Baseline Characterization of Water Quality and Aquatic Habitat

in the Budd Lake Watershed: Phase 1 & Phase 2

Project Summary/Narrative

Background: Urban development and climate change are resulting in large volumes of polluted stormwater runoff into Budd Lake, a natural lake in Mount Olive Township and the headwaters of the South Branch Raritan River in the Highlands Region of New Jersey. In 2022, a NJ Department of Environmental Protection (NJDEP) 319h grant was obtained by Raritan Headwaters (RHA) to address stormwater pollution that is contributing to poor water quality and Harmful Algal Blooms (HABs) in Budd Lake. RHA partnered with the Rutgers Cooperative Extension Water Resources Program, Mount Olive Township, and an advisory committee composed of representatives from The New Jersey Highlands Council, NJ Water Supply Authority, and local residents and business-owners to develop the "Budd Lake Watershed Restoration and Protection Plan," or Budd Lake Plan. In February of 2023, NJDEP approved the final draft of the Budd Lake Plan for implementation. The Plan includes the 9 points for watershed plans stipulated by the United States Environmental Protection Agency that identify pollutant loadings and sources, projects to address these sources, and ultimately to reduce pollutant loadings to Budd Lake through stormwater runoff management, riparian protections, and public outreach. Mount Olive Township and RHA are prepared to proceed with implementation of the Budd Lake Plan, which requires characterizing baseline water quality and aquatic habitat conditions so that future monitoring can be used to demonstrate improvements to the Lake and its watershed over time as elements of the Plan are implemented.

The final, NJDEP-approved Budd Lake Watershed Restoration and Protection Plan and the Budd Lake Monitoring Plan are available at: https://www.raritanheadwaters.org/wp-content/uploads/2024/05/Budd-Lake-WRPP_NJDEP-Approved.pdf https://www.raritanheadwaters.org/wp-content/uploads/2023/04/Budd-Lake-WRPP-Monitoring-Plan.pdf

Proposed Budd Lake Baseline Characterization

A key component of the Budd Lake Plan is the Monitoring Plan to establish changes in water quality over time and thus assess the success of the Budd Lake Plan projects in addressing stormwater inputs of targeted pollutants and the health of aquatic ecosystems pre- and post-plan implementation. While there have been some studies of water quality in the Lake, to our knowledge there have been no recent comprehensive water quality and hydrologic assessments of Budd Lake. RHA proposes to conduct a baseline characterization study of Budd Lake, its main tributaries (inlets), and the lake's outlet on the South Branch Raritan River.

Of note, this scope of work encompasses a proposal that will be split into two funding phases, which are discussed in more detail in the Project Deliverables section. However, to provide a holistic understanding of the project, we have included details of both phases in this scope of work. Importantly, currently, we request funding only for Phase 1 of this project. The respective funding requests for the two phases are divided accordingly in the Project Budget (Table 3).

The baseline characterization will inform the development of a Quality Assurance Project Plan (QAPP) for monitoring the Budd Lake Plan impacts going forward. Part of the baseline assessment will be to compile all data from past and current monitoring programs being conducted by RHA, NJDEP, and Mount Olive Township and its past consultants. Previous studies (published and gray literature) will be compiled as part of the development of the baseline characterization study and Budd Lake monitoring QAPP. RHA's biological and habitat monitoring already operates under a Tier 3.3 (regulatory), NJDEP-approved QAPP, which will apply to this project in the overall Budd Lake monitoring QAPP. However, chemical and bacterial parameters will require additional QAPP development and research certification by NJDEP to ensure these data are accepted for regulatory purposes.

In summary, this study will characterize pre-implementation, baseline water quality, hydrology, and habitat conditions within Budd Lake and its tributaries, which will serve as a point of comparison for changes in water quality post-implementation. In addition, the baseline characterization will guide in planning Budd Lake Monitoring QAPP development for a future, post-implementation monitoring program.

