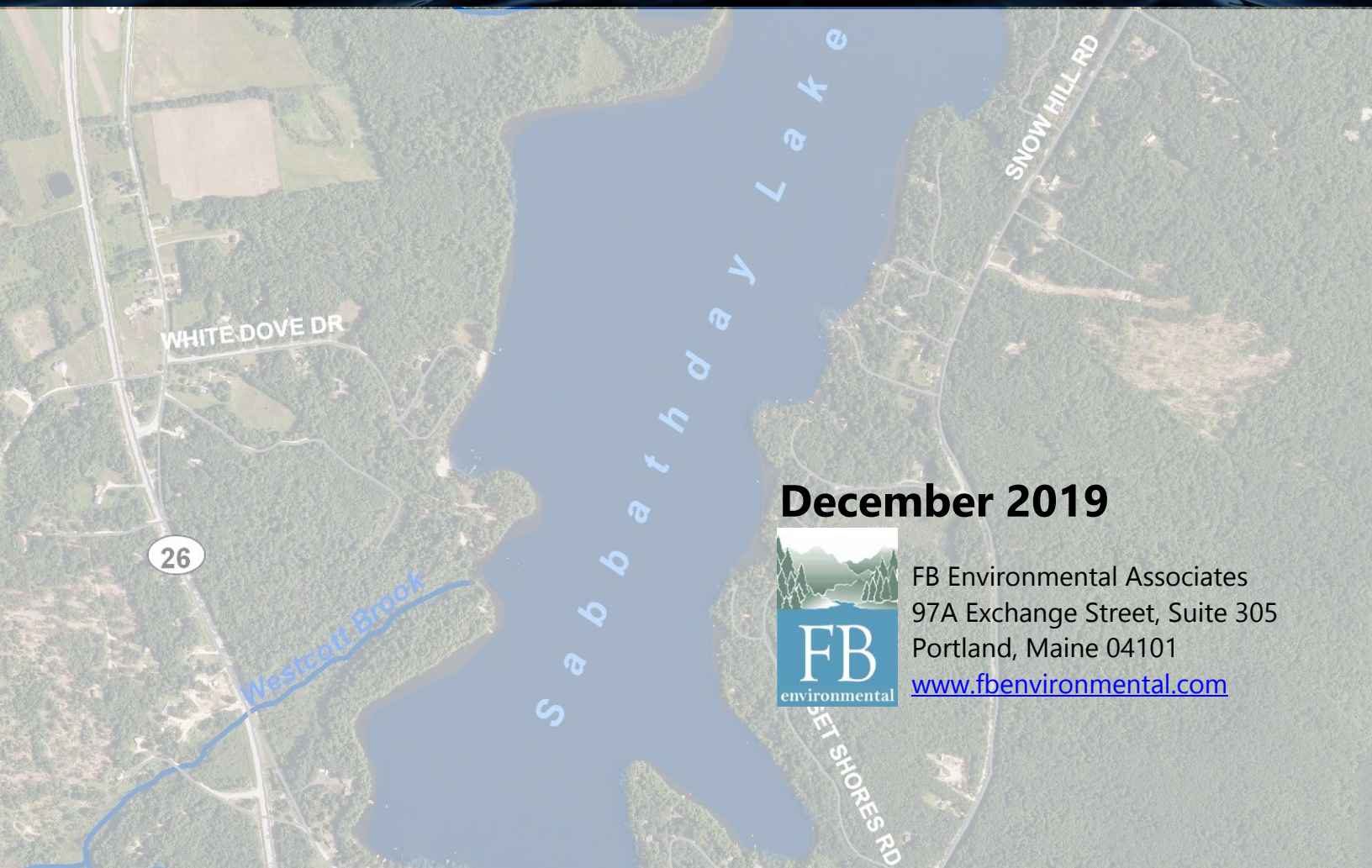
SABBATHDAY LAKE

2019 WATER QUALITY REPORT



December 2019

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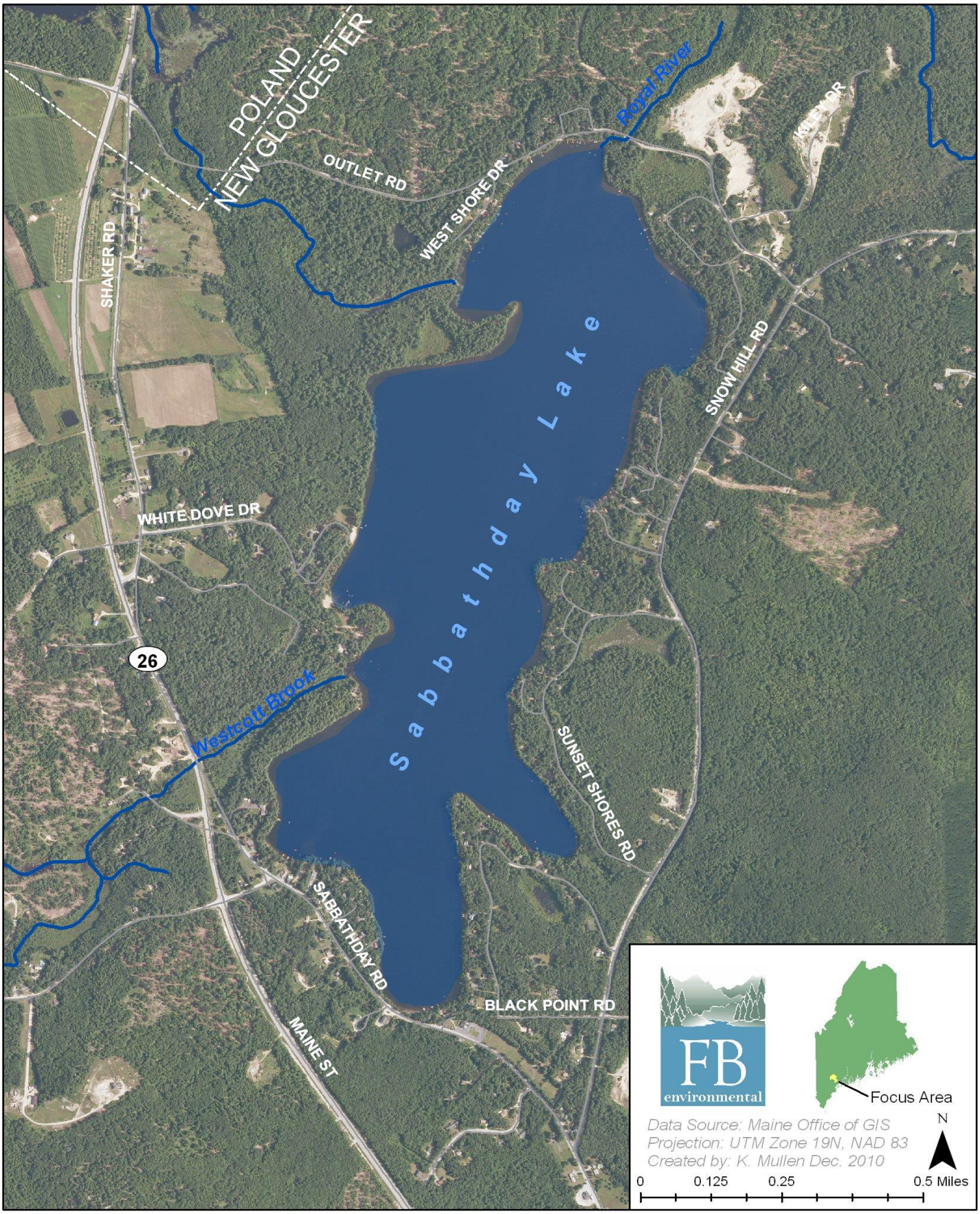
POLAND
NEW GLOUCESTER
Royal River
OUTLET RD
WEST SHORE DR
SHAKER RD
Sabbathday Lake
SNOW HILL RD
WHITE DOVE DR
26
Westcott Brook
SUNSET SHORES RD
SABBATHDAY RD
BLACK POINT RD
MAINE ST
FB
environmental
Focus Area
Data Source: Maine Office of GIS
Projection: UTM Zone 19N, NAD 83
Created by: K. Mullen Dec. 2010
N
0
0.125
0.25
0.5 Miles

SABBATHDAY LAKE

2019 WATER QUALITY REPORT

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Special thanks to Sabbathday Lake Association (SDLA) volunteers Rick and Cheryl Fortier for volunteering their time and boat over the course of the 2019 sampling season. Their ongoing support is greatly appreciated. Thanks to members of SDLA for supporting the long-term collection of water quality data.

Photo Credit: Whitney Baker of Ecological Instincts

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BACKGROUND

LAKE FACTS

Watershed: Royal River
Town: New Gloucester
Watershed Area: 5.33 sq. mi.
Mean Depth: 24 feet
Max Depth: 68 feet
Surface Area: 342 acres
Flushing Rate: 0.88 flushes/year

Sabbathday Lake is a 342-acre, non-colored waterbody located in the Town of New Gloucester, Cumberland County, Maine. The lake is part of the larger Royal River watershed and has a direct **watershed** area of 5.33 square miles, a maximum depth of 68 feet (20.7 meters), a mean depth of 24 feet (7.3 meters), and a flushing rate of 0.88 times per year (see DEP lake depth maps in Appendix A).

Historically, Sabbathday Lake has been an important natural resource for the local Shaker community and the Town of New Gloucester. Today, the lake provides recreational opportunities, such as swimming, boating, and fishing, as well as valuable habitat for fish, birds, and other wildlife.

