AUGUST 5, 2022

DRAFT BASIS OF DESIGN – WATER QUALITY
BARTLET MALL FROG POND
NEWBURYPORT, MASSACHUSETTS

PREPARED FOR:
City of Newburyport
PARKS DEPARTMENT

PREPARED BY:
Michael Igo, PE, D.WRE, LEED AP
AQUEOUS CONSULTANTS, LLC
2 Dundee Park Drive, Suite B07, Andover, MA

1. Executive Summary

The City of Newburyport (the City) initially retained Aqueous Consultants, LLC of Andover, Massachusetts (Aqueous) to investigate existing conditions and provide a feasibility study for rehabilitation of water quality at the Bartlet Mall Frog Pond along High Street in Newburyport, Massachusetts in February 2021. In November 2021, the City retained Aqueous to further our investigation and feasibility to develop a conceptual plan and in-depth study. This report is the culmination of our November 2021 proposal and months of research, communication with the City's Parks Department, Conservation Commission, our subconsultants, manufacturers, and the public at-large.

The adjacent Essex County Superior Court building, Bartlet Mall, and Frog Pond have local and national historical significance. The goal presented to us by the City's Parks Department are to achieve a water feature that maintains the formal integrity of a historically significant public space, while maintaining a water quality state that is safe for canoeing and incidental dermal water contact or ingestion, as what would be found in natural ponds with existing inflows and outflows. Ultimately, a clean and clear water feature during the spring, summer, and fall will, in turn, restore connectivity between Bartlet Mall, City residents, and visitors. It will draw people towards this space instead of repelling them with current algal blooms and murky water.

In conjunction with the feasibility report and work with GEI Consultants, Inc. of Woburn, Massachusetts (GEI), Geosphere Environmental Management (Geosphere) of Exeter, NH, and Engineering & Land Planning Associates, Inc. of High Bridge, New Jersey (E&LP), our primary recommendations to the City, and conclusions in this report are summarized as follows:

- Work with GEI's proposed liner and methane venting system installation to integrate a recirculation pump intake and return pipes.
- Add a mechanical water supply to maintain the newly lined Frog Pond with high water quantity and quality. By drilling a new bedrock well, as sited by Geosphere, the water will be continually filled and allowed to overflow periodically from rainfall and/or maintenance purposes into the existing City stormwater and emergency fire cistern network.
- Add continuous mechanical sand filtration of Frog Pond for particulate removal and continuous circulation.
- Add continuous oxygenation using surface aerators and/or air-entrainment through the return pipes of the pump recirculation system, and existing fountain mechanical restoration.
- Work with E&LP to reconfigure, replant, and repopulate Frog Pond with local aquatic wildlife to biomimic a natural pond to achieve balance in water quality.

- Aqueous' opinion of probable cost is $1.3M for construction costs (with contingencies) of infrastructure outlined in this report, as well as, the design, permitting, and construction oversight by Aqueous for City budgeting purposes.

The anticipated construction schedule is (subject to permitting):

Bid Advertisement	Mid-June 2023
Bid Ready Documents to City	July 7, 2023
Bid Period	July 10 – 28, 2023
Bid Evaluation	July 31 – August 11, 2023
Notice of Award	August 18, 2023
Notice to Proceed	September 1, 2023
Construction Phase	September 2023 – March 2024
Substantial Completion/Punchlist Phase	April 2024

The recommended yearly maintenance schedule is as follows:

Spring Start up – Pond Refilling	1st & 2nd week of April
Spring Start up – Start Pump System	April 15th – 17th
Spring Start up – Add Supplemental Pond Microorganisms	April 18th
Spring Start up – Pond recirculation (2 full change overs)	April 19th – April 30th
Open Pond to Public (Weather/Temperature Dependent)	May 1st – October 31st
Add Supplemental Pond Microorganisms	July 1st & September 1st
Winter Shutdown - Stop Recirculating and Filling Pond	November 1st
Winter Shutdown - Drain Pond by ¼ & winterize systems/equipment	1st week of November

2. Introduction and Project Background

The City approached Aqueous in February 2021 for an initial meeting to discuss Frog Pond. Aqueous and GEI were recommended to the Newburyport Parks Commission by our work on the Boston Public Garden Lagoon project. Both water bodies require a similar outcome for users – a water feature clean enough for incidental contact, but not "swimming pool clean". The City's goal is to reclaim Frog Pond as a functioning water feature incorporating as many elements as possible of a natural pond through biomimicry, while ensuring feasible management and maintenance given the City's resources.

In August 2021, Aqueous submitted their Preliminary Alternatives Evaluation – Water Quality report to the City for their review and comment. This report outlined the following:

- The history of Frog Pond
- Frog Pond's existing conditions
- Previous rehabilitation attempts
- The required water quality parameters to maintain a healthy water body
- The proposed usage limitations of the rehabilitated Frog Pond
- Anticipated maintenance needs and frequency of the rehabilitated Frog Pond
- Anticipated probable cost (construction, design, permitting, and construction administration)

Once Aqueous was approved to begin compiling this report, we allowed our subconsultant, Geosphere, to begin their Fracture Trace Analysis (FTA) to locate potential bedrock drilling sites. Concurrently, we began our subconsultant arrangement with E&LP to have them provide a plan to prevent future harmful algal blooms (HAB) in Frog Pond and provide means and methods for future ecological balance. These means and methods include work within and outside Frog Pond to best manage intrusion of stormwater pollutants and to consume future nutrients after Frog Pond has been lined that serve as a food supply for algae and cyanobacteria. These subconsultant reports are discussed in this Basis of Design and attached as appendices.

During this phase of work, Aqueous has been in communication with Lise Reid, now former Parks Director, Kimberly Turner, Special Projects Director, and various members of the Parks Committee on site. Additionally, Aqueous and GEI presented the preliminary design plan to the Committee on July 14, 2022. We have taken heed from concerns by members of the public at-large discussed during this presentation and they have been addressed in this report.

2.1. Acknowledgements

While the contents of this report are strictly the viewpoints, analysis, and findings of Aqueous, it could not be possible without the City of Newburyport as clients, Bartlet Mall stakeholders, the Newburyport public at-large, our partnership with GEI Consultants, Inc., and the subconsultant team assembled by Aqueous. This report is the culmination of a continuous feedback loop from over a dozen professionals with bachelor's, master's, and doctorate degrees from some of the best universities in the world, professional licenses in engineering, geology, landscape architecture, and Licensed Site Professionals with hundreds of years of combined experience. In addition, Aqueous' strong relationships with water system manufacturers and construction managers gives us confidence that the feasibility study and initial design approach presented within will result in a functional manmade Frog Pond usable for people, pets, plants, animals, and organisms for decades to come. Collectively, this project has an unprecedented number of qualifications, which we believe is required for such an important project.

The following organizations and people receive our thanks:

City of Newburyport

- Lise Reid, CPSI, (Former) Newburyport Parks Director
- Kimberly Turner, Newburyport Director of Special Projects
- Jon-Eric White, P.E., Newburyport City Engineer
- Newburyport Parks Commission
- Newburyport Public At-Large

GEI Consultants, Inc.

- Krista Wolfe, P.E.
- Michael Sabulis, L.S.P.
- James Ash, P.E., L.S.P.

Geosphere Environmental Management, Inc.

- Ray Talkington, Ph.D., P.G.

Environmental Land & Planning, Inc.

- Ed Confair P.E., P.L.A.
- Megan Schmidt
- Matt Connors P.E., LEED AP (Now with Hancock Associates)

2.2 Limitations

This report was prepared by Aqueous and its subconsultants for the exclusive use of the City of Newburyport as consultation towards a basis of design and eventual preparation of construction documents (drawings, details, and specifications) for water quality and site improvements for Frog Pond at Bartlet Mall. This report and basis of design shall not be construed or used as construction documents for bidding or installation: further assessment is required during the construction document preparation phase. The recommendations provided by Aqueous and its subconsultants in this report are based solely on the information gathered and provided in this report. Information that was not available to Aqueous during the compilation of this report, or future discoverable conditions in the field, may result in a change in recommendations from this report. Additionally, this report has been prepared in accordance with generally accepted engineering practices. No other representations and no warranty, express or implied, have been made. Any reference to construction costs, or permitting quantity and time, are strictly estimates for budgeting purposes and are subject to change based on global economic conditions, supply chain conditions, labor bandwidth, and regulation(s) at the time of permit application and is not a guarantee by Aqueous or its subconsultants.

3. Existing Conditions

Figure 1: Existing Frog Pond at Bartlet Mall (Taken April 27, 2021)

3.1. Site Description and Existing Conditions

Bartlet Mall, operated by the City of Newburyport (the City) is situated between High, Pond, Greenleaf, and Auburn Streets in Newburyport, Massachusetts. It includes the historic and still operating Essex County Superior Courthouse, as well as a surrounding park offering respite for residents and tourists alike. The centerpiece of Bartlet Mall is Frog Pond, a 2.3-acre surface water body that has an average depth across its center of about 4 feet based on previous depth measurements[1]. Frog Pond is at the bottom of slopes coming down from the surrounding streets. There is a walking path around the entire perimeter of Frog Pond with the Superior Courthouse against the northeast corner of the walking path (see Figure 1).

The history of Frog Pond is as old as Newburyport itself, as the water body is the result of continuous anthropogenic manipulation and alteration. Based on discussions with the City and review of previous studies, Aqueous understands that Frog Pond is the remnants of a glacial kettle hole after the last Ice Age ended. As described by Horsely Witten Group's 2014 report, there could be multiple explanations for the peat and muck stratigraphy within Frog Pond. In addition to review by City historians, Aqueous prefers to assume from a water quality rehabilitation perspective, that any wetlands that formed in the void space of the kettle hole were altered by colonial settlers as far back

[1] Sediment Evaluation Summary, Bartlet Mall Frog Pond, Submitted to Newburyport Parks Commission by Horsely Witten Group, October 2014

as the 17th century. Natural streams that ran through these wetlands most likely were dammed up by local livestock farmers to allow cattle to graze and drink water—not an unprecedented practice of the times. With a rising water level due to the impoundment, wetland or aquatic plant life within the kettle hole would drown, die, and the decaying plant material would join ancient flora and sediment as peat at the bottom, as observed in recent testing conducted by GEI. Portions of Bartlet Mall served as the "Trayning Ground" [sic] for militia during the American War for Independence (Revolutionary War) in the late 18th century.

The Courthouse was built in 1800 and the surrounding streets became more developed. The overflow and hydrology of Frog Pond became further altered. Busier, more well-defined streets likely created more uncontrolled runoff towards the lower lying areas. The construction of the growing city altered original groundwater patterns. After the Great Fire of 1811, Frog Pond was re-engineered again to serve as an emergency fire cistern filling source under the streets of Newburyport. Construction of the underground fire cistern network began in 1840 and was completed in 1908. The advent of motorized vehicles with brake dust and emissions, along with the urbanized transition of the Bartlet Mall from cow pasture to public park may have accounted for the nutrient increases seen from various studies. It is fair to state that the "Pond" has not been a natural water body for almost the entire existence of Newburyport from colonial times to the present day.

A critical piece to the observed degraded Frog Pond health is that, over time, the original inflow source(s) and outflow means for circulation were lost and/or permanently altered. Dye tests by City staff confirmed that there are currently no storm drainage structures within the surrounding streets empty into or receive water from Frog Pond. It was additionally confirmed by GEI in their March 2022 report[2] that 1.) the groundwater table is approximately 30 feet below the bottom of Frog Pond and 2.) surface water of Frog Pond is not hydraulically connected to the natural/existing groundwater table due to the low-permeability sediment, peat, and shallow low-permeability silty sand lenses in Frog basin. Thus, any water entering and leaving Frog Pond comes from:

- Direct Rainfall and Runoff from the Surrounding Areas Filling Frog Pond
- Evaporation in the Summer

As such, without any apparent natural inlet or outlet, Frog Pond suffers from lack of circulation, aeration, and water changeover.

[2] Investigation Summary, Detailed Alternatives Evaluation, and Recommendations by GEI Consultants, Inc., March 2022

In the course of Aqueous' preliminary work, the City provided maps, locations, and photographs of the existing outlet from Frog Pond to the fire cisterns throughout the streets of Newburyport (see Figure 2). At some point in the past, Frog Pond outlet valve allowing water from Frog Pond to the street was closed and never opened again. As such, the outlet valve, located next to the Courthouse stairs (see Figure 3) is now rusted and/or calcified shut (see Figure 4). Moreover, the street cistern network has been dormant for years and its current condition is unknown. The City is undergoing an investigation to reopen and reuse this network, and Aqueous will coordinate with the City during detailed design to verify that this overflow system is a viable option. Replacing and opening this outlet valve or reconfiguring this valve as an outlet control structure for Frog Pond overflow will be critical to achieve proper maintenance.

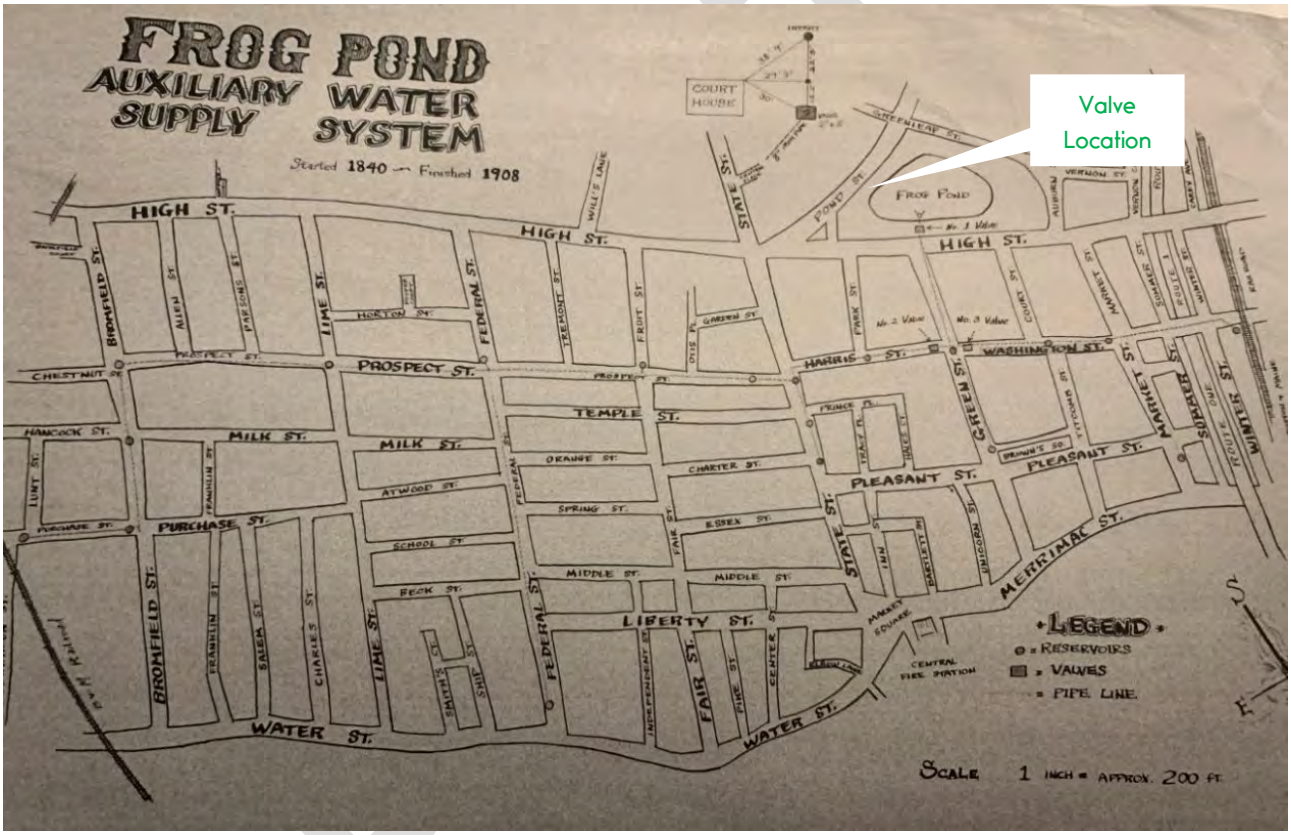


Figure 2: 1908 Map of Cistern Network

Figure 3: Valve Location next to Courthouse Steps

Figure 4: Valve and Condition in August 2021

Even if it were fully functional, the existing pipe outlet is limited in its ability to release Frog Pond water to the cistern network as it is piped and valved versus a natural overflow. For additional information related to Frog Pond outlet options, refer to Section 4.4.1.

Without a known or consistent water supply entering Frog Pond, no meaningful circulation and attenuation of water quality can take place. The preferred alternative would be water pumped from a deep bedrock well to refill Frog Pond to keep up with evaporation losses during the summer. An alternative to well water is domestic water, which was suggested by a member of the public at-large in attendance at our July 14, 2022 Parks Committee presentation. While Aqueous recommends a domestic water line for the refurbished fountain and for maintenance/emergency purposes, this alternative water resource was not preferred by the City from a sustainability and a public perception standpoint, with which Aqueous agrees. For additional information regarding the proposed water source options for Frog Pond, refer to Section 4.2.

3.2. Frog Pond Eutrophication

In the Spring of 2021, Aqueous met with the City, stakeholders, and GEI to observe Frog Pond, Bartlet Mall, Superior Courthouse, and discuss the potential rehabilitation goals for water quality. Historically, Frog Pond turns green annually and becomes turbid. During multiple site visits documented by Aqueous in April 2021 (see Figure 1 above), Frog Pond was clear, although it was already starting to express higher turbidity from suspended sediments and starting to turn green from algae. On-line aerial images generally show Frog Pond in the summer and fall as completely green (see Figure 5).

Figure 5: Google Earth Map of Bartlet Mall Frog Pond turned Green (Accessed in 2021; Map Data ©2021 Google)

Aqueous' observations and the various studies reviewed lead us to believe that Frog Pond is experiencing eutrophication—an overabundance of nutrients (nitrogen, N, phosphorous, P, and potassium, K, collectively, NPK) within its water column. As plants and phytoplankton (algae and cyanobacteria) require nutrients for growth, higher nutrient availability generally leads to higher growth. Phosphorous is generally the limiting nutrient for plant and phytoplankton growth. Nutrients adhere to soil particles over a long period time and are difficult to extract through natural processes. Moreover, the excess of sediment provides ideal cover for algae and cyanobacteria to retreat until the conditions are favorable for proliferation once again[3].

[3] Assessment of Frog Pond (Newburyport, MA) Water Quality and Its Restoration, concerned Newburyport citizen letter (uncompensated) by Professor Vladimir Novotny, Ph.D., P.E., B.C.E.E., updated January 28, 2019. Note: the views of this Basis of Design Report are strictly those of Aqueous and not those of Professor Novotny—we refer to his uncompensated citizen's letter for background information given his expertise and lifelong illustrious work. There is no affiliation or contractual consulting arrangement between Aqueous, its subconsultants, or GEI and Professor Novotny.

