2014

Kezar Lake Water Quality Report

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

FB Environmental Associates
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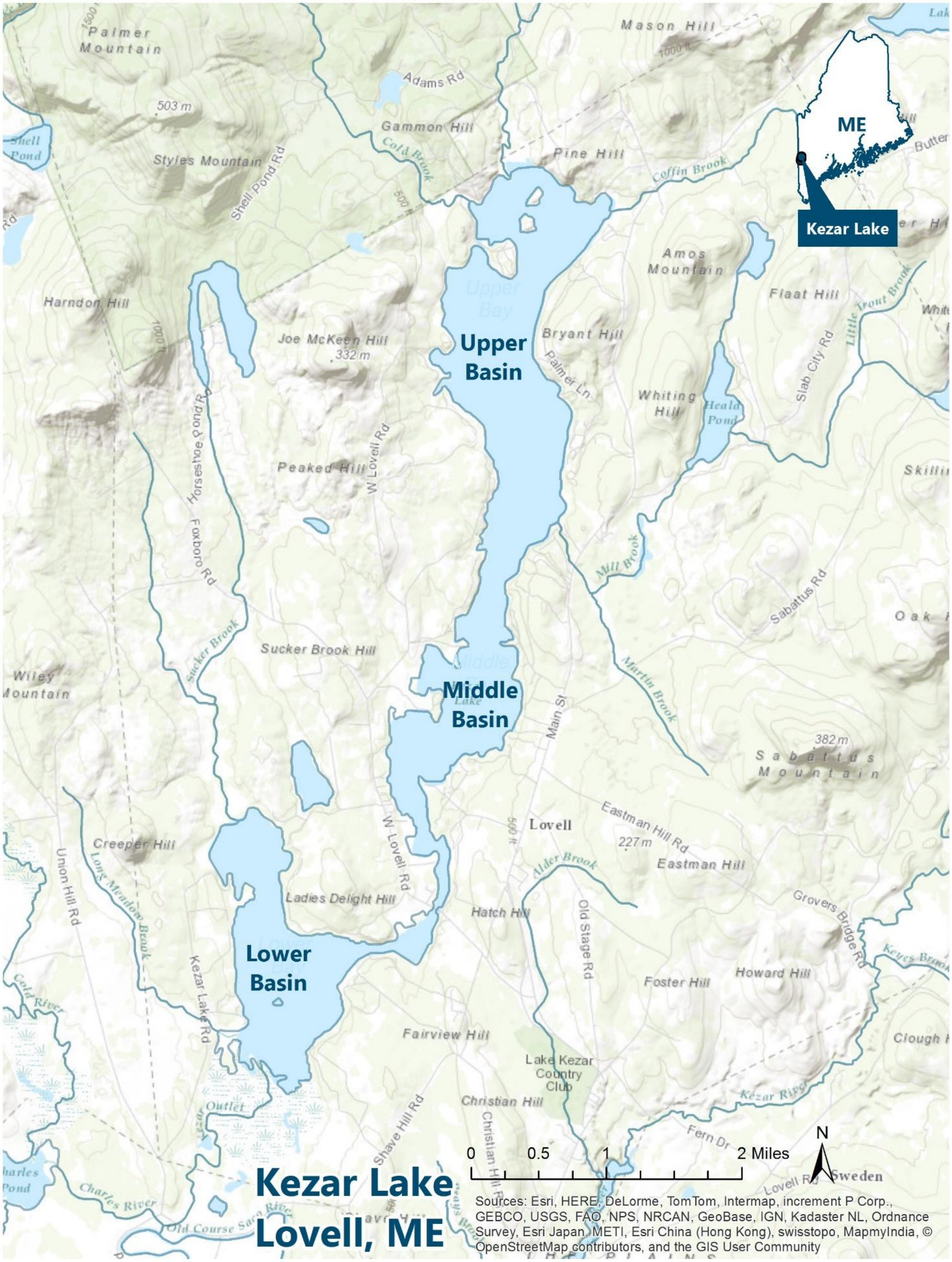

ME
Kezar Lake
Upper Basin
Middle Basin
Lower Basin
Upper Bay
Palmer Mountain
503 m
Styles Mountain
Shell Pond Rd
Shell Pond
Harndon Hill
Joe McKeen Hill
332 m
Horseshoe Pond Rd
Peaked Hill
W Lovell Rd
Foxboro Rd
Sucker Brook
Sucker Brook Hill
Wiley Mountain
Creeper Hill
Union Hill Rd
Long Meadow Brook
Kezar Lake Rd
Ladies Delight Hill
Cold River
Outlet
Charles Pond
Charles River
Old Course Saco River
Mason Hill
Adams Rd
Gammon Hill
Cold Brook
Pine Hill
Coffin Brook
Amos Mountain
Flaat Hill
Little Trout Brook
Bryant Hill
Palmer Ln
Whiting Hill
Heald Pond
Slab City Rd
Mill Brook
Sabattus Rd
Martin Brook
Main St
382 m
Sabattus Mountain
Lovell
Eastman Hill Rd
227 m
Eastman Hill
Alder Brook
Hatch Hill
Old Stage Rd
Grovers Bridge Rd
Foster Hill
Howard Hill
Keyes Brook
Fairview Hill
Lake Kezar Country Club
Christian Hill
Christian Hill Rd
Shave Hill Rd
Kezar River
Clough Hill
Fern Dr
Lovell Rd
Sweden
N
0 0.5 1 2 Miles
Kezar Lake
Lovell, ME
Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

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January 2015

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Special thanks to KLWA volunteers Ray Senecal (KLWA President), Charlie Dattelbaum (Boat Captain on Kezar Lake), Don Griggs (KLWA CCO), Sara Cope and Heinrich Wurm (KLWA Water Quality Chairs) for their help with coordinating the 2014 sampling season. A big thanks to Terri Mulks (Camp Susan Curtis - Trout Pond), Ralph Tedesco (Farrington Pond), Mrs. Sundsrom (Heald Pond), and Tom Hughes and the Emond family (Horseshoe Pond) for providing access, and/or equipment to help make the 2014 water quality monitoring season a success.

Cover photo: FBE, 2014

Table of Contents

List of Figures

List of Tables

Glossary of Key Terms Used in this Report

Chlorophyll-a (Chl-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 waterbody 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 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.

