LAKE PEEKSKILL 2022 WATER QUALITY AND MACROPHYTE REPORT

TOWN OF PUTNAM VALLEY, PUTNAM COUNTY, NEW YORK

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PREPARED FOR:
TOWN OF PUTNAM VALLEY
ATTN: MS. JACQUELINE ANNABI
265 OSCAWANA LAKE ROAD,
PUTNAM VALLEY, NY 10579

PREPARED BY:
PRINCETON HYDRO, LLC
PO BOX 3689
TRENTON, NEW JERSEY 08629
(908)-237-5660

1.0 INTRODUCTION

The report that follows has been prepared by Princeton Hydro, LLC for the Town of Putnam Valley. This report presents, reviews, and summarizes the findings of the various activities conducted at Lake Peekskill in 2022. This includes a water quality monitoring program and submerged aquatic vegetation survey conducted by Princeton Hydro.

In 2022, Princeton Hydro was contracted by the township to assess water quality and submerged aquatic vegetation (SAV) conditions in Lake Peekskill, particularly as they pertain to sterile grass carp (*Ctenopharyngodon idella*) that were stocked in the lake in 2003. Since the stocking of these fish, some changes have been observed in the water quality of the lake that are generally viewed as positive by the lake community. It is estimated that sterile grass carp live to approximately 12 to 15 years old. As this genetic strain of grass carp does not reproduce, it is presumed that most if not all of those stocked in the lake in 2003 have likely perished. As carp populations drop, increases may be observed in the lake's SAV populations. Princeton Hydro surveyed the SAV community and water quality in Lake Peekskill in 2022 in order to obtain data that may be used to inform future supplemental stocking of grass carp.

The 2022 monitoring program involved the collection of key water quality data for two (2) sites on the Lake, in addition to a line-intercept SAV survey conducted in several locations around the lake's shoreline. Data collected in Lake Peekskill was collected using monitoring protocols Princeton Hydro has successfully employed on numerous other lakes in the northeast. Specifically, the 2022 monitoring program consisted of the following:

- *In situ* (real-time) depth-specific water quality measurements of dissolved oxygen, temperature, pH, specific conductivity, and water clarity,
- Collection of discrete water quality samples for the laboratory analysis of nutrients and chlorophyll a,
- Collection and analysis of phytoplankton and zooplankton samples, and
- Sampling of the Lake's aquatic macrophyte (plant) community.

The collected data are used by Princeton Hydro to guide the township in management decisions used for the Lake. The overarching objective of a water quality monitoring program is to use the data in a pro-active manner to maximize the Lake's recreational usage, aesthetic attributes, and ecological services and functions. The monitoring program in 2022 focused on the collection of water quality and SAV data from in September and October, the end of what is often referred to as the "growing season". The balance of this report reviews the water quality and SAV data collected in Lake Peekskill in 2022. This report discusses this data in a streamlined format and concludes with a series of recommendations for the management of the Lake in 2023.

Princeton Hydro has also developed watershed-based best-management practices (BMPs) to address stormwater inputs into Lake Peekskill and associated nutrient and sediment input. The details of this assessment can be found in Section 5.0.

Finally, a brief historical data review was also conducted and can be found in Section 2.0

2.0 HISTORICAL DATA REVIEW

According to a Phase I Dam Inspection Report published in 1981 (NY District Corps of Engineers), Lake Peekskill's dam was designed in 1928 and is located on an unnamed tributary to Peekskill Hollow Brook. Prior to the construction of this dam, a smaller waterbody existed in its place known as Cranberry Pond (Muller, 1990). Since 1990, the lake has been sampled annually by members of the local community through the Citizens Statewide Lake Assessment Program (CSLAP). Water clarity measured by a Secchi disk was reported to be relatively high at times during the 90's, with an average of 2.6 m between 1990 and 1996 and a high clarity of 4.5 m recorded from 1993. The following two decades displayed an overall reduction water clarity, typically less than 2 m, and the 2020 season yielded clarities lower than past decadal trends, typically measuring between 1.1 – 1.3 m throughout most of the summer before increasing slightly in September. The 2020 report also indicated significant long-term increases in surface total phosphorus, surface ammonia, conductivity, and near-surface temperature. As part of the CSLAP program, a basic aquatic vegetation survey was also conducted. As of the 1996 CSLAP report, the most abundant vegetation species in the lake included coontail (*Ceratophyllum demersum*), *Chara* algae, water grass (*Graminea sp.*), and bigleaf pondweed (*Potamogeton amplifolius*). The invasive plant species curlyleaf pondweed (*Potamogeton crispus*) is known to also have occurred in Peekskill Lake, being first identified in 1992.

A water quality assessment performed by Princeton Hydro LLC in 2014 indicated that thermal stratification and associated decreases in dissolved oxygen at depth was occurring during. This survey also measured a Secchi depth of 0.9 m. While most discrete water quality parameters from this event were relatively low, surface Chlorophyll *a* concentrations were obtained at approximately 26 mg/m³, with the cyanobacteria *dolichospermum (*formerly known as *Anabaena*) being present in bloom-like densities. Little aquatic vegetation was observed during this event.

In 2018, the lake received an aeration system installation by Clean-Flo. The company also conducted water quality surveys in 2018 and 2019, showing problems with deep-water anoxia in 2018 but not in 2019, suggesting that the new aerator system had mitigated some of the issues associated with thermal stratification and dissolved oxygen reduction. Total phosphorus concentrations, found initially to be relatively high in 2018, also displayed a downward trend by 2019, with a 2019 seasonal high of 0.04 mg/L, and phytoplankton communities shifted from a cyanobacteria-dominated system to one dominated by Green algae. Follow-up surveys conducted in 2020 and 2021 found the lake in 2020 to feature deep phosphorus concentrations higher than those obtained in 2019, with a seasonal maximum of 0.09 mg/L. Phosphorus concentrations in 2021 were generally below 0.05 mg/L. Harmful cyanobacteria were found to dominate the phytoplankton community in August 2020, while 2021 featured communities largely dominated by green algae.

3.0 METHODS

Water quality monitoring and the SAV survey followed EPA-based protocols based on work conducted by Princeton Hydro in numerous lakes in the northeast. These methods aim to form a consistent long-term dataset that can be examined for trends and patterns useful in aiding the year-to-year management of the Lake.

Lake Peekskill was sampled twice over the course of the late summer/fall season of 2022. Each sampling event consisted of the following:

- ***In Situ* Sampling:** The measurement of various water quality parameters in real-time using a calibrated multi-probe water quality meter. Princeton Hydro is certified by the New Jersey Department of Environmental Protection (#10006) for the in-field collection of these data. Data is collected at every 1 meter in depth, from surface to bottom. Additionally, water clarity is measured at each *In situ* station using a Secchi disk.
- **Discrete Sampling:** The collection of water quality samples for specific laboratory analysis. Samples are collected at the surface and at a depth close to the bottom sediments to examine important vertical differences in lake water quality. The locations of these stations are provided in the map in Appendix I. All laboratory analyses are conducted by Environmental Compliance Monitoring (ECM) of Hillsborough, New Jersey, a NJDEP certified laboratory (#18630). ECM is the preferred contractor because of their excellent detection limits and focus on natural waterbodies rather than wastewater. Water samples were analyzed for the following:
  - Total Phosphorus (TP)
  - Soluble Reactive Phosphorus (SRP)
  - Chlorophyll *a* (Chl. *a*).
  - Nitrate – Nitrogen (NO_3-N)
  - Nitrate – Ammonia (NH_3)
  - Total Suspended Solids (TSS)
- **Plankton Analysis:** Plankton refers both to phytoplankton (or algae) and zooplankton. These organisms are most responsible for water quality conditions throughout the growing season. During each water quality sampling event, a sample was collected from the southern station using a plankton tow net drawn through a portion of the water column. Samples were preserved and assessed for community composition in Princeton Hydro's in-house laboratory.
- **Macrophyte Survey:** During the September field event, thirteen (13) transects measuring 100' in length were assessed for the growth of submerged aquatic vegetation (SAV) using line-intercept sampling methodology similar to that described by Madsen, 1999. Along each transect, the vegetation community was assessed using an Aqua Scope or a plant rake at 20' intervals, resulting in six (6) points being collected per transect. At each point, SAV was identified to the lowest practical taxon (usually species) and relative density was recorded using the following format:
  - Abundant (A): >50 % of the total plant community
  - Common (C): between 10% and 50% of the total plant community
  - Present (P): <10% of the total plant community
  - Not Present (N): species is not present at the sampling point.
- **General Observations:** Information pertaining to the aesthetics and appearance of the lake was recorded during each site visit. This observational data provides a context and background to better understand the sampling data. These observations also prove useful in identifying correlations between various water quality indicators and such factors as prevailing weather conditions and water color.

4.0 RESULTS AND CONCLUSIONS

4.1: IN SITU DATA

In situ data refers to Temperature, Dissolved Oxygen, pH, and specific conductivity data collected real-time in the field using a water quality meter. Temperature and dissolved oxygen (DO) in particular drive the main conditions of a lake that can influence nutrient loading and subsequent plant, algae, and specific cyanobacteria growth. By measuring these parameters at multiple points through the water column, differences between the surface and bottom-most depths of a lake can be determined. For example, thermal stratification is the natural process during which a lake will be divided into two or more layers of differing temperature. This will occur during the summer months, when surface waters warm and become less dense, while water near the bottom of the water column remains relatively cold and dense. The point along the water column at which the temperature drops the quickest between two measured depths is referred to as the thermocline. A major impact of this process is the depletion of dissolved oxygen (DO) near the bottom of the water column as a product of reduced surface mixing and deep-water microbial activity. Under these conditions, not only is cold-water fish habitat reduced, but a total lack of oxygen at the bottom sediments (referred to as anoxia) may allow for redox reactions to occur, resulting in phosphorus normally bound to the sediment to become soluble in the water column. The mixing of the water column as a result of temperature decreases at the end of the year or a large storm event can allow this phosphorus to then move to the top of the water column, where it is available for assimilation by algae and cyanobacteria present in the photic zone. For this reason, many lakes experience algae blooms in the fall season, shortly following "lake turnover". All *In situ* data collected in 2022 is provided in Appendix II.

During both of the water quality events, Lake Peekskill was measured to be well-mixed thermally. The lake's aeration system likely contributed to this, as likely did decreasing fall air temperatures. Dissolved oxygen concentrations were sufficient throughout the water column during both events. During the September event, dissolved oxygen was measured at somewhat supersaturated concentrations (>100%); this likely was contributed to by the cyanobacteria bloom that was observed to be occurring on the lake during this date. Increased amounts of cyanobacteria, algae, and/or plants can often add larger concentrations of dissolved oxygen into the water column through photosynthesis.

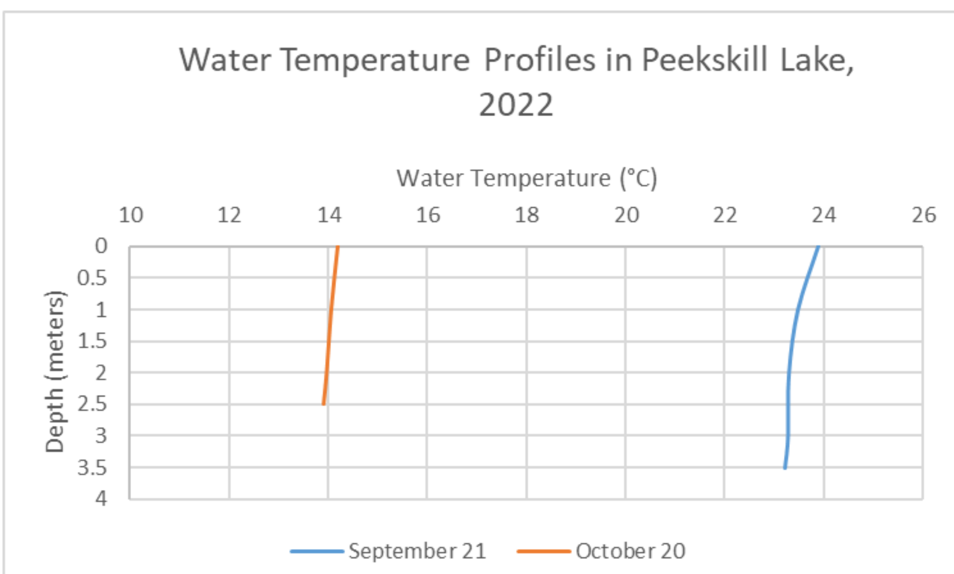

Figure 1. Temperature profiles at the south station at Peekskill Lake during two dates in 2022.