Late spring and summer at Frog Pond appear to be the perfect breeding ground conditions for algae and cyanobacteria. As the days get longer and warmer with more sun and the water level drops due to evaporation, the high nutrient loading that already exists in Frog Pond accelerates the growth of algae and cyanobacteria that have been lying dormant during the winter. Aqueous observed Frog Pond water elevation to be 48.5 feet above sea level on January 28, 2022 and 47.0 on June 20, 2022—a 1.5-foot or 18-inch water level drop. For an average depth of 4 feet across, Frog Pond lost approximately 38% of its depth from this winter to summer. This is typical without a natural inflow or outflow. The lack of rainfall in 2022 highlights the need for a supplemental water supply besides runoff.

Catalysts for the proliferation of algae and cyanobacteria are:

- Sunlight for Photosynthesis
  - Shallow water for sunlight to reach the bottom, drawing algae and cyanobacteria out of sediment and onto Frog Pond surface
- Warmer Temperatures
  - Gradually increasing during the year without incoming freshwater
- Consistent Nutrient Supply
  - Abundance of nutrients in sediment leaching into water for algae and cyanobacteria to consume

To summarize, in the existing condition, algae and cyanobacteria have an endless supply of direct sunlight with shallow water and no surrounding shade, warm water temperatures, and nutrients in the summer. Thus, their proliferation causes Frog Pond to be green, opaque, turbid, and a potential health risk for humans, pets, and wildlife during incidental contact. There is too much nutrient loading, contaminated sediment, and dormant cyanobacteria within Frog Pond to rehabilitate the existing condition. The City must start anew to achieve a water feature for interaction with humans and animals. Following GEI's recommendation to line Frog Pond, Aqueous recommends implementing a water quality management system on a pond-sized scale that uses both mechanical means and biomimicry of natural processes that healthy ponds possess.

4. Frog Pond Water Quality Parameters and Equipment

Water bodies are very similar to human bodies in that there are basic elements, compounds, nutrients, and organisms required to maintain health and well-being. When any of these are out of balance, such as the existing Frog Pond's condition, the water body can become sick. Aqueous outlines the necessary elements of water body health, in our opinion of order of importance. The most important constituents of water health have an influence on the remaining factors. Figure 6 shows the progression of water quality parameters to consider for a healthy Frog Pond once it is lined and refilled with clean water.

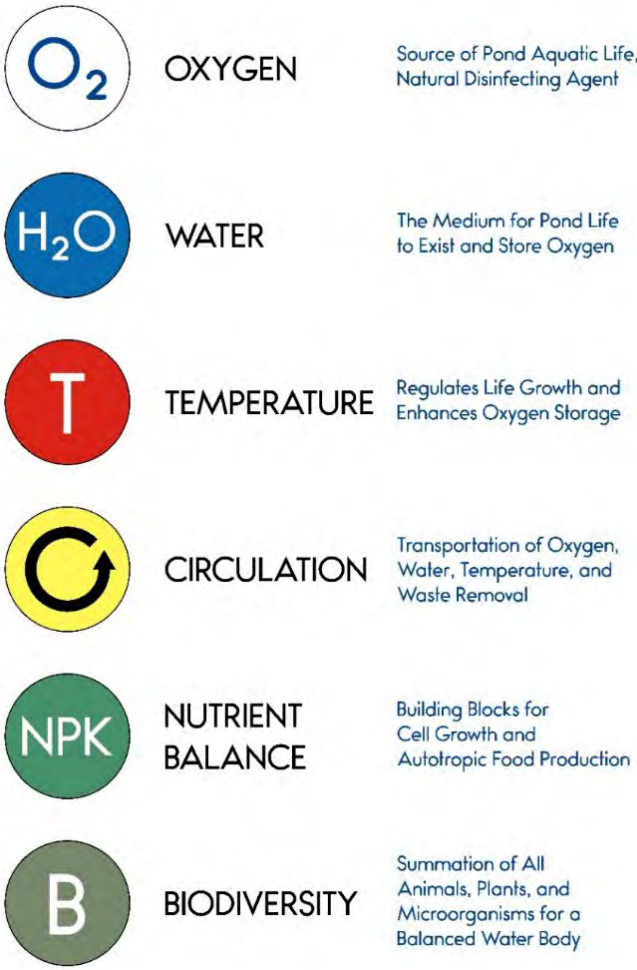


Figure 6: Water Quality Parameters in Descending Order of Importance for Water Health

The first step, prior to any water quality rehabilitation is to remedy the source of the nutrients through lining Frog Pond, the design of which is being spearheaded by GEI. One strong alternative proposed by GEI is to not scrape the existing sediment layer to minimize disruption of the sediment and laying the High-Density Polyethylene (HDPE) liner directly on top, followed by 3-inch crushed stone armor layer and 3-inch sand layer. The combination of the HDPE liner and crushed stone will create a barrier

for the water column from the phosphorus-rich sediment below, and the sand layer will act as a benthic layer providing ecological balance for organisms living at the bottom of the proposed water body. See GEI's report for further information. Once the liner, stone, and sand are installed, Frog Pond's transformation into a healthy water feature biomimicing a natural pond to the extent practicable can truly begin.

To maintain the minimum required water depth, a series of granite curbing and benches, desired by the City of Newburyport for aesthetic purposes, will be set 6 inches higher than the existing bank to allow for the 6 inches of water depth lost to the armor stone and benthic sand layers. The granite curbing will be integrated into the liner, stone, and sand design to serve as an additional anchor and barrier for bottom and sidewall from potential intrusion of groundwater and nutrients. The newly lined Frog Pond will be closed hydraulically from its surroundings in the proposed conditions. The granite curbing is a critical aesthetic design element for the City to establish it more as a formal water feature and less as a natural pond. A rendering provided to Aqueous by the City is included in Figure 7 below. This rendering is conceptual in nature at this point, but there is precedent in historical water features with the Boston Public Garden Lagoon (Figure 8).

Figure 7: Rendering of Frog Pond Provided by City of Newburyport

Figure 8: Granite Curbing Circumscribing Boston Public Garden Lagoon
(Shallower Curb Height and Pond Depth than Proposed for Newburyport Frog Pond)

Aqueous also proposes installing a new recirculating pump and aeration system that can increase circulation and oxygen within Frog Pond. Water would be partially filtered through an underground pump station and discharged back to Frog Pond through a series of pipes integrated above the liner, but below the stone armor system proposed by GEI. The filter would automatically backflush to an on-site dry well that would not be hydraulically connected to Frog Pond. Water would only be partially filtered because dissolved constituents cannot by filtered out through a screen or an inactive media such as sand. The pump and filter system would be installed below grade in a vault built into the side slopes of Bartlet Mall to not disrupt the visual appeal of Frog Pond (see Error! Reference source not found.). This is a current desired requirement of the City of Newburyport at this stage of planning. However, there are less expensive above-grade options that will be considered during the construction document phase, such as architectural sheds and metal enclosures. While these are less desirable aesthetically, they provide a more practical solution with the opportunity to add aesthetic features as the City sees fit. Vault appurtenances such as vents and manholes should be "hidden in plain sight" to not draw attention to them.

Figure 9: Frog Pond Underground Pump Station

The pump system will be fully automated to monitor the water level within Frog Pond, initiate refilling from the bedrock well, schedule aeration, monitor key water quality parameters, such as pH, oxidation reduction potential (ORP), and temperature to maintain balance and clarity within Frog Pond. Additionally, Aqueous recommends that internet-based controls be included through cellular data service for Newburyport Parks Department to monitor and receive alerts for maintenance of the recirculating pump system. For additional information regarding the pump station, refer to Section 4.4.2.

The goal is to provide moderate filtration within Frog Pond in order to maintain clarity and to recirculate cleaner water. The intent is to biomimic, or mimic the natural process of, groundwater that has been filtered through sand by returning the water at the bottom, similar to a spring or side or bottom groundwater baseflow. Sand filtering does not fully disinfect a pond or water feature—it is intended to be one necessary mechanical system to maintain water clarity without an existing natural inflow of water, such as a stream or brook. Sand filtering will allow for microorganisms and pond life to find balance, unlike a fully chlorinated or ultraviolet disinfection recirculation system. This is another reason why domestic water is not recommended. As established by GEI's testing, there is no connection between groundwater and Frog Pond's water level, thus, any filtration of water to replicate a natural pond will have to be by mechanical means. Sand filters, circulation, oxygenation, and plant and animal biodiversity will maintain balance within Frog Pond to biomimic, natural processes.

4.1. Oxygen

The source of beneficial life within Frog Pond is oxygen. Dissolved Oxygen (DO) within the water supply provides natural disinfection of excess bacteria and viruses. While Frog Pond is not currently stocked with fish, DO allows for other beneficial aquatic life (such as amphibians) to draw oxygen from and restore balance. Based on previous studies on the existing condition, oxygen also plays a critical role in keeping Total Phosphorous (TP) locked in the existing pond sediment and slows down its diffusion into Frog Pond water. As oxygen depletes in the summer due to increased water temperature and evaporated water surfaces, TP concentrations within the water increases. TP is a nutrient and is sustains the proliferation of algae and cyanobacteria observed in Frog Pond.

The City has expressed a desire to add as much natural character to Frog Pond as possible amidst the surrounding urban environment. Therefore, the existing fountain in the center of Frog Pond will be refurbished to assist in providing additional oxygen. The fountain operation can provide a level of aesthetic appeal and minor surface aeration near its base. However, additional water surface and sub-water surface aeration systems above the proposed liner can be installed to greatly increase the amount of DO within Frog Pond to stave off future algal blooms and water turbidity and promote aquatic life without disrupting natural operations.

It should be noted that due to the age of the fountain, lead could be present within the paint and/or any welded joints. Lead-based paint testing should be completed prior to construction, unless the City can provide documentation that lead-based paint is not present. Should lead-based paint be encountered on the fountain, language will be included within the Construction Documents for lead-based paint abatement.

Two mechanical system alternatives for subsurface aeration are offered:

1. Subsurface Aeration
    - Subsurface aeration can be achieved through diffusion of air/oxygen beneath the water surface via the return pipes within the stone armor layer using a compressor within the underground vault.
    - The compressor system would draw surrounding air in and then be pumped into perforated weighted tubes that diffuse small bubbles into the waterbody.
    - Based on the water temperature (discussed below), the air and oxygen within the bubbles are dissolved into the water, thus increasing DO.

2. Surface Aerators

   - Floating surface bubblers will provide additional aeration at the water surface of Frog Pond by moving water around near the onboard pump (see Figure 10 below).

Figure 10: Surface Aeration at Boston Public Garden Lagoon

Similar to the Boston Public Garden, canoeing and/or paddle boating can occur within Frog Pond after the rehabilitation efforts are complete. Not only would the recreation activity be beneficial to the local community, but it would also aid in the recirculation and mixing of the water and dissolved oxygen. For additional information regarding public recreation at Frog Pond, refer to Section 8.

4.2. Water and Water Depth

Water is the medium for pond life and health to exist and is the means of how oxygen is dissolved for beneficial aquatic life. To improve pond health, increase and maintain maximum water depth by:

1. Setting the surrounding granite curb and benches 6 inches higher to allow for the 6 inches lost to the proposed stone and sand set on top of the HDPE liner.

2. Continually fill Frog Pond from the bedrock well to keep the water level as deep as possible, counteracting evaporation. See Section 4.2.2. below for further bedrock well information.
3. See GEI's Investigation Summary, Detailed Alternatives Evaluation, and Recommendations (under separate cover) pond lining recommendation.

Basically, more water equals more oxygen. Besides the primary function of oxygen, DO in water also has secondary impacts by limiting release of latent nutrients (nitrogen, N; phosphorous, P; and potassium, K) in future (post-lining) sedimentary pond material that autotrophs, such as algae and cyanobacteria, can use as food to reproduce.

GEI confirmed through geotechnical borings that the groundwater table is approximately 30 feet below the bottom of Frog Pond. It was also confirmed by GEI that the surface water of Frog Pond is not hydraulicly connected to the groundwater table due to the low-permeability sediment, peat, and shallow low-permeability silty sand lenses in Frog Pond basin. It had also been theorized to simply install a shallow groundwater well to recirculate Pond water; however, there is no expression of groundwater table into Frog Pond and, thus, will provide no benefit as Frog Pond will continue to evaporate while recirculation occurs. A new source of water is needed to mimic a pond inlet that is preferably not primarily domestic potable water.

There are two artificial, mechanical means to keep Frog Pond full which are discussed in the following sections.

4.2.1. Domestic Water Source (Emergencies Only, Refurbished Fountain)

While not desired by the City of Newburyport, the option of filling Frog Pond primarily with domestic water from nearby street water mains is possible, albeit costly from fees and could prove to be inequitable for the citizens of Newburyport during time of drought that need drinking water (especially in the current drought of 2022). The preferred procedure would be to only use domestic water during a bedrock well pump failure and for use with the refurbished fountain outlet spray. However, use of domestic water in pond filling applications is not unprecedented, as it the only source of water at the Boston Public Garden Lagoon, and does have some benefits for water features:

- Domestic water is already treated with disinfecting chlorine to drinking water standards and can assist in helping to keeping Frog Pond clean.
- However, this should not be relied upon as a primary disinfectant over oxygenation. Residual chlorine, the measure by which a water supply can disinfect itself, drops over time as the water supply is held in storage.

- In addition, chlorine degrades in ultraviolet (UV) light from the sun. Thus, without continually filling Frog Pond with domestic water, the impacts from the chlorinated supply will be minimized after a short period of time.

Domestic water should not be use as the primary source of water because the chlorine, fluoride, and other chemicals added for human consumption could harm the biomimicry implementations for Frog Pond proposed.

Aqueous does recommend a small amount of domestic water to be used as the refurbished water supply for the fountain as that water would spray out of the top it and possibly come in contact with boaters. The domestic water supply for the fountain would be small relative to the recirculation pump rate or bedrock inflow rate and would not have a deleterious effect on proposed aquatic life.

4.2.2. Bedrock Well Water (Primary Source)

A bedrock well, as opposed to a dug or drilled sand-and-gravel well, will have to be drilled to get any appreciable yield (flow) into Frog Pond. Prior to field verification, Geosphere, a subconsultant to Aqueous performed an FTA of Bartlet Mall. FTA is a remote sensing method that is used to mark the intersections of a fractures within the bedrock at the ground surface. Fracture traces often represent zones of weakness in rock where surface water and groundwater travel through open fractures in the rock. Therefore, areas of high concentration of fractures typically yield high amounts of groundwater. On February 22, 2022, Geosphere and Aqueous, field located the three (3) potential drilling locations, refer to Figure 11. Location "A" was selected as the most feasible well location and is in the wide-open triangle path area at the eastern corner of Frog Pond. Location "C" was excluded due to a mature tree that is to remain, and Location "B" was also excluded due to potential tree and utility damage as a result of drilling.

Based on typical drilling operations for bedrock wells in the Merrimack Valley area, the well will be drilled 600 to 1,000 feet below the ground surface. The well will undergo 72 hours of pump testing to confirm that it can be pumped 24 hours per day throughout the spring, summer, and fall to maintain maximum pond water level. Additionally, the well will also be tested for water quality to confirm that it is safe for disposal into Frog Pond and does not present a risk for human or wildlife. Aqueous recommends drilling at least an 8-inch diameter well with the realistic desire of achieving a sustainable flow of 40 – 50 gallons per minute (gpm) at the surface, see Figure 12. With constant non-stop pumping, the required daily volume of well water is approximately 60,000 – 70,000 gallons per day (gpd) to fill Frog Pond to combat water lost to peak summer evaporation of up to 1 inch of water across the 100,000 square feet of pond surface. With an estimated pond volume of 3,000,000 gallons, it would take 40 – 50 days to fill Frog Pond, or completely change over the existing water within Frog Pond with an outlet, not the proposed recirculating pump system.

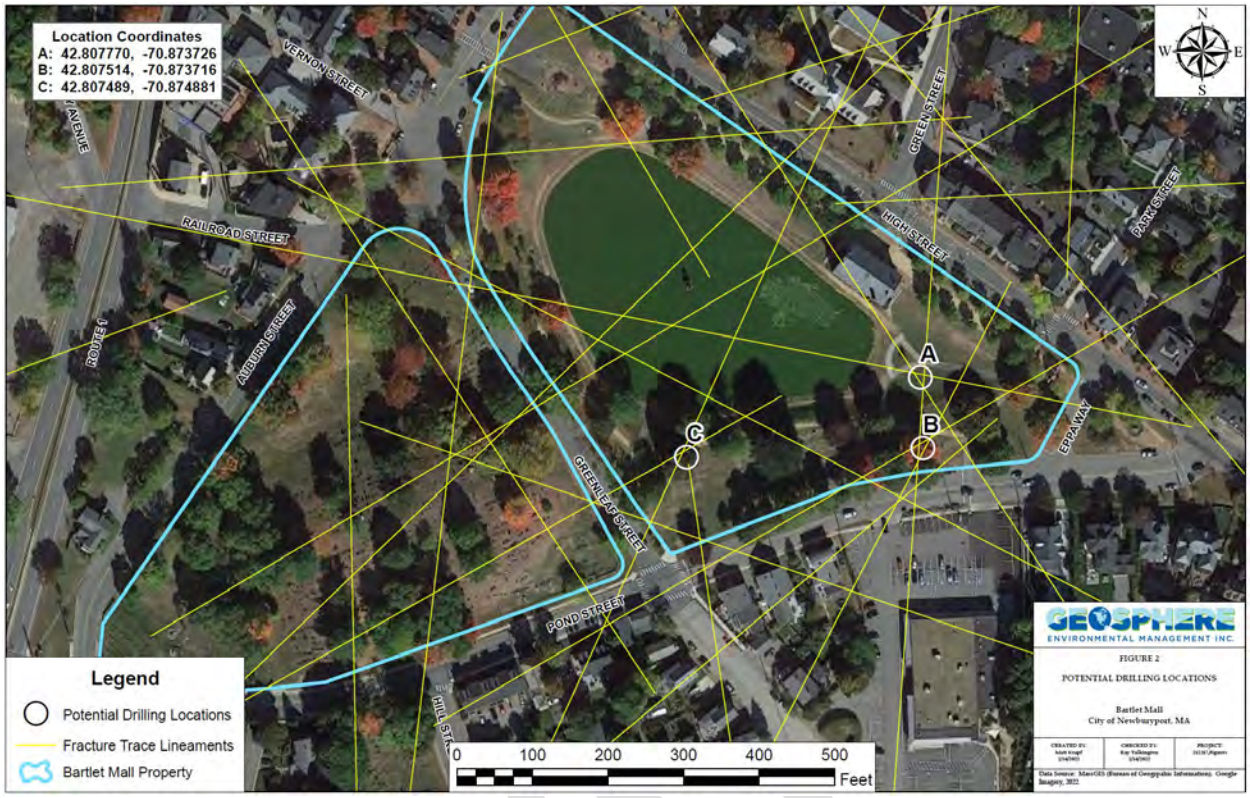


Figure 11: Potential Bedrock Well Drilling Locations

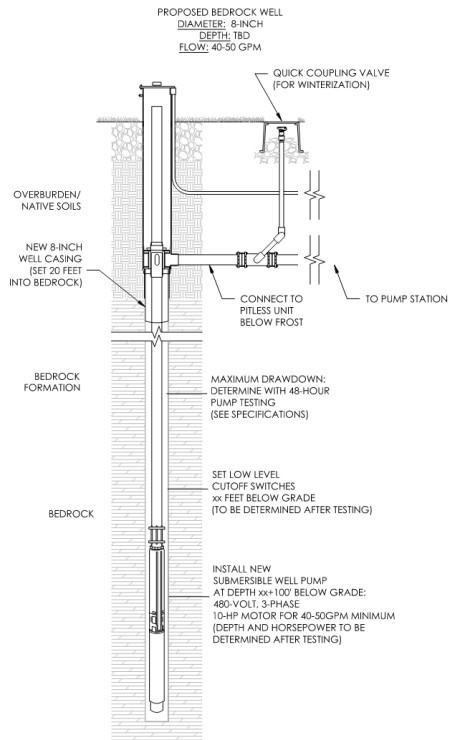


Figure 12: Typical Bedrock Well Section

Aqueous estimates that a 10-horsepower well pump will have to be installed within the 8-inch diameter well borehole and controlled by a pump station closer to the surface within an underground vault. It is also anticipated that well water can be discharged both untreated and treated prior to entering Frog Pond, however, minimum water quality preferences should be discussed with the City during detailed design. It should also be noted that poor water quality or environmental hazards discovered during the well testing process may preclude the use of well water, requiring the City to re-examine other drilling locations, or the domestic water alternative (see Section 4.2.1). The top contaminant to watch for with bedrock wells in Northeastern Massachusetts is naturally occurring arsenic (As). For additional information regarding the fracture trace analysis, refer to Appendix A: FTA Analysis (GEOSPHERE).