Sabbathday Lake supports a cold- and warm-water fishery, which include largemouth bass, rainbow smelt, brown trout, brook trout, chain pickerel, and black crappie. Maine Inland Fisheries and Wildlife has stocked the lake with brown trout and brook trout since 1989. Cold-water fish, such as trout, need at least 5 parts per million (ppm) of **dissolved oxygen (DO)** in the water to survive and even higher levels to grow. Historically, Sabbathday Lake has experienced critically-low DO concentrations in the deepest areas of the lake in August and September. Low DO in Sabbathday Lake can release **phosphorus** from bottom sediments into the water column where it can fuel algal growth. Thus, DO monitoring is an important part of the annual water quality evaluation.

Based on historical measures of Secchi disk transparency (SDT) or **water clarity**, total phosphorus (TP), and **chlorophyll-a (Chl-a)**, the water quality of Sabbathday

A **watershed** is an area of land that drains water to a single location such as the outlet of a lake.

Dissolved Oxygen (DO) is the concentration of oxygen dissolved in water. DO is critical to the healthy metabolism of many organisms that reside in the water. DO concentrations may change dramatically with lake depth due to the natural process of thermal stratification in summer. Oxygen is produced in the top portion of a lake (where sunlight drives photosynthesis), and consumed near the bottom of a lake (where organic matter accumulates and decomposes).

Phosphorus is an essential nutrient for plant growth naturally present in small amounts in lake water and sediments. Stormwater runoff, lawn/garden fertilizers, and malfunctioning wastewater systems can supply excess phosphorus can lead to increased plant and algae growth in lakes.

Water clarity is a vertical measure of transparency or the ability of light to penetrate water, obtained by lowering a black and white disk into the water until it is no longer visible. Changes in transparency may be due to increased or decreased algal growth or the amount of dissolved or particulate suspended material in a lake, resulting from human disturbance or other impacts.

Lake is considered above average since monitoring began in 1975 (Maine VLMP 2015). However, Sabbathday Lake is sensitive to pollutants in stormwater runoff from the watershed. Significant amounts of stormwater runoff can temporarily reduce water clarity and, if erosion in the watershed increases, long-term degradation in water clarity can become extremely difficult to reverse.

