

# 2024 Report on the Health of the Norway Lakes

Prepared by Stephan Zeeman, Ph.D.

Water Quality Team: Paul Shook, Jim O'Brien, Jeanne Silverman

March 20, 2024

## Table of Contents

Overview .....	1
Explanation of Measurements .....	2
Lake Comparisons .....	4
Hobbs Pond .....	7
Sand Pond .....	11
Pennesseewassee .....	14
North Pond .....	17
Methods .....	19
Appendix 1 .....	22

## Overview

This year's annual report will focus more on each lake for 2024. To find more of a historical look at trends since the monitoring began, please look at last year's report on the LAON website (<https://norwaylakes.org/wp-content/uploads/2024/09/2023-Water-Quality-Report.pdf>).

Table 1 Secchi depth, Total Phosphorus and Chlorophyll concentrations for 2024 compared to 2023 and the historical average for the four lakes. Data are presented for the seasonal average of the past two years and the long-term average.

Lake	Average 2024 (2023)					Historical Avg (1976-2023)*							
	Secchi (m)	Avg P (ppb)	P Surf (ppb)	P Bot (ppb)	Chl-0m (ppb)	Secchi	Avg P	P Surf	P Mid**	P Bot	Chl-0m	Chl Cores**	
Sand Pond	6.83 (7.12)	9.1 (8.9)	3.8 (3.8)	14.4 (14)	1.74 (2.6)	7.37	8.41	3.91	5.8	15.33	1.66	2.58	
Little Pennesseewassee	5.51 (4.88)	16.5 (14.12)	3.75 (7.5)	35.4 (20.5)	2.22 (3.0)	5.45	13.43	8.13	9.59	22.79	2.48	4.31	
Pennesseewassee	5.4 (4.27)	9.8 (15.4)	6.2 (8.4)	13.4 (22.4)	2.82 (4.6)	5.72	10.1	8.37	8.73	14.17	3.32	4.45	
North Pond	2.99 (3.1)	19.5 (13.7)	19.86 (13.17)	18.67 (NA)	6.65 (4.0)	2.93	17.52	16.57	17.65	22.46	5.18	6.06	
Secchi - higher number is better			2024 Average vs Historical Average										
P - lower number is better			Improved										
			Worsened										
			Less than 1 unit change										

\* Historical data through 2018 can be found through : <https://www.lakesofmaine.org/index.html?r=1681319726>

\*\* Prior to 2018 samples were often collected with a "core" (a hose) that extended from the surface to the thermocline (rapid change in temperature) in order to obtain an upper water layer average.

The average (surface and bottom) phosphorus concentrations were higher compared to last year in three of the lakes. The exception was Lake Pennesseewassee, which dropped relative to the high

levels experienced in the previous two years, along with reduced algal concentrations. In comparison to the 1976-2023 averages, Sand Pond and Norway lake remained the same, while Hobbs and North Ponds had higher P levels. Cyanobacteria remained a concern in Hobbs Pond, but surface P levels were half the historical values, and the increase in the average was due to bottom concentrations. Sand Pond conditions remained unchanged relative to last year and the historical data. North Pond saw increases in both P concentrations and algal Chlorophyll.

## Explanation of Measurements

Source:

<https://www.lakesofmaine.org/data/Explanation%20of%20Individual%20Lake%20Water%20Quality%20Report.pdf>

**SECCHI DISK TRANSPARENCY AND GRAPHS:** Secchi Disk Transparency (SDT) is a measure of the water clarity, or transparency, of the lake. All Secchi disk readings are in meters [1 meter (m) = 3.28 feet]. Factors which reduce clarity, are algae, zooplankton, water color and silt. Since algae are generally the most abundant, measuring transparency indirectly measures algal productivity. SDT readings can be used to track changes in water quality over time. Transparency values in Maine vary from 0.2m (8 inches) to 21.27m (70 ft), with the overall average being 4.83m (15.8 ft). Unless a lake is highly colored (see explanation of color below) or some other factor interferes, a transparency of less than 2m (6.6 ft) indicates a water quality problem that has resulted in an algal bloom. In Maine, the mean (average) SDT readings are related to algal productivity using the following guidelines: Productive or Eutrophic=4m (13 ft) or less; Moderately productive or Mesotrophic=4.1-7.9m (13-26.5 ft); Unproductive or Oligotrophic=8m (26.5 ft) or greater.

**COLOR:** The amount of “color” in a lake refers to the concentration of natural dissolved organic acids such as tannins and lignin’s, which give the water a tea color. Color is measured by comparing a sample of the lake water to Standard Platinum Units (SPU). Colored lakes (>30 SPU) can have reduced transparency readings and increased phosphorus values. This does not mean the lakes are more productive, the color simply interferes with the test so better results can not be achieved. Chlorophyll a (Chla) is the best indicator of productivity in colored lakes and should be used if possible. Color varies from 1 to 630, with the average in Maine being 28 SPU.

**pH:** The pH of a lake reflects how acidic or basic the water is and helps determine which plant and animal species are present. The measure of the acidity of water is based on a scale of 1-14, with 7 being neutral. Acid waters are below 7; alkaline waters are above 7. Epilimnetic pH varies, from 4.23 to 9.70, the average being 6.81. A one unit change in pH represents a 10 fold change in acidity or alkalinity.

**ALKALINITY:** Alkalinity is a measure of the capacity of water to neutralize acids and is also known as the buffering capacity. It is due primarily to the presence of naturally available bicarbonate, carbonate, and hydroxide ions, with bicarbonate being the major form. Epilimnetic alkalinity in Maine varies from -1.5 milligram per liter (mg/l) to 190.0 mg/l, with the average being 12.0 mg/l.

**CONDUCTIVITY:** Conductivity is a measure of the ability of water to carry an electrical current and is directly related to the dissolved ions (charged particles) present in water. Epilimnetic conductivity varies from 2 umhos/cm to 7900 us/cm, with the average being 46 us/cm. Fishery biologists use conductivity values to calculate fish yield estimates. Conductivity will increase if there is an increase of pollutants entering the lake or pond.

**TOTAL PHOSPHORUS MEANS (ppb):** Total Phosphorus (TP) is one of the major nutrients needed for plant growth. It is generally present in small amounts and limits the plant growth in lakes. It is measured in parts per billion (ppb). As phosphorus increases, the abundance of algae also increases. Epilimnetic TP varies from 1 ppb to 426 ppb with the average being 12 ppb. EPI Core = Epilimnetic core sample (mixed sample from epilimnion) was taken; Surf Grab = Surface grab sample taken; Bot. Grab = Bottom grab sample taken (1 m above bottom of lake), PRO. Grab = Profile grab samples taken and averaged.

**CHLOROPHYLL A (ppb):** CHLOROPHYLL A (Chla) is a measurement of the green pigment found in all plants including microscopic plants such as algae. It is used as an estimate of algal biomass, the higher the Chla number the higher the abundance of algae in the lake. Epilimnetic Chla, varies from 0.10 ppb to 238 ppb, with the average 5.3 ppb. MIN. = minimum or lowest Chla depth recorded for that year. Summary would have the lowest Chla reading ever recorded for that lake. MEAN = Average Chla reading for that year. Summary would be average of the data for all years. MAX. = Maximum or highest Chla reading taken for that year.

**TROPHIC STATE INDICES:** The Trophic State Index (TSI) is a scale which ranks lakes from 0 to 100+ with 0 supporting very little algae and 100+ being very productive. TSI can be calculated from the Secchi disk, Chla or total phosphorus results. TSI for a year is only calculated when there are at least five months of data. Lakes with TSI values greater than 60 may support blooms (less than 2m SDT). Lakes with TSI values over 100 indicate extreme productivity and annual algal blooms. TSI values can be used to compare lakes and track water quality trends within a lake. Lakes with color over 30 SPU will only have a valid TSI if the value is calculated from Chla. The range of TSI is from 5-136 with an average of 45. EPI PHOS = Epilimnetic Phosphorus samples taken to determine the TSI; C = core G = grab samples taken; SEC = TSI value calculated using the mean Secchi disk (water color < 30 SPU to ensure valid TSI); CHL = TSI calculated using the mean Chla. For an in depth explanation of these indices see <https://www.nalms.org/secchidipin/monitoring-methods/trophic-state-equations/>. A table of Trophic State and possible changes which may occur in a lake is shown in [Appendix 1](#).

Caveat: The TSI is often misinterpreted and/or misused from its original purpose, which is simply to describe the level of biological productivity. It is not meant to rate a lake's water quality. For example, higher TSI values represent lakes that support an abundance of algae, plants and wildlife. If you love to fish, this type of lake would not be considered to have "poor" water quality. However, if you are a swimmer or water skier, you might prefer a lake with lower TSI values.

**LATE SUMMER TEMPERATURE / DISSOLVED OXYGEN PROFILES:** Dissolved Oxygen (D.O.) is the measure of the amount of oxygen dissolved in the water. All living organisms, except for certain types of bacteria, need oxygen to survive. Organisms living in the water can use the oxygen dissolved in the water to breathe. Too little oxygen severely reduces the diversity and population of aquatic communities. Therefore, the amount of D.O. in the water is very important to aquatic life.

Low oxygen can directly kill or stress organisms such that they will not be able to successfully reproduce or grow. Water with less than 1 part per million (ppm) of oxygen is considered anoxic (no oxygen present); less than 5 ppm of oxygen is generally considered so stressful that most coldwater fish will avoid these areas. Anoxic conditions can also promote TP release from sediments.