Eutrophication: Refers to lakes with high productivity, high levels of phosphorus and chlorophyll, low Secchi disk readings, and abundant biomass with significant accumulation of 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 dire 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 TP 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

This report documents the results of water quality monitoring conducted by FB Environmental Associates (FBE) for the Kezar Lake Watershed Association (KLWA) in 2014. 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 (Figure 1). Several of the six ponds are hydrologically connected, and they all ultimately drain to Kezar Lake. Additionally, FBE monitored two tributaries of Kezar Lake: Great Brook and Boulder Brook. Great Brook drains to 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 a 40-year analysis 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 conducted for the subwatersheds of the six ponds surrounding Kezar Lake: Bradley, Cushman, Farrington, Heald, Horseshoe, and Trout Ponds.*

2. Methods and Parameters

The sample stations at the three basins of Kezar Lake and four tributary stations along Great Brook (GB-1) and Boulder Brook (BB-1, BB-3, and BB-4) were sampled on June 16, August 12, and September 18, 2014; the sample stations at the deep holes of the six ponds (Bradley, Cushman, Farrington, Heald, Horseshoe, and Trout Ponds) were sampled on June 16 and August 12, 2014 (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 (USEPA), and the Maine Volunteer Lake Monitoring Program (VLMP). All lab samples were analyzed at the Health and Environmental Testing Lab (HETL) in Augusta.

KLWA volunteer Charlie Dattelbaum (above) has helped FBE collect water quality samples in Kezar Lake for many years.

Table 1. 2014 sampling summary of Kezar Lake, six ponds, and two tributaries in the Kezar Lake watershed.

Date	Weather: Prior 24 hr Precip (in)*	Weather: Prior 48 hr Precip (in)*	Weather: Prior 96 hr Precip (in)*	Weather: Sampling Day Conditions	Sampling Sites
6/16/2014	0	0	0.94	Bright	KEZA-0097-01,-02,-03 HORS-3196-01 FARR-3200-01 HEAL-3222-01 CUSH-3224-01 BRAD-3220-01 TROU-3212-01 BB-1, BB-3, BB-4, GB-1
8/12/2014	0	0	0	Overcast	KEZA-0097-01,-02,-03 HORS-3196-01 FARR-3200-01 HEAL-3222-01 CUSH-3224-01 BRAD-3220-01 TROU-3212-01 BB-1, BB-3, BB-4, GB-1
9/18/2014	0	0.11	0.11	Cloudy	KEZA-0097-01,-02,-03 BB-1, BB-3, BB-4, GB-1

* Source: Weather Underground, Fryeburg, ME weather station (KIZG)

With the help of KLWA volunteers, FBE collects temperature and dissolved oxygen profiles at the deep holes of the three Kezar Lake basins and six ponds in the Kezar Lake watershed. This information is used to determine where the epilimnion (or upper part of the thermocline) occurs and at what depth an integrated epilimnetic core will be taken. The water collected from this core is analyzed for natural color, total alkalinity, pH, total phosphorus (TP), and chlorophyll-a (Chl-a). In addition, water clarity is also measured by Secchi disk transparency (SDT) readings. The three parameters (SDT, TP, and Chl-a) are trophic state indicators, or indicators of biological productivity in lake ecosystems. The combination of these parameters helps determine the extent and effects of eutrophication in lakes.

The tributary stations were sampled for dissolved oxygen, temperature, TP, pH, and *E. coli*.

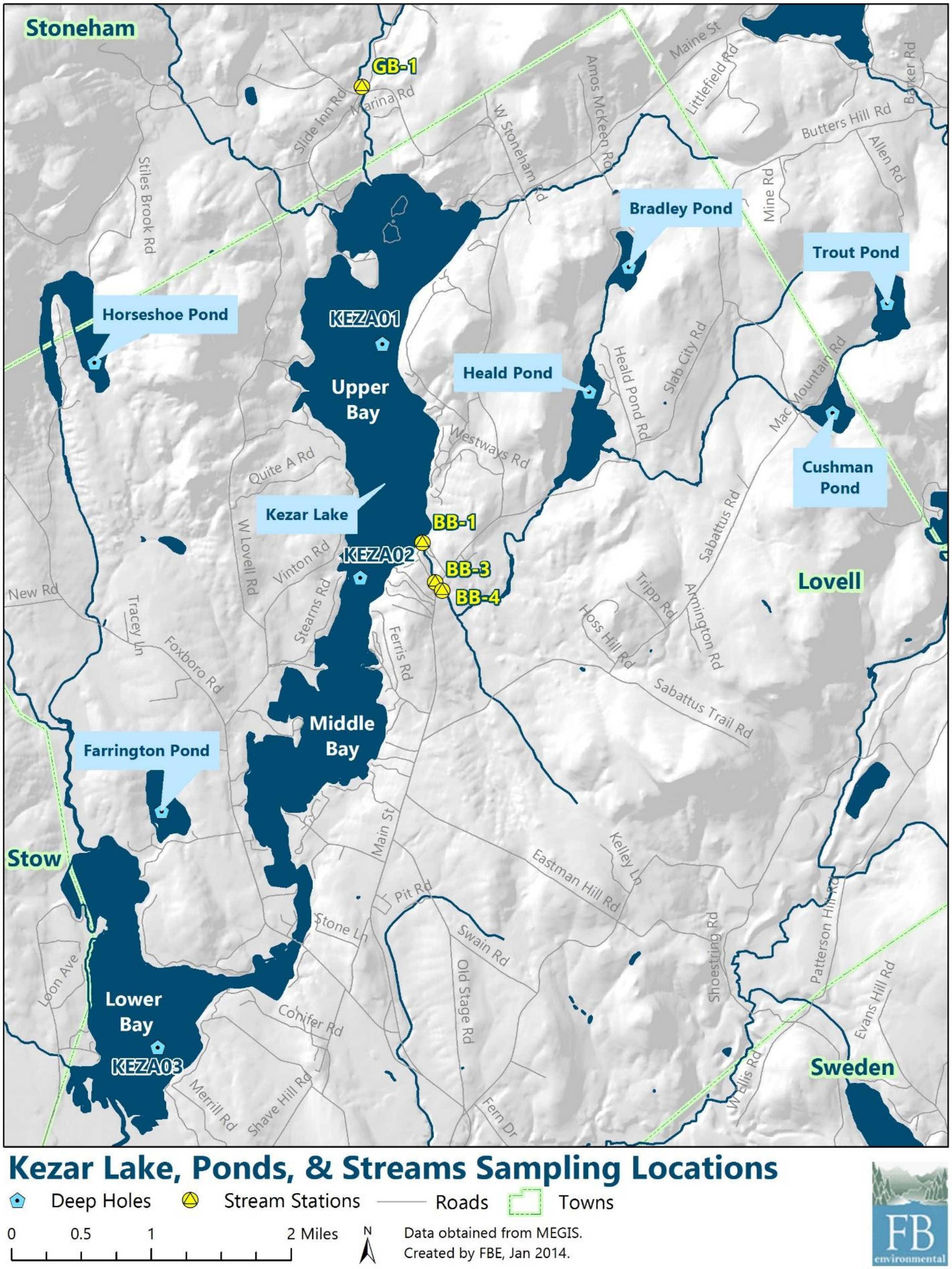

Figure 1. Map of 2014 sampling locations.

