PRINCETON HYDRO

SCIENCE ENGINEERING DESIGN

Lake Hopatcong
Water Quality Report 2020
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

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1.0 Introduction

Princeton Hydro, LLC conducted general water quality monitoring of Lake Hopatcong during the 2020 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 annual water quality monitoring program was funded by the Lake Hopatcong Commission from 2018 through 2020. Additionally, the 2020 water quality monitoring program was used as a match toward the Harmful Algal Bloom (HAB) State grant awarded to the Commission in April of 2020.

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. Finally, some additional monitoring was conducted during each sampling event in 2020, again as part of the HAB grant. A separate, subsequent report will be submitted on the 2020 results of the HAB 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. The monitoring program also 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. Finally, much of the data collected in 2020 will be used to assess the relative effectiveness of in-lake and watershed-based projects, designed to prevent or minimize the impacts of HABs in 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

During the 2020 season, sampling was conducted on 19 May, 12 June, 22 July, 24 August, and 23 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, mid-depths 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
- soluble reactive 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, phytoplankton and zooplankton samples were collected at the surface and mid-depths at the deep sampling station (Station 2). Phytoplankton samples were collected at the surface and mid-depths utilizing a Van Dorn sampling device and quantitatively assessed, while zooplankton samples were collected utilizing a Schindler sampling device at each of those depths and qualitatively assessed.

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.

Temperatures observed during the 2020 season were generally comparable to those noted in previous sampling years. During the May sampling event, Station 2 was well-mixed throughout the majority of the water column with an epilimnion extending through 9 m. Surface concentrations steadily declined from 14.28°C to 10.90°C at 13.5 m during this event. The epilimnion shrunk considerably during the June sampling with consistent temperatures through

4 m, declining from 23.28°C to 22.34°C. The thermocline provided a sharp decline in temperatures through 9 m, ultimately declining to 11.00°C at 13 m. Seasonally high temperatures of 28.17°C were observed during the July sampling event. Thermal stratification persisted through this sampling with the epilimnion extending through 3 m, before sharply declining through 9 m. The epilimnion extended through 6 m by the August sampling as overall temperatures began to decline. Overall, temperatures declined from 25.83°C at the surface to 11.28°C at 13 m. The water column yielded steady temperatures through 9 m during the final sampling, before declining to the bottom. Thermal stratification was observed during all of the 2020 sampling events, with exception to May.

Weak degrees of thermal stratification were noted at three of the shallower stations during the May sampling event, including Stations 3, 4 and 6. These three stations became stratified in the bottom meter of the waterbody, varying by 2-4°C. By the June sampling, a total of six stations yielded varying degrees of stratification. Weak stratification was noted at Stations 3, 4, 6 and 11. Stations 8 and 9 had more extensive stratification during this event. By the July and August samplings, only Station 9 was stratified, while other stations yielded steadily declining temperatures. Only the mid-lake sampling station (2) was thermally stratified during the final sampling event.

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.

In addition to collecting temperature data over the 2020 growing season, the long-term, surface water temperatures from Station 2 during the month of July have been graphed and shown below in Figure 1. This exercise was conducted to assess the potential impacts of climate change on Lake Hopatcong. The Station 2, mid-lake, data were used since there was no chance of shading from near-shore trees or structures at this location and the July data were used since it is typically the warmest month of the year in the Mid-Atlantic States.

As shown in Figure 1, there has been a statistically significant increase in surface water temperatures at Lake Hopatcong over the past 30 years. Additionally, the July 2020 surface water temperature at Station 2 was the second highest recorded at 28.17°C. The highest surface water July temperature at Station 2 was recorded in 2005 and was 28.52°C. These data provide evidence that climatic change is impacting Lake Hopatcong. In turn, increasing water temperatures makes the lake more favorable for larger and more frequent Harmful Algal Blooms (HABs).

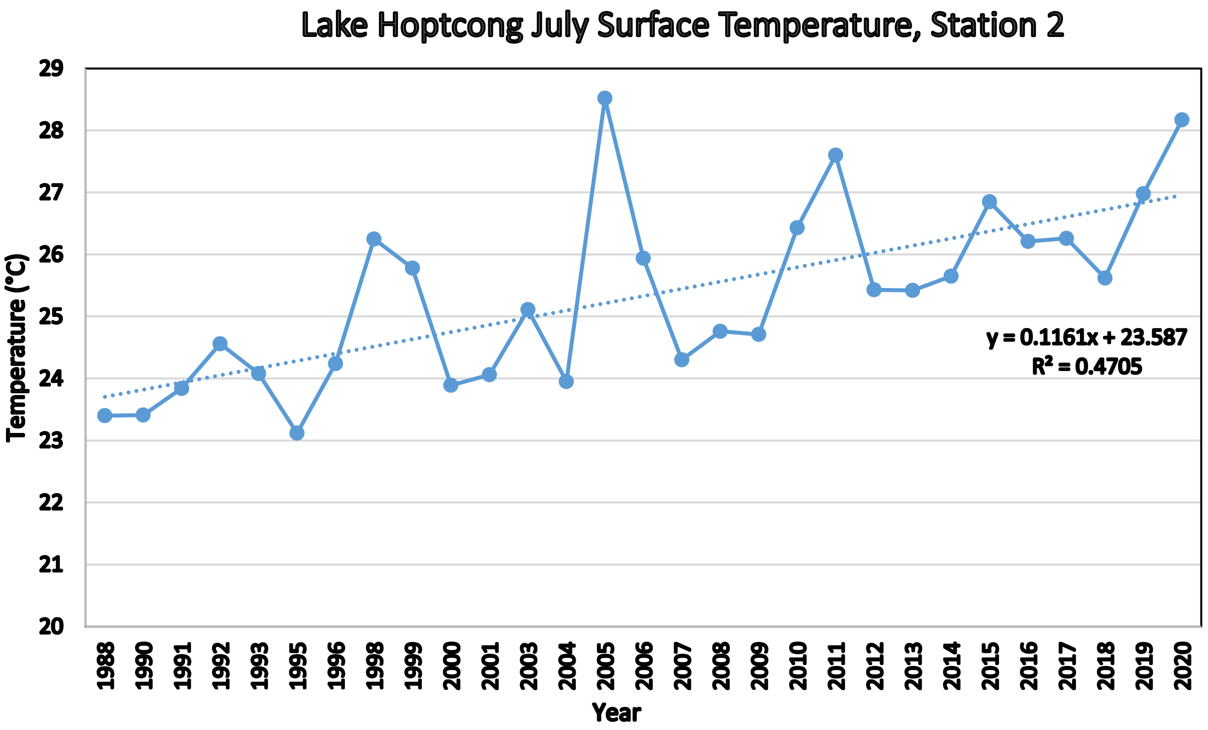


Figure 1: Long-Term, July, Surface Water, Temperatures at the Mid-Lake Sampling Station at Lake Hopatcong, New Jersey

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.

During the May sampling event, DO at Station 2 declined steadily with depth, but retained ample DO throughout the water column. Surface concentrations declined from supersaturated (DO>100%) measures of 10.44 mg/L to 6.86 mg/L at 13.5 m. Ample DO remained in the surface waters through 5 m during the June sampling event, ranging from 8.84 mg/L to 9.39 mg/L. DO concentrations fell below the NJDEP 5.0 mg/L threshold at 7 m, dropping to anoxic conditions (DO<1 mg/L) at 12 m to the bottom. Supersaturated surface measures persisted during the July sampling event. DO increased from 8.66 mg/L at the surface to 9.19 mg/L at 3 m, before declining below the NJDEP threshold at 5 m. Anoxia was observed from 6 m through to the bottom of the waterbody during this event due to the persistent thermal stratification throughout the year. Overall, DO declined at Station 2 by the August event, with surface concentrations of 6.72 mg/L. DO slightly declined through 5 m before declining below the NJDEP threshold. The water column once again became anoxic at 7 m to the bottom during this time. By the final sampling event in September, surface DO concentrations increased to 9.14 mg/L. Ample DO was noted through 9 m during this event, turning anoxic at 10 m.

DO concentrations remained above the recommended threshold at the remaining stations during the May sampling event, with supersaturated concentrations noted in the surface waters of the majority of stations. By the June sampling, both Stations 3 and 9 yielded DO below the NJDEP threshold in the bottom waters. All of the shallower stations were well oxygenated by the July sampling, while deeper stations, such as Stations 8 and 9, yielded DO concentrations below the threshold. The bottom waters were below 2 mg/L at Station 8 and anoxic at Station 9. Surface waters were mostly still supersaturated during this event. Overall, DO measures were lower across the entire lake during this event, with most surface measures in the 5 mg/L and 6 mg/L range. Stations 5, 8, 9 and 11 all yielded measures below the NJDEP threshold in the deeper waters. Anoxia was present in the bottom waters of Station 9. By the final sampling, only Station 9 had lower DO in the deeper waters dropping to 1.27 mg/L at the bottom. The remaining stations yielded ample DO, with often supersaturated concentrations

Overall, a depression of DO was mainly limited to the hypolimnion of Station 2, with instances of anoxic conditions in the bottom meters of various stations, especially 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.

The pH ranged widely during the May 2020 sampling event, with surface values between 7.44 and 10.00. Stations 2 (8.56), 3 (10.00), 4 (8.60) and 5 (9.38) all yielded pH values exceeding the NJDEP optimal range of 6.5 to 8.5. For the most part pH declined with depth during this sampling event. The pH range declined greatly by the June sampling event varying from 7.20 to 8.08, with all surface measures well within the NJDEP optimal range. Multiple stations experienced an increase in pH in the first few meters before declining with depth. Station 3 increased above the optimal range at 1 m during this event (8.83). Vegetation, such as curly leaf pondweed and Eurasian watermilfoil were noted growing on the bottom during this event. This plant growth, alongside increased algal densities resulted in higher photosynthetic rates, causing a rise in pH at this location. All measures were optimal during both the July and September samplings. The August sampling was mostly within the optimal range, only contravening the threshold at Station 10 (8.96). Overall, surface pH was mainly within optimal range, but yielded elevated values at certain stations during May and August.

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 2020, Secchi depths ranged from 1.0 m to 2.2 m. Overall, all of the stations yielded clarity at or greater than the New Jersey recommended threshold of 1.0 m. Both Stations 3 and 5 yielded Secchi depths greater than 2.0 m and were clear to the sediment at this time. By June, a decline in clarity was noted at multiple stations, with a Secchi depth range of 0.9 m to 2.1 m. Stations 1, 10 and 11 yielded Secchi depths of 0.9 m during this event. The range of clarity across the lake further declined by the July sampling to 0.60 m – 1.7 m. Clarity was once again below the recommended threshold at Stations 1 and 10 during this event. Secchi depths continued this trend across Lake Hopatcong for the remaining two samplings. During these events Stations 1, 3, 5 (August only) and 10 yielded clarity below the 1.0 m threshold. Reduced water clarity noted as the season progressed can be attributed to algal productivity increases, as cyanobacteria became dominant.

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 the majority of sampling events during the 2020 season. Both the May and September sampling events yielded non-detectable (ND<0.01 mg/L) concentrations across all surface stations, while July and August remained well below the 0.05 mg/L threshold. The June sampling was the only event to contravene the threshold with measurements ranging from 0.01 mg/L to 0.17 mg/L. Stations 7 (0.08 mg/L), 10 (0.13 mg/L) and 11 (0.17 mg/L) were all above the threshold at this time.

Mid-depth samples collected throughout the sampling season at Station 2 varied between non-detectable concentrations (May, September) and 0.13 mg/L (June). The June sample was the only sample to exceed the 0.05 mg/L recommended threshold. Deep water ammonia concentrations were low during the May sampling, only yielding concentrations of 0.01 mg/L. By the June sampling event, ammonia measures spiked to 0.22 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 0.25 mg/L during the July 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 overall low through the majority of the season, only exceeding recommended thresholds during the June sampling, with the highest measures in areas where near-shore septic systems are utilized.

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 elevated nitrogen-loading, however, concentrations below 0.50 mg/L are still considered acceptable water quality.

During the May 2020 sampling event, nitrate-N concentrations at the surface stations ranged between 0.02 and 0.40 mg/L. Three of these stations contained concentrations greater than the recommended threshold of 0.10 mg/L, while only Station 10 exceeded the 0.30 mg/L nitrogen-loading threshold. It should be noted that these sampling stations are located close to near-shore septic systems, which may explain the elevated concentrations. A total of 2.7 inches of rain fell in the weeks prior to sampling, which may have aided in the more elevated nitrate concentrations seen during this event (CLIMOD, Jefferson Twp. 4.4 SW, NJ). Nitrates were highest during this sampling event, ultimately declining as productivity increased, utilizing these nutrients. The range declined by the June event to non-detectable (ND<0.01 mg/L) concentrations at five stations to 0.11 mg/L at Station 10. Only Station 10 contravened the 0.10 mg/L threshold during this event. The remaining sampling events all yielded low nitrate concentrations, staying below recommended thresholds during each.