Temperature is the measure of heat in the water and can affect the water’s chemistry and biology. For example, the amount of oxygen water can hold is directly related to the temperature of the water. The higher the temperature the less oxygen the water can hold. Oxygen will naturally decline during the summer months as water temperatures rise. Lakes deeper than 25-30 feet can also stratify, with warm water riding over cooler deep water, restricting circulation in the lake. This can contribute to oxygen loss in the lower waters. Temperature can also determine the kinds of plants and animals found in the lake or pond. Certain species of fish, insects and algae will predominate during the cooler temperatures of the spring and fall yet disappear during the warmer temperatures of summer. For instance, salmonids generally prefer temperatures below 18°C (65°F) but can tolerate slightly higher temperatures for short periods of time. However, constant exposure to temperatures greater than 18°C (65°F) may result in some fish being more susceptible to disease or not being able to reproduce as well. Conversely, other more tolerant species will predominate during the more stressful summer months. The late summer temperature and dissolved oxygen profiles in data report represent the lake’s most stressed open water period. m = Depth data was recorded, in meters; °C = Temperature in degrees Celsius; Date is sampling date; ppm = Dissolved oxygen reading in parts per million (ppm).

## Lake Comparisons

Over the 2024 season Secchi depth improved (became deeper) in all lakes except Hobbs Pond which is only 3 m deep and does not vary significantly (Figure 1). Sand Pond had the clearest water and all the lakes were in the expected range.

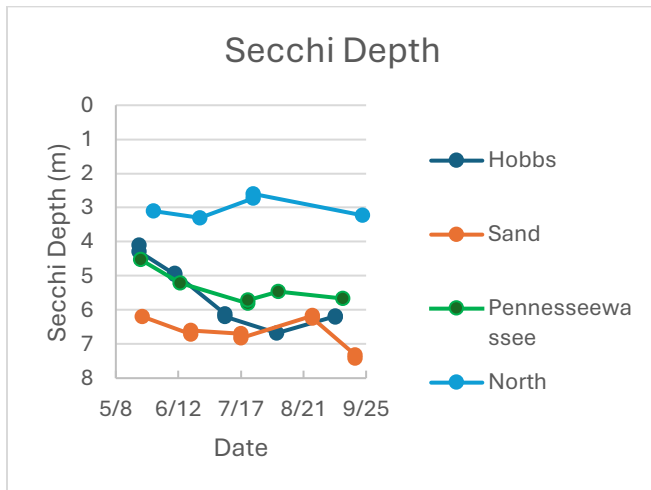


Figure 1 Secchi depth for 2024.

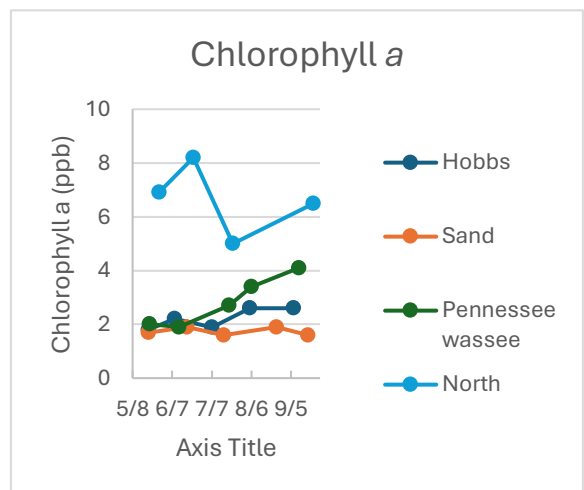


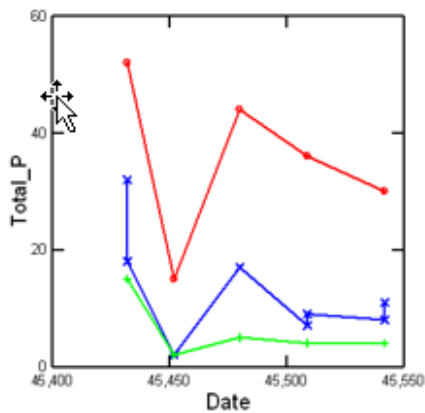
Figure 2 Chlorophyll a for 2024.

Chlorophyll a values were the highest in North Pond (Figure 2). These were higher than last year and higher than the historical average. The other lakes were within the expected range. The increase in

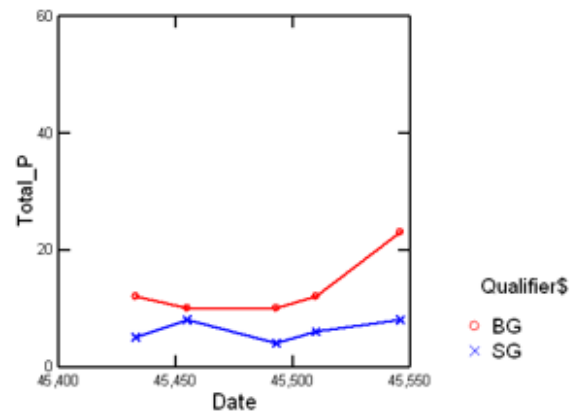
chlorophyll toward the end of the season in Hobbs and Pennesseewassee seems to contradict the increased Secchi depths, but this could be due to other particulates in the water early in the season, such as pollen.

Total phosphorus concentrations are shown in Figure 3. Phosphorus was highest in Hobbs Pond and lowest in Sand Pond. Paul Shook sampled additional depth for phosphorus, taking samples not only at the surface and bottom, but also at 3 and 6 m which are shown as PG in the graph. These values are higher than at the surface and lower than at the bottom, which is typical of most lakes. In Hobbs the values were initially high but decreased as the season progressed. The dip in values in June for Hobbs Pond is suspect, and it is our feeling that these values were higher. In the other lakes, the values at a particular depth seemed to be steadier, with some increase in the bottom in both Pennesseewassee and Sand Pond. Phosphorus levels in the lakes were comparable to the historical values observed in the lakes, except for bottom water in Hobbs Pond and the concentrations in North Pond which were higher than expected.

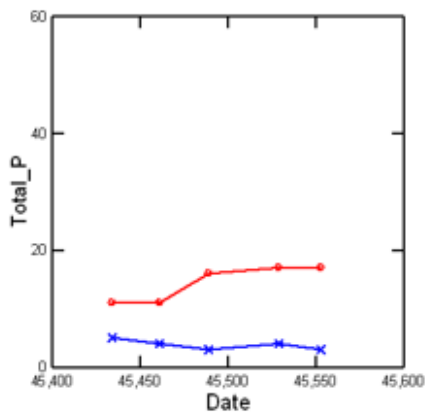
Lake\$ = Little Pennesseewassee



Lake\$ = Pennesseewassee (Norway)



Lake\$ = Sand Pond



Lake\$ = North Pond

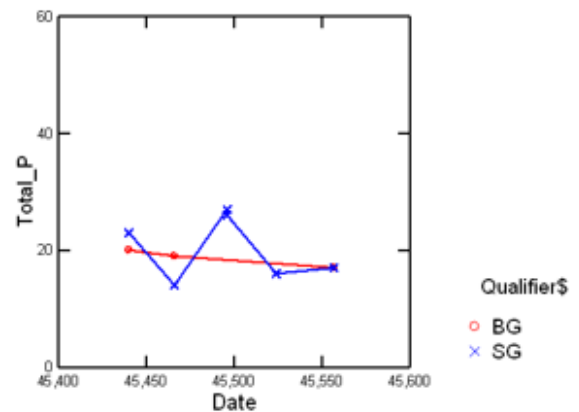


Figure 3. Total phosphorus concentrations during 2024. SG = surface grab, PG = profile grab (middle of the water column), BG = bottom grab.

Trophic state based on Secchi depth, Chlorophyll, and Total Phosphorus are shown in Table 2. TSI(SD) is not calculated for North Pond due to its shallowness (the Secchi disk hits the bottom before it can't be seen anymore). TSI(Chl) is probably the most reliable estimate of Trophic Status because Chlorophyll is a measure of biomass, while Phosphorus and water clarity may not be.

Table 2. Trophic Status Indices for the four lakes, based on Secchi Depth, Chlorophyll, and Phosphorus concentrations.

Lake	TSI(SD)	TSI(Chl)	TSI(Tpavg)	TSI(Tpsurf)
Hobbs	35	38	45	23
Sand	32	36	36	23
North		49	47	47
Penn	36	41	37	30

According to the criteria shown in Appendix 1, Sand Pond might be considered Oligotrophic, while the other three lakes are considered Mesotrophic. Oligotrophic less than 40, Mesotrophic 40-50, Eutrophic greater than 50.

We want to note that in 2024 we changed our sampling methods for Alkalinity and Water Color. The new methods are more in line with what other lake monitors are using, making them more comparable.

Alkalinity is now measured with a titration technique and Color of Water is measured with a Hach color comparator disc. See Methods section for details on the methodology.

Water color is derived from dissolved and particulate matter in the water. The tea coloration of our lakes is due to tannins, which are the breakdown products of organic matter like leaves. Other colors can be due to particles such as clay or algae suspended in the water. Color can also be a result of reflection of the sky off the water, causing it to look blue. Highly colored water may decrease the amount of photosynthesis by algae and can affect ecosystem functioning. Important here is that there have been recent studies showing color values increasing due to changing climates (<https://phys.org/news/2022-09-climate-lakes-blue.html>). The implication is that ecosystems may be undergoing changes because of this.

Apparent color is that which is seen by the naked eye, true color is that which is due solely to dissolved substances. In 2024 we switched our methods to measure true color, by filtering the sample prior to measurement. The results are recorded as Platinum Cobalt Color Units (Figure 4). All samples tested were less than 50 PCU except for one bottom sample in Sand Pond which reached 80 PCU.



Figure 4. Platinum Cobalt Color Unit scale.

## Hobbs Pond

Hobbs Pond appears to be continuing its recovery trend. We say appears because it is still unclear. Surface water Total Phosphorus dropped from 7.5 ppb in 2023 to 3.75 ppb in 2024. However average bottom water concentrations rose by 15 ppb over 2023 and were 12.6 ppb above the 1976-2023 bottom water average. The surface and bottom water concentrations are shown in Figure 5. Hobbs Pond surface concentrations were similar to those of Sand Pond, our best lake in terms of water quality. The values of both surface and bottom started off high early in the season but followed a downward trend into September. As pointed out earlier, the lower values in June were not consistent and are suspect. The decline during the season might be an indication that P is being flushed from the system and is different from other lakes which see increases of bottom P during the season. It does not seem to be related to oxygen levels in the bottom waters, which, if anything, should increase concentration due to the decreasing DO values throughout the season (Figure 6).

