Final Report to the Missoula Conservation District

Priority Water Quality Monitoring in the Clearwater Valley

Contract Agreement Number: 23G-22-3705

Sponsored by MT DNRC HB 223 Grant

Total Funding to CRC: $9,793.88

Total Project Cost: $54,967.89

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Executive Summary

Water quality sampling was performed in 2021 and 2022 on lakes within the Clearwater River watershed. The sampled lakes include Alva, Inez, Placid, Salmon, Seeley and Big Sky. The findings generally supported that most of the lakes are all in an oligotrophic to mesotrophic condition with most lake parameters consistent with natural lakes in these conditions. Oligotrophic lakes are generally characterized as having clear water and good water quality. Mesotrophic lakes typically have moderately clear water but more likely to have low dissolved oxygen in deep water during the summer.

Dissolved oxygen (DO) readings decreased in deeper waters of all lakes as the summer progressed, with all lakes dropping below 5 mg/L in the hypolimnion by fall. Big Sky Lake had low DO levels in its deeper areas throughout the year. Nutrient sampling of the lakes generally found moderate levels of total nitrogen and phosphorous. Higher levels of nutrients were found in deeper samples than in surface samples. Big Sky Lake is of particular concern. In 2022 nitrogen levels in two samples of surface water were 374 ug/L and 402 ug/L, while deep samples recorded 1700 ug/L and 1860 ug/L. An interesting finding for Seeley Lake was in samples collected at the outlet of the lake, where consistently higher levels of nitrogen and phosphorous were found. This outlet is at the end of the relatively shallow and narrow still water section of the Clearwater River. Causes for this increase are unknown, but the shallow waters slowly flowing through this area with the presence of cabins along the shore may be a factor.

Sampling for whitening agents and E. coli in Seeley Lake did not indicate the influence of septic leachate. However, this does not mean that septic leachate is not entering the lake, given the limited number of samples taken and multiple confounding factors.

Estimates of total algal production and estimates of cyanobacteria (blue green algae) were made using measurements of the fluorescence of chlorophyll and phycocyanin. Fluorescence is measured in relative fluorescence units (RFUs), or how much light is reflected. Waters with high levels of chlorophyll indicate that such lakes are typically high in nutrients, specifically phosphorus and nitrogen that support the growth of algae. Sampling results for chlorophyll and blue-green algae were all found to be in relatively low levels, except for Big Sky Lake. Big Sky Lake exhibited relative fluorescence units (RFUs) for chlorophyll and phycocyanin (a pigment in algae) that were sometimes twice as high as those measured for the other lakes. While algal blooms have been noted in several of the lakes over recent years, the sampling that was conducted did not find clear indictors of locations or times when conditions may be contributing to these blooms.

Because the sampling of nutrients across the six lakes was quite limited for some lakes and varied across sampling dates, more sampling of nutrients is needed to establish a thorough baseline for water quality conditions. Additional nutrient sampling is planned for 2023 and should provide additional insights into nutrient concentrations in the lakes.

Project Overview

The Missoula Conservation District entered into a sponsored grant agreement with the Clearwater Resource Council to gain a preliminary baseline assessment of water quality conditions occurring across the 6 primary lakes in the Clearwater Valley. Additional objectives included evaluating potential conditions contributing to blue-green algae blooms on lakes, assessing selected indicators of potential septic leachate impacts to surface water of the lakes, and to inform future sampling plans. The study evaluated conditions on Lake Alva, Lake Inez, Seeley Lake, Big Sky Lake, Salmon Lake, and Placid Lake within the Clearwater River Basin during 2021, with more focused sampling on Seeley Lake in 2022.

Understanding the scope and extent of surface water contamination is the first step to correct potential accelerating problems and protect drinking water supplies. Missoula County residents will benefit from water quality monitoring to better assess the potential impact of septic system leachate in the lakes and the need for wastewater treatment systems. Such data will be invaluable to the Missoula County Public Health Department and the Seeley Lake Sewer District to plan and protect water quality in the Clearwater Valley.

The Clearwater Watershed containing what is termed the Chain of Lakes, lies on the southern end of the Crown of the Continent ecoregion. It is recognized as one the most pristine watersheds in the Pacific Northwestern region. The surface water feeds into the Blackfoot River and Clark Fork River basins. Both basins are part of the headwater of the Columbia River Basin, and the clean water of these systems benefit the state of Montana and the larger Northwest region.

Approximately 2,000 residents live in the Clearwater Valley, with tourist visitation estimated to exceed 20,000 visitors per year. The beautiful Chain of Lakes supports extensive recreational activities and supplies the town of Seeley Lake with its drinking water. Concerns over possible septic system contamination has led the Seeley Lake Sewer District to expand ground water monitoring to determine if problems exist. Whether or not impacts are occurring to surface waters, including Seeley Lake, need additional monitoring and was one of the impetuses for this grant.

Acknowledgements

We would like to express our utmost appreciation and gratitude to the Clearwater Resource Council's volunteers and partner organizations. The following individuals and organizations helped to make the work contained in this report possible:

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Missoula Conservation District
Montana Department of Natural Resources, Conservation and Resource Development Division

Introduction:

The Missoula Conservation District (MCD) has prioritized a goal to improve and protect water quality by conserving streams and rivers in a natural state and conserving soil and promoting wise land use practices, specifically through working with local partners to limit resource impacts of suburban development in rural areas.

The Clearwater Resource Council's (CRC) mission is to engage the community and facilitate efforts that will enhance, conserve, sustain, and protect the natural resources and rural lifestyle of the Clearwater Watershed for present and future generations.

The parties entered into a sponsored grant Agreement Number: 23G-22-3705, titled "Priority Water Quality Monitoring in the Clearwater Valley" for an amount of $9,809.00. The purpose of the grant was to collect and analyze water quality data to better understand the impact of septic systems on the lakes in the Clearwater Valley. Funding for the project came through a Montana Department of Natural Resources & Conservation (DNRC) HB 223 Grant (Agreement No. 23G-22-3705) obtained by the MCD.

The sponsored grant agreement between CRC and MCD was signed on June 14, 2021, with a scheduled termination date of December 31, 2022. Due to CRC staff transitions during the project and the need to complete all contract deliverables, an amendment was approved to extend the termination date until June 30, 2023.

Problem Statement:

The Clearwater Watershed (Figure 1) supporting the Chain of Lakes, lies on the southern end of the Crown of the Continent ecoregion. It is recognized as one the most pristine watersheds in the Pacific Northwestern region. The surface water feeds into the Blackfoot River and Clark Fork River basins. Both basins are part of the headwater of the Columbia River Basin, and the clean water of these systems benefit the state of Montana and the larger ecosystem.

The Clearwater Watershed is increasingly becoming a destination location for residential housing and outdoor recreation. Approximately 2,000 residents live in the Clearwater Valley, with tourist visitation reported to exceed 20,000 visitors per year.

Significant housing occurs along or near the shorelines of 5 of the 6 lakes in the Chain of Lakes. The Appendix shows maps of the locations of septic systems occurring around each of the 6 lakes. Concern exists that septic leachate may be entering groundwater and surface waters and cause detrimental damage to aquatic ecosystems. Over the past several years, the Seeley Lake Sewer District has initiated more intensive monitoring of groundwater around Seeley Lake to determine if septic system leachates are affecting groundwater quality. Concern exist that the quality of surface waters may be decreasing as a number of blue-green algal blooms in areas lakes has been reported in recent years.

Understanding the scope and extent of surface water contamination is the first step to correct these potential problems and protect drinking water supplies, recreational opportunities, and ecosystem health. Missoula County residents will benefit from water quality monitoring to better assess the impact of the septic system leachate in the lakes and the potential need for wastewater treatment systems. Such data will be invaluable to the Missoula County Public Health Department, the Seeley Lake Sewer District, and the Seeley Lake Water District. It will also be useful in protecting the growing tourism-based economy in the Clearwater Valley that includes recreational activities such as boating, fishing, and wildlife viewing in the ecoregion.

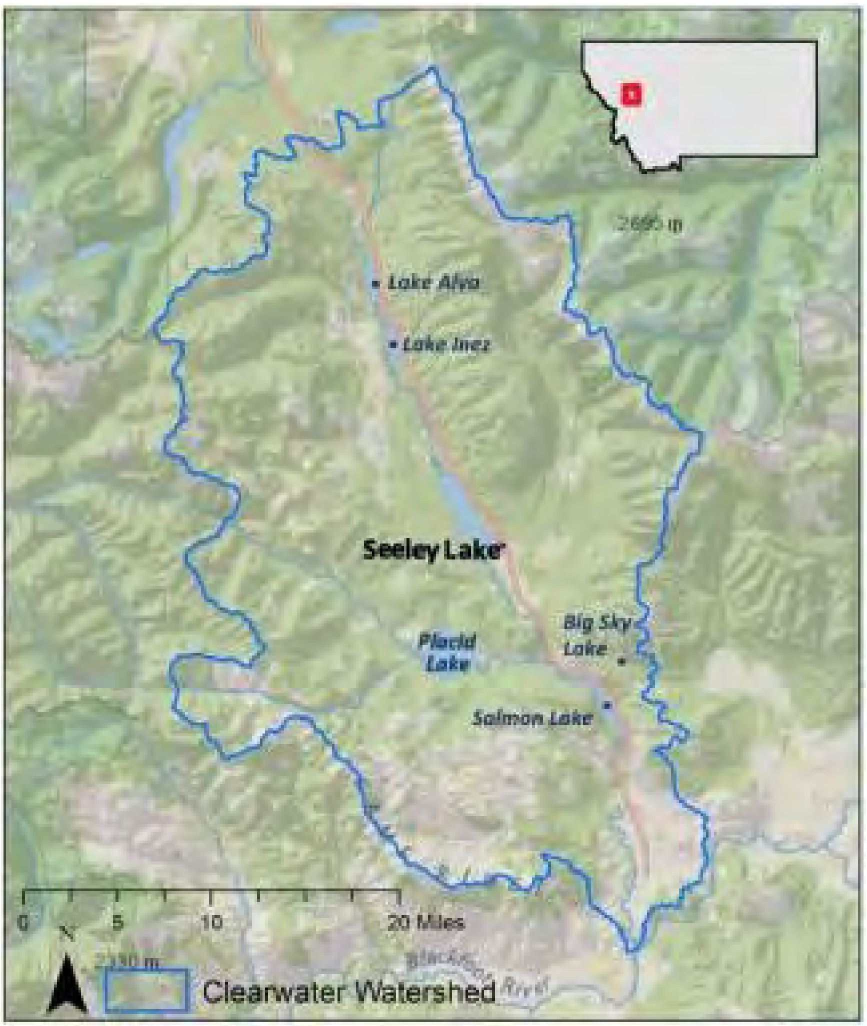


Figure 1. Clearwater Watershed and lakes included in these project.

Project Purpose

The purpose of this project was to conduct a preliminary baseline data assessment of the status of water quality in lakes and to evaluate conditions potentially contributing to blue-green algae blooms on the lakes. The project also evaluated indicators of potential septic leachate impacts to surface waters, and to help inform future sampling plans.

Project Description

This project evaluated nutrient status and other lake parameters for six lakes to establish baseline data to better assess the impacts of septic systems on surface waters in the Clearwater Valley in order to better inform future management decisions aimed at protecting aquatic resources, the local economy, and drinking water sources. The methods used for this project are explained in the SAP 2021 and SAP 2022 documents that are listed as supporting documents.

Project Location

The water quality sampling occurred at predetermined sampling sites on Lake Alva, Lake Inez, Seeley Lake, Big Sky Lake, Salmon Lake, and Placid Lake within the Clearwater River Basin as specifically designated within the 2021 and 2022 Sampling and Analysis Plans (SAP).

Results of Lake Sample Analyses

The study began in spring of 2021 utilizing matching funding and continued through the end of 2022. Water sampling occurred at predetermined sampling sites on Lake Alva, Lake Inez, Seeley Lake, Big Sky Lake, Salmon Lake, and Placid Lake within the Clearwater Watershed. The Sampling and Analysis Plan (SAP 2021 and SAP 2022) details the procedures and control standards used to collect, store, and ship samples to the University of Montana Flathead Lake Biological (FLBS) for analysis or that were collected in the field using on-board equipment.

2021 Sampling Analyses

Dissolved Oxygen and Temperature Profiles

In all six lakes, dissolved oxygen (DO) declined as depth increased. The change in DO was most dramatic at the thermocline, the layer of rapidly changing water temperature, in each lake. Typically, DO is correlated with water temperature, and colder water holds more oxygen. However, in lake ecosystems, there are usually higher concentrations of oxygen near the surface, even though the water is warmer there. This is because the main route that oxygen enters the lake is from the air. Due to a difference in oxygen concentrations in the air versus the water, oxygen is absorbed by surface water.

The second main route oxygen enters the lake is through photosynthesis by phytoplankton or rooted aquatic plants, and the third is from rivers and streams. Most of these processes occur in the upper layer, the epilimnion. The hypolimnion, the colder (and thus, denser and heavier) deep layer that is separated from the epilimnion by the thermocline and metalimnion, receives very little oxygen from the atmosphere and is usually too dark for photosynthesizing plants. In the summer, when the lakes are stratified and there is limited mixing between layers, the hypolimnion is often oxygen deficient. This oxygen deficit at depth often becomes greater as time passes throughout the summer because biological processes, such as decomposition by microorganisms, deplete oxygen levels within that deeper layer.

Dissolved oxygen and temperature profiles for each lake are discussed in each of the following sections. On Lake Alva, DO was highest in May, peaking at 9.68 mg/L at 2 meters deep and with a surface water reading of 9.1 mg/L (Figure 2). In May, Lake Alva was not fully stratified yet and DO was 8.13 mg/L at 25 meters deep. By July, Lake Alva was stratified and on July 27, DO at the lake's surface was 6.78 mg/L, peaked at 8.63 mg/L at 6 meters deep, and dropped to 4.34 mg/L at 24 meters. Our last DO reading on Lake Alva, taken on September 28, showed 6.83 mg/L at the surface, a similar reading of 6.87 mg/L at 7 meters, and a low of 0.33 mg/L at 26 meters. While the temperature profile on this September date still showed a significant thermocline (Figure 3), it appears that the cooler temperatures had led to some lake water mixing, as evident by the less dramatic change in DO concentrations in the metalimnion. However, summer stratification is very apparent by the anoxic DO levels at the bottom of the lake. For all months, the thermocline occurred between 4- and 8-meter depth. For most of the lakes, including Lake Alva, surface temperatures peaked in July and were lowest in May and September.

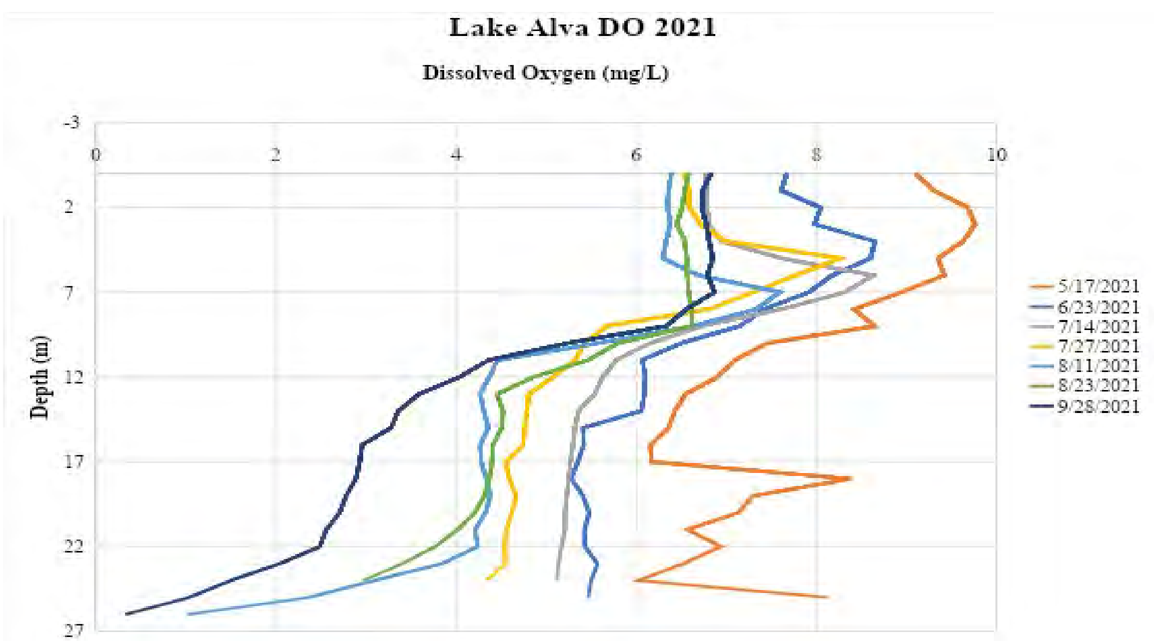


Figure 2. Dissolved oxygen (mg/L) profile one site in Lake Alva, from May through September 2021.

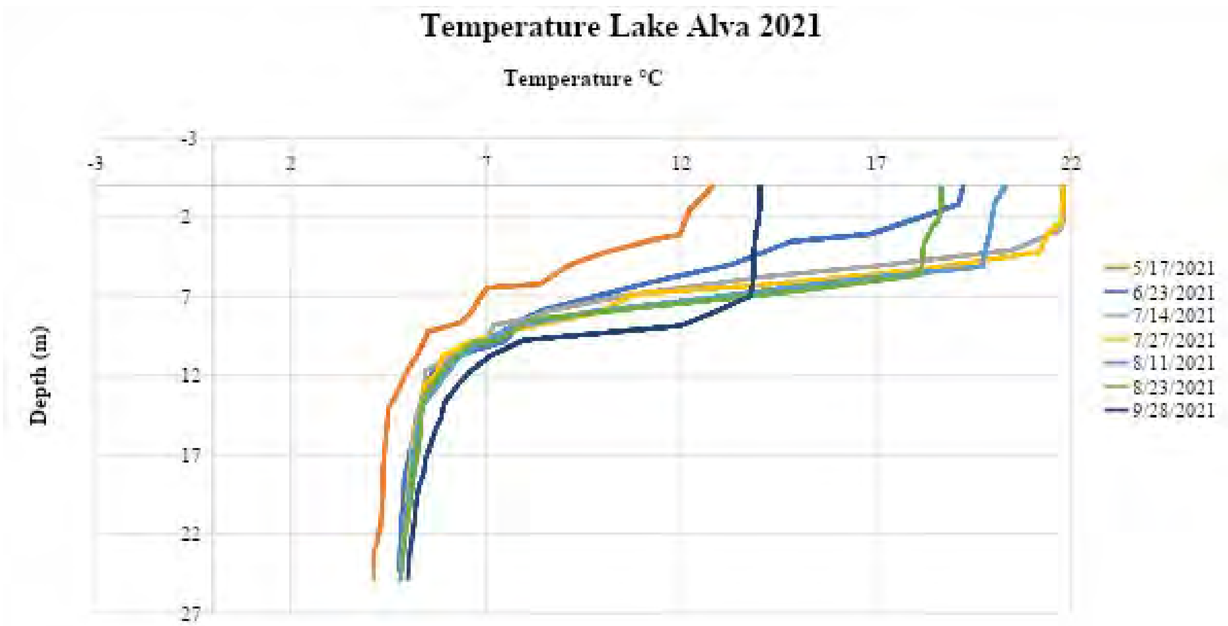


Figure 3. Temperature (°C) profile recorded at one site in Lake Alva, from May through September 2021.

Big Sky Lake recorded some of the highest DO levels in 2021 (Figure 4), compared to the other five lakes. However, it also recorded values close to 0 mg/L at the lake bottom consistently all summer, while other lakes gradually reached 0 mg/L at their deepest readings as the summer progressed. In May, the DO profile read 10.18 mg/L at the surface, a peak of 12.12 mg/L at 4 meters, and 0.34 mg/L at 14 meters (Figure 4). Mid-summer, on July 26, Big Sky Lake's profile recorded 6.35 mg/L at the surface, 7.55 mg/L at 7 meters, and 0.42 mg/L at 14 meters. Near the end of the summer, just a few weeks later, September 13, the profile read 6.37 mg/L at the surface, 6.38 mg/L at 2 meters, and 0.28 mg/L at 14 meters. The hypolimnion of Big Sky Lake appears to be anoxic at all times of the year that we monitored. Like Lake Alva, Big Sky Lake's water temperatures were highest in July and lowest in May and September. The thermocline consistently occurred between 4 and 6 meters (Figure 5).

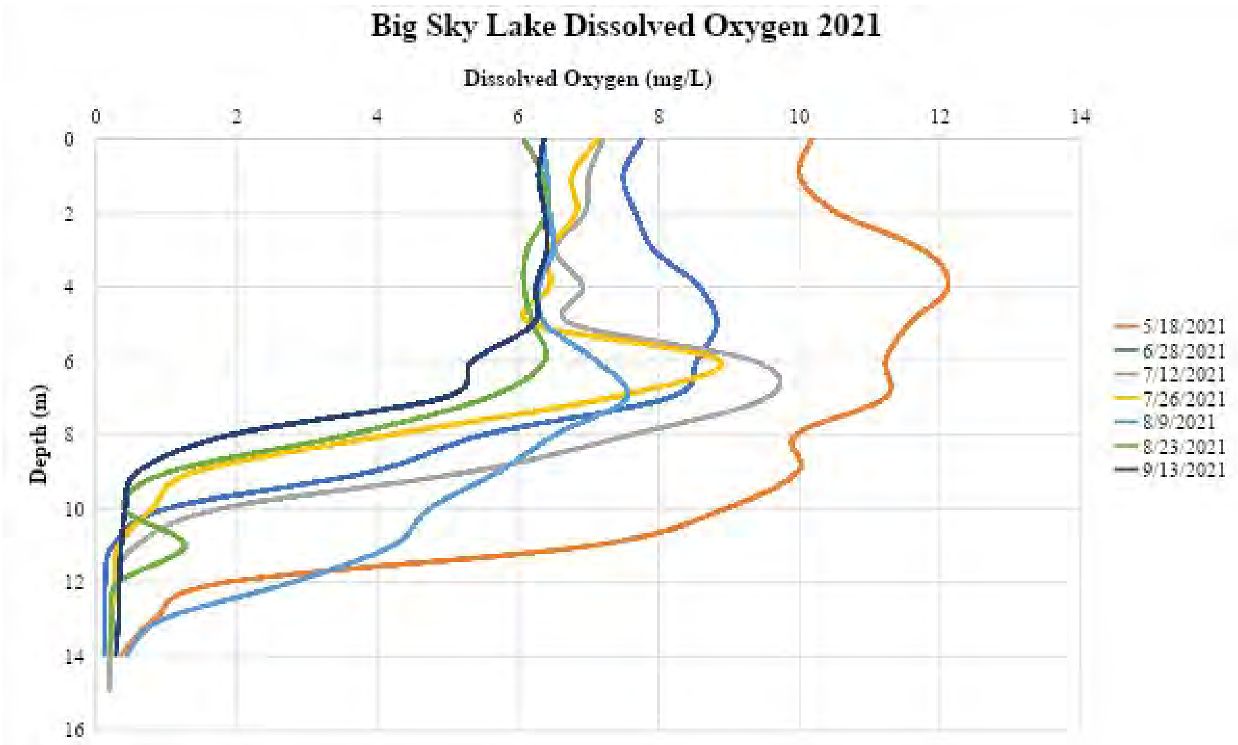


Figure 4. Dissolved oxygen (mg/L) profile recorded at one site in Big Sky Lake, from May through September 2021.

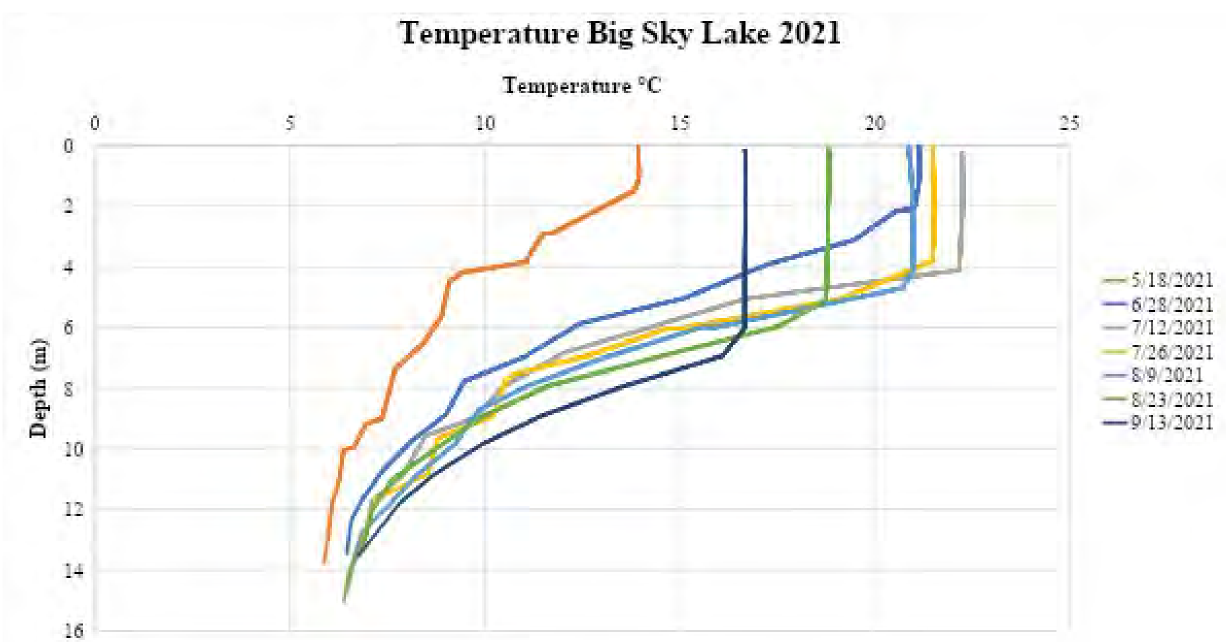


Figure 5. Temperature (°C) profile recorded at one site in Big Sky Lake, from May through September 2021.

