WATER QUALITY ANALYSIS | MEMORANDUM

TO: Glenn Pogust (Town of Sutton), Kyle Hubbard, and Polly Crocker (Kezar Lake Protective Association)
FROM: Christine Bunyon and Tim Kirsten (FB Environmental Associates)
SUBJECT: **Kezar Lake Water Quality Analysis**
DATE: October 30, 2025
CC: Forrest Bell, Laura Diemer (FB Environmental Associates)

This memo summarizes available water quality data for the Kezar Lake watershed in Sutton, New Hampshire through 2024 and identifies additional data needs to support future assessment as part of the development and implementation of a watershed-based management plan.

1 PROBLEM BACKGROUND

Kezar Lake faces several ongoing water quality concerns that threaten its ecological integrity. The lake is currently listed on the NH Department of Environmental Services (NHDES) 2024 303(d) list of threatened or impaired waters as a Class B water, impaired for Aquatic Life Integrity (ALI) due to low dissolved oxygen saturation and pH. Lyon Brook, the primary inlet into the lake, is also impaired for ALI due to low pH. Upstream of Kezar Lake, Messer Pond is impaired for ALI due to elevated chlorophyll-a, total phosphorus, and low pH. This indicates a pattern of nutrient enrichment and acidification across the watershed.

Kezar Lake has a long history of water quality challenges, prompting various management strategies to control harmful algal blooms. In the early 20th century, the lake was valued for its scenic and recreational qualities, leading the State to choose to establish Wadleigh State Park on its shores in 1934. Just a few years earlier, however, the Town of New London had constructed a wastewater treatment plant (1931) that discharged treated but nutrient-rich effluent into Lyon Brook, a tributary of the lake. Elevated nutrient levels eventually triggered cyanobacteria blooms beginning in 1963, resulting in a major fish kill and declining lakeshore property values. In response, NHDES applied nearly three tons of copper sulfate, an algicide, during the 1960s in addition to performing mechanical destratification in the late 1960s, early 1970s by pumping compressed air to the lake bottom in an effort to reduce phosphorus concentrations. These measures proved ineffective, largely because the dominant cyanobacterium, *Aphanizomenon flos-aquae,* was resistant to copper sulfate treatments. The Kezar Lake Protective Association (KLPA) was formed in 1971 to serve as a voice for the community and advocate for lake health.

A 1978 Clean Water Act Section 314 study identified Kezar Lake as a high priority for restoration, initiating a 19-year, three-phase restoration effort which began in 1980. The three phases were, (1) assessment and planning, (2) implementation, and (3) monitoring. A NHDES Diagnostic and Feasibility study in 1983 confirmed elevated nutrient levels and significant internal phosphorus loading from sediments impacted by decades of wastewater effluent. Although the treatment plant was shut down in 1981, algal blooms continued.

During the second phase of restoration, NHDES implemented measures from the Diagnostic and Feasibility study to reduce phosphorus levels in Kezar Lake. In 1983, flashboards were installed at the outlet of the Chadwick Meadows wetlands (along Lyon Brook) to expand the size of the wetland and increase the settling of phosphorus-laden particulates before entering the lake. Also in 1983, the KLPA joined the state's Volunteer Lake Assessment Program (VLAP) to support long-term monitoring. In 1984, aluminum salts were applied to

100 acres of lake bottom to bind phosphorus and limit its availability to phytoplankton and cyanobacteria. This was the first alum treatment conducted within the state of New Hampshire. Chadwick Meadows wetland enhancements continued in 1985 with the planting of wild rice, selected for its capacity to absorb phosphorus.

Phase III of the project evaluated 19 years of pre- and post-treatment monitoring. Although aluminum salts can become toxic to aquatic life at pH levels below 5 (NHDES, 2000), Kezar Lake monitoring did not indicate pH-related toxicity following treatment. Following the alum treatment, phytoplankton communities shifted, with cyanobacteria declining and diatoms and golden-brown phytoplankton becoming dominant. These changes corresponded with a tenfold reduction in chlorophyll-a and a marked increase in water clarity, from less than 0.6 m in 1978 to 4.5 m in the 1984 NHDES trophic survey. As such, the 1984 survey reported a shift from eutrophic to mesotrophic status. Zooplankton composition changed as well, likely reflecting altered algal food sources, while in-situ sediment macroinvertebrate sampling was inconclusive—no benthic organisms were found 15 days post treatment, but this may have been due to seasonal migration or maturation patterns. Laboratory studies found no adverse effects on midge or alderfly larvae, though whole-fish analyses indicated elevated aluminum concentrations post-treatment (NHDES, 2000). Phosphorus monitoring showed declines in both hypolimnetic concentrations and overall internal loading between 1980–1981 and 1990–1991, reducing the amount available for phytoplankton growth. Finally, data from Chadwick Meadows indicated that raising the water level to expand the wetland further reduced phosphorus inputs to Kezar Lake (NHDES, 2000).

Despite these improvements, long-term monitoring shows that several stressors persist. In the 2003 NHDES trophic survey, trophic values remained stable, but elevated chloride and conductivity were recorded for the first time. In 2008, Kezar Lake was listed on the Section 303(d) impaired waters list for low dissolved oxygen (ALI) and for primary contact recreation (PCR) due to cyanobacteria hepatotoxic microcystins. The 2010 cycle expanded the ALI category to include total phosphorus and chlorophyll-a, and the lake was listed as impaired for both. pH was also identified as impaired due to naturally occurring organic acids and atmospheric deposition; a very common occurrence in New Hampshire lakes. The phosphorus and chlorophyll-a impairments were removed in 2012, but pH, dissolved oxygen, and cyanobacteria impairments continued through 2014 and 2016. In 2018, the cyanobacteria impairment was lifted, though low pH and dissolved oxygen remained. These impairments have persisted through the 2018, 2020/22, and 2024 assessment cycles.

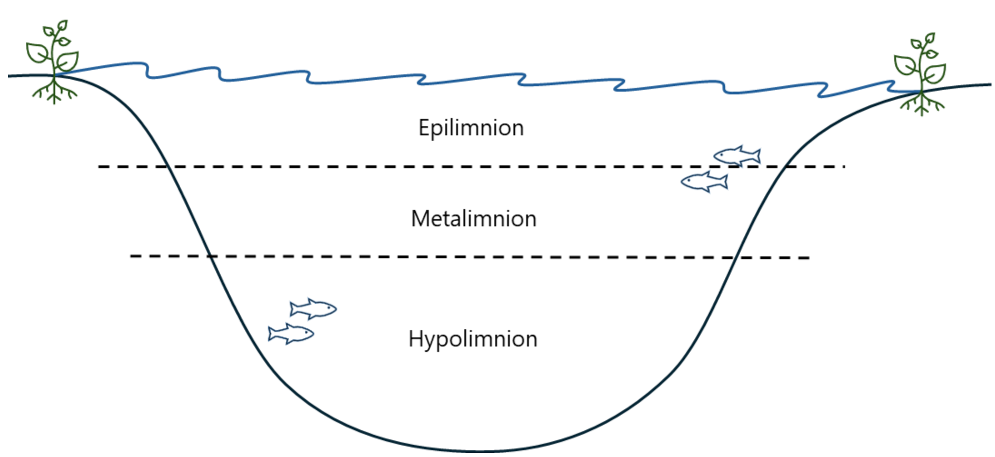


Figure 1. Graphic of a lake experiencing thermal stratification to visualize the epilimnion, metalimnion, and hypolimnion of a lake.

The 2024 Volunteer Lake Assessment Program (VLAP) report for Kezar Lake highlights a slight exceedance of NHDES total phosphorus thresholds for mesotrophic lakes. In late summer 2023, elevated hypolimnetic phosphorus levels at the Kezar Lake deep spot suggested some level of internal loading, with nutrients likely released from bottom sediments under anoxic conditions. Elevated phosphorus concentrations were again noted in the hypolimnion (see Figure 1) in 2024, though sediment was also present in the samples. Once present in the water column, phosphorus can be used by phytoplankton such as cyanobacteria. Beyond this, certain species of cyanobacteria commonly found in the epi- and metalimnion can take advantage of higher hypolimnion phosphorus levels due to their ability to regulate their buoyancy in the water column. Enhanced loading of phosphorus to surface waters, whether from internal (i.e., from lake-bottom sediments) or external sources, particularly when compounded by the impacts from environmental variability, can stimulate excessive plant, phytoplankton, and cyanobacteria growth and degrade mean annual water quality. The 2023 and 2024 VLAP reports note that hypolimnetic turbidity levels increased as the summer progressed, indicating the accumulation of organic matter and other particulates, including precipitated metals like iron and manganese from sediment, under anoxic conditions.

