Lake Hopatcong
Water Quality Report 2018
Morris and Sussex Counties, New Jersey

Prepared for:
The Lake Hopatcong Commission
PO Box 8515
Landing, NJ 07850

Prepared by:
Princeton Hydro, LLC
1108 Old York Road, Suite 1
P.O. Box 720
Ringoes, New Jersey 08551
(P) 908.237.5660
(F) 908.237.5666
www.princetonhydro.com
Offices in New Jersey, Pennsylvania and Connecticut

February 2019

Table of Contents

1.0 Introduction

Princeton Hydro, LLC conducted general water quality monitoring of Lake Hopatcong during the 2018 growing season (May through September). This monitoring program represents a continuation of the long-term monitoring program of Lake Hopatcong. While the 2010 through 2012 water quality monitoring programs were conducted with funds awarded to the Lake Hopatcong Commission by NJDEP through the Non-Point Source (319(h) of the Clean Water Act) grant program (Project Grant RP10-087), the water quality monitoring program of 2013 was funded through the Lake Hopatcong Foundation as a monetary match toward the grant. Remaining funds in the 319(h) grant were made available for the 2014, 2015 and 2016 water quality monitoring programs. The 2018 water quality monitoring program was funded by the Lake Hopatcong Commission.

The current water quality monitoring program is a modified version of the program that was originally initiated in the Phase I Diagnostic / Feasibility Study of Lake Hopatcong (PAS, 1983) and continued through the Phase II Implementation Projects. Both the Phase I and Phase II projects were funded by the US EPA Clean Lakes (314) Program. The modified monitoring program also continued through the development, revision and approval of the TMDL-based Restoration Plan, as well as through the installation of a series of watershed projects funded through two NJDEP 319 grants and a US EPA Targeted Watershed grant.

The current water quality monitoring program is valuable in terms of continuing to assess the overall “health” of the lake on a year to year basis, identifying long-term trends or changes in water quality, and quantifying and objectively assessing the success and potential impacts of restoration efforts. In addition, the in-lake water quality monitoring program continues to be an important component in the evaluation of the long-term success of the implementation of the phosphorus TMDL-based Restoration Plan, which was approved by NJDEP in April of 2006. Finally, the monitoring program provides the data necessary to support the Foundation’s and Commission’s requests for grant funding to implement both watershed-based and in-lake projects to improve the water quality of Lake Hopatcong.

2.0 Materials and Methods

In-lake water quality monitoring was conducted at the following eleven (11) locations in Lake Hopatcong (represented as red circles in Figure 1, Appendix A) during the study period:

Station Number	Location
1	Woodport Bay
2	Mid-Lake
3	Crescent Cove/River Styx
4	Point Pleasant/King Cove
5	Outlet
6	Henderson Cove
7	Inlet from Lake Shawnee
8*	Great Cove
9*	Byram Cove
10	Northern Woodport Bay
11	Jefferson Canals

* *In-situ* monitoring only

The 2018 sampling dates were 24 May, 27 June, 19 July, 16 August and 10 September. A Eureka Amphibian PDA with Manta multi-probe unit was used to monitor the *in-situ* parameters: dissolved oxygen (DO), temperature, pH, and specific conductance during each sampling event. Data were recorded at 1.0 m increments starting at 0.25 m below the water's surface and continued to within 0.5-1.0 m of the lake sediments at each station during each sampling date. In addition, water clarity was measured at each sampling station with a Secchi disk.

Discrete water quality samples were collected with a Van Dorn sampling device at 0.5 m below the lake surface and 0.5 m above the sediments at the mid-lake sampling site (Station #2). Discrete samples were collected from a sub-surface (0.5 m) position at the remaining six (6) original sampling stations (Stations #1, 3, 4, 5, 6 and 7) and additionally at the Northern Woodport Bay and Jefferson Canals sites (Stations #10 and #11, respectively) on each date. Discrete water samples were appropriately preserved, stored on ice, and transported to a State-certified laboratory for the analysis of the following parameters:

- total suspended solids
- total phosphorus-P
- nitrate-N
- ammonia-N

- chlorophyll *a*

All laboratory analyses were performed in accordance with *Standard Methods for the Examination of Water and Wastewater, 18th Edition* (American Public Health Association, 1992). Monitoring at the Great Cove (Station #8) and Byram Cove (Station #9) sampling stations consisted of collecting *in-situ* and Secchi disk data; no discrete water samples were collected from these two stations for laboratory analyses. It should be noted that prior to 2005, Station #10 had been monitored for *in-situ* observations only. However, due to observations made at Station #10 by the Lake Hopatcong Commission operations staff, it was decided that this sampling station should be added to the discrete sampling list.

During each sampling event, vertical plankton tows were also conducted at the deep sampling station (Station #2). A 50-µm mesh plankton net was used to sample both the phytoplankton and zooplankton. The vertical tows were deployed starting immediately above the anoxic zone (DO concentrations < 1 mg/L) and conducted through the water column to the surface.

3.0 Results and Discussion

Thermal Stratification

Thermal stratification is a condition where the warmer surface waters (called the epilimnion) are separated from the cooler bottom waters (called the hypolimnion) through differences in density, and hence, temperature. Thermal stratification separates the bottom waters from the surface waters with a layer of water that displays a sharp decline in temperature with depth (called the metalimnion or thermocline). In turn, this separation of the water layers can have a substantial impact on the ecological processes of a lake (for details see below). Thermal stratification tends to be most pronounced in the deeper portions of a lake. Thus, for convenience, the discussion on thermal stratification in Lake Hopatcong focuses primarily on the deep, mid-lake (Station #2) sampling station.

In-situ measurements during the 2018 growing season were generally consistent with values recorded in previous monitoring programs. By the late May event, Station #2 exhibited thermal stratification with the epilimnion extending to 4.0 m and the thermocline located between 4.0 m and 8.0 m. Stratification persisted throughout the rest of the sampling season at this station with seasonally maximum temperatures observed on 16 August 2018. Varying degrees of thermal stratification were noted at three of the shallower stations during the May event, including Stations #5, #6 and #9. Only Station #9 was stratified during the June and September samplings. Only Station 2 was thermally stratified during the final sampling event in September 2018. A probe malfunction occurred during the July event, and *in-situ* data was not obtained at Stations #5-6 and #9-11.

Strong and extensive amounts of thermal stratification can effectively "seal off" the bottom waters from the surface waters and overlying atmosphere, which can result in a depletion of dissolved oxygen (DO) in the bottom waters. With the exception of a few groups of bacteria, all aquatic organisms require measurable amounts of DO (> 1 mg/L) to exist. Thus, once the bottom waters of a lake are depleted of DO, a condition termed anoxia, that portion of the lake is no longer available as viable habitat.

Dissolved Oxygen

Atmospheric oxygen enters water by diffusion from the atmosphere, facilitated by wind and wave action and as a by-product of photosynthesis. Adequate dissolved oxygen (DO) is necessary for acceptable water quality. Oxygen is a necessary element for most forms of life. As DO concentrations fall below 5.0 mg/L, aquatic life is put under stress. DO concentrations that remain below 1.0 – 2.0 mg/L for a few hours can result in large fish kills and loss of other aquatic life. Although some aquatic organisms require a minimum of 1.0 mg/L of DO to survive, the NJDEP State criteria for DO concentrations in surface waters is 5.0 mg/L or greater, for a healthy and diverse aquatic ecosystem.

In addition to a temporary loss of bottom habitat, anoxic conditions (DO < 1 mg/L) can produce chemical reactions that result in a release of dissolved phosphorus from the sediments and into the overlying waters. In turn, a storm event can transport this phosphorus to the upper waters and stimulate additional algal growth. This process is called internal loading. Given the temporary loss of bottom water habitat and the increase in the internal phosphorus load, anoxic conditions are generally considered undesirable in a lake.

DO at Station #2 decreased sharply with depth starting at the thermocline during all sampling events during the 2018 season. The bottom of the lake exhibited conditions above the recommended State threshold during the May sampling event. These conditions did not persist into the June sampling event, becoming anoxic (DO concentration < 1 mg/L) at 8 m. Similar conditions were observed during the remaining sampling events, with anoxia beginning at either 7 or 9 m.

DO concentrations remained above the recommended threshold at the remaining stations during the May sampling event, with exception to the bottom waters at ST-9, dropping to 3.65 mg/L. Similarly ST-9 had depressed oxygen concentration during the June sampling, becoming anoxic at 7 m. Due to a probe malfunction, *in-situ* measures were not taken at Stations #5-6 and #9-11, but the remaining stations had adequate DO. ST-9 was again anoxic over the sediments during August. Well-oxygenated conditions were re-established at these stations by the September 2018 sampling event, but did drop slightly below the 5.0 mg/L threshold at Station #7.

Overall, a depression of DO was mainly limited to the hypolimnion of Station #2, with instances of anoxic conditions in the bottom meters of Stations #9. Thus, the majority of the lake had a sufficient amount of DO to support a diverse and healthy aquatic ecosystem (Appendix B).

pH

The pH is defined as the negative logarithm of the hydrogen ion concentration in water. When pH values are greater than 7 they are termed alkaline while those less than 7 are acidic; a pH value of 7 is neutral. The optimal range of pH for most freshwater organisms is between 6.0 and 9.0. However, the NJDEP State water quality standard for pH is for an optimal range between 6.5 and 8.5.

Throughout the majority of the lake in May 2018, surface pH values were acceptable, ranging from 7.06 to 7.95. Slightly higher measures at Station #3 can be attributed to high amounts of weeds and mat algae, resulting in high amounts of photosynthesis, which in turn elevates the pH. pH continued to remain with an acceptable range during all sampling events at all stations, with exception to the September event. Station #4 was elevated above the NJDEP recommended range with a value 8.61. pH typically declines with depth at Station #2 throughout the season. Values observed during the September sampling declined through 8 m before inclining back to surface measures along the sediments.

Water Clarity (as measured with a Secchi disk)

Water clarity or transparency was measured at each in-lake monitoring station, during each monitoring event, with a Secchi disk. Based on Princeton Hydro's in-house, long-term database of lakes in northern New Jersey, water clarity is considered acceptable for recreational activities when the Secchi depth is equal to or greater than 1.0 m (3.3 ft).