Mid-depth and deep-water samples were also analyzed for nitrates during the 2020 season. Overall, mid-depth samples remained below the 0.10 mg/L threshold, ranging between non-detectable concentrations during the June event and 0.06 mg/L during the May event. The deep-water nitrate concentrations were variable throughout the 2020 season. Seasonal minimum values were noted during the June sampling with concentrations of 0.01 mg/L observed. Peak nitrate concentrations were noted during the September sampling event, spiking to 0.23 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 May and June at a select few stations. 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 (greater than 50 years old), near-shore septic systems contribute to the pollutant load of Lake Hopatcong and thus have a direct impact on its water quality. While not as obvious during some of the past drier growing seasons, these stations still displayed elevated concentrations during a few of the sampling events. While an extremely wet year was not observed during the 2020 season, a few large-scale storms followed by many smaller scale rainfall events likely aided in increases in nitrate concentrations. Overall, a total of 21.80 inches of rainfall were noted during the growing season between May and September 2020.

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 or less 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 have an increasing change of developing of algal blooms / mats.

Surface TP concentrations throughout the waterbody were highly variable throughout the 2020 growing season. The May sampling event was characterized by relatively low TP concentrations ranging from 0.02 mg/L to 0.04 mg/L. At this time, only Station 10 exceeded the 0.03 mg/L threshold. This range persisted through the June sampling, but contained four stations contravening the threshold, including Stations 3, 6, 7 and 10. TP began to increase overall by July, with only Stations 2, 5 and 6 having TP measurements of 0.03 mg/L. The remaining sampling stations yielded concentrations between 0.04 mg/L and 0.06 mg/L. This trend continued by the August sampling event, with only Station 2 yielding TP concentrations below 0.03 mg/L. Seasonal maximum TP concentrations were noted during this event at Station 3 (0.08 mg/L). Overall, TP decline by the September sampling to a range of 0.02 mg/L to 0.06 mg/L. At this time, all except Station 10 remained at or below the recommended threshold. Monthly averages for the 2020 growing season ranged from 0.024 mg/L during May and 0.046 mg/L during August, contravening the TMDL average of 0.03 mg/L from June through July.

Mid-depth and deep-water TP samples were also collected at Station 2 throughout the 2020 season. Mid depth concentrations were for the most part low, with measurements of 0.02 mg/L during May, August, and September, and 0.03 mg/L in July. TP concentrations spiked at mid-depth during the June sampling to 0.09 mg/L. Deep water concentrations were at the 0.03 mg/L threshold during May, before spiking to elevated concentrations of 0.34 mg/L by June due to thermal stratification. Elevated TP concentrations persisted in the bottom waters of this station through the remainder of the season due to 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. Consistently elevated concentrations at certain stations may have been influenced by near-shore septic systems, but lake-wide elevations are likely attributed to the stormwater influence and extended internal loading during the 2020 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 each 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, four stations were compliant with this TMDL. Station 2 yielded the lowest average of 0.020 mg/L, while Stations 4, 5 and 6 each had averages of 0.030 mg/L. The remaining sampling stations had a mean 2020 growing season concentration that exceeded 0.03 mg/L to varying degrees. These stations yielded TP averages ranging from 0.034 mg/L to 0.048 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. While an extremely wet year was not observed during the 2020 season, a few large-scale storms followed by many smaller scale rainfall events, combined with persistent anoxia causing internal phosphorus loading likely aided in these nutrient elevations.

Soluble Reactive Phosphorus (SRP)

Soluble reactive phosphorus (SRP) represents the dissolved inorganic portion of total phosphorus metrics. This species of phosphorus is readily available for assimilation by all algal forms for growth and is therefore normally present in limited concentrations except in very eutrophic lakes. Princeton Hydro recommends concentrations of SRP not exceed 0.005 mg/L to prevent nuisance algal blooms.

Overall, SRP concentrations were low throughout the 2020 season at the surface stations of Lake Hopatcong. SRP concentrations for the most part ranged between non-detectable concentrations (ND<0.002 mg/L) and 0.004 mg/L throughout the entire year, only exceeding the 0.005 mg/L threshold once during the May sampling at Station 10, which yielded a measurement of 0.007 mg/L. Samples were also collected in the mid-depths and deep waters of Station 2 during the 2020 season. Mid-depth samples yielded low SRP throughout the year with either non-detectable concentrations or 0.002 mg/L. Deep-water SRP was more variable than its surface counterparts. Concentrations were non-detectable during the May sampling, before increasing to 0.008 mg/L during both the June and July samplings. This increase can be attributed to the extended thermal stratification and resulting anoxia causing a release of phosphorus from the sediments. SRP spiked further during the August and September samplings to measurements of 0.061 mg/L and 0.113 mg/L, respectively.

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.

Overall, 2020 chlorophyll-*a* concentrations were higher than those observed in previous years, despite the severe lake-wide blooms noted in 2019. Chlorophyll-*a* concentrations at the surface during May ranged from 2.7 µg/L at Station 3 to 21.0 µg/L at Station 2. Stations 2, 6 and 10 all exceeded the 14.0 µg/L maximum threshold during this event. A similar range was observed by the June sampling event, with concentrations between 8.3 µg/L and 21.0 µg/L, containing four sampling stations exceeding the target threshold. By the July and August samplings chlorophyll-*a* concentrations greatly increased overall, contravening the maximum threshold at each station, except Station 7 and 11. Seasonal maximum concentrations of 55 µg/L were noted at Station 3 at this time. Elevated chlorophyll-*a* measurements were still observed during the final sampling event at Stations 1, 2, 3, 5 and 10. Mid-depth samples were also collected at Station 2, with measures ranging between 14.0 mg/L during the August event and 21 mg/L during the June event. Overall, Stations 1, 3 and 10 yielded the highest chlorophyll-*a* concentrations through the 2020 season. While severe lake-wide blooms were not observed throughout the season like they were in 2019, cyanobacteria were often the dominant organism observed within collected samples.

Overall, monthly averages increased as the season progressed from 11.3 µg/L during the May event to a maximum of 25.3 µg/L during the August event. Each event exceeded the targeted average by at least 3.3 µg/L, mostly attributed to the cyanobacteria community observed at Lake Hopatcong. Similar to monthly averages, the growing season averages at each station were well above the 8 µg/L TMDL average, ranging from 9.8 µg/L (Station 11) and 25.2 µg/L (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.

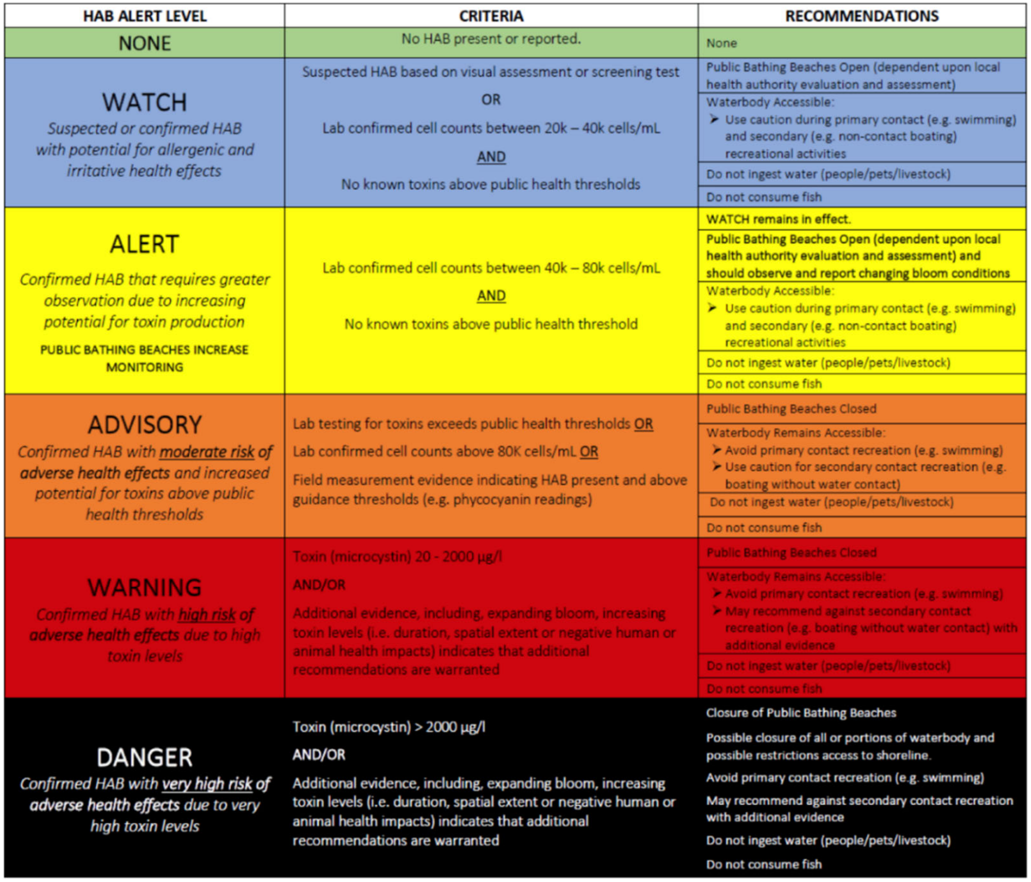
Overall, TSS concentrations remained low throughout the 2020 season. Surface concentrations ranged from non-detectable concentrations (ND < 2 mg/L) to a maximum of 14 mg/L. Each of the sampling events yielded TSS concentrations below the 25 mg/L recommended threshold. Similarly, low TSS measurements were noted in the mid and deep waters at Station 2 during each sampling event, ranging from 2 mg/L to 6 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. Phytoplankton samples were collected from the surface and mid-depths during the 2020 season and were quantitatively analyzed to be compared to NJDEP standards. New Jersey has implemented advanced harmful algal bloom (HAB) screening and response protocols in 2020 and as such may be utilized as a surrogate in this instance. NJ HAB standards are provided below in Figure 2.

Figure 2: NJDEP HAB Response Guidelines



HAB ALERT LEVEL	CRITERIA	RECOMMENDATIONS
NONE	No HAB present or reported.	None
WATCH *Suspected or confirmed HAB with potential for allergenic and irritative health effects*	Suspected HAB based on visual assessment or screening test OR Lab confirmed cell counts between 20k – 40k cells/mL AND No known toxins above public health thresholds	Public Bathing Beaches Open (dependent upon local health authority evaluation and assessment) Waterbody Accessible: ➢ Use caution during primary contact (e.g. swimming) and secondary (e.g. non-contact boating) recreational activities Do not ingest water (people/pets/livestock) Do not consume fish
ALERT *Confirmed HAB that requires greater observation due to increasing potential for toxin production* **PUBLIC BATHING BEACHES INCREASE MONITORING**	Lab confirmed cell counts between 40k – 80k cells/mL AND No known toxins above public health threshold	**WATCH remains in effect.** **Public Bathing Beaches Open (dependent upon local health authority evaluation and assessment) and should observe and report changing bloom conditions** Waterbody Accessible: ➢ Use caution during primary contact (e.g. swimming) and secondary (e.g. non-contact boating) recreational activities Do not ingest water (people/pets/livestock) Do not consume fish
ADVISORY *Confirmed HAB with moderate risk of **adverse health effects** and increased potential for toxins above public health thresholds*	Lab testing for toxins exceeds public health thresholds OR Lab confirmed cell counts above 80K cells/mL OR Field measurement evidence indicating HAB present and above guidance thresholds (e.g. phycocyanin readings)	Public Bathing Beaches Closed Waterbody Remains Accessible: ➢ Avoid primary contact recreation (e.g. swimming) ➢ Use caution for secondary contact recreation (e.g. boating without water contact) Do not ingest water (people/pets/livestock) Do not consume fish
WARNING *Confirmed HAB with high risk of **adverse health effects** due to high toxin levels*	Toxin (microcystin) 20 - 2000 µg/l AND/OR Additional evidence, including, expanding bloom, increasing toxin levels (i.e. duration, spatial extent or negative human or animal health impacts) indicates that additional recommendations are warranted	Public Bathing Beaches Closed Waterbody Remains Accessible: ➢ Avoid primary contact recreation (e.g. swimming) ➢ May recommend against secondary contact recreation (e.g. boating without water contact) with additional evidence Do not ingest water (people/pets/livestock) Do not consume fish
DANGER *Confirmed HAB with very high risk of **adverse health effects** due to very high toxin levels*	Toxin (microcystin) > 2000 µg/l AND/OR Additional evidence, including, expanding bloom, increasing toxin levels (i.e. duration, spatial extent or negative human or animal health impacts) indicates that additional recommendations are warranted	Closure of Public Bathing Beaches Possible closure of all or portions of waterbody and possible restrictions access to shoreline. Avoid primary contact recreation (e.g. swimming) May recommend against secondary contact recreation with additional evidence Do not ingest water (people/pets/livestock) Do not consume fish

The phytoplankton assemblage observed at the surface at Station 2 during the May sampling event was dominated by cyanobacteria, specifically *Aphanizomenon* (27,109 cells/mL). Cyanobacteria made up 87% of the community, with a measured density of 28,681 cells/mL, which designates this event as 'Watch" by NJDEP standards. Diatoms, green algae and cryptomonads were also observed in lower densities during this event. An increase in cyanobacteria densities was observed during the June sampling event to 53,600 cells/mL. This event was mainly dominated by *Aphanizomenon* and *Dolichospermum*. Based on cyanobacteria counts, this event would be labeled as 'Alert'. This event was also characterized by seasonal maximum species richness, with 21 identified genera. By the July sampling event, the HAB alert was reduced to 'None'. While cyanobacteria remained dominant, cell counts declined to below 20,000 cells/mL. August yielded the highest plankton densities overall in 2020 totaling 176,614 cells/mL, with cyanobacteria making up 162,260 cells/mL. This blue-green community was comprised of *Aphanizomenon*, *Planktothrix*, *Pseudanabaena*, *Dolichospermum*, *Coelosphaerium* and *Calothrix*. This sampling event would be labeled as 'Advisory', as further evidence would be required to label it as higher. By the final sampling event, the lake was once again considered a 'Watch' with cyanobacteria counts of 26,964 cells/mL. This sample also contained various diatoms, green algae and cryptomonads.