METHODS

FB Environmental Associates, with assistance from Ecological Instincts staff and SDLA volunteers, collected water quality data at the deep spot (Station 1) of Sabbathday Lake on three sampling days in 2019 (July 26, August 20, and September 10). Sampling was conducted in accordance with standard methods and procedures for lake monitoring established by the Maine Department of Environmental Protection (Maine DEP), the U.S. Environmental Protection Agency (USEPA), and the Maine Volunteer Lake Monitoring Program (VLMP). All water samples were analyzed at the Health and Environmental Testing Lab (HETL) in Augusta.

An integrated **epilimnetic core** was collected at the deep spot (Station 1) of Sabbathday Lake during each sampling event. Due to thermal stratification, the depth of the core sample (or upper part of the thermocline) varied throughout the season. Parameters measured included **Trophic State Indicators** (i.e., water clarity, TP, and Chl-a), DO and water temperature profiles, **true color**, **total alkalinity,** and **pH**.

Sabbathday Lake is a mesotrophic lake and has intermediate levels of phosphorus and chlorophyll-a and water clarity at depths between 4 and 8 meters.

Chlorophyll-a (Chl-a): a measurement of the green pigment found in all plants, including microscopic plants like algae. It is used as an estimate of algal biomass; higher Chl-a equates to greater amounts of algae.

Trophic State Indicators are measures of biological productivity in lake ecosystems, including water clarity, total phosphorus, and chlorophyll-a. The combination of these parameters helps determine lake trophic state and productivity – the amount of growth of algae, cyanobacteria such as **Gloeotrichia**, and other photosynthetic organisms – and serves as a signal of changing water quality.

Eutrophic, mesotrophic, and oligotrophic lakes have high, medium, and low productivity, respectively. A eutrophic lake will have high phosphorus, high chlorophyll-a, and low water clarity; an oligotrophic lake will have low phosphorus, low chlorophyll-a, and high water clarity; and a mesotrophic lake will have moderate values for all indicators. Sabbathday Lake is classified as a mesotrophic lake by Maine DEP.

True Color measures the influence of suspended and dissolved particles in water from weathered geologic material, vegetation cover, and land use activity. Colored lakes (>25 PCU) can have reduced water clarity and increased phosphorus concentrations.

Total Alkalinity is a measure of the capacity of water to neutralize acids (i.e., buffering capacity). Total alkalinity above 20 ppm buffers against drastic changes in pH that could impact aquatic plants and animals.

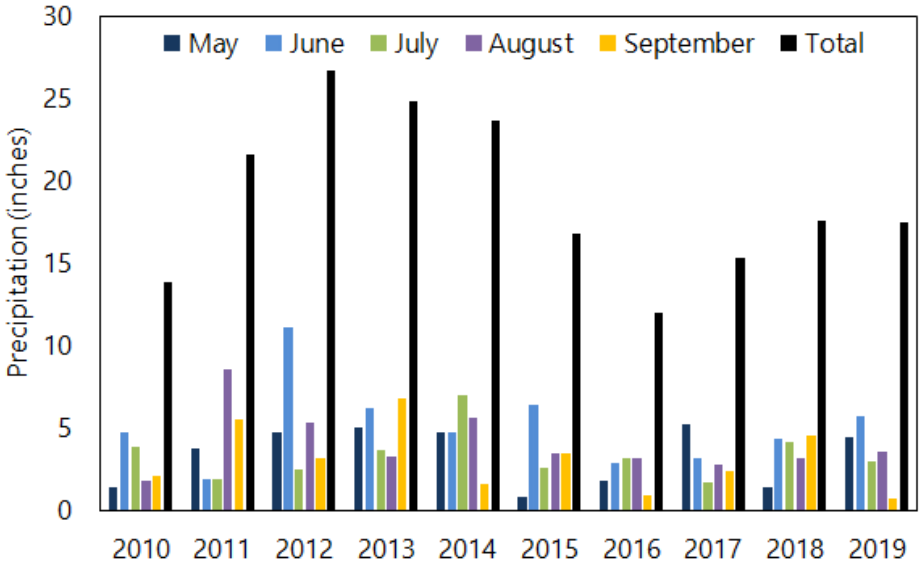
pH measures of the acidity of a solution on a scale of 0-14. Most aquatic species require a pH between 6.5 and 8.0.

An **epilimnetic core** is a lake water sample taken by lowering a vertical tube down from the surface of the lake to the upper part of thermocline (the depth at which temperature begins to decrease dramatically during summer stratification). This technique allows lake scientists to capture water from the entire upper layer of the lake where most photosynthetic algae and cyanobacteria reside, including the **metalimnetic maximum** or "oxygen bubble."

RESULTS

WEATHER

Weather is one of the major factors influencing inter-annual variability in lake water quality. Abnormally dry summer conditions (as experienced in 2010 and 2016) reduce the amount of runoff, containing sediment and nutrients, to the lake, resulting in improved water quality (e.g., higher water clarity, lower phosphorus, and lower chlorophyll-a or algae). Conversely, wetter years transport more material from the landscape to the lake, resulting in degraded water quality. The region experienced the lowest total summer rainfall of the decade in 2016, with only 12 inches in New Gloucester, Maine (Figure 1). With a total of 17.5 inches, 2019 was an average year for the current decade even with September of 2019 receiving the least amount rainfall recorded from May-September (2010-2019) (Figure 1).



Year	May	June	July	August	September	Total
2010	1.4	4.7	3.9	1.8	2.1	13.9
2011	3.8	1.9	1.9	8.6	5.6	21.7
2012	4.8	11.2	2.4	5.3	3.1	26.8
2013	5.0	6.2	3.7	3.2	6.8	24.9
2014	4.7	4.7	7.0	5.6	1.6	23.7
2015	0.8	6.4	2.6	3.5	3.5	16.9
2016	1.8	2.9	3.2	3.2	0.9	12.0
2017	5.2	3.2	1.7	2.8	2.4	15.3
2018	1.4	4.3	4.1	3.1	4.5	17.6
2019	**4.5**	**5.7**	**3.0**	**3.6**	**0.7**	**17.5**

FIGURE 1. Monthly precipitation for Sabbathday Lake from May-September (2010-2019). All units are in inches of rainfall. Data are from NOAA NCDC for station GHCND: US1MECM0003 - New Gloucester 3.0, SE, ME, US.

