Lake Hopatcong
Water Quality Report 2019
Morris and Sussex Counties, New Jersey

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1.0 Introduction

Princeton Hydro, LLC conducted general water quality monitoring of Lake Hopatcong during the 2019 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 and 2019 water quality monitoring program were 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 2019 sampling dates were 15 May, 14 June, 10 July, 14 August and 5 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

3.1 In-situ Parameters

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 2019 growing season were generally consistent with values recorded in previous monitoring programs. Station #2 was well-mixed during the May sampling event, declining slightly from 13.60°C at the surface to 10.93°C at 14.0 m. By the June sampling event, the water column at Station #2 exhibited thermal stratification with the epilimnion extending to 6.0 m and the thermocline located from 6.0 m to 8.0 m. Stratification persisted throughout the rest of the sampling season at this station with seasonally maximum temperatures observed on 10 July 2019.

Weak degrees of thermal stratification were noted at two of the shallower stations during the May event, including Stations #10 and #11. Only Station #9 was stratified during the June event. By the July sampling event, thermal stratification was noted at Stations #7, #8 and #9, albeit weak at #7 and #8. Stratification persisted at Stations #8 and #9 during the August sampling event. Only the mid-lake sampling station (#2) was thermally stratified during the final sampling event in September 2019.

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 declined with depth starting at the thermocline during all sampling events during the 2019 season. During the May sampling, DO declined below the NJDEP recommended threshold of 5.0 mg/L in the bottom two meters of the lake. By June, the water column became thermally stratified causing a sharp decline in DO, dropping below 5.0 mg/L at 7.0 m. Anoxic conditions (DO<1.0 mg/L) were present from 8.0 m through the bottom of the waterbody during this time. This pattern persisted through each of the remaining sampling events during the 2019 season.

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 3.91 mg/L in the bottom meter of the water column. Similarly, ST-9 had depressed oxygen concentration during the June sampling, dropping to a minimum of 1.80 mg/L. By the July sampling event, both Stations #8 and #9 yielded DO concentrations below the 5.0 mg/L threshold. The bottom two meters became anoxic at Station #9 during this time. Both Stations #8 and #9 became anoxic over the sediments during the August sampling event. Well-oxygenated conditions were re-established at these stations by the September 2019 sampling event.

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 #8 and #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 2019, surface pH values were acceptable, ranging from 7.29 to 7.77. Overall, pH remained within the NJDEP optimal range of 6.0 and 8.5 during the June sampling, only slightly exceeding the upper limit at Station #3 (8.51). Station #3 is often characterized by dense plant growth and sporadic mat algae densities, resulting in high amounts of photosynthesis, which in turn elevates the pH. pH increased at multiple stations during the July sampling event, caused by the lake-wide harmful algal bloom (HAB), exceeding the optimal range at multiple sampling stations. Each sampling station fell within the optimal range during the final sampling event. Overall pH was increased compared to the previous year, attributed to the elevated cyanobacteria densities observed during the height of the growing season. pH typically declines with depth at Station #2 throughout the season.

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 2019, Secchi depths ranged from 0.9 m to 1.6 m. Overall, each of the stations yielded clarity greater than the New Jersey recommended threshold of 1.0 m with exception to Station #10. Clarity increased overall at the majority of stations within Lake Hopatcong, widening the range to 0.7 m and 2.0 m. Once again Station #10 was the only area to yield reduced clarity. Similar results were observed during the July event, with Secchi depths below 1.0 m at Stations #3 and #10. Due to the prolonged lake-wide cyanobacteria bloom, reduced water clarity was noted, with the majority of stations yielding Secchi depths at or below 1.3 m. Three stations fell below the recommended threshold during this event (#1, #4, #10). By the final event, Secchi depths ranged from 0.7 m to 1.5 m, once again dropping below 1.0 m at Stations #1 and #10. Station #10 was the only station to have reduced clarity throughout the 2019 season. The HAB identified throughout the height of the summer caused a reduction in clarity during August and September.

3.2 Discrete Parameters

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 remained low during each sampling event during the 2019 season. Overall, concentrations ranged from non-detectable measures (ND < 0.01 mg/L) to 0.03 mg/L. Deep water ammonia concentrations were low during the May sampling, only yielding concentrations of 0.02 mg/L. By the June sampling event, ammonia measures spiked to 0.19 mg/L, above the 0.05 mg/L recommended threshold. Concentrations remained elevated in the deep waters for the remainder of the season, reaching seasonal maximums of 0.28 mg/L during the August 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, at no point exceeding recommended thresholds.

Nitrate-Nitrogen (NO_3-N)

Nitrate-N concentrations greater than 0.10 mg/L are considered excessive relative to algal and aquatic plant growth. Typically, lakes with concentrations above 0.30 mg/L indicates nitrogen-loading, however, concentrations below 0.50 mg/L are still considered acceptable water quality. During the May 2019 sampling, Nitrate-N concentrations at the surface stations ranged between 0.10 and 0.58 mg/L. Seven of these stations contained concentrations greater than the recommended threshold of 0.10 mg/L. Stations #5, #7 and #10 exceeded the 0.30 mg/L nitrogen-loading threshold, while Station #3 exceeded 0.50 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 4.98 inches of rain fell in the weeks prior to sampling, which also have aided in the especially elevated nitrate concentrations (Climod, Mount Arlington 0.8 S). The range lessened slightly by the June event to 0.07 mg/L at Station #7 and 0.30 mg/L at Station #3. With exception to Station #7, each station exceeded the 0.10 mg/L threshold but remained at or below the 0.30 mg/L. Similar to the May event, 4.84 inches of rain fell in the weeks prior to sampling. Elevated nitrates are typical early on in the season, declining as phytoplankton and plant productivity increase. Overall, nitrates declined to a range of 0.04 mg/L to 0.12 mg/L by July, continuing to lessen as a lake-wide bloom occurred. Only Stations #10 and #11 exceeded 0.10 mg/L. By August, nitrate concentrations ranged from 0.03 mg/L to 0.19 mg/L. Stations #6 through #11 all yielded concentrations above the recommended 0.10 mg/L threshold, but well below those that would indicate nitrogen loading. The range of measures greatly declined by the final event, with non-detectable concentrations observed at four of the nine stations and maximum concentrations of 0.07 mg/L at Station #11.

The deep-water nitrate concentrations were variable throughout the 2019 season. Seasonal minimum values were noted during the May sampling with concentrations of 0.05 mg/L observed. Peak nitrate concentrations were noted during the June and August samplings spiking to 0.20 mg/L. Nitrate concentrations declined by the June sampling event, falling below 0.10 mg/L. By the final sampling event, nitrate concentrations exceeded 0.10 mg/L with measures of 0.14 mg/L.

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 at the surface exceeded the 0.10 mg/L threshold (stimulates elevated amounts of algal and aquatic plant growth) during each sampling event, with exception to the September sampling. 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 2019 growing season also appeared to have a significant impact on nitrate concentrations. A total of 27.54 inches accumulated between May and September during the 2019 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 a wide range of surface TP concentrations, with measures between 0.01 mg/L at Station #2 and 0.06 mg/L at Station #3. Five sampling stations exceeded the Princeton Hydro recommended threshold of 0.03 mg/L at that time. Overall, TP increased by the June sampling event, with all but two stations contravening the threshold. Stations #4 and #6 both yielded measures of 0.03 mg/L during this time. TP declined at the majority of sampling stations by the July event, ranging from measures of 0.02 mg/L to 0.05 mg/L. Only two stations exceeded the recommended threshold during this event. Declines continued during the August event, with all one sampling station (#4: 0.04 mg/L) below the 0.03 mg/L threshold. By the final sampling event, TP concentrations ranged from a minimum of 0.02 mg/L at Station #2 to a maximum measure of 0.05 mg/L at Station #10. Three of the nine stations during this event contravened to recommended threshold. Monthly averages for the 2019 growing season ranged from 0.017 mg/L during August and 0.043 mg/L during June, contravening the TMDL average of 0.03 mg/L during May (0.034 mg/L), June (0.043 mg/L) and September (0.033 mg/L).

Deep water TP concentrations at Station #2 were low during the May sampling, with a measure of 0.01 mg/L. Deep water concentrations increased to 0.04 mg/L by the June event, before spiking to 0.18 mg/L due to the continued thermal stratification observed at Station #2. TP concentrations continued to increase as the season progressed, inclining to a seasonal maximum measure of 0.33 mg/L. Similar measures were noted during the final event. Elevated TP concentrations in the bottom waters of this station were caused by the extended thermal stratification and prolific anoxia observed causing internal loading of phosphorus.