The Data Summary presented in the 2024 VLAP report indicates that although total phosphorus levels exceed the NHDES threshold for mesotrophic lakes, chlorophyll-a concentrations and Secchi disk transparency have significantly improved since monitoring began, while epilimnetic and hypolimnetic phosphorus levels have remained variable but generally stable.

Lastly, the 2024 VLAP report indicates chloride and conductivity levels in both Kezar Lake and Lyon Brook are elevated and worsening, suggesting road salt, water softeners, or other pollution inputs. Conductivity has shown a gradual upward trend in the lake's epilimnion, and hypolimnetic turbidity increased through the 2024 season—both indicators of declining water quality. Although current chloride concentrations are greater than the state medians, they remain below the state chronic toxicity threshold. Kezar Lake is underlain by granite, an igneous rock composed primarily of quartz and feldspar with little carbonate content. As a result, soils and surface waters derived from this bedrock have low calcium and magnesium concentrations and low alkalinity, classifying the lake as a soft-water system. Such lakes have limited buffering capacity against acidification and may experience greater biological sensitivity to chloride and other pollutants than harder-water systems (McClymont and Arnott, 2023). A growing body of evidence indicates that chronic NHDES/EPA chloride criteria (230 mg/L, established in 1988) may not adequately protect the most sensitive taxa at all trophic levels (Hintz & Relyea, 2019), from zooplankton (McClymont and Arnott, 2023; Buren and Arnott, 2025) to amphibians (Hopkins et al., 2013). For contrast, the Canadian threshold for chloride in freshwater waterbodies is set to 120 mg/L. If current road-salting practices continue, many lakes in the Northeast are predicted to exceed the EPA threshold within the next 50 years (Dugan et al., 2017). The elevated levels of chloride and conductivity in Kezar Lake should therefore be understood in this context.

This memo summarizes the available historical water quality data for Kezar Lake submitted for review and filing within the NHDES Environmental Monitoring Database, emphasizing phosphorus, dissolved oxygen and temperature profiles, pH, chloride, and specific conductivity. These data include state-collected data for the trophic reports, volunteer-collected data through the VLAP, and data from Colby Sawyer College. The analysis focuses on monitoring from the Kezar Lake Deep Spot station (KEZSUTD), supplemented with stream data to assess watershed-level influences.

MAP 1. Map of analyzed water quality sampling sites within the Kezar Lake watershed.

2 WATER QUALITY SUMMARY

2.1 Phytoplankton and Zooplankton

2.1.1 Phytoplankton/Zooplankton Results

In New Hampshire lakes, the composition of phytoplankton and zooplankton communities varies throughout the growing season. This natural ebb and flow is driven by life cycles, the physical environment, and interactions with other organisms. Together, these groups of organisms play a key role in food webs and lake health. The 2023 Data Summary of the NH VLAP Individual Lake Report for Kezar Lake shows phytoplankton population (relative percent unit count per taxa) for 2012, 2014, 2015, 2016, 2018, 2019, 2022, and 2023. In 2023, golden-browns dominated (>90%) over other taxa for the first time. Cyanobacteria were dominant in 2022, making up approximately 45% of the total taxa, though they have been present (usually <15%) in all years of monitoring. Cyanobacteria are a naturally occurring group of phytoplankton in Northeastern lakes and only become a concern to lake and human health when they begin blooming or growing excessively. In 2019, cryptomonads dominated while in previous years golden-browns, diatoms, and dinoflagellates were observed in fluctuating proportions. **Phytoplankton communities in Kezar Lake have thus been variable, with no distinct trend in recent years**.

Samples of phytoplankton collected in the 2003 NHDES Trophic Survey identified *Asterionella* (diatom) as dominant in winter, while the 1984 and 1978 trophic survey reports state the dominant winter taxa included *Rhizosolenia* (diatom) and *Anacystis* (cyanobacteria), respectively. In the summer surveys of 1978, 1984, and 2003, *Mallomonas* (golden-brown), *Asterionella*, *Lyngbya* (cyanobacteria), *Melosira* (diatom), *Aphanizomenon* (cyanobacteria), and *Anacystis* were detected.

The dominant zooplankton species recorded in the winter 1984 and 2003 Trophic Surveys were *Keratella* (rotifer) and *Nauplius* larvae (copepod). In summer months, the dominant species were *Polyarthra* (rotifer), *Vorticella* (ciliate protozoan), *Keratella*, *Nauplius* larvae, and an unspecified cyclopoid copepod. Zooplankton were either not observed or not collected during the 1978 Trophic Survey. Copepods are small crustaceans that eat phytoplankton and provide an important food source to fish. Rotifers are small, micro-zooplankton whose population can respond quickly to environmental changes. Rotifers play a key role in the overall lake ecosystem food web. *Daphnia* are among the most efficient grazers of phytoplankton but were not shown to be a dominant zooplankton in Kezar Lake. Ciliate protozoa, such as *Vorticella*, also play a key role in microbial food webs by consuming bacteria and small phytoplankton, transferring energy to higher trophic levels. Maintaining a balance of phytoplankton and zooplankton are necessary components of a healthy lake ecosystem. **Though zooplankton communities have been analyzed through Trophic Surveys, they have not been assessed since 2003.**

2.1.2 Cyanobacteria Bloom History

Kezar Lake has not had any officially reported NHDES cyanobacteria bloom warnings (formerly known as advisories), nor have the other waterbodies in the watershed, Messer Pond or Clark Pond. Two small accumulations of cyanobacteria occurred in 2025, identified by NHDES as "watches", but did not trigger a cyanobacteria bloom warning due to the small area of the accumulations covered and their quick subsidence. **The statewide increase in the number and severity of cyanobacteria blooms highlights the need for proactive watershed-wide planning to maintain water quality and minimize conditions that could promote future blooms, including reducing sediment and nutrient transport into the waterbody.**

2.2 Trophic State Indicators

2.2.1 Total Phosphorus, Chlorophyll-a and Secchi Disk Transparency

Total phosphorus, chlorophyll-a, and Secchi disk transparency are trophic state indicators, or indicators of biological productivity in lake ecosystems. The combination of these parameters helps determine the extent and effect of eutrophication in lakes and helps signal changes in lake water quality over time. For example, changes in Secchi disk transparency may be due to a change in the amount and composition of phytoplankton communities (typically because of greater total phosphorus availability) or the amount of dissolved or particulate materials in a lake. Such changes are often the result of human disturbance or other impacts to the lake's watershed.

For Kezar Lake from 1978–2024, higher total phosphorus concentrations were most often measured in the metalimnion and hypolimnion compared to the epilimnion, indicating some amount of internal phosphorus loading is occurring (Figure 2). There are however numerous outliers where epilimnetic phosphorus levels were higher than the median metalimnion and hypolimnion values. The relatively higher hypolimnion values are also evident when considering only the most recent 10 years of data (2015–2024) (Figure 3). For both the full period of data and the more recent period, metalimnion grab samples have been infrequently collected.

The 1984 alum treatment greatly reduced internal load occurring from sediments at that point in time. Alum treatments have expected lifespans ranging around 11-15 years (Huser, et al., 2016). The enhanced longevity of the 1984 alum treatment may be attributed to a combination of eliminating the point source of phosphorus pollution to the lake, locking away phosphorus-bound particles and likely a smaller contribution of phosphorus to the lake from diffuse runoff from the watershed (non-point source pollution). Over time, sediments from the watershed are carried into the lake and cover the treatment compounds. What may be contributing to the current internal load are sediments that have entered the lake, post treatment, from actions within the watershed such as development, erosion, and stormwater runoff.