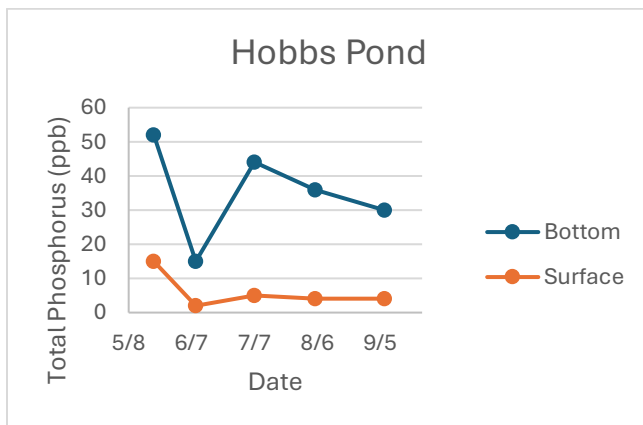


Figure 5. Total phosphorus concentrations during 2024 at surface and bottom.

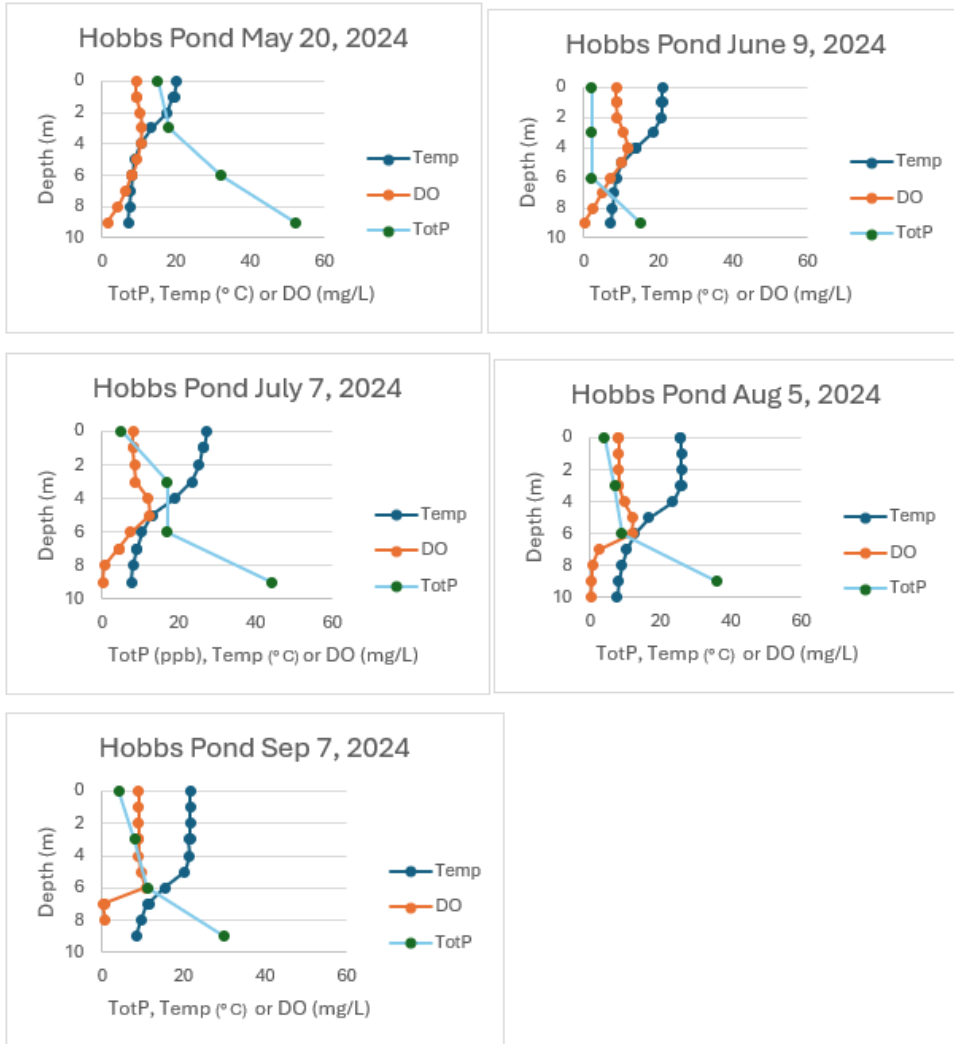


Figure 6 Water column profiles of Total Phosphorus, temperature and Dissolved Oxygen.

The profiles shown in Figure 5 clearly depict the deepening of the thermocline (a rapid change in temperature) which separates the surface and bottom water during the season and the decreasing oxygen content of the bottom water. You can also see the higher DO at the thermocline, an indication that algal growth is occurring at this interface where there is sufficient light for photosynthesis and ample nutrients derived from the lower water column. It is possible that this deep algal layer is helping to lower the concentration of phosphorus in the bottom water. If true, this phosphorus will end up settling to the bottom.

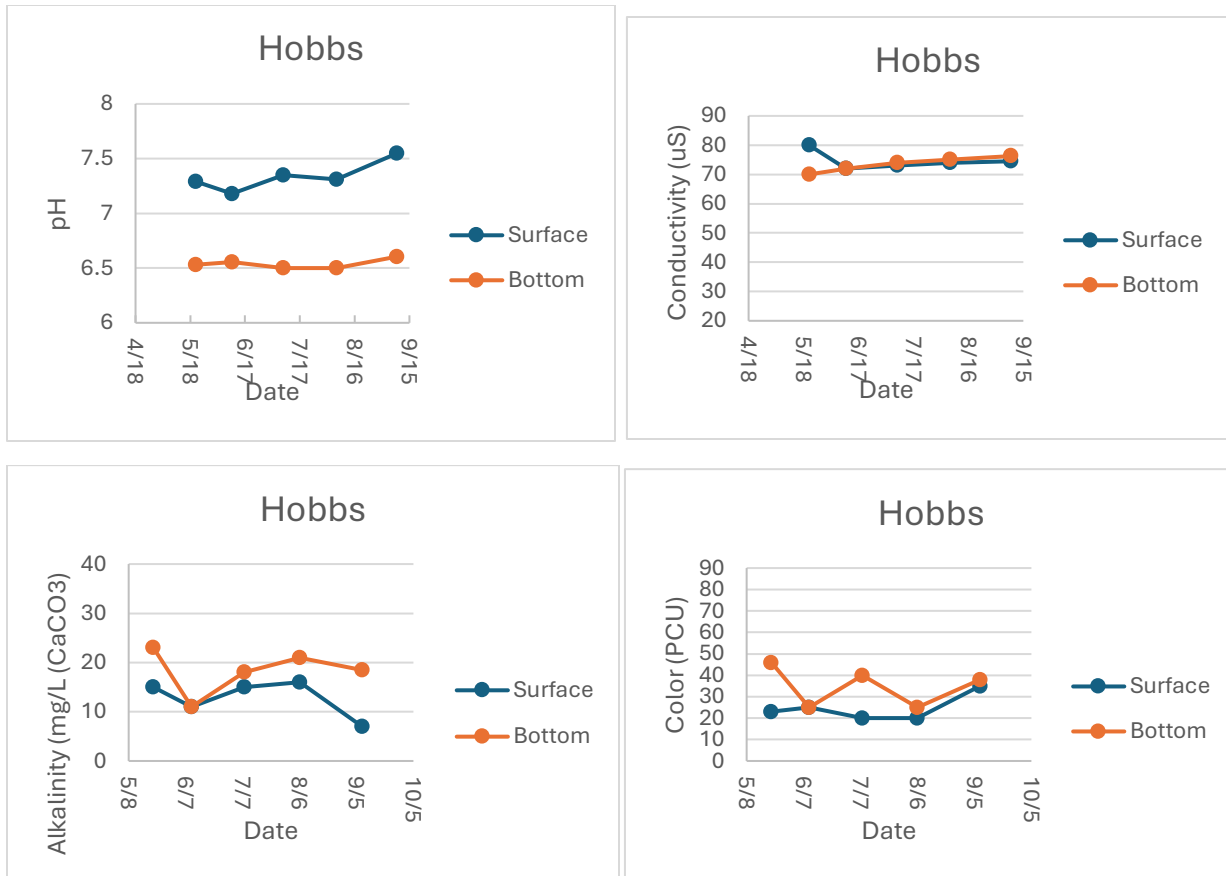


Figure 7. The 2024 seasonal pH, Conductivity, Alkalinity, and water color in Hobbs Pond.

The trends for pH, Conductivity, Alkalinity and color of water are shown in Figure 6. All are within expected ranges. The pH of the bottom water is slightly more acidic than the surface and is expected due to decomposition of organic matter in the bottom layer. The pH is important because pH values above 9 or below 6 are important regarding which organisms can survive.

Conductivity remained relatively constant throughout the summer. The values are in a good range as most surface waters are between 100 and 10,000  $\mu\text{S}$ . In comparison melted snow ranges between 2 and 42  $\mu\text{S}$ .

Alkalinity is a measure of how much acid can be neutralized by the water and is mostly derived from minerals in the local geology. In our region the rocks are mostly weather-resistant granites which lead to low alkalinity. Changes in alkalinity are also associated with changes in pH, among other things. The values in Hobbs Pond are well within the range of typical surface waters, 20-200 (mg/L  $\text{CaCO}_3$ ).

The Color of Water measurements were at the lower end of values, never exceeding 50 PCU.

The cyanobacterial blooms have continued since 2021 to varying degrees of intensity. Paul Shook has done extraordinary work in following this problem. He has documented the appearance of the cyanobacteria over time (Figure 8). Paul also did extra phosphorus sampling this year. He sampled stream inflows into Hobbs Pond on five dates (Figure 9). Samples were collected from the edge of

the lake in the stream inflows as well as some locations at critical points upstream. The phosphorus concentrations are shown in Figure 10. As expected, concentrations varied with stream flow magnitude. The greatest amount of phosphorus came in on the North side through sites 2 and 3. Additional high phosphorus levels are found at sites 7 and 9, although the flow rates are smaller than at sites 2 and 3, thus the total impact is smaller on lake phosphorus.

