2013

Kezar Lake Water Quality Report

A Report on the Water Quality of Kezar Lake, Two Tributaries, and Six Watershed Ponds

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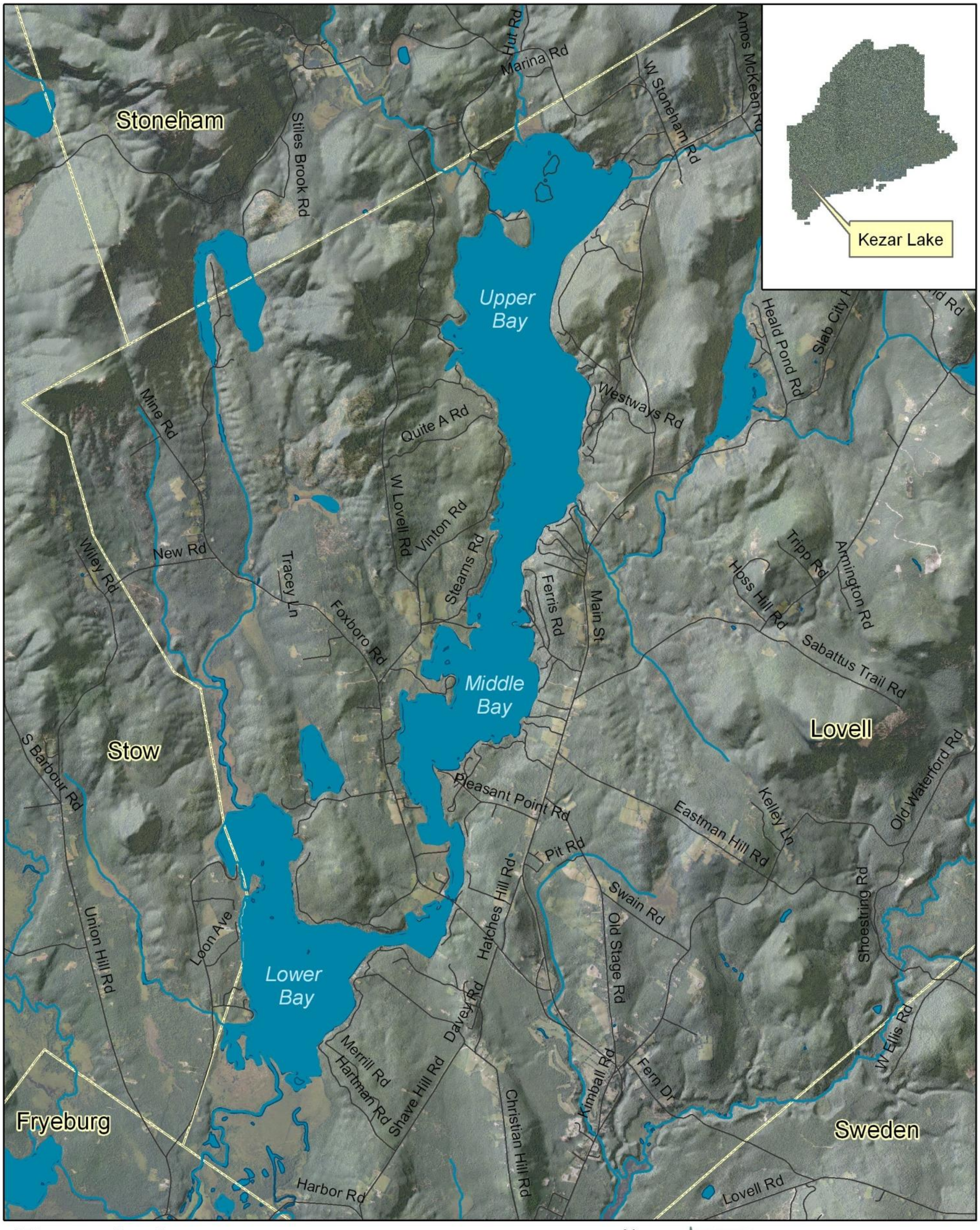

Kezar Lake
Lovell, ME

Data obtained from MEGIS.
Created by FB Environmental,
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Water Quality Report

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Cover photo: FB Environmental

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Glossary of Key Terms Used in this Report

Chlorophyll-a: 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; higher Chl-a equates to greater amount of algae in the lake.

Color: The influence of suspended and dissolved particles in the water as measured by Platinum Cobalt Units (PCU). A variety of sources contribute to the types and amount of suspended material in lake water, including weathered geologic material, vegetation cover, and land use activity. Colored lakes (>25 PCU) can have reduced transparency readings and increased TP values. When lakes are highly colored, the best indicator of algal growth is chlorophyll-a.

Dissolved Oxygen: The concentration of oxygen that is dissolved in the water. DO is critical to the healthy metabolism of many creatures that reside in the water. DO levels in lake water are influenced by a number of factors, including water temperature, concentration of algae and other plants in the water, and amount of nutrients and organic matter that flow into the water body from the watershed. Too little oxygen severely reduces the diversity and abundance of aquatic communities. DO concentrations may change dramatically with lake depth. Oxygen is produced in the top portion of a lake (where sunlight drives photosynthesis), and oxygen consumption is greatest near the bottom of a lake (where organic matter accumulates and decomposes).

Epilimnion: The top layer of lake water that is directly affected by seasonal air temperature and wind. This layer is well oxygenated by wind and wave action except times when the lake is covered by ice.

Escherichia coli (E. coli): An indicator of the presence of fecal contamination in the watershed. By itself, *E. coli* is generally not a threat to human health, but it can be associated with disease-causing organisms.

Eutrophic: Refers to lakes with high productivity, high levels of phosphorus and chlorophyll, low Secchi disk readings, and abundant biomass with a lot of accumulated organic matter on the bottom. Eutrophic lakes are susceptible to algal blooms and oxygen depletion in the hypolimnion.

Integrated Epilimnetic Core: A water sample that is taken with a long tube in order to determine average nutrient concentration in the epilimnion.

pH: The standard measure of the acidity or alkalinity of a solution on a scale of 0-14. Most aquatic species require a pH between 6.5 and 8. As the pH of a lake declines, particularly below 6, the reproductive capacity of fish populations can be greatly impacted as the availability of nutrients and metals changes. pH is influenced by bedrock, acid rain or snow deposition, wastewater discharge, and natural carbon dioxide fluctuations.

Platinum Cobalt Units (PCU): A unit of measurement used to determine the color of lake water. Lake water with 30 PCU will look slightly brown or tea-colored. (Formerly reported as SPU- Standard Platinum Units.)

Glossary of Key Terms (*Continued*)

Sample Station: Location where water quality readings and samples are taken. Some of the larger lakes or basins are sampled at more than one location, resulting in multiple station numbers. In lakes with more than one basin, at least one station is usually located in each basin.

Secchi disk transparency (SDT): A vertical measure of water transparency (ability of light to penetrate water) obtained by lowering a black and white disk into the water until it is no longer visible. Measuring SDT is one of the most useful ways to show whether a lake is changing from year to year. Changes in transparency may be due to increased or decreased algal growth, or the amount of dissolved or particulate materials in a lake, resulting from human disturbance or other impacts to the lake watershed area. Factors that affect transparency include algae, water color, and sediment. Since algae are usually the most common factor, transparency is an indirect measure of algal populations.

Thermocline: The uppermost point in the water column where the temperature drops at least a degree Celsius per meter of depth.

Total Alkalinity: A measure of the buffering capacity of a lake, or the capacity of water to neutralize acids. It is a measure of naturally-available bicarbonate, carbonate, and hydroxide ions in the water, which is largely determined by the geology of soils and rocks surrounding the lake. Alkalinity is important to aquatic life because it buffers against changes in pH that could have drastic effects on animals and plants.

Total Phosphorus (TP): The total concentration of phosphorus found in the water, including organic and inorganic forms. TP is one of the major nutrients needed for plant growth. It is generally present in small amounts and limits plant growth in freshwater ecosystems. As phosphorus increases, the amount of algae generally increases. Humans can add phosphorous to a lake through stormwater runoff, lawn or garden fertilizers, and leaky or poorly maintained septic tanks.

Trophic State Indicators: A scale from 0 to 100+, which ranks lakes for productivity. The low (zero) end of the scale supports very little algae, has excellent water quality (oligotrophic) and the high end 100+ is eutrophic and very productive. TSI can be calculated from the Secchi disk, Chl-a or total phosphorus results and requires at least five months of data per year. Lakes with TSI values greater than 65 may support algal blooms while values over 100 indicate extreme productivity and annual algae blooms. TSI values can be used to compare lakes with similar water color and track water quality trends within a lake.

Watershed: A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

1. Background and Historical Information

Kezar Lake Facts:
Watershed: Saco River
Surrounding Towns: Lovell, Stow, Stoneham
County: Oxford
Watershed Area: 35,732 acres (56 mi^2)
Mean Depth: 34 feet
Max Depth: 155 feet
Surface Area: 2,510 acres (3 mi^2)
Watershed Group: Kezar Lake Watershed Association
Midas Number: 0097
Fishery: Mixed warm and cold-water fishery

Kezar Lake is a waterbody located in the Town of Lovell in Oxford County, Maine. The lake stretches nine miles from north to south. The Kezar Lake watershed also encompasses nine smaller ponds and numerous streams.