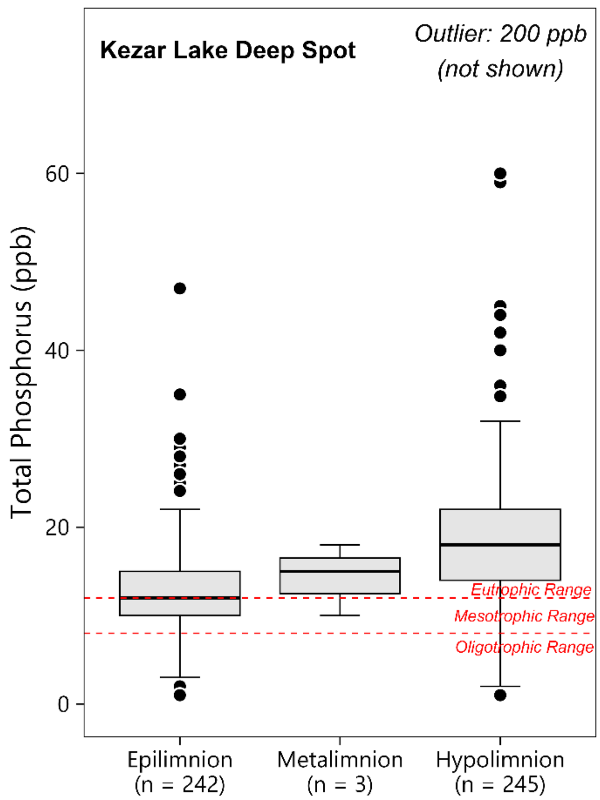


Figure 2. Boxplots showing median total phosphorus concentration in the epilimnion, metalimnion, and hypolimnion of the deep spot of Kezar Lake (KEZSUTD) for all available years of data (1978–2024).

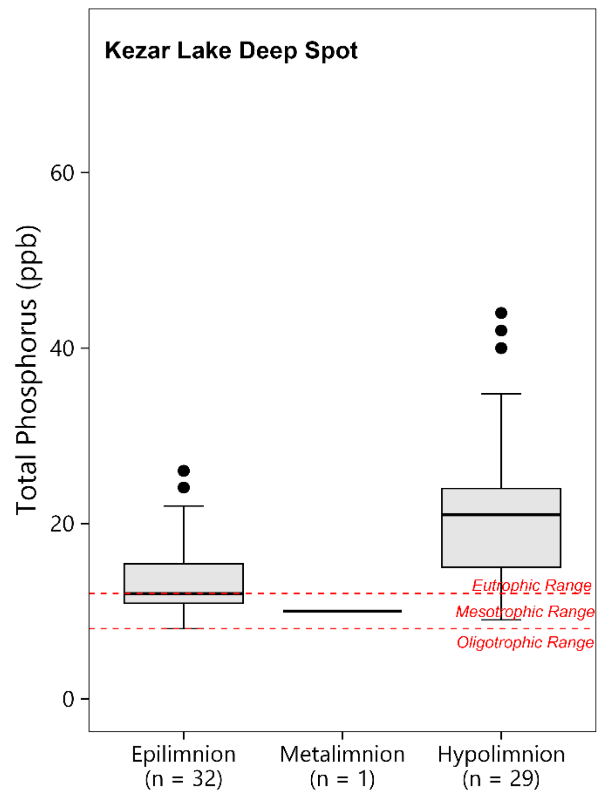


Figure 3. Boxplots showing median total phosphorus concentration in the epilimnion, metalimnion, and hypolimnion of the deep spot of Kezar Lake (KEZSUTD) from the past ten years (2015–2024).

For the available time period, 1978–2024, **no statistically significant trends were found for median epilimnetic total phosphorus or Secchi disk transparency at the deep spot of Kezar Lake (KEZSUTD)** (Figure 4). Although not shown in Figure 4, there has been no significant change in hypolimnion total phosphorus for either the whole period of available data (1978–2024) or the most recent 10 years only (2015–2024). **There is a decreasing (improving) trend in chlorophyll-a concentrations from 1978–2024, but concentrations are stable within the most recent 10 years (2015-2024).** Even when running the trend analysis on chlorophyll-a from 1984–2024 only, to exclude the high value recorded in 1978, a historically significant decreasing trend is still detected. This improving trend is likely due to the successful in-lake aluminum treatment conducted in the 1980s which altered the habitat for phytoplankton. These findings align with the 2024 Data Summary of the NH VLAP Individual Lake Report for Kezar Lake, which found variable but generally stable trends for total phosphorus and Secchi disk transparency and improving trends in chlorophyll-a. Total phosphorus and chlorophyll-a are generally related, but many other factors can impact chlorophyll-a. Phosphorus is a nutrient (chemical compound) and chlorophyll-a is a surrogate measurement for phytoplankton biomass. Other factors influence phytoplankton biomass including light, temperature, stratification, grazing by zooplankton, other nutrient levels, and more. These other factors may explain why chlorophyll-a levels are improving while total phosphorus concentration remains stable. Total phosphorus and chlorophyll-a are summarized relative to the state criteria for trophic classes in section 3, Table 1.

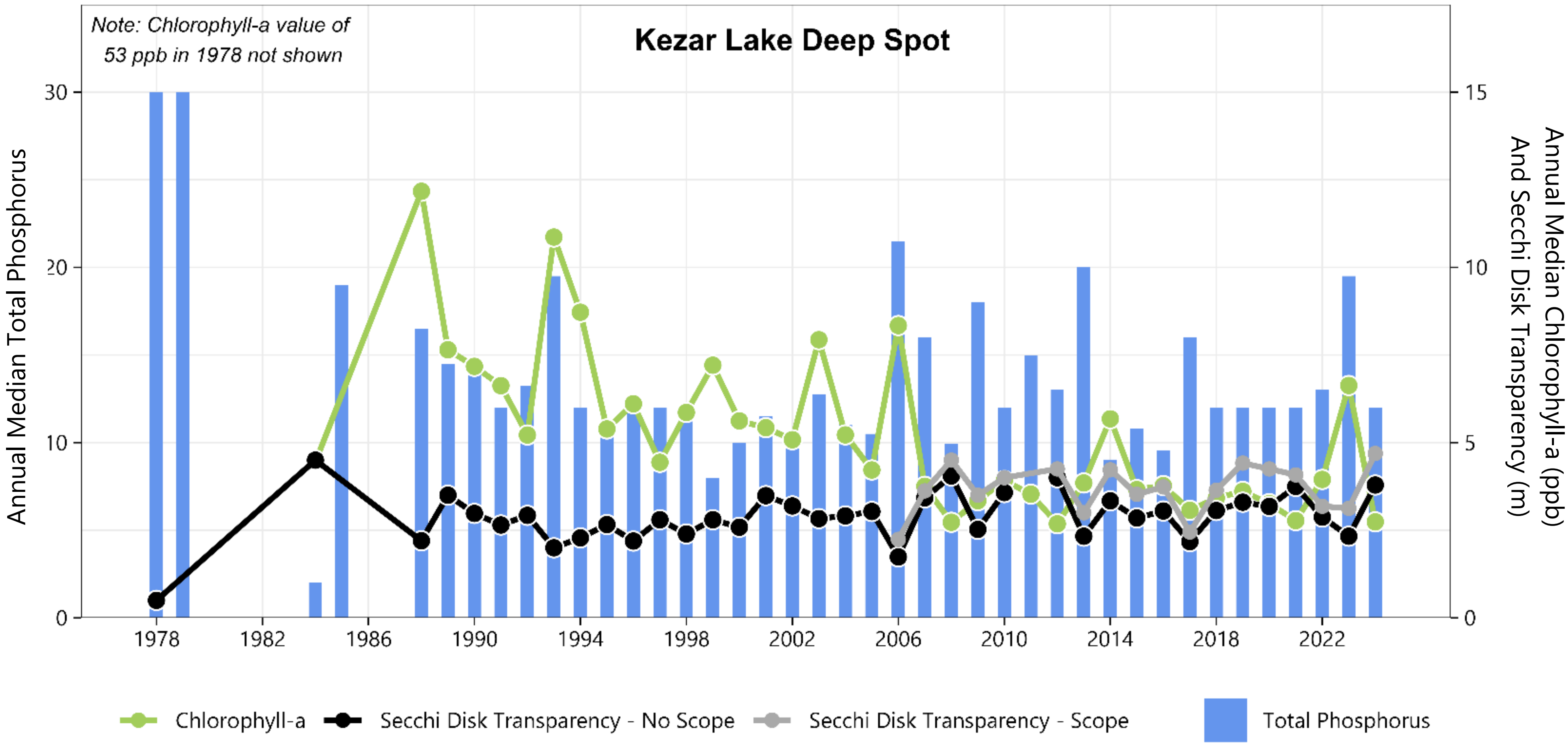


Figure 4. Median epilimnion grab samples (0–3 meters) total phosphorus, median composite epilimnion (0–6 meters) chlorophyll-a, and median water clarity (Secchi Disk transparency for scope and no scope methods) measured at Kezar Lake largely in June–September from 1978–2024 for the deep spot station (KEZSUTD). A statistically significant decreasing (improving) trend in chlorophyll-a was detected from the Mann-Kendall nonparametric trend test using *rkt* package in R Studio.