Mid-depth samples collected during this time varied somewhat from their surface counterparts. During the May sampling event, cyanobacteria densities were greater at mid-depths by approximately 9,000 cells/mL. By the June sampling event, densities and composition were comparable at both the surface and mid samples. An increase in plankton densities was observed in the deeper waters during July, almost doubling cyanobacteria densities to 36,068 cells/mL. While a bloom was observed in the surface waters during August, densities were approximately 100,000 cells/mL less at mid-depths. Densities greatly declined by the final sampling to event.

Cyanobacteria were once again dominant throughout the 2020 season. Cyanobacteria monitoring was conducted on near-shore sampling stations during July and August that consisted of quantifying cyanobacteria cell densities and cyanotoxin (microcystins, cylindrospermopsin and anatoxin-a). A separate report was prepared including the results and analysis of this data.

In addition to the cyanobacteria counts done at Station 2, Turner handheld fluorometers were utilized to measure phycocyanin and chlorophyll-*a* concentrations at the surface. Phycocyanin is a pigment that is produced solely by cyanobacteria and is currently being assessed by NJDEP in terms of monitoring and eventually predicting HABs. While standards have yet to be set for phycocyanin, this parameter will be sampled and entered into the historic database for the waterbody. Overall, phycocyanin ranged from 10 ppb in June to 20 ppb in August. Higher phycocyanin concentrations observed during the August sampling can be attributed to elevated cyanobacteria densities.

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.

The zooplankton community in the surface waters was dominated by the cladoceran *Bosmina* and rotifer *Keratella* during the May event. Moderate densities of copepods *Macrocyclops* and nauplii and the cladoceran *Chydorus* were also observed at this time. A total of 9 genera were identified during this first event. By the June event, community richness decreased to 7 genera and consisted mainly of moderate densities of *Bosmina* and the rotifer *Polyarthra.* Co-dominance was exerted by *Polyarthra* and *Keratella* during the July sampling event. Moderate densities of copepod nauplii were also observed at this time. The August sampling was characterized by a very low-density sample, with seven genera identified as present or rare. By the final sampling event, densities greatly increased. This sample was dominated by *Macrocyclops*, *Conochilus*, *Keratella* and copepod nauplii. Overall, mid-depth samples had comparable communities to those noted at the surface.

Herbivorous zooplankton were present within Lake Hopatcong during the 2020 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 throughout. Such conditions are indicative of a fishery community dominated by a large number of small, zooplankton-feeding fishes, such as 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 optimal summer water temperature range of 18 to 24°C (65 to 75°F) (USEPA, 1994). However, these fish can survive in waters as warm as 26°C (79°F) (Scott and Crossman, 1973), defined here as acceptable habitat. The 2020 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°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°C were considered acceptable or carry over habitat for brown trout.

Optimal brown trout habitat was present throughout the entire water column of Station 2 during the May event. The range of optimal brown trout habitat declined during the June sampling and was present in the surface waters through 6 m. By the July sampling, neither optimal nor carry over trout habitat was present at Station 2. Optimal habitat was not reestablished during the August sampling event, with only carry over habitat observed from the surface waters to 5 m. By the September sampling event optimal habitat was observed through the majority of the water column to 10 m, before anoxic conditions caused unsuitable trout habitat.

Optimal brown trout habitat was found throughout the water column at the remaining stations during the May sampling. By the June sampling, optimal habitat was observed in the entirety of Stations 4, 5, and 8, and portions of Stations 6 (2-2.5 m), 9 (1-6 m) and 11 (0.7 m). Carry over habitat was noted in the entirety of Stations 1, 7 and 10 and portions of Stations 3 (0.1-1 m), 6 (0.1-1 m), 9 (0.1 m) and 11 (0.1 m). Any unsuitable habitat observed during this time was caused by depressed dissolved oxygen concentrations. Trout habitat was not present at any of the stations during the July sampling event. Optimal habitat continued to be absent during the August sampling; however, carry over trout habitat was established at Station 4 at 2.5 m, Station 8 at 4 m, Station 11 at the surface and Station 9 from 3 m to 5 m. By the final event, all stations contained optimal habitat, with exception to the bottom waters of Station 9.

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.

Unfortunately, at the initiation of the 2020 weed harvesting program, an on-lake accident occurred which horrendously resulted in the death of one of the seasoned and well experienced operators. As a result of this tragic accident, the harvesting of aquatic vegetation at Lake Hopatcong was largely postponed over the 2020 growing season. However, toward the end of the growing season, a small amount of plant material was removed. It was estimated that approximately 20 cubic yards of plant biomass was removed with the LHC's harvesters and another 15 cubic yards were removed through a demonstration project conducted by a subcontractor, for a total of 35 cubic yards of harvested removed.

The removal of only 35 cubic yards (16 tons) of plant biomass from Lake Hopatcong in 2020 resulted in the removal of only 3 kgs (6 lbs) of TP from the lake. This was less than 0.1% of the TP load targeted for removal under the TMDL. The 6 lbs of TP removed through the limited amount of weed harvesting that occurred in 2020, had the potential to generate up to approximately 6,186 lbs of additional wet algal biomass. While these phosphorus and algal removal amounts are extremely low, they are recognized as the result of a unique and tragic set of circumstances over the 2020 growing season.

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 2020. The annual mean values for Station 2 were graphed, along with the long-term, "running mean" for the lake. The 2020 mean Secchi depths yielded a low of 1.5 m, which was also noted during the 2019 sampling season. Clarity during these two sampling years showed a marked decline from previous years. The 2019 and 2020 growing seasons yielded historically minimum clarity values. Secchi depth was below the long-term mean of 2.07 m for the third year in a row (Figure 2 in Appendix A). This decline in clarity can once again be attributed moderate to high densities of cyanobacteria.

The mean chlorophyll-*a* concentration for the 2020 season was 20.2 µg/L, almost doubling the long-term mean of 10.6 µg/L. Chlorophyll-*a* concentrations observed during the 2020 season were the highest observed within this historic database. The 2020 average exceeded the targeted average of 8 µg/L. The mean 2020 chlorophyll *a* concentration was the highest measured out of the entire 1991 – 2020 dataset, replacing 2014 which had an average concentration of 18 µg/L. 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. Overall, 2020 was comparable to normal precipitation values, with only a few large storms, yielding more smaller rainfall events throughout the growing season. However, overall temperatures were elevated from late June through mid-September. These factors likely contributed to stimulated phytoplankton growth, ultimately causing the increased chlorophyll-*a* concentrations.

The 2020 mean TP concentration was 0.02 mg/L (Figure 4 in Appendix A), the same mean value measured in 2019. The 2020 value remained slightly below the long-term mean. While average TP concentrations were elevated compared to previous sampling seasons, they remained below 0.03 mg/L State and TMDL standard. TP concentrations noted throughout the 2020 season remained at or below 0.03 mg/L.

3.7 Water Quality Impairments, Established TMDL Criteria and Evaluation of Station 3

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 endpoint, was established to identify compliance with the TMDL. For the sake of this 2020 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 2020 seasonal mean (0.020 mg/L) and single TP concentrations at Station 2 were all consistently at or below the targeted mean TP concentration recognized under the TMDL (0.03 mg/L). Overall, TP ranged from 0.01 mg/L during 24 August to 0.03 mg/L during 22 July. The seasonal mean chlorophyll-*a* concentration (20.2 µg/L) greatly exceeded the targeted mean chlorophyll *a* concentration of 8 µg/L. Overall, chlorophyll-*a* concentrations ranged between 16.0 µg/L during 22 July and 24.0 µg/L during 24 August. Each sampling event exceeded the targeted maximum chlorophyll *a* concentration endpoint of 14 µg/L during the 2020 season.

Mean TP concentrations at Station 3, exceeded the targeted mean of 0.03 mg/L, with an average of 0.046 mg/L. Average concentrations increased slightly from 0.042 mg/L, observed during the 2019 season. This station had experienced a steady decline over the past few years prior to 2019. Overall, 2020 TP concentrations ranged from 0.02 mg/L to 0.08 mg/L. The May and September samplings yielded concentrations at or below 0.03 mg/L, while the remaining values were elevated. Similar to Station 2, the seasonal 2020 mean chlorophyll *a* concentration exceeded targeted mean with a measure of 25.1 µg/L. Chlorophyll-*a* concentrations during May and June were below the targeted maximum chlorophyll *a* concentration ranging between 2.7 µg/L and 9.6 µg/L. The remainder of the growing season yielded elevated chlorophyll *a* ranging between 28 µg/L during the September event and 55.0 µg/L during the August event.

At Station 10, the mean TP concentration in 2020 was 0.06 mg/L, increasing from previous sampling periods. Each sampling event conducted during 2020 exceeded the 0.03 mg/L target, with measures ranging from 0.04 mg/L to 0.06 mg/L. The mean concentration of chlorophyll-*a* (24.0 µg/L) also greatly exceeded the targeted mean concentration of 8 µg/L. All five of the sampling events had a value greater than the targeted maximum chlorophyll-*a* concentration endpoint of 14 µg/L, ranging between 16.0 during the 24 August event and 32.0 µg/L during the 23 September event.

As previously mentioned, the LHC was awarded a HAB grant in 2020 to implement a variety of in-lake and watershed project to mitigate, control or prevent the development of HABs. In addition to this, the Borough of Hopatcong was also awarded a grant to install a circulation system in the River Styx / Crescent Cove section of the lake. Since Princeton Hydro has a long-term monitoring sampling location (Station 3) in this section of the lake, a brief review of water quality conditions was conducted before and after the circulation system was installed and operational.

The circulation system was installed and operational by the 23 of July 2020 and Princeton Hydro's July monitoring event was on the 22 of July 2020. Thus, the July data will represent pre-circulation conditions, while the August and September 2020 monitoring events will represent conditions under circulation. In addition, the Station 3 conditions will also be compared to Station 2, the mid-lake station.

As shown in Figure 3, Secchi depth (water clarity) declined after the system was installed and operational at Station 3 from 1.1 m (3.6 ft) in July to 0.7 m (2.3 ft) in August. While Secchi depth slightly increased from August to September, to 0.9 m (3.0 ft), it was still below the targeted threshold of 1.0 m (3.3 ft). This is in sharp contrast to Station 2 where Secchi depth slightly improved from July to August, 1.4 m (4.6 ft) to 1.5 m (5.0 ft) and then declined to 1.3 (4.3 ft) in September. Thus, Secchi depths at Station 2 were above the targeted threshold of 1.0 (3.3 ft).