4.2.3. Review of Other Wells and Groundwater Activity in the Area

To assess groundwater conditions near Bartlet Mall and to identify wells that may be within the capture zone of the proposed well, Aqueous reviewed the following information from the Massachusetts Department of Environmental Protection (MassDEP):

- MassDEP Well Database
- MassDEP Bureau of Waste Site Cleanup's (BWSC) Phase 1 Site Assessment Map: 500 feet and 0.5 Mile Radii
- MassDEP BWSC Waste Site & Reportable Releases Database

The MassDEP BWSC map with the nearby wells and spills superimposed is included as Figure 13 on the next page. Aqueous focused on reviewing the Well Database to water supply wells, including those designated as domestic, irrigation, or "new well". Wells designated as decommissioned, geothermal, or decommissioned were excluded.

The MassDEP BWSC map identifies, among other things, groundwater aquifers, public water supplies and protection areas, hydrography, and surface water basins within a 500-foot and 0.5-mile radius of Bartlet Mall. As indicated in Figure 13, the groundwater in the area is not used as a public water supply, nor is Bartlet Mall within a water supply protection area, or aquifer.

The watershed divide between the Parker River and the Merrimack River is approximately coincident with Greenleaf Street to the south of Bartlet Mall; surface water north of the divide (including Bartlet Mall) flows to the Merrimack River and surface water south of the divide flows to the Parker River. Surface water flow direction often provides an indication as to groundwater flow direction; however, due to irregularities in the subsurface (e.g., subterranean faults) surface water and groundwater flow directions can differ.

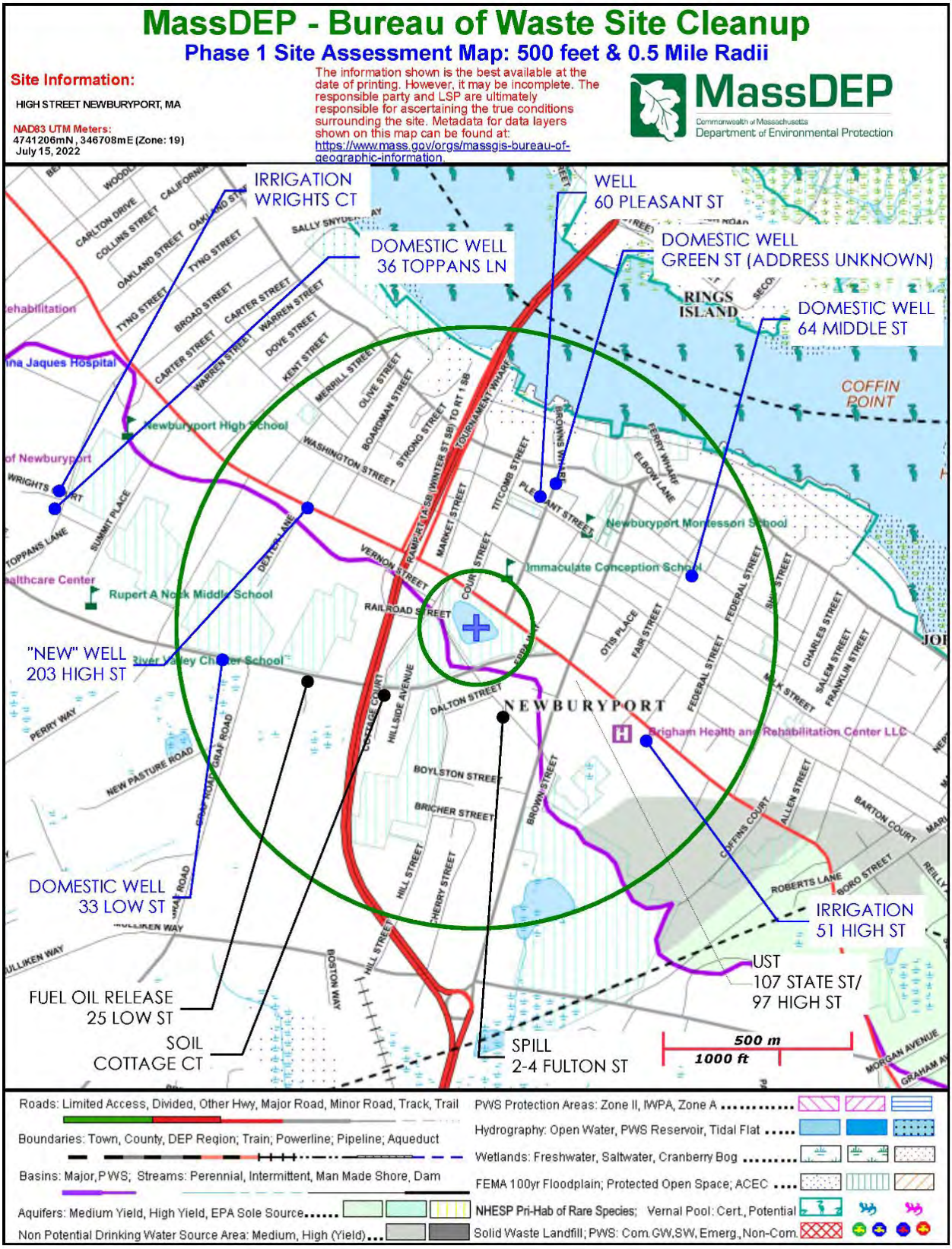


Figure 13: MassDEP Phase 1 Site Assessment Map for Frog Pond at Bartlet Mall

Additionally, Aqueous reviewed the MassDEP BWSC's Waste Site & Reportable Releases Database to identify spills of oil and/or hazardous materials within 0.5 miles and potentially hydrologically upgradient of Bartlet Mall. Releases to groundwater upgradient of Bartlet Mall may have impacted groundwater quality. These sites, plus nearby cross-gradient sites, are also shown on Figure 13. Five releases at four different addresses have been identified, all of which have reached closure with the MassDEP, and are discussed below.

Of the four addresses, two are cross-gradient (25 Low Street and 107 State Street). Given these releases are cross-gradient and have reached MassDEP closure, it is assumed that groundwater at Bartlet Mall is not impacted. The other two releases are upgradient but are within the Parker River watershed (Cottage Court/Hillside Avenue and 2-4 Fulton Street/5 Greenleaf Street). Aqueous conservatively assumed these addresses were upgradient for groundwater flow.

The Cottage Court/Hillside Avenue release (MassDEP Release Tracking Number [RTN] 3-29097, approximately 800 feet southwest of Bartlet Mall) was related to soil contamination associated with historical filling at this property in the early 1900s. The release was identified in 2009 and closed in 2017. Contaminated soil was excavated and transported off-site for disposal. Post-excavation contaminant concentrations in groundwater were below applicable MassDEP standards indicating that groundwater at Bartlet Mall would not be impacted by this release.

The 2-4 Fulton Street/5 Greenleaf Street release (RTNs 3-1690 and 3-20998, approximately 600 feet south of Bartlet Mall) was related to the historical use of the property as an electroplating facility. According to the closure report for the site, groundwater contamination included nickel, chromium, and cyanide were present at "low" levels, along with trichloroethylene and chloroform at "trace" levels. The identification of the release predates the MassDEP BWSC database (1987) and was closed in 2001. The site was remediated by removal and off-site disposal of contaminated concrete, debris, and soil and removal of an abandoned fuel oil underground storage tank. Contaminant concentrations at the property achieved a level of "No Significant Risk" to receptors but were above background concentrations. Groundwater modeling was used to demonstrate that contaminants would not reach the Merrimack River, located approximately 2,500 feet northeast of the property

4.2.4. Drilling Operations

The best location not only from an FTA perspective, but also from an access vehicle and drilling perspective, is Location "A" as indicated previously in Figure 11. The gentle slope from the corner of Pond and High Streets down to the open area of the northeast pond shore provide the ideal vehicular access and staging areas for a drilling rig. Trees can be avoided during transport and space exists to drill. Underground utilities will be marked out by Dig-Safe prior to drilling, but none are expected in this area. A typical drilling rig is shown in Figure 14.

Figure 14: Typical Drilling Rig (Courtesy of Skilling & Sons Drilling, New Hampshire)

Initially, Aqueous recommended a 12-inch well diameter. However, the well diameter can be reduced down to 8 inches for the updated flow requirements needed to replace water lost to evaporation.

Bedrock drilling first starts by drilling through upper soil layers, or overburden. Once the overburden has been drilled through, then the top 20 feet of bedrock is drilled into to receive a steel casing that extends to the surface. The outside of the well casing is sealed with lean concrete to prevent surface runoff and soil from seeping and eroding into the bedrock well. Once the casing is in place, the drilling rig drill bit is advanced through the bedrock for anywhere from 600 – 1,000 feet. As the drill bit advances, the driller will note how soft the formation by the ease of drilling and the amount of water present. To increase the amount and efficiency of flow into the deep bedrock borehole, hydrofracturing, or hydrofracking, can be performed to clean out any debris, soil, and loose bedrock to open fractures further.

During drilling, precautions will be made to protect the existing pond and courthouse. The drilling operation will be given a protective space surrounding Location "A" and should be performed to not interfere with courthouse operations. Coordination will have to be made with the courthouse to drill on holidays, weekends, and when court is not in session. We expect the drilling operation to take three (3) consecutive days, depending on the ease of drilling.

After drilling, it is necessary to perform an extensive well pumping test to confirm and validate the flow the bedrock well can produce. As we will be pumping constantly to battle evaporation in the hottest days of the year, we need a water supply that will be able to be pump 24 hours per day for many days in a row. Prior to installing the rest of Frog Pond mechanical systems, this test is necessary. In essence, the goal of a Safe Yield test is to confirm what the maximum sustainable flow rate is through pumping for 72 hours and then setting the pump at some percentage of that flow rate to ensure that in drought conditions, a reliable flow rate can be maintained.

As discovered by GEI, Frog Pond water has no connection to the groundwater supply—it is uncirculated, standing rainwater from the surrounding area sitting on an impervious layer of sediment. The nearest groundwater level is 30 feet below Frog Pond. It is expected with these findings that pumping bedrock well water will not impact pond water level before or after construction.

4.3. Temperature

Water temperature is a major factor with biological growth in water, including algae and bacteria. Frog Pond, for the most part, is exposed to full sun year-round. As air temperature and solar intensity rise in the spring and peak in the summer, the water temperature increases. Compounded by surface evaporation from solar radiation, the temperature will rise further as the effective water depth decreases.

Generally, it is best to keep temperatures as cold as possible to increase DO and to mitigate evaporation. The sun evaporates water from the surface, thereby decreasing depth, decreasing DO, increasing temperature, increasing evaporation, etc. Temperature left unchecked will accelerate the demise of any water body.

Water temperatures need only be 60° F for algae and bacterial growth to begin to manifest without proper oxygen, circulation, and water quality. Whereas sunlight is more of a controlling factor for algae, temperature needs to be managed and monitored for effective pond management. In relatively shallow water, such as this case, water temperatures of 70° F and higher would not be unreasonable if left unchecked.

Colder water can also hold more gaseous oxygen than warm water. Thus, to keep more DO in Frog Pond, colder and more consistent water temperatures are required. Cold water settles to the bottom of a water body and the surface water is warmer. Without consistent circulation and temperature control, stratification can occur within the water profile which leads to a relatively cold bottom but warm surface which can serve as an algal breeding ground. In addition, without a consistent water temperature, the densities of water at the bottom and surface will vary greatly, causing an imbalance to turn up sediment and dormant microorganisms at the bottom. This will make the water body cloudy.

There are several methods that will be implemented to maintain temperatures around 60° F.

1. Eliminate Street and Roof Runoff into Frog Pond
    - Latent Heat within Paved Surfaces is an often-forgotten pollutant in stormwater
    - Add granite curbing along Greenleaf Street.
    - Reroute roof runoff from the Courthouse to a drywell.
2. Install a Bedrock Well Water System to Continually Fill Pond
    - Groundwater is typically 50° – 55° F. Continually filling Frog Pond will keep temperatures lower, increasing DO and benefitting aquatic life.
3. Monitor Water Temperature through Internet-Based Controls
    - Sensors will be immersed in Frog Pond and transmit information to a control system that can notify the system managers to either manually or automatically add cold well water to reduce temperature.
4. Maintain the Current Water Depth
    - While Frog Pond is not considered deep (average depth of 4 feet), raising the surrounding granite curb and benches 6-inches to accommodate the liner system (including the stone and sand layers) will ensure that the minimum water depth is achieved to maintain water quality.
    - By introducing submerged aeration or water refilling as described above, colder water from the bottom can be moved to the surface and mix temperature and oxygen consistently.

E&LP in their findings (see Appendix B) have suggested preventing street runoff from Greenleaf Street and roof leaders from the Courthouse from entering the water body, both from a water temperature and nutrient loading standpoint.

4.4. Circulation

A healthy water body requires circulatory functions (inlet, outlet, etc.) to provide oxygen, water, and temperature regulation in order to maintain water quality. The existing fountain within Frog Pond has not been operational for several years. In addition, the Reverse Osmosis (RO) system currently installed within the courthouse is not operational and does not move water at any appreciable rate. With no authorized boating or mechanical refilling of Frog Pond, there is basically no circulation of water. As such, stagnant water accelerates the loss of oxygen, water, and increase in water temperature. Moreover, there is no natural inlet or outlet of Frog Pond, as it is a manmade

impoundment. Adding the mechanical aeration, filling, and temperature control systems proposed above will induce circulation of water vertically and horizontally throughout Frog Pond.

Aqueous has proposed a recirculating pump system that would filter and recirculate pond water at a "changeover" rate of once or twice per week. Water is recirculated in Frog Pond through sand filters to maintain high water quality for larger floating particulate (not for total disinfection and sanitation) and continually filled to the maximum water level along the curb line using well water. Aqueous proposes to allow periodic overtopping of Frog Pond water level either onto High Street's underground fire cistern drainage system or an on-site infiltration drywell when Frog Pond needs to be "skimmed" for any excess floating debris to mimic an outlet or when excess runoff from rain on the surrounding slopes fill Frog Pond. The outlet will have the ability to be actuated by a valve to empty Frog Pond partially or fully if needed.

4.4.1. Overflow

Aqueous proposes to keep Frog Pond full by constantly pumping bedrock well water and allowing water to periodically overflow to the City's existing fire cistern drain system or on-site infiltration drywell as part of the new construction. It may seem like a waste of water to continuously pump into Frog Pond, but evaporation is also constant and needs to continuously counteract to maintain water depth and water quality. Providing an overflow allows for proper water levels to achieve a long-term equilibrium. Occasionally overtopping Frog Pond on purpose will allow Frog Pond to be skimmed of film from pollen, dust, leaves, bird feathers, and floating trash that can be strained before falling into the City's existing fire cistern collection system or infiltration drywell.

If the City's efforts and investigations determine that the existing fire cistern system is no longer a feasible option due to its existing conditions and/or prohibitive costs, a drywell can be explored further during later phase of design. A drywell system could be designed to handle an overflow of Frog Pond from a 100-year storm event and backflush water from when the filtration system is being cleaned. This option is defined as an Underground Injection Control (UIC) Class V stormwater drainage well and is regulated by EPA under the Safe Drinking Water Act (SDWA) and MassDEP under 310 CMR 27.00.

Geotechnical borings will need to be performed within the proposed area of drywell(s), in addition to those at the proposed pump station location, to confirm existing conditions, perform a percolation test and a sieve analysis.

4.4.1.1. Drywell Overflow Structure

A drywell allows for subsurface infiltration into subsurface structure that is either perforated with casings radiating outward or via opening leading to a stone envelop, refer to Figure 15. A drywell

can also be used to recharge the groundwater table. Should this option be selected by the City, it will be determined during final design if multiple drywells will need to be installed (i.e., daisy-chained together) to provide sufficient capacity for Frog Pond's overflow and backflushing needs.

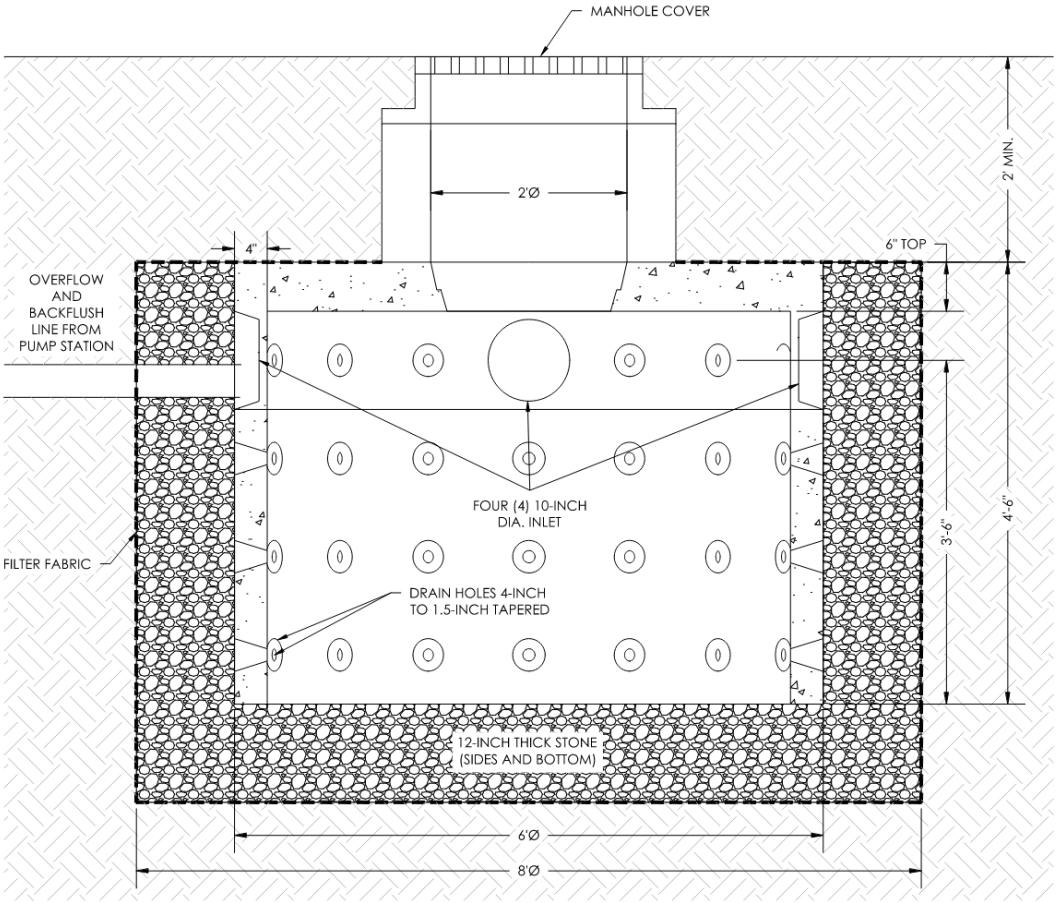


Figure 15: Typical Drywell Section

4.4.1.2. Overflow Recommendation Summary

While there are advantages of being able to drain Frog Pond through the fire cistern system, Aqueous would recommend providing an additional drywell system as a backup at least, if not the primary means of overflowing pond water.