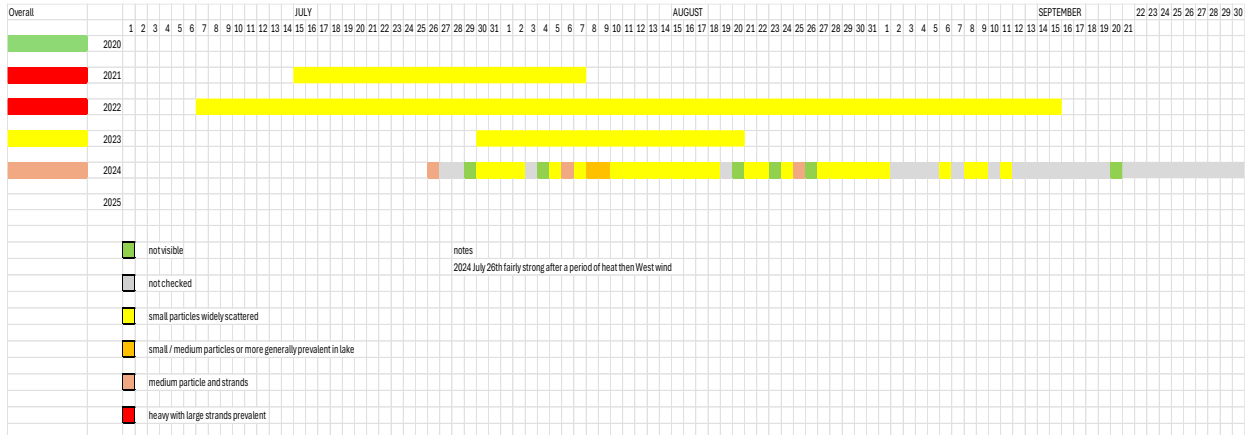


Figure 8. Appearance of cyanobacteria in Hobbs Pond over the period of 2021-2024.

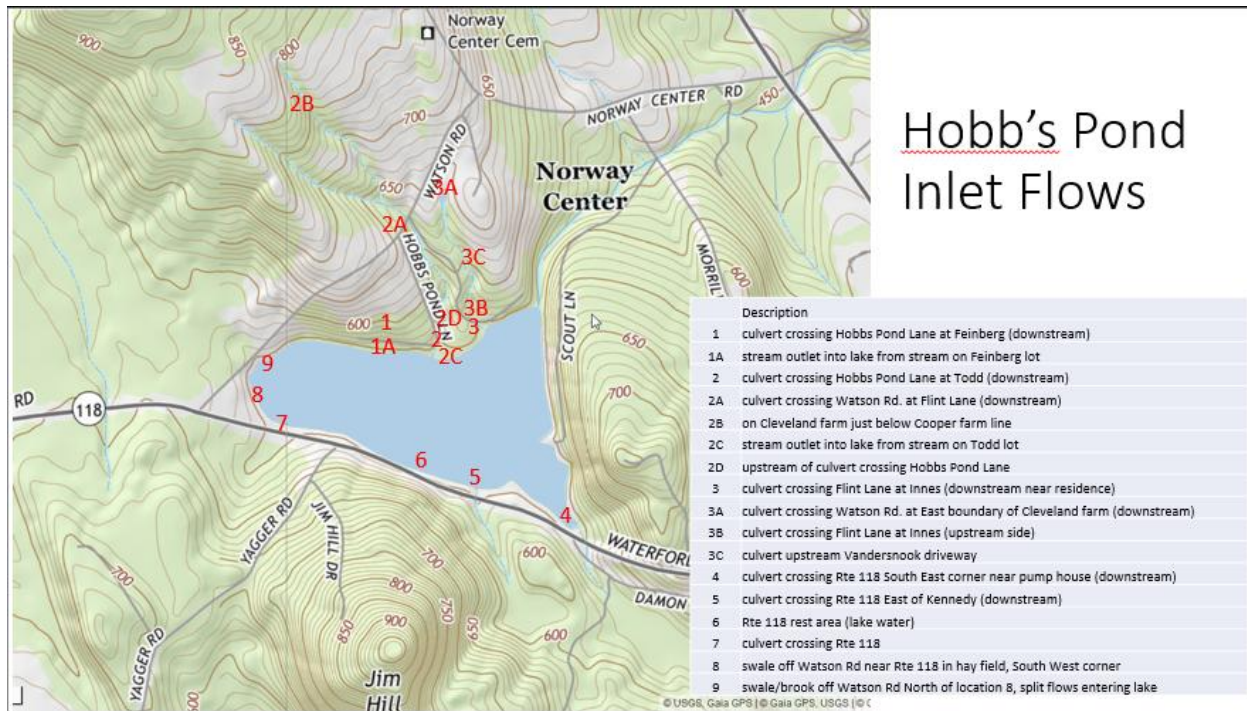


Figure 9. Sampling locations for phosphorus in inflow streams.

Figure 10 also shows results of sampling the presence or absence of DNA in streams leading to Hobbs Pond on two dates. We tested specifically for human and cow DNA, as well as for E. coli (bacterial indicators of fecal matter from warm-blooded animals). These were tested because they are all potential sources of phosphorus to the lake through direct contact or being carried by

inflowing stream water. The results were negative for human DNA, but did show cow DNA. E. coli bacteria were also detected at sites 2 and 3.

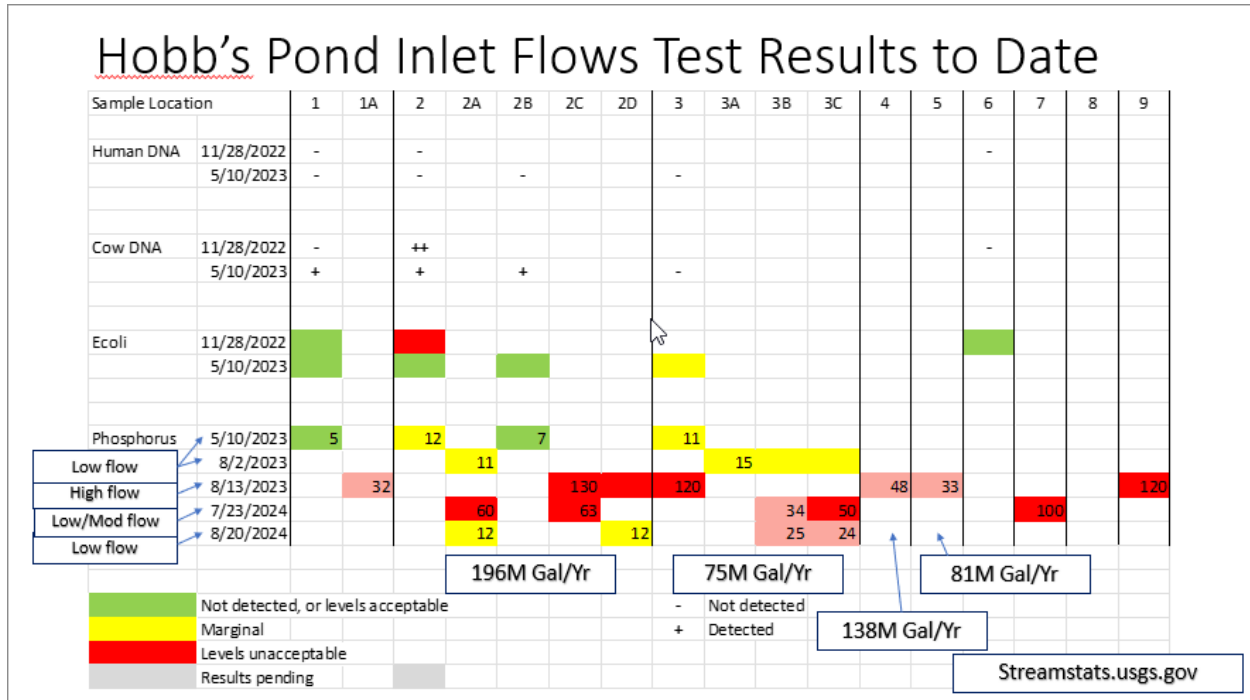


Figure 10. Phosphorus concentrations at various inflow streams. Also shown are results of presence or absence of DNA. The flow rates for several of the streams are shown in the boxes at the bottom.

We will continue to monitor both the lake phosphorus levels as well as that of the inflowing streams. Our work in watershed management has led to the identification of erosion problem areas which we are hoping to address through grant funding.

## Sand Pond

Sand Pond remains as the lake with the best water quality in the area. Not much has changed since last year and levels are also comparable to historical values (Table 1). Average surface phosphorus concentrations were around 4 ppb while at the bottom it was close to 14.5 ppb (Figure 11). At the surface there was a slight decline in P concentrations during the season, but the bottom saw a larger increase. This increase is probably due to the sediment-water interface face becoming anoxic (devoid of oxygen). Note the decline of oxygen levels in Figure 12 from near 4 on June 18, to 1.2 on July 16 at the bottom of the lake. The DO effectively becomes zero three meters above the bottom for the rest of the summer. The low oxygen allows phosphorus trapped in the sediments to be released into the water column.