In summary, surface concentrations were elevated throughout the growing season at various sampling stations. Elevated measures may have been caused by near-shore septic systems in some areas, but is likely attributed to the high accumulations of rain and extended internal loading during the 2019 season. Deep water concentrations were elevated during all but the first sampling event. 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 three stations were compliant with the TMDL. Stations #2, #6 and #11 each had respective averages of 0.020 mg/L, 0.022 mg/L and 0.024 mg/L, which are in compliance with the TMDL average of 0.03 mg/L. The remaining sampling stations had a mean 2019 growing season concentration that exceeded 0.03 mg/L in varying degrees. These stations yielded TP averages ranging from 0.032 mg/L to 0.042 mg/L. It should be noted that some of these stations are notable for being in an area with a substantial number of near-shore septic systems. The wet season observed during 2019 and persistent anoxia causing internal phosphorus loading likely aided in these nutrient elevations.

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* concentrations, ranging from 2.6 µg/L and 13 µg/L at all stations. A wider range of chl *a* concentrations was observed during the June sampling with measures between 0.5 µg/L at Station #5 and 31.0 µg/L at Station #1. Both Stations #1 and #10 yielded concentrations that exceeded the 14 µg/L threshold during this event. Concentrations increased overall during the July event, with six of the nine sampling stations producing measures above the 14.0 mg/L threshold. Chl *a* concentrations continued to increase at the majority of sampling stations during the August sampling event, with exception to Stations #7 and #11. A similar pattern was observed during the final event, with elevated chl a at all stations, with exception to #7 and #11. High chlorophyll concentrations were attributed to the cyanobacteria bloom that persisted throughout the majority of the 2019 growing season.

Overall, monthly averages increased as the season progressed from 9.9 µg/L during the May event to a maximum of 23.6 µg/L during the September event. Each event exceeded the targeted average by at least 1.9 µg/L, attributed to the elevated densities of cyanobacteria observed throughout the 2019 season. Of the nine water quality monitoring stations, only growing season averages at Station #11 remained compliant with the TMDL average of 8 µg/L. The remaining stations ranged between 8.96 µg/L at Station #7 and 27.60 µg/L at Station #1.

Total Suspended Solids

The concentration of suspended particles in a waterbody that will cause turbid or “muddy” conditions, total suspended solids is often a useful indicator of sediment erosion and stormwater inputs into a waterbody. Because suspended solids within the water column reduce light penetration through reflectance and absorbance of light waves and particles, suspended solids tend to reduce the active photic zone of a lake while contributing a “muddy” appearance at values over 25 mg/L. Total suspended solids measures include suspended inorganic sediment, algal particles, and zooplankton particles.

Overall, TSS concentrations remained low throughout the 2019 season. Surface concentrations ranged from non-detectable concentrations (ND < 2 mg/L) during the May event at multiple stations to 12 mg/L during the September sampling at Station #1. Each of the sampling events yielded TSS concentrations below the 25 mg/L recommended threshold. Similarly, low TSS measures were noted in the deep waters at Station #2 during each sampling event, ranging from 2 mg/L to 9 mg/L.

3.3 Biological Parameters

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 an abundance of the cyanobacteria *Aphanizomenon*. Species richness was high during this event, yielding 18 identified genera. While richness declined during the June sampling, densities increased with co-dominance exerted by *Aphanizomenon*, *Dolichospermum* (formerly *Anabaena*), and *Dinobryon*. Moderate densities of various diatoms and other cyanobacteria were also noted. Cyanobacteria became exclusively dominant by the July event. Moderate densities of other cyanobacteria, green algae and dinoflagellates were also present during this time. Peak seasonal richness of 25 genera was observed during the August sampling event, with representations from diatoms, cryptomonads, chlorophytes, dinoflagellates and cyanobacteria. Co-dominance was exerted by the diatoms *Melosira* and *Tabellaria* and the filamentous blue-green *Lyngbya*. By this event, seven cyanobacteria species were observed increasing from previous sampling events. Due to the lake-wide cyanobacteria bloom, an extra surface grab was collected at Station #2 for quantitative analysis. *Aphanizomenon* was the dominant algae during this event with 11,690 cells/mL. Overall, cyanobacterial cell densities were below the NJ Health Advisory Guidance Level of 20,000 cells/mL. By September, a slight decline in richness was observed with 21 identified genera. *Tabellaria* and *Dolichospermum* exerted co-dominance, with moderate densities of *Aphanizomenon*, *Coelosphaerium* and *Ceratium*.

Cyanobacteria were dominant throughout the year as a lake-wide HAB persisted through the majority of the 2019 season. Cyanobacteria monitoring was conducted during 2 July and 12 August that consisted of quantifying cyanobacteria cell densities and cyanotoxin (microcystin, cylindrospermopsin and anatoxin-a). Overall, microcystin, cylindrospermopsin and anatoxin-a levels remained below their respective NJDEP draft recreational health advisories at each station during these sampling events. The NJDEP has established cell count-based criteria for the relative probability of acute health effects of these HABs. As mentioned above, NJDEP has a Health Advisory Guidance Level of 20,000 cells/mL. During the July monitoring event, two of the eight stations exceeded the NJ Health Advisory Guidance Level. By August, all eight of these sampling stations exceeded the NJ Health Advisory standards.

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 copepod *Microcyclops* during the May event. Moderate densities of copepod nauplii and rotifers *Asplanchna* and *Keratella* were also observed at this time. A total of 11 genera were identified during this first event. By the June event, community richness increased to 13 genera, dominated by *Bosmina* and *Polyarthra.* The herbivorous cladoceran *Daphnia* was identified as present during both the May and June sampling events. Co-dominance was exerted by *Microcyclops* and the rotifer *Conochilus* during the July sampling event. Moderate densities of copepod nauplii and various cladocerans were also observed at this time. Peak species richness of 15 genera was noted during the August sampling, dominated by *Microcyclops*. Richness declined to 12 genera during the final event, where dominance of *Microcyclops* persisted. This sample contained high densities of rotifers with moderate amounts of the copepod nauplii.

Herbivorous zooplankton were present within Lake Hopatcong during the 2019 sampling period. Low densities of the large-bodied cladoceran *Daphnia* were noted early on in the season, while other smaller herbivores were noted in various densities. 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.

3.4 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 2019 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 11 m, only lapsing in the bottom few meters 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 6 m. Trout habitat drastically declined by the July sampling due to elevated temperatures. Neither optimal nor carry over habitat were present at Station #2 during this time. Optimal habitat was not reestablished during the August sampling event, with only carry over habitat observed from the surface waters to 6 m. While temperatures dropped to the optimal range past 6 m, the bottom waters yielded unsuitable habitat as DO declined sharply. Optimal trout habitat was reestablished at Station #2 by the final sampling event. Optimal habitat was once again present from the surface waters through 7 m, before oxygen declined causing unsuitable habitat.

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. These conditions persisted through the June sampling event. Optimal trout habitat was not present at any of the stations during the July sampling event. Unsuitable habitat was observed at Stations #1-6 and # 8 during this event due to elevated temperatures, while carry over habitat was noted in various degrees at the remaining stations. Optimal trout habitat was reestablished at Station #11 during the August sampling event. Stations #1 through #7 and #10 had carry over habitat throughout the entire water column during this event, while the remaining stations only exhibited unsuitable habitat above the sediment. By the final event, all stations contained optimal habitat.

3.5 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 2006 to 2008, approximately 6-8% of the total phosphorus load targeted for reduction under the established TMDL was removed through the mechanical weed harvesting program.

In sharp contrast to the 2006 – 2008 harvesting years, only 1.2% of the phosphorus load targeted for reduction under the TMDL was removed through mechanical weed harvesting during the 2009 growing season. This substantial reduction in the amount of plant biomass and phosphorus removed in 2009 was due to severe budgetary cuts that resulted in laying off the Commission's full time Operation Staff, as well as initiating the harvesting program later in the growing season. In turn, this resulted in only 1.2% of the phosphorus associated with plant biomass being harvested in 2009. However, the 2010 harvesting season resulted in the estimated removal of approximately 6% of the phosphorus load targeted for reduction under the TMDL, similar to the percentages removed in 2006 – 2008.

In contrast to the 2012 growing season, the mechanical weed harvesting program ran longer in 2013 through 2016. This was primarily due to the fact that the program was initiated earlier in these years relative to 2012. NJDEP has directly overseen the operation of the weed harvesting program for the last seven years and each year displays a higher rate of removal, which was attributed to hired staff becoming more familiar with the operations and lake-specific conditions. In addition, the operations staff has been excellent at maximizing high rates of efficiency during harvesting operations.