Budd Lake Study Area: Budd Lake is a 374-acre glacial lake located in Mount Olive Township, Morris County, New Jersey and is contained in HUC-14-02030105010030 (Raritan River South Branch; above Rt 46). The Lake and its watershed is located in the Highlands Preservation Area and thus under the jurisdiction of the New Jersey Highlands Council. It is the largest naturally formed lake in New Jersey and is the source of the South Branch Raritan River, which is the water supply for 1.8 million New Jersey residents. Budd Lake is a Category 1 (C1) waterbody. A Total Maximum Daily Load (TMDL) for fecal coliform has been developed to identify and characterize potential pathogen sources and the load reductions necessary to meet Surface Water Quality Standards (SWQS). In addition, Budd Lake has experienced Harmful Algal Blooms (HABs) over the past several years, which has impacted recreational uses because of threats to human health. It is our hope that through this characterization study, we will identify necessary water quality conditions to understand targeted pathways for restoration and impairment mitigation. Ultimately, understanding and improving Budd Lake will support the cultural and economic revitalization of this important New Jersey landmark.

Personnel: RHA's Science Program boasts an award-winning Stream Monitoring Program, which is certified at Tier 3.3 for regulatory-level data use by NJDEP and will be certified for additional chemical and bacterial parameters in the coming year. RHA's Science Program includes: a Ph.D.-level Director, who provides development and oversight of all science programs and staff; a Master's-level Watershed Scientist who oversees the collection of water quality data by other staff, interns and volunteers as well as analysis and reporting; a Water Quality Technician who assists with data collection in the field and lab and data analysis; and seasonal research interns. In addition, RHA has a Science Associate/Municipal Outreach Coordinator who assists with science program operations and outreach programs such as Budd Lake Plan implementation with municipal liaisons. Finally, RHA's Director of GIS/IT is responsible for database management and data communication/visualization using maps. These staff would all participate to some degree in the baseline characterization and future monitoring project for Budd Lake.

The baseline characterization study and monitoring plan will also incorporate a community/citizen science component, meaning RHA will engage community volunteers in the collection of baseline data. Before and during the monitoring season, RHA will recruit and train volunteers within and beyond the Mount Olive community to participate in research we conduct in the Lake and its tributaries. These community volunteers will be supported by an RHA staff member when collecting data. They will also receive training on the Budd Lake Plan, the stormwater issues it addresses, proposed green infrastructure projects, River Friendly programs, and best management practices (BMPs) for a healthy Budd Lake watershed. This aspect of our monitoring program will promote implementation of watershed restoration and protection pathways as outlined in the Plan.

Baseline sampling will be scheduled considering lake management activities, including work by Mount Olive's environmental consultants who monitor and treat aquatic plants and algae.

Project Deliverables: The proposed characterization study includes four main deliverables including project development, outreach, implementation, and reporting. The Deliverables may be split into two phases as follows: Phase 1 will include Deliverable 1, Deliverable 2, and part of Deliverable 3 (Deliverable 3a); Phase 2 will include the latter part of Deliverable 3 (Deliverable 3b) and Deliverable 4. Due to the extent of the sampling regime planned for Deliverable 3, a single phase–as they are proposed in this scope of work–will not accommodate the entire deliverable. Thus, this deliverable must be split into two parts.

- **Deliverable 1 (Phase 1), QAPP Development for Baseline Characterization and Future Monitoring:** This deliverable covers the development of a QAPP, which will be used to establish quality assurance with NJDEP for the use of this data at a regulatory level, as well as providing guidance on data quality. Through QAPP development and thus collaboration in developing this study with NJDEP, we will ensure this study–and data thereof–are of the highest possible quality. A piece of QAPP approval and study validation will include certification of our research laboratory and research instruments. This deliverable will also include compilation of historical and recent lake studies and management efforts for Mount Olive Township's utilization and comparison to this proposed characterization study to understand lake changes through time.