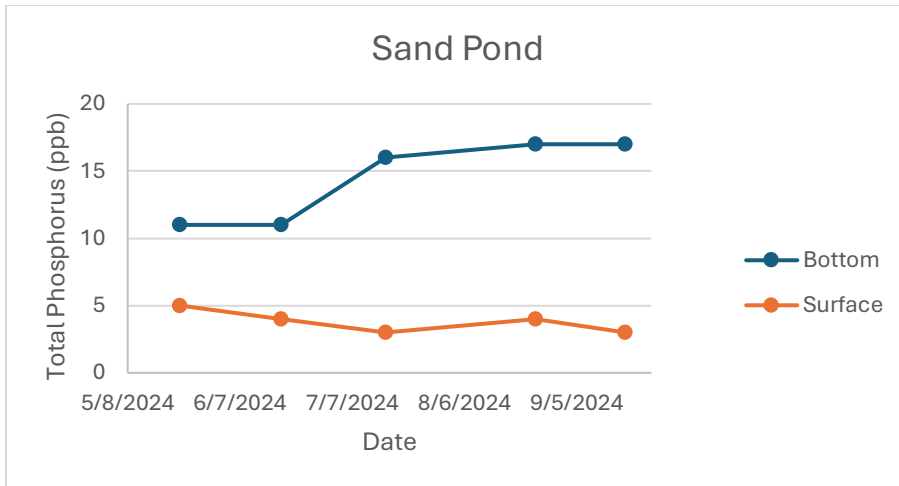


Figure 11. Surface and bottom Phosphorus concentrations during 2024.

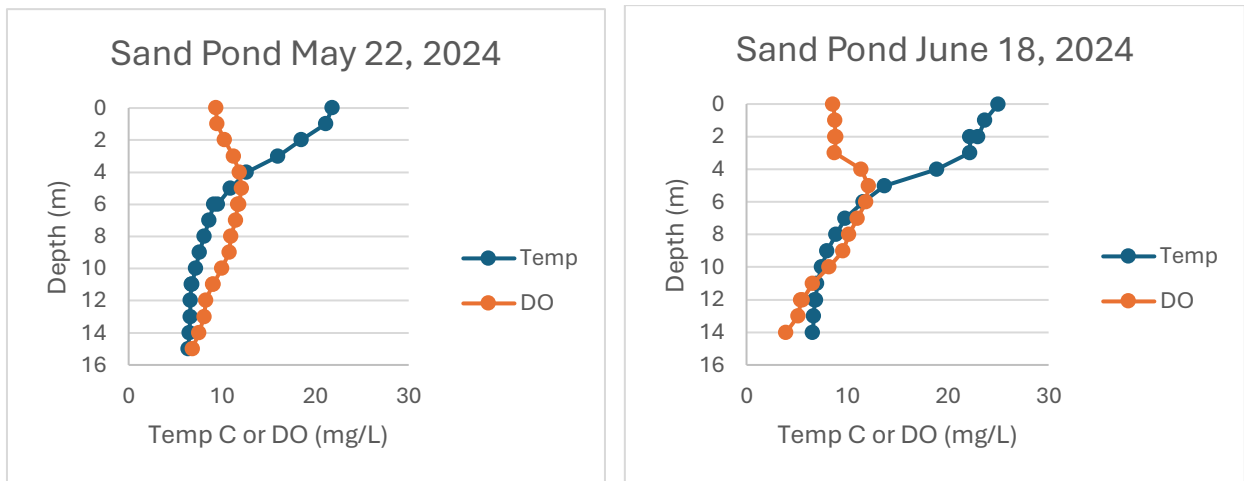
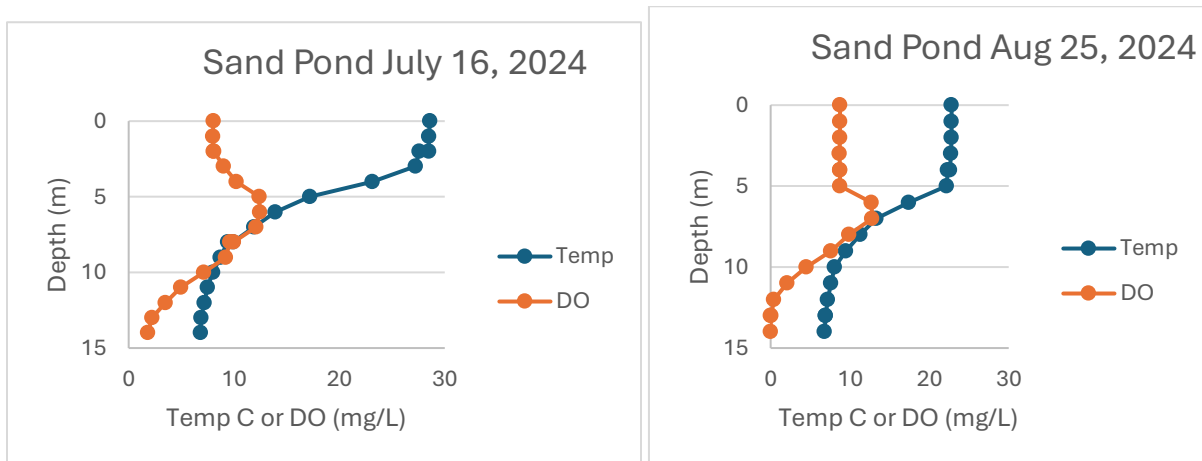


Figure 12. Dissolved Oxygen and temperature profiles in Sad Pond.



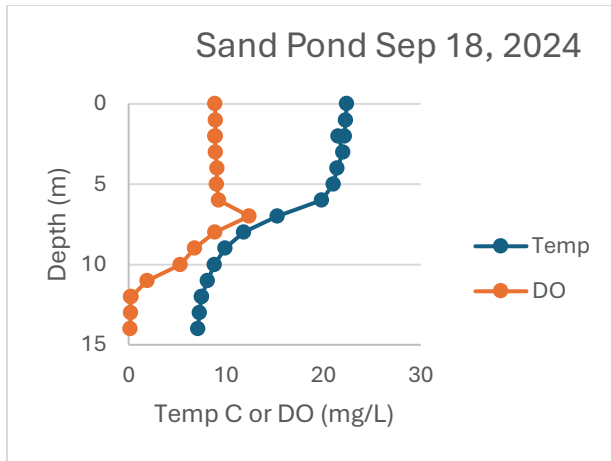


Figure 12 continued. Dissolved Oxygen and temperature profiles in Sad Pond.

The pH of the surface waters was between 7 and 7.5, typical of lakes (Fig 13). The bottom, as expected, was slightly acidic between 6.2 and 6.9, which is also typical of lakes due to organic matter decomposition in the deeper water. The conductivity of the lake is relatively low, near 30  $\mu\text{S}$  (Fig 13).

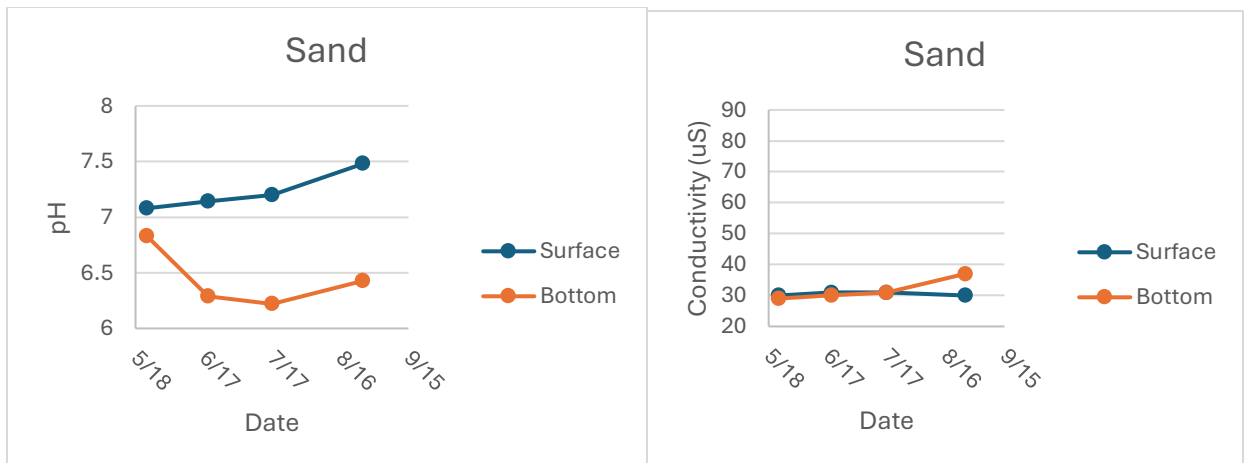


Figure 13. pH and conductivity in San Pond.

This is a good result since the low conductivity reflects no road salt getting into the lake, unlike some of our other lakes.

Water color in our lakes is usually caused by tannins from decomposition of plants and algae, some coming from outside the lake through runoff. The values in Sand Pond are relatively low, with one high value near the bottom in July (Figure 14). The high value might be a result of the bottom accidentally being stirred up.

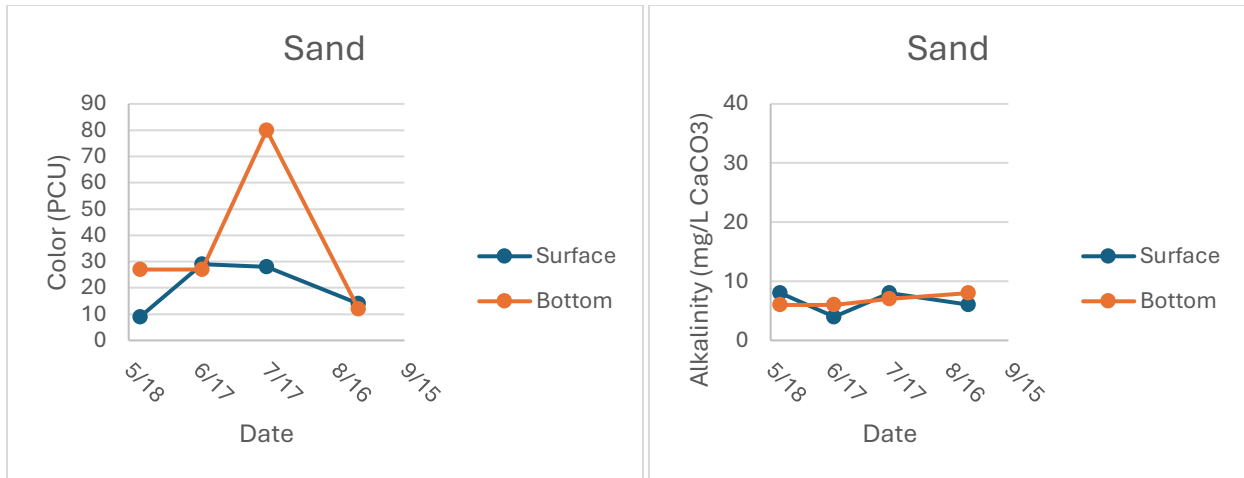


Figure 13. Water color and Alkalinity.