TROPHIC STATE INDICATORS

Water Clarity

Measuring water clarity is one of the most useful ways for determining if a lake is changing from year to year. Changes in water clarity may be due to a change in the amount and composition of algal communities or the amount of dissolved or particulate suspended materials in a lake. Such changes are likely the result

of human disturbance or other impacts to the lake's watershed. Water clarity varies widely in Maine lakes, ranging from 0.5 to 15.5 meters, with an average of 4.81 meters (Maine VLMP, 2015). Generally, water clarity of 2 meters or less indicates a water quality problem and a higher potential for severe algal blooms. Maine DEP classifies productive or eutrophic lakes as 4 meters or less, moderately productive or mesotrophic lakes as 4-7 meters, and unproductive or oligotrophic lakes as 7 meters or greater.

Since 1975, water clarity in Sabbathday Lake has ranged from 4.0 to 9.2 meters, with an all data average of 6.6 meters (Gulf of Maine Knowledge Base 2019). Sabbathday Lake is generally clearer than the average water clarity of Maine lakes (Lakes of Maine 2017) and has shown a relatively stable trend in water clarity over the sampling record (Figure 2). In 2019, water clarity in Sabbathday Lake ranged from 6.7 to 8.2 meters, with an average of 7.7 meters, which is slightly more shallow than the deepest annual average over the entire sampling record (8.1 m, set in 2016) and is 1.1 meters deeper than the all data average (Table 1). As previously discussed, 2019 was an average year for precipitation (see Weather), leaving the cause of the higher than normal clarity uncertain. September 2019 was extremely dry with 0.7 inches of precipitation. The September 2019 water quality measurements were taken September 10 and had a SDT reading 0.1 meters shallower than on August 20, 2019.

Total Phosphorus

Since 1982, total phosphorus in Sabbathday Lake has ranged from 3.0 to 15.0 parts per billion (ppb), with an all data average of 6.6 ppb (Gulf of Maine Knowledge Base, 2019). Sabbathday Lake has low phosphorus compared to average phosphorus levels in Maine lakes and has shown a relatively stable trend in phosphorus over the sampling record (Figure 2). In 2019, total phosphorus in Sabbathday Lake ranged from 4.0 to 6.0 ppb, with an average of 5.0 ppb, which is the second lowest annual average on record (average of 5.0 ppb was also recorded in 1982, 1987, 2010, and 2016). The lowest annual average on record is 4.0 ppb from 2018. The 2019 average of 5.0 ppb is 1.6 ppb lower than the all data average of 6.6 ppb (Table 1).

Maine DEP also collected bottom grab samples in summer (June-September) for total phosphorus at Sabbathday Lake from 1982 to 2011. Phosphorus at the bottom of the lake ranged from 6.0 to 22.0 ppb, with an all data average of 11.9 ppb (almost double the all data average for epilimnetic phosphorus). High levels of phosphorus in bottom waters of the lake indicate that phosphorus from the lake bottom sediment is entering the water column in a process known as internal phosphorus cycling. Briefly, conditions of low summer DO enable phosphorus to be chemically released from bonds with iron oxides in the sediment, which would otherwise be an effective storage mechanism. A profile sample collected shortly after both spring and fall turnover would provide more information about potential internal phosphorus cycling.

Chlorophyll-a

Since 1975, chlorophyll-a in Sabbathday Lake has ranged from 1.6 to 10.6 ppb, with an all data average of 3.8 ppb (Gulf of Maine Knowledge Base, 2019). Sabbathday Lake has low chlorophyll-a (algae) compared to average chlorophyll-a levels in Maine lakes and has shown a relatively stable trend in chlorophyll-a over the sampling record (Figure 2). In 2019, chlorophyll-a in Sabbathday Lake ranged from 3.0 to 5.0 ppb and averaged 4.0 ppb, which is 0.2 ppb higher than the all data average of 3.8 ppb (Table 1).

Gloeotrichia is a genus of planktonic freshwater cyanobacteria. In an effort to further understand why blooms of *Gloeotrichia* are occurring on some lakes throughout New England and to assess which lakes may be or become vulnerable to these blooms, Maine DEP has included a presence or absence box on the lake profile sampling form. Here, lake monitors can record the presence of *Gloeotrichia* if applicable and the density of the colony. The presence of *Gloeotrichia* in the water column was not noted on the July and August sampling dates and was marked as not present on the September sampling date.