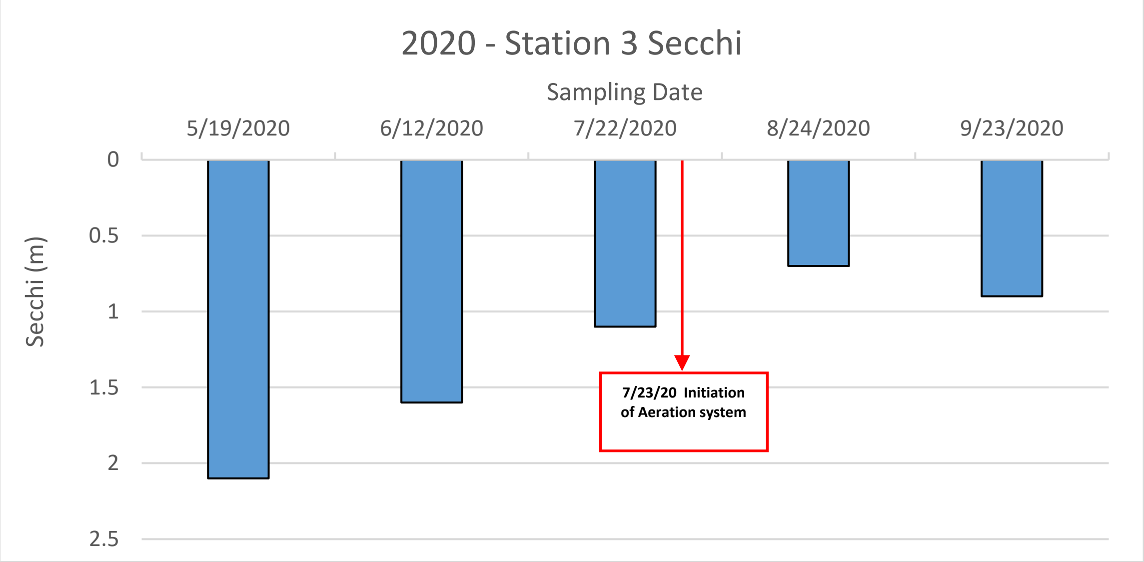


Figure 3: Secchi depth values at Station 3 over the 2020 Growing Season.

As shown in Figure 4, TP concentrations were already elevated in July, at 0.06 mg/L, prior to the operation of the circulation system. However, after the system was in operation TP concentrations increased to 0.08 mg/L in August but then declined to an acceptable concentration of 0.03 mg/L in September (Figure 4). In contrast, at Station 2 the July, August and September TP concentrations were 0.03, 0.01 and 0.02 mg/L, respectively, and were consistently at or below the targeted mean threshold for TP of 0.03 mg/L.

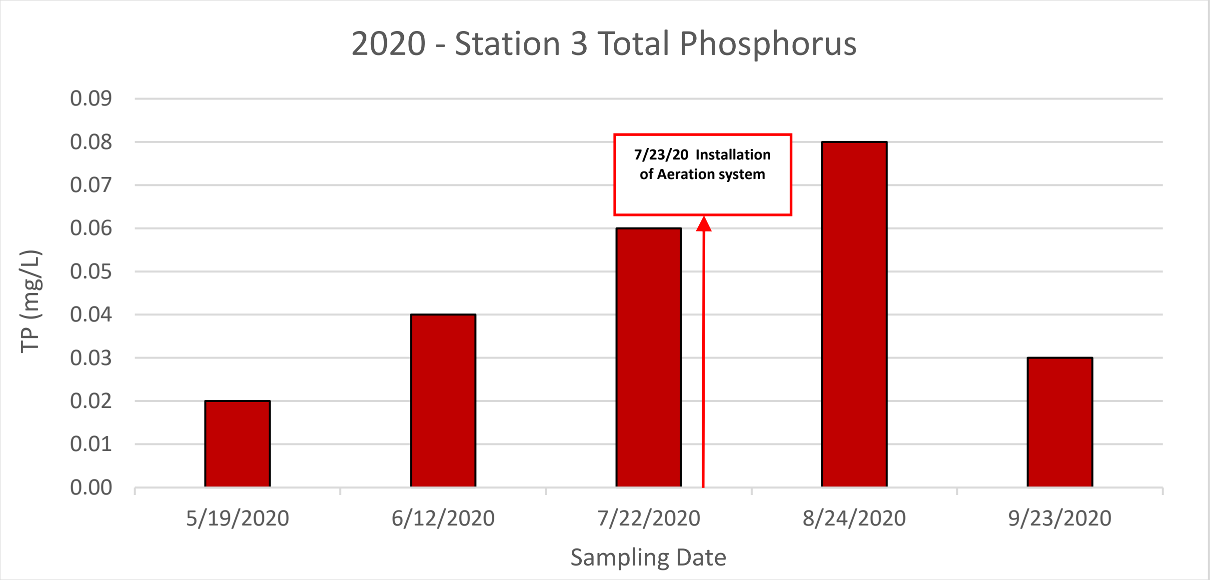


Figure 4: TP concentrations at Station 3 over the 2020 Growing Season.

As shown in Figure 5, SRP concentrations were consistently < 0.002 mg/L (and thus graphed below as 0.001 mg/L) from May through July (pre-circulation) but then increased to 0.002 mg/L in August and September (during circulation). At Station 2 SRP concentrations were consistently < 0.002 mg/L from May through August but then increased to 0.004 mg/L in September.

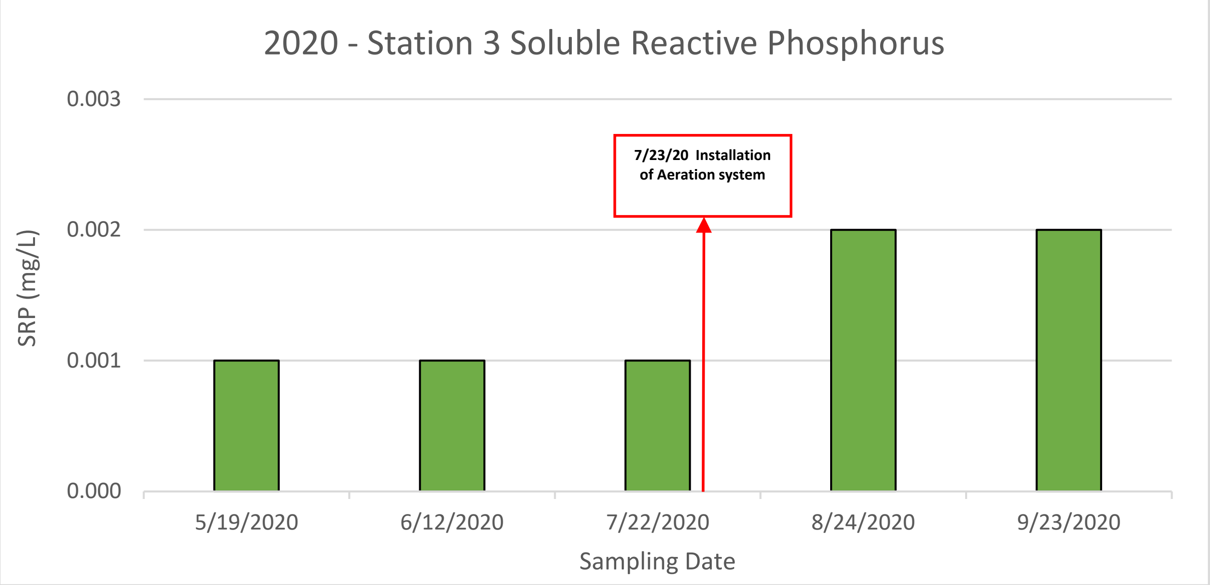


Figure 5: SRP concentrations at Station 3 over the 2020 Growing Season.

As shown in Figure 6, prior to the operation of the circulation system, the July chlorophyll-*a* concentration at Station 3 was one of the highest throughout Lake Hopatcong, at 30 ug/L. Only Station 1 had a higher July concentration at 32 ug/L. From July to August, after the circulation system was operational for approximately one month, the chlorophyll-*a* concentration at Station 3 increased to 55 ug/L (Figure 6). This was the highest August chlorophyll-*a* concentration in Lake Hopatcong. At Station 2 the chlorophyll-*a* concentration increased from 16 ug/L in July to 24 ug/L in August. From August to September chlorophyll-*a* concentrations declined at both Stations but the concentration at Station 3 was still quite high at 28 ug/L.

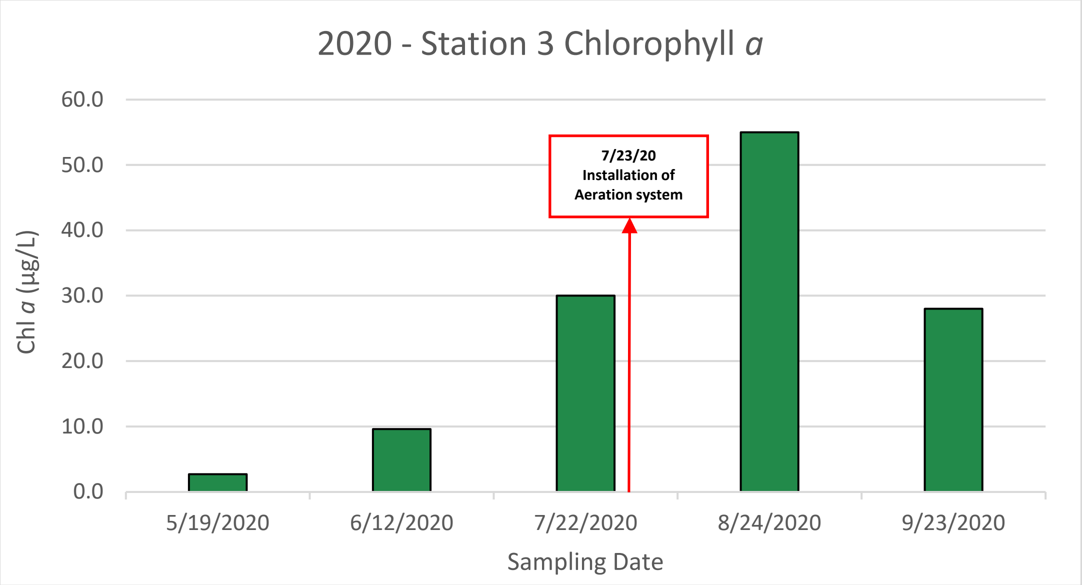


Figure 6: Chlorophyll-*a* concentrations at Station 3 over the 2020 Growing Season.

Finally, dissolved oxygen (DO) concentrations were measured with a calibrated meter at Station 3 from surface to bottom and are shown in Figure 7. Station 3 remained oxygenated from surface to bottom at Station both prior to and during the operation of the circulation system. Additionally, DO concentrations were more consistent throughout the water column from surface to bottom after the circulation system was operational (Figure 7).

While no quantitative data were collected on the aquatic vegetation throughout Station 3, observations revealed that a decline in the densities of aquatic plants occurred after the circulation system was installed. However, a seasonal reduction in aquatic vegetation was also observed throughout the lake over the last summer season. Thus, it is strongly recommended that an aquatic plant monitoring program be initiated in 2021 to provide some quantitative data on aquatic plant community at Lake Hopatcong.

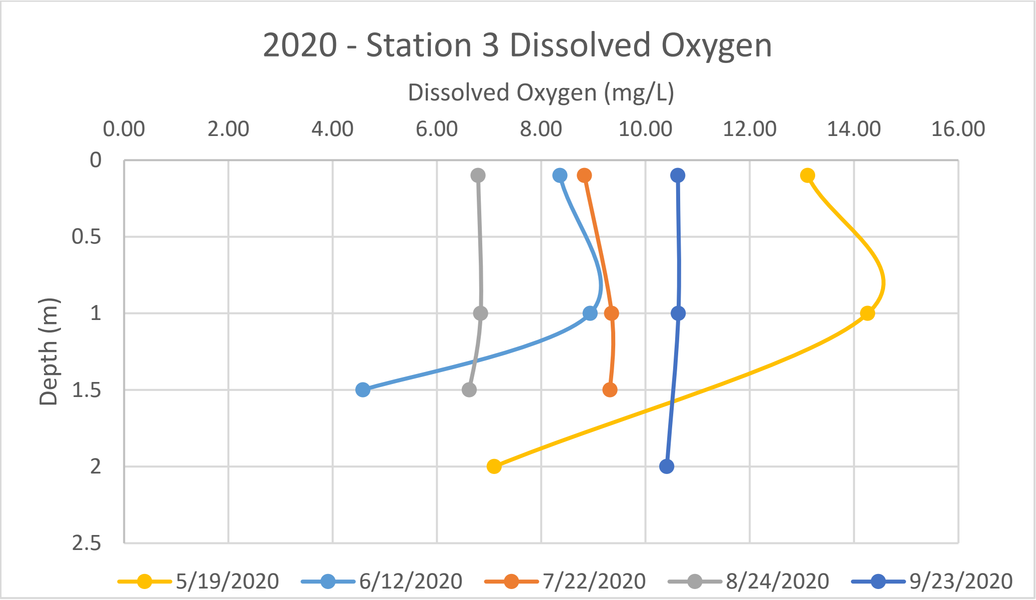


Figure 7: Dissolved Oxygen concentrations from surface to bottom at Station 3 over the 2020 Growing Season.

4.0 Summary

This section provides a summary of the 2020 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, declining with depth but remaining above NJDEP thresholds throughout the water column. By the June sampling event, the water column became anoxic in the bottom waters of Station 2. Anoxic conditions persisted through the September sampling event.