Alkalinity is a measure of how much acid can be neutralized by the water and is mostly derived from minerals in the local geology. In our region the rocks are mostly weather-resistant granites which lead to low alkalinity. Changes in alkalinity are also associated with changes in pH, among other things. The values in Sand Pond are on the low side of the range of typical surface waters, 20-200 (mg/L CaCO<sub>3</sub>). The low values could mean that Sand Pond could be impacted by changes in pH due to things like acid precipitation, although that threat has dwindled since the Clean Air Act was instituted.

## Pennesseewassee

Lake Pennesseewassee is one of the two deeper lakes (15 m). It is mesotrophic meaning that it is in the middle of the productivity range. Oligotrophic lakes are low productivity (e.g. crystal-clear mountain lakes), while eutrophic lakes are high productivity (e.g. usually green-colored due to high algal abundance). We do not want our lakes to become eutrophic! Hence our interest in keeping nutrients like phosphorus out. The total phosphorus concentrations in Lake Pennesseewassee were typical of mesotrophic lakes, the exception was in the bottom layer during the September sampling which was 23 µg/L, and more indicative of eutrophic conditions (Figure 14).

The high phosphorus concentration is likely due to “internal recycling”. This happens when phosphorus from decaying plants and animals is absorbed by bottom sediments, only to be released from the sediments when the oxygen concentration above the sediments is depleted.

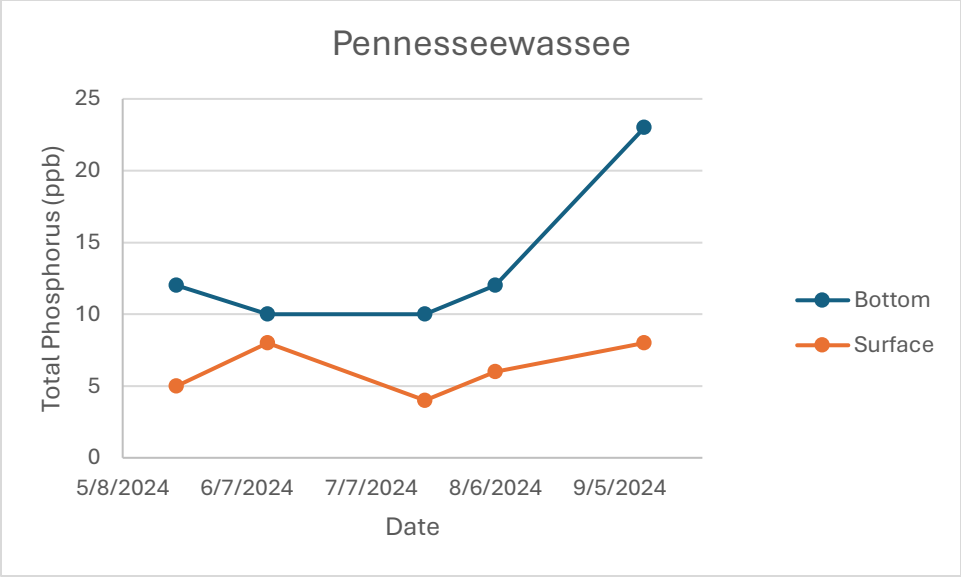


Figure 14. Phosphorus concentration at the surface and bottom of Lake Pennesseewassee.

As seen in Figure 15, the dissolved oxygen concentrations are relatively uniform in May but progressively get depleted at the bottom as the summer progresses. In 2024 oxygen levels fell to zero at the bottom by July. The zero oxygen levels continued to rise through the water column during the following months, indicative of decomposition of organic matter in the bottom waters. This allowed the release of phosphorus from the sediments as seen in Figure 14.

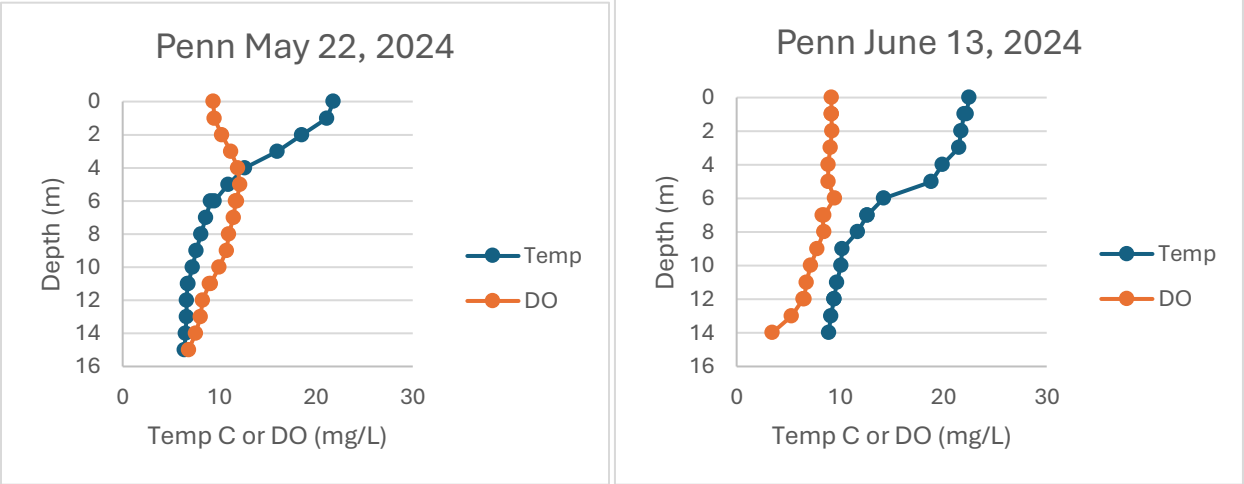


Figure 15. Temperature and Dissolved Oxygen concentrations vs Depth in Lake Pennesseewassee.

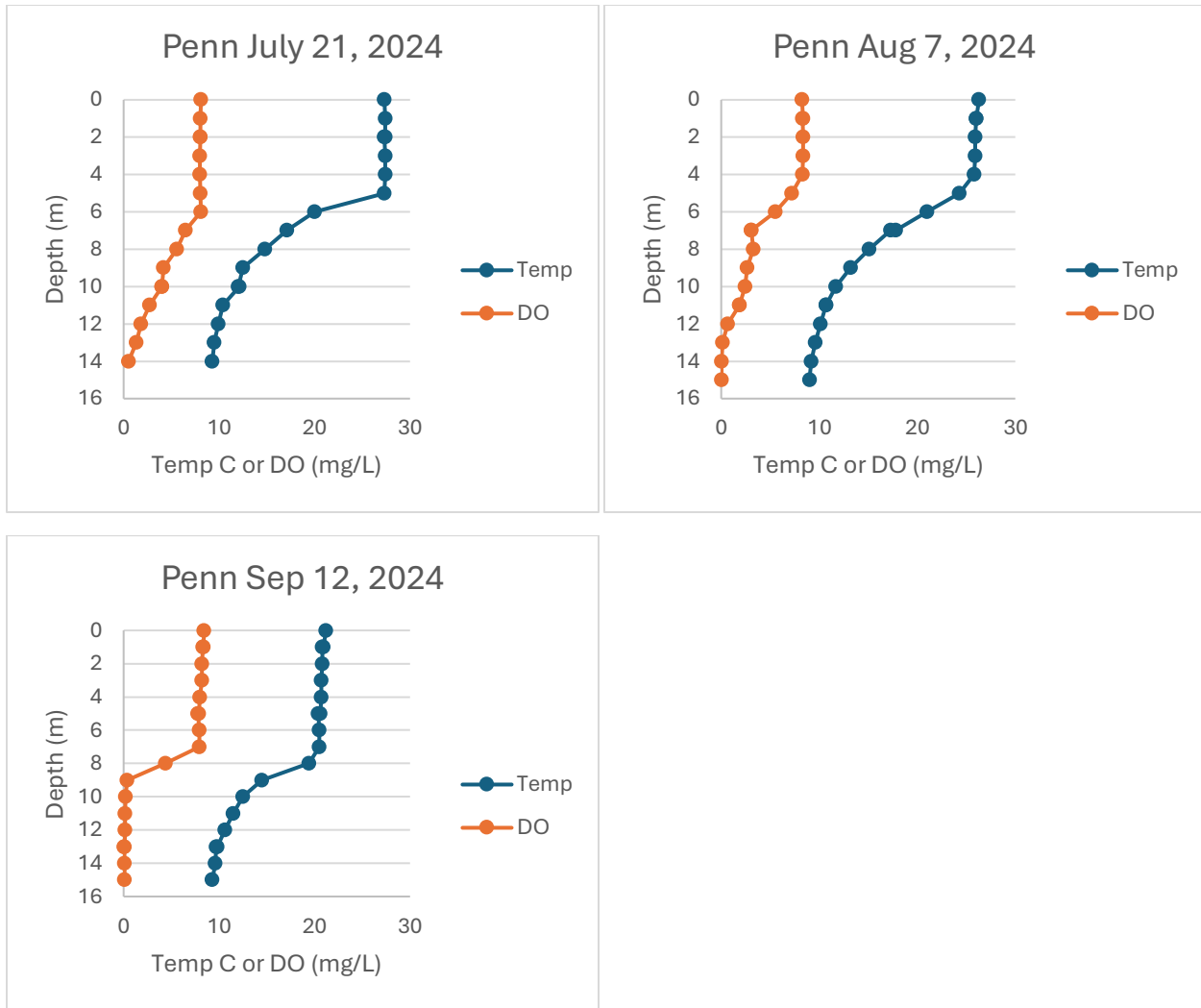


Figure 16 (cont.). Temperature and Dissolved Oxygen concentrations vs Depth in Lake Pennesseewassee.