In May 2018, Secchi depths were all exceptional, with Secchi depths ranging from 1.3 m to 2.0 m. During the June sampling, all Secchi depths were 1.0 m or greater, with exception to Station #1, which yielded 0.8 m. Similar results were observed during the July event, with reduced clarity at Station #10. A green hue was observed in the water at this station during this event. By the August event both Station #1 and #10 yielded Secchi depths below the recommended 1.0 m threshold. Clarity rebounded by the final event with Secchi depths ranging from 1.1 m to 2.3 m.

Station #2 had high densities of cyanobacteria and green algae during the majority of the season, indicating the shallower stations may also have had plankton densities that affected clarity.

Ammonia-Nitrogen (NH_3-N)

Surface water NH_3-N concentrations above 0.05 mg/L tend to stimulate elevated rates of algal growth. Surface ammonia concentrations measured during the May event were low throughout the lake with non-detectable measures (ND<0.01mg/L) at all stations. Deep water concentrations were also well below the recommended threshold. Ammonia measures spiked to seasonal highs during June at all surface stations, with a range of 0.07 mg/L at Station #11 to 0.19 mg/L at Station #5. Each station exceeded the recommended 0.05 mg/L threshold during this event. Deep water concentrations were elevated during this event with concentrations of 0.46 mg/L. Elevated concentrations of NH_3 are a natural occurrence in the bottom waters of lakes due to the bacterial decomposition of organic material. By the July sampling, ammonia concentration decline to either non-detectable measures or 0.01 mg/L. Low surface water concentrations persisted through the remainder of the year. Deep water concentrations were elevated during both the July and August samplings, yielding 0.12 and 0.47 mg/L, respectively. Concentrations declined back below the recommended threshold during the final sampling.

In summary, the excessively high concentration of NH_3-N in the deep (hypolimnetic) waters at Station #2 was attributed to the depletion of DO and the bacterial decomposition of the organic matter raining to the bottom from the surface waters. Surface water NH_3-N concentrations were consistently low through the majority of the season, exceeding thresholds lake wide during the June sampling.

Nitrate-Nitrogen (NO_3-N)

Nitrate-N concentrations greater than 0.10 mg/L are considered excessive relative to algal and aquatic plant growth. During the May 2018 sampling, Nitrate-N concentrations at the surface stations ranged between 0.03 and 0.81 mg/L. Five of these stations contained concentrations greater than the recommended threshold of 0.10 mg/L. These stations include #2 (0.15 mg/L), #3 (0.40 mg/L), #5 (0.81 mg/L), #7 (0.15 mg/L) and #10 (0.25 mg/L). It should be noted that some of these sampling stations are located close to near-shore septic systems, which may explain the elevated concentrations. A total of 4.06 inches of rain fell in the month prior to sampling, which also may be the cause of elevations (Climod, Mount Arlington 0.8 S). The deep-water nitrate concentrations were slightly above the threshold, yielding 0.11 mg/L. Elevated nitrates are typical early on in the season, declining as phytoplankton and plant productivity increase. The range lessened by the June event, yielding non-detectable measures (ND<0.02 mg/L) at three stations and maximum concentrations of 0.17 mg/L at Station #5. Only the surface stations #3 and #5 and the deep water sample at Station #2 exceeded the recommended threshold at this time. Nitrate increased by the July event to a range of 0.07 mg/L at Station #4 and 0.37 mg/L at Station #10. All surface and deep stations yielded elevated concentrations during this event, with exception to Station #4. A rain event of 0.99 inches occurred the day prior to sampling, which may have caused the increase in nutrients.

By August, nitrate concentrations ranged from 0.05 mg/L at Station #1 to 0.29 mg/L at Station #7. Stations #4 through Stations #11 all yielded concentrations above the recommended threshold of 0.10 mg/L. Deep water concentrations were also elevated at this time with a measure of 0.16 mg/L. As 2018 was a wet year, high accumulations of range were once again noted in the two weeks prior to sampling. A total of 5.67 inches of rain fell in the first half of the month of August. The range of measures decline slightly by the final event, with non-detectable concentrations observed at Stations #1 and #2 and maximum concentrations of 0.015 mg/L at Station #10. Only measures at Station #10 and in the deeper waters exceeded recommended thresholds.

In summary, all in-lake nitrate-N concentrations were consistently below the State and Federal drinking water standard of 10.0 mg/L. Nitrate-N concentrations exceeded the 0.10 mg/L threshold (stimulates elevated amounts of algal and aquatic plant growth) during each event at least one station. In 2014, exceedances typically occurred in those sections of the lake immediately adjacent to lands that have homes using septic systems (Borough of Hopatcong around Crescent Cove / River Styx; Township of Jefferson around Woodport and in the Canals). This indicates that aged, near-shore septic systems contribute to the pollutant load of Lake Hopatcong and thus have a direct impact on its water quality. While not very obvious during the past few, drier growing seasons, these stations still displayed elevated concentrations during a few of the sampling events. High accumulations of rain throughout the growing season also appeared to have a significant impact on nitrate concentrations. A total of 30.08 inches accumulated between May and September during the 2018 season.

Total Phosphorus (TP)

Phosphorus has been identified as the primary limiting nutrient for algae and aquatic plants in Lake Hopatcong. Essentially, a small increase in the phosphorus load will result in a substantial increase in algal and aquatic plant growth. For example, one pound of phosphorus can generate as much as 1,100 lbs of wet algae biomass. This fact emphasizes the continued need to reduce the annual phosphorus load entering Lake Hopatcong, as detailed in the lake’s revised TMDL and associated Restoration Plan.

The State's Surface Water Quality Standard (SWQS, N.J.A.C. 7:9B – 1.14(c) 5) for TP in the surface waters of a freshwater lake or impoundment is 0.05 mg/L. This established TP concentration is for any freshwater lake or impoundment in New Jersey that does not have an established TMDL. Lake Hopatcong has established a phosphorus TMDL, which was revised and approved by NJDEP in June 2006. Based on its refined phosphorus TMDL, the long-term management goal is to maintain an average growing season TP concentration of 0.03 mg/L within the surface waters of Lake Hopatcong. Based on Princeton Hydro's in-house database on northern New Jersey lakes, TP concentrations equal to or greater than 0.03 mg/L will typically result in the development of algal blooms / mats.

The May event was characterized by very low TP concentrations, with non-detectable surface measures at all stations. Deep water TP concentrations were also non-detectable at this time. Phosphorus was typically low during the June event, with measures ranging from 0.02 and 0.03 mg/L at all stations except for #10. Elevated concentrations of 0.06 mg/L were observed at Station #10, increasing the overall mean to 0.031 mg/L, just exceeding the TMDL. Deep water concentrations remained low during this event. Phosphorus concentrations increased overall during the July event, ranging between 0.02 and 0.08 mg/L. Five stations exceeded the recommended 0.03 mg/L threshold at this time, including #1, #3, #7, #10 and #11. The overall monthly mean increased to 0.039 mg/L, exceeding the lakes TMDL goal. Deep water concentrations remained low during this sampling, but spiked to 0.26 mg/L by the August sampling due to extended anoxic conditions at this station. Surface water concentrations in August were similar to those observed during the July event, with all but three stations exceeding the recommended threshold. Monthly averages continued to increase to 0.041 mg/L, before decreasing to 0.01 mg/L during the final event, indicating it exceeded the TMDL during three months of the 2018 sampling year. Low TP measures were observed during the final event, ranging from non-detectable to 0.02 mg/L. Deep water concentrations remained elevated due to prolonged anoxia at Station #2

In summary, surface concentrations were elevated from June through August. Elevated measures may have been caused by near-shore septic systems in some areas, but is likely attributed to the high accumulations of rain during the 2018 season. Deep water concentrations were elevated during the last two sampling events. These elevations in TP can explained by the continuing anoxic conditions and internal loading of phosphorus.

The mean TP concentration was calculated for each surface water sampling station to determine if they complied with or exceeded the concentration of 0.03 mg/L established under the lake's TMDL. Of the nine, long-term water quality monitoring stations, only one station was not in compliance with the TMDL. Meaning each station had a mean 2018 growing season concentration at or less than 0.03 mg/L. Stations #10 had an average of 0.044 mg/L, which is out of compliance with the TMDL average of 0.03 mg/L. It should be noted that this stations is notable for being in an area with a substantial number of near-shore septic systems.

Chlorophyll a

Chlorophyll *a* is a pigment possessed by all algal groups, used in the process of photosynthesis. Its measurement is an excellent means of quantifying algal biomass. In general, an algal bloom is typically perceived as a problem by the layperson when chlorophyll *a* concentrations are equal to or greater than 25 to 30.0 µg/L. In contrast, the targeted average and maximum chlorophyll *a* concentrations, once Lake Hopatcong is in complete compliance with the TMDL, are predicted to be 8 and 14 µg/L, respectively.

The May sampling event was mainly characterized by low chlorophyll a measures, ranging from 5.2 µg/L and 13 µg/L at all stations except Station #11, which spiked to 21 µg/L. This was the only station that exceeded the 14 µg/L threshold during this event. Concentrations observed during the June event shared a similar pattern to the May event. The majority of sampling stations were below the recommended threshold, with non-detectable measures to 13 µg/L. Stations #1 and #10 exceeded this threshold with 15 µg/L and 19 µg/L, respectively. These stations remained elevated through the August sampling event. The remaining stations were below the recommended threshold during both the July and August events. By the final event, three stations exceeded the recommended threshold, including Stations #1, #6 and #10.

Overall, monthly averages increased as the season progressed from 9.5 µg/L during the May event to a maximum of 13.3 µg/L during the September event. Each event exceeded the targeted average by at least 1.5 µg/L, attributed to the moderate to high densities of green algae and cyanobacteria observed during 2018. Of the nine water quality monitoring stations, only two stations were compliant with the TMDL average of 8 µg/L. Meaning only Stations #7 and #11 had a mean 2018 growing season concentration below 8 µg/L. The remaining stations ranged between 8.10 and 19.38 µg/L.

Phytoplankton

Phytoplankton are algae that are freely floating in the open waters of a lake or pond. These algae are vital to supporting a healthy ecosystem, since they are the base of the aquatic food web. However, high densities of phytoplankton can produce nuisance conditions. The majority of nuisance algal blooms in freshwater ecosystems are the result of cyanobacteria, also known as blue-green algae. Some of the more common water quality problems created by blue-green algae include bright green surface scums, taste and odor problems and the generation of cyanotoxins.

