WATER QUALITY GOAL | MEMORANDUM

TO:	Town of Kingston, Kingston Lake Association, YMCA Camp Lincoln
FROM:	Laura Diemer & Evan Ma, FB Environmental Associates
SUBJECT:	Kingston Lake Water Quality Goal Documentation
DATE:	May 29, 2024
CC:	Forrest Bell, FB Environmental Associates

This memo summarizes steps undertaken in determining a recommended water quality goal and objectives for Kingston Lake. The final water quality goal was determined based on discussions among project partners and stakeholders at a Technical Advisory Committee meeting on 5/1/2024. The goal will be used to measure the success of future watershed management actions recommended in the Kingston Lake Watershed-Based Management Plan (WBMP).

PROBLEM BACKGROUND

According to the 2021 and 2022 Data Summary of the New Hampshire Volunteer Lake Assessment Program (VLAP) Individual Lake Reports for Kingston Lake, the lake suffers from low dissolved oxygen and worsening trends in conductivity across the north and south stations, though trends in chlorophyll-a appear to be improving. NHDES assessed Kingston Lake as potentially not supporting (3-PNS) for Aquatic Life Integrity due to elevated turbidity and marginally impaired (5-M) for Aquatic Life Integrity due to low dissolved oxygen saturation and low pH. NHDES Lake Trophic Survey Reports (1976, 1985, 2004, 2009) classify the lake as mesotrophic or eutrophic with an abundance of rooted plants across all surveys, with pickerelweed being the most common. The most recent assessment in 2009 classifies the lake as eutrophic and describes it as a “borderline meso-eutrophic pond.” Kingston Lake is known to be tea-colored, which signifies high levels of dissolved organic carbon in the water. Three cyanobacteria blooms have been reported in the past 15 years, leading to warnings for a cumulative 44 days. The most recent bloom in 2021 was likely a result of the high amount of summer precipitation, which increased lake phosphorus levels, according to the 2021 Data Summary of the NH VLAP Individual Lake Report. Both deep spots of Kingston Lake are known to experience anoxia, which can trigger the release of phosphorus from bottom sediments and be mixed up into the water column for use by phytoplankton such as cyanobacteria. This phenomenon known as internal loading is already evident in Kingston Lake. Enhanced loading of phosphorus to surface waters, whether from internal or external sources, particularly when compounded by the impacts from climate change, can stimulate excessive plant, algae, and cyanobacteria growth and degrade water quality.

WATER QUALITY SUMMARY

Trophic State Indicators

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 algae communities (typically because of greater total phosphorus availability) or the amount of dissolved or particulate materials in a lake. Such changes are likely the result of human disturbance or other impacts to the lake’s watershed.

For the north and south deep spots of Kingston Lake, no statistically significant trends were found for epilimnetic total phosphorus or Secchi disk transparency over the time period of 1995-2022 (Figure 1). Statistically significant decreasing (improving) trends were found for chlorophyll-a at both the north and south deep spots of Kingston Lake. The 2021 and 2022 Data Summary of the NH VLAP Individual Lake Reports for the north and south deep spots on Kingston Lake also indicate similar trends for these parameters.

For the deep spots of Kingston Lake, generally higher total phosphorus concentrations were measured in the hypolimnion compared to the epilimnion and metalimnion, indicating some amount of internal phosphorus loading is occurring in the lake (Figure 2). Both deep spots of Kingston Lake show similar median total phosphorus concentrations for respective depth zones.