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 throughout Lake Hopatcong were highly variable ranging between 0.01 mg/L (Station 2) and 0.08 mg/L (Station 3). Deep water concentrations were low during the first sampling event, before increasing as the season progressed to a maximum of 0.41 mg/L during the September event. Elevated TP in the deep waters is attributed to extended periods of anoxia causing internal loading of P.

3. While the previous long-term water quality database had value, the HABs experienced in 2019 identified the need to slightly expand the monitoring program. Specifically, soluble reactive phosphorus (SRP) was added to the monitoring parameters at each sampling station, more detailed plankton monitoring, including phytoplankton counts (in particular with the cyanobacteria) were conducted at surface and mid-depths and additional vertical sampling at Station 2 to cover surface, mid-depth and deep-water samples were added to the program as well. This increased sampling scope allowed for a more detailed look at nutrients and the affected phytoplankton communities through the lake.

4. Based on the *in-situ* conditions, optimal brown trout habitat was available in varying degrees in May, June, and September 2020 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 event, at Stations 4, 5 and 8 in June, and at all stations during the September event, only declining to unsuitable habitat in the deep waters of Station 9. Carry over habitat was identified at various stations during the June, and August sampling events. Brown trout habitat was not observed in any capacity during the July 2020 sampling event and based on the long-term temperature data climate change is contributing to this loss of brown trout habitat.

5. As a result of a tragic accident at the initiation of the mechanical weed harvesting, the program was cancelled over the majority of the 2020 growing season. However, some very limited harvesting was conducted toward the end of the season with both the Commission's harvesting equipment as well through the harvesting demonstration conducted by a subcontractor with their equipment. During the limited 2020 harvesting program, only about 35 cubic yards of wet plant biomass was removed. This resulted in removing 6 lbs of TP, accounting for < 0.1% of the TP targeted for removal under the TMDL.

6. While mid-lake (Station 2) TP concentrations remained low, the highest recorded mean chlorophyll-*a* concentration and lowest mean Secchi depth (same as 2019) were documented in 2020. These data indicate that higher amounts of algal biomass in the main body of the lake originated from near-shore areas and/or from deeper sections of the water column. The 319-grant, awarded in 2020, will aid in better understanding algal dynamics in Lake Hopatcong.

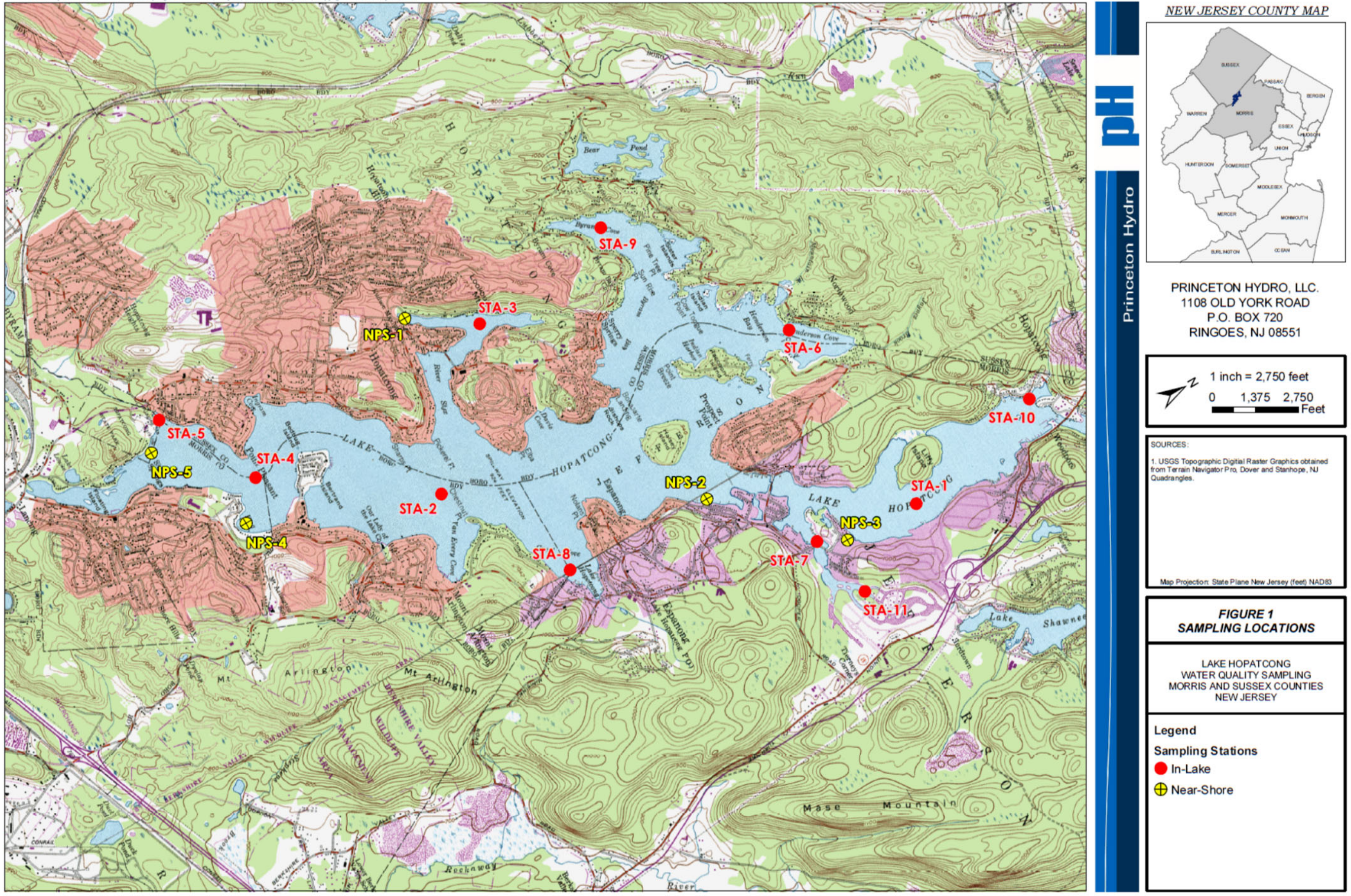
7. The circulation system installed in the River Styx / Crescent Cove section of the lake kept the water column well oxygenated with a fairly consistent amount of DO from surface to bottom. Additionally, it may have contributed to a decline in rooted aquatic plants in this section of the lake. However, both TP and chlorophyll-*a* increased from July to August once the circulation system was operational. This emphasizes the need to continue to focus on reducing watershed-based phosphorus loading to the lake, particularly in this section of the lake were some of the highest TP concentrations are measured. In turn, this means continuing long-term efforts in stormwater management and sewering the local communities.

8. Finally, it is recommended that an additional sampling station be included in the southern end of the lake (Landing Channel) to continue to assess the post-PhosLock conditions in 2021. In addition, samples should also be collected for the identification and enumeration of phytoplankton at Station 3 and an aquatic plant monitoring program should be conducted in 2021.

APPENDIX A

FIGURES

File: P:\0003\Projects\0003047\GIS\MXD\SamplingLocations.mxd, May 25, 2010, Drawn by CLP, Copyright Princeton Hydro, LLC.



PRINCETON HYDRO, LLC.
1108 OLD YORK ROAD
P.O. BOX 720
RINGOES, NJ 08551

SOURCES:

1. USGS Topographic Digitial 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

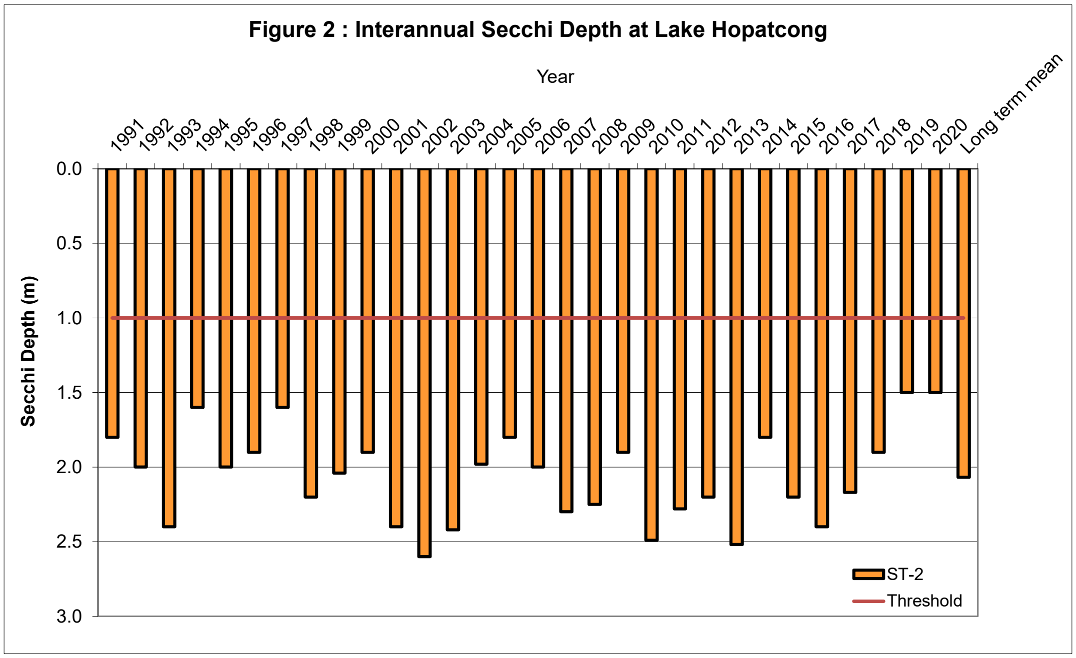


Figure 2 : Interannual Secchi Depth at Lake Hopatcong

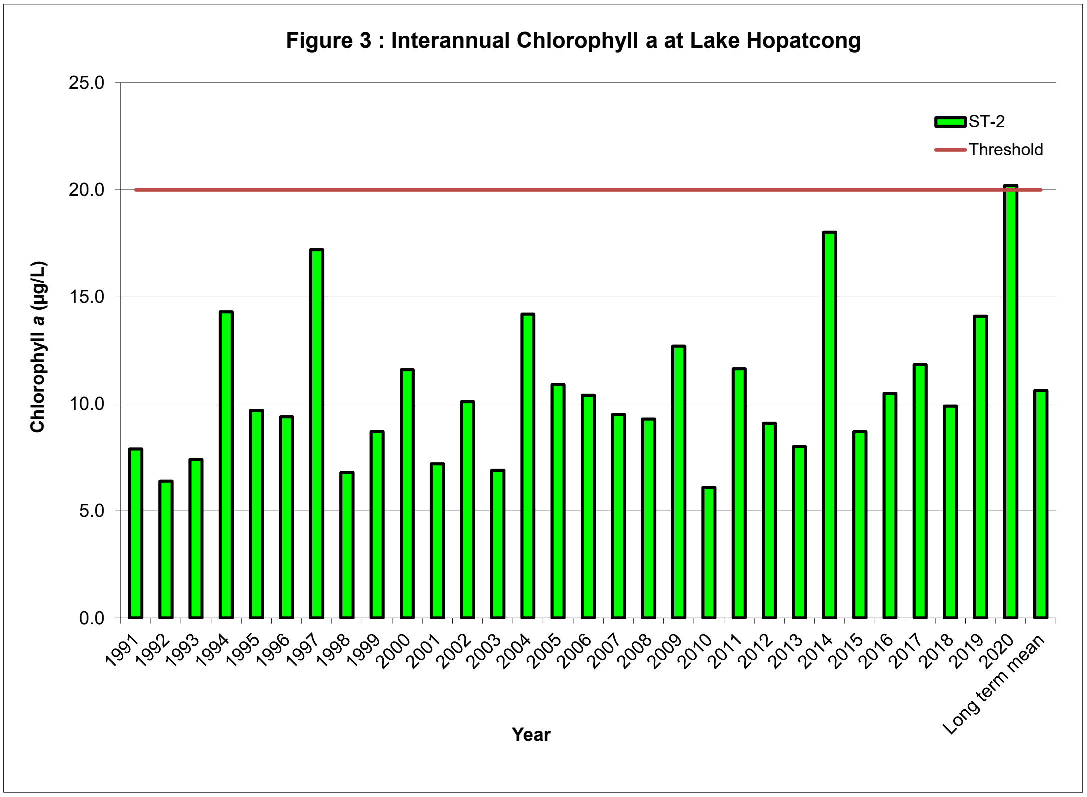
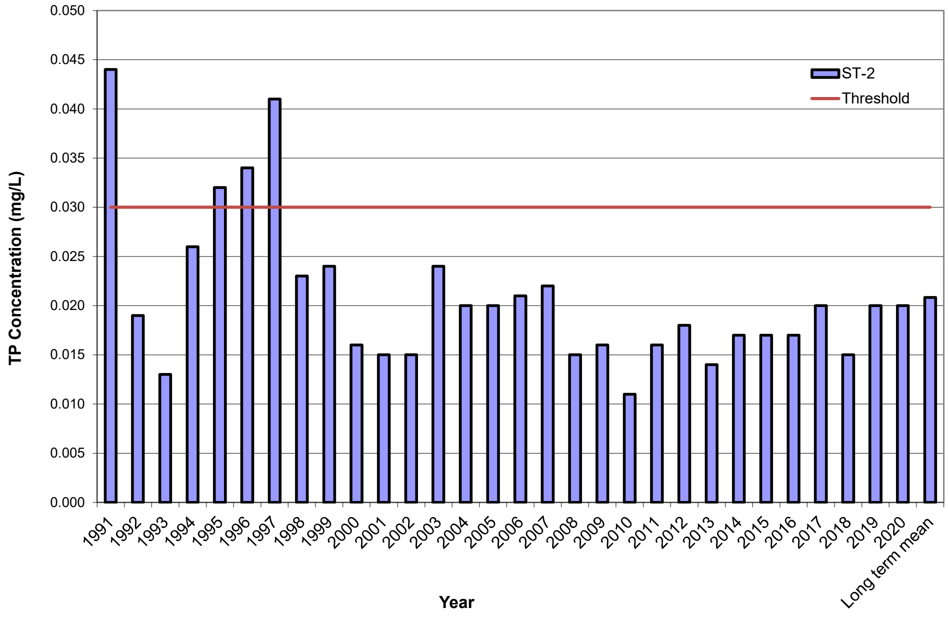