The other parameters measured were pH, Conductivity, Water Color and Alkalinity (Figure 17). The pH of the surface and bottom water was consistent with expectations, surface being in the mid-7 range while the bottom water was in the high-6 range. The surface tends to be slightly above neutral due to photosynthesis while the bottom water is slightly acidic due to decomposition of organic matter.

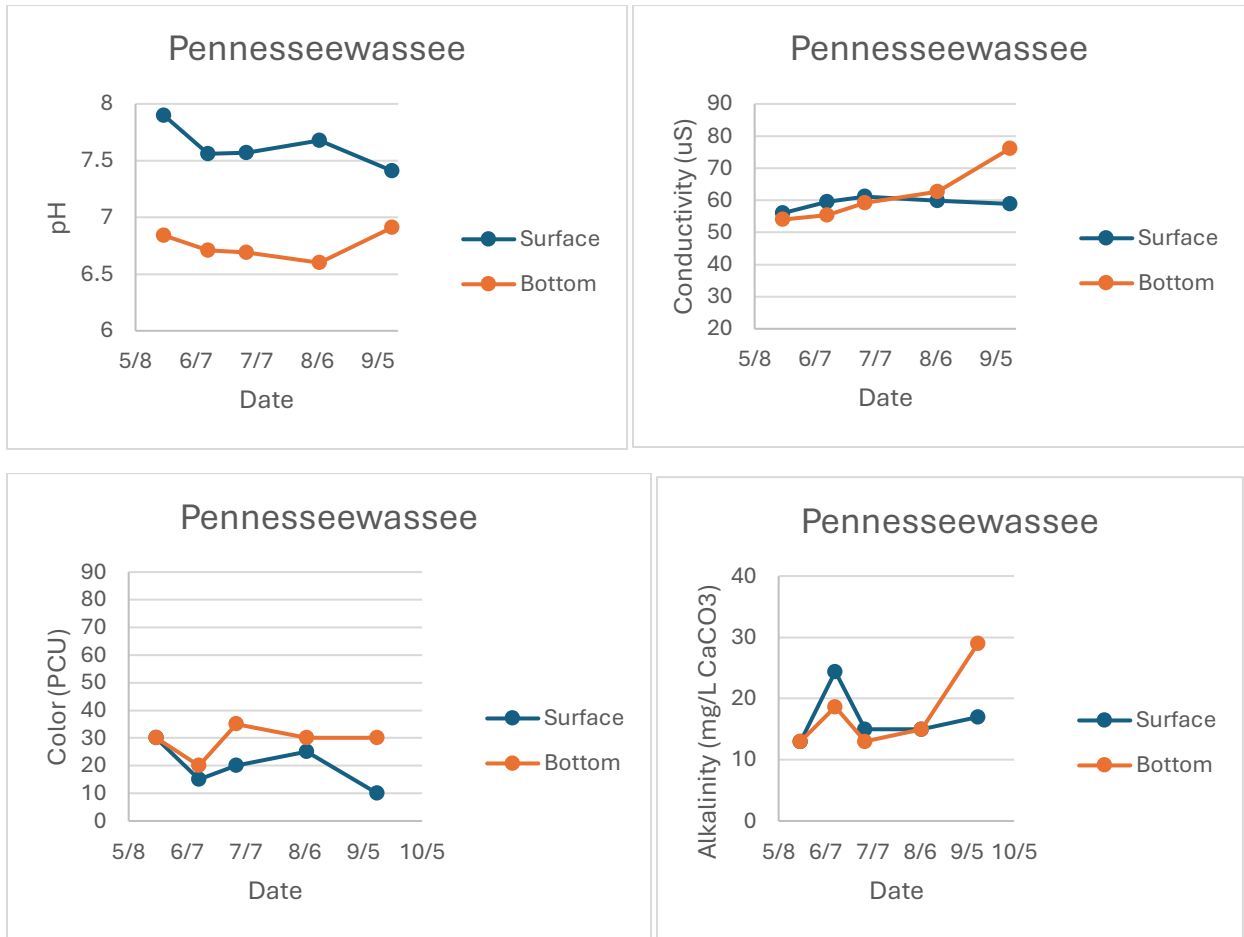


Figure 17. pH, Conductivity, Water Color, and Alkalinity in Lake Pennesseewassee.

## North Pond

North Pond is our shallowest lake, 3 m at its deepest. This means it is highly susceptible to wind mixing, which distributes materials relatively evenly in the water column (Figure 19). Total phosphorus did exhibit some variability between surface and bottom however (Figure 19).

The pH was typical at slightly above neutral. The Conductivity was around 40 the entire sampling period, indicating little to no outside influence such as road salt. The Color of the water remained between 20-30 Platinum Cobalt Color Units, which is normal. The alkalinity was between 20 – 30 mg/L, which is on the low-normal side.

Overall, the water quality in North Pond does not seem to have changed from prior years.

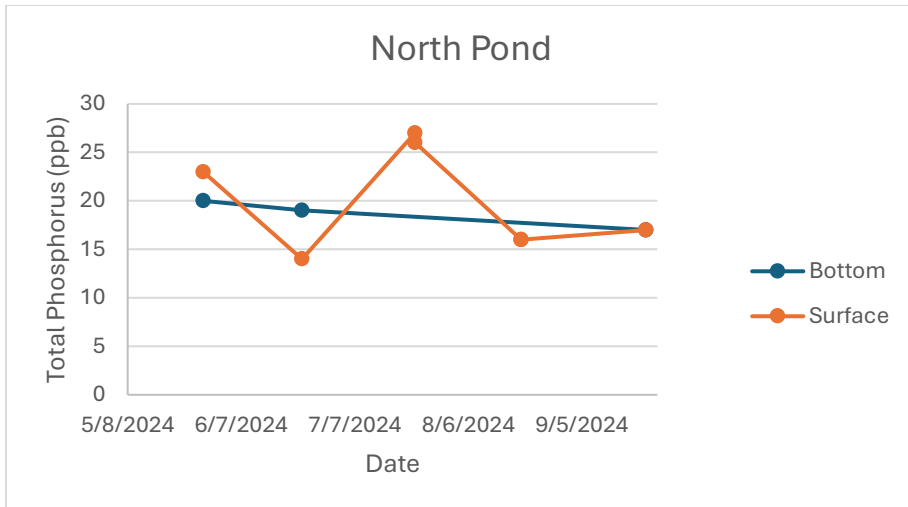


Figure 18. Total phosphorus concentrations.

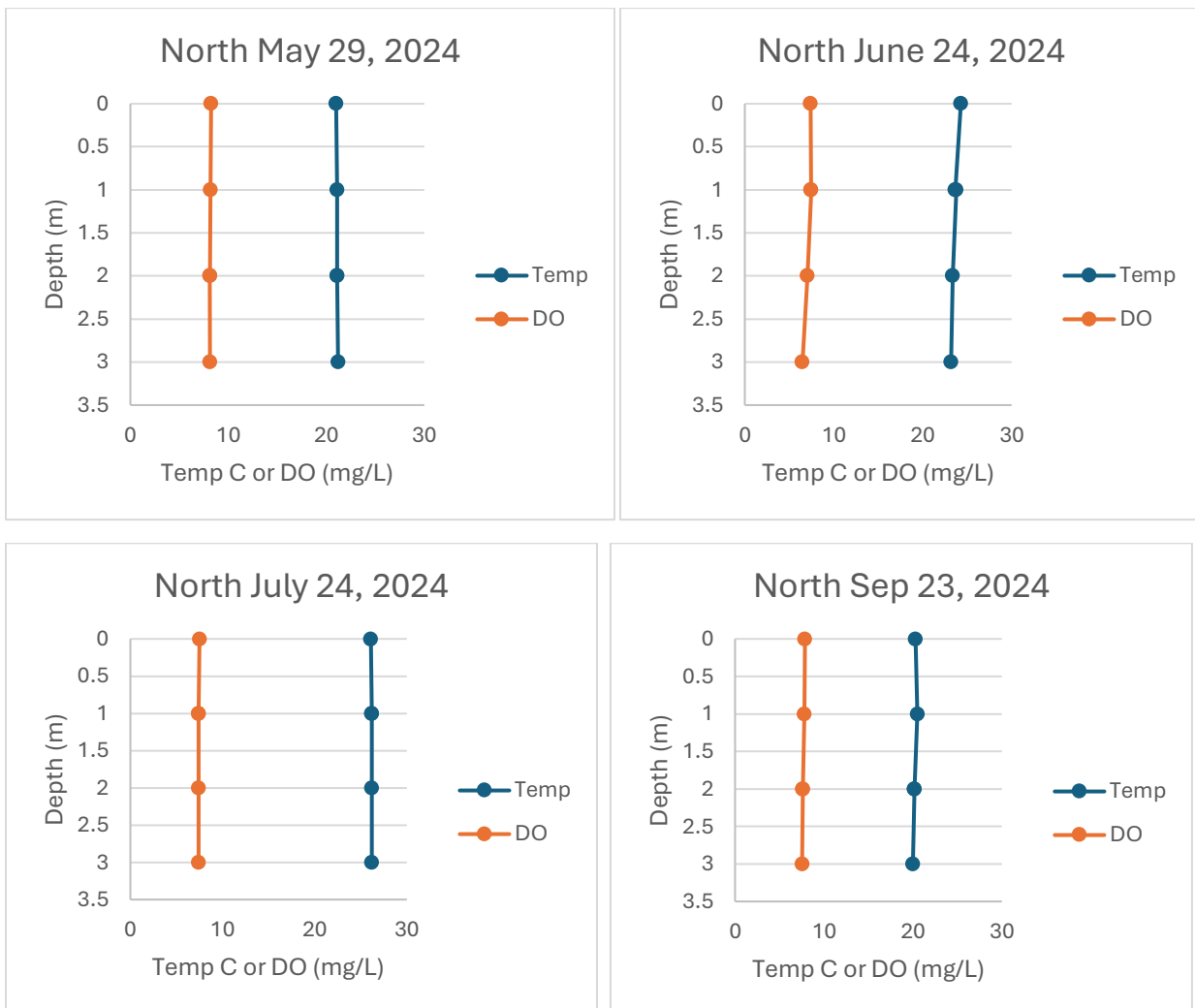


Figure 19. Temperature and DO profiles.