- **Deliverable 2 (Phase 1), Development of Community Science Program:** This deliverable includes the development of a community volunteer-based monitoring team including members of the Mount Olive community and beyond. Deliverable 2 ensures that RHA staff are engaging community members within this research program and thus improving environmental awareness

and literacy throughout the community. Additionally, the presence of a volunteer monitoring team will lessen costs associated with time required to carry out this characterization study. RHA staff will recruit volunteers at five education programs planned for the year. In addition, RHA will enlist the help of existing stream monitoring volunteers, several of which live in Mount Olive Township, to help with the project. Following volunteer recruitment, we will fully train volunteers (community scientists) as part of our corps of community scientists to carry out research protocols–in collaboration with an RHA staff member at each sampling. Volunteers will also be certified by NJDEP staff as part of our existing Biological QAPP. Our target is a team of 10 new community scientists for this project.

- **Deliverables 3a & 3b (Phases 1 & 2, respectively), Baseline Characterization of Budd Lake:** Our third deliverable covers the baseline characterization of Budd Lake. There are three main tasks associated with this deliverable: summer HABs monitoring; lake and tributary water quality monitoring, as well as a monitoring site just below Budd Lake on the South Branch Raritan River (see Table 1 for monitoring parameters, locations, schedules, and methods); and sediment testing of the lake-bottom and select tributaries. Summer HABs monitoring occurred biweekly in July through September of 2024, which is included in this proposal. This monitoring included quantification of phycocyanin at three sites in the lake, as well as microcystin (a cyanotoxin) and identification of cyanobacteria blooms. The opportunity to study HABs was provided by Montclair State University through a citizen science grant, and we capitalized on the opportunity to document HAB presence and toxin production during the summer cyanobacteria growth season.

  Water quality testing in the lake, tributaries, the outlet to the South Branch Raritan River, and along the shoreline below Rt. 46 will allow us to identify pollutants present in the lake, as well as their respective sources from tributaries and stormwater outfalls (only if actively discharging, with a max of ten stormwater outfall samples). Rainfall data from nearest CoCoRaHS precipitation stations (https://www.cocorahs.org/state.aspx?state=nj) will be compiled and summarized.

  We will use a hand-held sensor to develop vertical profiles within the lake–and measurements within tributaries and at stormwater outfalls–of temperature, dissolved oxygen, pH, and conductivity. We will use hand-held sensors for measurement of chlorophyll-α and phycocyanin, as well as a turbidimeter for measurement of turbidity. We will use a subcontracted lab for measurements of total nitrogen, total phosphorus, total suspended solids, chloride, *E. coli*, surfactants, and PFAS. These lake and tributary water tests will occur monthly during Winter, early Spring, and late Fall, and every two weeks from April through August; this will be a total of seventeen sampling events at twelve sites. The twelve sites cover seven inlets to the lake, the one outlet (South Branch Raritan River) adjacent to the beach, three mid-lake samples of the epilimnion, metalimnion, and hypolimnion, and a shoreline stormwater outfall samples along Rt. 46. Water testing will also cover expenses associated with RHA's current climate station–a sensor present near the outlet of Budd Lake that continuously measures temperature, conductivity, and water depth to understand fluxes associated with the lake outflow (see https://www.raritanheadwaters.org/climate-stations/). Finally, this deliverable will cover the biological (benthic macroinvertebrate sampling) and visual habitat assessments leading to High Gradient Macroinvertebrate Indices (HGMI) and Total Habitat Scores to understand impacts of stormwater within the tributaries to Budd Lake and below Budd Lake on the South Branch Raritan River.

As part of our characterization, we will map the bathymetry of Budd Lake to determine the volume of the lake for physical studies. We will also study the flow of the tributaries and outlet to understand water input and output of the lake. Using bathymetry, water flow, and temperature profiles, we can understand the lake's turnover, stability, and water residence time. These metrics are useful in determining the rate at which the lake receives and discharges pollutants and nutrients, and thus its tendency to retain these substances.

Quarterly lake-bottom sediment testing will include collecting sediment samples for measurement of iron and phosphorus to determine phosphorus loads and sequestration capacity present in the lake. Lake sediments rich in iron are able to bind much phosphorus and under certain conditions can contribute to internal loading of phosphorus into the water, which can contribute to HAB growth.
A one-time testing will take place for determining the presence of toxic contaminants in the lake sediments & tributary sediments that may enter the lake through groundwater inputs. Contaminants in this category will include PFAS, mercury, arsenic, lead, cadmium, 1,4 dioxane, persistent pesticides and VOCs to establish the presence of these potential legacy contaminants in the lake.