This report documents the results of water quality monitoring conducted by FB Environmental Associates (FBE) for the Kezar Lake Watershed Association (KLWA) in 2013. In addition to monitoring water quality in the three basins of Kezar Lake, FBE also collected water quality data at six ponds in the Kezar Lake watershed: Bradley, Cushman, Farrington, Heald, Horseshoe and Trout ponds. Several of the six ponds are hydrologically connected, and they all ultimately drain into Kezar Lake. Additionally, FBE monitored two tributaries to Kezar Lake: Great Brook and Boulder Brook. Great Brook drains into the upper basin at the north end of Kezar Lake, and Boulder Brook flows into Kezar Lake between the middle and upper basins on the east side of the lake.

Background and historical information about Kezar Lake, Great Brook, Boulder Brook and the six ponds has been presented in detail in previous reports. Please refer to the following reports for more information:

- Historical Trend Analysis: Kezar Lake & Ponds (July 2012) - *Provides and analysis of 40 years worth of water quality monitoring data for Kezar Lake and six ponds within the Kezar Lake watershed.*
- Kezar Lake 2012 Water Quality Report (January 2013) - *Summarizes the results of the 2012 water quality monitoring for Kezar Lake, Boulder Brook, Great Brook, and the six ponds.*
- Kezar Lake Nutrient Modeling (June 2013) - *Estimates Phosphorus Loads using Lake Loading Response Modeling.*
- Kezar Lake Watershed Ponds NPS Survey Report (January 2013) - *Summarizes the watershed survey within the subwatersheds of six ponds surrounding Kezar Lake: Bradley, Cushman, Farrington, Heald, Horseshoe and Trout ponds.*

2. Water Quality Monitoring Methods and Parameters

Sampling locations, dates, and weather conditions of water samples collected by FBE in 2013 are listed in Table 1 (below):

Table 1. 2013 Sampling Summary.

Date	Weather			Sampling Sites
	Prior 24 h precip (in)*	Prior 48 h precip (in)*	Sampling Day Weather Conditions	
6/18/2013	0.23	0.24	Partly cloudy	Kezar Lake, Kezar Lake Tributaries (2), Kezar Lake Watershed Ponds (Trout, Cushman, Bradley, Heald, Farrington, Horseshoe)
8/14/2013	1.09	1.09	Cloudy, bright	Kezar Lake Watershed Ponds (Trout, Cushman, Bradley, Heald, Farrington, Horseshoe)
8/20/2013	0.01	0.02	Sunny and clear	Kezar Lake[+]
9/17/2013	0.06	0.06	Sunny and clear	Kezar Lake, Kezar Lake Tributaries (2)

**Source: Weather Underground, Fryeburg Airport Weather Station (KIZG)*
[+]TP profile collected, samples sent to Sawyer Environmental Lab in Orono, ME for analysis.

Kezar Lake Monitoring

The three basins of Kezar Lake were sampled on June 18, August 20 and September 17, 2013 (Table 1). Sampling was conducted in accordance with standard methods and procedures for lake monitoring established by the Maine Department of Environmental Protection (Maine DEP), the US Environmental Protection Agency, and the Maine Volunteer Lake Monitoring Program (VLMP). With the exception of the Maine DEP sample collected on 8/20/13, which was analyzed at the Sawyer Environmental Lab in Orono, all lab samples were analyzed at the Health and Environmental Testing Lab (HETL) in Augusta.

The following parameters were measured:

Trophic State Indicators: Maine DEP defines trophic state as the ability of a waterbody to produce algae and other aquatic plants; the trophic state of a waterbody is a function of its nutrient content. Water clarity (measured by **Secchi disk transparency (SDT)** readings), **total phosphorus (TP)**, and **chlorophyll-a (Chl-a)** are trophic state indicators, or indicators of biological productivity in lake ecosystems. The combination of these parameters helps determine the extent of and effects of eutrophication in lakes.

Additional indicators of lake water quality measured in 2013 include **dissolved oxygen (DO)**, **temperature**, **natural color**, **total alkalinity** and **pH**.

An integrated epilimnetic core method was used to collect samples at the deep hole of each of Kezar Lake's three basins and the smaller watershed ponds. With this method, a core of water is collected from the water surface to the upper part of the thermocline. Sampling results reflect the average concentration for each of the measured parameters.

At the request of the Maine DEP, FBE collected additional samples to test for anions, cations, dissolved organic carbon (DOC), aluminum, iron and silica. Samples were collected from a core profile in a 500 mL Nalgene sampling bottle and were mailed to the Sawyer Environmental Lab in Orono in the same day. Laboratory results are not yet available for this analysis.

Additional TP samples were taken during the August 20th sampling event at the deep hole (Station 1) in order to evaluate the distribution of phosphorous in the water column. A Kemmerer sampler was used to obtain four TP samples from the surface (grab sample), epilimnion (above thermocline), metalimnion (at thermocline) and hypolimnion (1 m above lake bottom).

Kezar Lake Tributary Monitoring

Tributary sampling was conducted on June 18 and September 17, 2013, upstream of the Adams Road crossing off Hut Road at Great Brook (GB-1), and at three locations on Boulder Brook: at the outlet to Kezar Lake on the Boulder Brook Club property (BB-1), and upstream (BB-4) and downstream (BB-3) of the Route 5 crossing (Table 1). Water quality parameters measured included **DO**, **temperature**, **TP**, and ***E. coli***.

Kezar Lake Watershed Pond Monitoring

On June 18 and August 14, 2013, monitoring was conducted at the deep hole of Bradley, Cushman, Farrington, Heald, Horseshoe, and Trout Ponds (Table 1). Water quality parameters measured were the same as those described above for Kezar Lake.

KLWA volunteer Charlie Dattelbaum (above) and FBE scientist Whitney Baker (right) collecting water quality samples in Kezar Lake in August 2013.

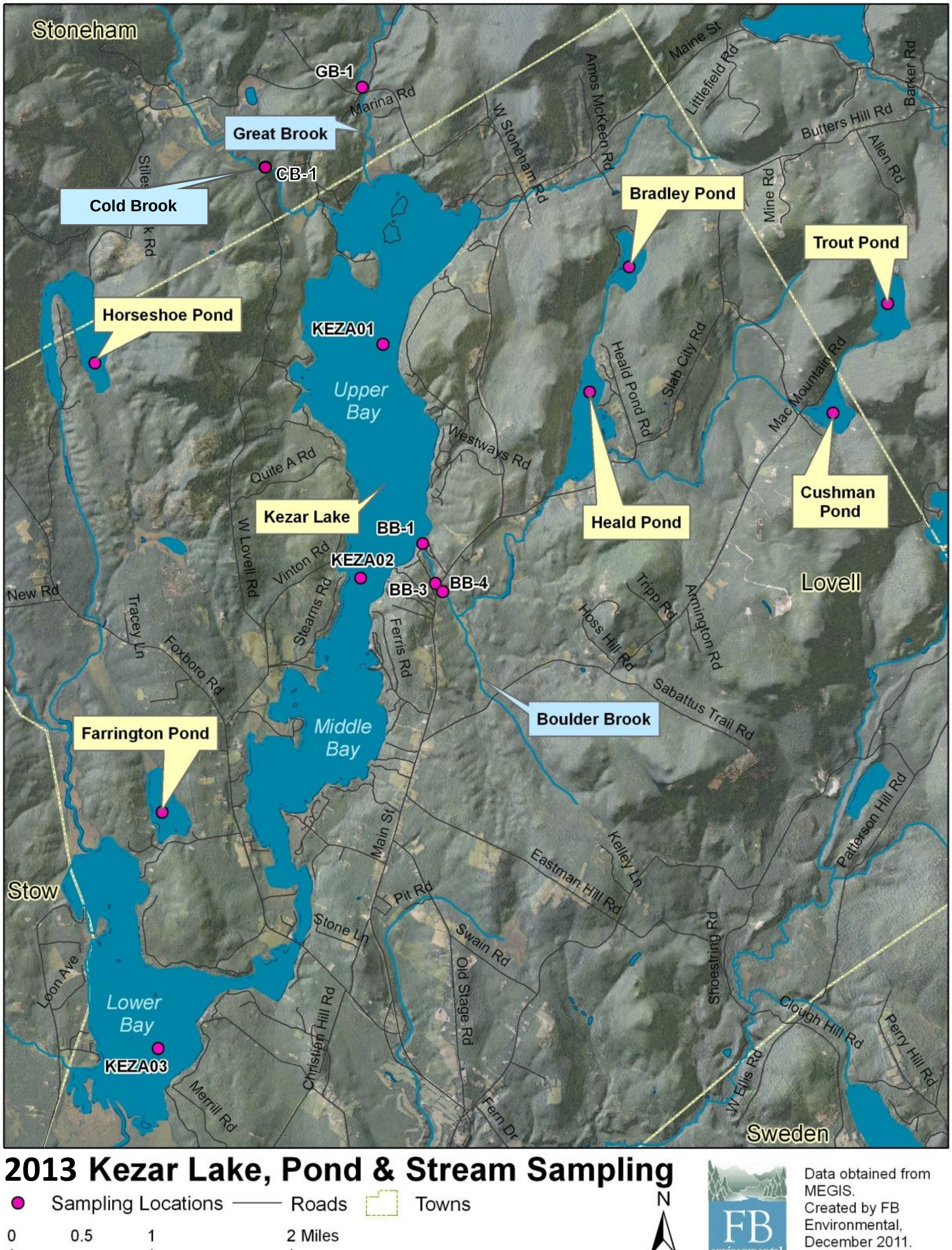


Figure 1. Map of Sampling Locations.