2.3 Dissolved Oxygen & Water Temperature

> ***Lake Stratification and Mixing***
>
> *Kezar Lake is a dimictic lake, undergoing two cycles of stratification and mixing annually. Stratification takes place during summer, as surface waters warm, forming a thermal barrier due to differences in water densities. Additionally, winter months see stratification when the lake freezes over, with colder surface waters sitting atop warmer bottom waters. Dimictic lakes undergo both "fall turnover" and "spring turnover," characterized by the loss of these temperature gradients which enable water and nutrient mixing once again.*

The depletion of dissolved oxygen in the deepest part of a waterbody throughout the summer months is a common occurrence in New Hampshire's lakes. This happens when thermal stratification prevents warmer (less dense), oxygenated surface waters from mixing with cooler (denser), oxygen-depleted bottom waters in the lake. Chemical and biological processes occurring in bottom waters deplete the available oxygen throughout the summer, and because these waters are colder and denser, the oxygen cannot be replenished through mixing with surface waters. Dissolved oxygen levels below 5 ppm (and water temperature above 24°C) can stress and reduce habitat for cold-water fish and other sensitive aquatic organisms. In addition, anoxia (low dissolved oxygen) at lake bottom can result in the release of sediment-bound phosphorus (internal phosphorus loading), which can increase in-lake phosphorus concentrations and fuel phytoplankton thus increasing chlorophyll-a concentrations. **While thermal stratification and depletion of oxygen in bottom waters is a natural phenomenon in dimictic lakes such as Kezar Lake, it is important to track these parameters to make sure the extent and duration of low oxygen does not change drastically because of human disturbance in the watershed resulting in excess phosphorus loading.**

Figure 5 shows temperature and dissolved oxygen profiles for Kezar Lake averaged across sampling dates (1978–2023) during thermal stratification largely in summer (between spring and fall turnover; see box to the right). The change in temperature, seen most dramatically between 3 and 7 m, indicates thermal stratification in the water column. The average dissolved oxygen of <2 ppm at 6–8 m depth indicates the possibility of internal loading under anoxic conditions. Historic recording of temperature and dissolved oxygen profiles includes multiple water column profiles per sampling season which provide insight to seasonal changes in the lake. Additional profiles into October can provide further insight into the possible duration of internal loading in Kezar Lake.

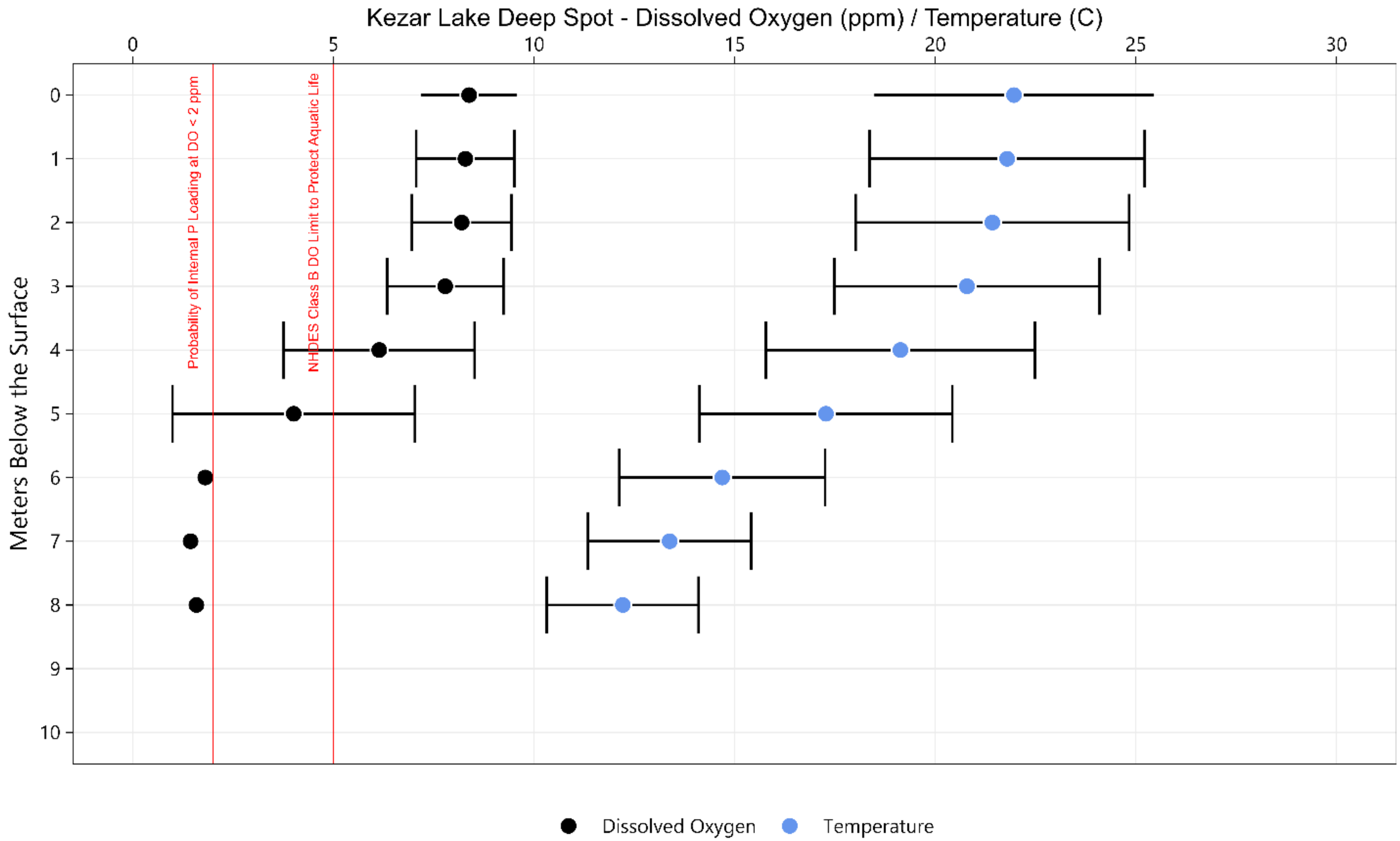


Figure 5. Dissolved oxygen (black) and water temperature (blue) depth profiles for the deep spot of Kezar Lake (KEZSUTD). Dots represent average values across sampling dates for each respective depth. Error bars represent standard deviation. Data represents an average of data points by depth for all profiles collected from 1978, 1984, 1988–2010, 2012, 2014–2016, 2018, 2019, 2022, 2023, and 2024 (n = 78 for dissolved oxygen, and n = 92 for temperature).