This deliverable is split between the two proposed phases of this project as Deliverable 3a and Deliverable 3b, where the division will occur at the end of September/beginning of October. Thus, funding for this deliverable is split at this time division.

<table>
<tr><th colspan="4">Table 1. Monitoring Parameters, Locations, Timing, and Methods</th></tr>
<tr><th>Parameters</th><th>Sampling Frequency</th><th>Locations[1]</th><th>Monitoring Methodology</th></tr>
<tr><td colspan="4">Water Quality Monitoring</td></tr>
<tr><td>Total Nitrogen</td><td rowspan="12">Once per month January through March & October through December; twice per month April through September (with at least one sample obtained during summer within 24 hours of significant rainfall and a max of ten stormwater samples)</td><td rowspan="6">Mid-lake epilimnion, metalimnion, hypolimnion[2]; seven inlets, one outlet, one shoreline sample, intermittent stormwater drainage samples</td><td rowspan="6">Grab-sample with analyses by subcontracted laboratory</td></tr>
<tr><td>Total Phosphorus</td></tr>
<tr><td>Total Suspended Solids</td></tr>
<tr><td>Chloride</td></tr>
<tr><td>E. coli</td></tr>
<tr><td>Surfactants</td></tr>
<tr><td>Turbidity</td><td rowspan="6">Full mid-lake vertical profile[3], seven inlets, one outlet, one shoreline, intermittent stormwater drainage samples</td><td rowspan="6">Hand-held sensor</td></tr>
<tr><td>Temperature</td></tr>
<tr><td>Dissolved Oxygen</td></tr>
<tr><td>Conductivity</td></tr>
<tr><td>Total dissolved solids</td></tr>
<tr><td>pH</td></tr>
</table>

[1] Approximate sampling locations can be found below in Figure 1.

[2] Lake water columns are delineated between the epilimnion (top lake, near the surface), metalimnion (middle lake), and hypolimnion (bottom lake). Sampling at different depths ensures a more comprehensive understanding of lake water quality dynamics.

[3] Vertical profiles are measurements taken at set depths (e.g., every foot) from the bottom of the lake to the surface. This improves understanding of lake stratification and turnover.

PFAS	Once during dry conditions (summer)	Mid-lake epilimnion, metalimnion, hypolimnion, seven inlets, one outlet, one shoreline sample	Grab-sample with analyses by subcontracted laboratory
Continuous Monitoring			
Temperature	Continuous measurements every 15 minutes.	South Branch Raritan River downstream of outlet	Deployed sensor
Conductivity			
Depth			
Biological Monitoring			
HGMI	Once during summer	Seven inlets and one outlet	Macroinvertebrate preservation with analyses by subcontracted laboratory
Hydric Soil Monitoring			
Total Iron (also includes Lead, Arsenic, Cadmium)	Quarterly in lake, once in inlets/outlet during dry season (summer)	Bottom of mid-lake, seven inlets, and one outlet, one shoreline	Grab-samples with analyses by subcontracted laboratory
Total Phosphorus			
PFAS	Once during dry conditions (summer)		
Mercury			
Copper			
PCBs			
Persistent Pesticides			
PAHs			

Hydrogeomorphological Monitoring			
Visual Habitat Assessments	Once	Seven inlets and one outlet	NJDEP-approved worksheet
Flow Monitoring	Once per month January through March & October through December; twice per month April through September		Hand-held sensor & computer modeling
Bathymetric Mapping	Once	Entire lake	