3. Kezar Lake Water Quality Monitoring Results

Water Clarity

In 2013, average Secchi Disk Transparency (SDT) readings for the upper, middle, and lower basins of Kezar Lake were 7.2, 6.8, and 3.5 m, respectively (Figure 2). When compared to the other basins, water clarity in the lower basin appears to be less than at the other basins. However, since the lower basin is very shallow, the Secchi disk is visible while resting on the lake bottom. Therefore, SDT values for the lower basin do not accurately reflect water clarity in this location. The decreasing SDT values at the lower basin are likely due to small decreases in water level as the summer season progressed. Annual fluctuations in clarity are common, and often result from variable weather patterns from year to year. Historically, water clarity in Kezar Lake has been variable on an annual basis, yet remains consistent over the historical sampling period (Figure 3).

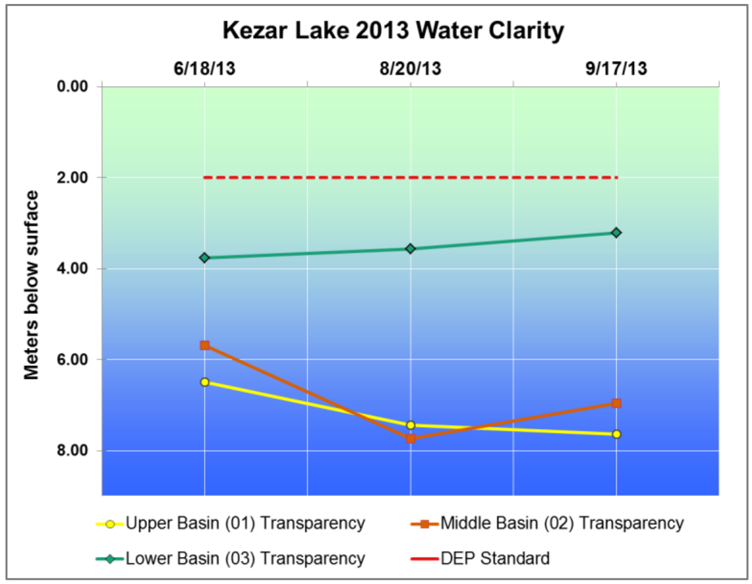


Figure 2. Kezar Lake 2013 water clarity.

In Maine, SDT values vary from 0.5 m to 15.5 m, with an average of 4.8 m. Average SDT readings are related to algal productivity using the following guidelines:

- **4 meters or less = Productive**
- **4 -7 meters = Moderately Productive**
- **7 meters or greater = Non-productive**

According to these guidelines, the upper basin of Kezar Lake is on the lower end of non-productive, and the middle basin is moderately productive.

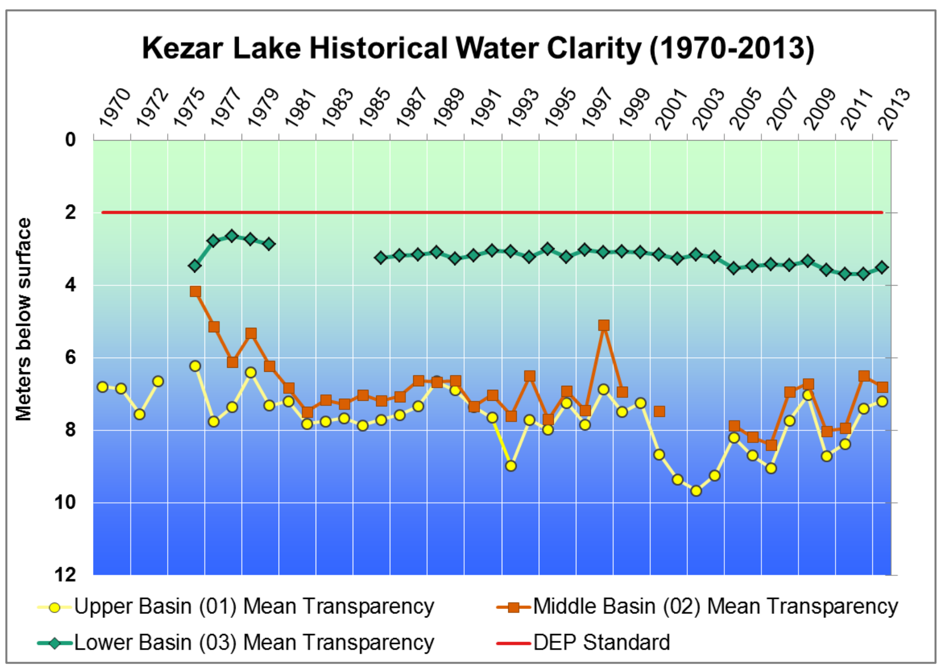


Figure 3. Kezar Lake Historical Water Clarity, 1970-2013.

Dissolved Oxygen

A common problem in Maine lakes is the depletion of dissolved oxygen (DO) in the deepest part of the lake throughout the summer months. This occurs when thermal stratification prevents the oxygenated surface water from mixing with water deep in the lake, and chemical or biological processes use up the available dissolved oxygen at the bottom of the water column. DO levels below 5 ppm can stress some species of cold-water fish, and over time reduce habitat for sensitive cold-water species. In addition, anoxia (complete absence of oxygen) at the lake bottom can result in the release of phosphorous from the sediments and which become a readily available food source to algae.

Historically, Kezar Lake has experienced some DO depletion in the upper and middle basins in late summer and fall. Evidence of moderate DO depletion (near or below 5 ppm) was documented in the upper basin in June and September 2013 (Figure 4). DO levels were observed to be as low as 5.0 ppm on 6/18/2013 and 3.2 ppm on 9/17/2013 in the hypolimnion. Typically during the hottest summer months, DO concentrations in the middle basin are less than 5 ppm, as was seen in 2011 and 2009. However, in 2013, DO in the middle basin remained high, never measuring below 6.4 ppm. Overall, Kezar Lake has adequate levels of DO for aquatic species.

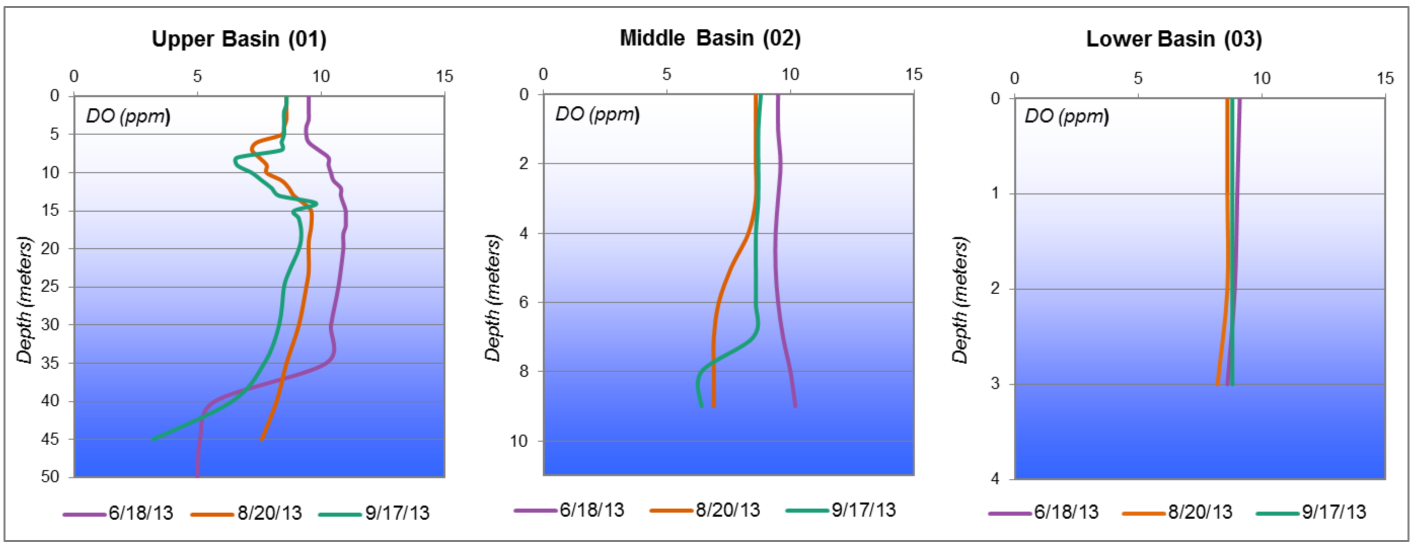


Figure 4. Kezar Lake 2013 Dissolved Oxygen Profiles.