Lake Inez recorded its highest DO readings in May (Figure 6) with decreasing concentrations throughout the summer. In May, the DO profile recorded 9.53 mg/L at the surface, a peak of 10.81 mg/L at 5 meters, and 5.18 mg/L at 20 meters (Figure 6). The DO profile in late July recorded 6.36 mg/L at the surface, 7.68 mg/L at 6 meters, and 0.47 mg/L at 20 meters. Our last profile, taken on September 28, read 6.3 mg/L at the surface, 6.59 mg/L at 5 meters deep, and 0.28 mg/L at 21 meters. The July and September readings are comparable, but very different from the May reading. In May, the lake was probably not fully stratified. However, the anoxic conditions at the lake bottom in July and September suggest full stratification and continual oxygen depletion. Lake Inez's water temperatures are displayed in Figure 7. Its thermocline occurred between 2 and 7 meters.

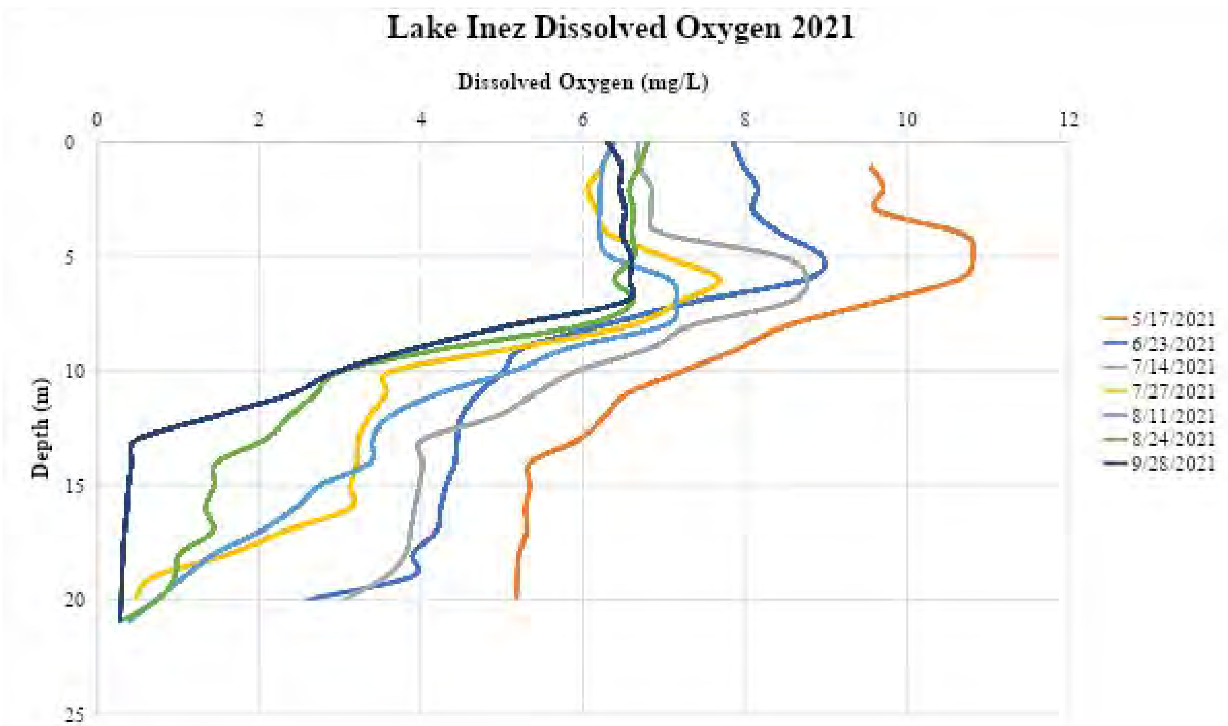


Figure 6. Dissolved oxygen (mg/L) profile recorded at one site in Lake Inez, from May through September 2021.

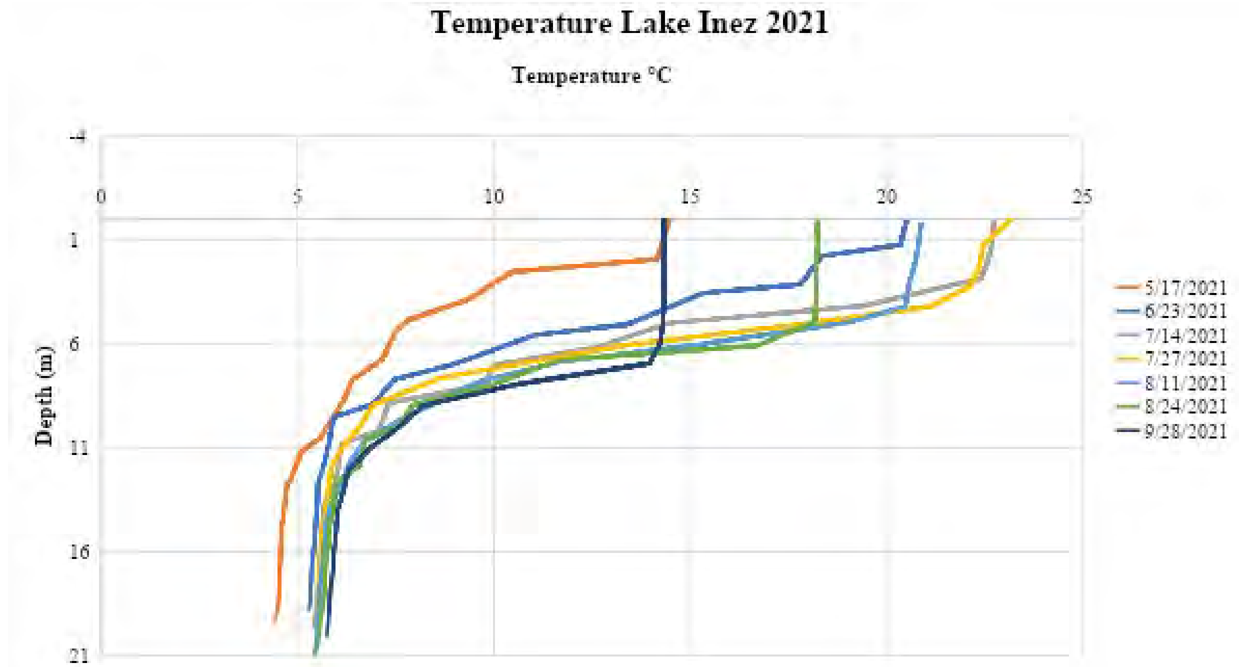


Figure 7. Temperature (°C) profile recorded at one site in Lake Inez, from May through September 2021.

In Placid Lake, DO was measured once while the lake was still frozen on March 9. These data provide an idea of what lake chemistry is like before either spring or summer mixing and stratification occurs. In March, the surface water recorded the highest DO of the entire profile at 10.53 mg/L (Figure 8). Throughout the water column on this day, temperature ranged from 3 to 4 degrees Celsius, so there was no definitive thermocline. The lake was warmest at the bottom, recording a temperature of 3.8 degrees Celsius at 25 meters. Despite the lack of thermocline, DO dropped from being around 10 mg/L to being consistently around 7.75 mg/L from 5 to 15 meters. DO then dropped to 0.21 mg/L at 25 meters, right above lake bottom. The data from this winter date indicate that the lake was not stratified and instead was mixed, despite having a low DO measure at the bottom.

The next DO monitoring on Placid Lake took place on June 2, the first of the summer monitoring season. On this day, the DO profile read 8.12 mg/L at the surface, 9.69 mg/L at 4 meters, and 5.41 mg/L at 26 meters (Figure 8). These data indicate that the lake had continued to be mixed since March and had not completely stratified yet. We saw a slight increase in DO a few meters below the surface, which is a normal result of plant growth and photosynthesis. At the bottom there was still significant levels of oxygen indicating oxygen depletion had not occurred yet and oxygen may still be getting introduced into the hypolimnion. By August 10, however, we can assume the lake was stratified from the profile recording 6.37 mg/L at the surface, 7.16 mg/L at 7 meters, and a low of 0.42 mg/L at 27 meters. Our last DO profile of the season was recorded on October 1, showing 6.08 mg/L at the surface, 6.18 mg/L at 4 meters, and dropping to 0.2 mg/L at 26 meters. Surface temperature on Placid Lake peaked on June 28 and was also high in July, but lowest on June 2 and October 1 (Figure 9).

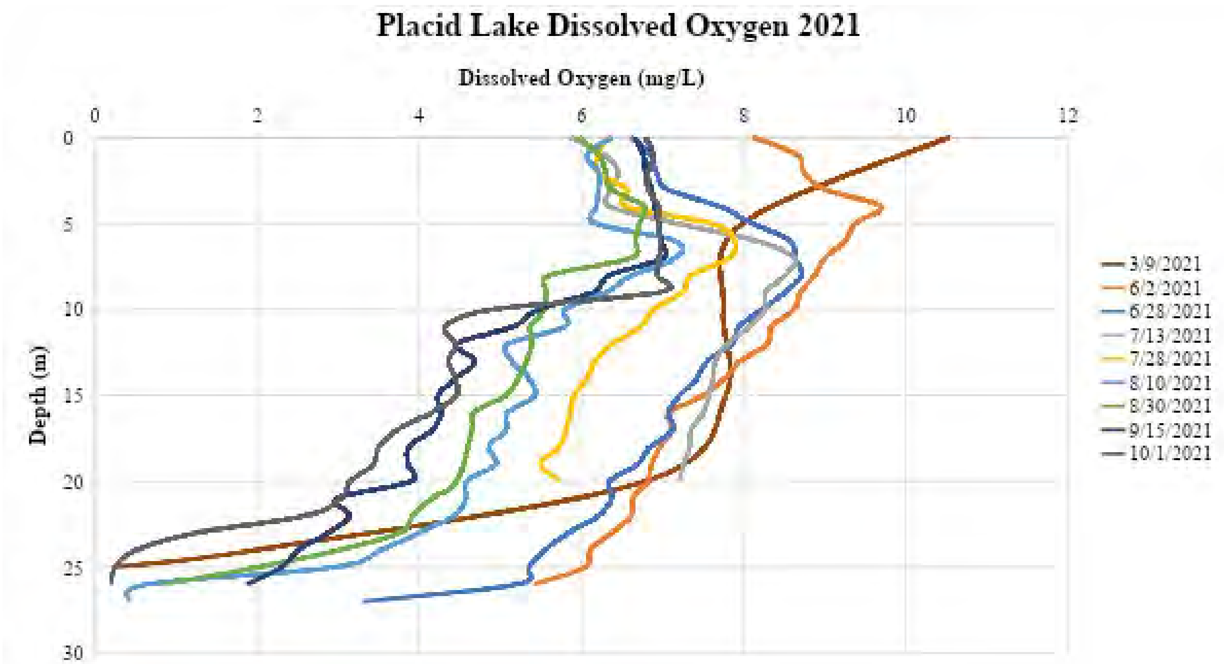


Figure 8. Dissolved oxygen (mg/L) profile recorded at one site in Placid Lake, from May through October 2021.

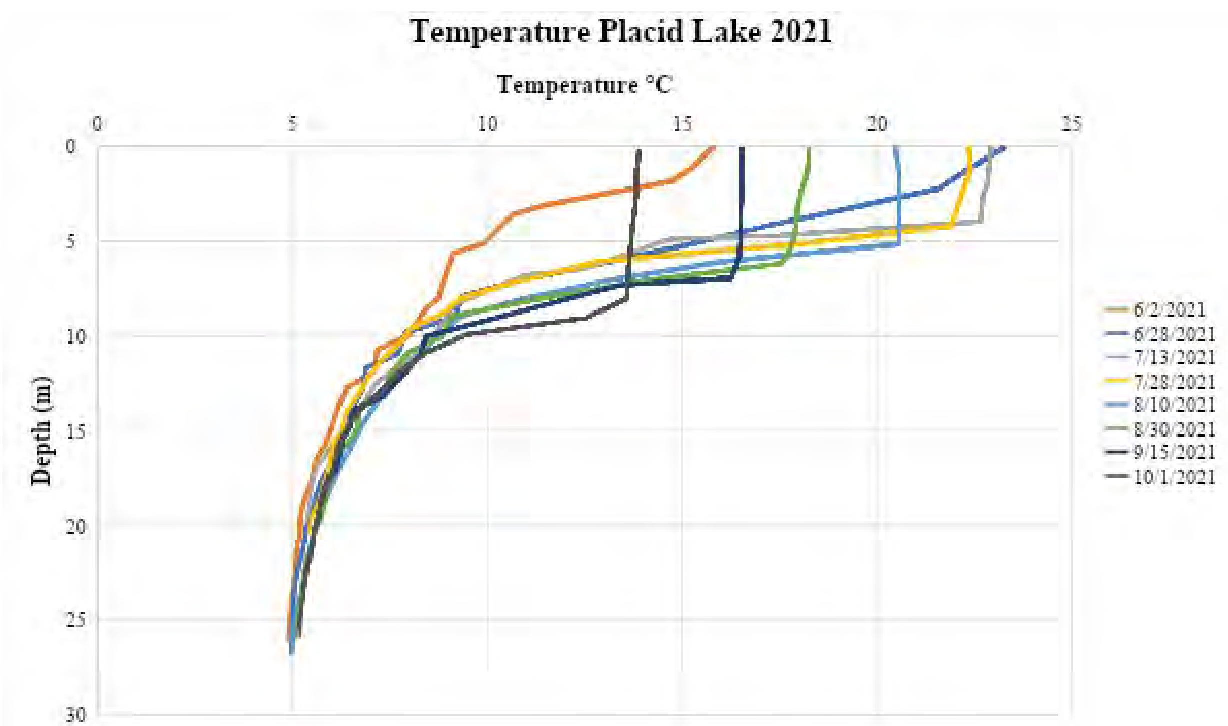


Figure 9. Temperature (°C) profile recorded at one site in Placid Lake, from May through October 2021.

Salmon Lake was also monitored on the same March date as Placid Lake. Water temperatures throughout the water column on this day ranged from 3.6 to 4.3 degrees Celsius, showing no definitive thermocline. Like Placid Lake, Salmon Lake was also warmest at the bottom of the lake in March, indicating that the lake was not stratified. The DO profile on that day read 7.72 mg/L at the surface, 6.99 mg/L at 10 meters, and 2.42 mg/L at 17 meters (Figure 10). Unlike Placid Lake, Salmon Lake was not hypoxic or anoxic at the lake bottom in March.

Summer DO readings on Salmon Lake were like Placid Lake, Lake Alva, and Lake Inez. In early summer on June 1, the DO profile read 8.16 mg/L at the surface, 8.65 mg/L at 7 meters, and 6.82 mg/L at 17 meters (Figure 9). This indicates that the lake was not stratified yet in early June. By August 12, DO at the surface was 6.5 mg/L, 6.73 at 4 meters, and dropping to 0.26 mg/L at 17 meters. Stratification, and thus oxygen depletion at depth, was occurring by this point in the summer. On our last monitoring day on Salmon Lake (September 29), the DO profile read 6.08 mg/L at the surface, 6.18 mg/L at 4 meters, and a low of 0.16 mg/L at 17 meters. Temperatures on Salmon Lake were highest in July and lowest in early June and late September (Figure 10). Depending on the time of year, the thermocline occurred between 2-7 meters during Summer 2021.

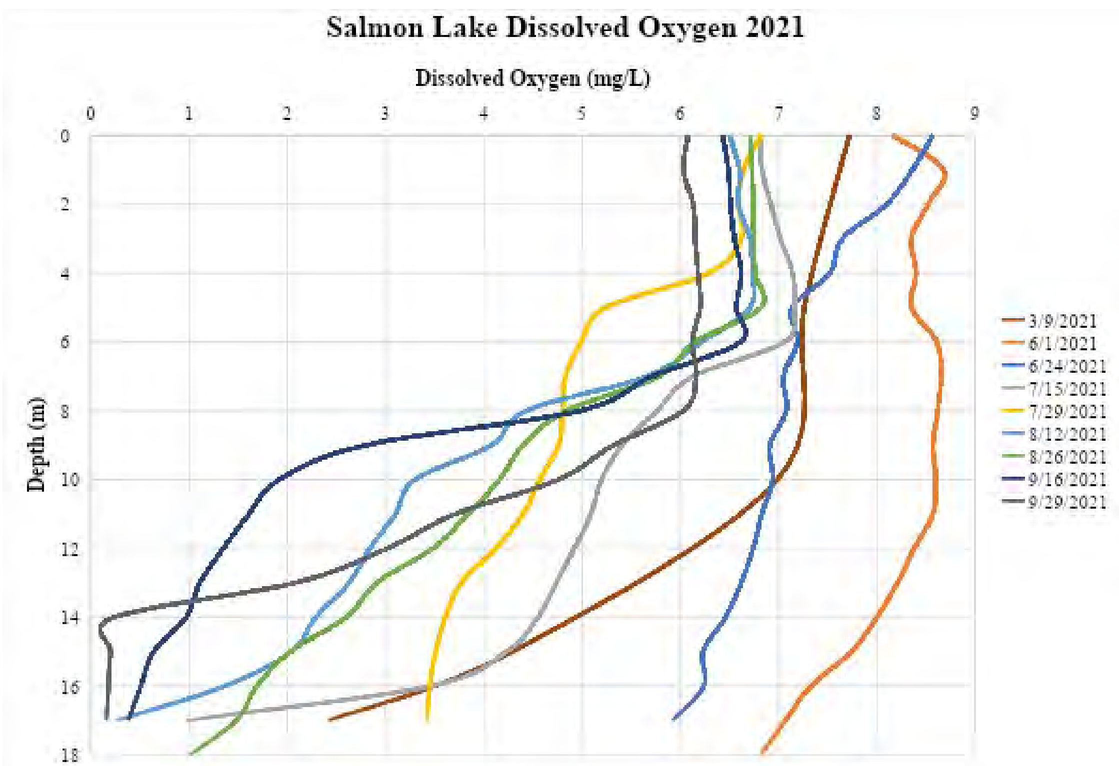


Figure 9. Dissolved oxygen (mg/L) profile recorded at one site in Salmon Lake, from March through September 2021.

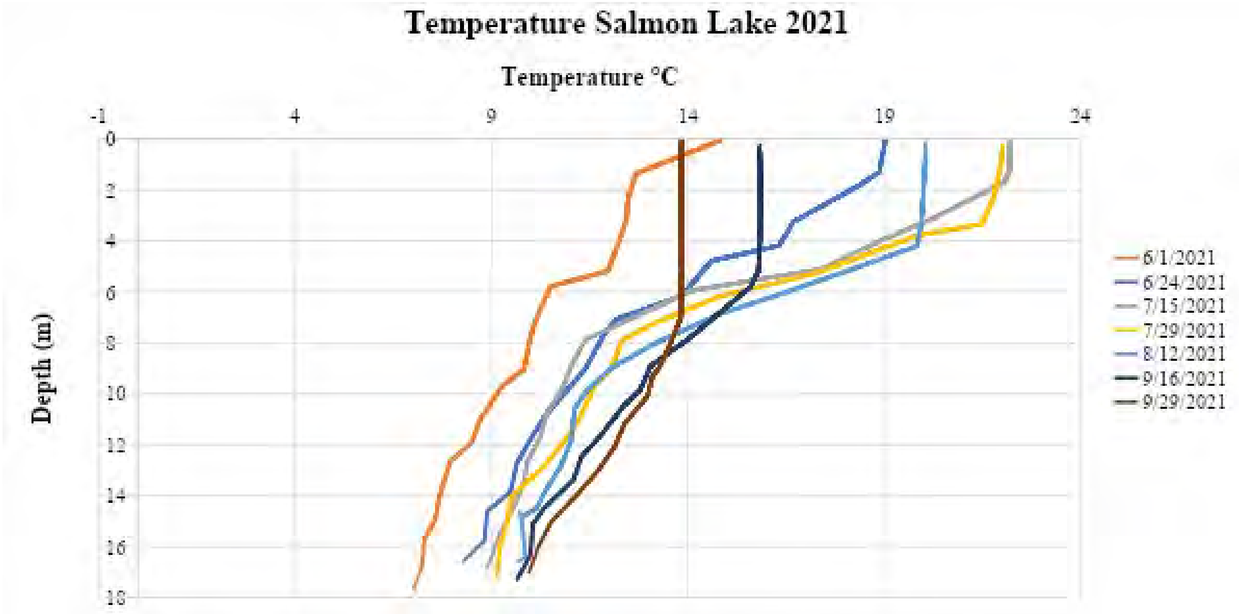


Figure 10. Temperature (°C) profile recorded at one site in Salmon Lake, from June through September 2021.

Seeley Lake has three deep holes, but only two are within the correct range to use our DO meter. All deep-water monitoring in 2021 took place on Seeley Lake's Middle Hole and South Hole. At the Seeley Lake Middle Hole, the first monitoring of the season took place on May 27, recording a profile with 9.83 mg/L at the surface, 10.38 mg/L at 3 meters, and a low of 7.41 mg/L at 21 meters (Figure 11). Like other lakes in May, Seeley Lake appeared to still be mixed and not stratified yet. The water temperature on that day seemed to gradually decrease with depth, and it was hard to determine a specific depth point for the thermocline. On July 30, the Middle Hole DO profile had lower DO concentrations, but still not hypoxic or anoxic, recording a low of 5.76 mg/L at the bottom. By September 30, though, oxygen depletion was occurring in the hypolimnion. The DO profile on this day recorded 6.58 mg/L at the surface but 1.69 mg/L at 19 meters. Since the DO value is below 2 mg/L, this classifies as hypoxic conditions. Water temperatures were highest in July and lowest in May and September (Figure 12).

Seeley Lake's South Hole was part of the winter monitoring that took place on March 9. Unlike the other lakes monitored on that day, DO levels were within hypoxic limits at depth in this location (Figure 13). The profile taken on that day read 8.85 mg/L at the surface and continued to decrease, reaching 1.72 mg/L at 18 meters. Water temperatures on that day increased with depth, starting at 1 degree Celsius at the surface and reaching 4.4 degrees Celsius at the bottom (Figure 14). We are unsure why DO levels would be this low in March. It could be attributed to the fact that this monitoring location is in the southernmost bay of the lake, farther away from any input or outlet and where limited water movement takes place.

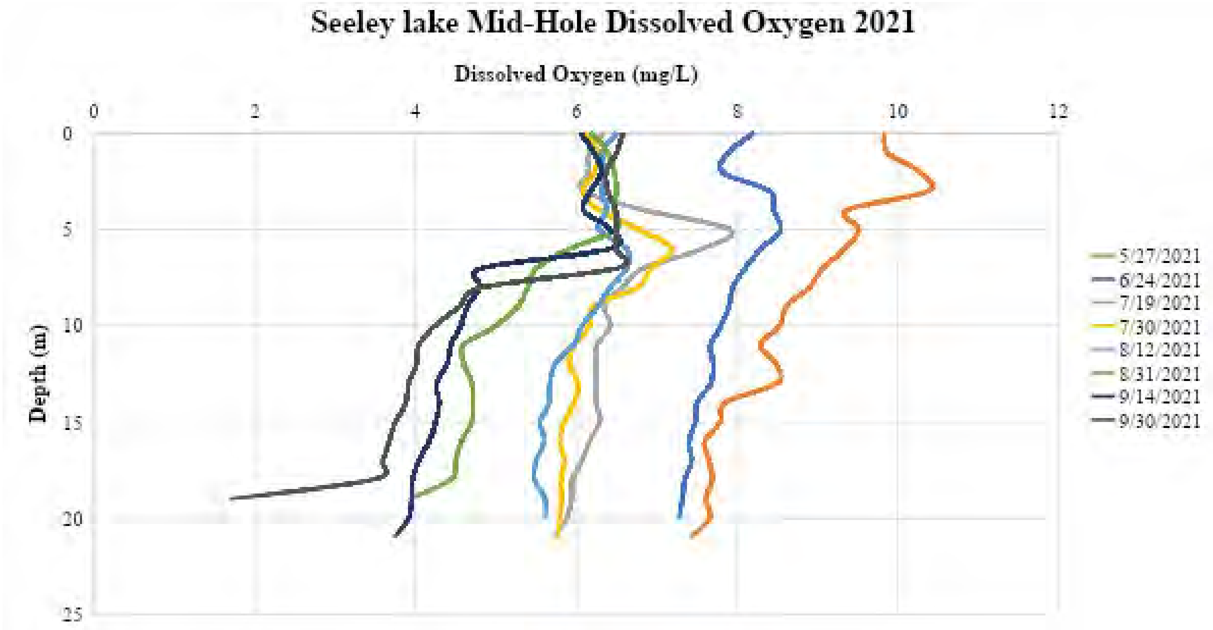


Figure 11. Dissolved oxygen (mg/L) profile recorded at the Middle Hole in Seeley Lake, from May through September 2021.