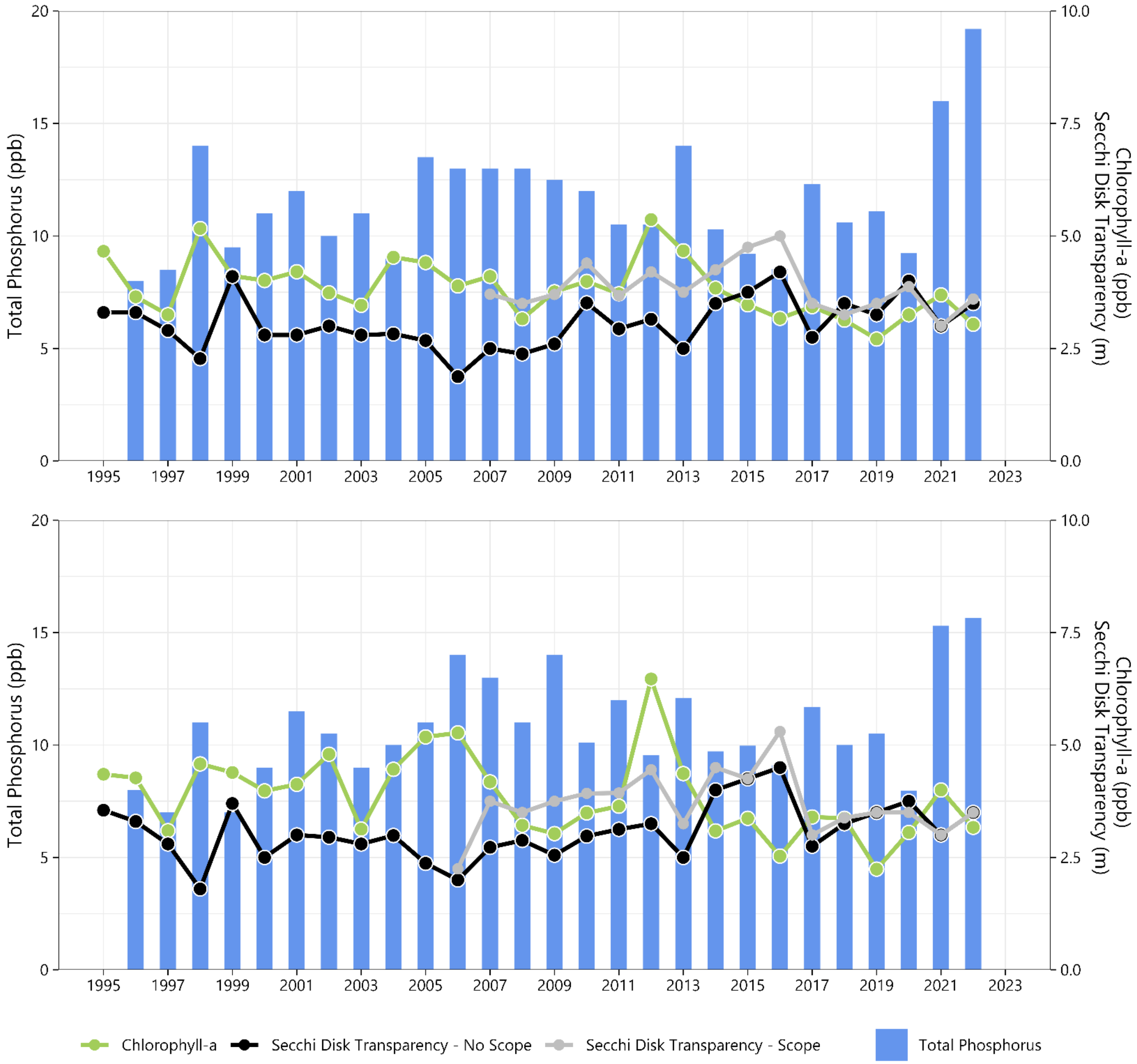

FIGURE 1. Median epilimnion total phosphorus, epilimnion chlorophyll-a, and water clarity (Secchi disk depth for scope and no scope methods) measured at the north deep spot of Kingston Lake [GRTKINND] (top) and the south deep spot of Kingston Lake [GRTKINSD] (bottom) largely in June-September from 1995-2022. Statistically significant decreasing trends in chlorophyll-a for both stations were detected by the Mann-Kendall nonparametric trend test using *rkt* package in R Studio.

Phytoplankton and Zooplankton

<u>Bloom History</u>

There have been three NHDES-issued cyanobacteria bloom warnings for Kingston Lake, the first of which lasted for two days in 2009. The bloom had a cell count of 144,000 cyanobacterial cells/mL and was primarily composed of *Anabaena* (now *Dolichospermum*). Another bloom in September 2017 that lasted eight days was composed of *Microcystis* and had a much higher cell count of 1,300,000 cells/mL. The longest warning lasted for 34 days beginning in September 2021 following a high amount of rainfall that summer. The dominant types of cyanobacteria were *Microcystis* and *Dolichospermum*, which are potentially toxin-producing taxa, with a cell count of 7,500,000 cells/mL.

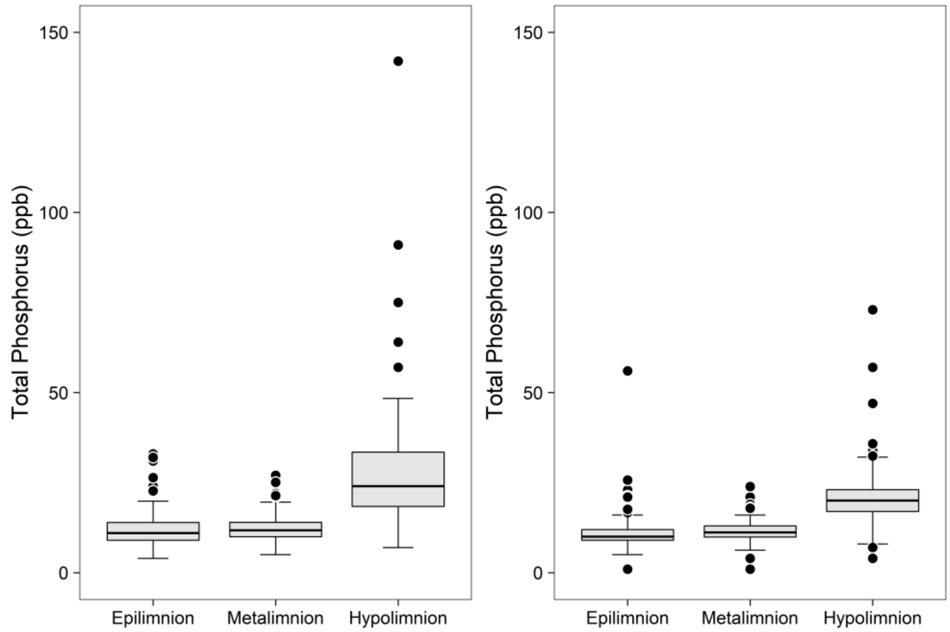

FIGURE 2. Boxplots showing median total phosphorus concentration in the epilimnion, metalimnion, and hypolimnion of the north deep spot of Kingston Lake [GRTKINND] (left) and south deep spot of Kingston Lake [GRTKINSD] (right).