3. Water Quality Monitoring Results

Kezar Lake Basins

Water Clarity

Kezar Lake with a clouded view of the White Mountain National Forest. Photo credit: FBE, 2014.

In 2014, average SDT readings for the upper, middle, and lower basins of Kezar Lake were 8.6, 8.2, and 3.2 m, respectively (Figure 2; Table 2). Mean annual SDT for the upper, middle, and lower, basins of Kezar Lake are 7.7, 6.9, and 3.2 m, respectively (Table 3). Water clarity at the lower basin is less than at the other basins; however, the lower basin is very shallow and the Secchi disk is usually still visible on the lake bottom. Because of this, SDT values for the lower basin do not accurately reflect water clarity at this location. The variability in SDT values at the lower basin is likely due to small decreases and increases in water level as the seasons change. 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 2).

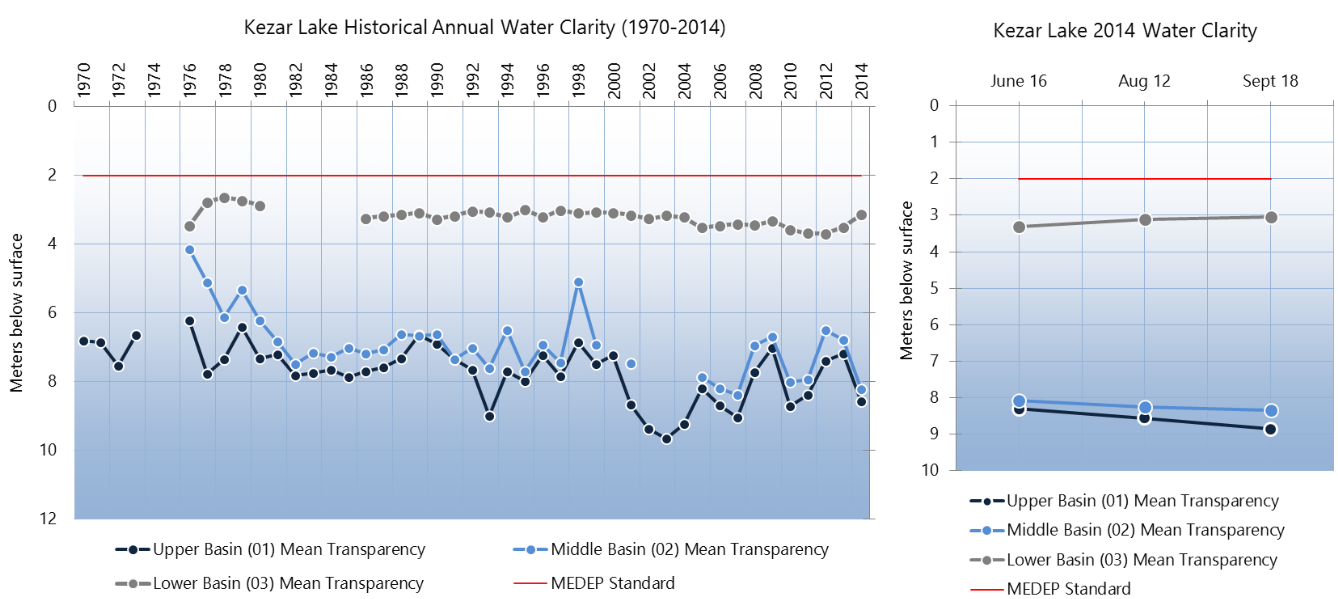

Figure 2. Kezar Lake historical water clarity (1970-2014) for the three basins (left) and Kezar Lake 2014 water clarity (right). Red line denotes Maine DEP water quality standard of 2 m for water clarity. The lower basin (03) is limited by its shallow depth and the Secchi disk typically hits bottom during readings.

In Maine, SDT values vary from 0.5 m to 15.5 m, with an average of 4.8 m (VLMP, 2013). Average SDT readings are related to algal productivity using the following guidelines:

- **< 4 m = productive**
- **4-7 m = moderately productive**
- **> 7 m = 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 on the upper end of moderately productive (nearly non-productive).

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 deeper water in the lake, and chemical or biological processes use up the available DO at the bottom of the water column. DO levels below 5 mg/L can stress some species of cold-water fish and reduce habitat for sensitive cold-water species over time. In addition, anoxia (complete absence of oxygen) at the lake bottom can result in the release of sediment-bound phosphorus, which becomes a readily-available food source for algae.

Historically, Kezar Lake has experienced some DO depletion in the upper and middle basins in spring, late summer, and early fall. Evidence of DO depletion (near or below 5 mg/L) was documented in the upper basin in June 2014 when DO levels fell to 2.0 mg/L at 45 m below the water surface (Figure 3). Typically during the hottest summer months, DO concentrations in the middle basin are less than 5 mg/L, as was seen in 2011 and 2009. In 2013 and 2014, DO in the middle basin remained high, never measuring below 6.4 mg/L. Overall, DO is excellent at Kezar Lake.

Temperature profiles in 2014 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 3). A thermocline cannot develop at the lower basin due to the shallow depth of the water.

In addition to baseline temperature data presented above, since 2013, the KLWA has been working with Dr. Dan Buckley at the University of Maine at Farmington (UMF) to collect continuous annual in-lake temperature data using HOBO data loggers in Kezar Lake from May - October. The loggers are deployed by KLWA volunteers in the spring and then sent to UMF in the fall. Dr. Buckley uses the KLWA data as part of a statewide climate change study of Maine lakes. In that sense, changes in lake temperature in Kezar Lake can be compared to other lakes across the State. Data loggers were deployed at all three basins in Kezar Lake in 2013, and expanded to include Horseshoe Pond in 2014.