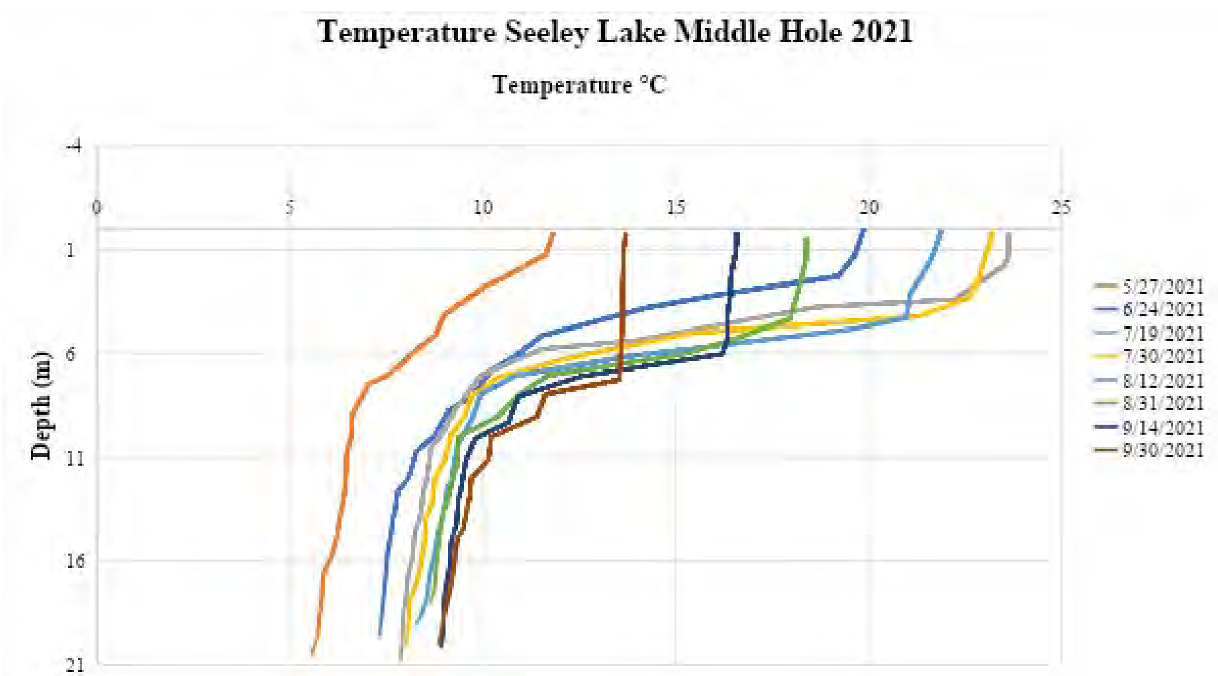


Figure 12. Temperature (°C) profile recorded at the Middle Hole in Seeley Lake, from May through September 2021.

Data collected in May at the South Hole of Seeley Lake were very different from that from March. While the surface DO reading was the same (8.85 mg/L), DO peaked at 9.39 mg/L at 4 meters and was 6.95 mg/L at 6 meters. DO was higher in May than it was in March, indicating that the lake was more mixed and with increased temperatures, there was probably increased plant activity. On July 30, the DO profile had slightly lower DO concentrations, reading 5.98 mg/L at the surface, 6.69 mg/L at 6 meters, and a low of 4.79 mg/L at 16 meters. However, unlike other lakes, Seeley Lake is still not near anoxic levels in July.

In September, DO had greatly increased though, with a profile reading 6.23 mg/L at the surface, 6.53 mg/L at 5 meters, and a low of 0.92 mg/L at 17 meters. Water temperatures were highest in July and lowest in May and September, and the thermocline ranged between 2 and 7 meters during the summer (Figure 14).

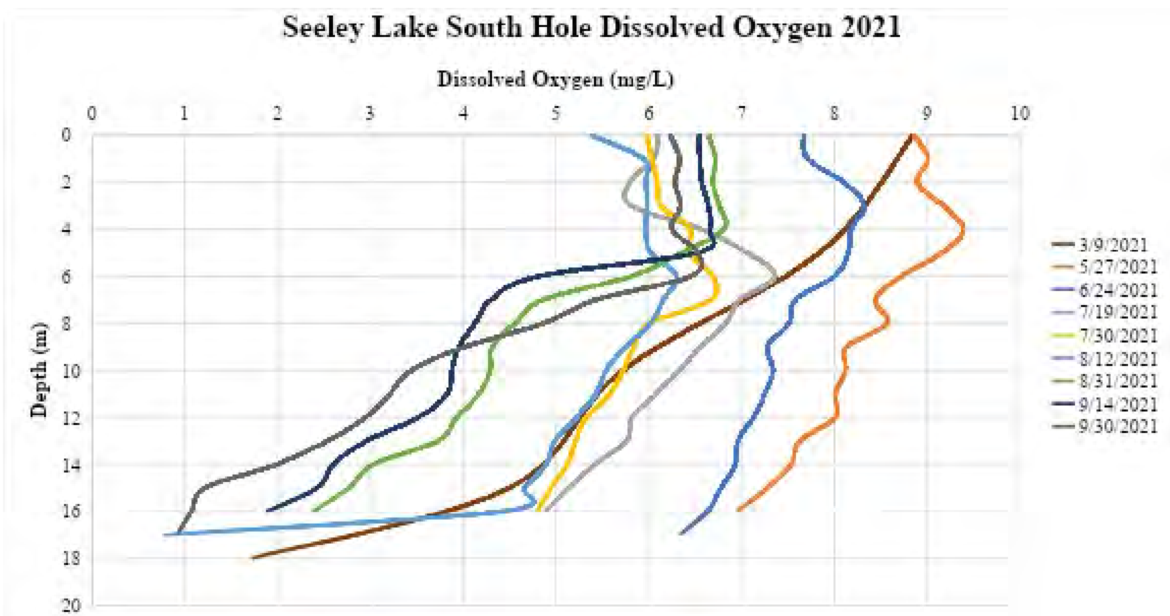


Figure 13. Dissolved oxygen (mg/L) profile recorded at the South Hole in Seeley Lake, from March through September 2021.

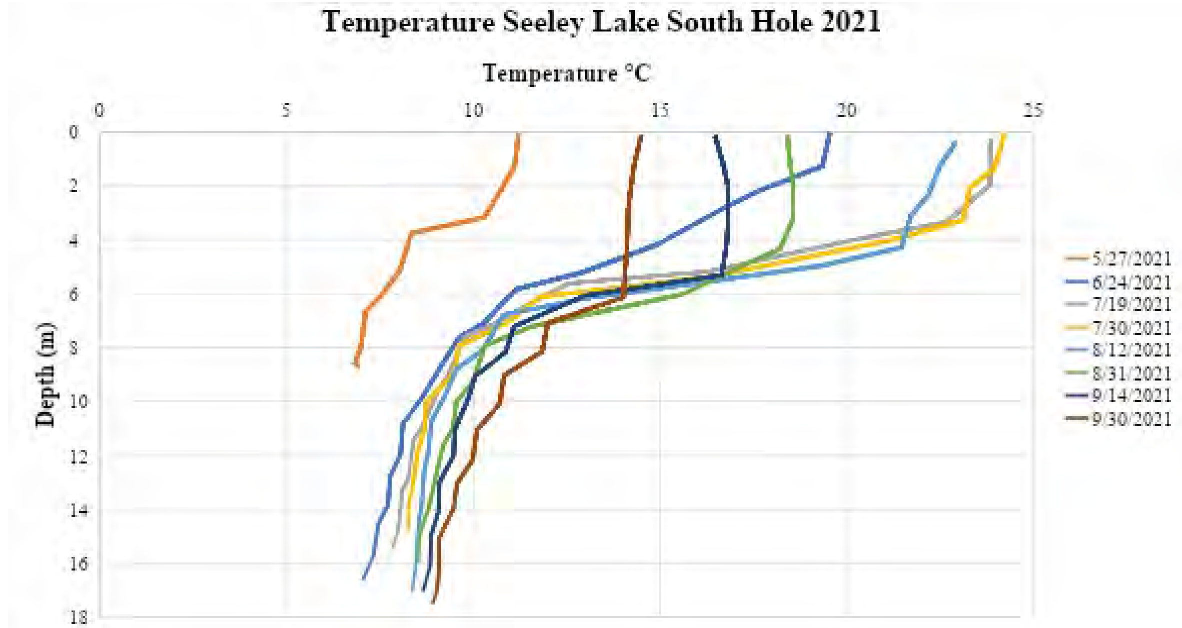


Figure 14. Temperature (°C) profile recorded at the South Hole in Seeley Lake, from May through September 2021.

Most of the lakes remained mixed through early summer and became stratified around late June or early July. Along the same lines, DO levels in lakes were within healthy, life-supporting levels in May, before reaching hypoxic or anoxic conditions in the hypolimnion later in the summer. Big Sky Lake is an anomaly among the six lakes and was anoxic at lake bottom even in late May, while the other lakes didn't reach DO levels near zero until July.

One challenge in DO data collection is keeping a boat stationary in wind and other weather conditions. Even in larger boats, wind often affected the monitoring process and caused the DO line to drift slightly changing the recorded depths of the readings. Profiles that appear shorter than the known lake depth can be attributed to drifting from wind and/or current. Also, winter data were only collected at three sites in 2021, and it may be helpful to conduct one round of monitoring prior to ice off on all six lakes in the future. The data presented here provide an opportunity to learn more about the aquatic ecosystem health in the Clearwater Valley and can be used for comparisons as this program continues in the future.

DO deficits in deeper waters of the lakes were pronounced particularly over time after the establishment of the hypolimnion. This will limit the organisms able to utilize deeper areas in the water column. Anoxic or hypoxic conditions are not suitable for most aquatic species, such as trout, that require high oxygen levels. Some species may also be limited by water temperatures, not being able to occur in warmer waters. Higher nutrient loadings may lead to greater eutrophication of the lakes that may cause overall reductions in DO. If this occurs, at some point increasing amounts of each lake may become unsuitable as habitat for such species. If the correct combinations of temperature and DO are not present, some species may find conditions uninhabitable in the future. These data suggest that it is necessary to continue collecting data and studying the trends in historical data to better understand the changes occurring to DO levels in our surface waters.

Chlorophyll and Blue-Green Algae

Cyanobacteria are photosynthetic bacteria commonly found in lakes. In lakes, the occurrence of cyanobacterial blooms may be attributed to many factors including temperature, turbulence and mixing, sunlight, nutrient levels, lake morphology, and lake ecology (Bellinger and Sigee 2010). Monitoring of cyanobacteria can be performed using measurement of fluorescence of chlorophyll and phycocyanin. Fluorescence is a technology for measuring the direct fluorescence of pigments in living algal cells in the water, and then determining algal production in terms of relative fluorescence units (RFUs). Waters with high levels of chlorophyll may indicate that such lakes are typically high in nutrients, specifically phosphorus and nitrogen that support the growth of algae. Other factors also affect the growth of algae including water temperatures, seasonal variations, and presence of macrophytes that may compete with algae for nutrients, to name a few.

If algae blooms occur, these outbreaks may then crash and die with changes to available nutrients, temperatures or other factors. When algae die they sink to the bottom of the lake and get decomposed by microbes and invertebrates. This decomposition process consumes oxygen. The greater level of algae in a lake, the greater the risk of a die off and the more decomposition that will occur. This can reduce DO near the bottom of the lake. When this happens, fish may be unable to use this portion of the lake, and must move up to the shallower areas of the lake where there is still oxygen available. However, if water temperatures or other habitat features such as structure are not suitable in these shallower areas, the lake may cease to support some species of fish.

Levels of chlorophyll-a found in a lake can indicate the trophic state of the lake. Generally, chlorophyll-a amounts in a lake correspond to trophic status at these levels:

Lake Trophic Classification for Chlorophyll

Oligotrophic	< 2 ppb or ug/L
Mesotrophic	2 to 6 ppb or ug/L
Eutrophic	6 to 40 ug/L
Hypereutrophic	> 40 ug/L

To monitor plant and algae growth, we used a multiparameter sonde to measure chlorophyll-a and phycocyanin (the main pigment found in cyanobacteria, or blue-green algae). Measurements were taken in relative fluorescence units (RFU). It should be noted that amount of sunlight available to algae may affect the RFU's measurements, with higher levels of sunlight causing reduced readings of RFU's from the algae present. In oligotrophic lakes, waters near the surface may be receiving high levels of sunlight with a corresponding reduction in RFU's from the algae present causing this measurement to increase in depth until the amount of sunlight is reduced in passage through the water column. Chlorophyll can be presented in either RFU's or ug/L measurements. These measurements are strongly related, but different. One study reported the relationship as: ug/L=0.00856RFU + 0.07298 with an R^2 of 0.98. We report chlorophyll and blue green algae measurements in RFU's.

Larson (2000) reported on chlorophyll in high mountain lakes in Rainier National Park in Washington state. He found that the highest levels of chlorophyll occurred at depths where sunlight was at 0.1-1% of the surface incidence light. He speculated that near the surface, less chlorophyll is needed to sustain algae as there is a high level of sunlight available. As available sunlight diminishes with lake depth, algae increase the amount of chlorophyll to produce the level of photosynthesis needed. Thus, the level of chlorophyll in lakes with very clear water may not be an accurate indicator of the level of algae in different depths of the lake, as higher levels of algae where there is abundant available sunlight may have lower amounts of chlorophyll in the algae nearer the surface of the lake. Larson (2000) also speculated that there may also be an increase in algae and thus RFU's near the lake bottom in oligotrophic lakes as nutrient availability near the settled bottom materials may be higher close to these sources of nutrients. This finding may explain similar observations on Lake Alva, as described below.

On Lake Alva, chlorophyll measurements were recorded between 0 and 1 RFU throughout the water column before increasing in the last three meters above lake bottom on all monitoring days. The highest chlorophyll value recorded was on September 28 at 24.87 meters, reading 4.38 RFU (Figure 15). Phycocyanin was between 0 and 0.3 RFU throughout all profiles until about 24 meters deep when it spiked (Figure 16). Like chlorophyll, the highest phycocyanin measurement recorded was on September 28, reading 3.23 RFU at 24.87 meters. This indicates a correlation between chlorophyll and phycocyanin, which is not unusual given they are both related to plant growth and algae.

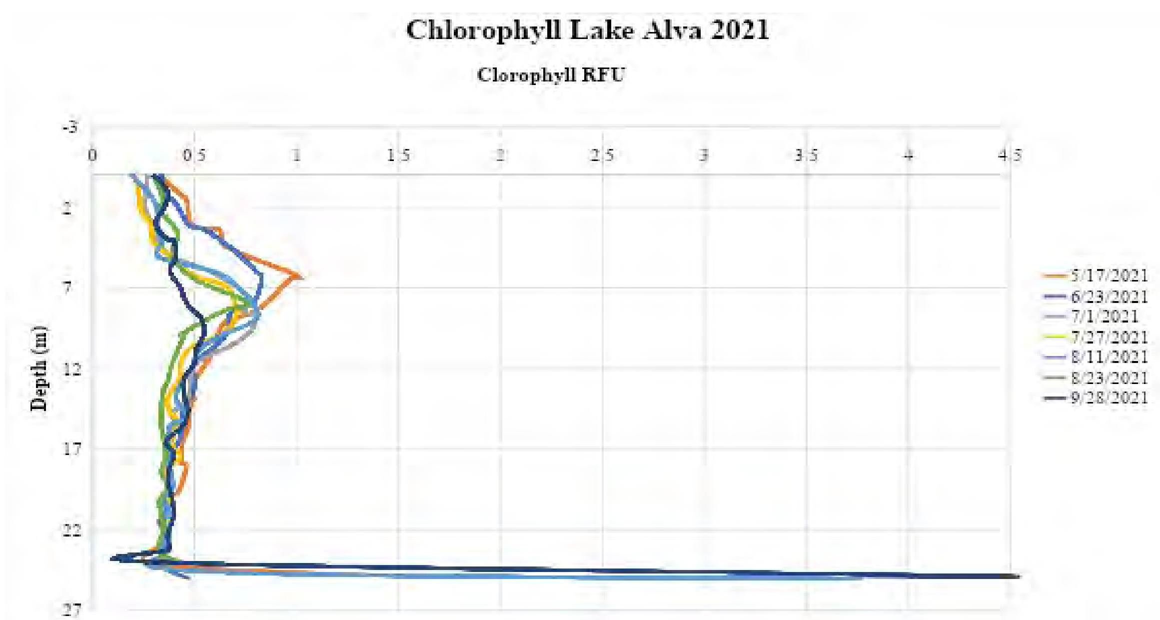


Figure 15. Chlorophyll (RFU) profile recorded at one site in Lake Alva, from May through September 2021.

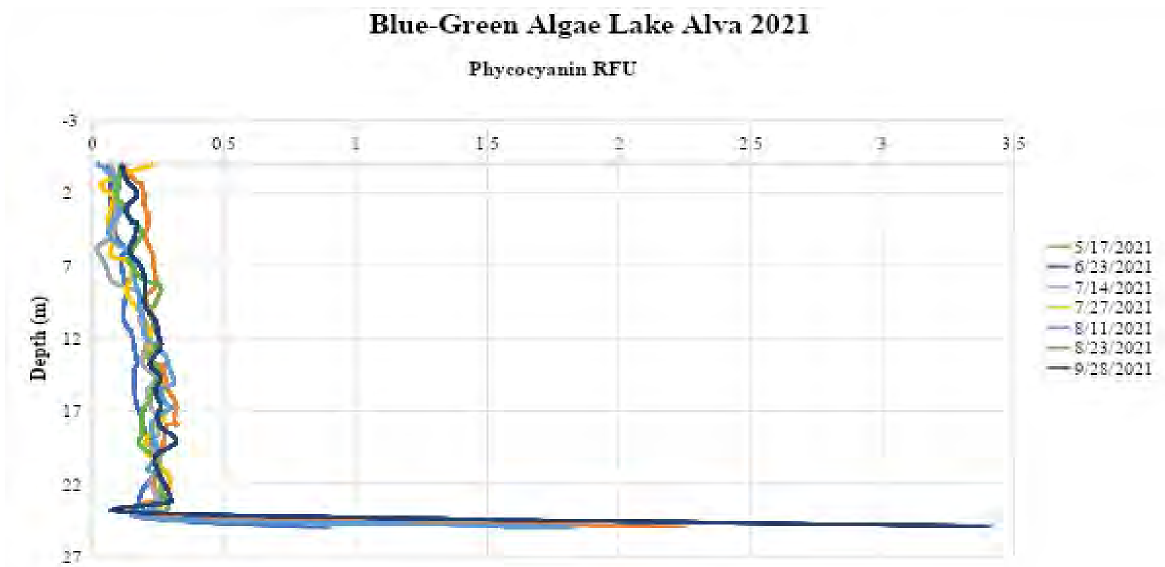


Figure 16. Blue-Green Algae (Phycocyanin RFU) profile recorded at one site in Lake Alva, from May through September 2021.

Unlike other lakes, Big Sky Lake experienced peaks in chlorophyll about 3-4 meters above lake bottom, before dropping to lower values again around 14 meters deep (Figure 17). For example, on May 18, chlorophyll was between 0 and 0.7 RFU until 7 meters when it started increasing. It spiked to 8.18 RFU at 11.1 meters, and then dropped to 1.9 RFU at 13.8 meters. Similarly, but less dramatically, on September 13, chlorophyll was between 0 and 0.9 RFU until it spiked to 2.77 RFU at 10.8 meters, and then dropped back to 1.36 RFU at 13.57 meters.

Phycocyanin on Big Sky Lake didn't correlate with chlorophyll as much as seen on other lakes. Phycocyanin was highest on September 13 and August 9, (Figure 18) while chlorophyll was highest on May 18. In general, August and September had elevated levels of phycocyanin on Big Sky Lake, recording 7.3 RFU at 10.821 meters on September 13 and 7.49 RFU at 10.86 meters on August 9. These measurements are higher than those on any other lakes. This raises some concern because blue-green algae have the potential to create harmful cyanotoxins. Big Sky Lake is shallower than other lakes, and thus gets warm throughout the summer, which is an ideal condition for algae growth. Visual assessment on this monitoring day did not identify any algae of concern, suggesting that this was a harmless growth. Without lab analysis, we cannot determine whether this algae growth was harmful or not.

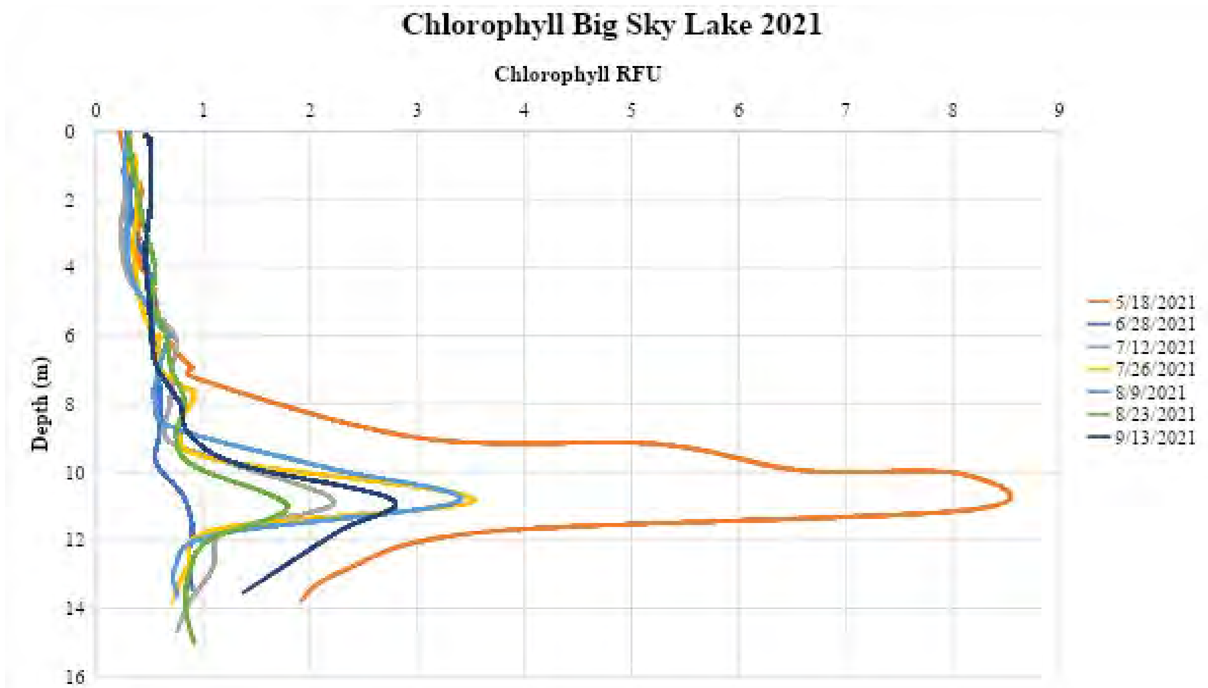


Figure 17. Chlorophyll (RFU) profile recorded at one site in Big Sky Lake, from May through September 2021.

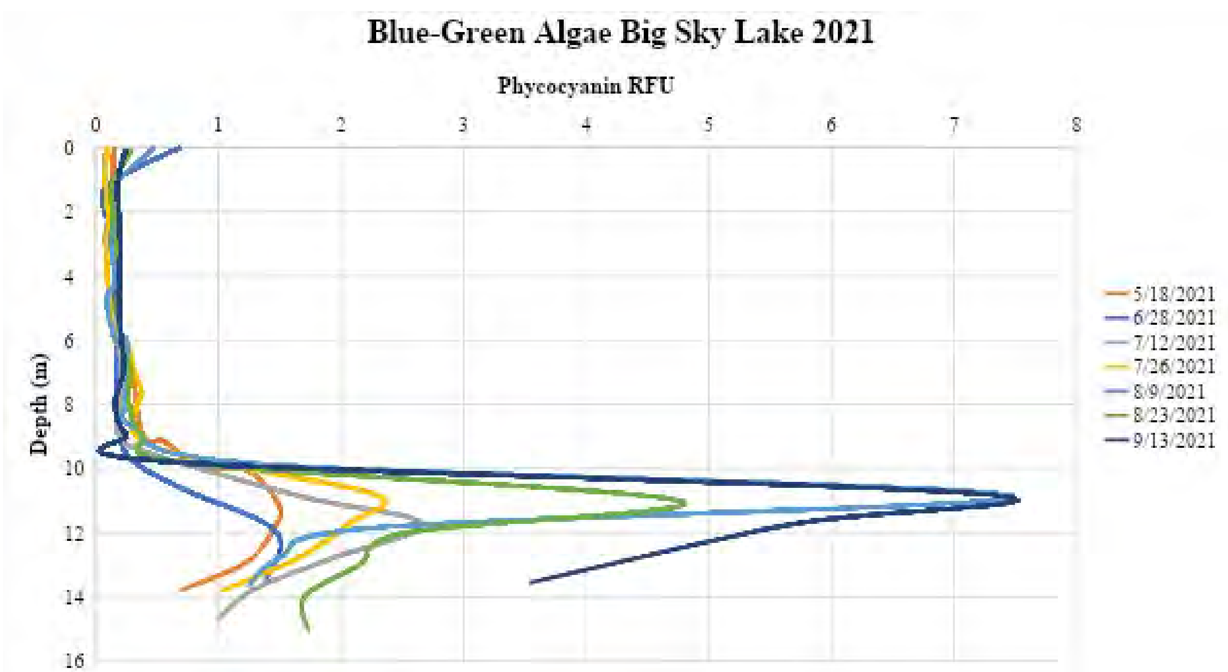


Figure 18. Blue-Green Algae (Phycocyanin RFU) profile recorded at one site in Big Sky Lake, from May through September 2021.