The current condition of the existing auxiliary water supply system that feed fire cisterns throughout Newburyport is not known, nor has said system been maintained to Aqueous' knowledge. Intensive investigations, such as CCTV, would need to occur prior to reconnecting Frog Pond's overflow system to confirm that both cisterns and their connecting piping are functional and there is permittable and accessible outlet point for the system.

Drywells do not require specialty contractors to install and are not likely to be impacted by potential supply chain issues since they are comprised of concrete, stone, and a manhole. Additionally, the depth of the drywell can be controlled such that it would not be within the zone of influence of the true groundwater table 30 feet below grade. The drywells would be designed in a way so as to ensure water flows directly downward and not laterally back under the proposed Frog Pond liner.

4.4.2. Automatic Recirculation Pumping

Frog Pond is approximately 2.3 acres or 100,000 square feet (ft^2). At an estimated average depth of 4 feet, the volume of Frog Pond is approximately 400,000 cubic feet or 3 million gallons. Ideally, a pond water feature that is mechanically recirculated with pumps should be turned over multiple times per day. However, it is the City's intention to not provide a "swimming pool" effect or level of water quality. The goal is to maintain a level of natural attenuation for water quality and management through mechanical means and landscape architecture best practices implemented.

With constant refilling of Frog Pond, it lessens the water change over rate as the well pump discharge will be providing significant contribution to circulation. Thus, a separate pump system that only filters and recirculates water at a changeover rate of once or twice per week is acceptable.

Any circulation is better than the no circulation that currently exists. To run 3 million gallons through a pump station 1-2 times per week requires a pump that can flow 300 – 600 gallons per minute. This equates to a 10 – 20 hp pump motor system (in addition to the 10 hp well pump filling Frog Pond). With an automatic recirculation pump station, it is possible to also automate well pumping and temperature controls (an "all-in-one" system).

The automatic recirculation system will also automatically filter and backflush pond water. As pond water is pumped through the pump station, it will be filtered through sand media that will allow particles less than 100 microns to pass back into Frog Pond. The result will be clear water while not sterilizing Frog Pond water. Aqueous can further refine the filtration rate and media selection during the construction document phase. With automatic backflushing, maintenance is negligible since the backflush cycle (dictated based on sensed pressure differential on the filter inlet and outlet) can be discharged to a dry well and not re-enter Frog Pond hydrology.

The discharge path of the recirculation pump system will be a piped loop that has several discharges spaced out around Frog Pond to move water throughout the water body to promote oxygen, water, and temperature control. The return pipes are anticipated to be enveloped by the stone armor and sand layer, refer to Figure 16.

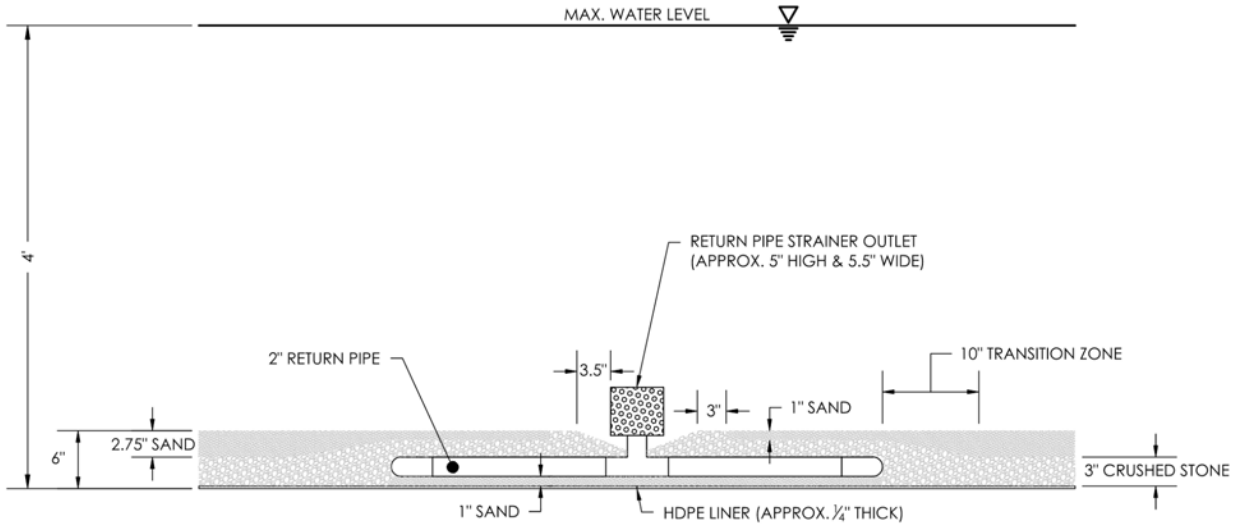


Figure 16: Typical Return Pipe Section

Aqueous has provided a rendered photo showing a sample pump station in **Error! Reference source not found.**. This pump station would require review by Aqueous and the City for utility needs and to ensure that the system is inconspicuous amongst the current landscape and layout. Aqueous recommends that installation work for this pump station be performed while Frog Pond is drained to install the intake pipes and structures. As part of the City's proposed curbing program around Frog Pond, discharge pipes will be coordinated and installed as part of that work. Aqueous proposes that the recirculating pump station be housed within an underground vault and/or bunker to minimize the potential impact to the final aesthetic of the Bartlett Mall, refer to Figure 17.

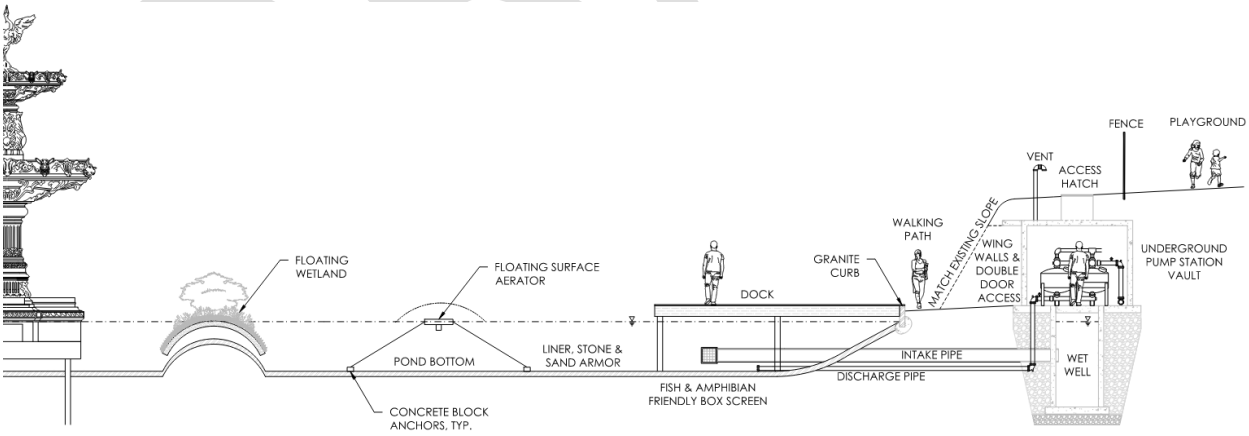


Figure 17: Frog Pond Conceptual Layout

This underground pump station vault will be located under the existing playground and will be accessible via an H-20 loading access hatch (top of vault) and by double doors (Pond-side). The water to be recirculated will enter a fish and amphibian friendly box screen at the end of the intake

pipe and "drain" via gravity back to the wet well. Within the wet well, a vertical turbine pump will pump the water through sand filters, and then back through various discharge pipes throughout Frog Pond.

It should be noted that the pump station will require an electrical feed, which will power the pump(s) and the ventilation system within the vault, and a domestic water connection for the refurbished fountain water supply and emergencies.

Additionally, it should be noted that Aqueous does not recommend admittance of non-authorized people into the pump station. Should the City prefer storage for recreational equipment (refer to Section 6 for additional information), a separate underground vault or architectural shed should be provided.

If the proposed underground pump station becomes cost-prohibitive due to the current economic climate, the pump station can be housed within an architectural shed (Figure 18) or within a pre-fabricated enclosure (Figure 19), and situated and styled in a way to minimize their impact on the surrounding aesthetic of Bartlet Mall. The prefabricated enclosure can either be aluminum or a composite material, both of which can be painted.

Figure 18: Architectural Shed

Figure 19: Prefabricated Pump Station Enclosure (During Construction)

4.4.3. Sand Media Filtration

Sand and gravel are nature's standard filters. When rainwater enters the ground surface and water moves through the soil matrix, the soil purifies the water as it passes between particles. When groundwater reappears as base flow in rivers, streams, and ponds it has gone through an extensive natural filtration process. Mechanical sand filtration has been in use for over 60 years and employs a lot of the same principles as natural soil filtration.

Sand filters are used quite often in water treatment facilities, reservoirs, water feature ponds, and swimming pools. Sand filters are used in these applications as a first pass to get larger particles and some organic matter out of a water supply prior to further water treatment finishing, such as finer filtration, chlorination, and ultraviolet sterilization. Our proposed use of sand filters for Frog Pond is to only use it as a first and only pass, thus filtering out inorganic and organic material floating within Frog Pond down to 100 microns. Anything that is below 100 microns will be allowed to pass through the system, including microorganisms that would be beneficial to the artificially created pond ecosystem. These microorganisms can continue to float within Frog Pond or thrive within the sand benthic layer created by GEI Consultants, serving as the bottom of the food chain for other organisms that live within Frog Pond. Again, the goal is not to sterilize Frog Pond, rather to keep it with a high level of clarity to make Frog Pond appealing and safe for potential watercraft and incidental entry into Frog Pond.

Aqueous has specified sand media filters for water features and reservoir systems alike, including ponds, to achieve a high level of clarity for the water supply. The proposed product manufacturer states that sand media filters have applications in the removal of algae, slime, and other organic contaminant, as well as sand, rock, grit, and other inorganic contaminants.

Filtration as part of the recirculation process will create a much clearer pond with low turbidity. Water bodies with high turbidity, as is the case with the existing Frog Pond, are subject to a potential variety of water quality problems. Turbidity is basically a measure of how clear the water is. Low turbidity equals clear water, high turbidity equals cloudy or opaque water. Excess suspended solids floating within a water body can cause the appearance of water to become murky. While appearance is an important element to this project, cloudy water due to high turbidity and suspended solids can serve as a habitat for pathogens and bacteria to attach themselves to. While not proposed for this project, the reason fine filtration is required for ultraviolet disinfection is so that bacteria and other pathogens cannot hide in the shadows of particles when light passes through the chamber. Natural sunlight provides less intense ultraviolet light than a mechanical system but will used to balance water quality when clearer water is maintained.

Floating sediment that is not filtered can end up settling onto the benthic layer created by GEI. Settlement of sediment in stagnant ponds can greatly reduce oxygen supply and prevent any larvae or eggs from reaching their full gestation and/or the ability to escape and contribute to Frog Pond ecosystem. Finally, turbidity in water can disrupt the natural movement (predatory, breeding, respiration) of beneficial organisms that we would like to incorporate into Frog Pond.

Without a natural inlet or outlet, or the benefit of natural sand and ground water filtration, we must mechanically biomimic these necessary processes to maintain high water quality. The filtration

requirements to balance the natural aspects of Frog Pond, the prevention of reemergence of algae, and the interaction with humans make sand media filters necessary.

- Sand/Media Filter Benefits
  - Removes Algae, Slime, and Other Organic Components in Water
  - Provides Water Clarity/Reduces Turbidity
  - The ability to select different media to target different water quality parameters to mitigate
  - The ability to adjust flow rates to balance filtration loading
  - Backflushing is automatic to reduce maintenance
  - Water is not sterilized completely because of sand media filtration—it is put in place to naturally mimic filtration through soil and gravels through mechanical means
  - Sand filter will return clean water back to recirculation pipes within the liner armor to prevent clogging and minimize repairs.
  - Sand Media Filters are commonly used for man-made water features and water supply ponds for recirculation.

Below are common alternatives to Sand Media Filtration:

- Domestic Water
  - Boston Public Garden Lagoon already uses domestic water—it is not unprecedented, but a big waste of clean water that could be used for other purposes.
  - Chlorine could impact aquatic life, but chlorine breaks down in ultraviolet light and degrades over time. We would not re-chlorinate domestic water like a swimming pool or fountain (Boston Public Garden Lagoon does not re-chlorinate).
  - Lagoon has only added additional aeration recently with Aqueous design to improve water quality. Historically, only manual increases from valves have filled the Lagoon.
- Screen Filters
  - Will not provide enough water quality treatment for a fully interactive water feature pond.
  - More susceptible to replacement, higher maintenance costs
  - Can get organic growth on filter from pond

4.5. Nutrient/Chemical Balance

Nutrients and water chemistry have a profound effect on water health and appearance of water bodies. This can be plainly seen in the existing pond condition. NPK, typically, are considered a necessary staple in autotrophic and photosynthetic organisms to reproduce and create food for itself. Oxygen, water depth, cooler temperatures, and circulation mitigate the effects of nutrient imbalance. Bird and animal waste can and is often a contributor to nutrient loading. Similarly, fertilizer should be eliminated in the lawn area surrounding Frog Pond. It is important for the Newburyport Parks Department staff to continue to monitor trash, bird waste, and fertilizer use carefully as a continued Best Management Practice (BMP).

4.5.1. Runoff Diversion and Stormwater Management for Future Nutrient Mitigation

As discussed from a temperature perspective, site runoff into Frog Pond should be eliminated. In their on-site evaluation, E&LP recognized that the runoff from Greenleaf Street has a direct path down the slope and into Frog Pond due to the lack of curbing on the asphalt paving. Street drainage can carry not only nutrients, but oils, greases, sand, salt, and other inorganic particulate like brake dust to their ultimate discharge points. In addition, the current gutter system for the Courthouse drains directly into Frog Pond. Bird waste rich with nutrients can easily be mixed with rainwater to flow into Frog Pond.

While it does not appear to be functional, there Is a stormwater discharge pipe from Pond Street in the southeast corner of Frog Pond. Part of the construction document package should Include demolition of this pipe such that no stormwater from Pond Street can enter Frog Pond.

Hot surfaces such as asphalt paving and roofs in the spring and summer release their heat into rain runoff. Latent heat from paved surfaces in urban developments that are transported to rivers, streams, ponds, and lakes can destroy those aquatic ecosystems from an oxygen and habitat perspective. It is for this reason that Low Impact Development (LID) has gained favor over traditional development regarding stormwater management because:

- LID spreads runoff out across wider stretches, instead of channelizing it—causing erosion
- LID uses more infiltration practices to dissipate stormwater as opposed to ponding and piping
- LID uses less dark and impervious surfaces that create heat-island effect and hot stormwater runoff that can destroy aquatic ecosystems

Based on E&LP's and Aqueous' observations, we recommend the following nutrient prevention plan after Frog Pond has been sealed with a new liner:

- Install a bituminous berm curb along Greenleaf Street to divert water away from the Bartlet Mall and Frog Pond. Stormwater carries nutrients and pollutants from the street and further collects nutrients and pollutants from the surrounding park.

- Use LID techniques such as grassed swales (Figure 20, below) along the edges of the stone dust paths to prevent on-site runoff from directly entering Frog Pond. Frog Pond in its proposed condition should be an entirely closed loop to be able to effectively treat Frog Pond with recirculation and filtration. Any foreign water supply that is not accounted for within this report jeopardizes the long-term effectiveness of the treatment plan recommended. Grassed swales maintain the formal look desired by the City of Newburyport as it can be graded into the site. Grassed swales would direct stormwater downward away from Frog Pond and liner. With groundwater 30 feet below the surface, groundwater mounding due to infiltrating water is not expected to occur—potentially lifting the liner from underneath due to hydrostatic pressure.

Figure 20: Typical Grass Swale Collecting Runoff from Each Side
(Dashed Line is Bottom of Swale to Infiltration)

- Direct Courthouse gutter away from Frog Pond and discharge to an infiltration drywell. Heat and bird waste can greatly impact nutrient, water temperature, oxygen content, and aquatic habitat.

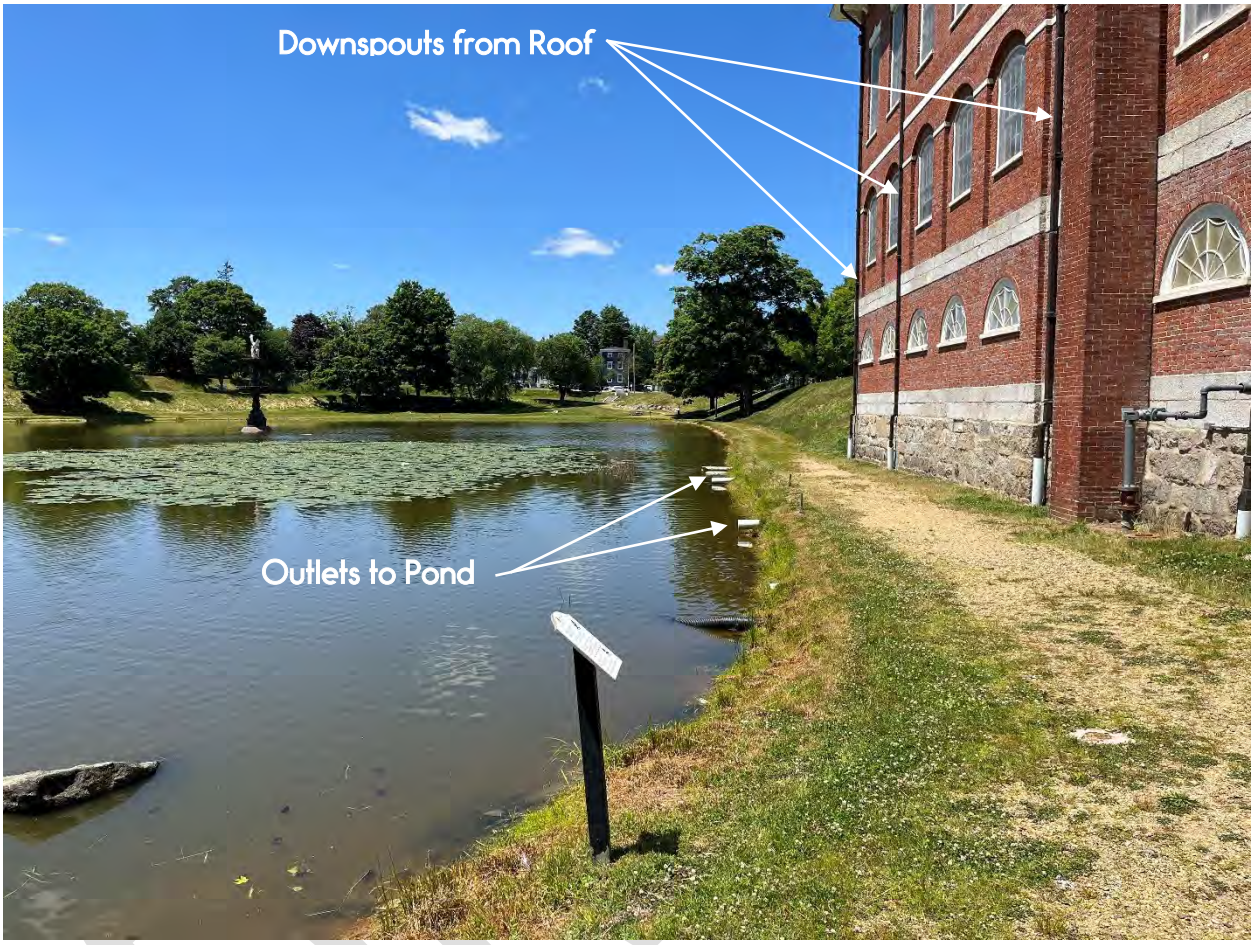


Figure 21: Courthouse Gutters to Frog Pond (Recommended Redirected to Dry Well)

4.5.2. Nutrient Uptake from Plants

Aquatic planting and floating wetlands within Frog Pond will assist in consuming any new nutrients that enter Frog Pond after It Is sealed with the proposed liner. Further discussion is below and in Appendix B: Frog Pond Ecological Evaluation (E&LP).