Temperature profiles in 2013 are in line with historic temperature profiles for all stations. Formation of the metalimnion occurred between 5 and 8 meters below the surface at the upper and middle basins (Figure 4). A thermocline cannot develop at the lower basin due to the shallow depth of the water.

Total Phosphorus

In Maine lakes, TP varies from 1 ppb to 158 ppb with an average of 12 ppb. In 2013, TP averaged 6.7, 6.0, and 8.0 ppb at the upper, middle, and lower basins of Kezar Lake, respectively (Table 3). These results are higher than the 2012 TP results at the upper (4.0 ppb) and middle (4.7 ppb) basins, and lower than the 2012 TP results at the lower (9.7 ppb) basin. As in 2010, 2011 and 2012, TP concentrations in the upper basin decreased as the season progressed. Kezar Lake TP samples collected in 2013, and seasonal averages for all basins, were below the statewide average.

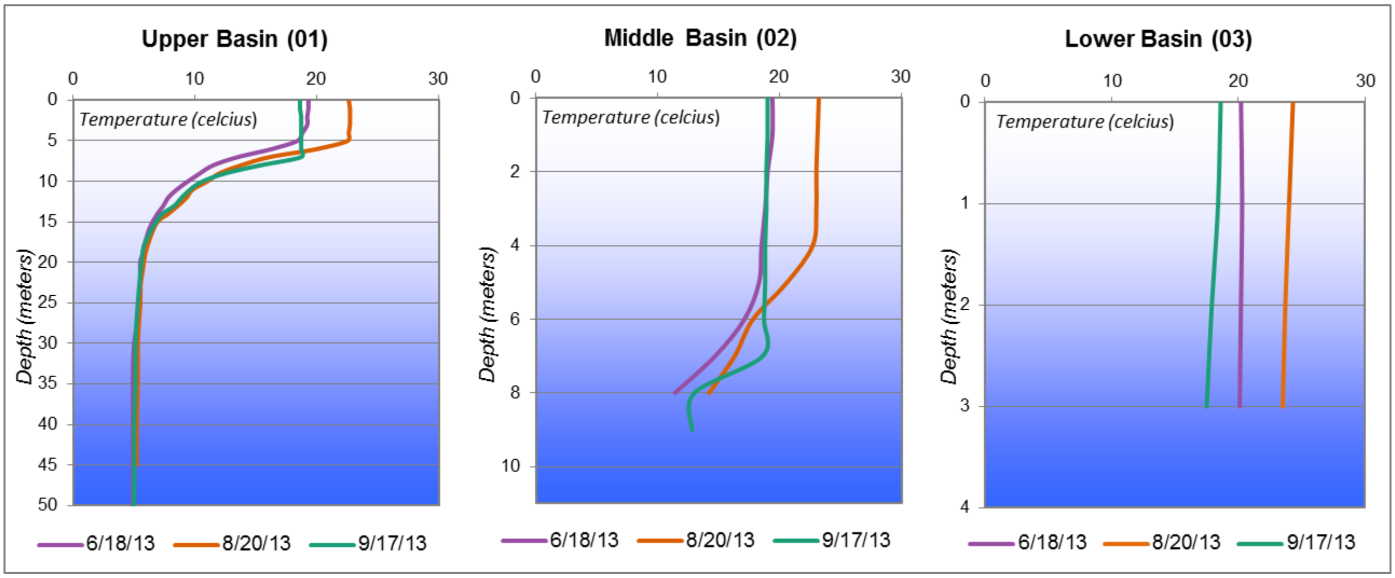


Figure 5. Kezar Lake 2013 Temperature Profiles.

A total phosphorus profile was collected during the August 20th sampling event to evaluate the distribution of phosphorus in the water column. Information from samples collected throughout the profile allow researchers to determine if phosphorus is being released from the lake sediments, which can happen if certain conditions at the sediment/water interface are met. When the deep waters of lakes remain oxygenated, the sediments can generally absorb phosphorus from the water column, as the phosphorus will chemically bind to sediment particles. However, in the absence of oxygen at the bottom of the lake, sediments may begin to release phosphorus back into the water column which can stimulate biological productivity and algal growth.

To determine the concentrations of phosphorus in the water column of Kezar Lake, five separate TP samples were collected in addition to the standard epilimnetic core. The depths of these samples were taken from different thermal zones of the lake which become established when a lake stratifies. Lakes generally stratify after mixing, which usually occurs in the fall and spring – warm waters stay near the surface ("epilimnion") while cooler, denser water sinks to the bottom ("hypolimnion"). The area in between these layers, where the water temperature exhibits the greatest change, is called the "thermocline" or "metalimnion." Samples were taken from each of these three zones in addition to the surface, and one meter above the lake bottom.

It was found that TP concentrations are relatively uniform throughout the water column of Kezar Lake (Table 2, Figure 6). Since higher TP values were not observed in the hypolimnion or bottom samples, it suggests that the lake sediments do not release phosphorus during summer stratification. An evaluation of the TP data with The DO profile suggests that the hypolimnion likely stays oxygenated enough through summer stratification to keep phosphorus retained in the lake sediments.

Table 2. Kezar Lake total phosphorus profile data, upper basin, 8/20/2013.

Sample Depth (m)	Lake Zone	TP (ppb)
0	Surface	5.0
3	Epilimnion	5.0
9	Metalimnion	4.0
21	Hypolimnion	3.0
45	Bottom	5.0

Further research, such as the collection of surface and bottom TP samples during spring or fall mixing events could provide more insight into the relationship between the sediments and TP in the water column of Kezar Lake. Additionally, collection of a winter DO profile could determine if the hypolimnion becomes anoxic during winter stratification.

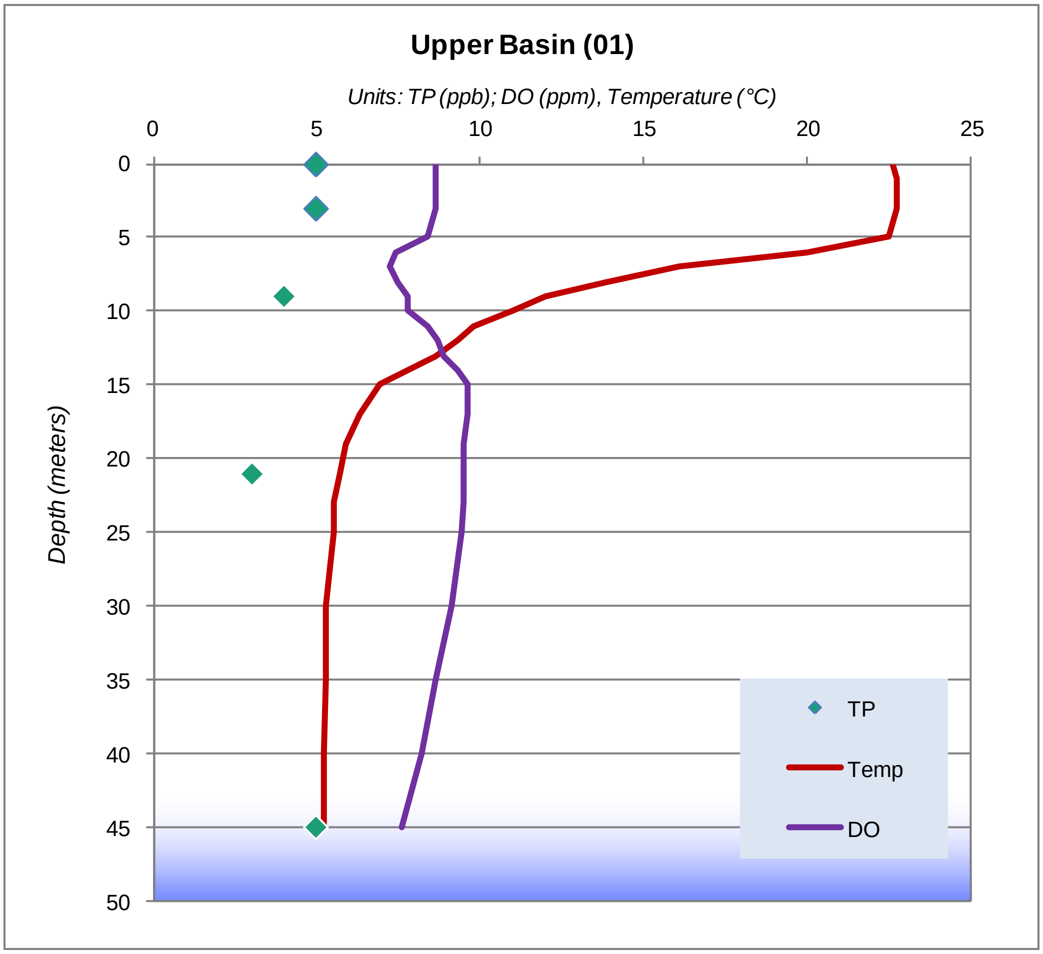


Figure 6. Kezar Lake 2013 Upper Basin Total Phosphorus Profile Data, with Dissolved Oxygen and Temperature profiles.