The waterbodies upstream of Kingston Lake also have a history of cyanobacteria blooms. Greenwood Pond had 11 NHDES-issued bloom warnings, starting with its first warning in 2004. Warnings have lasted between one and 56 days, usually beginning in July. Blooms on Greenwood Pond have been typically dominated by *Oscillatoria/Planktothrix*. Greenwood Pond has had a bloom warning every year since 2016. A water sample from the *Oscillatoria/Planktothrix* bloom in 2016 was analyzed for microcystin, a hepatotoxin that cyanobacteria can produce. The sample had a microcystin concentration of 3.2 μg/L, which falls under recreational guidelines but exceeds the drinking water standard recommended by EPA.

Halfmoon Pond has had two recorded NHDES-issued bloom warnings. The first occurred in late July of 2008 and was dominated by *Oscillatoria/Planktothrix*. The most recent bloom warning was issued in August 2022, with *Oscillatoria/Planktothrix* as the most abundant taxon. Both blooms lasted about 30 days.

<u>Phytoplankton/Zooplankton Results</u>

Phytoplankton and zooplankton samples were collected and analyzed during the 1976, 1985, 2004, and 2009 NHDES Trophic Surveys of Kingston Lake (Table 1), as well as during the 1999 Great Pond Diagnostic/Feasibility Study. The dominant phytoplankton species were *Asterionella* (diatom), *Chrysosphaerella* (golden-brown), *Tabellaria* (diatom), *Dinobyron* (golden-brown), *Ceratium* (diatom), *Anabaena* (cyanobacteria), and *Oscillatoria* (cyanobacteria). The dominant zooplankton species were *Nauplius* larvae (copepod), *Keratella* (rotifer), *Calanoid* (copepod), and *Vorticella* (rotifer). The Great Pond Diagnostic/Feasibility Study found that *Daphnia* and *Bosmina* are also common crustaceans. Bosmina are small and inefficient grazers. Copepods are small crustaceans that eat phytoplankton and provide an important food source to fish. *Daphnia* are among the most efficient grazers of phytoplankton. The relative abundance of each type of phytoplankton changes seasonally, with diatoms dominating in the spring and fall and cyanobacteria most abundant in late summer.

TABLE 1. Phytoplankton and zooplankton data summary for Kingston Lake, from Lake Trophic Survey Reports.

Date	Phytoplankton Species (% Total)	Total Phytoplankton Count (cells/mL)	Zooplankton Species (% Total)	Total Zooplankton Count (cells/L)
7/26/1976	*Chrysophaerella* (20%) *Anabaena* Asterionella		*Coelosphaerium* *Rhizosolenia* *Vorticella*	1000
8/19/1985	*Synura/Asterionella* (20%) *Ceratium/Dinobryon* (20%)		*Nauplius* larvae (45%)	113
2/27/1986	*Asterionella* (80%) *Tabellaria* (20%)		*Keratela* (50%)	26
7/15/2004	*Asterionella* (30%) *Chrysophaerella* (25%) *Synura* (25%)		Nauplis larvae (17%) *Calanoid* copepods (10%) *Keratella* (8%)	139
2/5/2005	*Asterionella* (99%)		*Nauplius* larvae (63%) *Polyarthra* (13%) *Calanoid* copepods (13%)	30
7/24/2009	*Asterionella* (45%) *Tabellaria* (20%) *Ceratium* (10%)		*Nauplius* larvae(20%) *Ciliate* (18%) *Keratella* (16%)	45
1/26/2010	*Asterionella* (90%)		*Nauplius* larvae (37%) *Calanoid* copepods (23%) *Keratella* (17%)	30

Dissolved Oxygen & Water Temperature

A common occurrence is the depletion of dissolved oxygen in the deepest part of lakes throughout the summer months. This occurs 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 more dense, 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 coldwater fish and other sensitive aquatic organisms. In addition, anoxia (low dissolved oxygen) at lake bottom can result in the release of sediment-bound phosphorus (otherwise known as internal phosphorus loading), which can become a readily available nutrient source for algae and cyanobacteria. While thermal stratification and depletion of oxygen in bottom waters is a natural phenomenon in dimictic lakes such as Kingston 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 3 shows temperature and dissolved oxygen profiles averaged across sampling dates (1991-2021) during thermal stratification largely in summer (between spring and fall turnover) for the north and south deep spots of Kingston Lake. The change in temperature, seen most dramatically between 4 and 7 m, indicates thermal stratification in the water column. The average dissolved oxygen of <2 ppm at 10-14 m depth indicates the possibility of internal loading under anoxic conditions. Historic recording of temperature and dissolved oxygen profiles includes only one water column profile per sampling season. While these data are useful in tracking major trends over time, monitoring consisting of several profiles per sampling season can provide better insight to seasonal changes in the lake. The 1999 NHDES Great Pond Diagnostic/Feasibility Study describes the seasonal variations of anoxia in the two deep spots. At the north deep spot of Kingston Lake [GRTKINND], the bottom three meters can become anoxic in early June. By late August, the extent of anoxia can extend from 6 m depth to the bottom of the lake. At the south deep spot of Kingston Lake [GRTKINSD], anoxia in the bottom three meters occurs in late July, later than at the north deep spot. The extent of anoxia extends from 5 m depth to the bottom by late August. The Diagnostic/Feasibility Study attributes the differences between the two stations to differences in lake morphometry.