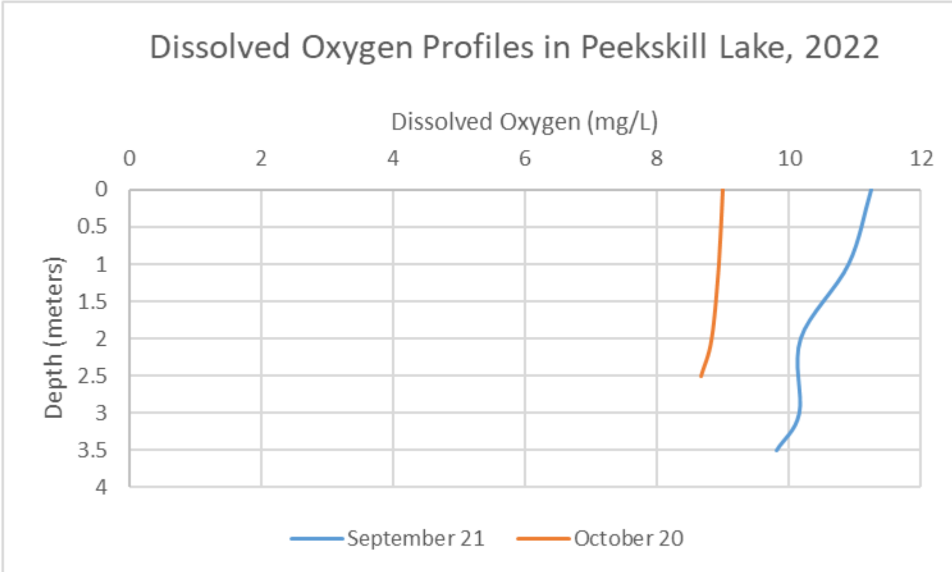

Figure 2. Dissolved oxygen profiles at the south station at Peekskill Lake during two dates in 2022.

Water clarities, represented by Secchi Depths, were somewhat low in September at only 1 m, likely due to cyanobacteria blooms. By October, these had increased by almost a full meter to 1.9 m. The changes between water clarity between the two dates track with the changes in chlorophyll *a*.

4.2: DISCRETE SAMPLING

In many northeastern lakes, algae and cyanobacteria growth is often the result of increases in nutrient loads, particularly phosphorus. This element is usually the limiting nutrient, or the nutrient that is in low supply relative to others. Even a small increase in phosphorus can result in a noticeable increase in algae and cyanobacteria growth. Phosphorus can enter the water column from outside the system as organic debris and pollutants (nutrients) are washed into a waterbody during increased runoff events. Additionally, as described above, phosphorus may enter the water column from the Lake's bottom sediments at an increased rate during periods of bottom anoxia. This is called internal loading. In 2022, water samples collected in Lake Peekskill were analyzed for total phosphorus (TP) and soluble reactive phosphorus (SRP). While TP represents the full amount of phosphorus present in the sample, SRP represents phosphorus that is not bound to algae cells and is thus still available for assimilation by other algae and cyanobacteria. This species of phosphorus is typically measured in very small amounts, and sharp increases can usually result in algae or cyanobacteria blooms.

In addition to phosphorus, water samples were analyzed for nitrogen and ammonia. While nitrogen is not typically the limiting nutrient in most northeastern lakes, it can be assimilated by plants and algae once it has been reduced to ammonia. Nitrogen often enters the waterbody during storm events as organic debris and fertilizers are washed into the waterbody, as well as through atmospheric sources. Additionally, groundwater inputs usually naturally contain relatively high nitrogen concentrations compared to surface water. Ammonia enters the water column through a variety of processes, such as the decomposition of organic matter.

Water samples collected from Lake Peekskill were also analyzed for chlorophyll *a,* a compound utilized during photosynthesis by most plants, algae, and cyanobacteria. Chlorophyll *a* is typically used as a proxy for overall algae and cyanobacteria growth and is usually positively correlated with phosphorus concentrations and negatively correlated with Secchi depths.

Lastly, water samples were analyzed for total suspended solids (TSS), a measure of organic debris and suspended sediments in the water column. A high TSS results in water that appears muddy and features poor water clarity and may explain these conditions in the absence of high chlorophyll *a* concentrations or plankton counts. Often, TSS will increase following a rain event as sediment washes into the waterbody.

A table displaying all discrete water quality data for 2022 is provided in Appendix III.

Lake Peekskill's late-September total phosphorous concentrations were detected to be 0.02 mg/L and 0.03 mg/L for the surface and deep samples, respectively. These are somewhat low; and while the deep sample yielded a slightly higher concentration, this is not a high enough difference to suggest that the lake was experiencing a large degree of internal phosphorus loading at this time. As noted above, the lake's aeration system appears to have maintained a well-oxygenated water column through the two sampling events, so advanced phosphorus loading due to anoxia likely was not prevalent in the lake during this time. By late October, both the surface and deep samples featured total phosphorus concentrations below the minimum detectable limit. Additionally, soluble reactive phosphorus was not measured at detectable limits at either depth for either of the two events.

The September sampling event yielded relatively high concentrations of chlorophyll *a,* with surface and deep samples yielding concentrations of 26 µg/L and 28 µg/L, respectively. This coincides with the apparent cyanobacteria bloom that was occurring during this event. It should be noted that not all species of cyanobacteria utilize chlorophyll *a* and instead rely on other pigments, such as phycocyanin. While it appears that the taxa present in the lake at this time utilized chlorophyll *a*, blooms of other cyanobacteria species can occur that do not yield high concentrations of chlorophyll *a.* A high concentration of chlorophyll *a* can also indicate an abundance of other taxa, such as green algae or diatoms. By the October event, chlorophyll *a* concentrations had decreased sharply, with the surface and deep samples yielding concentrations of 3.3 µg/L and 2.4 µg/L, respectively.

Total nitrogen concentrations were relatively low throughout the season, consistently measuring 0.03 mg/L for both depths during both dates. Again, the relatively well-mixed and well-oxygenated water column likely results in relatively uniform nitrogen concentrations at all depths. Higher concentrations of nitrogen towards the bottom of the water column would suggest the decomposition of organic matter and/or groundwater inputs.

Ammonia-nitrogen concentrations were low during the September event, measuring 0.01 mg/L at both the surface and deep samples. These increased to 0.08 mg/L at both depths by October. This may be due to the fixation of atmospheric nitrogen by bacterial activity. Colder temperatures may also have reduced abundances of microbes that usually convert ammonia into nitrite.

Total suspended solids concentrations were low throughout the season at both depths, with the surface and deep samples in September yielding concentration of 2 mg/L and 3 mg/L, respectively. By October, surface concentrations were below the detectable limit, while deep concentrations had increased slightly to 4 mg/L.

4.3: PHYTOPLANKTON AND ZOOPLANKTON

The data discussed above is primarily the means by which each lake's water quality conditions are documented and are used to determine the severity of episodic or seasonal trophic state impacts. The density and composition of the phytoplankton community and the density and distribution of macrophytes represent the extent of the trophic state impact caused by or associated with changes in water quality data. Greater amounts of plankton and macrophytes are in turn directly linked to greater dissatisfaction amongst lake users.

An emerging concern among many lake communities in the northeast is the increasing prevalence of cyanobacteria ("blue-green algae") blooms. Cyanobacteria tend to be most responsible for the dense algae blooms and surface scums that impact recreation, aesthetics, and environmental functions. These organisms are able to reach these densities because of various competitive advantages they have relative to other algae. Some cyanobacteria can fix atmospheric nitrogen, most can easily metabolically utilize organic forms of phosphorus, and none are effectively grazed by zooplankton. The ability to utilize organic phosphorus is also troubling as organic phosphorus is released following algicide treatments as the cells lyse and split. As a result, over-reliance on copper treatments often stimulates rather than eliminates cyanobacteria blooms.

Zooplankton are an important link between the primary producers (algae) and higher trophic groups, especially fish. Zooplankton feed on phytoplankton, and various aquatic organisms, such as young fish, feed on zooplankton. Monitoring zooplankton density and composition provides a more complete understanding of the trophic dynamics affecting a lake. Herbivorous zooplankters are the group of zooplankton represented by the larger species that have the ability through grazing (feeding) pressure to keep phytoplankton densities in check. *Daphnia* and *Diaptomus* are two example genera.

In many lakes, phytoplankton and zooplankton communities tend to be extremely variable throughout the year, changing seasonally and in response to water quality conditions, herbicide/algaecide treatments, and predator-prey cycles. The sampled zooplankton and phytoplankton data for each event are presented in Appendix IV.

Phytoplankton

During the September 21st sampling event, Lake Peekskill was experiencing a bloom of the cyanobacteria *Microcystis,* with a high abundance of the diatom *Melosira* also being present in the sample. This correlates with the lower Secchi depths, higher chlorophyll *a* concentrations, and green water color occurring during this event. By late-October, *Microcystis* was still common in the sample but had seen a large reduction in density in favor of the filamentous green algae genus *Mougeotia.* The green algae genera *Gloeotila* and *Pediastrum* were also common.

Zooplankton

In September, the zooplankton community was dominated by the smaller cladoceran genus *Bosmina,* with five additional zooplankton taxa being present in the sample in lower relative abundances. *Bosmina* was still abundant in the October 20th sample, with the rotifer *Polyarthra* also co-dominating the sample.

4.4: SUBMERGED AQUATIC VEGETATION

Macrophytes (aquatic plants) are also an important component of aquatic ecosystems. Macrophytes provide important habitat for fish, help stabilize the lake's shoreline and lakebed and compete to some extent with algae for nutrients. However, at excessive densities, macrophytes, especially of non-native invasive species, can be problematic by impeding boating, fishing, and swimming, and may cause additional ecological effects in some instances.

Table 1 below displays the aquatic macrophyte species observed in Lake Peekskill. During the plant survey conducted in September of 2022, Lake Peekskill was observed to contain relatively small amounts of macrophytes. Many transects yielded no macrophytes at all, while those that did usually yielded relatively small amounts of material either immediately along the shoreline or at most 20' from shore. The two most common macrophyte species collected during the survey were the native leafy pondweed (*Potamogeton foliosus*) and the invasive brittle naiad (*Najas minor*). These were not collected in particularly dense quantities, at most reaching the "common" abundance description. Macrophytes were most prevalent in the near-shore quadrats in Transect T9, which is located adjacent to the inlet entering the northern corner of the lake. This transect yielded a biomass of 104 g at the near-shore (0') quadrat. Emergent vegetation was also observed along the shoreline in many transects, largely consisting of cattails (*Typha sp.*). Full tables of macrophyte data from each transect are provided in Appendix V.

Table 1. Aquatic macrophyte species observed in Lake Peekskill, 21 September 2022.

Scientific name	**Common name**
Eleocharis sp.	Spikerush
Fontinalis sp.	Aquatic Moss
Najas minor	Brittle Naiad
Nitella sp.	Stonewort (algae)
Potamogeton foliosus	Leafy Pondweed
Sagittaria sp.	Arrowhead
Typha sp.	Cattail

5.0 POLLUTANT REMOVAL ACHIEVABLE THROUGH THE IMPLEMENTATION OF SPECIFIC WATERSHED BASED MANAGEMENT TECHNIQUES

INTRODUCTION

The primary focus of this task is to identify what can be done in the watershed of the lake to reduce the annual pollutant load which in turn can then minimize the occurrence and development of Harmful Algal Blooms (HABs). With this data, potential watershed-based management measures can be assessed, with the ultimate goal of controlling these HABs.

