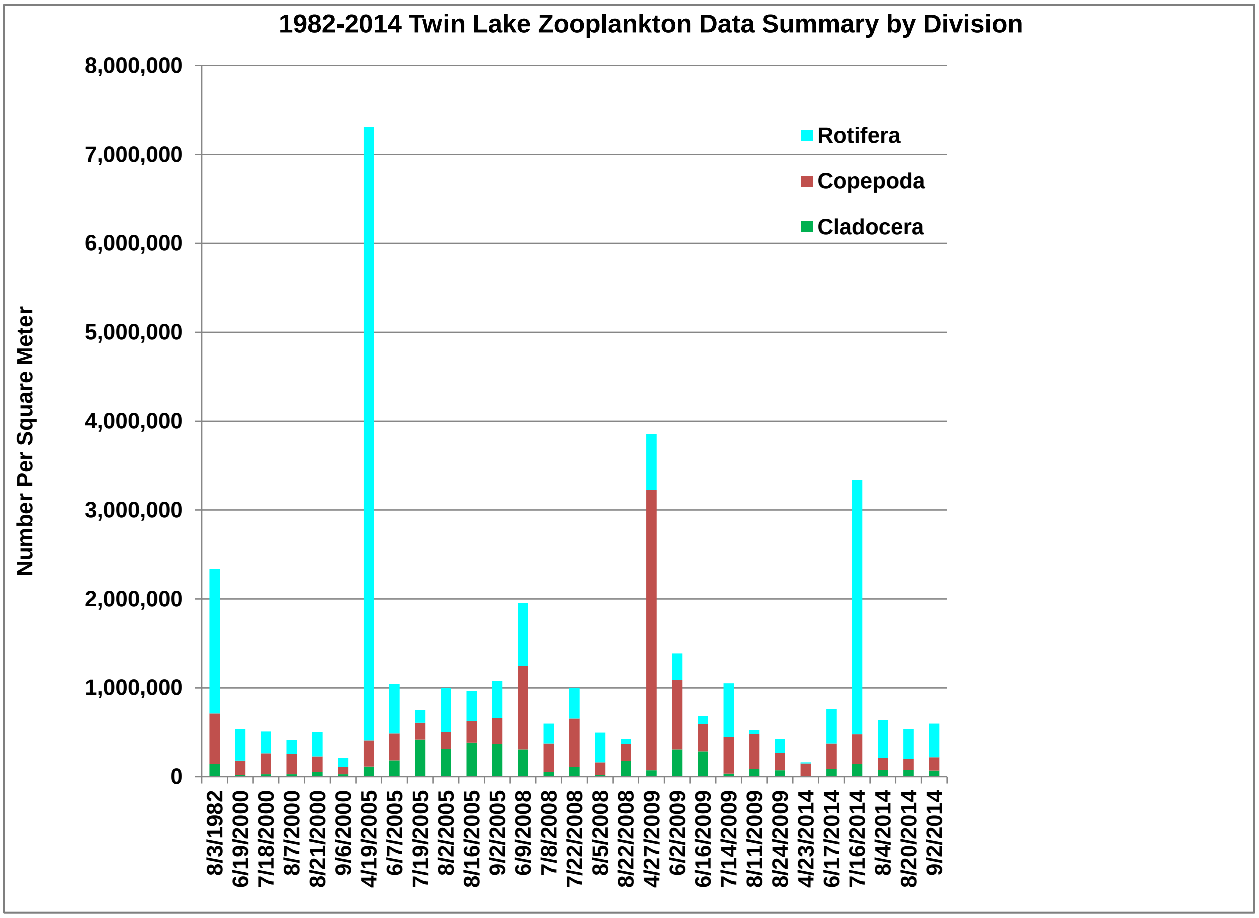


Figure 61 **1982-2014 Twin Lake Zooplankton Data Summary by Division**

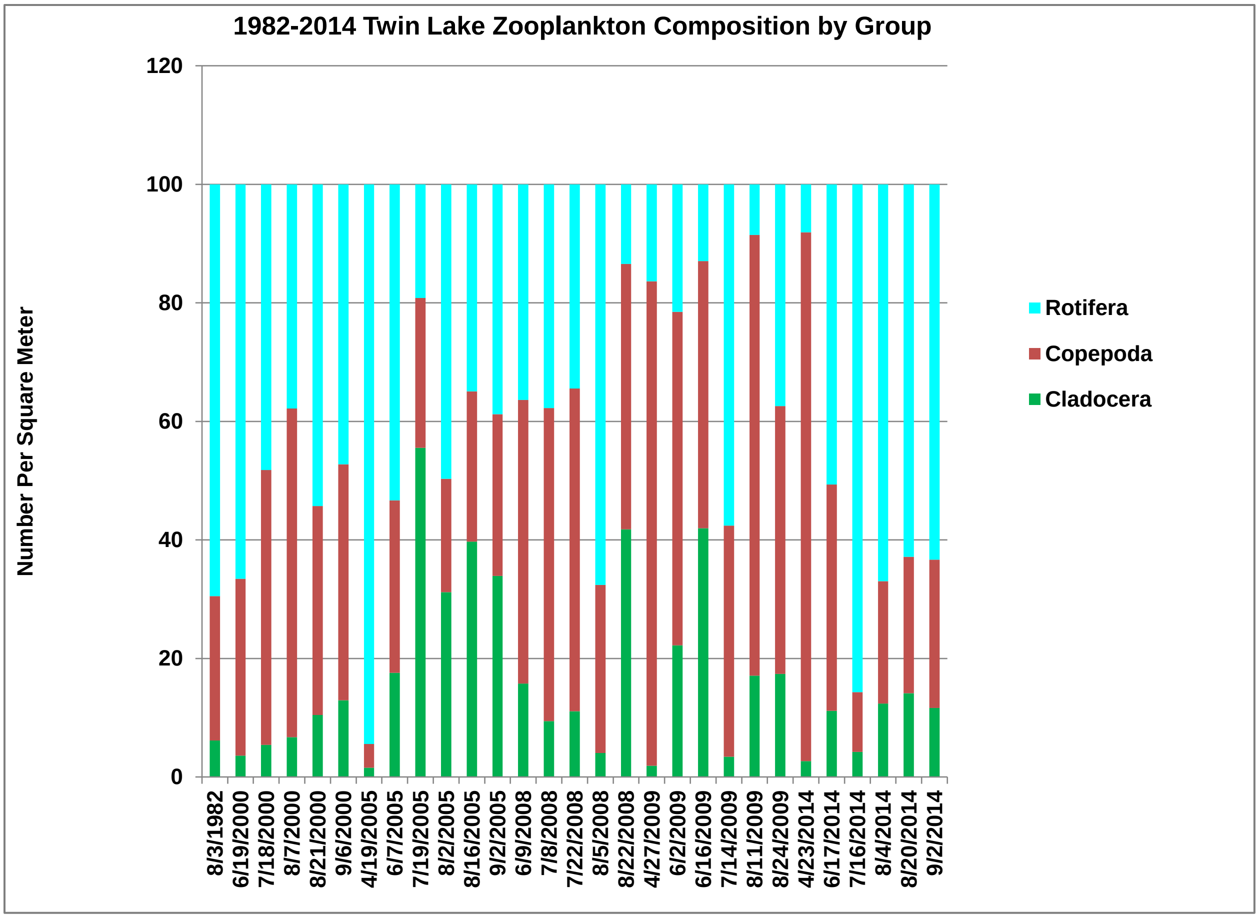


Figure 62 **1982-2014 Twin Lake Zooplankton Composition by Group**

4.7 Conclusions and Recommendation

4.7.1 Conclusions

Conclusions of the 2014 study of Twin Lake include:

- Average summer total phosphorus and chlorophyll *a* concentrations and Secchi disc transparency depth met the BCWMC/MPCA standard in 2014.
- Trend analyses indicate that during the period of record, changes in total phosphorus, chlorophyll *a*, and Secchi disc transparency values in Twin Lake are not significant.
- Since 1972, 70 percent of the summer averages for total phosphorus, 90 percent of the summer averages for chlorophyll *a*, and 90 percent of the summer averages for Secchi disc transparency depth have met the BCWMC/MPCA standard.
- Twin Lake water quality in 2014 was similar to water quality observed prior to 2008 and an improvement over 2008 and 2009 water quality. The long cold winter and late spring in 2014 resulted in lower water temperatures (compared with 2008 and 2009) and a more stable thermocline. The stable thermocline protected surface waters from the internal phosphorus load in the lake's hypolimnion; this, in turn, improved water quality.
- Reduced numbers of phytoplankton and blue-green algae verified the lake's improved water quality.
- The 2014 Twin Lake zooplankton community is both healthy and diverse and was relatively similar to previous years.
- The number of plant species in Twin Lake has consistently increased over time, doubling from 12 species in 1992 to 24 species in 2014.
- The Twin Lake plant community has generally been average in quality, but has exhibited steady improvement since 1982. The quality of the 2014 plant community was above average and the highest to date.
- Curly-leaf pondweed was observed at one location in the lake during both June and August. It is not a problem, but future data should be reviewed to detect changes.
- In 2014, purple loosestrife was found at three locations in June and another four locations by August. Because it is expanding, Barr recommends that the BCWMC explore the feasibility of managing the infestation with purple-loosestrife-eating beetles.
- In 2014, reed canary grass plants were scattered in disturbed areas, primarily along the southeastern shoreline. Because it was a minor component of the shoreline plant community, management does not appear warranted at this time. However, plant survey data collected in the future should be reviewed to identify any changes.