The phytoplankton community observed during the May sampling was characterized by a bloom of diatoms, with especially high densities of *Tabellaria* and *Asterionella*. Various cyanobacteria were identified during this event, with low to moderate densities of *Coelosphaerium*, *Microcystis* and *Lyngbya*. Multiple green algae, chrysophytes and dinoflagellates were also present at this time. Species richness increased from 12 to 14 genera during the June sampling, dominated by the cyanobacteria *Anabaena*. The community was made up of diatoms, dinoflagellates cyanobacteria, green algae and chrysophytes. The dinoflagellate *Peridinium*, the green algae *Pediastrum* and cyanobacteria *Aphanizomenon* were also observed in moderate densities in June. Richness continued to increase to its seasonal peak during the July event. The plankton assemblage during this time once again consisted of a mixture of diatoms, dinoflagellates, chrysophytes, cyanobacteria and green algae. Co-dominance was exerted by *Pediastrum*, Anabaena and *Aphanizomenon*. This sample also contained moderate densities of *Lyngbya*, *Microcystis*, *Fragilaria* and *Melosira,* yielding a densely populated sample. Richness and abundance persisted through the August sampling, with a notable bloom of *Aphanizomenon* and high densities of *Anabaena*, *Lyngbya* and *Tabellaria*. Richness began to decline during the final event to 13 genera, still yielding a diverse sample. *Tabellaria* bloomed during this event, dominating the sample with high densities of *Anabaena*. Moderate densities of *Fragilaria*, *Pediastrum*, *Lyngbya* and *Microcystis* were also identified.

Cyanobacteria were present throughout the entirety of the 2018 season, often dominating the samples. All events yielded very high densities of cyanobacteria, with exception to May, where only moderate amounts were observed.

Zooplankton

Zooplankton are the micro-animals that live in the open waters of a lake or pond. Some large-bodied zooplankton are a source of food for forage and/or young gamefish. In addition, many of these large-bodied zooplankton are also herbivorous (i.e. algae eating) and can function as a natural means of controlling excessive algal biomass. Given the important role zooplankton serve in the aquatic food web of lakes and ponds, samples for these organisms were collected at Station #2 during each monitoring event.

Due to elevated densities of phytoplankton throughout the year, zooplankton richness was continually high. The zooplankton community was dominated by the cladoceran *Bosmina* and rotifer *Asplanchna* during the May event. Moderate densities of copepod nauplii and *Cyclops* and rotifers *Synchaeta* and *Keratella* were also observed at this time. A total of 13 genera were identified during this first event. By the June event, the community was solely dominated by *Asplanchna*, with moderate densities noted of *Bosmina*, *Cyclops* and copepod nauplii. The herbivorous cladoceran *Daphnia* was identified as present during this sampling event. Dominance shifted to the cladoceran *Ceriodaphnia* by the July event. *Bosmina*, copepod nauplii and *Keratella* were all identified in moderate amounts. Species richness declined to 10 genera during this event, which persisted through the remainder of the season. Co-dominance was exerted by *Cyclops* and the rotifer *Polyarthra* during the August sampling. *Bosmina*, *Ceriodaphnia*, *Keratella* and copepod nauplii were all identified as common during this sampling. *Cyclops* retained dominance by the final event, with moderate densities of *Bosmina*, *Ceriodaphnia*, *Asplanchna* and copepod nauplii.

Similar to past monitoring years, herbivorous zooplankton were present during the 2018 sampling periods, albeit in low densities during one sampling event. Such conditions are indicative of a fishery community dominated by a large number of small, zooplankton-feeding fishes (e.g. golden shiners, alewife, young perch, where a large population of large-bodied zooplankton cannot exert a high degree of algal control through grazing.

Recreational Fishery and Potential Brown Trout Habitat

Of the recreational gamefish that reside or are stocked in Lake Hopatcong, trout are the most sensitive in terms of water quality. For their sustained management, all species of trout require DO concentrations of at least 4 mg/L or greater. However, the State's designated water quality criteria to sustain a healthy, aquatic ecosystem is a DO concentration of at least 5 mg/L.

While all trout are designated as cold-water fish, trout species display varying levels of thermal tolerance. Brown trout (*Salmo trutta*) have an <u>optimal</u> summer water temperature range of 18 to 24^{o}C (65 to 75^{o}F) (USEPA, 1994). However, these fish can survive in waters as warm as 26^{o}C (79^{o}F) (Scott and Crossman, 1973), defined here as acceptable habitat. The 2018 temperature and DO data for Lake Hopatcong were examined to identify the presence of optimal and acceptable brown trout habitat. As with previous monitoring reports, this analysis focused primarily on *in-situ* data collected at the mid-lake sampling station (Station #2).

For the sake of this analysis, sections of the lake that had DO concentrations equal to or greater than 5 mg/L and water temperatures less than 24^{o}C were considered optimal habitat for brown trout. In contrast, sections of the lake that had DO concentrations equal to or greater than 5 mg/L and water temperatures between 24 and 26^{o}C were considered acceptable or carry over habitat for brown trout.

Optimal brown trout habitat was present through the majority of the water column of Station #2 during the May event. Optimal habitat was observed through 12 m, only lapsing in the bottom meter of the water column due to declining DO. The range of optimal brown trout habitat declined during the June sampling and was present in the surface waters through 5 meters. Optimal habitat drastically declined by the July sampling and was only present at 6 m. Carry over habitat was present from the surface through 5 m during the event. Further decline was noted during the August event, where neither optimal nor carry over habitat was noted, due to elevated surface temperatures and then oxygen depleted deeper waters. Temperatures were slightly above the recommended carry over threshold from the surface to 5 m, ranging from 26.01 to 26.09 ^{o}C. Optimal conditions were reestablished during the final sampling event in the surface waters through 7 m. DO declined at 8 m, indicating no carry over habitat was present.

Optimal brown trout habitat was found at the remaining stations during the May sampling, only dropping to unsuitable habitat at the sediments of Station #9. Similarly, optimal habitat was noted at the majority of stations during the June sampling, with carry over habitat observed at Station #3. Unsuitable habitat was still observed at the sediments at Station #9. A water quality probe malfunction occurred during the July event, so *in-situ* measures could only be obtained at five stations. Carry over habitat was observed at each of the stations during this event. By the August event, optimal brown trout habitat was not recorded at any stations, with only four stations containing varying degrees of carry over habitat. By the final event, all stations contained optimal habitat with exception to the bottom waters of Station #9.

Mechanical Weed Harvesting Program

Many of the shallower sections of Lake Hopatcong are susceptible to the proliferation of nuisance densities of rooted aquatic plants. Given the size of Lake Hopatcong, the composition of its aquatic plant community, and its heavy and diverse recreational use, mechanical weed harvesting is the most cost effective and ecologically sound method of controlling nuisance weed densities. Thus, the weed harvesting program has been in operation at Lake Hopatcong since the mid-1980's with varying levels of success. However, one consistent advantage mechanical weed harvesting has over other management techniques, such as the application of aquatic herbicides, is that phosphorus is removed from the lake along with the weed biomass. In fact, based on a plant biomass study conducted at Lake Hopatcong in 2006 and the plant harvesting records from 2002 to 2018, approximately 1.2 and 11.7% of the total phosphorus (TP) load targeted for reduction under the established TMDL was removed through the mechanical weed harvesting program.

The actual amount of TP removed through harvesting is largely based on the amount of weed biomass removed, which in turn is based on number of factors such as prevailing weather conditions, relative amount of plant growth, availability of experience staff to operate machinery and amount of funding available for harvesting. However, the long-term (2002 – 2018) mean amount of TP removed through harvesting accounts for 6.1% of the annual TP load targeted for reduction under the established TMDL.

The mechanical weed harvesting program at Lake Hopatcong during the 2018 growing season ran from June through October. A total of 3,925 cubic yards of wet plant biomass was removed from Lake Hopatcong during the 2018 growing season. This was slightly higher than the 2017 total amount harvested, which was 3,872 cubic yards.

During the 2018 mechanical weed harvesting program, the removal of 3,925 cubic yards (1,768 tons) of plant material resulted in removing approximately 631 lbs of TP or 8.7% of the TP load targeted for removal under the TMDL. This is the third highest amount of TP removed from the lake out of the 2002 – 2018 database and since 2016 more than 8.5% of the TP load targeted for removal under the TMDL has been addressed through mechanical weed harvesting on an annual basis. The 631 lbs of TP removed through the 2018 weed harvesting program had the potential to generate up to 693,700 lbs of additional wet algal biomass. Using the entire 2002 – 2018 Lake Hopatcong weed harvesting database, the average amount of phosphorus removed through harvesting was estimated to be 440 lbs of TP per year or approximately 6% targeted for reduction under the TMDL.

Inter-annual Analysis of Water Quality Data

Annual mean values of Secchi depth, chlorophyll *a* and total phosphorus concentrations were calculated for the years 1991 through 2018. The annual mean values for Station #2 were graphed, along with the long-term, "running mean" for the lake. The 2018 mean Secchi depth was 1.9 meters, which declined from the past few years. Secchi depth was below the long-term mean of 2.1 for the first time since 2014 (Figure 2 in Appendix A). This decline in clarity can be attributed to the high densities of green algae and cyanobacteria observed throughout the 2018 season.

The mean chlorophyll *a* concentration for the 2018 season was 9.9 µg/L and was below the long-term mean of 10.2 µg/L. Chlorophyll a concentrations declined from the previous years' concentration of 11.8 µg/L. While the 2018 average declined from previous years, it still exceeded the targeted average of 8 µg/L. The mean 2014 chlorophyll *a* concentration was the highest measured out of the entire 1991 – 2018 dataset. The 2014 growing season was cool but unusually wet, transporting watershed-based nutrients and solids into the lake, which more than likely stimulated additional algal growth. Despite the very wet year recorded during 2018, only a few spikes were observed at various sampling stations.

The 2018 mean TP concentration was 0.015 mg/L (Figure 4 in Appendix A), declining from the 2017 sampling period. The 2018 mean was the lowest recorded mean TP concentration since 2013. TP concentrations were well below State Standards and TMDL thresholds. This indicates further improvement to the waterbody

Water Quality Impairments and Established TMDL Criteria

As identified in N.J.A.C. 7:9B-1.5(g)2 "Except as due to natural condition, nutrients shall not be allowed in concentrations that cause objectionable algal densities, nuisance aquatic vegetation or otherwise render the waters unsuitable for the designated uses." For Lake Hopatcong, these objectionable conditions specifically include both algal blooms and nuisance densities of aquatic vegetation.