2.4 Chloride & Specific Conductivity

Chloride pollution can cause harm to aquatic organisms and disrupt internal mixing processes when concentrations reach toxic levels. The State of New Hampshire sets a chronic toxicity threshold of 230 ppm for chloride (which roughly equates to 835 µS/cm for specific conductivity). Chloride concentrations in Kezar Lake are below the chronic threshold, however, both parameters are elevated compared to what is typical for high-quality lakes. **The median values for New Hampshire lakes are 5mg/L for chloride, and 42.3 µs/cm for specific conductivity, while the long-term median for Kezar Lake from 2015-2024, in the epilimnion, is 40 ppm for chloride and 168 µS/cm for specific conductivity.** Concerningly specific conductivity shows an increasing trend in the epilimnion and hypolimnion at the Kezar Lake deep spot between 2004 and 2024 (Figure 7), suggesting the problem is worsening. Note that the median chloride value was confirmed to follow the statewide chloride-specific conductance relationship equation as explained in point 5c on pages 88 and 89 of the 2024 New Hampshire Consolidated Assessment and Listing Methodology. This means specific conductance can be used as a surrogate for chloride in Kezar Lake if necessary.

The increasing trends indicate that chloride from winter salting practices in the watershed, water softeners, and septic discharges may be contaminating the lake. Though the application of deicing road salts is a common practice in New Hampshire for maintaining road safety during the winter months, there is no natural process that uses or breaks down chloride (NHDES, 2021). Chloride levels may also be increasing due to the use of water softeners within the watershed. In a water softening system, salts are often added to remove calcium and magnesium from household water. The result is a salty byproduct that enters the wastewater treatment system, and septic systems are traditionally not designed for salt removal (NH LAKES, 2024). Another potential source of chloride and specific conductivity is sediment loading from eroding, unpaved roads throughout the watershed. The steep slopes located in some areas of the watershed may make the watershed more susceptible to soil loss and road erosion. Other sources of pollution that may increase chloride and specific conductivity levels include inputs from fertilizers and agricultural runoff. While not an immediate concern for the health of the lake, chronic chloride toxicity will likely become an issue in the future without a proactive reduction in salt use in the watershed.

Chloride and Specific Conductance

Chloride and specific conductance are closely connected as chloride is a negative ion, and specific conductance is a measurement of how well water can carry an electrical current. Other ions that may affect specific conductance include nitrate, sulfate, phosphate, sodium, magnesium, calcium, iron, and aluminum. When chloride levels rise, often due to salt pollution, specific conductance typically rises as well. Naturally low in NH lakes, an increase in either is often due to human impact. Though NHDES sets the level of chronic toxicity at 230 ppm for chloride, newer studies indicate this limit may be too high (NHDES, 2020).

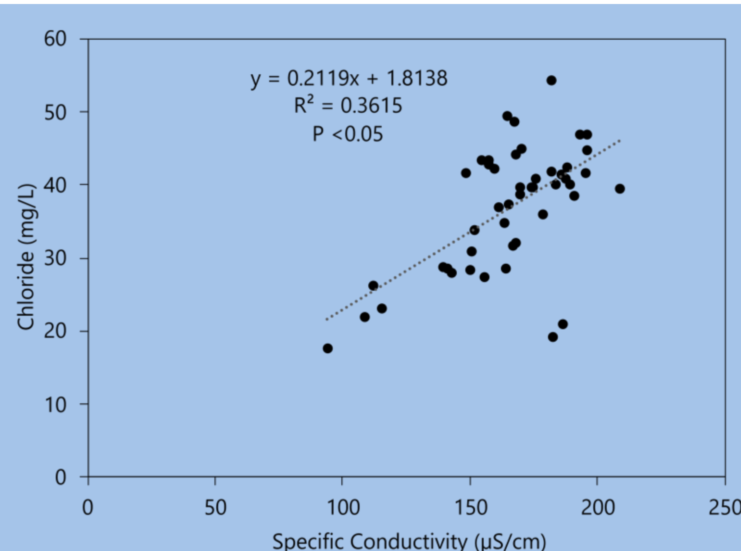


Figure 6. Samples collected on the same days for both chloride and specific conductivity at the Kezar Lake deep spot show a significant correlation to each other (n=48 pairs).