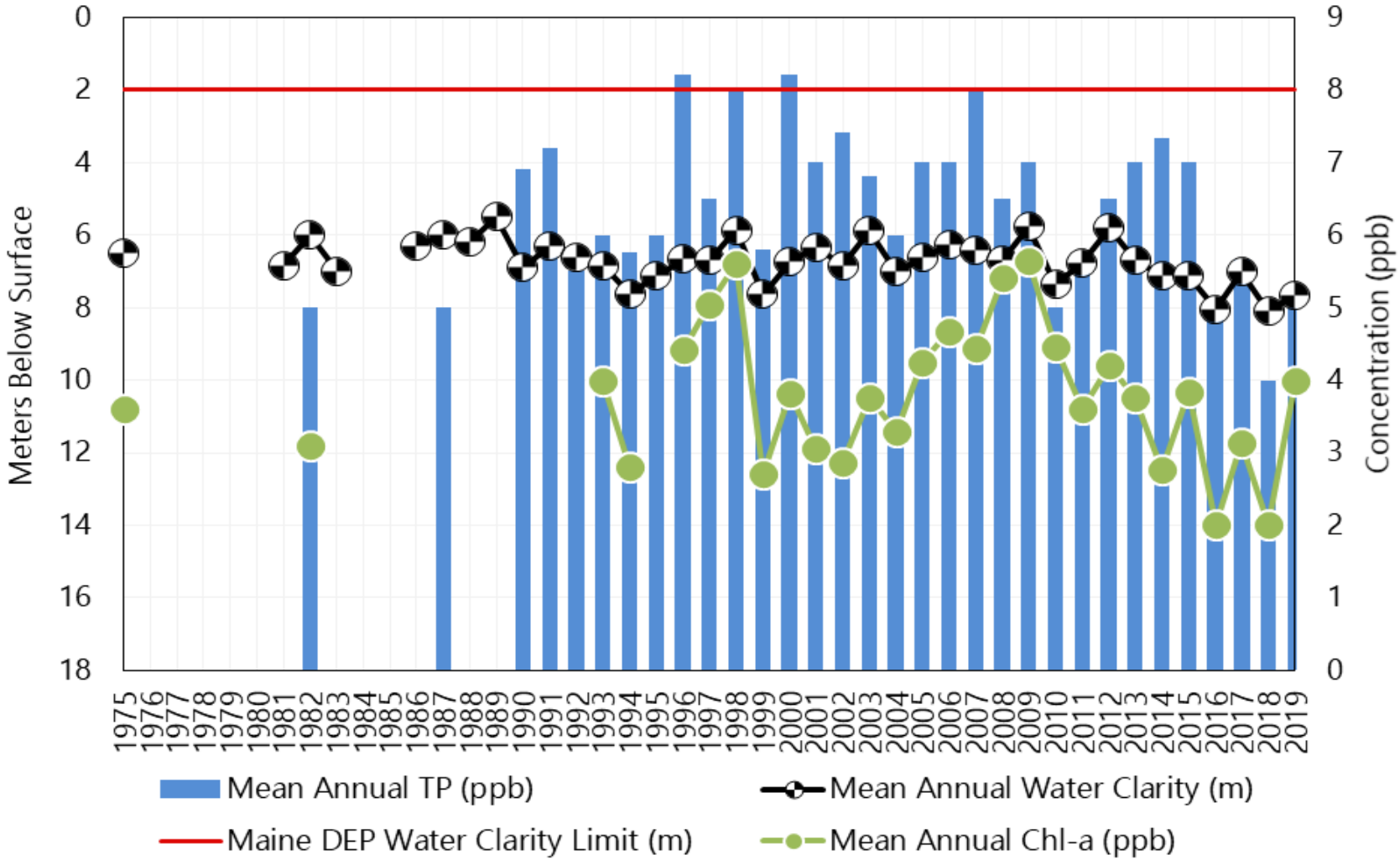


FIGURE 2. Average annual water quality data for trophic state indicators (water clarity, total phosphorus (TP), and chlorophyll-a (Chl-a)) for Sabbathday Lake. 2015-2019 annual averages include only data collected by FB Environmental and Ecological Instincts. Other data collected by SDLA volunteers pending final QA/QC and acceptance by the Maine DEP and VLMP.

DISSOLVED OXYGEN & TEMPERATURE

Sabbathday Lake has a history of DO depletion in deep, cold areas of the lake (below 8 meters) in late summer. In 2019, DO levels dropped below 5 ppm at approximately 14 meters in July, at 9 meters in August, and at 8 meters in September (Figure 3). The volume of the lake affected by DO concentrations less than 5 ppm was approximately 8% in July, 21% in August, and 25% in September. As in previous years, the most significant DO depletion occurred in September when DO levels dropped below 2 ppm beginning at 14 meters. On this date DO levels fell below 1 ppm at 17 and 18 meters below the surface.

A DO metalimnetic maximum (commonly referred to as an "oxygen bubble") occurred between 4 and 8 meters, accompanied by a marked decrease in water temperature, is indicative of the thermocline and persists all season. The upper part of the thermocline is where algae are most productive; below this, decreasing light penetration limits algal growth. In addition, cold-water fish prefer waters of 18°C and can tolerate waters up to 24°C. In summer of 2019, the upper 0-6 meters (67% of the lake volume) were warmer than 18°C, while deeper waters were oxygen-depleted. The suitable habitat of cooler, oxygenated waters was thus restricted to a layer at depths of 6 to 8 meters, comprising 9% of the total lake volume.