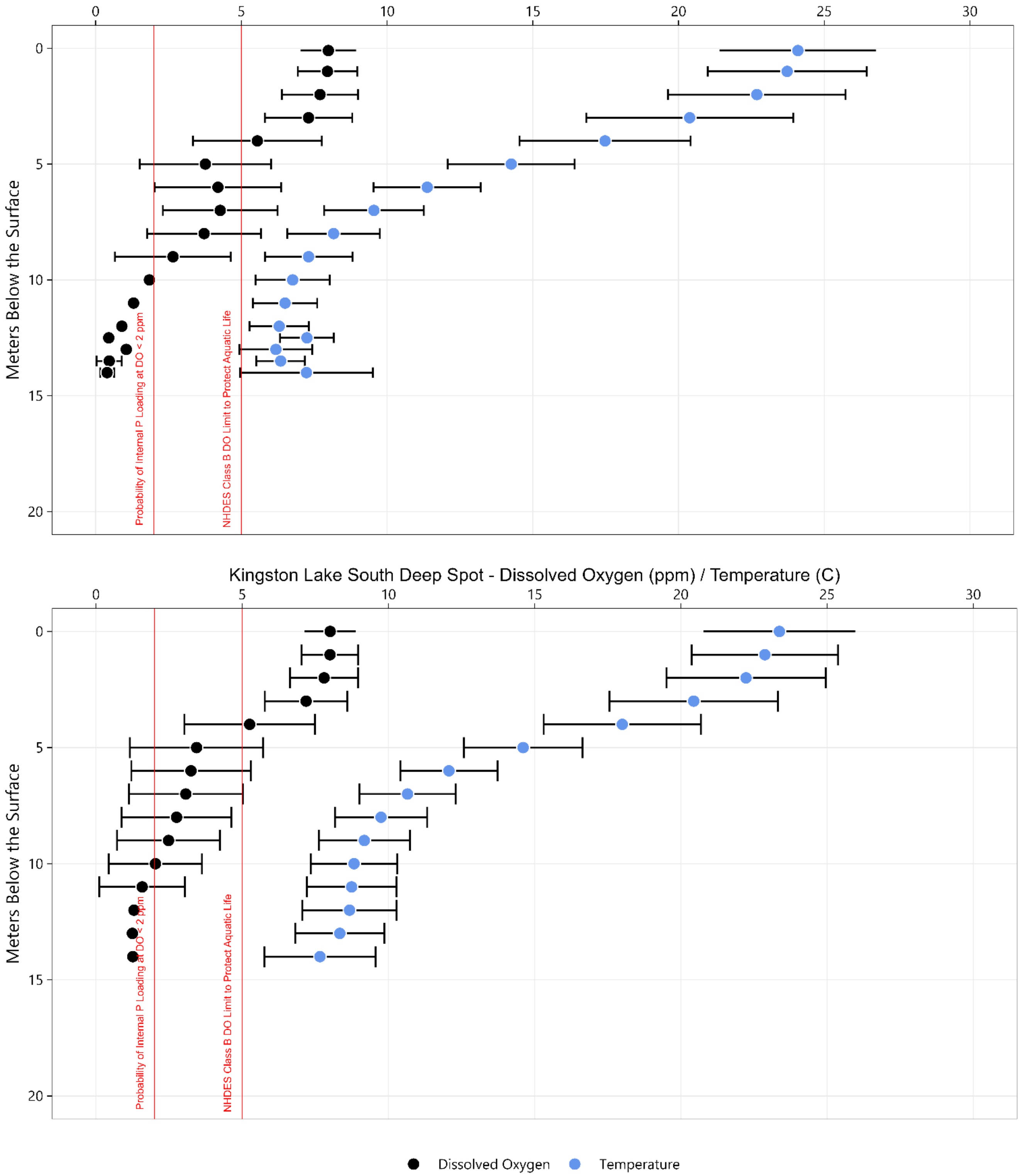

FIGURE 3. Dissolved oxygen (black) and water temperature (blue) depth profiles for the north deep spot [GRTKINND] (top) and south deep spot [GRTKINSD] of Kingston Lake. Dots represent average values across sampling dates for each respective depth. Error bars represent standard deviation. Profiles were collected in 1995-2021 with a few additional observations from 1976 and 1995 for the north deep spot (n=27). For the south deep spot, profiles were collected from 1991-2021 (n=31). The maximum depth of Kingston Lake is 16 m.