Color

In Maine lakes, color varies from 2 to 481 PCU with an average of 28 PCU. In 2013, color averaged 13.3, 13.0, and 14.7 PCU at the upper, middle, and lower basins of Kezar Lake, respectively (Table 4). For all samples, color was lower than 2012 levels but above historical averages of 11.2, 11.7, and 13.9 PCU for the upper, middle, and lower basins, respectively. Historical data indicate that high color values correspond with high precipitation years, as a result of increased runoff (see Table 8, Figure 7). Kezar lake is a non-colored lake with an average color that is less than the average for Maine lakes.

Chlorophyll-a

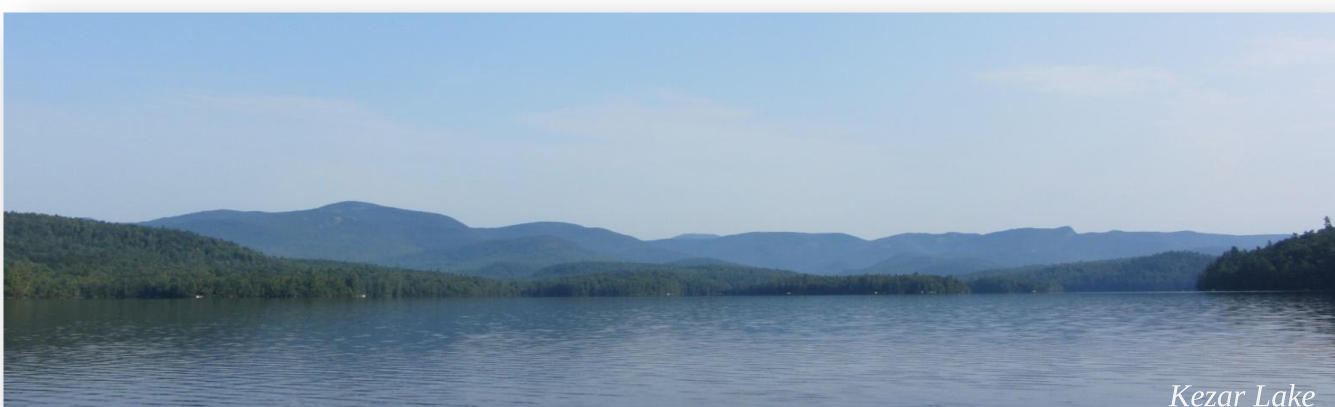
Chl-a in Maine lakes ranges from 0.7 ppb to 182 ppb, with an average of 5.3 ppb (Table 5). In 2013, Chl-a was observed to have decreased slightly from 2012 values in all three basins of Kezar Lake, with averages ranging from 1.8 to 2.4 ppb (Table 5). In previous years, the lower basin commonly had a higher average Chl-a concentration than the upper and middle basins. In general, this basin is more at risk to algal growth than other areas of the lake due to its shallow nature. Chl-a concentrations in all basins of Kezar Lake are still roughly half the Maine average.

Alkalinity

Kezar Lake has low alkalinity (buffering capacity). In 2013, all three basins in Kezar Lake averaged 4.0 mg/L over the course of the sampling season (Table 6). These low values indicate that Kezar Lake is susceptible to changes in pH, which can be caused by acidic deposition in the form of rain or snow. Alkalinity is important to aquatic life because it protects organisms against changes in the acidity of the water (pH) that could have dramatic effects on aquatic plants and animals. Without adequate buffering capacity, the lake is subject to both natural and anthropogenic swings in pH values which can jeopardize the health of freshwater fish species.

pH

Most aquatic species require a pH between 6.5 and 8. Measurements of pH at all three basins in Kezar Lake ranged from 6.9 – 7.1 (neutral) in 2013 (Table 7). Waters become more acidic when pH is less than 7; waters are alkaline when above 7. In Maine, pH varies from 4.23 to 9.70, the average being 6.8.



Kezar Lake

Table 3. Kezar Lake 2013 total phosphorus data.

Total Phosphorous (ppb)		
6/18/2013	Upper	8.0
	Middle	6.0
	Lower	8.0
8/20/2013	Upper	5.0
	Middle	6.0
	Lower	7.0
9/17/2013	Upper	7.0
	Middle	6.0
	Lower	9.0
2013 Average (Kezar Lake)	Upper	6.7
	Middle	6.0
	Lower	8.0
Maine Lakes Average	12.0	

Table 4. Kezar Lake 2013 color data.

Color (PCU)		
6/18/2013	Upper	13
	Middle	13
	Lower	15
8/20/2013	Upper	13
	Middle	12
	Lower	14
9/17/2013	Upper	14
	Middle	14
	Lower	15
2013 Average (Kezar Lake)	Upper	13.3
	Middle	13.0
	Lower	14.7
Maine Lakes Average	28.0	

Table 5. Kezar Lake 2013 chlorophyll-a data.

Chlorophyll-a (ppb)		
6/18/2013	Upper	1.5
	Middle	1.7
	Lower	3.4
8/20/2013	Upper	1.8
	Middle	2.0
	Lower	1.9
9/17/2013	Upper	2.0
	Middle	2.6
	Lower	1.8
2013 Average (Kezar Lake)	Upper	1.8
	Middle	2.1
	Lower	2.4
Maine Lakes Average	5.3	

Table 6. Kezar Lake 2013 alkalinity data.

Alkalinity (ppm)		
6/18/2013	Upper	4.0
	Middle	4.0
	Lower	4.0
8/20/2013	Upper	4.0
	Middle	4.0
	Lower	4.0
9/17/2013	Upper	4.0
	Middle	4.0
	Lower	4.0
2013 Average (Kezar Lake)	Upper	4.0
	Middle	4.0
	Lower	4.0
Maine Lakes Average	12.0	

Table 7. Kezar Lake 2013 pH data.

pH		
6/18/2013	Upper	7.1
	Middle	7.1
	Lower	7.0
8/20/2013	Upper	7.0
	Middle	7.0
	Lower	7.1
9/17/2013	Upper	6.9
	Middle	6.9
	Lower	7.0
2013 Average (Kezar Lake)	Upper	7.0
	Middle	7.0
	Lower	7.0
Maine Lakes Average	6.8	

Summary

Kezar Lake remains one of Maine's cleanest and clearest lakes, with above average water quality and clarity. Historically, Kezar Lake's TP and Chl-a results have been well below statewide averages. Similarly, the long-term average SDT for the lake's upper basin is 7.7 m compared to an average of 4.8 m for all Maine lakes. Water clarity in the middle basin is also consistently better than the state average (Table 8).

Table 8. Summary of Kezar Lake Historical and Recent Water Quality Averages.

Kezar Lake Historical and Recent Water Quality Averages							
Year	Basin	SDT (meters)	TP (ppb)	Chl-a (ppb)	pH	Alkalinity (mg/L)	Color (PCU)
2013	Upper (01)	7.2	6.7	1.8	7.0	4.0	13.3
	Middle (02)	6.8	6.0	2.1	7.0	4.0	13.0
	Lower (03)	3.5	8.0	2.4	7.0	4.0	14.7
2012	Upper (01)	7.4	4.0	2.2	7.0	4.0	15.0
	Middle (02)	6.5	4.7	2.3	6.9	4.0	14.0
	Lower (03)	3.7	9.7	2.1	6.9	4.0	16.0
2011	Upper (01)	8.3	5.0	2.0		3.7	10.3
	Middle (02)	8.1	6.0	2.2		3.3	10.7
	Lower (03)	3.6	8.0	2.6		3.7	13.7
2010	Upper (01)	8.7	9.0	2.1		3.7	8.3
	Middle (02)	8.1	3.0	1.8		4.0	8.7
	Lower (03)	3.6	11.0	2.4		4.0	9.0
2009	Upper (01)	7.0	8.0	2.3		3.3	21.3
	Middle (02)	6.7	5.0	2.1		3.3	12.7
	Lower (03)	3.3	8.0	2.3		4.0	16.0
Historical Average[1]	Upper (01)	7.7	6.0	2.8	6.7	4.5	11.2
	Middle (02)	6.9	5.0	2.1	6.5	3.4	11.7
	Lower (03)	3.2	9.0	2.4	6.7	4.6	13.9
Maine Lakes Average[2]		*4.8*	*12.0*	*5.3*	*6.8*	*11.9*	*28*

[1] *Includes FBE data from 2013, but does not include 2013 Maine DEP or VLMP data.*

[2] *2011 Maine Lakes Report (Maine VLMP)*

Water quality measures (SDT, TP, and Chl-a) in 2013 indicate that Kezar Lake's water quality is close to historical averages (Table 8). 2013 TP concentrations in the upper and middle basins were slightly higher than 2012 averages, but are approximate to historical averages.