This task allows for identification of those areas of the watershed having the greatest impact as well as those areas having the most manageable (correctable) loads. Through the proposed watershed assessment, our storm water engineers, and green infrastructure experts have provided a list of BMPs to the Town that can effectively manage the pollutant loads generated by each area's specific pollutant loads. Emphasis has been given to engineered bioretention type systems that can be implemented on a lot-specific or regional scale. Such BMPs have a high capacity for the removal of nutrients. However, given the severe watershed-based limitations (i.e., steep slopes, rock outcroppings, small lots and limited stormwater infrastructure), other options such as retrofitting existing catch basins or replacing them with Manufactured Treatment Devices (MTDs) was also considered.

An examination and discussion of the water quality benefits of restoring and/or creating wetland buffers, riparian buffers, and lakefront aquascape shorelines was also performed. Where possible, based on inspections of the watershed or information contained in reports made available, our field engineer and scientist identified examples of site-specific locations where wetland buffers, riparian buffers, and lakefront aqua-scaping could potentially be implemented as part of future watershed management efforts. Other green infrastructure options as well as MTDs were also considered.

Princeton Hydro reviewed desktop information including parcel boundaries, soils, topography, and land use/land cover as well as aerial imagery to identify potential sites. These sites were then field evaluated to determine recommendable best management practice(s), site constraints, and confirm feasibility to accommodate green infrastructure and provide efficient pollutant removal. Green infrastructure refers to natural and engineered ecological systems that treat stormwater in a way that mimics natural processes. Examples of such systems are bioretention systems or rain gardens that receive stormwater and sequester nutrients, vegetated filter strips and constructed wetlands. In addition to green infrastructure, general recommendations for stormwater management and riparian zone improvements are also included. Figures 3 and 4 below depict the water body and the site locations described in more detail in the subsequent sections. Table 2 presents a list of the proposed Best Management Practice (BMP), the amount of TSS removed, and a conceptual level estimated cost of each intervention.

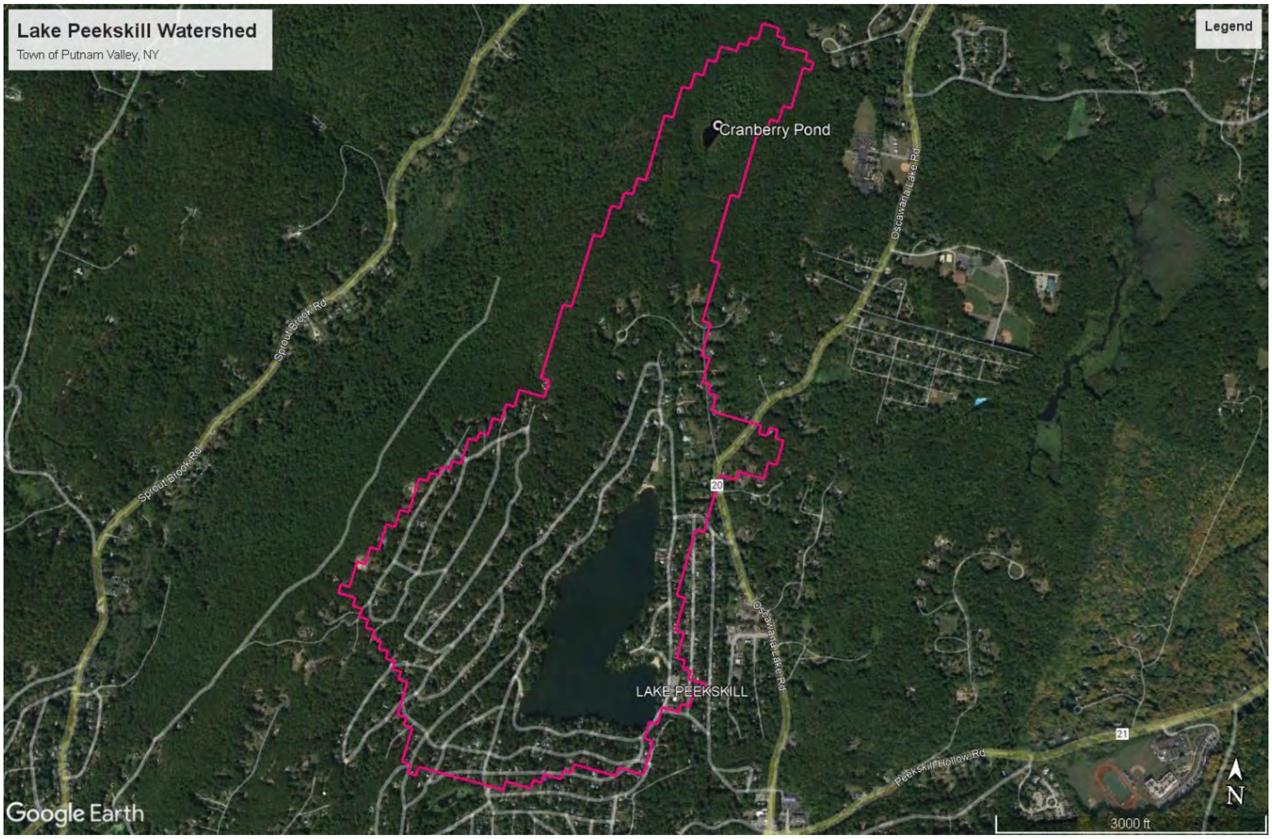

Figure 3: Site Overview of the Lake Peekskill Watershed

Figure 4: Site Overview of the Lake Peekskill Watershed (enlarged) with road names.

Site[1]	Proposed BMP	TSS Removal Rate (%)[2]	Potential Project Cost ($)[3]
1A	Site 1A: Carraras Beach Access Lot Vegetated paver with underdrainage	80	$100,000 - 200,000
1B	Site 1B: Carraras Beach Lakeshore- Boat ramp/storage Vegetated pavers and native aquatic plants	80	$200,000 - 450,000
2	Site 2: Becker Street and Laurel Road- Wooded lot at intersection Vegetated filter strip and bioretention system	80	$90,000 - 200,000
3	Site 3: Becker Street and Walnut Road- Wooded lot at intersection Regrading, stabilized conveyance and enhanced bioretention area	80	$150,000 - 400,000
4	Site 4: Reichert Street and Tanglewylde Road Vegetated conveyance system, soil replacement and native plantings	<50	$300,000 - 600,000
5	Site 5: Aspen Lane and Tanglewylde Road Stabilized vegetated conveyance system w/ stepped pools	<50	$200,000 - 300,000
6A	Site 6A: Pleasant Road East Scour hole, invasive plant treatment and native plantings	<50	$150,000 - $300,000
6B	Site 6B: Pleasant Road West Stabilized vegetated conveyance and bioretention with stone check dams	<50	$150,000 - 400,000
6C	Site 6C: Pleasant Road North Constructed wetland and increased vegetated riparian buffer between road and pond	90	$250,000 - 500,000
7	Site 7: Nardin Road Parcel Vegetated conveyance system, riparian buffer and rain garden	80	$500,000 - 1,200,000
8	Site 8: Lake Peekskill Community Center Building and Property Permeable pavement and rain garden	80	$85,000 - 200,000
9A	Site 9A: North Beach Playground and Recreation Area Vegetated pavers and shoreline buffer plantings	80	$300,000 - 800,000
9B	Site 9B: North Beach Parking Lot, Grass Area and Wet Basin Permeable pavement Wet basin retrofit Pipe daylighting and conveyance modification	80	$180,000 -300,000 $85,000 - 175,000 $70,000 - $300,000
10	Site 10: Lake Drive Stream Outfall Riparian planting	70	$5,000 - 200,000
11	Site 11: Singers Beach Vegetated conveyance system Lawn to meadow conversion Prermeable pavement Bioretention area	<50 70 80 80	$75,000- 150,000 $15,000 - 40,000 $50,000 - 150,000 $150,000 - 450,000
12	Site 12: Lake Drive and Morrissey Drive- Paved Parking Lot Porous pavment conversion with bioretention Manufactured treatment device	80 80	$500,000 - $1,000,000 $650,000 - 850,000

Notes:
1. Site locations are located on Figure 2.
2. Total Suspended Solids (TSS) removal efficiencies are based on the New Jersey Stormwater BMP Manual, Chapters 4 and 9
3. The costs presented are approximate and subject to variability over time and the sizing of the BMP.

Table 2: Best management practice site summary.

The cost estimates provided above are estimates for the entire project phase, including design, engineering, anticipated regulatory permitting, and implementation/installation (construction). While the cost estimates are predicted based on the entire project phase, final costs will vary based on many components that are involved in project design and implementation. Some of these components include, but are not limited to:

- **Site Investigations** – Part of the design process includes several different onsite investigation efforts including topographic survey, wetland delineation, and soils investigations. These investigations and the information gathered during them provide an understanding of the site conditions, any potential design challenges, and permitting pathways for the site.
    - **Depth to Bedrock** – The presence of shallow bedrock can result in implementation complications and a substantial increase in implementation costs.
    - **Depth to Water Table** – The presence of a shallow water table may indicate the presence of a wetland and/or recharge area for groundwater. Thus, this can result in complications as well as an increase in permitting and implementation costs.
    - **Utility Conflicts** – Location of sewer lines, gas lines, power lines, fiber optic lines all need to be located and mapped before any earth-moving or infrastructure work can be initiated. Without such information results could be extremely costly and even disastrous.

  - **Permit Requirements** – Depending on the site features and its location relative to the lake and associated waterways, regulatory permitting can vary from none to minimal to substantial. Thus, the potential required permitting must be determined to quantify the total costs associated with the design phase. While general permitting costs were estimated in the proposed cost for each project, the fees can vary based on access, size of the overall project and project type which have not been determined at this phase.

- **Access and Ownership** – Issues such as rights-of-way and easements need to be identified and agreements in place prior to the progression of the design. Additionally, the source of the funding for implementation may limit where a project can be implemented. For example, typically if a project is being funded through an NPS 319-grant, the project site typically must be located on public / community lands. Private land can be not used for a project site for such grant funding; however, private easements or access approval can be allowed.

- **Maintenance Requirements** – The key to the long-term effectiveness of any watershed / stormwater project is for it to be well maintained. This will include routine activities such as clean-outs and media replacements as well as non-routine activities such as repairs or additional work after particularly large storms. The party responsible for the maintenance of the project needs to be well established and that party needs to be well informed on the maintenance requirements and costs. Any shared services agreements need to be well established prior to the initiation of a project.

SITE RECOMMENDATIONS

GENERAL RECOMMENDATIONS

Along with the specific practices listed for the Best Management Practices (BMP's) at all 18 Sites, Princeton Hydro also provides the following general recommendations: bank stabilization, riparian zone enhancement, and defined stabilized access points for all applicable locations in the project area. The riparian zone is characterized as the buffer surrounding the border of a surface body of water including lakes, ponds and streams many times where hydrophilic vegetation resides. Sometimes, these locations can have vegetation enhancements to introduce more of this type of aquatic plantings into a specific area. Additionally, applying bank stabilization measures of reducing bank slopes, and stabilizing areas of exposed soil near bodies of water will aide in this riparian zone enhancement process. To compliment these actions, defining stabilized access points for people or watercraft to enter bodies of water is recommended. This will help preserve riparian areas, and limit bank erosion in areas with heavy watercraft traffic. While some areas are specifically defined within the following sites, these recommendations can be broadly applied to any waterbody within the watershed.

RIPARIAN ZONE ENHANCEMENT

During Princeton Hydro's site visits it was noted that banks of the lakes, ponds, streams, swales, or other conveyances systems have exposed soil containing little vegetation and/or invasive species. In aquatic settings, vegetation acts as a buffer between the pollutant-rich stormwater and the body of water it surrounds. Eroded and unvegetated banks can be a source of nutrients and sediment into the lake. Additionally, the vegetation on the banks will filter pollutants contained in the stormwater before it enters the water body. Vegetation within a riparian zone should consist of native species and include herbaceous groundcover, trees, and shrubs for soil stability. This vegetation can manage sediment and nutrient loads discharging into the lake. Some areas where this can be implemented are listed specifically below however this can be implemented along any segment of bank.