ASSIMILATIVE CAPACITY

The assimilative capacity of a waterbody describes the amount of pollutant that can be added to a waterbody without causing a violation of the water quality criteria and is based on lake trophic designation. Kingston Lake is a borderline mesotrophic/eutrophic waterbody, though it is currently classified as eutrophic. For enhanced protection of water quality, both mesotrophic and eutrophic designations were used to run the assimilative capacity analysis for Kingston Lake. 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 (28 ppb and 11 ppb, respectively, for eutrophic waterbodies). NHDES requires a portion of the difference between the best possible water quality and the water quality standard be kept in reserve as described in the 2020/2022 Section 305(b) and 303(d) Consolidated Assessment and Listing Methodology (CALM); therefore, according to Table 3-17 of the CALM, total phosphorus and chlorophyll-a must be at or below 11.6 ppb and 4.8 ppb, respectively, to achieve Tier 2 High Quality Water status under a mesotrophic designation.

Under the eutrophic designation, the parameters must be at or below 26.4 ppb and 10.4 ppb, respectively, to achieve Tier 2 High Water Quality status. 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. Results of the assimilative capacity analysis show that Kingston Lake meets Tier 2 (High Water Quality) for both trophic class designations (Table 2). Greenwood Pond would be considered impaired based on total phosphorus under both trophic class designations and chlorophyll-a under a mesotrophic designation. For Long Pond and Greenwood Pond, high total phosphorus levels for the trophic class paired with low chlorophyll-a levels suggest that there may be other controls on phytoplankton than just phosphorus.

TABLE 2. Assimilative capacity (AC) analysis results for Kingston Lake and other waterbodies within its watershed using mesotrophic and eutrophic thresholds. Chlorophyll-a dictates the assessment results.

Parameter	Mesotrophic AC Threshold (ppb)	Existing Median WQ (ppb)*	Remaining AC (ppb)	Results
KINGSTON LAKE – NORTH DEEP SPOT [GRTKINND]				
Total Phosphorus	11.6	11.1	0.5	Tier 2 (High Water Quality)
Chlorophyll-a	4.8	3.3	1.5	
KINGSTON LAKE– SOUTH DEEP SPOT [GRTKINSD]				
Total Phosphorus	11.6	10.5	1.1	Tier 2 (High Water Quality)
Chlorophyll-a	4.8	3.4	1.4	
LONG POND – DEEP SPOT [LONDVLD]				
Total Phosphorus	11.6	19.6	-8.8	Tier 2 (High Water Quality)
Chlorophyll-a	4.8	4.0	0.8	
GREENWOOD POND – DEEP SPOT [GREKIND]				
Total Phosphorus	11.6	27.7	-16.1	Impaired
Chlorophyll-a	4.8	9.0	-4.2	

Parameter	Eutrophic AC Threshold (ppb)	Existing Median WQ (ppb)*	Remaining AC (ppb)	Results
KINGSTON LAKE – NORTH DEEP SPOT [GRTKINND]				
Total Phosphorus	26.4	11.1	15.3	Tier 2 (High Water Quality)
Chlorophyll-a	10.4	3.3	7.1	
KINGSTON LAKE– SOUTH DEEP SPOT [GRTKINSD]				
Total Phosphorus	26.4	10.5	15.9	Tier 2 (High Water Quality)
Chlorophyll-a	10.4	3.4	7.0	
LONG POND – DEEP SPOT [LONDVLD]				
Total Phosphorus	26.4	19.6	6.8	Tier 2 (High Water Quality)
Chlorophyll-a	10.4	4.0	6.4	
GREENWOOD POND – DEEP SPOT [GREKIND]				
Total Phosphorus	26.4	27.7	-1.3	Tier 2 (High Water Quality)
Chlorophyll-a	10.4	9.0	1.4	

** Existing water quality data truncated to May 24-Sept 15 in the previous 10 years (2013-2022) for composite, epilimnion, or upper samples (in order of priority on a given day). Data were summarized by day, then month, then year using median statistic.*

LAKE LOADING RESPONSE MODEL RESULTS

A second analysis was used to link watershed loading conditions with in-lake total phosphorus and chlorophyll-a concentrations to predict past, current, and future water quality in Kingston Lake. An Excel-based model, known as the Lake Loading Response Model (LLRM), was used to develop a water and phosphorus loading budget for the lakes and their tributaries. Water and phosphorus loads (in the form of mass and concentration) are traced from sources in the watershed, through tributary basins, and into the lake. The model incorporates data about land cover, watershed boundaries, point sources, septic systems, waterfowl, rainfall, and an estimate of internal lake loading, combined with many coefficients and equations from scientific literature on lakes and nutrient cycles. Refer to the Kingston Lake Lake Loading Response Model Report (FBE, 2024).

Overall, model predictions were in good agreement with observed data for total phosphorus (1-3%), chlorophyll-a (5-9%), and Secchi disk transparency (6-31%) (Table 3). It is important to note that the LLRM does not explicitly account for all the biogeochemical processes occurring within a waterbody that contribute to overall water quality and is less accurate at predicting chlorophyll-a and Secchi disk transparency. For example, chlorophyll-a is estimated strictly from nutrient loading, but other factors strongly affect algae growth, including transport of phosphorus from the sediment-water interface to the water column by cyanobacteria, low light from suspended sediment, grazing by zooplankton, presence of heterotrophic algae, and flushing effects from high flows. There were insufficient data available to evaluate the influence of these other factors on observed chlorophyll-a concentrations and Secchi disk transparency readings.