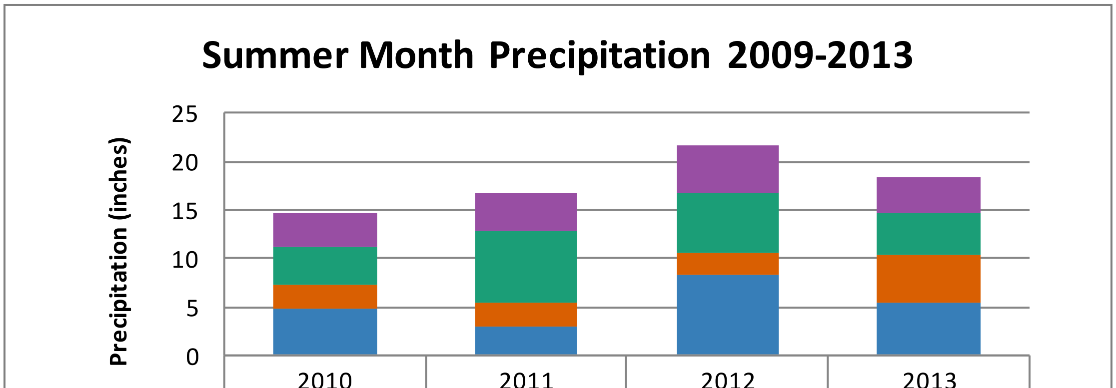
Year to year fluctuations in TP and transparency readings can be due to weather influences such as stronger winds or increased rainfall which can decrease water clarity and increase TP by increasing the amount of particles—particularly sand, silt, and clay sediments—suspended in the water column. A total of 21.6 inches of rain fell in the region last year during the summer months (June through September, 8.3

inches in June alone) (Figure 7), whereas only 18.4 inches fell in the same time period in 2013 (and only 5.4 inches in June). Only 14.7 inches and 46.8 inches of summer precipitation fell in 2010 and 2011, respectively. This may explain why Kezar Lake SDT readings in 2012 and 2013 were lower (less clear) than in the previous two years. Chl-a measurements have remained relatively stable at all basins in recent years.

A well-oxygenated hypolimnion can help cold-water fish species survive the warmest months of the year, when strongly stratified lakes may experience DO depletion in the hypolimnion. There is a greater chance of this occurring in very deep waters, such as the upper basin of Kezar Lake. DO depletion was especially evident in the upper basin in 2009 and 2011, when DO concentrations were observed to be below 5ppm during the August sampling events. DO concentrations in the middle basin are typically observed to be less than 5 ppm, as was seen in 2011 and 2009. However, in 2013, DO in the middle basin remained high, never measuring below 6.4 ppm.

While the water quality of Kezar Lake is generally excellent, the lake is sensitive to change. Continuing to monitor all three basins of the lake, as well as the small ponds that drain to Kezar Lake, will help the KLWA better understand long and short-term trends and maintain the high quality of the water in Kezar Lake for future generations.

Supplementing monitoring efforts by adding a July sampling event for Kezar Lake is highly recommended to better assess seasonal (summer) water quality during the most productive time of the year. Currently samples are collected in June, August and September. July is a missing link in assessing long-term water quality. Additionally, collecting TP profiles during sampling events will help to determine if sediments are releasing phosphorus into the water column. This is of special concern when a hypolimnion shows oxygen depletion, as is commonly observed in the middle and upper basins of Kezar Lake.



	2010	2011	2012	2013
September	3.5	3.9	4.8	3.62
August	3.9	7.5	6.3	4.46
July	2.5	2.4	2.3	4.91
June	4.8	3.0	8.3	5.42

Figure 7. Summer Precipitation, 2010-2013.

4. Kezar Lake Tributary Monitoring Results

In 2013, the water quality of two Kezar Lake tributaries, Boulder Brook and Great Brook, was monitored on two dates (June 18 and September 17). Great Brook is located on the northwest end of Kezar Lake off West Stoneham Road. Boulder Brook flows under Route 5 just north of Center Lovell and through the Boulder Brook Club, flowing into Kezar Lake at the swimming area.

Boulder Brook was sampled at the outlet to Kezar Lake on the Boulder Brook Club property (BB-1) as well as upstream (BB-4) and downstream (BB-3) of the Route 5 crossing. Great Brook was sampled upstream of the Adams Road crossing adjacent to Hut Road (GB-1). Temperature, dissolved oxygen (DO), total phosphorus (TP) and *E. coli* were measured at each sampling event.

The average DO concentration in both streams during the course of the sampling season was above 7 ppm, which is the Maine DEP standard for Class A streams, and a threshold required by most aquatic species for survival and growth (Great Brook averaged 11.4 ppm and Boulder Brook averaged 9.0 ppm). Only one station measured below 7 ppm at either of the visits during the 2013 sampling season (BB-4, 6/18/2013) (Tables 9 and 10). The average DO concentration for both streams was higher in 2013 compared to 2012. The two streams were also observed to be colder in 2013 than in 2012.

In 2013, the KLWA board expressed concern about E. coli in Cold Brook (Station CB-1), which flows southeast from the Evergreen Valley Resort, and eventually into Upper Bay. The concern is that Cold Brook may be contributing bacteria and nutrients to Kezar Lake as a result of the 70-unit housing development and large central sewer system upstream. Monitoring was conducted on August 20, 2013 by KLWA volunteers following training by FBE. The sampling location is located approximately 100 m upstream of the bridge on Slide Inn Rd.

Results of the monitoring indicate that the stream has high levels of dissolved oxygen and low levels of total phosphorus (refer to table), which are signs of a healthy natural stream. *E.coli* levels were low and do not indicate a bacteria problem at the time of sampling.

Table 9. 2013 Great Brook Water Quality Monitoring Results.

Date	Site Code	Temp. (C)	DO (ppm)	TP (ppb)	*E. coli* (col/100mL)
6/18/2013	GB-1	12.9	12.3	4	13
9/17/2013	GB-1	11.3	10.5	6	21
2013 Average		**12.1**	**11.4**	**5**	**17**
2012 Average		*13.9*	*10.0*	*4*	*19*

Table 10. 2013 Boulder Brook Water Quality Monitoring Results.

Date	Site Code	Temp. (C)	DO (ppm)	TP (ppb)	*E. coli* (col/100mL)
6/18/2013	BB-1	12.9	12.3	17	124.0
	BB-3	17.3	9.1	17	132.0
	BB-4	17.4	6.75	17	166.0
9/17/2013	BB-1	13.4	9.83	13	25.0
	BB-3	14.6	7.73	13	33.0
	BB-4	14.6	8.01	13	27.0
2013 Average		**15.0**	**9.0**	**15**	**85**
2012 Average		*18.5*	*7.8*	*11*	*180*

Table 11. 2013 Cold Brook Water Quality Monitoring Results.

Date	Site Code	Temp. (C)	DO (ppm)	TP (ppb)	*E. coli* (col/100mL)
8/20/2013	CB-1	17.5	9.55	13	65.0

TP is one of the most important nutrients to monitor in lakes because it is generally the limiting nutrient in freshwater systems. This means that the amount of phosphorus in the water usually governs biological productivity, such as algal and plant growth. High phosphorus concentrations often result in greater biomass of algae and aquatic plants. TP concentrations in the tributaries ranged from 4 to 17 ppb with an average of 5 ppb for Great Brook, and 15 ppm for Boulder Brook (Tables 9 and 10). These values are slightly higher than results from 2012 (4 ppb for Great Brook and 11 ppb for Boulder Brook). Boulder Brook is potentially contributing more TP to Kezar Lake than Great Brook, with all monitoring sites showing similar TP concentrations.

E. coli results in the tributaries were below the Maine DEP standard of 194 col/100 mL at both Great Brook and Boulder Brook (Tables 8 and 9) in 2013, though numbers were slightly elevated at all stations in Boulder Brook during the June sampling. In 2012, elevated *E. coli* levels were measured at Boulder Brook stations BB-3 (461 col/100mL) and BB-4 (548 col/100mL) in September. High *E. coli* measurements under lower flow conditions may indicate fecal contamination from septic systems, wildlife or pets. Further sampling and reconnaissance is needed under both dry and wet weather conditions, as wells as during peak summer months (July-August) to refine potential sources at this site. In general, the water quality in Great Brook appears to be better than in Boulder Brook.

5. Kezar Watershed Ponds Monitoring Results

In 2013, FB Environmental continued baseline monitoring for six ponds that drain directly or indirectly into Kezar Lake. Water quality data for Bradley, Cushman, Farrington, Heald, Horseshoe, and Trout Ponds was collected on June 18th and August 14th. June is the beginning of the "warm" season in Maine lakes, and August is generally the time when Maine lakes are most biologically productive. Therefore, August is when indications of stress and water quality degradation are most apparent.