DEFINED STABILIZED ACCESS POINTS

Throughout the watersheds there are multiple locations for storing and launching of boats including kayaks. Many of these locations do not have defined launch points and the banks are eroded and vertical which makes continued access difficult and can cause further sediment load to enter the lake. Some of these locations are specifically identified as a part of the sites listed below however there are other locations that are not specifically identified, such as on private properties. Defining a location for boaters to access the water, storage boats and equipment, and foot traffic in between these areas will allow for vegetate buffer to establish and start to stabilize the banks. These defined locations should be stabilized so they are not a direct conveyance. Vegetation can be planted in the non-access area to provide stabilization and to deter the use for access. Pending on the access location, stabilization methodology, and size permits may be required from regulatory agencies.

LAKE PEEKSKILL

SITE 1A: CARRARAS BEACH ACCESS LOT

Carraras Beach is in the southwestern corner of Lake Peekskill and the asphalt lot and shoulder lead to the gates that allow vehicular access to the sand boat launches. There are stored boats, a small structure, and a swimming beach within the cove. A portion of the stormwater from Lake Drive flows into inlet grates above and below the paved lot near the lake edge. The discharge point for these inlets was not observed due to lack of access to the gated area near the water's edge. Stormwater that does not get captured by these drainage structures appears to sheet flow or pond and flow from the roughly paved parking area onto the beach. Several timber curbs and rolled asphalt curbs have been placed assumably to prevent this runoff and/or define the limits of the paved lot. Sand looks to be brought in to relieve the erosion on the beach, notably where there is a drop in grade where the paving meets the sand at gates perpendicular to Lake Drive. Refer to Photos 1 and 2 to see the parking area and drainage structures. The drainage area to the potential BMP is paved roadway/shoulder, paved lot and an area of eroding slope that bounds the paved lot.

Photo 1: Access lot at Carraras Beach (looking north)

Photo 2: Access lot at Carraras Beach (looking south)

Recommendation Site 1A: The recommended Best Management Practice (BMP) would be to disconnect the impervious surface via a pavement conversion of portions of the access lot coupled with connecting the existing vegetated areas for potential conveyance, storage, and filtration of the runoff. The asphalt lot area could be partially converted to either a vegetated or a porous pavement system, which allows for filtration of stormwater prior to entering the lake or other drainage system thus reducing the total amount of sediment and excess nutrients discharged into the lake. The conversion of paved surfaces will also reduce stormwater velocities, ponding of stagnant water, provide filtration, and general enhancement to the public space. Vegetated pavers or porous pavement may require underdrains and have outlet structures connected to the existing stormwater collection system via piping under the lot.

Estimated Costs Site 1A: The approximate cost for design, permitting, and implementation of this BMP recommendation is anticipated to be between $100,000 and $200,000 the cost could vary based on the area of the improvements and potential infrastructure.

SITE 1B: CARRARAS BEACH LAKESHORE

The Carraras Beach lakeshore occupies the areas from the paved edge of Lake Drive and wraps the southwestern corner of the lake. There is a swimming beach, a northern boat launch with storage area, and a southern boat launch with storage area. The northern boat launch and storage area consists of a loose gravel and soil mix to the water's edge while the southern launch appears to be sand with the boat storage being on heavily compacted soil on a terrace built up with boulder facing. Areas of high use become compacted and impermeable over time.

Photo 3: Carraras Beach waterfront northern boat launch

Photo 4: Carraras Beach lakeshore looking south to southern boat launch.

Recommendation Site 1B: Converting the two existing boat ramps to vegetated pavers will filter the surrounding impervious surface runoff into the ground before the sediment and pollutants contained within it flow completely into the lake. In addition, portions of the beach shore could benefit from the introduction of native aquatic plants, potential regrading, and a vegetated buffer to provide increased nutrient uptake by the lake ecosystem and reduce additional nutrient loading from entering the lake. The lake would also benefit from increased aeration within the water column in this area with other in-lake measures such as Floating Wetland Islands or Biochar to increase the removal of nutrients from the pool's water column.

Estimated Costs Site 1B: The approximate cost for design, permitting, and implementation of this BMP is anticipated to be between $200,000 and $450,000. These recommendations may be implemented separately or as one larger improvement project. The costs assume implementation as a single project.

SITE 2: WOODED LOT AT INTERSECTION OF BECKER STREET AND LAUREL ROAD

Site 2 is the wooded lot at the northeast corner of the intersection of Becker Street and Laurel Road. Both Laurel Road and Becker Street have no observed stormwater inlets immediately above or below the lot. The asphalt surfaces from the centerline in both directions appear to drain toward the lot. The wooded lot has a significant depression compared to the surrounding area and was observed to have evidence of receiving runoff drainage in the recent past, though no piped outfalls were observed. In its current state the vegetation is a mixture of trees, areas of exposed rock outcrops, native and invasive shrubs and vines with little to no visible understory at the time of site visit in December. Refer to photos 5 and 6 for existing conditions.

Photo 5: Sheet flow condition at pavement edge

Photo 6: Existing depression and vegetation in wooded lot

Recommendation Site 2: The recommendation for this site is to take advantage of the natural low point in the woodlot and create a vegetated filter strip, bioswale or other bioretention area. This location already has a gradually sloping vegetative buffer between the impervious area and the recommended best management practice. Creating a bioswale at the edges and populating it with multi-stress tolerant perennial plants could be an additional beneficial use of this wooded lot. Any runoff from the residential houses that enter the roadway adjacent to this lot would also be slowed and filtered in addition to flow from the roads themselves. It is not recommended at this time to remove existing healthy trees for the purposes of stormwater management interventions. Property ownership and depth to bedrock/soil conditions would also need to be assessed and found suitable in order to utilize this area to further manage stormwater.

Estimated Costs Site 2: The approximate cost for design, permitting, and implementation of this BMP is anticipated to be between $90,000 and $200,000 depending on scale of practice.

SITE 3: WOODED LOT AT INTERSECTION OF BECKER STREET AND WALNUT ROAD

Site 3 is the wooded lot at the northern corner of the intersection of Becker Street and Walnut Road.

A grated inlet was observed on Walnut Road close to the corner as well as inlets at each of the two stop signs on either side of Becker Street. There is visible piped discharge from one or more of these inlets that outfalls into the wooded lot into an earthen swale that drains into the depressed area of the lot. Further to the northeast along Walnut Road, there is a headwall that discharges into the lot from an unobserved source and surface water was seen at this location on a dry weather day. The site is currently vegetated with trees and shrubs and was seen to have a grassy, weedy perennial layer from Google Earth imagery from the summer months. Refer to photos 7 and 8 for existing conditions.

Photo 7: Sheet flow condition at pavement edge

Photo 8: Existing depression in wooded lot

Recommendation Site 3: The recommendation for this site is to enhance the existing stormwater capture and retention function in the wooded lot by regrading the existing eroded and incised swale to a stabilized, vegetated stormwater conveyance and enhanced bioretention area. This location has a reasonable vegetated buffer between the impervious area and the recommended best management practice. Dense plantings and creating energy attenuation using stones at outfalls and at points along the swale would add to the ability of this site to filter sediment and absorb energy to reduce erosion from the discharge points during heavy flow events. In addition to providing scour protection, the stones will spread out the flow of water, thus increasing the treatment time. Due to the nature of this site, invasive plant species removal and treatment is also recommended. It is not recommended at this time to remove existing healthy trees or unnecessarily disturb their root zones for the purposes of stormwater management interventions. Property ownership and soil conditions would also need to be assessed and found suitable to utilize this area to further manage stormwater.

Estimated Costs Site 3: The approximate cost for design, permitting, and implementation of either alternative at this BMP location is anticipated to be between $150,000 and $400,000.

SITE 4: REICHERT STREET AND TANGLEWYLDE ROAD

This section of Tanglewylde Road is paved with an asphalt drainage swale that runs along the northwest side of the road and ends in an inlet at the northwest corner of the intersection with Reichert Street. Photo 9 shows the location of the inlet and the asphalt drainage swale. The swale borders approximately 350 linear feet of road with a portion of the road runoff draining into it and is bordered by residential landscaped areas and/or weedy, gravel verge on the non-roadside. The impervious area of the road combined with the surrounding drainage of the sloped and thinly planted landscape areas add excess sediment and nutrients to the drainage system. The existing conditions do not filter the stormwater runoff before conveying these excess pollutants into the overall drainage system and ultimately the lake.

Photo 9: Tanglewylde Road existing asphalt ditch with potential for conversion to bioswale prior to entering drain.

Recommendation Practice 4: Convert the approximately 350 linear feet of existing asphalt ditch with vegetated conveyance that drains to the existing inlet to reduce sediment and nutrient loading into the piped drainage system. Excavating existing compacted soils and replacing with a porous media and underdrainage in addition to and replacing the sparse vegetation with dense native vegetation will promote infiltration, utilize nutrients, and reduce runoff volumes through evapotranspiration. Note that the existing width of the ditch may need to be expanded to properly grade a proposed vegetated conveyance and discussions with private property owners may be necessary depending upon the width of any town right-of-way.

Estimated Costs Site 4: The approximate cost for design, permitting, and implementation of the recommended BMPs assuming they are completed as a single project is anticipated to be between $300,000 and $600,000.

SITE 5: ASPEN LANE AND TANGLEWYLDE ROAD

An existing 12-18" diameter HDPE pipe runs down the steep slope along the guardrail at Aspen Lane and is piped under Tanglewydle Road. The originating drainage areas that are collected into this pipe were not observed, but it is assumed that the source(s) are stormwater inlets in the right of way above the pipe possibly including portions of Pleasant and Nardin Roads. Given the steep slope that the pipe length travels, it can be assumed that the storm water that enters the pipes beneath Tanglewylde Road moves at a high velocity. Stomrwater with high velocities can carry sediment and nutrients while also being an erosive force.

Photo 10: Tanglewylde Road existing overland piped conveyance potential for conversion to stabilized vegetated conveyance system.

Recommendation Practice 5: The recommended Best Management Practice (BMP) for this location would be to construct a stabilized, vegetated conveyance swale in lieu of the existing pipe. Given the steepness of this site, a series of step structures and pools would also be needed to sequester water. This would provide the reduction in stormwater velocity flowing down the steep slope as well as sequestering nutrients and sediments before they enter the culvert and eventually discharge into the lake.

Estimated Costs Practice 5: The approximate cost for design, permitting, and implementation of this BMP recommendation is anticipated to be between $200,000 and $300,000.

SITE 6A: PLEASANT ROAD EAST

Pleasant Road is a residential street upslope of and on the western side of Lake Peekskill. A 12" HDPE pipe is seen in photos 11 and 12 that collects water and routes it under the paved road and discharges into a steeply sloped wooded lot that slopes downward to the lake. This pipe conveys assumably unfiltered sediment and nutrients from areas above and before conveying them onto the wooded slope. During heavy rainfall events, this concentrated zone of flow can lead to erosion and additional sediment deposition that can potentially end up in the lake or other intermittent water bodies in addition to destabilizing trees and soil upslope of existing structures.

Photo 11: Site 6A Culvert discharge point draining to steeply sloped wooded area.

Photo 12: Site 6A Discharge Location of 12 in. HDPE pipe

Recommendation Site 6A: Discharging this section of piped conveyance to a stone-lined scour hole would slow water flow as it travelled down the slope and provide increased time for infiltration before it is discharged further down the slope and ultimately into the lake. Treatment for existing invasive plant species may be needed prior to planting the slopes and perimeter of the scour hole practice. Depending on available area, property ownership and suitable subsurface material, this intervention could be replicated at multiple locations where piped culverts outfall to open ground.

Estimated Costs Site 6A: The approximate cost for design, permitting, and implementation of this BMP recommendation is anticipated to be between $150,000 and $300,000 depending on size of bioretention area.