4.7.2 Recommendation

Alum treatment

Barr recommends that BCWMC proceed with the alum treatment slated for completion in 2015. The alum treatment will reduce the pool of phosphorus in the hypolimnion and protect the lake's water quality from degradation.

Purple loosestrife control

Barr recommends that BCWMC or cities within the watershed introduce purple-loosestrife-eating beetles to the infested areas surrounding Twin Lake. Some beetles were observed on purple loosestrife plants at the southeast corner of Sweeney Lake and could possibly be introduced to the infested areas of Twin Lake. Introduction of the beetles is expected to control purple loosestrife and protect the native vegetation.

5.0 References

Anhorn, R.J. 2005. *A 2004 Study of the Water Quality of 145 Metropolitan Area Lakes*. Metropolitan Council Publication No. 32-04-015.

Bassett Creek Flood Control Commission. 1977. *1977 Water Quality Inventory: Lakes and Streams.* Prepared by Barr Engineering Company for the Bassett Creek Flood Control Commission.

Bassett Creek Flood Control Commission. 1982. *1982 Water Quality Monitoring Program: Stream Monitoring and Lake Monitoring.* Prepared by Barr Engineering Company for the Bassett Creek Flood Control Commission.

Bassett Creek Watershed Management Commission. 1993. *1992 Lake Water Quality Survey: Northwood Pond, Parker's Lake, Sweeney Lake, and Twin Lake*. Prepared by Barr Engineering Company for the Bassett Creek Watershed Management Commission.

Bassett Creek Watershed Management Commission. 1997. *1996 Lake Water Quality Study: Northwood Lake, Parker's Lake, Sweeney Lake, Twin Lake, and Grimes Pond*. Prepared by Barr Engineering Company for the Bassett Creek Watershed Management Commission.

Bassett Creek Watershed Management Commission. 2001. *2000 Lake Water Quality Study: Northwood Lake, Parker's Lake, Sweeney Lake, and Twin Lake*. Prepared by Barr Engineering Company for the Bassett Creek Watershed Management Commission.

Bassett Creek Watershed Management Commission. 2004. *Bassett Creek Watershed Management BCWMC Watershed Management Plan*. Prepared by Barr Engineering Company for the Bassett Creek Water Management Commission BCWMC.

Bassett Creek Watershed Management Commission. 2006. *2005 Lake Water Quality Study: Northwood Lake, Parker's Lake, Sweeney Lake, and Twin Lake*.

Bassett Creek Watershed Management Commission. 2009. *2008 Lake Water Quality Study: Sweeney Lake, and Twin Lake*.

Bassett Creek Watershed Management Commission. 2010. *2009 Lake Water Quality Study Sweeney Lake, Twin Lake, Northwood Lake, North Rice Pond, and South Rice Pond*.

Bassett Creek Watershed Management Commission. 2011. *Twin Lake Phosphorus Internal Loading Investigation.*

Metropolitan Council Environmental Services. CAMP Data for Sweeney Lake. Obtained in 2014.

Minnesota Pollution Control Agency. *Minnesota Administrative Rules, Chapter 7050 Waters of the State.* https://www.revisor.mn.gov/rules/?id=7050&view=chapter#rule.7050.0222 accessed on March 5, 2014.

Novotny, E.V, Murphy, D., Stefan, H.G. 2008. *Increase of Urban Lake Salinity by Road Deicing Salt*. Science of the Total Environment. 406, 131-144.

Osgood, R., A. 1989a. *An Evaluation of Lake and Stream Monitoring Programs in the Twin Cities Metropolitan Area*. Metropolitan Council Publication No. 590-89-128.

Osgood, R., A. 1989b. *1989 Study of the Water Quality of 20 Metropolitan Area Lakes.* Metropolitan Council Publication No. 590-89-130.

Osgood, R. A. 1989c. *Assessment of Lake Use-Impairment in the Twin Cities Metropolitan Area*. Metropolitan Council Publication No. 590-89-130.

Shaw, Byron, Christine Mechenich, and Lowell Klessig. 2004. *Understanding Lake Data (G3582).* UW-Extension.

World Health Organization (WHO). 2003. *Guidelines for Safe Recreational Water Environments, Volume 1, Coastal and Fresh Waters*. 253 pages.