Water quality is generally good in the six ponds. According to 2013 sampling results (Table 12), three of the six KLWA ponds had an average water clarity better than the Maine average of 4.8 meters. Cushman, Farrington and Heald Ponds had a SDT below the Maine average. However, SDT readings are limited by depth on Farrington, as the Secchi disk was visible on the lake bottom at the August sampling event. None of the six ponds fell below the Maine DEP minimum SDT standard of two meters. Cushman and Heald Ponds showed a decrease in SDT (less clear) from 2012, but Bradley, Horseshoe and Trout Ponds all showed increased SDT from 2012 (Farrington was observed to be the same). Trout Pond had the most significant increase in clarity from 2012 of more than 1 meter (Table 12).

All of the ponds in the Kezar Lake watershed showed a decrease in color from 2012, after showing increases from 2011-2012. These results are similar to the decrease in color in all three basins of Kezar Lake in 2013, and is likely related to higher than average summer precipitation in 2012 (as discussed on page 12).

Total phosphorus (TP) trends indicate lower TP concentrations in all ponds in 2013 compared with 2012 with the exception of Heald and Bradley ponds which remained the same (Table 12). Although Heald Pond had the highest TP average at 10 ppb, this is in-line with Heald's historical average of the past 40 years. Of note are the TP concentrations in Horseshoe, Farrington and Trout ponds in 2013. All of which had lower average TP concentrations this year compared to their historical average. In fact, Farrington Pond had the lowest TP concentration since sampling began in 1997.

All ponds are consistently lower than the state average for alkalinity (12 ppm), making these waterbodies highly sensitive to changes in pH. Changes in pH can be caused by acid rain or snow, or from polluted runoff entering the lake. Overall, pH values ranged from 6.5 (Bradley Pond) to 7.1 (Farrington Pond).

Annual variability in water quality is common for freshwater lakes, which is why collection of annual baseline data for the KLWA ponds is important. This information will provide the KLWA with long-term water quality trends for the Kezar Lake watershed.

Table 12. Kezar Watershed Ponds 2012 and 2013 Water Quality Monitoring Results.

Pond	SDT (m)		TP (ppb)		Chl-a (ppb)		pH		Alkalinity (mg/L)		Color (PCU)	
	2012	**2013**	***2012***	**2013**	***2012***	**2013**	***2012***	**2013**	***2012***	**2013**	***2012***	**2013**
Bradley	*5.3*	5.4	*9.0*	9.0	*5.8*	3.7	*6.5*	6.8	*3.5*	4.0	*32.0*	18.5
Cushman	*5.1*	4.5	*10.0*	7.5	*4.1*	2.8	*7.0*	7.1	*4.0*	4.5	*16.0*	19.0
Farrington*	*4.5*	4.5	*13.0*	9.0	*5.8*	4.5	*7.1*	7.2	*4.0*	5.0	*18.0*	15.5
Heald	*4.6*	4.1	*10.0*	10.0	*4.5*	5.7	*6.7*	6.9	*4.5*	5.5	*35.0*	33.0
Horseshoe	*6.3*	6.6	*8.0*	6.0	*6.2*	3.1	*6.9*	7.0	*3.5*	3.5	*15.0*	10.5
Trout	*6.3*	7.4	*4.0*	3.5	*2.6*	2.7	*7.0*	7.0	*3.0*	3.5	*15.0*	11.0
Maine Average	*4.8*		*12.0*		*5.3*		*6.8*		*12.0*		*28.0*	

**SDT Values limited by lake depth - secchi hits bottom*

Bradley Pond

Secchi disk transparency (SDT) and TP concentrations in Bradley Pond remained stable from 2012 to 2013. SDT increased by 0.1 m and TP did not show any change. Chl-a levels between 2012 and 2013 decreased by 1.1 µg/L. As seen in the current year's data, **DO concentrations in Bradley Pond again dropped below the aquatic life standard of 5 ppm between 5 and 6 meters depth in 2013** (Figure 8).

Color decreased from 32.0 PCU in 2012 to 19 PCU in Bradley Pond in 2013 while alkalinity increased by 0.5 mg/L (from 3.5 to 4 mg/L), and pH levels were 6.8, near the low end of the acceptable range for most aquatic species. As the pH of a lake declines, particularly below 6, the reproductive capacity of fish populations can be greatly impacted as the availability of nutrients and metals changes. As such, pH in Bradley Pond should be continued to be monitored in future years. The low DO conditions in the hypolimnion are of greater concern than low pH, however. While we saw an improvement in Chl-a and color in Bradley Pond in 2013 compared to 2012, some annual variation in water quality is common, and expected. Overall, results from 2013 are in-line with historical results for this pond.

Figure 8. Bradley Pond 2013 Dissolved Oxygen Profile.

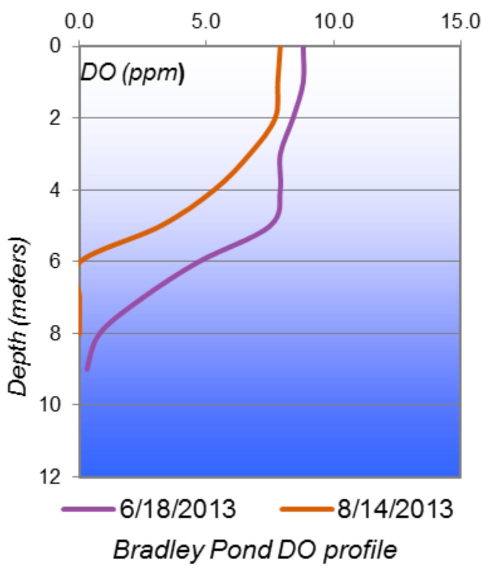
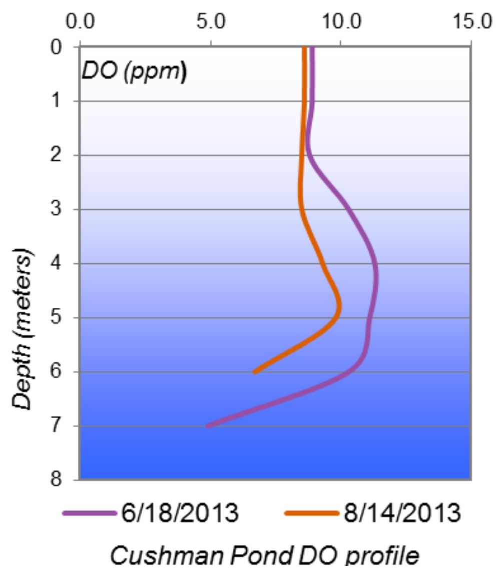


Figure 9. Cushman Pond 2013 Dissolved Oxygen Profile.



Cushman Pond

In 2013, as in previous years, only minimal DO depletion was observed at the bottom of the deepest area of Cushman Pond between five and six meters (Figure 9). **The Maine aquatic life standard of 5 ppm was observed to be passed on June 18th, when the deepest waters only showed 4.8 ppm DO.** SDT decreased from 5.1 m to 4.5 m, but TP decreased by 2.5 ppb and Chl-a decreased from 4.1 ppb to 2.8 ppb. Color increased by 3 PCU. Further monitoring is needed to support long-term trends in Cushman Pond to determine if short-term variations in water quality are being affected by environmental factors such as wind and precipitation. While there were some minor improvements in water quality between 2012 and 2013 in Cushman Pond (TP and Chl-a), these short-term variations are to be expected. **However, when**

compared to historical averages, 2013 results for Cushman Pond were elevated in all major parameters, indicating a decline in water quality.

Farrington Pond

Farrington Pond drains directly into the lower basin of Kezar Lake. The once stable TP concentrations in Farrington Pond increased to 19 ppb in 2011, 12.5 ppb in 2012, and were found to be 9 ppb in 2013, the lowest on record. Overall, Chl-a continued to show a decline from recent years. DO depletion has not been an issue for Farrington Pond, primarily due to the pond's shallow depth and lack of stratification (Figure 10).

Chl-a levels have been variable in Farrington Pond, increasing in 2011 to 15.5 ppb, then dropping to 5.8 ppb in 2012 and 4.5 ppb in 2013. Since 2012, alkalinity has increased from 4.0 to 5.0 mg/L. Color has varied from 10 PCU in 2010, 16.5 PCU in 2011, 18 PCU in 2012, and then down to 16 PCU in 2013. SDT was consistent with historical readings which typically reach the bottom of the pond. While annual variation in water quality is expected on an annual basis, long-term trends tell us more about the health of the water quality in Farrington Pond. **Of significance is that the TP concentrations in Farrington Pond in 2013 were the lowest on record, and Chl-a concentrations were also significantly lower than we've seen in the past several years.**

Why TP was elevated in some years more than others in Farrington Pond (2005 = 20 ppb, 2008 = 39 ppb, and 2011= 19 ppb) may very well be related to weather (heavy rainfall prior to sampling) and/or watershed disturbances (shoreline development) among other factors. Ongoing monitoring of this pond will provide clues to whether the annual improvement compared to the historical average is an anomaly, or if water quality is in fact continually improving in the pond.

Figure 10. Farrington Pond 2013 Dissolved Oxygen Profile.