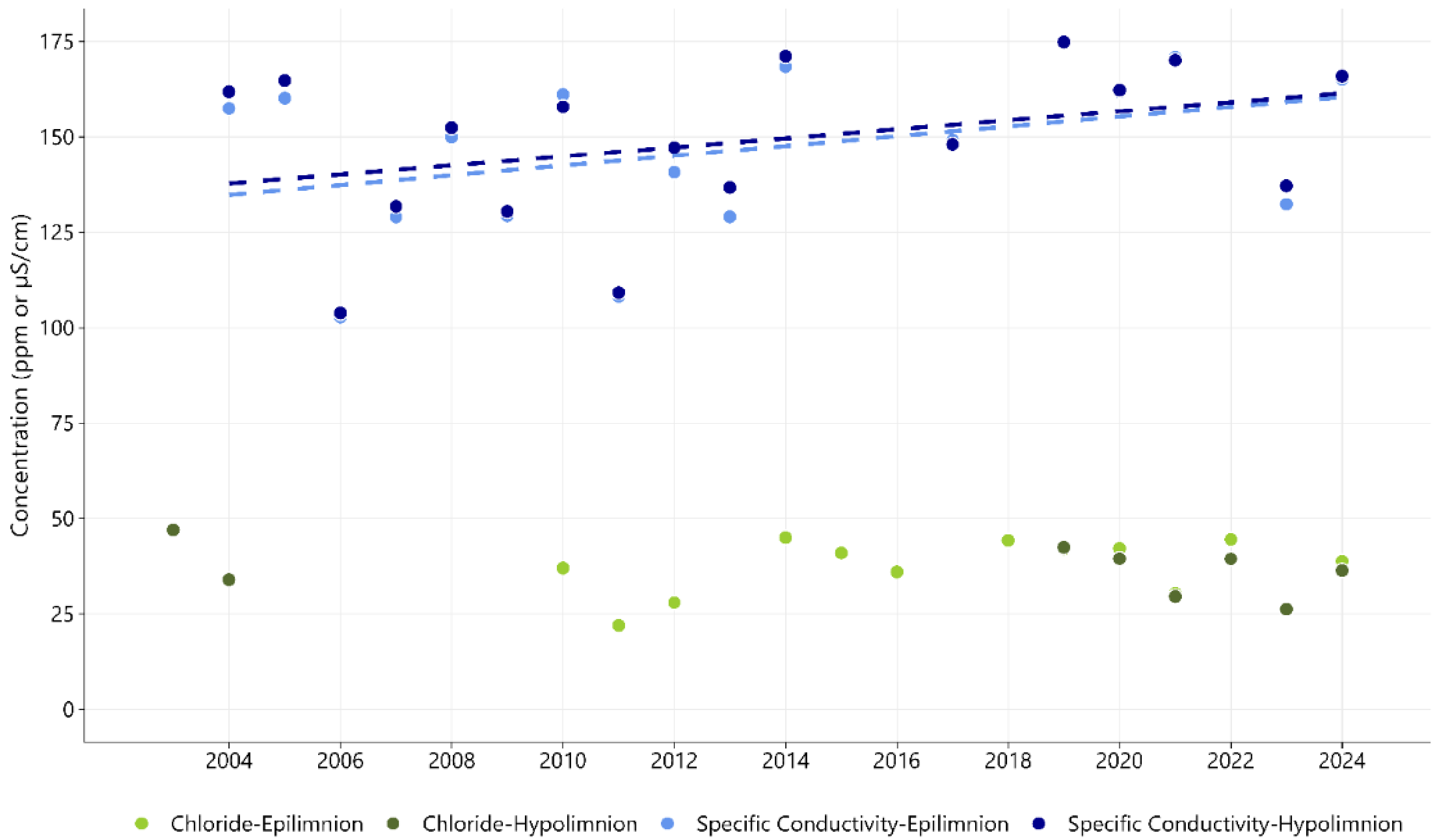


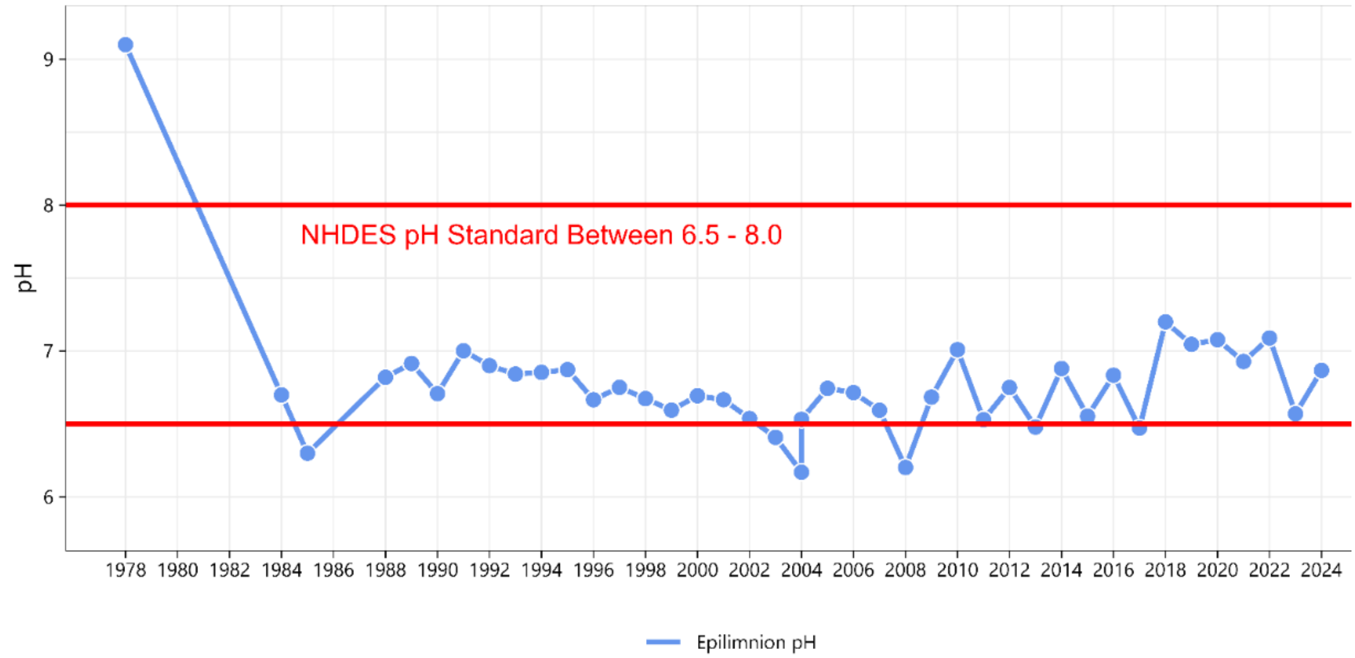
Figure 7. Yearly median of monthly medians for chloride and specific conductivity in the deep spot of Kezar Lake (KEZSUTD). Dashed lines indicate a statistically significant increasing (degrading) trend. Metalimnion data points are not plotted due to the low number of samples.

2.5 pH

The pH of a water body describes how acidic or basic the water is, with lower values representing more acid conditions, and a value of 7 representing neutral. The habitable range of pH for aquatic organisms is near neutral, with NHDES setting the standard for Class B waterbodies to have a pH between 6.5 and 8.0 to protect aquatic life. Monitoring the pH of Kezar Lake is especially important as the lake and its primary tributary are classified as impaired for low pH. **Many lakes in New Hampshire have pH values below the habitable range due to the lasting effects of acid rain, or acidic deposition.** This, coupled with New Hampshire lakes having relatively low natural alkalinity (the ability to naturally buffer themselves from acidic inputs) because of the minerals present in region's geology, has resulted in a lasting effect throughout the state from which Kezar Lake is not immune.

Median pH in the epilimnion of Kezar Lake at the deep spot (KEZSUTD) was elevated in 1978 (>9), possibly due to the wastewater treatment facility effluent, surpassing NHDES's acceptable level (8). pH has since dropped below the lower acceptable limit (<5) in some years. Nevertheless, median epilimnetic pH has been relatively stable from 1988–2024 and has generally been at the lower (more acidic) end of the acceptable range set by NHDES (Figure 8).

Across the different depth zones, pH has generally been higher (less acidic) in the epilimnion than in the hypolimnion (Figure 8). Higher pH in the epilimnion is typically expected because of the greater amount of photosynthesis occurring in the photic zone which raises the pH, and increased respiration occurring in lower depth zones has an acidifying effect on the water. The pH may be lowest in the hypolimnion due to the settling of detritus and other organic matter on the bottom sediments, which leads to increased respiration when oxygen is present. The hypolimnion has a median pH value just below the NHDES guidelines of 6.5 for supporting aquatic life. Low pH can have adverse effects on aquatic biota, and extremely low pH can promote the release of iron or even aluminum bound phosphorus (pH < 5.5) from the bottom sediments. With only one recorded pH measurement from the metalimnion over the past 10 years, there is limited insight into acidity trends within this depth zone.



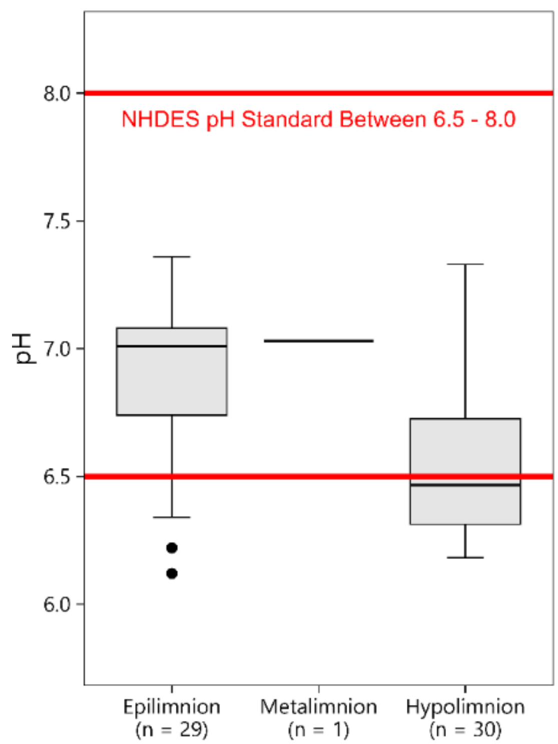


Figure 8. (Top) Yearly median of monthly medians for epilimnion pH in the deep spot of Kezar Lake (KEZSUTD). (Bottom) Boxplots showing median pH in the epilimnion, metalimnion, and hypolimnion of the deep spot of Kezar Lake (KEZSUTD) for the past 10 years, 2015–2024. Values were converted to the concentration of hydrogen ions before being summarized and logarithmically transformed back to the pH scale.

3 ASSIMILATIVE CAPACITY

The assimilative capacity of a waterbody describes the amount of a pollutant that can be added to a waterbody without causing an exceedance of the water quality criteria based on lake trophic designation. Kezar Lake is a mesotrophic waterbody. For mesotrophic waterbodies, the water quality criteria are set at 12 ppb for total phosphorus and 5.0 ppb for chlorophyll-a, above which the waterbody is considered impaired. NHDES requires 10% of the difference between the best possible water quality and the water quality standard be kept in reserve; therefore, total phosphorus and chlorophyll-a must be at or below 11.6 ppb and 4.2 ppb, respectively, to achieve Tier 2 High Quality Water status by NHDES. Support determinations are based on the nutrient stressor (phosphorus) and response indicator (chlorophyll-a), with chlorophyll-a dictating the assessment if both chlorophyll-a and total phosphorus data are available, and the assessments differ. Additionally, for toxic chemicals such as chloride, Tier 2 status is achieved if the parameter averages below 207 ppm (10% less than the chronic threshold), while Tier 1 is obtained when the parameter is between 207 and 230 ppm.

Results of the assimilative capacity analysis show that Kezar Lake attains Tier 2: Highest Water Quality status for the mesotrophic class designation (Table 1, Figure 9). Although the existing median total phosphorus concentration exceeds the assimilative capacity threshold, chlorophyll-a is below the 10% reserve threshold, and this parameter dictates the assessment result. Nevertheless, total phosphorus exceeding the 10% reserve (and equaling the impairment threshold) is a cause for concern for Kezar Lake and indicates that reductions in the total phosphorus load are needed to improve the lake's water quality. Chloride is below the chronic threshold set by the state and is fully supporting (n = 23 between 2015 and 2024).