Chlorophyll on Lake Inez was typically between 0 and 1 RFU throughout the water column until about 18 meters deep (Figure 19). Some spikes outside of this range can be identified on May 17 (1.57 RFU at 4.8 meters) and on June 23 (2.17 RFU at 5.58 meters). Otherwise, the highest values recorded were on September 28, reading 4.01 RFU at 21 meters, and on June 23, reading 3.58 RFU at 18.8 meters. Phycocyanin on Lake Inez correlated with chlorophyll readings, showing the highest measurements on June 23 (2.74 RFU at 18.8 meters) and September 28 (2.62 RFU at 21 meters) (Figure 20).

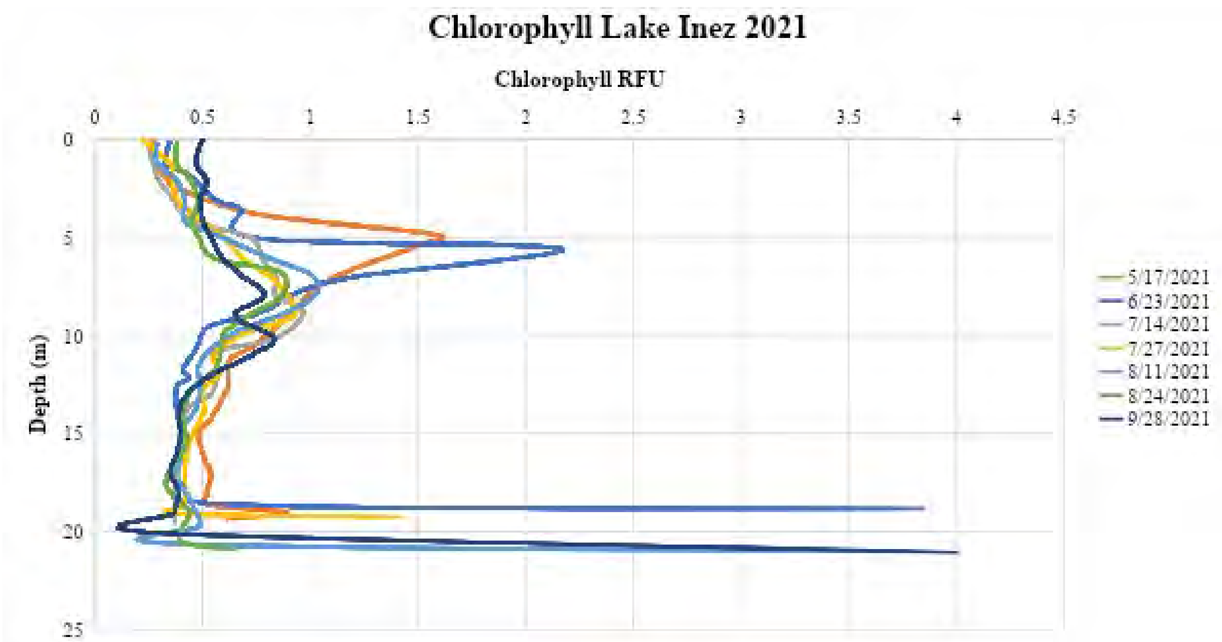


Figure 19. Chlorophyll (RFU) profile recorded at one site in Lake Inez, from May through September 2021.

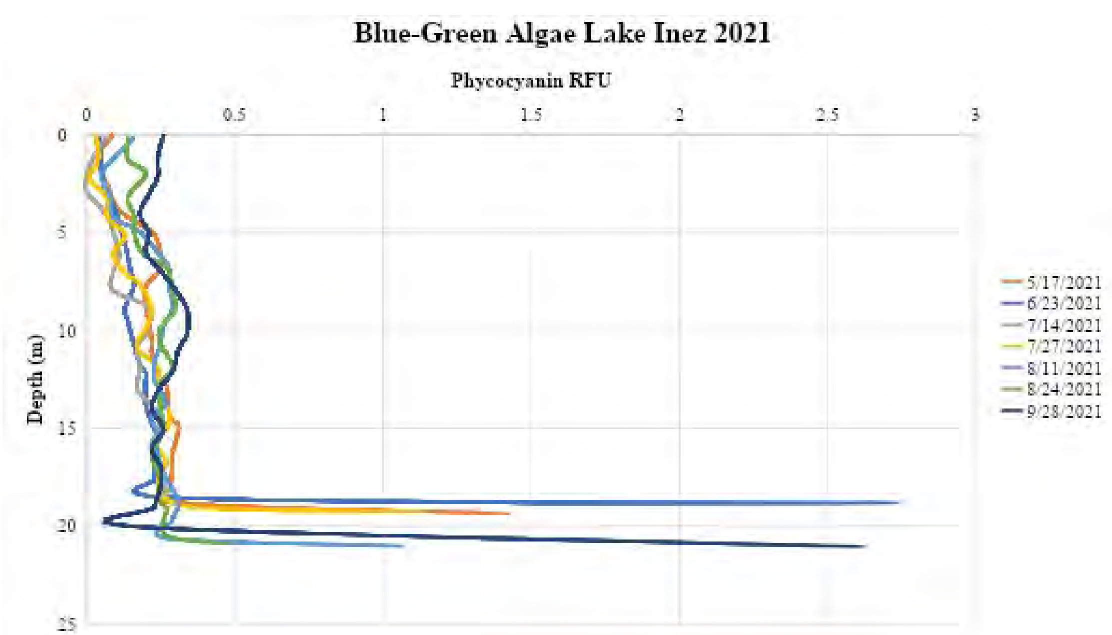


Figure 20. Blue-Green Algae (Phycocyanin RFU) profile recorded at one site in Lake Inez, from May through September 2021.

Placid Lake had similar values to other lakes in that chlorophyll was generally between 0.2 and 1 RFU throughout the water column until near lake bottom (Figure 21). Three exceptions were July 13 (4.73 RFU at 4.7 meters), June 28 (1.95 RFU at 7.19 meters), and August 10 (1.64 RFU at 6 meters). At depth, there were spikes on August 10 (7.14 RFU at 26.47 meters) and June 28 (5.36 RFU at 26.8 meters). Phycocyanin correlated with chlorophyll on Placid Lake; there were spikes at depth on June 28 (3.1 RFU at 26.8 meters) and August 10 (2.15 RFU at 26.47 meters) (Figure 22). Otherwise phycocyanin values ranged between 0 and 0.5 RFU throughout the water column. The profile on September 15 showed some elevated levels, but still around 0.5 RFU.

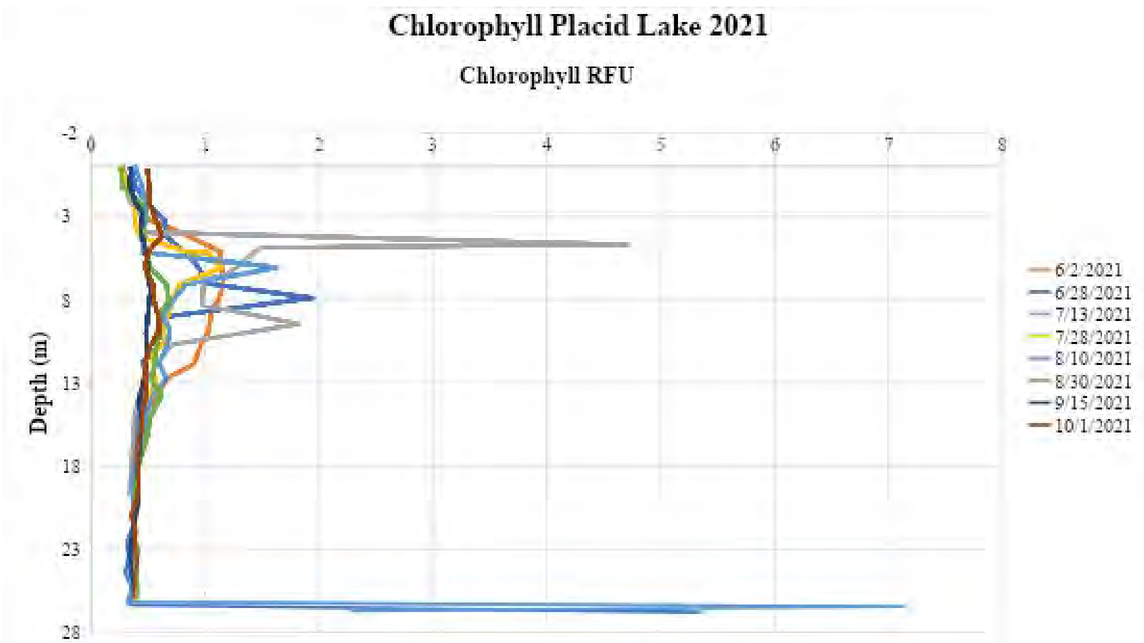


Figure 21. Chlorophyll (RFU) profile recorded at one site in Placid Lake, from June through September 2021.

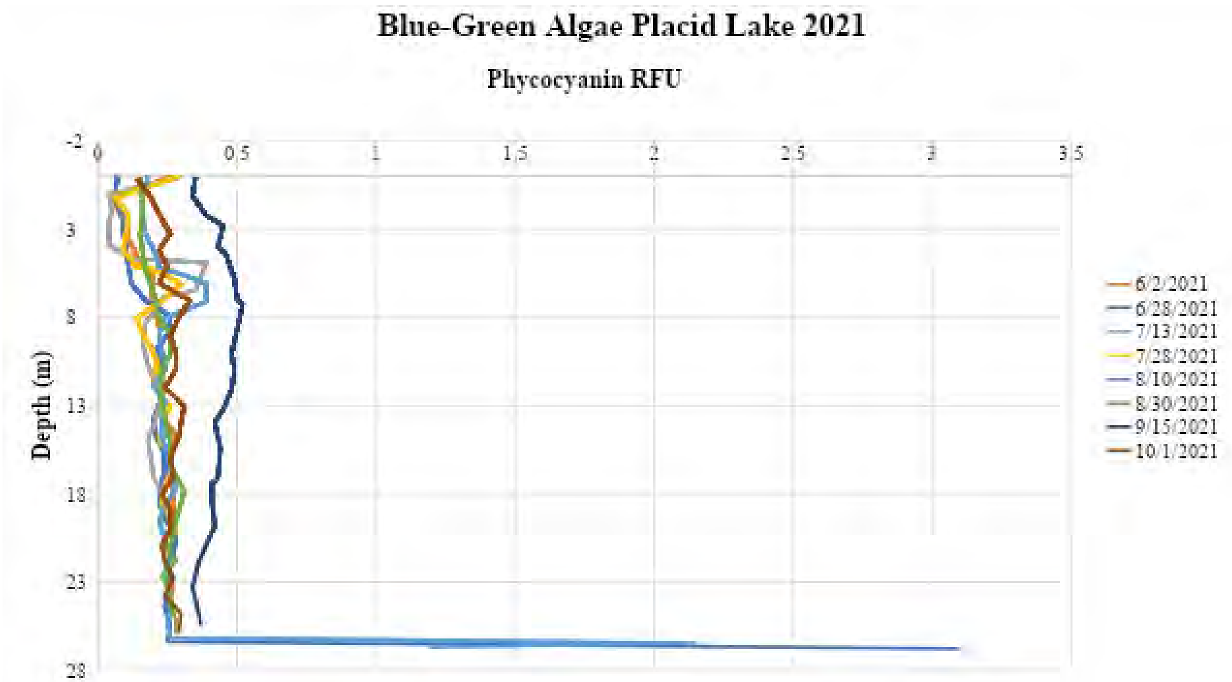


Figure 22. Blue-Green Algae (Phycocyanin RFU) profile recorded at one site in Placid Lake, from June through September 2021.

Salmon Lake chlorophyll levels were consistently between 0 and 1 RFU until near lake bottom on most monitoring days (Figure 23). One exception was on August 12 when chlorophyll increased to 1.22 RFU at 4.19 meters. Like other lakes, chlorophyll tended to be elevated near the bottom of this hole, as seen on August 12 (3.98 RFU at 16.59 meters) and September 16 (3.88 RFU at 17.2 meters). Phycocyanin levels were relatively low in 2021, but a relationship can be seen between it and chlorophyll, as elevated levels were also recorded on August 12 (1.99 RFU at 14.76 meters) and September 16 (2.36 RFU at 17.2 meters) (Figure 24).

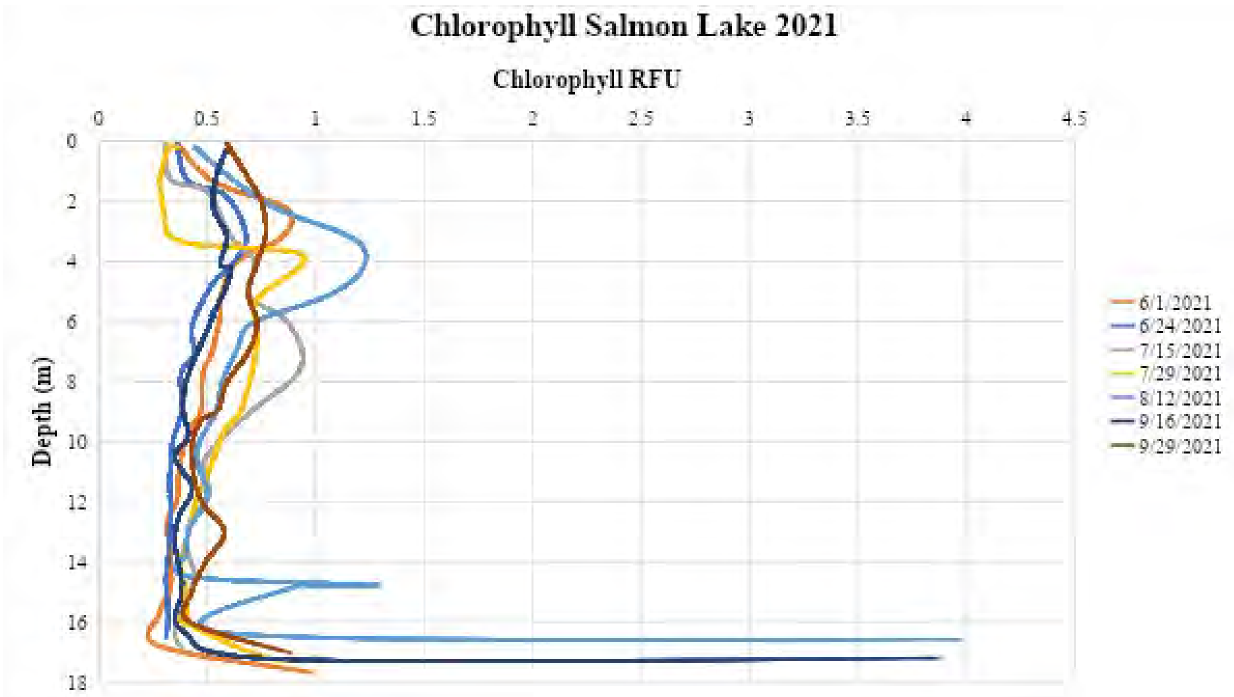


Figure 23. Chlorophyll (RFU) profile recorded at one site in Salmon Lake, from June through September 2021.

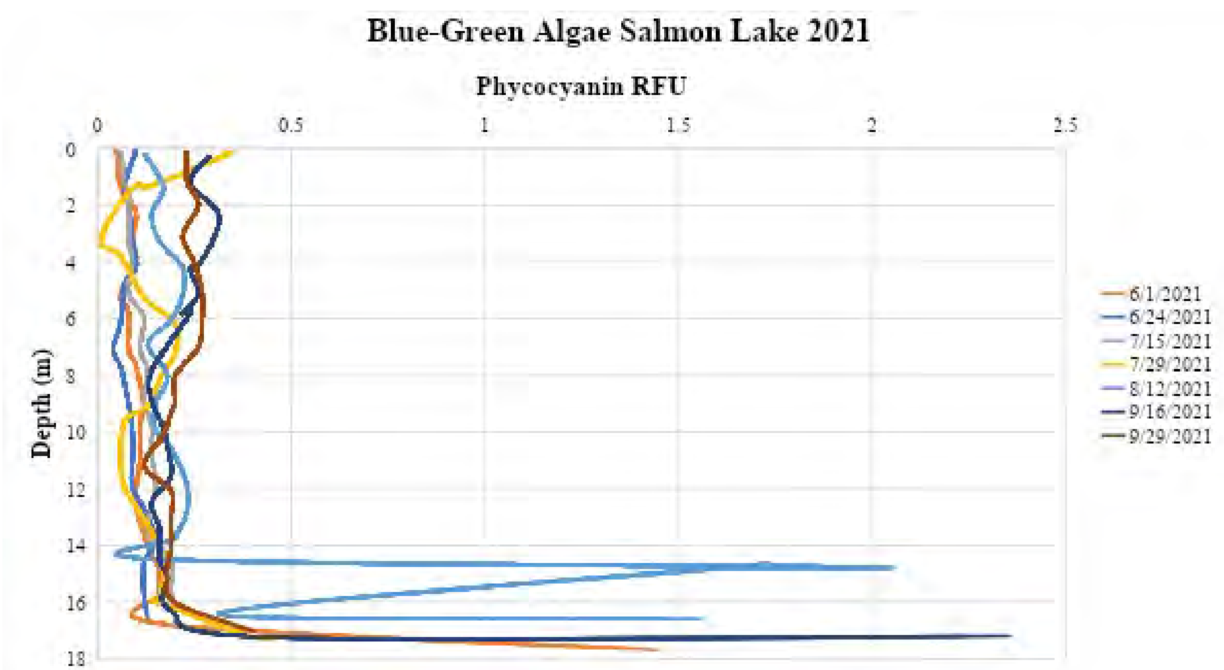


Figure 24. Blue-Green Algae (Phycocyanin RFU) profile recorded at one site in Salmon Lake, from June through September 2021.

Chlorophyll profiles at the Seeley Lake Middle Hole ranged between 0 and 1.25 RFU. One main spike was observed on September 14 (4.43 RFU at 4.05 m) (Figure 25). Otherwise, higher values were only seen near the lake bottom. Phycocyanin ranged between 0 and 0.4 RFU for all profiles until about 19 meters when it increased slightly (Figure 26). For example, on July 30 2.85 RFU was observed at 19.9 meters and on September 24 2.24 RFU was observed at 20.7 meters.

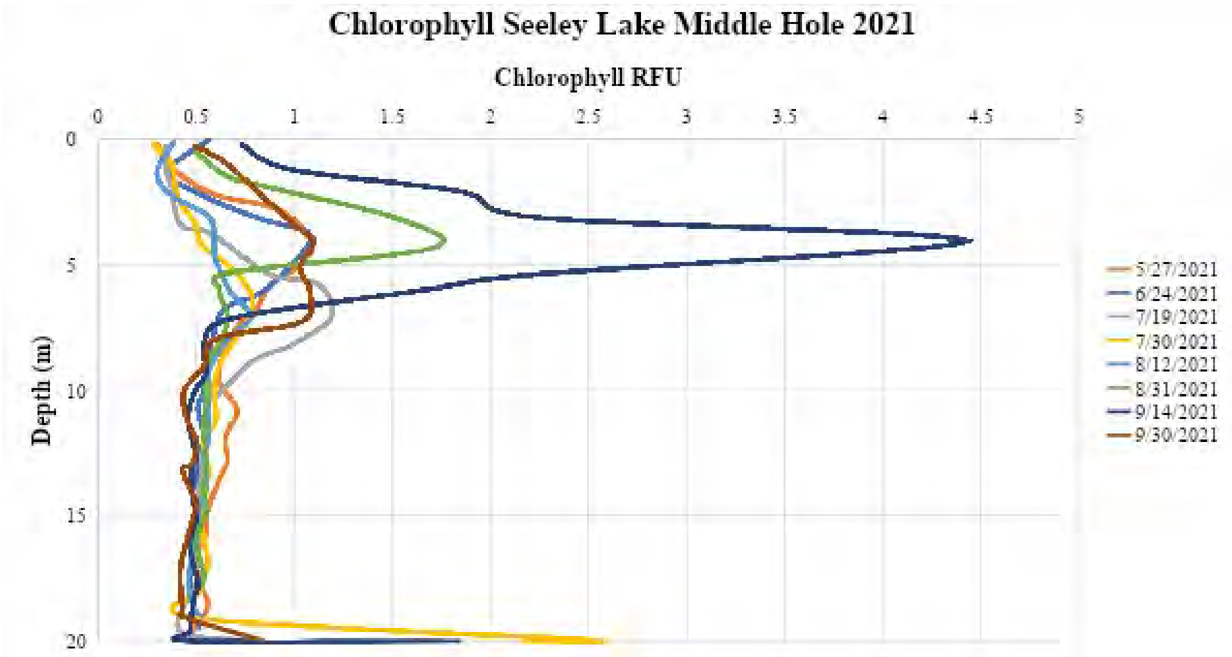


Figure 25. Chlorophyll (RFU) profile recorded at the Middle Hole in Seeley Lake, from May through September 2021.

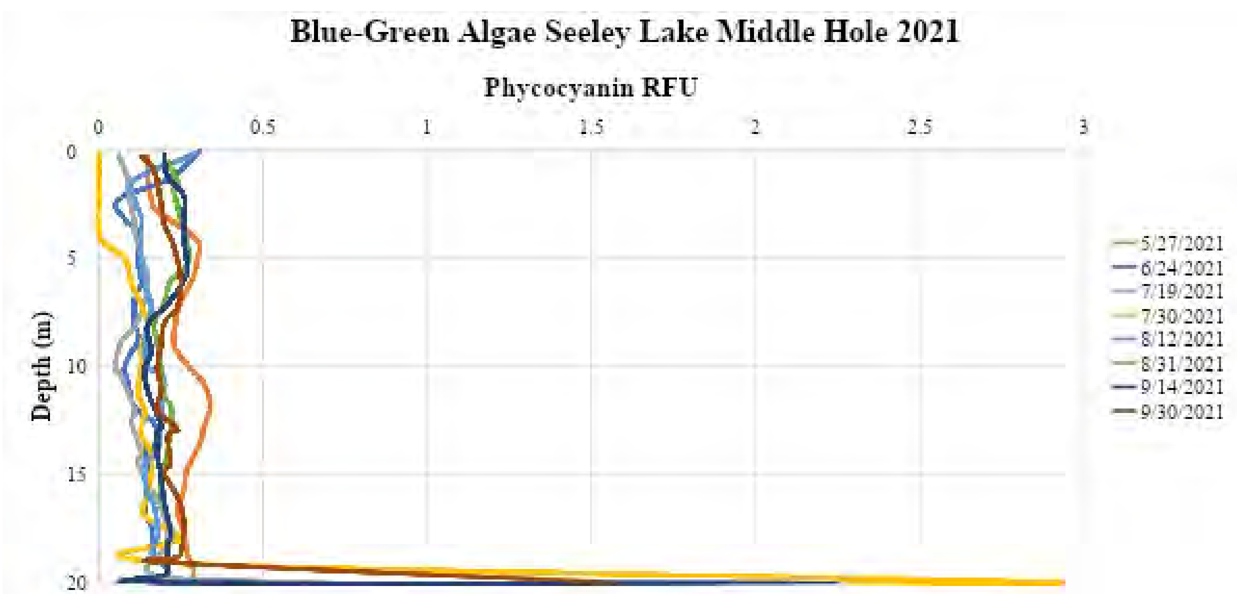


Figure 26. Blue-Green Algae (Phycocyanin RFU) profile recorded at one site in Salmon Lake, from May through September 2021.

Chlorophyll at the Seeley Lake South Hole was quite variable. On May 27, high levels were recorded around mid-deep in the profile (3.13 RFU at 8.39 meters) and on September 14 high levels were recorded near the lake surface (3.09 RFU at 2 meters) (Figure 27). In July and August, elevated levels of chlorophyll were observed near the lake bottom. Otherwise, values ranged between 0.3 and 1.3 RFU, which was slightly higher than all other lakes, even if the individual peaks were lower. One explanation for this might be the location of the monitoring site.

The South Hole is in the southern bay of the lake, which is shallower and has less water movement as it is farther away from both the inlet and the outlet. These conditions may facilitate more plant growth. Phycocyanin typically ranged between 0 and 0.5 RFU, with three main exceptions (Figure 28). On May 27, phycocyanin was elevated mid-deep, recording 2.05 RFU. On July 30, there were elevated levels near the surface (1.96 RFU) and on August 31 there were elevated levels near the lake bottom (4.72 RFU at 15.97 meters). Visual assessments never raised concern.