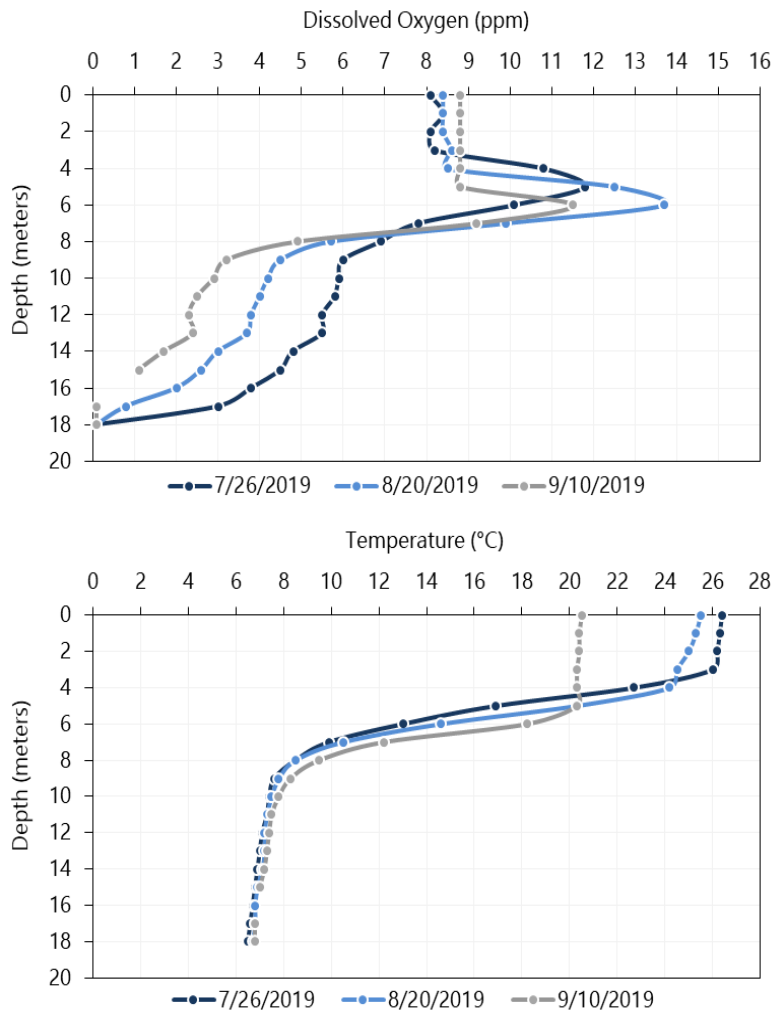


FIGURE 3. Dissolved oxygen (top) and temperature (bottom) profiles collected in 2019 at Sabbathday Lake.

Continued monitoring of DO is needed to characterize oxygen depletion over time in Sabbathday Lake. Collecting regular phosphorus samples near the bottom of the lake could also provide information on internal phosphorus cycling. Internal Phosphorus Loading is the process whereby phosphorus bound to lake bottom sediments is released back into the water column during periods of anoxia. The phosphorus can be used a fuel for algae growth, creating a positive feedback to eutrophication and low DO concentrations.

CHEMICAL PARAMETERS

Color

Since 1982, color in Sabbathday Lake has ranged from 5 to 32 platinum-cobalt units (PCU), with an all data average of 12.9 PCU (Gulf of Maine Knowledge Base, 2019). Sabbathday Lake has low color compared to average color in Maine lakes and has shown a relatively stable trend in color over the sampling record (Figure 4). In 2019, color in Sabbathday Lake consistently measured between 11 and 14 PCU (for an average of 12 PCU) – 0.9 PCU better than the all data average (Table 1). The lowest annual average over the entire sampling record was recorded at 7 PCU in 2016.

TABLE 1. Summary of 2019 data and historical averages for water clarity, total phosphorus (TP), chlorophyll-a (Chl-a), color, alkalinity, and pH at Sabbathday Lake. Average Maine lake values were obtained from VLMP (2018).

Date	Water Clarity (m)	TP (ppb)	Chl-a (ppb)	Color (PCU)	Alkalinity (ppm)	pH
7/26/2019	6.7	6.0	5.0	14.0	11.0	7.3
8/20/2019	8.2	4.0	3.0	11.0	11.0	7.4
9/10/2019	8.1	5.0	4.0	11.0	12.0	7.4
2019 Average (SDL)	7.7	5.0	4.0	12.0	11.3	7.4
Historical Avg. (SDL)	6.6	6.6	3.8	13.0	10.8	7.0
Average (Maine Lakes)	5.5	11.2	5.6	20.5	11.6	6.9

Alkalinity

Since 1982, total alkalinity in Sabbathday Lake has ranged from 7.1 to 17.5 ppm, with an all data average of 10.9 ppm (Gulf of Maine Knowledge Base, 2019). Sabbathday Lake has slightly lower alkalinity compared to average alkalinity in Maine lakes and has shown stability over the sampling record (Figure 4). In 2019, total alkalinity in Sabbathday Lake ranged from 11.0 to 12.0 ppm for an average of 11.3 ppm, which is 0.5 ppm higher than the all data average (Table 1). Per the USEPA, these average total alkalinity levels in Sabbathday Lake fall in the "sensitive" category of 10 ppm to 20 ppm. A lake is well-buffered against changes in pH if total alkalinity is greater than 20 ppm.

pH

Since 1982, pH in Sabbathday Lake has ranged from 6.6 to 7.5, with an all data average of 7.0 (Gulf of Maine Knowledge Base 2019). Sabbathday Lake has slightly higher pH compared to average pH in Maine lakes and has shown a relatively stable trend in pH over the sampling record (Figure 4). In 2019, pH in Sabbathday Lake ranged from 7.3 to 7.4, with an average of 7.4, which is 0.4 above the all data average (Table 1).