The mechanical weed harvesting program at Lake Hopatcong during the 2019 growing season ran from May through October. A total of 1,415 cubic yards of wet plant biomass was removed from Lake Hopatcong during the 2019 growing season. This was substantially lower and the 2017 (3,872 cubic yards) and 2018 (3,925 cubic yards) harvested amounts. A number of factors account for the lower amount of plant biomass harvested in 2019 relative to 2017 and 2018. First, the spring of 2019 was relatively wet. Second, the extended drawdown was conducted over the winter of 2018 – 2019. Third, the HABs over the 2019 growing season reduced the amount of light reaching the sediments, limiting plant growth. Thus, the substantially lower amount of plant biomass removed over the 2019 growing season is understandable.

During the 2019 mechanical weed harvesting program, a total of 1,415 cubic yards (637 tons) of plant material was removed from Lake Hopatcong, resulting in the removal of approximately 227 lbs of TP or 2.6% of the TP load targeted for removal under the TMDL. This is the third lowest amount of TP removed from the lake out of the 2002 – 2019 database. The 227 lbs of TP removed through the 2019 weed harvesting program had the potential to generate up to approximately 250,000 lbs of additional wet algal biomass. Using the entire 2002 – 2019 Lake Hopatcong weed harvesting database, the average amount of phosphorus removed through harvesting was estimated to be 428 lbs of TP per year or approximately 6% targeted for reduction under the TMDL.

3.6 Interannual Analysis of Water Quality Data

Annual mean values of Secchi depth, chlorophyll *a* and total phosphorus concentrations were calculated for the years 1991 through 2019. The annual mean values for Station #2 were graphed, along with the long-term, "running mean" for the lake. The 2019 mean Secchi depth was 1.5 meters, which markedly declined from the past few years. This growing season yielded historically minimum clarity. Secchi depth was below the long-term mean of 2.1 for the second year in a row (Figure 2 in Appendix A). This decline in clarity can be attributed to the lake-wide cyanobacteria bloom observed throughout the 2019 season.

The mean chlorophyll *a* concentration for the 2019 season was 14.1 µg/L and was below the long-term mean of 10.3 µg/L. Chlorophyll *a* concentrations increased from the previous years' concentration of 9.9 µg/L. The 2019 average exceeded the targeted average of 8 µg/L. The mean 2014 chlorophyll *a* concentration was the highest measured out of the entire 1991 – 2019 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. The hot and wet year recorded during 2019 stimulated a HAB observed throughout the season, causing the increased chlorophyll *a* concentrations.

The 2019 mean TP concentration was 0.02 mg/L (Figure 4 in Appendix A), increasing from the 2018 sampling period. While TP concentrations were elevated compared to previous sampling seasons, they remained below State Standards and TMDL thresholds. 2019 was a wet year which likely caused an influx of nutrients to the waterbody.

3.7 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 *an* ecological endpoint, was established to identify compliance with the TMDL. For the sake of this 2019 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 2019 seasonal mean (0.02 mg/L) and single TP concentrations at Station #2 were all consistently below the targeted mean TP concentration recognized under the TMDL (0.03 mg/L), with exception to measure observed during the June sampling (0.04 mg/L). The seasonal mean chlorophyll *a* concentration (14.10 µg/L) exceeded the targeted mean chlorophyll *a* concentration of 8 µg/L. The first three sampling events yielded chlorophyll *a* concentrations in Station #2 at or below the targeted maximum chlorophyll *a* concentration endpoint of 14 µg/L. Chlorophyll *a* increased during August and September to 17.0 µg/L and 19 µg/L, respectively.

Mean TP concentrations at Station #3, exceeded the targeted mean of 0.03 mg/L, with measures of 0.04 mg/L. This increased from the previous year, which yielded an average of 0.02 mg/L. This station had experienced a steady decline over the past few years prior to 2019. Each of the sampling events, with exception to August, exceeded the targeted mean, reaching a high of 0.06 mg/L. Similar to Station #2, the seasonal 2019 mean chlorophyll *a* concentration exceeded targeted mean with a measure of 21.72 µg/L. Chlorophyll *a* concentrations during May and June were below the targeted maximum chlorophyll *a* concentration ranging between 6.6 and 13.0 µg/L. The remainder of the growing season yielded elevated chlorophyll *a* reaching a seasonal maximum of 33.0 µg/L.

At Station #10, the mean TP concentration in 2019 was 0.04 mg/L, persisting over the past few sampling periods. Three of the sampling events were above this target, ranging between 0.04 or 0.07 mg/L. The mean concentration of chlorophyll *a* (24.40 µg/L) greatly exceeded the targeted mean concentration of 8 µg/L. Four of the five sampling events had a value greater than the targeted maximum chlorophyll *a* concentration endpoint of 14 µg/L, ranging between 23.0 and 35.0 µg/L. The May sampling yielded concentrations of 12 µg/L.

4.0 Summary

This section provides a summary of the 2019 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 by the June sampling event, which then persisted throughout the remainder of the growing season. The waters were well oxygenated 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 0.01 mg/L and 0.07 mg/L. Deep water concentrations were low during the first sampling event, before increasing as the season progressed to a maximum of 0.33 mg/L during the July event. Elevated TP in the deep waters is attributed 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 and September 2019 at Station # 2. Carry-over brown trout habitat was only present during the August sampling event at this station. Optimal habitat was noted 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 July and August samplings. Brown trout habitat was seen during all months in 2019 in some capacity.

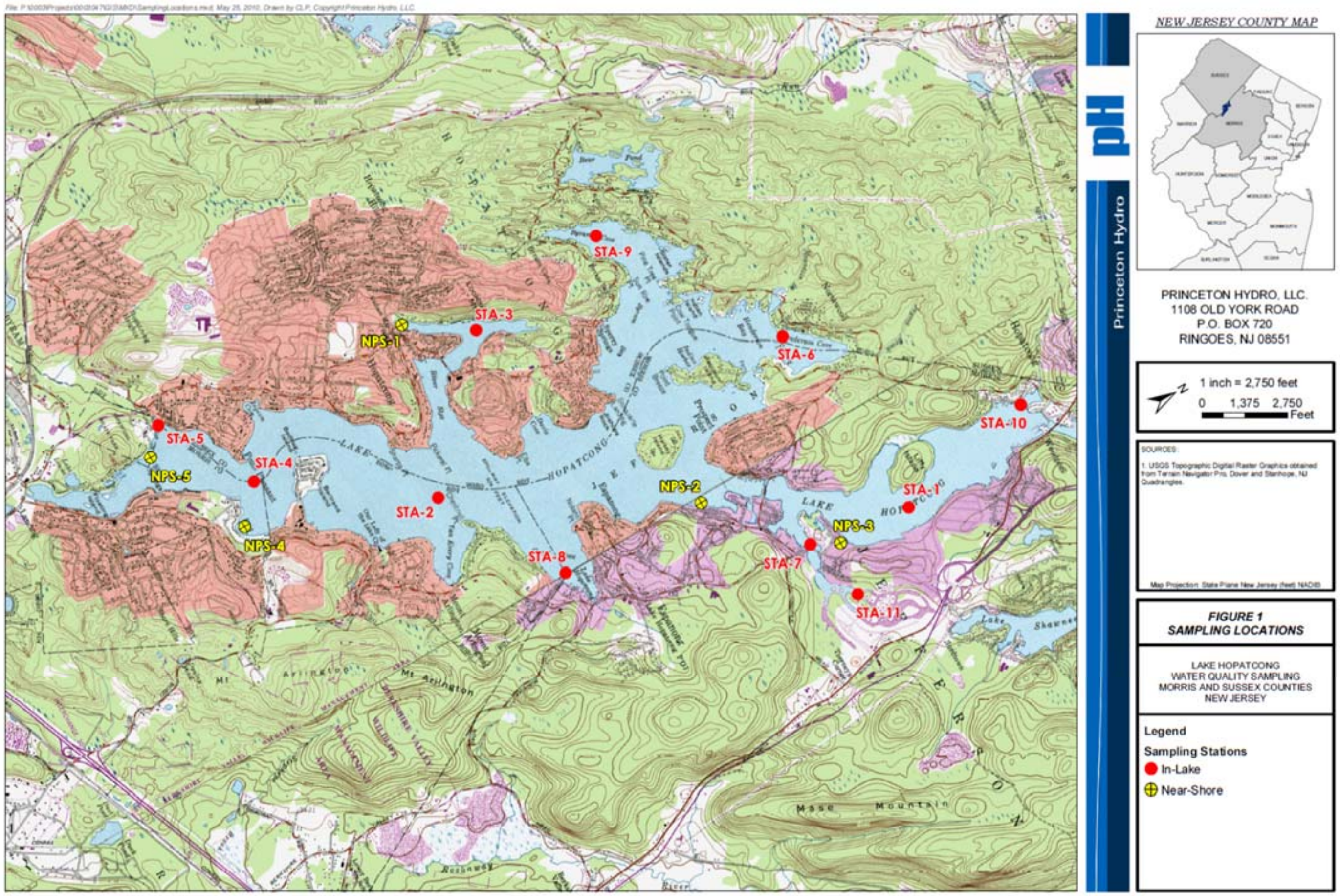
4. Due wet spring, 2018-2019 winter drawdown and the HABs impacting the lake over the entire summer season, the amount of aquatic plant biomass harvested in the lake over the 2019 growing season was low. In fact, it was the third lowest amount removed over the 2002 – 2019 database. During the 2019 harvesting program, approximately 1,415 cubic yards of wet plant biomass was removed. This resulted in removing 227 lbs of TP, accounting for 2.6% of the TP targeted for removal under the TMDL. Using the entire 2002 – 2019 database, the long-term, mean amount of TP removed through mechanical weed harvesting in Lake Hopatcong is 428 lbs per year or approximately 6% of the phosphorus targeted for reduction under the TMDL.