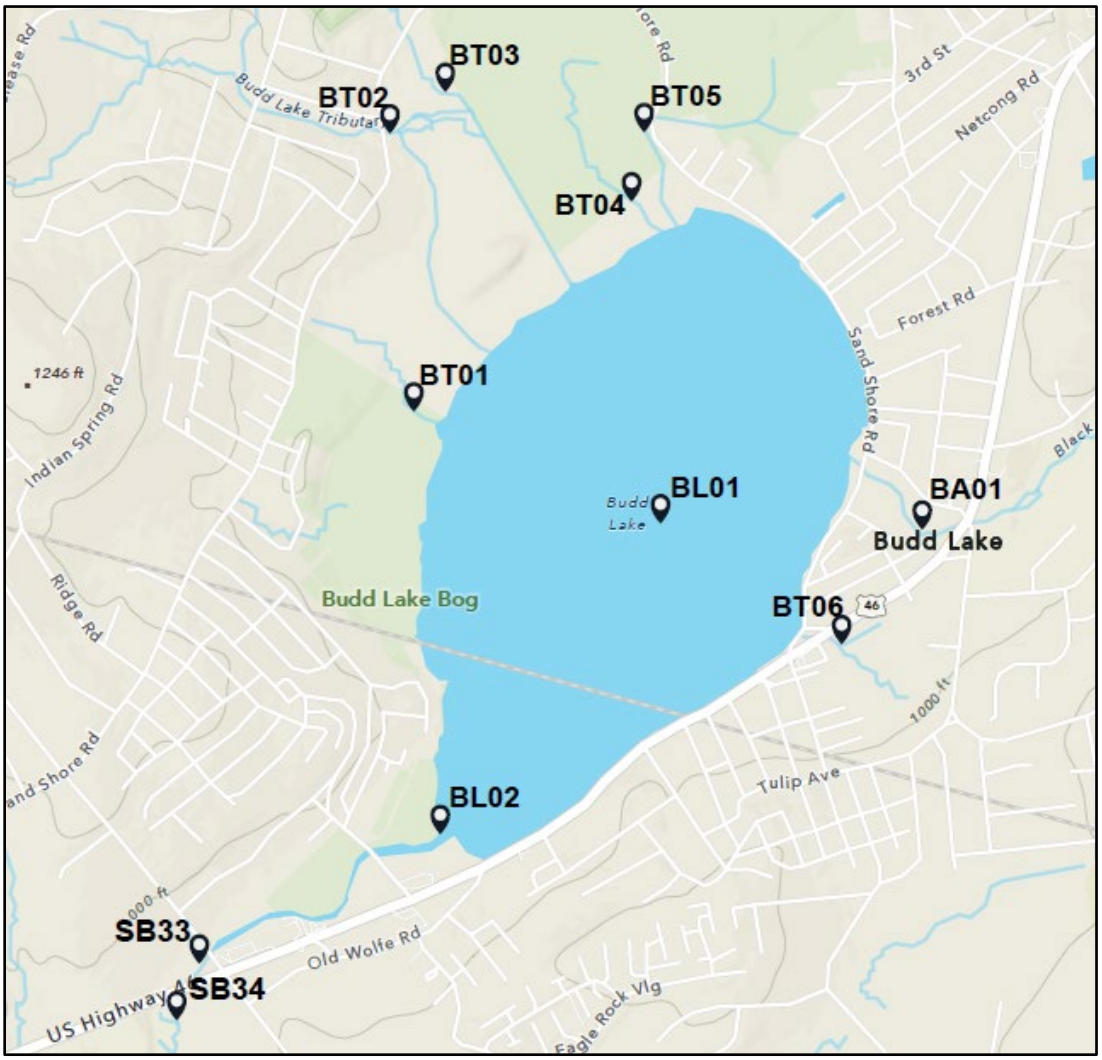

Figure 1: Approximate site locations for the Budd Lake characterization. BL01 is the mid-lake sample; BL02 is the outlet; BT and BA are tributaries (unnamed tributaries and Black Brook, respectively); SB33 is the outlet location for macroinvertebrate studies; SB34 is the in-place continuous sensor location.

- **Deliverable 4 (Phase 2), Reporting and Data Sharing:** This deliverable will cover the analysis and distribution of data collected throughout the characterization study. This includes generating data summary and analysis reports—both for a scientific audience and for a lay, community-based audience—as well as implementing educational programs to help community members understand water quality of the lake and community-based restoration opportunities. Additionally, this deliverable covers the submission of a dataset developed throughout Deliverable 3 to Mount Olive Township, The New Jersey Highlands Council, NJDEP and the EPA's Water Quality Exchange portal (WQX). Deliverables and associated tasks are summarized in Table 2.