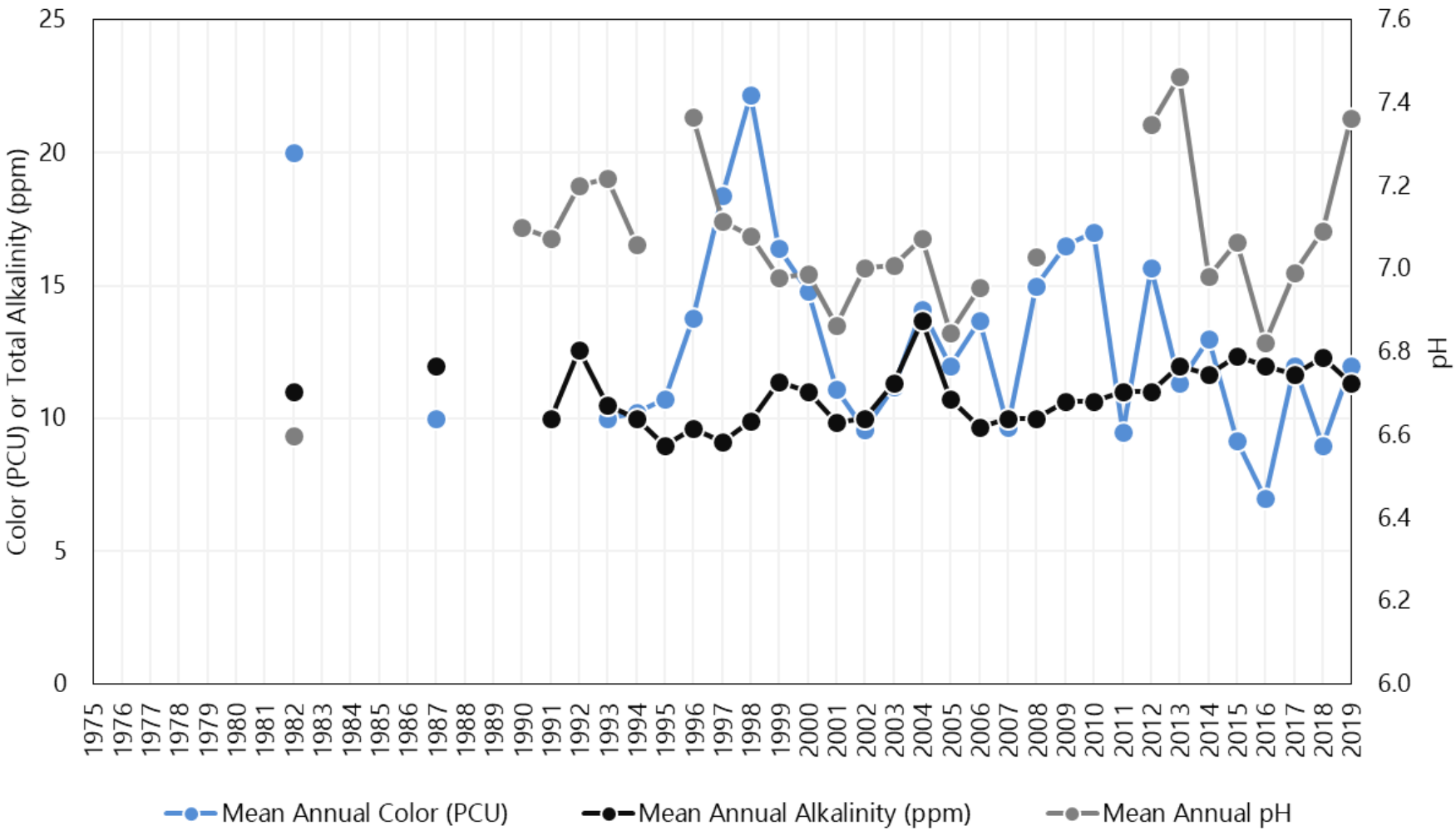


FIGURE 4. Average annual water quality data for chemical parameters (color, total alkalinity, and pH) for Sabbathday Lake. 2015-2019 annual averages include only data collected by FB Environmental and Ecological Instincts. Other data collected by SDLA volunteers pending final QA/QC and acceptance by the Maine DEP and VLMP.

SUMMARY

Sabbathday Lake continues to have above-average water quality compared to the average for Maine lakes (Table 1).

All water quality parameters measured at Sabbathday Lake show no trends in annual averages over the entire sampling record.

The 2019 monitoring season received an average amount or precipitation although water quality results reflect those of drier sampling seasons.

- Water clarity, total phosphorus, color, alkalinity, and pH annual averages for 2019 show an improvement from the historical average.
- Water clarity in 2019 was very high, surpassed only by the 2016 and 2018 yearly averages in the historical record.
- Average total phosphorus in 2019 was only 1 ppb higher than the lowest yearly average which was recorded in 2018.
- pH was higher than average in 2019, only 0.1 lower than the highest yearly average which was recorded in 2013.
- Chlorophyll-a was slightly elevated above the historical average.

It is possible that runoff was limited by the timing or the intensity of rainfall events, thereby producing water quality characteristics of a drier year. 2019 also had the driest September of the decade. Further studies would be necessary to determine if these or other factors were at play.

DO profiles at the Sabbathday Lake deep spot continue to show that depletion is a consistent issue, with depths as shallow as 8-9 meters showing DO levels at or below 5 ppm 2019. Desirable habitat of cool, oxygenated water for cold-water fish was restricted to between 6 and 8 meters below the water surface in 2019. This low DO may also be releasing biologically available phosphorus from bottom sediments, though phosphorus remains low overall in Sabbathday Lake.

RECOMMENDATIONS

- Continue the baseline annual water quality monitoring program at Sabbathday Lake.
- Consider adding hypolimnion (bottom) grab samples for phosphorus to the three sampling events.
- Consider collecting water quality data (especially DO and temperature profiles and epilimnion and/or hypolimnion grab samples for phosphorus and chlorophyll-a) immediately after spring and fall turnover to better characterize internal phosphorus cycling in Sabbathday Lake. Low oxygen in late summer when thermal stratification sets in (creating a barrier to lake mixing, so oxygen-rich surface waters cannot replenish bottom waters) causes a chemical reaction with iron-bound phosphorus in bottom sediments that can re-release phosphorus into the water column and fuel algal growth.
- In addition to collecting water quality data after spring and fall turnover, consider collecting water quality data (DO and temperature profiles and epilimnion and hypolimnion grab samples for phosphorus) during winter stratification if ice conditions are safe. Biological and ecological

processes persist during the winter months and little is known about the limnological chemistry during this time within Sabbathday Lake. Shedding light on this data gap can help assess the quality and extent of aquatic habitats within the water column during winter stratification.

- Consider adding a water quality monitoring buoy that continuously measures DO and temperature throughout the ice-free season (can also measure temperature during the winter months). This will help pinpoint spring and fall turnover and the extent and duration of low DO in Sabbathday Lake.
- Consider collecting benthic sediment core samples for phosphorus analysis at the two deep spots in the lake.