As described in detail in the Lake Hopatcong TMDL Restoration Plan, a targeted mean TP concentration, as well as mean and maximum chlorophyll *a* ecological endpoints, was established to identify compliance with the TMDL. For the sake of this 2018 analysis, the mid-lake (Station #2), Crescent Cove / River Styx (Station #3) and Northern Woodport Bay (Station #10) monitoring stations were reviewed. To provide guidance for this review, the criteria developed under Lake Hopatcong's TMDL are provided below:

TMDL Criteria for Lake Hopatcong

Targeted mean TP concentration	0.03 mg/L
Targeted mean chlorophyll *a* concentration endpoint	8 µg/L
Targeted maximum chlorophyll *a* concentration endpoint	14 µg/L

The 2018 seasonal mean and single TP concentrations at Station #2 were all consistently below or equal to the targeted mean TP concentration, recognized under the TMDL (0.03 mg/L). The seasonal mean chlorophyll *a* concentration exceeded the targeted mean chlorophyll a concentration of 8 µg/L. All five sampling events yielded chlorophyll *a* concentrations in Station #2 below the targeted maximum chlorophyll *a* concentration endpoint with a range of 6.3 to 13 µg/L.

Mean TP concentrations at Station #3, while slightly higher than those observed at Station #2, were below the targeted mean of 0.03 mg/L. This decreased from the previous year, which yielded an average of 0.04 mg/L. This station has had a steady decline over the past few years. Two of the five concentrations exceeded the targeted mean, reaching a high of 0.04 mg/L. Similar to Station #2 the seasonal 2018 mean chlorophyll *a* concentration exceeded targeted mean with a measure of 9.8 µg/L. All of these samplings were below the targeted maximum chlorophyll *a* concentration ranging between 7.4 and 12 µg/L.

At Station #10, the mean TP concentration in 2018 was 0.04 mg/L, persisting through the 2017 sampling period. This was the only station throughout the lake to exceed the targeted mean of 0.03 mg/L. Three of the samples were above this target, yielding between 0.06 or 0.08 mg/L. The mean concentration of chlorophyll *a* (19.38 µg/L) greatly exceeded the targeted mean concentration of 8 µg/L. Four of the sampling events had a value greater than the targeted maximum chlorophyll *a* concentration endpoint of 14 µg/L, ranging between 17.0 and 27.0 µg/L.

4.0 Summary

This section provides a summary of the 2018 water quality conditions, as well as recommendations on how to preserve the highly valued aquatic resources of Lake Hopatcong.

1. Thermally stratified waters were noted during the early May sampling event, which then persisted throughout the remainder of the growing season. The waters were well oxygenated from surface to 12 m during the first sampling event, only dropping below the recommended DO threshold at the sediments. By the June event, the water column became anoxic at 8 meters. Anoxic conditions persisted through the September sampling.

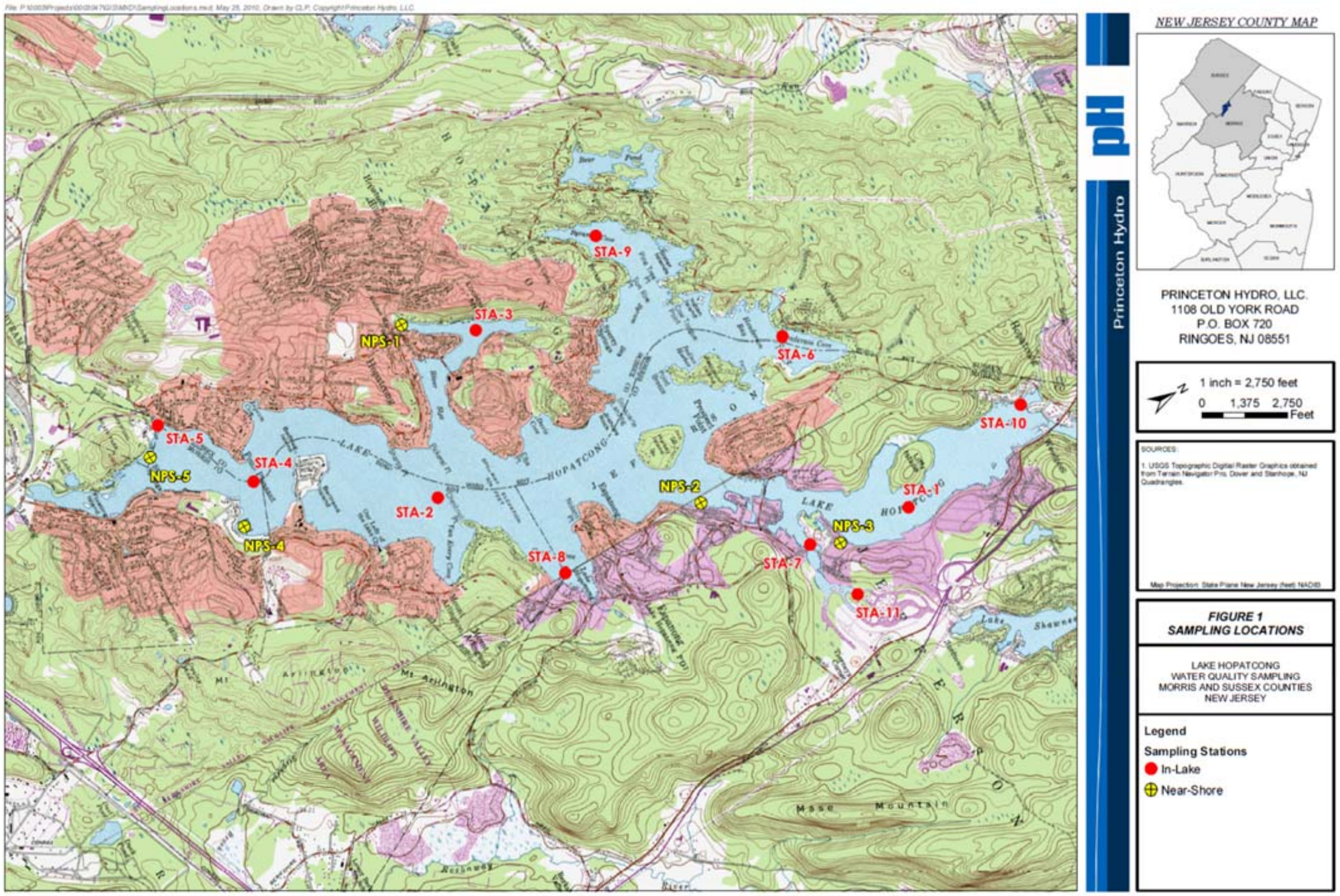
2. It has been well documented that phosphorus is the primary limiting nutrient in Lake Hopatcong. That is, a slight increase in phosphorus will result in a substantial increase amount of algal and/or aquatic plant biomass. TP concentrations in the surface waters of Lake Hopatcong varied between non-detectable (ND<0.01 mg/L) and 0.08 mg/L. Deep water concentrations were low during the first three sampling events, spiking to 0.27 and 0.20 mg/L during the final events due to extended periods of anoxia causing internal loading of P.

3. Based on the *in-situ* conditions, optimal brown trout habitat was available in varying degrees in May, June, July, and September 2018 at Station # 2. Carry-over brown trout habitat was only present during the July sampling event at this station. DO was optimal at the remaining stations during the May, June and September events, only declining to unsuitable habitat in the deep waters of Station #9. Carry over habitat was identified at various stations during the June, July and August samplings. Brown trout habitat was seen during all months in 2018 in one form or another.

4. During the 2018 harvesting program, approximately 3,925 cubic yards of wet plant biomass was removed, which was slightly higher than the 2017 harvested amount. This resulted in removing 631 lbs of TP, accounting for 8.7% of the TP targeted for removal under the TMDL. Since 2016, the amount of TP removed through the mechanical weed harvesting program has been between 8.6 and 8.9% of the amount of TP targeted for reduction under the TMDL.

APPENDIX A

FIGURES


NEW JERSEY COUNTY MAP
STA-1
STA-2
STA-3
STA-4
STA-5
STA-6
STA-7
STA-8
STA-9
STA-10
STA-11
NPS-1
NPS-2
NPS-3
NPS-4
NPS-5
LAKE HOPATCONG
Princeton Hydro
PRINCETON HYDRO, LLC.
1108 OLD YORK ROAD
P.O. BOX 720
RINGOES, NJ 08551
1 inch = 2,750 feet
0 1,375 2,750
Feet
SOURCES:
1. USGS Topographic Digital Raster Graphics obtained from Terrain Navigator Pro, Dover and Stanhope, NJ Quadrangles.
Map Projection: State Plane New Jersey (feet) NAD83
FIGURE 1
SAMPLING LOCATIONS
LAKE HOPATCONG
WATER QUALITY SAMPLING
MORRIS AND SUSSEX COUNTIES
NEW JERSEY
Legend
Sampling Stations
In-Lake
Near-Shore