5. A lake-wide harmful algal bloom (HAB) was observed throughout the majority of the 2019 season, resulting in NJDEP posting Advisories and some of the local Health Departments closing some of the beaches during the height of the summer season. However, the 2019 long-term water quality data provided the information needed to identify the cause for the HABs (the high frequency of storms in June transporting nutrients, in particular phosphorus, to the lake) as well as why they persisted over the growing season (internal phosphorus loading). Finally, the long-term water quality database was also useful in identifying how consistent funding for the Lake Hopatcong Commission, in its efforts to manage submerged aquatic vegetation through weed harvesting and reducing the nutrient loads entering the lake, results in quantifiable improvements in water quality (i.e. increases in water clarity, reductions in available phosphorus and declines in algal biomass measured as chlorophyll-*a*).

6. While the existing long-term water quality database has value, the HABs experienced in 2019 have identified the need to slightly expand the monitoring program. Specifically, it is recommended that soluble reactive phosphorus (SRP) be added to the monitoring parameters, more detailed plankton monitoring be conducted (in particular with the cyanobacteria) and additional vertical sampling be integrated into the program as well.

APPENDIX A

FIGURES


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
NEW JERSEY COUNTY MAP
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

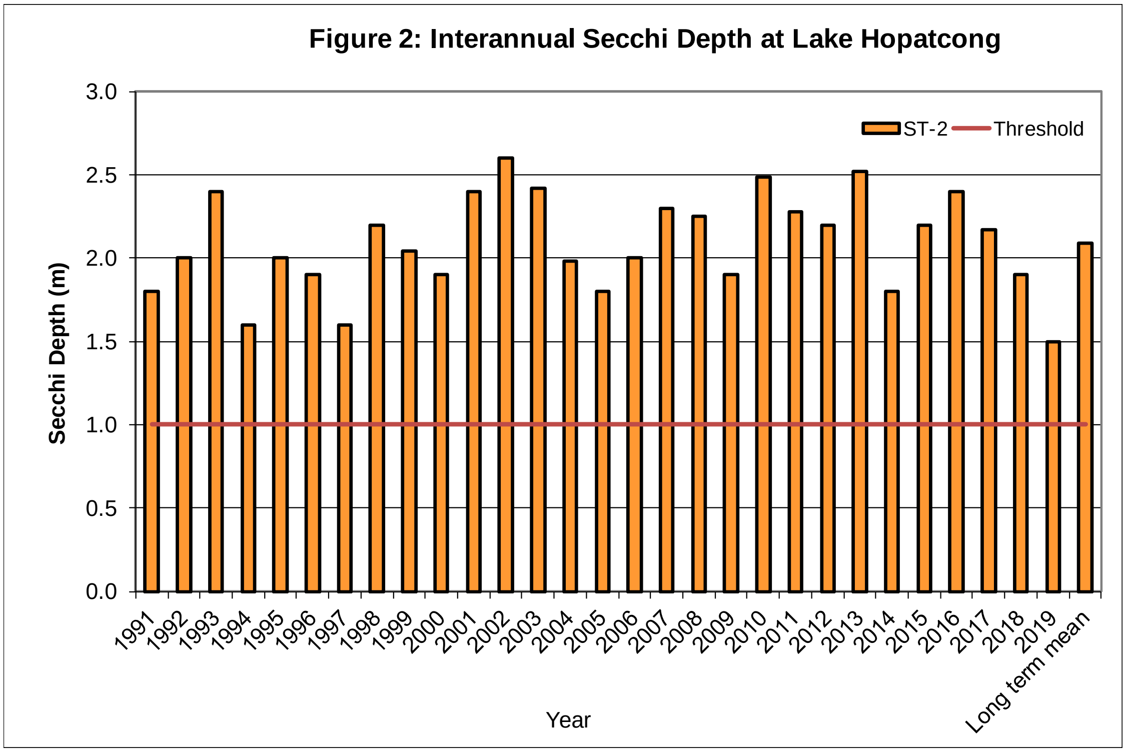


Figure 2: Interannual Secchi Depth at Lake Hopatcong
ST-2
Threshold
Secchi Depth (m)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 Long term mean
Year

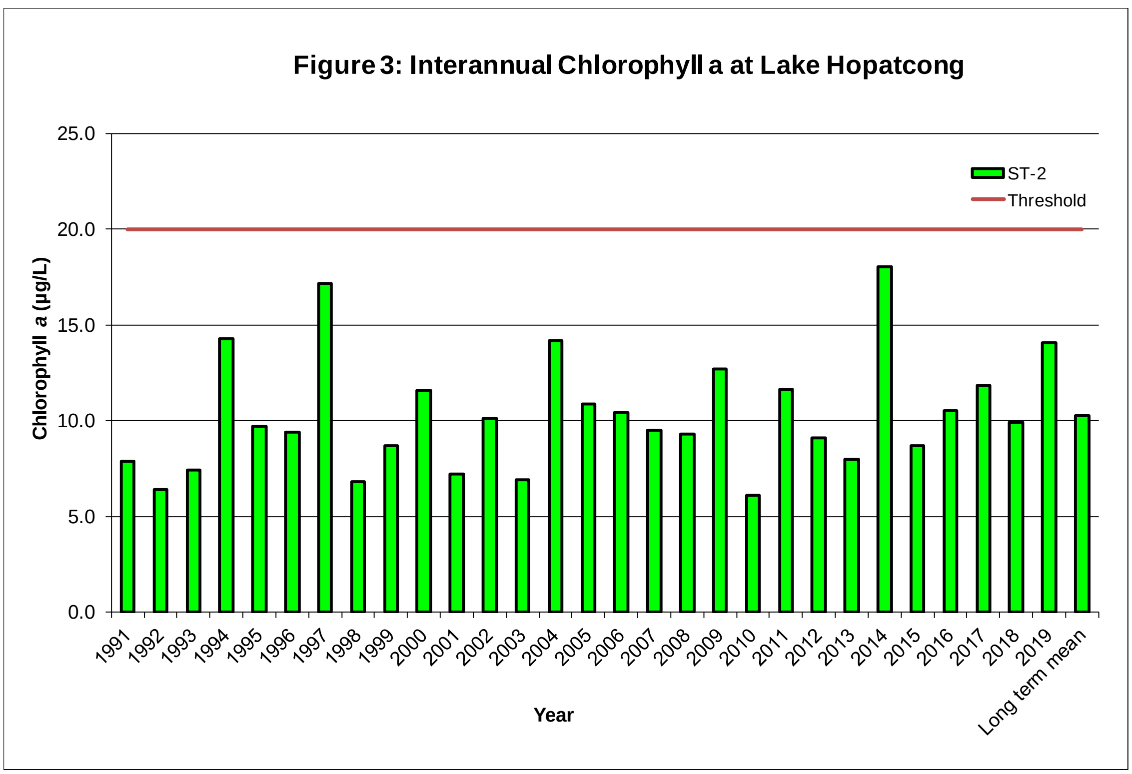


Figure 3: Interannual Chlorophyll a at Lake Hopatcong
ST-2
Threshold
Chlorophyll a (µg/L)
25.0
20.0
15.0
10.0
5.0
0.0
1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 Long term mean
Year