WAYS TO PROTECT THE LAKE

There are many ways that individual landowners can help reduce sediment and nutrient input to Sabbathday Lake to protect and even improve water quality, including:

- Join the Sabbathday Lake Association (SDLA)
- Participate in a watershed survey every 10 years
- Pump your septic system every 2-3 years, participate in a septic survey, and inspect your septic system if older than 20 years
- Help form a road association
- Participate in volunteer surveys, including water quality and aquatic plants surveys
- Use phosphorus-free fertilizers and household products
- Plant a vegetated buffer (100-250 feet wide is ideal) along your shorefront area
- Vegetate and mulch bare soils using native materials
- Terrace and vegetate steep slopes
- Create meandering footpaths to slow storm flow to the lake
- Repair eroding driveways to prevent erosion
- Line eroding ditches with rock
- Educate neighbors about lake science
- Become LakeSmart by contacting SDLA and the Maine Lakes Society (207-495-2301 or email info@mainelakessociety.org) for a free LakeSmart evaluation; or become a certified LakeSmart evaluator

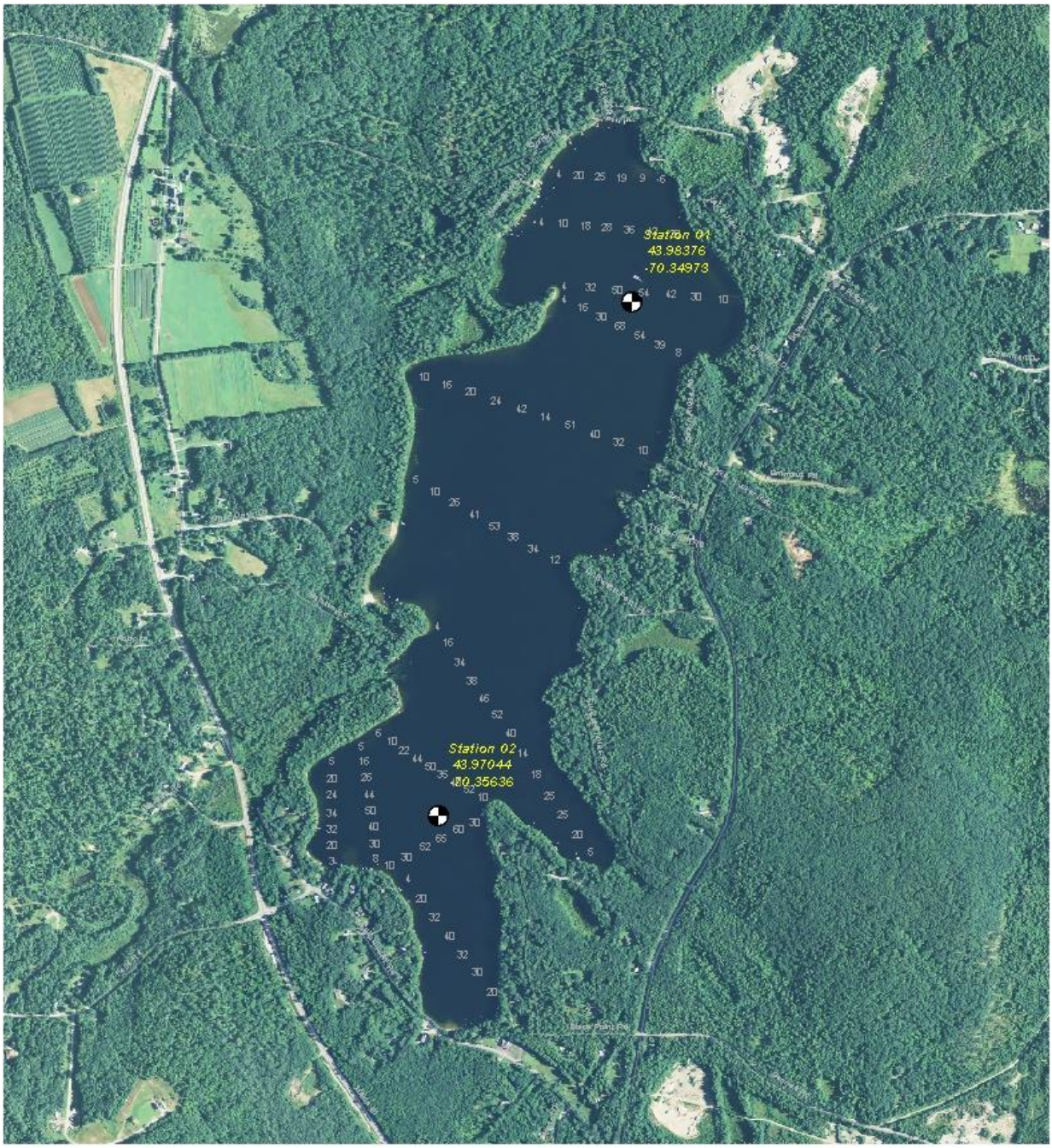
REFERENCES

Gulf of Maine Knowledge Base, 2019, Maine Lakes Transparency, Color & Chemistry: Annual Mean Values. http://www.gulfofmaine.org/kb/2.0/record.html?recordid=9679.

Lakes of Maine, 2017, Water Quality Summary: Sabbathday Lake, New Gloucester, Midas 3700, Sample Station # 1. Revised July, 2017 by Maine DEP, Augusta, Maine. Accessed online at: http://www.lakesofmaine.org/data/2017-reports/3700_SABB_1.pdf.

Maine VLMP, 2015, Lake Water Quality Indicators. Retrieved from http://www.mainevlmp.org/programs/water-quality-monitoring/water-quality-indicators/.

APPENDIX A | DEPTH MAPS



Sabbathday Lake MIDAS # 3700

New Gloucester, Cumberland Co. - Delorme Page 5 - 342 acres

Boat Launch Lake Sample Stations # Depth (FT)

0 0.25 0.5 0.75 1 1.25 Miles

Source: Lakes of Maine, Online: http://www.lakesofmaine.org/lake-overview.html?m=3700

Sabbathday Lake

MIDAS # 3700

New Gloucester, Cumberland Co. - Delorme Page 5 - 342 acres

Boat Launch | Lake Sample Stations | # Depth (FT) | Roads | Town Lines

0 0.3 0.6 0.9 1.2 1.5 Miles

Source: Lakes of Maine, Online: http://www.lakesofmaine.org/lake-overview.html?m=3700