Table 1. Assimilative capacity (AC) analysis results for Kezar Lake (station KEZSUTD). Thresholds are for mesotrophic lakes. Chlorophyll-a dictates the final assessment result if it differs from total phosphorus.

Parameter	AC Threshold	Existing Median WQ*	Remaining AC	Assessment Results
Total Phosphorus Chlorophyll-a	11.6 ppb 4.8 ppb	12.0 ppb 3.8 ppb	-0.4 ppb 1.0 ppb	Attaining Tier 2: Highest Water Quality
Chloride	207 ppm	40 ppm	167 ppm	Attaining Tier 2: Highest Water Quality

** Existing water quality data were truncated to May 24–Sept 15 in the previous 10 years (2015–2024) for composite, epilimnion, or upper samples (in order of priority on a given day) for total phosphorus and chlorophyll-a. Chloride data were truncated to 2015–2024. Data for all parameters were summarized by day, then month, then year using median statistics.*

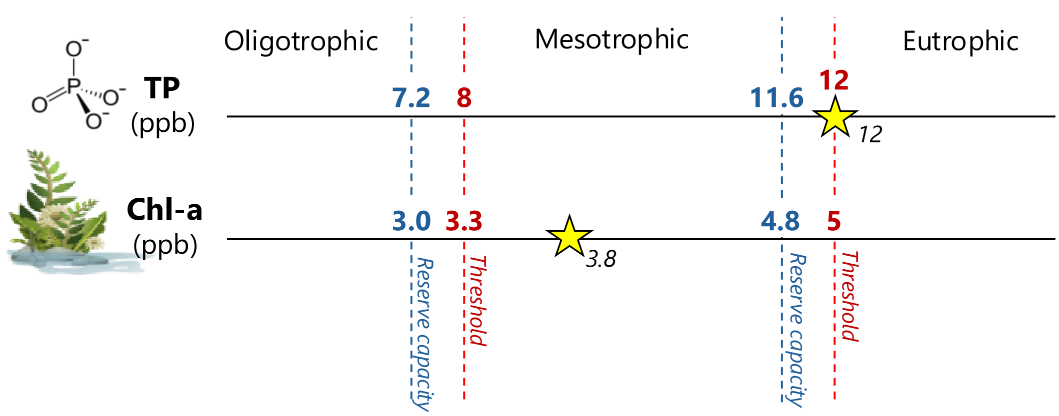


Figure 9. Graphic of trophic state thresholds and AC thresholds (reserve capacity) for Kezar Lake with stars indicating existing median water quality results for Kezar Lake.

4 STREAM WATER QUALITY SUMMARY

4.1 Chloride & Specific Conductivity

The water quality of streams that contribute water, nutrients, contaminants, and more, to Kezar Lake can reveal areas throughout the watershed contributing disproportionate amounts of certain parameters. Stream health is also critical because they often abut wetlands and serve as the home to various aquatic biota and macroinvertebrates. This analysis focuses on streams around the lake that have been sampled at least five times: Birch Brook, King Hill Brook, Kezar Lake Outlet, Kezar Lake Inlet, Lyon Brook at Trussel Ridge, Rowe Creek (Map 1).

Specific conductivity relates to the concentration of ionic compounds in the water. Inputs to streams that affect specific conductivity include various types of salts (road salt and water softeners), ions bound in soil, and ions found in wastewater and agricultural runoff. Chloride and specific conductivity levels in all analyzed tributary stations are below the chronic toxicity threshold of 230 ppm for chloride (which roughly equates to 835 μS/cm for specific conductivity). However, results from Kezar Lake are above the state's median values; 5mg/L for chloride, and 42.3 µs/cm for specific conductivity. **Statistically significant increasing trends were found for specific conductivity at the Kezar Lake Inlet, Kezar Lake Outlet and Lyon Brook at Trussel Ridge from 1988–2024** (Figure 10, top). Although no specific conductivity data was collected in 2018, this parameter still showed a significant increase over the most recent 10 data points (2015–2024) at the Kezar Lake Outlet and Lyon Brook at Trussel Ridge. **There is not enough chloride data from any stream yet to run a statistical trend test** (a minimum of 10 data points is needed). Increasing trends in specific conductance indicate that pollution from the watershed is reaching the inlet, outlet and primary stream feeding Kezar Lake, Lyon Brook. Birch Brook has also displayed elevated chloride and specific conductivity levels since monitoring began there in 2020, while King Hill Brook and Rowe Creek both measured low levels of both parameters (Figure 10).

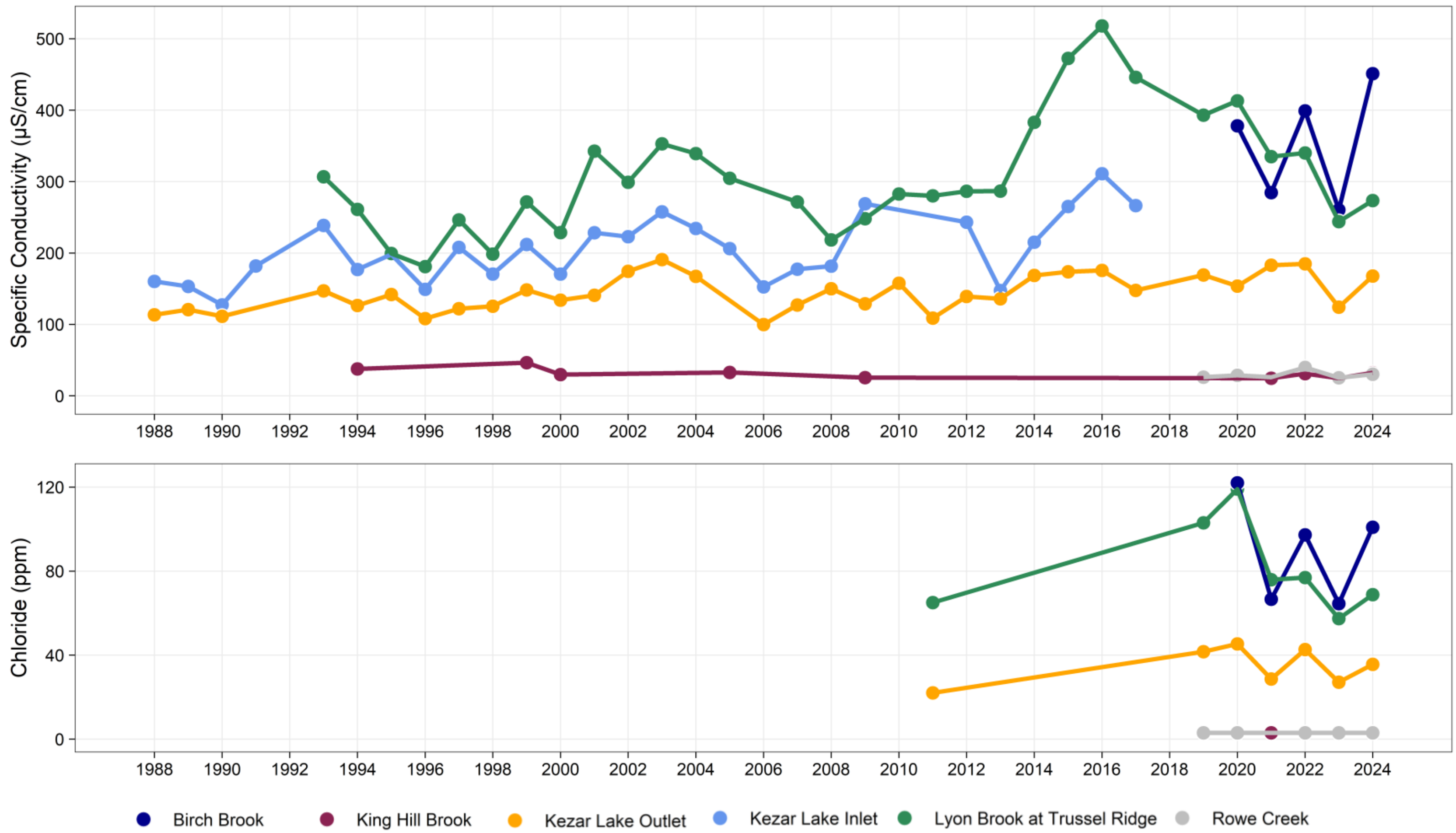


Figure 10. [Top] Yearly median of monthly medians for specific conductivity at the Kezar Lake Inlet (KEZSUTI), Kezar Lake Outlet (KEZSUTO), Lyon Brook at Trussel Ridge (KEZSUTL), King Hill Brook (KEZSUTKB), Rowe Creek (KEZSUTRC) and Birch Brook (KEZSUTBB). [Bottom] Yearly median of monthly medians for chloride at all streams except Kezar Lake Inlet (KEZSUTI). Statistically significant increasing (worsening) trends were found for specific conductivity for the Kezar Lake Inlet and Outlet and Lyon Brook at Trussel Ridge between 1988 and 2024 using a Mann-Kendall nonparametric trend test. All datapoints are currently below the NHDES thresholds, but are higher than the state medians (5 mg/L for chloride, 42.3 µs/cm for specific conductivity).