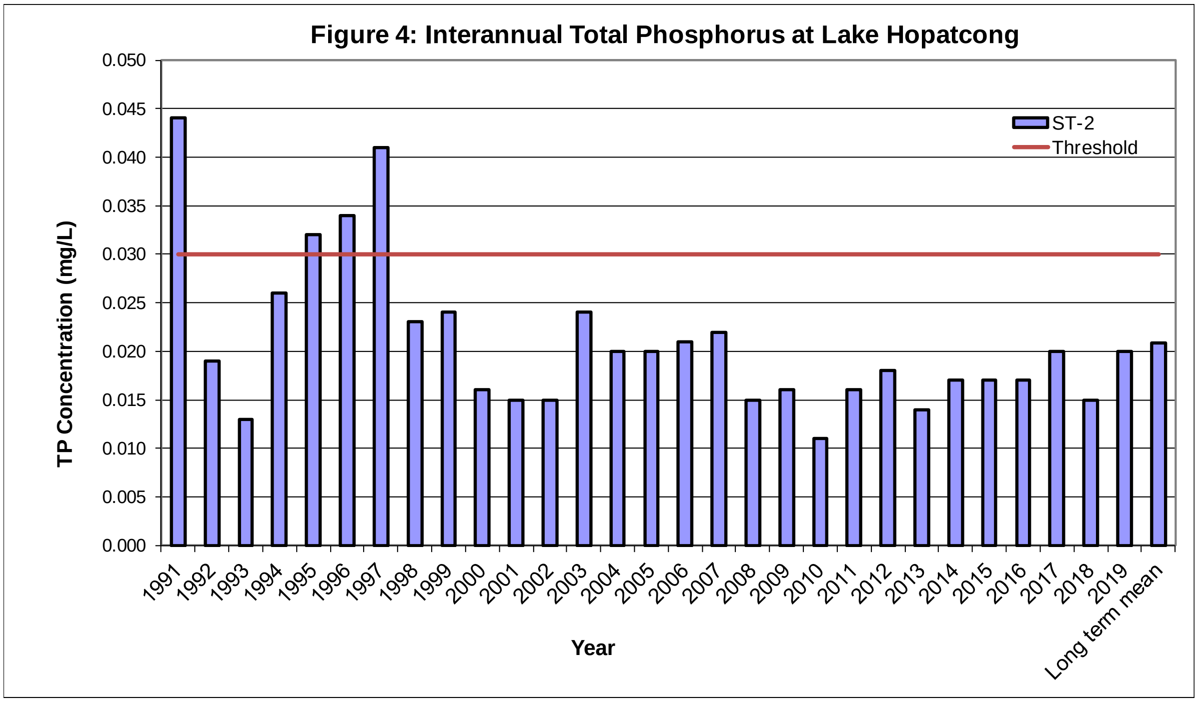


Figure 4: Interannual Total Phosphorus at Lake Hopatcong
TP Concentration (mg/L)
0.050
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
ST-2
Threshold
1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 Long term mean
Year

APPENDIX B

IN-SITU DATA

In-Situ Monitoring for Lake Hopatcong 5/15/2019								
Station	DEPTH (meters)			Temperature	Specific Conductance	Dissolved Oxygen		pH
	Total	Secchi	Sample	°C	mS/cm	mg/L	% Sat.	S.U.
STA-1	2.00	1.00	0.1	14.09	0.335	8.62	85.9	7.36
			1.0	14.01	0.335	8.54	85.0	7.35
			1.7	13.68	0.334	8.51	84.0	7.32
STA-2	14.20	1.60	0.1	13.60	0.430	9.22	90.9	7.60
			1.0	13.58	0.430	9.05	89.2	7.55
			2.0	13.54	0.429	8.97	88.4	7.49
			3.0	13.50	0.429	8.97	88.2	7.46
			4.0	13.43	0.429	8.97	88.2	7.45
			5.0	13.37	0.429	8.94	87.7	7.44
			6.0	13.35	0.429	8.86	86.9	7.42
			7.0	13.35	0.429	8.83	86.6	7.42
			8.0	13.35	0.429	8.79	86.2	7.41
			9.0	13.30	0.428	8.76	85.9	7.41
			10.0	12.76	0.432	7.99	77.4	7.31
			11.0	12.27	0.433	5.76	55.1	7.14
			12.0	12.01	0.434	5.22	49.7	7.08
			13.0	11.58	0.438	3.53	33.3	7.00
			14.0	10.93	0.504	1.51	14.0	6.88
STA-3	2.20	1.30	0.1	13.25	0.790	10.29	100.8	7.77
			1.0	12.99	0.808	10.35	100.8	7.81
			1.7	12.88	0.820	10.09	98.1	7.73
STA-4	3.10	1.50	0.1	12.91	0.429	9.90	96.2	7.66
			1.0	12.87	0.429	9.85	95.5	7.67
			2.0	12.67	0.429	9.63	93.0	7.63
			3.0	12.67	0.429	9.32	90.0	7.57
STA-5	1.20	1.20	0.1	12.90	0.434	9.37	91.0	7.29
			1.0	12.85	0.435	9.24	89.7	7.38
STA-6	3.20	1.50	0.1	14.25	0.418	9.04	90.5	7.55
			1.0	14.03	0.419	9.06	90.2	7.53
			2.0	13.46	0.419	9.20	90.4	7.55
			3.0	12.81	0.402	8.61	83.4	7.44
STA-7	1.90	1.20	0.1	12.32	0.141	8.88	85.0	7.61
			1.0	11.91	0.158	8.81	83.6	7.37
STA-8	5.80	1.60	0.1	13.64	0.425	9.82	97.0	7.76
			1.0	13.61	0.425	9.63	95.0	7.70
			2.0	13.48	0.426	9.64	94.9	7.67
			3.0	13.45	0.426	9.63	94.6	7.66
			4.0	13.43	0.427	9.65	94.8	7.65
			5.0	13.27	0.427	9.75	95.5	7.65
STA-9	7.90	1.60	0.1	14.64	0.430	9.00	90.8	7.54
			1.0	14.29	0.431	8.97	89.8	7.50
			2.0	13.38	0.432	8.78	86.2	7.43
			3.0	13.16	0.423	8.15	79.6	7.34
			4.0	13.04	0.428	7.04	68.6	7.23
			5.0	12.96	0.424	6.83	66.4	7.19
			6.0	12.40	0.434	5.44	52.3	7.10
			7.0	12.01	0.436	3.91	37.2	7.00
STA-10	1.50	0.90	0.1	14.75	0.347	8.28	83.7	7.32
			1.0	13.65	0.347	7.58	74.9	7.25
STA-11	1.20	1.20	0.1	13.36	0.115	9.23	90.5	7.34
			1.0	11.58	0.114	9.49	89.4	7.28