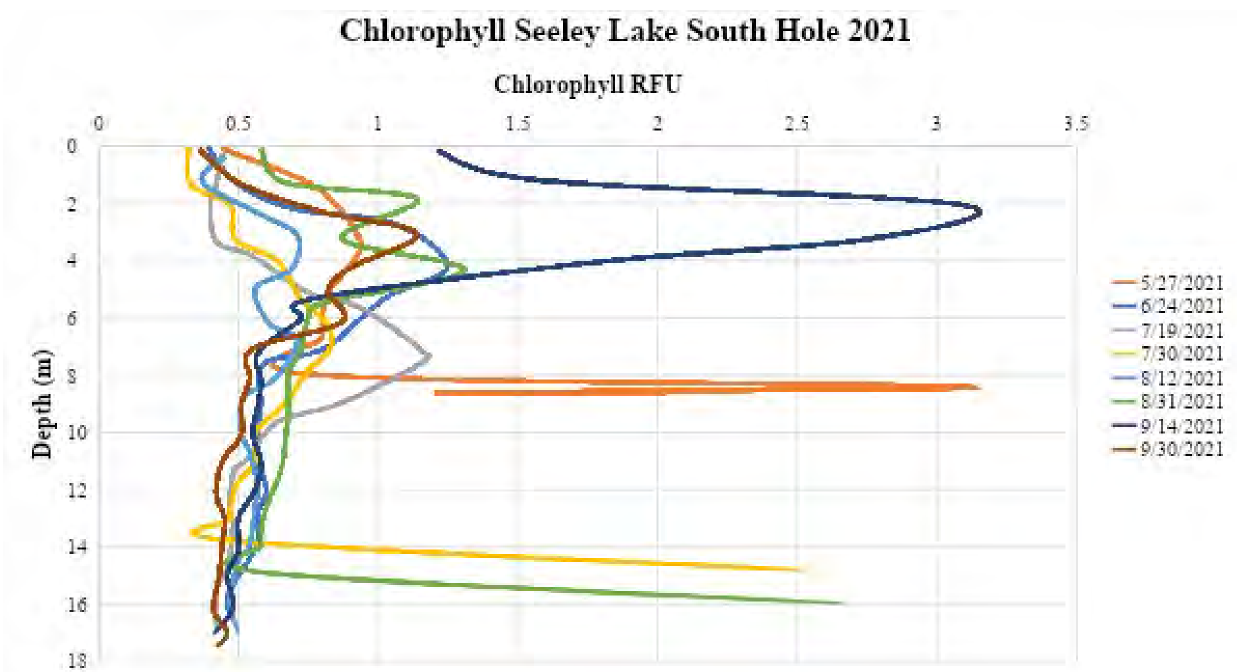


Figure 27. Chlorophyll (RFU) profile recorded at the South Hole in Seeley Lake, from May through September 2021.

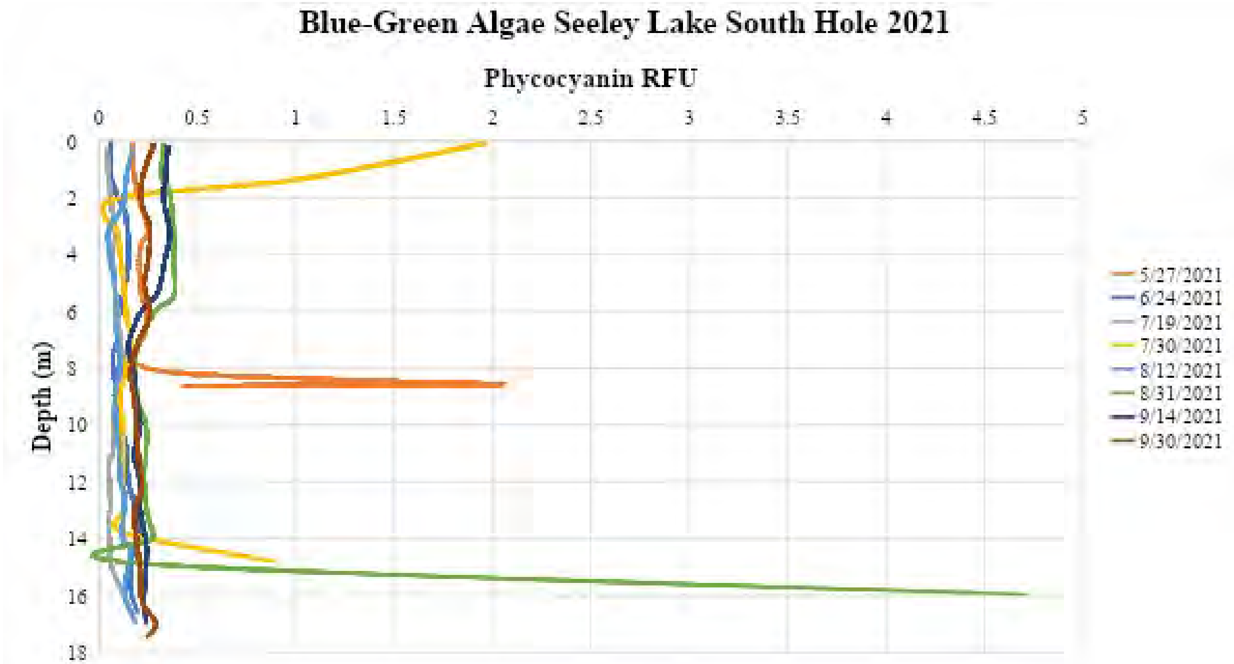


Figure 28. Blue-Green Algae (Phycocyanin RFU) profile recorded at the South Hole in Seeley Lake, from May through September 2021.

One limitation of these chlorophyll and phycocyanin measurements is that the sensors rely on fluorescence, which means it is measuring the emission of light by a substance that has absorbed light. The measurements used in this study are relative fluorescence units (RFU). This limits accuracy to an extent because variations in sensor measurements not related to chlorophyll concentrations can occur due to changing light or temperature conditions that can affect the fluorescence of algal cells. If chlorophyll and algae become larger concerns, corresponding laboratory measurements and analysis may be necessary to provide information about actual chlorophyll or phycocyanin concentrations.

pH Analysis

On all six lakes, pH slightly increased on the surface water as the summer progressed. The lowest pH observed on surface water was 7.53 on Lake Alva on May 17 (Figure 29), while the highest observed on surface water was 9.13 on Big Sky Lake on September 13 (Figure 30). pH recorded at depth (right above lake bottom) was generally consistent throughout the summer in each individual lake. All deep-water pH levels ranged from 7.3-8. On all lakes monitored, pH data never dropped below 7 and never were above 9.2. This indicates that our lakes are slightly basic but are very close to neutral. Neutral waters are typically good for aquatic health and the function of aquatic ecosystems. Moving forward, any changes in pH will indicate a change in the landscape and watershed and be cause for further investigation.

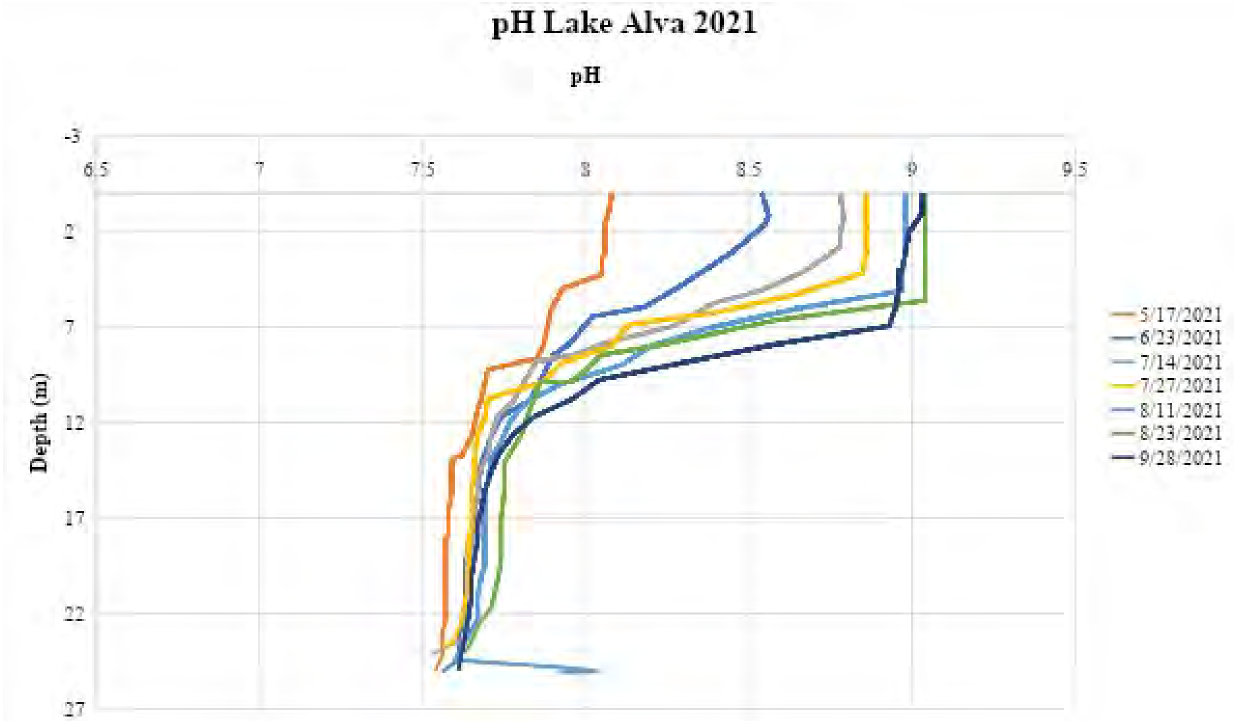


Figure 29. pH profile recorded at one site in Lake Alva, from May through September 2021.

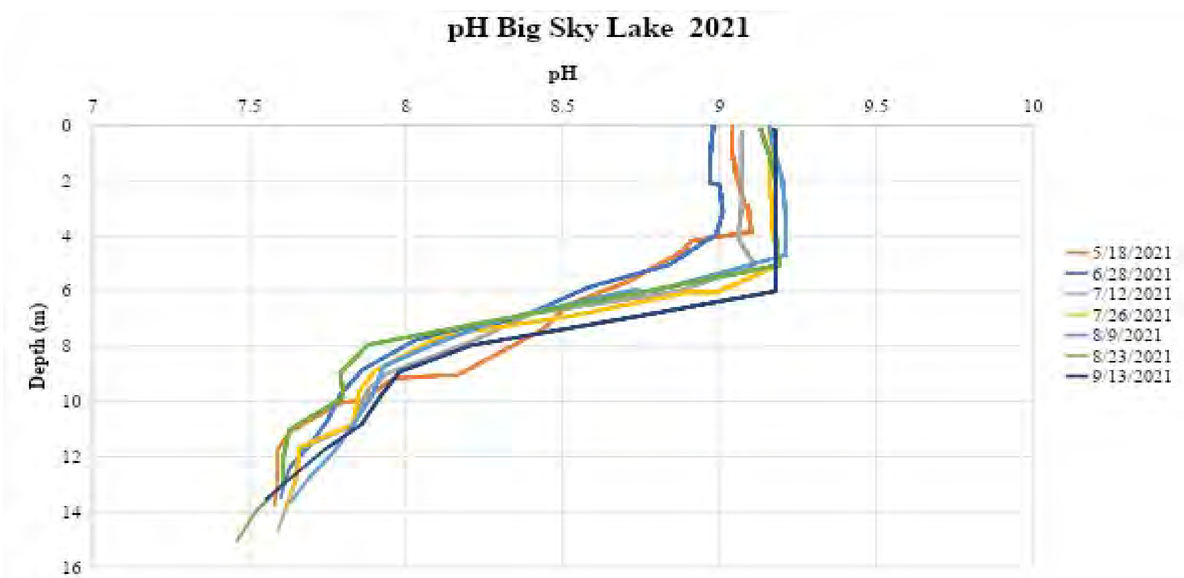


Figure 30. pH profile recorded at one site in Big Sky Lake, from May through September 2021.

Conductivity

Conductivity of lake waters increases as levels of dissolved materials increases. A baseline for conductivity in the Chain of Lakes was established in 2021. None of the data raised concern, as they were all within a range of 80-300 µS/cm. Low conductivity is usually classified when levels are between 0 and 200 µS/cm, indicating natural lake conditions. Mid-range conductivity levels (200-1000 µS/cm) are still considered “normal” for lakes and streams. High conductivity (above 1000 µS/cm) indicates pollution and suggests that the water is not suitable for some fish or macroinvertebrate species. It is important to use conductivity data in combination with monitoring of other parameters, as there can be additional indicators of issues at hand.

The lake with the lowest specific conductance (SPC) measured was Seeley Lake (Figure 31a and b). On the surface of both deep sites on Seeley Lake, SPC ranged from 86-102 µS/cm. For both holes, there was slight variance in the lower epilimnion, but SPC remained in the 85-111 µS/cm range. Near lake bottom of each hole, SPC ranged between 89 and 98 µS/cm.

The lake with the highest SPC was Big Sky Lake (Figure 32). This is interesting because although Big Sky Lake drains into Salmon Lake, Big Sky Lake is not directly in what we typically refer to as the Chain of Lakes. SPC levels ranged from 242-251 µS/cm on the surface and 263-292 µS/cm at the lake bottom. Private property and homes (each with septic systems near the lake) surround Big Sky Lake, so potential septic leachate as well as road runoff could be entering the lake, and could contribute to these higher SPC levels. However, they are still within a healthy range for aquatic environments. The other lakes in the Clearwater Valley all had SPC levels ranging from 100-207 µS/cm.

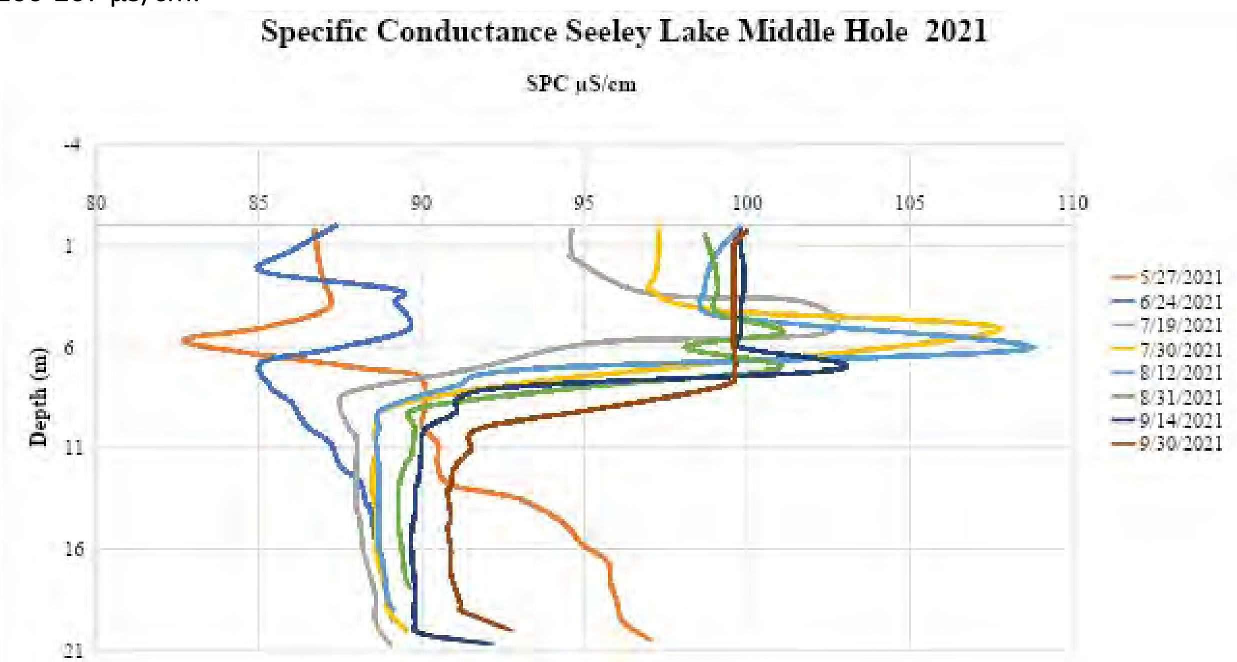


Figure 31a. Conductivity (µS/cm) profile recorded on the Middle Hole of Seeley Lake , from May through September 2021.

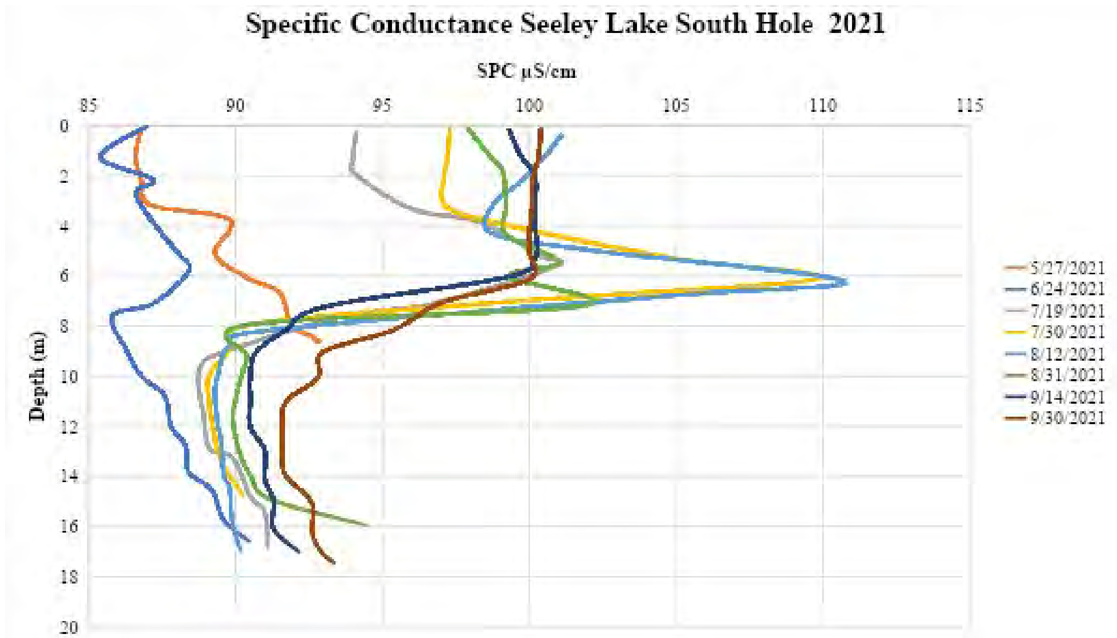


Figure 31b. Conductivity (uS/cm profile recorded on the South Hole of Seeley Lake from May through September 2021.

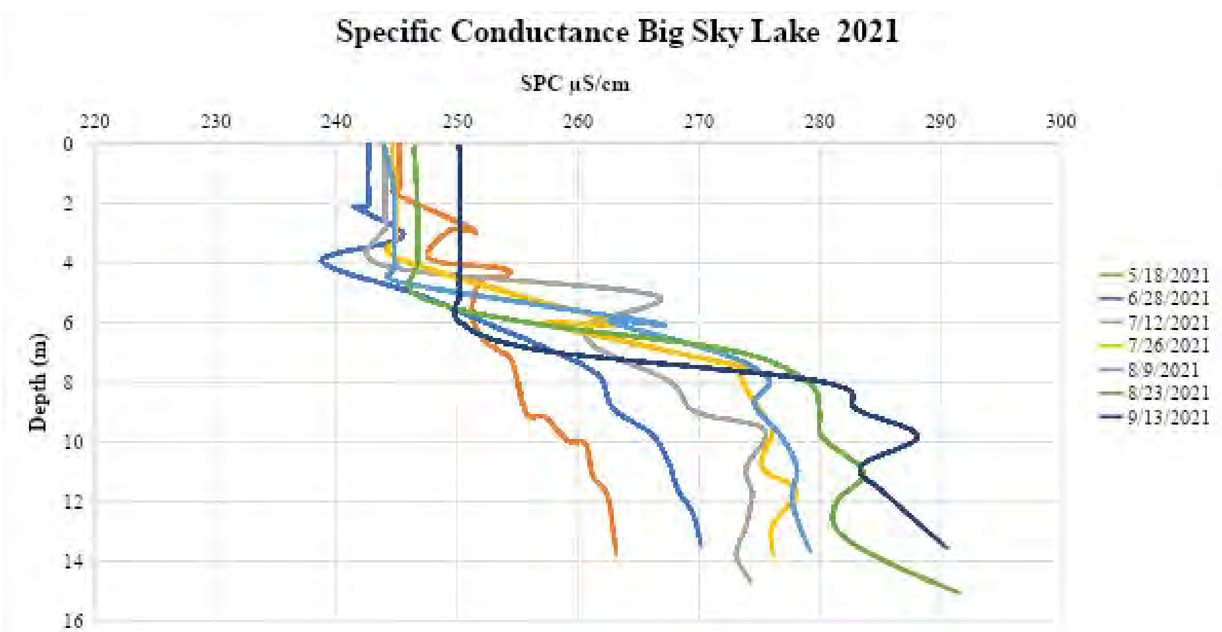


Figure 32. Conductivity (µS/cm) profile recorded at one site in Big Sky Lake, from May through September 2021.

Nutrient Analyses

Baseline data collected in 2021 suggest that all the lakes undergo seasonal variation. However, data also show that the lakes with development experience seasonal variation to a greater extent than the lakes that have little to no development along their shores. Six lakes in the

Clearwater Valley were sampled for various nutrients and the presence of both Aquatic Invasive Species (AIS) and coliforms (E. coli): Lake Alva, Lake Inez, Seeley Lake, Placid Lake, Big Sky Lake, and Salmon Lake. Various sites were sampled at both surface and deep levels to allow a more comprehensive understanding of the state of the lakes. Total Nitrogen (TN), Total Phosphorus (TP), Soluble Reactive Phosphorus (SRP), and Nitrates/Nitrites (NO3/NO2) were the nutrients analyzed. The number of locations, depths, and timing of samples collected varied across the lakes, so our initial round of sampling gives an incomplete picture of how the lakes are faring.

Total nitrogen (TN) is the sum-total of nitrogen (ammonia, organic, and reduced nitrogen) and nitrate-nitrite. Possible sources of nitrogen in the lakes include runoff from forest lands, fertilized lawns, failing septic systems, and runoff from animal manure/storage areas. Nitrogen serves as a fertilizer for plants and can contribute to algal blooms.

Total phosphorus (TP) is a measure of all forms of phosphorus that are found within a sample. Phosphorus, like nitrogen, can be sourced from runoff from forest lands, lawns, sewage, or animal manure that enters surface waters. Phosphorus acts as a fertilizer for many plants and can also contribute to algal blooms.

Because a full sampling of all six lakes at all locations at surface and deep depths across all sampling times was not conducted due to budget limitations for nutrient sample analyses, the interactions of these variables could not be thoroughly analyzed. So, this initial sampling effort provides various insights into lake nutrient levels, but does not present a comprehensive picture of the nutrient status of each lake.

Figure 33 shows that Big Sky Lake had the highest sampled concentration of total nitrogen. While lake standards for total nitrogen have not been defined by the state of Montana, compared to standards for streams, Big Sky Lake exceeded this standard for TN. The remaining lakes show similar concentrations of TN but lacked enough locations and depths of samples to fully characterize the water quality. Results (Figure 34) also show that Big Sky Lake had the highest concentration of total phosphorus. State water quality standards for TP in lakes has also not been set, but Big Sky Lake is closest to exceeding state standards for streams of 20 micrograms per liter of TP. Again, a single sample is insufficient to characterize water quality in any lake, but this gives us a snapshot of what may be going on in the surface waters.

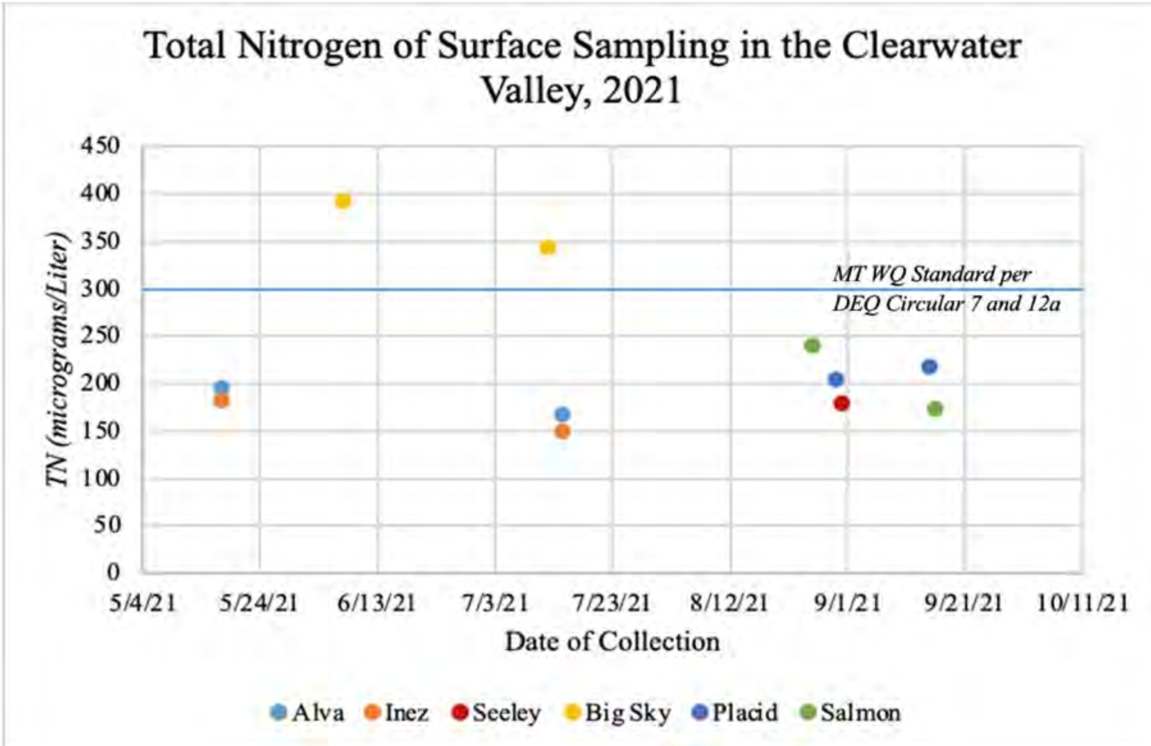


Figure 33. The Total Nitrogen of various surface samples taken across the six lakes in the Clearwater during the 2021 samplings season.