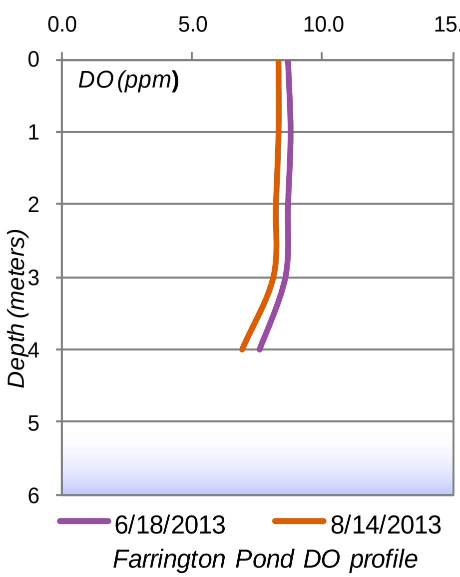
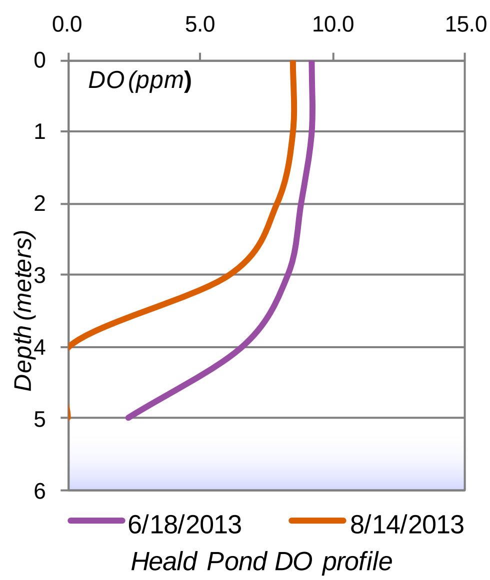


Figure 11. Heald Pond 2013 Dissolved Oxygen Profile.



Heald Pond

Heald Pond outlets into Mill Brook, which flows southwest until it meets Boulder Brook. Boulder Brook then flows northwest, into the upper basin of Kezar Lake at the Boulder Brook Club. As described in Section 4 (above), water quality samples were collected at three locations on Boulder Brook in 2013. DO concentrations in Heald Pond are low (< 5 ppm) below 4 meters (13.7 feet) in the summer months (Figure 11). TP concentrations remained stable from 2012 to 2013, and Chl-a increased from 4.5 ppb in 2012 to 5.7 ppb in 2013. Though color decreased slightly from 2012, Heald Pond remains the most colored pond in the watershed (33 PCU). Water clarity decreased by 0.5 m between 2012 and 2013.

When compared to the historical average (FBE, 2012), **2013 monitoring results indicate that both color and Chl-a are significantly higher than the historical average** (23 PCU and 3.9 ppb, respectively). **In fact, average annual Chl-a in 2013 was the highest on record for Heald Pond** (next lowest was 5.5 ppb in 1999), and the August reading of 6.2 ppb was the highest on record. These higher than normal Chl-a results are in line with high color, and lower than average SDT readings. **Since TP concentrations, Chl-a and color in Heald Pond are the highest in the watershed, and considered elevated in terms of water quality, Heald Pond may be at risk for algal blooms if water quality continues to decline.** Whereas Chl-a and SDT are an indirect measure of algal productivity, it will be important to track the changes in these parameters in the future. In addition, adding a July sample for Heald Pond is highly recommended.

Horseshoe Pond

Due to volunteer efforts, there is more historical data for Horseshoe Pond than any other small pond in the Kezar Lake watershed. While there was some annual variation in water quality between 2012 and 2013 (Table 8), the water quality of Horseshoe Pond has changed little over recent years. Findings from 2013 indicate some improvement in water quality, where average water clarity increased by nearly 1 meter from 6.6 to 7.4 m, TP decreased from 8.0 to 6.0 ppb, and Chl-a decreased by half from 6.2 to 3.1 ppb. Additionally, color decreased from 15 to 11 PCU. Alkalinity appeared to be stable from 2012 to 2013. **Dissolved oxygen, however, fell below 5 ppm at 11 meters in June and 8 meters in August** (Figure 12). **Of note, TP and Chl-a in Horseshoe Pond in 2013 were below the historical average, indicating that with the exception of the low DO at the deepest part of the lake, water quality in 2013 was very good.**

Trout Pond

Trout Pond drains into Cushman Pond which drains into Heald Pond, which flows into Boulder Brook, and eventually into Kezar Lake. **Water quality in Trout Pond is considered the best among the small ponds in the Kezar Lake watershed.** This may be due to the limited development on the shoreline of this waterbody compared to other developed ponds in the watershed. Development is limited to a large summer camp on the north end of the lake known as Camp Susan Curtis.

From 2012 to 2013, average water clarity increased by almost 1 meter, TP decreased by 1.5 ppb, Chl-a was relatively unchanged, color decreased by 4 PCU, and alkalinity increased by 0.5 mg/L (Table 8), **showing an overall improvement in water quality in 2013.** While some annual variation is expected, the historical trend analysis for Trout Pond indicated, though minor, there are signs of declining trends in water quality in Trout Pond (FBE, 2012). However, these trends were not evident in 2013**. In fact, in line with many of the other ponds in the watershed this year, total phosphorus (TP) and Chl-a were below the historical average for Trout Pond.** The August TP concentration of 3 ppb is similar to low TP documented in August of 2009 and 2010 (the only two years with TP concentrations as low as 2013), and half of what was measured in August of 2012.

Figure 12. Horseshoe Pond 2013 Dissolved Oxygen Profile.

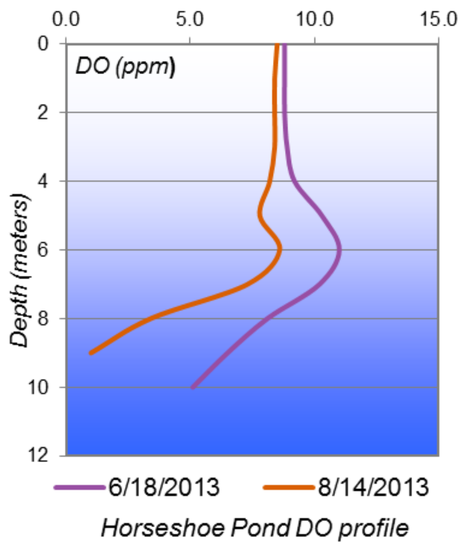
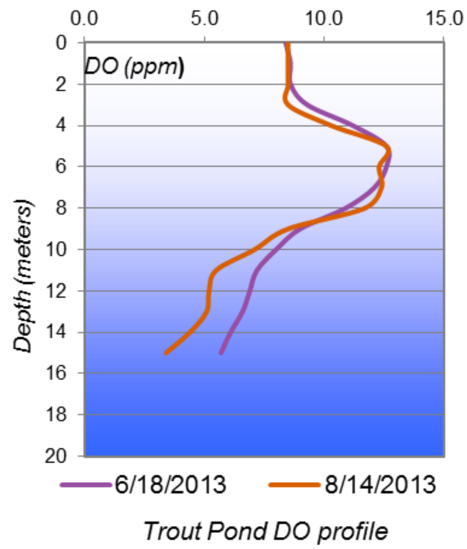


Figure 13. Trout Pond 2013 Dissolved Oxygen Profile.



Kezar Watershed Ponds - Key Findings

Bradley Pond

- DO concentrations in Bradley Pond again dropped below the aquatic life standard of 5 ppm between 5 and 6 meters depth in 2013 (Figure 8).

Cushman Pond

- The Maine aquatic life standard of 5 ppm was observed to be passed on June 18th, when the deepest waters only showed 4.8 ppm DO.
- When compared to historical averages, 2013 results for Cushman Pond were elevated in all major parameters, indicating a decline in water quality.

Farrington Pond

- TP concentrations in Farrington Pond in 2013 were the lowest on record, and Chl-a concentrations were also significantly lower than we've seen in the past several years.

Heald Pond

- When compared to the historical average monitoring results indicate that both color and Chl-a are significantly higher than the historical average. Average annual Chl-a in 2013 was the highest on record for Heald Pond
- Since TP concentrations, Chl-a and color in Heald Pond are the highest in the watershed, and considered elevated in terms of water quality, Heald Pond may be at risk for algal blooms if water quality continues to decline.

Horseshoe Pond

- Dissolved oxygen fell below 5 ppm at 11 meters in June and 8 meters in August. TP and Chl-a in Horseshoe Pond in 2013 were below the historical averages, indicating that with the exception of the low DO at the deepest part of the lake, water quality in 2013 was very good.

Trout Pond

- Water quality in Trout Pond is considered the best among the small ponds in the Kezar Lake watershed.
- From 2012 to 2013, average water clarity increased by almost 1 meter, TP decreased by 1.5 ppb, Chl-a was relatively unchanged, color decreased by 4 PCU, and alkalinity increased by 0.5 mg/L showing an overall improvement in water quality in 2013.
- Total phosphorus (TP) and Chl-a were below the historical average for Trout Pond.

Cushman Pond

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