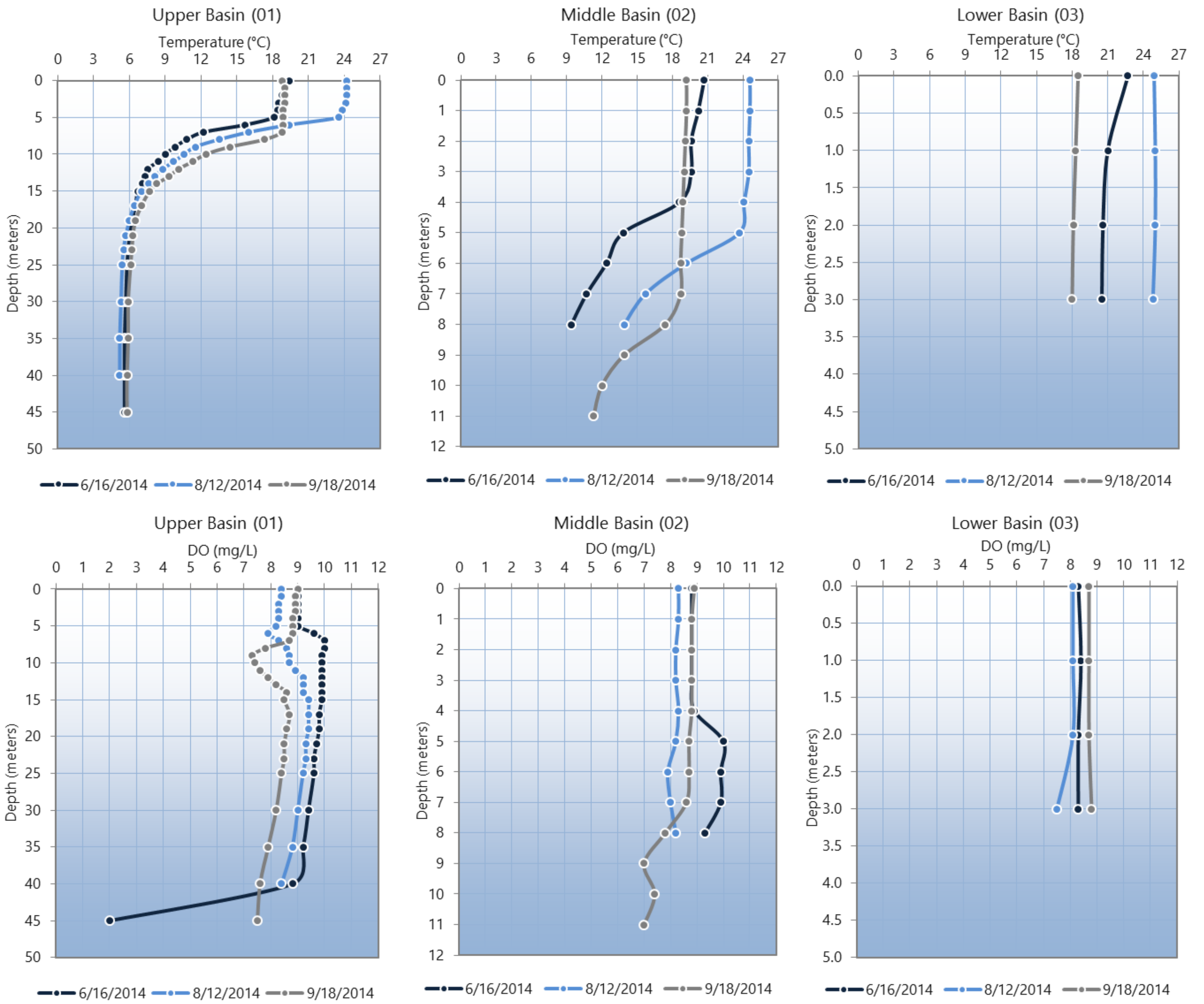

Figure 3. 2014 temperature (top panel) and dissolved oxygen (bottom panel) profiles for the upper, middle, and lower basins of Kezar Lake.

Total Phosphorus

In Maine lakes, total phosphorus (TP) varies from 1 ppb to 139 ppb with an average of 12 ppb (VLMP, 2013). In 2014, TP averaged 6.0, 4.0, and 8.7 ppb at the upper, middle, and lower basins of Kezar Lake, respectively (Table 2). TP results at the upper basin in 2014 (6.0 ppb) were lower than in 2013 (6.7 ppb), but still higher than in 2012 (4.0 ppb; Table 3). TP results for the middle basin in 2014 (4.0 ppb) were lower than in both 2013 (6.3 ppb) and 2012 (4.7 ppb). TP results for the lower basin in 2014 (8.7 ppb) were higher than in 2013 (8.3 ppb), but lower than in 2012 (9.7 ppb). TP samples collected over the course of the summer from 2010-2013 showed decreasing TP concentration from late spring to early fall at the upper basin. In 2014, there was a spike in TP in August at 11.0 ppb that disrupted this expected trend. Despite this, individual samples and seasonal averages in 2014 were below the statewide average for TP at all three basins on Kezar Lake (VLMP, 2013).

Color

In Maine lakes, color varies from 2 to 493 Platinum Color Units (PCU) with an average of 28 PCU (VLMP, 2013). In 2014, color averaged 10.7, 11.0, and 13.0 PCU at the upper, middle, and lower basins of Kezar Lake, respectively (Table 2). These results were lower than the averages observed in 2013 and 2012 (Table 3). Historical data indicate that high color values are positively correlated to high precipitation years, as a result of increased runoff (Figure 4). Overall, Kezar Lake is a non-colored lake with an average color that is less than the average for Maine lakes.

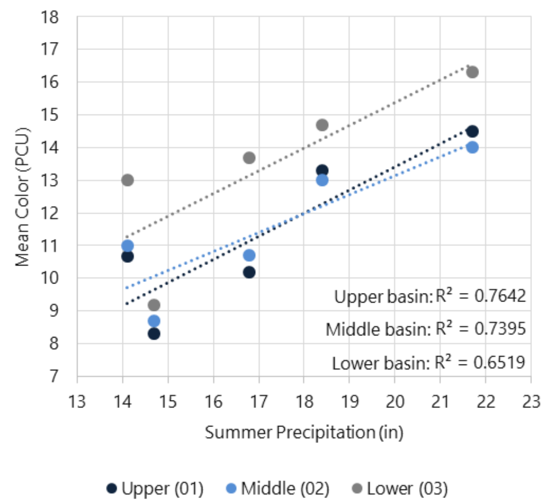

Figure 4. Summer precipitation partly drives mean annual color at the upper, middle, and lower basins of Kezar Lake. Note the scale on the x and y axes.

Chlorophyll-a

Chlorophyll-a (Chl-a) in Maine lakes ranges from 0.7 ppb to 182 ppb, with an average of 5.4 ppb (VLMP, 2013). In 2014, Chl-a averaged 1.8, 1.4, and 2.1 ppb at the upper, middle, and lower basins of Kezar Lake, respectively (Table 2). These results were lower or unchanged compared to mean annual Chl-a results since 2010 (Table 3). The lower basin commonly shows a higher average Chl-a concentration than the upper and middle basins. 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 (or buffering capacity) as a result of its contributing geology (i.e. granite) that lacks carbonates, bicarbonates, and carbonic acid. Alkalinity in Maine lakes ranges from -0.3 to 155.7 mg/L with an average of 11.8 mg/L (VLMP, 2013). Since 2012, all three basins in Kezar Lake have averaged 4.0 mg/L over the course of each sampling season (Tables 2 and 3). These low values indicate that Kezar Lake is susceptible to changes in pH, particularly from 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). Without adequate buffering capacity, the lake is subject to both natural and anthropogenic swings in pH values that 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 at Kezar Lake were 6.5 in 2014, which was more acidic than in 2013 at 7.0 (Tables 2 and 3). Water becomes more acidic when pH is less than 7 and is alkaline above a pH of 7. In Maine lakes, pH varies from 4.23 to 9.51 with an average of 6.8. This year, Kezar Lake was slightly more acidic than the average pH for Maine lakes.