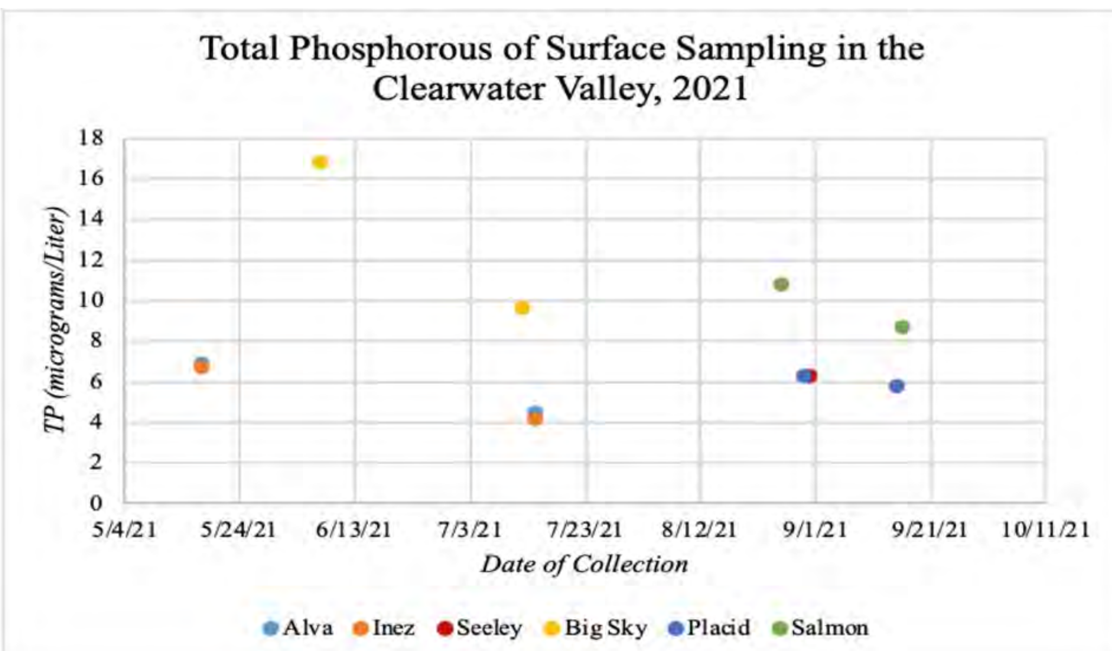


Figure 34. The Total Phosphorus of various surface samples taken across the six lakes in the Clearwater during the 2021 sampling season.

TN:TP ratios are used to indicate is most likely to be limiting, so that nutrient can be controlled.

They can also be indicative of underlying issues including uptake of these elements by algae, especially blue-green algae. Low TN:TP ratios tend to favor nitrogen fixing blue green algae. . Bluegreen algae (cyanobacteria) favor low nitrogen to phosphorus ratios. Eutrophication is the process in which a body of water is progressively enriched with an excess of nutrients, particularly nitrogen and phosphorus, potentially leading to algal blooms as well as other associated issues. Results of the 2021 sampling of surface samples (Figure 35) show the ratio of TN to TP while Figure 36 shows the TN:TP ratios at deep (~50 ft) locations on the six lakes.

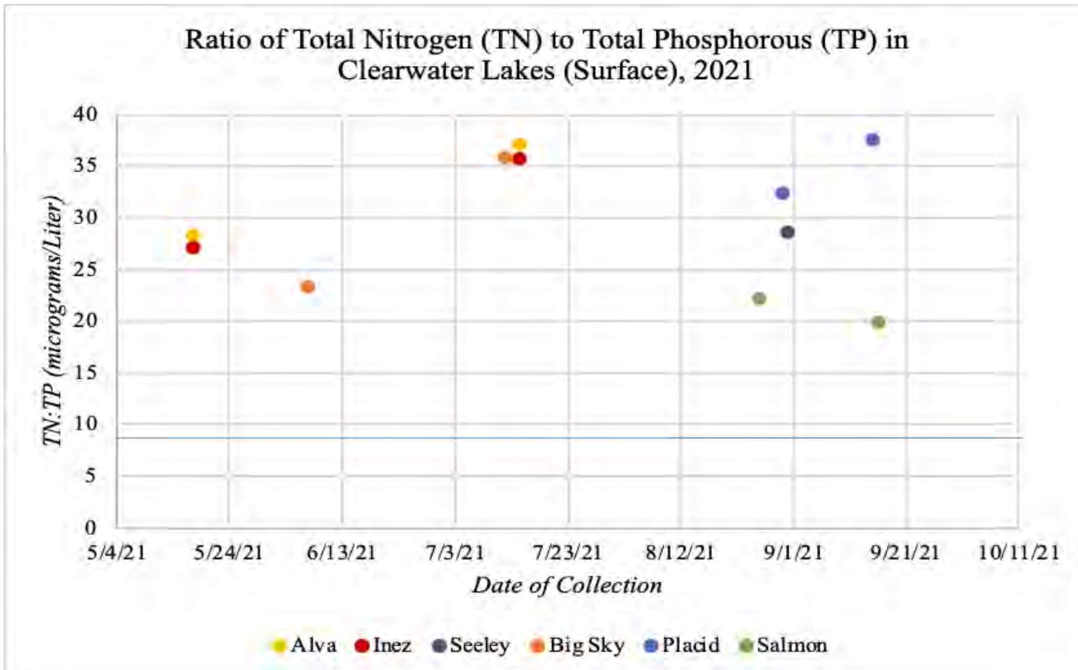


Figure 35. The ratio of Total Nitrogen (TN) to Total Phosphorus (TP) in Clearwater Lakes at the surface level in 2021.

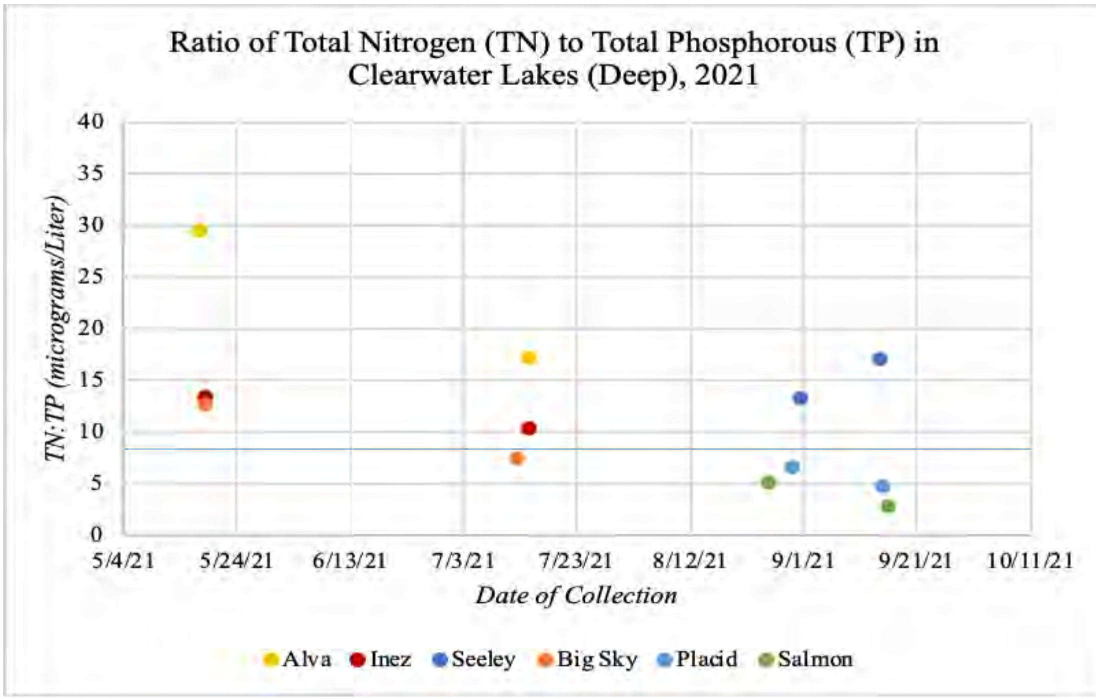


Figure 36. The ratio of Total Nitrogen (TN) to Total Phosphorus (TP) in Clearwater Lakes at the deep level in 2021.

Results for SRP and NO3/NO2, levels were only given if the concentration exceeded the detection threshold of 0.8 micrograms/Liter and 1.5 micrograms/Liter, respectively. For Lake Alva, of the data recorded, the only location with readings above the threshold for both SRP and NO3/NO2 was the mid lake deep location. For NO3/NO2, Lake Alva had an elevated reading in May (53.6µg/L-N) and another in July (60.3µg/L-N). The corresponding SRP levels were also elevated at 2.3 µg/L-P in May and 4.1 µg/L-P in July. As for Lake Inez, of the SRP readings, only two were recorded as above the threshold of 0.8 µg/L-P (1.8 µg/L-P in May and 3.9 µg/L-P in September). Both recordings were from the mid-lake deep location. As for the NO3/NO2 readings, only three were recorded as above the threshold of 1.5 µg/L-N, two belonging to the mid-lake deep location and the third belonging to the W Homes location.

As for Placid Lake, because the data were from more than two locations with readings of SRP above the threshold of 0.8 µg/L-P, the data are shown in (Figure 37). As for the NO3/NO2 recordings, only the mid lake deep location was above the threshold of 1.5 µg/L-N at 61.7 µg/LN in June and 61.3 µg/L-N in July.

Of the four samples recorded for Big Sky Lake during 2021, three SRP readings were above the threshold of 0.8 µg/L-P. Two of these samples belonged to the mid lake deep location, while the third belonged to the mid lake surface location. As for the NO3/NO2, only one reading was above the threshold of 1.5 µg/L-N. That sample belonged to the mid lake deep surface and was a recording from mid-May.

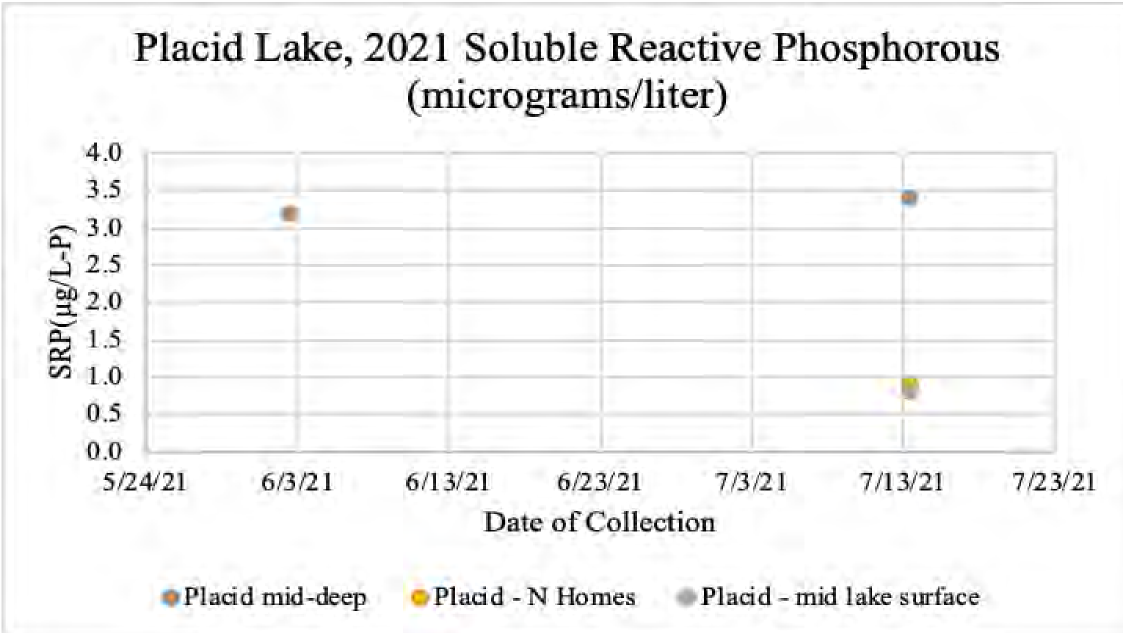


Figure 37. Soluble Reactive Phosphorus in Placid Lake in 2021.

Of the samples recorded for Seeley Lake, there is a singular data point above the threshold for NO3/NO2 in mid-September at 1.6 µg/L-N. As for SRP, only four data points had readings above the threshold of 0.8 µg/L-P, shown in (Figure 38).

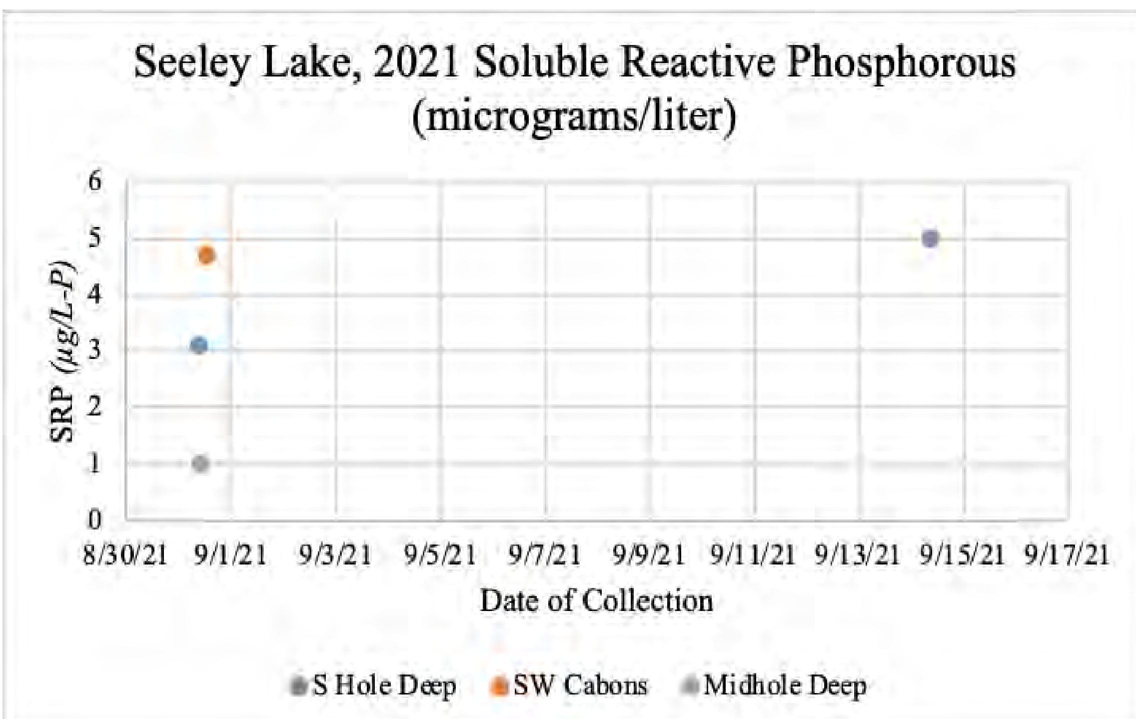


Figure 38. Soluble Reactive Phosphorus in Seeley Lake in 2021.

Data recorded for Salmon Lake in 2021 found the only location to exceed the threshold for the SRP and NO3/NO2 readings, 0.8 µg/L-P and 1.5 µg/L-N respectively, was the Mid- Lake Deep location.

Secchi Transparency

There were no drastic changes or trends apparent with the addition of the 2021 transparency data. In general, there are consistent differences among the lakes and common trends within each lake in the long-term data set we have acquired and built upon. There is year to year variability in each lake's transparencies, but overall, there have been no major or consistent changes in transparencies during the past 13 years of monitoring (Figure 39). Transparencies during the 2021 field season ranged from a low of approximately 10 feet on Lake Inez in May to 25.8 feet on Big Sky Lake in June. Transparencies are generally lowest early in the year, probably due to lake mixing and spring runoff. As sediment settles and growth continues, transparencies typically increase in depth as the summer progresses. Fall is often when elevated levels of plant growth and algae blooms are observed, and thus transparencies decrease again.

Transparencies naturally vary through time in response to differences in precipitation, streamflow, temperature, and plant growth. Data can also vary due to inherent limitations in the methodology of collecting data via the Secchi disk. As discussed previously, many factors can influence Secchi data, such as a change in weather conditions, time of day of observation, or the person making observations. As of 2021, no long-term continual changes in transparency have been observed.

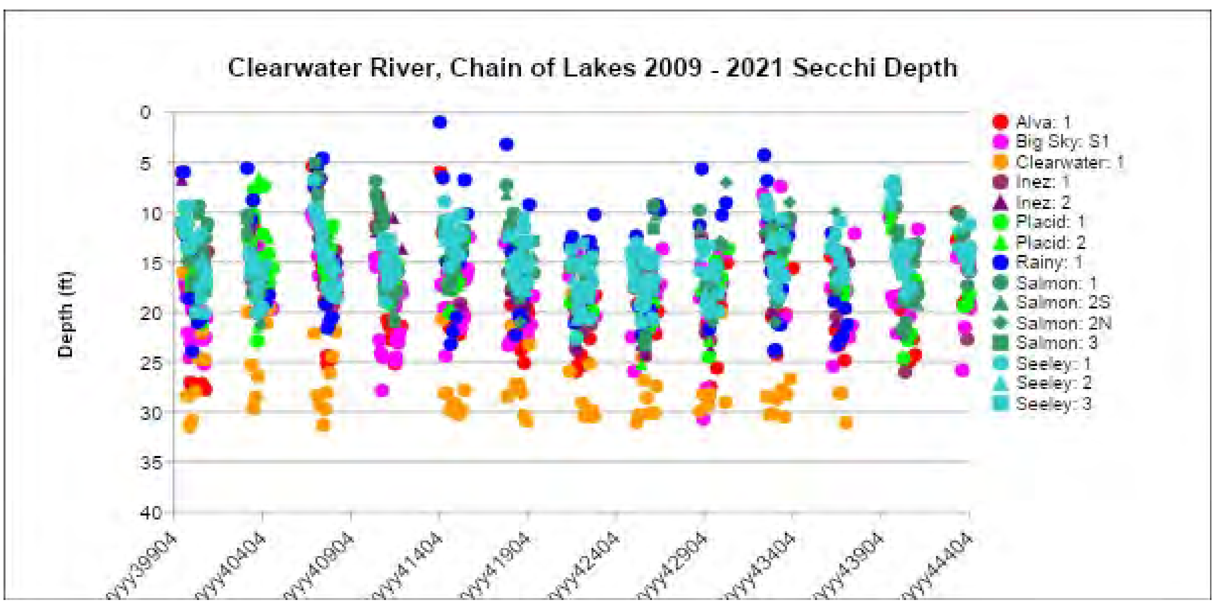


Figure 39. Secchi transparencies (depths) recorded at one or more sites in eight lakes in the Clearwater Watershed, 2009 through 2021. Note that as of 2020, Clearwater and Rainy Lakes were omitted from monitoring.

2022 Sampling Analysis

Dissolved Oxygen Profiles, 2022

In 2022, Lake Inez was not sampled. On other five lakes sampled dissolved oxygen (DO) declined as depth increased. The trends observed throughout 2021 persisted into 2022, the most dramatic change also being at the thermocline at each lake. (Figures 40-44).

Placid Lake

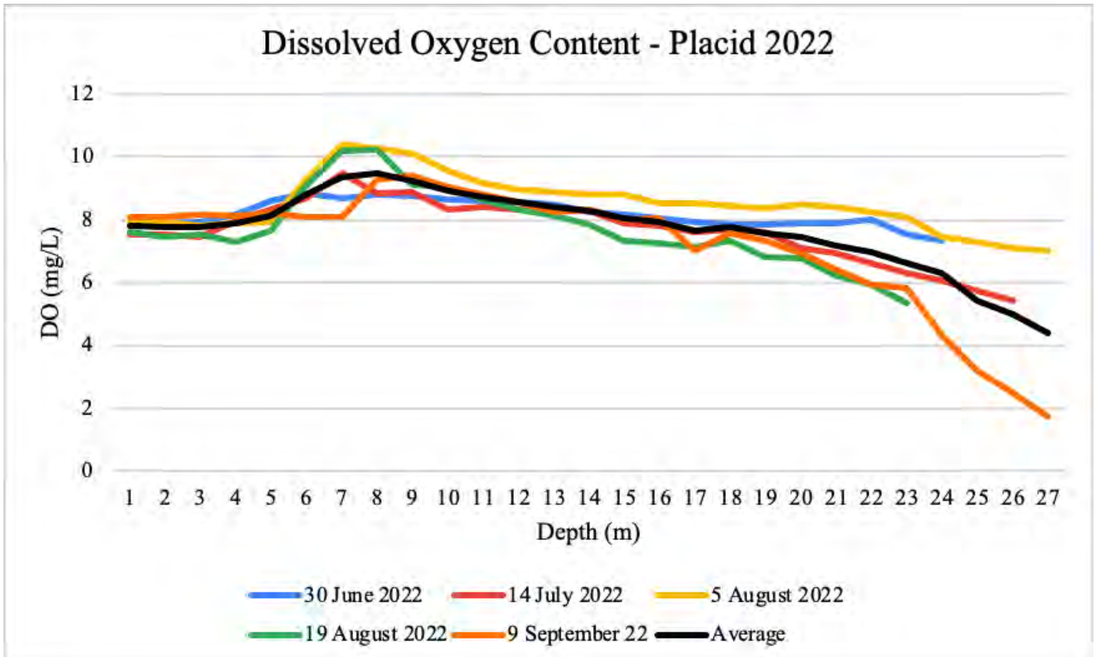


Figure 40. Dissolved oxygen readings for Placid Lake in 2022.

Seeley Lake

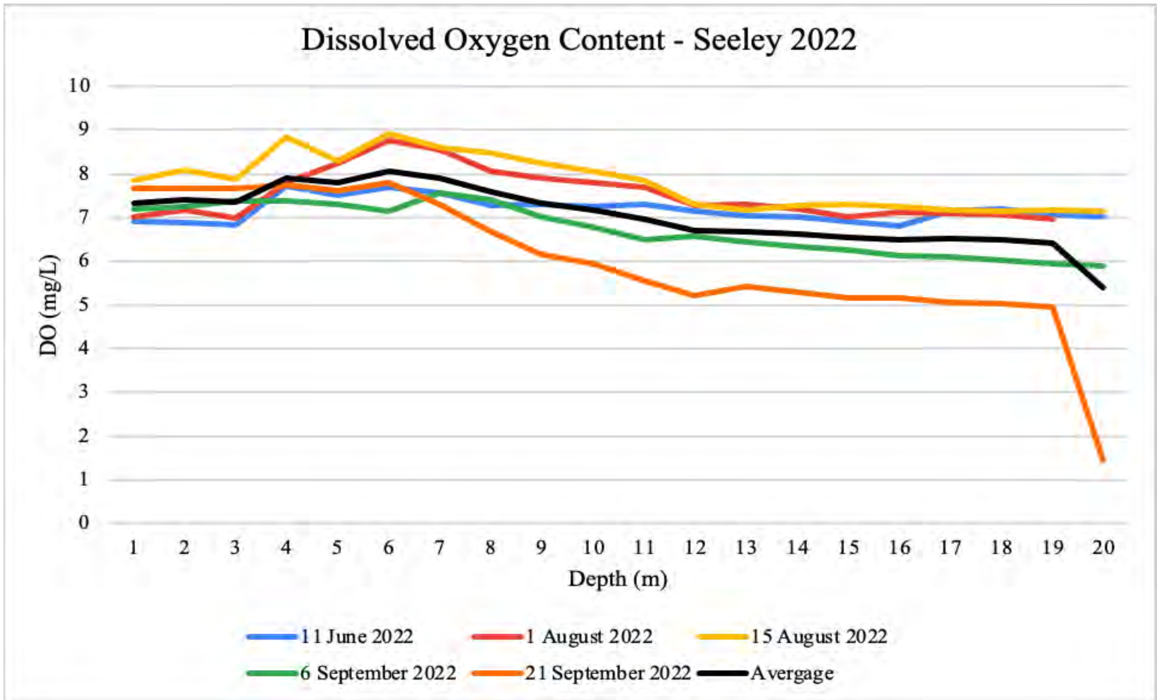


Figure 41. Dissolved oxygen readings for Seeley Lake in 2022. Salmon

Lake

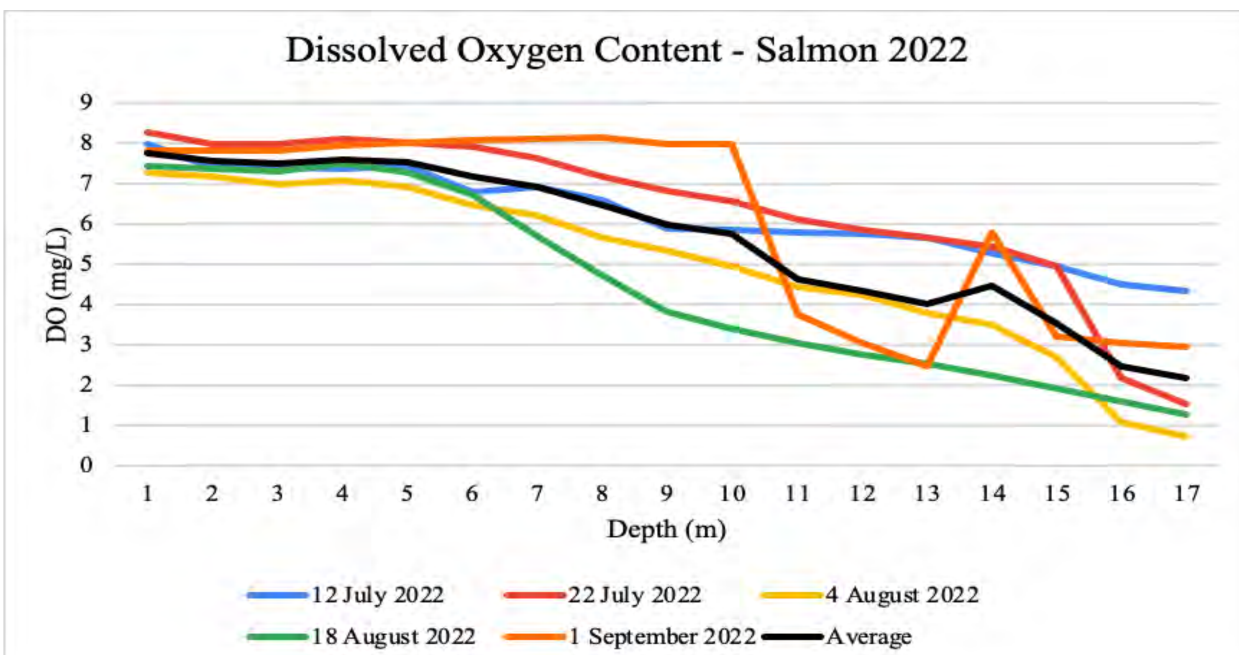


Figure 42. Dissolved oxygen readings for Salmon Lake in 2022.