In-Situ Monitoring for Lake Hopatcong 06/14/2019								
Station	DEPTH (meters)			Temperature	Specific Conductance	Dissolved Oxygen		pH
	Total	Secchi	Sample	°C	mS/cm	mg/L	% Sat.	S.U.
STA-1	2.10	1.00	0.10	20.71	0.323	9.11	105.0	7.74
			1.00	20.70	0.323	9.09	104.6	7.80
			2.00	20.27	0.323	9.14	104.3	7.87
STA-2	14.50	1.80	0.1	20.15	0.418	8.34	95.0	7.50
			1.0	20.16	0.417	8.29	94.5	7.51
			2.0	20.16	0.417	8.26	94.2	7.50
			3.0	20.14	0.417	8.20	93.4	7.51
			4.0	20.15	0.417	8.16	93.0	7.51
			5.0	20.14	0.417	8.17	93.1	7.51
			6.0	20.11	0.417	8.13	92.6	7.50
			7.0	18.71	0.421	3.51	38.8	7.01
			8.0	14.78	0.424	0.62	6.3	6.87
			9.0	14.39	0.425	0.22	2.2	6.82
			10.0	14.06	0.426	0.12	1.3	6.80
			11.0	13.44	0.428	0.10	1.0	6.78
			12.0	13.07	0.431	0.09	0.9	6.76
			13.0	12.47	0.437	0.09	0.9	6.75
			14.0	12.42	0.438	0.09	0.9	6.76
STA-3	2.20	2.00	0.1	20.88	0.852	8.89	102.9	8.51
			1.0	20.74	0.824	8.77	101.2	8.50
			2.0	20.52	0.809	8.57	98.5	8.43
STA-4	3.10	1.70	0.1	20.25	0.426	7.70	88.0	7.41
			1.0	20.26	0.426	7.62	87.1	7.40
			2.0	20.24	0.426	7.62	87.0	7.41
			3.0	20.23	0.426	7.60	86.7	7.40
STA-5	2.30	1.90	0.1	20.79	0.436	7.88	90.9	7.55
			1.0	20.77	0.436	7.76	89.6	7.51
			2.0	20.67	0.438	7.75	89.2	7.50
STA-6	3.00	1.80	0.1	20.55	0.410	8.83	101.4	7.70
			1.0	20.54	0.410	8.75	100.5	7.67
			2.0	20.51	0.410	8.70	99.9	7.62
			3.0	20.39	0.409	8.57	98.1	7.58
STA-7	1.80	1.40	0.1	19.85	0.230	8.00	90.5	7.35
			1.0	19.84	0.231	7.75	87.7	7.26
STA-8	3.40	1.90	0.1	20.06	0.415	8.40	95.5	7.60
			1.0	20.06	0.415	8.41	95.7	7.62
			2.0	20.04	0.415	8.43	95.8	7.61
			3.0	19.74	0.420	8.47	95.8	7.60
STA-9	8.00	2.00	0.1	20.68	0.416	8.43	97.1	7.56
			1.0	20.66	0.416	8.42	97.0	7.55
			2.0	20.64	0.416	8.40	96.6	7.52
			3.0	20.63	0.416	8.38	96.5	7.54
			4.0	20.36	0.421	7.93	90.7	7.43
			5.0	18.96	0.417	5.49	61.1	7.16
			6.0	18.44	0.418	3.81	42.0	7.03
			7.0	16.63	0.423	1.80	19.1	6.91
STA-10	1.30	0.70	0.1	20.96	0.330	9.03	104.5	7.78
			1.0	20.92	0.330	8.96	103.7	7.72
STA-11	1.30	1.30	0.1	19.41	0.168	7.87	88.3	7.16
			1.0	19.28	0.167	7.31	81.8	7.03

In-Situ Monitoring for Lake Hopatcong 7/10/2019								
Station	DEPTH (meters)			Temperature	Specific Conductance	Dissolved Oxygen		pH
	Total	Secchi	Sample	°C	mS/cm	mg/L	% Sat.	S.U.
STA-1	**2.00**	**1.00**	**0.1**	27.64	0.333	8.02	101.7	7.37
			1.0	27.11	0.333	8.08	101.5	7.43
			2.0	27.04	0.333	7.54	94.5	7.37
STA-2	**14.10**	**1.80**	**0.1**	26.98	0.421	9.32	116.8	8.54
			1.0	26.84	0.421	9.50	118.7	8.59
			2.0	26.69	0.422	9.55	119.0	8.62
			3.0	26.63	0.423	9.55	118.9	8.61
			4.0	23.98	0.419	4.33	51.3	7.18
			5.0	21.77	0.417	2.77	31.5	6.96
			6.0	20.61	0.417	1.98	22.0	6.87
			7.0	19.31	0.419	0.37	4.0	6.75
			8.0	17.63	0.422	0.18	1.9	6.73
			9.0	16.32	0.426	0.13	1.3	6.71
			10.0	14.87	0.432	0.10	0.9	6.70
			11.0	13.93	0.433	0.09	0.9	6.74
			12.0	13.25	0.441	0.09	0.9	6.77
			13.0	12.69	0.447	0.09	0.9	6.84
			14.0	12.39	0.461	0.09	0.9	6.81
STA-3	**1.70**	**0.90**	**0.1**	27.04	0.608	8.96	112.5	8.05
			1.0	26.54	0.624	9.02	112.1	7.93
STA-4	**2.80**	**1.50**	**0.1**	27.04	0.434	8.31	104.2	7.86
			1.0	26.97	0.432	8.36	104.7	7.90
			2.0	26.74	0.431	8.26	103.0	7.80
STA-5	**1.30**	**1.30**	**0.1**	26.65	0.440	8.13	101.3	7.69
			1.0	26.48	0.440	7.85	97.4	7.59
STA-6	**3.30**	**1.60**	**0.1**	27.52	0.421	9.36	118.4	8.40
			1.0	27.31	0.420	9.42	118.8	8.42
			2.0	26.76	0.418	9.42	117.5	8.36
			3.0	26.45	0.418	8.75	108.6	7.99
STA-7	**1.40**	**1.10**	**0.1**	26.96	0.274	7.85	98.3	7.34
			1.0	25.95	0.262	7.27	89.3	7.15
STA-8	**4.90**	**1.80**	**0.1**	27.14	0.421	9.24	116.1	8.50
			1.0	26.83	0.420	9.37	117.0	8.56
			2.0	26.72	0.420	9.45	117.8	8.53
			3.0	26.53	0.421	9.28	115.3	8.44
			4.0	24.97	0.427	4.85	58.6	7.30
STA-9	**7.80**	**1.70**	**0.1**	27.42	0.425	9.78	123.5	8.62
			1.0	26.67	0.428	9.93	123.6	8.59
			2.0	26.40	0.422	9.91	122.8	8.71
			3.0	26.19	0.425	9.91	122.4	8.56
			4.0	24.50	0.421	5.22	62.5	7.33
			5.0	22.13	0.420	2.64	30.2	6.98
			6.0	20.20	0.420	0.67	7.4	6.82
			7.0	18.98	0.422	0.35	3.8	6.77
STA-10	**1.20**	**0.80**	**0.1**	27.50	0.334	8.68	109.7	7.64
			1.0	26.00	0.351	8.91	109.7	7.74
STA-11	**1.00**	**1.00**	**0.1**	25.64	0.190	7.46	91.1	7.07
			0.7	25.16	0.193	6.30	76.4	6.83

In-Situ Monitoring for Lake Hopatcong 8/14/2019								
Station	DEPTH (meters)			Temperature	Specific Conductance	Dissolved Oxygen		pH
	Total	Secchi	Sample	°C	mS/cm	mg/L	% Sat.	S.U.
STA-1	1.70	0.70	0.1	25.49	0.319	8.13	100.7	7.73
			1.0	25.46	0.319	8.06	99.8	7.74
STA-2	13.70	1.30	0.1	25.48	0.413	7.94	98.4	7.91
			1.0	25.47	0.412	7.94	98.3	7.92
			2.0	25.49	0.412	7.96	98.6	7.90
			3.0	25.48	0.412	7.96	98.6	7.91
			4.0	25.48	0.412	7.92	98.1	7.99
			5.0	25.43	0.413	6.77	83.9	7.83
			6.0	23.95	0.412	0.36	4.4	7.39
			7.0	20.43	0.424	0.73	8.3	7.14
			8.0	17.64	0.426	0.46	4.9	7.09
			9.0	16.27	0.429	0.85	8.8	7.09
			10.0	15.40	0.434	0.78	7.9	7.07
			11.0	14.75	0.436	0.46	4.6	7.06
			12.0	13.70	0.442	0.85	8.3	7.03
			13.0	12.96	0.451	0.31	3.0	6.94
STA-3	1.90	1.00	0.1	25.36	0.533	8.68	107.5	7.74
			1.0	25.33	0.531	8.67	107.2	7.93
STA-4	2.90	0.90	0.1	25.32	0.421	7.44	91.9	7.71
			1.0	25.36	0.420	7.38	91.2	7.68
			2.0	25.38	0.421	7.31	90.4	7.61
STA-5	1.70	1.00	0.1	25.45	0.425	7.67	95.0	7.79
			1.0	25.44	0.425	7.63	94.5	7.76
STA-6	2.90	1.30	0.1	25.89	0.403	8.34	104.1	8.13
			1.0	25.89	0.403	8.50	106.1	8.12
			2.0	25.77	0.403	8.03	100.1	7.93
STA-7	1.90	1.70	0.1	24.50	0.278	7.78	94.7	7.58
			1.0	24.17	0.255	7.46	90.2	7.52
STA-8	6.40	1.30	0.1	25.69	0.411	8.22	102.3	7.99
			1.0	25.72	0.411	8.24	102.5	8.12
			2.0	25.69	0.410	8.17	101.6	8.11
			3.0	25.66	0.410	7.24	90.0	7.87
			4.0	25.58	0.412	6.62	82.1	7.73
			5.0	24.73	0.409	3.48	42.5	7.46
			6.0	23.31	0.412	0.26	3.1	7.27
STA-9	7.70	1.30	0.1	25.84	0.410	8.64	107.8	8.28
			1.0	25.85	0.409	8.76	109.3	8.31
			2.0	25.74	0.409	8.61	107.2	8.21
			3.0	25.72	0.410	8.43	104.9	8.14
			4.0	25.71	0.410	8.33	103.4	8.15
			5.0	25.67	0.410	8.17	101.5	8.20
			6.0	25.19	0.415	6.05	74.7	7.80
			7.0	18.85	0.432	0.69	7.5	7.16
STA-10	1.00	0.70	0.1	25.48	0.339	9.80	121.4	8.54
			0.7	25.44	0.339	9.71	120.1	8.51
STA-11	1.10	1.10	0.1	23.91	0.196	6.39	76.9	7.32
			0.9	23.77	0.186	6.15	73.7	7.23