Table 2. Deliverables & Associated Tasks		
Tasks		**Timeline**
Phase 1		
Deliverable 1: Monitoring Program QAPP		
1.1	Budd Lake Monitoring QAPP Development & Lab Certification (RHA Probes and Sensors for chemical parameters; bacteria, nutrient, and chloride analyses by a state-certified lab)	January 2025-April 2025
1.2	Budd Lake and Tributary site reconnaissance	January 2025
1.3	QAPP submission and approval	April 2025
1.4	Compilation of historic data & management efforts	January 2025-February 2025
Deliverable 2: Community Volunteer Recruitment and Training		
2.1	Education & outreach programs (including program preparation)	February 2025-May 2025
2.2	Volunteer research trainings (including training preparation)	April 2025-June 2025
Deliverable 3a: Baseline Data Collection		
3a.1	Lake and tributary water quality monitoring	April 2025-September 2025
3a.2	Lake-bottom & tributary sediment testing	April 2025-September 2025
Phase 2		
Deliverable 3b: Baseline Data Collection		
3b.1	Lake and tributary water quality monitoring	October 2025-April 2026
3b.2	Lake-bottom & tributary sediment testing	October 2025-April 2026
Deliverable 4: Budd Lake Baseline Characterization and Data Sharing		
4.1	Data management and analyses	September 2025-June 2026

4.2	Written report to Highlands Council and Mount Olive Twp.	May 2026-June 2026
4.3	Public presentations/education programs covering lake conditions and restoration opportunities in the Budd Lake Plan	May 2026-July 2026
4.4	Data submission to Highlands Council and WQX/NJDEP	May 2026-June 2026

Table 3. Project Budget		
Tasks		**Cost**
Phase 1		
Deliverable 1: Monitoring Program QAPP and Certification		
1.1	8 hours/week; 15 weeks (research tech & manager), 5 weeks (supervisor); *includes cost of lab certification and laptop for research tech	$21,438.00
1.2	8 hours (manager & supervisor)	$800.00
1.3	8 hours (research tech)	$244.00
1.4	2 hours/week; 20 weeks (research tech)	$1,220.00
Cost of Deliverable 1:		**$23,702.00**
Deliverable 2: Community Volunteer Monitoring Recruitment and Training		
2.1	5 hours per program (including prep & coordination); 5 programs (manager & associate)	$2,075.00
2.2	5 hours per training (including prep & coordination); 5 trainings (manager & research tech)	$1,837.50
Cost of Deliverable 2:		**$3,912.500**
Deliverable 3a: Baseline Characterization Data Collection		
3a.1	Sample costs and consumables for water quality and macroinvertebrate studies, with travel costs and monitoring time	$47,305.50
3a.2	Sample costs for soil monitoring	$10,710.00
Cost of Deliverable 3a:		**$58,015.50**
Total Funding Request of Phase 1:		**$85,630.00**
Phase 2		
Deliverable 3b: Baseline Characterization Data Collection		
3b.1	Sample costs and consumables for water quality and macroinvertebrate studies, with travel costs and monitoring time	**$26,355.00**
3b.2	Sample costs for soil monitoring	**$800.00**
Cost of Deliverable 3b:		**$27,355.00**

Deliverable 4: Budd Lake Baseline Characterization Report and Data Sharing		
4.1	4 hours/week; 12 weeks (manager & research tech), 4 weeks (IT/data specialist)	$4,504.00
4.2	8 hours/week; 8 weeks (manager & research tech), 2 weeks (supervisor)	$5,616.00
4.3	5 hours per program (including prep); 3 programs (manager & associate)	$1,245.00
4.4	8 hours/week; 3 weeks (research tech & IT/data specialist)	$2,196.00
Cost of Deliverable 4:		**$13,561.00**
Total Funding Request of Phase 2:		**$40,916.00**

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