Figure 3 : Interannual Chlorophyll a at Lake Hopatcong

Figure 4 : Interannual Total Phosphorus at Lake Hopatcong



APPENDIX B

IN-SITU DATA

In-Situ Monitoring for Lake Hopatcong 5/19/2020

Station	DEPTH (meters)			Temperature	Specific Conductance	Dissolved Oxygen		pH
	Total	Secchi	Sample	°C	mS/cm	mg/L	% Sat.	S.U.
STA-1	2.00	1.30	0.1	17.34	0.324	9.25	97.8	7.44
			1.0	17.33	0.324	9.42	99.6	7.44
			1.5	17.31	0.324	9.48	100.1	7.45
STA-2	13.70	1.50	0.1	14.28	0.415	10.44	103.4	8.56
			1.0	14.27	0.415	10.64	105.4	8.37
			2.0	14.27	0.415	10.74	106.3	8.27
			3.0	14.25	0.415	10.79	106.8	8.20
			4.0	14.23	0.415	10.82	107.0	8.16
			5.0	14.21	0.415	10.81	106.8	8.11
			6.0	14.17	0.416	10.78	106.5	8.08
			7.0	14.04	0.416	10.76	106.0	8.03
			8.0	14.01	0.416	10.75	105.8	8.00
			9.0	13.17	0.417	9.44	91.3	7.82
			10.0	11.57	0.417	9.80	91.3	7.79
			11.0	11.17	0.417	8.87	81.9	7.66
			12.0	11.07	0.417	8.58	79.1	7.61
			13.0	10.92	0.418	8.15	74.9	7.55
			13.5	10.90	0.418	6.86	63.0	7.36
STA-3	2.10	2.10	0.1	17.45	0.792	13.11	139.6	10.00
			1.0	17.41	0.830	14.26	151.0	10.01
			2.0	13.13	0.931	7.10	69.0	8.51
STA-4	3.00	1.80	0.1	15.49	0.425	10.65	108.2	8.60
			1.0	15.50	0.425	10.82	110.0	8.54
			2.0	15.46	0.425	10.41	105.7	8.32
			2.7	13.77	0.420	10.48	102.6	8.22
STA-5	2.20	2.20	0.1	16.86	0.438	11.36	118.9	9.38
			1.0	16.88	0.437	11.51	120.4	9.40
			2.0	16.85	0.435	11.55	120.8	9.41
STA-6	2.90	1.80	0.1	15.56	0.418	10.66	108.7	8.26
			1.0	15.60	0.418	10.90	111.0	8.26
			2.0	12.78	0.420	10.91	104.5	8.18
			2.5	12.50	0.420	10.73	102.1	8.09
STA-7	1.60	1.20	0.1	18.63	0.186	8.41	91.2	7.49
			1.0	18.40	0.198	8.11	87.5	7.41
STA-8	7.00	1.80	0.1	12.85	0.418	10.05	96.4	7.69
			1.0	12.83	0.419	10.04	96.3	7.66
			2.0	12.79	0.419	10.06	96.3	7.65
			3.0	12.33	0.418	9.99	94.7	7.64
			4.0	11.73	0.418	9.79	91.6	7.60
			5.0	11.54	0.418	9.42	87.7	7.56
			6.0	11.33	0.419	8.67	80.4	7.49
			6.7	11.35	0.419	8.35	77.4	7.43
STA-9	7.90	1.80	0.1	15.98	0.425	10.39	106.7	8.15
			1.0	15.80	0.423	10.72	109.7	8.18
			2.0	15.59	0.418	10.83	110.3	8.15
			3.0	15.46	0.418	10.82	109.9	8.11
			4.0	15.41	0.417	10.80	109.6	8.09
			5.0	15.40	0.417	10.78	109.4	8.07
			6.0	15.38	0.417	10.73	108.8	8.05
			7.0	15.37	0.417	10.71	108.6	8.04
STA-10	1.20	1.00	0.1	18.50	0.368	10.19	110.3	8.07
			1.0	18.06	0.381	10.45	112.2	8.08
STA-11	1.20	1.20	0.1	18.64	0.137	8.88	96.2	7.48
			1.0	18.55	0.137	8.77	95.0	7.37

***In-Situ* Monitoring for Lake Hopatcong 06/12/2020**

Station	DEPTH (meters)			Temperature	Specific Conductance	Dissolved Oxygen		pH
	Total	Secchi	Sample	°C	mS/cm	mg/L	% Sat.	S.U.
STA-1	**2.00**	**0.90**	**0.10**	25.11	0.316	8.44	102.5	7.31
			1.00	24.92	0.315	8.56	103.6	7.38
			1.50	24.73	0.314	8.38	101.0	7.38
STA-2	**13.60**	**1.80**	**0.1**	23.28	0.425	9.25	108.7	7.81
			1.0	23.27	0.424	9.32	109.5	7.86
			2.0	23.01	0.425	9.39	109.8	7.87
			3.0	22.86	0.428	9.34	108.8	7.83
			4.0	22.34	0.429	8.84	102.1	7.68
			5.0	21.09	0.426	7.97	89.7	7.54
			6.0	18.86	0.422	6.97	75.2	7.44
			7.0	14.30	0.423	4.47	43.7	7.31
			8.0	12.60	0.421	3.78	35.7	7.26
			9.0	12.11	0.421	3.02	28.2	7.15
			10.0	11.66	0.422	2.92	27.0	7.12
			11.0	11.30	0.424	2.04	18.6	7.03
			12.0	11.10	0.426	0.93	8.5	6.95
			13.0	11.00	0.428	0.64	5.8	6.94
STA-3	**2.00**	**1.60**	**0.1**	24.65	0.690	8.36	100.9	8.08
			1.0	24.23	0.833	8.94	107.0	8.83
			1.5	23.02	0.807	4.58	53.7	8.06
STA-4	**3.00**	**2.10**	**0.1**	23.07	0.436	8.32	97.4	7.36
			1.0	23.07	0.436	8.09	94.7	7.36
			2.0	22.78	0.435	8.11	94.3	7.37
			2.5	20.57	0.425	7.98	88.9	7.39
STA-5	**1.35**	**1.35**	**0.1**	22.97	0.437	7.66	89.5	7.52
			1.0	22.38	0.436	6.58	76.0	7.44
STA-6	**2.90**	**1.70**	**0.1**	24.93	0.423	8.96	108.8	8.07
			1.0	24.55	0.422	9.39	113.0	8.20
			2.0	23.25	0.427	9.66	113.4	8.17
			2.5	22.83	0.429	8.46	98.6	7.97
STA-7	**2.00**	**1.00**	**0.1**	25.27	0.211	8.21	100.0	7.62
			1.0	24.43	0.202	7.95	95.3	7.42
			1.5	24.27	0.200	7.20	86.1	7.31
STA-8	**6.60**	**1.90**	**0.1**	23.56	0.422	9.23	109.0	7.93
			1.0	23.53	0.422	9.41	111.0	8.01
			2.0	23.46	0.422	9.48	111.7	8.04
			3.0	23.33	0.422	9.52	112.0	8.03
			4.0	23.28	0.422	9.49	111.5	8.01
			5.0	21.12	0.422	8.57	96.6	7.81
			6.0	19.06	0.420	7.35	79.6	7.66
STA-9	**8.00**	**1.80**	**0.1**	24.10	0.427	9.26	110.4	8.07
			1.0	23.92	0.426	9.59	114.1	8.10
			2.0	23.07	0.428	9.78	114.4	8.05
			3.0	20.26	0.425	8.11	89.9	7.74
			4.0	19.00	0.424	7.59	82.0	7.67
			5.0	17.58	0.424	7.16	75.2	7.62
			6.0	16.45	0.423	6.23	63.9	7.55
			7.0	14.86	0.424	3.83	38.0	7.42
			7.5	12.81	0.429	2.74	26.0	7.34
STA-10	**1.20**	**0.90**	**0.1**	25.43	0.392	9.20	112.5	7.95
			1.0	24.72	0.359	9.41	113.6	8.10
STA-11	**1.10**	**0.90**	**0.1**	25.03	0.157	6.75	81.8	7.20
			0.7	23.89	0.156	6.30	74.8	7.07

In-Situ Monitoring for Lake Hopatcong 7/22/2020

Station	DEPTH (meters)			Temperature	Specific Conductance	Dissolved Oxygen		pH
	Total	Secchi	Sample	°C	mS/cm	mg/L	% Sat.	S.U.
STA-1	**2.00**	**0.80**	**0.1**	29.86	0.333	8.44	110.8	7.53
			1.0	29.10	0.336	8.64	112.0	7.64
			1.5	28.83	0.336	8.81	113.6	7.61
STA-2	**13.50**	**1.40**	**0.1**	28.17	0.439	8.66	110.5	8.00
			1.0	27.96	0.438	9.04	114.9	8.10
			2.0	27.92	0.438	9.16	116.3	8.10
			3.0	27.73	0.439	9.19	116.2	8.05
			4.0	26.21	0.436	7.45	91.7	7.72
			5.0	24.28	0.430	3.84	45.6	7.32
			6.0	22.16	0.424	0.71	8.1	7.04
			7.0	18.42	0.431	0.27	2.9	6.98
			8.0	14.91	0.426	0.16	1.5	6.98
			9.0	13.07	0.428	0.13	1.2	6.94
			10.0	12.15	0.427	0.12	1.1	6.94
			11.0	11.57	0.432	0.12	1.1	6.91
			12.0	11.12	0.442	0.12	1.1	6.87
			13.0	10.90	0.449	0.12	1.1	6.87
STA-3	**2.00**	**1.10**	**0.1**	28.80	0.574	8.83	113.9	7.86
			1.0	28.49	0.572	9.35	119.9	8.08
			1.5	28.12	0.563	9.32	118.7	8.00
STA-4	**3.00**	**1.20**	**0.1**	28.45	0.444	8.90	114.1	8.24
			1.0	28.34	0.443	9.07	116.0	8.28
			2.0	27.54	0.438	9.04	114.0	8.07
			2.5	26.80	0.437	5.25	65.5	7.49
STA-5	**1.20**	**1.10**	**0.1**	28.12	0.446	8.82	112.5	8.17
			1.0	28.06	0.446	8.88	113.0	8.10
STA-6	**3.00**	**1.40**	**0.1**	29.19	0.434	8.78	113.9	7.96
			1.0	28.69	0.433	9.04	116.3	7.96
			2.0	28.23	0.432	9.13	116.3	7.91
			2.7	27.62	0.433	7.93	100.3	7.68
STA-7	**2.10**	**1.00**	**0.1**	29.85	0.263	7.91	103.9	7.34
			1.0	29.25	0.257	7.94	103.1	7.33
			1.7	28.51	0.249	7.82	100.3	7.31
STA-8	**6.50**	**1.70**	**0.1**	29.07	0.435	8.82	114.2	8.08
			1.0	28.54	0.435	9.13	117.2	8.23
			2.0	28.00	0.436	9.27	117.9	8.13
			3.0	27.23	0.436	9.13	114.5	8.01
			4.0	26.51	0.432	7.07	87.5	7.59
			5.0	25.53	0.430	4.38	53.3	7.27
			6.0	23.17	0.432	1.31	15.2	7.00
STA-9	**7.90**	**1.50**	**0.1**	28.89	0.437	9.54	123.3	8.28
			1.0	28.29	0.436	9.81	125.4	8.31
			2.0	27.95	0.435	9.95	126.3	8.33
			3.0	27.74	0.435	9.81	124.2	8.25
			4.0	26.72	0.434	8.76	108.9	8.00
			5.0	24.84	0.430	4.93	59.2	7.54
			6.0	22.99	0.427	2.08	24.1	7.25
			7.0	15.90	0.437	0.96	9.7	7.08
			7.5	14.56	0.441	0.58	5.7	7.05
STA-10	**1.20**	**0.60**	**0.1**	29.76	0.345	9.15	119.7	8.15
			0.8	29.00	0.370	10.23	132.1	8.39
STA-11	**1.10**	**1.10**	**0.1**	28.65	0.201	7.00	90.0	7.15
			0.7	28.30	0.199	7.74	98.8	7.19