4.6. Biodiversity and Artificial Selection

Frog Pond is not as biologically diverse as a natural pond or lake as there is little to no plant life within the water body to absorb nutrients. In turn, there are no fish and few amphibians to eat plants and microorganisms. To improve water quality and health through natural attenuation or biomimicry, a more biodiverse aquatic ecosystem will have to be implemented. Moreover, the City and its design

team should artificially select (as opposed to allowing "natural selection" over eons) which organisms should be allowed and those that need eradication.

4.6.1. Microorganisms

As previously studied over several years by the City and outlined in this report, cyanobacteria are a major, recurring problem for Frog Pond and other hypertrophic water bodies. Cyanobacteria can settle into sediment when there is a reduction in phosphorous, which is rich in TP for nourishment and reappear as HAB next year. Once embedded within the sediment of Frog Pond, it is difficult to remove through natural processes. Cyanobacteria can cause a variety of health problems for people and animals that encounter infested water. Therefore, GEI recommends the installation of an HDPE liner over the full extents of Frog Pond bottom to seal the existing sediment layer off and start anew with both mechanical and natural water quality measures.

Commercially available solutions of beneficial bacteria can be applied to Frog Pond to maintain microorganism balance once the rehabilitation process has been completed. These bacteria help to remove excess ammonia, nitrates, and NPK nutrients from water. Some bacteria also can eat the bottom sludge of ponds that can accumulate from organic processes from plants and animals. Aqueous recommends beneficial bacteria supplements as part of the management plan after full build-out.

4.6.2. Plants

There is currently little to no aquatic plant life observed within Frog Pond. Simple plant structures may exist in certain parts of Frog Pond, but nothing to positively impact water quality or biodiversity. As part of our recommendation to the City, Aqueous recommends adding aquatic plant life as a means of not only improving pond aesthetics but also for phytoremediation of excess nutrients. Plants consume NPK as part of their own photosynthetic processes and can also provide a food source for other aquatic life. Additionally, aquatic plant materials are recommended to be installed within center of Frog Pond, as constructed floating wetlands (CFWs) and on graded mounds of sediment, refer to Figure 22. The roots to the CFWs can also provide shelter for fish and sunning/nesting areas for reptiles, birds, and amphibians. For additional information regarding CFWs, refer to Appendix B: Frog Pond Ecological Evaluation (E&LP).

Depending on the scenarios selected from GEI's report, graded mounds of pond sediment can create Islands around the center of Frog Pond and fountain. Topped with clean aquatic planting soil and subsoil, new plants within these Islands can create a serene backdrop while assisting in nutrient uptake through plant roots. It can also provide habitat for different bird and animal species.

Figure 22: Constructed Floating Wetlands

The Team will work with the City, the Newburyport Conservation Commission, and the City's Architects to select non-invasive, native species for appearance and management.

4.6.3. Aquatic Wildlife

To attenuate Frog Pond naturally, Aqueous recommends working with E&LP, an ecology and wetlands reconstruction expert, to introduce native aquatic wildlife into Frog Pond. Fish, amphibians, and other wildlife will complete Frog Pond ecosystem as a driver and indicator of pond health. Aquatic wildlife will proliferate and provide environmental balance once other water quality factors (oxygen, water depth, temperature, circulation, and nutrient balance) have been remedied.

E&LP recommends that once Frog Pond has been rehabilitated (lined and refilled), that it be stocked with fish and turtles. Fish stocking should be conducted on a per acre basis and may consist of bass, bluegill, and sunfish. The exact species of fish introduced to Frog Pond can be adjusted according to the City and the Conservation Commissions' preferences. To provide cover and nesting areas for the fish, boulders and rock piles will be added to Frog Pond bottom, refer to Figure 23.

Figure 23: Typical Rock Pile Fish Habitat

If the City decides to stock Frog Pond with fish, rock piles can be positioned throughout Frog Pond to hide and add an additional layer of protection to the return pipe outlets, refer to Figure 24.

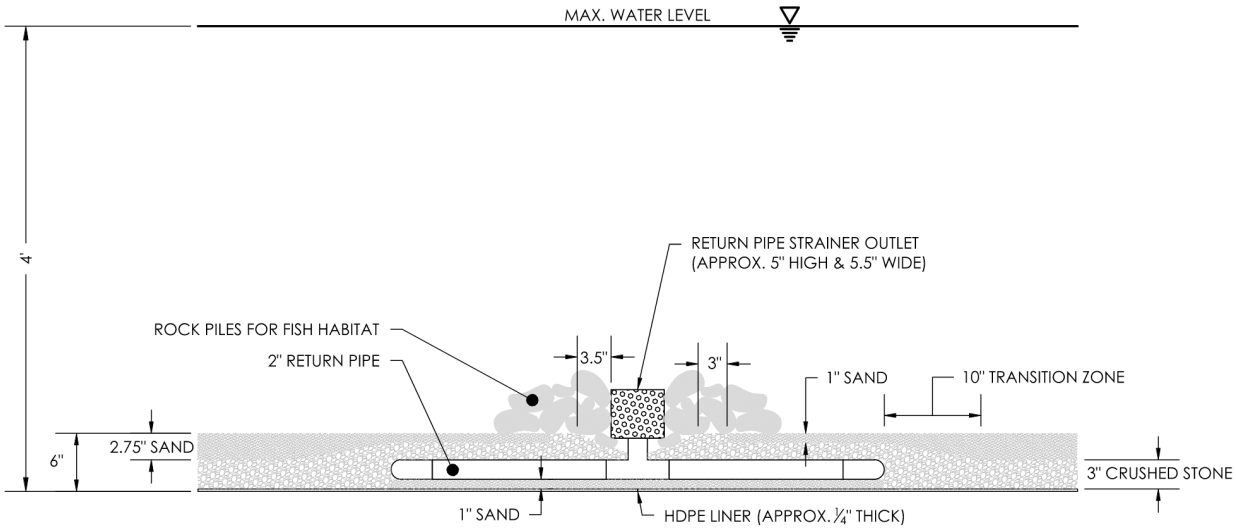


Figure 24: Typical Return Pipe Integration with Rock Pile Section

Additionally, the turtles introduced to Frog Pond can be those captured prior to the rehabilitation of Frog Pond. In addition to the CFWs discussed previously, turtle platforms should be added to add sunning spots for reptiles, refer to Figure 25.

Figure 25: Typical Turtle Platforms

The proposed granite curbing will create a barrier that will reduce the intrusion of Canada Geese to Frog Pond and Bartlet Mall. Canada Geese are attracted to water but will not settle in around a water area that they cannot easily walk in and out of.

5. Expected and Estimated Permitting

Permitting requirements for the rehabilitation of Frog Pond will be completed in concert with the design effort, construction document preparation, and during construction. Outlined below are key concerns and time frames for submission of applications for the critical permits required for the project. Table 1 and Table 2 lists each permit, the regulating agency and the expected timing required to submit each permit. Aqueous will support GEI in the permitting effort for construction documents. This is not an exhaustive list, but rather known permits at the time of this report. For additional permitting efforts related to Frog Pond liner, refer to GEI's report.

Table 1: Permitting Schedule for the Contractor

Permitting Agency	Permit	Timing
US EPA	NPDES 2022 Construction General Permit (CGP)	Submit an NOI minimum of 14 days prior to start of construction

Table 2: Permitting Schedule for the Design Team

Permitting Agency	Permit	Timing
MassDEP	Chapter 91 BRP WW 04: Request for Determination of Applicability (RDA)	Applicability to be Reviewed Concurrent with Conservation Commission NOI
Conservation Commission / MassDEP	Abbreviated Notice of Resource Area Delineation (ANRAD) Notice of Intent (NOI)	Pre-Construction Document Preparation 75%-90% Construction Document Submission (Substantial Completion)
Massachusetts Historical Commission	Project Notification Form (PNF)	30% Construction Document Submission
MassDEP	UIC (Drywell)	75%-90% Construction Document Submission (Substantial Completion)

5.1. Wetlands Regulations Applicability to Frog Pond

Based on a cursory review of previous work and discussion, Aqueous would presume to submit an Abbreviated Notice of Resource Area Delineation (ANRAD) to submit to the Newburyport Conservation Commission as a first step. Frog Pond has a well-defined history of being manmade

for centuries, let alone prior to the Wetlands Protection Act of 1972 and subsequent regulations thereafter. The intent of filing an ANRAD is to demonstrate that, while some wildlife does live within Frog Pond (turtles, amphibians, etc.), there does not appear to be anything that would make it a defined Bordering or Isolated Vegetated Wetland, Land Subject to Flooding, or other similar Resource Area. We believe that Frog Pond is Land Under Water with an associated Bank as Resource Areas defined by the Wetlands Protection Act.

Once the Resource Areas have been delineated and accepted by the Newburyport Conservation Commission, Aqueous and the design team will commence construction documents of the proposed conditions with these Resource Areas in mind. Once we reach substantial completion of the construction documents, the next step would be to file a Notice of Intent (NOI) with the Newburyport Conservation Commission for the work proposed. We will work with the Conservation Commission and public at-large throughout the design process to give them updates and to ensure we are compliant with the issued ANRAD when we file the NOI.

5.2. Massachusetts Historical Commission (MHC)

The Massachusetts Historical Commission (MHC) complies data on its Massachusetts Cultural Resource Information System (MACRIS) site which includes, but is not limited to, the Inventory of Historic Assets of the Commonwealth, National Register of Historic Places nominations, State Register of Historic Places listings, and local historic district study reports. As is indicated on the MACRIS site, the Bartlet Mall, including Frog Pond, is within the Newburyport Historic District (ID NWB.L). Additionally, Frog Pond Fountain Swans are also a historic site/object (ID NWB.951). Prior to the restoration of Frog Pond, the City should complete and submit a Project Notification Form (PNF) to the MHC. Proposed recommendations during detailed design will be in accordance with the rules and regulations mandated by the MHC.

5.3. City of Newburyport Permitting

During detailed design, it should be confirmed with the Newburyport Historical Commission that no additional permits and/or variances are needed for rehabilitation to Frog Pond, the surrounding walkway, and/or the existing fountain.

Additionally, it should be confirmed with the Engineering Department and the Department of Public Services that Contractor-specific permits are not needed to be included in the Contract Documents.

6. Pond Usage and Limitations

The proposed curbing by the City will limit entry points and direct access to the water body—preventing trash, dirt, and debris from entering. A canoe or paddleboat program on Frog Pond is another strategy to help circulate water.

The new pond rehabilitation design and program should focus people away from the required pump and mechanical systems that will be required. We will work with the City to best hide this equipment and limit access to these areas through vegetation, underground vaults, etc. Aqueous recommends limiting direct water access to the west area as a canoe/paddleboat launch. Signage throughout Frog Pond will be placed to instruct visitors on what uses and behaviors are allowed.

Like the Boston Public Garden Lagoon, a set, City-supervised boating path should be adhered to in order to prevent accidents and promote circulation. The City should have staff (full- or part-time) distribute its own purchased canoes or paddleboats that should be rated primarily for safety and stability and not speed and agility. We recommend charging to rent any aquatic equipment to offset maintenance costs. A new shed or "A-frame" rack can house canoes and paddleboats at the end of each day. The City should have a strict policy that users of canoes and paddleboat users must have proper lifejackets and floatation devices. Waivers should be signed by users in the presence of City staff prior to rental or use. Standup paddleboards should not be used or issued by the City, given the frequency of falling. Boating activities should promote always staying within the vessel. Boating should be strictly weather-dependent, i.e., no one should be allowed out in Frog Pond during rainstorms, excessive heat, cold, etc.

Fishing (from boats or shore) should not be allowed to maintain ecological balance and prevent trash accumulation (hooks, line, bait, etc.).

Skating should only be allowed in the winter in the shallower portions of Frog Pond. Aqueous does not recommend draining Frog Pond in the winter because this would disrupt ecological balance year-round with cold-blooded fish and amphibians.

7. Operation and Maintenance

7.1. Infrastructure Program and Operations

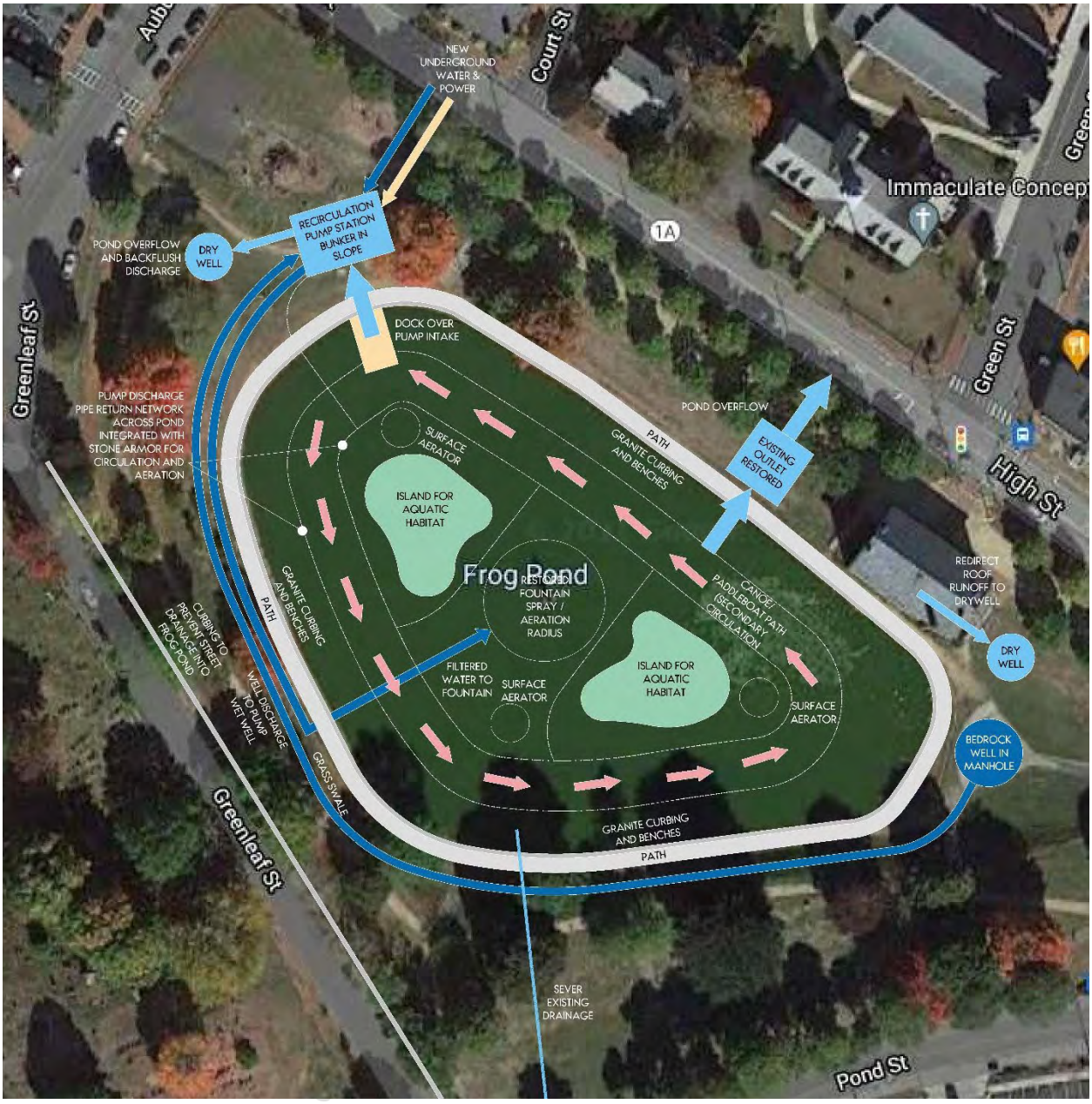


Figure 26: Infrastructure Recommendations based on City Goals and Water Quality after Lining at Bartlet Mall Frog Pond

Figure 26 above summarizes the equipment and water quality measures recommended in this report. As one can see, a pond-wide system Is required to maintain water quality for Interaction with humans and animals. Once the liner system Is Installed, subsurface pipe Inside and outside Frog Pond will be Installed to move and circulate water, the underground pump station bunker will be Installed to house

filtration, pumps, and control equipment. A bedrock well will be Installed to continually feed fresh water to Frog Pond counteracting evaporation and Increasing water temperatures. A restored fountain will aesthetic and aeration benefits for people to enjoy from the shore or from a canoe as boating will help circulate Frog Pond. Allowing for an overflow to be operated manually either at the existing fire cistern outlet along High Street or a dry well within the property will allow for periodic maintenance of Frog Pond for cleaning and flushing. Mitigating the deleterious effects of current stormwater Inflows by directing them away from the lined Frog Pond will control nutrient levels. Finally, adding biodiversity through plants (floating wetlands and island plantings) and animals within Frog Pond (amphibians and possibly fish), along with beneficial microbes will allow for Frog Pond to find natural balance.

7.2. Annual Maintenance

The key to any infrastructure lasting and fulfilling its design intent is maintenance. It will be critical for the City to dedicate public works or parks staff members to be aware and trained on the operation of pumps, structures, and internet-based remote control. Aqueous, as part of its design tasks, will create a maintenance calendar and request a formal training on the system that the awarded contractor must provide prior to final payment.