Watershed runoff combined with baseflow (73%) was the largest phosphorus loading contribution across all sources to Kingston Lake, followed by shorefront septic systems at 9%, atmospheric deposition at 8%, and internal loading at 7% (Table 4). Waterfowl (2%) were a relatively minor source. The watershed load includes the watershed load from Long Pond (32%) and the direct land area to Kingston Lake (41%). Greenwood Pond and Halfmoon Pond were not modeled separately, and their land areas were therefore included in the Kingston Lake direct watershed. Development in the watershed is most concentrated in pockets near waterbodies, particularly between Greenwood Pond and Kingston Lake, the Great Pond Park area, and around lake shorelines where septic systems are located within a short distance to the water, leaving little horizontal (and sometimes vertical) space for proper filtration of wastewater effluent. Improper maintenance or siting of these systems can cause failures, which leach untreated, nutrient-rich wastewater effluent to the lake. Note that 1) the estimate for the septic system load is only for those systems directly along the shoreline and potentially short-circuiting minimally treated effluent to the lake; and 2) the load from septic systems throughout the rest of the watershed is inherent to the coefficients used to generate the watershed load. Internal loading, whereby low dissolved oxygen in bottom waters is causing a release of phosphorus from sediments, was estimated as a relatively minor source of phosphorus to the lake; however, the limited amount of dissolved oxygen and total phosphorus data in the hypolimnion add uncertainty to internal loading estimates. Although internal loading is not estimated to be a major source of phosphorus, careful monitoring of the severity and extent of anoxia in Kingston Lake should be conducted both to gauge the potential for internal loading and for the protection of aquatic life. In the meantime, watershed protection efforts should focus on reducing the watershed and septic system loads.

Once the model is calibrated for current in-lake total phosphorus concentration, we can then manipulate land use and other factor loadings to estimate historical and future phosphorus loading (e.g., what in-lake total phosphorus concentration was prior to human development and what in-lake total phosphorus concentration will be following full buildout of the watershed under current zoning restrictions). A comparison of historical, current, and future water quality for Kingston Lake is shown in Table 3.

Pre-development loading estimation showed that total phosphorus loading to Kingston Lake increased by 444%, from 53.1 kg/yr prior to European settlement to 289.0 kg/yr under current conditions (Table 4). These additional phosphorus sources are coming from development in the watershed (especially from the direct shoreline of Kingston Lake and Long Pond), internal loading, septic systems, and atmospheric dust (Table 4). Water quality prior to settlement was predicted to be excellent with extremely low phosphorus and chlorophyll-a concentrations and high water clarity (Table 3).

Future loading estimation showed that total phosphorus loading to Kingston Lake may increase by 23%, from 289.0 kg/yr under current conditions to 356.1 kg/yr at full build-out (2110) under current zoning for Kingston Lake (Table 4). Additional phosphorus will be generated from more development in the watershed (especially from suburban and undeveloped areas near tributaries to Long Pond and Kingston Lake), enhanced internal loading, and greater atmospheric dust (Table 4). The buildout analysis predicted very few new residences within the direct shoreline zone of Long Pond (3) and Kingston Lake (0). There is unlikely to be major increases in phosphorus loading from shoreline septic systems aside from the conversion of the final remaining seasonal properties to year-round use; however, converting to year-round usage would require designing and installing a new septic system on the property, which would likely be an upgrade compared to the older systems on these parcels At full buildout, the model predicted higher (worse) phosphorus (19.9 ppb), higher (worse) chlorophyll-a (5.6 ppb), and lower (worse) water clarity (2.3 m) compared to current conditions for Kingston Lake (Table 3). The number of bloom days may increase from an average of 21 days currently to an average of 60 days at full build-out (Table 3).

TABLE 3. In-lake water quality predictions for Long Pond and Kingston Lake. TP = total phosphorus. Chl-a = chlorophyll-a. SDT = Secchi disk transparency. Bloom Days represent average annual probability of chlorophyll-a exceeding 8 ppb.

Model Scenario	Median TP (ppb)	Predicted Median TP (ppb)	Mean Chl-a (ppb)	Predicted Mean Chl-a (ppb)	Mean SDT (m)	Predicted Mean SDT (m)	Bloom Days
Long Pond							
Pre-Development	--	3.4	--	0.5	--	9.0*	0
Current -2022	15.3	15.5	4.1	4.3	2.7	2.8	25
Future (2110)	--	19.3	--	5.9	--	2.4	73
Kingston Lake							
Pre-Development	--	2.9	--	0.3	--	10.0	0
Current -2022	15.7	16.1	3.7	4.1	3.7	2.7	21
Future (2110)	--	19.9	--	5.6	--	2.3	60

**The maximum depth of Long Pond is around 3 meters. The model predicts the mean Secchi disk transparency (SDT) based on the predicted total phosphorus concentration and other lake variables, which do not include the maximum depth of the pond. For the pre-development model scenario for Long Pond, the mean SDT is predicted at a deeper depth than the lake bottom. For lake management purposes, the predicted mean SDT in the pre-development scenario should be considered as the lake bottom.*

TABLE 4. Total phosphorus (TP) and water loading summary by source for Kingston Lake and Long Pond.