***In-Situ* Monitoring for Lake Hopatcong 8/24/20**

Station	DEPTH (meters)			Temperature	Specific Conductance	Dissolved Oxygen		pH
	Total	Secchi	Sample	°C	mS/cm	mg/L	% Sat.	S.U.
STA-1	**2.00**	**0.75**	**0.1**	26.98	0.308	6.31	95.0	7.53
			1.0	26.68	0.307	6.55	97.8	7.68
STA-2	**13.90**	**1.50**	**0.1**	25.83	0.401	6.72	98.9	7.98
			1.0	25.80	0.403	6.60	97.0	8.03
			2.0	25.70	0.400	6.52	95.6	8.04
			3.0	25.60	0.400	6.41	93.9	8.00
			4.0	25.52	0.400	6.27	91.8	7.94
			5.0	25.06	0.398	5.42	78.5	7.76
			6.0	24.13	0.395	3.03	43.2	7.50
			7.0	21.52	0.402	0.22	3.0	7.22
			8.0	17.44	0.419	0.11	1.2	7.11
			9.0	14.06	0.412	0.07	0.8	6.99
			10.0	12.69	0.414	0.06	0.7	7.01
			11.0	12.19	0.415	0.05	0.6	7.03
			12.0	11.68	0.422	0.04	0.5	7.03
			13.0	11.28	0.427	0.04	0.4	7.02
STA-3	**2.10**	**0.70**	**0.1**	26.79	0.546	6.79	101.6	8.02
			1.0	26.32	0.552	6.84	101.5	8.18
			1.5	26.15	0.544	6.62	98.0	8.12
STA-4	**3.10**	**1.05**	**0.1**	26.24	0.405	5.95	88.1	7.64
			1.0	26.19	0.406	5.92	87.6	7.66
			2.0	26.05	0.408	5.70	84.2	7.64
			2.5	25.68	0.404	5.66	83.0	7.63
STA-5	**3.10**	**0.80**	**0.1**	26.32	0.407	5.99	88.9	7.58
			1.0	26.24	0.408	5.98	88.5	7.64
			2.0	26.19	0.407	5.86	86.7	7.67
			2.5	25.96	0.407	4.65	68.5	7.48
STA-6	**3.00**	**1.40**	**0.1**	26.97	0.396	7.04	105.6	8.19
			1.0	26.87	0.397	6.90	103.4	8.17
			2.0	26.40	0.401	6.47	96.1	8.00
			2.5	26.25	0.398	6.29	93.2	7.85
STA-7	**1.70**	**1.10**	**0.1**	26.99	0.275	6.18	92.9	7.69
			1.0	26.71	0.279	6.24	93.2	7.69
STA-8	**6.00**	**1.50**	**0.1**	26.60	0.403	6.96	103.8	8.37
			1.0	26.56	0.401	6.83	101.8	8.41
			2.0	26.35	0.404	6.94	103.0	8.43
			3.0	26.19	0.405	6.98	103.3	8.28
			4.0	25.52	0.402	5.52	80.7	7.96
			5.0	25.03	0.403	3.73	54.0	7.62
			5.5	24.70	0.400	3.27	47.1	7.41
STA-9	**8.20**	**1.55**	**0.1**	26.95	0.398	7.11	106.8	8.24
			1.0	26.68	0.398	7.09	105.9	8.31
			2.0	26.20	0.398	6.97	103.2	8.32
			3.0	25.96	0.399	6.46	95.2	8.15
			4.0	25.72	0.401	6.60	96.8	8.13
			5.0	25.36	0.402	5.94	86.6	7.97
			6.0	24.80	0.398	4.64	67.1	7.73
			7.0	21.28	0.405	0.34	4.1	7.36
			8.0	18.81	0.432	0.10	1.3	7.22
STA-10	**1.20**	**0.90**	**0.1**	27.30	0.352	8.60	129.6	8.96
			0.8	26.72	0.357	8.47	126.7	8.97
STA-11	**1.18**	**1.18**	**0.1**	24.70	0.251	5.07	72.9	7.35
			0.7	24.55	0.252	4.93	70.7	7.25

***In-Situ* Monitoring for Lake Hopatcong 9/23/2020**

Station	DEPTH (meters)			Temperature	Specific Conductance	Dissolved Oxygen		pH
	Total	Secchi	Sample	°C	mS/cm	mg/L	% Sat.	S.U.
STA-1	**2.20**	**0.90**	**0.1**	17.12	0.346	10.57	109.7	8.00
			1.0	17.11	0.347	10.50	109.0	7.92
			2.0	16.37	0.348	10.31	105.4	7.92
STA-2	**14.20**	**1.30**	**0.1**	18.74	0.429	9.14	98.1	7.80
			1.0	18.73	0.429	9.09	97.6	7.81
			2.0	18.70	0.429	9.03	96.9	7.76
			3.0	18.69	0.429	8.89	95.4	7.71
			4.0	18.64	0.429	8.80	94.3	7.78
			5.0	18.61	0.429	8.56	91.6	7.74
			6.0	18.57	0.429	8.49	90.8	7.60
			7.0	18.58	0.430	8.49	90.8	7.63
			8.0	18.49	0.430	8.45	90.2	7.57
			9.0	18.15	0.433	8.49	90.4	7.67
			10.0	14.89	0.453	0.56	5.9	7.30
			11.0	12.63	0.448	0.56	5.3	7.02
			12.0	11.80	0.447	0.38	3.5	6.89
			13.0	11.37	0.453	0.31	2.8	6.79
			14.0	11.13	0.457	0.27	2.4	6.70
STA-3	**2.20**	**0.90**	**0.1**	17.25	0.513	10.62	110.4	7.80
			1.0	16.81	0.515	10.63	109.7	7.93
			2.0	16.62	0.521	10.41	107.0	7.89
STA-4	**3.10**	**1.30**	**0.1**	17.32	0.431	10.19	106.3	8.13
			1.0	17.31	0.431	10.17	106.0	8.17
			2.0	17.25	0.431	10.16	105.7	8.13
			3.0	17.14	0.432	9.67	100.5	8.08
STA-5	**3.10**	**1.10**	**0.1**	16.72	0.439	10.16	104.6	8.00
			1.0	16.71	0.439	10.12	104.2	8.01
			2.0	16.60	0.439	10.14	104.2	8.01
			2.5	16.54	0.439	10.04	103.0	8.05
STA-6	**3.20**	**1.30**	**0.1**	18.62	0.427	8.11	86.9	7.42
			1.0	18.59	0.427	8.05	86.1	7.47
			2.0	18.09	0.427	8.14	86.3	7.48
			3.0	17.35	0.429	8.70	90.7	7.54
STA-7	**1.50**	**1.20**	**0.1**	16.42	0.368	10.40	106.3	8.12
			1.0	16.21	0.373	10.35	105.3	8.06
STA-8	**6.10**	**1.20**	**0.1**	18.42	0.428	8.77	93.6	7.62
			1.0	18.40	0.429	8.73	93.1	7.66
			2.0	18.37	0.429	8.71	92.8	7.63
			3.0	18.34	0.429	8.66	92.3	7.65
			4.0	18.33	0.428	8.61	91.7	7.66
			5.0	18.28	0.429	8.60	91.5	7.62
			5.5	18.12	0.429	8.57	91.0	7.60
STA-9	**8.20**	**1.00**	**0.1**	18.74	0.429	6.50	69.8	7.43
			1.0	18.65	0.428	6.30	67.5	7.39
			2.0	18.57	0.428	6.27	67.4	7.37
			3.0	18.26	0.429	5.84	62.0	7.34
			4.0	18.21	0.429	5.68	60.5	7.32
			5.0	18.21	0.428	5.87	62.3	7.33
			6.0	18.19	0.428	6.08	64.5	7.35
			7.0	17.58	0.432	2.76	28.9	7.14
			8.0	17.10	0.438	1.27	13.2	7.14
STA-10	**1.10**	**0.60**	**0.1**	16.45	0.383	10.88	111.5	8.46
			0.6	16.45	0.382	10.97	112.3	8.43
STA-11	**1.00**	**1.00**	**0.1**	15.13	0.335	9.47	94.3	7.75
			0.7	15.14	0.336	9.44	93.9	7.62

APPENDIX C

DISCRETE DATA

Discrete Data 5/19/2020

STATION	Chlorophyll a (ug/L)	NH3-N (mg/L)	NO3-N (mg/L)	SRP (mg/L)	TP (mg/L)	TSS (mg/L)
ST-1	14.0	ND<0.01	0.10	ND<0.002	0.03	3
ST-2 SURFACE	21.0	ND<0.01	0.02	ND<0.002	0.02	2
ST-2 MID	20.0	ND<0.01	0.06	ND<0.002	0.02	2
ST-2 DEEP		0.01	0.08	ND<0.002	0.03	4
ST-3	2.7	ND<0.01	0.26	ND<0.002	0.02	2
ST-4	6.9	ND<0.01	0.02	0.007	0.02	ND<2
ST-5	5.5	ND<0.01	0.02	ND<0.002	0.02	ND<2
ST-6	17.0	ND<0.01	0.02	ND<0.002	0.02	2
ST-7	9.2	ND<0.01	0.08	ND<0.002	0.03	6
ST-10	19.0	ND<0.01	0.40	ND<0.002	0.04	8
ST-11	6.6	ND<0.01	0.13	ND<0.002	0.02	ND<2

Discrete Data 6/12/20

STATION	Chlorophyll a (ug/L)	NH3-N (mg/L)	NO3-N (mg/L)	SRP (mg/L)	TP (mg/L)	TSS (mg/L)
ST-1	16.0	0.02	0.01	ND<0.002	0.03	7
ST-2 SURFACE	21.0	0.01	ND<0.01	ND<0.002	0.02	3
ST-2 MID	21.0	0.13	ND<0.01	0.002	0.09	6
ST-2 DEEP		0.22	0.01	0.008	0.34	5
ST-3	9.6	0.01	ND<0.01	ND<0.002	0.04	2
ST-4	9.1	0.01	ND<0.01	0.003	0.03	3
ST-5	9.4	0.02	ND<0.01	ND<0.002	0.03	4
ST-6	8.3	0.02	ND<0.01	ND<0.002	0.04	3
ST-7	14.0	0.08	0.03	ND<0.002	0.04	4
ST-10	16.0	0.13	0.11	ND<0.002	0.04	9
ST-11	18.0	0.17	0.04	0.003	0.03	5

Discrete Data 7/22/20

STATION	Chlorophyll a (ug/L)	NH3-N (mg/L)	NO3-N (mg/L)	SRP (mg/L)	TP (mg/L)	TSS (mg/L)
ST-1	32.0	0.01	0.03	ND<0.002	0.04	9
ST-2 SURFACE	16.0	0.01	0.02	ND<0.002	0.03	2
ST-2 MID	19.0	0.02	0.01	ND<0.002	0.03	3
ST-2 DEEP		0.25	0.13	0.008	0.27	5
ST-3	30.0	0.02	0.03	ND<0.002	0.06	5
ST-4	19.0	0.01	0.02	ND<0.002	0.04	3
ST-5	22.0	0.01	0.03	ND<0.002	0.03	4
ST-6	15.0	0.01	0.02	ND<0.002	0.03	4
ST-7	13.0	0.01	0.04	ND<0.002	0.04	8
ST-10	28.0	0.01	0.04	ND<0.002	0.05	12
ST-11	8.2	0.01	0.05	0.003	0.05	2