The recommended yearly maintenance schedule is as follows:

Spring Start up – Pond Refilling	1st & 2nd week of April
Spring Start up – Start Pump System	April 15th – 17th
Spring Start up – Add Supplemental Pond Microorganisms	April 18th
Spring Start up – Pond recirculation (2 full change overs)	April 19th – April 30th
Open Pond to Public (Weather/Temperature Dependent)	May 1st – October 31st
Add Supplemental Pond Microorganisms	July 1st & September 1st
Winter Shutdown - Stop Recirculating and Filling Pond	November 1st
Winter Shutdown - Drain Pond by ¼ & winterize systems/equipment	1st week of November

In general, the awarded contractor is responsible for providing quality workmanship and non-defective parts, guaranteeing the entire project with repairs, parts, and labor for one (1) year after the City and Aqueous agree the project has achieved completion. Manufacturers of certain products may offer longer warranties. Prior to the turnkey with City, the awarded contractor will provide the following training and materials (in Aqueous' presence) to verify the City has the information and tools necessary to allow the system to run continuously as much as possible:

- Purchase a Tablet that Resides with Parks Specifically for Frog Pond
  - Tablet will be used at Frog Pond as Remote Control for Pumps and Valves on site through cellular data Internet.
  - Calendar, notes, and maintenance forms can be directly uploaded to a shared cloud server with other City maintenance works and stakeholders.
  - Tablet will have touchscreen and stylus/pencil capabilities for data logging, calendar, record of repair, etc.
- Operation and Maintenance (O&M) Manual
  - O&M Manual serves to use as a reference of design criteria (original plans and specifications), product submittals, as-built plans, and explicit instructions for:
    - Routine Maintenance
    - Basic Troubleshooting the City can perform
    - Company Names and Contacts for repair companies for questions, annual service, and beyond basic troubleshooting
  - O&M Manual will be provided in three (3) hard copies, and electronic copies that can reside on the tablet and cloud server for reference
- On-Line Technical Support
  - If a recirculation pump system is installed and connected to the internet through cellular modem, Aqueous will specify and coordinate on-line technical support with the pump station manufacturer.
  - In the event of alarms and faults that cannot be diagnosed immediately by City staff, the pump station manufacturer can be called to go directly into the control system interface over the internet.

- Technical support can either fix the problem immediately through the interface, instruct the City staff worker over the phone, and/or, send a local repair company to fix the problem.

- Spare Parts
  - Prior to final payment, the awarded contractor will provide spare parts such as valves and fittings to greatly reduce downtime.
  - The City should keep the necessary spare parts stocked to prevent downtime in the future.

When the management staff responsible for Frog Pond leave their positions, it is critical for the City to identify replacement staff to avoid a potential knowledge gap and ensure that the replacement staff managing Frog Pond are trained by the outgoing staff, the original contractor, and the product manufacturers. Ideally, there is a seamless transition with City staff members during personnel turnover to avoid paying additional time and materials to the original contractor and product manufacturers. Having a consistent calendar or log that is initialed and reviewed regularly will ensure the maintenance of the system will not fall behind.

7.3. Maintenance Program

Aqueous anticipates that Frog Pond will be in operation for 30 weeks each year from April to November, weather permitting. The anticipated annual maintenance is as follows:

- April 1: Spring Startup
  - Pond Refilling with Well Water (1 – 2 Weeks Unmanned/Periodic Checking, depending on Well Flow)
- April 15: Start Pump System (1 or 2 Days)
  - Only When Pond is Full
    - Startup Control Panel in Bunker
    - Check Water Level via Display on Panel
    - Check Flow Rate of Well
    - Slow Fill and Startup Sand Media Filtration System
    - Initiate Backflush Cycles for Filters
    - Turn on Fountain
    - Turn on Supplementary Aeration (Fed through Pump Return Pipe Network Below Bottom Armor Stone)

    - Provide Initial Water Flowing Over the Top of Control Weir to Street Drainage or Dry Well to First Pond Skimming

- April 18: Add Supplemental Pond Microorganisms for Nutrient and Bacteria Management (if necessary)
- April 30: 2 Full Pond Change Overs, Pond Can Be Open for Canoeing (Weather/Temperature Dependent)
- July 1: Add Supplemental Pond Microorganisms for Nutrient and Bacteria Management
- September 1: Add Supplemental Pond Microorganisms for Nutrient and Bacteria Management
- November 1: Stop Recirculating Pond and Adding Well Water, Drain Pond by one-fourth (1 Week)
- November 1: Drain and Winterize Pump and Water Lines above Frost, Fountain with Compressed Air

8. Pond vs. Water Feature

8.1. Critique on Methods Proposed

There has been critique from the public at-large as to the methods presented in this report. Namely, the concern lies with the premise that somehow the Bartlet Mall Frog Pond is already a natural pond in a bucolic setting. These viewpoints generally assert that the only way to create a viable pond is one that is rife with edge and aquatic plantings, extensive fauna with a large migration radius, and minimal to no means of mechanical water movement or to assume that the natural groundwater table will supply water to Frog Pond. This is counter to the precedents, renderings, and goals put forth by the City of Newburyport, which falls more in line with a water feature incorporating pond biomimicry versus a fully naturally attenuated pond. A fully naturally attenuated pond is not possible for the following reasons:

1. Frog Pond is a former kettle hole that has been manipulated by the colonization and urbanization of humans for centuries. Any natural means of inflow and outflow out of this pond to assist in circulation has been long lost due to human exertion.

2. Throughout history, this pond has had more cultural significance than environmental significance. Former uses for this pond have included livestock watering, Revolutionary War training, fire suppression, boating, and aesthetic enjoyment in an urban park setting. This water body does not provide the same environmental benefit that a natural pond would for bordering vegetated wetlands, the associated buffer zones, and rivers/streams.

3. GEI confirmed through extensive water and sediment sampling that this Pond does not intercept the groundwater table. The sediment creates an impermeable barrier that simply holds localized runoff from the surrounding buildings, lawn, and urbanized areas. In essence, this Pond is a puddle whose water level is solely dependent on rainfall and evaporation. It is Aqueous' opinion that Frog Pond is, and has been for a long time, a puddle that life happened to find its way into versus a life-producing and sustaining water body evolving over eons of geologic and biological exertion as natural lakes, ponds, streams, and rivers are. The existing biomass of harmful organisms such as cyanobacteria and algae far outweigh those that could be considered beneficial in the existing condition, such as turtles. Thus, substantial action should be taken.

4. Ponds in nature benefit from a buffer of natural woodlands, meadows, and wetlands to protect them over time. Frog Pond does not have these natural surrounding areas to protect it. In fact, it is the complete opposite: fertilized lawn, urban runoff, pavement, vehicular pollution, and close contacts with humans depositing dirt and garbage that has caused the contamination of sediment, hyper-eutrophication, and breeding grounds for harmful algal blooms (HAB). To create a working natural pond, the entire area surrounding Frog Pond and its surrounding

watershed would also have to be renovated. The current and intended use as a place of social gathering would have to be abandoned as well. Frog Pond has and will continue to exist to be a social focal point, not necessarily a pristine sanctuary.

5. The City of Newburyport desires this waterbody to be a focal point in a formal landscape of historical cultural significance. The City provided renderings of Frog Pond's future condition to show boating, light wading, and granite curbing with benches circumscribing Frog Pond edge. This desired outcome lends for Frog Pond's use to be more of a water feature than a pond. Thus, because there is no natural inlet or outlet, circulation, or any biodiversity, Frog Pond must be treated as a water feature instead. Water draws people towards it. The number one goal of this urban pond is to ensure that the water quality is acceptable for humans and their pets to prevent sickness and forms of dermatitis. It should not be a means of creating a naturalized ideal in a theoretical vacuum that would be impossible to maintain given the urban setting and the close contact with humans. Means of biomimicry that are proposed are to enhance water quality for human contact, including floating wetlands to consume nutrients, organics added to the sand benthic layer, select biodiversity with amphibians and fish, grading, and drainage to reroute urban runoff, and islands with aquatic plants in Frog Pond center. Since this Pond has no expression with streams or the groundwater table, these effects must be mechanically created to experience their benefits. This will be achieved through a bedrock well for water flow, pumps to move water around, sand filters to mimic the cleansing effect of soil, and an overflow to maintain water level and allow for floating debris and trash to be skimmed off the surface.
6. Natural attenuation would take much longer (many more years) than what the City is expecting.

8.2. Summary and Approach

It is Aqueous' opinion that to achieve the look and use desired by the City, the infrastructure outlined within this report should be installed and maintained. However, if the City desires to move forward with only a few of the items outlined, then water quality in Frog Pond will be improved, albeit, harder to sustain and more susceptible to degradation. In our opinion, this is why smaller systems such as the defunct reverse osmosis system in the Courthouse did not work. It is possible to install certain items over several years and see how Frog Pond responds. For example, installing the outlet control structure and a well to continually keep Frog Pond full will improve water quality immediately. However, it may not address cyanobacteria, water clarity, circulation, and aquatic ecology for different variations of climate year after year. The approach for construction documents should be to cure the problems at Frog Pond, rather than to continually diagnose and treat the symptoms of poor water quality with "band-aids and aspirin". There will be a learning curve that the City will have to undertake in the first year, but the awarded contractor for this work will guarantee the system

during this timeframe to work and support the City in its needs. It will take effort, patience, and funding to provide a complete system.

9. Cost Estimates

9.1. Construction Costs

Based on the information provided within this report, Aqueous presents the following estimate on construction costs in Table 4 below. Presumably, any construction work for this project would have to begin in FY2023, using City FY2022 (July 1, 2021, to June 30, 2022) for professional design, permitting, capital budgeting, and bidding.

It is our professional opinion that price increases due to supply chain issues and labor shortages due to the economic upheaval of the 2020 – 2021 coronavirus pandemic will not come down by the time bidding and construction begins. Moreover, we are assuming inflation to continue annually over the next couple of years until construction is ready to begin. Aqueous makes estimates on our professional fees for design, permitting, bid procurement, sub-consulting (survey, aquatic ecology, and hydrogeology), and construction administration. However, a formal proposal will be provided under separate cover after reviewing this report with the City and Frog Pond stakeholders.

Aqueous' cost estimates are intended to not overlap or contradict any estimates by GEI in their report in June 2021. Finally, these are budgetary numbers to provide an order of magnitude for the City to prepare its stakeholders for a range of possible public bids and a discussion launching point. As part of our recommended design services, we will procure the services of a construction cost estimator when developing a plan in further detail.

9.2. Annual Maintenance Costs

Estimates on annual maintenance costs are provided below in 2022 Dollars. These include spare parts, electrical costs, annual service by third-party contractors, and manhours by full-time City staff. Note: costs are subject to change based global economic conditions (see Limitations).

- $24,000 per year electrical costs to operate pumps and controls (conservative, Aqueous provide as an energy-efficient a system as possible during construction documents).
- $5,000 Service Contract for Technician Calls
- $1,500 for 3 Applications of Supplemental Pond Microorganisms for Nutrient and Bacteria Management
- $3,500 for Water Quality Sampling Supplies and Testing
- iPad/Tablet Part of Construction Contract for Remote Management
    - Remote Notification of Control Panel Alerts/Faults

- Parks Staff Drive by Daily, Check Water Quality, Take Water Quality Samples for Lab Testing Monthly, Take Litmus/Quick Tests Weekly
  - Parks Department Estimated 90 Hours over 30 Weeks Annually for Testing and Observation
  - 60 Hours of Spring Startup and Winterization Annually
  - Park Staff / Summer Help for Canoe / Lifejacket Rentals (Extra)

Table 4: Water Quality Maintenance System Costs: Pump, Overflow, Aeration, & Well Water

	Quantities		Comments
Estimated water volume	2,824,000	gallons	Bathymetric survey by GEI's subcontractor

	Unit Cost		Subtotal	Comments
Construction Bid Documents (Design)	$140,000	lump sum	$140,000	Aqueous to serve as prime for water quality, civil utilities (water and power), curbing and pathways, street drainage connection and/or drywell design, underground vault basis of design geotechnical report via subconsultant, power connection in street via subconsultant, bedrock well with subconsultant review, pond ecology and landscape architect subconsultant, review bids, confirm qualifications, recommend proceeding with construction to City. Travel and Expenses charged to City at 0% markup. Subconsultants marked up at 15%
Construction Administration by Design Team	$40,000	lump sum	$40,000	Product submittal review, weekly meetings, on site meetings, answer contractor questions prior to and during construction, observe installation, approve operation and maintenance manuals, observe training with City staff, provide final punchlist report, enforce 1-year guarantee by awarded contractor
Recirculating Pump Station w/ Wet Well Manhole, Intake Pond Pipe, Filtration, Pond and Pump Controls, Vault Buried into Mall Slope	$350,000	lump sum	$350,000	• Work with Landscape Architect to Hide Pump System Underground Auburn St. Playground • Underground Domestic Water from Street • Wet Well Intake Manhole with Pipe to Pond • Vertical Turbine Pump inside Wet Well • Continuous Recirculation Pumping • Liquid Level Sensing in Pond/Wet Well • Control of Bedrock Well Pump • Control of Surface or Subsurface Aeration System • Automatic Filtration and Backflushing • Dry Well with Stone (for Filter Backflush and Pond Overflow) • One-Time Complete Refill with Domestic or Well Water • Remote Control Access with Phone/Tablet
8-Inch Diameter Bedrock Well Pump System	$120,000	lump sum	$120,000	• Up to 1,000 feet of drilling in Bedrock (at Trayning Field) • 50-Foot Casing to Protect Aquifer • Hydrofracturing to Increase Efficiency/Flow • Deep Well Pump and Steel Drop Pipe • 72 Hours Continuous Testing • Continuous Filling of Frog Pond as Required to Counteract Evaporation
Outlet Control Structure to Existing Street Drain/Fire Cistern System	$80,000	lump sum	$80,000	• Reconstruction of Valve and Outlet Control Structure • Include Weir and Sluice Gate Controls in order to Set Water Level (from Well/Rainfall)

	Unit Cost		Subtotal	Comments
				• Concrete Manhole with Iron Rim and Cover • Pipe and Intake System to Pond • Allow for Manual Draining of Pond for Winter Ice Skating, Maintenance, etc. • Potential Savings with Dry Well: $25,000
Pump Discharge and Return Pipe within Pond Liner Stone Armor	$50,000	lump sum	$50,000	• 800 feet of 6-inch PVC Return Pipe • Discharge at Various Locations for Circulation
Surface Aeration System	$50,000	lump sum	$50,000	• Three (3) Surface Aerators with Power Supplies Derived from Pump Station • Coordinate for Remote Control with Phone/Tablet through Pump Station • Lighting System Extra
Fountain Refurbishment	$50,000	lump sum	$50,000	• Coordinate with Recirculation Pump Station Control (Recommended) • Coordinate for Remote Control with Phone/Tablet • Supply with Domestic Water or Filtered Pond Water • Up-lighting or Choreographed Light Show with Submersible Lighting Extra
Granite Curb Edging and Pathway Refurbishment	$100,000	lump sum	$100,000	• Coordinate with Recirculation Pump Station • Coordinate for Remote Control with Phone/Tablet • Automatic Backflushing to New Dry Well • Supply with Clean, Filtered Water
Pond Shaping, Plantings, and Aquatic Life	$150,000	lump sum	$150,000	• Regrading for islands and variability for pond bottom for turtles, birds, amphibians • Pond shaping, regrading, grass swales • Erosion control and maintenance • Aquatic Plants along Perimeter and/or Island • Restocking Pond with Amphibians, Fish, Beneficial Bacteria Treatment
		Subtotal	*$1,130,000*	
		20% Contingency	$226,000	
		Rounded Total	$1,360,000	

* Does not include work involving Auburn Street Playground renovations

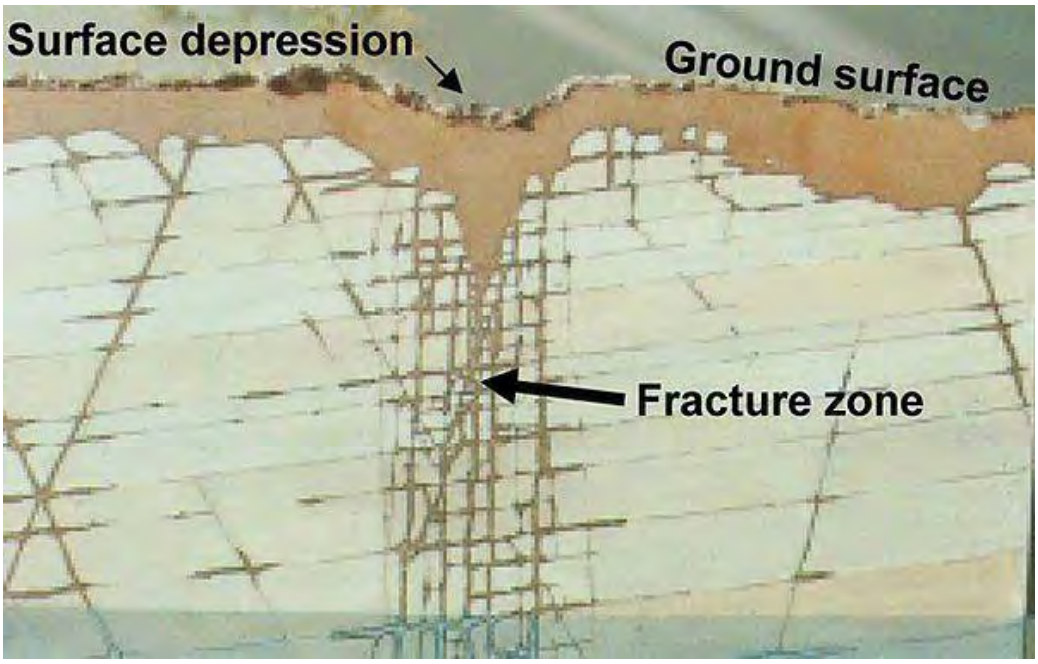
Appendix A: FTA Analysis (GEOSPHERE)

Fracture Trace Analysis – A Remote Sensing Method

Fracture trace analysis (FTA) is a remote sensing (i.e. use of aerial photographs) method used to identify and map the locations of fracture traces on the surface of the Earth. A fracture trace or photolinear is a line (2-dimensional) that marks the intersection of a fracture (i.e. break) in the crystalline bedrock with the ground surface. Fractures in the bedrock can form as the magma cools and the newly-formed rock shrinks (primary fractures). More commonly in the New England area, these fractures have been formed after the cooling of the magma, or in the case of metamorphic or sedimentary rocks, when compressional forces during the movement of tectonic plates rupture and break the rocks (secondary fractures). These secondary fractures are more common in this area of New England and they are typically oriented both parallel and perpendicular to the compressional forces applied to the rock. For example, the more common fracture orientations in this part of New England are NE-SW and NW-SE.

Fracture traces often represent zones of weakness in a rock where surface water and groundwater travel through open fractures in the rock. As such, the goal of a FTA is to identify areas on aerial photographs that contain a high concentration of fractures that might yield high amounts of groundwater. A fracture trace or photolinear is a line that marks the intersection of a fracture in bedrock with the ground surface.