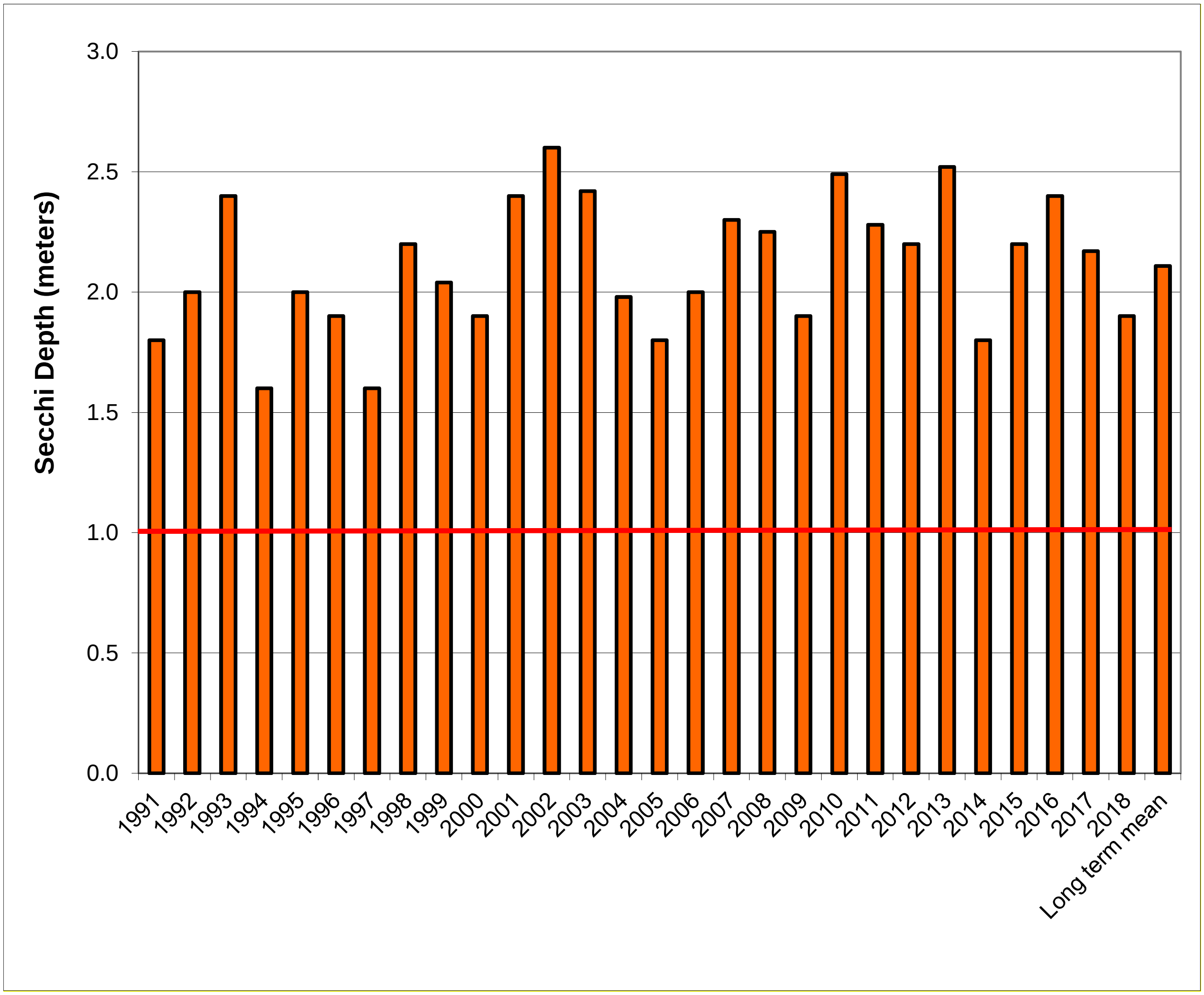


Figure 2 - Lake Hopatcong Long-Term Secchi Depth (meters)

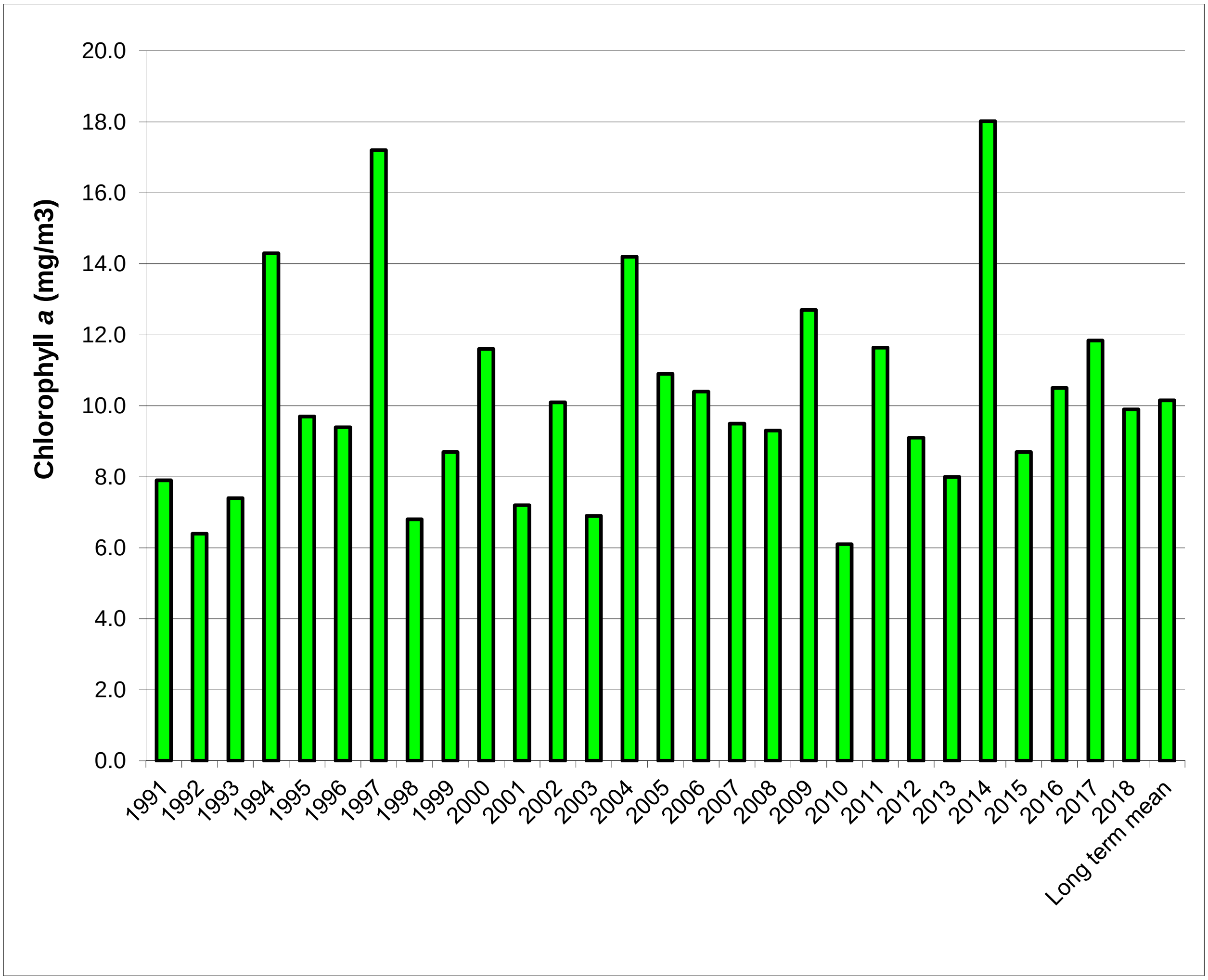


Figure 3 - Lake Hopatcong Long-Term Chlorophyll a Concentrations (mg/m^3)

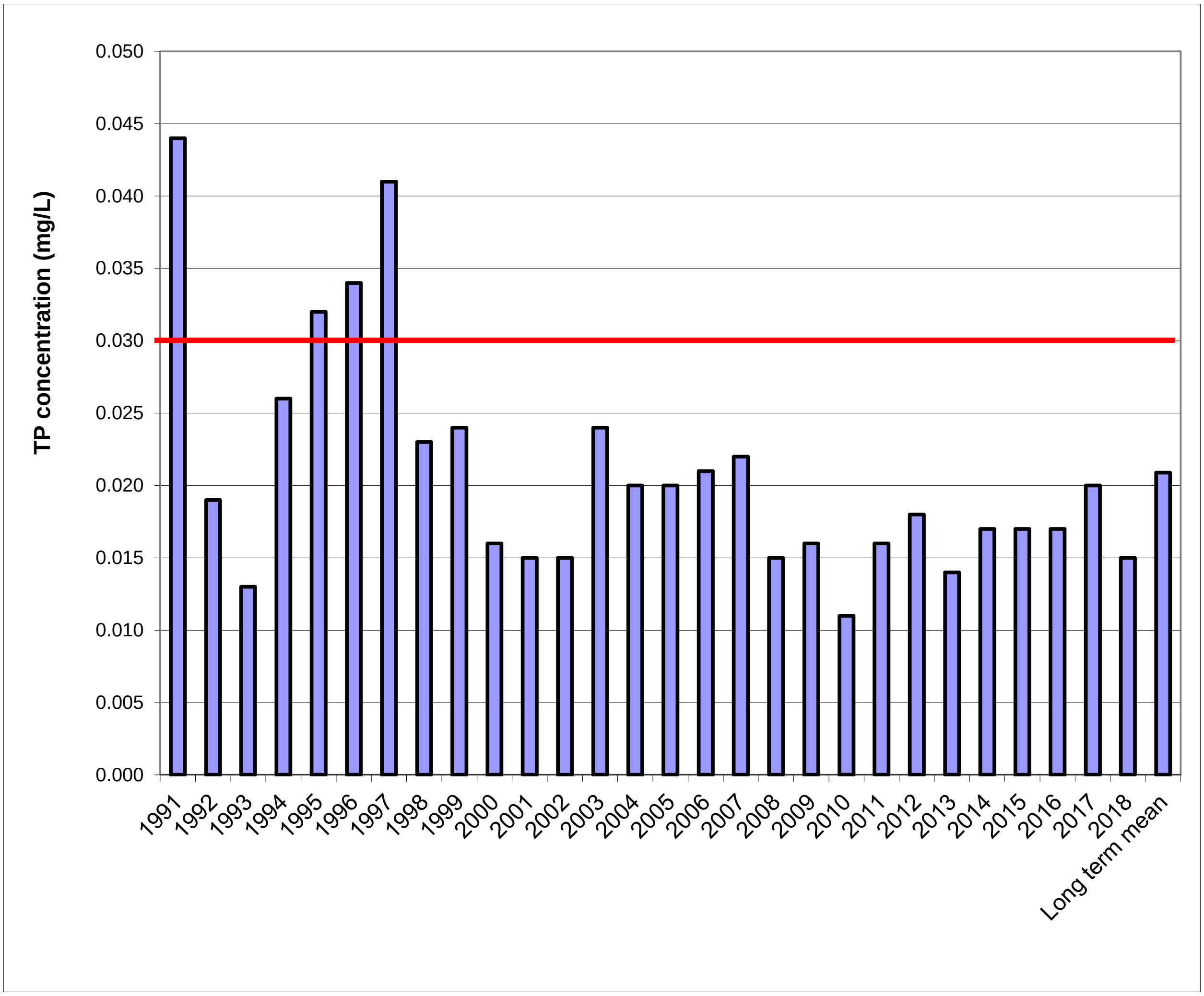


Figure 4 - Lake Hopatcong Long-Term Total Phosphorus Concentrations (mg/L)