SITE 6B: PLEASANT ROAD WEST

This portion of Pleasant Road is a residential street upslope of and on the western side of Lake Peekskill that relies on de facto, semi-vegetated roadside ditches and piped HDPE culverts to drain stormwater that runs down the adjacent slopes and from the asphalt road surface itself. As seen in photos 13 and 14, the ditches are sparsely vegetated and weedy in the warmer months with shallow-rooted vegetation. Bare soil and gravel are visible indicating signs of past erosion. This ditch conveys semi-filtered sediment and nutrients from road surfaces and other runoff downstream and ultimately into the lake. During heavy rainfall events, increased flows can lead to erosion and additional sediment deposition that can potentially end up in the lake or other intermittent water bodies in addition to destabilizing the road shoulder and the root zones of roadside trees creating potential fall hazards.

Photo 23: Pleasant Road existing ditch and culvert pipe; looking south.

Photo 14: Pleasant Road existing ditch with bare soil; looking north.

Recommendation Site 6B: The recommendation for this site is creating a stabilized vegetated conveyance system along the sides of the road upstream and downstream of the culvert with additional bioretention area at the culvert discharge point. The use of stone check dams within the vegetated conveyance would reduce gravel and debris from washing downstream. Increased vegetation with deep root systems would also allow water to be taken up through root structures, which could assist in slowing and filtering the flow.

Estimated Costs Site 6B: The approximate cost for design, permitting, and implementation of this BMP recommendation is anticipated to be between $150,000 and $400,000 depending on the width and length of the conveyance system being addressed.

SITE 6C: PLEASANT ROAD NORTH

The northernmost site along Pleasant Road is an intermittent pond just off the asphalt shoulder and otherwise bordered by trees and shrubs. The source of the pond was not observed other than what appears to be sheet flow from the road and possibly piped drainage received from upslope areas. There is what appears to be an outlet structure that is piped under Pleasant Road and discharges to the east. Though this pond is observed to be intermittent, it could be a source of nutrient input to the lake and more investigation would be needed prior to implementing any recommendation and estimating nutrient removal efficiencies.

Recommendation Site 6C: The conversion of this pond to a constructed wetland to more effectively treat water entering the greater drainage system as well as enhancing the vegetated buffer between the pond and the road will add to this feature's function. See Figure 5 below for proposed practice. Some ecological improvements can be made by adding native emergent vegetation to provide additional nutrient assimilation before the water is discharged downstream. The stabilization of the accumulated material in the existing pond and potential use by vegetation can also serve to reduce the nutrient load to the lake.

Minor regrading, treatment of existing invasive plant species and potential replacement of the existing outlet structure may be required. Soil modification may also need to be investigated to achieve desired retention times. The combination of ecological activity improvement along with the stormwater drainage improvements described above will not only increase the water quality of the lake but improve the climate resiliency of this location.

Photo 35: Pleasant Road intermittent pond, winter

Photo 46: Pleasant Road intermittent pond, summer

Estimated Costs Site 6C: The approximate cost for design, permitting, and implementation of this BMP recommendation is anticipated to be between $250,000 and $500,000.

Figure 5: Sites 6C and 7 Overview*

Aerial imagery for this figure dated 2016 for purposes of leaf-off imagery to show waterbodies

SITE 7: NARDIN ROAD PARCEL

The open parcel spanning from the east side of Nardin Road through to Pleasant Road collects both sheet flow from a portion of the roads as well as piped discharge from a set of twin storm inlets on the west side of Nardin Road. Evidence of channel flow along the east side of Nardin Road in the grassy area as well as some evidence of past water movement from the Pleasant Road side are also indicative that the depression in this wooded parcel receives flow from road surface runoff. There was visible surface water in the center of the parcel at time of visiting in December as well as summertime Google imagery that may be an existing stream or wetland. The conditions of the site are shown in Photos 17, 18 and 19. The edges of the site are bordered by areas of invasive shrubs and vines, deciduous trees and an area of lawn on the Pleasant Road side. The presence of groundwater on this site would need to be assessed as part of further pre-design investigation.

Photo 17: Site 7 Vegetation and visible water on the east side of Nardin Road.

Photo 58: Site 7 Entrance Area and Discharge Inlet

Photo 19: Site 7 Twin stormwater inlets piped across Nardin Road to site.

Recommendation Site 7: The recommended BMP for this location would be to install a vegetated conveyance system along the eastern side of Nardin Road and to increase the riparian buffer plantings around the conveyance and the existing wet areas. Should the area be found to contain an existing wetland, a further wetland enhancement planting using native plants adapted to these conditions for filtration function. The portion of the site on the west site of Pleasant Road where surface flows enter the grassed area from the road would benefit from the installation of a rain garden that could filter sediment prior to entering the existing water body. Further investigation of flows and subsurface drainage would be needed to ensure proper system function and size.

Estimated Costs Site 7: The approximate cost for design, permitting, and implementation of this BMP recommendation is anticipated to be between $500,000 and $1.2 million.

SITE 8: LAKE PEEKSKILL COMMUNITY CENTER BUILDING AND PROPERTY

Site 8 is the Lake Peekskill Community Center building and grounds at the south end of Northway and adjacent to the beach and associated parking lot. This site consists of asphalt paths, lawn areas (one of which contains the septic tanks) and roof leaders that drain to the street. From past Google Earth imagery, many large shrubs have recently been removed from the front lawn areas. The contributing drainage area to the storm sewer is primarily from the area below the storm inlet that sits just above the property on Northway, an uncurbed road that is steeply sloped toward the lake and the building's roofs, paths and compacted lawns. The catch basins here and in the parking further south all presumably drain to the retention basin (Site 9B) located to the southeast of the site. See photos 20 and 21 of the existing conditions.

Photo 20: Grassed area with septic, upstream storm inlet and small existing asphalt path.

Photo 21: South grassed area for potential rain garden and downstream storm inlet.

Recommendation Site 8:

Being the last property down slope before the parking lot, beach, and lake as well as a community gathering place, this property is uniquely situated to be an educational site that features some of the recommended BMP practices that can be replicated on residential properties. The recommended BMP is to replace the existing asphalt paths with permeable pavement to capture and infiltrate stormwater that would otherwise run to the next catch basin down and ultimately into the retention basin. A rain garden to capture roof runoff and intercept flows from the roadway between the two storm inlets could be created on the southern area of lawn by performing a regrade of that area and planting with native plants suitable to rain garden water regimes. The rain garden would treat the stormwater for excess sediment/nutrients and use the existing conveyance system to discharge the treated stormwater into the Lake. This site would only be viable if there is the ability to conduct construction in the grassed area (does not contain subsurface utilities).

Estimated Costs Site 8:

The approximate cost for design, permitting, and implementation of this BMP recommendation is anticipated to be between $85,000 and $200,000.

SITE 9A: NORTH BEACH PLAYGROUND AND RECREATION AREA

Site 9A is the located within the fenced enclosure for North Beach and focuses on the grassed recreation areas adjacent the lake and the asphalt paths that run from the basketball court and to the south. The parking lot that is directly to the north of this site will be addressed separately as part of site 9B, as it has its own inlets that capture runoff and bring it to the retention basin. For recreation area itself, there were no observed stormwater management measures in place thus these impervious areas sheet flow untreated into the Lake.

Photo 22: Site 9A Compacted lawn and basketball court

Photo 23: Site 9A Roads and overview of shoreline adjacencies

Recommendation Site 9A:

The road that travels the site from the basketball court south and including the short, compacted dirt path at the main entry gate are ideal candidates for pavement conversion. These areas can be removed and replaced with porous pavement or a vegetated paver to increase infiltration and reduce sediment and nutrients that would otherwise flow over the compacted grass areas and enter directly into the Lake. These conversions will reduce overall functionally impervious area on the site. Additionally, there are opportunities for shoreline stabilization or vegetated buffer plantings along the shoreline where there is no swimming on the southwestern shore to reduce sedimentation in those areas with the addition of riparian zones.

Estimated Costs Site 9A:

The approximate cost for design, permitting, and implementation of this BMP recommendation is anticipated to be between $300,000 and $800,000 depending on the area converted.

SITE 9B & 10: NORTH BEACH- PARKING LOT, GRASS AREA, AND WET BASIN

This site contains a stormwater conveyance system consisting of pipes and inlets from surrounding streets and the parking lot that convey stormwater from its drainage area to its discharge point into a wet basin (which contains the invasive species *Phragmites*) located at the edge of Lake Peekskill.

A gravel parking area which serves North Beach, sits at the bottom of Northway and two steep, wooded slopes to the east and west. The inlets from Northway, the parking area and a piped discharge that exits under Lake

Drive to the north (see Site 10) all appear to drain via pipe to the grassed area to the east of the parking and ultimately into the existing wet basin.

Evidence of compaction and ponding of water are seen in the parking lot likely from heavy use which has caused low spots to collect water, meaning that the inlets are likely not collecting as much stormwater as they originally had due to settlement and compaction of the surrounding grades. As a result, sediment laden runoff can enter the beach and lake as well as creating stagnant pools of water after rains and ice pockets in the winter. An open channel and saturated area in the grass was also observed as the pipe daylights to the wet basin. Photo 24 shows the general location where the conveyance system converges at the grassed area before daylighting briefly from the grass and exiting to the wet basin (photo 23). Due to the size of the drainage area, this site will be a significant contributor of unwanted sediment, Total Suspended Solids (TSS), and Total Phosphorus (TP).

Recommendation Site 9B:

See Figure 6 below for reference. Converting the parking area to a permeable or vegetated paver will allow runoff to be infiltrated and filtered prior to entering the conveyance as well as reducing ponding by creating a more consistently graded surface. Daylighting the piped conveyance and existing stream channel where they join and empty into the grassed area to create an extended flow path for water to remove nutrients and sediments as it moves toward the wet basin will serve both to visually enhance the site by using natural materials

Photo 74: Looking south at parking lot and wet basin with grass area to the left.

Photo 65: Entry of piped flow to existing wet basin.

and attractive native plantings. Retrofitting the existing wet basin to increase flow path may also be an option to enhance filtration capabilities and overall function of the feature. Finally, given the vegetative cover on the surrounding steep slopes, it is not thought that they are a significant contributor of sediment, however nutrient-rich leaf litter that falls downslope should be kept from entering the lake in large quantity. This can be achieved by planting a dense, shade-tolerant buffer that will retain some of the leaf-litter upslope.

Estimated Costs Site 9B:

The approximate cost for design, permitting, and implementation of the permeable or grass paver system recommendation is anticipated to be between $180,000 and $300,000.

The approximate cost for design, permitting, and implementation of the wet basin retrofit recommendation is anticipated to be between $85,000 and $175,000.

The approximate cost for design, permitting, and implementation of the pipe daylighting and conveyance modification recommendation is anticipated to be between $70,000 and $300,000.

There may be realizable cost savings in combining design, permitting and construction efforts for the recommended practices.