Table 2. 2014 water quality monitoring results for the upper, middle, and lower basins of Kezar Lake.

Date	Station	TP (ppb)	Color (PCU)	Alkalinity (mg/L)	Chl-a (ppb)	pH
6/16/2014	Upper	4.0	11	4.0	1.8	6.6
	Middle	4.0	12	4.0	1.5	6.6
	Lower	9.0	14	4.0	2.1	6.5
8/12/2014	Upper	11.0	11	4.0	1.4	6.8
	Middle	4.0	11	4.0	1.2	6.8
	Lower	8.0	13	4.0	2.3	6.8
9/18/2014	Upper	3.0	10	4.0	2.3	6.3
	Middle	4.0	10	4.0	1.5	6.3
	Lower	9.0	12	4.0	2	6.4
2014 Mean (Kezar Lake)	Upper	6.0	11	4.0	1.8	6.5
	Middle	4.0	11	4.0	1.4	6.5
	Lower	8.7	13	4.0	2.1	6.5
Maine Lakes	Mean	12.0	28	11.8	5.4	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 and middle basins is 7.7 and 6.9 m, respectively, compared to an average of 4.8 m for all Maine lakes (Table 3).

Kezar Lake 2014 sampling on a cloudy day.

Water quality measures (SDT, TP, Chl-a, and color) in 2014 indicate that Kezar Lake's water quality is close to or better than historical averages, particularly for Chl-a and color (Table 3). Year to year fluctuations in TP and transparency readings can be due to weather influences such as stronger winds or increased rainfall that can decrease water clarity and increase TP by increasing the amount of particles (e.g. sand, silt, and clay) suspended in the water column. Summer 2014 was relatively dry, totaling only 14.1 inches of rain during the summer months (from June to September; Figure 5). This likely explains why Secchi disk readings were deeper (water more clear), Chl-a was lower, TP was generally lower, and color was lower (less suspended material). In addition, July 2014 saw the highest total rainfall compared to the last 4 years (2010-2013), but since no data was collected in July, it is unclear what effect high precipitation may have had on water quality during this time.

The hypolimnion of the upper and middle basins was also fairly well-oxygenated throughout the 2014 sampling season with the exception of low DO readings at the bottom of the upper basin in June. A well-oxygenated hypolimnion can help cold-water fish species survive the warmest months of the year.

Table 3. 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)
	Upper (01)	8.6	6.0	1.8	6.5	4.0	10.7
2014	Middle (02)	8.2	4.0	1.4	6.5	4.0	11.0
	Lower (03)	3.2	8.7	2.1	6.5	4.0	13.0
	Upper (01)	7.2	6.7	1.8	7.0	4.0	13.3
2013	Middle (02)	6.8	6.3	2.1	7.0	4.0	13.0
	Lower (03)	3.5	8.3	2.4	7.0	4.0	14.7
	Upper (01)	7.4	4.0	2.2	6.9	4.0	14.5
2012	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	16.3
	Upper (01)	8.3	5.3	2.0	--	3.7	10.2
2011	Middle (02)	7.9	5.7	2.2	--	3.3	10.7
	Lower (03)	3.7	8.3	2.6	--	3.7	13.7
	Upper (01)	8.7	9.3	2.1	--	3.7	8.3
2010	Middle (02)	8.0	3.3	1.8	--	4.0	8.7
	Lower (03)	3.6	10.2	2.4	--	3.8	9.2
	Upper (01)	7.7	5.9	2.8	6.7	4.5	11.3
Historical Average[a]	Middle (02)	6.9	6.6	2.0	6.7	3.7	12.1
	Lower (03)	3.2	8.8	2.5	6.7	4.5	14.3
	Maine Lakes Average[b]	4.8	12.0	5.4	6.8	11.8	28

[a] Includes FBE data from 2014, but does not include 2014 Maine DEP or VLMP data

[b] 2013 Maine Lakes Report (Maine VLMP)

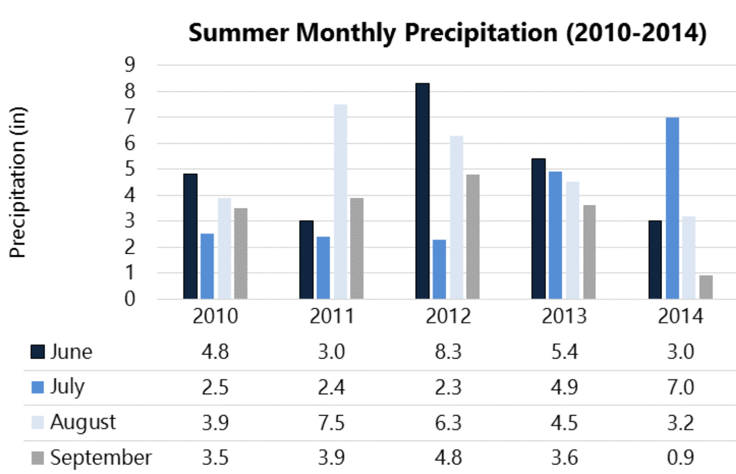

Figure 5. Summer monthly precipitation amounts from 2010-2014. Data sourced from Weather Underground for the Fryeburg, ME weather station.

Tributaries

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, DO, pH, TP, and *E. coli* were measured at each sampling event (Table 4).

Table 4. 2014 water quality monitoring results for Kezar Lake tributaries (Great Brook and Boulder Brook).