Discrete Data 8/24/20

STATION	Chlorophyll a (ug/L)	NH3-N (mg/L)	NO3-N (mg/L)	SRP (mg/L)	TP (mg/L)	TSS (mg/L)
ST-1	36.0	0.02	0.04	ND<0.002	0.06	14
ST-2 SURFACE	24.0	0.01	0.02	ND<0.002	0.01	10
ST-2 MID	14.0	0.01	0.02	0.002	0.02	6
ST-2 DEEP		0.17	0.12	0.061	0.28	6
ST-3	55.0	0.01	0.04	0.002	0.08	13
ST-4	20.0	0.01	0.02	ND<0.002	0.04	11
ST-5	28.0	ND<0.01	0.02	ND<0.002	0.04	10
ST-6	17.0	0.01	0.02	ND<0.002	0.04	8
ST-7	10.0	0.01	0.05	0.002	0.04	6
ST-10	25.0	ND<0.01	0.05	0.002	0.05	13
ST-11	13.0	ND<0.01	0.04	ND<0.002	0.05	14

Discrete Data 9/23/20

STATION	Chlorophyll a (ug/L)	NH3-N (mg/L)	NO3-N (mg/L)	SRP (mg/L)	TP (mg/L)	TSS (mg/L)
ST-1	28.0	ND<0.01	0.04	ND<0.002	0.03	8
ST-2 SURFACE	19.0	ND<0.01	0.02	0.004	0.02	2
ST-2 MID	15.0	ND<0.01	0.04	ND<0.002	0.02	3
ST-2 DEEP		0.20	0.23	0.113	0.41	6
ST-3	28.0	ND<0.01	0.07	0.002	0.03	3
ST-4	14.0	ND<0.01	0.02	ND<0.002	0.02	2
ST-5	17.0	ND<0.01	0.04	ND<0.002	0.03	2
ST-6	14.0	ND<0.01	0.03	ND<0.002	0.02	2
ST-7	8.3	ND<0.01	0.05	ND<0.002	0.02	9
ST-10	32.0	ND<0.01	0.09	ND<0.002	0.06	14
ST-11	3.2	ND<0.01	0.04	ND<0.002	0.02	ND<2

APPENDIX D

PLANKTON DATA

Phytoplankton and Zooplankton Community Composition Analysis

Sampling Location: Lake Hopatcong			**Sampling Date: 5/19/20**			**Examination Date: 5/19/20**		
Site 1: ST2 Surface			**Site 2: ST2 Mid**					
Phytoplankton								
Bacillariophyta (Diatoms)	**1**	**2**	**Chlorophyta (Green Algae)**	**1**	**2**	**Cyanophyta (Blue-Green Algae)**	**1**	**2**
Asterionella	705	349	*Chlorella*	380	489	*Aphanizomenon*	27,109	35,849
Fragilaria	976	4,403	*Atractomorpha*	54		*Pseudanabaena*	1,572	1,677
Synedra	271	1,258	*Haematococcus*	54				
Tabellaria	1,139	3,005	*Scenedesmus*		559			
Cyclotella	108					**Cryptomonads**		
Chrysophyta (Golden Algae)						*Cryptomonas*	542	559
Zooplankton								
Cladocera (Water Fleas)	**1**	**2**	**Copecoda (Copepods)**	**1**	**2**	**Rotifera (Rotifers)**	**1**	**2**
Chydorus	C	C	*Microcyclops*	C	C	*Conochilus*	R	
Bosmina	A	C	nauplii	C	C	*Polyarthra*	P	R
Daphnia		R				*Asplanchna*	P	C
Leptodora		R				*Keratella*	A	A
						Trichocerca	R	R
Sites:	**1**	**2**	**Comments:**					
Total Phytoplankton Cells/mL	32,910	48,148						
Total Cyanobacteria Cells/mL	28,681	37,526						
Total Zooplankton Genera	9	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);					

Phytoplankton and Zooplankton Community Composition Analysis

Sampling Location: Lake Hopatcong			**Sampling Date: 6/12/20**			**Examination Date: 6/17/20**		
Site 1: ST2 Surface*			**Site 2: ST2 Mid**					
Phytoplankton								
Bacillariphyta (Diatoms)	**1**	**2**	**Chlorophyta (Green Algae)**	**1**	**2**	**Cyanophyta (Blue-Green Algae)**	**1**	**2**
Asterionella	67		*Chlorella*	183	435	*Aphanizomenon*	41,833	46,734
Fragilaria	1,950	532	*Gloeotila*	450	484	*Pseudanabaena*		2,467
Synedra	100	629	*Haematococcus*	50		*Dolichospermum*	8,150	2,806
Pinnularia		48	*Pediastrum*	600		*Coelosphaerium*	867	290
Tabellaria	5,708	339	*Dictyosphaerium*	100		*Microcystis*	2,500	
Melosira	1,700		*Scenedesmus*	133		*Aphanocapsa*	250	
			Eudorina	83		**Cryptomonads**		
Chrysophyta (Golden Algae)			*Desmidium*	83		*Cryptomonas*	67	145
Dinobryon	1,050							
Mallomonas		97	*Coelastrum*		581	**Dinoflagellates**		
			Crucigenia		48	*Ceratium*	8	
			Ankistrodesmus		48			
Zooplankton								
Cladocera (Water Fleas)	**1**	**2**	**Copecoda (Copepods)**	**1**	**2**	**Rotifera (Rotifers)**	**1**	**2**
Bosmina	C	C	nauplii	P	P	*Conochilus*	R	R
						Polyarthra	C	C
						Asplanchna		R
						Keratella	P	C
						Trichocerca	P	P
						Ploesoma	R	
Sites:	**1**	**2**	**Comments: * ST2 surface grab collected through Schindler**					
Total Phytoplankton Cells/mL	65,932	55,683						
Total Cyanobacteria Cells/mL	53,600	52,297						
Total Zooplankton Genera	7	7						
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: 7/22/20**			**Examination Date: 7/23/20**		
Site 1: ST2 Surface			**Site 2: ST2 Mid**					
Phytoplankton								
Bacillariphyta (Diatoms)	**1**	**2**	**Chlorophyta (Green Algae)**	**1**	**2**	**Cyanophyta (Blue-Green Algae)**	**1**	**2**
Melosira	356	861	*Chlorella*	2,854	1,206	*Aphanizomenon*	7,493	9,132
Fragilaria		516	*Chlamydomonas*		57	*Aphanocapsa*	892	8,845
Tabellaria	981	804	*Ankistrodesmus*	446	114	*Dolichospermum*	5,798	12,348
			Crucigenia	1,784		*Coelosphaerium*	4,460	5,743
Dinoflagellates			*Golenkinia*		57			
Gymnodinium	89		*Oocystis*		114			
			Scenedesmus	713		**Cryptomonads**		
Chrysophyta (Golden Algae)			*Sphaerocystis*	4,192	1,321	*Chroomonas*	892	
Dinobryon		57	*Staurastrum*	535				
Mallomonas		57				**Euglenophyta**		
						Trachelomonas	178	57
Zooplankton								
Cladocera (Water Fleas)	**1**	**2**	**Copecoda (Copepods)**	**1**	**2**	**Rotifera (Rotifers)**	**1**	**2**
Bosmina	R	A	nauplii	C	A	*Conochilus*	P	
Ceriodaphnia	P	P	Microcyclops	P	C	*Filinia*	R	R
						Lepadella	R	
						Keratella	A	C
						Monostyla	R	R
						Polyarthra	A	C
						Pompholyx		R
						Trichocerca	R	P
Sites:	**1**	**2**	**Comments:**					
Total Phytoplankton Cells/mL	31,663	41,289						
Total Cyanobacteria Cells/mL	18,643	36,068						
Total Zooplankton organisms/L	11	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);					

Phytoplankton and Zooplankton Community Composition Analysis

Sampling Location: Lake Hopatcong			**Sampling Date: 8/24/20**			**Examination Date: 8/26/20**		
Site 1: ST2 Surface			**Site 2: ST2 Mid**					
Phytoplankton								
Bacillariphyta (Diatoms)	**1**	**2**	**Chlorophyta (Green Algae)**	**1**	**2**	**Cyanophyta (Blue-Green Algae)**	**1**	**2**
Synedra	683	1,377	*Chlorella*		230	*Aphanizomenon*	36,443	5,050
Tabellaria	3,644	918	*Chlamydomonas*		918	*Calothrix*	23,916	
			Carteria	228		*Dolichospermum*	3,961	2,295
			Sphaerocystis	7,289		*Pseudanabaena*	56,942	16,297
			Golenkinia		230	*Coelosphaerium*	6,833	
Dinoflagellates	**1**	**2**	*Bambusina*		918	*Plankothrix*	34,165	16,068
			Scenedesmus	456		*Merismopedia*		20,658
			Staurastrum	228		**Cryptomonads**	**1**	**2**
Chrysophyta (Golden Algae)	**1**	**2**	*Gloeocystis*	683				
Dinobryon		689	*Rhizoclonium*		6,197			
Mallomonas		230				**Euglenophyta**	**1**	**2**
Chrysophaera	456	230						
Ochoromonas	683	918						
Zooplankton								
Cladocera (Water Fleas)	**1**	**2**	**Copecoda (Copepods)**	**1**	**2**	**Rotifera (Rotifers)**	**1**	**2**
Bosmina		P	nauplii	P	P	*Conochilus*	R	P
Ceriodaphnia	R	P	*Cyclops*	P	C	*Keratella*	P	P
			Diaptomus	R		*Trichocerca*	R	R
						Brachionus		R
						Asplanchna		R
						Polyarthra		R
Sites:	**1**	**2**	**Comments:**					
Total Phytoplankton Cells/mL	176,614	73,231						
Total Cyanobacteria Cells/mL	162,260	60,368						
Total Zooplankton organisms/L	7	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);					

Phytoplankton and Zooplankton Community Composition Analysis

Sampling Location: Lake Hopatcong			**Sampling Date: 9/23/20**			**Examination Date: 9/24/20**		
Site 1: ST2 Surface			**Site 2: ST2 Mid**					
Phytoplankton								
Bacillariphyta (Diatoms)	**1**	**2**	**Chlorophyta (Green Algae)**	**1**	**2**	**Cyanophyta (Blue-Green Algae)**	**1**	**2**
Melosira		592	*Scenedesmus*	963	592	*Aphanizomenon*	4717	13615
Synedra	963	592	*Chlamydomonas*	193		*Pseudanabaena*	6642	1578
Tabellaria	2407	2960	*Ankistrodesmus*	96		*Dolichospermum*	4621	
			Staurastrum		296	*Cylindrospermopsis*	1348	3749
Dinoflagellates			*Crucigenia*		2072	*Coelosphaerium*	9626	
						Cryptomonads		
Chrysophyta (Golden Algae)						*Cryptomonas*	1059	691
Mallomonas		197						
						Euglenophyta		
						Trachelomonas		99
Zooplankton								
Cladocera (Water Fleas)	**1**	**2**	**Copecoda (Copepods)**	**1**	**2**	**Rotifera (Rotifers)**	**1**	**2**
Bosmina	P	P	nauplii	A	A	*Conochilus*	A	A
Ceriodaphnia	R	R	Microcyclops	A	A	*Asplanchna*	P	
						Keratella	A	A
						Trichocerca	R	C
						Ploesoma		R
						Polyarthra	C	C
Sites:	**1**	**2**	**Comments:**					
Total Phytoplankton Cells/mL	32,635	27,033						
Total Cyanobacteria Cells/mL	26,954	18,942						
Total Zooplankton organisms/L	9	9						
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: 9/23/20**			**Examination Date: 9/24/20**		
Site 1: ST2 Surface			**Site 2: ST2 Mid**					
Phytoplankton								
Bacillariphyta (Diatoms)	**1**	**2**	**Chlorophyta (Green Algae)**	**1**	**2**	**Cyanophyta (Blue-Green Algae)**	**1**	**2**
Melosira		592	*Scenedesmus*	963	592	*Aphanizomenon*	4717	13615
Synedra	963	592	*Chlamydomonas*	193		*Pseudanabaena*	6642	1578
Tabellaria	2407	2960	*Ankistrodesmus*	96		*Dolichospermum*	4621	
			Staurastrum		296	*Cylindrospermopsis*	1348	3749
Dinoflagellates			*Crucigenia*		2072	*Coelosphaerium*	9626	
						Cryptomonads		
Chrysophyta (Golden Algae)						*Cryptomonas*	1059	691
Mallomonas		197						
						Euglenophyta		
						Trachelomonas		99
Zooplankton								
Cladocera (Water Fleas)	**1**	**2**	**Copecoda (Copepods)**	**1**	**2**	**Rotifera (Rotifers)**	**1**	**2**
Bosmina	P	P	nauplii	A	A	*Conochilus*	A	A
Ceriodaphnia	R	R	Microcyclops	A	A	*Asplanchna*	P	
						Keratella	A	A
						Trichocerca	R	C
						Ploesoma		R
						Polyarthra	C	C
Sites:	**1**		**Comments:**					
Total Phytoplankton Cells/mL	32,635	27,033						
Total Cyanobacteria Cells/mL	26,954	18,942						
Total Zooplankton organisms/L	9	9						
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);					