APPENDIX B

IN-SITU DATA

In-Situ Monitoring for Lake Hopatcong 5/24/2018								
Station	DEPTH (meters)			Temperature	Specific Conductance	Dissolved Oxygen		pH
	Total	Secchi	Sample	°C	mS/cm	mg/L	% Sat.	S.U.
STA-1	2.60	1.60	0.1	20.02	0.460	8.54	94.1	7.25
			1.0	19.98	0.459	8.68	95.5	7.22
			2.0	19.95	0.459	8.71	95.8	7.24
STA-2	13.60	2.00	0.1	18.34	0.509	9.48	101.0	7.80
			1.0	18.33	0.509	9.55	101.7	7.79
			2.0	18.29	0.509	9.57	101.8	7.78
			3.0	18.22	0.509	9.56	101.6	7.77
			4.0	18.04	0.510	9.47	100.3	7.72
			5.0	16.99	0.509	9.29	96.3	7.65
			6.0	15.11	0.513	8.05	80.1	7.41
			7.0	11.93	0.513	7.69	71.3	7.35
			8.0	10.53	0.511	7.74	69.6	7.25
			9.0	9.88	0.511	7.02	62.1	7.13
			10.0	9.52	0.511	6.57	57.7	7.10
			11.0	9.01	0.513	5.95	51.6	7.04
			12.0	8.91	0.513	5.20	44.9	7.01
			13.0	8.61	0.515	4.35	37.3	6.98
STA-3	2.30	1.50	0.1	19.19	0.931	8.07	87.6	7.95
			1.0	19.00	0.965	8.03	86.8	7.95
			1.7	18.49	1.040	6.26	67.0	7.58
STA-4	2.60	1.90	0.1	18.58	0.514	8.92	95.5	7.58
			1.0	18.59	0.514	8.92	95.5	7.57
			2.0	18.41	0.512	8.96	95.6	7.58
STA-5	2.30	1.90	0.1	20.47	0.535	8.85	98.5	7.40
			1.0	19.81	0.534	9.02	99.0	7.45
			1.8	17.94	0.538	7.43	78.5	7.21
STA-6	3.20	1.90	0.1	19.27	0.510	8.39	91.1	7.51
			1.0	16.93	0.518	9.08	93.9	7.46
			2.0	15.78	0.521	8.91	90.0	7.43
			3.0	15.58	0.521	8.53	85.8	7.37
STA-7	1.70	1.40	0.1	20.09	0.194	8.01	88.3	7.20
			1.0	19.71	0.196	7.82	85.6	6.94
STA-8	4.60	2.00	0.1	18.52	0.510	9.12	97.5	7.76
			1.0	18.54	0.509	9.28	99.2	7.70
			2.0	18.43	0.508	9.34	99.6	7.66
			3.0	18.21	0.506	9.37	99.6	7.63
			4.0	17.91	0.504	9.16	96.7	7.57
STA-9	7.40	2.00	0.1	19.24	0.533	9.23	100.2	7.57
			1.0	19.14	0.535	9.45	102.3	7.61
			2.0	16.96	0.522	9.46	97.9	7.61
			3.0	16.17	0.522	9.10	92.7	7.52
			4.0	15.20	0.524	8.50	84.8	7.41
			5.0	14.01	0.525	8.05	78.3	7.33
			6.0	13.38	0.525	7.62	73.1	7.27
			7.0	10.69	0.530	3.65	32.9	7.05
STA-10	1.5	1.3	0.1	19.28	0.470	9.57	103.9	7.61
			1.0	18.77	0.488	9.94	106.9	7.69
STA-11	1.80	1.5	0.1	20.00	0.155	8.15	89.7	7.06
			1.0	19.45	0.157	7.93	86.3	6.78

In-Situ Monitoring for Lake Hopatcong 06/27/2018								
Station	DEPTH (meters)			Temperature	Specific Conductance	Dissolved Oxygen		pH
	Total	Secchi	Sample	°C	mS/cm	mg/L	% Sat.	S.U.
STA-1	1.8	0.8	0.10	23.37	0.437	8.17	96.0	6.98
			1.00	23.37	0.438	7.80	91.7	7.07
STA-2	13.6	1.8	0.1	23.31	0.495	9.02	106	8.05
			1.0	23.34	0.495	9.01	105.9	8.04
			2.0	23.33	0.495	9.02	105.9	8.04
			3.0	23.33	0.495	9.01	105.9	8.04
			4.0	23.27	0.495	9.02	105.8	8.02
			5.0	22.48	0.494	8.51	98.4	7.79
			6.0	17.29	0.489	4.65	48.4	7.38
			7.0	14.76	0.489	1.34	13.2	7.11
			8.0	11.70	0.490	0.94	8.7	7.07
			9.0	10.80	0.489	1.40	12.6	6.94
			10.0	9.84	0.492	0.38	3.4	6.89
			11.0	9.34	0.496	0.26	2.2	6.88
			12.0	9.11	0.497	0.17	1.4	6.87
			13.0	8.95	0.501	0.13	1.1	6.85
STA-3	1.8	1.1	0.1	24.14	0.831	8.80	105.0	7.98
			1.0	24.13	0.827	8.70	103.8	8.11
STA-4	2.7	1.5	0.1	23.29	0.504	8.54	100.4	7.65
			1.0	23.41	0.504	8.37	98.5	7.64
			2.0	23.40	0.504	8.35	98.2	7.64
STA-5	2.4	1.9	0.1	23.86	0.139	7.71	91.4	7.46
			1.0	23.89	0.513	7.63	90.6	7.38
			2.0	23.87	0.512	7.62	90.4	7.34
STA-6	3.1	1.6	0.1	23.74	0.492	8.52	100.9	7.62
			1.0	23.74	0.492	8.53	101.0	7.61
			2.0	23.73	0.492	8.55	101.2	7.58
			3.0	23.73	0.493	8.47	100.3	7.57
STA-7	1.3	1.0	0.1	23.82	0.364	8.29	98.3	7.47
			1.0	23.82	0.364	7.99	94.7	7.36
STA-8	5.1	1.7	0.1	23.48	0.494	8.93	105.2	8.03
			1.0	23.52	0.494	8.94	105.4	8.02
			2.0	23.52	0.495	8.93	105.3	7.99
			3.0	23.33	0.492	8.83	103.7	7.91
			4.0	23.23	0.492	8.77	102.8	7.82
			5.0	22.94	0.493	7.95	92.7	7.57
STA-9	7.8	1.9	0.1	23.58	0.493	9.05	106.9	7.83
			1.0	23.59	0.493	9.04	106.7	7.90
			2.0	23.59	0.493	9.08	107.1	7.94
			3.0	23.60	0.493	9.10	107.5	7.96
			4.0	23.59	0.493	9.11	107.6	7.95
			5.0	23.34	0.494	8.78	103.1	7.78
			6.0	20.78	0.488	6.08	68.0	7.32
			7.0	14.32	0.491	0.81	8.0	6.95
STA-10	1.2	1.0	0.1	23.19	0.448	7.93	92.9	7.23
			0.7	23.22	0.448	7.68	90.1	7.26
STA-11	1.9	1.5	0.1	23.05	0.284	7.39	86.3	7.23
			1.0	23.04	0.284	6.01	70.2	6.97

In-Situ Monitoring for Lake Hopatcong 7/19/2018								
Station	DEPTH (meters)			Temperature	Specific Conductance	Dissolved Oxygen		pH
	Total	Secchi	Sample	°C	mS/cm	mg/L	% Sat.	S.U.
STA-1	1.8	1	0.1	Probe malfunction				
			1.0					
			2.0					
STA-2	13.7	2.1	0.1	25.62	0.521	8.23	100.9	7.57
			1.0	25.63	0.521	8.10	99.4	7.57
			2.0	25.61	0.520	8.06	98.8	7.56
			3.0	25.59	0.520	8.05	98.6	7.55
			4.0	25.54	0.519	8.02	98.2	7.53
			5.0	25.49	0.519	7.96	97.3	7.51
			6.0	20.27	0.508	5.25	58.2	7.24
			7.0	16.41	0.506	3.20	32.7	7.10
			8.0	13.05	0.505	1.64	15.6	7.05
			9.0	11.60	0.506	0.64	5.9	6.99
			10.0	10.52	0.505	0.46	4.1	6.98
			11.0	9.74	0.508	0.23	2.0	6.96
			12.0	9.32	0.512	0.18	1.5	6.95
			13.0	8.98	0.525	0.14	1.2	6.91
STA-3	1.8	1.5	0.1	25.94	0.761	8.78	108.3	8.20
			1.0	25.94	0.762	8.82	108.8	8.21
STA-4	2.8	1.3	0.1	25.46	0.530	8.03	98.2	7.38
			1.0	25.46	0.529	7.66	93.6	7.36
			2.0	25.40	0.528	7.59	92.7	7.36
STA-5	2.0	1.2	0.1	Probe malfunction				
			1.0					
			2.0					
STA-6	3.3	2.0	0.1	Probe malfunction				
			1.0					
			2.0					
			3.0					
STA-7	1.8	1.8	0.1	25.83	0.457	7.60	93.5	7.30
			1.0	25.39	0.461	7.34	89.6	7.20
STA-8	5.8	2.0	0.0	25.69	0.520	8.30	101.9	7.81
			1.0	25.58	0.519	8.07	98.9	7.70
			2.0	25.59	0.519	7.97	97.6	7.66
			3.0	25.55	0.518	7.86	96.2	7.60
			4.0	25.43	0.518	7.82	95.5	7.56
			5.0	25.32	0.518	7.43	90.6	7.44
STA-9	8.2	1.6	0.1	Probe malfunction				
			1.0					
			2.0					
			3.0					
			4.0					
			5.0					
			6.0					
			7.0					
STA-10	1.4	0.6	0.1	Probe malfunction				
			1.0					
STA-11	1.7	1.4	0.1	Probe malfunction				
			1.0					
			2.0					