SOURCE	PRE-DEVELOPMENT			CURRENT (2022)			FUTURE (2110)		
	TP (KG/YR)	%	WATER (CU.M/YR)	TP (KG/YR)	%	WATER (CU.M/YR)	TP (KG/YR)	%	WATER (CU.M/YR)
LONG POND									
ATMOSPHERIC	3.0	8%	252,563	8.6	5%	252,563	10.8	5%	252,563
INTERNAL	0.0	0%	0	4.3	3%	0	5.4	3%	0
WATERFOWL	2.6	7%	0	2.6	1%	0	2.6	1%	0
SEPTIC SYSTEM	0.0	0%	0	10.1	6%	8,325	11.1	5%	9,630
WATERSHED LOAD	31.0	85%	5,761,873	140.4	85%	5,717,707	176.1	86%	5,701,534
TOTAL LOAD TO LAKE	**36.6**	**100%**	**6,014,435**	**166.0**	**100%**	**5,978,595**	**205.9**	**100%**	**5,963,726**
KINGSTON LAKE									
ATMOSPHERIC	7.8	15%	655,572	22.4	8%	655,572	27.9	8%	655,572
INTERNAL	0.0	0%	0	21.3	8%	0	26.2	7%	0
WATERFOWL	6.7	13%	0	6.7	2%	0	6.7	2%	0
SEPTIC SYSTEM	0.0	0%	0	26.5	9%	21,804	28.8	8%	23,681
WATERSHED LOAD	38.5	72%	9,884,603	212.2	73%	9,795,802	266.5	75%	9,763,161
Long Pond	*20.6*			*92.7*			*115.1*		
Direct Land Use Load	*17.9*			*119.5*			*151.4*		
TOTAL LOAD TO LAKE	**53.1**	**100%**	**10,540,175**	**289.0**	**100%**	**10,473,179**	**356.1**	**100%**	**10,442,565**

WATER QUALITY GOAL & OBJECTIVES

The model results revealed changes in total phosphorus loading and in-lake total phosphorus concentrations over time from pre-development through future conditions, showing that the water quality of Kingston Lake is threatened by current development activities in the watershed and will degrade further with continued development in the future. We can use these results to make informed management decisions and set an appropriate water quality goal for Kingston Lake. In-lake chlorophyll-a and total phosphorus concentrations indicate that there may not be reserve capacity for the lake to assimilate additional nutrients under a "business as usual" scenario. Thus, it is highly recommended that strong objectives be established to protect the water quality of Kingston Lake over the long term, especially given that the lake is experiencing cyanobacteria blooms and is threatened by new development.

We recommend that the annual average total phosphorus concentration for Long Pond be reduced from a predicted 15.5 ppb to 11.6 ppb, the mesotrophic water quality criterion for phosphorus. This equates to a 25% (41.5 kg/yr) reduction in the total phosphorus load to Long Pond, which represents a significant reduction, more of which may be needed to meet the mesotrophic water quality criterion for phosphorus since the criterion is based on average summer total phosphorus which is higher in the summer for Long Pond due to internal phosphorus loading. More data would be needed to adjust this recommended goal any more stringently.

We recommended that the annual average total phosphorus concentration for Kingston Lake be reduced from a predicted 16.1 ppb to 13.9 ppb, the mesotrophic water quality criterion for phosphorus plus 20% to represent annual average conditions. This equates to a 14% (39.5 kg/yr) reduction in the total phosphorus load to Kingston Lake, of which 44% (17.5 kg/yr) total phosphorus reduction could come from Long Pond if the goal is met. The remaining 56% (22 kg/yr) could come from the direct watershed to Kingston Lake. It is important to note that meeting a mesotrophic water quality criterion for phosphorus for Kingston Lake may not be enough to prevent cyanobacteria blooms. More data and evaluation of changes in Kingston Lake's water quality response to stressors would be needed to adjust this recommended goal any more stringently.

Reality Check: The watershed survey identified 55 sites impacting the lake. Remediating these sites could prevent up to 13.7 kg/yr and 5.1 kg/yr of phosphorus from entering Kingston Lake and Long Pond, respectively. Thirteen (13) sites in the Kingston Lake direct watershed were already addressed by the Kingston Department of Public Works (DPW), meaning 2.8 kg/yr of phosphorus has already been prevented from reaching the lake because of these efforts. Treating shoreline sites could reduce the phosphorus load to Kingston Lake by 0.6 kg/yr[1] for the one high impact site (disturbance score 11+), 2.6 kg/yr[2] for the 9 medium impact sites (disturbance score between 7-10), and 7.1[3] kg/yr for the 49 low impact sites (disturbance score between 7-8) identified from the shoreline survey. Upgrading the 49 shorefront septic systems older than 25 years is estimated to reduce the phosphorus load to Kingston Lake by 4.9 kg/yr. **In sum, treating existing pollutant sources identified as coming from the external watershed load could reduce the phosphorus load to Kingston Lake by 28.9 kg/yr (2.8 kg/yr of which has already been addressed by the Kingston DPW on washed out roads from the 2023 storms, refer to the watershed survey results memorandum for further details), which in addition to the 17.5 kg/yr total phosphorus reduction possible from identified remediation efforts in the Long Pond subwatershed, meets 117% of Objective 1 for Kingston Lake.** The committee agreed to adjust the water quality goal slightly more stringently to meet 100% of the identified pollutant load reduction opportunities or 46.4 kg/yr to Kingston Lake. Non-structural best management practices (BMPs) such as educating homeowners about septic system maintenance, fertilizer use, and residential stormwater management may be effective at reducing phosphorus loading to Kingston Lake and meet the water quality goal by preventing septic system failures, reducing the amount of fertilizer used on residential lawns, and encouraging stormwater management at the property-scale. **Though we did not provide a separate analysis and goal for Greenwood Pond, we recommend that future work focus on evaluating and remediating sources of phosphorus to Greenwood Pond for the benefit of the pond's water quality itself as well as for Kingston Lake.**