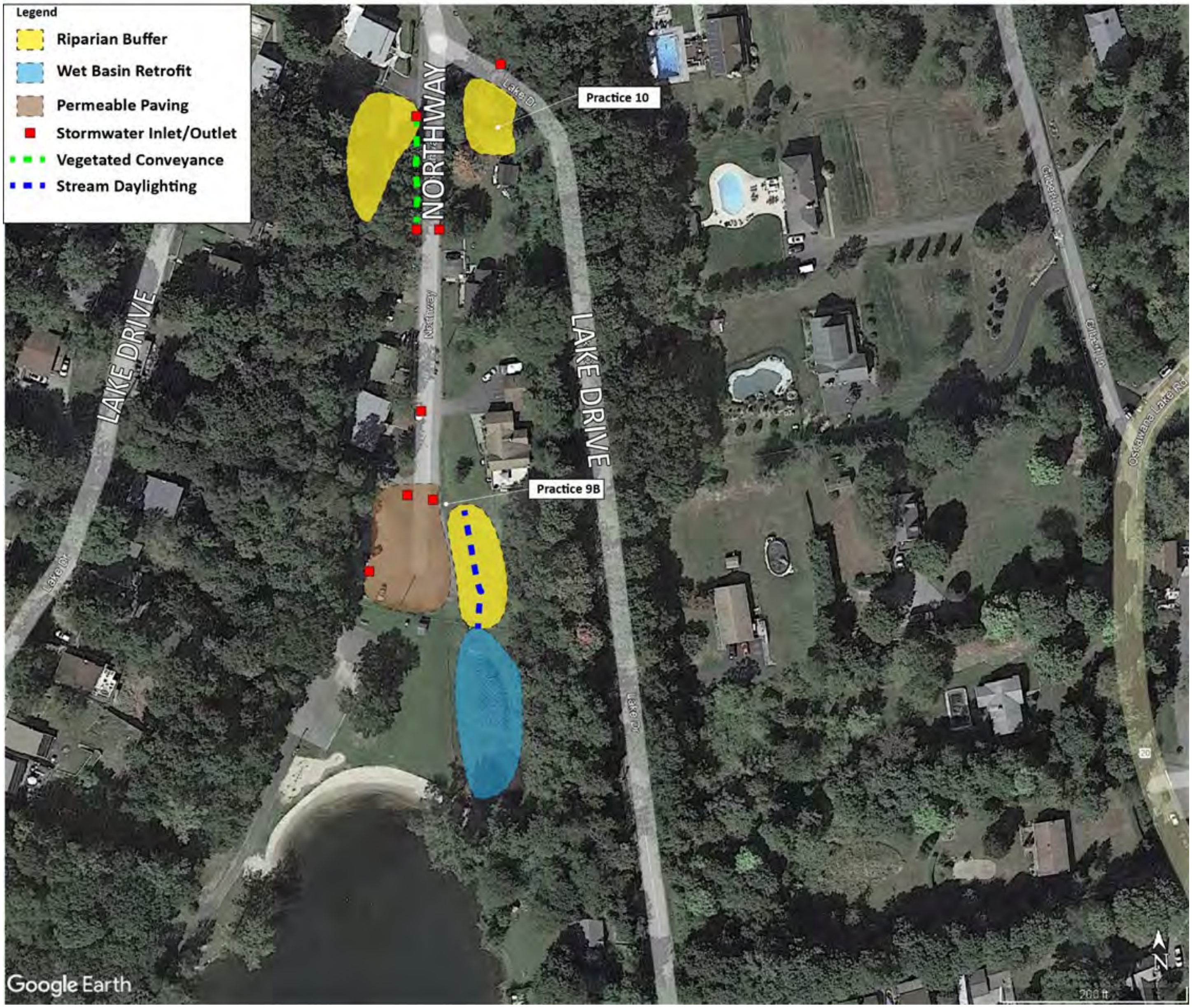

Figure 6: Sites 9B and 10 Overview

Site 10: Lake Drive Stream Outfall

The class C stream that exits via piped discharge under Lake Drive drains an unknown area above via inlets, piped conveyance and natural drainage into the channel. There is also a riverine wetland that flows under the west side of Northway and crosses, underground to the east side prior to exiting to the wet basin. Downstream of Lake Drive the Class C stream runs underground through several private parcels before reaching the lake parcel. It is not known if the stream and/or the riverine wetland is piped or daylighted for their lengths in this area, but they both appear to discharge into the grassed area adjacent to the parking lot for North Beach to the south prior to entering the lake via the wet basin. Evidence of erosion and lack of riparian buffer were observed near the stream outfall. The riverine wetland was observed to flow beneath a wall on private property, but was not accessible for observation beyond this point due to access.

Recommendation Site 10: The recommendation for this site is to increase the riparian plantings along all portions of the channel(s) to reduce erosion and help remove nutrient and sediments from the water. Due to the positioning on private, residential lots, further investigation of daylighting and restoring the tributary channel may be prohibitive. Further investigation of the stream hydrology and discussions with neighboring landowners would need to be conducted to further inform any advanced design of this site.

Estimated Costs Site 10: The approximate cost for design, permitting, and implementation of riparian planting for this BMP recommendation is anticipated to be between $5,000 and $200,000.

Photo 86: Driveway to Boat Launch Area Near Mohawk Trail

SITE 11: SINGERS BEACH

Singers Beach consists of a sand beach, small, shed structure, paved drive, and grass slope that surrounds the beach to the north and east. Only a portion of Point Drive is curbed along the beach boundary with the remaining portions sheet flowing from the road onto the compacted grass area, onto the beach and ultimately into the lake. No formal stormwater infrastructure exists on the site nor the adjacent roads. Runoff is conveyed along the roadway that is curbed and then is a concentrated discharge. At the top of the slope on Lake Drive between Morrissey Drive and Point Drive South, there is a flat area with several spruce trees that is extremely compacted and drains to the sparsely vegetated slope behind it down to the recreation area and lake.

Photo 107: Singers Beach sparsely vegetated slope.

Photo 98: Curbed portion of Point Drive and paved drive at gated entry; no storm inlets.

Photo 119: Compacted soil area with spruce trees at top of slope on Lake Drive between Morrissey Drive and Point Drive South.

Photo 30: Location of proposed vegetated conveyance along fence line.

Recommendation Site 11: Four types of BMPs can be implemented within the site. These solutions include a vegetated conveyance system along the fence line at the top of the recreation area's grassed slope to capture sheet flow from the road and direct it toward the storm inlet further down Point Drive. As a potential addition to the above, the existing grass slope could be converted, all or in part, to a meadow planting that will be better able to absorb and slow down runoff due to a deeper root system than lawn grass. Property stakeholders will need to evaluate the need for the existing lawn in terms of its active recreation uses and what can be converted to meadow. Third, the paved drive leading from the road into the site can be converted to a vegetated or permeable paver so that water can infiltrate and be filtered by subdrainage layers below. Thirdly, the compacted area on Lake Drive with the spruce trees could be converted to a bioretention area to capture and treat stormwater before it moves downslope and down Point Drive. Combining this with enhancing the vegetated buffer on the slope below this area to the lawn will also slow and filter runoff prior to entering the lake and recreation area.

Estimated Costs Practice 11: The approximate cost for design, permitting, and implementation of the vegetated conveyance BMP recommendations is anticipated to be between $75,000 and $150,000.

The approximate cost for design, permitting, and implementation of the lawn to meadow conversion recommendations is anticipated to be between $15,000 and $40,000.

The approximate cost for design, permitting, and implementation of the vegetated or permeable paver conversion BMP recommendations is anticipated to be between $50,000 and $150,000.

The approximate cost for design, permitting, and implementation of the bioretention area BMP recommendations is anticipated to be between $150,000 and $450,000.

A cost savings for design, permitting and construction may be realized if these projects are done simultaneously.

SITE 12: LAKE DRIVE AND MORRISSEY DRIVE- PAVED PARKING LOT

Photo 31: Parking Lot, Looking south

Photo 32: Outlet of parking lot drainage

This large, asphalt parking lot is located at the intersection of Lake and Morrissey Drives and appears to serve the businesses and facilities at that intersection as well as possibly serving Singers Beach in the summer months. The lot is roughly 16,000 square feet of asphalt pavement with no observed storm drainage structures within its area. Inlets at the perimeter are on both bordering streets and the lot is graded to drain out to the street. The lot appears to be oversized at the time the site visit. Further investigation and understanding of the seasonal use of the parking will be necessary to make a more specific recommendation.

Recommendation Site 12: The recommended Best Management Practice (BMP) for this site would be to conduct a pavement modification on the parking area from regular asphalt pavement to a porous paver or porous asphalt to allow stormwater filtration. Switching to a surface practice in the parking lot will allow the water draining to this area to be filtered directly into the subsurface soils, assuming the geotechnical conditions on the site allow for water percolation. Filtering the stormwater at this location into the ground would greatly reduce the amount of TSS and TP that enters the lake, which improves the water quality. If subsurface soils area not conducive to this practice, a manufactured treatment device (MTD) could also be explored. There are additional opportunities on the site to combine porous paving with planted bioretention areas if a reduction in parking spaces would be considered. Planting shade trees in parking lots has the added benefit of shading and reducing the urban heat island effect in addition to taking up stormwater.

Estimated Costs Site 12: The approximate cost for design, permitting, and implementation of a pavement conversion without an MTD for this site is anticipated to be between $500,000 and $1,000,000. The design and installation for the MTD is not included in this cost.

The cost for an MTD varies greatly based on size and model, but a baseline cost for the design, permitting and implementation is anticipated to be between $650,000 and $850,000.

6.0 SUMMARY AND RECOMMENDATIONS

Data and observations collected in late 2022 at Lake Peekskill suggest that the lake is typically maintained in a relatively well-mixed and well-oxygenated state, at least in the late summer/early fall. While nutrient levels were not measured at particularly high concentrations during either event, the lake shows a propensity towards occasional cyanobacteria blooms. Princeton Hydro recommends that further water quality testing spanning the entirety of the growing season (May-October) be conducted in order to obtain further information on whether or not the conditions observed in 2022 were merely late-season conditions or if they are representative of conditions throughout a majority of the warmer months as well. Based on the very limited data collected in 2022, the use of an aeration system to maintain a relatively well-mixed and oxygenated water column appears to be aiding the lake at this time. Princeton Hydro recommends that this system continue to be employed properly, with all aerators online by the end of April, so as to best benefit the lake. Given the lake's relatively low densities of aquatic macrophytes, the town may wish to wait an additional year or two before stocking any new grass carp into Lake Peekskill, or to stock a smaller density of grass carp than have been stocked in the past. As noted above, a small community of native aquatic macrophytes can actually be beneficial by providing fish habitat, sequestering nutrients that algae or cyanobacteria might otherwise use, and providing some stabilization to bottom sediments. The only macrophyte of concern observed by Princeton Hydro staff is brittle naiad, which is an invasive plant that can grow to dense quantities and become a nuisance, particularly in the late summer, when this plant is typically at its peak growth. Should the town elect to reduce grass carp stocking or to not stock at all, populations of this plant in Lake Peekskill should be monitored.

As data collected in fall 2022 does not suggest that a large degree of internal phosphorus loading is occurring in Lake Peekskill, nutrient inputs from outside the lake (E.g. stormwater impacts) should be modeled and calculated. Princeton Hydro has detailed in Section 5 of this report recommendations for watershed-based BMPs for Lake Peekskill.

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APPENDIX I – PROJECT MAPS

File: P:\0075\Projects\0075017\GIS\APRX\Peekskill_Sampling\Peekskill_Sampling.aprx, Layout: Water Quality Sampling, Exported: 1/9/2023, Drawn by bsmith, Copyright Princeton Hydro, LLC.

NOTES:
1. Water quality sampling locations are approximate.
2. 2022 orthoimagery and roads obtained from the New York State GIS Clearinghouse: gis.ny.gov

0 200 400 Feet

Spatial Reference: NAD 1983 2011 StatePlane New York East FIPS 3101 Ft US

WATER QUALITY SAMPLING LOCATION MAP

LAKE PEEKSKILL LAKE MANAGEMENT
TOWN OF PUTNAM VALLEY
PUTNAM COUNTY, NEW YORK

PRINCETON HYDRO
SCIENCE DESIGN ENGINEERING
www.PrincetonHydro.com

File: P:\0075\Projects\0075017\GIS\APRX\Peekskill_Sampling\Peekskill_Sampling.aprx, Layout: SAV Sampling, Exported: 1/6/2023, Drawn by bsmith, Copyright Princeton Hydro, LLC.

NOTES:
1. Submerged aquatic vegetation (SAV) sampling locations are approximate.
2. 2022 orthoimagery and roads obtained from the New York State GIS Clearinghouse: gis.ny.gov

0 200 400 Feet

Spatial Reference: NAD 1983 2011 StatePlane New York East FIPS 3101 Ft US

SAV SAMPLING LOCATION MAP

LAKE PEEKSKILL LAKE MANAGEMENT
TOWN OF PUTNAM VALLEY
PUTNAM COUNTY, NEW YORK

PRINCETON HYDRO
SCIENCE DESIGN ENGINEERING
www.PrincetonHydro.com

APPENDIX II – IN-SITU DATA

Peekskill Lake
9.21.22

Partially cloudy, cyanobacteria bloom observable throughout much of the waterbody.