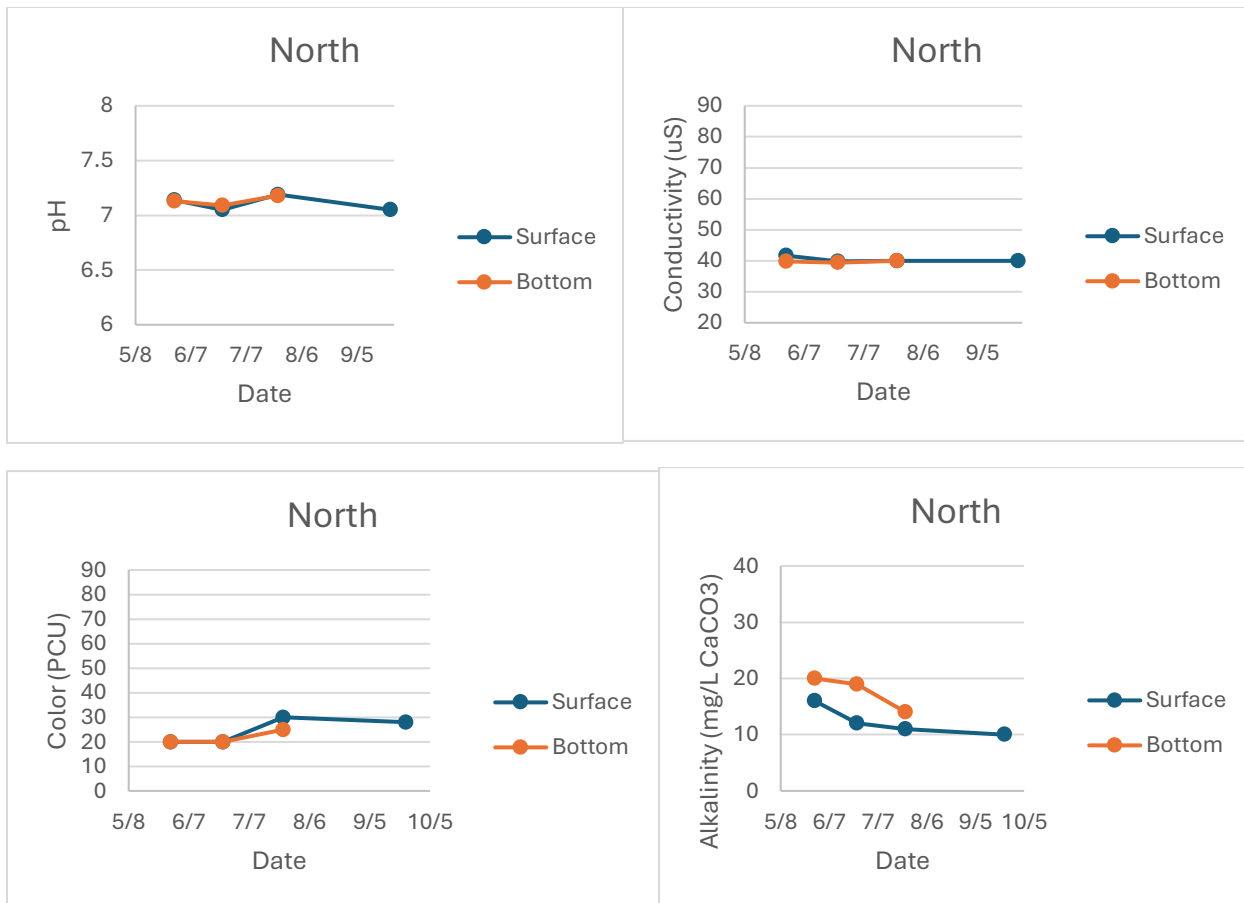


Figure 20. pH, Conductivity, Color, and Alkalinity.

## Methods

The methods described here are the ones currently employed. In the historical records discussed in this Report, other methods may have been used.

### Water Clarity:

Water transparency was measured with a standard Secchi disk, 20 cm in diameter, with black and white quadrants. It was lowered on a measuring tape marked in meters. A measurement was made to the nearest centimeter, while looking through an Aquascope II®, at the point where the disk disappeared.

### Water Samples:

Water samples were collected in 2-liter polycarbonate bottles. The first was immersed, inverted at the surface and filled by turning it right-side up. A second 2 liter polycarbonate bottle was filled from a van Dorn sampler. The van Dorn bottle can be lowered to a specific depth with a marked line, and then closed at depth by sending a weight, called a messenger, down the line. The weight triggers the closing of the ends of the sampler. The 2-liter bottles were covered to seal out light with aluminum foil and duct tape. They were kept in a cooler on ice until they were returned to shore for sample processing.

One exception to this was the collection of total phosphorus samples. For surface samples, a conical tube was inverted and passed through the surface in an arc so that the tube emerged right-side up. The deep samples for total phosphorus were collected in a conical tube directly from the van Dorn sampler prior to any other sample being taken.

#### *Total Phosphorus:*

Total phosphorus samples were collected as described in Water Samples. Both samples were collected in 50 ml tubes to measure out the volume and then transferred into Erlenmeyer flasks and sealed with a screw top. These samples were kept refrigerated and sent to the Maine State Health and Environmental Testing Laboratory (HETL) in Augusta to be analyzed.

#### *Chlorophyll:*

Chlorophyll was sampled from the 2-liter bottles collected at the surface and at depth as described in Water Samples above. The water was then vacuum filtered with an electric pump at  $< 8$  in Hg vacuum, through a 0.45 micrometer pore-size filter. The volume filtered was recorded and typically was between 300-600 mL. After filtration was complete, the filters were frozen and sent to the Maine State Health and Environmental Testing Laboratory (HETL) in Augusta to be analyzed spectrophotometrically.

#### *Dissolved Oxygen:*

DO was measured at 1-meter intervals from surface to the bottom with a YSI ProSolo meter. The meter was calibrated daily with air-saturated water. This was done by filling a container with tap water and bubbling air through it with the use of an aquarium pump and air stone. Barometric pressure was obtained for the calibration from the National Weather Service, using the Lewiston-Auburn station. The meter has a stated accuracy  $\pm 0.1$  mg/L for DO and  $\pm 0.2^\circ\text{C}$  for temperature.

#### *Temperature:*

Temperature was measured at 1-meter intervals from surface to the bottom with a YSI ProSolo meter. The meter has a stated accuracy of  $\pm 0.2^\circ\text{C}$  for temperature.

#### *Conductivity:*

Conductivity was sampled from the 2-liter bottles collected at the surface and at depth as described in Water Samples above. The conductivity was then measured on a subsample of about 100 ml, with an Orion VersaStar meter and an Orion 013005MD conductivity cell. The probe was calibrated with a 84 microSiemens standard solution. The stated accuracy of the instrument is  $\pm 0.5\%$  of reading,  $\pm 1$  digit.

*pH:*

The pH was sampled from the 2-liter bottles collected at the surface and at depth as described in Water Samples above. The pH was then measured with an Orion VersaStar meter and an Orion 8302BNUMD Ross Ultra pH/ATC triode. The probe was calibrated each sampling day with a pH 10.0, 7.0 and 4.0 buffer solutions. The meter has a stated accuracy of  $\pm 0.002$  pH units.

*Alkalinity*

Water samples were obtained from the 2-liter bottles collected at the surface and bottom as described in Water Samples above. Alkalinity was measured with a Hach Model AL-DT digital titrator. It measures both phenolphthalein and total alkalinity as mg-CaCO<sub>3</sub> in the range of 10-4,000 mg/L.

*Color:*

Water samples were obtained from the 2-liter bottles collected at the surface and bottom as described in Water Samples above. The color of water was measured with a Hach CO-1 test kit. It uses a comparator disc that allows the user to compare a water sample to standard colors on the disc. We filtered the sample water through a 0.22  $\mu\text{m}$  filter to obtain the true color of water. The results were read in the 0–100 APHA platinum cobalt color units range of the disc.



## Appendix 1.

A list of possible changes that might be expected in a north temperate lake as the amount of algae changes along the trophic state gradient.						
TSI	Chl( $\mu\text{g/L}$ )	SD(m)	TP ( $\mu\text{g/L}$ )	Attributes	Water Supply	Fisheries & Recreation
< 30	< 0.95	> 8	< 6	<b>Oligotrophy:</b> Clear water, oxygen throughout the year in the hypolimnion.	Water may be suitable for an unfiltered water supply.	Salmonid fisheries dominate.
30 – 40	0.95 – 2.6	8 – 4	6 – 12	Hypolimnia of shallower lakes may become anoxic.		Salmonid fisheries in deep lakes only.
40 – 50	2.6 – 7.3	4 – 2	12 – 24	<b>Mesotrophy:</b> Water moderately clear; increasing probability of hypolimnetic anoxia during summer.	Iron, manganese, taste, and odor problems worsen. Raw water turbidity requires filtration.	Hypolimnetic anoxia results in loss of salmonids. Walleye may predominate.
50 – 60	7.3 – 20	2 – 1	24 – 48	<b>Eutrophy:</b> Anoxic hypolimnia, macrophyte problems possible.		Warm-water fisheries only. Bass may dominate.
60 – 70	20 – 56	0.5 – 1	48 – 96	Blue-green algae dominate, algal scums and macrophyte problems.	Episodes of severe taste and odor possible.	Nuisance macrophytes, algal scums, and low transparency may discourage swimming and boating.
70 – 80	56 – 155	0.25 – 0.5	96 – 192	<b>Hypereutrophy:</b> (light limited productivity). Dense algae and macrophytes.		
> 80	> 155	< 0.25	192 – 384	Algal scums, few macrophytes		Rough fish dominate; summer fish kills possible.