In-Situ Monitoring for Lake Hopatcong 9/5/2019								
Station	DEPTH (meters)			Temperature	Specific Conductance	Dissolved Oxygen		pH
	Total	Secchi	Sample	°C	mS/cm	mg/L	% Sat.	S.U.
STA-1	1.90	0.90	0.1	22.92	0.328	9.31	108.5	7.74
			1.0	22.81	0.327	9.37	109.0	7.92
STA-2	13.80	1.40	0.1	23.08	0.412	8.55	100.0	7.63
			1.0	23.08	0.412	8.29	97.0	7.60
			2.0	23.09	0.412	8.16	95.4	7.58
			3.0	23.08	0.412	8.12	95.0	7.56
			4.0	23.09	0.412	8.09	94.7	7.54
			5.0	23.07	0.412	8.08	94.5	7.53
			6.0	23.07	0.412	8.05	94.1	7.52
			7.0	23.02	0.412	7.96	93.1	7.49
			8.0	18.60	0.445	0.59	6.3	6.99
			9.0	16.55	0.434	0.33	3.4	6.92
			10.0	14.91	0.437	0.20	2.0	6.90
			11.0	14.28	0.439	0.16	1.6	6.89
			12.0	13.45	0.445	0.13	1.3	6.88
			13.0	12.94	0.425	0.12	1.1	6.85
STA-3	2.20	1.00	0.1	23.04	0.485	8.32	97.2	7.37
			1.0	23.01	0.483	8.13	95.0	7.40
			2.0	22.98	0.479	7.00	81.7	7.38
STA-4	2.90	1.00	0.1	22.94	0.421	8.67	101.2	7.65
			1.0	22.94	0.420	8.34	97.3	7.63
			2.0	22.94	0.420	8.23	96.1	7.61
STA-5	1.20	1.00	0.1	22.68	0.424	8.71	101.2	7.67
			1.0	22.72	0.424	8.48	98.5	7.66
STA-6	3.30	1.30	0.1	23.47	0.410	8.89	104.8	8.04
			1.0	23.49	0.409	8.85	104.3	7.87
			2.0	23.15	0.409	8.49	99.5	7.73
			3.0	23.09	0.408	7.30	85.5	7.50
STA-7	1.30	1.30	0.1	23.04	0.341	8.37	97.7	7.30
			1.0	22.96	0.343	8.06	94.0	7.31
STA-8	5.90	1.40	0.1	23.29	0.412	8.76	102.9	7.53
			1.0	23.31	0.412	8.42	99.0	7.58
			2.0	23.28	0.411	8.41	98.7	7.56
			3.0	23.26	0.411	8.26	97.0	7.54
			4.0	22.99	0.410	7.39	86.3	7.39
			5.0	22.72	0.411	5.93	68.9	7.23
STA-9	7.90	1.50	0.1	23.49	0.409	8.76	103.3	7.68
			1.0	23.28	0.409	8.59	100.9	7.63
			2.0	23.19	0.409	8.55	100.3	7.63
			3.0	23.16	0.409	8.50	99.6	7.62
			4.0	23.14	0.409	8.43	98.7	7.59
			5.0	23.12	0.409	8.41	98.4	7.59
			6.0	23.10	0.409	8.27	96.8	7.56
			7.0	23.04	0.409	8.27	96.7	7.57
STA-10	1.20	0.70	0.1	23.15	0.341	9.66	113.1	8.48
			1.0	22.80	0.356	10.55	122.8	8.69
STA-11	1.10	1.10	0.1	22.10	0.271	6.88	79.0	7.22
			1.0	22.01	0.270	6.15	70.4	7.11

APPENDIX C

DISCRETE DATA

Discrete Data 5/15/2019					
STATION	Chlorophyll a (ug/L)	NH3-N (mg/L)	NO3-N (mg/L)	TP (mg/L)	TSS (mg/L)
ST-1	11.0	0.02	0.16	0.05	2
ST-2	11.0	ND<0.01	0.15	0.01	ND<2
ST-3	13.0	ND<0.01	0.58	0.06	ND<2
ST-4	11.0	0.01	0.10	0.04	ND<2
ST-5	11.0	0.01	0.32	0.04	2
ST-6	13.0	0.01	0.10	0.02	ND<2
ST-7	4.5	0.01	0.34	0.03	ND<2
ST-10	12.0	0.02	0.33	0.04	6
ST-11	2.6	ND<0.01	0.15	0.02	ND<2
ST-2 DEEP		0.02	0.05	0.01	2
MEAN	**9.9**	**0.01**	**0.23**	**0.032**	**3.0**

Discrete Data 6/14/19					
STATION	Chlorophyll a (ug/L)	NH3-N (mg/L)	NO3-N (mg/L)	TP (mg/L)	TSS (mg/L)
ST-1	31.0	0.01	0.11	0.05	5
ST-2	9.5	0.02	0.12	0.04	5
ST-3	6.6	0.02	0.30	0.04	2
ST-4	7.9	0.03	0.19	0.03	2
ST-5	0.5	0.02	0.11	0.04	5
ST-6	10.0	0.02	0.14	0.03	4
ST-7	5.7	0.02	0.07	0.05	4
ST-10	23.0	0.02	0.20	0.07	7
ST-11	4.1	0.02	0.28	0.04	3
ST-2 DEEP		0.19	0.20	0.04	9
MEAN	**10.9**	**0.04**	**0.17**	**0.043**	**4.6**

Discrete Data 7/10/19					
STATION	Chlorophyll a (ug/L)	NH3-N (mg/L)	NO3-N (mg/L)	TP (mg/L)	TSS (mg/L)
ST-1	24.0	0.02	0.06	0.03	5
ST-2	14.0	0.01	0.06	0.02	3
ST-3	29.0	0.01	0.05	0.05	4
ST-4	15.0	0.01	0.10	0.03	3
ST-5	16.0	0.01	0.10	0.03	2
ST-6	10.0	0.01	0.04	0.02	3
ST-7	15.0	0.01	0.09	0.04	4
ST-10	26.0	ND<0.01	0.12	0.03	7
ST-11	8.0	ND<0.01	0.12	0.02	4
ST-2 DEEP		0.15	0.09	0.18	5
MEAN	**17.4**	**0.03**	**0.08**	**0.045**	**4.0**

Discrete Data 8/14/19					
STATION	Chlorophyll a (ug/L)	NH3-N (mg/L)	NO3-N (mg/L)	TP (mg/L)	TSS (mg/L)
ST-1	34.0	0.02	0.06	0.02	11
ST-2	17.0	0.02	0.03	0.01	3
ST-3	33.0	0.02	0.03	0.02	6
ST-4	25.0	0.02	0.03	0.04	6
ST-5	26.0	0.01	0.06	0.02	5
ST-6	16.0	0.02	0.14	0.01	2
ST-7	7.6	0.01	0.19	0.01	2
ST-10	26.0	0.02	0.17	0.01	8
ST-11	4.5	0.01	0.18	0.01	2
ST-2 DEEP		0.28	0.20	0.33	3
MEAN	**21.0**	**0.04**	**0.11**	**0.048**	**4.8**

Discrete Data 9/5/19					
STATION	**Chlorophyll a (ug/L)**	**NH3-N (mg/L)**	**NO3-N (mg/L)**	**TP (mg/L)**	**TSS (mg/L)**
ST-1	38.0	0.01	0.04	0.04	12
ST-2	19.0	0.01	ND <0.01	0.02	5
ST-3	27.0	0.01	ND <0.01	0.04	10
ST-4	27.0	0.01	ND <0.01	0.03	8
ST-5	24.0	0.01	0.02	0.03	7
ST-6	22.0	0.01	ND <0.01	0.03	4
ST-7	12.0	ND <0.01	0.02	0.03	4
ST-10	35.0	ND <0.01	0.02	0.05	9
ST-11	8.2	ND <0.01	0.07	0.03	2
ST-2 DEEP		0.24	0.14	0.31	3
MEAN	**23.6**	**0.04**	**0.05**	**0.061**	**6.4**