GPS pt 1064

Station	Secchi Depth (m)	Total Depth (m)	Sample Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (%)	specific conductivity (mS/cm)	pH
South	1	3.7	0	23.88	11.24	133.7	0.521	7.77
South	1	3.7	1	23.47	10.9	127.9	0.52	7.84
South	1	3.7	2	23.29	10.18	119.3	0.52	7.8
South	1	3.7	3	23.27	10.16	119.4	0.52	7.85
South	1	3.7	3.5	23.21	9.82	115.3	0.52	7.84

GPS pt 1072

Station	Secchi Depth (m)	Total Depth (m)	Sample Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (%)	specific conductivity (mS/cm)	pH
North	1	3	0	24.56	11	132.5	0.521	8.16
North	1	3	1	23.86	11.2	132.5	0.52	8.25
North	1	3	2	23.47	11	128.9	0.52	8.23
North	1	3	2.5	23.24	9.83	114.1	0.52	8.05

10/20/2022

Station	Secchi Dep	Total Dept	Sample Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (%)	specific conductivity (mS/cm)	pH
South	2	2.7	0	14.2	8.99	88.0	0.495	7.50
South	2	2.7	1	14.07	8.93	87.4	0.495	7.45
South	2	2.7	2	13.98	8.82	86.2	0.495	7.41
South	2	2.7	2.5	13.92	8.66	84.6	0.495	7.36

Slightly green/yellow aeration on
planktonic particulates

Station	Secchi Dep	Total Dept	Sample Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (%)	specific conductivity (mS/cm)	pH
north	1.9	2.4	0	14.1	9.05	88.7	0.499	7.29
north	1.9	2.4	1	14.18	9	87.9	0.498	7.33
north	1.9	2.4	2	14.17	8.96	87.7	0.497	7.39

slight scums by launch
water green around shore but generally no surface scums
water level slightly lower

APPENDIX III – DISCRETE DATA

ECM

environmental compliance monitoring, inc.

November 3, 2022

Chris Mikolajczyk
Princeton Hydro. LLC.
P.O. Box 3689
Trenton, NJ 08629

Dear Mr. Mikolajczyk:

Analysis of the Peekskill Lake samples received September 22, 2022 has been completed. The results are presented in the attached tables. An invoice is attached.

If you have any questions pertaining to the analysis, please feel free to contact me.

Very truly yours,

ENVIRONMENTAL COMPLIANCE MONITORING, INC.

Thomas Grenci

Thomas Grenci
Laboratory Manager

#2073/7470

REPORT OF ANALYSIS

COMPANY Princeton Hydro, LLC. REPORT DATE 11/03/22
ADDRESS P.O. Box 3689 JOB # 2073 LOT # 7470
CITY Trenton STATE NJ ZIP 08629 PO # Verbal INVOICE # 222973
TO ATTN. OF Chris Mikolajczyk SAMPLE DATE 09/21/22
LAB CERTIFICATION # 18630

CLIENT SAMPLE ID Peekskill Lake – South Surface

ECM, Inc. SAMPLE # 67408

Test Parameter	Method # *	Analysis Date/Time	Dilution Factor	MDL (mg/L)	Result (mg/L)
Chlorophyll-a	10200H 1&2	09/22/22; 1425	3.3	1.0	26
Ammonia-N	4500-NH_3B& D	10/06/22; 1219	1	0.01	0.01
Nitrate-N	352.1	09/22/22; 1029	1	0.01	0.03
Soluble Reactive Phosphate-P	4500-P E	09/23/22; 0948	1	0.002	ND <0.002
Total Phosphate-P	4500-P B5&E	10/06/22; 1130	1	0.01	0.02
Total Suspended Solids	2540D	09/27/22; 1730	1	2	2

* Standard Methods for the Examination of Water and Wastewater, 22nd Edition, 2012/USEPA 600-4/79-02
ND – Not detected at the Method Detection Limit (MDL)

REPORT OF ANALYSIS

COMPANY	Princeton Hydro, LLC.	REPORT DATE	11/03/22
ADDRESS	P.O. Box 3689	JOB # 2073	LOT # 7470
CITY Trenton	STATE NJ ZIP 08629	PO # Verbal	INVOICE # 222973
TO ATTN. OF	Chris Mikolajczyk	SAMPLE DATE	09/21/22
		LAB CERTIFICATION #	18630

CLIENT SAMPLE ID Peekskill Lake – South Deep

ECM, Inc. SAMPLE # 67409

Test Parameter	Method # *	Analysis Date/Time	Dilution Factor	MDL (mg/L)	Result (mg/L)
Chlorophyll-a	10200H 1&2	09/22/22; 1425	2.9	0.86	28
Ammonia-N	4500-NH_3B& D	10/06/22; 1219	1	0.01	0.01
Nitrate-N	352.1	09/22/22; 1029	1	0.01	0.03
Soluble Reactive Phosphate-P	4500-P E	09/23/22; 0948	1	0.002	ND <0.002
Total Phosphate-P	4500-P B5&E	10/06/22; 1130	1	0.01	0.03
Total Suspended Solids	2540D	09/27/22; 1730	1	2	3

* Standard Methods for the Examination of Water and Wastewater, 22nd Edition, 2012/USEPA 600-4/79-02
ND – Not detected at the Method Detection Limit (MDL)

QA Report – Duplicate and Matrix Spike Recovery

ANALYTE: Total Phosphate-P

MATRIX SPIKE

Lab Sample #	Result	Spike Addition	Spike Result	% Recovery	QC Limit
67371	0.05	0.3	0.37	107	86-128

MATRIX SPIKE DUPLICATE

Lab Sample #	Result	Spike Addition	Spike Result	% Recovery	RPD	QC Limit
67371	0.05	0.3	0.38	110	2.67	± 9

ANALYTE: Nitrate-N

MATRIX SPIKE

Lab Sample #	Result	Spike Addition	Spike Result	% Recovery	QC Limit
67405	2.5	2.0	4.1	80	56-158

MATRIX SPIKE DUPLICATE

Lab Sample #	Result	Spike Addition	Spike Result	% Recovery	RPD	QC Limit
67405	2.5	2.0	4.5	100	9.30	± 21

ANALYTE: Total Suspended Solids

MATRIX DUPLICATE

Lab Sample #	Result	Duplicate	RPD	QC Limit
67333	220	220	0	± 6

ANALYTE: Ammonia-N

MATRIX SPIKE

Lab Sample #	Result	Spike Addition	Spike Result	% Recovery	QC Limit
67363	0.02	0.04	0.05	75	0-148

MATRIX SPIKE DUPLICATE

Lab Sample #	Result	Spike Addition	Spike Result	% Recovery	RPD	QC Limit
67363	0.02	0.04	0.05	75	0	± 21

ANALYTE: Chlorophyll-a

MATRIX DUPLICATE

Lab Sample #	Result	Duplicate	RPD	QC Limit
67406	1.3	0.77	51.21	± 66

ANALYTE: Soluble Reactive Phosphate-P

MATRIX SPIKE

Lab Sample #	Result	Spike Addition	Spike Result	% Recovery	QC Limit
67408	<0.002	0.04	0.041	102	81-129

MATRIX SPIKE DUPLICATE

Lab Sample #	Result	Spike Addition	Spike Result	% Recovery	RPD	QC Limit
67408	<0.002	0.04	0.042	105	2.41	± 9

ECM 349 US Highway 206, Hillsborough NJ 08844 (908) 874-0990

COC NO: 011964

CHAIN OF CUSTODY RECORD

PROJECT NO.:

PROJECT NAME: Peekskill Lake

REGULATORY? ___ YES ✓ NO

DATE: 9/22/22

SAMPLERS NAME: J. Smith & K. Valston

LAB USE ONLY — JOB NO: 2073 — LOT NO: 7470

SAMPLE DATE	TIME	COMP OR GRAB	STATION LOCATION	NO. OF CONTAINERS	pH (For Nitrate/Nitrite)	NO PRESERVATIVE	SULFURIC ACID	pH<2 (initial if true, (*) if further action is needed)	NITRIC ACID	pH <2(initial if true, (*) if further action is needed)	HYDROCHLORIC ACID	pH <2(initial if true, (*) if further action is needed)	OTHER	SAMPLE NUMBERS
9/21/22	1110		South Surface	3	7.77	2	1	Cn						67408
↓	1115		South Deep	3	7.85	2	1	Cn						↓ 9

COOLER TEMP:

DATE & TIME:

INITIALS:

COMMENTS:

RELINQUISHED BY: (Signature)	DATE/TIME	RECEIVED BY: (Signature)	DATE/TIME
[signature]	9/22/22 0938	[signature]	9/22/22 0938
RELINQUISHED BY: (Signature)	DATE/TIME	RECEIVED BY: (Signature)	DATE/TIME
RELINQUISHED BY: (Signature)	DATE/TIME	RECEIVED BY: (Signature)	DATE/TIME

NOTE: The Chain of Custody Form is used to ensure and document compliance with sampling and laboratory protocol for regulatory programs. All information should be completed on the form to ensure samples are analyzed correctly. Unless specified on the Chain of Custody Form, ECM cannot presume regulatory compliance criteria

ECM

environmental compliance monitoring, inc.

November 22, 2022

Chris Mikolajczyk
Princeton Hydro. LLC.
P.O. Box 3689
Trenton, NJ 08629

Dear Mr. Mikolajczyk:

Analysis of the Peekskill samples received October 20, 2022 has been completed. The results are presented in the attached tables. An invoice is attached.

If you have any questions pertaining to the analysis, please feel free to contact me.

Very truly yours,

ENVIRONMENTAL COMPLIANCE MONITORING, INC.

Thomas Grenci

Thomas Grenci
Laboratory Manager

#2073/7535

349 Route 206, Hillsborough, New Jersey 08844
PHONE: 908-874-0990 FAX: 908-874-0920 *ecm-inc@att.net* 4787 Merlot Drive, Viera, Florida 32955
PH: (321) 636-5010 FAX: (321) 636-5010

REPORT OF ANALYSIS

COMPANY	Princeton Hydro, LLC.	REPORT DATE	11/22/22
ADDRESS	P.O. Box 3689	JOB # 2073	LOT # 7535
CITY Trenton	STATE NJ ZIP 08629	PO # Verbal	INVOICE # 222064
TO ATTN. OF	Chris Mikolajczyk	SAMPLE DATE	10/20/22
		LAB CERTIFICATION #	18630

CLIENT SAMPLE ID Peekskill Lake – South Surface

ECM, Inc. SAMPLE # 67637

Test Parameter	Method # *	Analysis Date/Time	Dilution Factor	MDL (mg/L)	Result (mg/L)
Chlorophyll-a	10200H 1&2	10/21/22; 1012	2	0.6	3.3
Ammonia-N	4500-NH_3B& D	11/10/22; 0815	1	0.01	0.08
Nitrate-N	352.1	10/21/22; 1001	1	0.01	0.03
Soluble Reactive Phosphate-P	4500-P E	10/21/22; 1126	1	0.002	ND <0.002
Total Phosphate-P	4500-P B5&E	11/10/22; 1040	1	0.01	ND <0.01
Total Suspended Solids	2540D	10/24/22; 0730	1	2	ND <2

* Standard Methods for the Examination of Water and Wastewater, 22nd Edition, 2012/USEPA 600-4/79-02
ND – Not detected at the Method Detection Limit (MDL)

REPORT OF ANALYSIS

COMPANY	Princeton Hydro, LLC.	REPORT DATE	11/22/22
ADDRESS	P.O. Box 3689	JOB # 2073	LOT # 7535
CITY Trenton	STATE NJ ZIP 08629	PO # Verbal	INVOICE # 222064
TO ATTN. OF	Chris Mikolajczyk	SAMPLE DATE	10/20/22
		LAB CERTIFICATION #	18630

CLIENT SAMPLE ID Peekskill Lake – South Deep

ECM, Inc. SAMPLE # 67638

Test Parameter	Method # *	Analysis Date/Time	Dilution Factor	MDL (mg/L)	Result (mg/L)
Chlorophyll-a	10200H 1&2	10/21/22; 1012	2.1	0.63	2.4
Ammonia-N	4500-NH_3B& D	11/10/22; 0815	1	0.01	0.08
Nitrate-N	352.1	10/21/22; 1001	1	0.01	0.03
Soluble Reactive Phosphate-P	4500-P E	10/21/22; 1126	1	0.002	ND <0.002
Total Phosphate-P	4500-P B5&E	11/10/22; 1040	1	0.01	ND <0.01
Total Suspended Solids	2540D	10/24/22; 0730	1	2	4