5 HISTORICAL DATA SUMMARY AND GAPS

Kezar Lake has an impressive amount of water quality data. As with any long-term dataset, the level of monitoring has fluctuated over time. Recently, monitoring has increased, which is fantastic. Identified below are some minor gaps or limitations within the existing dataset. These limitations will not hinder the creation of a comprehensive Watershed Based Plan (WBP). KLPA should continue the excellent data collection at present. Additionally, enhanced monitoring recommendations can be found in section 6.

1. **Temperature and Dissolved Oxygen:** Nearly 100 dissolved oxygen profiles have been conducted at the deep spot of Kezar Lake from 1987 through 2024. Profiles were consistently collected from 1988 through 2004, roughly three times a summer. Only one profile was conducted each year from 2005 to 2016, with some years skipped. Since 2018, profiles have been conducted three times a year, in varying months between May and September.

2. **Total Phosphorus:** The dataset for total phosphorus from the epilimnion and hypolimnion of Kezar Lake is also very robust. Within the past ten years, three to ten sample sets have been collected each year, and almost always include a grab sample from the epilimnion and the hypolimnion. This consistency extends back to the 1980's as well. No large gaps are present, keep up the great work!

3. **Phytoplankton/Zooplankton:** Results are more limited for these natural communities, as this is typically not an analysis included within the VLAP program. Phytoplankton and zooplankton communities are evaluated during the NHDES Trophic Surveys. These surveys are conducted on a rotating basis to cover all lakes within the state. There have been three surveys conducted for Kezar Lake, 1978, 1984, and 2003. The current status and composition of these communities remain a question.

4. **Chloride and Specific Conductivity** have been monitored less frequently than total phosphorus, as expected. These newly emerging parameters of concern are becoming more important and have been sampled more frequently from the deep spot in recent years (2019-2024) than in the past. Chloride has only been monitored at the deep spot since 2003, though specific conductivity has been monitored sporadically since 1978, and consistently since 1988. Specific conductivity data is most commonly collected from the epilimnion of the deep spot, and less so from the hypolimnion and metalimnion.

6 ENHANCED MONITORING RECOMMENDATIONS

Given the available historic data summarized in this memorandum, the following recommendations are identified to enhance existing monitoring efforts as resources and funding allow. Recommendations to enhance monitoring are prioritized below based on a combination of feasibility and importance. Additional data is not necessary to develop a robust WBP, through continued monitoring to evaluate the effectiveness of the plan is important. At a minimum, KLPA should continue the excellent data collection at present. Routine monitoring for temperature and dissolved oxygen, Secchi disk transparency, total phosphorus, conductivity, chloride, pH, and turbidity should remain a priority at all long-term monitoring locations such as KEZSUTD. KLPA should continue to collaborate with the VLAP program and submit all data to the NHDES for review and incorporation into the state Environmental Monitoring Database.

1. **Additional Dissolved Oxygen and Temperature Profiles**

   If KLPA has access to a dissolved oxygen and temperature meter, it is recommended that profiles are collected at least monthly from May through October each year between the hours of 10am and 2pm. If the group would like to go further, profiles may be collected every other week during this period. Enhanced monitoring of water temperature and dissolved oxygen as the season progresses would help identify the strength and duration of summer stratification and the full extent of anoxia within the lake during this time. As a best practice for sampling, a dissolved oxygen and temperature profile should accompany any VLAP grab sampling conducted at the deep spot, and this could serve as the monthly or bi-weekly profile.

2. Additional Phosphorus Sampling

Because Kezar Lake experiences periods of anoxia and concentrations of phosphorus tend to be greater in the hypolimnion than metalimnion or epilimnion, we recommend collecting additional phosphorus samples to better characterize the contribution of phosphorus from internal loading. If additional funding is available, we recommend:

a. Collecting discrete grab samples for total phosphorus collected roughly every 2 meters (at 1, 3, 5, and 7m) at the deep spot of Kezar Lake, for a total of 2-3 times in late July through September. This would further refine the concentrations of phosphorus within the water column during the time of the season when stratification is the strongest and anoxia is expected to be at its maximum, all to further refine the amount of phosphorus coming from internal loading.
b. Continue collecting a total phosphorus grab sample from the metalimnion through the VLAP monitoring. Samples are consistently collected from the epilimnion and the hypolimnion but are less consistently collected from the metalimnion. Each grab sample plays a key role in identifying phosphorus concentrations within the lake and the volume of water that may have the associated concentrations.
c. Pending the results of recommendation 2a, KLPA may investigate the chemistry of available phosphorus to contribute to internal loading within the lake's sediments. This analysis would analyze elemental ratios of phosphorus, aluminum, and iron and characterize biologically labile fractions of phosphorus, the type that could be used by organisms and contribute to lake productivity. Sediment samples were previously collected by Colby-Sawyer College but have not been analyzed. We recommend KLPA consider collecting additional sediment core samples for analysis at a different laboratory due to this long delay.

3. Additional Specific Conductivity and Chloride Sampling

Because a statistically significant increasing (worsening) trend in conductivity has been observed at the Kezar Lake deep spot, and there isn't enough recent chloride data to determine if the lake meets non-impairment criteria, it is recommended to increase the frequency of chloride sampling at the deep spot. To qualify as Fully Supported/Not Impaired for chloride, at least 10 samples must be collected, with 50% (minimum of 5) taken during the summer period (June 1–September 30) during a dry weather period (rainfall <0.25" for preceding three days), and 50% (minimum of 5) during the winter period (December 1–March 15). All samples should be collected from the epilimnion. If KLPA wishes to expand upon this recommendation, chloride and conductivity may be sampled in the metalimnion and hypolimnion zones during these sampling events, as data are relatively lacking for these zones at the deep spot.

4. The Establishment of Long-Term Monitoring at Select Tributary Sites

Tributaries play an important role in lake water quality and should also be routinely monitored throughout the year. Many lakes in New Hampshire, like Kezar Lake, are experiencing the effects of watershed practices on the lake water quality. KLPA currently monitors water quality at many tributary sites throughout the watershed. Long-term datasets for total phosphorus, chloride, and specific conductivity are extremely helpful when monitoring water quality changes over time, but take years to build. The tributary sites with the most current and consistent data for chloride and specific conductivity are Kezar Lake Inlet (KEZSUTI), Kezar Lake Outlet (KEZSUTO), Lyon Brook at Trussel Ridge (KEZSUTL), King Hill Brook (KEZSUTKB), Rowe Creek (KEZSUTRC), and Birch Brook (KEZSUTBB). Additional sites may be added, but the goal is to build a consistent long-term dataset, with sites that represent different areas or sub-watersheds throughout the greater Kezar Lake watershed. KLPA could also consider re-establishing the monitoring site on Lyon Brook at KEZSUT-FR (Kezar Lake-Felch Road; 43.374061°N, -71.966703°W). While this site has limited historical data from the 2005 and 2006 monitoring seasons, it is closer in proximity to Kezar Lake compared to the other Lyon Brook site (KEZSUTL) and may provide a more representative assessment of nutrient and chloride inputs from this sub-watershed.

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