Lake Alva

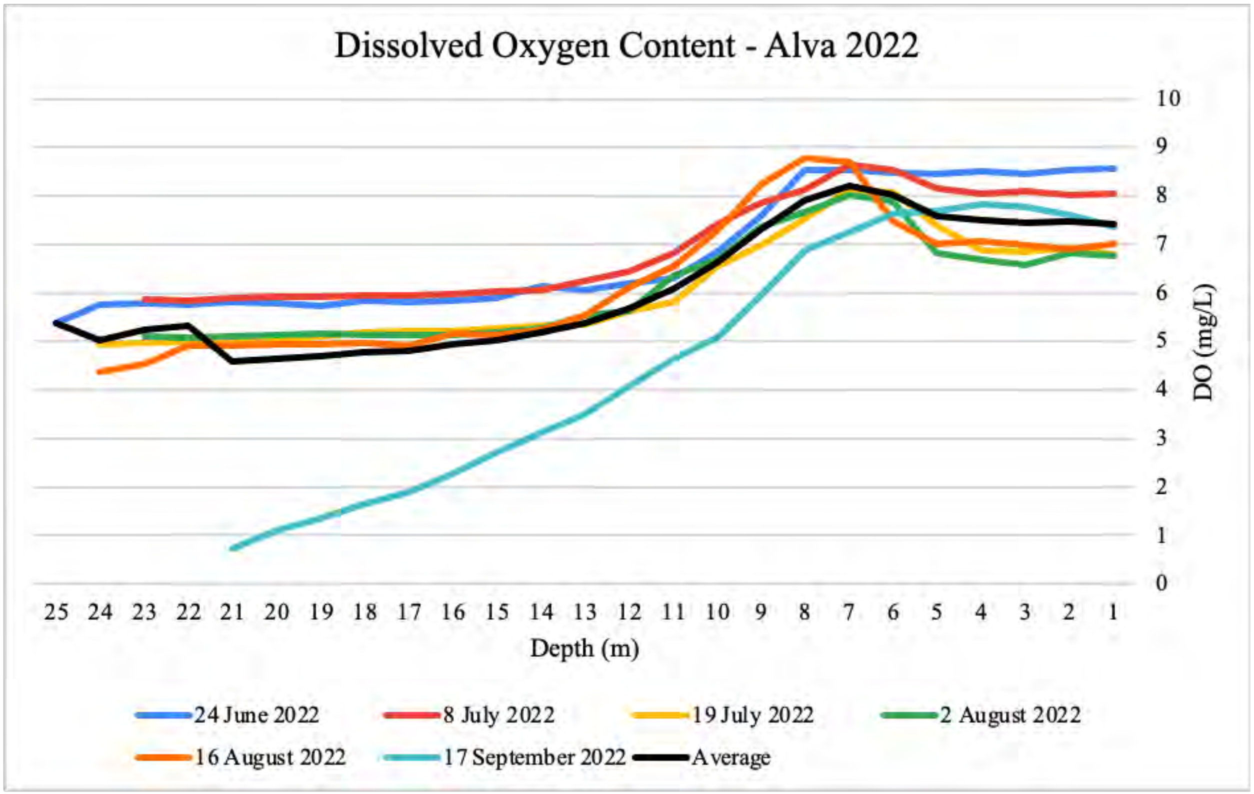


Figure 43. Dissolved oxygen readings for Lake Alva in 2022.

Big Sky Lake

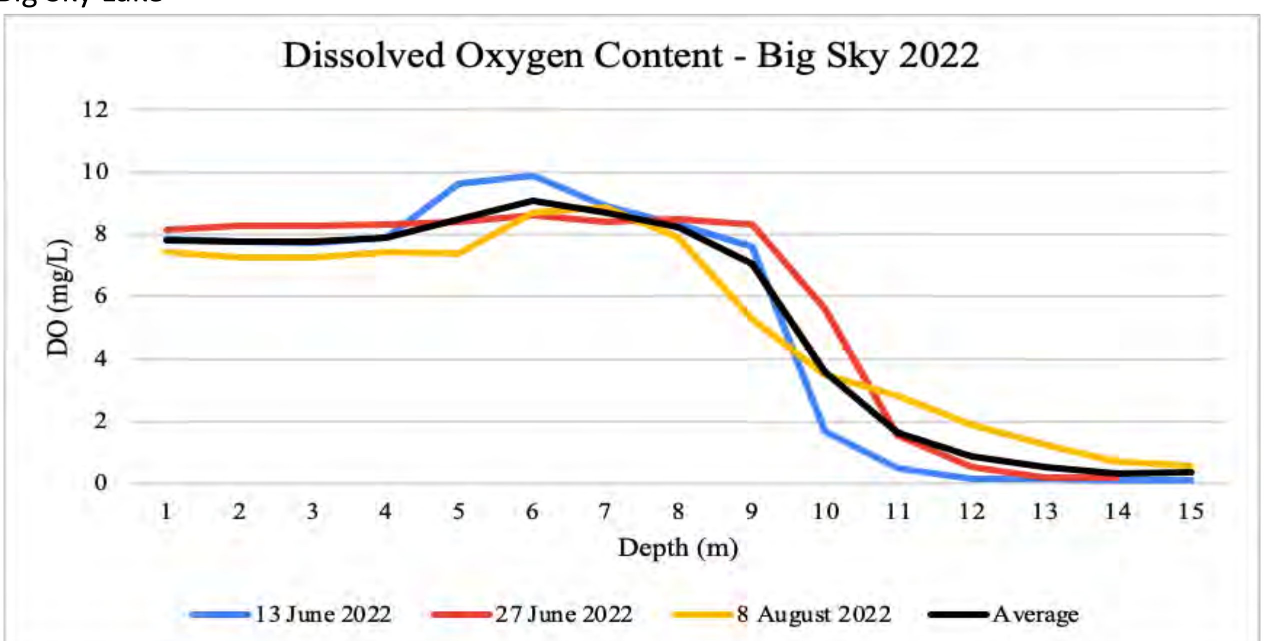


Figure 44. Dissolved oxygen readings for Big Sky Lake in 2022.

Nutrient Analyses, 2022

In 2022, primary nutrient analyses focused on Seeley Lake. Ten sample sites were chosen and sampled at various points throughout the season, beginning in July and extending into September. Data analysis included testing for the following nutrients: TN (Figure 45), TP (Figure 46) TN:TP ratio (Figure 47), sulfates (Figure 48), SRP (Figure 49), Chlorides (Figure 50) and nitrates. For nitrates, only two samples exceed the threshold of 1.5 µg/L-N for NO3/NO2, so no graph of these data is shown. Both samples occurred at the SE2 location. As for the SRP, most locations had at least one sample that exceeded the threshold of 0.8 µg/L-P, displayed in Figure 49.

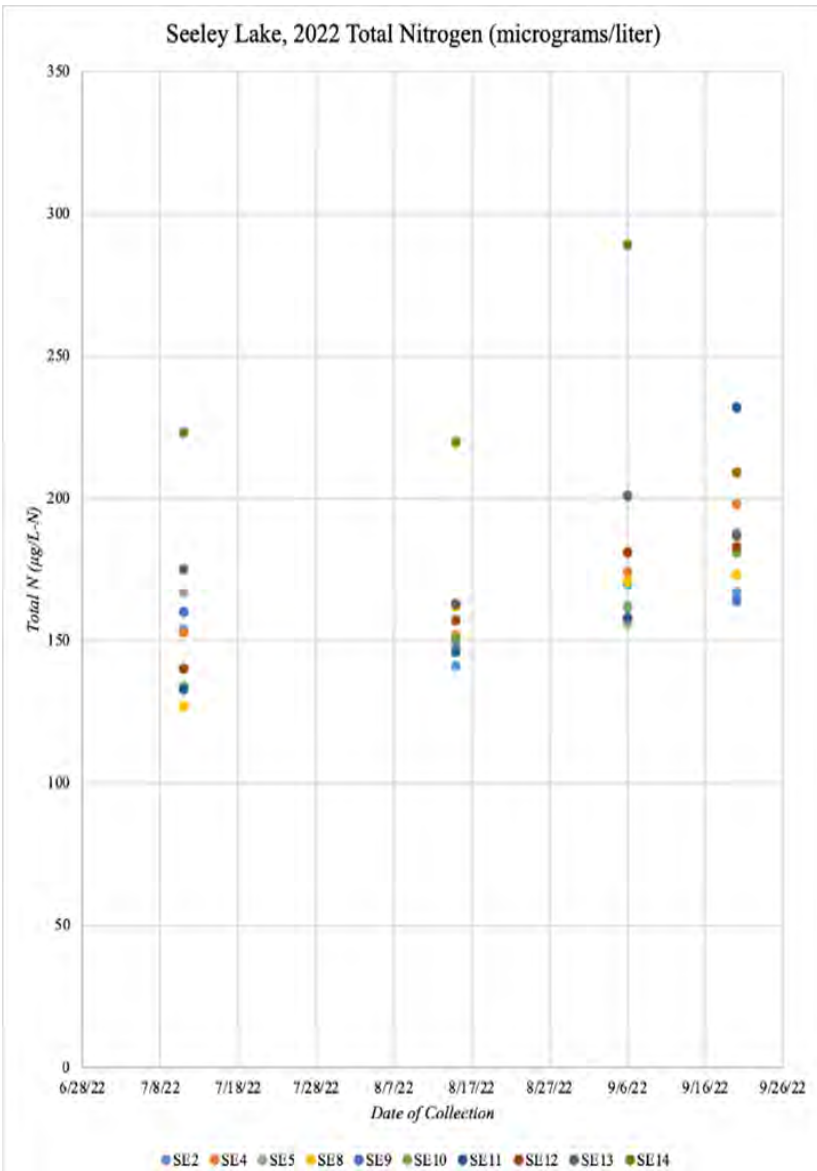


Figure 45. Total nitrogen readings for surface samples collected at indicated in locations in Seeley Lake in 2022.

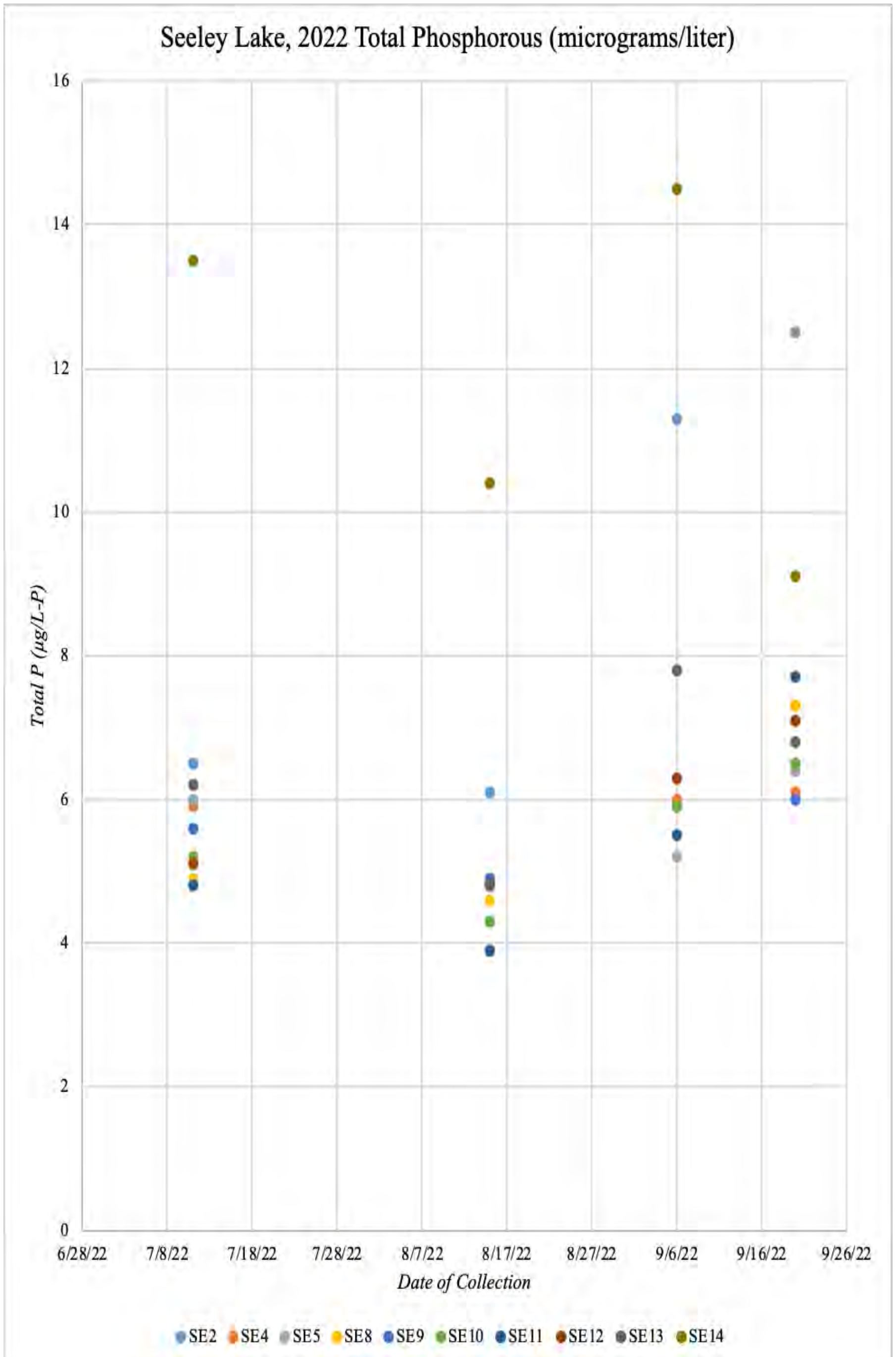


Figure 46. Seeley Lake Total Phosphorus (TP) from surface samples across ten sampling sites in 2022.

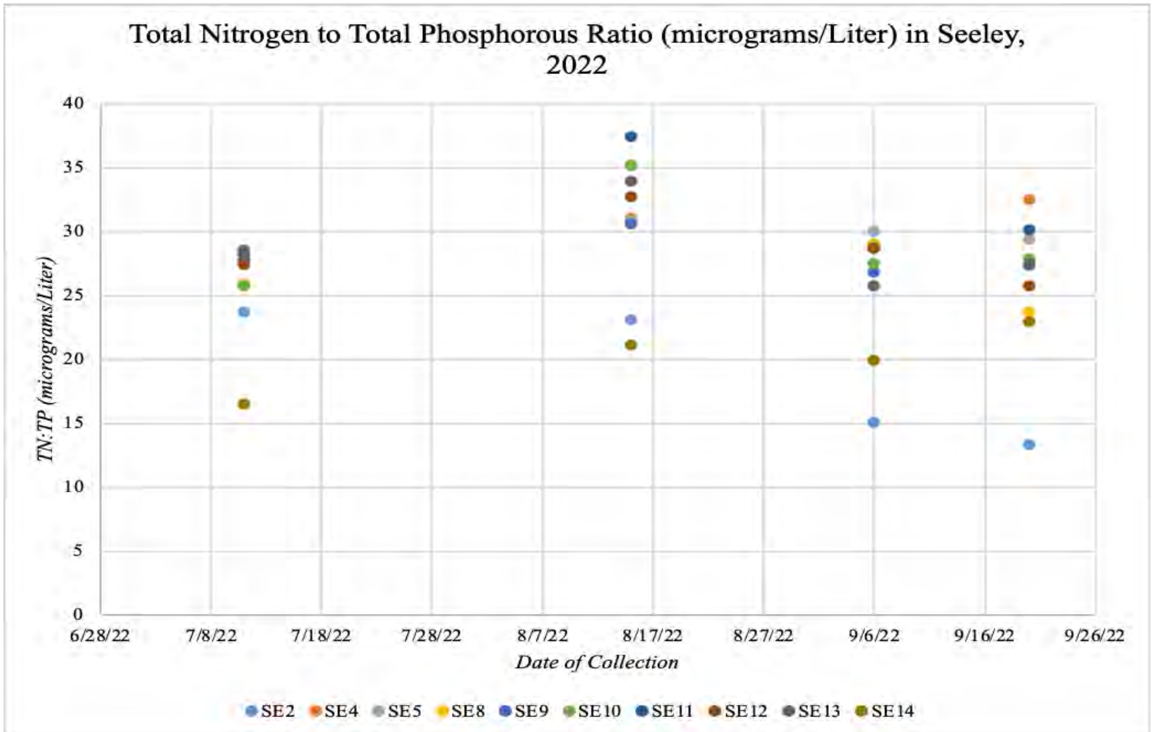


Figure 47. Total Nitrogen to Total Phosphorus ratio in surface samples of Seeley Lake sampled in 10 locations in 2022 sampling.

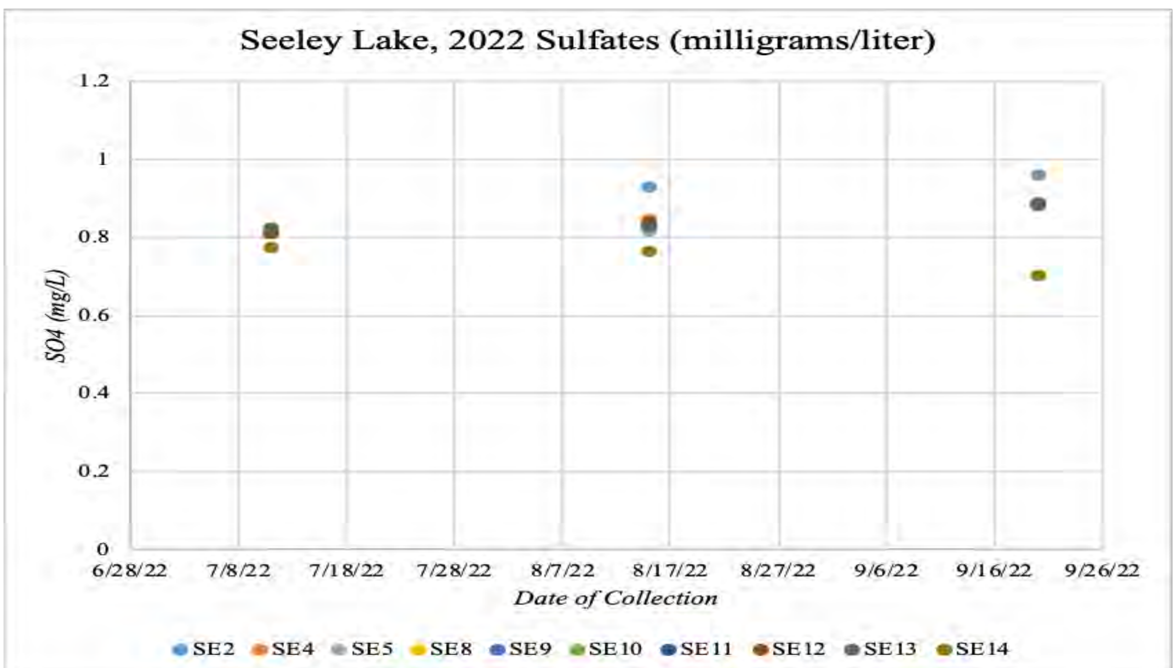


Figure 48. Sulfate levels in surface samples collected across 10 locations in Seeley Lake in 2022.

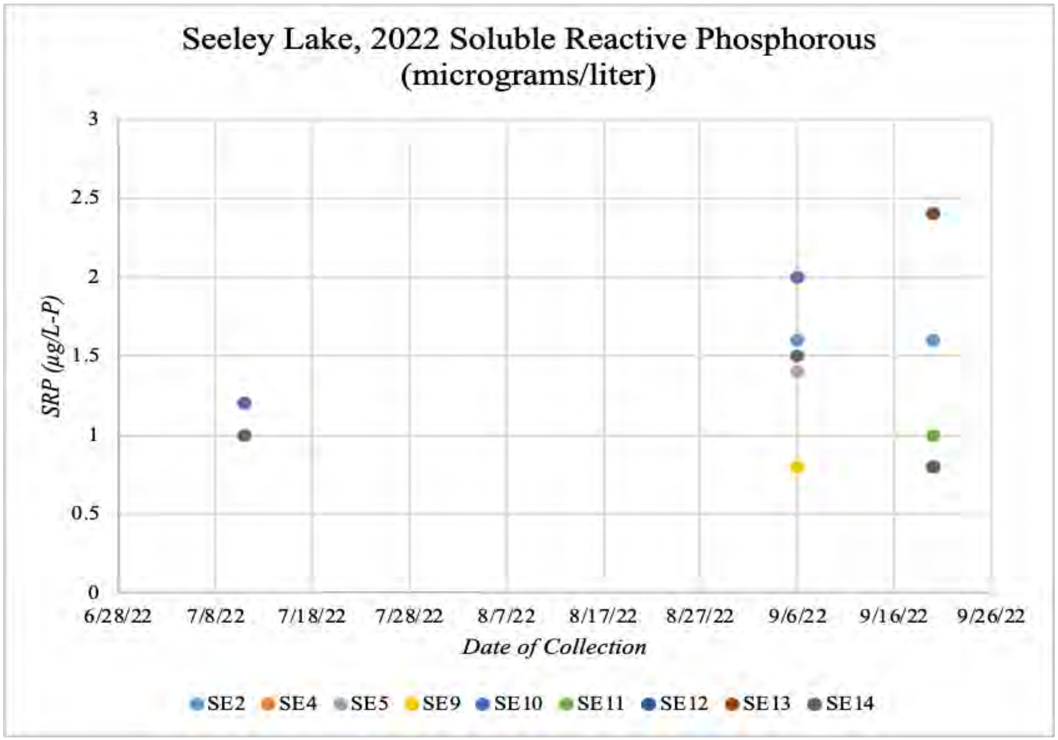


Figure 49. Soluble Reactive Phosphorus (SRP) levels from surface samples across 10 locations in Seeley Lake in 2022.

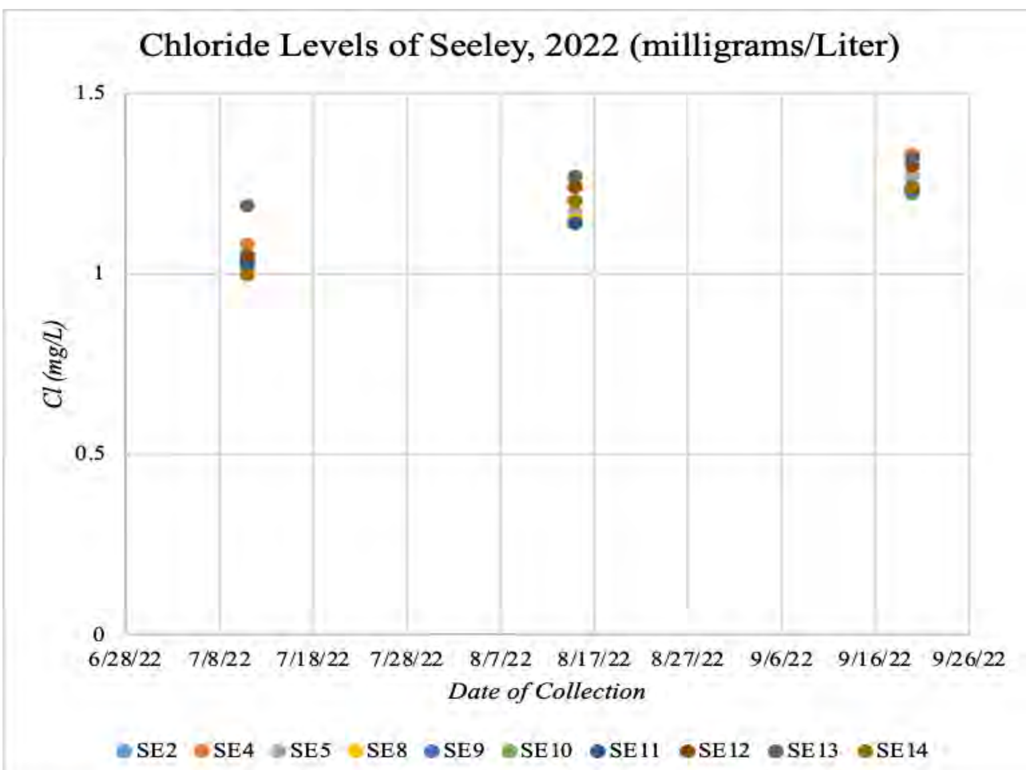


Figure 50. Chloride levels from surface samples in 10 locations in Seeley in 2022.