For Long Pond, upgrading the 21 systems older than 25 years is estimated to reduce the phosphorus load to the pond by 2.1 kg/yr. With these upgrades and remediation of watershed survey sites, **identified opportunities to reduce phosphorus loading to Long Pond may account for up to 7.2 kg/yr or 17% of the goal for Long Pond.** Additional pollutant load reduction opportunities should be identified specifically for Long Pond, including conducting a watershed survey specific to the Long Pond watershed and a shoreline survey. Pollutant load reduction opportunities from these planning efforts for Long Pond may provide additional recommendations for improving stormwater management and reducing phosphorus loading to Long Pond.

Objective 2 can be met through ordinance revisions that implement low impact development strategies and encourage cluster development with open space protection and/or through conservation of key parcels of forested and/or open land.

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[1] Based on Region 5 model bank stabilization estimate for silt loams, using 200 ft (length) by 3 ft (height) and moderate lateral recession rate of 0.1 ft/yr.

[2] Based on Region 5 model bank stabilization estimate for silt loams, using 100 ft (length) by 3 ft (height) and moderate lateral recession rate of 0.1 ft/yr.

[3] Based on Region 5 model bank stabilization estimate for silt loams, using 50 ft (length) by 3 ft (height) and moderate lateral recession rate of 0.1 ft/yr.

The goal of the Kingston Lake WBMP is to improve the water quality of Kingston Lake and Long Pond such that they meet state water quality standards for the protection of Aquatic Life Integrity (ALI) and substantially reduce the likelihood of harmful cyanobacteria blooms in the lake. This goal will be achieved by accomplishing the following objectives. More detailed action items to achieve these objectives will be provided in the action plan of the WBMP.

Objective 1: Reduce phosphorus loading from existing development by 16% (46.4 kg/yr) to Kingston Lake and 25% (41.5 kg/yr) to Long Pond to improve the average in-lake summer or annual total phosphorus concentration to 10.7 ppb for Kingston Lake and 11.6 ppb for Long Pond.

Objective 2: Mitigate (prevent or offset) phosphorus loading from future development by 8 kg/yr to Kingston Lake and 5 kg/yr to Long Pond to maintain average summer in-lake total phosphorus concentration in the next 10 years (2034).

The interim goals for each objective allow flexibility in re-assessing water quality objectives following more data collection and expected increases in phosphorus loading from new development in the watershed over the next 10 or more years (Table 5). Understanding where water quality will be following watershed improvements compared to where water quality should have been following no action will help guide adaptive changes to interim goals (e.g., goals are on track or goals are falling short). If the goals are not being met due to lack of funding or other resources for implementation projects versus due to increases in phosphorus loading from new development outpacing reductions in phosphorus loading from improvements to existing development, then this creates much different conditions from which to adjust interim goals. For each interim goal year, stakeholders should update the water quality data and model and assess why goals are or are not being met. Stakeholders will then decide on how to adjust the next interim goals to better reflect water quality conditions and practical limitations to implementation.

TABLE 5. Summary of water quality objectives for Kingston Lake and Long Pond. Interim goals/benchmarks are cumulative.

Water Quality Objective	Interim Goals/Benchmarks		
	2026	2029	2034
1. Reduce phosphorus loading from existing development by 16% (46.4 kg/yr) to Kingston Lake and 25% (41.5 kg/yr) to Long Pond to improve average in-lake summer or annual total phosphorus concentration to 10.7 ppb for Kingston Lake and 11.6 ppb for Long Pond.			
	Achieve 4% (11.6 kg/yr) reduction in TP loading to Kingston Lake and 5% (8.3 kg/yr) to Long Pond.	Achieve 8% (23.2 kg/yr) reduction in TP loading to Kingston Lake and 15% (24.9 kg/yr) to Long Pond; re-evaluate water quality and track progress	Achieve 16% (46.4 kg/yr) reduction in TP loading to Kingston Lake and 25% (41.5 kg/yr) to Long Pond; re-evaluate water quality and track progress
2. Mitigate (prevent or offset) phosphorus loading from future development by 8 kg/yr to Kingston Lake and 5 kg/yr to Long Pond to maintain average summer in-lake total phosphorus concentration in the next 10 years (2034).			
	Prevent or offset 2 kg/yr in TP loading from new development to Kingston Lake and 1 kg/yr to Long Pond.	Prevent or offset 4 kg/yr in TP loading from new development to Kingston Lake and 3 kg/yr to Long Pond; re-evaluate water quality and track progress	Prevent or offset 8 kg/yr in TP loading from new development to Kingston Lake and 5 kg/yr to Long Pond; re-evaluate water quality and track progress