* Standard Methods for the Examination of Water and Wastewater, 22nd Edition, 2012/USEPA 600-4/79-02
ND – Not detected at the Method Detection Limit (MDL)

QA Report – Duplicate and Matrix Spike Recovery

ANALYTE: Total Phosphate-P

MATRIX SPIKE

Lab Sample #	Result	Spike Addition	Spike Result	% Recovery	QC Limit
67624	<0.01	0.3	0.26	87	86-128

MATRIX SPIKE DUPLICATE

Lab Sample #	Result	Spike Addition	Spike Result	% Recovery	RPD	QC Limit
67624	<0.01	0.3	0.27	90	3.77	± 9

ANALYTE: Nitrate-N

MATRIX SPIKE

Lab Sample #	Result	Spike Addition	Spike Result	% Recovery	QC Limit
67620	1.0	2.0	3.1	105	56-158

MATRIX SPIKE DUPLICATE

Lab Sample #	Result	Spike Addition	Spike Result	% Recovery	RPD	QC Limit
67620	1.0	2.0	3.2	110	3.17	± 21

ANALYTE: Total Suspended Solids

MATRIX DUPLICATE

Lab Sample #	Result	Duplicate	RPD	QC Limit
67633	140	140	0	± 6

ANALYTE: Ammonia-N

MATRIX SPIKE

Lab Sample #	Result	Spike Addition	Spike Result	% Recovery	QC Limit
67602	<0.01	0.04	0.04	100	0-148

MATRIX SPIKE DUPLICATE

Lab Sample #	Result	Spike Addition	Spike Result	% Recovery	RPD	QC Limit
67602	<0.01	0.04	0.04	100	0	± 21

ANALYTE: Chlorophyll-a

MATRIX DUPLICATE

Lab Sample #	Result	Duplicate	RPD	QC Limit
67638	2.4	4.7	64.79	± 66

ANALYTE: Soluble Reactive Phosphate-P

MATRIX SPIKE

Lab Sample #	Result	Spike Addition	Spike Result	% Recovery	QC Limit
67637	<0.002	0.04	0.040	100	81-129

MATRIX SPIKE DUPLICATE

Lab Sample #	Result	Spike Addition	Spike Result	% Recovery	RPD	QC Limit
67637	<0.002	0.04	0.040	100	0	± 9

APPENDIX IV – PLANKTON DATA

Phytoplankton and Zooplankton Community Composition Analysis

Sampling Location: Peekskill Lake	Sampling Date: 9/21/22	
Site 1: Mid-Lake		

Phytoplankton

Bacillariphyta (Diatoms)	**1**			**Chlorophya (Green Algae)**	**1**			**Cyanophyta (Blue-Green Algae)**	**1**		
Achnanthes				Actinastrum				Dolichospermum			
Asterionella				Ankistrodesmus				Aphanizomenon			
Aulacoseira				Chlamydomonas				Aphanocapsa			
Cocconeis				Botryococcus				Chroococcus			
Cyclotella				Chlorella				Cylindrospermum			
Cymatopleura				Coelastrum				Lyngbya			
				Dictyosphaerium							
Cylindrotheca				Eudorina				Microcystis	B		
Cymbella				Gloeocystis				Nostoc			
Denticula				Golenkinia				Pseudoanabaena			
Fragilaria	P			Hydrodictyon				Oscillatoria			
Eunotia				Monoraphidium							
Gyrosigma				Mougeotia	C						
Melosira	A			Micrasterias							
Nedium				Microspora							
Rhizosolenia				Ochromonas							
Stauroneis				Oedogonium				**Euglenophyta (Euglenoids)**			
Stephanodiscus	R			Oocystis				Colacium			
Sururekka				Scenedesmus				Euglena (Phacus sp)			
Synedra				Spirogya				Euglena sp			
Tabellaria				Staurastrum	R			Trachelomonas	R		
				Treubaria							
Chrysophyta (Golden Algae)				Pediastrum				**Pyrrhophyta (Dinoflagellates)**			
Dinobryon				Volvex				Ceratium	P		
Chromulina				Zygnema				Peridinium			
Mallomonas				Klebsormidium							
Synura				**Desmids (Green Algae)**							
				Hyalotheca							
				Cosmarium							
				Spondylosium	P						
				Staurodesmus							

Zooplankton

Cladocera (Water Fleas)	**1**			**Copecoda (Copepods)**	**1**			**Rotifera (Rotifers)**	**1**		
Bosmina sp.	C			Cyclops sp.				Keratella sp.	P		
Daphnia sp.				Dipatomus (H)				Kellicottia longispina			
Eubosmina sp.				Nauplii	P			Asplanchna			
Chydorus				Skistodiaptomus oregonensis				Polyarthra	P		
Diaphniosoma				Microcyclops sp	P			Filinia			
Ceriodaphnia	P			Limnocalanus macrurus				Conochilus sp			
Leptodora kindti				Leptodiaptomus				**Arthropoda (Arthropods)**			
Scapholeberis mucronata								Chaoborus punctipennis			
Bosmina longirostris								Ostracoda			
Diaphnosoma brachyurum											
Diaphanosoma birgei											
Monia sp.											

Sites:	**1**		
Total Phytoplankton Genera	7		
Total Zooplankton Genera	6		

Phytoplankton Key: Bloom (B), Common (C), Present (P), and Rare (R)
Zooplankton Key: Dominant (D), Abundant (A), Present (P), and Rare (R); Herbivorous (H) or Carnivorous (C)

Phytoplankton and Zooplankton Community Composition Analysis

Sampling Location: Peekskill Lake	Sampling Date: 10/20/22	
Site 1: Mid-Lake		

Phytoplankton

Bacillariphyta (Diatoms)	**1**			**Chlorophya (Green Algae)**	**1**			**Cyanophyta (Blue-Green Algae)**	**1**		
Achnanthes				*Actinastrum*				*Dolichospermum*			
Asterionella				*Ankistrodesmus*				*Aphanizomenon*			
Aulacoseira				*Chlamydomonas*				*Aphanocapsa*			
Cocconeis				*Botryococcus*				*Chroococcus*			
Cyclotella				*Chlorella*				*Cylindrospermum*			
Cymatopleura				*Coelastrum*				*Lyngbya*			
				Dictyosphaerium							
Cylindrotheca				*Eudorina*				*Microcystis*	C		
Cymbella				*Gloeocystis*				*Nostoc*			
Denticula				*Gloeotila*	C			*Pseudoanabaena*			
Fragilaria	P			*Hydrodictyon*				*Oscillatoria*			
Eunotia				*Monoraphidium*				*Raphidiopsis*	P		
Gyrosigma				*Mougeotia*	A						
Melosira	P			*Micrasterias*							
Nedium				*Microspora*							
Rhizosolenia				*Ochromonas*							
Stauroneis				*Oedogonium*				**Euglenophyta (Euglenoids)**			
Stephanodiscus				*Oocystis*				*Colacium*			
Sururekka				*Scenedesmus*				*Euglena (Phacus sp)*			
Synedra				*Spirogya*				*Euglena sp*			
Tabellaria				*Staurastrum*				*Trachelomonas*			
				Treubaria							
Chrysophyta (Golden Algae)				*Pediastrum*	C			**Pyrrhophyta (Dinoflagellates)**			
Dinobryon				*Volvex*				*Ceratium*			
Chromulina				*Zygnema*				*Peridinium*			
Mallomonas				*Klebsormidium*							
Synura				**Desmids (Green Algae)**				**Cryptomonads**			
				Hyalotheca				*Cryptomonas*	P		
				Cosmarium							
				Spondylosium							
				Staurodesmus							

Zooplankton

Cladocera (Water Fleas)	**1**			**Copecoda (Copepods)**	**1**			**Rotifera (Rotifers)**	**1**		
Bosmina sp.	A			*Cyclops sp.*				*Keratella sp.*	P		
Daphnia sp.				*Dipatomus (H)*				*Kellicottia longispina*			
Eubosmina sp.				*Nauplii*				*Asplanchna*			
Chydorus				*Skistodiaptomus oregonensis*				*Polyarthra*	A		
Diaphniosoma				*Microcyclops sp*	P			*Trichocerca*	R		
Ceriodaphnia	P			*Limnocalanus macrurus*				*Conochilus sp*	P		
Leptodora kindti				*Leptodiaptomus*				**Arthropoda (Arthropods)**			
Scapholeberis mucronata								*Chaoborus punctipennis*			
Bosmina longirostris								*Ostracoda*			
Diaphnosoma brachyurum											
Diaphanosoma birgei											
Monia sp.											

Sites:	**1**		
Total Phytoplankton Genera	7		
Total Zooplankton Genera	6		

Phytoplankton Key: Bloom (B), Common (C), Present (P), and Rare (R)
Zooplankton Key: Dominant (D), Abundant (A), Present (P), and Rare (R); Herbivorous (H) or Carnivorous (C)

Princeton Hydro LLC
1108 Old York Rd, Ringoes, NJ 08551; Phone (908) 237-5660

APPENDIX V – SAV RAW DATA

Peekskill Lake
9.21.22

T1 GPS pt. 1062

0'	No plants	
20'	Leafy Pondweed - Present	
40'	No plants	
60'	No plants	Organic detritus, muck, filamentous algae, sandier closer to shore
80'	No plants	
100'	No plants	

T2 GPS pt. 1063

0'	Fontinalis moss - Present	
20'	No plants	
40'	No plants	muck, detritus, with some gravel closer to shore
60'	No plants	
80'	No plants	
100'	No plants	

T3 GPS pt. 1066

0'	Cattails - Abundant, Leafy Pondweed - Present (mostly fragments)	
20'	No plants	muck, detritus, with some rocks closer to shore
40'	No plants	
60'	No plants	
80'	No plants	
100'	No plants	

T4 GPS pt. 1067

0'	No plants	
20'	Nitella - Present	muck, detritus, with some rocks and sand closer to shore
40'	No plants	
60'	No plants	
80'	No plants	
100'	No plants	

T5 GPS pt. 1068

0'	No plants	
20'	No plants	muck, with some rocks and sand closer to shore, benthic algae
40'	No plants	
60'	No plants	
80'	No plants	
100'	No plants	

T6 GPS pt. 1069

0'	No plants	
20'	No plants	
40'	No plants	Deeper, rocky
60'	No plants	
80'	No plants	
100'	No plants	

T7 GPS pt. 1070

0'	No plants	
20'	No plants	
40'	No plants	Rocky near shore
60'	No plants	
80'	No plants	
100'	No plants	

T8 GPS pt. 1071

0'	No plants	
20'	No plants	Some filamentous algae near shore
40'	No plants	
60'	No plants	
80'	No plants	
100'	No plants	

T9 GPS pt. 1073

0'	Leafy Pondweed - Common, Brittle Naiad - Present (Dead/Dying), Cattails - Common	
20'	Spikerush - Present, Brittle Naiad - Present (Dead/Dying)	
40'	No Plants	
60'	No Plants	
80'	No Plants	Sandy near shore, benthic filamentous algae from 20' outwards
100'	No Plants	

T10 GPS pt. 1074

0'	Cattails - Common, Brittle Naiad - Present, Leafy Pondweed - Present	
20'	No Plants	
40'	No Plants	
60'	No Plants	
80'	No Plants	Some filamentous algae
100'	No Plants	

T11 GPS pt. 1075

0'	No Plants	
20'	No Plants	
40'	No Plants	
60'	No Plants	
80'	No Plants	Some filamentous algae. Floating fragment of brittle naiad observed
100'	No Plants	

T12 GPS pt. 1076

0'	Brittle Naiad - Present, Leafy Pondweed - Present	
20'	No Plants	
40'	No Plants	
60'	No Plants	
80'	No Plants	Arrowhead on shore adjacent to transect
100'	No Plants	

T13 GPS pt. 1077

0'	Fontinalis moss - present	
20'	No Plants	
40'	No Plants	
60'	No Plants	
80'	No Plants	
100'	No Plants	