Date	Site Code	Temp (°C)	DO (mg/L)	pH	TP (ppb)	*E. coli* (col/100 mL)
Great Brook						
6/16/2014	GB-1	15.3	9.5	6.5	5	25
8/12/2014	GB-1	17.0	9.0	6.5	6	22
9/18/2014	GB-1	12.0	10.1	6.2	4	16
2014 Average		**14.8**	**9.5**	**6.4**	**5**	**21**
2013 Average		*12.1*	*11.4*	*6.6*	*5*	*17*
Boulder Brook						
	BB-1	19.0	8.2	6.6	10	42
6/16/2014	BB-3	20.9	7.1	6.3	12	38
	BB-4	21.1	6.9	6.2	12	29
	BB-1	20.7	8.7	6.8	16	8
8/12/2014	BB-3	21.1	9.1	6.2	16	23
	BB-4	21.2	5.8	6.2	17	27
	BB-1	14.9	9.6	6.5	13	22
9/18/2014	BB-3	14.6	6.9	6.0	19	26
	BB-4	14.1	7.3	6.0	15	22
2014 Average		**18.6**	**7.7**	**6.3**	**14**	**26**
2013 Average		*15.0*	*9.0*	*6.7*	*15*	*85*

The average DO concentration in both streams in 2014 was above 7 mg/L, 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 9.5 mg/L and Boulder Brook averaged 7.7 mg/L; Table 4). Two sites on Boulder Brook had individual measurements below 7 mg/L during the 2014 sampling season (BB-4 on 6/16/2014 and 8/12/2014; BB-3 on 9/18/2014). The average DO concentration for both streams was lower in 2014 compared to 2013, but average temperature was also higher in 2014 than in 2013, which may help account for this difference.

pH in the tributaries ranged from 6.0 to 6.8 with an average of 6.4 for Great Brook and 6.3 for Boulder Brook in 2014 (Table 4). These average values were lower (more acidic) in 2014 compared to 2013 averages for both streams.

TP concentrations in the tributaries ranged from 4 to 19 ppb with an average of 5 ppb for Great Brook and 14 ppb for Boulder Brook (Table 4). These values remained slightly higher than results from 2012 (4 ppb for Great Brook and 11 ppb for Boulder Brook) for two consecutive years (2013-2014). Boulder Brook is potentially contributing more TP to Kezar Lake than Great Brook, with all monitoring sites showing similar TP concentrations. TP is one of the most important nutrients to monitor in lakes and streams that drain to 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.

E. coli results in the tributaries were below the Maine DEP standard of 194 col/100 mL at both Great Brook and Boulder Brook in 2014, though numbers were slightly elevated at all stations in Boulder Brook during the June sampling. All three sampling events occurred under dry weather conditions in 2014 (Table 1). In 2012, elevated *E. coli* levels were measured at Boulder Brook stations BB-3 (461col/100mL) and BB-4 (548 col/100mL) in September. High *E. coli* measurements under low 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 well 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.

Funded by the Sally Mead Hands Foundation, the Climate Change Observatory (CCO) was established for the Kezar Lake watershed with the mission to evaluate potential impacts of climate change on watershed resources and identify actions to mitigate climate change in the watershed. As part of this mission, the CCO purchased and deployed 5 HOBO temperature loggers in Coffin, Boulder, Bradley, Sucker, and Long Meadow Brooks and 2 HOBO stage loggers in Beaver and Great Brooks. The loggers were deployed on 5/1/2014 and retrieved on 11/25/2014 for a total of 208 days. These data will serve as a baseline for future comparisons of water quality to assess long-term temperature and flow trends.

Ponds

In 2014, FBE continued baseline monitoring for six ponds that drain directly or indirectly to Kezar Lake. Water quality data for Bradley, Cushman, Farrington, Heald, Horseshoe, and Trout Ponds were collected on June 16 and August 12. June is the beginning of the “warm” season for Maine lakes, and August is generally the time when Maine lakes are most biologically productive and when indications of stress and water quality degradation are most apparent.

Water quality is generally good in the six ponds. According to 2014 sampling results, four of the six KLWA ponds had an average water clarity better than the Maine average of 4.8 meters (Table 5). Farrington and Heald Ponds had SDT readings below the Maine average for both 2014 sampling and their historical averages. SDT readings are limited by depth at Farrington and Heald Ponds, as the Secchi disk is typically visible on the lake bottom for both of these lakes. For 2014, only Heald Pond had an SDT reading hit bottom during the August sampling event. None of the six ponds fell below the Maine DEP minimum SDT standard of 2 meters. All six ponds showed deeper SDT readings in 2014 compared to historical averages, with the exception of Farrington and Trout Ponds.

TP trends indicate lower TP concentrations in all ponds in 2014 compared to historical averages with the exception of Cushman Pond (Table 5). All ponds show historical averages below the average TP concentration for Maine lakes, again with the exception of Farrington Pond. Farrington Pond had the highest average TP in 2014, which is in line with Farrington Pond’s historical average over the past several decades.

Chl-a was lower in all ponds in 2014 compared to historical averages and well below the average for Maine lakes (Table 5). Farrington Pond had the highest Chl-a in 2014 and for historical averages compared to the other five ponds. Additionally, Cushman and Trout Ponds had the lowest Chl-a in 2014 and for historical averages compared to the other five ponds.

All ponds exhibited lower or stable pH in 2014 compared to historical averages (Table 5). Historical averages for Trout and Farrington Ponds are higher (less acidic) than the average pH for Maine Lakes; Cushman, Heald, and Horseshoe Ponds are in line with the average pH for Maine Lakes; and Bradley Pond is lower (more acidic) than the average pH for Maine Lakes. Three of the six ponds (Cushman, Heald, and Horseshoe Ponds) exhibited lower or stable alkalinity in 2014 compared to historical averages. All of the Kezar Lake watershed ponds are consistently lower than the State average for alkalinity (11.8 mg/L), 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. Less productive lakes show pH between 6.5 and 7.5, suggesting that these ponds are on the low end of low-productivity lakes.

All of the ponds in the Kezar Lake watershed showed a decrease in color in 2014 compared to historical averages with the exception of Farrington Pond. These results are similar to the decrease in color in all three basins of Kezar Lake in 2014, and is likely related to low summer precipitation.

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 5. Historical and recent (2014) averages for water quality parameters for six ponds of the Kezar Lake watershed.

Pond	SDT (m)		TP (ppb)		Chl-a (ppb)		pH		Alkalinity (mg/L)		Color (PCU)	
	Historical [b]	Recent 2014[c]	Historical [b]	Recent 2014[c]	Historical [b]	Recent 2014[c]	Historical [b]	Recent 2014[c]	Historical [b]	Recent 2014[c]	Historical [b]	Recent 2014[c]
Bradley	5.4	5.9	8.6	8.0	4.0	2.7	6.6	6.5	3.8	4.0	21.8	21.5
Cushman	5.5	5.8	7.3	8.5	2.6	1.9	6.8	6.8	4.7	4.5	12.1	11.0
Farrington*	4.4	3.9	15.3	15.0	7.3	6.1	6.9	6.8	4.2	5.0	15.7	16.0
Heald*	4.6	4.7	9.8	8.0	4.1	3.6	6.8	6.8	5.5	5.5	24.4	18.5
Horseshoe	6.9	7.0	6.6	6.5	3.6	2.8	6.8	6.6	3.8	3.0	10.5	10.0
Trout	7.9	7.4	4.7	4.0	2.3	2.0	6.9	6.7	3.4	4.0	9.7	9.5
Maine Lakes Average[a]	4.8		12.0		5.4		6.8		11.8		28.0	