As shown in the figure below, because water is one of the major weathering agents in rock, flow of water along fractures, in general, causes increased weathering and weakening of the bedrock along the fractures. This increased weathering causes geomorphic and soil moisture changes as well as changes in soil color, supporting increased biological processes, and vegetation. The weathering processes may manifest as straight stream segments, mark abrupt changes in course of a stream, alignment in a vegetation pattern (especially trees), and alignment of topographic features.

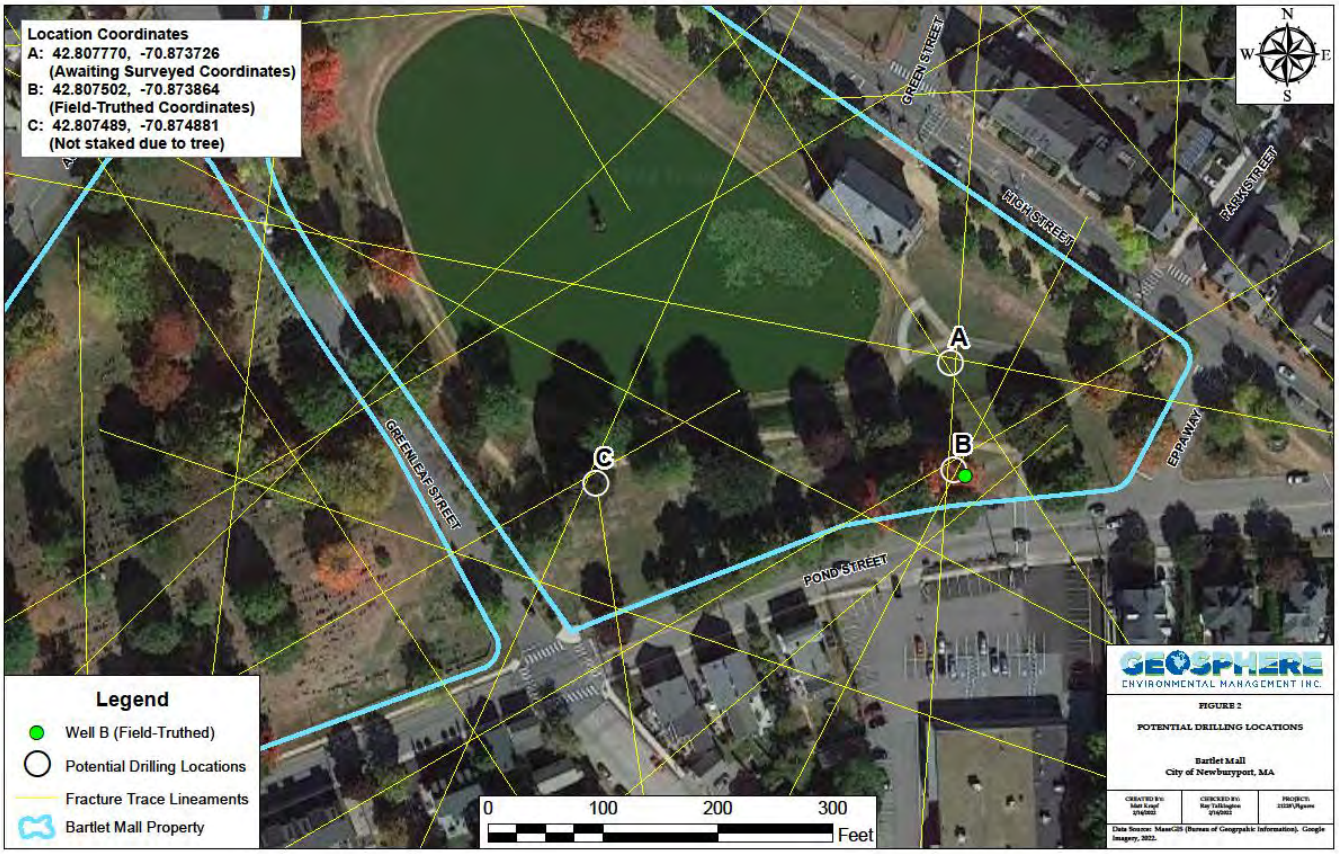


51 PORTSMOUTH AVENUE, EXETER, NEW HAMPSHIRE 03833
Telephone: 603-773-0075 Fax: 603-773-0077
www.geospherenh.com

GEOSPHERE typically performs a FTA of the entire area using aerial photographs (preferred scale - 1" = 500') to locate prominent surface expressions of subsurface bedrock lineaments in the underlying bedrock. Once these fracture traces (photolinears) have been identified, their field locations are evaluated to eliminate any man-made features.

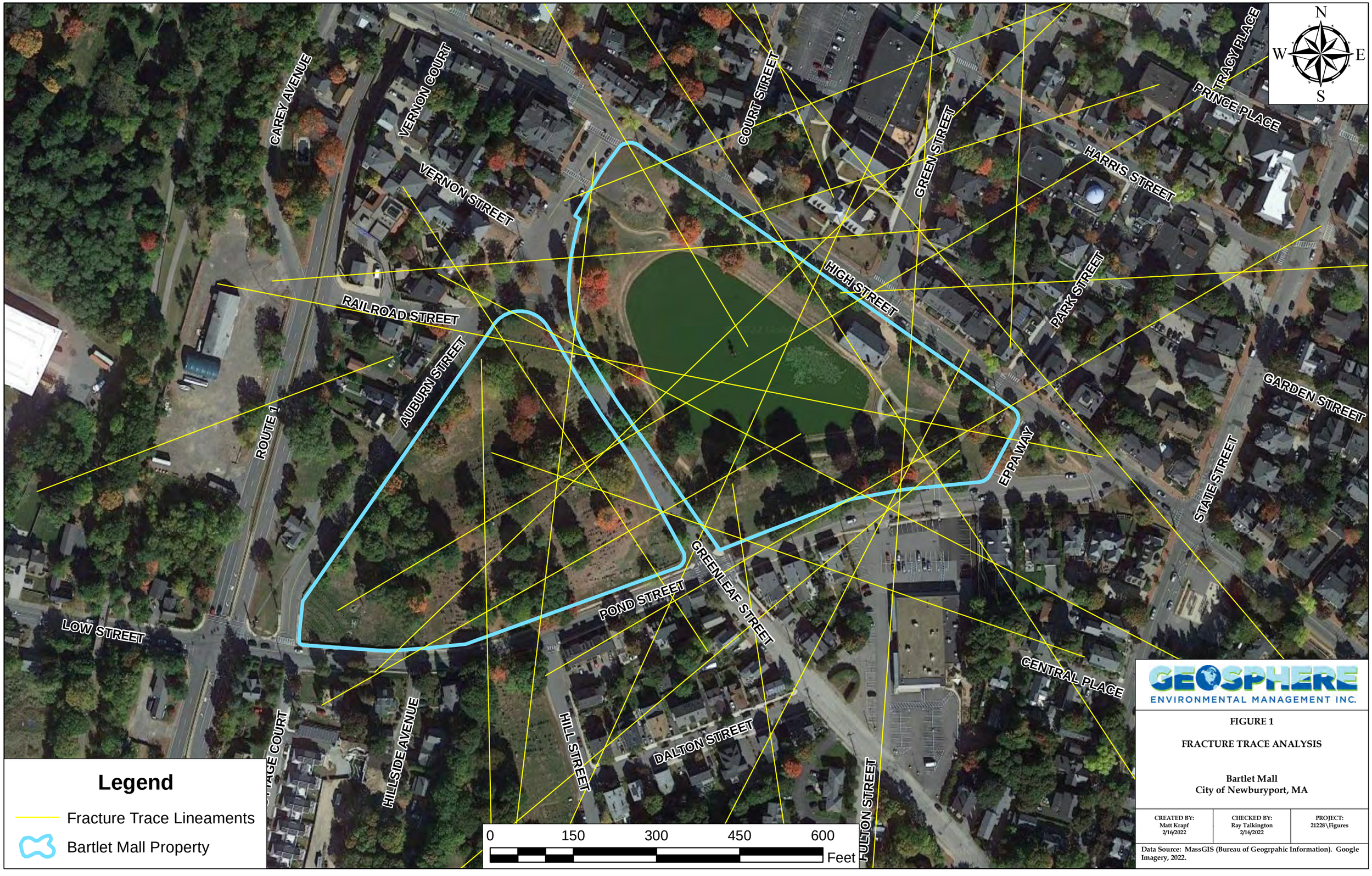
As indicated above, the most favorable location for a high yield bedrock well is at the intersections of multiple (at least three) fracture traces (photolinears). The results of a FTA are placed on a GIS-based site plan that contains the fracture traces (photolinears) along with the locations of all existing structures and other subsurface systems or utilities. The results of the FTA for Bartlet Mall are shown on the figures below.

Based on the locations of multiple intersecting fracture traces, three (3) potential drilling locations have been identified in the Bartlet Mall area. We also had to take into consideration when selecting potential drilling locations access to these locations by the drill rig and tender vehicles. The three (3) potential drilling locations are shown on the figure below.



On February 22, 2022, GEOSPHERE and Aqueous personnel field located the three (3) potential drilling locations (i.e. A, B, and C). Locations A and B were located and stakes were placed in the ground. GPS coordinates were collected for each of these two locations. Potential drilling location C was excluded because it coincided with the location of a large, mature tree.

GEOSPHERE is available to answer any questions you may have on the FTA method. Our personnel have completed hundreds of FTA for public water supplies and irrigation wells in rural and non-rural settings, cemeteries, shopping malls, private homes, athletic stadiums, and other locations.



Legend

- Fracture Trace Lineaments
- Bartlet Mall Property

GEOSPHERE ENVIRONMENTAL MANAGEMENT INC.

FIGURE 1

FRACTURE TRACE ANALYSIS

Bartlet Mall
City of Newburyport, MA

CREATED BY:	CHECKED BY:	PROJECT:
Matt Krapf 2/16/2022	Ray Talkington 2/16/2022	21228\Figures

Data Source: MassGIS (Bureau of Geogrpahic Information). Google Imagery, 2022.

Location Coordinates
A: 42.807770, -70.873726
B: 42.807514, -70.873716
C: 42.807489, -70.874881

VERNON STREET
RAILROAD STREET
ROUTE 1
AUBURN STREET
GREEN STREET
HIGH STREET
PARK STREET
EPPA WAY
GREENLEAF STREET
POND STREET
HILL STR

A
B
C

N
W
E
S

0 100 200 300 400 500 Feet

Legend

- Potential Drilling Locations
- Fracture Trace Lineaments
- Bartlet Mall Property

GEOSPHERE ENVIRONMENTAL MANAGEMENT INC.

FIGURE 2

POTENTIAL DRILLING LOCATIONS

Bartlet Mall
City of Newburyport, MA

CREATED BY:	CHECKED BY:	PROJECT:
Matt Krapf 2/16/2022	Ray Talkington 2/16/2022	21228\Figures

Data Source: MassGIS (Bureau of Geogrpahic Information). Google Imagery, 2022.

Appendix B: Frog Pond Ecological Evaluation (E&LP)

CIVIL ENGINEERING
ENVIRONMENTAL
SURVEYING
LANDSCAPE ARCHITECTURE

Frog Pond Ecological Evaluation

149 High Street
Bartlet Mall
Newburyport,
Essex County,
Massachusetts

PREPARED FOR:
THE CITY OF NEWBURYPORT
60 PLEASANT STREET
NEWBURYPORT, MA 01950

MARCH 1, 2022

E&LP

Headquarters
140 West Main Street | High Bridge, NJ 08829
T: 908.238.0544

Clinton | Asbury Park | Denville | Philadelphia

TABLE OF CONTENTS

Table of Contents 2
1. Introduction 3
1.1. Project Description 3
1.2. Site Description 3
2. Field Investigation 4
2.1. Water Quality 4
E. Coli 4
Nitrite 4
Nitrate 5
Total Nitrogen 5
Total Kjeldahl 5
Total Phosphorous 5
Chlorophyll A 5
DO 6
Specific Conductance 6
pH 6
Oxidation Reduction Potential 6
Turbidity 6
2.2. Ecology 6
2.3. Hydrology 7
3. Restoration Recommendations 8
3.1. Nutrient Loading 8
3.2. Impacted Nitrogen Process 8
3.3. Catchment Area 9
3.4. Pond Topography 9
3.5. Planting 9
3.6. Rebalancing 10
4. References 12

1. INTRODUCTION

As authorized by the City of Newburyport, c/o Aqueous Consultants, LLC, Engineering & Land Planning Associates, Inc. (E&LP) has conducted an evaluation of the Frog Pond to evaluate the existing conditions and provide opportunities to rejuvenate the pond. The purpose of the investigation is to document the pond as it exists in 2021/2022 and provide recommendations and alternatives in conjunction with environmental remediation of the pond by teammate, Aqueous and GEI. This report provides the account of conditions based on field observations and laboratory test results.

This report, prepared by a Massachusetts Licensed Professional Engineer provides the factual account of the pond conditions.

1.1. Project Description

The project is comprised of Frog Pond located on Bartlet Mall in the City of Newburyport, Massachusetts. The pond is adjacent to the Historic Essex County Courthouse, walkways, mature trees and public streets. There is a small playground area at the intersection of the Auburn and High Streets adjacent to the pond.

The project goals are to rejuvenate Frog Pond into a city resource the adds to the culture of the historic downtown area. The City of Newburyport has expressed interest in providing boating, fishing, swimming, beautification, and an ecological resource in the goals of the pond.

1.2. Site Description

The Site, Block 35, Lot 160 is located in the City of Newburyport, Essex County, Massachusetts, as shown on Figure 1. The site is bound by High Street to the north, Pond Street to the East, Greenleaf Street to the South, and Auburn Street to the West. Residential and commercial properties exist on all sides. The topography of the site is sloped toward the pond in all directions from the public right of ways. The pond is approximately elevation 48' and street elevation is approximately 60'.

The study was performed in the fall/winter if 2021/2022.

2.FIELD INVESTIGATION

E&LP performed a field investigation and obtained test results of water samples from GEI. The following provides a detailed summary of this work.

2.1. Water Quality

Water quality sampling was performed by GEI in December of 2021. Six samples were obtained from the pond. Three at the surface and three at one meter.

Sample Location Depth (M) Date	SW101A 0 11/30/21	SW101B 1 11/30/21	SW102A 0 11/30/21	SW102B 1 11/30/21	SW103A 0 11/30/21	SW103B 1 11/30/21
E. Coli (col/100ml)	2	86	120	86	70	130
Nitrite (mg/L)	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050
Nitrate (mg/L)	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
Nitrate/Nitrite (mg/L)	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
Total Nitrogen (mg/L)	1.8	1.8	1.8	1.6	1.8	1.8
Total Kjeldahl (mg/L)	1.75	1.75	1.77	1.61	1.75	1.78
Total Phosphorous(mg/L)	0.088	0.088	0.099	0.101	0.098	0.096
Chlorophyll A (mg/m3)	128	131	144	139	138	139
Temperature (C)	1.1	1	0.5	0.3	1.4	1.3
DO (mg/L)	12.81	12.39	13.99	13.71	13.01	12.46
SC (us/cm)	61.3	61.4	46.5	49.1	40.3	42.8
pH	8.26	7.02	6.96	6.66	6.74	6.66
ORP (mV)	86.2	172.8	181.6	191.7	183.3	187.2
NTU	11.68	11.36	11.2	10.7	11.76	12.18

E. Coli

Escherichia coli are bacteria found in the environment, foods, and intestines of people and animals. E. coli are a large and diverse group of bacteria. Massachusetts Department of Environmental Protection limits E Coli to a maximum of 235 cfu/100 ml at public swimming areas.

The maximum occurrence of E Coli occurred at SW103B, below the maximum allowed.

Nitrite

Nitrite is a naturally occurring chemical in ponds and is created through the breakdown of ammonia by bacteria as part of the Nitrogen cycle. The main causes of high nitrite are an impacted nitrogen cycle or overstocking of fish. Nitrite should be as low as possible and should not exceed 0.25 mg/L.

Nitrite were not detected in sampling.

Nitrate

Nitrates are the sequence in the Nitrogen cycle. Nitrites are typically not toxic compared to ammonia and nitrites but can kill fish at levels over 300 ppm. In most ponds, they are consumed by the algae in the pond well before killing the fish. Nitrate should be between 20-60 mg/L in a healthy pond.

Nitrates were not detected in sampling.

Total Nitrogen

Total nitrogen is a measure of all of the forms of nitrate, nitrite, and ammonium. Nitrogen is a is a nutrient like phosphorus needed for plant growth. Excessive quantities of nitrogen can cause overstimulation of growth of aquatic plants and algae. Excessive growth of these organisms, in turn, can clog water intakes, use up dissolved oxygen as they decompose, and block light to deeper waters.

Total Nitrogen was between 1.6 and 1.8 mg/L in the pond. As nitrites and nitrates were non-detected the remaining Total Nitrogen is a measure of Ammonia and related organics. Ammonia should be as low as possible and not greater than 0.5 mg/L.

Total Kjeldahl

Total Kjeldahl measures the amount of nitrogen that a water sample contains in the form of ammonia using the Kjeldahl process.

Total Kjeldahl was between 1.61 and 1.78 mg/L in the pond. Ammonia should be as low as possible and not greater than 0.5 mg/L.

Total Phosphorous

Total phosphorous is a nutrient in ponds. High concentrations of phosphorus may result from agriculture, runoff from urban areas and lawns, septic systems or sewage. Too much phosphorus causes increased growth of algae and large aquatic plants, which can result in decreased levels of dissolved oxygen. High levels of phosphorus can also lead to algae blooms that produce algal toxins which can be harmful to human and animal health. Total phosphorus should be less than 0.03 mg/L in healthy ponds.

Total phosphorus was between 0.088 and 0.101 mg/L.

Chlorophyll A

Chlorophyll a is a measure of the number of algae growing in a waterbody. It can be used to classify the trophic condition of a waterbody. Although algae are a natural part of freshwater ecosystems, too much algae can cause aesthetic problems such as green scums and bad odors, and can result in decreased levels of dissolved oxygen. Some algae also produce toxins that can be of public health concern when they are found in high concentrations.

Chloryphyll a was between 128 and 144. This is referred to as a hypereutrophic state characterized a very nutrient-rich impacted by frequent and severe nuisance algal blooms and low transparency

DO

Pond water can hold about 10 to 12 mg/L of oxygen between 15C and 12C. Dissolved oxygen is reduced by the biological decay of organic material such as decaying plants and animals or animal and human wastes. Dissolved oxygen levels below about 6 mg/L can begin to have detrimental effects on pond life.

DO was between 12.46 to 13.99 mg/L. The pond is near saturation.

Specific Conductance

In many cases, conductivity is linked directly to the total dissolved solids (TDS). High quality deionized water has a conductivity of about 0.05 QS/cm at 25 °C, typical drinking water is in the range of 200–800 QS/cm, pond water is <250 OS/cm, and sea water is about 50 mS/cm[2] (or 50,000 QS/cm).

SC was between 40.3 and 61.4.

pH

pH is a measure of whether water is acidic or basic. Fish have an average blood pH of 7.4, so pond water with a pH close to this is optimum. pH between 6.5 and 8.5 is acceptable.

pH was between 6.66 and 8.26.

Oxidation Reduction Potential

ORP is an index to the pollution levels of the pond. Unlike most of our other water quality readings, lower numbers are bad, while higher numbers are good. Readings below 150 indicate a pond in need of significant improvements.