In-Situ Monitoring for Lake Hopatcong 8/16/2018								
Station	DEPTH (meters)			Temperature	Specific Conductance	Dissolved Oxygen		pH
	Total	Secchi	Sample	°C	mS/cm	mg/L	% Sat.	S.U.
STA-1	1.6	0.8	0.1	26.56	0.432	8.83	110.1	7.84
			1.0	26.48	0.432	8.88	110.5	7.89
STA-2	13.6	2.0	0.1	26.07	0.513	8.21	101.10	7.96
			1.0	26.09	0.514	8.30	102.6	8.02
			2.0	26.08	0.514	8.31	102.7	8.06
			3.0	26.07	0.514	8.30	102.5	8.08
			4.0	26.03	0.516	8.25	101.9	8.08
			5.0	26.01	0.516	8.22	101.5	8.08
			6.0	24.02	0.533	2.77	32.9	7.78
			7.0	21.20	0.537	0.68	7.2	7.60
			8.0	17.50	0.541	0.33	3.5	7.53
			9.0	14.23	0.540	0.18	1.8	7.48
			10.0	11.68	0.539	0.19	1.8	7.42
			11.0	10.96	0.540	0.17	1.6	7.24
			12.0	10.01	0.543	0.18	1.6	7.17
			13.0	9.38	0.543	0.09	0.7	7.13
STA-3	1.7	1.6	0.1	26.59	0.785	10.57	131.9	8.22
			1.0	26.21	0.793	10.97	136.0	8.45
STA-4	2.7	1.7	0.1	26.08	0.529	7.50	92.7	7.89
			1.0	26.10	0.530	7.45	92.1	7.86
			2.0	26.10	0.530	7.46	92.3	7.85
STA-5	2.1	1.5	0.1	25.96	0.526	7.21	88.9	8.14
			1.0	25.94	0.527	7.38	91.0	8.02
			2.0	25.94	0.527	7.37	90.9	7.95
STA-6	2.1	1.5	0.1	26.58	0.479	8.87	110.6	8.05
			1.0	26.51	0.480	9.00	112.2	8.11
			2.0	26.31	0.482	8.99	111.5	8.14
STA-7	1.5	1.3	0.1	24.22	0.187	5.91	70.5	7.51
			1.0	24.17	0.185	5.75	68.5	7.40
STA-8	6.6	1.6	0.1	26.13	0.505	8.27	102.3	7.69
			1.0	26.15	0.505	8.31	102.9	7.77
			2.0	26.15	0.505	8.32	103.0	7.83
			3.0	26.15	0.505	8.31	102.9	7.87
			4.0	26.14	0.505	8.29	102.5	7.92
			5.0	26.14	0.505	8.26	102.2	7.95
			6.0	26.05	0.507	7.29	90.0	7.85
STA-9	7.5	1.2	0.1	26.30	0.513	8.65	107.4	8.15
			1.0	26.21	0.514	8.70	107.7	8.17
			2.0	26.09	0.514	8.71	107.7	8.17
			3.0	25.95	0.515	8.57	105.6	8.15
			4.0	25.83	0.516	7.95	97.8	8.06
			5.0	25.55	0.527	7.39	90.4	7.96
			6.0	23.67	0.545	2.51	29.7	7.74
			7.0	20.48	0.535	0.66	7.4	7.46
STA-10	1.3	0.8	0.1	26.35	0.432	8.81	109.4	7.54
			1.0	26.21	0.432	9.00	111.5	7.70
STA-11	1.3	1.2	0.1	24.24	0.150	5.86	69.6	7.90
			0.5	24.24	0.151	5.80	69.2	7.72

In-Situ Monitoring for Lake Hopatcong 9/10/2018								
Station	DEPTH (meters)			Temperature	Specific Conductance	Dissolved Oxygen		pH
	Total	Secchi	Sample	°C	mS/cm	mg/L	% Sat.	S.U.
STA-1	**1.8**	**1.1**	**0.1**	20.98	0.392	8.23	92.4	7.37
			1.0	21.02	0.392	8.08	90.7	7.48
STA-2	**13.6**	**1.8**	**0.1**	22.73	0.505	7.48	88.3	8.31
			1.0	22.73	0.505	7.13	84.2	8.05
			2.0	22.74	0.505	7.10	83.8	7.73
			3.0	22.74	0.505	7.09	83.7	7.50
			4.0	22.72	0.505	7.08	83.5	7.32
			5.0	22.72	0.505	7.07	83.4	7.21
			6.0	22.70	0.505	7.04	83.0	7.01
			7.0	22.60	0.506	6.89	81.1	6.93
			8.0	17.03	0.549	1.27	13.4	6.44
			9.0	13.71	0.547	0.51	5.0	6.45
			10.0	11.54	0.548	0.14	1.3	7.68
			11.0	10.44	0.548	0.10	0.9	8.19
			12.0	9.98	0.553	0.10	0.9	8.30
			13.0	9.45	0.562	0.10	0.8	8.36
STA-3	**2.3**	**2.3**	**0.1**	20.53	0.797	7.16	81.0	7.96
			1.0	20.55	0.797	6.64	75.2	7.96
			2.0	20.59	0.801	6.28	71.2	7.72
STA-4	**2.9**	**1.7**	**0.1**	20.26	0.509	8.03	90.2	8.61
			1.0	20.29	0.509	7.53	84.7	8.11
			2.0	20.27	0.510	7.47	84.0	7.47
STA-5	**1.2**	**1.2**	**0.1**	19.17	0.484	9.38	101.7	7.48
			1.0	19.20	0.484	9.17	99.4	7.38
STA-6	**3.1**	**1.5**	**0.1**	21.81	0.472	6.77	77.4	7.51
			1.0	21.86	0.472	6.68	76.2	7.52
			2.0	21.81	0.471	6.66	76.0	7.49
			3.0	20.99	0.469	6.73	75.6	7.50
STA-7	**1.9**	**1.7**	**0.1**	18.34	0.263	4.96	52.8	7.59
			1.0	18.26	0.263	4.85	51.6	7.51
STA-8	**5.2**	**1.5**	**0.1**	22.11	0.479	7.00	80.4	7.77
			1.0	22.11	0.479	6.96	79.9	7.73
			2.0	22.11	0.479	6.87	78.9	7.71
			3.0	22.12	0.479	6.82	78.3	7.69
			4.0	22.11	0.479	6.80	78.1	7.64
			5.0	22.00	0.479	6.64	76.1	7.63
STA-9	**7.8**	**1.7**	**0.1**	22.13	0.473	7.74	88.8	7.40
			1.0	22.15	0.473	7.64	87.8	7.43
			2.0	22.16	0.473	7.63	87.8	7.43
			3.0	22.16	0.473	7.63	87.8	7.49
			4.0	22.15	0.473	7.62	87.5	7.48
			5.0	22.16	0.473	7.59	87.2	7.46
			6.0	22.16	0.473	7.59	87.2	7.47
			7.0	22.16	0.473	7.56	86.8	7.47
STA-10	**1.4**	**1.1**	**0.1**	20.53	0.393	7.92	88.1	7.43
			1.0	20.21	0.394	7.63	84.4	7.50
STA-11	**1.6**	**1.6**	**0.1**	17.76	0.118	6.46	68.0	7.32
			1.0	17.74	0.224	6.02	63.3	7.24

APPENDIX C

DISCRETE DATA

Discrete Data 5/24/2018					
STATION	**Chlorophyll (ug/mL)**	**NH3-N (mg/L)**	**NO3-N (mg/L)**	**TP (mg/L)**	**TSS (mg/L)**
ST-1	8.7	ND<0.01	0.10	ND<0.01	ND<3
ST-2	6.3	ND<0.01	0.15	ND<0.01	3
ST-3	9.0	ND<0.01	0.40	ND<0.01	8
ST-4	5.2	ND<0.01	0.03	ND<0.01	ND<3
ST-5	8.0	ND<0.01	0.81	ND<0.01	4
ST-6	5.7	ND<0.01	0.07	ND<0.01	ND<3
ST-7	13.0	ND<0.01	0.15	ND<0.01	6
ST-10	8.9	ND<0.01	0.25	ND<0.01	8
ST-11	21.0	ND<0.01	0.08	ND<0.01	5
ST-2 DEEP		0.01	0.11	ND<0.01	3
MEAN	**9.5**	**0.01**	**0.22**	**ND<0.01**	**5.3**

Discrete Data 6/27/2018					
STATION	**Chlorophyll (ug/mL)**	**NH3-N (mg/L)**	**NO3-N (mg/L)**	**TP (mg/L)**	**TSS (mg/L)**
ST-1	15.0	0.10	ND<0.02	0.03	3
ST-2	13.0	0.11	0.03	0.02	ND<3
ST-3	12.0	0.11	0.12	0.03	ND<3
ST-4	6.9	0.16	ND<0.02	0.03	ND<3
ST-5	5.8	0.19	0.17	0.03	ND<3
ST-6	8.0	0.14	0.05	0.02	ND<3
ST-7	7.3	0.13	0.10	0.03	ND<3
ST-10	19.0	0.11	ND<0.02	0.06	8
ST-11	ND<0.9	0.07	0.05	0.03	ND<3
ST-2 DEEP		0.46	0.18	0.02	3
MEAN	**9.7**	**0.16**	**0.10**	**0.031**	**5.5**

Discrete Data 7/19/2018					
STATION	**Chlorophyll (ug/mL)**	**NH3-N (mg/L)**	**NO3-N (mg/L)**	**TP (mg/L)**	**TSS (mg/L)**
ST-1	19.0	0.01	0.17	0.05	11
ST-2	6.4	0.01	0.20	0.02	ND<3
ST-3	7.4	0.01	0.14	0.04	7
ST-4	9.7	0.01	0.07	0.03	7
ST-5	9.0	0.01	0.32	0.03	5
ST-6	4.0	ND<0.01	0.31	0.02	ND<3
ST-7	0.9	0.01	0.27	0.04	ND<3
ST-10	27.0	0.01	0.37	0.08	17
ST-11	5.7	0.01	0.26	0.04	ND<3
ST-2 DEEP		0.12	0.29	0.03	3
MEAN	**9.9**	**0.02**	**0.24**	**0.038**	**9.4**