* SDT Values limited by lake depth - Secchi hits bottom

[a] Mean values obtained from the VLMP's 2013 Maine Lakes Report (http://www.mainevlmp.org/maine-lake-report/)

[b] Mean values calculated by FBE from all raw data sent by the MEDEP; duplicate values/days were averaged; only epicore samples were used in the analyses; includes all data up through 2014

[c] Mean values calculated by FBE from data collected by FBE in 2014

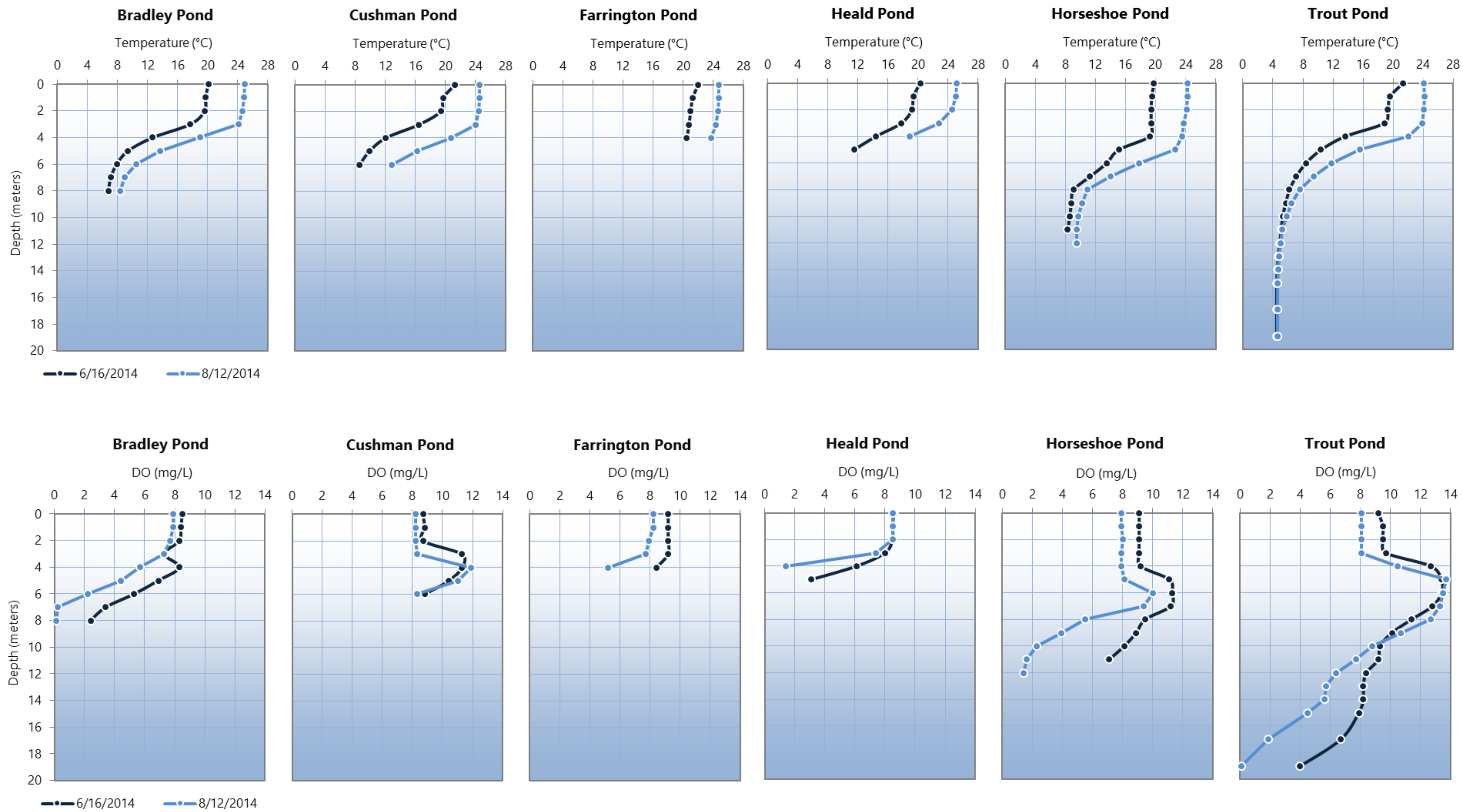

Figure 6. Temperature (top panel) and dissolved oxygen (bottom panel) profiles for six ponds in the Kezar Lake watershed.

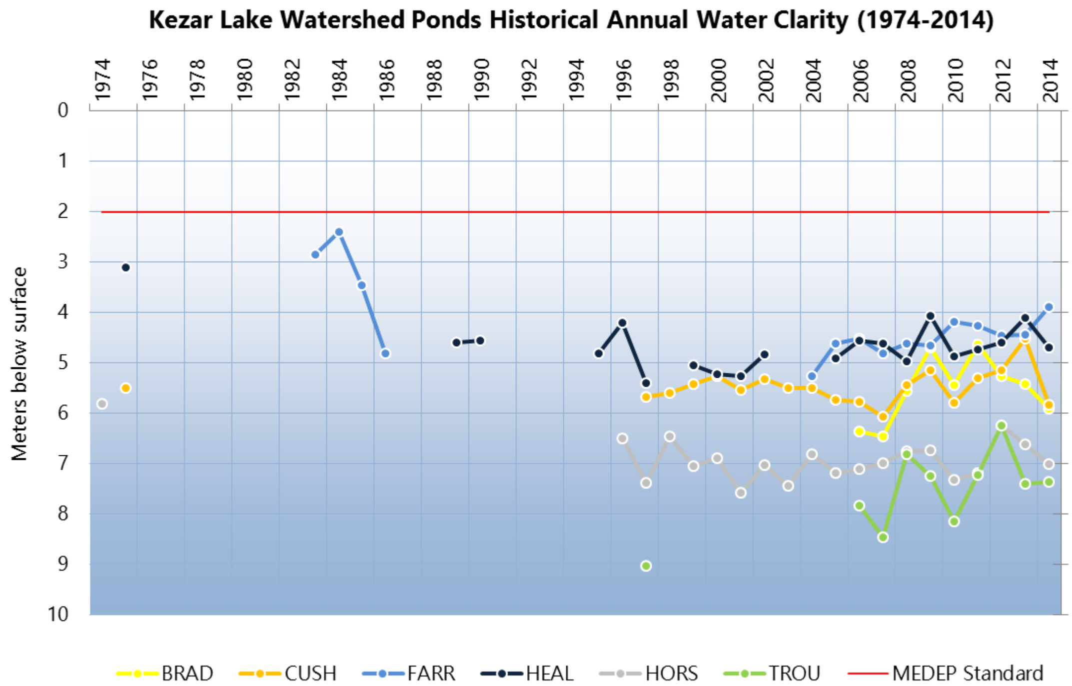

Figure 7. Kezar Lake watershed ponds historical water clarity (1974-2014).