ORP was between 86.2 and 191.7.

Turbidity

Turbidity is the measurement of water clarity which may be due to suspended solids, algae, and dissolved organic materials. Turbidity is commonly an aesthetic problem with regard to suspended solids. Turbidity in drinking water is 10 NTU, cold water fisheries 10 NTU, and cool/warm water fisheries 25 NTU.

Turbidity was between 10.7 and 12.18.

2.2. Ecology

Ponds consist of complex systems that support various forms of life. Phytoplankton, zooplankton, Invertebrates, plants, insects, amphibians, reptiles, fish and birds. A catch was not performed to evaluate all of the pond's life. Field observations and photographs we evaluated to identify know

species. Generally, the presence/absence of certain consumer species are an indicator of producer species.

Field observances identified large quantities of algae, invertebrates and insects.

In the terrestrial zone, water line up, plants were comprised of lawn only. A small growth of bushes were observed near the Courthouse. In the Littoral zone, emergent and submerged plants were not observed. Floating plants (lillys) were observed in the littoral and limnetic zones of the pond.

The native turtle species are present in the pond. At the time of the field visit fish and birds were not observed, however photographs identified ducks and geese present in the pond. White perch (bass) have been identified in past kills.

2.3. Hydrology

The pond is the low point in Bartlet Mall, i.e. all runoff heads toward the pond and no outlet is observed. The Mall is surrounded by public right of ways on all sides. The ROWs are curbed, limiting runoff into the park. Greenleaf Street to the south has a limited reveal on the curb and is likely a location where surface water enters the park during rainstorms. The park is approximately 7.5 acres. NCRS estimates water bodies in this area of New England need approximately 2 acres of drainage area per acre foot to maintain a healthy system. The pond is approximately 7 acre-feet and would need a 14-acre drainage area to maintain adequate hydrology.

The pond is overall an oval shape with a tow path around the bank. The pond bank slopes to the bottom at a ratio between 7:1 and 18:1. The pond bottom is between 44.0 and 44.5 feet and generally flat. The pond bottom to the north west and south show signs of sedimentation having a bottom elevation between 44.5 and 45. The pond bottom is approximately 67,500 sf and top is approximately 109,200 sf.

3.RESTORATION RECOMMENDATIONS

The pond suffers from

- High nutrient loading,
- Impacted Nitrogen Process
- Poor catchment area,
- Pond topography
- Planting

Refer to GEI report for information on contaminants within the soil and sludge.

The future use of the pond can include many of the City of Newburyport's requests. However, the City should be aware some of the opportunities will impact the management of the pond, as follows:

- Kayaking may introduce species and contaminates from the kayak's prior uses.
- Fishing may require stocking based on intensity of use
- Swimming will introduce E Coli and BOD loading.
- Beautification is in the eye of the beholder (formal pond verses a natural pond)

The following guidelines should be observed in the restoration of pond ecology.

3.1. Nutrient Loading

The pond is experiencing excessing nutrient loading from the soil, pond bottom and runoff. Total phosphorous in the pond was between 0.088 and 0.101 mg/L. This is more than 3 times the maximum. GEI soil sampling (out of scope of this report) indicated a significant source of phosphorus from the peat layer beneath the pond, in addition to the sludge layer and surface water runoff.

The source of the loading must be removed, as follows:

- The curb reveal on Greenleaf Street should be restored to remove ROW runoff from the park and runoff directed to the stormwater system.
- Sludge from the pond bottom should be treated or removed.
- Nutrient sources from the underlying peat should be mitigated.
- Terrestrial planting should be provided along the perimeter of the pond to create a buffer. The buffer should be as large as possible but not less than 15 feet.
- Geese should be discouraged from using the pond. A vegetated buffer will reduce geese usage.
- Dog waste should be minimized.

3.2. Impacted Nitrogen Process

The pond has high levels of ammonia which occurs through the breakdown of wastes and sludge. The ponds natural system is being impacted by the excessive algae growth caused by the nutrient loading. After the removal of excess nutrients, ammonia should be monitored.

3.3. Catchment Area

Unfortunately, the catchment area of city parks cannot be modified. The catchment area provides a source of fresh water to the pond to maintain water levels and mitigate evapotranspiration. In the ponds current configuration, runoff is added to the pond and evapotranspiration removes water from the pond while leaving contaminates behind. As there is no known outlet for the pond, contaminate concentrations will only increase through time. The natural process of water cycling can be mimicked through the installation of a well and pump and outlet.

Groundwater is typically high in CO2 and will impact the DO of ponds. A method of aeration may be required to mitigate the use of well water.

3.4. Pond Topography

The bank slope presents opportunities for amphibians and reptiles (slopes less then 4:1), however invasive plants will also thrive in this condition. While not present, at the time of inspection, after the rejuvenation, better water quality may invite a growing opportunity.

If the pond is to be restored in a historic nature the bank should be increased to a 3:1 slope to reduce the potential for invasives. If the pond is to be restored in a naturalistic manner, the slope should be segmented into areas of 3:1 and 8:1 to provide diversity.

The pond depth of four feet should be lowered to a minimum of 6 feet. The additional depth will reduce the opportunity for invasives, provide thermal buffering for the summer sun, and winter water temperatures.

The pond bottom should provide topographic changes for fish spawning. Boulders and rock piles will provide cover and nesting areas for large and small species.

Floating objects should be added to the pond for reptiles to sun on. Floats could be logs, floating wetlands, or rocks.

3.5. Planting

Plants offer biodiversity within pond and lake ecosystems and are effective in reducing nutrient loads in ponds and lakes. High phosphorus loads in lakes and ponds can threaten biodiversity of and disrupt natural processes that maintain healthy aquatic ecosystems. Increasing planting areas and introducing native plants to Frog Pond will bolster its ability to buffer nutrient loads. The diversity of a pond's vegetation community is maximized when 50 to 80 percent of the pond is covered by emergent and submerged vegetation and more than 90 percent of the shoreline is vegetated.

Plants are also effective at reducing nutrient loads and undesirable vegetation such as algae. As algae and plants utilize the same processes for consuming nutrients, a biological competition is created. The use of terrestrial, littoral and limnetic planting as well as floating wetlands are proven to be effective in similar conditions.

Terrestrial planting around the lake will provide a buffer to remove loading, erosion control and habitat. The existing perimeter is comprised of grass or exposed soils. Lawncare likely introduces cutting directly to the pond to decay. This in turn adds to the nutrient loading. The removal of grass with appropriate bushes and plantings will aid in the maintenance of the pond.

Littoral plantings of emerging types on 8:1 slopes will provide habitat for reptiles and young fish. Floating and submerged in the zone will provide habitat for young or small fish and invertebrates. Floating planting in the Limnetic zone will provide shade to reduce the impact of photosynthesis on algae.

Floating plants can take the form of water lilies or engineered systems called "constructed floating wetlands. Constructed floating wetlands (CFW) act similarly to planting in the littoral zone. The exposed root structure aids in the removal of nutrients and coagulates suspended solids. The area under the wetland provides shelter for fish, while the floats provide areas for reptiles to sun and nesting places for birds. CFW have been utilized in lake, pond, river restoration as well as waster water treatment. Natural wetland loading removals of which CFWs are modeled after, are as follows.

Pollutant	Removal
BOD5	70-96%
Suspended Solids	60-90%
Nitrogen	40-90%
Phosphorus	47-95%

Table 3.1 Natural Wetland Nutrient Removal

CFWs have demonstrated a range of nutrient removal rates based on scale of the project, type of water/wastewater, plant species, and location. Design of the CFWs should include the selection of plants shown to provide the greatest phosphorus removal rates.

Loading rates for CFW vary between 2,000cf/d/ac to 7,000 cf/d/ac in commercial conditions however due to the complexity of water body ecosystems, information is limited in natural conditions. Several studies for ponds receiving stormwater runoff have identified CFW sizing between 0.10 - 0.15% of the catchment area. The comparable CFW for the pond with the park catchment area of 7.5 acres would be 327 sf to 490 sf. Monitoring and maintenance will need to be provide to address sizing during and after the remediation.

3.6. Rebalancing

After rejuvenation the pond will be out of balance for one to two years. During the rebalancing the pond should be monitored for nutrient loading, planting, fish and reptiles to confirm the pond health is improving and stabilizing.

Water quality should be monitored for a minimum of pH, DO, TN, TP, BOD, Turbidity, E Coli, and chlorophyll a. A pond management plan should be provided to document the process.

Planting should be monitored for two years to confirm establishment in the ecosystems as well as proper stormwater BMP process has been established. A detailed maintenance regime should be established in order to minimize plant decay within the pond.

Assuming the pond will be drained for removing the pond sludge, restocking of the pond with fish should be at a per acre rate of:

Species	Quantity	Size	Stocking Month
Bass (Phase 1)	50	2-inch	June, year 1
Bass (Phase 2)	50	2-inch	June, year 2
Bluegill	500	1-inch	August
Sunfish	Up to 1/3 of Bluegill		August

Similar species can be substituted so long as they represent similar consumer/producer cycle. Restocking of the pond with turtles can be through a preconstruction/post construction capture and release.

4. REFERENCES

Constructed Floating Wetlands: A review of research, design, operation and management aspects, and data meta-analysis, Pavlineri, N., Tshirintzis, V., and Skoulikidis, N., 2016.

Performance Evaluation of a Floating Treatment Wetland in Urban Catchment, University of the Sunshine Coast, 2016.

EPA/625/1-88/022 Constructed Wetlands and Aquatic Plant Systems for Municipal Water Treatment, USEPA 1998

Farm Pond Ecosystems, NCRS Wildlife Habitat Council, 2005

The lake and Reservoir Restoration Guidance manual, USEPA 1990

Ponds, Planning, Design and Construction, Agriculture Handbook 590, USDA Natural Recourses Conservation Service, 1997

Pond Management Handbook of Ohio, Ohio NCRS Division of Wildlife

Pond Management 101, Virginia Department of Game and Inland Fisheries, 2021

Managing Filamentous Algae of Ponds, NM State University, 2017

Understanding and Preventing Fish Kills in Ponds, NM State University, 2017

Water quality guidelines for the management of pond fish culture, International Journal of Environmental Sciences, 2013

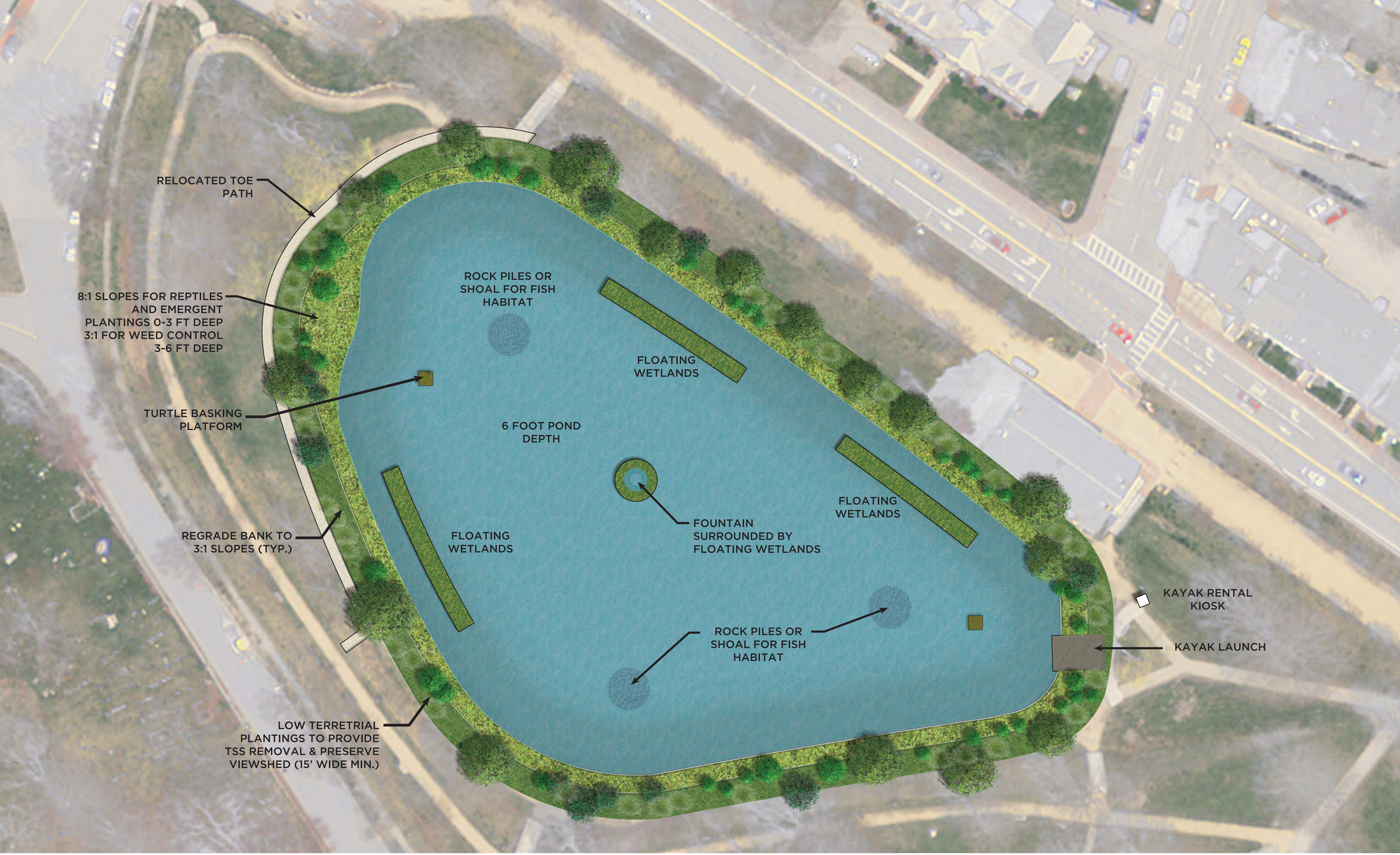
Pond Management, Purdue University, 2021

Water Quality Management in Pond Aquaculture, Auburn University, 1979

Floating Treatment Wetlands: an Innovative Option for Stormwater Quality
Applications, 11th International Conference on Wetland Systems for Water Pollution Control, 2008

Assessing nitrogen and phosphorus removal potential of five plant species in floating treatment wetlands receiving simulated nursery runoff, Spangler, J., Sample, D., Fox, L., Albano, J., White, S., 2018

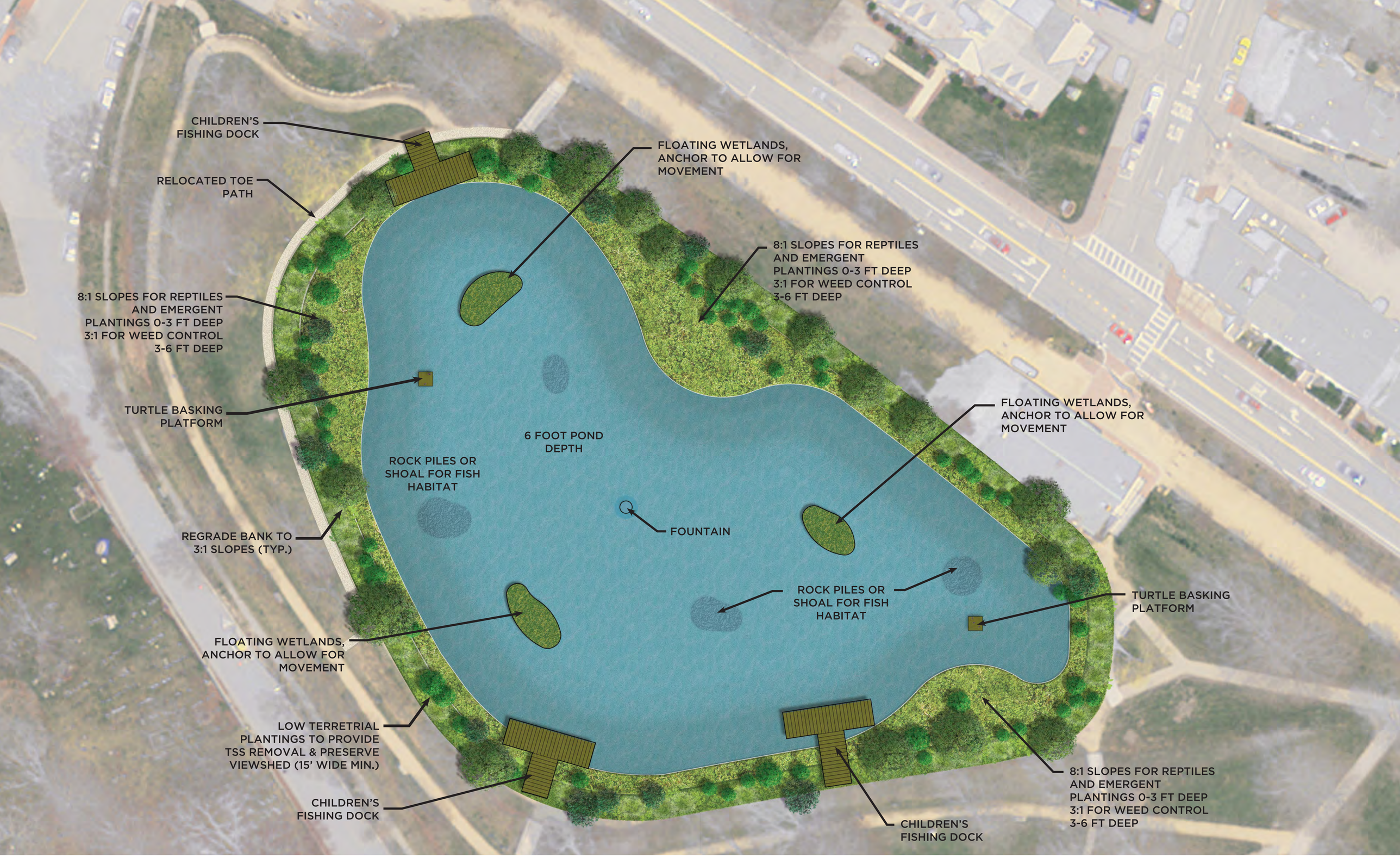
Trophic structure, species richness, and biodiversity in Danish lakes: changes along a phosphors gradient, Jeppesen, E., Jensen, J., Sondergaard, M., Lauridsen, T., and Landkildehus, F., 2000.



E&LP

SCHEMATIC DESIGN 1 - FORMAL CITY POND

FROG POND, NEWBURY PORT, MA
MARCH 1, 2022



E&LP

SCHEMATIC DESIGN 2 - WILD POND

FROG POND, NEWBURY PORT, MA
MARCH 1, 2022

PRECEDENTS

ROCK PILES FOR FISH HABITAT

FLOATING WETLANDS

LITTORAL PLANTINGS

ROCK PILES FOR FISH HABITAT

FLOATING WETLANDS

E&LP
140 West Main Street t: 908.238.0544
High Bridge, NJ 08829 f: 908.238.9572

PRECEDENTS

TURTLE PLATFORM

FISHING DOCK

CHILRDEN'S FISHING DOCK

STOCKED FISH

KAYAK RENTAL KIOSK

KAYAK LAUNCH

E&LP
140 West Main Street t: 908.238.0544
High Bridge, NJ 08829 f: 908.238.9572