Discrete Data 8/16/2018					
STATION	**Chlorophyll (ug/mL)**	**NH3-N (mg/L)**	**NO3-N (mg/L)**	**TP (mg/L)**	**TSS (mg/L)**
ST-1	17.0	ND<0.01	0.05	0.04	ND<3
ST-2	12.0	0.01	0.06	0.02	ND<3
ST-3	8.9	0.01	0.09	0.04	ND<3
ST-4	6.7	0.01	0.17	0.04	ND<3
ST-5	7.0	0.01	0.12	0.03	ND<3
ST-6	8.4	0.01	0.15	0.03	ND<3
ST-7	3.9	0.02	0.29	0.04	ND<3
ST-10	25.0	0.01	0.15	0.07	5
ST-11	5.8	0.02	0.21	0.06	23
ST-2 DEEP		0.47	0.28	0.26	5
MEAN	**10.5**	**0.06**	**0.16**	**0.063**	**11.0**

Discrete Data 9/10/2018					
STATION	**Chlorophyll (mg/m^3)**	**NH3-N (mg/L)**	**NO3-N (mg/L)**	**TP (mg/L)**	**TSS (mg/L)**
ST-1	27.0	0.01	ND<0.02	0.02	0.05
ST-2	12.0	0.01	ND<0.02	0.01	ND<3
ST-3	12.0	0.01	0.07	0.01	ND<3
ST-4	12.0	0.01	0.03	ND<0.01	6
ST-5	12.0	0.01	0.13	ND<0.01	ND<3
ST-6	20.0	0.03	0.14	0.01	3
ST-7	4.3	0.02	0.14	0.02	ND<3
ST-10	17.0	0.02	0.15	ND<0.01	4
ST-11	3.6	0.03	0.14	0.01	3
ST-2 DEEP		0.04	0.15	0.20	8
MEAN	**13.3**	**0.02**	**0.12**	**0.040**	**4.0**

APPENDIX D

Plankton Data

Phytoplankton and Zooplankton Community Composition Analysis								
Sampling Location: Lake Hopatcong			**Sampling Date: 5/24/2018**			**Examination Date: 6/5/2018**		
Site 1: Mid-Lake								
Phytoplankton								
Bacillariphyta (Diatoms)	**1**		**Chlorophyta (Green Algae)**	**1**		**Cyanophyta (Blue-Green Algae)**	**1**	
Asterionella	A		*Chlorella*	P		*Coelosphaerium*	C	
Fragilaria	C		*Ankistrodesmus*	P		*Microcystis*	P	
Melosira	P		*Pediastrum*	P		*Lyngbya*	P	
Tabellaria	B		**Chrysophyta (Golden Algae)**			**Pyrrhophyta (Dinoflagellates)**		
			Dinobryon	P		*Ceratium*	P	
Zooplankton								
Cladocera (Water Fleas)	**1**		**Copecoda (Copepods)**	**1**		**Rotifera (Rotifers)**	**1**	
Chydorus	R		*Cyclops sp.*	C		*Synchaeta*	C	
Bosmina sp.	A		nauplii	C		*Polyarthra*	R	
Arthropoda (Arthropods)			*Diaptomus*	R		*Asplanchna*	A	
Ostracoda	P					*Tricocerca*	P	
						Keratella	C	
						Notholca	R	
						Kelicottia	R	
Sites:	**1**		**Comments:**					
Total Phytoplankton Genera	12							
Total Zooplankton Genera	13							
Sample Volume (mL)			**Phytoplankton Key: Bloom (B), Common (C), Present (P), and Rare (R)**					
			Zooplankton Key: Dominant (D), Abundant (A), Present (P), and Rare					

Phytoplankton and Zooplankton Community Composition Analysis											
Sampling Location: Hopatcong				**Sampling Date: 6/27/2018**				**Examination Date: 6/28/2018**			
Site 1: ST2											
Phytoplankton											
Bacillariphyta (Diatoms)	**1**			**Chlorophyta (Green Algae)**	**1**			**Cyanophyta (Blue-Green Algae)**	**1**		
Asterionella				*Sphaerocystis*	P			*Aphanacapsa*	P		
Fragilaria	P			*Colonial greens*	P			*Microcystis*	P		
Tabellaria	P			*Pediastrum*	C			*Anabaena*	A		
Pyrrhophyta (Dinoflagellates)				**Desmids (Green Algae)**				*Lyngbya*	P		
Ceratium	P			*Staurastrum*	P			*Aphanizomenon*	C		
Peridinium	C							**Chrysophyta (Golden Algae)**			
								Dinobryon	R		
Zooplankton											
Cladocera (Water Fleas)	**1**			**Copecoda (Copepods)**	**1**			**Rotifera (Rotifers)**	**1**		
Bosmina sp.	C			*Cyclops sp.*	C			*Keratella* (H)	R		
Ceriodaphnia	P			*D Nauplius*	C			*Asplanchna*	A		
Daphnia	R			Diaptomus	P			*Kellicottia*	R		
								Conochilus	P		
								Tricocerca	R		
								Polyarthra	P		
Sites:	**1**	**2**		**Comments: High density sample for both zooplankton and phytoplankton**							
Total Phytoplankton Genera	14										
Total Zooplankton Genera	12										
Sample Volume (mL)				**Phytoplankton Key: Bloom (B), Common (C), Present (P), and Rare (R)**							
				Zooplankton Key: Dominant (D), Abundant (A), Present (P), and Rare (R);							

Phytoplankton and Zooplankton Community Composition Analysis											
Sampling Location: Lake Hopatcong				**Sampling Date: 7/19/2018**				**Examination Date: 7/19/2018**			
Site 1: Mid-Lake											
Phytoplankton											
Bacillariphyta (Diatoms)	**1**			**Chlorophyta (Green Algae)**	**1**			**Cyanophyta (Blue-Green Algae)**	**1**		
Asterionella	P			*Pediastrum*	A			*Anabaena*	A		
Fragilaria	C			Eudorina	P			*Aphanacapsa*	P		
Melosira	C			**Desmids (Green Algae)**				*Lyngbya*	C		
Synedra	R			*Staurastrum*	P			*Microcystis*	C		
Tabellaria	P							*Aphanizomenon*	A		
Chrysophyta (Golden Algae)								**Pyrrhophyta (Dinoflagellates)**			
Dinobryon	P							*Ceratium*	P		
Zooplankton											
Cladocera (Water Fleas)	**1**			**Copecoda (Copepods)**	**1**			**Rotifera (Rotifers)**	**1**		
Bosmina sp.	C			*Cyclops sp.*	P			*Keratella spp.*	C		
Ceriodaphnia	A			*Diaptomus (H)*	P			*Kellicottia*	R		
				D Nauplius	C			*Tricocerca*	R		
								Polyarthra	P		
								Conochilus	R		
Sites:	**1**			**Comments: High density sample**							
Total Phytoplankton Genera	15										
Total Zooplankton Genera	10										
Sample Volume (mL)				**Phytoplankton Key: Bloom (B), Common (C), Present (P), and Rare (R)**							
				Zooplankton Key: Dominant (D), Abundant (A), Present (P), and Rare (R); Herbivorous							

Phytoplankton and Zooplankton Community Composition Analysis											
Sampling Location: Lake Hopatcong				**Sampling Date: 8/16/2018**				**Examination Date: 8/16/2018**			
Site 1: Mid-Lake											
Phytoplankton											
Bacillariphyta (Diatoms)	**1**			**Chlorophyta (Green Algae)**	**1**			**Cyanophyta (Blue-Green Algae)**	**1**		
Fragilaria	P			*Pediastrum*	P			*Anabaena*	A		
Asterionella	R			*Sphaerocystis*	P			*Aphanizomenon*	B		
Melosira	R			**Desmids (Green Algae)**				*Lyngbya*	A		
Tabellaria	A			*Staurastrum*	P			*Coelosphaerium*	C		
Pyrrhophyta (Dinoflagellates)				**Chrysophyta (Golden algae)**				*Microcystis*	C		
Ceratium	P			*Synura*	P						
				Mallomonas	R						
Zooplankton											
Cladocera (Water Fleas)	**1**			**Copecoda (Copepods)**	**1**			**Rotifera (Rotifers)**	**1**		
Bosmina sp.	C			*Cyclops sp.*	A			*Keratella spp.*	C		
Ceriodaphnia	C			*D Nauplius*	C			*Trichocerca*	P		
				Diaptomus	R			*Asplanchna*	P		
								Polyarthra	A		
								Filinia	P		
Sites:	**1**			**Comments: High density sample**							
Total Phytoplankton Genera	15										
Total Zooplankton Genera	10										
Sample Volume (mL)				**Phytoplankton Key: Bloom (B), Common (C), Present (P), and Rare (R)**							
				Zooplankton Key: Dominant (D), Abundant (A), Present (P), and Rare (R); Herbivorous							

Phytoplankton and Zooplankton Community Composition Analysis											
Sampling Location: Hopatcong				**Sampling Date: 9/10/2018**				**Examination Date: 9/24/2018**			
Site 1: ST 2											
Phytoplankton											
Bacillariphyta (Diatoms)	**1**			**Chlorophyta (Green Algae)**	**1**			**Cyanophyta (Blue-Green Algae)**	**1**		
Fragilaria	C			*Pediastrum*	C			*Anabaena*	A		
Melosira	P			*Staurastrum*	P			*Lyngbya*	C		
Tabellaria	B			**Pyrrhophyta (Dinoflagellates)**				*Aphanacapsa*	P		
				Ceratium	P			*Oscillatoria*	P		
								Aphanizomenon	P		
								Coelosphaerium	P		
								Microcystis	C		
Zooplankton											
Cladocera (Water Fleas)	**1**			**Copecoda (Copepods)**	**1**			**Rotifera (Rotifers)**	**1**		
Bosmina sp.	C			*Cyclops sp.*	A			*Keratella* (H)	P		
Ceriodaphnia	C			*D Nauplius*	C			*Asplanchna*	C		
Diaphanasoma	P			*Diaptomus*	P			*Polyarthra*	P		
								Trichocerca	P		
Sites:	**1**	**2**		**Comments: moderate to high density sample for phyto and zooplankton**							
Total Phytoplankton Genera	13										
Total Zooplankton Genera	10										
Sample Volume				**Phytoplankton Key: Bloom (B), Common (C), Present (P), and Rare (R)**							
				Zooplankton Key: Dominant (D), Abundant (A), Present (P), and Rare (R); Herbivorous (H) or Carnivorous (C)							