Table 6. General water quality trends for six ponds of the Kezar Lake watershed from 1996-2014 based on Mann-Kendall tests for annual averages.

Lake/Pond	SDT	TP	Chl-a	pH	Alkalinity	Color
Bradley	Stable	No Trend	No Trend	Stable	Stable	Stable
Cushman	Stable	No Trend	**Improving**	No Trend	**Declining**	No Trend
Farrington	**Declining**	Stable	Stable	No Trend	No Trend	No Trend
Heald	**Declining**	Stable	No Trend	**Declining**	**Declining**	No Trend
Horseshoe	Stable	No Trend	Stable	Stable	**Declining**	Stable
Trout	**Declining**	Stable	No Trend	Stable	No Trend	No Trend

No Trend=significant scatter in concentration trend versus time.

Stable=limited variability in concentration trend versus time.

Bradley Pond

- DO concentrations in Bradley Pond dropped below the aquatic life standard of 5 mg/L between 5 and 7 meters depth on both sampling dates in 2014 (Figure 6). This is a continued concern for Bradley Pond.
- All water quality parameters have been stable since 1996 with the exceptions of TP and Chl-a which have been too variable to discern a trend (Table 6).

Cushman Pond

- Unlike in previous years, no DO depletion below the Maine aquatic life standard of 5 mg/L was observed at the bottom of the deepest area of Cushman Pond during the 2014 sampling (Figure 6).

- Only water clarity has been stable since 1996; Chl-a levels are improving, while alkalinity is declining; no trends are observed for TP, pH, or color (Table 6). Declining alkalinity may help explain a lack of trend in mean annual pH that tends to swing from 6.6 to 7.0. While pH at Cushman Pond falls below the Maine water quality standard of 7.0 for Class A waters, mean annual pH remains above 6.5, which is considered suitable for aquatic life.

Farrington Pond

- DO depletion has not been an issue for Farrington Pond, primarily due to the pond's shallow depth and lack of stratification (Figure 6).
- TP and Chl-a have been stable with no trends since 1996; water clarity is declining; no trends are observed for pH, alkalinity, or color (Table 6). SDT readings at Farrington Pond are limited by the pond's shallow depth, so the declining water clarity may be a function of weather conditions that affect the pond's water level. Despite the stable trends for TP and Chl-a at Farrington Pond, these parameters are both historically and recently high compared to the other five monitored ponds and tend to be more variable over time. The shallow nature of this pond makes is more vulnerable to sediment suspension as a result of heavy rainfall, wind storms, or watershed disturbances (e.g. shoreline development).

Heald Pond

- DO concentrations are consistently low (< 5 mg/L) below 4 meters (13.7 feet) in the summer months (Figure 6). This is a continued concern for Heald Pond.
- Water clarity, pH, and alkalinity have been declining at Heald Pond since 1996; TP is stable; no trends are observed for Chl-a or color (Table 6). SDT readings at Heald Pond are also limited by the pond's shallow depth, so the declining water clarity may be a function of weather conditions that affect the pond's water level.
- Historical average TP and Chl-a at Heald Pond is the second highest after Farrington Pond and is the most colored compared to the other ponds. Because of this, Heald Pond may be at risk for algal blooms if water quality continues to decline.
- The declining trends for both pH and alkalinity at Heald Pond is also of great concern to the health of its aquatic organisms. As the pH of a waterbody declines, particularly below 6, the reproductive capacity of fish populations can be greatly impacted as the availability of nutrients and metals changes. Fortunately, Heald Pond exhibits the highest historical average alkalinity (5.5 mg/L) of the six ponds.

Horseshoe Pond

- DO fell below 5 mg/L at 9 meters in August only (Figure 6). The spring DO profile was well-oxygenated through the entire water column compared to previous years. Overall, low DO is still a continued concern for Horseshoe Pond.
- Most of the water quality parameters for Horseshoe Pond are stable with the exception of a declining trend for alkalinity and no trend for TP (Table 6). Despite a declining alkalinity, mean annual pH remains stable. Additionally, while pH at Horseshoe Pond falls below the Maine water quality standard of 7.0 for Class A waters, mean annual pH remains above 6.5, which is considered suitable for aquatic life.

Trout Pond

- DO fell below 5 mg/L at 19 m in June and 15 m in August (Figure 6). This is expected given that Trout Pond is the deepest of the six ponds and is subject to thermal stratification that prevents surface water oxygen from reaching the bottom.
- TP and pH are stable for Trout Pond; water clarity is declining; no trends are observed for Chl-a, alkalinity, or color (Table 6).
- Water quality at Trout Pond is considered the best among the small ponds in the Kezar Lake watershed. Mean historical TP, Chl-a, and color are lowest and SDT is deepest at Trout Pond. This may be the result of limited development along the shoreline compared to the other ponds in the watershed. Development around Trout Pond includes only a single large summer camp on the north end of the lake, known as Camp Susan Curtis.
- Mean historical alkalinity is lowest at Trout Pond compared to the other ponds, and is at a high risk for pH swings, despite its current status of stable pH.
- The declining water clarity at Trout Pond (Figure 7) is of concern given its steady decline since 2004 with minimal variability.

Future Monitoring Recommendations

While the water quality of Kezar Lake and its tributaries and ponds is generally excellent, these waterbodies are sensitive to change. Continuing to monitor all three basins of the lake, two tributaries (Great Brook and Boulder Brook), and 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 the Kezar Lake watershed for future generations. The recent development of the Kezar Lake Climate Change Observatory (CCO) can help guide future water quality monitoring efforts that support on-going collection of long-term baseline data in the watershed.

The following is recommended for future monitoring of Kezar Lake, ponds and streams:

- Supplement monitoring efforts by adding a July sampling event for Kezar Lake and ponds to better assess seasonal (summer) water quality during the most productive time of the year.
- Expand in-lake monitoring to include spring and fall profiles during turn-over and include a geochemical analysis that may provide insight to the alkalinity and pH trends.
- Collect winter DO-temperature profiles and epicore sampling of key parameters in January and February (it has been shown that biological and chemical processes that occur over winter dictate the productivity of lakes in summer).
- Conduct stream macroinvertebrate analysis to determine macroinvertebrate richness and abundance during stream baseflow periods (late August - late September). This monitoring will provide baseline data for these streams, and can be replicated on a five-year (or more) cycle.
- Collect stream flow and continuous temperature data in targeted streams throughout the watershed.

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