APPENDIX D

PLANKTON DATA

Phytoplankton and Zooplankton Community Composition Analysis								
Sampling Location: Lake Hopatcong			**Sampling Date: 5/15/19**			**Examination Date: 5/15/19**		
Site 1: ST2								
Phytoplankton								
Bacillariphyta (Diatoms)	**1**		**Chlorophyta (Green Algae)**	**1**		**Cyanophyta (Blue-Green Algae)**	**1**	
Asterionella	P		*Chlorella*	P		*Coelosphaerium*	C	
Fragilaria	C		*Golenkinia*	P		*Aphanizomenon*	A	
Melosira	P		*Pediastrum*	P		*Lyngbya*	R	
Tabellaria	P		*Scenedesmus*	R		*Microcystis*	R	
Stephanodiscus	R		*Micrasterias*	R		**Cryptomonads**		
Chrysophyta (Golden Algae)						*Cryptomonas*	P	
Dinobryon	P							
Synura	P							
Mallomonas	R							
Zooplankton								
Cladocera (Water Fleas)	**1**		**Copecoda (Copepods)**	**1**		**Rotifera (Rotifers)**	**1**	
Chydorus	P		*Microcyclops*	A		*Conochilus*	P	
Bosmina	A		nauplii	C		*Polyarthra*	R	
Daphnia	R		*Diaptomus*	R		*Asplanchna*	C	
						Kellicottia	R	
						Keratella	C	
Sites:	**1**		**Comments:**					
Total Phytoplankton Genera	18							
Total Cyanobacteria Genera	4							
Total Zooplankton Genera	11							
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: Hopatcong			**Sampling Date: 6/14/2019**			**Examination Date: 6/14/2019**		
Site 1: ST2								
Phytoplankton								
Bacillariphyta (Diatoms)	**1**		**Chlorophyta (Green Algae)**	**1**		**Cyanophyta (Blue-Green Algae)**	**1**	
Asterionella	P		*Sphaerocystis*	R		*Coelosphaerium*	C	
Fragilaria	C		*Eudorina*	R		*Microcystis*	R	
Melosira	C		*Pediastrum*	P		*Dolichospermum (Anabaena)*	A	
Tabellaria	P		*Chlorella*	R		*Lyngbya*	P	
			Staurastrum	P		*Aphanizomenon*	A	
						Chrysophyta (Golden Algae)		
						Synura	R	
						Dinobryon	A	
Zooplankton								
Cladocera (Water Fleas)	**1**		**Copecoda (Copepods)**	**1**		**Rotifera (Rotifers)**	**1**	
Bosmina	A		*Microcyclops*	C		*Keratella*	R	
Ceriodaphnia	P		*Nauplii*	P		*Asplanchna*	P	
Daphnia	R		Diaptomus	C		*Kellicottia*	R	
Diaphanosoma	R					*Conochilus*	R	
						Tricocerca	P	
						Polyarthra	A	
Sites:	**1**		**Comments: High density sample for both zooplankton and phytoplankton**					
Total Phytoplankton Genera	16							
Total Cyanobacteria Genera	5							
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 (R);					

Phytoplankton and Zooplankton Community Composition Analysis								
Sampling Location: Hopatcong			**Sampling Date: 7/10/2019**			**Examination Date: 7/15/2019**		
Site 1: ST2								
Phytoplankton								
Bacillariphyta (Diatoms)	**1**		**Chlorophyta (Green Algae)**	**1**		**Cyanophyta (Blue-Green Algae)**	**1**	
Fragilaria	R		*Desmidium*	R		*Coelosphaerium*	A	
Melosira	P		*Closterium*	R		*Microcystis*	C	
Tabellaria	R		*Pediastrum*	C		*Dolichospermum (Anabaena)*	C	
			Eudorina	R		*Lyngbya*	A	
Cryptomonads			*Staurastrum*	R				
Cryptomonas	P		*Coelastrum*	P		**Pyrrhophyta (Dinoflagellates)**		
			Cosmarium	R		*Ceratium*	C	
Zooplankton								
Cladocera (Water Fleas)	**1**		**Copecoda (Copepods)**	**1**		**Rotifera (Rotifers)**	**1**	
Bosmina	C		*Microcyclops*	A		*Keratella*	P	
Ceriodaphnia	C		*Nauplii*	C		*Asplanchna*	R	
Chydorus	P		Diaptomus	R		*Kellicottia*	P	
						Conochilus	A	
						Tricocerca	P	
						Brachionus	R	
						Filinia	R	
						Polyarthra	R	
Sites:	**1**		**Comments: High density sample for both zooplankton and phytoplankton**					
Total Phytoplankton Genera	16							
Total Cyanobacteria Genera	4							
Total Zooplankton Genera	14							
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: Hopatcong			**Sampling Date: 8/14/2019**			**Examination Date: 8/15/2019**		
Site 1: ST2 Tow			**Site 2: ST2 Surface Grab**					
Phytoplankton								
Bacillariophyta (Diatoms)	**1**	**2**	**Chlorophyta (Green Algae)**	**1**	**2**	**Cyanophyta (Blue-Green Algae)**	**1**	**2**
Fragilaria	R		*Coelastrum*	P		*Aphanizomenon*	C	11690
Melosira	A	205	*Cosmarium*	R	205	*Microcystis*	C	1231
Tabellaria	A	1367	*Pediastrum*	C		*Dolichospermum (Anabaena)*	P	479
Synedra	C	2256	*Ankistrodesmus*	R		*Chroococcus*	P	
Cyclotella	P		*Eudorina*	P		*Lyngbya*	A	
Cryptomonads			*Staurastrum*	P	68	*Pseudanabaena*	P	3418
Cryptomonas	P	205	Gloeotila	P	547	*Coelosphaerium*	C	
			Scenedesmus	P	273	**Pyrrhophyta (Dinoflagellates)**		
			Oocystis	R		*Ceratium*	P	
			Haematococcus	R				
			Chlorella	P	342			
			Terastrum		205			

Zooplankton								
Cladocera (Water Fleas)	**1**		**Copecoda (Copepods)**	**1**		**Rotifera (Rotifers)**	**1**	
Bosmina	C		*Microcyclops*	A		*Keratella*	C	
Ceriodaphnia	P		*Nauplii*	C		*Asplanchna*	R	
Chydorus	P		Diaptomus	R		*Kellicottia*	P	
Diaphanosoma	R					*Conochilus*	P	
						Tricocerca	P	
						Brachionus	P	
						Filinia	R	
						Polyarthra	P	

Sites:	**1**		**Comments: High density sample for both zooplankton and phytoplankton**
Total Phytoplankton Genera/Counts	25	22491	
Total Cyanobacteria Genera/Counts	7	16818	
Total Zooplankton Genera	15		
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: Hopatcong			**Sampling Date: 9/5/2019**			**Examination Date: 9/5/2019**		
Site 1: ST2								
Phytoplankton								
Bacillariophyta (Diatoms)	**1**		**Chlorophyta (Green Algae)**	**1**		**Cyanophyta (Blue-Green Algae)**	**1**	
Fragilaria	R		*Coelastrum*	R		*Aphanizomenon*	C	
Melosira	R		*Chlorella*	P		*Microcystis*	P	
Tabellaria	A		*Pediastrum*	P		*Dolichospermum (Anabaena)*	A	
Synedra	P		*Ankistrodesmus*			*Aphanocapsa*	R	
Cyclotella			*Eudorina*	P		*Lyngbya*	P	
Cryptomonads			*Staurastrum*	P		*Coelosphaerium*	C	
Cryptomonas	P		*Oocystis*	P		*Merismopedia*	R	
						Pyrrhophyta (Dinoflagellates)		
Euglenophyta (euglenoids)						*Ceratium*	C	
Trachelomonas	R					*Gymnodinium*	R	
Zooplankton								
Cladocera (Water Fleas)	**1**		**Copecoda (Copepods)**	**1**		**Rotifera (Rotifers)**	**1**	
Bosmina	P		*Microcyclops*	A		*Keratella*	C	
Ceriodaphnia	R		*Nauplii*	C		*Asplanchna*	C	
						Kellicottia	P	
						Conochilus	C	
						Tricocerca	C	
						Brachionus	P	
						Gastropus	R	
						Polyarthra	C	
Sites:	**1**		**Comments: High density sample for both zooplankton and phytoplankton**					
Total Phytoplankton Genera	21							
Total Cyanobacteria Genera	7							
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);					