Limited nutrient sampling was conducted on other lakes in 2022, with only 2 sampling times at each lake, one in August and one in September. Sampling of Lake Alva included one surface and one deep sample, Big Sky Lake included one surface and one deep sample, Lake Inez included 4 surface sampling locations and one deep location, and Placid Lake included 4 surface and one deep sample locations. Nutrient analysis was conducted for nitrates, total nitrogen, orthophosphates, and total phosphorous.

Nitrogen sampling results for Lake Alva included surface levels of 163 ug/L in August and 151 ug/L in September, and deep levels of 196 ug/L in August and 182 ug/L in September. Nitrogen levels in Lake Inez in surface samples collected in August ranged from 163-185 ug/L and 159-182 ug/L in September. The deep samples were 294 ug/L in August and 281 ug/l in September. For Big Sky Lake, nitrogen in surface samples were 374 ug/L in August and 402 ug/L in September. Deep samples recorded 1700 ug/L in August and 1860 ug/L in September. No total nitrogen analyses were provided for Placid Lake Samples in 2022.

For nitrates, most samples from all of the lakes were less than the detection level of 1.5 ug/L. Exceptions included deep samples in Lake Alva recording 52.8 ug/L in August and 47.6 ug/L in September, and deep samples in Placid Lake that recorded 85.6 ug/L in August and 50.8 ug/L in September.

Similarly, only a limited number of samples exceeded the minimum detection level of 0.8 ug/L for orthophosphates. Deep samples from Big Sky Lake recorded a level of 175 ug/L in August and 214 ug/L in September. Deep samples from Lake Inez recorded 9.5 ug/L in August and 13.6 ug/L in September, while deep samples from Placid Lake recorded 7.2 ug/L in August and 11.2 ug/L in September.

Samples for total phosphorous were analyzed for Lake Alva, Lake Inez, and Big Sky Lake, but not Placid Lake. Lake Alva had a surface reading of 4.6 ug/L in August and 3.8 ug/L in September, with deep readings of 7.7 ug/L in August and 8.8 ug/L in September. Lake Inez had surface readings ranging from 5.3-10.2 ug/L in August, and 5.2- 6.9 ug/L in September, with deep readings of 33.8 ug/L in August and 61.6 ug/L in September. Big Sky Lake had a surface reading of 9.1 ug/L in August and 9.2 ug/L in September, with deep readings of 238 ug/L in August and 258 ug/L in September.

Chlorophyll and Blue-green Algae

In 2022, chlorophyll and blue-green algae data using the Sonde were collected at the surface and at the deep location for each lake on 5 sampling dates. All RFU's were less than 1.0 except for 4 readings. Salmon Lake had the highest reading of 7.17 from a deep sample taken on July 21, 2022. All other readings at other locations and times were less than 1.0. Placid Lake had one reading of 1.05 in a deep sample on September 5, 2022. Lake Inez had a reading of 3.31 from a deep sample taken on September 17, 2022. Lake Alva had two readings from deep samples greater than 1.0, a reading of 1.28 on July 6, 2022, and a reading of 3.34 taken on August 30, 2022.

Blue-green algae RFU's corresponded closely with the chlorophyll readings. The only readings that exceeded 1.0 were taken at the same time and location as the chlorophyll readings that exceeded 1.0, and all were from the same deep samples. These included a reading of 1.52 for Salmon Lake on July 21, 2.65 for Lake Inez on September 17, 2.02 for Lake Alva on July 6, and 3.34 for Lake Alva on August 30.

Specific Conductivity

As found in 2021 samples, specific conductivity was quite consistent across a lake, but varied across lakes. Conductivity was also fairly consistent across sampling times within each lake, with the exception of Salmon Lake where conductivity increased from spring to fall, measuring an average across sites of 115.6 uS/cm on July 12, 120.3 uS/cm on July 21, 127.4 uS/cm on August 4, 134.2 uS/cm on August 18, and 137.7 uS/cm on September 1. Similar to 2021, Seeley Lake had the lowest average conductivity across all surface samples and times of 100.1 uS/cm, Placid Lake averaged 115.4 uS/cm, Salmon Lake averaged 127.0 uS/cm, Lake Inez averaged 177.2 uS/cm, Lake Alva averaged 198.1 uS/cm and Big Sky Lake had the highest levels averaging 247.0 uS/cm. All of these levels are considered within the normal range for natural lakes.

pH readings

In 2022, pH readings showed a greater variability than in 2021. The highest pH reading was measured on Lake Inez on June 29 at 12.92, with another reading on June 30 at 11.45 both from surface samples. A reading of 7.27 was measured at the surface of Lake Inez on August 3 as the lowest pH reading for this lake. Seeley Lake had one reading of 10.6 in a deep sample on July 11, and a reading of 7.05 as the other extreme in a surface sample on August 1. Big Sky Lake had a surface reading of 10.11 on June 27, and a deep reading of 7.94 on August 22. Placid Lake had a surface reading of 11.46 on June 29, and a deep reading of 7.54 on September 9 as its range of values. All of Salmon Lake's readings were in the 8-9 range with the exception of a reading of 7.95 in a deep reading on August 18. Lake Alva had a surface reading of 11.13 on July 6, and a deep reading of 7.01 on June 24.

Optical Brightening Agents (OBAs) Sampling

Optical brightening agents (OBAs) are chemical compounds that are added to products such as laundry soaps, detergents, or cleaning agents. The presence of OBAs in water systems to which wastewater is being discharged can indicate failing septic systems or a lack of proper water treatment. In 2022, CRC conducted a study which sampled and tested surface water for the presence of OBAs. The report of this study in included as a supportive document to this report. The study was designed to help identify the potential septic contamination to six lakes in the Clearwater Watershed. After collecting samples and completing fluorometric testing, all of the samples were concluded to be negative for optical brightening agents. While the lack of a positive finding of the presence of OBAs is good news from a water quality perspective, it should not be concluded that OBAs are not present in the lakes that were studied. Variations in distributions of OBAs, limitations in the number of samples taken, and limitations to the methodologies used all can cause an underestimation of the presence of OBAs. Additional studies to continue to monitor for the possible presence of OBA's is recommended to fully understand the presence of OBAs as an indicator of potential septic leachate in the Clearwater Watershed.

E. coli sampling

E. coli samples were collected at various locations in Seeley Lake in 2021. Table 1 shows lists the results of this sampling.

	E. coli Results (cfu/100ml)					
Collection Date	S Bay	SLCG	Tamarack's	Ranger Station	RPCG	BLCG
6/7/2021	1	1	0	11	2	0
7/22/2021	27	7	25	6	2	6
9/1/2021	2	0	2	15	0	1
9/21/2021	1	1	1	1	1	0
10/19/2021	0	0				

Table 1. Results of E. coli sampling in Seeley Lake in 2021.

The highest E. coli result occurred at the South Bay site on July 22, 2021. This test showed an E. coli count of 27 cfu/100ml. This result (and therefore all the results) falls below the MT-DEQ threshold of 126 cfu/100ml.

Discussion

The lake sampling conducted in 2021 and 2022 established a number of baseline conditions for water quality parameters across the six lakes included in the analyses. The findings generally supported that the lakes are all in an oligotrophic to mesotrophic condition with most lake parameters consistent with natural lakes in these conditions. Some exceptions to this were found.

Dissolved oxygen (DO) readings decreased in deeper waters of all lakes as the summer progressed, with all lakes dropping below 5 mg/L in the hypolimnion by fall. Big Sky Lake had low DO levels in its deeper areas throughout the year. Nutrient sampling of the lakes generally found acceptable levels of total nitrogen and phosphorous. Higher levels of nutrients were found in deeper samples than in surface samples. Big Sky Lake stood out as a potential concern. In 2022 nitrogen levels in two samples of surface water were 374 ug/L and 402 ug/L, while deep samples recorded 1700 ug/L and 1860 ug/L. An interesting finding for Seeley Lake was in samples collected at the outlet of the lake, where consistently higher levels of nitrogen and phosphorous were found. This outlet is at the end of the relatively shallow and narrow still water section of the Clearwater River. Causes for this increase are not known, but the shallow waters slowly flowing through this area with the presence of cabins along the shore may be a factor.

Sampling for whitening agents and E. coli in Seeley Lake did not show results of significant concern for septic leachate. This does not mean that septic leachate is not entering the lake, given the limited number of samples taken and the various sources of variation that can influence results, but it does indicate that no high levels of leachate could be detected.

Sampling results for chlorophyll and blue-green algae were all found to be in relatively low levels. Only a few samples were found to have levels greater than 1.0 RFU for either measurement, and most of the higher levels were found in deep samples from the lakes. While algal blooms have been noted in several of the lakes over recent years, the sampling that was conducted did not find clear indictors of locations or times when conditions may be contributing to these blooms.

Because the sampling of nutrients across the 6 lakes was quite limited for some lakes and varied across sampling dates, more sampling of nutrients is needed to establish a thorough baseline for water quality conditions. Additional nutrient sampling is planned for 2023, and should provide additional insights into the condition of the lakes.

Natural Resource and Public Benefits of Water Quality Monitoring

The Clearwater Valley has a unique set of lakes that serve a variety of beneficial values. The economic importance of all six lakes is undeniable. They are the hub of recreational opportunities including fishing, swimming, and boating. Seeley Lake is the center of economic activity for a town of over 2,000 people. The six lakes in this study also serve important cultural and environmental functions. The watershed has unique cultural values to both the Confederated Salish and Kootenai Tribes and the Blackfeet Nation who referred to this area as the “backbone of the world.” The landscape and the species that reside on it rely on the watershed to maintain balance and health. From the endangered bull trout and iconic grizzly bears to the residents of Seeley Lake, protecting the water for generations to come is of paramount importance. Furthermore, the Clearwater Watershed sets in the Southern end of the Crown of the Continent group of pristine watersheds surrounded by wilderness areas.

Supporting Documents

To view supporting documentation, go to: http://crcmt.org/adoptalake-program
2021 Sampling and Analysis Plan (SAP)
2022 Sampling and Analysis Plan (SAP)
2021 Monitoring Montana Waters Final Report

Literature Cited

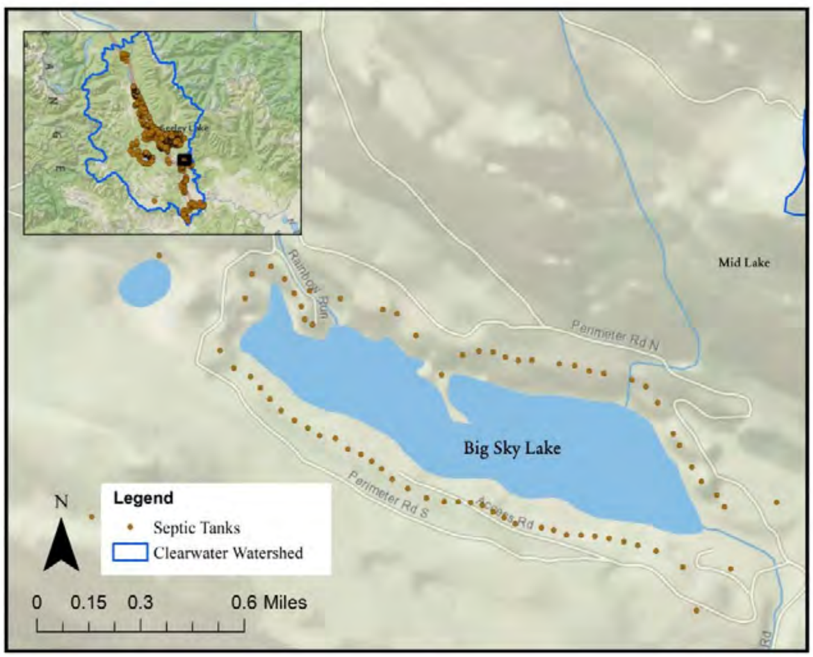
Bellinger, E.G. and D.C. Sigee. 2010. Freshwater Algae: Identification and Use as Bioindicators. Wiley-Blackwell, West Sussex.

Gary L. Larson (2000) Chlorophyll Maxima in Mountain Ponds and Lakes, Mount Rainier National Park, Washington State, USA. Lake and Reservoir Management 16:4 333-339.

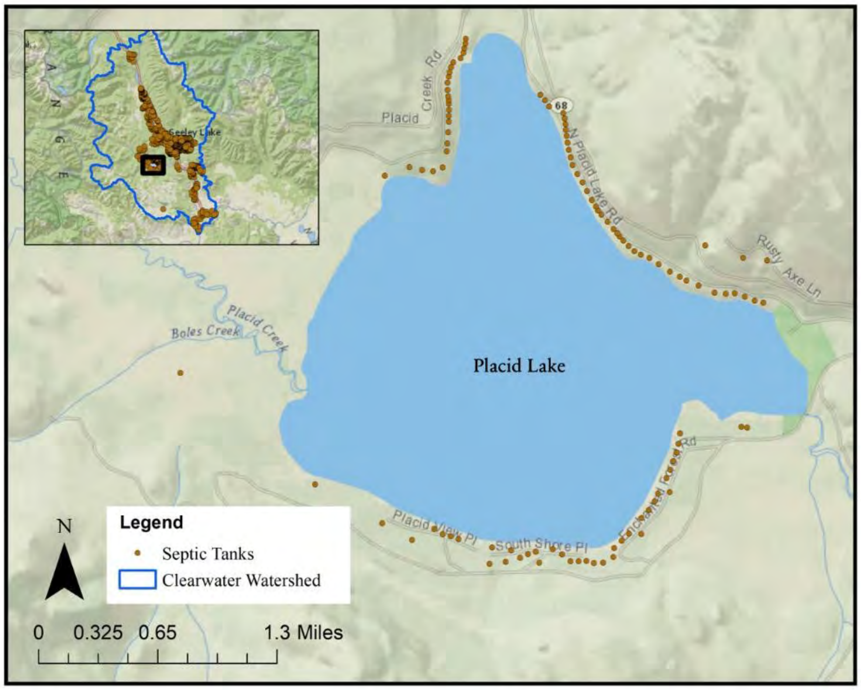
Appendix

Maps of Septic System Densities

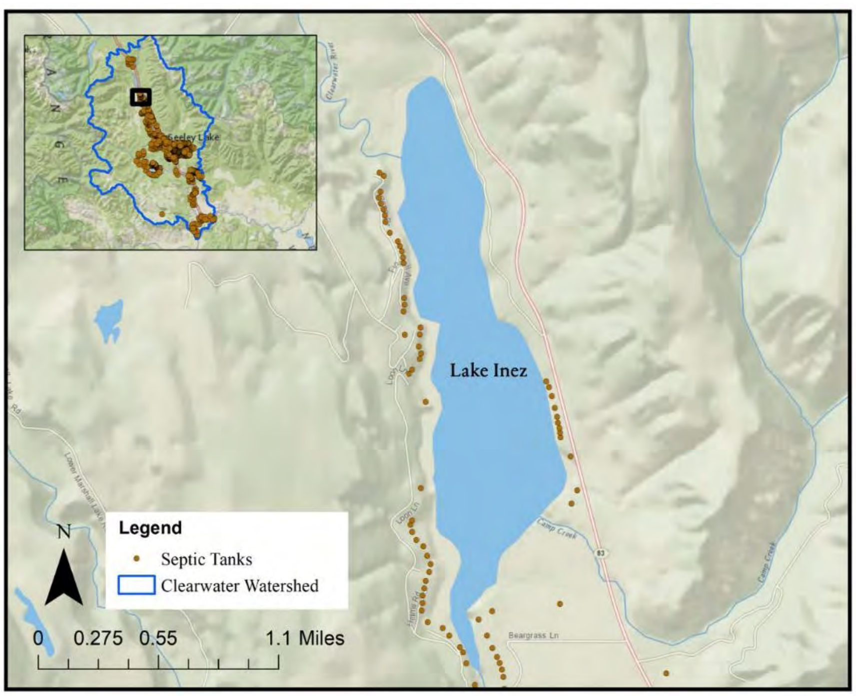
Big Sky Lake



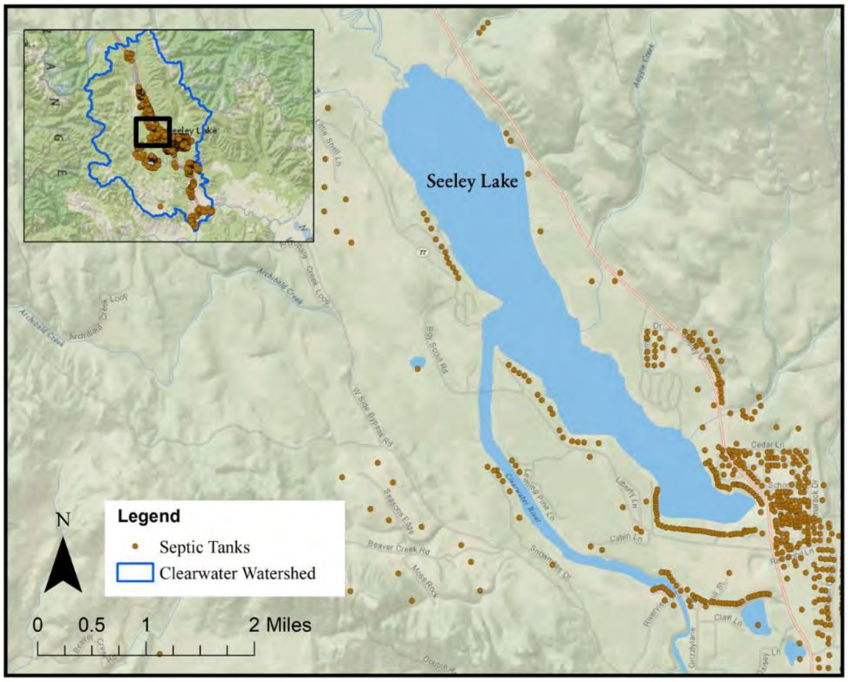
Placid Lake



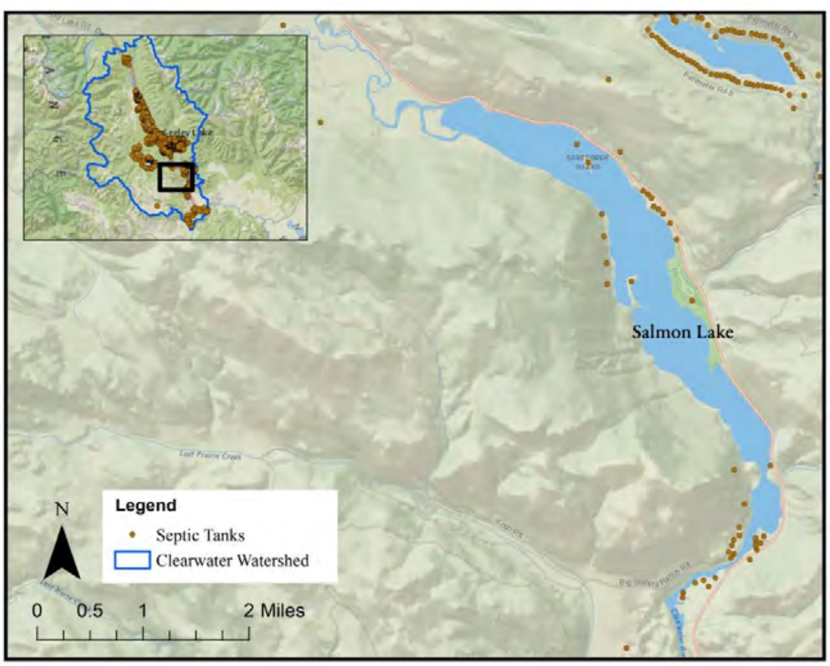
Lake Inez



Seeley Lake



Salmon Lake



Note: There are no septic systems on Lake Alva.

Sample Site Locations

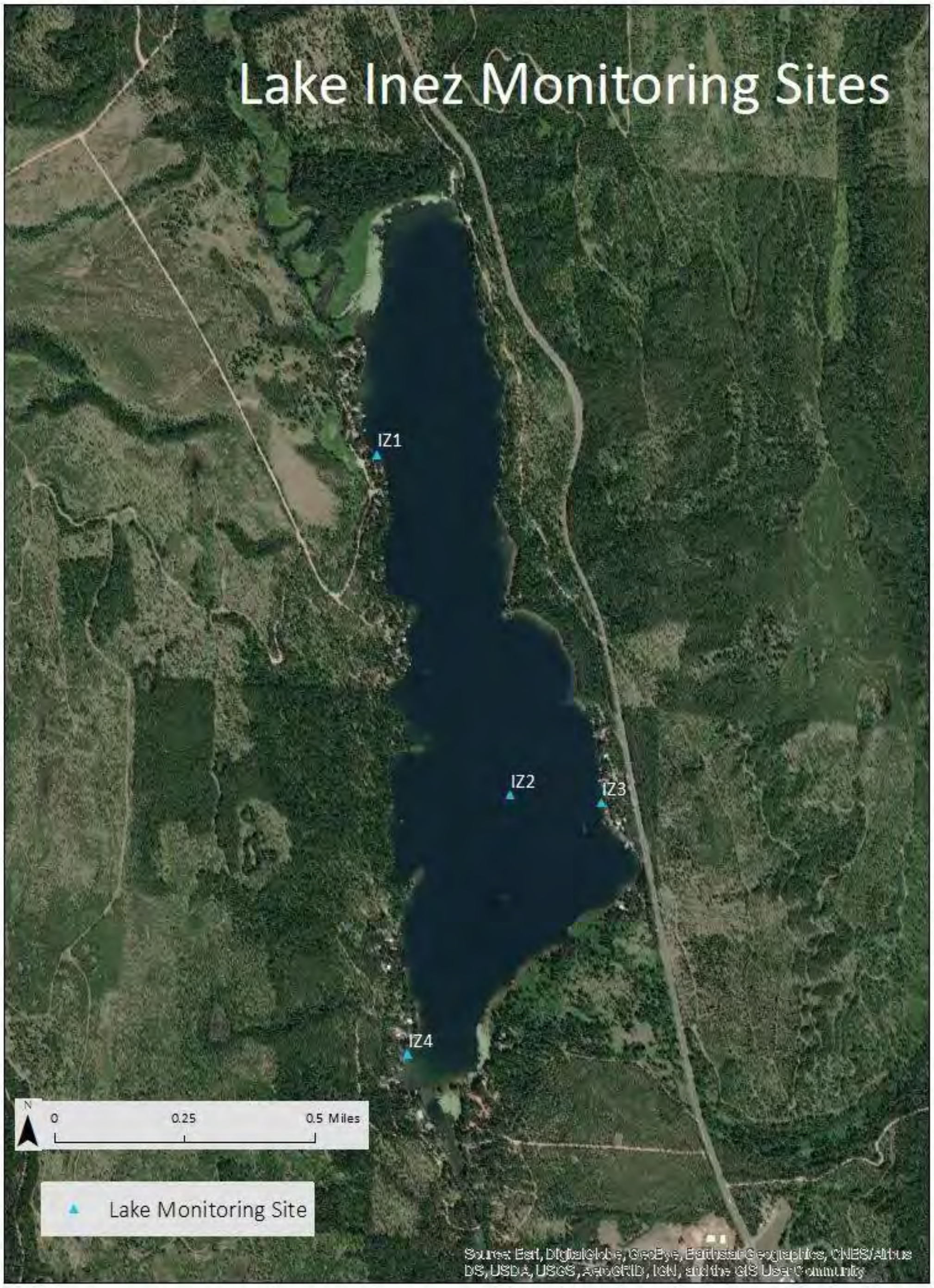
Big Sky Lake

Big Sky Lake Monitoring Site
BS1
0
0.25
0.5 Miles
Lake Monitoring Site
SA4
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Lake Alva

Lake Alva Monitoring Site
AL1
0
0.5
1 Miles
Lake Monitoring Site

Lake Inez


Lake Inez Monitoring Sites
IZ1
IZ2
IZ3
IZ4
N
0
0.25
0.5 Miles
Lake Monitoring Site
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Placid Lake

Placid Lake Monitoring Sites
PL3
PL1
PL2
PL4
N
0
0.5
1 Miles
Lake Monitoring Site
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Salmon Lake

Salmon Lake Monitoring Sites
BS1
SA5
SA4
SA2
SA3
SA1
N
0
0.5
1 Miles
Lake Monitoring Site
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

2022 Seeley Lake Sampling Locations